POWER SYSTEM STATE ESTIMATION USING PHASOR MEASUREMENT UNITS

BY

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Dedicated To

My Parents and Family

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ABSTRACT (ENGLISH)

NAME: **MUHAMMAD FARAZ SAHITO**

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The power system is growing rapidly in complexity while decision making for system operator for such huge system is still a big concern. System real time view is presented to the operator through the help of several sensors (current transformers, potential transformers, bus injection and line power flow meters, and latest introduced phasor measurement units). Measurement devices can have errors due to telemeter noises and malfunctioning or could be missing because of accidental isolation of part of power system. State estimator filters out these noises and estimates the correct system state variables (Voltage magnitudes and angles). Since the advancement of smart grid more data is available and requirement of system's state estimation accuracy is raised. Relevant research is focused on improving the accuracy of estimator in presence of different type of bad data measurements. Phasor measurement units (PMU) provide complex voltage and current with higher reliability and accuracy improving the performance of state estimators. This thesis has considered only the availability of complex voltage reading from PMU measurements. The impact of incorporating PMU's on state estimation is investigated using three estimators: Weighted Least Square (WLS), Iteratively Reweighted Least Square (IRLS), and Least Absolute Value (LAV) using IRLS. The performance of incorporating PMU in state estimators is tested under different bad-data scenarios: single, multiple non-interacting, and multiple interacting bad data. The

standard 6-bus test system will be used for validation purposes. The proposed estimator will be then tested on the IEEE 14-bus, IEEE 30-bus systems.

ملخص الرسالة

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ينمو نظام الطاقة في التعقيد بسرعة هائلة في حين أن صنع القرار لمشغل النظام للتعامل مع نظام ضخم من هذا القبيل لا يزال مصدر قلق كبير. يبين نظام عرض الوقت الحقيقي للمشغل من خلال المساعدة من عدة أجهزة استشعار (المحولات التيارية، ومحولات الجهد، وحقن bus وأجهزة قياس تدفق خطوط الطاقة، وإدخال أحدث وحدات القياس المطورة). يمكن أن تحتوي أجهزة القياس على أخطاء بسبب ضوضاء مقياس البعد، وقصور أجهزة القياس؛ أو يمكن أن تكون مفقودة بسبب حوادث العزل العرضية لجزء من نظام الطاقة. ويستخدم مقدر الحالة مرشحات تقوم بتصفية هذه الضوضاء، وتقدر المتغيرات الصحيحة لحالة النظام (مقادير الجهد والزوايا)، ومنذ النهوض بالشبكة الذكية أصبح المزيد من البيانات متاحا وارتفعت متطلبات الدقة لتقدير حالة النظام. وتركز البحوث ذات الصلة على تحسين دقة المقدّر في وجود أنواع مختلفة من البيانات السيئة القياسات. ويعطي نظام وحدات القياس المطور الجهد المركب وكذا التيار بأعلى درجة من الموثوقية والدقة محسنا أداء مقدر حالة النظام. وقد عنت هذه الرسالة فقط على إمكانية قراءة الجهد المركب باستخدام وحدات القياس المطور. إن أثر دمج وحدات القياس المطور على تقدير حالة النظام قد قيم باستخدام ثلاثة نظم للتقدير تقدير الوزن باستخدام طريقة المربعات الصغرى إعادة تقدير الوزن باستخدام طريقة المربعات الصغرى التكرارية إستخدام القيمة المطلقة الصغرى باستخدام طريقة المربعات الصغرى التكرارية ويتم اختبار أداء دمج وحدات القياس المطورة في تقدير حالة النظام في إطار مختلف وسيناريوهات سيئة البيانات إلى بيانات مفردة، وبيانات متعددة غير متفاعلة، وبيانات سيئة متعددة ومتفاعلة. وسيستخدم إختبارنظام 6-bus لأغراض التحقق من الصحة. وسيتم بعد ذلك اختبار المقدر المقترح على ال (IEEE) نظام 14- bus ، وال (IEEE) نظام 30-bus .

CHAPTER 1

INTRODUCTION

A power system comprises of generators, transmission network, distribution systems and loads. Generation for the sake of human safety is mostly far away from the load. Conventionally, the transmission systems are required to deliver the amount of generating power towards the load. To ensure the security and stability of the power system equipment, current state of the system needs to be monitored in order to take proper action in case of any emergency occurs. Since power system is large and too many variables like voltage, current and power flow are to be monitored, it's not economic to place multi-meter at each place and the meter can always be prone to faults. Considering these limitations state estimator is required to take care of all such defects.

The power system is growing rapidly in complexity, generation and load are increasing day by day, which is producing stress for transmission lines, and several real time decisions are required by the system operator. A power system is said to be observable if the number of measurements are sufficient enough to estimate the system state. System observability is detected through several sensors, where all the system parameters and measurement devices are prone to faults. In case of such faults, system's observability might be affected and can cause a system outage if not handled correctly. State Estimator is required between the control center and such devices to estimate the current system's state (normal, emergency or restorative). Utilities process the measurements from different sensors to estimate the operating condition of the system using an estimator. It is a technique to compute the best estimate of state variables (bus voltage magnitudes and angles) from the raw measurements, simple flow chart of state estimation (SE) process can be explained in Figure 1-1. The Operator based on providing estimates does further analysis and make decisions using a Supervisory Control and Data Acquisition (SCADA) system.

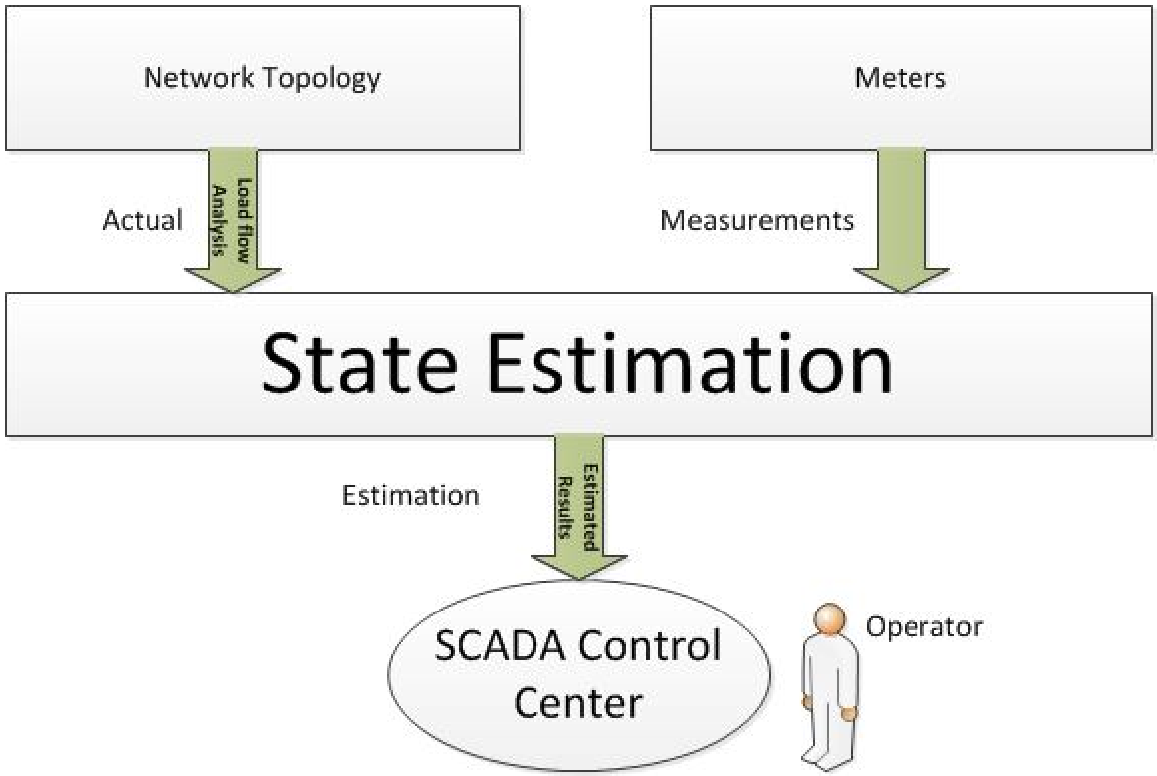

Figure 1-1: Flow Chart of State Estimation Process

1.1 State Estimator Challenges

Power control centers currently using basic state estimators with a certain level of accuracy and slow processing. In the literature several attempts are made to enhance the speed and accuracy of estimators to provide a real time view to the system operator and to help in making quicker and accurate decisions in case of emergency. The incorporation of Phasor measurement unit (PMU) with robust estimator like iteratively reweighted least square (IRLS) and least absolute value using iteratively reweighted least square (WLAVIRLS) is expected to improve more performance of these estimators.

The main challenging concern for estimating is the accuracy. Three types of measurement errors can be present in a power system like random errors (imprecise of measurement instruments), systematic errors (mainly from the nonlinearity of transformers and deterioration of the instrument because of environmental issues), and intermittent errors (large noise or temporary communication failures). An estimator must be able to handle all of these measurement errors.

A system operator also faces the problem of speed as real time monitoring is another challenge. This could be tackled down by use of high speed digital computers with a mathematical model of estimators in the computer. Redundancy is a term associated with the number of measurements available in the power system. If particular power system and maximum possible number of measurements are placed in the system, that system is said to be having full redundancy. Any number of measurements less than the maximum possible value would be considered as partial redundancy. The minimum number of measurements that could be placed would be equal to the number of system states (number of buses). Breakdown point of estimator is mainly affected by redundancy level used, even the most robust estimator could not allow to reject half measurements.

Measurements wrongly recorded are said to be Bad data. They can affect the estimation process on a large scale unless robust estimator is used. Outlier is another term used for measurements which lie away from the expected limit, Outlier might or might not be a bad data. Some bad data are obvious and easy to detect like negative voltage magnitudes and value of several orders, small or large, so they can be detected before estimation process. The only way to deal with remaining bad data is to suppress them during the estimation process so their effect gradually reduces. They can be induced by random noise, telemetry failure, broken instrument, and human error. Bad data can be mainly classified in two categories single and multiple bad data. Single bad data could be a single wrongly recorded measurement (like: polarity of meter reversed) available in the power system. Multiple bad data mostly occurs in large systems. Multiple bad data measurement can either be strongly correlated (interacting) or loosely correlated (non-interacting) [1]. The loose correlation between measurements can be caused by other errors. Multiple bad data measurements when they are consistent are called conforming [2].

Accuracy and speed could be obtained by the use of phasor measurement units replacing faulty meters. Remote power grid data reaching the control room produces an extra error due to lack of synchronization, which is overcome by the use of PMU's making available all synchronized voltage magnitude, voltage angle, current magnitude and current angle. The more accurate voltage angle will lead to a fast estimator, thus speed and accuracy is improved by the inclusion of PMU's.

1.2 Thesis Objective

This thesis focused on enhancing the performance of available state estimators for power system from system operator point of view. Objectives can be listed as:

1. Modifying state estimator algorithms (WLS, IRLS and LAV combined with IRLS (WLAVIRLS)) estimators to incorporate PMU measurements.

2. Investigating the impact of PMU under different bad-data measurements: single bad data, multiple non-interacting and multiple bad data interacting.
3. Investigating the enhancement and observing the breakdown point of (WLS, IRLS, and WLAVIRLS) state estimators after introducing PMU's.
4. Conducting Optimum PMU Placement (OPP) algorithm using a heuristic approach.

1.3 Contents Of Thesis

This thesis presents the improvement in accuracy of (WLS, IRLS, WLAVIRLS) state estimators, when PMU's are incorporated in the power system. In 1st Chapter brief introduction of the state estimation and related topics are discussed. In 2nd Chapter literature review of the whole topic including state estimation and PMU's are given. In 3rd Chapter state estimation based on WLS, IRLS and WLAVIRLS techniques are implemented. In 4th Chapter techniques for incorporation of PMU's in WLS, IRLS and WLAVIRLS estimators are elaborated. In 5th Chapter optimum PMU placement using a heuristic approach is discussed. In the 6th Chapter all results are summarized for several cases (single, multiple non-interacting, multiple interacting bad data) with (full and partial redundancy) are presented and the deviation of the estimator from actual power flow values is compared. In 7th Chapter brief conclusion is made and potential future works are discussed. In the very last test system data is presented in APPENDICES.

CHAPTER 2

LITERATURE REVIEW

Power system has grown complex and requires reliable data to work on with, state estimation is a solution to increase reliability of available data.

2.1 Importance Of State Estimation

State power system state estimation plays a vital role in system state protection and results are used for real time security analysis, optimal power flow and contingency analysis frequency control, etc. State estimator provides state of a power system (voltage magnitude and angle) using raw measurements from meters and sensors, which are used to calculate line flows, bus voltage limits by which system operator will be able to conclude line is overloaded or not and might take necessary actions before system goes uncontrollable. An estimator can estimate only in steady state operation.

To control and monitor a power system interconnected with prone to fault meters and unreliable topological network parameters, data require the accurate estimate of system state. Control center receives various measurements from parts of an electrical power grid for situational awareness of the system and controllability. The utilities monitor the operating condition of their system by processing the measurements received from these various sensors using a state estimator. A mesh of sensors (current transformer (CT), relay, voltage transformer (VT) and phasor measurement units (PMU's)) are placed around the system and measurements are transmitted to control center. Telemetry values can be subject to random noise, missing or having gross errors associated with equipment malfunction or the measurements could have clustered or scattered loss of data. Therefore, accurate and fast estimators are required to provide a reliable set of data.

Estimators provide a reliable data base by fitting the raw measurements from a system to a mathematical model for monitoring, security assessment and control functions [3]. In Literature several people have attempted on state estimation techniques, consideration on a number of practical difficulties are considered and estimators are implemented online on power systems. In the past several authors tried to solve estimation based on traditional derivative approaches such as gradient descent, Newton, linear programming [4], [5]. The Gradient descent and Newton both suffer solving inequality constraints [6]. On the other hand slow convergence and oscillation problems arise in linear programming approaches [7] when the iterative step is not chosen properly during the linearization process of the objective function and constraint functions [8].

Several attempts are made for solving power system state estimation (PSSE) process by optimization methods, but state estimation is a highly nonlinear problem whereas optimization methods go for local minima based approaches. High nonlinearity leads the optimization method towards several local minima in the search space, which provides local solution instead of global one. Local solution will provide huge error between estimated values and the actual ones. Convergence of optimization methods is highly dependent on selection of initial values of state variables [9].

A genetic algorithm (GA) uses genetics and the principle of natural selection, evolution and genetics for parallel search of complex spaces. In [10] develop a GA algorithm to solve for adaptive power state estimation. Author shows how to use genetic adaptive state estimator for estimating the states. GA evolves the model in a state estimator in real time, so that the state estimation error is driven to zero.

Artificial intelligence (AI) algorithms are a powerful tool for solving nonlinear problems and complicated search space [11]. They require only the (objective function) for guiding the search, and others also require gradient information. One of the powerful AI technique is Particle swarm optimization (PSO) as discussed in [12]. It is used for solving power system state estimation problem. Basic mathematical and logic operation and less parameter tuning is required by PSO. Tungadio used IEEE 6 bus system and MATLAB environment, two different approaches have been used for modelling the objective function Weighted least square (WLS) and Iteratively Reweighted Least Squares (IRLS) for PSSE. The author claims that WLS is providing higher accuracy than IRLS.

This thesis has focused on three widely used estimators:

2.1.1 Weighted Least Square

A power system state estimation is required to calculate the expected state of the system instead of the states mentioned by the sensors, this is due to unreliability or error could be present in sensor data or network data. A best estimate could be obtained using Least Square, WLS [13] or WLAV [14] estimators. Linear WLS regression depends on a simple updating formula by obtaining a set of converging iterations successively, at every updating step new deviation of state variables is not calculated by simple update formula instead sparse orthogonal triangular QR-decomposition is employed [15] due to QR-decomposition method is more stable.

State estimation algorithm fits measurement of the system to a mathematical model to provide reliable data for monitoring for the system operator, contingency analysis, load frequency control, and security assessment controls. WLS is a classical approach used for state estimation in Literature, These estimated state variables are used for calculating the line flows and real-time security analysis, SCADA (Supervisory Control and Data acquisition) shows Line flows based on these estimates in the control center. WLS assumes measurement errors are independent of one another and distributed according to the Gaussian distribution with zero mean and known variance. Measurement error variance is chosen based on the reliability of the meter, the more reliable meters are given very less variance value. The weighted least square could be performed using sparse orthogonal triangular QR decomposition or normal equations approach by solving a sequence of linearized problems [16], while the literature has focused more on QR decomposition technique as they prove to be more stable. The WLS fails in case of bad data available while it performs very well in case of Gaussian errors [17].

2.1.2 Weighted Least Absolute Value

Power system state estimation (PSSE) is used for calculating the most probable estimates of the state variables (voltage magnitudes and voltage angles) for every instant of time by solving non-linear equations whose parameters are obtained from sensor measurements [16]. The best fit could be determined by minimizing the (summation of absolute difference between actual and estimated). LAV state estimation objective function could be defined as:

$$\min \sum_{i=1}^{m} W_i \left| h(\mathrm{x}) - z \right| \qquad (2.1)$$

$$s.t.......z - Hx = r \tag{2.2}$$

It is possible to convert optimization problem given in (2.1),(2.2) to a linear programming problem as explained in [18], [19], [20], [14]. For LAV estimation, one can formulate the problem into Linear Programming (LP) [19], and can use famous LP solvers (Simplex Method, Interior Point Method). The connection between the LAV state estimator and LP is explained in detail in [19].

Earlier attempts of solving power system as Linear programming were mainly relying on simplex type algorithm [21], [22] which were suggested by Barrodale and Roberts. They have formulated the problem as an LP and used a simplex algorithm to solve it. There were considerable savings in computation time and numerical examples were shown. This simplex based algorithm was also able to handle equality and inequality constraints [23]. Later on, one algorithm focused on interior-point LP solvers. One study compared the use of a path-following interior-point method and a dual affine-scaling method [24]. N.K. Karmarkar in his paper has proposed a new method (interior point method) for solving LP problem and several variations of this original method has been developed in the literature. The solution is obtained by tracing a path interior to feasible region.

LAV is always classically solved by LP formulation whereas in [16] author presents a mixed approach implementation of LAV using IRLS power system state estimator by obtaining a sequence of L1-regression problem instead of (LP) problem, which is being implemented in this thesis. IRLS is being used to solve such problems and higher computation efficiency is achieved as compared to the non-linear IRLS estimator. IRLS possesses built in LS solver which is based on solving the linearized sub-problems using Orthogonal-triangular (QR) decomposition approach [17].

Tungadio and Numbi in their paper [12] present power system state estimation (PSSE) technique using particle swarm optimization technique. Two different objective function formulations are assessed weighted Least Square (WLS) and the second one is iteratively weighted least square (IRLS) implementation of weighted least absolute value (WLAV), the solution of Newton Raphson algorithm for power flow has been used. Solutions are compared using 6-bus system. Results are presented that both WLS and IRLS are able to solve the PSSE problem.

In [25] proposed a new hierarchal robust state estimation technique, simulation was carried out on an IEEE 14 bus system, where they are using some of PMU measurements and other line flow meters and using the local estimator to estimate for a certain area and a global estimator which estimates more accurate and is placed at global level near Power Control center.

2.1.3 Iteratively Reweighted Least Square

An estimator is statistically robust if estimated states remain insensitive to deviations in the number of redundant measurements and is able to mitigate multiple bad data. Accuracy for an estimator comes with the expense of computational complexity. WLS is not a robust estimator due to its internal assumptions like errors are considered to be normally distributed with zero mean and variance is according to the accuracy of the meters. WLS handles bad data as a separate post estimation process, while robust estimators have built in functionality which deals with outliers and bad data while estimating. During the estimation process bad data are identified and are given less weight for the next iteration, which removes the effect of bad data.

Instead of dealing with bad data as a post estimation process Merril and Schweppe proposed [26] to deal with them during the estimation process by suppressing the bad measurements during the iterative scheme. By using this proposed approach several robust estimators variations were proposed in literature like IRLS. The key to these algorithms was during each iteration they monitored each rapidly growing measurement residual and suppress their effect on the state estimation process.

Robson and Antonio in [27] paper discusses IRLS method for power system state estimation (PSSE), orthogonal implementation for solving non-quadratic criteria are introduced through giving rotations. The effect of the measurements and the location are taken by the weights given to measurements, method was being tested on IEEE 14, 30, 118 bus systems to validate the estimator performance. The proposed estimator named as LSDIR is based on orthogonal transformations and is capable of providing valid estimates without need of re-processing the measurements.

2.2 Importance Of PMU's In State Estimation

State estimators help to get a better real picture of the system, in the presence of the PMU sensors state estimator needs to be reformulated. With the passage of time PMU's will become affordable, many applications are currently being investigated, and one of them is state estimation. In a modern deregulated power system, PMU sensors are becoming increasingly popular and the use of GPS synchronization is becoming a major tool for monitoring because of accuracy improvement of state estimation. In terms of accuracy and convergence speed each estimator has improved to a certain level by PMU's addition. PMU's rapidly populate in substations of the transmission network. They provide an unprecedented advantage over other meters by providing complex voltage and current measurements with synchronized time clocks due to common time source GPS. PMU measures analog electrical waves on an electricity grid, multiple remote measurements which now can be synchronized in real time. PMU could be incorporated in a protective relay or could be a separate device.

PMU's are the latest technology in power system measuring GPS time stamped voltage and current measurement magnitudes with 0.01% accuracy and Voltage phase angle to 0.02 degrees. [28]. PMU's provide reliability of 99.87% and synchronization up to 1 microsecond [9]. The state estimation uses a combination of PMU's and SCADA measurements. PMU's could measure the system states (voltage magnitude and angle) with high accuracy, if PMU's were to be installed at every bus state estimation would have been less critical. System operator receives SCADA measurements (line flows, power injections, voltage magnitude) and PMU measurements (voltage magnitude and phase angle). Since PMU measurements are a linear function of the system states, they do not require any iterative procedure and could be solved directly. The traditional SCADA measurements need to be solved nonlinear problem iteratively to obtain states [29]. In Literature [30] and [31] several works have been performed for SCADA and PMU measurements collectively helping state estimator to improve accuracy. Ali Abur and Liang Zhao in [32] dealt with multi-area state estimation using PMU measurements. They made the assumption of PMU's placed at two tie lines at the boundary of two areas, each area had its own estimator. In [31] Ali Abur proposed one more approach for state estimation with traditional and PMU measurements without a slack bus. They observed PMU addition makes the process less static as PMU’s have higher scanning rates. Further, they also implemented bad data identification considering PMU’s.

2.3 History Of PMU Development

A historical review of the development of PMU from the beginning is provided in [33]. The root of PMU birth goes to the introduction of the initial development of symmetrical component distance relay in the late 1970s. PMU development stages could be broken down into several stages. At first very important invention of the symmetrical component distance relay (SCDR) whose main purpose was to protect high voltage transmission lines. SCDR relay used voltages and currents at the line terminal (zero, positive and negative sequence components) and could determine all types of fault location by solving just single equation. The main outcome of this relay was the introduction of the technique which could measure positive sequence components of voltages and currents very accurately with measurement response time of one cycle of fundamental frequency. Later on at the second stage synchronization of sampling clocks was achieved with the help of the GPS satellite system. PMU’s use GPS receivers and take several readings at distant places, but still all readings are synchronized. Synchronization is made through 36 GPS satellites out of which 24 are running for one time to produce synchronized signals at the earth's surface. PMU’s solve (x, y, z, t) coordinates by solving for time stamping the current and voltage [34].

Finally Virginia tech team in 1988 produced the first prototype of the Phasor measurement unit using SCDR relay and synchronized sampling clock. Later on PMU’s became commercially available in the market, advanced research on effects of PMU's in different fields is going on. Initial development and first prototype in research for PMU was done by Virginia Tech University in 1980s. Later on PMU's were commercially available with the high price product. Arun G. Phadke from Virginia while experimenting to calculate the phase angles of both the voltage and current developed the device known as a Phasor measurement unit (PMU). The prototype built by Arun. Phadke was used at the New York power, authority and American Electric Power Service Corporation and deployed at some substations of Bonneville Power Administration. After that first commercially available manufacturer with Virginia Tech for PMU's started in 1991 by Macrodyne [35]. IEEE published a standard to the format of data files for transmission and creation by PMU's in 1991 [28] which was later on revised in 2005.

PMU initially measured positive sequence components only at the fundamental frequency. The phase angle to be measured is referenced to universal time coordinated (UTC). Measured sinusoidal waveforms when sampled at appropriate time intervals and sampled over sufficient time produce phasors, which later on are estimated using Fourier transform methods. Synchronization of phasors is done using Global Positioning System (GPS) technology, which is a common time reference, therefore it is called Synchrophasors [36].

Power system engineers have always sought solutions to calculate phase angle of analog currents and voltages. Active (real) line power flow is approximately directly proportional to sine of angle difference of two adjacent buses. Initially in early 1980s calculation of direct phase angle differences was published [37], [38], [39]. In these papers discusses the systems for obtaining synchronization of reference time for two far locations. Using the difference of phase angle measurements at two locations with common reference the single phase angle difference between two adjacent bus voltages was calculated. Measurements accuracies of the order of 1 μs could be obtained using such approaches. Such techniques for obtaining phase angle differences are obsolete now.

In 1977 new symmetrical component based algorithm was published [40], on which modern phasor measurement systems are based which involved the computation of positive sequence currents and voltages. This paper realized the importance of positive sequence currents and voltages as they constitute state vector of a power grid utility system. In 1983 the first paper [41] was published showing the importance of positive sequence current and voltage phasor measurements which became the base of modern synchronized phasor measurement technology. In 1983 Global positioning system was being fully deployed around the globe [42] to be used to calculate phase angle at two very far places effectively without an error.

Conventional meters placed in power system do not include phase angle for measuring voltage and current. Phase angle was firstly measured with the invention of Phasor measurement units (PMU). PMU meets IEEE Surge Withstand Capability standard, C37.91 it is a device which with the help of GPS receiver provides synchronized voltage and current phasors. Global Positioning system (GPS) has the capability of providing accurate phase angles for different site measurements with common time signalling of the order of 1 microsecond [8]. GPS has the capability to time stamp measures values in format of seconds, minutes, hours, days, months and years [36].

Figure 2-1 provides the functional block diagram of PMU, where the analog current and Voltages are obtained from the secondary side of the CT and PT and can measure up to 48 samples per second for 50/60 Hz waveforms. Unwanted frequencies higher than a particular Nyquist frequency are filtered out by the antialiasing filter. Analog to digital (A/D) converter converts analog signals into digital waveforms. The phase locked oscillator converts GPS pulses received through the antenna to sequence of high speed pulses from one pulse in one second to be utilized in waveform sampling. Digital signals are forwarded to Phasor microprocessor for Discrete Fourier transform (DFT) phasor calculations to be executed.

PMU's can take analog measurement values of voltage with 0.01% accuracies and 0.02 degrees angle accuracy [28]. GPS is used to reduce the small time laps error between measurement errors placed at different places of power system. In [43] PMU's provide reliability of up to 99.87% and synchronization up to 0.2 microseconds. Weak meters can be replaced with PMU and state estimation than can use a combination of PMU and SCADA measurements. Two approaches can be used whether to use the combination of PMU and SCADA measurements or on the other hand one can use just SCADA measurements and perform traditional state estimation which than can be reprocessed in another state estimation program with incorporating PMU's.

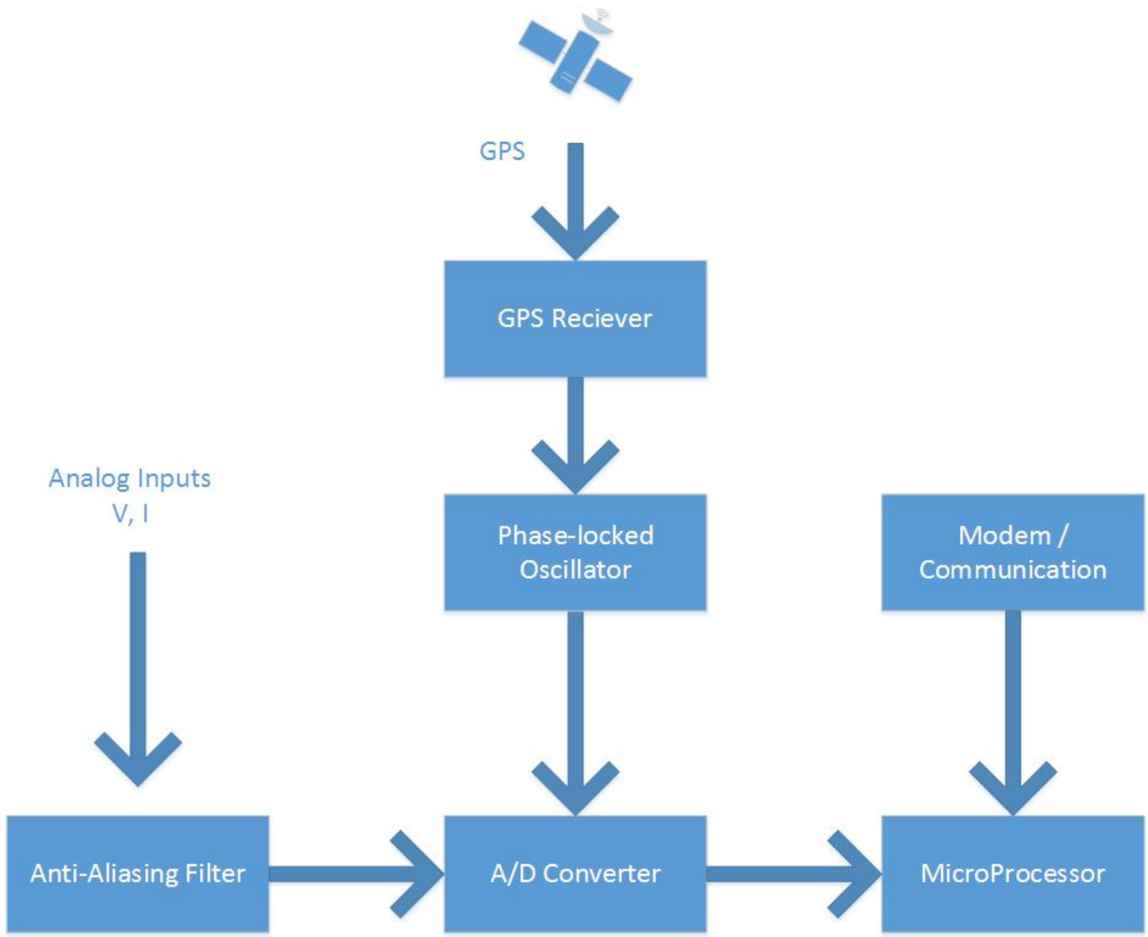

Figure 2-1: PMU Block Diagram [43]

PMU's application in different fields is still a question of research. Currently PMU improves the accuracy and increases the speed of State Estimation process by providing more accurate meter readings. PMU's are being widely adopted in the field of monitoring and controlling. For a power system containing several substations can have PMU's located to each substation, Measurement data from all such substations are gathered at Phasor Data Concentrator (PDC) known as the central collection point for synchrophasors. PDC uses time stamped info with each measurement to sort them out. Such sorted data from PDC can be further used in wide area measurement system [29].

2.4 Effect Of Bad Data In State Estimators

System operator in the SCADA control center is always monitoring power system. Any change in the system must reflect quickly as soon as possible on the display. In presence of bad data errors and loss of data it becomes difficult for the state estimator to provide exact states. Various sensors across the power system network provide measurements to the system operator for monitoring of the system through the use of (Current Transformers, Voltage Transformers, Phasor measurement unit and relays). All measurements received are processed and refined through an estimator, which provides the actual snapshot of the system by neglecting bad measurements and compensating for the loss of data. Power system meters are vulnerable to human faults, physical disturbance and blackouts causing loss of data or sensor failure or communication failure from the control center. This research also focuses on checking the performance of selected state estimators in the presence of single, multiple gross bad data and with some loss of data.

Bad data processing is another process performed by state estimation where measurement error needs to be detected, located and corrected. It can be the part of estimation process or can be performed as a post estimation process depending on the estimator. A measurement set could be either redundant (removal does not make the system unobservable) or critical (removal makes the system unobservable). Bad data error on critical measurement are undetectable and will lead towards system un-observability. Adding some extra PMU’s will transform any available critical measurement into redundant and bad data error will now be detectable. PMU inclusion improves drastically the capability of state estimator for bad data identification and detection. In [44] a different formulation of state estimation in presence of PMU's is presented. Results show that PMU's incorporation in power system enhances the bad data detection capability, different size of test systems are presented.

Bad data is a wrongly recorded measurement from a meter, in the presence of bad data several state estimators start to perform less efficiently and error between estimated state variables and actual ones is increased, several resistant and robust estimators are also proposed in literature like IRLS and LAV using IRLS. An efficient estimator must be able to detect, identify and eliminate bad data measurements. Detection is the process of determining if any measurement is bad data or not, identifying is to locate which measurements are bad data. Any bad data can be identified if and only if it is not redundant measurement. Bad data identification is a post estimation process for WLS, while in some robust estimators IRLS bad data filtration is done during estimation. There are three types of bad data (single bad data, multiple non interacting bad data, and multiple interacting but non-conforming bad data). Multiple bad data could be interacting when estimation of one measurement strongly affects the other, in this case if one estimation is in error other will also be in error due to this correlation between them. Multiple bad data could also be confirming which means those are consistent with one another.

Measurement errors could be due to finite accuracy of meters, telemetry failure, and wrong connection errors. If sufficient redundancy is present such errors could be filtered out by state estimator. Different estimators filter out the errors differently and thus their robustness is measured from there estimation performance. Topology errors or network parameters could also be present, which is very hard to deal with by the estimators. In

WLS analysis is based on the probability distribution function of the measurement and each measurement is treated differently [19]. Garcia and Monticelli in [3] presented fast decoupled state estimators by eliminating the bad data using pseudo-measurement generation. Two estimator algorithm decoupled and model decoupled were tested here on IEEE 30, 835 Bus system. The performances of decoupled estimators over computation speed and accuracy of the algorithm, bad data processing, and modeling accuracies.

2.5 Impact Of PMU On Accuracy Of State Estimation

State estimation plays vital role in power system operations, control and contingency analysis. Based on available SCADA and PMU measurements, model data it provides an estimate of the current state of the system. In Past state variables (voltage magnitude and angle) were not available as measurements even they were estimated after performing state estimation. With the invent of PMU system states could be placed as direct measurements in the system as well. PMU data improves state estimation and the factors affecting depend on PMU locations, number of PMU's placed, PMU calibration and PMU measurement accuracy and SCADA data accuracy level. Certain practical implementation issues in real life implementation could be calibration of different vendors PMU's together, synchronization of PMU's to global reference and PMU data weights for optimal PMU performance [45].

The Power system is said to be observable when the available measurements are sufficient enough to solve for system states. In other words system is observed if the rank of the Jacobian matrix is equal to the number of system states. In case of state values are higher than measurements than estimator will break down [46]. PMU placement on a certain bus will provide you the accurate voltage reading of that bus and current reading of all incident buses. In such manner observability of the system will be improved.

State estimation is the process of estimating voltage magnitude and angle, where high accuracy is required. Several robust and advanced estimators are already being proposed in the literature, but all have a certain threshold after which they start to perform poorly. The main cause of such poor performance is the measurement meters don't provide accurate information or are unreliable. Alternative to increase the estimation accuracy is the use of the Phasor measurement unit at several substations which can directly provide accurate voltage magnitude and angle [47]. With the increase in the number of PMU’s accuracy of all the estimators increases rapidly.

PMU’s play important role in enhancing estimator performance. Recently, efforts have been made to explore the advantages of PMU’s with different techniques to improve state estimation. In [50] synchrophasors with dynamic state estimations (DSE) are used, it uses mixed integer programming for DSE formulation and studies are conducted on 3-bus and IEEE 157 bus system. Where as in [51] suggests unscented Kalman filter (UKF) to solve the estimation problem using PMU’s.

2.6 Optimum PMU Placement And Number Of PMU’s

Through The power system is usually too large and complex with the high cost of monitoring equipment’s making it unfeasible for full system monitoring. Conventional system operators use current and voltages of transmission lines for observability which severely affects protection and analysis of the system. Strategic limited number of PMU’s placement is crucially needed for monitoring [52]. Due to the expensive nature of PMU’s limited number could be allowed by utilities to utilize at their availability at their best. By such limitation in numbers optimal placement issue has been recognized by researchers in detail [53], [54].

Power system faults, fluctuation in the network has created the need of monitoring the system, and protection of the equipment. In Literature some papers have opted for placement of single monitor to each bus for voltage and current monitoring of entire network, which is a costly option for grid utilities. A small number of phasors voltage and current measurements at selected location can provide complete state of the system (bus voltages, power flows). Determination of optimal location for the PMU's and the least number of PMU's required for sufficient desired accuracy of the estimators of the system is the main concern [55]. In [56] have briefly explained the acceptable number of PMU's and locations, where [56] have used binary search algorithm and explained method for complete observability of the system with single line outage and with the normal steady state operation.

PMU's are the sensors which, when placed on a bus can provide the phasor voltages of that bus and the phasor current values of all the incident transmission lines [57]. Therefore PMU's widespread availability in a large network has the capability of providing the state of the system with very high accuracy. Abur in [44] has shown one of the benefit of PMU placement with bad data processing, which is greatly dependent on the measurement redundancy. Bad data appearing inside critical measurements are undetectable. This paper proposes a strategy to transform all critical measurements into redundant by placing the PMU's at strategic positions in the system, which will make critical bad data now detectable and bad data processing is greatly improved.

PMU will be the leading measuring instrument of the future, due to its ability to use synchronized sampling clocks from GPS to calculate accurately positive sequence bus voltage phasors of the bus on which it is equipped and all incident buses branch currents [58]. For the first time in history, phase angle was measured accurately with very high precision, PMU's several applications are discussed earlier, one of them is the improvement in state estimation accuracy which is the core focus of this thesis [48]. Energy management system (EMS) is the center of power system protection and monitoring operations. State estimation uses available bus voltage measurements and line flow measurements and estimates the states (voltage magnitude and phase angle of each bus) [19]. Remote terminal unit (RTU) is installed at every substation, which transmits set of measurements every few seconds to Supervisory Control and Data Acquisition (SCADA) for state estimation. Real time actions are taken on the basis of state estimation like load dispatching, removal of the line, isolating faults, therefore accuracy of the estimator is the main concern for research.

Power system utilities if place PMU at every bus of the system, estimators will provide the best possible estimate. However PMU's cost is so high that only 1% of substation contain PMU's worldwide. Hence the current SCADA meters are still in place and existing measurement configuration is redundant enough to make the power system fully observable. Utilities are interested to know the least number of PMU's and the optimal locations for improving estimation performance [59]. For the time being an efficient approach is the mixture of SCADA and PMU measurements to boost up the estimator performance.

State estimator accuracy can be increased by increasing the number of available measurements or by optimal PMU placement. In paper [59], the optimal PMU placement sequence is obtained using an incremental placement algorithm to enhance estimation accuracy, which firstly was proposed in [60]. Estimating accuracy is related to the inverse of the gain matrix, which is the covariance matrix of bus voltage angles and magnitude. In these papers accurate phasor voltage inclusion by PMU is considered, phasor currents are excluded for time being. In [61] paper Li uses statistics to formulate PMU placement problem and a greedy approach for optimal PMU placement sequence is presented. This paper also considers only voltage phasors for saving computation burden.

Chen and Y. Liao in [62] proposed a heuristic approach for optimal PMU placement for state estimation accuracy improvement where weighted least square (WLS) estimator was used on IEEE 14 bus test system. PMU's have the ability to provide more accurate current phasors incident to buses where PMU's are placed and voltage phasors for the bus on which PMU is placed. Due to economic cost constraints for PMU placement power grid utilities require limited number of PMU's to be placed in power system for estimator performance improvement. This heuristic approach finds the least number of PMU's to achieve the desired estimation accuracy level by searching all candidate buses and their optimal locations exhaustively. This paper discusses two approaches to include PMU's by either mixing the PMU measurements with conventional SCADA measurements or PMU's could be added as a post processing step after estimation [63]. Both methods provide quite the similar results, but with different computation time, the second method is more time efficient and does not require modification in the existing EMS estimation software. It includes PMU in WLS and WLAV with clustered and scattered loss.

Optimal PMU placement is required for power system to save cost of deployment, In [66] optimal placement of PMU on network branches is done instead of busses, it considers the branch PMU's which monitor a single branch by measuring the associated current and terminal voltage phasors, With the help of multi-channel PMU's it provides optimal locations for PMU's to make the entire network observable. This paper also considers network contingencies and PMU's failure. The method is tested for small and large utility bad data detectability using PMU's is also presented.

In [67] proposes OPP solution using a Memetic algorithm (MA), which combines both genetic algorithms (global optimization problem) and hill-climbing methods. The proposed approach was tested on Idaho region power networks plus IEEE benchmark systems. In [68] proposes multi criteria (cost, observability, security and importance) based OPP problem using the Fuzzy Weighted Average (FWA). Initially, it uses genetic algorithms to obtain OPP solution and on later stage it uses Fuzzy optimization to rank PMU installation sites.

PMU is an expensive technology and needs to be economically placed in power system, literature discussed here indicates the attempts so far done for optimum PMU placement. Robust state estimator accuracy increases with PMU inclusion, such work has not been attempted so far.

CHAPTER 3

STATE ESTIMATION ALGORITHMS

In this research WLS, IRLS, WLAV using IRLS are chosen for comparison. These estimators were tested on 6, IEEE 14 and IEEE 30 bus systems. WLS, IRLS, WLAVIRLS all estimators contain different objective functions for minimization of measurement error. Power system measurements are nonlinear functions of system states. Measurement Jacobian could be obtained by taking the partial derivatives of these equations. After solving the minimization of the objective function for each algorithm separately final equation is obtained which uses measurements and measurement Jacobian to obtain the bus voltage magnitudes and angles (state variables). For all three algorithms measurements and Jacobian measurements are calculated in the same way, the only way they differ is the numerical method and minimization equation.

State estimation is a process just before the Energy management system collecting the topological data and SCADA measurements. It uses complex line flows, complex power injections, the SCADA voltage magnitude of buses to estimate the system states. State estimation results could be used at several applications like optimal power flow, security enhancement, contingency analysis as shown in Figure 3-1.

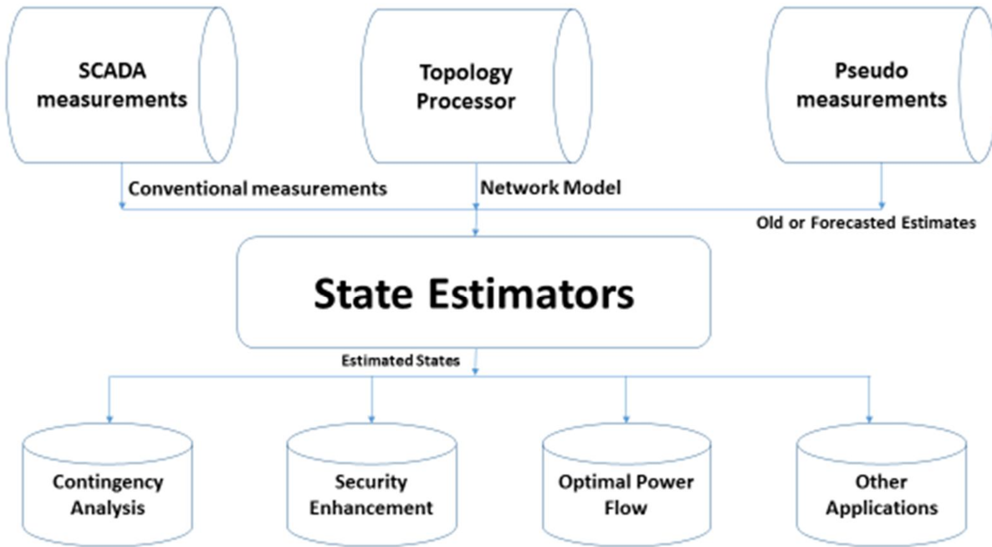

Figure 3-1: State Estimation Role in Power System Control and Operations [69]

System states are the complex bus voltages, which can be obtained either using a state estimator or one can place PMU on a bus to measure that bus accurate voltage magnitude and angle. Once all the bus states are known then the power flows real (3.1) and reactive (3.2), power injections real (3.3) and reactive (3.4) can be calculated. There is a nonlinear relationship between power flows and voltage magnitude and angle, which makes the estimation process as iterative one.

$$P_{ij} = |V_i|^2 (G_{si} + G_{ij}) - |V_i||V_j|(G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij}) \tag{3.1}$$

$$Q_{ij} = -|V_i|^2 (B_{si} + B_{ij}) - |V_i||V_j|(G_{ij}\sin\theta_{ij} - B_{ij}\cos\theta_{ij}) \tag{3.2}$$

$$P_i = |V_i| \sum_{j \in N_i}^{N} |V_j| (\mathrm{G}_{ij}\cos\theta_{ij} + \mathrm{B}_{ij}\sin\theta_{ij}) \tag{3.3}$$

$$Q_i = |V_i| \sum_{j \in N_i}^{N} |V_j| (\mathrm{G}_{ij} \sin\theta_{ij} - \mathrm{B}_{ij} \cos\theta_{ij}) \quad (3.4)$$

Where P_{ij} and Q_{ij} are the real and reactive power flows from ith to jth bus, P_i and Q_i are real and reactive power injections on a particular bus. $|V_i|$ and $|V_j|$ are the voltage magnitudes for ith and jth buses. θ_{ij} is the phase angle difference. G_{ij} and B_{ij} are the real and imaginary parts of the element in the bus admittance matrix.

State estimation was unable to directly calculate system state variables as there is nonlinear relationship between measurements and states, states were inferred from unsynchronized power flow measurements. A large complex power system collecting a large number of unsynchronized measurements forced the system operator to make certain compromises that persist today as well and effects the way PMU needs to be integrated in the system.

State estimation is used to detect, identify and eliminate errors which could be present in network parameters, network model and measurements. An estimator is considered robust if the estimator is strong enough to remain insensitive to major deviations for a limited number of redundant measurements and remains unbiased even in the presence of outliers. Robustness comes at the expense of computational speed, which could be determined by large breakdown point of the estimator. Breakdown point is mainly affected by redundancy level, even the most robust estimator could not allow to reject half measurements. The famous weighted least square is not a robust estimator, it assumes errors to be independent with Gaussian distribution, having zero mean and known variance. Historical data on measurement errors and metering accuracy reflect the error variance to be selected for measurement.

In this chapter problem formulation is done on the basis of which algorithms will be compared in terms of error indices (Total sum of error between actual and estimated measurements). To identify a better estimator different performance indices in the form of norms can be used in presence of different number of bad data errors and redundancy level. The method to introduce random errors in meters due to the low accuracy level is presented here. There is always certain accuracy level with a certain meter (CT, PT, relay and PMU's), which needs to be modelled as random noise in the measurement from the actual value, this could be due to noise, aging of meters, accuracy limit, bad calibration and communication error. The error can be induced using an equation:

$$z_i = actual_i * (1 + RND * \sigma_i) \tag{3.5}$$

Where i= 1,2,…..m; $actual_i$ are the actual values from power flow program and z_i are the measurements from m meters and σ_i is the variance related to the deviation of the meter from actual measurement of ith meter.

The Phasor measurement unit can provide voltage magnitude and angle, current magnitude and angle, but in this thesis for simplicity only voltage magnitude and angle are being considered. PMU's are more accurate than classical meters, that's why their variance is very low to show higher accuracy of PMU meters.

For stopping criteria of estimation process, the estimator will terminate if the current iteration is less than the maximum limit (100 iterations) that means with given number of meters estimation is diverging and estimation process needs to be stopped. Every estimator uses a particular norm, it must be greater than a certain threshold usually (1e-04) for the next iteration to exist.

A quantity describing extent, length, effect or size of an object is norm [70]. They represent the deviation between estimated and measured value. Smaller the norm more efficient the Estimator is and could perform better in the presence of single, multiple bad errors or with certain loss of data. Different type of norms are presented in [71] and [70]. If one takes out the maximum value of the absolute difference of estimated and measured is called the infinity norm [71]. By taking the sum of absolute residual vectors (measurement subtracted from estimated) is L_1 norm [71]. For WLS infinity norm has been used as dictated by [72], for IRLS norm explanation has been given in [16].

3.1 Weighted Least Square

The power system provides the nonlinear relationship between system states and measurements. For understanding purposes, very base of the state estimation is elaborated here. Weighted Least square represents an estimation problem that selects the criterion of a solution to the over-defined matrix equations when less states and more measurements are available in the power system. Suppose the states (x) and the measurements (z) are related to linear equations $z = Ax$ where A is the relation matrix with less columns and more rows. Such equation has no solution and will be expressed as $z = Ax + \varepsilon$, In this equation ε is an error term representing error in measurements. Least Square assumes measurement errors are identically distributed and independent, with zero mean and one variance which is denoted by **I** identity matrix. If errors do not have same weight and does not form **I** matrix instead it forms **W** diagonal covariance weighting matrix $E(\varepsilon\varepsilon^T)=W$ then different errors can be weighted differently depending on the measurement meter accuracy level.

Least squares is an optimization problem which tries to minimize the square of the error. Weighted least square have the objective function that minimizes the square of the error. If the z measurements have the nonlinear relationship $z = h(\mathrm{x}) + \varepsilon$ with the x states and the expected mean is $E(\varepsilon) = 0$ and the covariance $E(\varepsilon\varepsilon^T)=W$ then the algorithm is called nonlinear weighted least square. Nonlinear objective function is to minimize:

$$J(\mathrm{x})=[\mathrm{z}-\mathrm{h}(\mathrm{x})]^T W^{-1}[\mathrm{z}-\mathrm{h}(\mathrm{x})] \tag{3.6}$$

by linearizing $h(\mathrm{x})$ around x^k , which will lead the next iteration solution to:

$$H^T W^{-1} H \,\Delta x = H^T W^{-1} \Delta z \tag{3.7}$$

$$\Delta x=(\mathrm{H}^T \mathrm{W}^{-1}\mathrm{H})^{-1}\,\mathrm{H}^T \mathrm{W}^{-1}\,\Delta \mathrm{z} \tag{3.8}$$

Where $\Delta x = x - x^k$ and $\Delta z = z - h(\mathrm{x}^k)$. H represents matrix of partial derivatives of $h(\mathrm{x})$ with respect to state variables x.

Estimation is based on statistical criteria that by maximizing or minimizing selected criteria estimates system state variables. Different estimation algorithms are proposed in like Least Square (LS) used since the nineteenth century. LS when subjected to normally distributed errors in measurements provides better estimation, LS collapses in the presence of even single bad data. Several estimators have been proposed such that outliers have less or no effect at all on estimation result. Most commonly used estimator WLS is being considered here.

For a power network with N buses contains state vector x having (N-1) angles and N voltage magnitudes, where the slack bus is given zero degrees. x is the state vector having n dimensions where n=2*N−1, for 14 bus system there will 27 state variables in the state vector x. After estimating states one can easily find flows of every line and injection at every bus using (3.1), (3.2), (3.3) and (3.4).

Traditional state estimator utilizes SCADA measurements whose relationship with system states:

$$z = h(\mathrm{x}) + \mathrm{e} \tag{3.9}$$

x (n x 1) size is estimated state values vector, z having (m x 1) size are SCADA measurement vector, h correspond to nonlinear functions vector relating measurements to states, e is the error vector between estimated and measured values of size (m x 1). For equations to hold Jacobian matrix $h(\mathrm{x})$ must have rank n and $m \geq n$. Power system state estimation is a system of over determined nonlinear equations and must be solved as an unconstrained WLS problem. For weighted least square the sum of square of residuals needs to be minimized:

$$\min_x J(\mathrm{x}) = \sum_{i=1}^{N_m} \frac{[\mathrm{z}_i - \mathrm{f}_i(\mathrm{x})]^2}{\sigma_i^2} \tag{3.10}$$

$$\min_{x \in \mathbb{R}^n} J(\mathrm{x}) = \frac{1}{2}(\mathrm{z} - \mathrm{h}(\mathrm{x}))^T R^{-1}(\mathrm{z} - \mathrm{h}(\mathrm{x})) \tag{3.11}$$

By taking the partial derivative of $h(\mathrm{x})$ with respect to state vector x, Jacobian matrix $[\mathrm{H}]$ will be obtained. There is a nonlinear relationship between power flows, voltage magnitude and voltage angle, then an iterative technique to minimize J(x) is required. To minimize J(x) its gradient must be equal to zero resulting:

$$\nabla_x J(\mathrm{x}) = \begin{bmatrix} \frac{\partial J(\mathrm{x})}{\partial x_1} \\ \frac{\partial J(\mathrm{x})}{\partial x_2} \\ \vdots \\ \end{bmatrix} = -2 \begin{bmatrix} \frac{\partial h_1}{\partial x_1} & \frac{\partial h_2}{\partial x_1} & \cdots \\ \frac{\partial h_1}{\partial x_2} & \frac{\partial h_2}{\partial x_2} & \cdots \\ \vdots & \vdots & \ddots \\ \end{bmatrix} \begin{bmatrix} \frac{1}{\sigma_1^{\ 2}} & 0 & \cdots & 0 \\ 0 & \frac{1}{\sigma_2^{\ 2}} & \cdots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & 0 & \frac{1}{\sigma_m^{\ 2}} \end{bmatrix} \begin{bmatrix} z_1 - h_1(\mathrm{x}) \\ z_2 - h_2(\mathrm{x}) \\ \vdots \\ z_m - h_m(\mathrm{x}) \end{bmatrix} \tag{3.12}$$

$$\nabla_x J(\mathrm{x}) = -2[\mathrm{H}]^T [\mathrm{R}]^{-1} \begin{bmatrix} z_1 - h_1(\mathrm{x}) \\ z_2 - h_2(\mathrm{x}) \\ \vdots \\ z_m - h_m(\mathrm{x}) \end{bmatrix} \tag{3.13}$$

$$\frac{\partial J(\mathrm{x})}{\partial x} = -H(\mathrm{x})^T R^{-1}[\mathrm{z} - \mathrm{h}(\mathrm{x})] = 0 \tag{3.14}$$

According to Newton method to minimize a function f(x), where $x^{k+1} = x^k + \Delta x$ is

$$\Delta x = [\mathrm{f}^{'}(\mathrm{x})]^{-1}[-\mathrm{f}(\mathrm{x})] = \left[\frac{\partial \nabla_x J(\mathrm{x})}{\partial x}\right]^{-1} \left[-\nabla_x J(\mathrm{x})\right] \tag{3.15}$$

Where $\frac{\partial \nabla_x J(\mathrm{x})}{\partial x} = 2[\mathrm{H}]^T [\mathrm{R}]^{-1}[\mathrm{H}]$ and the whole formula becomes:

$$\Delta x = \frac{1}{2}[[\mathrm{H}]^T [\mathrm{R}]^{-1}[\mathrm{H}]]^{-1} \left\{ 2[\mathrm{H}]^T [\mathrm{R}]^{-1} \begin{bmatrix} z_1 - f_1(\mathrm{x}) \\ \vdots \end{bmatrix} \right\} \tag{3.16}$$

$$\Delta x = [[\mathrm{H}]^T [\mathrm{R}]^{-1} [\mathrm{H}]]^{-1} [\mathrm{H}]^T [\mathrm{R}]^{-1} \begin{bmatrix} \mathrm{z}_1 - f_1(\mathrm{x}) \\ \vdots \end{bmatrix} \tag{3.17}$$

Assuming at k_{th} iteration x_k is the state vector, for x_{k+1} next iteration can be calculated when only SCADA measurements are used:

$$x_{k+1} = x_k + \Delta x = x_k + [H^T R^{-1} H]^{-1} H^T R^{-1} [\mathrm{z} - \mathrm{h}(\mathrm{x}_k)] \tag{3.18}$$

Δx is the measurement mismatch, which is used as an iteration step for next iteration, for Δx to exists non-singularity of gain matrix ($(\mathrm{H}^T \mathrm{R}^{-1} \mathrm{H})$) is must. R_1 (error covariance matrix of SCADA measurements), iterative procedure terminates when Δx goes below a certain low threshold value, e.g. 1e-4. WLS estimator process can be summarized into one block diagram shown in Figure 3-2:

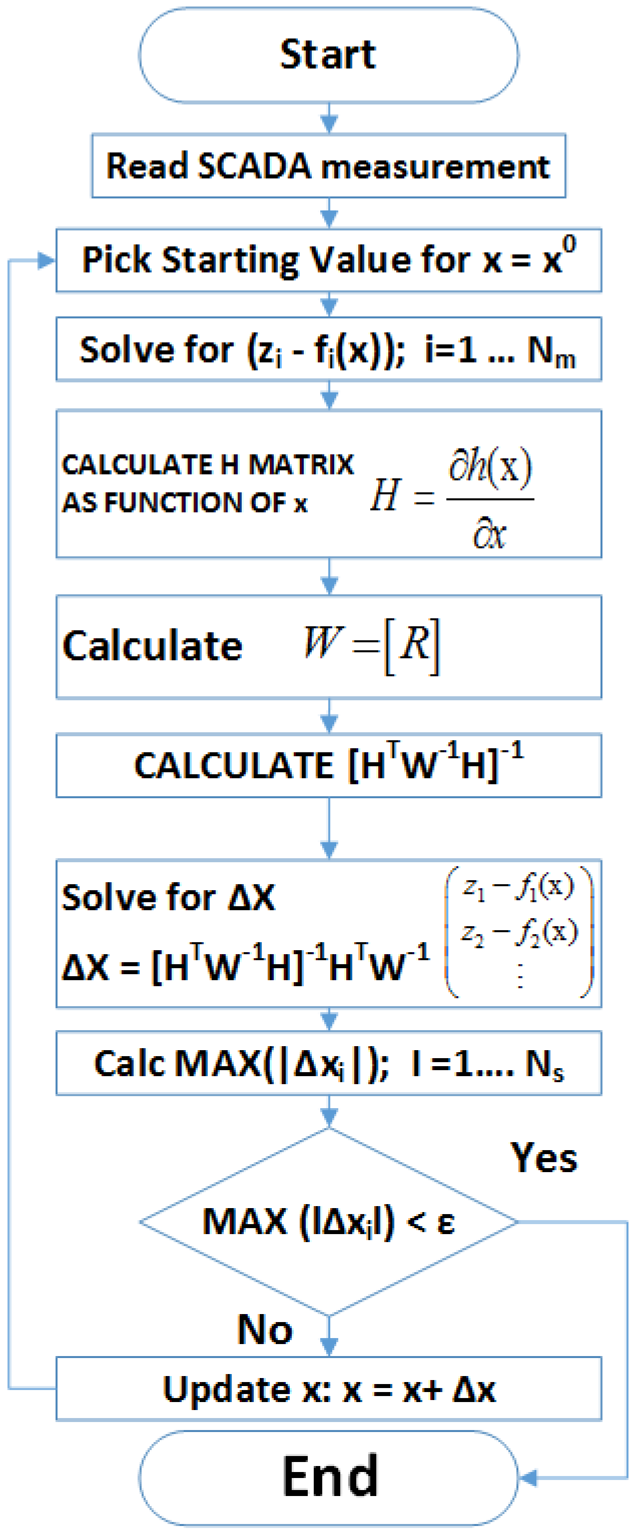

Figure 3-2 WLS State Estimator (SCADA Measurements Only)

3.2 Iteratively Reweighted Least Square

Iteratively reweighted least square (IRLS) is the alternative to the newton's algorithm for state estimation, which is reweighting scheme. In [73] Scheweppe-Hubber showed the application of IRLS as the robust estimator which can avoid leverage points and suppress bad data. Details of the IRLS estimator can be found in [73], [19], whereas basic formulation is discussed here.

The Power system estimate can be obtained through IRLS by solving an optimization problem whose objective function and constraint can be described as:

$$\underset{J(\mathrm{r})}{\mathrm{Min}}\, J(\mathrm{r}) = \sum_{i=1}^{m} \rho(\mathrm{r}_i) \tag{3.19}$$

$$z = h(\mathrm{x}) + \mathrm{r} \tag{3.20}$$

With the help of Karush Kuhn Tucker (KKT) condition $\frac{\partial J}{\partial x} = 0$ and Taylor approximation, optimization problem will result finally to:

$$H^T.\Phi.H\,\Delta x^k = H^T.\Phi.r^k \tag{3.21}$$

Where $r^k = z - h(\mathrm{x}^k)$ indicates residual vector, $H = [\mathrm{h}_1^T, \mathrm{h}_2^T \ldots \mathrm{h}_m^T]$ indicates Jacobian matrix, and Φ is diagonal weighting matrix, which can be defined as:

$$\Phi_i = \begin{cases} \dfrac{1}{\sigma_i^2} & |r_i/\sigma_i\omega_i| \le a \\ \dfrac{q.\omega_i}{r_i\sigma_i} sign(\mathrm{r}_i) & otherwise \end{cases} \tag{3.22}$$

$$\omega_i = \min\left\{1, \left[\frac{\chi^2_{v,p}}{PS_i}\right]^2\right\} \tag{3.23}$$

Further detail on the selection and meaning of the variables is elaborated in [73]. IRLS contains iteratively implementing least square estimator with adjusting weights at every iteration. At every iteration bad data are given less weight to reduce their effect on estimation for the next iteration. IRLS estimator steps are summarized in Figure 3-3.

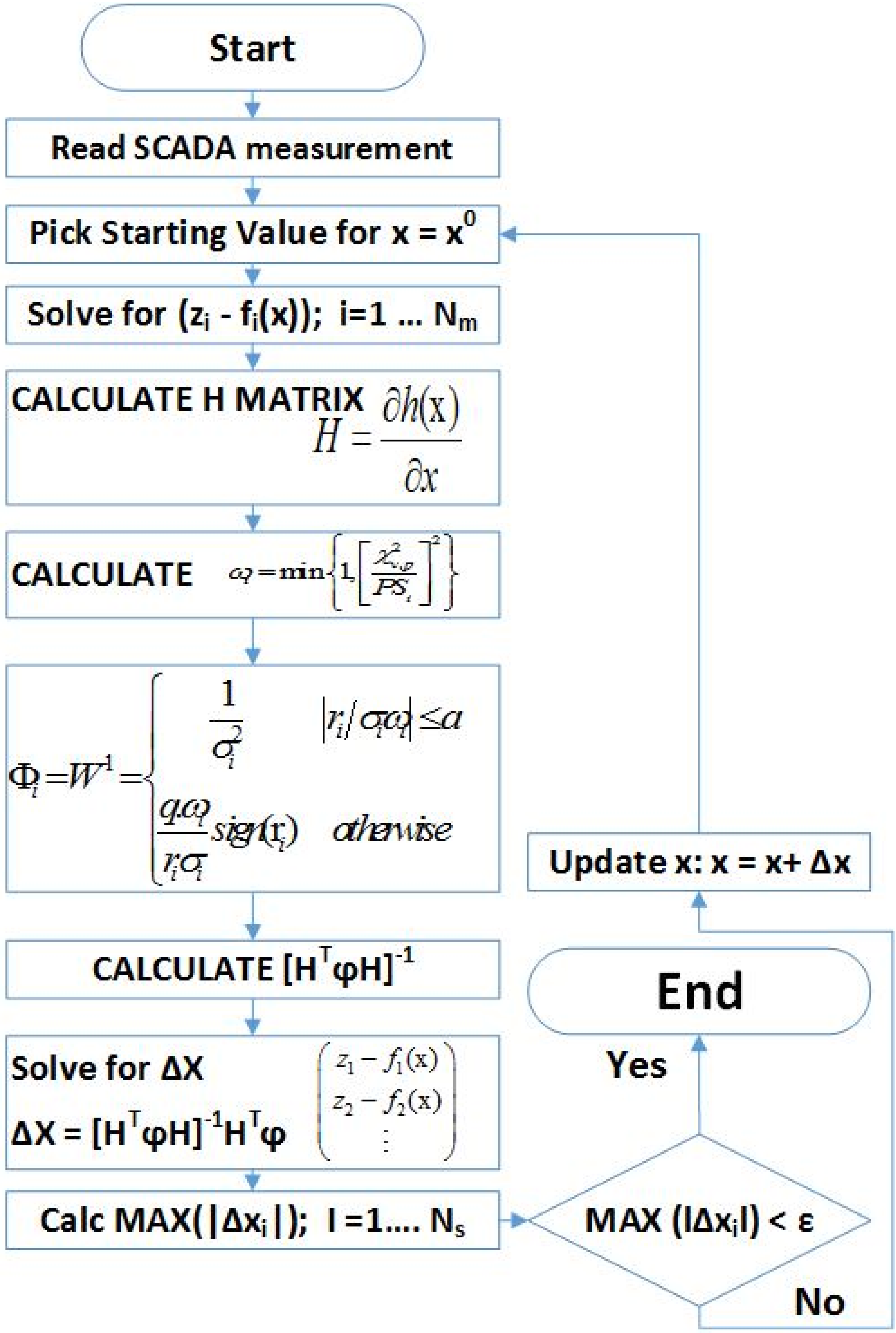

Figure 3-3 IRLS State Estimator (SCADA Measurements Only)

3.3 Weighted Least Absolute Value Using IRLS

In this section formulation for estimate of network using WLAV will be done. Usually with WLAV best estimate is found using linear programming (LP) approaches (simplex method, interior point method) by solving the linearized problem [18]. In this thesis WLAV using IRLS algorithm collectively called (WLAVIRLS) has been implemented [16], [15]. It enables to integrate WLS and LAV functionalities together in energy management system. The Resulting approach contains a sequence of WLS problems being solved in every iteration and has competitive estimation results and bad data rejection ability with standard WLAV using linear programming interior point method approach [15]. A Set of equations yielding critical points are solved using Newton Raphson power flow procedure objective function of WLAV can be minimized. In this manner WLAVIRLS dynamically adjusts the weights of measurement during each iteration and solves WLS problem is each iteration. Thus the process is called iteratively reweighted least square (IRLS).

3.3.1 Weighted Least Absolute Value

WLS has an explicit formula for calculation of estimator, whereas WLAV regression problem do not contain explicit formula. Therefore, in literature WLAV problem is usually formulated as Linear Programming and solved. Earlier WLAV implementation used L-1 norm specialized techniques. WLAV performs much better for bad data rejection, but fails in case of leverage points [74].

The Power system is made of n buses with meters placed at m locations to provide a measurement vector z_i of size (m x 1) to obtain system state vector x of size (n x 1). ε_i

of size (m x 1) is the error induced in the measurements. $h_i(.)$ of size (m x 1) is the nonlinear functions relating system states and measurements.

$$z_i = h_i(\mathrm{x}) + \varepsilon_i, i = 1, ..., m \tag{3.24}$$

WLAV estimator minimizes the objective function:

$$f(\mathrm{x}) = \sum_{i=1}^{m} W_i \left| h_i(\mathrm{x}) - \mathrm{z}_i \right| \tag{3.25}$$

where $k = 1, ..., n$. W_i represents ith measurement error variance reciprocal. x is the estimate minimizing $f(\mathrm{x})$ by:

$$\frac{\partial f}{\partial x_k} = \sum_{i=1}^{m} W_i \frac{\partial \left| h_i(\mathrm{x}) - \mathrm{z}_i \right|}{\partial x_k} = 0 \tag{3.26}$$

Given an estimate x^{p} , a better estimate of the system state is obtained by solving the following L1-regression problem $\min_{\Delta x^p} f(\mathrm{x}^p + \Delta \mathrm{x}^p) = \min_{\Delta x^p} \sum_{i=1}^{m} \left| h_i(\mathrm{x}^p) + \sum_{j=1}^{n} H_{ij}^p \Delta x_j^p - z_i \right|$.

Where ($H_{ij}^p = \frac{\partial h_i(\mathrm{x})}{\partial x_j} |^p$), After the solution of given equation is obtained via the $\mathrm{IRLS_{L1}}$ method, the new iterate is computed as $x^{p+1} = x^p + \Delta x^p$. This process is repeated until the convergence criteria ($\frac{\left\| \Delta x^p \right\|_1}{1 + \left\| x^p \right\|_1} \le tol_{LAV}$) is met, where $\left\| . \right\|_1$ stands for the L_1 norm and $\mathrm{tol_{LAV}}$ is usually 1×10^{-5} .

3.3.2 Iteratively Reweighted Least Square Method For L1-Regression

Absolute function $g(\mathrm{y}) = |y|$ differentiation is differentiable everywhere except $y = 0$ point. To solve this problem for differentiation, following formula is required [75]:

$$g'(\mathrm{y}) = \frac{y}{|y|} \tag{3.27}$$

Inserting (3.27) in (3.26) critical points equation is obtained:

$$\frac{\partial f}{\partial x_k} = \sum_{i=1}^{m} W_i \frac{h_i(\mathrm{x}) - \mathrm{z}_i}{|h_i(\mathrm{x}) - \mathrm{z}_i|} \frac{\partial h_i(\mathrm{x})}{\partial x_k} = 0 \tag{3.28}$$

Let's assume $e_i(\mathrm{x}) = |h_i(\mathrm{x}) - \mathrm{z}_i| / W_i$, than placing $e_i(\mathrm{x})$ value the resulting equation will be:

$$\sum_{i=1}^{m} \frac{\partial h_i(\mathrm{x})}{\partial x_k} \frac{z_i}{e_i(\mathrm{x})} = \sum_{i=1}^{m} \frac{\partial h_i(\mathrm{x})}{\partial x_k} \frac{h_i(\mathrm{x})}{e_i(\mathrm{x})} \tag{3.29}$$

Newton Raphson is used to solve (3.29) and $h_i(\mathrm{x})$ function could be linearized on the initial point $x(0)$ using Taylor series expansion

$$h_i(\mathrm{x}) = h_i(\mathrm{x}^0) + \sum_{j=1}^{n} H_{ij}^0 \Delta x_j^0 \tag{3.30}$$

Where $H_{ij}^0 = \left\langle \frac{\partial h_i(\mathrm{x})}{\partial x_j} \right|^0$, (3.30) when inserted in (3.29) and rearranged:

$$\sum_{i=1}^{m} H_{ik}^0 \frac{\mathrm{z}_i - h_i(\mathrm{x}^0)}{e_i(\mathrm{x}^0)} = \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{H_{ik}^0 H_{ij}^0}{e_i(\mathrm{x}^0)} \Delta x_j^0 \tag{3.31}$$

Now assume a diagonal matrix $E_x(0)$ containing $e_i(\mathrm{x}^0)$ elements at its diagonal, (3.31) could be represented in matrix format:

$$\left[H^0\right]^T\left[E_x^0\right]^{-1}(\mathrm{z}-\mathrm{h}(\mathrm{x}^0)) = \left[H^0\right]^T\left[E_x^0\right]^{-1}\left[H^0\right]\Delta x^0 \tag{3.32}$$

If $\left[A^0\right]=\left[E_x^0\right]^{-\frac{1}{2}}\left[H^0\right]$ and $b^0=\left[E_x^0\right]^{-\frac{1}{2}}(\mathrm{z}-\mathrm{h}(\mathrm{x}^0))$ are assumed and inverse of $[\mathrm{A}^0]^T[\mathrm{A}^0]$ multiplied on both sides will result in:

$$\Delta x^0 = (\left[A^0\right]^T\left[A^0\right])^{-1}\left[A^0\right]^T b^0 \tag{3.33}$$

Where Δx^0 is the iteration step and iterative scheme converging to a solution will be $x^1 = x^0 + \Delta x^0$. If system states are initialized by x^0 than on qth iteration:

$$x^{q+1} = x^q + (\left[A^q\right]^T\left[A^q\right])^{-1}\left[A^q\right]^T b^q \tag{3.34}$$

WLAV using IRLS is an iterative technique which either can converge or diverge. If the iteration exceeds 100 count algorithm is declared as the diverging and does not provide any solution. If the algorithm is converging then it is repeated till the required criteria is met.

$$\frac{\|\Delta x\|_1}{1+\|x\|_1} \le tol \tag{3.35}$$

Where $tol = 1\times 10^{-5}$ and $\|.\|_1$ represents L_1 norm. Weighted least absolute value when formulated as L1 regression problem and solved by IRLS estimator considering only the available SCADA measurements, steps could be summarized as shown in Figure 3-4:

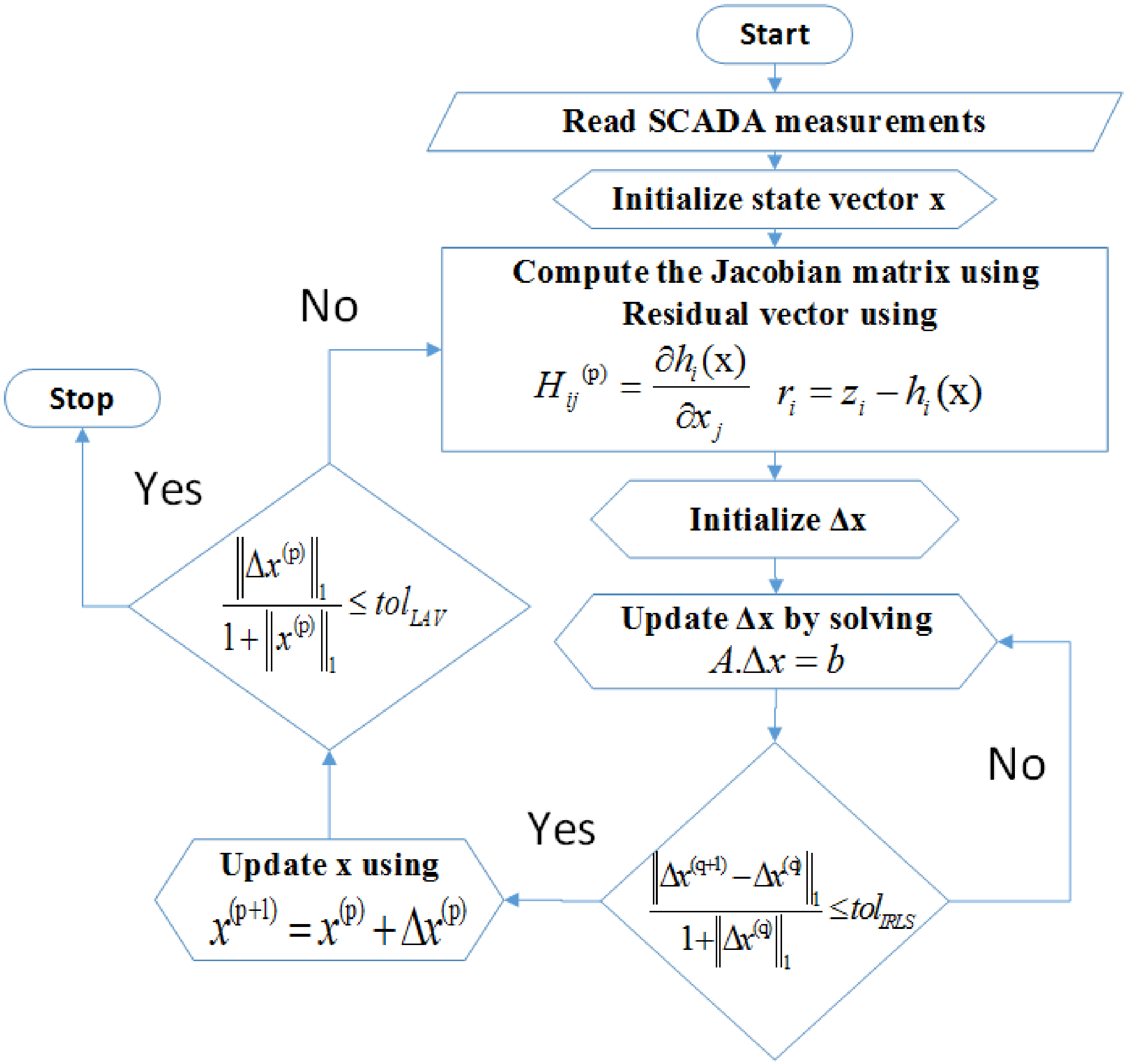

Figure 3-4 WLAV Using IRLS State Estimator (SCADA Measurements Only)

CHAPTER 4

STATE ESTIMATOR INCORPORATING PMU'S

Power system state estimation plays a vital role in controlling of power system. System operator always requires real time picture of the system so they can make important decisions when required in the presence of faults. Several estimators try to achieve speed and accuracy as the PMU is the emerging technology, which when applied to state estimation field increases convergence and accuracy of the estimator. State estimation uses line flow (real and reactive), power injections (real and reactive), SCADA bus voltage magnitude and PMU voltage magnitude and angle measurements to estimate the system states. These results could be used in several applications of the power system as indicated in Figure 4-1.

This chapter presents a combination of PMU technology with conventional SCADA measurements for WLS, IRLS and WLAVIRLS estimators, which so far has not been attempted in the literature. Results show a considerable reduction in cumulative state estimation error and improvement in estimator efficiency when PMU's are incorporated even in the presence of bad data or loss of data. With the increase in the number of PMU's replacing SCADA meters accuracy and speed of the estimator is increasing.

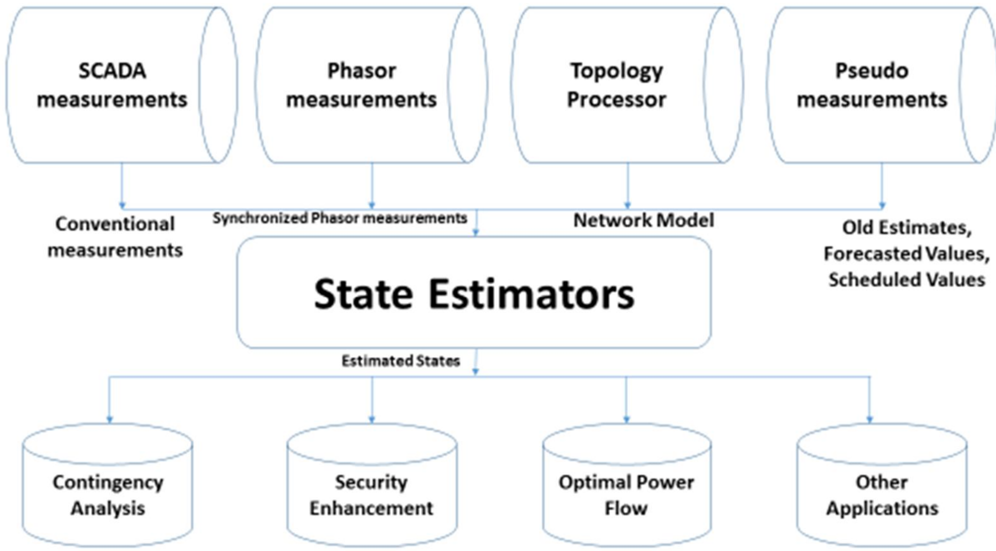

Figure 4-1 Role of State Estimation in Power System Control and Operations with PMU Measurements [69]

SE plays a vital role in today's complex power system to perform corrective actions in the presence of several contingencies. SE is an important tool of energy management system (EMS), it gives estimation of system states based on measurements gathered. Traditionally, input meters are conventional SCADA meters which are unsynchronized. Figure 4-2 explains State estimation process containing network parameters (transmission line reactance, resistance and susceptance), network topology (network connections) and measurements (line power flows, bus injections and voltage magnitude and angles) from substations [76]. WLS is one of the widely adopted estimator at power system control centers [77].

Figure 4-2 Input / Output of Power System State Estimator

which can measure 50/60 Hz waveforms at a rate of (2400 samples per second). The PMU technology provides voltage and current phasors, it provides high precision accuracy by time stamping analog voltage and current. Initially Symmetrical Component Distance Relay (SCDR) was developed for this purpose calculating symmetrical components of current and voltage through a recursive algorithm [33]. PMU placed at different sites were synchronized using Global Positioning System (GPS), difference between phases could be measured with high accuracy and measurement could be accurately time stamped. The biggest advantage using PMU is the synchronization and provides direct angular measurement where PMU is placed.

PMU's have wider applications one of them is state estimation. It uses both SCADA and PMU measurements with state estimation. Conventional SCADA meters are not synchronized that makes state estimation non-precise during dynamic phenomena. With the advent of synchronized PMU's monitoring of dynamic phenomena was made possible. This paper [78] presents the effect of a synchronicity of measurements to the accuracy of the estimator. It counted for two events (load change, topology change) in the system and a synchronicity of input measurements proved to have a bad effect on accuracy of state estimator.

This chapter shows state estimation installing PMU measurements in conjunction with the existing conventional SCADA measurements in the presence of multiple bad data. PMU's synchronization improves accuracy of the estimator, they provide current and voltage phasors, whereas here only voltage magnitude and angle was utilized. It was observed that PMU inclusion reduces considerably high cumulative estimation error. With the increase in number of PMU's replacing conventional SCADA voltage meters at several substations estimation error rapidly decreases. In other words estimation accuracy, convergence, speed and observability of estimators increases with the inclusion of PMU's. All three estimators WLS, IRLS, WLAVIRLS incorporating PMU are discussed here:

4.1 Weighted Least Square Incorporating PMU's

Complex growing power systems require fast, accurate and robust estimators which can withstand certain loss of data and bad error data availability. State estimation of a power system for system operator is a major concern and needs to be accurate in such cases, otherwise wrong decisions made by system operator will lead the system towards abnormalities. In this regard, several estimation techniques are proposed in the literature like WLS.

Estimation algorithms always try to minimize the deviation of estimated from actual measurements. Complex growing power systems require fast, accurate and robust estimators which can withstand certain loss of data and bad error data availability. To improve the performance of Estimators one of the options is to include latest PMU technology with the SCADA measurements to provide more reliable estimates. This section implements PMU's measurements with SCADA measurements to improve performance of WLS state estimation. WLS when combined with PMU technology increases convergence, accuracy, speed, observability of the Estimation capability. The results are tested on 6 bus, IEEE 14 and 30 bus systems. This section tasks could be divided into:

- Implementing WLS estimator, and developing algorithm to incorporate PMU's measurement with SCADA measurement, implementing the modified algorithm.
- Evaluate PMU impact on estimator with bad data errors and loss of data.
- Evaluate increase in number of PMU's reduces estimation error. After a certain number of PMU's error does not reduce, calculating those numbers of PMU's.
- WLS when reached to a level of bad data errors starts to perform poor, observe estimator ability to mitigate such errors in presence of PMU's.

The traditional estimator use traditional SCADA meter readings for power flows, injections, and voltage magnitude. The estimator estimates using [19]:

$$z_1 = h_1(\mathrm{x}) + \mathrm{e}_1 \qquad (4.1)$$

Where h_1 is nonlinear in nature and relates measurements with system states x of vector size (n x 1). z_1 (m x 1) and e_1 (m x 1) are the SCADA measurements and measurement error vector. The condition for system observability is that $m \geq n$ and $h_1(\mathrm{x})$ which is called the Jacobian matrix has rank n.

Weighted least square estimator initializes at flat start for state vector x . Where x_k is the current state of the state vector at kth iteration and x_{k+1} is for the next iteration [19], both can be related using:

$$x_{k+1} = x_k + \Delta x = x_k + [H_1^T R_1^{-1} H_1]^{-1} H_1^T R_1^{-1} [\mathrm{z}_1 - \mathrm{h}_1(\mathrm{x}_k)] \tag{4.2}$$

Where $W_1 = [\mathrm{H}_1^T \mathrm{R}_1^{-1} \mathrm{H}_1]^{-1}$ is the error covariance matrix, Δx represents the measurement mismatch which when reaches to a prescribed low threshold value like: 1e-4 the estimator will terminate the iteration count. After the final iteration V_{SCADA} denoting the converged system states are obtained [69]:

$$V_{SCADA} = x^T = [\delta_2 \delta_3 ... \delta_N |V_1||V_2|...|V_N|] \tag{4.3}$$

So far so concerned only SCADA measurements were used in the estimator, these measurements had the nonlinear relationship with system states (Voltage magnitude and angle) and were solved to obtain the system states. After the invention of accurate PMU meters, direct system state readings were available in the power system. Current estimator algorithms needed to be modified for adding PMU measurement effect. Two methods were introduced:

4.1.1 Mixing PMU With Conventional Measurements In Estimator

As So far conventional SCADA measurements are used for estimation purpose, PMU measurement incorporation could be done in two methods. Either they can be combined with SCADA measurements or PMU measurement can be added as a post estimation process, both have similar estimation improvement. In this thesis first approach is used, where z_2 denoting PMU measurements (voltage magnitudes, voltage angles) are combined with SCADA measurements. The measurement error covariance matrix of z_2 is assumed to be R_2. The new measurement set z is obtained by adding PMU measurements z_2 to the previous conventional measurement vector z_1 .

$$z = \begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = \begin{bmatrix} z_1 \\ V_{PMU\_mag} \\ V_{PMU\_\mathrm{ang}} \end{bmatrix} \tag{4.4}$$

Where, V_{PMU_mag} and V_{PMU_ang} are respective PMU bus voltage magnitude and angle measurements. Let $h_1(\mathrm{x})$ and $h_2(\mathrm{x})$ be the nonlinear equations of SCADA measurements z_1 and PMU measurements z_2 respectively. The updated Jacobian matrix corresponding to the measurement set z will be:

$$H = \begin{bmatrix} H_1 \\ H_2 \end{bmatrix} = \begin{bmatrix} \dfrac{\partial h_1(\mathrm{x})}{\partial x} \\ \dfrac{\partial h_2(\mathrm{x})}{\partial x} \end{bmatrix} \tag{4.5}$$

Accordingly, the WLS state estimation solution proceeds as before and can be written as follows:

$$x_{k+1} = x_k + [\mathrm{H}^T \mathrm{W}^{-1} \mathrm{H}]^{-1} H^T W^{-1} [\mathrm{z} - \mathrm{h}(\mathrm{x}_k)] \tag{4.6}$$

Where, the error covariance matrix of measurement set z is

$$W = \begin{bmatrix} R_1 & 0 \\ 0 & R_2 \end{bmatrix} \tag{4.7}$$

The whole algorithm steps of weighted least square using combination of SCADA and PMU measurements could be summarized as shown in Figure 4-3. It shows the block diagram for iterative weighted least square algorithm incorporating PMU's. Iterative process ends when Δx goes below a threshold value

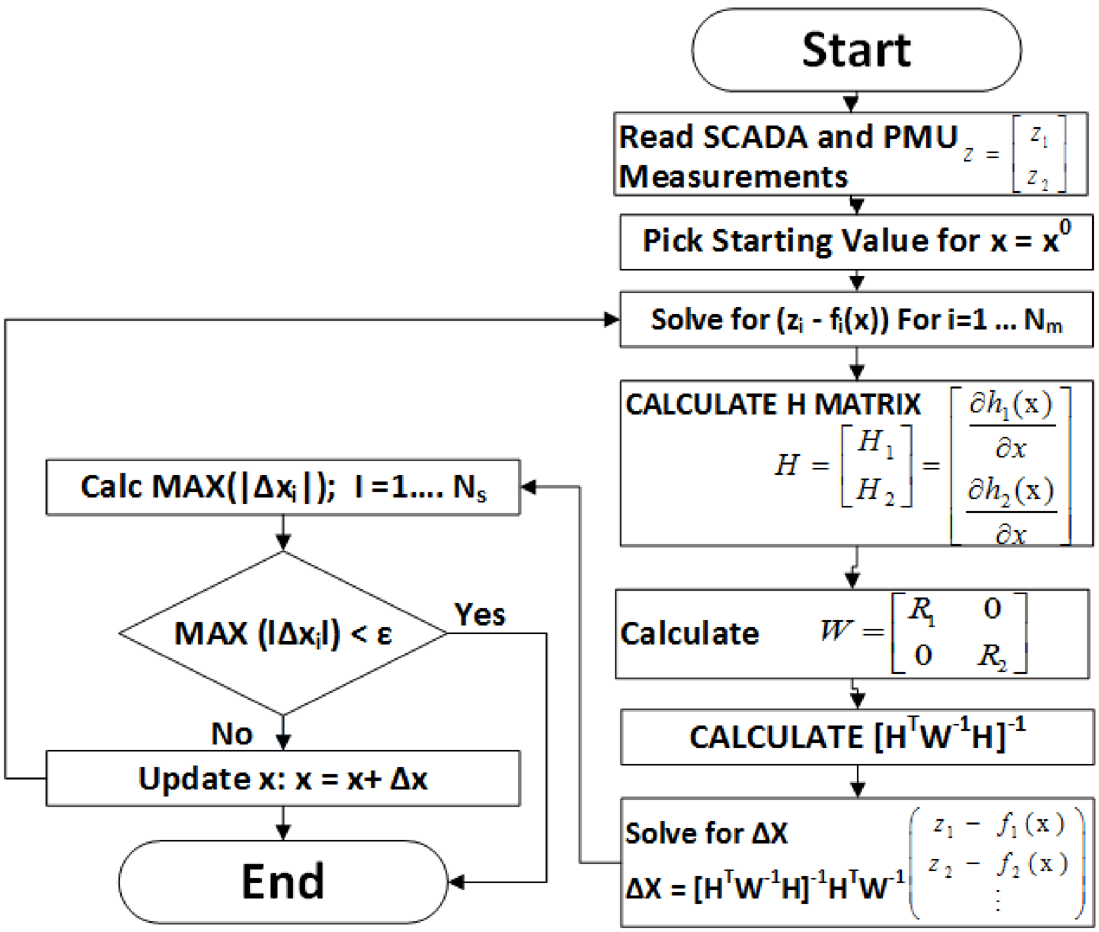

Figure 4-3 Weighted Least Square State Estimator (SCADA and PMU)

WLS performs best with full redundancy and efficiency deteriorates when subjected to loss of data which is due to (insufficient meters placed, power system part disconnected from control center due to transmission line fault). PMU's in such cases help estimator as one PMU on a bus contains more information for voltage, injection of that bus and all line flows connected to that bus, that increased amount of information increases observability of system and performance increases. Estimator performance decreases when subjected to bad data errors, with multiple bad data errors WLS performs very poor. PMU inclusion in such multiple bad data errors performs better and thus efficiency is improved.

4.1.2 Incorporating PMU Measurements Through A Post Processing Step

Both methods are equivalent to one another and obtain the similar estimation results [63]. This second method which was proposed in [63] solves weighted least square initially with SCADA measurements only to obtain system states. PMU measurements are considered in the second stage where all estimated results are considered as pseudo measurements along with PMU's. The first approach was chosen for this thesis, therefore the second approach has not been discussed in detail.

4.2 Iteratively Reweighted Least Square Incorporating PMU's

IRLS works on the principle of iteratively solving the least square sequence with weights are being adjusted in each iteration. In the event of measurements wrongly recorded or missing, those measurements have been given less weight to reduce their effect. IRLS proves to be a robust estimator able to solve single, multiple bad data with loss of certain measurements. Every robust estimator has a threshold point known as the number of multiple bad data, after which estimator accuracy starts to reduce.

PMU provides complex voltage and current information, whereas this thesis considers only the availability of accurate voltage magnitude and angle taken into account. IRLS when in the presence of less accurate SCADA voltage magnitude measurements and a few more accurate PMU voltage magnitude and angle measurements and power flow and injection measurements performs considerably better and have a high threshold breakdown point. IRLS algorithm when incorporated with combination of SCADA and PMU measurements, where z_1 represent SCADA voltage magnitude measurements, z_2 represent PMU voltage magnitude and angle measurements, x are the system states to be estimated.

$$z = \begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = \begin{bmatrix} z_1 \\ V_{PMU\_mag} \\ V_{PMU\_\mathrm{ang}} \end{bmatrix} \tag{4.8}$$

Where, V_{PMU_mag} and V_{PMU_ang} are respective PMU bus voltage magnitude and angle measurements. Let $h_1(\mathrm{x})$ and $h_2(\mathrm{x})$ be the nonlinear equations of SCADA measurements z_1 and PMU measurements z_2 respectively. Residual vectors r will be constituted r_1 for SCADA measurements, r_2 for PMU measurements.

$$r = \begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} z_1 - h_1(\mathrm{x}) \\ z_2 - h_2(\mathrm{x}) \end{bmatrix} \tag{4.9}$$

Jacobian matrix H will be updated constituting H_1 for SCADA and H_2 for PMU measurements.

$$H = \begin{bmatrix} H_1 \\ H_2 \end{bmatrix} = \begin{bmatrix} \dfrac{\partial h_1(\mathrm{x})}{\partial x} \\ \dfrac{\partial h_2(\mathrm{x})}{\partial x} \end{bmatrix} \tag{4.10}$$

Accordingly $W = \begin{bmatrix} R_1 & 0 \\ 0 & R_2 \end{bmatrix}$ is error covariance matrix of measurement set z. IRLS state estimation solution will be iteratively reweighted at every iteration and the updated system states will be:

$$x_{k+1} = x_k + [\mathrm{H}^T \mathrm{W}^{-1} \mathrm{H}]^{-1} H^T W^{-1} [\mathrm{z} - \mathrm{h}(\mathrm{x}_k)] \tag{4.11}$$

4.3 Weighted Least Absolute Value Using IRLS Incorporating PMU's

Weighted least absolute value when formulated as L1 regression problem and solved by IRLS estimator considering the available SCADA measurements for bus voltage magnitude and PMU measurements (voltage magnitude and angle) both, estimator steps becomes easier as direct state variables are given as measurements by PMU's. WLAVIRLS estimator using PMU's all the steps could be summarized as shown in Figure 4-4, where x are the system states to be estimated, z_1 are the SCADA voltage measurements, z_2 are the PMU voltage magnitude and angle measurements, Δx is the iteration step for each iteration.

where z_1 (SCADA measurements) and z_2 (PMU measurements), when combined together $z = \begin{bmatrix} z_1 \\ z_2 \end{bmatrix}$. Residual vectors r combines both r_1 (SCADA measurements residual) and r_2 (PMU measurements residual).

$$r = \begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} z_1 - h_1(\mathrm{x}) \\ z_2 - h_2(\mathrm{x}) \end{bmatrix} \tag{4.12}$$

Jacobian matrix H is formulated with combination of (H_1 for SCADA) and (H_2 for PMU) measurements.

$$H = \begin{bmatrix} H_1 \\ H_2 \end{bmatrix} = \begin{bmatrix} \dfrac{\partial h_1(\mathrm{x})}{\partial x} \\ \dfrac{\partial h_2(\mathrm{x})}{\partial x} \end{bmatrix} \tag{4.13}$$

WLAVIRLS contains outer and inner iterative loop, whereas outer loop is for WLAV forming L1 regression problem and inner loop solves L1 regression problem using IRLS estimator. The termination criteria of WLAV loop will be:

$$\frac{\left\| \Delta x^p \right\|_1}{1 + \left\| x^p \right\|_1} \le tol_{LAV} \tag{4.14}$$

The termination criteria IRLS estimator for solving L1 regression problem will be:

$$\frac{\left\| \Delta x^{q+1} - \Delta x^q \right\|_1}{1 + \left\| \Delta x^q \right\|_1} \le tol_{IRLS} \tag{4.15}$$

Where Δx^p is the iteration step obtained at pth iteration, IRLS initializes iteration step $\Delta x^p = 0$ at the start of every L1 regression problem. The system states (voltage magnitude and angles) are updated at every iteration using the Δx^p obtained from IRLS estimator ($x^{p+1} = x^p + \Delta x^p$).

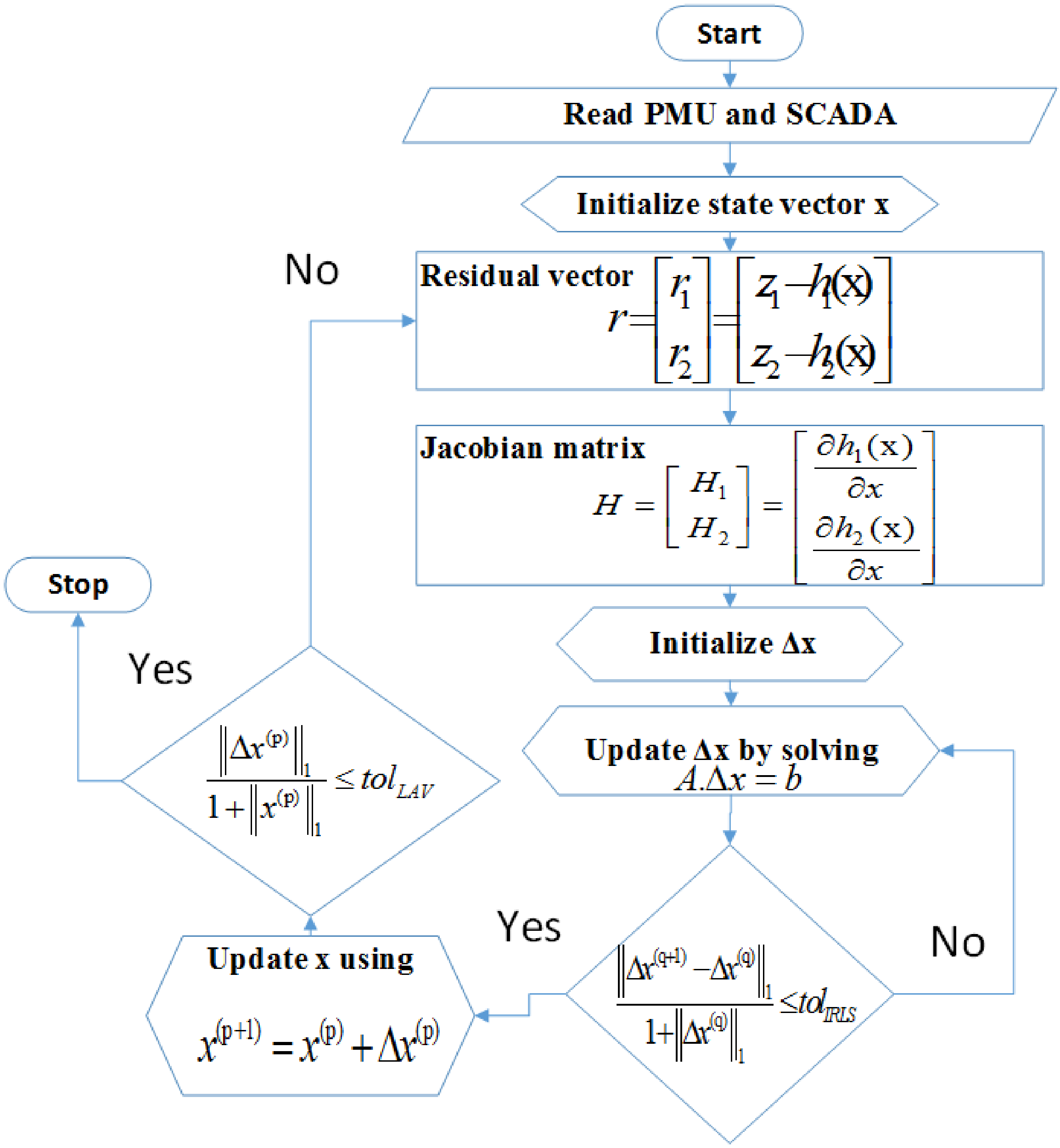

Figure 4-4 WLAV Using IRLS State Estimator (SCADA with PMU)

CHAPTER 5

Optimum PMU Placement and number of PMU's

PMU meters are expensive than conventional meters, Due to such economic constraint power companies placed PMU's in gradual phases in power system [79]. Optimal PMU placement (OPP) was thus introduced locating a minimum number of buses where PMU needs to be placed to obtain full system observability.

In this thesis combination of PMU with conventional SCADA measurements has been adopted. This chapter provides an insight of optimum PMU placement algorithms, where section 5.1 elaborates basic OPP algorithm and section 5.2 provides the implementation of heuristic approach for optimum PMU placement.

5.1 Heuristic PMU Placement Algorithm

PMU's are too expensive to be used at every bus on a very large complex power system, instead one can use fewer number of PMU's with desired level of accuracy and convergence by the utilities. In literature several techniques are used with certain claims of improved accuracy level. In this thesis, heuristic OPP have been implemented for improving state estimation accuracy. Heuristic technique search all candidate buses and tries to find minimum number of PMU's and optimal location as well.

In this thesis 6 Bus, IEEE 14 and IEEE 30 as test cases have been considered. Assume Utilities have m available PMU's for deployment in n bus power system utilities where $m > n$ holds. Every bus can have maximum of single PMU to be deployed, after each PMU deployment state estimation is performed to obtain system states ($|V|, \delta$).

At each step estimator accuracy is evaluated in terms of Mean absolute percentage error ($MAPE_{avg}$):

$$MAPE_{avg} = (MAPE_{V_{mag}} + MAPE_{V_{del}})/2 \tag{5.1}$$

$$MAPE_{V_{mag}} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{|V(\mathrm{t})|_{act} - |V(\mathrm{t})|_{est}}{|V(\mathrm{t})|_{est}}\right| \times 100\% \tag{5.2}$$

$$MAPE_{V_{del}} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{\delta(\mathrm{t})_{act} - \delta(\mathrm{t})_{est}}{\delta(\mathrm{t})_{est}}\right| \times 100\% \tag{5.3}$$

$MAPE_{V_{mag}}$ and $MAPE_{V_{del}}$ represents MAPE values of voltage magnitude and angle and are given weight of 0.5 for $MAPE_{avg}$ calculation. $|V(\mathrm{t})|_{act}$ and $|V(\mathrm{t})|_{est}$ represent actual and estimated voltage magnitude, where $\delta(\mathrm{t})_{act}$ and $\delta(\mathrm{t})_{est}$ represent actual and estimated voltage angles for bus t .

In problem formulation Bus 1 has been chosen as the reference bus and have placed a single PMU to provide reference for other buses. PMU placed on bus 1 will not be counted in PMU placement problem. Remaining are $n-1$ buses and m available PMU's to be placed in the power system. Total number of possible places for placement of PMU's will be:

$$P_{n-1}^{m} = (\mathrm{n}-1)(\mathrm{n}-2)...(\mathrm{n}-m) = \frac{(\mathrm{n}-1)!}{(\mathrm{n}-m-1)!} \tag{5.4}$$

$MAPE_{avg}$ indicates the accuracy level of estimation, lower value indicates higher accuracy and higher value reflects lower accuracy. With every placement of PMU from m available PMU's has $MAPE_{avg}$ value. For every loop the bus location with the least $MAPE_{avg}$ will be selected as the optimal place for the next available PMU. Heuristic OPP algorithm solves above placement problem, all the steps in the algorithm are elaborated in a single block diagram Figure 5-1. There are certain variables used in the Algorithm. Z_{ori} (vector of original measurements), Z (measurement vector with noise), m (number of available PMU's), Ri_{ori} (vector of original measurement error variance), Ri (measurement error variance vector), $BuswithPMU$ (Vector of bus numbers having PMU's placed already), $AllBus$ (all candidate bus numbers vector), $BusToPlace$ ($AllBus - BuswithPMU$ vector of bus number where PMU's will be placed), Num ($BusToPlace$ vector length), $BusNum$ (bus number where PMU will be placed), $KnownPMUBus$ ($BuswithPMU$ union $BusNum$), $MAPE\_array$ (vector containing $MAPE_{avg}$ values of state estimation).

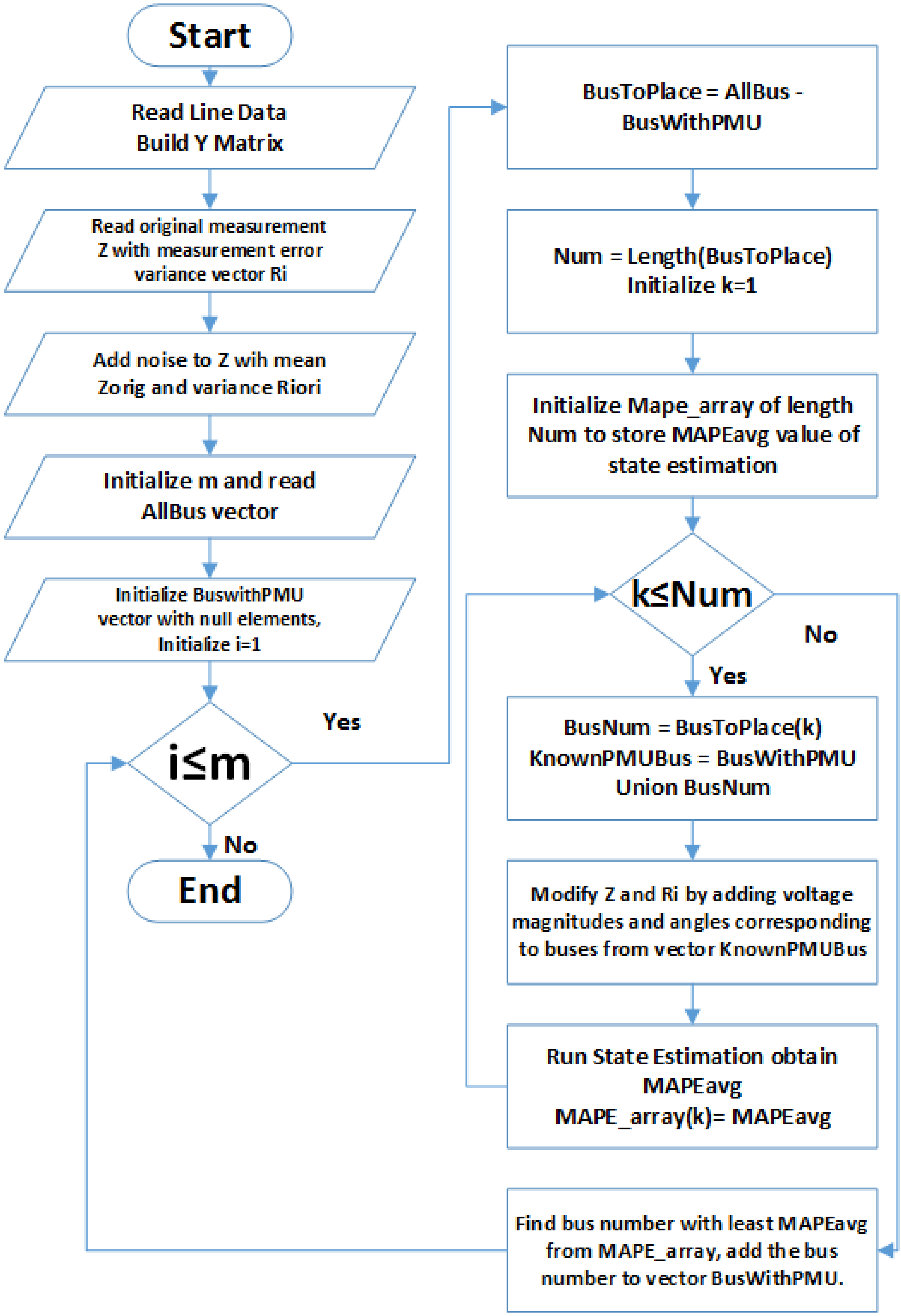

Figure 5-1 Heuristic PMU Placement Algorithm

CHAPTER 6

RESULTS AND DISCUSSION

In this chapter results are presented and simulation are carried out. WLS, IRLS and WLAVIRLS estimators are compared in terms of accuracy. Results show with the increase in the number of measurement estimator accuracy is improved as full redundancy performs better than partial redundancy. Power system when subjected to single, multiple bad data errors degrades estimator performance and accuracy is severely affected. Solution to such problem is the addition of PMU's in power system. Further on heuristic Optimum PMU Placement (OPP) algorithm is implemented for IEEE 14 Bus, IEEE 30 Bus and results are discussed. All codes were written in MATLAB 2013 platform.

In this thesis simulations were carried out on 6 bus, IEEE 14 and 30 bus test systems. The statistics of the test bus systems for two cases considered as full redundancy and low redundancy are provided in (Table 6-1 and Table 6-2). Full redundancy is a test case scenario where maximum number of possible measurement meters are placed in the system. For low or partial redundancy less number of measurements are placed, it contains sufficient SCADA measurements to make system observable. Redundancy is indicated by the ratio of actual number of measurement placed to maximum measurements could be placed $\rho = \frac{m}{2*(n-1)}$.

Table 6-1: Full Redundancy Test Systems

# of buses	6 Bus	IEEE 14 Bus	IEEE 30 Bus
# of lines	11	20	41
# of Real power flow measurements from side	11	20	41
# of Real power flow measurements to side	11	20	41
# of Reactive power flow measurements from side	11	20	41
# of Reactive power flow measurements to side	11	20	41
# of Real injection measurements	6	14	30
# of Reactive injection measurements	6	14	30
# of voltage magnitude measurements	6	14	30
# of voltage angle measurements	6	14	30
Total measurements	68	136	284

Table 6-2: Partial Redundancy Test Systems

# of buses	6 Bus	IEEE 14 Bus	IEEE 30 Bus
# of lines	11	20	41
# of Real power flow measurements from side	7	12	21
# of Real power flow measurements to side	1	12	21
# of Reactive power flow measurements from side	7	12	21
# of Reactive power flow measurements to side	1	12	21
# of Real injection measurements	5	14	28
# of Reactive injection measurements	5	14	28
# of voltage magnitude measurements	2	10	12
# of voltage angle measurements	2	10	12
Total measurements	30	96	164
Redundancy Ratio	$\rho = 2.72$	$\rho = 3.55$	$\rho = 2.77$

Table 6-1 and Table 6-2 show the type of measurements that could be placed in power system (real and reactive power flow meter on transmission line, real and reactive power injection meter on buses, PMU measurement for voltage magnitude and angle on buses). Considering 6 bus the maximum measurement that could be placed in the system is 68, and distribution of measurements is explained in Table 6-1 and Table 6-2.

The Comparison was carried out between three estimation techniques WLS (minimized the sum of square residuals [19]), IRLS (an iterative process that converges to a L1 regression problem solution if properly initialized [27]), WLAVIRLS (WLAV objective function solved using IRLS estimator for L1 regression problem [16]).

6.1 6 Bus System

The power system 6 bus Figure 6-1 is taken for consideration. All three estimators were applied to the same 6 bus system configuration where estimator performance comparison between three widely used estimators (WLS, IRLS and WLAVIRLS) showing LAV using IRLS achieved the best results with lowest cumulative estimation error. All the bus and line data is given in (Table A-1, Table A-2). The estimated values for six bus system for (partial redundancy case) for WLS, IRLS and WLAVIRLS estimators are presented in Table B-2.

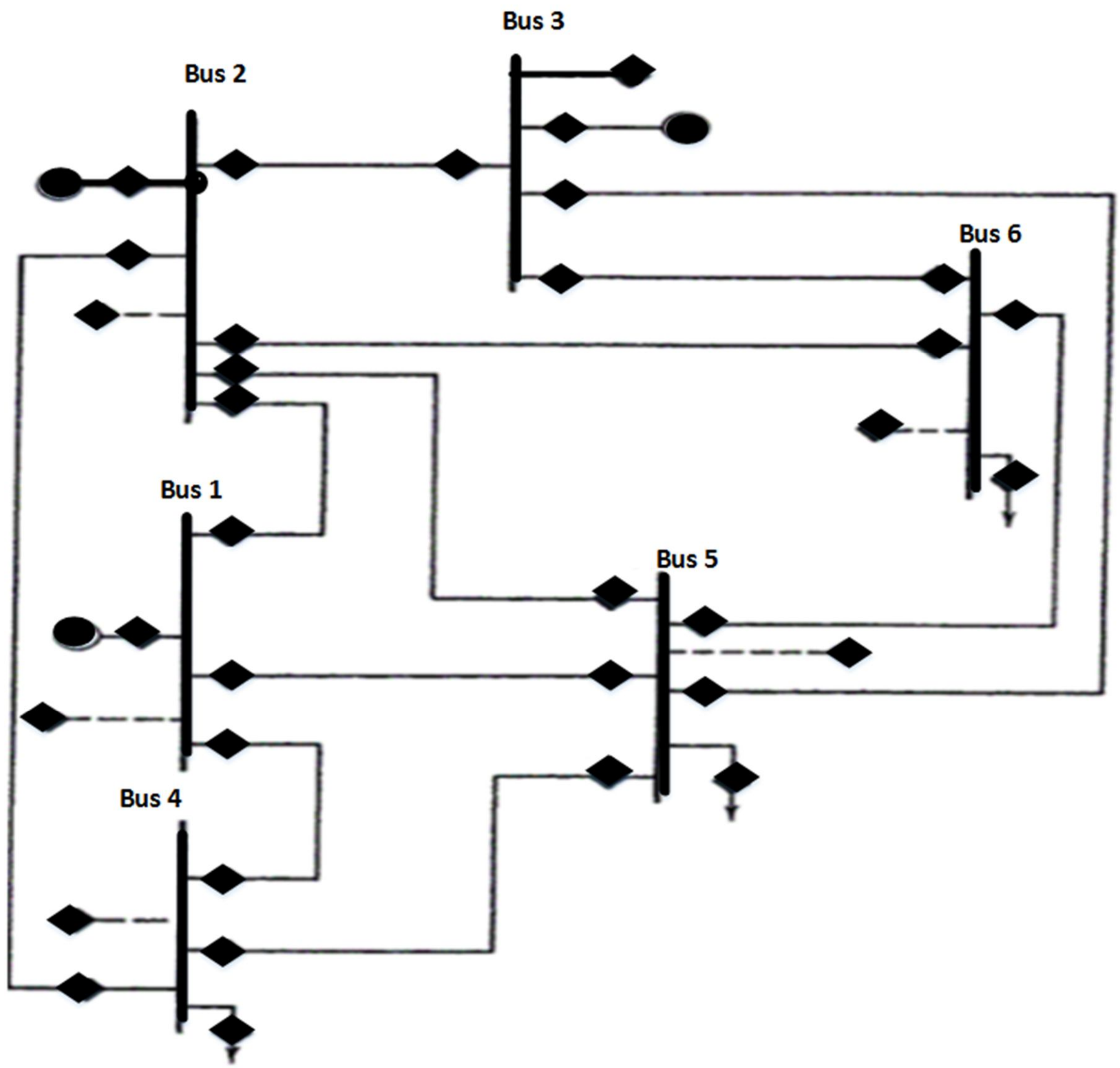

Figure 6-1: 6 Bus System from [72]

6.1.1 Measurement Redundancy

In Table 6-3 for cumulative summation error shows two different cases (Full and partial redundancy) for all estimators separately. Estimated values for each line flow, injection, load and voltages of buses are stated in **Error! Reference source not found.**. Results indicate that with the decrease in available number of measurement accuracy of all estimators decrease and estimation error increases. Measurement redundancy significantly impacts the quality of state estimation solution.

Table 6-3 6 Bus Cumulative Estimation Error Redundancy Comparison

Estimator	Full Redundancy	Partial redundancy
WLS	0.0190606	0.123908
IRLS	0.0134518	0.016842
WLAVIRLS	0.0134516	0.014568

6.1.2 Optimum PMU Placement Naïve Approach

For accuracy one can increase the number of measurements or can replace existing weak meters by more accurate Phasor measurement units (PMU's). Due to limited available PMU's efficient optimum PMU placement strategy is required. PMU's provide complex voltage and current measurements, whereas in this thesis only complex voltage is considered. The estimator will give the least cumulative estimation error with the inclusion of PMU's. The optimal PMU placement is considered when only two PMU's are available. The first PMU is placed on the slack bus and provides reference for voltage magnitude for other, whereas second PMU placement is optimally selected. Table 6-4 shows the bus number 2 location as optimal (least cumulative estimation error).

Table 6-4: 6 Bus Cumulative Optimum PMU Placement for Full Redundancy (Naive Approach)

Location of PMU	Cumulative estimation error
No PMU	0.0717
Bus1	0.07126
Bus2	0.0431
Bus3	0.06
Bus4	0.0725
Bus5	0.07499
Bus6	0.06807

6.1.3 Optimum PMU Placement Heuristic Approach

Heuristics involve more detailed analysis and produces more better optimum PMU placement (OPP) sequence for power system. The main goal of this thesis is to enhance the accuracy of the available robust estimators. With the placement of PMU's accuracy is increased, whereas optimal placement of PMU's enhance the accuracy more.

Table 6-5: 6 Bus WLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error
1	6.707540415
1,5	5.162895179
1,5,3	4.534612164
1,5,3,6	2.800258548
1,5,3,6,4	2.393728598
1,5,3,6,4,2	0.002768594

Table 6-6: 6 Bus WLS - Heuristic OPP (Partial Redundancy) With Single Error (P1 Reversed)

Location	Cumulative estimation error
1	13.01398509
2,1	8.934910526
5,2,1	6.27972433
4,5,2,1	2.480744532
6,4,5,2,1	2.166575238
3,6,4,5,2,1	0.002442049

Table 6-7: 6 Bus IRLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error
1	0.027124828
4,1	0.024703212
6,4,1	0.022401328
3,6,4,1	0.012282659
2,3,6,4,1	0.011581208
5,2,3,6,4,1	0.012902065

Table 6-8: 6 Bus IRLS - Heuristic OPP (Partial Redundancy) With Single Error (P2 Reversed)

Location	Cumulative estimation error
1	0.17721714
4,1	0.141590235
2,4,1	0.077106704
6,2,4,1	0.036241279
5,6,2,4,1	0.03308061
3,5,6,2,4,1	0.027796257

Table 6-9: 6 Bus WLAVIRLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error
1	0.007609248
1,2	0.007026864
1,2,5	0.006377525
1,2,5,4	0.006100683
1,2,5,4,6	0.00735359
1,2,5,4,6,3	0.008736803

Table 6-10: 6 Bus WLAVIRLS - Heuristic OPP (Partial Redundancy) With Single Error (P3 Reversed)

Location	Cumulative estimation error
1	0.034767106
1,4	0.034254694
1,4,5	0.034025174
1,4,5,3	0.033844458
1,4,5,3,2	0.032143286
1,4,5,3,2,6	0.030031997

Table 6-5 to Table 6-10 represents the partial redundancy case for 6 bus power system with six available PMU's for placement for WLS, IRLS and WLAVIRLS. With the change of estimator optimum PMU placement location is altered. These tables also conclude that including a single bad data error will completely alter the optimum PMU placement sequence. After a certain number of PMU's estimation error becomes almost constant that is the economic threshold number of PMU's to place, which is also varying in all tables.

This observation concludes all Optimum PMU placement strategies, algorithms and optimum place for PMU are totally system dependent. Any change in system data (redundancy level changed, single error happened) will completely alter the optimal placement sequence.

6.1.4 PMU Incorporation Effect

Results indicate that cumulative estimation error is greatly reduced with the inclusion of PMU's replacing weak voltage meters shown in Table 6-11 (Partial redundancy with single bad data. It shows the performance of WLS, IRLS and WLAVIRLS estimators comparing two cases (all buses with SCADA measurements only, combination of PMU'S and SCADA used). It shows estimator performance for 6 bus system having partial redundancy and single error. Total two PMU's are placed at bus number 1 and 2 for SCADA and PMU case. For Table 6-11 estimated values for line flows, injections, load and voltages for SCADA only case and SCADA with PMU case are given in comparison in Table B-3.

Table 6-11 6 Bus PMU Incorporation Effect on Accuracy

Estimator	SCADA only	SCADA and PMU
WLS	0.123908	0.015992
IRLS	0.016842	0.01466
WLAVIRLS	0.014568	0.014659

6.1.5 Bad Data Error Effect

This section discusses the case having full redundancy, where single, double non-interacting and double interacting bad data were introduced into the power system by reversing the polarity of the adjacent measurements to create a bad data error. Different types of bad data (line, generation, and voltage magnitude error) were tried for 6 bus system using WLS estimator. These bad data errors were either single or double i.e. (line error on single location, line error on two locations).

Table 6-12 to Table 6-14 show the cumulative estimation error for WLS, IRLS and WLAVIRLS respectively for partial redundancy having single, double non-interacting and double interacting errors without any PMU, whereas estimated values of line flows, injections, loads and bus voltages are given in (Table B-4 to Table B-12). Table 6-15 to Table 6-17 presents the cumulative estimation error using heuristic optimum PMU placement for case where combination of SCADA and PMU is used. For SCADA and PMU case total two PMU's were placed on bus 1 and 2. Estimated values of line flows, injections, loads and bus voltages are given in (Table B-13 to Table B-21). Bad data errors that were generated are also mentioned in the tables i.e. (L4-5, G1, Vm6).

This section conclude PMU placement reduces cumulative estimation error in the presence of single, double non-interacting and interacting errors for WLS, IRLS and WLAVIRLS estimators. For WLS the case of partial redundancy having single generation error on bus 1 (by reversing the polarity of the generation measurement) has cumulative estimation error of 4.651, whereas by including two PMU's that cumulative estimation error is reduced to 0.00265. For the case of partial redundancy having double non-interacting generation error on bus 1 and 3 cumulative estimation error was 10.42, whereas two PMU's inclusion reduced cumulative estimation error to 0.00547. For double interacting error on bus 2 and 3, cumulative estimation error is 11.43, which when two PMU's added reduces to 0.0065. Same observation could be seen for IRLS and WLAVIRLS, where cumulative estimation error is reduced with the inclusion of PMU's.

Table 6-12: 6 Bus WLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L4-5	0.104	G1	4.651	Vm6	3.169
Double Non Interacting	(L1-4 | L2-3)	0.728	(G1 | G3)	10.424	(Vm3 | Vm4)	3.670
Double Interacting	(L1-4 | L1-5)	0.831	(G2 | G3)	11.437	(Vm3 | Vm6)	6.356

Table 6-13: 6 Bus IRLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L4-5	0.010	G1	4.724	Vm6	2.194
Double Non Interacting	(L1-4 | L2-3)	0.726	(G1 | G3)	10.482	(Vm3 | Vm4)	3.504
Double Interacting	(L1-4 | L1-5)	0.832	(G2 | G3)	11.352	(Vm3 | Vm6)	4.463

Table 6-14: 6 Bus WLAVIRLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L4-5	0.289	G1	0.314	Vm6	0.291
Double Non Interacting	(L1-4 | L2-3)	0.303	(G1 | G3)	0.535	(Vm3 | Vm4)	0.295
Double Interacting	(L1-4 | L1-5)	0.309	(G2 | G3)	0.650	(Vm3 | Vm6)	0.295

Table 6-15: 6 Bus WLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L4-5	0.002197	G1	0.00265	Vm6	0.28495
Double Non Interacting	(L1-4 | L2-3)	0.002199	(G1 | G3)	0.00547	(Vm3 | Vm4)	0.41950
Double Interacting	(L1-4 | L1-5)	0.002207	(G2 | G3)	0.00640	(Vm3 | Vm6)	1.16167

Table 6-16: 6 Bus IRLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L4-5	0.00220	G1	0.00226	Vm6	0.00616
Double Non Interacting	(L1-4 | L2-3)	0.00220	(G1 | G3)	0.00501	(Vm3 | Vm4)	0.01140
Double Interacting	(L1-4 | L1-5)	0.00223	(G2 | G3)	0.00609	(Vm3 | Vm6)	0.14931

Table 6-17: 6 Bus WLAVIRLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L4-5	0.01573	G1	0.18308	Vm6	0.00734
Double Non Interacting	(L1-4 | L2-3)	0.09150	(G1 | G3)	0.34763	(Vm3 | Vm4)	0.01156
Double Interacting	(L1-4 | L1-5)	0.15784	(G2 | G3)	0.48965	(Vm3 | Vm6)	0.01228

6.2 IEEE 14 Bus System

The power system IEEE 14 bus Figure 6-2 is taken for consideration. WLS, IRLS, WLAVIRLS were implemented on the IEEE 14 bus system configuration. WLAVIRLS produced the lowest cumulative estimation error, where IRLS produced second lowest and WLS produced the highest. All the bus and line data is given in (Table A-3, Table A-4). The estimated values for IEEE 14 bus system for (partial redundancy case) for WLS, IRLS and WLAVIRLS estimators are presented in Table B-22.

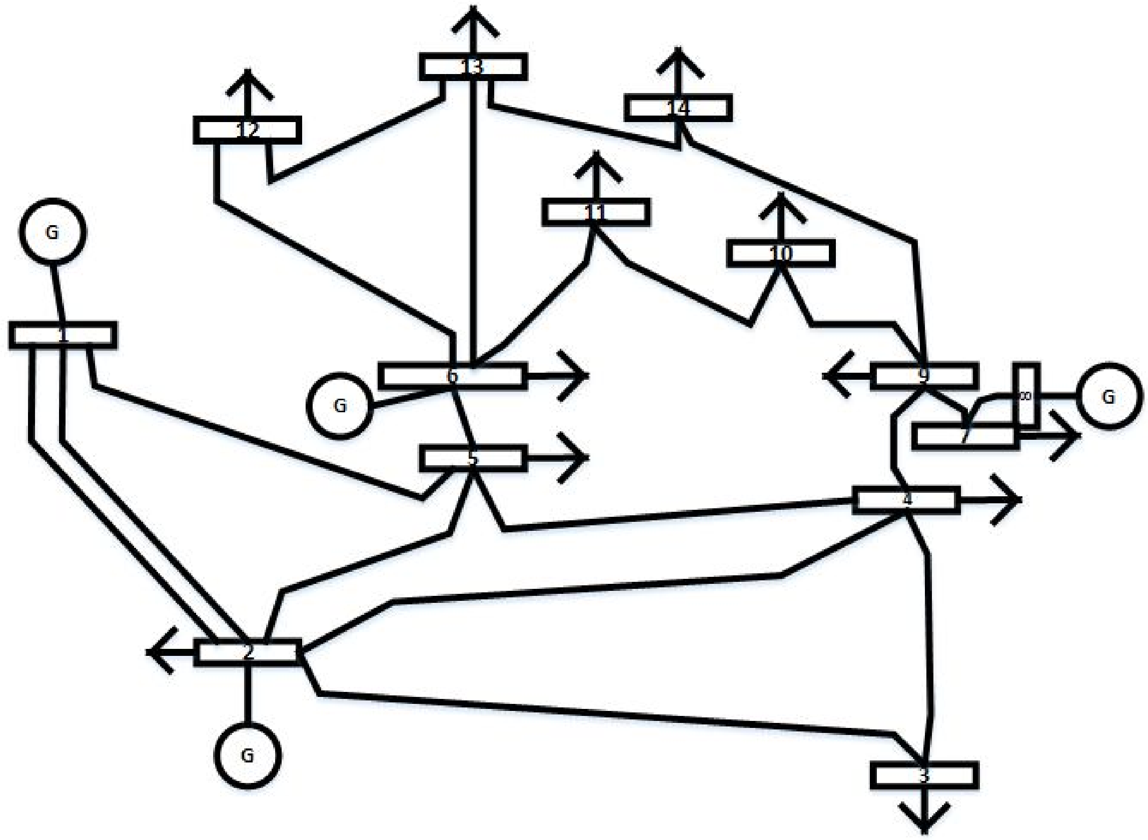

Figure 6-2 IEEE 14 Bus System

6.2.1 Measurement Redundancy

Redundancy is the key towards the higher accuracy of the state estimator, but it comes with the loss of money by placing extra measurement meters in the system, which is not the best option for utilities. In Table 6-18 two different cases (Full and partial redundancy) cases are taken for (WLS, IRLS, WLAVIRLS) estimators, whereas full redundancy produces better estimation results. WLAVIRLS producing the best estimation results by having the least cumulative estimation error.

Table 6-18 14 Bus Cumulative Estimation Error Redundancy Comparison

Estimator	Full Redundancy	Partial redundancy
WLS	0.196253	0.213538

IRLS	0.008892	0.008282
WLAVIRLS	0.008133	0.007886

6.2.2 Optimum PMU Placement Naïve Approach

PMU's are costly and efficient usage requires less number of PMU's to be used to obtain sufficient accuracy. Optimum PMU placement approach uses the principle to place the PMU on each bus and the bus producing the least cumulative estimation error is the optimal place for PMU shown in Table 6-19. The optimal PMU placement is considered for two available PMU's out of which one is placed on slack bus and the other location is optimally selected having the least estimation error from actual values. Table 6-19 shows location on bus number 14 as the optimal place for second PMU placement for IEEE 14 bus system.

Table 6-19: 14 Bus Cumulative Optimum PMU Placement for Full Redundancy (Naive Approach)

Location of PMU	Cumulative estimation error	Location of PMU	Cumulative estimation error
No PMU	1.8497	Bus8	1.8493
Bus1	1.8769	Bus9	1.8877
Bus2	1.849	Bus10	1.8492
Bus3	1.8891	Bus11	1.8504
Bus4	1.8543	Bus12	1.8779
Bus5	1.8432	Bus13	1.8835
Bus6	1.8491	Bus14	1.8432
Bus7	1.8741		

6.2.3 Optimum PMU Placement Heuristic Approach

Heuristics involve more detailed analysis. Table 6-20 to Table 6-25 shows with the inclusion of PMU's cumulative estimation error reduces. With the inclusion of each PMU in power system, OPP heuristic algorithm is ran again and the best optimal location for the next available PMU is determined. As in these tables could be seen first PMU is always placed on slack bus (bus 1). In Table 6-20 OPP heuristic algorithm indicates the best optimal place for second PMU is bus 11 which is giving the least estimation error. After 6th PMU is placed in the system, if more PMU's are incorporated in the system cumulative estimation error is not considerably reduced further.

From Table 6-20 to Table 6-21 represents WLS estimator cumulative estimation error for (partial redundancy, and partial redundancy with single error). These tables prove that if any system parameter is changed or if some bad data error is included in the system OPP sequence will change. From Table 6-22 to Table 6-23 represents IRLS estimator performance for the same two cases and the same conclusion could be obtained that OPP sequence is totally system dependent. From

Table 6-24 to Table 6-25 represents results for WLAVIRLS estimator for same two cases.

After these observations it is concluded that all Optimum PMU placement strategies and algorithms are totally system dependent. Any change in system data (redundancy level changed, single error happened) or estimator (WLS, IRLS, WLAVIRLS) or any network parameter alters will completely change the optimal placement sequence. With the increase in number of PMU's replacing weak bus voltage meter estimation error reduces and after a certain number of PMU's estimation error becomes almost constant.

Table 6-20: 14 Bus WLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error
1	6.629328832
1,11	6.117450238
1,11,9	5.837612164
1,11,9,14	4.670342747
1,11,9,14,2	3.512393729
1,11,9,14,2,7	2.008229475
1,11,9,14,2,7,13	1.689454363

1,11,9,14,2,7,13,12	1.007594759

Table 6-21: 14 Bus WLS - Heuristic OPP (Partial Redundancy) With Single Error (P3 Reversed)

Location	Cumulative estimation error
1	12.73973283
1,9	12.1323823
1,9,13	10.63292717
1,9,13,2	9.756034824
1,9,13,2,3	9.129431021
1,9,13,2,3,4	8.894673532
1,9,13,2,3,4,14	7.450735735
1,9,13,2,3,4,14,12	7.845654646

Table 6-22: 14 Bus IRLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error
1	0.009683082
1,11	0.00845739
1,11,14	0.008304587
1,11,14,9	0.007683653
1,11,14,9,12	0.007082035
1,11,14,9,12,7	0.006957139
1,11,14,9,12,7,2	0.006849622
1,11,14,9,12,7,2,8	0.00676165

Table 6-23: 14 Bus IRLS - Heuristic OPP (Partial Redundancy) With Single Error (P3 Reversed)

Location	Cumulative estimation error
1	0.090852516
1,3	0.01630435
1,3,9	0.015510884
1,3,9,5	0.01062619
1,3,9,5,2	0.008333801
1,3,9,5,2,14	0.008295989
1,3,9,5,2,14,11	0.00818644
1,3,9,5,2,14,11,7	0.007990133

Table 6-24: 14 Bus WLAVIRLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error
1	0.008446356
1,4	0.008321842
1,4,2	0.008214589
1,4,2,11	0.00807947
1,4,2,11,8	0.007862973
1,4,2,11,8,10	0.007708499
1,4,2,11,8,10,14	0.006935681
1,4,2,11,8,10,14,3	0.007126981

Table 6-25: 14 Bus WLAVIRLS - Heuristic OPP (Partial Redundancy) With Single Error (P3 Reversed)

Location	Cumulative estimation error
1	0.01213786
1,12	0.011130362
1,12,3	0.010455878
1,12,3,7	0.010345101
1,12,3,7,6	0.01015747
1,12,3,7,6,9	0.009884186
1,12,3,7,6,9,4	0.009693302
1,12,3,7,6,9,4,10	0.011230003

6.2.4 PMU Incorporation Effect

Results indicate that cumulative estimation error is greatly reduced with the inclusion of PMU's replacing weak voltage meters shown in Table 6-26 (partial redundancy with single bad data). These tables shows the performance of all three estimators comparing two cases (SCADA only, SCADA with PMU's). It shows performance for 14 bus system having partial redundancy and single error, Total ten PMUs were placed at (1 to 10) buses for SCADA and PMU case. Total two PMU's are placed at bus number 1 and 2 for SCADA and PMU case. For Table 6-26 estimated values for line flows, injections, loads and voltages for SCADA only case and SCADA with PMU case are given in comparison in Table B-23.

Table 6-26 14 Bus PMU Incorporation Effect on Accuracy

Estimator	SCADA only	SCADA and PMU
WLS	0.213538	0.010424
IRLS	0.008282	0.008838
WLAVIRLS	0.007886	0.007875

6.2.5 Bad Data Error Effect

This section represents partial redundancy case for WLS, IRLS and WLAVIRLS respectively. Different types of bad data error (line, generation, and voltage magnitude error) were added in power system by reversing the polarity of the certain measurement i.e. (L4-5, G1, Vm6). Single, double non-interacting and double interacting bad data were introduced with SCADA only and with combination of SCADA and PMU.

Table 6-27 to Table 6-29 show the cumulative estimation error for WLS, IRLS and WLAVIRLS respectively for partial redundancy having single, double non-interacting and double interacting errors without any PMU, whereas estimated values of line flows, injections, loads and bus voltages are given in (Table B-24 to Table B-32). Table 6-30 to Table 6-32 presents the cumulative estimation error using heuristic optimum PMU placement for case where combination of SCADA and PMU is used. For SCADA and PMU case total eight PMU’s were placed on bus (1, 9, 13, 2, 3, 4, 14, 12). Estimated values of line flows, injections, loads and bus voltages are given in (Table B-33 to Table B-41). Bad data errors that were generated are also mentioned in the tables i.e. (L4-5, G1, Vm6).

These results prove that, cumulative estimation error is greatly reduced with the inclusion of PMU’s in the presence of single, double non-interacting and interacting errors for WLS, IRLS and WLAVIRLS estimators. If we consider Table 6-27 WLS estimator was used and cumulative estimation error was (9.54, 15.78, 23.70) for single, double non-interacting and interacting errors respectively. With the inclusion of eight PMU's on bus (1, 9, 13, 2, 3, 4, 14, 12), cumulative estimation is reduced to (0.03, 0.28, 0.79) for single, double non-interacting and interacting errors respectively. For IRLS, WLAVIRLS there is also great reduction in cumulative estimation error with the inclusion of ten PMU's.

Table 6-27: 14 Bus WLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.528	G4	1.064	Vm12	9.542
Double Non Interacting	(L6-11 | L7-9)	0.836	(G3 | G8)	2.274	(Vm10 | Vm14)	15.785
Double Interacting	(L4-5 | L4-7)	1.921	(G1 | G2)	9.558	(Vm13 | Vm14)	23.704

Table 6-28: 14 Bus IRLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.718	G4	1.148	Vm12	0.012
Double Non Interacting	(L6-11 | L7-9)	0.851	(G3 | G8)	2.433	(Vm10 | Vm14)	0.016
Double Interacting	(L4-5 | L4-7)	1.988	(G1 | G2)	10.077	(Vm13 | Vm14)	0.076

Table 6-29: 14 Bus WLAVIRLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.924	G4	1.041	Vm12	0.898
Double Non Interacting	(L6-11 | L7-9)	1.025	(G3 | G8)	1.032	(Vm10 | Vm14)	0.991
Double Interacting	(L4-5 | L4-7)	1.123	(G1 | G2)	1.475	(Vm13 | Vm14)	1.193

Table 6-30: 14 Bus WLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.01061	G4	0.01205	Vm12	0.03015
Double Non Interacting	(L6-11 | L7-9)	0.01227	(G3 | G8)	0.01232	(Vm10 | Vm14)	0.28099
Double Interacting	(L4-5 | L4-7)	0.01231	(G1 | G2)	0.01213	(Vm13 | Vm14)	0.79232

Table 6-31: 14 Bus IRLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.00843	G4	0.00774	Vm12	0.00840
Double Non Interacting	(L6-11 | L7-9)	0.01056	(G3 | G8)	0.01228	(Vm10 | Vm14)	0.01136
Double Interacting	(L4-5 | L4-7)	0.01098	(G1 | G2)	0.01038	(Vm13 | Vm14)	0.12146

Table 6-32: 14 Bus WLAVIRLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.15873	G4	0.30730	Vm12	0.13824
Double Non Interacting	(L6-11 | L7-9)	0.34823	(G3 | G8)	0.47153	(Vm10 | Vm14)	0.16911
Double Interacting	(L4-5 | L4-7)	0.29811	(G1 | G2)	0.47779	(Vm13 | Vm14)	0.21242

6.3 IEEE 30 Bus System

The power system IEEE 30 bus Figure 6-3 was taken as the test case. Thesis simulations were run on this test bus system and similar results were found as in the previous section. Partial redundancy case when tested on all three estimators, WLAVIRLS and IRLS performs extraordinary, whereas WLS perform poor. All the bus and line data is given in (Table A-5, Table A-6). The estimated values for IEEE 30 bus system for (partial redundancy case) for WLS, IRLS, WLAVIRLS estimators are presented in Table B-42.

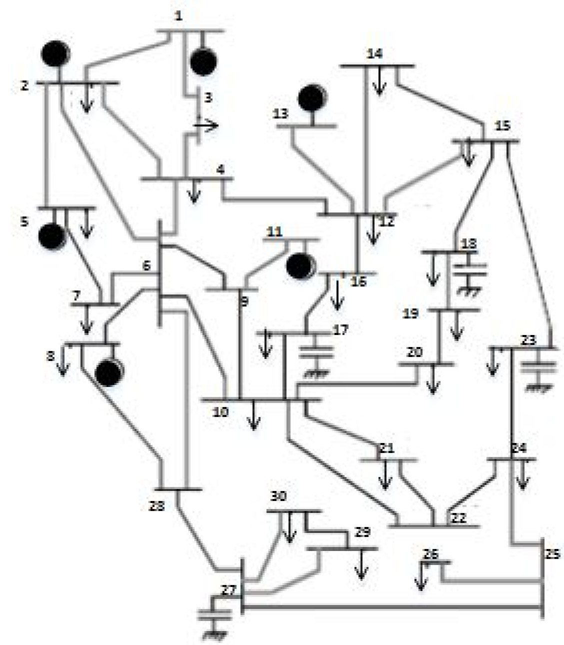

Figure 6-3 IEEE 30 Bus System

6.3.1 Measurement Redundancy

Power system with very expensive protection equipment requires an estimator which must be very accurate. With the increase in the number of available measurements it becomes easier for the estimator to estimate more accurate values of the state variables (voltage magnitude and angle). Redundancy increases accuracy but with the expense of money. In Table 6-33 two different cases (Full Redundancy, partial redundancy) are elaborated to show that full redundancy increases the accuracy.

Table 6-33 30 Bus Cumulative Estimation Error Redundancy Comparison

Estimator	Full Redundancy	Partial redundancy
WLS	0.449580189	3.274436621

IRLS	0.039463641	0.043463146
WLAVIRLS	0.029934705	0.030848885

6.3.2 Optimum PMU Placement Naïve Approach

Transmission companies can't afford the higher number of measurements in the power system. Although another alternative for getting higher accuracy of the estimator is the optimal placement of PMU's replacing SCADA measurements. Optimum PMU placement naïve (simple) approach is presented in Table 6-34, where PMU is placed at each bus and the bus producing the least estimation error is the optimal place for the available PMU. It shows location of bus number 30 as the optimal place for next available PMU placement for IEEE 30 bus system.

Table 6-34: 30 Bus Cumulative Optimum PMU Placement for Full Redundancy (Naive Approach)

Location of PMU	Cumulative estimation error	Location of PMU	Cumulative estimation error	Location of PMU	Cumulative estimation error
No PMU	0.4495	Bus11	0.4383	Bus22	0.4435
Bus1	0.4492	Bus12	0.4522	Bus23	0.4562
Bus2	0.4395	Bus13	0.4439	Bus24	0.4466
Bus3	0.4447	Bus14	0.4444	Bus25	0.4345
Bus4	0.4493	Bus15	0.4425	Bus26	0.4427
Bus5	0.4377	Bus16	0.4255	Bus27	0.4376
Bus6	0.4552	Bus17	0.4465	Bus28	0.4115
Bus7	0.449	Bus18	0.4244	Bus29	0.4443
Bus8	0.4556	Bus19	0.4375	Bus30	0.3807
Bus9	0.4525	Bus20	0.4542		
Bus10	0.4579	Bus21	0.4477		

6.3.3 Optimum PMU Placement Heuristic Approach

Naïve approach leads to good optimum PMU location sequence, although it does not involve detailed analysis of the power system to produce better optimal placement sequence. In this thesis, a heuristics approach have been adopted with detailed analysis of the system to produce the optimum PMU placement (OPP) sequence.

From Table 6-35 to Table 6-36 represents WLS estimator cumulative estimation error for (partial redundancy, and partial redundancy with single error) up to eight available PMU's. From Table 6-37 to Table 6-38 represents IRLS estimator performance for the same two cases and with eight available PMU's. From Table 6-39 to Table 6-40 represents results for WLAVIRLS for same two cases with eight available PMU's.

After these observations it is concluded that all Optimum PMU placement strategies and algorithms are totally system dependent. Any change in system data (redundancy level changed, single error happened) or change of the estimator (WLS, IRLS, WLAVIRLS) or change in any network parameter will completely alter the optimal placement sequence. With the increase in number of PMU's replacing weak bus voltage meter estimation error reduces and after a certain number of PMU's estimation error becomes almost constant.

Table 6-35: 30 Bus WLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error
1	7.497409782
1,26	7.137088981
1,26,29	7.033018207
1,26,29,22	6.828179753
1,26,29,22,25	6.193409211
1,26,29,22,25,5	5.703872222

1,26,29,22,25,5,20	5.601700984
1,26,29,22,25,5,20,30	5.5037573

Table 6-36: 30 Bus WLS - Heuristic OPP (Partial Redundancy) With Single Error (P2 Reversed)

Location	Cumulative estimation error
1	14.43872401
1,4	11.74676119
1,4,26	11.17513972
1,4,26,22	10.72094776
1,4,26,22,5	10.53910385
1,4,26,22,5,24	10.38766268
1,4,26,22,5,24,29	10.35908472
1,4,26,22,5,24,29,25	9.924839012

Table 6-37: 30 Bus IRLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error
1	6.21057274
1,29	4.905897104
1,29,27	3.996102904
1,29,27,26	3.736064981
1,29,27,26,16	3.672199025
1,29,27,26,16,13	3.600880167
1,29,27,26,16,13,25	3.556297952
1,29,27,26,16,13,25,17	3.426881667

Table 6-38: 30 Bus IRLS - Heuristic OPP (Partial Redundancy) With Single Error (P2 Reversed)

Location	Cumulative estimation error
1	6.203870624
1,29	4.938126766
1,29,27	3.882207907
1,29,27,26	3.874831791
1,29,27,26,25	3.760611307
1,29,27,26,25,17	3.646535311
1,29,27,26,25,17,24	3.529569116
1,29,27,26,25,17,24,30	3.531720733

Table 6-39: 30 Bus WLAVIRLS - Heuristic Optimum PMU Placement (Partial Redundancy)

Location	Cumulative estimation error

1	1.918520149
1,16	1.802220013
1,16,26	1.580655343
1,16,26,30	1.571598379
1,16,26,30,28	1.534532402
1,16,26,30,28,11	1.511194376
1,16,26,30,28,11,29	1.492152225
1,16,26,30,28,11,29,5	1.457901732

Table 6-40: 30 Bus WLAVIRLS - Heuristic OPP (Partial Redundancy) With Single Error (P2 Reversed)

Location	Cumulative estimation error
1	2.019369048
1,16	1.824285361
1,16,17	1.713107427
1,16,17,30	1.651045467
1,16,17,30,26	1.559539906
1,16,17,30,26,20	1.563468688
1,16,17,30,26,20,24	1.452517256
1,16,17,30,26,20,24,29	1.478804014

6.3.4 PMU Incorporation Effect

PMU's replacement of weak voltage meters reduce cumulative estimation error by a great margin. In

by a great margin. In

Table 6-41 (partial redundancy and single bad data) all three estimator compares the cases where all SCADA meters are present (withoutPMU) and where all 30 SCADA meters are replaced by PMU's (withPMU). It shows performance with SCADA meters and with PMU meters for IEEE 30 bus system having partial redundancy and single error, Total twelve PMU's are placed at (1 to 12) busses for SCADA and PMU case. For

Table 6-41 estimated values for line flows, injections, loads and voltages for SCADA only case and SCADA with PMU case are given in comparison in Table B-43.

Table 6-41 30 Bus PMU Incorporation Effect on Accuracy

Estimator	SCADA only	SCADA and PMU
WLS	3.274436621	0.024762243
IRLS	0.043463146	0.018552451
WLAVIRLS	0.030520328	0.018431078

6.3.5 Bad Data Error Effect

This section shows effect of single, double non-interacting and double interacting bad data for (line, generation, and voltage magnitude error) by reversing the polarities of the measurement to create a bad data. Double error produces higher error than single error, whereas double interacting has higher cumulative estimation error than non-interacting double error.

Table 6-42 to Table 6-44 show the cumulative estimation error for WLS, IRLS and WLAVIRLS respectively for partial redundancy having single, double non-interacting and double interacting errors without any PMU, whereas estimated values of line flows, injections, loads and bus voltages are given in (Table B-44 to Table B-52). Table 6-45 to Table 6-47 presents the cumulative estimation error using heuristic optimum PMU placement for case where combination of SCADA and PMU is used. For SCADA and PMU case total eight PMU's were placed on bus (1, 4, 26, 22, 5, 24, 29, 25). Estimated values of line flows, injections, loads and bus voltages are given in (Table B-53 to Table B-61). Bad data errors that were generated are also mentioned in the tables i.e. (L1-2, G5, Vm22).

In this section partial redundancy is used for WLS, IRLS, WLAVIRLS estimators for single, double non-interacting and interacting errors. Two scenarios are presented (only SCADA measurements, combination of SCADA and PMU measurements). With the inclusion of PMU's cumulative estimation error is greatly reduced. If we consider Table 6-42 where WLS estimator is used and (14.6, 15.8, 24.7) are obtained for single, double non-interacting and interacting errors respectively. With the inclusion of eight PMU's on bus (1, 4, 26, 22, 5, 24, 29, 25) cumulative estimation error is reduced to (0.025, 0.026, 0.037) for single, double non-interacting and interacting errors respectively.

Table 6-42: 30 Bus WLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	1.194	G5	2.698	Vm29	14.663
Double Non Interacting	(L1-2 | L6-9)	3.765	(G2 | G8)	8.363	(Vm4 | Vm29)	15.820
Double Interacting	(L1-2 | L1-3)	3.817	(G1 | G2)	13.842	(Vm29 | Vm30)	24.783

Table 6-43: 30 Bus IRLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	1.480	G5	0.919	Vm29	0.091
Double Non Interacting	(L1-2 | L6-9)	3.927	(G2 | G8)	1.530	(Vm4 | Vm29)	0.112
Double Interacting	(L1-2 | L1-3)	4.224	(G1 | G2)	2.267	(Vm29 | Vm30)	0.275

Table 6-44: 30 Bus WLAVIRLS Cumulative Estimation Error With SCADA

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.037	G5	0.035	Vm29	0.046
Double Non Interacting	(L1-2 | L6-9)	2.302	(G2 | G8)	1.976	(Vm4 | Vm29)	0.091
Double Interacting	(L1-2 | L1-3)	3.957	(G1 | G2)	2.654	(Vm29 | Vm30)	0.173

Table 6-45: 30 Bus WLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.02138	G5	0.02259	Vm29	0.02516
Double Non Interacting	(L1-2 | L6-9)	0.02174	(G2 | G8)	0.02842	(Vm4 | Vm29)	0.02644
Double Interacting	(L1-2 | L1-3)	0.02297	(G1 | G2)	0.02922	(Vm29 | Vm30)	0.03753

Table 6-46: 30 Bus IRLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.02143	G5	0.02226	Vm29	0.02145
Double Non Interacting	(L1-2 | L6-9)	0.02176	(G2 | G8)	0.02925	(Vm4 | Vm29)	0.08481
Double Interacting	(L1-2 | L1-3)	0.02298	(G1 | G2)	0.02262	(Vm29 | Vm30)	0.08786

Table 6-47: 30 Bus WLAVIRLS Cumulative Estimation Error With SCADA & PMU

	Line error		Generation error		Voltage mag error	
	Location	Error Value	Location	Error Value	Location	Error Value
Single	L2-5	0.02259	G5	0.02504	Vm29	0.02347
Double Non Interacting	(L1-2 | L6-9)	0.04837	(G2 | G8)	0.02902	(Vm4 | Vm29)	0.02445
Double Interacting	(L1-2 | L1-3)	0.04946	(G1 | G2)	0.05385	(Vm29 | Vm30)	0.03630

CHAPTER 7

CONCLUSIONS

7.1 Conclusions

In this thesis, three state estimators were implemented and estimator algorithms were modified to incorporate PMU's replacing some of the SCADA voltage meters. Only complex voltage reading from PMU's was considered. WLS, IRLS and WLAVIRLS with PMU's proved to be performing better and faster. Full and partial redundancy with single and multiple non-interacting and interacting bad data were tested. Optimum PMU placement (OPP) with naive and heuristic algorithms were implemented. It was observed that OPP algorithms are totally system dependent. After a certain number of PMU added in system which replace weak voltage meters estimation error reduction becomes almost constant. That threshold number of PMU's for the 6-bus system and the IEEE 14-bus, and 30-bus networks were investigated.

Redundancy plays an important role in state estimation. For full redundancy case, each estimator performs very well. WLS and other ordinary estimators cannot perform better in the presence of single or multiple errors which are not Gaussian. Bad data rejection for such estimators is post estimation process. IRLS and WLAVIRLS have the ability to identify, locate and suppress bad data during the estimation process which makes it a robust Estimator. IRLS and WLAVIRLS always perform better than WLS as it is a robust algorithm. As number of bad data error increase the accuracy of the estimator decreases and error of estimation from the actual increases. Multiple interacting bad data prove to affect the estimation accuracy more than non-interacting bad data.

In ideal situation PMU placement at every bus will result in near to perfect estimation to actual values, but this will not be an economical solution as GENCO companies need to invest less money with highest robustness could be achieved thus optimal PMU placement is required. In this thesis results show, Optimum PMU placement is totally system dependent (type of estimator, redundancy level, type, number and location of bad data errors, system parameters). There is a great improvement in SE performance for WLS, IRLS, and WLAVIRLS by incorporating few number of PMU's on optimal locations using heuristic approach. This could be observed from the results obtained in Chapter 6 for (full and partial redundancy case), (single, double non-interacting and interacting errors presence). With the increase in number of bad data errors cumulative estimation error is increases, but with the inclusion of few number of PMU's on optimal location greatly reduce the cumulative estimation error.

Overall conclusion to this thesis could be made to use WLAVIRLS or IRLS estimators for the utilities to obtain better estimation results. PMU's should be optimally included in the system using heuristic OPP algorithm when needed. Optimal PMU placement is totally system dependent, which makes this algorithm a run time process, which will obtain the optimal locations and number of PMU's every period of time where the best estimation results are achievable.

7.2 Future Work

For future work Optimal PMU placement needs to be studied more deeply. It is totally system dependent, it needs to be investigated why is this and provide solution for the permanent OPP algorithm. After a certain PMU's addition, reduction in estimation error becomes constant, that threshold number of PMU's should be investigated further for all bus systems. Impact of PMU on Observability needs to be analyzed. The impact of PMU on estimator execution time need to be reduced further. Each State Estimator's breakdown point needs to be obtained and case studies could be made for each state estimator. PMU's with most advanced and latest state estimators need to be tested.

Though IRLS combined with LAV proves to be an efficient estimator algorithm, it also contains the demerits of the both. LAV has problem converging on leverage points, IRLS has its own threshold of limitation and cannot converge in some kind of bad data with low redundancy or extreme low redundancy. Those limitation cases for IRLS need to be identified and studied. Robust algorithm takes longer time to execute, Estimator execution speed is still a concern for real time review, work needs to be done for enhancing the speed of robust algorithms.

PMU's replacement of SCADA measurements have a strong positive effect on observability. The scope of this thesis was mainly focused on the accuracy of the estimators. Observability and controllability of power system with the presence of PMU's needs to be studied further. GENCO Companies always go for the most economical and robust strategy, Optimal PMU placement when provided fewer PMU's need to be studied more deeply. In this thesis for every different case optimal place for the PMU placement sequence changes because OPP algorithm is totally system dependent. Work needed to be done to observe that pattern of change and to investigate the threshold number of PMU’s after which reduction in estimation error almost becomes constant.

APPENDIX A : SYSTEM RAW DATA

6 Bus system data is taken from the book [72], whereas standard IEEE 14 bus and IEEE 30 bus data were taken for testing of these estimators from the university of Washington Power systems test case archive [80]. Network models for DC load flow and AC load flow was based on [81].

A.1 6 Bus System

Table A-1- Bus Data of 6-bus

Bus	Type	Voltage		Load		Generator		Gs	Bs	Qmax	Qmin
		Mag (p.u)	Ang (deg)	Real (MW)	Reac (MVAR)	Real (MW)	Reac (MVAR)				
1	3	1.05	0	0	0	0	0	0	0	100	-100
2	2	1.05	0	0	0	50	0	0	0	100	-100
3	2	1.07	0	0	0	60	0	0	0	100	-100
4	1	1	0	70	70	0	0	0	0	0	0
5	1	1	0	70	70	0	0	0	0	0	0
6	1	1	0	70	70	0	0	0	0	0	0

Table A-2 - Line Data of 6-bus

From Bus	To Bus	R (p.u)	X (p.u)	B (p.u)	Tap
1	2	0.1	0.2	0.04	1
1	4	0.05	0.2	0.04	1
1	5	0.08	0.3	0.06	1
2	3	0.05	0.25	0.06	1
2	4	0.05	0.1	0.02	1
2	5	0.1	0.3	0.04	1
2	6	0.07	0.2	0.05	1
3	5	0.12	0.26	0.05	1
3	6	0.02	0.1	0.02	1
4	5	0.2	0.4	0.08	1
5	6	0.1	0.3	0.06	1

A.2 14 Bus System

Table A-3 - Bus Data of 14-bus

		Voltage		Load		Generator					
Bus	Type	Mag (p.u)	Ang (deg)	Real (MW)	Reac (MVAR)	Real (MW)	Reac (MVAR)	Gs	Bs	Qmax	Qmin
1	3	1.06	0	0	0	232.4	-16.9	0	0	10	0
2	2	1.045	-4.98	21.7	12.7	40	42.4	0	0	50	-40
3	2	1.01	-12.72	94.2	19	0	23.4	0	0	40	0
4	1	1.019	-10.33	47.8	-3.9	0	0	0	0	0	0
5	1	1.02	-8.78	7.6	1.6	0	0	0	0	0	0
6	2	1.07	-14.22	11.2	7.5	0	12.2	0	0	24	-6
7	1	1.062	-13.37	0	0	0	0	0	0	0	0
8	2	1.09	-13.36	0	0	0	17.4	0	0	24	-6
9	1	1.056	-14.94	29.5	16.6	0	0	0	19	0	0
10	1	1.051	-15.1	9	5.8	0	0	0	0	0	0
11	1	1.057	-14.79	3.5	1.8	0	0	0	0	0	0
12	1	1.055	-15.07	6.1	1.6	0	0	0	0	0	0
13	1	1.05	-15.16	13.5	5.8	0	0	0	0	0	0
14	1	1.036	-16.04	14.9	5	0	0	0	0	0	0

Table A-4 - Line Data of 14-bus

From Bus	To Bus	R (p.u)	X (p.u)	B (p.u)	Tap
1	2	0.01938	0.05917	0.0528	1
1	5	0.05403	0.22304	0.0492	1
2	3	0.04699	0.19797	0.0438	1
2	4	0.05811	0.17632	0.034	1
2	5	0.05695	0.17388	0.0346	1
3	4	0.06701	0.17103	0.0128	1
4	5	0.01335	0.04211	0	1
4	7	0	0.20912	0	0.978
4	9	0	0.55618	0	0.969
5	6	0	0.25202	0	0.932
6	11	0.09498	0.1989	0	1
6	12	0.12291	0.25581	0	1
6	13	0.06615	0.13027	0	1
7	8	0	0.17615	0	1
7	9	0	0.11001	0	1
9	10	0.03181	0.0845	0	1
9	14	0.12711	0.27038	0	1
10	11	0.08205	0.19207	0	1
12	13	0.22092	0.19988	0	1
13	14	0.17093	0.34802	0	1

A.3 30 Bus System

Table A-5 - Bus Data of 30-bus

Bus	Type	Voltage		Load		Generator		Gs	Bs	Qmax	Qmin
		Mag (p.u)	Ang (deg)	Real (MW)	Reac (MVAR)	Real (MW)	Reac (MVAR)				
1	3	1.06	0	0	0	260.2	-16.1	0	0	10	0
2	2	1.043	-5.48	21.7	12.7	40	50	0	0	50	-40
3	1	1.021	-7.96	2.4	1.2	0	0	0	0	0	0
4	1	1.012	-9.62	7.6	1.6	0	0	0	0	0	0
5	2	1.01	-14.37	94.2	19	0	37	0	0	40	-40
6	1	1.01	-11.34	0	0	0	0	0	0	0	0
7	1	1.002	-13.12	22.8	10.9	0	0	0	0	0	0
8	2	1.01	-12.1	30	30	0	37.3	0	0	40	-10
9	1	1.051	-14.38	0	0	0	0	0	0	0	0

10	1	1.045	-15.97	5.8	2	0	0	0	19	0	0
11	2	1.082	-14.39	0	0	0	16.2	0	0	24	-6
12	1	1.057	-15.24	11.2	7.5	0	0	0	0	0	0
13	2	1.071	-15.24	0	0	0	10.6	0	0	24	-6
14	1	1.042	-16.13	6.2	1.6	0	0	0	0	0	0
15	1	1.038	-16.22	8.2	2.5	0	0	0	0	0	0
16	1	1.045	-15.83	3.5	1.8	0	0	0	0	0	0
17	1	1.04	-16.14	9	5.8	0	0	0	0	0	0
18	1	1.028	-16.82	3.2	0.9	0	0	0	0	0	0
19	1	1.026	-17	9.5	3.4	0	0	0	0	0	0
20	1	1.03	-16.8	2.2	0.7	0	0	0	0	0	0
21	1	1.033	-16.42	17.5	11.2	0	0	0	0	0	0
22	1	1.033	-16.41	0	0	0	0	0	0	0	0
23	1	1.027	-16.61	3.2	1.6	0	0	0	0	0	0
24	1	1.021	-16.78	8.7	6.7	0	0	0	4.3	0	0
25	1	1.017	-16.35	0	0	0	0	0	0	0	0
26	1	1	-16.77	3.5	2.3	0	0	0	0	0	0
27	1	1.023	-15.82	0	0	0	0	0	0	0	0
28	1	1.007	-11.97	0	0	0	0	0	0	0	0
29	1	1.003	-17.06	2.4	0.9	0	0	0	0	0	0
30	1	0.992	-17.94	10.6	1.9	0	0	0	0	0	0

Table A-6 - Line Data of 30-bus

From Bus	To Bus	R (p.u)	X (p.u)	B (p.u)	Tap
1	2	0.0192	0.0575	0.0528	1
1	3	0.0452	0.1652	0.0408	1
2	4	0.057	0.1737	0.0368	1
3	4	0.0132	0.0379	0.0084	1
2	5	0.0472	0.1983	0.0418	1
2	6	0.0581	0.1763	0.0374	1
4	6	0.0119	0.0414	0.009	1
5	7	0.046	0.116	0.0204	1
6	7	0.0267	0.082	0.017	1
6	8	0.012	0.042	0.009	1
6	9	0	0.208	0	0.978
6	10	0	0.556	0	0.969
9	11	0	0.208	0	1
9	10	0	0.11	0	1
4	12	0	0.256	0	0.932
12	13	0	0.14	0	1
12	14	0.1231	0.2559	0	1

12	15	0.0662	0.1304	0	1
12	16	0.0945	0.1987	0	1
14	15	0.221	0.1997	0	1
16	17	0.0524	0.1923	0	1
15	18	0.1073	0.2185	0	1
18	19	0.0639	0.1292	0	1
19	20	0.034	0.068	0	1
10	20	0.0936	0.209	0	1
10	17	0.0324	0.0845	0	1
10	21	0.0348	0.0749	0	1
10	22	0.0727	0.1499	0	1
21	22	0.0116	0.0236	0	1
15	23	0.1	0.202	0	1
22	24	0.115	0.179	0	1
23	24	0.132	0.27	0	1
24	25	0.1885	0.3292	0	1
25	26	0.2544	0.38	0	1
25	27	0.1093	0.2087	0	1
28	27	0	0.396	0	0.968
27	29	0.2198	0.4153	0	1
27	30	0.3202	0.6027	0	1
29	30	0.2399	0.4533	0	1
8	28	0.0636	0.2	0.0428	1
6	28	0.0169	0.0599	0.013	1

APPENDIX B: RESULTS

In this thesis, three test bus systems (6 bus, IEEE 14, IEEE 30) are used. Sufficient partial redundancy (more than 100 percentage of the minimum possible measurements) have been used. Minimum possible measurements are 6 bus system (11 measurements), IEEE 14 bus system (27 measurements), IEEE 30 bus system (59 measurements).

B.1 6 Bus System

Table B-1: 6 Bus Estimated Values for (Full Redundancy vs Partial Redundancy)

				Full Redundancy			Partial Redundancy		
	Actual	Full Meas	Partial Meas	WLS	IRLS	WLAVIRLS	WLS	IRLS	WLAVIRLS
V1	1.050	1.050	1.053	1.0500	1.0500	1.0500	1.0500	1.0500	1.0500
V2	1.050	1.050	1.034	1.0500	1.0500	1.0500	1.0500	1.0500	1.0500
V3	1.070	1.070		1.0700	1.0700	1.0700	1.0700	1.0700	1.0700
V4	0.989	0.989		0.9894	0.9894	0.9894	0.9894	0.9894	0.9894
V5	0.985	0.985		0.9854	0.9854	0.9855	0.9854	0.9854	0.9855
V6	1.004	1.004		1.0044	1.0044	1.0044	1.0044	1.0044	1.0044
P1	1.079	1.079	1.079	1.0787	1.0787	1.0786	1.0787	1.0787	1.0786
P2	0.500	0.500	0.500	0.5000	0.5000	0.4997	0.5000	0.5000	0.4997
P3	0.600	0.600		0.6000	0.6000	0.6000	0.6000	0.6000	0.6000
P4	0.700	0.700	0.700	0.7000	0.7000	0.6997	0.7000	0.7000	0.6997
P5	0.700	0.700	0.700	0.7000	0.7000	0.6997	0.7000	0.7000	0.6997
P6	0.700	0.700	0.700	0.7001	0.7001	0.7002	0.7001	0.7001	0.7002
Q1	0.160	0.160	0.160	0.1596	0.1596	0.1590	0.1596	0.1596	0.1590
Q2	0.744	0.744	0.744	0.7435	0.7435	0.7429	0.7435	0.7435	0.7429
Q3	0.896	0.896		0.8961	0.8961	0.8962	0.8961	0.8961	0.8962
Q4	0.700	0.700	0.700	0.7001	0.7001	0.6993	0.7001	0.7001	0.6993
Q5	0.700	0.700	0.700	0.7001	0.7001	0.6993	0.7001	0.7001	0.6993
Q6	0.700	0.700	0.700	0.6997	0.6997	0.7004	0.6997	0.6997	0.7004
P1-2	0.287	0.287	0.287	0.2869	0.2869	0.2869	0.2869	0.2869	0.2869
P1-4	0.436	0.436	0.436	0.4358	0.4358	0.4358	0.4358	0.4358	0.4358
P1-5	0.356	0.356	0.356	0.3560	0.3560	0.3560	0.3560	0.3560	0.3560
P2-3	0.029	0.030	0.030	0.0293	0.0293	0.0293	0.0293	0.0293	0.0293

P2-4	0.331	0.331	0.331	0.3309	0.3309	0.3306	0.3309	0.3309	0.3306
P2-5	0.155	0.155	0.155	0.1551	0.1551	0.1551	0.1551	0.1551	0.1551
P2-6	0.262	0.262	0.262	0.2625	0.2625	0.2625	0.2625	0.2625	0.2625
P3-5	0.191	0.191		0.1912	0.1912	0.1911	0.1912	0.1912	0.1911
P3-6	0.438	0.438		0.4378	0.4378	0.4378	0.4378	0.4378	0.4378
P4-5	0.041	0.041		0.0408	0.0408	0.0408	0.0408	0.0408	0.0408
P5-6	0.016	0.016		0.0161	0.0161	0.0162	0.0161	0.0161	0.0162
P2-1	-0.278	-0.278	-0.278	-0.2778	-0.2778	-0.2778	-0.2778	-0.2778	-0.2778
P4-1	-0.425	-0.425		-0.4250	-0.4250	-0.4249	-0.4250	-0.4250	-0.4249
P5-1	-0.345	-0.345		-0.3453	-0.3453	-0.3452	-0.3453	-0.3453	-0.3452
P3-2	-0.029	-0.029		-0.0289	-0.0289	-0.0289	-0.0289	-0.0289	-0.0289
P4-2	-0.316	-0.316		-0.3159	-0.3159	-0.3156	-0.3159	-0.3159	-0.3156
P5-2	-0.150	-0.150		-0.1502	-0.1502	-0.1501	-0.1502	-0.1502	-0.1501
P6-2	-0.257	-0.257		-0.2567	-0.2567	-0.2567	-0.2567	-0.2567	-0.2567
P5-3	-0.180	-0.180		-0.1802	-0.1802	-0.1801	-0.1802	-0.1802	-0.1801
P6-3	-0.428	-0.428		-0.4277	-0.4277	-0.4278	-0.4277	-0.4277	-0.4278
P5-4	-0.040	-0.041		-0.0405	-0.0405	-0.0405	-0.0405	-0.0405	-0.0405
P6-5	-0.016	-0.016		-0.0157	-0.0157	-0.0158	-0.0157	-0.0157	-0.0158
Q1-2	-0.154	-0.154	-0.154	-0.1542	-0.1542	-0.1542	-0.1542	-0.1542	-0.1542
Q1-4	0.201	0.201	0.201	0.2012	0.2012	0.2009	0.2012	0.2012	0.2009
Q1-5	0.113	0.113	0.113	0.1126	0.1126	0.1123	0.1126	0.1126	0.1123
Q2-3	-0.123	-0.123	-0.123	-0.1227	-0.1227	-0.1227	-0.1227	-0.1227	-0.1227
Q2-4	0.461	0.461	0.461	0.4606	0.4606	0.4600	0.4606	0.4606	0.4600
Q2-5	0.154	0.154	0.154	0.1536	0.1536	0.1533	0.1536	0.1536	0.1533
Q2-6	0.124	0.124	0.124	0.1239	0.1239	0.1240	0.1239	0.1239	0.1240
Q3-5	0.232	0.232		0.2318	0.2318	0.2315	0.2318	0.2318	0.2315
Q3-6	0.607	0.607		0.6071	0.6071	0.6074	0.6071	0.6071	0.6074
Q4-5	-0.049	-0.049		-0.0494	-0.0494	-0.0494	-0.0494	-0.0494	-0.0494
Q5-6	-0.097	-0.097		-0.0967	-0.0967	-0.0964	-0.0967	-0.0967	-0.0964
Q2-1	0.128	0.129	0.129	0.1282	0.1282	0.1282	0.1282	0.1282	0.1282
Q4-1	-0.199	-0.199		-0.1994	-0.1994	-0.1990	-0.1994	-0.1994	-0.1990
Q5-1	-0.134	-0.135		-0.1345	-0.1345	-0.1343	-0.1345	-0.1345	-0.1343
Q3-2	0.057	0.057		0.0573	0.0573	0.0573	0.0573	0.0573	0.0573
Q4-2	-0.451	-0.451		-0.4513	-0.4513	-0.4508	-0.4513	-0.4513	-0.4508
Q5-2	-0.180	-0.180		-0.1801	-0.1801	-0.1799	-0.1801	-0.1801	-0.1799
Q6-2	-0.160	-0.160		-0.1600	-0.1600	-0.1602	-0.1600	-0.1600	-0.1602
Q5-3	-0.261	-0.261		-0.2610	-0.2610	-0.2608	-0.2610	-0.2610	-0.2608
Q6-3	-0.579	-0.579		-0.5784	-0.5784	-0.5787	-0.5784	-0.5784	-0.5787

Q5-4	-0.028	-0.028		-0.0279	-0.0279	-0.0279	-0.0279	-0.0279	-0.0279
Q6-5	0.039	0.039		0.0388	0.0388	0.0385	0.0388	0.0388	0.0385

Table B-2: 6 Bus Estimated values for (Partial Redundancy)

	Actual	Measurement	WLS	IRLS	WLAVIRLS
V1	1.050	1.053	1.0483	1.0499	1.0500
V2	1.050	1.034	1.0498	1.0500	1.0500
V3	1.070		1.0699	1.0700	1.0700
V4	0.989		0.9893	0.9894	0.9894
V5	0.985		0.9853	0.9854	0.9854
V6	1.004		1.0043	1.0044	1.0044
P1	1.079	1.079	1.0906	1.0786	1.0787
P2	0.500	0.500	0.4963	0.5001	0.4999
P3	0.600		0.5889	0.5992	0.6000
P4	0.700	0.700	0.6988	0.6995	0.6998
P5	0.700	0.700	0.6977	0.6998	0.6999
P6	0.700	0.700	0.7001	0.6999	0.7000
Q1	0.160	0.160	0.1581	0.1597	0.1597
Q2	0.744	0.744	0.7445	0.7436	0.7436
Q3	0.896		0.9004	0.8963	0.8965
Q4	0.700	0.700	0.7009	0.7001	0.7000
Q5	0.700	0.700	0.7007	0.7000	0.7000
Q6	0.700	0.700	0.7002	0.7001	0.7003
P1-2	0.287	0.287	0.2922	0.2869	0.2869
P1-4	0.436	0.436	0.4392	0.4357	0.4358
P1-5	0.356	0.356	0.3592	0.3560	0.3560
P2-3	0.029	0.030	0.0330	0.0296	0.0293
P2-4	0.331	0.331	0.3269	0.3307	0.3308
P2-5	0.155	0.155	0.1546	0.1552	0.1551
P2-6	0.262	0.262	0.2647	0.2626	0.2625
P3-5	0.191		0.1877	0.1910	0.1912
P3-6	0.438		0.4337	0.4374	0.4377
P4-5	0.041		0.0414	0.0409	0.0408
P5-6	0.016		0.0181	0.0162	0.0162
P2-1	-0.278	-0.278	-0.2828	-0.2779	-0.2778
P4-1	-0.425		-0.4282	-0.4248	-0.4249
P5-1	-0.345		-0.3483	-0.3453	-0.3452
P3-2	-0.029		-0.0326	-0.0292	-0.0289

P4-2	-0.316		-0.3119	-0.3156	-0.3158
P5-2	-0.150		-0.1496	-0.1502	-0.1501
P6-2	-0.257		-0.2588	-0.2568	-0.2566
P5-3	-0.180		-0.1768	-0.1800	-0.1802
P6-3	-0.428		-0.4237	-0.4274	-0.4277
P5-4	-0.040		-0.0410	-0.0405	-0.0405
P6-5	-0.016		-0.0176	-0.0157	-0.0157
Q1-2	-0.154	-0.154	-0.1554	-0.1541	-0.1541
Q1-4	0.201	0.201	0.2012	0.2012	0.2012
Q1-5	0.113	0.113	0.1124	0.1126	0.1126
Q2-3	-0.123	-0.123	-0.1238	-0.1227	-0.1227
Q2-4	0.461	0.461	0.4616	0.4606	0.4605
Q2-5	0.154	0.154	0.1534	0.1535	0.1535
Q2-6	0.124	0.124	0.1232	0.1240	0.1241
Q3-5	0.232		0.2333	0.2318	0.2318
Q3-6	0.607		0.6087	0.6073	0.6074
Q4-5	-0.049		-0.0497	-0.0494	-0.0494
Q5-6	-0.097		-0.0970	-0.0966	-0.0966
Q2-1	0.128	0.129	0.1301	0.1281	0.1281
Q4-1	-0.199		-0.1988	-0.1994	-0.1994
Q5-1	-0.134		-0.1337	-0.1345	-0.1345
Q3-2	0.057		0.0585	0.0573	0.0573
Q4-2	-0.451		-0.4524	-0.4513	-0.4513
Q5-2	-0.180		-0.1799	-0.1801	-0.1801
Q6-2	-0.160		-0.1591	-0.1601	-0.1602
Q5-3	-0.261		-0.2626	-0.2610	-0.2610
Q6-3	-0.579		-0.5802	-0.5787	-0.5788
Q5-4	-0.028		-0.0275	-0.0278	-0.0279
Q6-5	0.039		0.0391	0.0387	0.0387

Table B-3: 6 Bus Estimated values for Partial Redundancy (optimal PMU incorporation using heuristic approach)

				WLS		IRLS		WLAVIRLS	
	Actual	Meas SCADA	Meas SCADA + PMU	SCADA	SCADA + PMU	SCADA	SCADA + PMU	SCADA	SCADA+PMU
V1	1.05	-1.0533	-1.0533	1.0497	1.0500	1.0494	1.0500	1.0496	1.0500

V2	1.05	1.0336	1.0336	1.0490	1.0500	1.0500	1.0500	1.0500	1.0500
V3	1.07			1.0676	1.0700	1.0700	1.0700	1.0700	1.0700
V4	0.989			0.9887	0.9894	0.9894	0.9894	0.9894	0.9894
V5	0.985			0.9844	0.9854	0.9854	0.9854	0.9854	0.9854
V6	1.004			1.0026	1.0044	1.0044	1.0044	1.0044	1.0044
P1	1.079	1.0786	1.0786	1.0482	1.0787	1.0782	1.0787	1.0786	1.0787
P2	0.5	0.4997	0.4997	0.5082	0.5000	0.5004	0.5000	0.4999	0.5000
P3	0.6			0.6254	0.6000	0.6001	0.6001	0.5998	0.6001
P4	0.7	0.6998	0.6998	0.7014	0.7000	0.7002	0.7000	0.6998	0.7000
P5	0.7	0.6998	0.6998	0.7044	0.7000	0.6999	0.6999	0.6999	0.6999
P6	0.7	0.6999	0.6999	0.6992	0.7001	0.6999	0.7002	0.6999	0.7002
Q1	0.16	0.1597	0.1597	0.1802	0.1596	0.1598	0.1596	0.1597	0.1596
Q2	0.744	0.7436	0.7436	0.7363	0.7435	0.7436	0.7436	0.7436	0.7436
Q3	0.896			0.8700	0.8961	0.8961	0.8963	0.8962	0.8963
Q4	0.7	0.7001	0.7001	0.6961	0.7001	0.7001	0.7000	0.7000	0.7000
Q5	0.7	0.7000	0.7000	0.6947	0.7001	0.7000	0.7000	0.7000	0.7000
Q6	0.7	0.7001	0.7001	0.7003	0.6997	0.7001	0.7001	0.7001	0.7001
P1-2	0.287	0.2869	0.2869	0.2739	0.2869	0.2867	0.2869	0.2869	0.2869
P1-4	0.436	0.4357	0.4357	0.4267	0.4358	0.4357	0.4358	0.4358	0.4358
P1-5	0.356	0.3559	0.3559	0.3476	0.3560	0.3558	0.3560	0.3560	0.3560
P2-3	0.029	0.0296	0.0296	0.0200	0.0293	0.0292	0.0293	0.0293	0.0293
P2-4	0.331	0.3312	0.3312	0.3400	0.3309	0.3312	0.3309	0.3308	0.3309
P2-5	0.155	0.1553	0.1553	0.1567	0.1551	0.1551	0.1551	0.1551	0.1551

P2-6	0.262	0.2625	0.2625	0.2573	0.2625	0.2624	0.2625	0.2625	0.2625
P3-5	0.191			0.1985	0.1912	0.1912	0.1912	0.1911	0.1912
P3-6	0.438			0.4467	0.4378	0.4377	0.4378	0.4376	0.4378
P4-5	0.041			0.0397	0.0408	0.0408	0.0408	0.0408	0.0408
P5-6	0.016			0.0114	0.0161	0.0161	0.0162	0.0161	0.0162
P2-1	-0.278	-0.2777	-0.2777	-0.2657	-0.2778	-0.2776	-0.2779	-0.2778	-0.2779
P4-1	-0.425			-0.4160	-0.4250	-0.4249	-0.4250	-0.4249	-0.4250
P5-1	-0.345			-0.3372	-0.3453	-0.3451	-0.3453	-0.3452	-0.3453
P3-2	-0.029			-0.0197	-0.0289	-0.0288	-0.0289	-0.0289	-0.0289
P4-2	-0.316			-0.3250	-0.3159	-0.3161	-0.3158	-0.3158	-0.3158
P5-2	-0.15			-0.1516	-0.1502	-0.1502	-0.1502	-0.1501	-0.1502
P6-2	-0.257			-0.2515	-0.2567	-0.2566	-0.2567	-0.2566	-0.2567
P5-3	-0.18			-0.1877	-0.1802	-0.1803	-0.1802	-0.1802	-0.1802
P6-3	-0.428			-0.4367	-0.4277	-0.4277	-0.4278	-0.4276	-0.4278
P5-4	-0.04			-0.0393	-0.0405	-0.0404	-0.0405	-0.0405	-0.0405
P6-5	-0.016			-0.0110	-0.0157	-0.0156	-0.0157	-0.0156	-0.0157
Q1-2	-0.154	-0.1541	-0.1541	-0.1437	-0.1542	-0.1541	-0.1542	-0.1541	-0.1542
Q1-4	0.201	0.2010	0.2010	0.2062	0.2012	0.2013	0.2012	0.2012	0.2012
Q1-5	0.113	0.1127	0.1127	0.1177	0.1126	0.1126	0.1126	0.1126	0.1126
Q2-3	-0.123	-0.1226	-0.1226	-0.1149	-0.1227	-0.1226	-0.1227	-0.1227	-0.1227
Q2-4	0.461	0.4606	0.4606	0.4523	0.4606	0.4605	0.4606	0.4605	0.4606
Q2-5	0.154	0.1536	0.1536	0.1533	0.1536	0.1535	0.1535	0.1535	0.1535
Q2-6	0.124	0.1240	0.1240	0.1296	0.1239	0.1241	0.1240	0.1241	0.1240

Q3-5	0.232			0.2227	0.2318	0.2317	0.2317	0.2317	0.2317
Q3-6	0.607			0.5980	0.6071	0.6072	0.6073	0.6073	0.6073
Q4-5	-0.049			-0.0478	-0.0494	-0.0494	-0.0494	-0.0494	-0.0494
Q5-6	-0.097			-0.0927	-0.0967	-0.0966	-0.0966	-0.0966	-0.0966
Q2-1	0.128	0.1286	0.1286	0.1160	0.1282	0.1280	0.1282	0.1281	0.1282
Q4-1	-0.199			-0.2053	-0.1994	-0.1994	-0.1994	-0.1994	-0.1994
Q5-1	-0.134			-0.1408	-0.1345	-0.1346	-0.1345	-0.1345	-0.1345
Q3-2	0.057			0.0493	0.0573	0.0572	0.0573	0.0572	0.0573
Q4-2	-0.451			-0.4430	-0.4513	-0.4512	-0.4513	-0.4513	-0.4513
Q5-2	-0.18			-0.1797	-0.1801	-0.1801	-0.1801	-0.1801	-0.1801
Q6-2	-0.16			-0.1658	-0.1600	-0.1602	-0.1602	-0.1602	-0.1602
Q5-3	-0.261			-0.2521	-0.2610	-0.2609	-0.2609	-0.2609	-0.2609
Q6-3	-0.579			-0.5694	-0.5784	-0.5786	-0.5787	-0.5786	-0.5787
Q5-4	-0.028			-0.0294	-0.0279	-0.0279	-0.0279	-0.0279	-0.0279
Q6-5	0.039			0.0348	0.0388	0.0387	0.0387	0.0387	0.0387
Va1	0		0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000
Va2	-0.064		-0.0641	-0.0608	-0.0641	-0.0640	-0.0641	-0.0640	-0.0641
Va3	-0.075		-0.0746	-0.0689	-0.0746	-0.0745	-0.0746	-0.0745	-0.0746
Va4	-0.073		-0.0732	-0.0712	-0.0732	-0.0732	-0.0732	-0.0732	-0.0732
Va5	-0.092		-0.0921	-0.0893	-0.0921	-0.0920	-0.0921	-0.0920	-0.0921
Va6	-0.104		-0.1038	-0.0992	-0.1038	-0.1037	-0.1038	-0.1037	-0.1038

Table B-4: 6 Bus -WLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.049	1.089	1.025
V2	1.05	1.034	1.034	1.034	1.05	1.089	1.026
V3	1.07				1.069	1.116	1.024
V4	0.989				0.989	1.028	0.976
V5	0.985				0.985	1.029	0.956
V6	1.004	1.0039	1.0039	***-1.0039***	1.004	1.054	0.95
P1	1.079	1.079	***-1.079***	1.079	1.083	0.655	1.152
P2	0.5	0.5	0.5	0.5	0.49	0.694	0.483
P3	0.6				0.602	0.542	0.563
P4	-0.7	0.7	0.7	0.7	-0.703	-0.48	-0.665
P5	-0.7	0.7	0.7	0.7	-0.697	-0.584	-0.684
P6	-0.7	0.7	0.7	0.7	-0.697	-0.762	-0.763
Q1	0.16	0.16	***-0.16***	0.16	0.162	-0.272	0.429
Q2	0.744	0.744	0.744	0.744	0.747	0.815	0.789
Q3	0.896				0.893	0.967	0.803
Q4	-0.7	0.7	0.7	0.7	-0.696	-0.643	-0.635
Q5	-0.7	0.7	0.7	0.7	-0.704	-0.643	-0.691
Q6	-0.7	0.7	0.7	0.7	-0.702	-0.62	-0.93
P1-2	0.287	0.287	0.287	0.287	0.289	0.126	0.326
P1-4	0.436	0.436	0.436	0.436	0.438	0.266	0.451
P1-5	0.356	0.356	0.356	0.356	0.355	0.263	0.375
P2-3	0.029	0.03	0.03	0.03	0.026	0.069	0.043
P2-4	0.331	0.331	0.331	0.331	0.331	0.285	0.293
P2-5	0.155	0.155	0.155	0.155	0.153	0.157	0.159
P2-6	0.262	0.262	0.262	0.262	0.26	0.301	0.305
P3-5	0.191				0.191	0.17	0.163
P3-6	0.438				0.437	0.44	0.443
P4-5	0.041	***-0.0409***	0.0409	0.0409	0.04	0.053	0.055
P5-6	0.016				0.016	0.038	0.039
P2-1	-0.278	-0.278	-0.278	-0.278	-0.28	-0.118	-0.317
P4-1	-0.425				-0.427	-0.263	-0.438
P5-1	-0.345				-0.345	-0.258	-0.36
P3-2	-0.029				-0.026	-0.069	-0.043
P4-2	-0.316				-0.316	-0.269	-0.282

P5-2	-0.15				-0.148	-0.153	-0.154
P6-2	-0.257				-0.254	-0.295	-0.293
P5-3	-0.18				-0.18	-0.159	-0.155
P6-3	-0.428				-0.427	-0.431	-0.431
P5-4	-0.04				-0.039	-0.052	-0.054
P6-5	-0.016				-0.016	-0.037	-0.039
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.285	-0.051
Q1-4	0.201	0.201	0.201	0.201	0.201	0.034	0.269
Q1-5	0.113	0.113	0.113	0.113	0.114	-0.02	0.211
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.121	-0.166	-0.032
Q2-4	0.461	0.461	0.461	0.461	0.459	0.516	0.363
Q2-5	0.154	0.154	0.154	0.154	0.155	0.145	0.169
Q2-6	0.124	0.124	0.124	0.124	0.126	0.065	0.262
Q3-5	0.232				0.231	0.266	0.17
Q3-6	0.607				0.607	0.603	0.664
Q4-5	-0.049	***0.0483***	-0.0483	- 0.0483	-0.048	-0.071	-0.016
Q5-6	-0.097				-0.096	-0.129	-0.023
Q2-1	0.128	0.129	0.129	0.129	0.128	0.255	0.027
Q4-1	-0.199				-0.199	-0.064	-0.258
Q5-1	-0.134				-0.136	-0.026	-0.217
Q3-2	0.057				0.055	0.098	-0.031
Q4-2	-0.451				-0.449	-0.508	-0.362
Q5-2	-0.18				-0.181	-0.176	-0.191
Q6-2	-0.16				-0.163	-0.106	-0.277
Q5-3	-0.261				-0.261	-0.299	-0.203
Q6-3	-0.579				-0.578	-0.581	-0.622
Q5-4	-0.028				-0.029	-0.013	-0.057
Q6-5	0.039				0.039	0.067	-0.031

Table B-5: 6 Bus -IRLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.089	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.089	1.05
V3	1.07				1.07	1.117	1.07

V4	0.989				0.989	1.027	0.989
V5	0.985				0.985	1.028	0.985
V6	1.004	1.0039	1.0039	***-1.0039***	1.004	1.054	1.004
P1	1.079	1.079	***-1.079***	1.079	1.078	0.654	1.078
P2	0.5	0.5	0.5	0.5	0.499	0.708	0.5
P3	0.6				0.601	0.533	0.6
P4	-0.7	0.7	0.7	0.7	-0.7	-0.48	-0.699
P5	-0.7	0.7	0.7	0.7	-0.7	-0.583	-0.701
P6	-0.7	0.7	0.7	0.7	-0.7	-0.767	-0.7
Q1	0.16	0.16	***-0.16***	0.16	0.16	-0.266	0.161
Q2	0.744	0.744	0.744	0.744	0.744	0.817	0.744
Q3	0.896				0.896	0.968	0.895
Q4	-0.7	0.7	0.7	0.7	-0.7	-0.652	-0.7
Q5	-0.7	0.7	0.7	0.7	-0.7	-0.653	-0.7
Q6	-0.7	0.7	0.7	0.7	-0.7	-0.607	-0.701
P1-2	0.287	0.287	0.287	0.287	0.287	0.125	0.287
P1-4	0.436	0.436	0.436	0.436	0.436	0.266	0.436
P1-5	0.356	0.356	0.356	0.356	0.356	0.264	0.356
P2-3	0.029	0.03	0.03	0.03	0.029	0.074	0.029
P2-4	0.331	0.331	0.331	0.331	0.331	0.286	0.331
P2-5	0.155	0.155	0.155	0.155	0.155	0.159	0.155
P2-6	0.262	0.262	0.262	0.262	0.262	0.305	0.263
P3-5	0.191				0.191	0.168	0.191
P3-6	0.438				0.438	0.439	0.438
P4-5	0.041	***-0.0409***	0.0409	0.0409	0.041	0.053	0.041
P5-6	0.016				0.016	0.039	0.016
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.117	-0.278
P4-1	-0.425				-0.425	-0.262	-0.425
P5-1	-0.345				-0.345	-0.259	-0.345
P3-2	-0.029				-0.029	-0.073	-0.029
P4-2	-0.316				-0.316	-0.271	-0.316
P5-2	-0.15				-0.15	-0.154	-0.15
P6-2	-0.257				-0.256	-0.299	-0.257
P5-3	-0.18				-0.18	-0.157	-0.18
P6-3	-0.428				-0.428	-0.429	-0.428
P5-4	-0.04				-0.04	-0.053	-0.041
P6-5	-0.016				-0.016	-0.038	-0.016

Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.285	-0.153
Q1-4	0.201	0.201	0.201	0.201	0.201	0.037	0.202
Q1-5	0.113	0.113	0.113	0.113	0.113	-0.018	0.113
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.168	-0.122
Q2-4	0.461	0.461	0.461	0.461	0.46	0.523	0.46
Q2-5	0.154	0.154	0.154	0.154	0.154	0.146	0.154
Q2-6	0.124	0.124	0.124	0.124	0.124	0.061	0.125
Q3-5	0.232				0.232	0.27	0.231
Q3-6	0.607				0.607	0.598	0.607
Q4-5	-0.049	***0.0483***	-0.0483	-0.0483	-0.049	-0.071	-0.049
Q5-6	-0.097				-0.097	-0.133	-0.096
Q2-1	0.128	0.129	0.129	0.129	0.128	0.255	0.127
Q4-1	-0.199				-0.199	-0.067	-0.2
Q5-1	-0.134				-0.135	-0.028	-0.135
Q3-2	0.057				0.057	0.1	0.057
Q4-2	-0.451				-0.451	-0.514	-0.451
Q5-2	-0.18				-0.18	-0.178	-0.18
Q6-2	-0.16				-0.16	-0.101	-0.161
Q5-3	-0.261				-0.261	-0.303	-0.261
Q6-3	-0.579				-0.578	-0.577	-0.579
Q5-4	-0.028				-0.028	-0.012	-0.028
Q6-5	0.039				0.039	0.072	0.038

Table B-6: 6 Bus -WLAVIRLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.049	1.05
V2	1.05	1.034	1.034	1.034	1.049	1.05	1.049
V3	1.07				1.07	1.07	1.07
V4	0.989				0.989	0.99	0.989
V5	0.985				0.986	0.986	0.985
V6	1.004	1.0039	1.0039	***-1.0039***	1.004	1.005	1.004
P1	1.079	1.079	***-1.079***	1.079	1.089	1.087	1.089
P2	0.5	0.5	0.5	0.5	0.436	0.438	0.435
P3	0.6				0.61	0.611	0.61

P4	-0.7	0.7	0.7	0.7	-0.679	-0.679	-0.679
P5	-0.7	0.7	0.7	0.7	-0.695	-0.697	-0.696
P6	-0.7	0.7	0.7	0.7	-0.682	-0.682	-0.681
Q1	0.16	0.16	***-0.16***	0.16	0.158	0.152	0.159
Q2	0.744	0.744	0.744	0.744	0.745	0.748	0.744
Q3	0.896				0.895	0.895	0.895
Q4	-0.7	0.7	0.7	0.7	-0.701	-0.699	-0.701
Q5	-0.7	0.7	0.7	0.7	-0.696	-0.697	-0.697
Q6	-0.7	0.7	0.7	0.7	-0.705	-0.702	-0.703
P1-2	0.287	0.287	0.287	0.287	0.298	0.296	0.298
P1-4	0.436	0.436	0.436	0.436	0.436	0.435	0.436
P1-5	0.356	0.356	0.356	0.356	0.356	0.356	0.356
P2-3	0.029	0.03	0.03	0.03	0.018	0.018	0.018
P2-4	0.331	0.331	0.331	0.331	0.31	0.31	0.31
P2-5	0.155	0.155	0.155	0.155	0.148	0.148	0.148
P2-6	0.262	0.262	0.262	0.262	0.248	0.248	0.248
P3-5	0.191				0.192	0.193	0.192
P3-6	0.438				0.435	0.435	0.435
P4-5	0.041	***-0.0409***	0.0409	0.0409	0.041	0.041	0.041
P5-6	0.016				0.014	0.014	0.014
P2-1	-0.278	-0.278	-0.278	-0.278	-0.288	-0.287	-0.288
P4-1	-0.425				-0.425	-0.424	-0.425
P5-1	-0.345				-0.345	-0.345	-0.345
P3-2	-0.029				-0.018	-0.018	-0.017
P4-2	-0.316				-0.295	-0.296	-0.295
P5-2	-0.15				-0.143	-0.143	-0.143
P6-2	-0.257				-0.243	-0.243	-0.243
P5-3	-0.18				-0.181	-0.182	-0.182
P6-3	-0.428				-0.425	-0.426	-0.425
P5-4	-0.04				-0.04	-0.041	-0.04
P6-5	-0.016				-0.014	-0.014	-0.014
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.157	-0.154
Q1-4	0.201	0.201	0.201	0.201	0.201	0.198	0.201
Q1-5	0.113	0.113	0.113	0.113	0.112	0.111	0.112
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123
Q2-4	0.461	0.461	0.461	0.461	0.461	0.461	0.461
Q2-5	0.154	0.154	0.154	0.154	0.152	0.153	0.153

Q2-6	0.124	0.124	0.124	0.124	0.125	0.124	0.124
Q3-5	0.232				0.23	0.231	0.23
Q3-6	0.607				0.607	0.607	0.607
Q4-5	-0.049	***0.0483***	-0.0483	-0.0483	-0.049	-0.049	-0.049
Q5-6	-0.097				-0.095	-0.096	-0.096
Q2-1	0.128	0.129	0.129	0.129	0.13	0.132	0.129
Q4-1	-0.199				-0.199	-0.197	-0.199
Q5-1	-0.134				-0.134	-0.133	-0.134
Q3-2	0.057				0.057	0.058	0.058
Q4-2	-0.451				-0.453	-0.453	-0.453
Q5-2	-0.18				-0.18	-0.18	-0.18
Q6-2	-0.16				-0.163	-0.162	-0.162
Q5-3	-0.261				-0.259	-0.26	-0.26
Q6-3	-0.579				-0.579	-0.579	-0.579
Q5-4	-0.028				-0.028	-0.028	-0.028
Q6-5	0.039				0.037	0.038	0.038

Table B-7: 6 Bus -WLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.054	1.074	1.013
V2	1.05	1.034	1.034	1.034	1.054	1.075	1.014
V3	1.07	1.071	1.071	***-1.071***	1.071	1.022	1.009
V4	0.989	0.977	0.977	**-0.977**	0.997	1.027	0.955
V5	0.985				0.988	1.015	0.946
V6	1.004				1.006	1.011	0.944
P1	1.079	1.079	***-1.079***	1.079	1.039	0.664	1.201
P2	0.5	0.5	0.5	0.5	0.492	0.815	0.474
P3	0.6	0.6	***-0.6***	0.6	0.596	-0.055	0.533
P4	-0.7	0.7	0.7	0.7	-0.634	-0.423	-0.721
P5	-0.7	0.7	0.7	0.7	-0.711	-0.414	-0.668
P6	-0.7	0.7	0.7	0.7	-0.707	-0.543	-0.728
Q1	0.16	0.16	***-0.16***	0.16	0.103	-0.148	0.621
Q2	0.744	0.744	0.744	0.744	0.772	1.053	0.77
Q3	0.896	0.877	***-0.877***	0.877	0.874	-0.116	0.675

Q4	-0.7	0.7	0.7	0.7	-0.657	-0.498	-0.791
Q5	-0.7	0.7	0.7	0.7	-0.701	-0.372	-0.681
Q6	-0.7	0.7	0.7	0.7	-0.706	-0.348	-0.805
P1-2	0.287	0.287	0.287	0.287	0.275	0.136	0.349
P1-4	0.436	***-0.436***	0.436	0.436	0.411	0.26	0.471
P1-5	0.356	0.356	0.356	0.356	0.353	0.268	0.381
P2-3	0.029	***-0.03***	0.03	0.03	0.033	0.196	0.043
P2-4	0.331	0.331	0.331	0.331	0.297	0.242	0.324
P2-5	0.155	0.155	0.155	0.155	0.159	0.162	0.155
P2-6	0.262	0.262	0.262	0.262	0.269	0.344	0.291
P3-5	0.191				0.191	-0.009	0.153
P3-6	0.438				0.438	0.148	0.422
P4-5	0.041				0.052	0.066	0.043
P5-6	0.016				0.016	0.062	0.035
P2-1	-0.278	-0.278	-0.278	-0.278	-0.266	-0.131	-0.338
P4-1	-0.425				-0.402	-0.257	-0.454
P5-1	-0.345				-0.342	-0.263	-0.365
P3-2	-0.029				-0.032	-0.193	-0.043
P4-2	-0.316				-0.284	-0.233	-0.31
P5-2	-0.15				-0.154	-0.158	-0.149
P6-2	-0.257				-0.263	-0.334	-0.281
P5-3	-0.18				-0.18	0.01	-0.147
P6-3	-0.428				-0.428	-0.147	-0.412
P5-4	-0.04				-0.052	-0.065	-0.042
P6-5	-0.016				-0.016	-0.062	-0.035
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.17	-0.215	0.004
Q1-4	0.201	***-0.201***	0.201	0.201	0.168	0.04	0.372
Q1-5	0.113	0.113	0.113	0.113	0.105	0.027	0.245
Q2-3	-0.123	***0.123***	-0.123	-0.123	-0.112	0.154	-0.019
Q2-4	0.461	0.461	0.461	0.461	0.447	0.38	0.422
Q2-5	0.154	0.154	0.154	0.154	0.159	0.138	0.16
Q2-6	0.124	0.124	0.124	0.124	0.135	0.201	0.231
Q3-5	0.232				0.228	0.007	0.15
Q3-6	0.607				0.601	0.08	0.566
Q4-5	-0.049				-0.043	-0.044	-0.034
Q5-6	-0.097				-0.095	-0.036	-0.033
Q2-1	0.128	0.129	0.129	0.129	0.143	0.18	-0.024

Q4-1	-0.199				-0.173	-0.07	-0.344
Q5-1	-0.134				-0.128	-0.07	-0.245
Q3-2	0.057				0.046	-0.204	-0.042
Q4-2	-0.451				-0.441	-0.384	-0.413
Q5-2	-0.18				-0.185	-0.168	-0.182
Q6-2	-0.16				-0.17	-0.226	-0.25
Q5-3	-0.261				-0.258	-0.059	-0.184
Q6-3	-0.579				-0.573	-0.098	-0.535
Q5-4	-0.028				-0.034	-0.038	-0.037
Q6-5	0.039				0.037	-0.024	-0.02

Table B-8: 6 Bus -IRLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.055	1.074	1.015
V2	1.05	1.034	1.034	1.034	1.054	1.074	1.015
V3	1.07	1.071	1.071	***-1.071***	1.071	1.021	1.012
V4	0.989	0.977	0.977	**-0.977**	0.997	1.027	0.956
V5	0.985				0.988	1.014	0.947
V6	1.004				1.006	1.009	0.946
P1	1.079	1.079	***-1.079***	1.079	1.039	0.663	1.197
P2	0.5	0.5	0.5	0.5	0.492	0.822	0.468
P3	0.6	0.6	***-0.6***	0.6	0.596	-0.059	0.536
P4	-0.7	0.7	0.7	0.7	-0.634	-0.419	-0.717
P5	-0.7	0.7	0.7	0.7	-0.711	-0.412	-0.669
P6	-0.7	0.7	0.7	0.7	-0.707	-0.552	-0.724
Q1	0.16	0.16	***-0.16***	0.16	0.103	-0.14	0.605
Q2	0.744	0.744	0.744	0.744	0.772	1.063	0.758
Q3	0.896	0.877	***-0.877***	0.877	0.874	-0.124	0.692
Q4	-0.7	0.7	0.7	0.7	-0.658	-0.498	-0.786
Q5	-0.7	0.7	0.7	0.7	-0.7	-0.375	-0.681
Q6	-0.7	0.7	0.7	0.7	-0.706	-0.351	-0.803
P1-2	0.287	0.287	0.287	0.287	0.275	0.136	0.348
P1-4	0.436	***-0.436***	0.436	0.436	0.411	0.258	0.469
P1-5	0.356	0.356	0.356	0.356	0.353	0.269	0.38

P2-3	0.029	***-0.03***	0.03	0.03	0.033	0.199	0.041
P2-4	0.331	0.331	0.331	0.331	0.297	0.24	0.321
P2-5	0.155	0.155	0.155	0.155	0.159	0.164	0.154
P2-6	0.262	0.262	0.262	0.262	0.269	0.35	0.288
P3-5	0.191				0.19	-0.012	0.155
P3-6	0.438				0.438	0.149	0.422
P4-5	0.041				0.052	0.068	0.043
P5-6	0.016				0.016	0.065	0.034
P2-1	-0.278	-0.278	-0.278	-0.278	-0.266	-0.131	-0.337
P4-1	-0.425				-0.402	-0.255	-0.453
P5-1	-0.345				-0.342	-0.263	-0.364
P3-2	-0.029				-0.032	-0.196	-0.041
P4-2	-0.316				-0.284	-0.231	-0.307
P5-2	-0.15				-0.154	-0.159	-0.148
P6-2	-0.257				-0.263	-0.339	-0.278
P5-3	-0.18				-0.18	0.012	-0.149
P6-3	-0.428				-0.428	-0.148	-0.412
P5-4	-0.04				-0.051	-0.067	-0.042
P6-5	-0.016				-0.016	-0.064	-0.034
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.17	-0.213	0
Q1-4	0.201	***-0.201***	0.201	0.201	0.168	0.041	0.365
Q1-5	0.113	0.113	0.113	0.113	0.105	0.031	0.24
Q2-3	-0.123	***0.123***	-0.123	-0.123	-0.112	0.159	-0.026
Q2-4	0.461	0.461	0.461	0.461	0.447	0.38	0.421
Q2-5	0.154	0.154	0.154	0.154	0.159	0.14	0.158
Q2-6	0.124	0.124	0.124	0.124	0.134	0.206	0.225
Q3-5	0.232				0.227	0.006	0.155
Q3-6	0.607				0.601	0.079	0.572
Q4-5	-0.049				-0.044	-0.042	-0.035
Q5-6	-0.097				-0.095	-0.035	-0.035
Q2-1	0.128	0.129	0.129	0.129	0.143	0.177	-0.02
Q4-1	-0.199				-0.173	-0.072	-0.339
Q5-1	-0.134				-0.128	-0.074	-0.24
Q3-2	0.057				0.046	-0.208	-0.035
Q4-2	-0.451				-0.441	-0.384	-0.413
Q5-2	-0.18				-0.185	-0.17	-0.18
Q6-2	-0.16				-0.17	-0.23	-0.245

Q5-3	-0.261				-0.257	-0.057	-0.188
Q6-3	-0.579				-0.573	-0.096	-0.541
Q5-4	-0.028				-0.034	-0.039	-0.036
Q6-5	0.039				0.037	-0.025	-0.018

Table B-9: 6 Bus -WLAVIRLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.049	1.051	1.05
V2	1.05	1.034	1.034	1.034	1.049	1.051	1.049
V3	1.07	1.071	1.071	***-1.071***	1.07	1.071	1.07
V4	0.989	0.977	0.977	**-0.977**	0.99	0.992	0.989
V5	0.985				0.986	0.989	0.986
V6	1.004				1.005	1.006	1.004
P1	1.079	1.079	***-1.079***	1.079	1.088	1.081	1.089
P2	0.5	0.5	0.5	0.5	0.436	0.44	0.435
P3	0.6	0.6	***-0.6***	0.6	0.61	0.604	0.61
P4	-0.7	0.7	0.7	0.7	-0.679	-0.678	-0.679
P5	-0.7	0.7	0.7	0.7	-0.696	-0.687	-0.696
P6	-0.7	0.7	0.7	0.7	-0.682	-0.684	-0.681
Q1	0.16	0.16	***-0.16***	0.16	0.156	0.125	0.159
Q2	0.744	0.744	0.744	0.744	0.745	0.752	0.744
Q3	0.896	0.877	***-0.877***	0.877	0.895	0.873	0.896
Q4	-0.7	0.7	0.7	0.7	-0.699	-0.692	-0.701
Q5	-0.7	0.7	0.7	0.7	-0.698	-0.665	-0.697
Q6	-0.7	0.7	0.7	0.7	-0.703	-0.704	-0.702
P1-2	0.287	0.287	0.287	0.287	0.297	0.294	0.298
P1-4	0.436	***-0.436***	0.436	0.436	0.435	0.434	0.436
P1-5	0.356	0.356	0.356	0.356	0.356	0.354	0.356
P2-3	0.029	***-0.03***	0.03	0.03	0.018	0.019	0.018
P2-4	0.331	0.331	0.331	0.331	0.31	0.309	0.31
P2-5	0.155	0.155	0.155	0.155	0.148	0.147	0.148
P2-6	0.262	0.262	0.262	0.262	0.248	0.249	0.248
P3-5	0.191				0.193	0.188	0.193
P3-6	0.438				0.435	0.434	0.435

P4-5	0.041				0.041	0.04	0.041
P5-6	0.016				0.014	0.016	0.014
P2-1	-0.278	-0.278	-0.278	-0.278	-0.288	-0.284	-0.288
P4-1	-0.425				-0.425	-0.423	-0.425
P5-1	-0.345				-0.345	-0.343	-0.345
P3-2	-0.029				-0.017	-0.018	-0.017
P4-2	-0.316				-0.295	-0.295	-0.295
P5-2	-0.15				-0.143	-0.142	-0.143
P6-2	-0.257				-0.243	-0.244	-0.243
P5-3	-0.18				-0.182	-0.178	-0.182
P6-3	-0.428				-0.425	-0.425	-0.425
P5-4	-0.04				-0.041	-0.039	-0.04
P6-5	-0.016				-0.014	-0.016	-0.014
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.155	-0.164	-0.154
Q1-4	0.201	***-0.201***	0.201	0.201	0.199	0.189	0.201
Q1-5	0.113	0.113	0.113	0.113	0.112	0.1	0.112
Q2-3	-0.123	***0.123***	-0.123	-0.123	-0.123	-0.119	-0.124
Q2-4	0.461	0.461	0.461	0.461	0.46	0.459	0.461
Q2-5	0.154	0.154	0.154	0.154	0.153	0.147	0.153
Q2-6	0.124	0.124	0.124	0.124	0.125	0.126	0.124
Q3-5	0.232				0.23	0.221	0.23
Q3-6	0.607				0.607	0.599	0.607
Q4-5	-0.049				-0.049	-0.052	-0.049
Q5-6	-0.097				-0.096	-0.09	-0.096
Q2-1	0.128	0.129	0.129	0.129	0.131	0.139	0.13
Q4-1	-0.199				-0.198	-0.188	-0.199
Q5-1	-0.134				-0.134	-0.123	-0.134
Q3-2	0.057				0.058	0.053	0.058
Q4-2	-0.451				-0.452	-0.451	-0.453
Q5-2	-0.18				-0.18	-0.175	-0.18
Q6-2	-0.16				-0.162	-0.164	-0.162
Q5-3	-0.261				-0.26	-0.252	-0.26
Q6-3	-0.579				-0.579	-0.572	-0.579
Q5-4	-0.028				-0.028	-0.025	-0.028
Q6-5	0.039				0.038	0.031	0.038

Table B-10: 6 Bus -WLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.056	0.992	1.002
V2	1.05	1.034	1.034	1.034	1.057	0.991	1.002
V3	1.07	1.071	1.071	***-1.071***	1.078	0.984	0.969
V4	0.989				0.998	0.981	0.962
V5	0.985				0.994	0.983	0.924
V6	1.004	1.0039	1.0039	***-1.0039***	1.013	0.971	0.896
P1	1.079	1.079	1.079	1.079	1.016	1.199	1.226
P2	0.5	0.5	***-0.5***	0.5	0.489	-0.023	0.475
P3	0.6	0.6	***-0.6***	0.6	0.593	0.113	0.49
P4	-0.7	0.7	0.7	0.7	-0.644	-0.48	-0.626
P5	-0.7	0.7	0.7	0.7	-0.673	-0.408	-0.662
P6	-0.7	0.7	0.7	0.7	-0.708	-0.357	-0.8
Q1	0.16	0.16	0.16	0.16	0.065	0.46	0.713
Q2	0.744	0.744	***-0.744***	0.744	0.751	-0.053	0.847
Q3	0.896	0.877	***-0.877***	0.877	0.903	0.012	0.576
Q4	-0.7	0.7	0.7	0.7	-0.669	-0.364	-0.56
Q5	-0.7	0.7	0.7	0.7	-0.683	-0.217	-0.677
Q6	-0.7	0.7	0.7	0.7	-0.692	-0.215	-1.046
P1-2	0.287	0.287	0.287	0.287	0.268	0.411	0.366
P1-4	0.436	***-0.436***	0.436	0.436	0.408	0.442	0.465
P1-5	0.356	***-0.356***	0.356	0.356	0.341	0.346	0.394
P2-3	0.029	0.03	0.03	0.03	0.031	0.064	0.063
P2-4	0.331	0.331	0.331	0.331	0.303	0.079	0.254
P2-5	0.155	0.155	0.155	0.155	0.15	0.068	0.165
P2-6	0.262	0.262	0.262	0.262	0.263	0.161	0.346
P3-5	0.191				0.185	0.017	0.125
P3-6	0.438				0.438	0.16	0.427
P4-5	0.041				0.044	0.028	0.071
P5-6	0.016				0.022	0.04	0.06
P2-1	-0.278	-0.278	-0.278	-0.278	-0.259	-0.395	-0.353
P4-1	-0.425				-0.398	-0.43	-0.449
P5-1	-0.345				-0.331	-0.335	-0.374

P3-2	-0.029				-0.031	-0.063	-0.062
P4-2	-0.316				-0.289	-0.079	-0.247
P5-2	-0.15				-0.145	-0.068	-0.158
P6-2	-0.257				-0.258	-0.159	-0.326
P5-3	-0.18				-0.174	-0.017	-0.121
P6-3	-0.428				-0.428	-0.159	-0.415
P5-4	-0.04				-0.043	-0.028	-0.069
P6-5	-0.016				-0.021	-0.039	-0.059
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.181	0.092	0.059
Q1-4	0.201	***-0.201***	0.201	0.201	0.161	0.243	0.337
Q1-5	0.113	***-0.113***	0.113	0.113	0.086	0.124	0.318
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.129	-0.012	0.087
Q2-4	0.461	0.461	0.461	0.461	0.458	0.053	0.259
Q2-5	0.154	0.154	0.154	0.154	0.15	-0.013	0.186
Q2-6	0.124	0.124	0.124	0.124	0.116	0.021	0.39
Q3-5	0.232				0.234	-0.027	0.09
Q3-6	0.607				0.606	0.084	0.626
Q4-5	-0.049				-0.051	-0.056	0.02
Q5-6	-0.097				-0.099	-0.005	0.042
Q2-1	0.128	0.129	0.129	0.129	0.154	-0.101	-0.075
Q4-1	-0.199				-0.167	-0.236	-0.315
Q5-1	-0.134				-0.113	-0.147	-0.3
Q3-2	0.057				0.062	-0.045	-0.141
Q4-2	-0.451				-0.451	-0.071	-0.265
Q5-2	-0.18				-0.178	-0.024	-0.203
Q6-2	-0.16				-0.154	-0.063	-0.377
Q5-3	-0.261				-0.265	-0.021	-0.127
Q6-3	-0.579				-0.579	-0.1	-0.581
Q5-4	-0.028				-0.028	-0.02	-0.088
Q6-5	0.039				0.04	-0.052	-0.088

Table B-11: 6 Bus -IRLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.056	0.99	1.049

V2	1.05	1.034	1.034	1.034	1.057	0.991	1.05
V3	1.07	1.071	1.071	***-1.071***	1.078	0.983	1.07
V4	0.989				0.998	0.98	0.989
V5	0.985				0.994	0.982	0.985
V6	1.004	1.0039	1.0039	***-1.0039***	1.013	0.969	1.004
P1	1.079	1.079	1.079	1.079	1.016	1.201	1.078
P2	0.5	0.5	***-0.5***	0.5	0.489	-0.017	0.501
P3	0.6	0.6	***-0.6***	0.6	0.593	0.121	0.6
P4	-0.7	0.7	0.7	0.7	-0.644	-0.483	-0.7
P5	-0.7	0.7	0.7	0.7	-0.672	-0.405	-0.7
P6	-0.7	0.7	0.7	0.7	-0.708	-0.373	-0.701
Q1	0.16	0.16	0.16	0.16	0.066	0.468	0.162
Q2	0.744	0.744	***-0.744***	0.744	0.751	-0.047	0.744
Q3	0.896	0.877	***-0.877***	0.877	0.902	0.022	0.895
Q4	-0.7	0.7	0.7	0.7	-0.67	-0.37	-0.7
Q5	-0.7	0.7	0.7	0.7	-0.683	-0.215	-0.7
Q6	-0.7	0.7	0.7	0.7	-0.691	-0.233	-0.701
P1-2	0.287	0.287	0.287	0.287	0.268	0.412	0.287
P1-4	0.436	***-0.436***	0.436	0.436	0.407	0.443	0.436
P1-5	0.356	***-0.356***	0.356	0.356	0.341	0.346	0.356
P2-3	0.029	0.03	0.03	0.03	0.031	0.064	0.029
P2-4	0.331	0.331	0.331	0.331	0.303	0.081	0.331
P2-5	0.155	0.155	0.155	0.155	0.15	0.068	0.155
P2-6	0.262	0.262	0.262	0.262	0.264	0.166	0.263
P3-5	0.191				0.185	0.017	0.191
P3-6	0.438				0.438	0.168	0.438
P4-5	0.041				0.044	0.028	0.041
P5-6	0.016				0.022	0.043	0.016
P2-1	-0.278	-0.278	-0.278	-0.278	-0.259	-0.395	-0.278
P4-1	-0.425				-0.398	-0.431	-0.425
P5-1	-0.345				-0.331	-0.335	-0.345
P3-2	-0.029				-0.031	-0.064	-0.029
P4-2	-0.316				-0.289	-0.08	-0.316
P5-2	-0.15				-0.145	-0.068	-0.15
P6-2	-0.257				-0.258	-0.164	-0.257
P5-3	-0.18				-0.174	-0.017	-0.18
P6-3	-0.428				-0.428	-0.167	-0.428

P5-4	-0.04				-0.043	-0.028	-0.041
P6-5	-0.016				-0.021	-0.042	-0.016
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.181	0.095	-0.153
Q1-4	0.201	***-0.201***	0.201	0.201	0.161	0.248	0.202
Q1-5	0.113	***-0.113***	0.113	0.113	0.086	0.126	0.113
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.129	-0.012	-0.122
Q2-4	0.461	0.461	0.461	0.461	0.459	0.055	0.46
Q2-5	0.154	0.154	0.154	0.154	0.15	-0.013	0.154
Q2-6	0.124	0.124	0.124	0.124	0.116	0.026	0.125
Q3-5	0.232				0.234	-0.027	0.231
Q3-6	0.607				0.606	0.095	0.607
Q4-5	-0.049				-0.051	-0.057	-0.049
Q5-6	-0.097				-0.099	-0.001	-0.096
Q2-1	0.128	0.129	0.129	0.129	0.154	-0.103	0.127
Q4-1	-0.199				-0.167	-0.24	-0.2
Q5-1	-0.134				-0.113	-0.149	-0.135
Q3-2	0.057				0.062	-0.045	0.057
Q4-2	-0.451				-0.452	-0.073	-0.451
Q5-2	-0.18				-0.178	-0.025	-0.18
Q6-2	-0.16				-0.154	-0.068	-0.161
Q5-3	-0.261				-0.265	-0.021	-0.261
Q6-3	-0.579				-0.578	-0.11	-0.579
Q5-4	-0.028				-0.028	-0.02	-0.028
Q6-5	0.039				0.041	-0.055	0.038

Table B-12: 6 Bus -WLAVIRLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.049	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.049	1.049
V3	1.07	1.071	1.071	***-1.071***	1.07	1.069	1.07
V4	0.989				0.99	0.991	0.989
V5	0.985				0.986	0.988	0.985
V6	1.004	1.0039	1.0039	***-1.0039***	1.005	1.004	1.004
P1	1.079	1.079	1.079	1.079	1.088	1.087	1.089

P2	0.5	0.5	***-0.5***	0.5	0.436	0.421	0.435
P3	0.6	0.6	***-0.6***	0.6	0.61	0.602	0.61
P4	-0.7	0.7	0.7	0.7	-0.679	-0.67	-0.679
P5	-0.7	0.7	0.7	0.7	-0.696	-0.684	-0.696
P6	-0.7	0.7	0.7	0.7	-0.682	-0.681	-0.681
Q1	0.16	0.16	0.16	0.16	0.155	0.143	0.159
Q2	0.744	0.744	***-0.744***	0.744	0.746	0.711	0.744
Q3	0.896	0.877	***-0.877***	0.877	0.895	0.87	0.895
Q4	-0.7	0.7	0.7	0.7	-0.699	-0.678	-0.701
Q5	-0.7	0.7	0.7	0.7	-0.697	-0.662	-0.697
Q6	-0.7	0.7	0.7	0.7	-0.703	-0.697	-0.703
P1-2	0.287	0.287	0.287	0.287	0.297	0.298	0.298
P1-4	0.436	***-0.436***	0.436	0.436	0.435	0.434	0.436
P1-5	0.356	***-0.356***	0.356	0.356	0.356	0.354	0.356
P2-3	0.029	0.03	0.03	0.03	0.018	0.018	0.018
P2-4	0.331	0.331	0.331	0.331	0.31	0.3	0.31
P2-5	0.155	0.155	0.155	0.155	0.148	0.145	0.148
P2-6	0.262	0.262	0.262	0.262	0.248	0.247	0.248
P3-5	0.191				0.193	0.187	0.192
P3-6	0.438				0.435	0.433	0.435
P4-5	0.041				0.041	0.04	0.041
P5-6	0.016				0.014	0.017	0.014
P2-1	-0.278	-0.278	-0.278	-0.278	-0.287	-0.289	-0.288
P4-1	-0.425				-0.425	-0.423	-0.425
P5-1	-0.345				-0.345	-0.344	-0.345
P3-2	-0.029				-0.018	-0.018	-0.017
P4-2	-0.316				-0.295	-0.287	-0.295
P5-2	-0.15				-0.143	-0.14	-0.143
P6-2	-0.257				-0.243	-0.242	-0.243
P5-3	-0.18				-0.182	-0.177	-0.182
P6-3	-0.428				-0.425	-0.423	-0.425
P5-4	-0.04				-0.041	-0.04	-0.04
P6-5	-0.016				-0.014	-0.016	-0.014
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.156	-0.152	-0.154
Q1-4	0.201	***-0.201***	0.201	0.201	0.199	0.192	0.201
Q1-5	0.113	***-0.113***	0.113	0.113	0.111	0.104	0.112
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.122	-0.123

Q2-4	0.461	0.461	0.461	0.461	0.461	0.441	0.461
Q2-5	0.154	0.154	0.154	0.154	0.153	0.143	0.153
Q2-6	0.124	0.124	0.124	0.124	0.125	0.121	0.124
Q3-5	0.232				0.23	0.218	0.23
Q3-6	0.607				0.607	0.596	0.607
Q4-5	-0.049				-0.049	-0.051	-0.049
Q5-6	-0.097				-0.096	-0.088	-0.096
Q2-1	0.128	0.129	0.129	0.129	0.131	0.127	0.129
Q4-1	-0.199				-0.197	-0.191	-0.199
Q5-1	-0.134				-0.134	-0.127	-0.134
Q3-2	0.057				0.058	0.056	0.058
Q4-2	-0.451				-0.453	-0.435	-0.453
Q5-2	-0.18				-0.18	-0.171	-0.18
Q6-2	-0.16				-0.162	-0.159	-0.162
Q5-3	-0.261				-0.26	-0.249	-0.26
Q6-3	-0.579				-0.579	-0.569	-0.579
Q5-4	-0.028				-0.028	-0.026	-0.028
Q6-5	0.039				0.038	0.03	0.038

Table B-13: 6 Bus -WLS Estimated values for partial redundancy with SCADA & PMU having single error

	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07				1.07	1.07	1.07
V4	0.989				0.989	0.989	0.989
V5	0.985				0.985	0.985	0.986
V6	1.004	1.0039	1.0039	***-1.0039***	1.004	1.004	1.002
P1	1.079	1.079	***-1.079***	1.079	1.079	1.079	1.08
P2	0.5	0.5	0.5	0.5	0.5	0.5	0.448
P3	0.6				0.6	0.6	0.475
P4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
P5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.733
P6	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.492
Q1	0.16	0.16	***-0.16***	0.16	0.16	0.16	0.158
Q2	0.744	0.744	0.744	0.744	0.744	0.744	0.774

Q3	0.896				0.896	0.896	0.949
Q4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.702
Q5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.683
Q6	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.801
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.287
P1-4	0.436	0.436	0.436	0.436	0.436	0.436	0.436
P1-5	0.356	0.356	0.356	0.356	0.356	0.356	0.356
P2-3	0.029	0.03	0.03	0.03	0.029	0.029	0.031
P2-4	0.331	0.331	0.331	0.331	0.331	0.331	0.331
P2-5	0.155	0.155	0.155	0.155	0.155	0.155	0.155
P2-6	0.262	0.262	0.262	0.262	0.262	0.263	0.209
P3-5	0.191				0.191	0.191	0.191
P3-6	0.438				0.438	0.438	0.315
P4-5	0.041	***-0.0409***	0.0409	0.0409	0.041	0.041	0.041
P5-6	0.016				0.016	0.016	-0.017
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278
P4-1	-0.425				-0.425	-0.425	-0.425
P5-1	-0.345				-0.345	-0.345	-0.346
P3-2	-0.029				-0.029	-0.029	-0.03
P4-2	-0.316				-0.316	-0.316	-0.316
P5-2	-0.15				-0.15	-0.15	-0.15
P6-2	-0.257				-0.257	-0.257	-0.204
P5-3	-0.18				-0.18	-0.18	-0.18
P6-3	-0.428				-0.428	-0.428	-0.305
P5-4	-0.04				-0.04	-0.04	-0.04
P6-5	-0.016				-0.016	-0.016	0.018
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.155
Q1-4	0.201	0.201	0.201	0.201	0.201	0.201	0.201
Q1-5	0.113	0.113	0.113	0.113	0.113	0.113	0.112
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123	-0.124
Q2-4	0.461	0.461	0.461	0.461	0.461	0.461	0.463
Q2-5	0.154	0.154	0.154	0.154	0.154	0.154	0.154
Q2-6	0.124	0.124	0.124	0.124	0.124	0.124	0.152
Q3-5	0.232				0.232	0.232	0.234
Q3-6	0.607				0.607	0.607	0.656
Q4-5	-0.049	***0.0483***	-0.0483	-0.0483	-0.049	-0.049	-0.05
Q5-6	-0.097				-0.097	-0.097	-0.079

Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.129
Q4-1	-0.199				-0.199	-0.199	-0.199
Q5-1	-0.134				-0.135	-0.135	-0.134
Q3-2	0.057				0.057	0.057	0.059
Q4-2	-0.451				-0.451	-0.451	-0.453
Q5-2	-0.18				-0.18	-0.18	-0.18
Q6-2	-0.16				-0.16	-0.16	-0.191
Q5-3	-0.261				-0.261	-0.261	-0.263
Q6-3	-0.579				-0.578	-0.578	-0.63
Q5-4	-0.028				-0.028	-0.028	-0.028
Q6-5	0.039				0.039	0.039	0.02
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.064
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.075
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.073
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.092

Table B-14: 6 Bus -IRLS Estimated values for partial redundancy with SCADA & PMU having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07				1.07	1.07	1.07
V4	0.989				0.989	0.989	0.989
V5	0.985				0.985	0.985	0.985
V6	1.004	1.0039	1.0039	***-1.0039***	1.004	1.004	1.004
P1	1.079	1.079	***-1.079***	1.079	1.079	1.079	1.079
P2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
P3	0.6				0.6	0.6	0.6
P4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
P5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
P6	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
Q1	0.16	0.16	***-0.16***	0.16	0.16	0.159	0.16
Q2	0.744	0.744	0.744	0.744	0.744	0.744	0.744

Q3	0.896				0.896	0.896	0.896
Q4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
Q5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
Q6	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.287
P1-4	0.436	0.436	0.436	0.436	0.436	0.436	0.436
P1-5	0.356	0.356	0.356	0.356	0.356	0.356	0.356
P2-3	0.029	0.03	0.03	0.03	0.029	0.029	0.029
P2-4	0.331	0.331	0.331	0.331	0.331	0.331	0.331
P2-5	0.155	0.155	0.155	0.155	0.155	0.155	0.155
P2-6	0.262	0.262	0.262	0.262	0.262	0.262	0.262
P3-5	0.191				0.191	0.191	0.191
P3-6	0.438				0.438	0.438	0.438
P4-5	0.041	***-0.0409***	0.0409	0.0409	0.041	0.041	0.041
P5-6	0.016				0.016	0.016	0.016
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278
P4-1	-0.425				-0.425	-0.425	-0.425
P5-1	-0.345				-0.345	-0.345	-0.345
P3-2	-0.029				-0.029	-0.029	-0.029
P4-2	-0.316				-0.316	-0.316	-0.316
P5-2	-0.15				-0.15	-0.15	-0.15
P6-2	-0.257				-0.257	-0.257	-0.257
P5-3	-0.18				-0.18	-0.18	-0.18
P6-3	-0.428				-0.428	-0.428	-0.428
P5-4	-0.04				-0.04	-0.04	-0.041
P6-5	-0.016				-0.016	-0.016	-0.016
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154
Q1-4	0.201	0.201	0.201	0.201	0.201	0.201	0.201
Q1-5	0.113	0.113	0.113	0.113	0.113	0.113	0.113
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123	-0.122
Q2-4	0.461	0.461	0.461	0.461	0.461	0.461	0.461
Q2-5	0.154	0.154	0.154	0.154	0.154	0.154	0.154
Q2-6	0.124	0.124	0.124	0.124	0.124	0.124	0.124
Q3-5	0.232				0.232	0.232	0.232
Q3-6	0.607				0.607	0.607	0.607
Q4-5	-0.049	***0.0483***	-0.0483	-0.0483	-0.049	-0.049	-0.049
Q5-6	-0.097				-0.097	-0.097	-0.097

Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.128
Q4-1	-0.199				-0.199	-0.199	-0.199
Q5-1	-0.134				-0.135	-0.134	-0.135
Q3-2	0.057				0.057	0.057	0.057
Q4-2	-0.451				-0.451	-0.451	-0.451
Q5-2	-0.18				-0.18	-0.18	-0.18
Q6-2	-0.16				-0.16	-0.16	-0.16
Q5-3	-0.261				-0.261	-0.261	-0.261
Q6-3	-0.579				-0.578	-0.578	-0.578
Q5-4	-0.028				-0.028	-0.028	-0.028
Q6-5	0.039				0.039	0.039	0.039
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.064
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.075
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.073
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.104

Table B-15: 6 Bus -WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07				1.07	1.07	1.07
V4	0.989				0.99	0.991	0.989
V5	0.985				0.985	0.987	0.986
V6	1.004	1.0039	1.0039	***-1.0039***	1.004	1.004	1.004
P1	1.079	1.079	***-1.079***	1.079	1.079	1.077	1.079
P2	0.5	0.5	0.5	0.5	0.5	0.494	0.5
P3	0.6				0.6	0.599	0.6
P4	-0.7	0.7	0.7	0.7	-0.699	-0.694	-0.7
P5	-0.7	0.7	0.7	0.7	-0.7	-0.696	-0.7
P6	-0.7	0.7	0.7	0.7	-0.7	-0.702	-0.7
Q1	0.16	0.16	***-0.16***	0.16	0.159	0.149	0.159
Q2	0.744	0.744	0.744	0.744	0.743	0.73	0.743

Q3	0.896				0.896	0.895	0.896
Q4	-0.7	0.7	0.7	0.7	-0.698	-0.685	-0.699
Q5	-0.7	0.7	0.7	0.7	-0.701	-0.686	-0.699
Q6	-0.7	0.7	0.7	0.7	-0.7	-0.708	-0.7
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.287
P1-4	0.436	0.436	0.436	0.436	0.436	0.435	0.436
P1-5	0.356	0.356	0.356	0.356	0.356	0.355	0.356
P2-3	0.029	0.03	0.03	0.03	0.029	0.029	0.029
P2-4	0.331	0.331	0.331	0.331	0.33	0.326	0.331
P2-5	0.155	0.155	0.155	0.155	0.155	0.154	0.155
P2-6	0.262	0.262	0.262	0.262	0.263	0.263	0.263
P3-5	0.191				0.191	0.189	0.191
P3-6	0.438				0.438	0.438	0.438
P4-5	0.041	***-0.0409***	0.0409	0.0409	0.041	0.041	0.041
P5-6	0.016				0.016	0.018	0.016
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278
P4-1	-0.425				-0.425	-0.424	-0.425
P5-1	-0.345				-0.345	-0.345	-0.345
P3-2	-0.029				-0.029	-0.029	-0.029
P4-2	-0.316				-0.315	-0.311	-0.316
P5-2	-0.15				-0.15	-0.149	-0.15
P6-2	-0.257				-0.257	-0.257	-0.257
P5-3	-0.18				-0.18	-0.179	-0.18
P6-3	-0.428				-0.428	-0.428	-0.428
P5-4	-0.04				-0.041	-0.041	-0.04
P6-5	-0.016				-0.016	-0.017	-0.016
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154
Q1-4	0.201	0.201	0.201	0.201	0.201	0.195	0.201
Q1-5	0.113	0.113	0.113	0.113	0.113	0.109	0.112
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123
Q2-4	0.461	0.461	0.461	0.461	0.459	0.45	0.46
Q2-5	0.154	0.154	0.154	0.154	0.154	0.15	0.153
Q2-6	0.124	0.124	0.124	0.124	0.124	0.125	0.124
Q3-5	0.232				0.232	0.228	0.231
Q3-6	0.607				0.607	0.61	0.607
Q4-5	-0.049	***0.0483***	-0.0483	-0.0483	-0.049	-0.049	-0.049
Q5-6	-0.097				-0.097	-0.092	-0.096

Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.128
Q4-1	-0.199				-0.199	-0.194	-0.199
Q5-1	-0.134				-0.135	-0.131	-0.134
Q3-2	0.057				0.057	0.057	0.057
Q4-2	-0.451				-0.45	-0.442	-0.451
Q5-2	-0.18				-0.18	-0.177	-0.18
Q6-2	-0.16				-0.16	-0.161	-0.16
Q5-3	-0.261				-0.261	-0.258	-0.261
Q6-3	-0.579				-0.579	-0.581	-0.579
Q5-4	-0.028				-0.028	-0.028	-0.028
Q6-5	0.039				0.039	0.034	0.038
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.064
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.075
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.073
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.104

Table B-16: 6 Bus -WLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07	1.071	1.071	***-1.071***	1.07	1.07	1.068
V4	0.989	0.977	0.977	**-0.977**	0.989	0.989	0.988
V5	0.985				0.985	0.985	0.986
V6	1.004				1.004	1.004	1.005
P1	1.079	1.079	***-1.079***	1.079	1.079	1.079	1.083
P2	0.5	0.5	0.5	0.5	0.5	0.5	0.503
P3	0.6	0.6	***-0.6***	0.6	0.6	0.6	0.587
P4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.706
P5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.694
P6	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.695
Q1	0.16	0.16	***-0.16***	0.16	0.16	0.16	0.164
Q2	0.744	0.744	0.744	0.744	0.744	0.744	0.78

Q3	0.896	0.877	***-0.877***	0.877	0.896	0.896	0.847
Q4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.73
Q5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.691
Q6	-0.7	0.7	0.7	0.7	-0.7	-0.699	-0.672
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.289
P1-4	0.436	***-0.436***	0.436	0.436	0.436	0.436	0.438
P1-5	0.356	0.356	0.356	0.356	0.356	0.356	0.357
P2-3	0.029	***-0.03***	0.03	0.03	0.029	0.029	0.031
P2-4	0.331	0.331	0.331	0.331	0.331	0.331	0.335
P2-5	0.155	0.155	0.155	0.155	0.155	0.155	0.154
P2-6	0.262	0.262	0.262	0.262	0.262	0.263	0.262
P3-5	0.191				0.191	0.191	0.186
P3-6	0.438				0.438	0.438	0.432
P4-5	0.041				0.041	0.041	0.039
P5-6	0.016				0.016	0.016	0.017
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.28
P4-1	-0.425				-0.425	-0.425	-0.427
P5-1	-0.345				-0.345	-0.345	-0.346
P3-2	-0.029				-0.029	-0.029	-0.031
P4-2	-0.316				-0.316	-0.316	-0.319
P5-2	-0.15				-0.15	-0.15	-0.149
P6-2	-0.257				-0.257	-0.257	-0.256
P5-3	-0.18				-0.18	-0.18	-0.176
P6-3	-0.428				-0.428	-0.428	-0.422
P5-4	-0.04				-0.04	-0.04	-0.039
P6-5	-0.016				-0.016	-0.016	-0.016
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.157
Q1-4	0.201	***-0.201***	0.201	0.201	0.201	0.201	0.21
Q1-5	0.113	0.113	0.113	0.113	0.113	0.113	0.112
Q2-3	-0.123	***0.123***	-0.123	-0.123	-0.123	-0.123	-0.112
Q2-4	0.461	0.461	0.461	0.461	0.461	0.461	0.481
Q2-5	0.154	0.154	0.154	0.154	0.154	0.154	0.155
Q2-6	0.124	0.124	0.124	0.124	0.124	0.124	0.124
Q3-5	0.232				0.232	0.232	0.223
Q3-6	0.607				0.607	0.607	0.577
Q4-5	-0.049				-0.049	-0.049	-0.053
Q5-6	-0.097				-0.097	-0.097	-0.098

Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.132
Q4-1	-0.199				-0.199	-0.199	-0.207
Q5-1	-0.134				-0.135	-0.135	-0.134
Q3-2	0.057				0.057	0.057	0.046
Q4-2	-0.451				-0.451	-0.451	-0.47
Q5-2	-0.18				-0.18	-0.18	-0.181
Q6-2	-0.16				-0.16	-0.16	-0.16
Q5-3	-0.261				-0.261	-0.261	-0.254
Q6-3	-0.579				-0.578	-0.578	-0.552
Q5-4	-0.028				-0.028	-0.028	-0.024
Q6-5	0.039				0.039	0.039	0.04
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.065
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.075
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.073
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.104

Table B-17: 6 Bus -IRLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07	1.071	1.071	***-1.071***	1.07	1.07	1.07
V4	0.989	0.977	0.977	**-0.977**	0.989	0.989	0.989
V5	0.985				0.985	0.985	0.985
V6	1.004				1.004	1.004	1.004
P1	1.079	1.079	***-1.079***	1.079	1.079	1.079	1.075
P2	0.5	0.5	0.5	0.5	0.5	0.5	0.49
P3	0.6	0.6	***-0.6***	0.6	0.6	0.6	0.604
P4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.685
P5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.703
P6	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.703
Q1	0.16	0.16	***-0.16***	0.16	0.16	0.16	0.168
Q2	0.744	0.744	0.744	0.744	0.744	0.744	0.749

Q3	0.896	0.877	***-0.877***	0.877	0.896	0.896	0.896
Q4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.713
Q5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.699
Q6	-0.7	0.7	0.7	0.7	-0.7	-0.699	-0.699
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.288
P1-4	0.436	***-0.436***	0.436	0.436	0.436	0.436	0.431
P1-5	0.356	0.356	0.356	0.356	0.356	0.356	0.356
P2-3	0.029	***-0.03***	0.03	0.03	0.029	0.029	0.028
P2-4	0.331	0.331	0.331	0.331	0.331	0.331	0.323
P2-5	0.155	0.155	0.155	0.155	0.155	0.155	0.155
P2-6	0.262	0.262	0.262	0.262	0.262	0.263	0.263
P3-5	0.191				0.191	0.191	0.192
P3-6	0.438				0.438	0.438	0.441
P4-5	0.041				0.041	0.041	0.043
P5-6	0.016				0.016	0.016	0.016
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.279
P4-1	-0.425				-0.425	-0.425	-0.42
P5-1	-0.345				-0.345	-0.345	-0.346
P3-2	-0.029				-0.029	-0.029	-0.028
P4-2	-0.316				-0.316	-0.316	-0.308
P5-2	-0.15				-0.15	-0.15	-0.15
P6-2	-0.257				-0.257	-0.257	-0.257
P5-3	-0.18				-0.18	-0.18	-0.181
P6-3	-0.428				-0.428	-0.428	-0.43
P5-4	-0.04				-0.04	-0.04	-0.042
P6-5	-0.016				-0.016	-0.016	-0.016
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.152
Q1-4	0.201	***-0.201***	0.201	0.201	0.201	0.201	0.206
Q1-5	0.113	0.113	0.113	0.113	0.113	0.113	0.114
Q2-3	-0.123	***0.123***	-0.123	-0.123	-0.123	-0.123	-0.123
Q2-4	0.461	0.461	0.461	0.461	0.461	0.461	0.467
Q2-5	0.154	0.154	0.154	0.154	0.154	0.154	0.154
Q2-6	0.124	0.124	0.124	0.124	0.124	0.124	0.124
Q3-5	0.232				0.232	0.232	0.232
Q3-6	0.607				0.607	0.607	0.607
Q4-5	-0.049				-0.049	-0.049	-0.051
Q5-6	-0.097				-0.097	-0.097	-0.097

Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.126
Q4-1	-0.199				-0.199	-0.199	-0.204
Q5-1	-0.134				-0.135	-0.135	-0.136
Q3-2	0.057				0.057	0.057	0.057
Q4-2	-0.451				-0.451	-0.451	-0.458
Q5-2	-0.18				-0.18	-0.18	-0.18
Q6-2	-0.16				-0.16	-0.16	-0.16
Q5-3	-0.261				-0.261	-0.261	-0.261
Q6-3	-0.579				-0.578	-0.578	-0.578
Q5-4	-0.028				-0.028	-0.028	-0.026
Q6-5	0.039				0.039	0.039	0.039
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.064
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.074
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.072
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.104

Table B-18: 6 Bus -WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07	1.071	1.071	***-1.071***	1.07	1.07	1.07
V4	0.989	0.977	0.977	**-0.977**	0.99	0.991	0.989
V5	0.985				0.986	0.988	0.985
V6	1.004				1.004	1.006	1.004
P1	1.079	1.079	***-1.079***	1.079	1.078	1.076	1.079
P2	0.5	0.5	0.5	0.5	0.496	0.489	0.5
P3	0.6	0.6	***-0.6***	0.6	0.6	0.594	0.6
P4	-0.7	0.7	0.7	0.7	-0.695	-0.694	-0.7
P5	-0.7	0.7	0.7	0.7	-0.7	-0.69	-0.7
P6	-0.7	0.7	0.7	0.7	-0.701	-0.698	-0.7
Q1	0.16	0.16	***-0.16***	0.16	0.154	0.143	0.159
Q2	0.744	0.744	0.744	0.744	0.735	0.716	0.743

Q3	0.896	0.877	***-0.877***	0.877	0.896	0.874	0.896
Q4	-0.7	0.7	0.7	0.7	-0.688	-0.684	-0.7
Q5	-0.7	0.7	0.7	0.7	-0.698	-0.67	-0.699
Q6	-0.7	0.7	0.7	0.7	-0.702	-0.688	-0.7
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.287
P1-4	0.436	***-0.436***	0.436	0.436	0.435	0.435	0.436
P1-5	0.356	0.356	0.356	0.356	0.356	0.354	0.356
P2-3	0.029	***-0.03***	0.03	0.03	0.029	0.029	0.029
P2-4	0.331	0.331	0.331	0.331	0.327	0.325	0.331
P2-5	0.155	0.155	0.155	0.155	0.155	0.153	0.155
P2-6	0.262	0.262	0.262	0.262	0.263	0.261	0.263
P3-5	0.191				0.191	0.187	0.191
P3-6	0.438				0.438	0.436	0.438
P4-5	0.041				0.042	0.04	0.041
P5-6	0.016				0.017	0.018	0.016
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278
P4-1	-0.425				-0.424	-0.424	-0.425
P5-1	-0.345				-0.345	-0.344	-0.345
P3-2	-0.029				-0.029	-0.029	-0.029
P4-2	-0.316				-0.312	-0.31	-0.316
P5-2	-0.15				-0.15	-0.148	-0.15
P6-2	-0.257				-0.257	-0.255	-0.257
P5-3	-0.18				-0.18	-0.177	-0.18
P6-3	-0.428				-0.428	-0.426	-0.428
P5-4	-0.04				-0.041	-0.039	-0.04
P6-5	-0.016				-0.016	-0.017	-0.016
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154
Q1-4	0.201	***-0.201***	0.201	0.201	0.197	0.194	0.201
Q1-5	0.113	0.113	0.113	0.113	0.112	0.103	0.112
Q2-3	-0.123	***0.123***	-0.123	-0.123	-0.123	-0.123	-0.123
Q2-4	0.461	0.461	0.461	0.461	0.453	0.448	0.46
Q2-5	0.154	0.154	0.154	0.154	0.153	0.145	0.153
Q2-6	0.124	0.124	0.124	0.124	0.124	0.118	0.124
Q3-5	0.232				0.231	0.222	0.232
Q3-6	0.607				0.608	0.594	0.607
Q4-5	-0.049				-0.048	-0.052	-0.049
Q5-6	-0.097				-0.096	-0.093	-0.096

Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.128
Q4-1	-0.199				-0.195	-0.193	-0.199
Q5-1	-0.134				-0.134	-0.127	-0.134
Q3-2	0.057				0.057	0.057	0.057
Q4-2	-0.451				-0.444	-0.44	-0.451
Q5-2	-0.18				-0.179	-0.173	-0.18
Q6-2	-0.16				-0.16	-0.155	-0.16
Q5-3	-0.261				-0.26	-0.253	-0.261
Q6-3	-0.579				-0.579	-0.567	-0.579
Q5-4	-0.028				-0.029	-0.026	-0.028
Q6-5	0.039				0.038	0.034	0.039
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.064
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.075
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.073
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.104

Table B-19: 6 Bus -WLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07	1.071	1.071	***-1.071***	1.07	1.07	1.069
V4	0.989				0.989	0.989	0.989
V5	0.985				0.985	0.985	0.986
V6	1.004	1.0039	1.0039	***-1.0039***	1.004	1.004	1.004
P1	1.079	1.079	1.079	1.079	1.079	1.079	1.08
P2	0.5	0.5	***-0.5***	0.5	0.5	0.5	0.449
P3	0.6	0.6	***-0.6***	0.6	0.6	0.6	0.467
P4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.702
P5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.733

P6	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.483
Q1	0.16	0.16	0.16	0.16	0.16	0.16	0.158
Q2	0.744	0.744	***-0.744***	0.744	0.744	0.743	0.77
Q3	0.896	0.877	***-0.877***	0.877	0.896	0.896	0.912
Q4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.702
Q5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.685
Q6	-0.7	0.7	0.7	0.7	-0.7	-0.699	-0.764
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.287
P1-4	0.436	***-0.436***	0.436	0.436	0.436	0.436	0.437
P1-5	0.356	***-0.356***	0.356	0.356	0.356	0.356	0.356
P2-3	0.029	0.03	0.03	0.03	0.029	0.029	0.032
P2-4	0.331	0.331	0.331	0.331	0.331	0.331	0.332
P2-5	0.155	0.155	0.155	0.155	0.155	0.155	0.155
P2-6	0.262	0.262	0.262	0.262	0.262	0.262	0.207
P3-5	0.191				0.191	0.191	0.189
P3-6	0.438				0.438	0.438	0.309
P4-5	0.041				0.041	0.041	0.041
P5-6	0.016				0.016	0.016	-0.019
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278
P4-1	-0.425				-0.425	-0.425	-0.426
P5-1	-0.345				-0.345	-0.345	-0.346
P3-2	-0.029				-0.029	-0.029	-0.031
P4-2	-0.316				-0.316	-0.316	-0.317
P5-2	-0.15				-0.15	-0.15	-0.15
P6-2	-0.257				-0.257	-0.257	-0.202
P5-3	-0.18				-0.18	-0.18	-0.178
P6-3	-0.428				-0.428	-0.428	-0.3
P5-4	-0.04				-0.04	-0.04	-0.04
P6-5	-0.016				-0.016	-0.016	0.019
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.155
Q1-4	0.201	***-0.201***	0.201	0.201	0.201	0.201	0.201
Q1-5	0.113	***-0.113***	0.113	0.113	0.113	0.113	0.112
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123	-0.12
Q2-4	0.461	0.461	0.461	0.461	0.461	0.46	0.463
Q2-5	0.154	0.154	0.154	0.154	0.154	0.153	0.154
Q2-6	0.124	0.124	0.124	0.124	0.124	0.124	0.144
Q3-5	0.232				0.232	0.232	0.23

Q3-6	0.607				0.607	0.607	0.627
Q4-5	-0.049				-0.049	-0.049	-0.05
Q5-6	-0.097				-0.097	-0.097	-0.084
Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.129
Q4-1	-0.199				-0.199	-0.199	-0.199
Q5-1	-0.134				-0.135	-0.135	-0.134
Q3-2	0.057				0.057	0.057	0.055
Q4-2	-0.451				-0.451	-0.451	-0.453
Q5-2	-0.18				-0.18	-0.18	-0.18
Q6-2	-0.16				-0.16	-0.16	-0.184
Q5-3	-0.261				-0.261	-0.261	-0.26
Q6-3	-0.579				-0.578	-0.578	-0.605
Q5-4	-0.028				-0.028	-0.028	-0.028
Q6-5	0.039				0.039	0.039	0.025
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.064
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.075
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.073
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.092

Table B-20: 6 Bus -IRLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07	1.071	1.071	***-1.071***	1.07	1.07	1.07
V4	0.989				0.989	0.989	0.989
V5	0.985				0.985	0.985	0.985
V6	1.004	1.0039	1.0039	***-1.0039***	1.004	1.004	1.004
P1	1.079	1.079	1.079	1.079	1.079	1.079	1.079
P2	0.5	0.5	***-0.5***	0.5	0.5	0.5	0.5

P3	0.6	0.6	***-0.6***	0.6	0.6	0.6	0.599
P4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
P5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
P6	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
Q1	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Q2	0.744	0.744	***-0.744***	0.744	0.744	0.743	0.744
Q3	0.896	0.877	***-0.877***	0.877	0.896	0.896	0.895
Q4	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
Q5	-0.7	0.7	0.7	0.7	-0.7	-0.7	-0.7
Q6	-0.7	0.7	0.7	0.7	-0.7	-0.699	-0.7
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.287
P1-4	0.436	***-0.436***	0.436	0.436	0.436	0.436	0.436
P1-5	0.356	***-0.356***	0.356	0.356	0.356	0.356	0.356
P2-3	0.029	0.03	0.03	0.03	0.029	0.029	0.03
P2-4	0.331	0.331	0.331	0.331	0.331	0.331	0.331
P2-5	0.155	0.155	0.155	0.155	0.155	0.155	0.155
P2-6	0.262	0.262	0.262	0.262	0.262	0.262	0.263
P3-5	0.191				0.191	0.191	0.191
P3-6	0.438				0.438	0.438	0.437
P4-5	0.041				0.041	0.041	0.041
P5-6	0.016				0.016	0.016	0.016
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278
P4-1	-0.425				-0.425	-0.425	-0.425
P5-1	-0.345				-0.345	-0.345	-0.345
P3-2	-0.029				-0.029	-0.029	-0.029
P4-2	-0.316				-0.316	-0.316	-0.316
P5-2	-0.15				-0.15	-0.15	-0.15
P6-2	-0.257				-0.257	-0.257	-0.257
P5-3	-0.18				-0.18	-0.18	-0.18
P6-3	-0.428				-0.428	-0.428	-0.427
P5-4	-0.04				-0.04	-0.04	-0.041
P6-5	-0.016				-0.016	-0.016	-0.016
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154
Q1-4	0.201	***-0.201***	0.201	0.201	0.201	0.201	0.201
Q1-5	0.113	***-0.113***	0.113	0.113	0.113	0.113	0.113
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123	-0.122
Q2-4	0.461	0.461	0.461	0.461	0.461	0.46	0.46

Q2-5	0.154	0.154	0.154	0.154	0.154	0.153	0.154
Q2-6	0.124	0.124	0.124	0.124	0.124	0.124	0.124
Q3-5	0.232				0.232	0.232	0.232
Q3-6	0.607				0.607	0.607	0.607
Q4-5	-0.049				-0.049	-0.049	-0.049
Q5-6	-0.097				-0.097	-0.097	-0.097
Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.128
Q4-1	-0.199				-0.199	-0.199	-0.2
Q5-1	-0.134				-0.135	-0.135	-0.135
Q3-2	0.057				0.057	0.057	0.057
Q4-2	-0.451				-0.451	-0.451	-0.451
Q5-2	-0.18				-0.18	-0.18	-0.18
Q6-2	-0.16				-0.16	-0.16	-0.16
Q5-3	-0.261				-0.261	-0.261	-0.261
Q6-3	-0.579				-0.578	-0.578	-0.578
Q5-4	-0.028				-0.028	-0.028	-0.028
Q6-5	0.039				0.039	0.039	0.039
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.064
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.075
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.073
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.104

Table B-21: 6 Bus -WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.05	1.053	1.053	1.053	1.05	1.05	1.05
V2	1.05	1.034	1.034	1.034	1.05	1.05	1.05
V3	1.07	1.071	1.071	***-1.071***	1.07	1.07	1.07
V4	0.989				0.99	0.992	0.989
V5	0.985				0.987	0.989	0.986
V6	1.004	1.0039	1.0039	**-**	1.004	1.006	1.004

				1.0039			
P1	1.079	1.079	1.079	1.079	1.077	1.075	1.079
P2	0.5	0.5	***-0.5***	0.5	0.495	0.483	0.5
P3	0.6	0.6	***-0.6***	0.6	0.599	0.592	0.6
P4	-0.7	0.7	0.7	0.7	-0.695	-0.689	-0.7
P5	-0.7	0.7	0.7	0.7	-0.696	-0.69	-0.7
P6	-0.7	0.7	0.7	0.7	-0.702	-0.696	-0.7
Q1	0.16	0.16	0.16	0.16	0.151	0.136	0.159
Q2	0.744	0.744	***-0.744***	0.744	0.732	0.702	0.743
Q3	0.896	0.877	***-0.877***	0.877	0.895	0.865	0.896
Q4	-0.7	0.7	0.7	0.7	-0.687	-0.671	-0.699
Q5	-0.7	0.7	0.7	0.7	-0.687	-0.669	-0.699
Q6	-0.7	0.7	0.7	0.7	-0.707	-0.677	-0.701
P1-2	0.287	0.287	0.287	0.287	0.287	0.287	0.287
P1-4	0.436	***-0.436***	0.436	0.436	0.435	0.434	0.436
P1-5	0.356	***-0.356***	0.356	0.356	0.355	0.354	0.356
P2-3	0.029	0.03	0.03	0.03	0.029	0.029	0.029
P2-4	0.331	0.331	0.331	0.331	0.326	0.32	0.331
P2-5	0.155	0.155	0.155	0.155	0.154	0.152	0.155
P2-6	0.262	0.262	0.262	0.262	0.263	0.26	0.263
P3-5	0.191				0.19	0.186	0.191
P3-6	0.438				0.438	0.434	0.438
P4-5	0.041				0.041	0.04	0.041
P5-6	0.016				0.017	0.017	0.016
P2-1	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278	-0.278
P4-1	-0.425				-0.424	-0.423	-0.425
P5-1	-0.345				-0.345	-0.344	-0.345
P3-2	-0.029				-0.029	-0.029	-0.029
P4-2	-0.316				-0.312	-0.306	-0.316
P5-2	-0.15				-0.149	-0.147	-0.15
P6-2	-0.257				-0.257	-0.254	-0.257
P5-3	-0.18				-0.179	-0.176	-0.18
P6-3	-0.428				-0.428	-0.425	-0.428
P5-4	-0.04				-0.041	-0.04	-0.04
P6-5	-0.016				-0.017	-0.017	-0.016
Q1-2	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154	-0.154
Q1-4	0.201	***-0.201***	0.201	0.201	0.196	0.188	0.201

Q1-5	0.113	***-0.113***	0.113	0.113	0.109	0.102	0.112
Q2-3	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123	-0.123
Q2-4	0.461	0.461	0.461	0.461	0.451	0.439	0.46
Q2-5	0.154	0.154	0.154	0.154	0.15	0.143	0.153
Q2-6	0.124	0.124	0.124	0.124	0.125	0.114	0.124
Q3-5	0.232				0.228	0.221	0.231
Q3-6	0.607				0.61	0.587	0.607
Q4-5	-0.049				-0.049	-0.051	-0.049
Q5-6	-0.097				-0.093	-0.094	-0.096
Q2-1	0.128	0.129	0.129	0.129	0.128	0.128	0.128
Q4-1	-0.199				-0.194	-0.188	-0.199
Q5-1	-0.134				-0.131	-0.125	-0.134
Q3-2	0.057				0.057	0.057	0.057
Q4-2	-0.451				-0.443	-0.432	-0.451
Q5-2	-0.18				-0.177	-0.171	-0.18
Q6-2	-0.16				-0.161	-0.151	-0.16
Q5-3	-0.261				-0.258	-0.252	-0.261
Q6-3	-0.579				-0.581	-0.56	-0.579
Q5-4	-0.028				-0.028	-0.027	-0.028
Q6-5	0.039				0.035	0.035	0.038
Va1	0	0	0	0	0	0	0
Va2	-0.0641	-0.0641	-0.0641	-0.0641	-0.064	-0.064	-0.064
Va3	-0.0746	-0.0746	-0.0746	-0.0746	-0.075	-0.075	-0.075
Va4	-0.0732	-0.0732	-0.0732	-0.0732	-0.073	-0.073	-0.073
Va5	-0.0921	-0.0921	-0.0921	-0.0921	-0.092	-0.092	-0.092
Va6	-0.1038	-0.1038	-0.1038	-0.1038	-0.104	-0.104	-0.104

14 Bus System

Table B-22: 14 Bus Estimated values for (Partial redundancy)

	Actual	Measurement	WLS	IRLS	WLAVIRLS

V1	1.0600	1.0692	1.0600	1.0600	1.0600
V2	1.0450	1.0491	1.0449	1.0450	1.0450
V3	1.0100	1.0292	1.0100	1.0100	1.0100
V4	1.0177	0.9931	1.0173	1.0177	1.0177
V5	1.0195	1.0186	1.0192	1.0195	1.0195
V6	1.0700	1.0698	1.0692	1.0700	1.0700
V7	1.0615	1.0635	1.0603	1.0615	1.0615
V8	1.0900	1.0796	1.0884	1.0900	1.0900
V9	1.0559	1.0612	1.0545	1.0559	1.0559
V10	1.0510	1.0288	1.0494	1.0510	1.0510
V11	1.0569		1.0557	1.0569	1.0569
V12	1.0552		1.0545	1.0552	1.0552
V13	1.0504		1.0496	1.0504	1.0504
V14	1.0355		1.0344	1.0355	1.0355
P1	2.3239	2.3243	2.3214	2.3240	2.3240
P2	0.4000	0.4000	0.4048	0.3998	0.3998
P3	0.0000	-0.0001	-0.0033	-0.0001	-0.0001
P4	0.0000	-0.0001	-0.0019	0.0003	0.0005
P5	0.0000	0.0001	-0.0001	0.0000	0.0000
P6	0.4780	0.4779	0.4784	0.4781	0.4781
P7	-0.0760		-0.0784	-0.0760	-0.0760
P8	0.0000		0.0081	-0.0001	0.0000
P9	-0.2950		-0.2944	-0.2946	-0.2946
P10	-0.0900		-0.0871	-0.0900	-0.0900
P11	-0.0350		-0.0327	-0.0351	-0.0351
P12	-0.0610	0.0608	-0.0596	-0.0612	-0.0609
P13	-0.1350	0.1346	-0.1331	-0.1346	-0.1347
P14	-0.1490	0.1490	-0.1481	-0.1490	-0.1490
Q1	-0.1655	-0.1654	-0.1622	-0.1655	-0.1655
Q2	0.4356	0.4356	0.4361	0.4356	0.4356
Q3	0.2508	0.2508	0.2547	0.2508	0.2508
Q4	-0.1273	0.1276	-0.1276	-0.1276	-0.1276
Q5	-0.1762	0.1762	-0.1735	-0.1762	-0.1762
Q6	-0.0390	-0.0390	-0.0391	-0.0389	-0.0389
Q7	-0.0160		-0.0160	-0.0161	-0.0161
Q8	0.0000		-0.0004	0.0000	0.0000
Q9	-0.1660		-0.1665	-0.1661	-0.1661
Q10	-0.0580		-0.0624	-0.0581	-0.0579

Q11	-0.0180		-0.0191	-0.0182	-0.0183
Q12	-0.0160	0.0156	-0.0157	-0.0159	-0.0159
Q13	-0.0580	0.0580	-0.0581	-0.0580	-0.0580
Q14	-0.0500	0.0500	-0.0503	-0.0500	-0.0500
P1-2	1.5688	1.5689	1.5669	1.5689	1.5689
P1-5	0.7551	0.7550	0.7545	0.7551	0.7551
P2-3	0.7324	0.7323	0.7346	0.7324	0.7324
P2-4	0.5613	0.5613	0.5619	0.5613	0.5613
P2-5	0.4152	0.4151	0.4153	0.4151	0.4151
P3-4	-0.2329	-0.2329	-0.2341	-0.2329	-0.2329
P4-5	-0.6116	-0.6111	-0.6131	-0.6115	-0.6115
P4-7	0.2807	0.2805	0.2820	0.2805	0.2806
P4-9	0.1608	0.1606	0.1599	0.1607	0.1607
P5-6	0.4409	0.4409	0.4366	0.4409	0.4409
P6-11	0.0735	0.0735	0.0734	0.0735	0.0735
P6-12	0.0779	0.0777	0.0768	0.0779	0.0777
P6-13	0.1775		0.1762	0.1772	0.1772
P7-8	0.0000		-0.0001	0.0000	0.0000
P7-9	0.2807		0.2739	0.2806	0.2806
P9-10	0.0523		0.0473	0.0525	0.0525
P9-14	0.0943		0.0922	0.0942	0.0942
P10-11	-0.0379		-0.0400	-0.0377	-0.0377
P12-13	0.0161		0.0166	0.0160	0.0161
P13-14	0.0564		0.0576	0.0564	0.0564
P2-1	-1.5259	-1.5261	-1.5240	-1.5259	-1.5259
P5-1	-0.7275	-0.7274	-0.7269	-0.7275	-0.7275
P3-2	-0.7091	-0.7092	-0.7112	-0.7092	-0.7092
P4-2	-0.5445	-0.5443	-0.5451	-0.5445	-0.5445
P5-2	-0.4061	-0.4061	-0.4063	-0.4061	-0.4061
P4-3	0.2366	0.2365	0.2379	0.2366	0.2366
P5-4	0.6167	0.6167	0.6182	0.6166	0.6166
P7-4	-0.2807	-0.2808	-0.2820	-0.2805	-0.2806
P9-4	-0.1608	-0.1605	-0.1599	-0.1607	-0.1607
P6-5	-0.4409	-0.4410	-0.4366	-0.4409	-0.4409
P11-6	-0.0730	-0.0733	-0.0728	-0.0730	-0.0730
P12-6	-0.0771	-0.0772	-0.0761	-0.0772	-0.0770
P13-6	-0.1754		-0.1741	-0.1751	-0.1751
P8-7	0.0000		0.0001	0.0000	0.0000

P9-7	-0.2807		-0.2739	-0.2806	-0.2806
P10-9	-0.0521		-0.0472	-0.0523	-0.0523
P14-9	-0.0931		-0.0911	-0.0931	-0.0931
P11-10	0.0380		0.0401	0.0378	0.0378
P13-12	-0.0161		-0.0165	-0.0159	-0.0161
P14-13	-0.0559		-0.0570	-0.0559	-0.0559
Q1-2	-0.2040	-0.2040	-0.2023	-0.2040	-0.2040
Q1-5	0.0385	0.0384	0.0401	0.0386	0.0386
Q2-3	0.0356	0.0356	0.0351	0.0356	0.0356
Q2-4	-0.0155	-0.0154	-0.0137	-0.0155	-0.0155
Q2-5	0.0117	0.0115	0.0131	0.0117	0.0117
Q3-4	0.0447	0.0448	0.0476	0.0448	0.0448
Q4-5	0.1582	0.1581	0.1568	0.1582	0.1582
Q4-7	-0.0968	-0.0967	-0.0928	-0.0968	-0.0968
Q4-9	-0.0043	-0.0047	-0.0024	-0.0043	-0.0043
Q5-6	0.1247	0.1243	0.1262	0.1246	0.1246
Q6-11	0.0356	0.0359	0.0378	0.0358	0.0358
Q6-12	0.0250	0.0250	0.0249	0.0250	0.0250
Q6-13	0.0722		0.0726	0.0721	0.0721
Q7-8	-0.1716		-0.1690	-0.1716	-0.1716
Q7-9	0.0578		0.0597	0.0578	0.0578
Q9-10	0.0422		0.0456	0.0422	0.0422
Q9-14	0.0361		0.0358	0.0360	0.0360
Q10-11	-0.0162		-0.0171	-0.0162	-0.0161
Q12-13	0.0075		0.0077	0.0076	0.0076
Q13-14	0.0175		0.0180	0.0176	0.0175
Q2-1	0.2768	0.2770	0.2746	0.2768	0.2768
Q5-1	0.0223	0.0227	0.0206	0.0223	0.0223
Q3-2	0.0160	0.0160	0.0171	0.0160	0.0160
Q4-2	0.0302	0.0302	0.0286	0.0302	0.0302
Q5-2	-0.0210	-0.0208	-0.0224	-0.0210	-0.0210
Q4-3	-0.0484	-0.0485	-0.0511	-0.0484	-0.0484
Q5-4	-0.1420	-0.1423	-0.1405	-0.1420	-0.1420
Q7-4	0.1138	0.1138	0.1098	0.1138	0.1138
Q9-4	0.0173	0.0174	0.0153	0.0173	0.0173
Q6-5	-0.0805	-0.0805	-0.0827	-0.0804	-0.0804
Q11-6	-0.0344	-0.0347	-0.0366	-0.0347	-0.0347
Q12-6	-0.0235	-0.0237	-0.0234	-0.0235	-0.0235

Q13-6	-0.0680		-0.0684	-0.0680	-0.0680
Q8-7	0.1762		0.1735	0.1762	0.1762
Q9-7	-0.0498		-0.0520	-0.0498	-0.0498
Q10-9	-0.0418		-0.0452	-0.0419	-0.0418
Q14-9	-0.0336		-0.0334	-0.0335	-0.0336
Q11-10	0.0164		0.0175	0.0165	0.0164
Q13-12	-0.0075		-0.0076	-0.0076	-0.0075
Q14-13	-0.0164		-0.0168	-0.0165	-0.0164

Table B-23: 14 Bus Estimated values for Partial Redundancy (optimal PMU incorporation using heuristic approach)

				WLS		IRLS		WLAVIRLS	
	Actual	Meas SCADA	Meas SCADA + PMU	SCADA	SCADA + PMU	SCADA	SCADA + PMU	SCADA	SCADA + PMU
V1	1.0600	1.0692	1.0692	1.0592	1.0594	1.0595	1.0597	1.0598	1.0599
V2	1.0450	1.0491	1.0491	1.0449	1.0450	1.0450	1.0450	1.0450	1.0450
V3	1.0100	1.0292	1.0292	1.0100	1.0100	1.0100	1.0100	1.0100	1.0100
V4	1.0177	0.9931	0.9931	1.0173	1.0177	1.0177	1.0177	1.0177	1.0177
V5	1.0195	1.0186	1.0186	1.0192	1.0195	1.0195	1.0195	1.0195	1.0195
V6	1.0700	1.0698	1.0698	1.0692	1.0700	1.0700	1.0700	1.0700	1.0700
V7	1.0615	1.0635	1.0635	1.0603	1.0615	1.0615	1.0615	1.0615	1.0615
V8	1.0900	1.0796	1.0796	1.0884	1.0900	1.0900	1.0900	1.0900	1.0900
V9	1.0559	1.0612	1.0612	1.0545	1.0559	1.0559	1.0559	1.0559	1.0559
V10	1.0510	1.0288	1.0288	1.0494	1.0510	1.0510	1.0510	1.0510	1.0510
V11	1.0569			1.0557	1.0569	1.0569	1.0569	1.0569	1.0569
V12	1.0552			1.0545	1.0552	1.0552	1.0552	1.0552	1.0552

V13	1.0504			1.0496	1.0504	1.0504	1.0504	1.0504	1.0504
V14	1.0355			1.0344	1.0355	1.0355	1.0355	1.0355	1.0355
P1	2.3239	2.3243	2.3243	2.3214	2.3240	2.3240	2.3242	2.3240	2.3242
P2	0.4000	0.4000	0.4000	0.4048	0.3998	0.3998	0.3997	0.3998	0.3997
P3	0.0000	-0.0001	-0.0001	-0.0033	0.0002	-0.0001	-0.0001	-0.0001	-0.0001
P4	0.0000	0.0001	0.0001	-0.0019	0.0003	0.0003	0.0004	0.0005	0.0002
P5	0.0000	-0.0001	-0.0001	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0001
P6	0.4780	0.4779	0.4779	0.4784	0.4783	0.4781	0.4779	0.4781	0.4779
P7	-0.0760			-0.0784	-0.0757	-0.0760	-0.0760	-0.0760	-0.0760
P8	0.0000			0.0081	0.0000	-0.0001	0.0000	0.0000	-0.0001
P9	-0.2950			-0.2944	-0.2948	-0.2946	-0.2948	-0.2946	-0.2947
P10	-0.0900			-0.0871	-0.0901	-0.0900	-0.0900	-0.0900	-0.0900
P11	-0.0350			-0.0327	-0.0350	-0.0351	-0.0350	-0.0351	-0.0350
P12	-0.0610	-0.0608	-0.0608	-0.0596	-0.0610	-0.0612	-0.0609	-0.0609	-0.0609
P13	-0.1350	-0.1346	-0.1346	-0.1331	-0.1348	-0.1346	-0.1347	-0.1347	-0.1348
P14	-0.1490	-0.1490	-0.1490	-0.1481	-0.1491	-0.1490	-0.1492	-0.1490	-0.1492
Q1	-0.1655	-0.1654	-0.1654	-0.1622	-0.1655	-0.1655	-0.1654	-0.1655	-0.1655
Q2	0.4356	0.4356	0.4356	0.4361	0.4358	0.4356	0.4355	0.4356	0.4355
Q3	0.2508	0.2508	0.2508	0.2547	0.2506	0.2508	0.2508	0.2508	0.2508
Q4	-0.1273	-0.1276	-0.1276	-0.1276	-0.1271	-0.1276	-0.1276	-0.1276	-0.1275
Q5	-0.1762	-0.1762	-0.1762	-0.1735	-0.1763	-0.1762	-0.1763	-0.1762	-0.1762
Q6	-0.0390	-0.0390	-0.0390	-0.0391	-0.0394	-0.0389	-0.0389	-0.0389	-0.0390
Q7	-0.0160			-0.0160	-0.0165	-0.0161	-0.0161	-0.0161	-0.0160

Q8	0.0000			-0.0004	0.0003	0.0000	0.0001	0.0000	0.0000
Q9	-0.1660			-0.1665	-0.1657	-0.1661	-0.1661	-0.1661	-0.1661
Q10	-0.0580			-0.0624	-0.0581	-0.0581	-0.0579	-0.0579	-0.0579
Q11	-0.0180			-0.0191	-0.0179	-0.0182	-0.0183	-0.0183	-0.0183
Q12	-0.0160	-0.0156	-0.0156	-0.0157	-0.0160	-0.0159	-0.0158	-0.0159	-0.0159
Q13	-0.0580	-0.0580	-0.0580	-0.0581	-0.0579	-0.0580	-0.0580	-0.0580	-0.0580
Q14	-0.0500	-0.0500	-0.0500	-0.0503	-0.0500	-0.0500	-0.0500	-0.0500	-0.0500
P1-2	1.5688	1.5689	1.5689	1.5669	1.5689	1.5689	1.5691	1.5689	1.5690
P1-5	0.7551	0.7550	0.7550	0.7545	0.7551	0.7551	0.7551	0.7551	0.7551
P2-3	0.7324	0.7323	0.7323	0.7346	0.7323	0.7324	0.7324	0.7324	0.7324
P2-4	0.5613	0.5613	0.5613	0.5619	0.5613	0.5613	0.5613	0.5613	0.5612
P2-5	0.4152	0.4151	0.4151	0.4153	0.4151	0.4151	0.4151	0.4151	0.4151
P3-4	-0.2329	-0.2329	-0.2329	-0.2341	-0.2328	-0.2329	-0.2329	-0.2329	-0.2329
P4-5	-0.6116	-0.6111	-0.6111	-0.6131	-0.6118	-0.6115	-0.6115	-0.6115	-0.6115
P4-7	0.2807	0.2805	0.2805	0.2820	0.2807	0.2805	0.2807	0.2806	0.2806
P4-9	0.1608	0.1606	0.1606	0.1599	0.1608	0.1607	0.1608	0.1607	0.1608
P5-6	0.4409	0.4409	0.4409	0.4366	0.4409	0.4409	0.4409	0.4409	0.4409
P6-11	0.0735	0.0735	0.0735	0.0734	0.0735	0.0735	0.0735	0.0735	0.0735
P6-12	0.0779	0.0777	0.0777	0.0768	0.0778	0.0779	0.0777	0.0777	0.0778
P6-13	0.1775			0.1762	0.1773	0.1772	0.1773	0.1772	0.1774
P7-8	0.0000			-0.0001	0.0000	0.0000	0.0000	0.0000	0.0001
P7-9	0.2807			0.2739	0.2807	0.2806	0.2807	0.2806	0.2807
P9-10	0.0523			0.0473	0.0524	0.0525	0.0523	0.0525	0.0523

P9-14	0.0943			0.0922	0.0943	0.0942	0.0944	0.0942	0.0944
P10-11	-0.0379			-0.0400	-0.0378	-0.0377	-0.0378	-0.0377	-0.0378
P12-13	0.0161			0.0166	0.0161	0.0160	0.0162	0.0161	0.0162
P13-14	0.0564			0.0576	0.0565	0.0564	0.0566	0.0564	0.0565
P2-1	-1.5259	-1.5261	-1.5261	-1.5240	-1.5259	-1.5259	-1.5261	-1.5259	-1.5260
P5-1	-0.7275	-0.7274	-0.7274	-0.7269	-0.7274	-0.7275	-0.7275	-0.7275	-0.7275
P3-2	-0.7091	-0.7092	-0.7092	-0.7112	-0.7091	-0.7092	-0.7092	-0.7092	-0.7091
P4-2	-0.5445	-0.5443	-0.5443	-0.5451	-0.5445	-0.5445	-0.5445	-0.5445	-0.5445
P5-2	-0.4061	-0.4061	-0.4061	-0.4063	-0.4061	-0.4061	-0.4061	-0.4061	-0.4061
P4-3	0.2366	0.2365	0.2365	0.2379	0.2365	0.2366	0.2366	0.2366	0.2367
P5-4	0.6167	0.6167	0.6167	0.6182	0.6169	0.6166	0.6167	0.6166	0.6167
P7-4	-0.2807	-0.2808	-0.2808	-0.2820	-0.2807	-0.2805	-0.2807	-0.2806	-0.2806
P9-4	-0.1608	-0.1605	-0.1605	-0.1599	-0.1608	-0.1607	-0.1608	-0.1607	-0.1608
P6-5	-0.4409	-0.4410	-0.4410	-0.4366	-0.4409	-0.4409	-0.4409	-0.4409	-0.4409
P11-6	-0.0730	-0.0733	-0.0733	-0.0728	-0.0729	-0.0730	-0.0730	-0.0730	-0.0730
P12-6	-0.0771	-0.0772	-0.0772	-0.0761	-0.0771	-0.0772	-0.0770	-0.0770	-0.0771
P13-6	-0.1754			-0.1741	-0.1752	-0.1751	-0.1751	-0.1751	-0.1753
P8-7	0.0000			0.0001	0.0000	0.0000	0.0000	0.0000	-0.0001
P9-7	-0.2807			-0.2739	-0.2807	-0.2806	-0.2807	-0.2806	-0.2807
P10-9	-0.0521			-0.0472	-0.0523	-0.0523	-0.0522	-0.0523	-0.0522
P14-9	-0.0931			-0.0911	-0.0932	-0.0931	-0.0932	-0.0931	-0.0932
P11-10	0.0380			0.0401	0.0380	0.0378	0.0380	0.0378	0.0380
P13-12	-0.0161			-0.0165	-0.0161	-0.0159	-0.0161	-0.0161	-0.0161

P14-13	-0.0559			-0.0570	-0.0559	-0.0559	-0.0560	-0.0559	-0.0560
Q1-2	-0.2040	-0.2040	-0.2040	-0.2023	-0.2041	-0.2040	-0.2040	-0.2040	-0.2040
Q1-5	0.0385	0.0384	0.0384	0.0401	0.0386	0.0386	0.0386	0.0386	0.0385
Q2-3	0.0356	0.0356	0.0356	0.0351	0.0357	0.0356	0.0356	0.0356	0.0356
Q2-4	-0.0155	-0.0154	-0.0154	-0.0137	-0.0155	-0.0155	-0.0155	-0.0155	-0.0155
Q2-5	0.0117	0.0115	0.0115	0.0131	0.0118	0.0117	0.0117	0.0117	0.0117
Q3-4	0.0447	0.0448	0.0448	0.0476	0.0446	0.0448	0.0448	0.0448	0.0447
Q4-5	0.1582	0.1581	0.1581	0.1568	0.1586	0.1582	0.1582	0.1582	0.1582
Q4-7	-0.0968	-0.0967	-0.0967	-0.0928	-0.0968	-0.0968	-0.0968	-0.0968	-0.0968
Q4-9	-0.0043	-0.0047	-0.0047	-0.0024	-0.0043	-0.0043	-0.0043	-0.0043	-0.0043
Q5-6	0.1247	0.1243	0.1243	0.1262	0.1247	0.1246	0.1246	0.1246	0.1246
Q6-11	0.0356	0.0359	0.0359	0.0378	0.0356	0.0358	0.0358	0.0358	0.0358
Q6-12	0.0250	0.0250	0.0250	0.0249	0.0250	0.0250	0.0249	0.0250	0.0250
Q6-13	0.0722			0.0726	0.0721	0.0721	0.0721	0.0721	0.0721
Q7-8	-0.1716			-0.1690	-0.1717	-0.1716	-0.1717	-0.1716	-0.1716
Q7-9	0.0578			0.0597	0.0576	0.0578	0.0578	0.0578	0.0578
Q9-10	0.0422			0.0456	0.0423	0.0422	0.0421	0.0422	0.0421
Q9-14	0.0361			0.0358	0.0361	0.0360	0.0360	0.0360	0.0360
Q10-11	-0.0162			-0.0171	-0.0162	-0.0162	-0.0161	-0.0161	-0.0161
Q12-13	0.0075			0.0077	0.0075	0.0076	0.0076	0.0076	0.0076
Q13-14	0.0175			0.0180	0.0175	0.0176	0.0175	0.0175	0.0175
Q2-1	0.2768	0.2770	0.2770	0.2746	0.2768	0.2768	0.2767	0.2768	0.2768
Q5-1	0.0223	0.0227	0.0227	0.0206	0.0222	0.0223	0.0223	0.0223	0.0223

Q3-2	0.0160	0.0160	0.0160	0.0171	0.0159	0.0160	0.0160	0.0160	0.0160
Q4-2	0.0302	0.0302	0.0302	0.0286	0.0302	0.0302	0.0302	0.0302	0.0302
Q5-2	-0.0210	-0.0208	-0.0208	-0.0224	-0.0211	-0.0210	-0.0210	-0.0210	-0.0210
Q4-3	-0.0484	-0.0485	-0.0485	-0.0511	-0.0483	-0.0484	-0.0484	-0.0484	-0.0483
Q5-4	-0.1420	-0.1423	-0.1423	-0.1405	-0.1423	-0.1420	-0.1420	-0.1420	-0.1419
Q7-4	0.1138	0.1138	0.1138	0.1098	0.1138	0.1138	0.1138	0.1138	0.1138
Q9-4	0.0173	0.0174	0.0174	0.0153	0.0174	0.0173	0.0173	0.0173	0.0173
Q6-5	-0.0805	-0.0805	-0.0805	-0.0827	-0.0805	-0.0804	-0.0804	-0.0804	-0.0804
Q11-6	-0.0344	-0.0347	-0.0347	-0.0366	-0.0344	-0.0347	-0.0347	-0.0347	-0.0347
Q12-6	-0.0235	-0.0237	-0.0237	-0.0234	-0.0235	-0.0235	-0.0235	-0.0235	-0.0235
Q13-6	-0.0680			-0.0684	-0.0679	-0.0680	-0.0680	-0.0680	-0.0680
Q8-7	0.1762			0.1735	0.1763	0.1762	0.1763	0.1762	0.1762
Q9-7	-0.0498			-0.0520	-0.0496	-0.0498	-0.0498	-0.0498	-0.0498
Q10-9	-0.0418			-0.0452	-0.0420	-0.0419	-0.0418	-0.0418	-0.0418
Q14-9	-0.0336			-0.0334	-0.0336	-0.0335	-0.0336	-0.0336	-0.0336
Q11-10	0.0164			0.0175	0.0165	0.0165	0.0164	0.0164	0.0164
Q13-12	-0.0075			-0.0076	-0.0075	-0.0076	-0.0075	-0.0075	-0.0075
Q14-13	-0.0164			-0.0168	-0.0164	-0.0165	-0.0164	-0.0164	-0.0164
Va1	0		-0.0004	-0.0004	0.0000	-0.0004	0.0000	-0.0004	0.0000
Va2	- 5.156621229		-4.8948	-4.0144	-4.9828	-4.9833	-4.9832	-4.9833	-4.9832
Va3	- 12.60507412		- 12.7692	- 12.1101	- 12.7241	- 12.7260	-12.7260	- 12.7259	- 12.7257
Va4	- 10.31324246		- 10.2916	-9.8382	- 10.3131	- 10.3132	-10.3131	-	-

								10.3130	10.3129
Va5	-8.594368715		-8.7868	-8.3394	-8.7733	-8.7744	-8.7742	-8.7742	-8.7741
Va6	-14.32394786		-14.1569	-14.1211	-14.2214	-14.2208	-14.2217	-14.2218	-14.2214
Va7	-13.17803203		-13.4220	-13.2858	-13.3593	-13.3583	-13.3591	-13.3571	-13.3585
Va8	-13.17803203		-13.3578	-13.3770	-13.3592	-13.3578	-13.3592	-13.3578	-13.3592
Va9	-14.89690577		-14.9069	-14.8916	-14.9379	-14.9358	-14.9379	-14.9355	-14.9372
Va10	-14.89690577		-15.0342	-15.0591	-15.0970	-15.0950	-15.0970	-15.0952	-15.0963
Va11	-14.89690577		-14.7021	-14.7370	-14.7906	-14.7901	-14.7902	-14.7903	-14.7897
Va12	-14.89690577		-15.0707	-15.0428	-15.0755	-15.0751	-15.0753	-15.0769	-15.0755
Va13	-14.89690577		-15.2417	-15.1284	-15.1561	-15.1541	-15.1556	-15.1552	-15.1560
Va14	-16.0428216		-16.0762	-16.0783	-16.0341	-16.0308	-16.0349	-16.0311	-16.0344

Table B-24: 14 Bus-WLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.044	1.044	1.036

V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.04
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.002
V4	1.018	0.9931	0.9931	0.9931	1.018	1.017	0.995
V5	1.02	1.0186	1.0186	1.0186	1.02	1.018	0.993
V6	1.07	1.0698	1.0698	1.0698	1.071	1.058	0.938
V7	1.062	1.0635	1.0635	1.0635	1.062	1.061	1.019
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.05
V9	1.056	1.0612	1.0612	1.0612	1.056	1.056	1
V10	1.051	1.0288	1.0288	1.0288	1.051	1.05	0.988
V11	1.057				1.057	1.053	0.964
V12	1.055	1.045	1.045	***-1.045***	1.056	1.051	0.815
V13	1.05				1.051	1.045	0.893
V14	1.036				1.036	1.035	0.943
P1	2.324	2.3243	2.3243	2.3243	2.327	2.32	2.328
P2	0.4	0.4	0.4	0.4	0.356	0.404	0.406
P3	0	-0.0001	-0.0001	-0.0001	-0.01	-0.003	0.016
P6	0	-0.0001	-0.0001	-0.0001	0.005	-0.008	0.091
P8	0	0.0001	0.0001	0.0001	-0.002	0	-0.001
P4	-0.478	-0.4779	***0.4779***	-0.4779	-0.461	-0.479	-0.509
P5	-0.076				-0.029	-0.083	-0.117
P7	0				-0.007	-0.005	0.002
P9	-0.295				-0.295	-0.291	-0.24
P10	-0.09				-0.089	-0.083	-0.039
P11	-0.035				-0.031	-0.026	0.016
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.063	-0.053	-0.329
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.144	-0.143	-0.063
P14	-0.149	-0.149	-0.149	-0.149	-0.153	-0.147	-0.1
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.166	-0.159	0.044
Q2	0.436	0.4356	0.4356	0.4356	0.427	0.441	0.587
Q3	0.251	0.2508	0.2508	0.2508	0.255	0.258	0.317
Q6	0.127	0.1276	0.1276	0.1276	0.124	-0.041	0.072
Q8	0.176	0.1762	0.1762	0.1762	0.174	0.176	0.187
Q4	0.039	0.039	***-0.039***	0.039	0.042	0.044	0.103

Q5	-0.016				-0.012	0.005	0.108
Q7	0				-0.001	0.003	0.012
Q9	-0.166				-0.167	-0.161	-0.126
Q10	-0.058				-0.061	-0.051	-0.005
Q11	-0.018				-0.021	0.008	0.001
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.015	0.018	-0.457
Q13	-0.058	-0.058	-0.058	-0.058	-0.053	-0.021	-0.148
Q14	-0.05	-0.05	-0.05	-0.05	-0.047	-0.037	-0.018
P1-2	1.569	1.5689	1.5689	1.5689	1.582	1.567	1.581
P1-5	0.755	0.755	0.755	0.755	0.745	0.753	0.747
P2-3	0.732	0.7323	0.7323	0.7323	0.731	0.735	0.736
P2-4	0.561	0.5613	0.5613	0.5613	0.548	0.562	0.569
P2-5	0.415	***-0.4151***	0.4151	0.4151	0.398	0.414	0.421
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.244	-0.234	-0.214
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.627	-0.615	-0.603
P4-7	0.281	0.2805	0.2805	0.2805	0.287	0.282	0.272
P4-9	0.161	0.1606	0.1606	0.1606	0.163	0.161	0.155
P5-6	0.441	0.4409	0.4409	0.4409	0.446	0.428	0.404
P6-11	0.074	0.0735	0.0735	0.0735	0.072	0.061	-0.029
P6-12	0.078	0.0777	0.0777	0.0777	0.081	0.074	0.202
P6-13	0.177				0.186	0.174	0.211
P7-8	0				0.002	0	0.001
P7-9	0.281				0.278	0.277	0.273
P9-10	0.052				0.048	0.049	0.055
P9-14	0.094				0.098	0.098	0.133
P10-11	-0.038				-0.041	-0.034	0.016
P12-13	0.016				0.017	0.021	-0.15
P13-14	0.056				0.058	0.05	-0.025
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.538	-1.524	-1.538
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.718	-0.726	-0.718
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.708	-0.711	-0.712
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.532	-0.545	-0.552

P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.39	-0.405	-0.411
P4-3	0.237	0.2365	0.2365	0.2365	0.248	0.238	0.218
P5-4	0.617	0.6167	0.6167	0.6167	0.632	0.62	0.608
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.287	-0.282	-0.272
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.163	-0.161	-0.155
P6-5	-0.441	-0.441	-0.441	-0.441	-0.446	-0.428	-0.404
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.072	-0.06	0.031
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.08	-0.073	-0.179
P13-6	-0.175				-0.184	-0.172	-0.204
P8-7	0				-0.002	0	-0.001
P9-7	-0.281				-0.278	-0.277	-0.273
P10-9	-0.052				-0.048	-0.049	-0.055
P14-9	-0.093				-0.096	-0.097	-0.128
P11-10	0.038				0.041	0.034	-0.015
P13-12	-0.016				-0.017	-0.02	0.166
P14-13	-0.056				-0.057	-0.05	0.028
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.201	-0.203	-0.117
Q1-5	0.039	0.0384	0.0384	0.0384	0.035	0.044	0.161
Q2-3	0.036	0.0356	0.0356	0.0356	0.033	0.034	0.051
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.018	-0.013	0.084
Q2-5	0.012	***-0.0115***	0.0115	0.0115	0.009	0.018	0.134
Q3-4	0.045	0.0448	0.0448	0.0448	0.047	0.05	0.124
Q4-5	0.158	0.1581	0.1581	0.1581	0.158	0.172	0.239
Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.094	-0.098	-0.001
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.003	-0.005	0.056
Q5-6	0.125	0.1243	0.1243	0.1243	0.127	0.17	0.562
Q6-11	0.036	0.0359	0.0359	0.0359	0.039	-0.004	-0.111
Q6-12	0.025	0.025	0.025	0.025	0.024	-0.006	0.352
Q6-13	0.072				0.068	0.02	0.212
Q7-8	-0.172				-0.17	-0.171	-0.181
Q7-9	0.058				0.058	0.059	0.178

Q9-10	0.042				0.045	0.048	0.122
Q9-14	0.036				0.034	0.035	0.149
Q10-11	-0.016				-0.016	-0.003	0.116
Q12-13	0.008				0.007	0.01	-0.153
Q13-14	0.017				0.018	0.006	-0.115
Q2-1	0.277	0.277	0.277	0.277	0.276	0.275	0.191
Q5-1	0.022	0.0227	0.0227	0.0227	0.022	0.017	-0.095
Q3-2	0.016	0.016	0.016	0.016	0.018	0.018	0.003
Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.028	-0.065
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	-0.027	-0.137
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.05	-0.053	-0.126
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.141	-0.155	-0.221
Q7-4	0.114	0.1138	0.1138	0.1138	0.111	0.115	0.016
Q9-4	0.017	0.0174	0.0174	0.0174	0.016	0.018	-0.041
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.081	-0.125	-0.456
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.037	0.005	0.114
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.022	0.007	-0.304
Q13-6	-0.068				-0.064	-0.016	-0.199
Q8-7	0.176				0.174	0.176	0.187
Q9-7	-0.05				-0.05	-0.051	-0.166
Q10-9	-0.042				-0.045	-0.048	-0.12
Q14-9	-0.034				-0.031	-0.033	-0.139
Q11-10	0.016				0.016	0.004	-0.113
Q13-12	-0.007				-0.006	-0.01	0.166
Q14-13	-0.016				-0.016	-0.005	0.121

Table B-25: 14 Bus-IRLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.045	1.044	1.045
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.019	1.017	1.018

V5	1.02	1.0186	1.0186	1.0186	1.021	1.019	1.019
V6	1.07	1.0698	1.0698	1.0698	1.071	1.059	1.07
V7	1.062	1.0635	1.0635	1.0635	1.064	1.063	1.061
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.057	1.057	1.056
V10	1.051	1.0288	1.0288	1.0288	1.052	1.051	1.051
V11	1.057				1.059	1.055	1.057
V12	1.055	1.045	1.045	***-1.045***	1.057	1.053	1.055
V13	1.05				1.053	1.047	1.05
V14	1.036				1.036	1.035	1.035
P1	2.324	2.3243	2.3243	2.3243	2.327	2.321	2.324
P2	0.4	0.4	0.4	0.4	0.355	0.403	0.4
P3	0	-0.0001	-0.0001	-0.0001	-0.011	-0.004	0
P6	0	-0.0001	-0.0001	-0.0001	0	-0.01	-0.001
P8	0	0.0001	0.0001	0.0001	-0.002	0	0
P4	-0.478	-0.4779	***0.4779***	-0.4779	-0.461	-0.48	-0.478
P5	-0.076				-0.026	-0.082	-0.076
P7	0				-0.005	-0.003	0
P9	-0.295				-0.295	-0.29	-0.295
P10	-0.09				-0.092	-0.086	-0.09
P11	-0.035				-0.027	-0.023	-0.034
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.062	-0.052	-0.061
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.139	-0.14	-0.135
P14	-0.149	-0.149	-0.149	-0.149	-0.157	-0.15	-0.149
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.167	-0.161	-0.164
Q2	0.436	0.4356	0.4356	0.4356	0.425	0.438	0.436
Q3	0.251	0.2508	0.2508	0.2508	0.252	0.255	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.114	-0.046	0.128
Q8	0.176	0.1762	0.1762	0.1762	0.164	0.166	0.176
Q4	0.039	0.039	***-0.039***	0.039	0.034	0.036	0.038
Q5	-0.016				-0.011	0.005	-0.017
Q7	0				0.029	0.032	0
Q9	-0.166				-0.166	-0.16	-0.166

Q10	-0.058				-0.07	-0.06	-0.058
Q11	-0.018				-0.013	0.016	-0.018
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.013	0.02	-0.017
Q13	-0.058	-0.058	-0.058	-0.058	-0.043	-0.013	-0.058
Q14	-0.05	-0.05	-0.05	-0.05	-0.055	-0.046	-0.05
P1-2	1.569	1.5689	1.5689	1.5689	1.582	1.567	1.569
P1-5	0.755	0.755	0.755	0.755	0.745	0.753	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.731	0.735	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.548	0.562	0.561
P2-5	0.415	***-0.4151***	0.4151	0.4151	0.397	0.414	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.245	-0.234	-0.233
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.629	-0.616	-0.611
P4-7	0.281	0.2805	0.2805	0.2805	0.288	0.282	0.28
P4-9	0.161	0.1606	0.1606	0.1606	0.163	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.447	0.428	0.441
P6-11	0.074	0.0735	0.0735	0.0735	0.071	0.06	0.073
P6-12	0.078	0.0777	0.0777	0.0777	0.08	0.073	0.078
P6-13	0.177				0.184	0.173	0.178
P7-8	0				0.002	0	0
P7-9	0.281				0.28	0.279	0.281
P9-10	0.052				0.049	0.05	0.052
P9-14	0.094				0.099	0.1	0.095
P10-11	-0.038				-0.043	-0.036	-0.038
P12-13	0.016				0.017	0.021	0.016
P13-14	0.056				0.06	0.052	0.056
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.538	-1.524	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.718	-0.726	-0.727
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.708	-0.711	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.532	-0.545	-0.544
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.389	-0.405	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.249	0.238	0.237

P5-4	0.617	0.6167	0.6167	0.6167	0.634	0.621	0.616
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.288	-0.282	-0.28
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.163	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.447	-0.428	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.07	-0.059	-0.072
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.079	-0.072	-0.077
P13-6	-0.175				-0.182	-0.171	-0.175
P8-7	0				-0.002	0	0
P9-7	-0.281				-0.28	-0.279	-0.281
P10-9	-0.052				-0.049	-0.05	-0.052
P14-9	-0.093				-0.098	-0.098	-0.094
P11-10	0.038				0.043	0.036	0.038
P13-12	-0.016				-0.017	-0.021	-0.016
P14-13	-0.056				-0.059	-0.052	-0.056
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.201	-0.203	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.034	0.042	0.039
Q2-3	0.036	0.0356	0.0356	0.0356	0.034	0.035	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.02	-0.014	-0.015
Q2-5	0.012	***-0.0115***	0.0115	0.0115	0.007	0.016	0.012
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	0.047	0.045
Q4-5	0.158	0.1581	0.1581	0.1581	0.158	0.171	0.158
Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.103	-0.108	-0.097
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.005	-0.006	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.167	0.125
Q6-11	0.036	0.0359	0.0359	0.0359	0.035	-0.007	0.036
Q6-12	0.025	0.025	0.025	0.025	0.021	-0.008	0.026
Q6-13	0.072				0.063	0.016	0.072
Q7-8	-0.172				-0.16	-0.161	-0.172
Q7-9	0.058				0.068	0.068	0.058
Q9-10	0.042				0.05	0.053	0.042
Q9-14	0.036				0.038	0.039	0.036
Q10-11	-0.016				-0.02	-0.008	-0.016

Q12-13	0.008				0.007	0.01	0.007
Q13-14	0.017				0.022	0.01	0.017
Q2-1	0.277	0.277	0.277	0.277	0.276	0.275	0.276
Q5-1	0.022	0.0227	0.0227	0.0227	0.024	0.018	0.022
Q3-2	0.016	0.016	0.016	0.016	0.018	0.017	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.032	0.029	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.019	-0.025	-0.022
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.047	-0.051	-0.049
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.14	-0.155	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.121	0.125	0.114
Q9-4	0.017	0.0174	0.0174	0.0174	0.018	0.019	0.017
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.08	-0.122	-0.081
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	0.008	-0.035
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.019	0.01	-0.024
Q13-6	-0.068				-0.059	-0.013	-0.068
Q8-7	0.176				0.164	0.166	0.176
Q9-7	-0.05				-0.06	-0.06	-0.05
Q10-9	-0.042				-0.05	-0.052	-0.042
Q14-9	-0.034				-0.035	-0.037	-0.034
Q11-10	0.016				0.021	0.008	0.016
Q13-12	-0.007				-0.007	-0.01	-0.007
Q14-13	-0.016				-0.02	-0.009	-0.016

Table B-26: 14 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.046	1.046	1.045
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.069	1.07

V7	1.062	1.0635	1.0635	1.0635	1.062	1.063	1.062
V8	1.09	1.0796	1.0796	1.0796	1.087	1.088	1.087
V9	1.056	1.0612	1.0612	1.0612	1.056	1.057	1.056
V10	1.051	1.0288	1.0288	1.0288	1.051	1.052	1.051
V11	1.057				1.058	1.059	1.057
V12	1.055	1.045	1.045	***-1.045***	1.058	1.059	1.057
V13	1.05				1.053	1.054	1.052
V14	1.036				1.037	1.038	1.037
P1	2.324	2.3243	2.3243	2.3243	2.297	2.297	2.297
P2	0.4	0.4	0.4	0.4	0.457	0.457	0.457
P3	0	-0.0001	-0.0001	-0.0001	-0.018	-0.018	-0.017
P6	0	-0.0001	-0.0001	-0.0001	0.014	0.001	0.017
P8	0	0.0001	0.0001	0.0001	0.007	0.007	0.007
P4	-0.478	-0.4779	***0.4779***	-0.4779	-0.458	-0.456	-0.459
P5	-0.076				-0.107	-0.108	-0.107
P7	0				-0.032	-0.032	-0.032
P9	-0.295				-0.281	-0.282	-0.282
P10	-0.09				-0.088	-0.087	-0.088
P11	-0.035				-0.028	-0.025	-0.029
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.056	-0.054	-0.058
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.153	-0.143	-0.152
P14	-0.149	-0.149	-0.149	-0.149	-0.15	-0.151	-0.149
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.165	-0.166	-0.165
Q2	0.436	0.4356	0.4356	0.4356	0.43	0.431	0.431
Q3	0.251	0.2508	0.2508	0.2508	0.257	0.255	0.257
Q6	0.127	0.1276	0.1276	0.1276	0.093	0.061	0.098
Q8	0.176	0.1762	0.1762	0.1762	0.154	0.153	0.155
Q4	0.039	0.039	***-0.039***	0.039	0.03	0.029	0.031
Q5	-0.016				-0.011	-0.011	-0.01
Q7	0				0.028	0.031	0.026
Q9	-0.166				-0.171	-0.171	-0.175
Q10	-0.058				-0.063	-0.063	-0.064
Q11	-0.018				-0.014	-0.008	-0.016

Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.009	-0.004	-0.013
Q13	-0.058	-0.058	-0.058	-0.058	-0.031	-0.013	-0.031
Q14	-0.05	-0.05	-0.05	-0.05	-0.046	-0.047	-0.043
P1-2	1.569	1.5689	1.5689	1.5689	1.541	1.541	1.541
P1-5	0.755	0.755	0.755	0.755	0.756	0.756	0.756
P2-3	0.732	0.7323	0.7323	0.7323	0.745	0.745	0.745
P2-4	0.561	0.5613	0.5613	0.5613	0.569	0.569	0.569
P2-5	0.415	***-0.4151***	0.4151	0.4151	0.426	0.426	0.426
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.239	-0.239	-0.239
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.598	-0.598	-0.599
P4-7	0.281	0.2805	0.2805	0.2805	0.289	0.289	0.289
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.16
P5-6	0.441	0.4409	0.4409	0.4409	0.435	0.434	0.435
P6-11	0.074	0.0735	0.0735	0.0735	0.07	0.067	0.071
P6-12	0.078	0.0777	0.0777	0.0777	0.078	0.075	0.079
P6-13	0.177				0.189	0.181	0.19
P7-8	0				-0.007	-0.007	-0.007
P7-9	0.281				0.264	0.265	0.264
P9-10	0.052				0.047	0.046	0.046
P9-14	0.094				0.097	0.097	0.096
P10-11	-0.038				-0.041	-0.041	-0.041
P12-13	0.016				0.021	0.02	0.02
P13-14	0.056				0.055	0.056	0.055
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.499	-1.499	-1.499
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.728	-0.728	-0.728
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.721	-0.721	-0.721
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.551	-0.551	-0.551
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.416	-0.416	-0.416
P4-3	0.237	0.2365	0.2365	0.2365	0.243	0.243	0.242
P5-4	0.617	0.6167	0.6167	0.6167	0.603	0.602	0.603
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.289	-0.289	-0.289

P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.16
P6-5	-0.441	-0.441	-0.441	-0.441	-0.435	-0.434	-0.435
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.07	-0.066	-0.07
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.077	-0.074	-0.078
P13-6	-0.175				-0.187	-0.179	-0.187
P8-7	0				0.007	0.007	0.007
P9-7	-0.281				-0.264	-0.265	-0.264
P10-9	-0.052				-0.046	-0.046	-0.046
P14-9	-0.093				-0.096	-0.095	-0.095
P11-10	0.038				0.041	0.041	0.041
P13-12	-0.016				-0.021	-0.02	-0.02
P14-13	-0.056				-0.055	-0.056	-0.054
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.038	0.038	0.038
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.016	-0.016	-0.015
Q2-5	0.012	***-0.0115***	0.0115	0.0115	0.011	0.011	0.011
Q3-4	0.045	0.0448	0.0448	0.0448	0.047	0.047	0.048
Q4-5	0.158	0.1581	0.1581	0.1581	0.154	0.156	0.153
Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.1	-0.103	-0.098
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.005	-0.006	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.124	0.127	0.123
Q6-11	0.036	0.0359	0.0359	0.0359	0.033	0.026	0.035
Q6-12	0.025	0.025	0.025	0.025	0.015	0.009	0.017
Q6-13	0.072				0.05	0.035	0.051
Q7-8	-0.172				-0.151	-0.15	-0.151
Q7-9	0.058				0.061	0.06	0.061
Q9-10	0.042				0.046	0.045	0.046
Q9-14	0.036				0.03	0.029	0.028
Q10-11	-0.016				-0.018	-0.018	-0.018
Q12-13	0.008				0.004	0.003	0.003
Q13-14	0.017				0.019	0.021	0.019

Q2-1	0.277	0.277	0.277	0.277	0.272	0.272	0.272
Q5-1	0.022	0.0227	0.0227	0.0227	0.023	0.023	0.023
Q3-2	0.016	0.016	0.016	0.016	0.019	0.019	0.019
Q4-2	0.03	0.0302	0.0302	0.0302	0.031	0.032	0.031
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.019	-0.019	-0.019
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.051	-0.05	-0.051
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.139	-0.141	-0.137
Q7-4	0.114	0.1138	0.1138	0.1138	0.118	0.121	0.116
Q9-4	0.017	0.0174	0.0174	0.0174	0.018	0.019	0.017
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.081	-0.084	-0.08
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.032	-0.026	-0.034
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.013	-0.007	-0.016
Q13-6	-0.068				-0.046	-0.031	-0.047
Q8-7	0.176				0.154	0.153	0.155
Q9-7	-0.05				-0.053	-0.053	-0.054
Q10-9	-0.042				-0.046	-0.045	-0.045
Q14-9	-0.034				-0.027	-0.027	-0.025
Q11-10	0.016				0.018	0.018	0.019
Q13-12	-0.007				-0.004	-0.003	-0.003
Q14-13	-0.016				-0.018	-0.02	-0.018

Table B-27: 14 Bus-WLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.045	1.043	1.034
V2	1.045	1.0491	1.0491	1.0491	1.044	1.042	1.033
V3	1.01	1.0292	1.0292	1.0292	1.01	0.984	0.992
V4	1.018	0.9931	0.9931	0.9931	1.017	1.016	0.963
V5	1.02	1.0186	1.0186	1.0186	1.019	1.019	0.971
V6	1.07	1.0698	1.0698	1.0698	1.07	1.075	0.911
V7	1.062	1.0635	1.0635	1.0635	1.06	1.06	0.897
V8	1.09	1.0796	1.0796	1.0796	1.086	1.068	0.934

V9	1.056	1.0612	1.0612	1.0612	1.057	1.059	0.832
V10	1.051	1.0288	1.0288	***-1.0288***	1.053	1.055	0.817
V11	1.057				1.06	1.062	0.859
V12	1.055	1.045	1.045	1.045	1.054	1.061	0.891
V13	1.05				1.05	1.056	0.849
V14	1.036	1.033	1.033	***-1.033***	1.038	1.042	0.632
P1	2.324	2.3243	2.3243	2.3243	2.325	2.328	2.345
P2	0.4	0.4	0.4	0.4	0.408	0.402	0.41
P3	0	-0.0001	***0.0001***	-0.0001	-0.001	-0.021	0.039
P6	0	-0.0001	-0.0001	-0.0001	-0.009	0.005	0.119
P8	0	0.0001	***-0.0001***	0.0001	0.003	0	-0.005
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.48	-0.471	-0.568
P5	-0.076				-0.078	-0.074	-0.145
P7	0				-0.07	-0.003	0.013
P9	-0.295				-0.238	-0.292	-0.127
P10	-0.09				-0.078	-0.087	-0.094
P11	-0.035				-0.018	-0.028	-0.009
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.063	-0.06	0.036
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.146	-0.141	-0.084
P14	-0.149	-0.149	-0.149	-0.149	-0.15	-0.15	-0.375
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.159	-0.13	0.248
Q2	0.436	0.4356	0.4356	0.4356	0.437	0.51	0.75
Q3	0.251	0.2508	-0.2508	0.2508	0.253	0.004	0.418
Q6	0.127	0.1276	0.1276	0.1276	0.118	0.135	0.171
Q8	0.176	0.1762	-0.1762	0.1762	0.165	0.048	0.197
Q4	0.039	0.039	0.039	0.039	0.036	0.118	0.286
Q5	-0.016				-0.019	0.019	0.157
Q7	0				-0.022	0.081	-0.02
Q9	-0.166				-0.159	-0.136	-0.217
Q10	-0.058				-0.051	-0.049	-0.281
Q11	-0.018				-0.002	-0.016	-0.028
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.021	-0.013	0.043

Q13	-0.058	-0.058	-0.058	-0.058	-0.057	-0.049	0.042
Q14	-0.05	-0.05	-0.05	-0.05	-0.038	-0.037	-0.679
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.57	1.598
P1-5	0.755	0.755	0.755	0.755	0.757	0.758	0.747
P2-3	0.732	0.7323	0.7323	0.7323	0.735	0.73	0.739
P2-4	0.561	0.5613	0.5613	0.5613	0.564	0.565	0.576
P2-5	0.415	0.4151	0.4151	0.4151	0.417	0.417	0.431
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.232	-0.257	-0.188
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.615	-0.622	-0.592
P4-7	0.281	0.2805	0.2805	0.2805	0.292	0.277	0.243
P4-9	0.161	0.1606	0.1606	0.1606	0.155	0.159	0.14
P5-6	0.441	0.4409	0.4409	0.4409	0.439	0.438	0.393
P6-11	0.074	***-0.0735***	0.0735	0.0735	0.055	0.07	0.105
P6-12	0.078	0.0777	0.0777	0.0777	0.08	0.079	0.059
P6-13	0.177				0.183	0.183	0.236
P7-8	0				-0.003	0	0.005
P7-9	0.281	***-0.276***	0.276	0.276	0.226	0.274	0.251
P9-10	0.052				0.042	0.046	0.008
P9-14	0.094				0.101	0.095	0.256
P10-11	-0.038				-0.037	-0.041	-0.087
P12-13	0.016				0.016	0.018	0.095
P13-14	0.056				0.051	0.057	0.229
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.527	-1.554
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.729	-0.731	-0.716
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.711	-0.706	-0.715
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.547	-0.548	-0.555
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.408	-0.408	-0.418
P4-3	0.237	0.2365	0.2365	0.2365	0.236	0.262	0.195
P5-4	0.617	0.6167	0.6167	0.6167	0.62	0.627	0.597
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.292	-0.277	-0.243
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.155	-0.159	-0.14

P6-5	-0.441	-0.441	-0.441	-0.441	-0.439	-0.438	-0.393
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.055	-0.069	-0.099
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.079	-0.078	-0.058
P13-6	-0.175				-0.181	-0.18	-0.223
P8-7	0				0.003	0	-0.005
P9-7	-0.281				-0.226	-0.274	-0.251
P10-9	-0.052				-0.042	-0.046	-0.007
P14-9	-0.093				-0.1	-0.094	-0.199
P11-10	0.038				0.037	0.042	0.091
P13-12	-0.016				-0.016	-0.018	-0.09
P14-13	-0.056				-0.051	-0.056	-0.176
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.201	-0.168	-0.017
Q1-5	0.039	0.0384	0.0384	0.0384	0.041	0.039	0.265
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.16	0.072
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.013	-0.017	0.231
Q2-5	0.012	0.0115	0.0115	0.0115	0.014	-0.001	0.226
Q3-4	0.045	0.0448	0.0448	0.0448	0.047	-0.084	0.242
Q4-5	0.158	0.1581	0.1581	0.1581	0.156	0.115	0.011
Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.091	-0.1	0.417
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.008	-0.014	0.295
Q5-6	0.125	0.1243	0.1243	0.1243	0.123	0.103	0.561
Q6-11	0.036	***-0.0359***	0.0359	0.0359	0.025	0.036	0.188
Q6-12	0.025	0.025	0.025	0.025	0.027	0.021	0.043
Q6-13	0.072				0.07	0.063	0.317
Q7-8	-0.172				-0.161	-0.048	-0.189
Q7-9	0.058	***-0.051***	0.051	0.051	0.03	0.012	0.536
Q9-10	0.042				0.029	0.03	0.143
Q9-14	0.036				0.029	0.025	0.494
Q10-11	-0.016				-0.022	-0.019	-0.14
Q12-13	0.008				0.004	0.006	0.084
Q13-14	0.017				0.013	0.016	0.414
Q2-1	0.277	0.277	0.277	0.277	0.273	0.241	0.094
Q5-1	0.022	0.0227	0.0227	0.0227	0.02	0.023	-0.188

Q3-2	0.016	0.016	0.016	0.016	0.016	-0.102	-0.014
Q4-2	0.03	0.0302	0.0302	0.0302	0.028	0.033	-0.2
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.022	-0.008	-0.221
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.05	0.084	-0.237
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.14	-0.099	0.005
Q7-4	0.114	0.1138	0.1138	0.1138	0.109	0.116	-0.367
Q9-4	0.017	0.0174	0.0174	0.0174	0.02	0.027	-0.235
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.079	-0.06	-0.452
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.024	-0.035	-0.177
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.026	-0.02	-0.041
Q13-6	-0.068				-0.066	-0.059	-0.292
Q8-7	0.176				0.165	0.048	0.197
Q9-7	-0.05				-0.025	-0.005	-0.488
Q10-9	-0.042				-0.029	-0.03	-0.141
Q14-9	-0.034				-0.026	-0.022	-0.373
Q11-10	0.016				0.022	0.019	0.148
Q13-12	-0.007				-0.004	-0.006	-0.08
Q14-13	-0.016				-0.012	-0.015	-0.306

Table B-28: 14 Bus-IRLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.045	1.043	1.045
V2	1.045	1.0491	1.0491	1.0491	1.045	1.043	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	0.984	1.01
V4	1.018	0.9931	0.9931	0.9931	1.017	1.016	1.018
V5	1.02	1.0186	1.0186	1.0186	1.019	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.076	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.063	1.062
V8	1.09	1.0796	1.0796	1.0796	1.087	1.069	1.09
V9	1.056	1.0612	1.0612	1.0612	1.058	1.061	1.056
V10	1.051	1.0288	1.0288	**-**	1.054	1.057	1.051

				1.0288			
V11	1.057				1.062	1.064	1.057
V12	1.055	1.045	1.045	1.045	1.055	1.063	1.055
V13	1.05				1.051	1.058	1.051
V14	1.036	1.033	1.033	***-1.033***	1.037	1.042	1.036
P1	2.324	2.3243	2.3243	2.3243	2.325	2.328	2.324
P2	0.4	0.4	0.4	0.4	0.407	0.402	0.4
P3	0	-0.0001	***0.0001***	-0.0001	-0.002	-0.022	0
P6	0	-0.0001	-0.0001	-0.0001	-0.014	-0.003	0
P8	0	0.0001	***-0.0001***	0.0001	0.004	0	0
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.479	-0.471	-0.478
P5	-0.076				-0.076	-0.072	-0.076
P7	0				-0.072	-0.001	0
P9	-0.295				-0.233	-0.291	-0.295
P10	-0.09				-0.083	-0.09	-0.09
P11	-0.035				-0.013	-0.023	-0.035
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.063	-0.059	-0.061
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.141	-0.136	-0.135
P14	-0.149	-0.149	-0.149	-0.149	-0.155	-0.155	-0.15
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.16	-0.132	-0.166
Q2	0.436	0.4356	0.4356	0.4356	0.435	0.506	0.436
Q3	0.251	0.2508	-0.2508	0.2508	0.251	0	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.108	0.12	0.128
Q8	0.176	0.1762	-0.1762	0.1762	0.156	0.034	0.176
Q4	0.039	0.039	0.039	0.039	0.028	0.11	0.038
Q5	-0.016				-0.018	0.02	-0.017
Q7	0				0.004	0.115	0
Q9	-0.166				-0.158	-0.132	-0.166
Q10	-0.058				-0.059	-0.057	-0.058
Q11	-0.018				0.009	-0.006	-0.018
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.02	-0.01	-0.016
Q13	-0.058	-0.058	-0.058	-0.058	-0.05	-0.038	-0.058

Q14	-0.05	-0.05	-0.05	-0.05	-0.047	-0.046	-0.05
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.57	1.569
P1-5	0.755	0.755	0.755	0.755	0.757	0.758	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.735	0.73	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.564	0.565	0.561
P2-5	0.415	0.4151	0.4151	0.4151	0.417	0.417	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.232	-0.258	-0.233
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.616	-0.623	-0.611
P4-7	0.281	0.2805	0.2805	0.2805	0.293	0.278	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.155	0.159	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.439	0.438	0.441
P6-11	0.074	***-0.0735***	0.0735	0.0735	0.053	0.067	0.073
P6-12	0.078	0.0777	0.0777	0.0777	0.079	0.077	0.078
P6-13	0.177				0.181	0.179	0.177
P7-8	0				-0.004	0	0
P7-9	0.281	***-0.276***	0.276	0.276	0.226	0.276	0.281
P9-10	0.052				0.044	0.047	0.052
P9-14	0.094				0.104	0.097	0.095
P10-11	-0.038				-0.039	-0.043	-0.038
P12-13	0.016				0.016	0.018	0.016
P13-14	0.056				0.053	0.059	0.057
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.527	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.729	-0.731	-0.727
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.711	-0.706	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.547	-0.548	-0.544
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.408	-0.408	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.236	0.263	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.621	0.628	0.617
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.293	-0.278	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.155	-0.159	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.439	-0.438	-0.441

P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.053	-0.067	-0.073
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.078	-0.076	-0.077
P13-6	-0.175				-0.179	-0.177	-0.175
P8-7	0				0.004	0	0
P9-7	-0.281				-0.226	-0.276	-0.281
P10-9	-0.052				-0.044	-0.047	-0.052
P14-9	-0.093				-0.102	-0.096	-0.093
P11-10	0.038				0.039	0.044	0.038
P13-12	-0.016				-0.016	-0.018	-0.016
P14-13	-0.056				-0.053	-0.058	-0.056
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.2	-0.168	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.04	0.037	0.038
Q2-3	0.036	0.0356	0.0356	0.0356	0.037	0.161	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.014	-0.019	-0.016
Q2-5	0.012	0.0115	0.0115	0.0115	0.012	-0.003	0.012
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	-0.087	0.045
Q4-5	0.158	0.1581	0.1581	0.1581	0.156	0.116	0.158
Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.099	-0.112	-0.097
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.01	-0.017	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.122	0.101	0.124
Q6-11	0.036	***-0.0359***	0.0359	0.0359	0.019	0.03	0.036
Q6-12	0.025	0.025	0.025	0.025	0.025	0.017	0.025
Q6-13	0.072				0.066	0.056	0.072
Q7-8	-0.172				-0.153	-0.034	-0.172
Q7-9	0.058	***-0.051***	0.051	0.051	0.039	0.021	0.058
Q9-10	0.042				0.032	0.035	0.042
Q9-14	0.036				0.034	0.03	0.036
Q10-11	-0.016				-0.027	-0.022	-0.016
Q12-13	0.008				0.004	0.006	0.008
Q13-14	0.017				0.017	0.02	0.018
Q2-1	0.277	0.277	0.277	0.277	0.273	0.241	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.021	0.025	0.022
Q3-2	0.016	0.016	0.016	0.016	0.016	-0.103	0.016

Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.035	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	-0.006	-0.021
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.049	0.088	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.14	-0.099	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.118	0.129	0.114
Q9-4	0.017	0.0174	0.0174	0.0174	0.022	0.03	0.018
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.078	-0.058	-0.08
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.018	-0.029	-0.034
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.024	-0.016	-0.023
Q13-6	-0.068				-0.062	-0.052	-0.068
Q8-7	0.176				0.156	0.034	0.176
Q9-7	-0.05				-0.033	-0.013	-0.05
Q10-9	-0.042				-0.032	-0.035	-0.042
Q14-9	-0.034				-0.031	-0.027	-0.034
Q11-10	0.016				0.028	0.023	0.017
Q13-12	-0.007				-0.004	-0.006	-0.008
Q14-13	-0.016				-0.016	-0.019	-0.016

Table B-29: 14 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.046	1.046	1.046
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.062	1.062
V8	1.09	1.0796	1.0796	1.0796	1.087	1.083	1.087
V9	1.056	1.0612	1.0612	1.0612	1.058	1.056	1.056
V10	1.051	1.0288	1.0288	***-1.0288***	1.054	1.051	1.051

V11	1.057				1.06	1.058	1.057
V12	1.055	1.045	1.045	1.045	1.058	1.058	1.058
V13	1.05				1.053	1.053	1.052
V14	1.036	1.033	1.033	***-1.033***	1.039	1.038	1.037
P1	2.324	2.3243	2.3243	2.3243	2.297	2.297	2.297
P2	0.4	0.4	0.4	0.4	0.457	0.457	0.457
P3	0	-0.0001	***0.0001***	-0.0001	-0.018	-0.019	-0.017
P6	0	-0.0001	-0.0001	-0.0001	0.005	0.012	0.016
P8	0	0.0001	***-0.0001***	0.0001	0.007	0.007	0.007
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.458	-0.457	-0.459
P5	-0.076				-0.107	-0.106	-0.107
P7	0				-0.031	-0.032	-0.032
P9	-0.295				-0.284	-0.282	-0.281
P10	-0.09				-0.087	-0.087	-0.088
P11	-0.035				-0.021	-0.028	-0.029
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.056	-0.056	-0.056
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.151	-0.151	-0.153
P14	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149	-0.15
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.166	-0.165	-0.166
Q2	0.436	0.4356	0.4356	0.4356	0.431	0.431	0.432
Q3	0.251	0.2508	-0.2508	0.2508	0.256	0.252	0.257
Q6	0.127	0.1276	0.1276	0.1276	0.073	0.089	0.098
Q8	0.176	0.1762	-0.1762	0.1762	0.155	0.126	0.156
Q4	0.039	0.039	0.039	0.039	0.03	0.034	0.031
Q5	-0.016				-0.011	-0.01	-0.011
Q7	0				0.001	0.051	0.024
Q9	-0.166				-0.151	-0.171	-0.173
Q10	-0.058				-0.06	-0.063	-0.064
Q11	-0.018				0	-0.014	-0.016
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.009	-0.01	-0.01
Q13	-0.058	-0.058	-0.058	-0.058	-0.028	-0.027	-0.032
Q14	-0.05	-0.05	-0.05	-0.05	-0.042	-0.044	-0.046

P1-2	1.569	1.5689	1.5689	1.5689	1.541	1.541	1.541
P1-5	0.755	0.755	0.755	0.755	0.756	0.756	0.756
P2-3	0.732	0.7323	0.7323	0.7323	0.745	0.745	0.745
P2-4	0.561	0.5613	0.5613	0.5613	0.569	0.568	0.569
P2-5	0.415	0.4151	0.4151	0.4151	0.426	0.426	0.426
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.239	-0.24	-0.238
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.598	-0.598	-0.598
P4-7	0.281	0.2805	0.2805	0.2805	0.288	0.289	0.288
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.16
P5-6	0.441	0.4409	0.4409	0.4409	0.435	0.435	0.435
P6-11	0.074	***-0.0735***	0.0735	0.0735	0.064	0.07	0.071
P6-12	0.078	0.0777	0.0777	0.0777	0.077	0.078	0.078
P6-13	0.177				0.187	0.188	0.19
P7-8	0				-0.007	-0.007	-0.007
P7-9	0.281	***-0.276***	0.276	0.276	0.265	0.264	0.264
P9-10	0.052				0.045	0.046	0.046
P9-14	0.094				0.097	0.096	0.097
P10-11	-0.038				-0.042	-0.041	-0.041
P12-13	0.016				0.02	0.02	0.021
P13-14	0.056				0.054	0.055	0.055
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.499	-1.499	-1.499
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.728	-0.728	-0.728
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.721	-0.721	-0.721
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.551	-0.551	-0.552
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.416	-0.416	-0.416
P4-3	0.237	0.2365	0.2365	0.2365	0.243	0.244	0.242
P5-4	0.617	0.6167	0.6167	0.6167	0.603	0.603	0.603
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.288	-0.289	-0.288
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.16
P6-5	-0.441	-0.441	-0.441	-0.441	-0.435	-0.435	-0.435
P11-6	-0.073	-	-0.0733	-	-0.064	-0.069	-0.071

		0.0733		0.0733			
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.077	-0.077	-0.077
P13-6	-0.175				-0.184	-0.186	-0.188
P8-7	0				0.007	0.007	0.007
P9-7	-0.281				-0.265	-0.264	-0.264
P10-9	-0.052				-0.045	-0.046	-0.046
P14-9	-0.093				-0.096	-0.095	-0.095
P11-10	0.038				0.042	0.041	0.041
P13-12	-0.016				-0.02	-0.02	-0.021
P14-13	-0.056				-0.053	-0.055	-0.055
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.203	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.039	0.038	0.039
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.038	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.015	-0.016	-0.015
Q2-5	0.012	0.0115	0.0115	0.0115	0.011	0.01	0.011
Q3-4	0.045	0.0448	0.0448	0.0448	0.048	0.045	0.048
Q4-5	0.158	0.1581	0.1581	0.1581	0.155	0.154	0.153
Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.097	-0.099	-0.098
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.008	-0.005	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.124	0.124
Q6-11	0.036	***-0.0359***	0.0359	0.0359	0.021	0.033	0.036
Q6-12	0.025	0.025	0.025	0.025	0.014	0.014	0.016
Q6-13	0.072				0.045	0.047	0.052
Q7-8	-0.172				-0.151	-0.123	-0.152
Q7-9	0.058	***-0.051***	0.051	0.051	0.037	0.058	0.061
Q9-10	0.042				0.041	0.045	0.046
Q9-14	0.036				0.03	0.028	0.03
Q10-11	-0.016				-0.02	-0.018	-0.018
Q12-13	0.008				0.003	0.003	0.004
Q13-14	0.017				0.016	0.019	0.02
Q2-1	0.277	0.277	0.277	0.277	0.272	0.271	0.272
Q5-1	0.022	0.0227	0.0227	0.0227	0.023	0.023	0.023
Q3-2	0.016	0.016	0.016	0.016	0.019	0.017	0.019
Q4-2	0.03	0.0302	0.0302	0.0302	0.031	0.032	0.031

Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.019	-0.018	-0.019
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.051	-0.048	-0.051
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.139	-0.138	-0.138
Q7-4	0.114	0.1138	0.1138	0.1138	0.115	0.117	0.115
Q9-4	0.017	0.0174	0.0174	0.0174	0.021	0.018	0.017
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.082	-0.081	-0.081
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.02	-0.032	-0.034
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.012	-0.013	-0.014
Q13-6	-0.068				-0.041	-0.043	-0.047
Q8-7	0.176				0.155	0.126	0.156
Q9-7	-0.05				-0.03	-0.051	-0.054
Q10-9	-0.042				-0.041	-0.045	-0.045
Q14-9	-0.034				-0.027	-0.026	-0.027
Q11-10	0.016				0.02	0.018	0.018
Q13-12	-0.007				-0.003	-0.003	-0.004
Q14-13	-0.016				-0.015	-0.018	-0.019

Table B-30: 14 Bus-WLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.044	1.042	1.03
V2	1.045	1.0491	1.0491	1.0491	1.045	1.043	1.031
V3	1.01	1.0292	1.0292	1.0292	1.01	1.035	0.987
V4	1.018	0.9931	0.9931	0.9931	1.015	1.037	0.946
V5	1.02	1.0186	1.0186	1.0186	1.017	1.038	0.95
V6	1.07	1.0698	1.0698	1.0698	1.067	1.089	0.784
V7	1.062	1.0635	1.0635	1.0635	1.05	1.083	0.867
V8	1.09	1.0796	1.0796	1.0796	1.076	1.111	0.918
V9	1.056	1.0612	1.0612	1.0612	1.045	1.077	0.77
V10	1.051	1.0288	1.0288	1.0288	1.041	1.071	0.791
V11	1.057				1.05	1.075	0.806
V12	1.055	1.045	1.045	1.045	1.054	1.071	0.727

V13	1.05	1.044	1.044	***-1.044***	1.047	1.067	0.625
V14	1.036	1.0298	1.0298	***-1.0298***	1.028	1.053	0.173
P1	2.324	2.3243	***-2.3243***	2.3243	2.342	1.421	2.347
P2	0.4	0.4	***-0.4***	0.4	0.406	0.99	0.408
P3	0	-0.0001	-0.0001	-0.0001	0.014	0.01	0.056
P6	0	-0.0001	-0.0001	-0.0001	-0.002	-0.028	0.224
P8	0	0.0001	0.0001	0.0001	-0.014	-0.053	-0.011
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.34	-0.243	-0.589
P5	-0.076				-0.281	0.382	-0.185
P7	0				0.036	-0.079	0.048
P9	-0.295				-0.295	-0.356	0.119
P10	-0.09				-0.096	-0.129	0.094
P11	-0.035				-0.028	-0.073	0.076
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.049	-0.105	0.106
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.135	-0.185	-0.168
P14	-0.149	-0.149	-0.149	-0.149	-0.156	-0.186	-0.243
Q1	-0.165	-0.1654	***0.1654***	-0.1654	-0.15	-0.016	0.401
Q2	0.436	0.4356	***-0.4356***	0.4356	0.446	-0.236	0.873
Q3	0.251	0.2508	0.2508	0.2508	0.262	0.422	0.48
Q6	0.127	0.1276	0.1276	0.1276	0.146	0.114	0.177
Q8	0.176	0.1762	0.1762	0.1762	0.159	0.181	0.262
Q4	0.039	0.039	0.039	0.039	0.016	0.167	0.378
Q5	-0.016				0.028	0.081	0.303
Q7	0				-0.039	0.021	0.119
Q9	-0.166				-0.188	-0.157	0.178
Q10	-0.058				-0.07	-0.051	0.111
Q11	-0.018				-0.02	-0.015	0.111
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.013	-0.011	0.041
Q13	-0.058	-0.058	-0.058	-0.058	-0.047	-0.049	-0.082
Q14	-0.05	-0.05	-0.05	-0.05	-0.05	-0.047	-0.49
P1-2	1.569	1.5689	1.5689	1.5689	1.567	0.874	1.609
P1-5	0.755	0.755	0.755	0.755	0.775	0.547	0.739

P2-3	0.732	0.7323	0.7323	0.7323	0.722	0.721	0.74
P2-4	0.561	0.5613	0.5613	0.5613	0.551	0.535	0.581
P2-5	0.415	0.4151	0.4151	0.4151	0.442	0.377	0.434
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.229	-0.234	-0.171
P4-5	-0.612	***0.6111***	-0.6111	-0.6111	-0.465	-0.667	-0.58
P4-7	0.281	***-0.2805***	0.2805	0.2805	0.268	0.465	0.23
P4-9	0.161	0.1606	0.1606	0.1606	0.159	0.24	0.137
P5-6	0.441	0.4409	0.4409	0.4409	0.428	0.612	0.353
P6-11	0.074	0.0735	0.0735	0.0735	0.068	0.111	-0.032
P6-12	0.078	0.0777	0.0777	0.0777	0.071	0.117	0.084
P6-13	0.177				0.174	0.243	0.414
P7-8	0				0.014	0.053	0.011
P7-9	0.281				0.291	0.332	0.268
P9-10	0.052				0.056	0.093	-0.134
P9-14	0.094				0.098	0.123	0.657
P10-11	-0.038				-0.039	-0.037	-0.042
P12-13	0.016				0.022	0.011	0.185
P13-14	0.056				0.059	0.065	0.326
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.524	-0.861	-1.564
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.746	-0.533	-0.705
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.699	-0.698	-0.715
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.535	-0.519	-0.557
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.431	-0.37	-0.418
P4-3	0.237	0.2365	0.2365	0.2365	0.233	0.238	0.18
P5-4	0.617	0.6167	0.6167	0.6167	0.468	0.673	0.585
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.268	-0.465	-0.23
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.159	-0.24	-0.137
P6-5	-0.441	-0.441	-0.441	-0.441	-0.428	-0.612	-0.353
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.068	-0.11	0.033
P12-6	-0.077	-	-0.0772	-	-0.071	-0.116	-0.079

		0.0772		0.0772			
P13-6	-0.175				-0.172	-0.24	-0.335
P8-7	0				-0.014	-0.053	-0.011
P9-7	-0.281				-0.291	-0.332	-0.268
P10-9	-0.052				-0.056	-0.092	0.136
P14-9	-0.093				-0.097	-0.122	-0.15
P11-10	0.038				0.04	0.037	0.043
P13-12	-0.016				-0.021	-0.011	-0.159
P14-13	-0.056				-0.059	-0.064	-0.093
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.197	0.009	0.039
Q1-5	0.039	0.0384	0.0384	0.0384	0.048	-0.025	0.362
Q2-3	0.036	0.0356	0.0356	0.0356	0.035	-0.104	0.076
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.001	-0.133	0.305
Q2-5	0.012	0.0115	0.0115	0.0115	0.016	-0.099	0.325
Q3-4	0.045	0.0448	0.0448	0.0448	0.058	0.08	0.307
Q4-5	0.158	***-0.1581***	0.1581	0.1581	0.105	0.201	0.102
Q4-7	-0.097	***0.0967***	-0.0967	-0.0967	-0.052	-0.095	0.469
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	0.011	0	0.369
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.148	0.971
Q6-11	0.036	0.0359	0.0359	0.0359	0.057	0.024	-0.068
Q6-12	0.025	0.025	0.025	0.025	0.023	0.022	0.135
Q6-13	0.072				0.074	0.06	0.747
Q7-8	-0.172				-0.155	-0.175	-0.248
Q7-9	0.058				0.049	0.06	0.775
Q9-10	0.042				0.035	0.046	-0.145
Q9-14	0.036				0.023	0.04	1.391
Q10-11	-0.016				-0.036	-0.006	-0.04
Q12-13	0.008				0.008	0.008	0.166
Q13-14	0.017				0.031	0.012	0.653
Q2-1	0.277	0.277	0.277	0.277	0.27	-0.027	0.04
Q5-1	0.022	0.0227	0.0227	0.0227	0.02	0.03	-0.273
Q3-2	0.016	0.016	0.016	0.016	0.014	0.152	-0.017
Q4-2	0.03	0.0302	0.0302	0.0302	0.014	0.145	-0.265
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.022	0.085	-0.309

Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.061	-0.084	-0.297
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.096	-0.182	-0.085
Q7-4	0.114	0.1138	0.1138	0.1138	0.067	0.137	-0.408
Q9-4	0.017	0.0174	0.0174	0.0174	0.002	0.028	-0.279
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.083	-0.067	-0.712
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.056	-0.022	0.07
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.022	-0.019	-0.125
Q13-6	-0.068				-0.07	-0.053	-0.593
Q8-7	0.176				0.159	0.181	0.262
Q9-7	-0.05				-0.04	-0.049	-0.676
Q10-9	-0.042				-0.035	-0.045	0.151
Q14-9	-0.034				-0.021	-0.036	-0.311
Q11-10	0.016				0.036	0.007	0.041
Q13-12	-0.007				-0.008	-0.008	-0.143
Q14-13	-0.016				-0.03	-0.011	-0.179

Table B-31: 14 Bus-IRLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.045	1.041	1.046
V2	1.045	1.0491	1.0491	1.0491	1.045	1.042	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.033	1.01
V4	1.018	0.9931	0.9931	0.9931	1.015	1.037	1.018
V5	1.02	1.0186	1.0186	1.0186	1.017	1.038	1.02
V6	1.07	1.0698	1.0698	1.0698	1.068	1.09	1.071
V7	1.062	1.0635	1.0635	1.0635	1.051	1.087	1.062
V8	1.09	1.0796	1.0796	1.0796	1.076	1.113	1.09
V9	1.056	1.0612	1.0612	1.0612	1.046	1.08	1.056
V10	1.051	1.0288	1.0288	1.0288	1.041	1.073	1.052
V11	1.057				1.051	1.078	1.058
V12	1.055	1.045	1.045	1.045	1.055	1.074	1.057
V13	1.05	1.044	1.044	***-1.044***	1.049	1.07	1.052
V14	1.036	1.0298	1.0298	**-**	1.027	1.054	1.036

				1.0298			
P1	2.324	2.3243	***-2.3243***	2.3243	2.342	1.409	2.324
P2	0.4	0.4	***-0.4***	0.4	0.406	1.001	0.4
P3	0	-0.0001	-0.0001	-0.0001	0.013	-0.005	0
P6	0	-0.0001	-0.0001	-0.0001	-0.007	-0.042	0
P8	0	0.0001	0.0001	0.0001	-0.015	-0.053	0
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.335	-0.229	-0.478
P5	-0.076				-0.283	0.399	-0.076
P7	0				0.039	-0.085	0
P9	-0.295				-0.296	-0.36	-0.295
P10	-0.09				-0.099	-0.134	-0.09
P11	-0.035				-0.025	-0.066	-0.035
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.048	-0.104	-0.061
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.13	-0.179	-0.135
P14	-0.149	-0.149	-0.149	-0.149	-0.159	-0.189	-0.15
Q1	-0.165	-0.1654	***0.1654***	-0.1654	-0.149	0.01	-0.167
Q2	0.436	0.4356	***-0.4356***	0.4356	0.445	-0.266	0.435
Q3	0.251	0.2508	0.2508	0.2508	0.26	0.408	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.138	0.092	0.126
Q8	0.176	0.1762	0.1762	0.1762	0.155	0.162	0.176
Q4	0.039	0.039	0.039	0.039	0.009	0.157	0.038
Q5	-0.016				0.03	0.08	-0.018
Q7	0				-0.022	0.074	0
Q9	-0.166				-0.189	-0.149	-0.166
Q10	-0.058				-0.078	-0.061	-0.058
Q11	-0.018				-0.013	-0.003	-0.018
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.01	-0.006	-0.014
Q13	-0.058	-0.058	-0.058	-0.058	-0.038	-0.033	-0.053
Q14	-0.05	-0.05	-0.05	-0.05	-0.057	-0.057	-0.05
P1-2	1.569	1.5689	1.5689	1.5689	1.567	0.865	1.569
P1-5	0.755	0.755	0.755	0.755	0.775	0.544	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.722	0.727	0.732

P2-4	0.561	0.5613	0.5613	0.5613	0.55	0.534	0.561
P2-5	0.415	0.4151	0.4151	0.4151	0.442	0.375	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.23	-0.243	-0.233
P4-5	-0.612	***0.6111***	-0.6111	-0.6111	-0.463	-0.673	-0.611
P4-7	0.281	***-0.2805***	0.2805	0.2805	0.269	0.473	0.28
P4-9	0.161	0.1606	0.1606	0.1606	0.159	0.243	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.428	0.616	0.441
P6-11	0.074	0.0735	0.0735	0.0735	0.068	0.108	0.074
P6-12	0.078	0.0777	0.0777	0.0777	0.07	0.116	0.078
P6-13	0.177				0.172	0.239	0.178
P7-8	0				0.015	0.053	0
P7-9	0.281				0.293	0.335	0.281
P9-10	0.052				0.057	0.094	0.052
P9-14	0.094				0.099	0.125	0.095
P10-11	-0.038				-0.042	-0.041	-0.038
P12-13	0.016				0.022	0.01	0.017
P13-14	0.056				0.062	0.067	0.057
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.524	-0.852	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.746	-0.529	-0.728
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.699	-0.704	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.534	-0.518	-0.544
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.431	-0.368	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.234	0.247	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.466	0.679	0.616
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.269	-0.473	-0.28
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.159	-0.243	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.428	-0.616	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.067	-0.107	-0.073
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.069	-0.114	-0.077

P13-6	-0.175				-0.17	-0.236	-0.176
P8-7	0				-0.015	-0.053	0
P9-7	-0.281				-0.293	-0.335	-0.281
P10-9	-0.052				-0.057	-0.093	-0.052
P14-9	-0.093				-0.098	-0.123	-0.093
P11-10	0.038				0.042	0.041	0.038
P13-12	-0.016				-0.022	-0.01	-0.016
P14-13	-0.056				-0.061	-0.066	-0.056
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.196	0.034	-0.205
Q1-5	0.039	0.0384	0.0384	0.0384	0.047	-0.023	0.038
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	-0.098	0.035
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.001	-0.138	-0.016
Q2-5	0.012	0.0115	0.0115	0.0115	0.016	-0.105	0.011
Q3-4	0.045	0.0448	0.0448	0.0448	0.057	0.07	0.045
Q4-5	0.158	***-0.1581***	0.1581	0.1581	0.102	0.201	0.158
Q4-7	-0.097	***0.0967***	-0.0967	-0.0967	-0.057	-0.116	-0.098
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	0.011	-0.006	-0.005
Q5-6	0.125	0.1243	0.1243	0.1243	0.123	0.143	0.121
Q6-11	0.036	0.0359	0.0359	0.0359	0.055	0.014	0.037
Q6-12	0.025	0.025	0.025	0.025	0.02	0.016	0.023
Q6-13	0.072				0.069	0.048	0.069
Q7-8	-0.172				-0.151	-0.158	-0.172
Q7-9	0.058				0.057	0.072	0.056
Q9-10	0.042				0.039	0.053	0.041
Q9-14	0.036				0.026	0.046	0.035
Q10-11	-0.016				-0.04	-0.009	-0.017
Q12-13	0.008				0.009	0.007	0.008
Q13-14	0.017				0.035	0.016	0.019
Q2-1	0.277	0.277	0.277	0.277	0.269	-0.052	0.278
Q5-1	0.022	0.0227	0.0227	0.0227	0.02	0.028	0.023
Q3-2	0.016	0.016	0.016	0.016	0.013	0.148	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.014	0.15	0.031
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	0.091	-0.021
Q4-3	-0.048	-	-0.0485	-	-0.06	-0.073	-0.048

		0.0485		0.0485			
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.093	-0.182	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.072	0.16	0.115
Q9-4	0.017	0.0174	0.0174	0.0174	0.002	0.034	0.018
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.081	-0.062	-0.077
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.054	-0.012	-0.035
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.019	-0.013	-0.021
Q13-6	-0.068				-0.065	-0.042	-0.065
Q8-7	0.176				0.155	0.162	0.176
Q9-7	-0.05				-0.048	-0.061	-0.048
Q10-9	-0.042				-0.038	-0.052	-0.041
Q14-9	-0.034				-0.023	-0.042	-0.032
Q11-10	0.016				0.041	0.01	0.017
Q13-12	-0.007				-0.008	-0.007	-0.008
Q14-13	-0.016				-0.034	-0.015	-0.018

Table B-32: 14 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.044	1.045	1.046
V2	1.045	1.0491	1.0491	1.0491	1.045	1.044	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.063	1.063
V8	1.09	1.0796	1.0796	1.0796	1.09	1.088	1.088
V9	1.056	1.0612	1.0612	1.0612	1.056	1.057	1.057
V10	1.051	1.0288	1.0288	1.0288	1.051	1.052	1.052
V11	1.057				1.057	1.058	1.058
V12	1.055	1.045	1.045	1.045	1.057	1.056	1.057
V13	1.05	1.044	1.044	***-1.044***	1.051	1.051	1.052
V14	1.036	1.0298	1.0298	***-1.0298***	1.035	1.036	1.036

P1	2.324	2.3243	***-2.3243***	2.3243	2.324	2.323	2.297
P2	0.4	0.4	***-0.4***	0.4	0.399	0.396	0.457
P3	0	-0.0001	-0.0001	-0.0001	-0.001	0	-0.019
P6	0	-0.0001	-0.0001	-0.0001	-0.001	-0.002	0.018
P8	0	0.0001	0.0001	0.0001	-0.001	-0.001	0.007
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.478	-0.478	-0.457
P5	-0.076				-0.078	-0.075	-0.107
P7	0				0.001	0.003	-0.032
P9	-0.295				-0.294	-0.294	-0.28
P10	-0.09				-0.088	-0.093	-0.087
P11	-0.035				-0.025	-0.03	-0.028
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.055	-0.06	-0.055
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.141	-0.134	-0.158
P14	-0.149	-0.149	-0.149	-0.149	-0.155	-0.151	-0.153
Q1	-0.165	-0.1654	***0.1654***	-0.1654	-0.166	-0.153	-0.166
Q2	0.436	0.4356	***-0.4356***	0.4356	0.434	0.413	0.433
Q3	0.251	0.2508	0.2508	0.2508	0.251	0.251	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.105	0.106	0.1
Q8	0.176	0.1762	0.1762	0.1762	0.171	0.158	0.157
Q4	0.039	0.039	0.039	0.039	0.034	0.037	0.031
Q5	-0.016				-0.01	-0.01	-0.011
Q7	0				0.01	0.027	0.027
Q9	-0.166				-0.166	-0.163	-0.167
Q10	-0.058				-0.062	-0.062	-0.063
Q11	-0.018				-0.016	-0.011	-0.013
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.009	-0.009	-0.009
Q13	-0.058	-0.058	-0.058	-0.058	-0.041	-0.049	-0.038
Q14	-0.05	-0.05	-0.05	-0.05	-0.053	-0.054	-0.051
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.541
P1-5	0.755	0.755	0.755	0.755	0.755	0.754	0.756
P2-3	0.732	0.7323	0.7323	0.7323	0.733	0.732	0.745
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.56	0.569

P2-5	0.415	0.4151	0.4151	0.4151	0.415	0.414	0.426
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.234	-0.234	-0.24
P4-5	-0.612	***0.6111***	-0.6111	-0.6111	-0.611	-0.613	-0.598
P4-7	0.281	***-0.2805***	0.2805	0.2805	0.28	0.28	0.289
P4-9	0.161	0.1606	0.1606	0.1606	0.16	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.439	0.439	0.435
P6-11	0.074	0.0735	0.0735	0.0735	0.067	0.071	0.07
P6-12	0.078	0.0777	0.0777	0.0777	0.076	0.077	0.078
P6-13	0.177				0.182	0.177	0.192
P7-8	0				0.001	0.001	-0.007
P7-9	0.281				0.279	0.283	0.264
P9-10	0.052				0.046	0.053	0.046
P9-14	0.094				0.099	0.096	0.099
P10-11	-0.038				-0.042	-0.04	-0.041
P12-13	0.016				0.02	0.017	0.023
P13-14	0.056				0.058	0.057	0.055
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.499
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.728
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.708	-0.721
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.543	-0.551
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.405	-0.416
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.244
P5-4	0.617	0.6167	0.6167	0.6167	0.616	0.618	0.603
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.28	-0.28	-0.289
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.16	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.439	-0.439	-0.435
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.067	-0.071	-0.069
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.076	-0.077	-0.078
P13-6	-0.175				-0.18	-0.174	-0.19

P8-7	0				-0.001	-0.001	0.007
P9-7	-0.281				-0.279	-0.283	-0.264
P10-9	-0.052				-0.046	-0.053	-0.046
P14-9	-0.093				-0.098	-0.095	-0.098
P11-10	0.038				0.042	0.04	0.041
P13-12	-0.016				-0.02	-0.017	-0.023
P14-13	-0.056				-0.058	-0.057	-0.055
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.192	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.038	0.038	0.038
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.034	0.038
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.016	-0.019	-0.015
Q2-5	0.012	0.0115	0.0115	0.0115	0.011	0.008	0.011
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	0.043	0.045
Q4-5	0.158	***-0.1581***	0.1581	0.1581	0.155	0.158	0.155
Q4-7	-0.097	***0.0967***	-0.0967	-0.0967	-0.098	-0.103	-0.101
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.004	-0.006	-0.006
Q5-6	0.125	0.1243	0.1243	0.1243	0.126	0.126	0.124
Q6-11	0.036	0.0359	0.0359	0.0359	0.035	0.03	0.032
Q6-12	0.025	0.025	0.025	0.025	0.018	0.02	0.016
Q6-13	0.072				0.06	0.064	0.057
Q7-8	-0.172				-0.167	-0.154	-0.153
Q7-9	0.058				0.061	0.061	0.061
Q9-10	0.042				0.045	0.045	0.045
Q9-14	0.036				0.036	0.038	0.035
Q10-11	-0.016				-0.017	-0.017	-0.017
Q12-13	0.008				0.007	0.009	0.006
Q13-14	0.017				0.021	0.019	0.02
Q2-1	0.277	0.277	0.277	0.277	0.276	0.264	0.272
Q5-1	0.022	0.0227	0.0227	0.0227	0.023	0.022	0.023
Q3-2	0.016	0.016	0.016	0.016	0.016	0.018	0.017
Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.034	0.031
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.02	-0.017	-0.019
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.047	-0.048

Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.139	-0.142	-0.139
Q7-4	0.114	0.1138	0.1138	0.1138	0.115	0.12	0.119
Q9-4	0.017	0.0174	0.0174	0.0174	0.017	0.019	0.019
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.082	-0.082	-0.081
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	-0.029	-0.031
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.016	-0.018	-0.015
Q13-6	-0.068				-0.055	-0.06	-0.052
Q8-7	0.176				0.171	0.158	0.157
Q9-7	-0.05				-0.053	-0.053	-0.054
Q10-9	-0.042				-0.045	-0.045	-0.045
Q14-9	-0.034				-0.033	-0.036	-0.032
Q11-10	0.016				0.017	0.018	0.018
Q13-12	-0.007				-0.007	-0.009	-0.006
Q14-13	-0.016				-0.02	-0.018	-0.019

Table B-33: 14 Bus-WLS Estimated values for partial redundancy with SCADA & PMU having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.062	1.062
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.056	1.056	1.056
V10	1.051	1.0288	1.0288	1.0288	1.051	1.051	1.051
V11	1.057				1.057	1.057	1.057
V12	1.055	1.045	1.045	***-1.045***	1.055	1.055	1.055
V13	1.05				1.05	1.05	1.05
V14	1.036				1.036	1.036	1.036
P1	2.324	2.3243	2.3243	2.3243	2.324	2.324	2.324

P2	0.4	0.4	0.4	0.4	0.399	0.399	0.399
P3	0	-0.0001	-0.0001	-0.0001	0	0	0
P6	0	-0.0001	-0.0001	-0.0001	0	0	0.001
P8	0	0.0001	0.0001	0.0001	0	0	0
P4	-0.478	-0.4779	***0.4779***	-0.4779	-0.478	-0.478	-0.478
P5	-0.076				-0.076	-0.076	-0.076
P7	0				0	0	0
P9	-0.295				-0.295	-0.295	-0.295
P10	-0.09				-0.09	-0.09	-0.09
P11	-0.035				-0.035	-0.035	-0.035
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.061	-0.061	-0.062
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.135	-0.135	-0.135
P14	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.166	-0.166	-0.166
Q2	0.436	0.4356	0.4356	0.4356	0.436	0.436	0.436
Q3	0.251	0.2508	0.2508	0.2508	0.251	0.251	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.127	0.127	0.129
Q8	0.176	0.1762	0.1762	0.1762	0.176	0.176	0.176
Q4	0.039	0.039	***-0.039***	0.039	0.039	0.039	0.039
Q5	-0.016				-0.017	-0.016	-0.016
Q7	0				0	0	0
Q9	-0.166				-0.166	-0.166	-0.166
Q10	-0.058				-0.058	-0.058	-0.058
Q11	-0.018				-0.018	-0.018	-0.018
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.016	-0.016	-0.019
Q13	-0.058	-0.058	-0.058	-0.058	-0.058	-0.058	-0.057
Q14	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	***-0.4151***	0.4151	0.4151	0.415	0.415	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.233	-0.233	-0.233
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.612	-0.612	-0.611
P4-7	0.281	0.2805	0.2805	0.2805	0.281	0.281	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.441

P6-11	0.074	0.0735	0.0735	0.0735	0.073	0.073	0.074
P6-12	0.078	0.0777	0.0777	0.0777	0.078	0.078	0.078
P6-13	0.177				0.177	0.177	0.178
P7-8	0				0	0	0
P7-9	0.281				0.281	0.281	0.281
P9-10	0.052				0.052	0.052	0.052
P9-14	0.094				0.094	0.094	0.094
P10-11	-0.038				-0.038	-0.038	-0.038
P12-13	0.016				0.016	0.016	0.015
P13-14	0.056				0.056	0.056	0.056
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.728
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.544	-0.544
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.406	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.617	0.617	0.616
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.281	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.073	-0.073	-0.073
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.077	-0.077	-0.078
P13-6	-0.175				-0.175	-0.175	-0.176
P8-7	0				0	0	0
P9-7	-0.281				-0.281	-0.281	-0.281
P10-9	-0.052				-0.052	-0.052	-0.052
P14-9	-0.093				-0.093	-0.093	-0.093
P11-10	0.038				0.038	0.038	0.038
P13-12	-0.016				-0.016	-0.016	-0.015
P14-13	-0.056				-0.056	-0.056	-0.056
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.039	0.039	0.039
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.015	-0.015	-0.015
Q2-5	0.012	***-0.0115***	0.0115	0.0115	0.012	0.012	0.012
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	0.045	0.045
Q4-5	0.158	0.1581	0.1581	0.1581	0.159	0.159	0.158

Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.097	-0.097	-0.097
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.004	-0.004	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.125	0.124
Q6-11	0.036	0.0359	0.0359	0.0359	0.036	0.036	0.036
Q6-12	0.025	0.025	0.025	0.025	0.025	0.025	0.027
Q6-13	0.072				0.072	0.072	0.072
Q7-8	-0.172				-0.172	-0.172	-0.172
Q7-9	0.058				0.058	0.058	0.058
Q9-10	0.042				0.042	0.042	0.042
Q9-14	0.036				0.036	0.036	0.036
Q10-11	-0.016				-0.016	-0.016	-0.016
Q12-13	0.008				0.008	0.008	0.006
Q13-14	0.017				0.017	0.017	0.018
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.022	0.022	0.022
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.03	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	-0.021	-0.021
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.048	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.142	-0.142	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.114	0.114	0.114
Q9-4	0.017	0.0174	0.0174	0.0174	0.017	0.017	0.017
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.08	-0.08	-0.08
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	-0.034	-0.035
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.024	-0.023	-0.025
Q13-6	-0.068				-0.068	-0.068	-0.068
Q8-7	0.176				0.176	0.176	0.176
Q9-7	-0.05				-0.05	-0.05	-0.05
Q10-9	-0.042				-0.042	-0.042	-0.042
Q14-9	-0.034				-0.034	-0.034	-0.034
Q11-10	0.016				0.016	0.016	0.017
Q13-12	-0.007				-0.007	-0.007	-0.006
Q14-13	-0.016				-0.016	-0.016	-0.017
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.263
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.265
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.28

Table B-34: 14 Bus-IRLS Estimated values for partial redundancy with SCADA & PMU having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.062	1.062
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.056	1.056	1.056
V10	1.051	1.0288	1.0288	1.0288	1.051	1.051	1.051
V11	1.057				1.057	1.057	1.057
V12	1.055	1.045	1.045	***-1.045***	1.055	1.055	1.055
V13	1.05				1.05	1.05	1.05
V14	1.036				1.036	1.036	1.035
P1	2.324	2.3243	2.3243	2.3243	2.324	2.324	2.324

P2	0.4	0.4	0.4	0.4	0.4	0.399	0.4
P3	0	-0.0001	-0.0001	-0.0001	0	0	0
P6	0	-0.0001	-0.0001	-0.0001	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P4	-0.478	-0.4779	***0.4779***	-0.4779	-0.478	-0.478	-0.478
P5	-0.076				-0.076	-0.076	-0.076
P7	0				0	0	0
P9	-0.295				-0.295	-0.295	-0.295
P10	-0.09				-0.09	-0.09	-0.09
P11	-0.035				-0.035	-0.035	-0.035
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.061	-0.061	-0.061
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.135	-0.135	-0.135
P14	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.165	-0.166	-0.165
Q2	0.436	0.4356	0.4356	0.4356	0.436	0.436	0.436
Q3	0.251	0.2508	0.2508	0.2508	0.251	0.251	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.127	0.127	0.128
Q8	0.176	0.1762	0.1762	0.1762	0.176	0.176	0.176
Q4	0.039	0.039	***-0.039***	0.039	0.039	0.039	0.039
Q5	-0.016				-0.016	-0.016	-0.016
Q7	0				0	0	0
Q9	-0.166				-0.166	-0.166	-0.166
Q10	-0.058				-0.058	-0.058	-0.058
Q11	-0.018				-0.018	-0.018	-0.018
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.016	-0.016	-0.016
Q13	-0.058	-0.058	-0.058	-0.058	-0.058	-0.058	-0.058
Q14	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	***-0.4151***	0.4151	0.4151	0.415	0.415	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.233	-0.233	-0.233
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.612	-0.612	-0.612
P4-7	0.281	0.2805	0.2805	0.2805	0.281	0.281	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.441

P6-11	0.074	0.0735	0.0735	0.0735	0.073	0.073	0.073
P6-12	0.078	0.0777	0.0777	0.0777	0.078	0.078	0.078
P6-13	0.177				0.177	0.177	0.178
P7-8	0				0	0	0
P7-9	0.281				0.281	0.281	0.281
P9-10	0.052				0.052	0.052	0.052
P9-14	0.094				0.094	0.094	0.095
P10-11	-0.038				-0.038	-0.038	-0.038
P12-13	0.016				0.016	0.016	0.016
P13-14	0.056				0.056	0.056	0.057
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.727
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.544	-0.545
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.406	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.617	0.617	0.617
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.281	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.073	-0.073	-0.073
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.077	-0.077	-0.077
P13-6	-0.175				-0.175	-0.175	-0.175
P8-7	0				0	0	0
P9-7	-0.281				-0.281	-0.281	-0.281
P10-9	-0.052				-0.052	-0.052	-0.052
P14-9	-0.093				-0.093	-0.093	-0.093
P11-10	0.038				0.038	0.038	0.038
P13-12	-0.016				-0.016	-0.016	-0.016
P14-13	-0.056				-0.056	-0.056	-0.056
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.039	0.039	0.039
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.015	-0.015	-0.015
Q2-5	0.012	***-0.0115***	0.0115	0.0115	0.012	0.012	0.012
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	0.045	0.045
Q4-5	0.158	0.1581	0.1581	0.1581	0.158	0.158	0.158

Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.097	-0.097	-0.097
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.004	-0.004	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.125	0.125
Q6-11	0.036	0.0359	0.0359	0.0359	0.036	0.036	0.036
Q6-12	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Q6-13	0.072				0.072	0.072	0.072
Q7-8	-0.172				-0.172	-0.172	-0.172
Q7-9	0.058				0.058	0.058	0.058
Q9-10	0.042				0.042	0.042	0.042
Q9-14	0.036				0.036	0.036	0.036
Q10-11	-0.016				-0.016	-0.016	-0.016
Q12-13	0.008				0.008	0.008	0.007
Q13-14	0.017				0.017	0.017	0.018
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.022	0.022	0.022
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.03	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	-0.021	-0.021
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.048	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.142	-0.142	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.114	0.114	0.114
Q9-4	0.017	0.0174	0.0174	0.0174	0.017	0.017	0.017
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.08	-0.08	-0.081
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	-0.034	-0.035
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.024	-0.023	-0.024
Q13-6	-0.068				-0.068	-0.068	-0.068
Q8-7	0.176				0.176	0.176	0.176
Q9-7	-0.05				-0.05	-0.05	-0.05
Q10-9	-0.042				-0.042	-0.042	-0.042
Q14-9	-0.034				-0.034	-0.034	-0.034
Q11-10	0.016				0.016	0.016	0.016
Q13-12	-0.007				-0.007	-0.007	-0.007
Q14-13	-0.016				-0.016	-0.016	-0.016
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.263
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.265
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.28

Table B-35: 14 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.063	1.064	1.063
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.057	1.058	1.057
V10	1.051	1.0288	1.0288	1.0288	1.052	1.053	1.052
V11	1.057				1.058	1.059	1.058
V12	1.055	1.045	1.045	***-1.045***	1.057	1.058	1.056
V13	1.05				1.051	1.053	1.051
V14	1.036				1.036	1.037	1.035
P1	2.324	2.3243	2.3243	2.3243	2.324	2.324	2.324

P2	0.4	0.4	0.4	0.4	0.398	0.398	0.399
P3	0	-0.0001	-0.0001	-0.0001	-0.001	0	0
P6	0	-0.0001	-0.0001	-0.0001	-0.009	-0.019	-0.005
P8	0	0.0001	0.0001	0.0001	0	0	0
P4	-0.478	-0.4779	***0.4779***	-0.4779	-0.477	-0.477	-0.478
P5	-0.076				-0.074	-0.074	-0.075
P7	0				0	0	0
P9	-0.295				-0.293	-0.294	-0.293
P10	-0.09				-0.092	-0.092	-0.092
P11	-0.035				-0.032	-0.029	-0.032
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.058	-0.055	-0.06
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.132	-0.126	-0.134
P14	-0.149	-0.149	-0.149	-0.149	-0.152	-0.152	-0.151
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.167	-0.167	-0.166
Q2	0.436	0.4356	0.4356	0.4356	0.431	0.432	0.434
Q3	0.251	0.2508	0.2508	0.2508	0.249	0.249	0.25
Q6	0.127	0.1276	0.1276	0.1276	0.108	0.086	0.117
Q8	0.176	0.1762	0.1762	0.1762	0.166	0.161	0.168
Q4	0.039	0.039	***-0.039***	0.039	0.034	0.028	0.032
Q5	-0.016				-0.01	-0.01	-0.013
Q7	0				0.02	0.028	0.018
Q9	-0.166				-0.162	-0.161	-0.161
Q10	-0.058				-0.063	-0.063	-0.062
Q11	-0.018				-0.011	-0.004	-0.011
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.011	-0.005	-0.014
Q13	-0.058	-0.058	-0.058	-0.058	-0.05	-0.04	-0.055
Q14	-0.05	-0.05	-0.05	-0.05	-0.055	-0.054	-0.055
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	***-0.4151***	0.4151	0.4151	0.414	0.414	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.234	-0.234	-0.233
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.613	-0.612	-0.612
P4-7	0.281	0.2805	0.2805	0.2805	0.281	0.281	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.441

P6-11	0.074	0.0735	0.0735	0.0735	0.071	0.068	0.071
P6-12	0.078	0.0777	0.0777	0.0777	0.076	0.073	0.077
P6-13	0.177				0.174	0.169	0.176
P7-8	0				0	0	0
P7-9	0.281				0.281	0.282	0.281
P9-10	0.052				0.054	0.053	0.053
P9-14	0.094				0.096	0.096	0.096
P10-11	-0.038				-0.039	-0.039	-0.039
P12-13	0.016				0.017	0.017	0.017
P13-14	0.056				0.057	0.058	0.057
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.727
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.544	-0.544
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.405	-0.405	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.618	0.618	0.617
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.281	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.07	-0.068	-0.071
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.075	-0.072	-0.076
P13-6	-0.175				-0.172	-0.167	-0.174
P8-7	0				0	0	0
P9-7	-0.281				-0.281	-0.282	-0.281
P10-9	-0.052				-0.053	-0.053	-0.053
P14-9	-0.093				-0.095	-0.094	-0.095
P11-10	0.038				0.039	0.039	0.039
P13-12	-0.016				-0.017	-0.017	-0.016
P14-13	-0.056				-0.057	-0.057	-0.057
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.037	0.037	0.038
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.018	-0.017	-0.016
Q2-5	0.012	***-0.0115***	0.0115	0.0115	0.01	0.01	0.011
Q3-4	0.045	0.0448	0.0448	0.0448	0.043	0.043	0.044
Q4-5	0.158	0.1581	0.1581	0.1581	0.158	0.158	0.158

Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.103	-0.107	-0.103
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.006	-0.008	-0.006
Q5-6	0.125	0.1243	0.1243	0.1243	0.127	0.127	0.126
Q6-11	0.036	0.0359	0.0359	0.0359	0.03	0.024	0.03
Q6-12	0.025	0.025	0.025	0.025	0.02	0.015	0.023
Q6-13	0.072				0.065	0.055	0.07
Q7-8	-0.172				-0.162	-0.157	-0.163
Q7-9	0.058				0.061	0.06	0.061
Q9-10	0.042				0.045	0.045	0.045
Q9-14	0.036				0.039	0.038	0.04
Q10-11	-0.016				-0.018	-0.018	-0.018
Q12-13	0.008				0.008	0.009	0.008
Q13-14	0.017				0.019	0.02	0.019
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.024	0.024	0.023
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.032	0.032	0.031
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.019	-0.019	-0.02
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.046	-0.047	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.141	-0.142	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.121	0.125	0.12
Q9-4	0.017	0.0174	0.0174	0.0174	0.019	0.021	0.019
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.082	-0.083	-0.081
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.029	-0.023	-0.029
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.019	-0.013	-0.022
Q13-6	-0.068				-0.062	-0.051	-0.066
Q8-7	0.176				0.166	0.161	0.168
Q9-7	-0.05				-0.053	-0.052	-0.053
Q10-9	-0.042				-0.045	-0.045	-0.045
Q14-9	-0.034				-0.037	-0.036	-0.037
Q11-10	0.016				0.018	0.019	0.018
Q13-12	-0.007				-0.008	-0.008	-0.008
Q14-13	-0.016				-0.018	-0.019	-0.018
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.263
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.265
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.28

Table B-36: 14 Bus-WLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.062	1.062
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.056	1.056	1.056
V10	1.051	1.0288	1.0288	***-1.0288***	1.051	1.051	1.049
V11	1.057				1.057	1.057	1.057
V12	1.055	1.045	1.045	1.045	1.055	1.055	1.055
V13	1.05				1.05	1.05	1.05
V14	1.036	1.033	1.033	***-1.033***	1.036	1.036	1.035
P1	2.324	2.3243	2.3243	2.3243	2.324	2.324	2.324

P2	0.4	0.4	0.4	0.4	0.399	0.399	0.4
P3	0	-0.0001	***0.0001***	-0.0001	0	0	0
P6	0	-0.0001	-0.0001	-0.0001	0	0	-0.001
P8	0	0.0001	***-0.0001***	0.0001	0	0	0.001
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.478	-0.478	-0.477
P5	-0.076				-0.076	-0.076	-0.074
P7	0				0	0	0.003
P9	-0.295				-0.295	-0.295	-0.3
P10	-0.09				-0.09	-0.09	-0.096
P11	-0.035				-0.035	-0.035	-0.032
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.061	-0.061	-0.061
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.135	-0.135	-0.134
P14	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149	-0.148
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.166	-0.166	-0.166
Q2	0.436	0.4356	0.4356	0.4356	0.436	0.436	0.436
Q3	0.251	0.2508	-0.2508	0.2508	0.251	0.251	0.25
Q6	0.127	0.1276	0.1276	0.1276	0.127	0.127	0.126
Q8	0.176	0.1762	-0.1762	0.1762	0.176	0.176	0.176
Q4	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Q5	-0.016				-0.017	-0.017	-0.017
Q7	0				0	0	-0.003
Q9	-0.166				-0.166	-0.166	-0.127
Q10	-0.058				-0.058	-0.058	-0.099
Q11	-0.018				-0.018	-0.018	-0.006
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.016	-0.016	-0.016
Q13	-0.058	-0.058	-0.058	-0.058	-0.058	-0.058	-0.057
Q14	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.054
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	0.4151	0.4151	0.4151	0.415	0.415	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.233	-0.233	-0.233
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.612	-0.612	-0.613
P4-7	0.281	0.2805	0.2805	0.2805	0.281	0.281	0.282
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.162
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.441

P6-11	0.074	***-0.0735***	0.0735	0.0735	0.073	0.073	0.074
P6-12	0.078	0.0777	0.0777	0.0777	0.078	0.078	0.078
P6-13	0.177				0.177	0.177	0.177
P7-8	0				0	0	-0.001
P7-9	0.281	***-0.276***	0.276	0.276	0.281	0.281	0.286
P9-10	0.052				0.052	0.052	0.055
P9-14	0.094				0.094	0.094	0.093
P10-11	-0.038				-0.038	-0.038	-0.041
P12-13	0.016				0.016	0.016	0.016
P13-14	0.056				0.056	0.056	0.057
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.727
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.544	-0.545
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.406	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.236
P5-4	0.617	0.6167	0.6167	0.6167	0.617	0.617	0.618
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.281	-0.282
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.162
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.073	-0.073	-0.073
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.077	-0.077	-0.077
P13-6	-0.175				-0.175	-0.175	-0.175
P8-7	0				0	0	0.001
P9-7	-0.281				-0.281	-0.281	-0.286
P10-9	-0.052				-0.052	-0.052	-0.055
P14-9	-0.093				-0.093	-0.093	-0.092
P11-10	0.038				0.038	0.038	0.041
P13-12	-0.016				-0.016	-0.016	-0.016
P14-13	-0.056				-0.056	-0.056	-0.056
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.039	0.039	0.039
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.015	-0.015	-0.016
Q2-5	0.012	0.0115	0.0115	0.0115	0.012	0.012	0.012
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	0.045	0.044
Q4-5	0.158	0.1581	0.1581	0.1581	0.159	0.159	0.159

Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.097	-0.097	-0.097
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.004	-0.004	-0.005
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.125	0.125
Q6-11	0.036	***-0.0359***	0.0359	0.0359	0.036	0.036	0.035
Q6-12	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Q6-13	0.072				0.072	0.072	0.072
Q7-8	-0.172				-0.172	-0.172	-0.171
Q7-9	0.058	***-0.051***	0.051	0.051	0.058	0.058	0.054
Q9-10	0.042				0.042	0.042	0.073
Q9-14	0.036				0.036	0.036	0.04
Q10-11	-0.016				-0.016	-0.016	-0.027
Q12-13	0.008				0.008	0.008	0.007
Q13-14	0.017				0.017	0.017	0.018
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.022	0.022	0.022
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.03	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	-0.021	-0.021
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.048	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.142	-0.142	-0.143
Q7-4	0.114	0.1138	0.1138	0.1138	0.114	0.114	0.114
Q9-4	0.017	0.0174	0.0174	0.0174	0.017	0.017	0.018
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.08	-0.08	-0.08
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	-0.034	-0.033
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.024	-0.024	-0.024
Q13-6	-0.068				-0.068	-0.068	-0.068
Q8-7	0.176				0.176	0.176	0.176
Q9-7	-0.05				-0.05	-0.05	-0.046
Q10-9	-0.042				-0.042	-0.042	-0.072
Q14-9	-0.034				-0.034	-0.034	-0.037
Q11-10	0.016				0.016	0.016	0.027
Q13-12	-0.007				-0.007	-0.007	-0.007
Q14-13	-0.016				-0.016	-0.016	-0.017
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.263
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.265
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.28

Table B-37: 14 Bus-IRLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.062	1.062
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.056	1.056	1.056
V10	1.051	1.0288	1.0288	***-1.0288***	1.051	1.051	1.051
V11	1.057				1.057	1.057	1.057
V12	1.055	1.045	1.045	1.045	1.055	1.055	1.055
V13	1.05				1.05	1.05	1.05
V14	1.036	1.033	1.033	***-1.033***	1.036	1.036	1.035
P1	2.324	2.3243	2.3243	2.3243	2.324	2.324	2.324

P2	0.4	0.4	0.4	0.4	0.399	0.399	0.4
P3	0	-0.0001	***0.0001***	-0.0001	0	0	0
P6	0	-0.0001	-0.0001	-0.0001	0	0	0
P8	0	0.0001	***-0.0001***	0.0001	0	0	0
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.478	-0.478	-0.478
P5	-0.076				-0.076	-0.076	-0.076
P7	0				0	0	0
P9	-0.295				-0.295	-0.295	-0.295
P10	-0.09				-0.09	-0.09	-0.09
P11	-0.035				-0.035	-0.035	-0.035
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.061	-0.061	-0.061
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.135	-0.135	-0.135
P14	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.166	-0.166	-0.165
Q2	0.436	0.4356	0.4356	0.4356	0.436	0.436	0.436
Q3	0.251	0.2508	-0.2508	0.2508	0.251	0.251	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.127	0.127	0.128
Q8	0.176	0.1762	-0.1762	0.1762	0.176	0.176	0.176
Q4	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Q5	-0.016				-0.016	-0.017	-0.016
Q7	0				0	0	0
Q9	-0.166				-0.166	-0.166	-0.166
Q10	-0.058				-0.058	-0.058	-0.058
Q11	-0.018				-0.018	-0.018	-0.018
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.016	-0.016	-0.016
Q13	-0.058	-0.058	-0.058	-0.058	-0.058	-0.058	-0.058
Q14	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	0.4151	0.4151	0.4151	0.415	0.415	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.233	-0.233	-0.233
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.612	-0.612	-0.612
P4-7	0.281	0.2805	0.2805	0.2805	0.281	0.281	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.441

P6-11	0.074	***-0.0735***	0.0735	0.0735	0.073	0.073	0.073
P6-12	0.078	0.0777	0.0777	0.0777	0.078	0.078	0.078
P6-13	0.177				0.177	0.177	0.178
P7-8	0				0	0	0
P7-9	0.281	***-0.276***	0.276	0.276	0.281	0.281	0.281
P9-10	0.052				0.052	0.052	0.052
P9-14	0.094				0.094	0.094	0.094
P10-11	-0.038				-0.038	-0.038	-0.038
P12-13	0.016				0.016	0.016	0.016
P13-14	0.056				0.056	0.056	0.056
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.727
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.544	-0.545
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.406	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.617	0.617	0.617
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.281	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.073	-0.073	-0.073
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.077	-0.077	-0.077
P13-6	-0.175				-0.175	-0.175	-0.175
P8-7	0				0	0	0
P9-7	-0.281				-0.281	-0.281	-0.281
P10-9	-0.052				-0.052	-0.052	-0.052
P14-9	-0.093				-0.093	-0.093	-0.093
P11-10	0.038				0.038	0.038	0.038
P13-12	-0.016				-0.016	-0.016	-0.016
P14-13	-0.056				-0.056	-0.056	-0.056
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.039	0.039	0.039
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.015	-0.015	-0.016
Q2-5	0.012	0.0115	0.0115	0.0115	0.012	0.012	0.012
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	0.045	0.045
Q4-5	0.158	0.1581	0.1581	0.1581	0.159	0.159	0.158

Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.097	-0.097	-0.097
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.004	-0.004	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.125	0.125
Q6-11	0.036	***-0.0359***	0.0359	0.0359	0.036	0.036	0.036
Q6-12	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Q6-13	0.072				0.072	0.072	0.072
Q7-8	-0.172				-0.172	-0.172	-0.172
Q7-9	0.058	***-0.051***	0.051	0.051	0.058	0.058	0.058
Q9-10	0.042				0.042	0.042	0.042
Q9-14	0.036				0.036	0.036	0.036
Q10-11	-0.016				-0.016	-0.016	-0.016
Q12-13	0.008				0.008	0.008	0.008
Q13-14	0.017				0.017	0.017	0.018
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.022	0.022	0.022
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.03	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	-0.021	-0.021
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.048	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.142	-0.142	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.114	0.114	0.114
Q9-4	0.017	0.0174	0.0174	0.0174	0.017	0.017	0.017
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.08	-0.08	-0.08
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	-0.034	-0.035
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.024	-0.024	-0.023
Q13-6	-0.068				-0.068	-0.068	-0.068
Q8-7	0.176				0.176	0.176	0.176
Q9-7	-0.05				-0.05	-0.05	-0.05
Q10-9	-0.042				-0.042	-0.042	-0.042
Q14-9	-0.034				-0.034	-0.034	-0.034
Q11-10	0.016				0.016	0.016	0.016
Q13-12	-0.007				-0.007	-0.007	-0.008
Q14-13	-0.016				-0.016	-0.016	-0.016
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.263
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.265
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.28

Table B-38: 14 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.065	1.062
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.058	1.059	1.056
V10	1.051	1.0288	1.0288	***-1.0288***	1.053	1.054	1.051
V11	1.057				1.06	1.06	1.057
V12	1.055	1.045	1.045	1.045	1.057	1.057	1.056
V13	1.05				1.052	1.052	1.05
V14	1.036	1.033	1.033	***-1.033***	1.037	1.037	1.035
P1	2.324	2.3243	2.3243	2.3243	2.324	2.324	2.324

P2	0.4	0.4	0.4	0.4	0.399	0.398	0.399
P3	0	-0.0001	***0.0001***	-0.0001	0	-0.001	0
P6	0	-0.0001	-0.0001	-0.0001	-0.014	-0.014	-0.002
P8	0	0.0001	***-0.0001***	0.0001	0	0	0
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.478	-0.475	-0.478
P5	-0.076				-0.075	-0.074	-0.075
P7	0				0.001	0.001	0
P9	-0.295				-0.294	-0.293	-0.293
P10	-0.09				-0.092	-0.092	-0.092
P11	-0.035				-0.028	-0.028	-0.033
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.057	-0.057	-0.059
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.13	-0.131	-0.134
P14	-0.149	-0.149	-0.149	-0.149	-0.151	-0.152	-0.151
Q1	-0.165	-0.1654	-0.1654	-0.1654	-0.166	-0.168	-0.166
Q2	0.436	0.4356	0.4356	0.4356	0.434	0.431	0.435
Q3	0.251	0.2508	-0.2508	0.2508	0.25	0.248	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.097	0.096	0.123
Q8	0.176	0.1762	-0.1762	0.1762	0.173	0.154	0.172
Q4	0.039	0.039	0.039	0.039	0.034	0.027	0.034
Q5	-0.016				-0.013	-0.011	-0.015
Q7	0				-0.01	0.039	0.011
Q9	-0.166				-0.144	-0.159	-0.162
Q10	-0.058				-0.062	-0.062	-0.063
Q11	-0.018				-0.004	-0.003	-0.014
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.009	-0.009	-0.014
Q13	-0.058	-0.058	-0.058	-0.058	-0.047	-0.049	-0.056
Q14	-0.05	-0.05	-0.05	-0.05	-0.054	-0.055	-0.055
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	0.4151	0.4151	0.4151	0.415	0.414	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.233	-0.234	-0.233
P4-5	-0.612	-0.6111	-0.6111	-0.6111	-0.612	-0.612	-0.612
P4-7	0.281	0.2805	0.2805	0.2805	0.281	0.282	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.441

P6-11	0.074	***-0.0735***	0.0735	0.0735	0.068	0.067	0.073
P6-12	0.078	0.0777	0.0777	0.0777	0.075	0.075	0.077
P6-13	0.177				0.172	0.173	0.177
P7-8	0				0	0	0
P7-9	0.281	***-0.276***	0.276	0.276	0.281	0.282	0.281
P9-10	0.052				0.053	0.053	0.053
P9-14	0.094				0.096	0.097	0.096
P10-11	-0.038				-0.039	-0.039	-0.038
P12-13	0.016				0.017	0.017	0.017
P13-14	0.056				0.057	0.057	0.057
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.727
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.544	-0.544
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.405	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.238	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.617	0.617	0.617
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.282	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.068	-0.067	-0.072
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.074	-0.074	-0.076
P13-6	-0.175				-0.17	-0.171	-0.175
P8-7	0				0	0	0
P9-7	-0.281				-0.281	-0.282	-0.281
P10-9	-0.052				-0.053	-0.053	-0.053
P14-9	-0.093				-0.095	-0.096	-0.095
P11-10	0.038				0.039	0.039	0.039
P13-12	-0.016				-0.017	-0.017	-0.017
P14-13	-0.056				-0.057	-0.056	-0.057
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.038	0.036	0.038
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.016	-0.018	-0.016
Q2-5	0.012	0.0115	0.0115	0.0115	0.011	0.009	0.011
Q3-4	0.045	0.0448	0.0448	0.0448	0.044	0.042	0.045
Q4-5	0.158	0.1581	0.1581	0.1581	0.158	0.16	0.158

Q4-7	-0.097	-0.0967	-0.0967	-0.0967	-0.099	-0.11	-0.1
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.008	-0.009	-0.005
Q5-6	0.125	0.1243	0.1243	0.1243	0.126	0.127	0.125
Q6-11	0.036	***-0.0359***	0.0359	0.0359	0.024	0.022	0.034
Q6-12	0.025	0.025	0.025	0.025	0.018	0.019	0.024
Q6-13	0.072				0.061	0.063	0.071
Q7-8	-0.172				-0.168	-0.151	-0.167
Q7-9	0.058	***-0.051***	0.051	0.051	0.043	0.062	0.061
Q9-10	0.042				0.043	0.045	0.045
Q9-14	0.036				0.039	0.041	0.039
Q10-11	-0.016				-0.019	-0.018	-0.018
Q12-13	0.008				0.008	0.008	0.008
Q13-14	0.017				0.019	0.018	0.019
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.023	0.024	0.022
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.031	0.033	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.02	-0.019	-0.021
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.046	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.142	-0.143	-0.141
Q7-4	0.114	0.1138	0.1138	0.1138	0.116	0.128	0.118
Q9-4	0.017	0.0174	0.0174	0.0174	0.021	0.022	0.018
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.081	-0.083	-0.081
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.023	-0.021	-0.032
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.017	-0.018	-0.022
Q13-6	-0.068				-0.057	-0.059	-0.067
Q8-7	0.176				0.173	0.154	0.172
Q9-7	-0.05				-0.035	-0.053	-0.053
Q10-9	-0.042				-0.043	-0.044	-0.045
Q14-9	-0.034				-0.036	-0.039	-0.037
Q11-10	0.016				0.019	0.018	0.018
Q13-12	-0.007				-0.008	-0.008	-0.008
Q14-13	-0.016				-0.018	-0.017	-0.018
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.263
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.265
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.28

Table B-39: 14 Bus-WLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.062	1.062
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.056	1.056	1.056
V10	1.051	1.0288	1.0288	1.0288	1.051	1.051	1.051
V11	1.057				1.057	1.057	1.057
V12	1.055	1.045	1.045	1.045	1.055	1.055	1.055
V13	1.05	1.044	1.044	***-1.044***	1.05	1.05	1.05
V14	1.036	1.0298	1.0298	***-1.0298***	1.036	1.036	1.035
P1	2.324	2.3243	***-2.3243***	2.3243	2.324	2.324	2.324

P2	0.4	0.4	***-0.4***	0.4	0.399	0.4	0.4
P3	0	-0.0001	-0.0001	-0.0001	0	0	0
P6	0	-0.0001	-0.0001	-0.0001	0	0	0.002
P8	0	0.0001	0.0001	0.0001	0	0	0
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.478	-0.479	-0.478
P5	-0.076				-0.076	-0.075	-0.076
P7	0				0	0	-0.002
P9	-0.295				-0.295	-0.295	-0.292
P10	-0.09				-0.09	-0.09	-0.092
P11	-0.035				-0.035	-0.035	-0.035
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.061	-0.061	-0.059
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.135	-0.135	-0.14
P14	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149	-0.148
Q1	-0.165	-0.1654	***0.1654***	-0.1654	-0.166	-0.165	-0.166
Q2	0.436	0.4356	***-0.4356***	0.4356	0.436	0.435	0.436
Q3	0.251	0.2508	0.2508	0.2508	0.251	0.251	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.127	0.127	0.137
Q8	0.176	0.1762	0.1762	0.1762	0.176	0.176	0.176
Q4	0.039	0.039	0.039	0.039	0.039	0.04	0.039
Q5	-0.016				-0.016	-0.016	-0.016
Q7	0				0	0	0
Q9	-0.166				-0.166	-0.166	-0.166
Q10	-0.058				-0.058	-0.058	-0.058
Q11	-0.018				-0.018	-0.018	-0.019
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.016	-0.016	-0.014
Q13	-0.058	-0.058	-0.058	-0.058	-0.058	-0.058	-0.07
Q14	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.048
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	0.4151	0.4151	0.4151	0.415	0.415	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.233	-0.233	-0.233
P4-5	-0.612	***0.6111***	-0.6111	-0.6111	-0.611	-0.612	-0.611
P4-7	0.281	***-0.2805***	0.2805	0.2805	0.281	0.281	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.442

P6-11	0.074	0.0735	0.0735	0.0735	0.073	0.073	0.073
P6-12	0.078	0.0777	0.0777	0.0777	0.078	0.078	0.078
P6-13	0.177				0.177	0.177	0.18
P7-8	0				0	0	0
P7-9	0.281				0.281	0.281	0.28
P9-10	0.052				0.052	0.052	0.054
P9-14	0.094				0.094	0.094	0.095
P10-11	-0.038				-0.038	-0.038	-0.038
P12-13	0.016				0.016	0.016	0.018
P13-14	0.056				0.056	0.056	0.055
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.728
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.545	-0.545
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.406	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.236
P5-4	0.617	0.6167	0.6167	0.6167	0.617	0.617	0.616
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.281	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.442
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.073	-0.073	-0.073
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.077	-0.077	-0.077
P13-6	-0.175				-0.175	-0.175	-0.178
P8-7	0				0	0	0
P9-7	-0.281				-0.281	-0.281	-0.28
P10-9	-0.052				-0.052	-0.052	-0.054
P14-9	-0.093				-0.093	-0.093	-0.093
P11-10	0.038				0.038	0.038	0.038
P13-12	-0.016				-0.016	-0.016	-0.018
P14-13	-0.056				-0.056	-0.056	-0.055
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.039	0.039	0.039
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.015	-0.016	-0.016
Q2-5	0.012	0.0115	0.0115	0.0115	0.012	0.012	0.012
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	0.045	0.045
Q4-5	0.158	***-0.1581***	0.1581	0.1581	0.158	0.159	0.158

Q4-7	-0.097	***0.0967***	-0.0967	-0.0967	-0.097	-0.097	-0.097
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.004	-0.004	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.125	0.124
Q6-11	0.036	0.0359	0.0359	0.0359	0.036	0.036	0.037
Q6-12	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Q6-13	0.072				0.072	0.072	0.08
Q7-8	-0.172				-0.172	-0.172	-0.172
Q7-9	0.058				0.058	0.058	0.058
Q9-10	0.042				0.042	0.042	0.042
Q9-14	0.036				0.036	0.036	0.036
Q10-11	-0.016				-0.016	-0.016	-0.016
Q12-13	0.008				0.008	0.008	0.01
Q13-14	0.017				0.017	0.017	0.015
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.022	0.022	0.022
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.03	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	-0.021	-0.021
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.048	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.142	-0.142	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.114	0.114	0.114
Q9-4	0.017	0.0174	0.0174	0.0174	0.017	0.017	0.017
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.08	-0.08	-0.08
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	-0.034	-0.035
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.024	-0.024	-0.024
Q13-6	-0.068				-0.068	-0.068	-0.075
Q8-7	0.176				0.176	0.176	0.176
Q9-7	-0.05				-0.05	-0.05	-0.05
Q10-9	-0.042				-0.042	-0.042	-0.041
Q14-9	-0.034				-0.034	-0.034	-0.034
Q11-10	0.016				0.016	0.016	0.016
Q13-12	-0.007				-0.007	-0.007	-0.01
Q14-13	-0.016				-0.016	-0.016	-0.014
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.264
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.265
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.28

Table B-40: 14 Bus-IRLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.062	1.061
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.056	1.056	1.056
V10	1.051	1.0288	1.0288	1.0288	1.051	1.051	1.051
V11	1.057				1.057	1.057	1.057
V12	1.055	1.045	1.045	1.045	1.055	1.055	1.055
V13	1.05	1.044	1.044	***-1.044***	1.05	1.05	1.05
V14	1.036	1.0298	1.0298	***-1.0298***	1.036	1.036	1.032
P1	2.324	2.3243	***-2.3243***	2.3243	2.324	2.324	2.324

P2	0.4	0.4	***-0.4***	0.4	0.399	0.4	0.4
P3	0	-0.0001	-0.0001	-0.0001	0	0	0
P6	0	-0.0001	-0.0001	-0.0001	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.478	-0.478	-0.478
P5	-0.076				-0.076	-0.076	-0.076
P7	0				0	0	0
P9	-0.295				-0.295	-0.295	-0.296
P10	-0.09				-0.09	-0.09	-0.09
P11	-0.035				-0.035	-0.035	-0.035
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.061	-0.061	-0.061
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.135	-0.135	-0.135
P14	-0.149	-0.149	-0.149	-0.149	-0.149	-0.149	-0.148
Q1	-0.165	-0.1654	***0.1654***	-0.1654	-0.166	-0.165	-0.165
Q2	0.436	0.4356	***-0.4356***	0.4356	0.436	0.435	0.436
Q3	0.251	0.2508	0.2508	0.2508	0.251	0.251	0.251
Q6	0.127	0.1276	0.1276	0.1276	0.127	0.127	0.129
Q8	0.176	0.1762	0.1762	0.1762	0.176	0.176	0.176
Q4	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Q5	-0.016				-0.016	-0.016	-0.016
Q7	0				0	0	0
Q9	-0.166				-0.166	-0.166	-0.152
Q10	-0.058				-0.058	-0.058	-0.058
Q11	-0.018				-0.018	-0.018	-0.018
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.016	-0.016	-0.016
Q13	-0.058	-0.058	-0.058	-0.058	-0.058	-0.058	-0.049
Q14	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.075
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	0.4151	0.4151	0.4151	0.415	0.415	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.233	-0.233	-0.233
P4-5	-0.612	***0.6111***	-0.6111	-0.6111	-0.611	-0.612	-0.612
P4-7	0.281	***-0.2805***	0.2805	0.2805	0.281	0.281	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.441

P6-11	0.074	0.0735	0.0735	0.0735	0.073	0.073	0.074
P6-12	0.078	0.0777	0.0777	0.0777	0.078	0.078	0.078
P6-13	0.177				0.177	0.177	0.177
P7-8	0				0	0	0
P7-9	0.281				0.281	0.281	0.281
P9-10	0.052				0.052	0.052	0.052
P9-14	0.094				0.094	0.094	0.093
P10-11	-0.038				-0.038	-0.038	-0.038
P12-13	0.016				0.016	0.016	0.016
P13-14	0.056				0.056	0.056	0.056
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.728
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.544	-0.545
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.406	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.617	0.617	0.617
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.281	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.073	-0.073	-0.073
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.077	-0.077	-0.077
P13-6	-0.175				-0.175	-0.175	-0.175
P8-7	0				0	0	0
P9-7	-0.281				-0.281	-0.281	-0.281
P10-9	-0.052				-0.052	-0.052	-0.052
P14-9	-0.093				-0.093	-0.093	-0.092
P11-10	0.038				0.038	0.038	0.038
P13-12	-0.016				-0.016	-0.016	-0.016
P14-13	-0.056				-0.056	-0.056	-0.055
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.039	0.039	0.039
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.015	-0.016	-0.015
Q2-5	0.012	0.0115	0.0115	0.0115	0.012	0.012	0.012
Q3-4	0.045	0.0448	0.0448	0.0448	0.045	0.045	0.045
Q4-5	0.158	***-0.1581***	0.1581	0.1581	0.158	0.158	0.158

Q4-7	-0.097	***0.0967***	-0.0967	-0.0967	-0.097	-0.097	-0.097
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.004	-0.004	-0.004
Q5-6	0.125	0.1243	0.1243	0.1243	0.125	0.125	0.125
Q6-11	0.036	0.0359	0.0359	0.0359	0.036	0.036	0.036
Q6-12	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Q6-13	0.072				0.072	0.072	0.073
Q7-8	-0.172				-0.172	-0.172	-0.172
Q7-9	0.058				0.058	0.058	0.058
Q9-10	0.042				0.042	0.042	0.042
Q9-14	0.036				0.036	0.036	0.051
Q10-11	-0.016				-0.016	-0.016	-0.016
Q12-13	0.008				0.008	0.008	0.008
Q13-14	0.017				0.017	0.017	0.028
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.022	0.022	0.022
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.03	0.03	0.03
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.021	-0.021	-0.021
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.048	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.142	-0.142	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.114	0.114	0.114
Q9-4	0.017	0.0174	0.0174	0.0174	0.017	0.017	0.017
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.08	-0.08	-0.081
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	-0.034	-0.035
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.024	-0.024	-0.024
Q13-6	-0.068				-0.068	-0.068	-0.069
Q8-7	0.176				0.176	0.176	0.176
Q9-7	-0.05				-0.05	-0.05	-0.05
Q10-9	-0.042				-0.042	-0.042	-0.042
Q14-9	-0.034				-0.034	-0.034	-0.048
Q11-10	0.016				0.016	0.016	0.016
Q13-12	-0.007				-0.007	-0.007	-0.008
Q14-13	-0.016				-0.016	-0.016	-0.027
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.263
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.264
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.278

Table B-41: 14 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0692	1.0692	1.0692	1.06	1.06	1.06
V2	1.045	1.0491	1.0491	1.0491	1.045	1.045	1.045
V3	1.01	1.0292	1.0292	1.0292	1.01	1.01	1.01
V4	1.018	0.9931	0.9931	0.9931	1.018	1.018	1.018
V5	1.02	1.0186	1.0186	1.0186	1.02	1.02	1.02
V6	1.07	1.0698	1.0698	1.0698	1.07	1.07	1.07
V7	1.062	1.0635	1.0635	1.0635	1.062	1.063	1.063
V8	1.09	1.0796	1.0796	1.0796	1.09	1.09	1.09
V9	1.056	1.0612	1.0612	1.0612	1.056	1.057	1.057
V10	1.051	1.0288	1.0288	1.0288	1.051	1.052	1.051
V11	1.057				1.057	1.058	1.058
V12	1.055	1.045	1.045	1.045	1.056	1.056	1.055
V13	1.05	1.044	1.044	***-1.044***	1.051	1.051	1.05
V14	1.036	1.0298	1.0298	***-1.0298***	1.035	1.036	1.035
P1	2.324	2.3243	***-2.3243***	2.3243	2.324	2.324	2.324

P2	0.4	0.4	***-0.4***	0.4	0.399	0.398	0.399
P3	0	-0.0001	-0.0001	-0.0001	0	-0.001	0
P6	0	-0.0001	-0.0001	-0.0001	-0.004	-0.009	-0.002
P8	0	0.0001	0.0001	0.0001	0	0	0
P4	-0.478	-0.4779	-0.4779	-0.4779	-0.479	-0.477	-0.478
P5	-0.076				-0.074	-0.074	-0.075
P7	0				0	0	0
P9	-0.295				-0.293	-0.293	-0.292
P10	-0.09				-0.092	-0.092	-0.092
P11	-0.035				-0.034	-0.031	-0.033
P12	-0.061	-0.0608	-0.0608	-0.0608	-0.059	-0.058	-0.06
P13	-0.135	-0.1346	-0.1346	-0.1346	-0.132	-0.132	-0.135
P14	-0.149	-0.149	-0.149	-0.149	-0.151	-0.152	-0.152
Q1	-0.165	-0.1654	***0.1654***	-0.1654	-0.167	-0.167	-0.166
Q2	0.436	0.4356	***-0.4356***	0.4356	0.434	0.431	0.435
Q3	0.251	0.2508	0.2508	0.2508	0.25	0.249	0.25
Q6	0.127	0.1276	0.1276	0.1276	0.119	0.107	0.122
Q8	0.176	0.1762	0.1762	0.1762	0.173	0.165	0.17
Q4	0.039	0.039	0.039	0.039	0.037	0.034	0.034
Q5	-0.016				-0.01	-0.011	-0.014
Q7	0				0.006	0.022	0.014
Q9	-0.166				-0.164	-0.161	-0.162
Q10	-0.058				-0.062	-0.062	-0.062
Q11	-0.018				-0.016	-0.01	-0.013
Q12	-0.016	-0.0156	-0.0156	-0.0156	-0.012	-0.011	-0.014
Q13	-0.058	-0.058	-0.058	-0.058	-0.052	-0.051	-0.057
Q14	-0.05	-0.05	-0.05	-0.05	-0.054	-0.055	-0.056
P1-2	1.569	1.5689	1.5689	1.5689	1.569	1.569	1.569
P1-5	0.755	0.755	0.755	0.755	0.755	0.755	0.755
P2-3	0.732	0.7323	0.7323	0.7323	0.732	0.732	0.732
P2-4	0.561	0.5613	0.5613	0.5613	0.561	0.561	0.561
P2-5	0.415	0.4151	0.4151	0.4151	0.415	0.414	0.415
P3-4	-0.233	-0.2329	-0.2329	-0.2329	-0.233	-0.234	-0.233
P4-5	-0.612	***0.6111***	-0.6111	-0.6111	-0.613	-0.612	-0.612
P4-7	0.281	***-0.2805***	0.2805	0.2805	0.281	0.281	0.281
P4-9	0.161	0.1606	0.1606	0.1606	0.161	0.161	0.161
P5-6	0.441	0.4409	0.4409	0.4409	0.441	0.441	0.441

P6-11	0.074	0.0735	0.0735	0.0735	0.073	0.07	0.072
P6-12	0.078	0.0777	0.0777	0.0777	0.076	0.076	0.077
P6-13	0.177				0.175	0.174	0.177
P7-8	0				0	0	0
P7-9	0.281				0.281	0.282	0.281
P9-10	0.052				0.053	0.054	0.053
P9-14	0.094				0.095	0.096	0.096
P10-11	-0.038				-0.038	-0.039	-0.039
P12-13	0.016				0.017	0.017	0.017
P13-14	0.056				0.058	0.057	0.057
P2-1	-1.526	-1.5261	-1.5261	-1.5261	-1.526	-1.526	-1.526
P5-1	-0.727	-0.7274	-0.7274	-0.7274	-0.727	-0.727	-0.727
P3-2	-0.709	-0.7092	-0.7092	-0.7092	-0.709	-0.709	-0.709
P4-2	-0.545	-0.5443	-0.5443	-0.5443	-0.544	-0.544	-0.544
P5-2	-0.406	-0.4061	-0.4061	-0.4061	-0.406	-0.405	-0.406
P4-3	0.237	0.2365	0.2365	0.2365	0.237	0.237	0.237
P5-4	0.617	0.6167	0.6167	0.6167	0.618	0.617	0.617
P7-4	-0.281	-0.2808	-0.2808	-0.2808	-0.281	-0.281	-0.281
P9-4	-0.161	-0.1605	-0.1605	-0.1605	-0.161	-0.161	-0.161
P6-5	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441	-0.441
P11-6	-0.073	-0.0733	-0.0733	-0.0733	-0.073	-0.07	-0.071
P12-6	-0.077	-0.0772	-0.0772	-0.0772	-0.076	-0.075	-0.077
P13-6	-0.175				-0.173	-0.172	-0.175
P8-7	0				0	0	0
P9-7	-0.281				-0.281	-0.282	-0.281
P10-9	-0.052				-0.053	-0.053	-0.053
P14-9	-0.093				-0.094	-0.095	-0.095
P11-10	0.038				0.039	0.039	0.039
P13-12	-0.016				-0.017	-0.017	-0.017
P14-13	-0.056				-0.057	-0.057	-0.057
Q1-2	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204	-0.204
Q1-5	0.039	0.0384	0.0384	0.0384	0.037	0.037	0.038
Q2-3	0.036	0.0356	0.0356	0.0356	0.036	0.036	0.036
Q2-4	-0.016	-0.0154	-0.0154	-0.0154	-0.016	-0.018	-0.016
Q2-5	0.012	0.0115	0.0115	0.0115	0.01	0.01	0.011
Q3-4	0.045	0.0448	0.0448	0.0448	0.044	0.043	0.044
Q4-5	0.158	***-0.1581***	0.1581	0.1581	0.156	0.158	0.158

Q4-7	-0.097	***0.0967***	-0.0967	-0.0967	-0.098	-0.104	-0.101
Q4-9	-0.004	-0.0047	-0.0047	-0.0047	-0.004	-0.006	-0.005
Q5-6	0.125	0.1243	0.1243	0.1243	0.126	0.127	0.125
Q6-11	0.036	0.0359	0.0359	0.0359	0.035	0.029	0.032
Q6-12	0.025	0.025	0.025	0.025	0.022	0.021	0.024
Q6-13	0.072				0.068	0.065	0.072
Q7-8	-0.172				-0.169	-0.161	-0.166
Q7-9	0.058				0.06	0.061	0.061
Q9-10	0.042				0.045	0.045	0.045
Q9-14	0.036				0.038	0.04	0.041
Q10-11	-0.016				-0.018	-0.018	-0.018
Q12-13	0.008				0.008	0.008	0.008
Q13-14	0.017				0.02	0.019	0.019
Q2-1	0.277	0.277	0.277	0.277	0.277	0.277	0.277
Q5-1	0.022	0.0227	0.0227	0.0227	0.023	0.024	0.023
Q3-2	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Q4-2	0.03	0.0302	0.0302	0.0302	0.031	0.032	0.031
Q5-2	-0.021	-0.0208	-0.0208	-0.0208	-0.02	-0.019	-0.02
Q4-3	-0.048	-0.0485	-0.0485	-0.0485	-0.048	-0.046	-0.048
Q5-4	-0.142	-0.1423	-0.1423	-0.1423	-0.14	-0.142	-0.142
Q7-4	0.114	0.1138	0.1138	0.1138	0.115	0.121	0.119
Q9-4	0.017	0.0174	0.0174	0.0174	0.017	0.019	0.018
Q6-5	-0.08	-0.0805	-0.0805	-0.0805	-0.081	-0.082	-0.081
Q11-6	-0.034	-0.0347	-0.0347	-0.0347	-0.034	-0.028	-0.031
Q12-6	-0.024	-0.0237	-0.0237	-0.0237	-0.021	-0.019	-0.023
Q13-6	-0.068				-0.064	-0.061	-0.068
Q8-7	0.176				0.173	0.165	0.17
Q9-7	-0.05				-0.052	-0.053	-0.053
Q10-9	-0.042				-0.045	-0.045	-0.044
Q14-9	-0.034				-0.035	-0.037	-0.038
Q11-10	0.016				0.018	0.018	0.018
Q13-12	-0.007				-0.008	-0.008	-0.008
Q14-13	-0.016				-0.019	-0.018	-0.018
Va1	0	-0.0004	-0.0004	-0.0004	0	0	0
Va2	-0.087	-4.8948	-4.8948	-4.8948	-0.087	-0.087	-0.087
Va3	-0.2221	-12.7692	-12.7692	-12.7692	-0.222	-0.222	-0.222

Va4	-0.18	-10.2916	-10.2916	-10.2916	-0.18	-0.18	-0.18
Va5	-0.1531	-8.7868	-8.7868	-8.7868	-0.153	-0.153	-0.153
Va6	-0.2482	-14.1569	-14.1569	-14.1569	-0.248	-0.248	-0.248
Va7	-0.2332	-13.422	-13.422	-13.422	-0.233	-0.233	-0.233
Va8	-0.2332	-13.3578	-13.3578	-13.3578	-0.233	-0.233	-0.233
Va9	-0.2607	-14.9069	-14.9069	-14.9069	-0.261	-0.261	-0.261
Va10	-0.2635	-15.0342	-15.0342	-15.0342	-0.263	-0.263	-0.263
Va11	-0.2581	-14.7021	-14.7021	-14.7021	-0.258	-0.258	-0.258
Va12	-0.2631	-15.0707	-15.0707	-15.0707	-0.263	-0.263	-0.263
Va13	-0.2645	-15.2417	-15.2417	-15.2417	-0.265	-0.265	-0.265
Va14	-0.2798	-16.0762	-16.0762	-16.0762	-0.28	-0.28	-0.28

B.3 30 Bus System

Table B-42: 30 Bus Estimated values for (Partial redundancy)

	Actual	Measurement	WLS	IRLS	WLAVIRLS
V1	1.0600	1.0562	1.0613	1.0602	1.0596
V2	1.0450	1.0539	1.0470	1.0450	1.0450
V3	1.0210	1.0207	1.0215	1.0212	1.0212
V4	1.0120	1.0135	1.0126	1.0123	1.0123
V5	1.0100	1.0178	1.0090	1.0100	1.0100
V6	1.0110	1.0003	1.0106	1.0106	1.0106
V7	1.0030	1.0054	1.0020	1.0026	1.0026
V8	1.0100	1.0116	1.0101	1.0100	1.0100
V9	1.0510	1.0546	1.0513	1.0512	1.0511
V10	1.0450	1.0316	1.0455	1.0454	1.0454
V11	1.0820	1.0880	1.0827	1.0820	1.0820
V12	1.0570	1.0628	1.0579	1.0574	1.0573
V13	1.0710		1.0717	1.0710	1.0710
V14	1.0430		1.0429	1.0425	1.0425

V15	1.0380		1.0382	1.0380	1.0379
V16	1.0450		1.0448	1.0446	1.0446
V17	1.0400		1.0402	1.0402	1.0402
V18	1.0280		1.0282	1.0284	1.0284
V19	1.0260		1.0256	1.0259	1.0259
V20	1.0300		1.0297	1.0300	1.0300
V21	1.0330		1.0330	1.0330	1.0330
V22	1.0340		1.0336	1.0335	1.0335
V23	1.0270		1.0278	1.0275	1.0275
V24	1.0220		1.0223	1.0219	1.0218
V25	1.0180		1.0193	1.0175	1.0175
V26	1.0000		1.0017	0.9998	0.9998
V27	1.0240		1.0259	1.0235	1.0235
V28	1.0070		1.0074	1.0071	1.0071
V29	1.0040		1.0068	1.0036	1.0036
V30	0.9920		0.9954	0.9921	0.9921
P1	2.6100	2.6096	2.2685	2.6090	2.6097
P2	0.4000	0.4001	0.8992	0.4005	0.4001
P5	0.0000	0.0002	-0.0127	0.0001	-0.0001
P8	0.0000	0.0001	-0.0151	0.0001	0.0003
P11	0.0000		-0.0095	-0.0001	-0.0001
P13	0.0000		-0.0049	0.0000	-0.0001
P3	0.0240	0.0239	0.0615	0.0239	0.0238
P4	0.0760	0.0761	0.0792	0.0761	0.0761
P6	0.0000	0.0003	-0.0033	0.0001	0.0003
P7	0.2280	0.2278	0.2632	0.2279	0.2278
P9	0.0000	-0.0002	0.0068	-0.0002	-0.0001
P10	0.0580	0.0579	0.0618	0.0579	0.0579
P12	0.1120	0.1121	0.1176	0.1121	0.1120
P14	0.0620	0.0620	0.0642	0.0620	0.0620
P15	0.0820	0.0819	0.0830	0.0819	0.0819
P16	0.0350	0.0351	0.0381	0.0351	0.0351
P17	0.0900	0.0901	0.0937	0.0901	0.0901
P18	0.0320		0.0341	0.0320	0.0320
P19	0.0950		0.0978	0.0951	0.0951
P20	0.0220		0.0251	0.0221	0.0221
P21	0.1750		0.1786	0.1749	0.1749
P22	0.0000		0.0038	0.0001	0.0001

P23	0.0320		0.0335	0.0319	0.0319
P24	0.0870		0.0894	0.0869	0.0869
P25	0.0000		0.0014	0.0000	0.0000
P26	0.0350		0.0364	0.0349	0.0350
P27	0.0000		0.0008	0.0000	0.0000
P28	0.0000		0.0009	0.0000	0.0001
P29	0.0240		0.0249	0.0241	0.0242
P30	0.1060		0.1066	0.1060	0.1060
Q1	-0.2040	-0.2042	-0.1609	-0.2040	-0.2042
Q2	0.5610	0.5607	0.4645	0.5601	0.5607
Q5	0.3570	0.3565	0.3418	0.3566	0.3569
Q8	0.3610	0.3610	0.3670	0.3610	0.3610
Q11	0.1610		0.1632	0.1606	0.1606
Q13	0.1050		0.1057	0.1044	0.1044
Q3	0.0120	0.0120	-0.0024	0.0121	0.0121
Q4	0.0160	0.0161	0.0105	0.0161	0.0161
Q6	0.0000	0.0001	-0.0030	0.0001	0.0001
Q7	0.1090	0.1090	0.0989	0.1088	0.1090
Q9	0.0000	0.0000	-0.0004	0.0000	0.0000
Q10	0.0200	0.0197	0.0204	0.0197	0.0198
Q12	0.0750	0.0748	0.0736	0.0749	0.0751
Q14	0.0160	0.0158	0.0152	0.0160	0.0158
Q15	0.0250	0.0247	0.0243	0.0248	0.0248
Q16	0.0180	0.0180	0.0176	0.0182	0.0182
Q17	0.0580	0.0578	0.0580	0.0579	0.0578
Q18	0.0090		0.0090	0.0090	0.0090
Q19	0.0340		0.0343	0.0341	0.0341
Q20	0.0070		0.0073	0.0070	0.0070
Q21	0.1120		0.1125	0.1120	0.1120
Q22	0.0000		0.0004	0.0000	-0.0001
Q23	0.0160		0.0155	0.0158	0.0158
Q24	0.0670		0.0668	0.0670	0.0670
Q25	0.0000		-0.0011	0.0002	0.0001
Q26	0.0230		0.0220	0.0233	0.0233
Q27	0.0000		-0.0020	-0.0001	-0.0001
Q28	0.0000		-0.0036	-0.0002	-0.0002
Q29	0.0090		0.0071	0.0090	0.0090
Q30	0.0190		0.0171	0.0191	0.0191

P1-2	1.7330	1.7333	1.4102	1.7326	1.7331
P1-3	0.8760	0.8767	0.8583	0.8764	0.8765
P2-4	0.4370	0.4364	0.5113	0.4366	0.4366
P3-4	0.8210	0.8213	0.7670	0.8214	0.8216
P2-5	0.8240	0.8236	0.8701	0.8236	0.8237
P2-6	0.6040	0.6042	0.6764	0.6038	0.6039
P4-6	0.7210	0.7211	0.7143	0.7211	0.7213
P5-7	-0.1480	-0.1479	-0.1173	-0.1478	-0.1479
P6-7	0.3810	0.3813	0.3855	0.3812	0.3812
P6-8	0.2960	0.2953	0.3107	0.2955	0.2954
P6-9	0.2770	0.2772	0.3016	0.2772	0.2773
P6-10	0.1580	0.1585	0.1691	0.1584	0.1584
P9-11	0.0000	0.0001	0.0095	0.0001	0.0001
P9-10	0.2770	0.2774	0.2852	0.2773	0.2773
P4-12	0.4420	0.4421	0.4635	0.4420	0.4421
P12-13	0.0000	-0.0002	0.0049	0.0000	0.0001
P12-14	0.0790	0.0789	0.0811	0.0786	0.0786
P12-15	0.1790	0.1788	0.1841	0.1789	0.1789
P12-16	0.0720	0.0727	0.0759	0.0725	0.0725
P14-15	0.0160	0.0159	0.0161	0.0158	0.0158
P16-17	0.0370	0.0372	0.0372	0.0368	0.0369
P15-18	0.0600		0.0636	0.0602	0.0602
P18-19	0.0280		0.0290	0.0278	0.0278
P19-20	-0.0670		-0.0689	-0.0673	-0.0673
P10-20	0.0900		0.0950	0.0904	0.0904
P10-17	0.0530		0.0567	0.0535	0.0535
P10-21	0.1580		0.1623	0.1578	0.1578
P10-22	0.0760		0.0785	0.0762	0.0762
P21-22	-0.0180		-0.0175	-0.0182	-0.0182
P15-23	0.0500		0.0514	0.0503	0.0503
P22-24	0.0570		0.0567	0.0574	0.0574
P23-24	0.0180		0.0175	0.0181	0.0181
P24-25	-0.0120		-0.0157	-0.0120	-0.0120
P25-26	0.0350		0.0368	0.0354	0.0354
P25-27	-0.0480		-0.0541	-0.0475	-0.0475
P28-27	0.1810		0.1895	0.1807	0.1807
P27-29	0.0620		0.0628	0.0620	0.0620
P27-30	0.0710		0.0715	0.0709	0.0709

P29-30	0.0370		0.0371	0.0370	0.0370
P8-28	-0.0050		-0.0057	-0.0054	-0.0054
P6-28	0.1870		0.1967	0.1867	0.1868
P2-1	-1.6810	-1.6810	-1.3757	-1.6805	-1.6810
P3-1	-0.8450	-0.8453	-0.8285	-0.8453	-0.8454
P4-2	-0.4260	-0.4263	-0.4975	-0.4264	-0.4264
P4-3	-0.8130	-0.8131	-0.7595	-0.8129	-0.8131
P5-2	-0.7940	-0.7943	-0.8374	-0.7941	-0.7943
P6-2	-0.5840	-0.5844	-0.6521	-0.5844	-0.5844
P6-4	-0.7150	-0.7151	-0.7082	-0.7148	-0.7150
P7-5	0.1500	0.1496	0.1184	0.1495	0.1496
P7-6	-0.3780	-0.3775	-0.3816	-0.3774	-0.3774
P8-6	-0.2950	-0.2946	-0.3095	-0.2944	-0.2943
P9-6	-0.2770	-0.2774	-0.3016	-0.2772	-0.2773
P10-6	-0.1580	-0.1582	-0.1691	-0.1584	-0.1584
P11-9	0.0000	0.0001	-0.0095	-0.0001	-0.0001
P10-9	-0.2770	-0.2771	-0.2852	-0.2773	-0.2773
P12-4	-0.4420	-0.4419	-0.4635	-0.4420	-0.4421
P13-12	0.0000	-0.0001	-0.0049	0.0000	-0.0001
P14-12	-0.0780	-0.0778	-0.0803	-0.0778	-0.0779
P15-12	-0.1770	-0.1764	-0.1818	-0.1767	-0.1767
P16-12	-0.0720	-0.0718	-0.0753	-0.0720	-0.0720
P15-14	-0.0160	-0.0159	-0.0161	-0.0157	-0.0157
P17-16	-0.0370	-0.0367	-0.0371	-0.0368	-0.0368
P18-15	-0.0600		-0.0631	-0.0598	-0.0598
P19-18	-0.0280		-0.0290	-0.0278	-0.0278
P20-19	0.0670		0.0690	0.0675	0.0675
P20-10	-0.0890		-0.0942	-0.0895	-0.0895
P17-10	-0.0530		-0.0565	-0.0534	-0.0533
P21-10	-0.1570		-0.1611	-0.1567	-0.1567
P22-10	-0.0760		-0.0779	-0.0756	-0.0756
P22-21	0.0180		0.0175	0.0182	0.0182
P23-15	-0.0500		-0.0511	-0.0499	-0.0500
P24-22	-0.0570		-0.0562	-0.0569	-0.0569
P24-23	-0.0180		-0.0174	-0.0180	-0.0180
P25-24	0.0120		0.0158	0.0121	0.0121
P26-25	-0.0350		-0.0364	-0.0349	-0.0350
P27-25	0.0480		0.0544	0.0478	0.0478

P27-28	-0.1810		-0.1895	-0.1807	-0.1807
P29-27	-0.0610		-0.0619	-0.0611	-0.0611
P30-27	-0.0690		-0.0699	-0.0693	-0.0693
P30-29	-0.0370		-0.0367	-0.0366	-0.0366
P28-8	0.0050		0.0057	0.0055	0.0054
P28-6	-0.1860		-0.1960	-0.1861	-0.1862
Q1-2	-0.2470	-0.2473	-0.2042	-0.2468	-0.2471
Q1-3	0.0430	0.0429	0.0433	0.0428	0.0429
Q2-4	0.0470	0.0473	0.0393	0.0474	0.0475
Q3-4	-0.0390	-0.0386	-0.0190	-0.0386	-0.0386
Q2-5	0.0280	0.0277	0.0397	0.0277	0.0277
Q2-6	0.0140	0.0139	0.0096	0.0136	0.0137
Q4-6	-0.1590	-0.1592	-0.1509	-0.1592	-0.1593
Q5-7	0.1150	0.1151	0.0980	0.1148	0.1150
Q6-7	-0.0280	-0.0281	-0.0221	-0.0280	-0.0280
Q6-8	-0.0720	-0.0719	-0.0783	-0.0719	-0.0719
Q6-9	-0.0810	-0.0807	-0.0805	-0.0810	-0.0810
Q6-10	0.0020	0.0015	0.0025	0.0018	0.0018
Q9-11	-0.1560	-0.1560	-0.1585	-0.1560	-0.1560
Q9-10	0.0590	0.0590	0.0594	0.0588	0.0587
Q4-12	0.1440	0.1442	0.1450	0.1440	0.1441
Q12-13	-0.1030	-0.1031	-0.1043	-0.1031	-0.1031
Q12-14	0.0240	0.0242	0.0234	0.0240	0.0239
Q12-15	0.0680	0.0676	0.0673	0.0678	0.0677
Q12-16	0.0330	0.0336	0.0338	0.0335	0.0336
Q14-15	0.0060	0.0070	0.0067	0.0064	0.0065
Q16-17	0.0140	0.0148	0.0150	0.0143	0.0142
Q15-18	0.0160		0.0167	0.0161	0.0160
Q18-19	0.0060		0.0068	0.0062	0.0062
Q19-20	-0.0280		-0.0276	-0.0280	-0.0280
Q10-20	0.0370		0.0372	0.0372	0.0372
Q10-17	0.0440		0.0437	0.0443	0.0442
Q10-21	0.1000		0.0997	0.1002	0.1002
Q10-22	0.0460		0.0456	0.0460	0.0460
Q21-22	-0.0140		-0.0153	-0.0142	-0.0143
Q15-23	0.0290		0.0285	0.0291	0.0290
Q22-24	0.0310		0.0287	0.0308	0.0307
Q23-24	0.0120		0.0123	0.0126	0.0126

Q24-25	0.0200		0.0184	0.0204	0.0204
Q25-26	0.0240		0.0227	0.0240	0.0239
Q25-27	-0.0040		-0.0035	-0.0039	-0.0039
Q28-27	0.0500		0.0455	0.0506	0.0505
Q27-29	0.0170		0.0146	0.0167	0.0167
Q27-30	0.0170		0.0150	0.0167	0.0167
Q29-30	0.0060		0.0058	0.0061	0.0061
Q8-28	-0.0050		-0.0063	-0.0055	-0.0055
Q6-28	0.0010		-0.0062	0.0011	0.0011
Q2-1	0.3450	0.3447	0.2489	0.3444	0.3447
Q3-1	0.0270	0.0262	0.0215	0.0265	0.0265
Q4-2	-0.0550	-0.0549	-0.0363	-0.0553	-0.0554
Q4-3	0.0540	0.0547	0.0317	0.0545	0.0545
Q5-2	0.0520	0.0521	0.0538	0.0518	0.0518
Q6-2	0.0060	0.0062	0.0245	0.0059	0.0058
Q6-4	0.1720	0.1721	0.1631	0.1720	0.1721
Q7-5	-0.1310	-0.1312	-0.1157	-0.1312	-0.1314
Q7-6	0.0220	0.0224	0.0169	0.0225	0.0224
Q8-6	0.0670	0.0665	0.0733	0.0665	0.0665
Q9-6	0.0970	0.0974	0.0995	0.0973	0.0972
Q10-6	0.0110	0.0109	0.0122	0.0110	0.0110
Q11-9	0.1610	0.1608	0.1632	0.1606	0.1606
Q10-9	-0.0510	-0.0507	-0.0509	-0.0508	-0.0507
Q12-4	-0.0970	-0.0971	-0.0939	-0.0971	-0.0972
Q13-12	0.1050	0.1047	0.1057	0.1044	0.1044
Q14-12	-0.0220	-0.0222	-0.0218	-0.0224	-0.0223
Q15-12	-0.0640	-0.0634	-0.0629	-0.0635	-0.0634
Q16-12	-0.0320	-0.0324	-0.0326	-0.0324	-0.0324
Q15-14	-0.0060	-0.0062	-0.0066	-0.0064	-0.0064
Q17-16	-0.0140	-0.0138	-0.0147	-0.0140	-0.0139
Q18-15	-0.0150		-0.0158	-0.0153	-0.0153
Q19-18	-0.0060		-0.0067	-0.0061	-0.0061
Q20-19	0.0280		0.0279	0.0283	0.0283
Q20-10	-0.0350		-0.0352	-0.0354	-0.0353
Q17-10	-0.0440		-0.0433	-0.0439	-0.0439
Q21-10	-0.0980		-0.0972	-0.0978	-0.0978
Q22-10	-0.0450		-0.0444	-0.0450	-0.0449
Q22-21	0.0140		0.0153	0.0143	0.0143

Q23-15	-0.0280		-0.0278	-0.0284	-0.0284
Q24-22	-0.0300		-0.0280	-0.0300	-0.0300
Q24-23	-0.0120		-0.0122	-0.0125	-0.0125
Q25-24	-0.0200		-0.0182	-0.0202	-0.0202
Q26-25	-0.0230		-0.0220	-0.0233	-0.0233
Q27-25	0.0040		0.0041	0.0043	0.0043
Q27-28	-0.0370		-0.0316	-0.0377	-0.0377
Q29-27	-0.0150		-0.0129	-0.0151	-0.0151
Q30-27	-0.0140		-0.0119	-0.0136	-0.0136
Q30-29	-0.0050		-0.0052	-0.0054	-0.0054
Q28-8	-0.0380		-0.0372	-0.0380	-0.0380
Q28-6	-0.0120		-0.0047	-0.0123	-0.0123

Table B-43: 30 Bus Estimated values for Partial Redundancy (optimal PMU incorporation using heuristic approach)

				WLS		IRLS		WLAVIRLS	
	Actual	Meas SCADA	Meas SCADA + PMU	SCADA	SCADA + PMU	SCADA	SCADA + PMU	SCADA	SCADA + PMU
V1	1.0600	1.0562	1.0562	1.0613	1.0599	1.0602	1.0596	1.0596	1.0598
V2	1.0450	1.0539	1.0539	1.0470	1.0450	1.0450	1.0450	1.0450	1.0450
V3	1.0210	1.0207	1.0207	1.0215	1.0212	1.0212	1.0212	1.0212	1.0212
V4	1.0120	1.0135	1.0135	1.0126	1.0123	1.0123	1.0123	1.0123	1.0123
V5	1.0100	1.0178	1.0178	1.0090	1.0100	1.0100	1.0100	1.0100	1.0100
V6	1.0110	1.0003	1.0003	1.0106	1.0106	1.0106	1.0106	1.0106	1.0106
V7	1.0030	1.0054	1.0054	1.0020	1.0026	1.0026	1.0026	1.0026	1.0026
V8	1.0100	1.0116	1.0116	1.0101	1.0100	1.0100	1.0100	1.0100	1.0100
V9	1.0510	1.0546	1.0546	1.0513	1.0512	1.0512	1.0511	1.0511	1.0511
V10	1.0450	1.0316	1.0316	1.0455	1.0454	1.0454	1.0454	1.0454	1.0454
V11	1.0820	1.0880	1.0880	1.0827	1.0820	1.0820	1.0820	1.0820	1.0820
V12	1.0570	1.0628	1.0628	1.0579	1.0573	1.0574	1.0574	1.0573	1.0574

V13	1.0710			1.0717	1.0710	1.0710	1.0710	1.0710	1.0710
V14	1.0430			1.0429	1.0425	1.0425	1.0426	1.0425	1.0426
V15	1.0380			1.0382	1.0379	1.0380	1.0380	1.0379	1.0380
V16	1.0450			1.0448	1.0446	1.0446	1.0446	1.0446	1.0446
V17	1.0400			1.0402	1.0401	1.0402	1.0402	1.0402	1.0402
V18	1.0280			1.0282	1.0284	1.0284	1.0284	1.0284	1.0284
V19	1.0260			1.0256	1.0259	1.0259	1.0259	1.0259	1.0259
V20	1.0300			1.0297	1.0300	1.0300	1.0300	1.0300	1.0300
V21	1.0330			1.0330	1.0330	1.0330	1.0330	1.0330	1.0330
V22	1.0340			1.0336	1.0335	1.0335	1.0335	1.0335	1.0335
V23	1.0270			1.0278	1.0274	1.0275	1.0274	1.0275	1.0274
V24	1.0220			1.0223	1.0219	1.0219	1.0218	1.0218	1.0218
V25	1.0180			1.0193	1.0176	1.0175	1.0175	1.0175	1.0176
V26	1.0000			1.0017	0.9999	0.9998	0.9999	0.9998	0.9999
V27	1.0240			1.0259	1.0235	1.0235	1.0235	1.0235	1.0235
V28	1.0070			1.0074	1.0071	1.0071	1.0071	1.0071	1.0071
V29	1.0040			1.0068	1.0037	1.0036	1.0036	1.0036	1.0036
V30	0.9920			0.9954	0.9922	0.9921	0.9921	0.9921	0.9922
P1	2.6100	2.6096	2.6096	2.2685	2.6095	2.6090	2.6096	2.6097	2.6096
P2	0.4000	0.4001	0.4001	0.8992	0.4001	0.4005	0.4000	0.4001	0.4000
P5	0.0000	0.0002	0.0002	-0.0127	0.0001	0.0001	-0.0001	-0.0001	-0.0001
P8	0.0000	0.0001	0.0001	-0.0151	0.0001	0.0001	0.0001	0.0003	0.0001
P11	0.0000			-0.0095	0.0000	-0.0001	-0.0001	-0.0001	-0.0001

P13	0.0000			-0.0049	-0.0001	0.0000	0.0001	-0.0001	0.0000
P3	0.0240	0.0239	0.0239	0.0615	0.0239	0.0239	0.0239	0.0238	0.0238
P4	0.0760	0.0761	0.0761	0.0792	0.0761	0.0761	0.0761	0.0761	0.0761
P6	0.0000	0.0003	0.0003	-0.0033	-0.0001	0.0001	0.0002	0.0003	0.0002
P7	0.2280	0.2278	0.2278	0.2632	0.2283	0.2279	0.2279	0.2278	0.2279
P9	0.0000	-0.0002	-0.0002	0.0068	0.0002	-0.0002	-0.0002	-0.0001	-0.0002
P10	0.0580	0.0579	0.0579	0.0618	0.0578	0.0579	0.0579	0.0579	0.0579
P12	0.1120	0.1121	0.1121	0.1176	0.1118	0.1121	0.1121	0.1120	0.1121
P14	0.0620	0.0620	0.0620	0.0642	0.0620	0.0620	0.0619	0.0620	0.0619
P15	0.0820	0.0819	0.0819	0.0830	0.0821	0.0819	0.0819	0.0819	0.0819
P16	0.0350	0.0351	0.0351	0.0381	0.0349	0.0351	0.0349	0.0351	0.0349
P17	0.0900	0.0901	0.0901	0.0937	0.0902	0.0901	0.0901	0.0901	0.0900
P18	0.0320			0.0341	0.0319	0.0320	0.0320	0.0320	0.0321
P19	0.0950			0.0978	0.0953	0.0951	0.0951	0.0951	0.0951
P20	0.0220			0.0251	0.0218	0.0221	0.0219	0.0221	0.0219
P21	0.1750			0.1786	0.1760	0.1749	0.1751	0.1749	0.1751
P22	0.0000			0.0038	-0.0009	0.0001	0.0001	0.0001	0.0001
P23	0.0320			0.0335	0.0320	0.0319	0.0321	0.0319	0.0320
P24	0.0870			0.0894	0.0869	0.0869	0.0869	0.0869	0.0869
P25	0.0000			0.0014	0.0001	0.0000	0.0001	0.0000	0.0001
P26	0.0350			0.0364	0.0350	0.0349	0.0350	0.0350	0.0350
P27	0.0000			0.0008	0.0000	0.0000	-0.0001	0.0000	-0.0001
P28	0.0000			0.0009	0.0000	0.0000	0.0001	0.0001	0.0001

P29	0.0240			0.0249	0.0240	0.0241	0.0240	0.0242	0.0240
P30	0.1060			0.1066	0.1060	0.1060	0.1061	0.1060	0.1060
Q1	-0.2040	-0.2042	-0.2042	-0.1609	-0.2040	-0.2040	-0.2042	-0.2042	-0.2042
Q2	0.5610	0.5607	0.5607	0.4645	0.5602	0.5601	0.5607	0.5607	0.5607
Q5	0.3570	0.3565	0.3565	0.3418	0.3567	0.3566	0.3565	0.3569	0.3565
Q8	0.3610	0.3610	0.3610	0.3670	0.3611	0.3610	0.3610	0.3610	0.3610
Q11	0.1610			0.1632	0.1605	0.1606	0.1606	0.1606	0.1606
Q13	0.1050			0.1057	0.1044	0.1044	0.1042	0.1044	0.1043
Q3	0.0120	0.0120	0.0120	-0.0024	0.0119	0.0121	0.0121	0.0121	0.0121
Q4	0.0160	0.0161	0.0161	0.0105	0.0157	0.0161	0.0160	0.0161	0.0161
Q6	0.0000	0.0001	0.0001	-0.0030	0.0000	0.0001	0.0001	0.0001	0.0001
Q7	0.1090	0.1090	0.1090	0.0989	0.1090	0.1088	0.1088	0.1090	0.1088
Q9	0.0000	0.0000	0.0000	-0.0004	-0.0005	0.0000	0.0000	0.0000	0.0000
Q10	0.0200	0.0197	0.0197	0.0204	0.0207	0.0197	0.0200	0.0198	0.0200
Q12	0.0750	0.0748	0.0748	0.0736	0.0747	0.0749	0.0749	0.0751	0.0749
Q14	0.0160	0.0158	0.0158	0.0152	0.0160	0.0160	0.0158	0.0158	0.0159
Q15	0.0250	0.0247	0.0247	0.0243	0.0250	0.0248	0.0247	0.0248	0.0247
Q16	0.0180	0.0180	0.0180	0.0176	0.0183	0.0182	0.0181	0.0182	0.0181
Q17	0.0580	0.0578	0.0578	0.0580	0.0578	0.0579	0.0579	0.0578	0.0579
Q18	0.0090			0.0090	0.0092	0.0090	0.0090	0.0090	0.0091
Q19	0.0340			0.0343	0.0337	0.0341	0.0340	0.0341	0.0340
Q20	0.0070			0.0073	0.0071	0.0070	0.0069	0.0070	0.0069
Q21	0.1120			0.1125	0.1117	0.1120	0.1120	0.1120	0.1120

Q22	0.0000			0.0004	0.0000	0.0000	0.0000	-0.0001	0.0000
Q23	0.0160			0.0155	0.0160	0.0158	0.0160	0.0158	0.0160
Q24	0.0670			0.0668	0.0670	0.0670	0.0670	0.0670	0.0670
Q25	0.0000			-0.0011	0.0001	0.0002	0.0001	0.0001	0.0001
Q26	0.0230			0.0220	0.0230	0.0233	0.0230	0.0233	0.0230
Q27	0.0000			-0.0020	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
Q28	0.0000			-0.0036	0.0001	-0.0002	-0.0002	-0.0002	-0.0002
Q29	0.0090			0.0071	0.0090	0.0090	0.0091	0.0090	0.0092
Q30	0.0190			0.0171	0.0190	0.0191	0.0191	0.0191	0.0189
P1-2	1.7330	1.7333	1.7333	1.4102	1.7330	1.7326	1.7331	1.7331	1.7331
P1-3	0.8760	0.8767	0.8767	0.8583	0.8765	0.8764	0.8765	0.8765	0.8765
P2-4	0.4370	0.4364	0.4364	0.5113	0.4365	0.4366	0.4365	0.4366	0.4365
P3-4	0.8210	0.8213	0.8213	0.7670	0.8215	0.8214	0.8216	0.8216	0.8216
P2-5	0.8240	0.8236	0.8236	0.8701	0.8236	0.8236	0.8236	0.8237	0.8236
P2-6	0.6040	0.6042	0.6042	0.6764	0.6038	0.6038	0.6038	0.6039	0.6038
P4-6	0.7210	0.7211	0.7211	0.7143	0.7213	0.7211	0.7214	0.7213	0.7214
P5-7	-0.1480	-0.1479	-0.1479	-0.1173	-0.1477	-0.1478	-0.1479	-0.1479	-0.1479
P6-7	0.3810	0.3813	0.3813	0.3855	0.3815	0.3812	0.3813	0.3812	0.3813
P6-8	0.2960	0.2953	0.2953	0.3107	0.2956	0.2955	0.2956	0.2954	0.2956
P6-9	0.2770	0.2772	0.2772	0.3016	0.2773	0.2772	0.2772	0.2773	0.2772
P6-10	0.1580	0.1585	0.1585	0.1691	0.1584	0.1584	0.1584	0.1584	0.1584
P9-11	0.0000	0.0001	0.0001	0.0095	0.0000	0.0001	0.0001	0.0001	0.0001
P9-10	0.2770	0.2774	0.2774	0.2852	0.2771	0.2773	0.2773	0.2773	0.2773

P4-12	0.4420	0.4421	0.4421	0.4635	0.4419	0.4420	0.4419	0.4421	0.4419
P12-13	0.0000	-0.0002	-0.0002	0.0049	0.0001	0.0000	-0.0001	0.0001	0.0000
P12-14	0.0790	0.0789	0.0789	0.0811	0.0786	0.0786	0.0785	0.0786	0.0785
P12-15	0.1790	0.1788	0.1788	0.1841	0.1790	0.1789	0.1789	0.1789	0.1789
P12-16	0.0720	0.0727	0.0727	0.0759	0.0725	0.0725	0.0724	0.0725	0.0724
P14-15	0.0160	0.0159	0.0159	0.0161	0.0159	0.0158	0.0159	0.0158	0.0159
P16-17	0.0370	0.0372	0.0372	0.0372	0.0370	0.0368	0.0370	0.0369	0.0370
P15-18	0.0600			0.0636	0.0602	0.0602	0.0602	0.0602	0.0602
P18-19	0.0280			0.0290	0.0279	0.0278	0.0278	0.0278	0.0278
P19-20	-0.0670			-0.0689	-0.0674	-0.0673	-0.0674	-0.0673	-0.0674
P10-20	0.0900			0.0950	0.0903	0.0904	0.0902	0.0904	0.0903
P10-17	0.0530			0.0567	0.0534	0.0535	0.0533	0.0535	0.0533
P10-21	0.1580			0.1623	0.1580	0.1578	0.1580	0.1578	0.1580
P10-22	0.0760			0.0785	0.0761	0.0762	0.0762	0.0762	0.0763
P21-22	-0.0180			-0.0175	-0.0191	-0.0182	-0.0182	-0.0182	-0.0182
P15-23	0.0500			0.0514	0.0504	0.0503	0.0504	0.0503	0.0504
P22-24	0.0570			0.0567	0.0574	0.0574	0.0574	0.0574	0.0574
P23-24	0.0180			0.0175	0.0180	0.0181	0.0181	0.0181	0.0181
P24-25	-0.0120			-0.0157	-0.0120	-0.0120	-0.0120	-0.0120	-0.0120
P25-26	0.0350			0.0368	0.0354	0.0354	0.0355	0.0354	0.0355
P25-27	-0.0480			-0.0541	-0.0477	-0.0475	-0.0477	-0.0475	-0.0477
P28-27	0.1810			0.1895	0.1807	0.1807	0.1807	0.1807	0.1807
P27-29	0.0620			0.0628	0.0619	0.0620	0.0619	0.0620	0.0619

P27-30	0.0710			0.0715	0.0709	0.0709	0.0710	0.0709	0.0709
P29-30	0.0370			0.0371	0.0371	0.0370	0.0371	0.0370	0.0370
P8-28	-0.0050			-0.0057	-0.0054	-0.0054	-0.0054	-0.0054	-0.0054
P6-28	0.1870			0.1967	0.1867	0.1867	0.1868	0.1868	0.1868
P2-1	-1.6810	-1.6810	-1.6810	-1.3757	-1.6809	-1.6805	-1.6810	-1.6810	-1.6810
P3-1	-0.8450	-0.8453	-0.8453	-0.8285	-0.8454	-0.8453	-0.8454	-0.8454	-0.8454
P4-2	-0.4260	-0.4263	-0.4263	-0.4975	-0.4263	-0.4264	-0.4264	-0.4264	-0.4263
P4-3	-0.8130	-0.8131	-0.8131	-0.7595	-0.8130	-0.8129	-0.8130	-0.8131	-0.8130
P5-2	-0.7940	-0.7943	-0.7943	-0.8374	-0.7942	-0.7941	-0.7942	-0.7943	-0.7942
P6-2	-0.5840	-0.5844	-0.5844	-0.6521	-0.5843	-0.5844	-0.5844	-0.5844	-0.5844
P6-4	-0.7150	-0.7151	-0.7151	-0.7082	-0.7150	-0.7148	-0.7150	-0.7150	-0.7150
P7-5	0.1500	0.1496	0.1496	0.1184	0.1494	0.1495	0.1496	0.1496	0.1496
P7-6	-0.3780	-0.3775	-0.3775	-0.3816	-0.3777	-0.3774	-0.3775	-0.3774	-0.3775
P8-6	-0.2950	-0.2946	-0.2946	-0.3095	-0.2945	-0.2944	-0.2945	-0.2943	-0.2945
P9-6	-0.2770	-0.2774	-0.2774	-0.3016	-0.2773	-0.2772	-0.2772	-0.2773	-0.2772
P10-6	-0.1580	-0.1582	-0.1582	-0.1691	-0.1584	-0.1584	-0.1584	-0.1584	-0.1584
P11-9	0.0000	0.0001	0.0001	-0.0095	0.0000	-0.0001	-0.0001	-0.0001	-0.0001
P10-9	-0.2770	-0.2771	-0.2771	-0.2852	-0.2771	-0.2773	-0.2773	-0.2773	-0.2773
P12-4	-0.4420	-0.4419	-0.4419	-0.4635	-0.4419	-0.4420	-0.4419	-0.4421	-0.4419
P13-12	0.0000	-0.0001	-0.0001	-0.0049	-0.0001	0.0000	0.0001	-0.0001	0.0000
P14-12	-0.0780	-0.0778	-0.0778	-0.0803	-0.0778	-0.0778	-0.0778	-0.0779	-0.0778
P15-12	-0.1770	-0.1764	-0.1764	-0.1818	-0.1768	-0.1767	-0.1768	-0.1767	-0.1768
P16-12	-0.0720	-0.0718	-0.0718	-0.0753	-0.0719	-0.0720	-0.0719	-0.0720	-0.0719

P15-14	-0.0160	-0.0159	-0.0159	-0.0161	-0.0158	-0.0157	-0.0158	-0.0157	-0.0158
P17-16	-0.0370	-0.0367	-0.0367	-0.0371	-0.0369	-0.0368	-0.0369	-0.0368	-0.0369
P18-15	-0.0600			-0.0631	-0.0598	-0.0598	-0.0599	-0.0598	-0.0599
P19-18	-0.0280			-0.0290	-0.0279	-0.0278	-0.0278	-0.0278	-0.0277
P20-19	0.0670			0.0690	0.0676	0.0675	0.0675	0.0675	0.0676
P20-10	-0.0890			-0.0942	-0.0894	-0.0895	-0.0894	-0.0895	-0.0894
P17-10	-0.0530			-0.0565	-0.0532	-0.0534	-0.0532	-0.0533	-0.0531
P21-10	-0.1570			-0.1611	-0.1569	-0.1567	-0.1569	-0.1567	-0.1569
P22-10	-0.0760			-0.0779	-0.0756	-0.0756	-0.0757	-0.0756	-0.0757
P22-21	0.0180			0.0175	0.0191	0.0182	0.0182	0.0182	0.0183
P23-15	-0.0500			-0.0511	-0.0500	-0.0499	-0.0501	-0.0500	-0.0501
P24-22	-0.0570			-0.0562	-0.0569	-0.0569	-0.0569	-0.0569	-0.0569
P24-23	-0.0180			-0.0174	-0.0179	-0.0180	-0.0180	-0.0180	-0.0180
P25-24	0.0120			0.0158	0.0121	0.0121	0.0121	0.0121	0.0121
P26-25	-0.0350			-0.0364	-0.0350	-0.0349	-0.0350	-0.0350	-0.0350
P27-25	0.0480			0.0544	0.0479	0.0478	0.0479	0.0478	0.0479
P27-28	-0.1810			-0.1895	-0.1807	-0.1807	-0.1807	-0.1807	-0.1807
P29-27	-0.0610			-0.0619	-0.0610	-0.0611	-0.0611	-0.0611	-0.0611
P30-27	-0.0690			-0.0699	-0.0693	-0.0693	-0.0693	-0.0693	-0.0693
P30-29	-0.0370			-0.0367	-0.0367	-0.0366	-0.0367	-0.0366	-0.0367
P28-8	0.0050			0.0057	0.0055	0.0055	0.0054	0.0054	0.0054
P28-6	-0.1860			-0.1960	-0.1861	-0.1861	-0.1862	-0.1862	-0.1862
Q1-2	-0.2470	-0.2473	-0.2473	-0.2042	-0.2468	-0.2468	-0.2470	-0.2471	-0.2471

Q1-3	0.0430	0.0429	0.0429	0.0433	0.0428	0.0428	0.0428	0.0429	0.0428
Q2-4	0.0470	0.0473	0.0473	0.0393	0.0474	0.0474	0.0475	0.0475	0.0475
Q3-4	-0.0390	-0.0386	-0.0386	-0.0190	-0.0385	-0.0386	-0.0386	-0.0386	-0.0386
Q2-5	0.0280	0.0277	0.0277	0.0397	0.0277	0.0277	0.0278	0.0277	0.0278
Q2-6	0.0140	0.0139	0.0139	0.0096	0.0136	0.0136	0.0137	0.0137	0.0137
Q4-6	-0.1590	-0.1592	-0.1592	-0.1509	-0.1589	-0.1592	-0.1592	-0.1593	-0.1592
Q5-7	0.1150	0.1151	0.1151	0.0980	0.1149	0.1148	0.1148	0.1150	0.1148
Q6-7	-0.0280	-0.0281	-0.0281	-0.0221	-0.0278	-0.0280	-0.0279	-0.0280	-0.0279
Q6-8	-0.0720	-0.0719	-0.0719	-0.0783	-0.0719	-0.0719	-0.0719	-0.0719	-0.0719
Q6-9	-0.0810	-0.0807	-0.0807	-0.0805	-0.0810	-0.0810	-0.0809	-0.0810	-0.0810
Q6-10	0.0020	0.0015	0.0015	0.0025	0.0019	0.0018	0.0019	0.0018	0.0018
Q9-11	-0.1560	-0.1560	-0.1560	-0.1585	-0.1559	-0.1560	-0.1560	-0.1560	-0.1560
Q9-10	0.0590	0.0590	0.0590	0.0594	0.0591	0.0588	0.0588	0.0587	0.0588
Q4-12	0.1440	0.1442	0.1442	0.1450	0.1441	0.1440	0.1440	0.1441	0.1440
Q12-13	-0.1030	-0.1031	-0.1031	-0.1043	-0.1031	-0.1031	-0.1029	-0.1031	-0.1029
Q12-14	0.0240	0.0242	0.0242	0.0234	0.0240	0.0240	0.0239	0.0239	0.0239
Q12-15	0.0680	0.0676	0.0676	0.0673	0.0679	0.0678	0.0678	0.0677	0.0677
Q12-16	0.0330	0.0336	0.0336	0.0338	0.0336	0.0335	0.0335	0.0336	0.0335
Q14-15	0.0060	0.0070	0.0070	0.0067	0.0065	0.0064	0.0065	0.0065	0.0065
Q16-17	0.0140	0.0148	0.0148	0.0150	0.0142	0.0143	0.0143	0.0142	0.0143
Q15-18	0.0160			0.0167	0.0160	0.0161	0.0160	0.0160	0.0160
Q18-19	0.0060			0.0068	0.0060	0.0062	0.0062	0.0062	0.0062
Q19-20	-0.0280			-0.0276	-0.0278	-0.0280	-0.0279	-0.0280	-0.0279

Q10-20	0.0370			0.0372	0.0371	0.0372	0.0370	0.0372	0.0370
Q10-17	0.0440			0.0437	0.0442	0.0443	0.0442	0.0442	0.0443
Q10-21	0.1000			0.0997	0.0999	0.1002	0.1001	0.1002	0.1001
Q10-22	0.0460			0.0456	0.0459	0.0460	0.0460	0.0460	0.0460
Q21-22	-0.0140			-0.0153	-0.0142	-0.0142	-0.0143	-0.0143	-0.0143
Q15-23	0.0290			0.0285	0.0291	0.0291	0.0292	0.0290	0.0292
Q22-24	0.0310			0.0287	0.0306	0.0308	0.0307	0.0307	0.0307
Q23-24	0.0120			0.0123	0.0125	0.0126	0.0125	0.0126	0.0125
Q24-25	0.0200			0.0184	0.0201	0.0204	0.0203	0.0204	0.0202
Q25-26	0.0240			0.0227	0.0237	0.0240	0.0237	0.0239	0.0237
Q25-27	-0.0040			-0.0035	-0.0038	-0.0039	-0.0038	-0.0039	-0.0038
Q28-27	0.0500			0.0455	0.0503	0.0506	0.0505	0.0505	0.0504
Q27-29	0.0170			0.0146	0.0167	0.0167	0.0168	0.0167	0.0168
Q27-30	0.0170			0.0150	0.0166	0.0167	0.0167	0.0167	0.0166
Q29-30	0.0060			0.0058	0.0060	0.0061	0.0061	0.0061	0.0060
Q8-28	-0.0050			-0.0063	-0.0054	-0.0055	-0.0055	-0.0055	-0.0055
Q6-28	0.0010			-0.0062	0.0012	0.0011	0.0011	0.0011	0.0011
Q2-1	0.3450	0.3447	0.3447	0.2489	0.3444	0.3444	0.3447	0.3447	0.3447
Q3-1	0.0270	0.0262	0.0262	0.0215	0.0266	0.0265	0.0265	0.0265	0.0265
Q4-2	-0.0550	-0.0549	-0.0549	-0.0363	-0.0553	-0.0553	-0.0554	-0.0554	-0.0554
Q4-3	0.0540	0.0547	0.0547	0.0317	0.0544	0.0545	0.0545	0.0545	0.0545
Q5-2	0.0520	0.0521	0.0521	0.0538	0.0518	0.0518	0.0517	0.0518	0.0517
Q6-2	0.0060	0.0062	0.0062	0.0245	0.0059	0.0059	0.0058	0.0058	0.0058

Q6-4	0.1720	0.1721	0.1721	0.1631	0.1717	0.1720	0.1719	0.1721	0.1720
Q7-5	-0.1310	-0.1312	-0.1312	-0.1157	-0.1313	-0.1312	-0.1312	-0.1314	-0.1312
Q7-6	0.0220	0.0224	0.0224	0.0169	0.0223	0.0225	0.0224	0.0224	0.0224
Q8-6	0.0670	0.0665	0.0665	0.0733	0.0665	0.0665	0.0665	0.0665	0.0665
Q9-6	0.0970	0.0974	0.0974	0.0995	0.0973	0.0973	0.0972	0.0972	0.0972
Q10-6	0.0110	0.0109	0.0109	0.0122	0.0109	0.0110	0.0110	0.0110	0.0110
Q11-9	0.1610	0.1608	0.1608	0.1632	0.1605	0.1606	0.1606	0.1606	0.1606
Q10-9	-0.0510	-0.0507	-0.0507	-0.0509	-0.0511	-0.0508	-0.0508	-0.0507	-0.0508
Q12-4	-0.0970	-0.0971	-0.0971	-0.0939	-0.0972	-0.0971	-0.0971	-0.0972	-0.0971
Q13-12	0.1050	0.1047	0.1047	0.1057	0.1044	0.1044	0.1042	0.1044	0.1043
Q14-12	-0.0220	-0.0222	-0.0222	-0.0218	-0.0225	-0.0224	-0.0223	-0.0223	-0.0223
Q15-12	-0.0640	-0.0634	-0.0634	-0.0629	-0.0636	-0.0635	-0.0635	-0.0634	-0.0635
Q16-12	-0.0320	-0.0324	-0.0324	-0.0326	-0.0325	-0.0324	-0.0324	-0.0324	-0.0324
Q15-14	-0.0060	-0.0062	-0.0062	-0.0066	-0.0064	-0.0064	-0.0064	-0.0064	-0.0064
Q17-16	-0.0140	-0.0138	-0.0138	-0.0147	-0.0140	-0.0140	-0.0141	-0.0139	-0.0140
Q18-15	-0.0150			-0.0158	-0.0152	-0.0153	-0.0152	-0.0153	-0.0152
Q19-18	-0.0060			-0.0067	-0.0059	-0.0061	-0.0061	-0.0061	-0.0061
Q20-19	0.0280			0.0279	0.0281	0.0283	0.0283	0.0283	0.0283
Q20-10	-0.0350			-0.0352	-0.0352	-0.0354	-0.0352	-0.0353	-0.0352
Q17-10	-0.0440			-0.0433	-0.0438	-0.0439	-0.0439	-0.0439	-0.0439
Q21-10	-0.0980			-0.0972	-0.0975	-0.0978	-0.0977	-0.0978	-0.0977
Q22-10	-0.0450			-0.0444	-0.0448	-0.0450	-0.0449	-0.0449	-0.0449
Q22-21	0.0140			0.0153	0.0142	0.0143	0.0143	0.0143	0.0143

Q23-15	-0.0280			-0.0278	-0.0284	-0.0284	-0.0285	-0.0284	-0.0285
Q24-22	-0.0300			-0.0280	-0.0299	-0.0300	-0.0300	-0.0300	-0.0300
Q24-23	-0.0120			-0.0122	-0.0123	-0.0125	-0.0124	-0.0125	-0.0124
Q25-24	-0.0200			-0.0182	-0.0200	-0.0202	-0.0201	-0.0202	-0.0201
Q26-25	-0.0230			-0.0220	-0.0230	-0.0233	-0.0230	-0.0233	-0.0230
Q27-25	0.0040			0.0041	0.0042	0.0043	0.0042	0.0043	0.0042
Q27-28	-0.0370			-0.0316	-0.0375	-0.0377	-0.0376	-0.0377	-0.0376
Q29-27	-0.0150			-0.0129	-0.0151	-0.0151	-0.0152	-0.0151	-0.0152
Q30-27	-0.0140			-0.0119	-0.0136	-0.0136	-0.0136	-0.0136	-0.0136
Q30-29	-0.0050			-0.0052	-0.0054	-0.0054	-0.0054	-0.0054	-0.0054
Q28-8	-0.0380			-0.0372	-0.0380	-0.0380	-0.0380	-0.0380	-0.0380
Q28-6	-0.0120			-0.0047	-0.0124	-0.0123	-0.0123	-0.0123	-0.0123
Va1	0.0000		0.0212	0.0212	0.0001	0.0212	0.0001	0.0212	0.0001
Va2	-5.3858		-5.4137	-4.3424	-5.3778	-5.3555	-5.3782	-5.3573	-5.3783
Va3	-7.5058		-7.4828	-7.3435	-7.5285	-7.5066	-7.5284	-7.5077	-7.5283
Va4	-9.2819		-9.2550	-8.9647	-9.2794	-9.2574	-9.2795	-9.2590	-9.2794
Va5	-14.1521		-14.1758	-13.5812	-14.1488	-14.1256	-14.1490	-14.1288	-14.1489
Va6	-11.0581		-11.0392	-10.7183	-11.0549	-11.0327	-11.0553	-11.0348	-11.0553
Va7	-12.8343		-12.7959	-12.5276	-12.8530	-12.8295	-12.8525	-12.8318	-12.8525
Va8	-11.8029		-11.7405	-11.5003	-11.7971	-11.7747	-11.7975	-11.7766	-11.7975
Va9	-14.0948		-14.0597	-14.0288	-14.0986	-14.0754	-14.0977	-14.0785	-14.0977
Va10	-15.6991		-15.6919	-15.6646	-15.6881	-15.6661	-15.6882	-15.6691	-15.6882
Va11	-14.0948		-14.1335	-14.1285	-14.0987	-14.0765	-14.0987	-14.0801	-14.0987

Va12	-14.9542		-14.9201	-14.8907	-14.9324	-14.9116	-14.9322	-14.9142	-14.9323
Va13	-14.9542			-14.9253	-14.9332	-14.9116	-14.9317	-14.9146	-14.9320
Va14	-15.8136			-15.8181	-15.8242	-15.8032	-15.8242	-15.8069	-15.8242
Va15	-15.9282			-15.9106	-15.9163	-15.8949	-15.9161	-15.8979	-15.9162
Va16	-15.5272			-15.5065	-15.5144	-15.4944	-15.5144	-15.4972	-15.5144
Va17	-15.8709			-15.8424	-15.8504	-15.8286	-15.8499	-15.8317	-15.8497
Va18	-16.5585			-16.5598	-16.5300	-16.5087	-16.5306	-16.5120	-16.5307
Va19	-16.7304			-16.7398	-16.7048	-16.6823	-16.7043	-16.6856	-16.7044
Va20	-16.5012			-16.5366	-16.5074	-16.4857	-16.5074	-16.4890	-16.5074
Va21	-16.1574			-16.1254	-16.1315	-16.1082	-16.1310	-16.1113	-16.1312
Va22	-16.1001			-16.1128	-16.1161	-16.0941	-16.1168	-16.0971	-16.1170
Va23	-16.3293			-16.3150	-16.3067	-16.2842	-16.3067	-16.2876	-16.3067
Va24	-16.5012			-16.4838	-16.4822	-16.4593	-16.4825	-16.4627	-16.4828
Va25	-16.0428			-16.0092	-16.0547	-16.0296	-16.0547	-16.0332	-16.0548
Va26	-16.5012			-16.4699	-16.4739	-16.4439	-16.4739	-16.4480	-16.4739
Va27	-15.5272			-15.4117	-15.5302	-15.5072	-15.5302	-15.5107	-15.5302
Va28	-11.6883			-11.3810	-11.6771	-11.6549	-11.6778	-11.6572	-11.6778
Va29	-16.7877			-16.6813	-16.7590	-16.7380	-16.7590	-16.7419	-16.7590
Va30	-17.6471			-17.5619	-17.6421	-17.6187	-17.6421	-17.6228	-17.6421

Table B-44: 30 Bus-WLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.044	1.042	1.043
V2	1.045	1.0539	1.0539	1.0539	1.045	1.043	1.042

V3	1.021	1.0207	1.0207	1.0207	1.021	1.022	1.013
V4	1.012	1.0135	1.0135	1.0135	1.013	1.013	1.003
V5	1.01	1.0178	1.0178	1.0178	1.014	0.977	1.006
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	0.997
V7	1.003	1.0054	1.0054	1.0054	1.005	0.995	0.994
V8	1.01	1.0116	1.0116	1.0116	1.011	1.011	0.996
V9	1.051	1.0546	1.0546	1.0546	1.052	1.054	1.04
V10	1.045	1.0316	1.0316	1.0316	1.046	1.049	1.032
V11	1.082	1.088	1.088	1.088	1.083	1.086	1.074
V12	1.057	1.0628	1.0628	1.0628	1.058	1.06	1.048
V13	1.071				1.071	1.074	1.062
V14	1.043				1.043	1.046	1.034
V15	1.038				1.038	1.041	1.027
V16	1.045				1.045	1.048	1.035
V17	1.04				1.04	1.044	1.028
V18	1.028				1.029	1.032	1.02
V19	1.026				1.026	1.03	1.017
V20	1.03				1.031	1.034	1.021
V21	1.033				1.033	1.036	1.017
V22	1.034				1.034	1.037	1.016
V23	1.027				1.028	1.031	1.007
V24	1.022				1.023	1.026	0.977
V25	1.018				1.02	1.022	0.859
V26	1				1.002	1.004	0.899
V27	1.024				1.026	1.028	0.728
V28	1.007				1.008	1.009	0.975
V29	1.004	1.003	1.003	***-1.003***	1.006	1.008	0.011
V30	0.992				0.995	0.997	0.52
P1	2.61	2.6096	2.6096	2.6096	2.636	2.614	2.626
P2	0.4	0.4001	0.4001	0.4001	0.306	0.389	0.406
P5	0	0.0002	-0.0002	0.0002	0.101	-0.026	0.011
P8	0	0.0001	0.0001	0.0001	-0.002	0.008	-0.004
P11	0				-0.003	-0.003	-0.004
P3	0				0.004	0.004	0.003
P4	-0.024	- 0.0239	-0.0239	- 0.0239	-0.022	-0.019	-0.024
P6	-0.076	-	-0.0761	-	-0.083	-0.072	-0.084

		0.0761		0.0761			
P7	0	-0.0003	-0.0003	-0.0003	-0.012	0.006	-0.016
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.232	-0.218	-0.223
P10	0	0.0002	0.0002	0.0002	0.001	0.005	0.004
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.059	-0.057	-0.047
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.111	-0.108
P14	-0.062	-0.062	-0.062	-0.062	-0.065	-0.065	-0.058
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.079	-0.079	-0.073
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.029	-0.03	-0.027
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.084
P18	-0.032				-0.023	-0.023	-0.019
P19	-0.095				-0.103	-0.103	-0.099
P20	-0.022				-0.024	-0.024	-0.018
P21	-0.175				-0.174	-0.174	-0.162
P22	0				0.003	0.003	0.037
P23	-0.032				-0.032	-0.032	-0.013
P24	-0.087				-0.091	-0.091	-0.042
P25	0				0.003	0.003	0.072
P26	-0.035				-0.034	-0.035	0.031
P27	0				0.002	0.003	0.319
P28	0				-0.014	-0.004	-0.059
P29	-0.024				-0.016	-0.017	-0.013
P30	-0.106				-0.116	-0.116	0.149
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.207	-0.172	-0.113
Q2	0.561	0.5607	0.5607	0.5607	0.544	0.644	0.631
Q5	0.357	0.3565	-0.3565	0.3565	0.355	-0.001	0.381
Q8	0.361	0.361	0.361	0.361	0.359	0.374	0.45
Q11	0.161				0.162	0.165	0.173
Q3	-0.105				-0.105	-0.106	-0.11
Q4	-0.012	-0.012	-0.012	-0.012	-0.014	0.002	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.018	0.006	0.001

Q7	0	-0.0001	-0.0001	-0.0001	-0.001	0.033	0.071
Q9	-0.109	-0.109	-0.109	-0.109	-0.101	0.011	-0.083
Q10	0	0	0	0	0	0.009	0.02
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.021	-0.017	-0.004
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.074	-0.071	-0.065
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.013	-0.012	-0.006
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.028	-0.027	-0.013
Q16	-0.018	-0.018	-0.018	-0.018	-0.021	-0.019	-0.014
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.059	-0.057	-0.053
Q18	-0.009				-0.013	-0.013	-0.006
Q19	-0.034				-0.03	-0.029	-0.024
Q20	-0.007				-0.005	-0.004	0.005
Q21	-0.112				-0.114	-0.112	-0.102
Q22	0				-0.003	-0.002	0.044
Q23	-0.016				-0.018	-0.018	0.019
Q24	-0.067				-0.065	-0.064	0.017
Q25	0				0.001	0.001	0.119
Q26	-0.023				-0.022	-0.023	0.073
Q27	0				0.001	0.003	0.294
Q28	0				0.001	0.014	0.282
Q29	-0.009				-0.014	-0.013	-0.025
Q30	-0.019				-0.011	-0.011	0.326
P1-2	1.733	1.7333	1.7333	1.7333	1.758	1.736	1.745
P1-3	0.876	0.8767	0.8767	0.8767	0.878	0.878	0.881
P2-4	0.437	0.4364	0.4364	0.4364	0.43	0.435	0.443
P3-4	0.821	0.8213	0.8213	0.8213	0.824	0.828	0.825
P2-5	0.824	***-0.8236***	0.8236	0.8236	0.767	0.816	0.825
P2-6	0.604	0.6042	0.6042	0.6042	0.596	0.604	0.613
P4-6	0.721	0.7211	0.7211	0.7211	0.712	0.732	0.729
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.1	-0.183	-0.136
P6-7	0.381	0.3813	0.3813	0.3813	0.336	0.407	0.365
P6-8	0.296	0.2953	0.2953	0.2953	0.3	0.289	0.306

P6-9	0.277	0.2772	0.2772	0.2772	0.278	0.275	0.272
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.157	0.155
P9-11	0	0.0001	0.0001	0.0001	0.003	0.003	0.004
P9-10	0.277	0.2774	0.2774	0.2774	0.276	0.277	0.273
P4-12	0.442	0.4421	0.4421	0.4421	0.441	0.441	0.435
P12-13	0	-0.0002	-0.0002	-0.0002	0.004	0.004	0.003
P12-14	0.079	0.0789	0.0789	0.0789	0.08	0.08	0.078
P12-15	0.179	0.1788	0.1788	0.1788	0.176	0.177	0.178
P12-16	0.072	0.0727	0.0727	0.0727	0.069	0.069	0.069
P14-15	0.016	0.0159	0.0159	0.0159	0.014	0.014	0.019
P16-17	0.037	0.0372	0.0372	0.0372	0.039	0.039	0.041
P15-18	0.06				0.058	0.059	0.054
P18-19	0.028				0.035	0.035	0.035
P19-20	-0.067				-0.067	-0.068	-0.064
P10-20	0.09				0.092	0.093	0.083
P10-17	0.053				0.051	0.051	0.043
P10-21	0.158				0.156	0.157	0.169
P10-22	0.076				0.075	0.076	0.086
P21-22	-0.018				-0.019	-0.019	0.005
P15-23	0.05				0.051	0.051	0.069
P22-24	0.057				0.058	0.059	0.127
P23-24	0.018				0.019	0.019	0.054
P24-25	-0.012				-0.015	-0.014	0.133
P25-26	0.035				0.034	0.035	-0.029
P25-27	-0.048				-0.046	-0.046	0.216
P28-27	0.181				0.18	0.179	0.14
P27-29	0.062				0.06	0.061	0.519
P27-30	0.071				0.075	0.075	0.122
P29-30	0.037				0.043	0.043	-0.005
P8-28	-0.005				-0.003	-0.004	0.001
P6-28	0.187				0.198	0.188	0.202
P2-1	-1.681	-1.681	-1.681	-1.681	-1.704	-1.684	-1.692
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.847	-0.847	-0.85
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.42	-0.425	-0.432
P4-3	-0.813	-	-0.8131	-	-0.816	-0.82	-0.817

		0.8131		0.8131			
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.741	-0.785	-0.795
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.577	-0.585	-0.592
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.706	-0.725	-0.723
P7-5	0.15	0.1496	0.1496	0.1496	0.101	0.185	0.138
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.333	-0.403	-0.361
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.299	-0.288	-0.305
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.278	-0.275	-0.272
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.157	-0.155
P11-9	0	0.0001	0.0001	0.0001	-0.003	-0.003	-0.004
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.276	-0.277	-0.273
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.441	-0.441	-0.435
P13-12	0	-0.0001	-0.0001	-0.0001	-0.004	-0.004	-0.003
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.079	-0.079	-0.077
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.174	-0.175	-0.176
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.069	-0.069	-0.068
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.014	-0.014	-0.019
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.039	-0.039	-0.041
P18-15	-0.06				-0.058	-0.058	-0.053
P19-18	-0.028				-0.035	-0.035	-0.035
P20-19	0.067				0.068	0.068	0.064
P20-10	-0.089				-0.092	-0.092	-0.082
P17-10	-0.053				-0.051	-0.051	-0.043
P21-10	-0.157				-0.155	-0.156	-0.167
P22-10	-0.076				-0.075	-0.075	-0.085
P22-21	0.018				0.019	0.019	-0.005
P23-15	-0.05				-0.051	-0.051	-0.068
P24-22	-0.057				-0.058	-0.059	-0.123

P24-23	-0.018				-0.018	-0.019	-0.053
P25-24	0.012				0.015	0.014	-0.115
P26-25	-0.035				-0.034	-0.035	0.031
P27-25	0.048				0.047	0.047	-0.182
P27-28	-0.181				-0.18	-0.179	-0.14
P29-27	-0.061				-0.06	-0.06	-0.008
P30-27	-0.069				-0.073	-0.073	-0.092
P30-29	-0.037				-0.043	-0.043	0.241
P28-8	0.005				0.003	0.004	0
P28-6	-0.186				-0.197	-0.187	-0.199
Q1-2	-0.247	-0.2473	-0.2473	-0.2473	-0.249	-0.206	-0.204
Q1-3	0.043	0.0429	0.0429	0.0429	0.042	0.034	0.091
Q2-4	0.047	0.0473	0.0473	0.0473	0.046	0.028	0.087
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.042	-0.033	0.006
Q2-5	0.028	***-0.0277***	0.0277	0.0277	0.009	0.188	0.037
Q2-6	0.014	0.0139	0.0139	0.0139	0.011	-0.001	0.077
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.166	-0.143	-0.057
Q5-7	0.115	0.1151	0.1151	0.1151	0.111	-0.09	0.147
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.037	0.061	-0.086
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.071	-0.088	-0.07
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.08	-0.095	-0.095
Q6-10	0.002	0.0015	0.0015	0.0015	0.003	-0.004	-0.001
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.157	-0.16	-0.168
Q9-10	0.059	0.059	0.059	0.059	0.06	0.057	0.076
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.136	0.139
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.104	-0.109
Q12-14	0.024	0.0242	0.0242	0.0242	0.023	0.022	0.021
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.067	0.079
Q12-16	0.033	0.0336	0.0336	0.0336	0.035	0.034	0.037
Q14-15	0.006	0.007	0.007	0.007	0.008	0.008	0.014
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.022
Q15-18	0.016				0.016	0.016	0.008

Q18-19	0.006				0.002	0.002	0.001
Q19-20	-0.028				-0.028	-0.028	-0.023
Q10-20	0.037				0.035	0.034	0.019
Q10-17	0.044				0.046	0.044	0.031
Q10-21	0.1				0.101	0.1	0.133
Q10-22	0.046				0.047	0.046	0.069
Q21-22	-0.014				-0.015	-0.015	0.029
Q15-23	0.029				0.029	0.029	0.067
Q22-24	0.031				0.028	0.028	0.14
Q23-24	0.012				0.01	0.011	0.085
Q24-25	0.02				0.018	0.019	0.274
Q25-26	0.024				0.023	0.024	-0.07
Q25-27	-0.004				-0.005	-0.004	0.43
Q28-27	0.05				0.047	0.043	0.715
Q27-29	0.017				0.017	0.017	0.98
Q27-30	0.017				0.013	0.013	0.186
Q29-30	0.006				0.002	0.002	-0.01
Q8-28	-0.005				-0.007	-0.008	0.085
Q6-28	0.001				-0.002	-0.018	0.305
Q2-1	0.345	0.3447	0.3447	0.3447	0.351	0.303	0.303
Q3-1	0.027	0.0262	0.0262	0.0262	0.028	0.035	-0.018
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.036	-0.092
Q4-3	0.054	0.0547	0.0547	0.0547	0.058	0.049	0.01
Q5-2	0.052	0.0521	0.0521	0.0521	0.053	-0.101	0.044
Q6-2	0.006	0.0062	0.0062	0.0062	0.007	0.021	-0.053
Q6-4	0.172	0.1721	0.1721	0.1721	0.178	0.156	0.07
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.129	0.075	-0.163
Q7-6	0.022	0.0224	0.0224	0.0224	0.029	-0.064	0.08
Q8-6	0.067	0.0665	0.0665	0.0665	0.066	0.082	0.065
Q9-6	0.097	0.0974	0.0974	0.0974	0.096	0.112	0.112
Q10-6	0.011	0.0109	0.0109	0.0109	0.01	0.017	0.013
Q11-9	0.161	0.1608	0.1608	0.1608	0.162	0.165	0.173
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.052	-0.049	-0.068
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.098	-0.09	-0.093

Q13-12	0.105	0.1047	0.1047	0.1047	0.105	0.106	0.11
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.021	-0.02
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.063	-0.074
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.034	-0.033	-0.036
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.008	-0.008	-0.014
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.013	-0.013	-0.022
Q18-15	-0.015				-0.015	-0.015	-0.007
Q19-18	-0.006				-0.002	-0.001	-0.001
Q20-19	0.028				0.028	0.028	0.023
Q20-10	-0.035				-0.033	-0.033	-0.018
Q17-10	-0.044				-0.046	-0.044	-0.031
Q21-10	-0.098				-0.099	-0.097	-0.13
Q22-10	-0.045				-0.046	-0.045	-0.068
Q22-21	0.014				0.015	0.015	-0.029
Q23-15	-0.028				-0.028	-0.028	-0.065
Q24-22	-0.03				-0.027	-0.028	-0.134
Q24-23	-0.012				-0.01	-0.01	-0.082
Q25-24	-0.02				-0.017	-0.019	-0.242
Q26-25	-0.023				-0.022	-0.023	0.073
Q27-25	0.004				0.005	0.004	-0.365
Q27-28	-0.037				-0.034	-0.031	-0.508
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.01	-0.01	-0.13
Q30-29	-0.005				-0.001	-0.001	0.456
Q28-8	-0.038				-0.037	-0.036	-0.124
Q28-6	-0.012				-0.009	0.007	-0.31

Table B-45: 30 Bus-IRLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.044	1.044	1.044
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.022	1.022	1.021

V4	1.012	1.0135	1.0135	1.0135	1.013	1.013	1.012
V5	1.01	1.0178	1.0178	1.0178	1.014	0.999	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.012	1.01
V7	1.003	1.0054	1.0054	1.0054	1.005	1.003	1.002
V8	1.01	1.0116	1.0116	1.0116	1.01	1.011	1.01
V9	1.051	1.0546	1.0546	1.0546	1.053	1.053	1.051
V10	1.045	1.0316	1.0316	1.0316	1.046	1.048	1.045
V11	1.082	1.088	1.088	1.088	1.083	1.084	1.082
V12	1.057	1.0628	1.0628	1.0628	1.06	1.06	1.057
V13	1.071				1.072	1.074	1.071
V14	1.043				1.043	1.045	1.042
V15	1.038				1.039	1.041	1.038
V16	1.045				1.045	1.047	1.044
V17	1.04				1.041	1.043	1.04
V18	1.028				1.029	1.031	1.028
V19	1.026				1.026	1.028	1.026
V20	1.03				1.03	1.033	1.03
V21	1.033				1.033	1.035	1.033
V22	1.034				1.034	1.036	1.033
V23	1.027				1.027	1.03	1.027
V24	1.022				1.022	1.024	1.021
V25	1.018				1.019	1.02	1.017
V26	1				1.002	1.002	1
V27	1.024				1.026	1.026	1.024
V28	1.007				1.008	1.008	1.007
V29	1.004	1.003	1.003	***-1.003***	1.006	1.006	1.004
V30	0.992				0.995	0.995	0.993
P1	2.61	2.6096	2.6096	2.6096	2.636	2.61	2.61
P2	0.4	0.4001	0.4001	0.4001	0.305	0.394	0.4
P5	0	0.0002	-0.0002	0.0002	0.101	-0.003	0
P8	0	0.0001	0.0001	0.0001	-0.003	0.001	0
P11	0				-0.003	0	0
P3	0				0.003	0.001	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.02	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.084	-0.076	-0.076

P7	0	-0.0003	-0.0003	-0.0003	-0.012	0.002	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.232	-0.225	-0.228
P10	0	0.0002	0.0002	0.0002	0	0.001	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.051	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.105	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.067	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.081	-0.081	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.031	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.092	-0.09	-0.09
P18	-0.032				-0.024	-0.032	-0.032
P19	-0.095				-0.103	-0.096	-0.095
P20	-0.022				-0.026	-0.022	-0.022
P21	-0.175				-0.174	-0.175	-0.175
P22	0				-0.002	0	-0.001
P23	-0.032				-0.033	-0.032	-0.032
P24	-0.087				-0.092	-0.087	-0.087
P25	0				0.002	0	0
P26	-0.035				-0.034	-0.035	-0.035
P27	0				0.003	0.001	0
P28	0				-0.014	0	0
P29	-0.024				-0.017	-0.022	-0.023
P30	-0.106				-0.116	-0.11	-0.108
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.207	-0.21	-0.202
Q2	0.561	0.5607	0.5607	0.5607	0.543	0.599	0.561
Q5	0.357	0.3565	-0.3565	0.3565	0.352	0.214	0.357
Q8	0.361	0.361	0.361	0.361	0.357	0.362	0.361
Q11	0.161				0.155	0.162	0.161
Q3	-0.105				-0.094	-0.107	-0.105
Q4	-0.012	-0.012	-0.012	-0.012	-0.01	-0.007	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.026	-0.013	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	-0.003	0.01	-0.001

Q9	-0.109	-0.109	-0.109	-0.109	-0.102	-0.034	-0.109
Q10	0	0	0	0	0.02	0.002	0
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.01	-0.019	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.033	-0.071	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.019	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.033	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.026	-0.019	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.064	-0.057	-0.058
Q18	-0.009				-0.015	-0.009	-0.009
Q19	-0.034				-0.033	-0.034	-0.034
Q20	-0.007				-0.006	-0.006	-0.007
Q21	-0.112				-0.123	-0.112	-0.112
Q22	0				-0.003	0	0
Q23	-0.016				-0.02	-0.016	-0.017
Q24	-0.067				-0.067	-0.067	-0.068
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0.004	0.001	0
Q28	0				-0.002	0.001	0
Q29	-0.009				-0.014	-0.011	-0.011
Q30	-0.019				-0.011	-0.016	-0.016
P1-2	1.733	1.7333	1.7333	1.7333	1.758	1.732	1.734
P1-3	0.876	0.8767	0.8767	0.8767	0.878	0.878	0.877
P2-4	0.437	0.4364	0.4364	0.4364	0.43	0.437	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.826	0.823	0.822
P2-5	0.824	***-0.8236***	0.8236	0.8236	0.767	0.817	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.596	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.712	0.723	0.722
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.1	-0.157	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.336	0.387	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.301	0.295	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.278	0.277	0.277

P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0.003	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.276	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.443	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0.003	0.001	0
P12-14	0.079	0.0789	0.0789	0.0789	0.082	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.181	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.071	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.014	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.04	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.035	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.094	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.159	0.158	0.158
P10-22	0.076				0.077	0.076	0.076
P21-22	-0.018				-0.016	-0.018	-0.018
P15-23	0.05				0.052	0.05	0.051
P22-24	0.057				0.059	0.057	0.057
P23-24	0.018				0.019	0.018	0.018
P24-25	-0.012				-0.015	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.047	-0.047	-0.047
P28-27	0.181				0.18	0.181	0.181
P27-29	0.062				0.061	0.062	0.062
P27-30	0.071				0.075	0.073	0.072
P29-30	0.037				0.043	0.039	0.038
P8-28	-0.005				-0.003	-0.005	-0.005
P6-28	0.187				0.198	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.704	-1.68	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.847	-0.846	-0.846
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.42	-0.427	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.818	-0.814	-0.813

P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.741	-0.787	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.577	-0.585	-0.585
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.706	-0.717	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.101	0.159	0.15
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.333	-0.384	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.299	-0.293	-0.295
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.278	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	-0.003	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.276	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.443	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	-0.003	-0.001	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.081	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.179	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.071	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.014	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.04	-0.037	-0.037
P18-15	-0.06				-0.059	-0.06	-0.06
P19-18	-0.028				-0.035	-0.028	-0.028
P20-19	0.067				0.067	0.068	0.068
P20-10	-0.089				-0.093	-0.09	-0.089
P17-10	-0.053				-0.052	-0.053	-0.053
P21-10	-0.157				-0.158	-0.157	-0.157
P22-10	-0.076				-0.077	-0.076	-0.076
P22-21	0.018				0.016	0.018	0.018
P23-15	-0.05				-0.052	-0.05	-0.05
P24-22	-0.057				-0.058	-0.057	-0.057
P24-23	-0.018				-0.019	-0.018	-0.018

P25-24	0.012				0.015	0.012	0.013
P26-25	-0.035				-0.034	-0.035	-0.035
P27-25	0.048				0.047	0.047	0.048
P27-28	-0.181				-0.18	-0.181	-0.181
P29-27	-0.061				-0.06	-0.061	-0.061
P30-27	-0.069				-0.073	-0.071	-0.07
P30-29	-0.037				-0.043	-0.039	-0.038
P28-8	0.005				0.003	0.005	0.005
P28-6	-0.186				-0.197	-0.186	-0.186
Q1-2	-0.247	-0.2473	-0.2473	-0.2473	-0.248	-0.246	-0.246
Q1-3	0.043	0.0429	0.0429	0.0429	0.04	0.036	0.044
Q2-4	0.047	0.0473	0.0473	0.0473	0.045	0.04	0.048
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.04	-0.041	-0.038
Q2-5	0.028	***-0.0277***	0.0277	0.0277	0.011	0.082	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.01	0.006	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.164	-0.16	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.11	0.027	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.034	-0.015	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.069	-0.074	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.087	-0.086	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.001	0	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.151	-0.157	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.068	0.058	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.136	0.139	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.093	-0.105	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.029	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.079	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.042	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.008	0.007	0.007
Q16-17	0.014	0.0148	0.0148	0.0148	0.015	0.014	0.014
Q15-18	0.016				0.019	0.016	0.016
Q18-19	0.006				0.003	0.006	0.006

Q19-20	-0.028				-0.03	-0.028	-0.028
Q10-20	0.037				0.038	0.036	0.037
Q10-17	0.044				0.05	0.044	0.044
Q10-21	0.1				0.109	0.1	0.101
Q10-22	0.046				0.05	0.046	0.046
Q21-22	-0.014				-0.017	-0.014	-0.014
Q15-23	0.029				0.032	0.03	0.03
Q22-24	0.031				0.029	0.03	0.031
Q23-24	0.012				0.011	0.013	0.012
Q24-25	0.02				0.017	0.02	0.02
Q25-26	0.024				0.023	0.024	0.024
Q25-27	-0.004				-0.006	-0.004	-0.005
Q28-27	0.05				0.046	0.048	0.05
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.014	0.015	0.015
Q29-30	0.006				0.001	0.004	0.004
Q8-28	-0.005				-0.007	-0.006	-0.005
Q6-28	0.001				0	-0.002	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.35	0.343	0.344
Q3-1	0.027	0.0262	0.0262	0.0262	0.029	0.034	0.026
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.054	-0.048	-0.056
Q4-3	0.054	0.0547	0.0547	0.0547	0.056	0.057	0.054
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	-0.003	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.008	0.013	0.005
Q6-4	0.172	0.1721	0.1721	0.1721	0.177	0.173	0.171
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.128	-0.044	-0.132
Q7-6	0.022	0.0224	0.0224	0.0224	0.026	0.01	0.023
Q8-6	0.067	0.0665	0.0665	0.0665	0.063	0.068	0.066
Q9-6	0.097	0.0974	0.0974	0.0974	0.103	0.102	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.013	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.155	0.162	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.06	-0.05	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.09	-0.092	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.094	0.107	0.105

Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.027	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.075	-0.064	-0.064
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.041	-0.033	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.008	-0.007	-0.007
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.015	-0.014	-0.014
Q18-15	-0.015				-0.018	-0.015	-0.015
Q19-18	-0.006				-0.003	-0.006	-0.006
Q20-19	0.028				0.031	0.028	0.028
Q20-10	-0.035				-0.036	-0.034	-0.035
Q17-10	-0.044				-0.049	-0.043	-0.044
Q21-10	-0.098				-0.106	-0.098	-0.098
Q22-10	-0.045				-0.049	-0.045	-0.045
Q22-21	0.014				0.017	0.014	0.014
Q23-15	-0.028				-0.031	-0.029	-0.029
Q24-22	-0.03				-0.029	-0.03	-0.03
Q24-23	-0.012				-0.011	-0.012	-0.012
Q25-24	-0.02				-0.017	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.006	0.004	0.005
Q27-28	-0.037				-0.034	-0.035	-0.037
Q29-27	-0.015				-0.016	-0.015	-0.015
Q30-27	-0.014				-0.01	-0.012	-0.012
Q30-29	-0.005				-0.001	-0.004	-0.004
Q28-8	-0.038				-0.037	-0.038	-0.038
Q28-6	-0.012				-0.011	-0.01	-0.012

Table B-46: 30 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.045	1.045	1.046
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	1.0135	1.012	1.012	1.012

V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.027	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.023	1.023	1.023
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.003	1.003	1.004
V30	0.992				0.992	0.992	0.992
P1	2.61	2.6096	2.6096	2.6096	2.61	2.61	2.61
P2	0.4	0.4001	0.4001	0.4001	0.4	0.4	0.4
P5	0	0.0002	-0.0002	0.0002	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0	0

P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.175	-0.175	-0.175
P22	0				0	0	0
P23	-0.032				-0.032	-0.032	-0.031
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	0
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.024
P30	-0.106				-0.106	-0.106	-0.107
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.204	-0.204	-0.204
Q2	0.561	0.5607	0.5607	0.5607	0.561	0.561	0.561
Q5	0.357	0.3565	-0.3565	0.3565	0.357	0.357	0.357
Q8	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Q11	0.161				0.161	0.161	0.161
Q3	-0.105				-0.104	-0.104	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	0	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109

Q10	0	0	0	0	0	0	0
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.02	-0.02	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.075	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0
Q28	0				0	0	0
Q29	-0.009				-0.009	-0.009	-0.01
Q30	-0.019				-0.019	-0.019	-0.018
P1-2	1.733	1.7333	1.7333	1.7333	1.733	1.733	1.733
P1-3	0.876	0.8767	0.8767	0.8767	0.876	0.876	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.437	0.437	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.822	0.822
P2-5	0.824	***-0.8236***	0.8236	0.8236	0.824	0.824	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.381	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.295
P6-9	0.277	0.2772	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158

P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.178
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158
P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.018	-0.018	-0.018
P15-23	0.05				0.05	0.05	0.05
P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.047	-0.047	-0.047
P28-27	0.181				0.181	0.181	0.181
P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.037
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794

P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.15	0.15	0.15
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.377	-0.377	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.295	-0.295	-0.294
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.176
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.067	0.068	0.068
P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.018	0.018	0.018
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012

P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.047	0.047	0.047
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.07	-0.07	-0.07
P30-29	-0.037				-0.037	-0.037	-0.037
P28-8	0.005				0.005	0.005	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	-0.2473	-0.2473	-0.2473	-0.247	-0.247	-0.247
Q1-3	0.043	0.0429	0.0429	0.0429	0.043	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.048	0.048	0.048
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.039	-0.039	-0.039
Q2-5	0.028	***-0.0277***	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.014	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.072	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.007	0.007	0.007
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028

Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.012	0.012
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.051	0.051	0.051
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.017	0.017	0.016
Q29-30	0.006				0.006	0.006	0.006
Q8-28	-0.005				-0.005	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.345	0.345	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.026
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.055	0.055	0.055
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.132
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	0.023
Q8-6	0.067	0.0665	0.0665	0.0665	0.066	0.066	0.066
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.161	0.161	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022

Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.063	-0.063	-0.063
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.007	-0.006	-0.007
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.029	-0.029	-0.029
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.038	-0.038	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.014	-0.014	-0.013
Q30-29	-0.005				-0.005	-0.005	-0.005
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.012	-0.012

Table B-47: 30 Bus-WLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.046	1.028	1.04
V2	1.045	1.0539	1.0539	1.0539	1.047	1.027	1.039
V3	1.021	1.0207	1.0207	1.0207	1.021	1.036	1.002
V4	1.012	1.0135	1.0135	***-1.0135***	1.012	1.027	0.991
V5	1.01	1.0178	1.0178	1.0178	1.009	1.028	0.999

V6	1.011	1.0003	1.0003	1.0003	1.01	1.024	0.985
V7	1.003	1.0054	1.0054	1.0054	1.002	1.023	0.983
V8	1.01	1.0116	1.0116	1.0116	1.01	1.014	0.984
V9	1.051	1.0546	1.0546	1.0546	1.046	1.074	1.028
V10	1.045	1.0316	1.0316	1.0316	1.041	1.069	1.021
V11	1.082	1.088	1.088	1.088	1.076	1.107	1.063
V12	1.057	1.0628	1.0628	1.0628	1.056	1.08	1.035
V13	1.071				1.07	1.093	1.049
V14	1.043				1.041	1.065	1.021
V15	1.038				1.036	1.06	1.015
V16	1.045				1.042	1.068	1.022
V17	1.04				1.036	1.064	1.017
V18	1.028				1.026	1.05	1.009
V19	1.026				1.023	1.048	1.007
V20	1.03				1.027	1.052	1.01
V21	1.033				1.029	1.057	1.006
V22	1.034				1.029	1.057	1.005
V23	1.027				1.025	1.05	0.996
V24	1.022				1.019	1.045	0.967
V25	1.018				1.018	1.041	0.852
V26	1				1.002	1.021	0.894
V27	1.024				1.025	1.048	0.72
V28	1.007				1.007	1.025	0.963
V29	1.004	1.003	1.003	***-1.003***	1.006	1.027	0.007
V30	0.992				0.995	1.016	0.516
P1	2.61	2.6096	2.6096	2.6096	2.281	2.784	2.64
P2	0.4	0.4001	***-0.4001***	0.4001	0.905	-0.07	0.415
P5	0	0.0002	0.0002	0.0002	-0.007	0.083	0.022
P8	0	0.0001	***-0.0001***	0.0001	-0.017	0.013	-0.007
P11	0				-0.014	-0.006	-0.003
P3	0				0.006	0.007	0.002
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.061	0.032	-0.032
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.084	0.004	-0.109
P7	0	-0.0003	-0.0003	-0.0003	-0.018	0.055	-0.026
P9	-0.228	-	-0.2278	-	-0.263	-0.195	-0.224

		0.2278		0.2278			
P10	0	0.0002	0.0002	0.0002	0.026	0.007	0.004
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.064	-0.058	-0.047
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.117	-0.106	-0.113
P14	-0.062	-0.062	-0.062	-0.062	-0.066	-0.069	-0.057
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.08	-0.081	-0.072
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.034	-0.032	-0.025
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.095	-0.093	-0.083
P18	-0.032				-0.023	-0.027	-0.016
P19	-0.095				-0.104	-0.106	-0.097
P20	-0.022				-0.026	-0.029	-0.015
P21	-0.175				-0.18	-0.178	-0.16
P22	0				-0.003	0.001	0.037
P23	-0.032				-0.032	-0.036	-0.012
P24	-0.087				-0.092	-0.094	-0.041
P25	0				0.002	0.002	0.072
P26	-0.035				-0.033	-0.039	0.034
P27	0				-0.003	0.007	0.313
P28	0				-0.03	0.012	-0.064
P29	-0.024				-0.016	-0.019	-0.008
P30	-0.106				-0.116	-0.122	0.15
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.158	-0.022	0.012
Q2	0.561	0.5607	***-0.5607***	0.5607	0.466	-0.174	0.691
Q5	0.357	0.3565	0.3565	0.3565	0.342	0.494	0.387
Q8	0.361	0.361	***-0.361***	0.361	0.371	0.044	0.435
Q11	0.161				0.154	0.173	0.174
Q3	-0.105				-0.106	-0.108	-0.108
Q4	-0.012	-0.012	-0.012	-0.012	0.003	0.089	-0.055
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.006	0.112	-0.079
Q7	0	-0.0001	-0.0001	-0.0001	0.016	0.155	0.042
Q9	-0.109	-0.109	-0.109	-0.109	-0.096	-0.016	-0.093
Q10	0	0	0	0	-0.02	0.035	0.017

Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.027	-0.009	-0.003
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.072	-0.06	-0.073
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.012	-0.01	-0.007
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.026	-0.025	-0.016
Q16	-0.018	-0.018	-0.018	-0.018	-0.02	-0.016	-0.015
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.061	-0.054	-0.05
Q18	-0.009				-0.013	-0.016	-0.004
Q19	-0.034				-0.03	-0.032	-0.021
Q20	-0.007				-0.004	-0.006	0.008
Q21	-0.112				-0.114	-0.109	-0.1
Q22	0				-0.005	0.001	0.044
Q23	-0.016				-0.017	-0.02	0.02
Q24	-0.067				-0.066	-0.066	0.017
Q25	0				0.002	0.003	0.12
Q26	-0.023				-0.022	-0.029	0.076
Q27	0				0.005	0.019	0.291
Q28	0				0.013	0.126	0.262
Q29	-0.009				-0.013	-0.015	-0.015
Q30	-0.019				-0.01	-0.012	0.326
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.417	1.924	1.753
P1-3	0.876	0.8767	0.8767	0.8767	0.864	0.86	0.887
P2-4	0.437	0.4364	0.4364	0.4364	0.516	0.339	0.453
P3-4	0.821	0.8213	0.8213	0.8213	0.773	0.862	0.822
P2-5	0.824	0.8236	0.8236	0.8236	0.87	0.73	0.825
P2-6	0.604	0.6042	0.6042	0.6042	0.684	0.504	0.621
P4-6	0.721	0.7211	0.7211	0.7211	0.725	0.734	0.717
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.111	-0.153	-0.124
P6-7	0.381	0.3813	0.3813	0.3813	0.379	0.353	0.355
P6-8	0.296	0.2953	0.2953	0.2953	0.318	0.282	0.309
P6-9	0.277	***-0.2772***	0.2772	0.2772	0.281	0.288	0.266
P6-10	0.158	0.1585	0.1585	0.1585	0.163	0.165	0.152
P9-11	0	0.0001	0.0001	0.0001	0.014	0.006	0.003

P9-10	0.277	0.2774	0.2774	0.2774	0.294	0.289	0.267
P4-12	0.442	0.4421	0.4421	0.4421	0.458	0.455	0.427
P12-13	0	-0.0002	-0.0002	-0.0002	0.006	0.007	0.002
P12-14	0.079	0.0789	0.0789	0.0789	0.081	0.084	0.075
P12-15	0.179	0.1788	0.1788	0.1788	0.18	0.186	0.171
P12-16	0.072	0.0727	0.0727	0.0727	0.073	0.072	0.065
P14-15	0.016	0.0159	0.0159	0.0159	0.015	0.015	0.017
P16-17	0.037	0.0372	0.0372	0.0372	0.039	0.039	0.039
P15-18	0.06				0.06	0.063	0.05
P18-19	0.028				0.037	0.036	0.033
P19-20	-0.067				-0.067	-0.071	-0.064
P10-20	0.09				0.095	0.101	0.08
P10-17	0.053				0.057	0.054	0.044
P10-21	0.158				0.163	0.163	0.165
P10-22	0.076				0.079	0.079	0.083
P21-22	-0.018				-0.019	-0.016	0.003
P15-23	0.05				0.052	0.054	0.065
P22-24	0.057				0.056	0.063	0.123
P23-24	0.018				0.019	0.018	0.052
P24-25	-0.012				-0.017	-0.014	0.129
P25-26	0.035				0.034	0.04	-0.031
P25-27	-0.048				-0.049	-0.051	0.214
P28-27	0.181				0.187	0.189	0.137
P27-29	0.062				0.06	0.065	0.511
P27-30	0.071				0.075	0.079	0.118
P29-30	0.037				0.043	0.045	-0.003
P8-28	-0.005				-0.001	-0.006	0.001
P6-28	0.187				0.218	0.184	0.203
P2-1	-1.681	-1.681	-1.681	-1.681	-1.382	-1.861	-1.701
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.834	-0.83	-0.854
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.502	-0.332	-0.441
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.765	-0.853	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.838	-0.706	-0.795
P6-2	-0.584	-	-0.5844	-	-0.659	-0.49	-0.599

		0.5844		0.5844			
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.718	-0.727	-0.711
P7-5	0.15	0.1496	0.1496	0.1496	0.112	0.154	0.127
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.375	-0.35	-0.351
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.316	-0.28	-0.308
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.281	-0.288	-0.266
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.163	-0.165	-0.152
P11-9	0	0.0001	0.0001	0.0001	-0.014	-0.006	-0.003
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.294	-0.289	-0.267
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.458	-0.455	-0.427
P13-12	0	-0.0001	-0.0001	-0.0001	-0.006	-0.007	-0.002
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.08	-0.084	-0.075
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.178	-0.184	-0.169
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.073	-0.072	-0.064
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.015	-0.015	-0.017
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.039	-0.039	-0.039
P18-15	-0.06				-0.06	-0.063	-0.049
P19-18	-0.028				-0.036	-0.035	-0.033
P20-19	0.067				0.067	0.071	0.064
P20-10	-0.089				-0.094	-0.1	-0.079
P17-10	-0.053				-0.057	-0.054	-0.043
P21-10	-0.157				-0.162	-0.162	-0.163
P22-10	-0.076				-0.078	-0.078	-0.082
P22-21	0.018				0.019	0.016	-0.003
P23-15	-0.05				-0.052	-0.054	-0.064
P24-22	-0.057				-0.056	-0.063	-0.119
P24-23	-0.018				-0.019	-0.018	-0.051
P25-24	0.012				0.017	0.014	-0.111
P26-25	-0.035				-0.033	-0.039	0.034

P27-25	0.048				0.049	0.052	-0.18
P27-28	-0.181				-0.187	-0.189	-0.137
P29-27	-0.061				-0.06	-0.064	-0.005
P30-27	-0.069				-0.073	-0.077	-0.089
P30-29	-0.037				-0.043	-0.044	0.24
P28-8	0.005				0.001	0.006	0
P28-6	-0.186				-0.217	-0.183	-0.201
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.203	0.028	-0.148
Q1-3	0.043	0.0429	0.0429	0.0429	0.045	-0.049	0.16
Q2-4	0.047	0.0473	0.0473	0.0473	0.04	-0.115	0.137
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.018	-0.025	0.028
Q2-5	0.028	0.0277	0.0277	0.0277	0.039	-0.147	0.057
Q2-6	0.014	0.0139	0.0139	0.0139	0.011	-0.143	0.123
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.151	-0.143	-0.069
Q5-7	0.115	0.1151	0.1151	0.1151	0.097	0.098	0.171
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.025	-0.107	-0.098
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.083	0.174	-0.057
Q6-9	-0.081	***0.0807***	-0.0807	-0.0807	-0.06	-0.129	-0.096
Q6-10	0.002	0.0015	0.0015	0.0015	0.009	-0.016	-0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.15	-0.168	-0.168
Q9-10	0.059	0.059	0.059	0.059	0.053	0.056	0.074
Q4-12	0.144	0.1442	0.1442	0.1442	0.151	0.116	0.139
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.105	-0.107	-0.107
Q12-14	0.024	0.0242	0.0242	0.0242	0.023	0.021	0.021
Q12-15	0.068	0.0676	0.0676	0.0676	0.07	0.067	0.073
Q12-16	0.033	0.0336	0.0336	0.0336	0.04	0.029	0.034
Q14-15	0.006	0.007	0.007	0.007	0.009	0.009	0.012
Q16-17	0.014	0.0148	0.0148	0.0148	0.019	0.012	0.018
Q15-18	0.016				0.019	0.017	0.003
Q18-19	0.006				0.005	0.001	-0.001
Q19-20	-0.028				-0.025	-0.031	-0.023
Q10-20	0.037				0.031	0.04	0.017

Q10-17	0.044				0.042	0.042	0.033
Q10-21	0.1				0.1	0.098	0.13
Q10-22	0.046				0.045	0.045	0.067
Q21-22	-0.014				-0.017	-0.014	0.026
Q15-23	0.029				0.03	0.03	0.062
Q22-24	0.031				0.022	0.031	0.136
Q23-24	0.012				0.012	0.009	0.08
Q24-25	0.02				0.013	0.02	0.265
Q25-26	0.024				0.022	0.03	-0.072
Q25-27	-0.004				-0.008	-0.007	0.427
Q28-27	0.05				0.045	0.035	0.695
Q27-29	0.017				0.016	0.019	0.965
Q27-30	0.017				0.013	0.015	0.181
Q29-30	0.006				0.001	0.002	-0.006
Q8-28	-0.005				-0.008	-0.077	0.083
Q6-28	0.001				-0.013	-0.07	0.307
Q2-1	0.345	0.3447	0.3447	0.3447	0.249	0.104	0.248
Q3-1	0.027	0.0262	0.0262	0.0262	0.021	0.113	-0.083
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.037	0.097	-0.138
Q4-3	0.054	0.0547	0.0547	0.0547	0.031	0.042	-0.011
Q5-2	0.052	0.0521	0.0521	0.0521	0.054	0.206	0.026
Q6-2	0.006	0.0062	0.0062	0.0062	0.025	0.148	-0.095
Q6-4	0.172	0.1721	0.1721	0.1721	0.164	0.155	0.082
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.115	-0.116	-0.186
Q7-6	0.022	0.0224	0.0224	0.0224	0.019	0.1	0.092
Q8-6	0.067	0.0665	0.0665	0.0665	0.078	-0.178	0.052
Q9-6	0.097	0.0974	0.0974	0.0974	0.076	0.148	0.112
Q10-6	0.011	0.0109	0.0109	0.0109	0.005	0.03	0.014
Q11-9	0.161	0.1608	0.1608	0.1608	0.154	0.173	0.174
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.044	-0.047	-0.066
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.101	-0.07	-0.093
Q13-12	0.105	0.1047	0.1047	0.1047	0.106	0.108	0.108
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.021	-0.019	-0.019
Q15-12	-0.064	-	-0.0634	-	-0.066	-0.062	-0.069

		0.0634		0.0634			
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.039	-0.028	-0.033
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.009	-0.009	-0.012
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.019	-0.012	-0.017
Q18-15	-0.015				-0.018	-0.017	-0.003
Q19-18	-0.006				-0.005	-0.001	0.001
Q20-19	0.028				0.025	0.031	0.023
Q20-10	-0.035				-0.029	-0.038	-0.015
Q17-10	-0.044				-0.042	-0.042	-0.033
Q21-10	-0.098				-0.097	-0.096	-0.126
Q22-10	-0.045				-0.044	-0.044	-0.065
Q22-21	0.014				0.017	0.014	-0.026
Q23-15	-0.028				-0.03	-0.029	-0.061
Q24-22	-0.03				-0.021	-0.03	-0.13
Q24-23	-0.012				-0.012	-0.008	-0.078
Q25-24	-0.02				-0.012	-0.02	-0.234
Q26-25	-0.023				-0.022	-0.029	0.076
Q27-25	0.004				0.008	0.007	-0.361
Q27-28	-0.037				-0.032	-0.022	-0.494
Q29-27	-0.015				-0.014	-0.017	-0.009
Q30-27	-0.014				-0.009	-0.011	-0.127
Q30-29	-0.005				-0.001	-0.001	0.453
Q28-8	-0.038				-0.036	0.033	-0.121
Q28-6	-0.012				0.003	0.058	-0.311

Table B-48: 30 Bus-IRLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.046	1.04	1.045
V2	1.045	1.0539	1.0539	1.0539	1.047	1.041	1.045
V3	1.021	1.0207	1.0207	1.0207	1.022	1.024	1.021
V4	1.012	1.0135	1.0135	***-1.0135***	1.012	1.015	1.012
V5	1.01	1.0178	1.0178	1.0178	1.009	1.014	1.01

V6	1.011	1.0003	1.0003	1.0003	1.01	1.014	1.011
V7	1.003	1.0054	1.0054	1.0054	1.002	1.006	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.012	1.01
V9	1.051	1.0546	1.0546	1.0546	1.048	1.055	1.051
V10	1.045	1.0316	1.0316	1.0316	1.042	1.049	1.045
V11	1.082	1.088	1.088	1.088	1.077	1.086	1.082
V12	1.057	1.0628	1.0628	1.0628	1.058	1.061	1.057
V13	1.071				1.071	1.075	1.071
V14	1.043				1.041	1.046	1.042
V15	1.038				1.037	1.042	1.038
V16	1.045				1.042	1.048	1.044
V17	1.04				1.036	1.044	1.04
V18	1.028				1.026	1.032	1.028
V19	1.026				1.023	1.03	1.026
V20	1.03				1.027	1.034	1.03
V21	1.033				1.029	1.037	1.033
V22	1.034				1.029	1.037	1.033
V23	1.027				1.025	1.031	1.027
V24	1.022				1.019	1.026	1.022
V25	1.018				1.018	1.021	1.018
V26	1				1.001	1.004	1
V27	1.024				1.026	1.027	1.024
V28	1.007				1.007	1.011	1.007
V29	1.004	1.003	1.003	***-1.003***	1.006	1.007	1.004
V30	0.992				0.995	0.996	0.995
P1	2.61	2.6096	2.6096	2.6096	2.278	2.653	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.909	0.298	0.4
P5	0	0.0002	0.0002	0.0002	-0.008	0.018	0
P8	0	0.0001	***-0.0001***	0.0001	-0.018	0.001	0
P11	0				-0.014	0	0
P3	0				0.006	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.062	-0.022	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.082	-0.058	-0.076
P7	0	-0.0003	-0.0003	-0.0003	-0.016	0.017	0
P9	-0.228	-	-0.2278	-	-0.263	-0.225	-0.228

		0.2278		0.2278			
P10	0	0.0002	0.0002	0.0002	0.027	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.11	-0.111	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.067	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.036	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.097	-0.09	-0.09
P18	-0.032				-0.024	-0.032	-0.032
P19	-0.095				-0.104	-0.095	-0.095
P20	-0.022				-0.028	-0.022	-0.022
P21	-0.175				-0.18	-0.175	-0.175
P22	0				-0.007	0	-0.001
P23	-0.032				-0.033	-0.032	-0.032
P24	-0.087				-0.093	-0.087	-0.087
P25	0				0.002	0	0
P26	-0.035				-0.034	-0.035	-0.035
P27	0				-0.002	0	0
P28	0				-0.03	0.001	0
P29	-0.024				-0.017	-0.024	-0.022
P30	-0.106				-0.116	-0.107	-0.108
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.161	-0.153	-0.203
Q2	0.561	0.5607	***-0.5607***	0.5607	0.462	0.377	0.561
Q5	0.357	0.3565	0.3565	0.3565	0.341	0.391	0.357
Q8	0.361	0.361	***-0.361***	0.361	0.369	0.319	0.361
Q11	0.161				0.149	0.161	0.161
Q3	-0.105				-0.096	-0.105	-0.105
Q4	-0.012	-0.012	-0.012	-0.012	0.008	0.006	-0.013
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.013	0.02	-0.017
Q7	0	-0.0001	-0.0001	-0.0001	0.016	0.055	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.097	-0.104	-0.109
Q10	0	0	0	0	-0.004	0.003	0

Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.017	-0.02	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.032	-0.074	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.017	-0.016	-0.015
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.031	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.025	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.066	-0.058	-0.058
Q18	-0.009				-0.015	-0.009	-0.009
Q19	-0.034				-0.033	-0.034	-0.034
Q20	-0.007				-0.005	-0.007	-0.007
Q21	-0.112				-0.122	-0.112	-0.112
Q22	0				-0.005	0	0
Q23	-0.016				-0.019	-0.016	-0.018
Q24	-0.067				-0.068	-0.067	-0.068
Q25	0				0.002	0	-0.001
Q26	-0.023				-0.022	-0.023	-0.024
Q27	0				0.008	0	0
Q28	0				0.011	0.015	0
Q29	-0.009				-0.014	-0.009	-0.013
Q30	-0.019				-0.01	-0.019	-0.011
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.414	1.776	1.733
P1-3	0.876	0.8767	0.8767	0.8767	0.864	0.877	0.877
P2-4	0.437	0.4364	0.4364	0.4364	0.516	0.416	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.772	0.823	0.822
P2-5	0.824	0.8236	0.8236	0.8236	0.871	0.804	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.684	0.582	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.725	0.722	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.112	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.38	0.379	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.318	0.295	0.296
P6-9	0.277	***-0.2772***	0.2772	0.2772	0.282	0.278	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.164	0.159	0.158
P9-11	0	0.0001	0.0001	0.0001	0.014	0	0

P9-10	0.277	0.2774	0.2774	0.2774	0.295	0.278	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.46	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0.006	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.083	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.185	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.076	0.073	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.015	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.039	0.037	0.037
P15-18	0.06				0.062	0.06	0.06
P18-19	0.028				0.037	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.096	0.09	0.09
P10-17	0.053				0.058	0.053	0.053
P10-21	0.158				0.165	0.158	0.158
P10-22	0.076				0.08	0.076	0.076
P21-22	-0.018				-0.016	-0.018	-0.018
P15-23	0.05				0.053	0.051	0.05
P22-24	0.057				0.057	0.058	0.057
P23-24	0.018				0.02	0.018	0.018
P24-25	-0.012				-0.017	-0.012	-0.013
P25-26	0.035				0.034	0.035	0.035
P25-27	-0.048				-0.049	-0.047	-0.048
P28-27	0.181				0.187	0.182	0.181
P27-29	0.062				0.061	0.062	0.061
P27-30	0.071				0.075	0.071	0.072
P29-30	0.037				0.043	0.037	0.039
P8-28	-0.005				-0.001	-0.006	-0.005
P6-28	0.187				0.219	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.379	-1.722	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.834	-0.846	-0.846
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.502	-0.407	-0.427
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.765	-0.815	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.838	-0.776	-0.794
P6-2	-0.584	-	-0.5844	-	-0.659	-0.564	-0.585

		0.5844		0.5844			
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.719	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.113	0.15	0.149
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.376	-0.375	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.317	-0.294	-0.295
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.282	-0.278	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.164	-0.159	-0.158
P11-9	0	0.0001	0.0001	0.0001	-0.014	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.295	-0.278	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.46	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	-0.006	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.082	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.182	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.075	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.015	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.039	-0.037	-0.037
P18-15	-0.06				-0.061	-0.06	-0.06
P19-18	-0.028				-0.037	-0.028	-0.028
P20-19	0.067				0.067	0.068	0.068
P20-10	-0.089				-0.095	-0.09	-0.09
P17-10	-0.053				-0.058	-0.053	-0.053
P21-10	-0.157				-0.164	-0.157	-0.157
P22-10	-0.076				-0.08	-0.076	-0.076
P22-21	0.018				0.016	0.018	0.018
P23-15	-0.05				-0.053	-0.051	-0.05
P24-22	-0.057				-0.056	-0.057	-0.057
P24-23	-0.018				-0.02	-0.018	-0.018
P25-24	0.012				0.017	0.012	0.013
P26-25	-0.035				-0.034	-0.035	-0.035

P27-25	0.048				0.05	0.047	0.048
P27-28	-0.181				-0.187	-0.182	-0.181
P29-27	-0.061				-0.06	-0.061	-0.06
P30-27	-0.069				-0.073	-0.07	-0.07
P30-29	-0.037				-0.043	-0.037	-0.038
P28-8	0.005				0.001	0.006	0.005
P28-6	-0.186				-0.218	-0.186	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.203	-0.177	-0.246
Q1-3	0.043	0.0429	0.0429	0.0429	0.042	0.023	0.044
Q2-4	0.047	0.0473	0.0473	0.0473	0.039	0.007	0.048
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.015	-0.039	-0.039
Q2-5	0.028	0.0277	0.0277	0.0277	0.039	-0.012	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.009	-0.026	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.15	-0.16	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.097	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.023	-0.033	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.082	-0.039	-0.072
Q6-9	-0.081	***0.0807***	-0.0807	-0.0807	-0.065	-0.084	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.008	0.001	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.145	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.143	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.095	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.028	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.081	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.047	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.009	0.006	0.007
Q16-17	0.014	0.0148	0.0148	0.0148	0.021	0.014	0.014
Q15-18	0.016				0.022	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.027	-0.028	-0.028
Q10-20	0.037				0.034	0.037	0.037

Q10-17	0.044				0.045	0.044	0.044
Q10-21	0.1				0.106	0.1	0.101
Q10-22	0.046				0.048	0.046	0.046
Q21-22	-0.014				-0.019	-0.014	-0.014
Q15-23	0.029				0.033	0.029	0.03
Q22-24	0.031				0.023	0.03	0.031
Q23-24	0.012				0.013	0.012	0.012
Q24-25	0.02				0.012	0.02	0.019
Q25-26	0.024				0.023	0.024	0.024
Q25-27	-0.004				-0.009	-0.004	-0.006
Q28-27	0.05				0.045	0.05	0.049
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.013	0.017	0.013
Q29-30	0.006				0.001	0.006	0.002
Q8-28	-0.005				-0.008	-0.014	-0.006
Q6-28	0.001				-0.012	-0.005	0
Q2-1	0.345	0.3447	0.3447	0.3447	0.248	0.281	0.344
Q3-1	0.027	0.0262	0.0262	0.0262	0.024	0.046	0.026
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.035	-0.018	-0.056
Q4-3	0.054	0.0547	0.0547	0.0547	0.028	0.055	0.054
Q5-2	0.052	0.0521	0.0521	0.0521	0.055	0.087	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.027	0.042	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.163	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.115	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.017	0.027	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.077	0.033	0.066
Q9-6	0.097	0.0974	0.0974	0.0974	0.082	0.1	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.006	0.012	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.149	0.161	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.05	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.093	-0.096	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.096	0.105	0.105
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.027	-0.022	-0.022
Q15-12	-0.064	-	-0.0634	-	-0.076	-0.063	-0.064

		0.0634		0.0634			
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.046	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.009	-0.006	-0.007
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.021	-0.014	-0.014
Q18-15	-0.015				-0.021	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.027	0.028	0.028
Q20-10	-0.035				-0.032	-0.035	-0.035
Q17-10	-0.044				-0.045	-0.044	-0.044
Q21-10	-0.098				-0.103	-0.098	-0.098
Q22-10	-0.045				-0.047	-0.045	-0.045
Q22-21	0.014				0.019	0.014	0.014
Q23-15	-0.028				-0.032	-0.028	-0.03
Q24-22	-0.03				-0.022	-0.03	-0.03
Q24-23	-0.012				-0.013	-0.012	-0.012
Q25-24	-0.02				-0.012	-0.02	-0.019
Q26-25	-0.023				-0.022	-0.023	-0.024
Q27-25	0.004				0.01	0.004	0.006
Q27-28	-0.037				-0.032	-0.038	-0.036
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.01	-0.013	-0.01
Q30-29	-0.005				-0.001	-0.005	-0.001
Q28-8	-0.038				-0.036	-0.029	-0.038
Q28-6	-0.012				0.002	-0.006	-0.012

Table B-49: 30 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.047	1.044	1.046
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.019	1.02	1.021
V4	1.012	1.0135	1.0135	***-1.0135***	1.009	1.011	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01

V6	1.011	1.0003	1.0003	1.0003	1.008	1.009	1.011
V7	1.003	1.0054	1.0054	1.0054	1.001	1.002	1.003
V8	1.01	1.0116	1.0116	1.0116	1.007	1.007	1.01
V9	1.051	1.0546	1.0546	1.0546	1.042	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.036	1.044	1.045
V11	1.082	1.088	1.088	1.088	1.072	1.081	1.082
V12	1.057	1.0628	1.0628	1.0628	1.053	1.058	1.057
V13	1.071				1.066	1.071	1.071
V14	1.043				1.037	1.043	1.043
V15	1.038				1.032	1.038	1.038
V16	1.045				1.036	1.044	1.045
V17	1.04				1.031	1.039	1.04
V18	1.028				1.023	1.029	1.028
V19	1.026				1.02	1.027	1.026
V20	1.03				1.024	1.03	1.03
V21	1.033				1.024	1.032	1.033
V22	1.034				1.025	1.033	1.034
V23	1.027				1.021	1.027	1.027
V24	1.022				1.016	1.021	1.022
V25	1.018				1.013	1.018	1.018
V26	1				0.997	1	1
V27	1.024				1.02	1.024	1.023
V28	1.007				1.004	1.006	1.007
V29	1.004	1.003	1.003	***-1.003***	1.002	1.004	1.004
V30	0.992				0.995	0.996	0.992
P1	2.61	2.6096	2.6096	2.6096	2.625	2.627	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.384	0.371	0.4
P5	0	0.0002	0.0002	0.0002	-0.005	-0.007	0
P8	0	0.0001	***-0.0001***	0.0001	0.033	0.02	0
P11	0				-0.007	-0.007	0
P3	0				0.006	0.006	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.017	-0.012	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.084	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	-0.004	0.014	0
P9	-0.228	-	-0.2278	-	-0.208	-0.209	-0.228

		0.2278		0.2278			
P10	0	0.0002	0.0002	0.0002	0.015	0.016	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.087	-0.086	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.105	-0.109	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.067	-0.067	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.079	-0.08	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.031	-0.027	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.087	-0.089	-0.09
P18	-0.032				-0.002	-0.003	-0.032
P19	-0.095				-0.131	-0.134	-0.095
P20	-0.022				-0.003	-0.004	-0.022
P21	-0.175				-0.234	-0.237	-0.175
P22	0				0.073	0.081	0
P23	-0.032				-0.032	-0.033	-0.032
P24	-0.087				-0.094	-0.099	-0.087
P25	0				0.003	0.003	0
P26	-0.035				-0.034	-0.034	-0.035
P27	0				0.005	0.006	0
P28	0				-0.057	-0.052	0
P29	-0.024				-0.017	-0.018	-0.024
P30	-0.106				-0.11	-0.113	-0.107
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.2	-0.196	-0.204
Q2	0.561	0.5607	***-0.5607***	0.5607	0.616	0.572	0.561
Q5	0.357	0.3565	0.3565	0.3565	0.376	0.366	0.357
Q8	0.361	0.361	***-0.361***	0.361	0.358	0.314	0.361
Q11	0.161				0.158	0.158	0.161
Q3	-0.105				-0.102	-0.102	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.025	-0.014	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.03	-0.025	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0.002	0.002	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.115	-0.117	-0.109
Q10	0	0	0	0	-0.036	0.01	0

Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.024	-0.016	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.053	-0.05	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.013	-0.013	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.034	-0.035	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.034	-0.026	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.062	-0.065	-0.058
Q18	-0.009				-0.019	-0.021	-0.009
Q19	-0.034				-0.003	-0.004	-0.034
Q20	-0.007				-0.018	-0.019	-0.007
Q21	-0.112				-0.105	-0.103	-0.112
Q22	0				-0.031	-0.02	0
Q23	-0.016				-0.018	-0.019	-0.016
Q24	-0.067				-0.053	-0.059	-0.067
Q25	0				-0.002	-0.002	0
Q26	-0.023				-0.022	-0.022	-0.023
Q27	0				-0.007	-0.003	0
Q28	0				0.011	0.025	0
Q29	-0.009				-0.02	-0.02	-0.009
Q30	-0.019				0.003	-0.001	-0.019
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.749	1.752	1.733
P1-3	0.876	0.8767	0.8767	0.8767	0.876	0.874	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.436	0.431	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.828	0.831	0.822
P2-5	0.824	0.8236	0.8236	0.8236	0.824	0.822	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.599	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.725	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.153	-0.157	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.367	0.371	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.277	0.287	0.295
P6-9	0.277	***-0.2772***	0.2772	0.2772	0.272	0.275	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.157	0.159	0.158
P9-11	0	0.0001	0.0001	0.0001	0.007	0.007	0

P9-10	0.277	0.2774	0.2774	0.2774	0.279	0.284	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.44	0.443	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0.006	0.006	0
P12-14	0.079	0.0789	0.0789	0.0789	0.081	0.081	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.175	0.177	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.074	0.07	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.013	0.013	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.042	0.042	0.037
P15-18	0.06				0.054	0.054	0.06
P18-19	0.028				0.052	0.051	0.028
P19-20	-0.067				-0.08	-0.083	-0.067
P10-20	0.09				0.084	0.088	0.09
P10-17	0.053				0.045	0.047	0.053
P10-21	0.158				0.155	0.156	0.158
P10-22	0.076				0.065	0.065	0.076
P21-22	-0.018				-0.08	-0.081	-0.018
P15-23	0.05				0.053	0.053	0.05
P22-24	0.057				0.058	0.065	0.057
P23-24	0.018				0.021	0.02	0.018
P24-25	-0.012				-0.017	-0.015	-0.012
P25-26	0.035				0.034	0.035	0.035
P25-27	-0.048				-0.048	-0.047	-0.047
P28-27	0.181				0.174	0.175	0.181
P27-29	0.062				0.059	0.06	0.062
P27-30	0.071				0.072	0.073	0.071
P29-30	0.037				0.041	0.042	0.037
P8-28	-0.005				0.009	0.006	-0.005
P6-28	0.187				0.222	0.221	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.696	-1.699	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.843	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.425	-0.421	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.82	-0.822	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.793	-0.794
P6-2	-0.584	-	-0.5844	-	-0.584	-0.58	-0.584

		0.5844		0.5844			
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.719	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.155	0.158	0.15
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.363	-0.368	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.276	-0.286	-0.294
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.272	-0.275	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.157	-0.159	-0.158
P11-9	0	0.0001	0.0001	0.0001	-0.007	-0.007	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.279	-0.284	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.44	-0.443	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	-0.006	-0.006	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.08	-0.081	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.173	-0.174	-0.176
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.073	-0.069	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.013	-0.013	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.042	-0.042	-0.037
P18-15	-0.06				-0.054	-0.054	-0.06
P19-18	-0.028				-0.052	-0.051	-0.028
P20-19	0.067				0.08	0.083	0.068
P20-10	-0.089				-0.083	-0.087	-0.089
P17-10	-0.053				-0.045	-0.047	-0.053
P21-10	-0.157				-0.154	-0.155	-0.157
P22-10	-0.076				-0.065	-0.065	-0.076
P22-21	0.018				0.08	0.082	0.018
P23-15	-0.05				-0.053	-0.053	-0.05
P24-22	-0.057				-0.057	-0.064	-0.057
P24-23	-0.018				-0.02	-0.02	-0.018
P25-24	0.012				0.017	0.015	0.012
P26-25	-0.035				-0.034	-0.034	-0.035

P27-25	0.048				0.048	0.047	0.047
P27-28	-0.181				-0.174	-0.175	-0.181
P29-27	-0.061				-0.058	-0.059	-0.061
P30-27	-0.069				-0.07	-0.072	-0.07
P30-29	-0.037				-0.04	-0.041	-0.037
P28-8	0.005				-0.009	-0.006	0.005
P28-6	-0.186				-0.222	-0.22	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.259	-0.244	-0.247
Q1-3	0.043	0.0429	0.0429	0.0429	0.059	0.048	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.068	0.052	0.048
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.035	-0.035	-0.039
Q2-5	0.028	0.0277	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.034	0.02	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.157	-0.153	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.134	0.124	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.041	-0.029	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.037	-0.072
Q6-9	-0.081	***0.0807***	-0.0807	-0.0807	-0.049	-0.085	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.013	0.001	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.154	-0.153	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.054	0.063	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.151	0.137	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.101	-0.101	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.025	0.025	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.075	0.075	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.052	0.042	0.034
Q14-15	0.006	0.007	0.007	0.007	0.01	0.01	0.007
Q16-17	0.014	0.0148	0.0148	0.0148	0.016	0.015	0.014
Q15-18	0.016				0.017	0.015	0.016
Q18-19	0.006				-0.003	-0.007	0.006
Q19-20	-0.028				-0.006	-0.011	-0.028
Q10-20	0.037				0.026	0.032	0.037

Q10-17	0.044				0.047	0.05	0.044
Q10-21	0.1				0.104	0.103	0.1
Q10-22	0.046				0.049	0.049	0.046
Q21-22	-0.014				-0.003	-0.003	-0.014
Q15-23	0.029				0.031	0.03	0.029
Q22-24	0.031				0.014	0.025	0.031
Q23-24	0.012				0.011	0.01	0.012
Q24-25	0.02				0.016	0.02	0.02
Q25-26	0.024				0.022	0.023	0.024
Q25-27	-0.004				-0.008	-0.005	-0.004
Q28-27	0.05				0.05	0.047	0.051
Q27-29	0.017				0.015	0.017	0.017
Q27-30	0.017				0.007	0.009	0.017
Q29-30	0.006				-0.006	-0.004	0.006
Q8-28	-0.005				-0.008	-0.018	-0.005
Q6-28	0.001				-0.006	-0.014	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.36	0.345	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.01	0.021	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.075	-0.061	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.051	0.052	0.055
Q5-2	0.052	0.0521	0.0521	0.0521	0.051	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	-0.014	-0.001	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.17	0.166	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.15	-0.14	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.035	0.023	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.066	0.032	0.067
Q9-6	0.097	0.0974	0.0974	0.0974	0.064	0.101	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0	0.012	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.158	0.158	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.046	-0.054	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.104	-0.09	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.102	0.102	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.023	-0.023	-0.022
Q15-12	-0.064	-	-0.0634	-	-0.07	-0.071	-0.063

		0.0634		0.0634			
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.05	-0.041	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.01	-0.01	-0.007
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.016	-0.015	-0.014
Q18-15	-0.015				-0.016	-0.015	-0.015
Q19-18	-0.006				0.003	0.007	-0.006
Q20-19	0.028				0.007	0.012	0.028
Q20-10	-0.035				-0.025	-0.031	-0.035
Q17-10	-0.044				-0.046	-0.05	-0.044
Q21-10	-0.098				-0.101	-0.1	-0.098
Q22-10	-0.045				-0.049	-0.048	-0.045
Q22-21	0.014				0.003	0.003	0.014
Q23-15	-0.028				-0.03	-0.03	-0.029
Q24-22	-0.03				-0.014	-0.024	-0.03
Q24-23	-0.012				-0.011	-0.01	-0.012
Q25-24	-0.02				-0.016	-0.02	-0.02
Q26-25	-0.023				-0.022	-0.022	-0.023
Q27-25	0.004				0.009	0.006	0.004
Q27-28	-0.037				-0.038	-0.035	-0.038
Q29-27	-0.015				-0.014	-0.016	-0.015
Q30-27	-0.014				-0.004	-0.006	-0.013
Q30-29	-0.005				0.007	0.005	-0.005
Q28-8	-0.038				-0.035	-0.026	-0.038
Q28-6	-0.012				-0.004	0.004	-0.012

Table B-50: 30 Bus-WLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.048	1.038	1.043
V2	1.045	1.0539	1.0539	1.0539	1.047	1.039	1.043
V3	1.021	1.0207	1.0207	1.0207	1.024	1.045	1.016
V4	1.012	1.0135	1.0135	1.0135	1.015	1.034	1.006
V5	1.01	1.0178	1.0178	1.0178	1.01	1.034	1.008
V6	1.011	1.0003	1.0003	1.0003	1.012	1.034	1

V7	1.003	1.0054	1.0054	1.0054	1.004	1.03	0.997
V8	1.01	1.0116	1.0116	1.0116	1.012	1.035	1
V9	1.051	1.0546	1.0546	1.0546	1.053	1.075	1.042
V10	1.045	1.0316	1.0316	1.0316	1.047	1.068	1.034
V11	1.082	1.088	1.088	1.088	1.084	1.106	1.076
V12	1.057	1.0628	1.0628	1.0628	1.059	1.08	1.049
V13	1.071				1.073	1.093	1.064
V14	1.043				1.044	1.063	1.035
V15	1.038				1.039	1.058	1.028
V16	1.045				1.046	1.066	1.036
V17	1.04				1.042	1.062	1.03
V18	1.028				1.03	1.048	1.021
V19	1.026				1.027	1.045	1.019
V20	1.03				1.032	1.05	1.022
V21	1.033				1.034	1.055	1.017
V22	1.034				1.035	1.055	1.016
V23	1.027				1.029	1.047	1.005
V24	1.022				1.024	1.043	0.97
V25	1.018				1.021	1.039	0.826
V26	1				1.004	1.018	0.868
V27	1.024				1.027	1.048	0.681
V28	1.007				1.009	1.032	0.978
V29	1.004	1.003	1.003	***-1.003***	1.008	1.024	0.05
V30	0.992	0.989	0.989	***-0.989***	0.997	1.012	0.249
P1	2.61	2.6096	***-2.6096***	2.6096	2.224	1.625	2.641
P2	0.4	0.4001	***-0.4001***	0.4001	0.879	1.147	0.416
P5	0	0.0002	0.0002	0.0002	-0.019	0.021	0.017
P8	0	0.0001	0.0001	0.0001	-0.018	-0.044	0.001
P11	0				-0.01	-0.031	-0.001
P3	0				0.011	0.037	0.001
P4	-0.024	-0.0239	-0.0239	-0.0239	0.04	0.448	-0.02
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.049	0.151	-0.082
P7	0	-0.0003	-0.0003	-0.0003	0.005	0.084	-0.026
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.267	-0.326	-0.215

P10	0	0.0002	0.0002	0.0002	-0.012	-0.046	0.011
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.066	-0.086	-0.039
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.122	-0.141	-0.104
P14	-0.062	-0.062	-0.062	-0.062	-0.07	-0.091	-0.056
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.084	-0.1	-0.07
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.055	-0.025
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.094	-0.11	-0.081
P18	-0.032				-0.024	-0.032	-0.018
P19	-0.095				-0.103	-0.109	-0.099
P20	-0.022				-0.026	-0.036	-0.016
P21	-0.175				-0.178	-0.192	-0.155
P22	0				0	-0.01	0.054
P23	-0.032				-0.034	-0.042	-0.002
P24	-0.087				-0.092	-0.098	-0.012
P25	0				0.001	-0.005	-0.115
P26	-0.035				-0.034	-0.039	0.065
P27	0				-0.007	-0.026	0.749
P28	0				-0.032	-0.062	-0.176
P29	-0.024				-0.018	-0.024	0.029
P30	-0.106				-0.117	-0.125	0.214
Q1	-0.204	-0.2042	***0.2042***	-0.2042	-0.178	-0.013	-0.148
Q2	0.561	0.5607	***-0.5607***	0.5607	0.459	-0.335	0.612
Q5	0.357	0.3565	0.3565	0.3565	0.343	0.474	0.379
Q8	0.361	0.361	0.361	0.361	0.37	0.432	0.468
Q11	0.161				0.162	0.165	0.174
Q3	-0.105				-0.105	-0.104	-0.11
Q4	-0.012	-0.012	-0.012	-0.012	-0.002	0.016	-0.008
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.005	0.108	0.011
Q7	0	-0.0001	-0.0001	-0.0001	0.008	0.106	0.098
Q9	-0.109	-0.109	-0.109	-0.109	-0.096	0.004	-0.076
Q10	0	0	0	0	0.002	0.016	0.024
Q12	-0.02	-	-0.0197	-	-0.02	-0.018	-0.004

		0.0197		0.0197			
Q13	-0.075	- 0.0748	-0.0748	- 0.0748	-0.073	-0.07	-0.064
Q14	-0.016	- 0.0158	-0.0158	- 0.0158	-0.012	-0.009	-0.005
Q15	-0.025	- 0.0247	-0.0247	- 0.0247	-0.027	-0.024	-0.011
Q16	-0.018	-0.018	-0.018	-0.018	-0.02	-0.017	-0.014
Q17	-0.058	- 0.0578	-0.0578	- 0.0578	-0.058	-0.056	-0.052
Q18	-0.009				-0.014	-0.017	-0.005
Q19	-0.034				-0.03	-0.033	-0.023
Q20	-0.007				-0.005	-0.01	0.005
Q21	-0.112				-0.113	-0.113	-0.103
Q22	0				-0.003	-0.001	0.05
Q23	-0.016				-0.018	-0.021	0.021
Q24	-0.067				-0.065	-0.068	0.015
Q25	0				0.001	0	0.205
Q26	-0.023				-0.023	-0.03	0.052
Q27	0				0.005	0.016	0.774
Q28	0				0.013	0.082	0.417
Q29	-0.009				-0.014	-0.019	0.051
Q30	-0.019				-0.011	-0.017	0.38
P1-2	1.733	***- 1.7333***	1.7333	1.7333	1.404	1.03	1.752
P1-3	0.876	***- 0.8767***	0.8767	0.8767	0.819	0.595	0.889
P2-4	0.437	0.4364	0.4364	0.4364	0.491	0.429	0.449
P3-4	0.821	0.8213	0.8213	0.8213	0.832	1.028	0.837
P2-5	0.824	0.8236	0.8236	0.8236	0.872	0.859	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.67	0.654	0.625
P4-6	0.721	0.7211	0.7211	0.7211	0.774	0.986	0.755
P5-7	-0.148	- 0.1479	-0.1479	- 0.1479	-0.123	-0.095	-0.13
P6-7	0.381	0.3813	0.3813	0.3813	0.395	0.427	0.35
P6-8	0.296	0.2953	0.2953	0.2953	0.32	0.358	0.314
P6-9	0.277	0.2772	0.2772	0.2772	0.307	0.399	0.26
P6-10	0.158	0.1585	0.1585	0.1585	0.171	0.213	0.15
P9-11	0	0.0001	0.0001	0.0001	0.01	0.031	0.001

P9-10	0.277	0.2774	0.2774	0.2774	0.285	0.322	0.271
P4-12	0.442	0.4421	0.4421	0.4421	0.478	0.598	0.429
P12-13	0	-0.0002	-0.0002	-0.0002	0.011	0.037	0.001
P12-14	0.079	0.0789	0.0789	0.0789	0.085	0.104	0.077
P12-15	0.179	0.1788	0.1788	0.1788	0.185	0.219	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.075	0.096	0.068
P14-15	0.016	0.0159	0.0159	0.0159	0.014	0.013	0.021
P16-17	0.037	0.0372	0.0372	0.0372	0.039	0.04	0.042
P15-18	0.06				0.06	0.069	0.053
P18-19	0.028				0.036	0.036	0.034
P19-20	-0.067				-0.068	-0.073	-0.064
P10-20	0.09				0.095	0.11	0.082
P10-17	0.053				0.055	0.069	0.04
P10-21	0.158				0.161	0.181	0.172
P10-22	0.076				0.078	0.089	0.089
P21-22	-0.018				-0.018	-0.012	0.016
P15-23	0.05				0.052	0.06	0.075
P22-24	0.057				0.059	0.066	0.157
P23-24	0.018				0.019	0.018	0.071
P24-25	-0.012				-0.015	-0.014	0.209
P25-26	0.035				0.035	0.04	-0.063
P25-27	-0.048				-0.049	-0.06	0.13
P28-27	0.181				0.193	0.239	0.085
P27-29	0.062				0.062	0.07	0.495
P27-30	0.071				0.076	0.083	0.425
P29-30	0.037				0.043	0.045	-0.008
P8-28	-0.005				0.001	0.012	0.014
P6-28	0.187				0.225	0.291	0.251
P2-1	-1.681	-1.681	-1.681	-1.681	-1.37	-1.012	-1.699
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.792	-0.58	-0.857
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.478	-0.418	-0.438
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.823	-1.015	-0.828
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.839	-0.826	-0.795
P6-2	-0.584	-	-0.5844	-	-0.646	-0.63	-0.603

		0.5844		0.5844			
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.767	-0.975	-0.748
P7-5	0.15	0.1496	0.1496	0.1496	0.124	0.096	0.132
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.391	-0.422	-0.346
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.319	-0.356	-0.313
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.307	-0.399	-0.26
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.171	-0.213	-0.15
P11-9	0	0.0001	0.0001	0.0001	-0.01	-0.031	-0.001
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.285	-0.322	-0.271
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.478	-0.598	-0.429
P13-12	0	-0.0001	-0.0001	-0.0001	-0.011	-0.037	-0.001
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.084	-0.103	-0.077
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.183	-0.216	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.075	-0.096	-0.067
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.014	-0.012	-0.021
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.039	-0.04	-0.042
P18-15	-0.06				-0.06	-0.068	-0.053
P19-18	-0.028				-0.035	-0.036	-0.034
P20-19	0.067				0.068	0.073	0.064
P20-10	-0.089				-0.094	-0.109	-0.081
P17-10	-0.053				-0.055	-0.069	-0.04
P21-10	-0.157				-0.16	-0.18	-0.17
P22-10	-0.076				-0.077	-0.088	-0.088
P22-21	0.018				0.018	0.012	-0.016
P23-15	-0.05				-0.052	-0.06	-0.073
P24-22	-0.057				-0.058	-0.066	-0.151
P24-23	-0.018				-0.018	-0.018	-0.069
P25-24	0.012				0.015	0.014	-0.182
P26-25	-0.035				-0.034	-0.039	0.065

P27-25	0.048				0.049	0.06	-0.086
P27-28	-0.181				-0.193	-0.239	-0.085
P29-27	-0.061				-0.061	-0.069	0.038
P30-27	-0.069				-0.074	-0.081	0.169
P30-29	-0.037				-0.043	-0.044	0.044
P28-8	0.005				-0.001	-0.012	-0.013
P28-6	-0.186				-0.224	-0.289	-0.248
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.211	0.047	-0.222
Q1-3	0.043	***-0.0429***	0.0429	0.0429	0.033	-0.061	0.074
Q2-4	0.047	0.0473	0.0473	0.0473	0.036	-0.117	0.074
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.024	-0.052	-0.007
Q2-5	0.028	0.0277	0.0277	0.0277	0.037	-0.128	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.004	-0.165	0.06
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.248	-0.079
Q5-7	0.115	0.1151	0.1151	0.1151	0.096	0.063	0.137
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.023	-0.091	-0.083
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.083	-0.147	-0.088
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.079	-0.076	-0.09
Q6-10	0.002	0.0015	0.0015	0.0015	0.003	0.008	0.003
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.158	-0.16	-0.169
Q9-10	0.059	0.059	0.059	0.059	0.06	0.069	0.088
Q4-12	0.144	0.1442	0.1442	0.1442	0.15	0.168	0.145
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.102	-0.109
Q12-14	0.024	0.0242	0.0242	0.0242	0.023	0.022	0.022
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.085
Q12-16	0.033	0.0336	0.0336	0.0336	0.035	0.029	0.038
Q14-15	0.006	0.007	0.007	0.007	0.009	0.01	0.015
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.011	0.023
Q15-18	0.016				0.016	0.019	0.006
Q18-19	0.006				0.002	0.001	0.001
Q19-20	-0.028				-0.028	-0.032	-0.023
Q10-20	0.037				0.035	0.045	0.019

Q10-17	0.044				0.045	0.047	0.03
Q10-21	0.1				0.101	0.103	0.145
Q10-22	0.046				0.046	0.048	0.077
Q21-22	-0.014				-0.015	-0.012	0.039
Q15-23	0.029				0.029	0.03	0.078
Q22-24	0.031				0.028	0.033	0.163
Q23-24	0.012				0.01	0.008	0.097
Q24-25	0.02				0.017	0.02	0.303
Q25-26	0.024				0.024	0.031	-0.048
Q25-27	-0.004				-0.006	-0.011	0.509
Q28-27	0.05				0.046	0.061	0.841
Q27-29	0.017				0.017	0.024	0.938
Q27-30	0.017				0.014	0.019	0.825
Q29-30	0.006				0.002	0.003	-0.018
Q8-28	-0.005				-0.008	-0.011	0.085
Q6-28	0.001				-0.013	-0.065	0.297
Q2-1	0.345	0.3447	0.3447	0.3447	0.255	-0.051	0.323
Q3-1	0.027	0.0262	0.0262	0.0262	0.022	0.068	-0.001
Q4-2	-0.055	- 0.0549	-0.0549	- 0.0549	-0.036	0.109	-0.079
Q4-3	0.054	0.0547	0.0547	0.0547	0.04	0.08	0.024
Q5-2	0.052	0.0521	0.0521	0.0521	0.057	0.221	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.029	0.198	-0.034
Q6-4	0.172	0.1721	0.1721	0.1721	0.175	0.279	0.094
Q7-5	-0.131	- 0.1312	-0.1312	- 0.1312	-0.114	-0.083	-0.153
Q7-6	0.022	0.0224	0.0224	0.0224	0.018	0.087	0.077
Q8-6	0.067	0.0665	0.0665	0.0665	0.078	0.144	0.083
Q9-6	0.097	0.0974	0.0974	0.0974	0.099	0.107	0.105
Q10-6	0.011	0.0109	0.0109	0.0109	0.012	0.014	0.008
Q11-9	0.161	0.1608	0.1608	0.1608	0.162	0.165	0.174
Q10-9	-0.051	- 0.0507	-0.0507	- 0.0507	-0.052	-0.059	-0.079
Q12-4	-0.097	- 0.0971	-0.0971	- 0.0971	-0.096	-0.087	-0.1
Q13-12	0.105	0.1047	0.1047	0.1047	0.105	0.104	0.11
Q14-12	-0.022	- 0.0222	-0.0222	- 0.0222	-0.021	-0.02	-0.021
Q15-12	-0.064	-	-0.0634	-	-0.064	-0.063	-0.081

		0.0634		0.0634			
Q16-12	-0.032	- 0.0324	-0.0324	- 0.0324	-0.033	-0.028	-0.037
Q15-14	-0.006	- 0.0062	-0.0062	- 0.0062	-0.009	-0.01	-0.015
Q17-16	-0.014	- 0.0138	-0.0138	- 0.0138	-0.013	-0.01	-0.023
Q18-15	-0.015				-0.016	-0.018	-0.005
Q19-18	-0.006				-0.002	-0.001	0
Q20-19	0.028				0.028	0.033	0.023
Q20-10	-0.035				-0.033	-0.043	-0.018
Q17-10	-0.044				-0.045	-0.046	-0.03
Q21-10	-0.098				-0.098	-0.101	-0.141
Q22-10	-0.045				-0.045	-0.046	-0.075
Q22-21	0.014				0.015	0.012	-0.039
Q23-15	-0.028				-0.028	-0.029	-0.076
Q24-22	-0.03				-0.027	-0.032	-0.155
Q24-23	-0.012				-0.01	-0.008	-0.093
Q25-24	-0.02				-0.017	-0.019	-0.256
Q26-25	-0.023				-0.023	-0.03	0.052
Q27-25	0.004				0.006	0.012	-0.424
Q27-28	-0.037				-0.032	-0.04	-0.564
Q29-27	-0.015				-0.015	-0.022	0.069
Q30-27	-0.014				-0.01	-0.015	0.294
Q30-29	-0.005				-0.001	-0.002	0.086
Q28-8	-0.038				-0.036	-0.034	-0.125
Q28-6	-0.012				0.003	0.056	-0.3

Table B-51: 30 Bus-IRLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.045	1.032	1.046
V2	1.045	1.0539	1.0539	1.0539	1.046	1.031	1.045
V3	1.021	1.0207	1.0207	1.0207	1.022	1.021	1.021
V4	1.012	1.0135	1.0135	1.0135	1.013	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.011	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.012	1.011	1.011

V7	1.003	1.0054	1.0054	1.0054	1.004	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.011	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.053	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.047	1.046	1.045
V11	1.082	1.088	1.088	1.088	1.084	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.059	1.058	1.057
V13	1.071				1.072	1.071	1.071
V14	1.043				1.044	1.043	1.043
V15	1.038				1.039	1.038	1.038
V16	1.045				1.046	1.045	1.045
V17	1.04				1.042	1.04	1.04
V18	1.028				1.03	1.029	1.028
V19	1.026				1.027	1.026	1.026
V20	1.03				1.031	1.03	1.03
V21	1.033				1.034	1.033	1.033
V22	1.034				1.035	1.034	1.033
V23	1.027				1.029	1.028	1.027
V24	1.022				1.023	1.022	1.022
V25	1.018				1.019	1.018	1.017
V26	1				1.002	1	1
V27	1.024				1.025	1.024	1.023
V28	1.007				1.008	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.005	1.004	1.003
V30	0.992	0.989	0.989	***-0.989***	0.994	0.992	0.992
P1	2.61	2.6096	***-2.6096***	2.6096	2.532	2.567	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.486	0.431	0.4
P5	0	0.0002	0.0002	0.0002	-0.002	0.002	0
P8	0	0.0001	0.0001	0.0001	0.001	0	0
P11	0				-0.003	0	0
P3	0				0.002	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.013	-0.022	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.074	-0.074	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0.003	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.23	-0.227	-0.228

P10	0	0.0002	0.0002	0.0002	-0.004	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.06	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.115	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.064	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.096	-0.095	-0.095
P20	-0.022				-0.023	-0.022	-0.022
P21	-0.175				-0.176	-0.175	-0.175
P22	0				0	0	0
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				-0.003	0	0
P28	0				0.001	0	0
P29	-0.024				-0.021	-0.024	-0.024
P30	-0.106				-0.111	-0.106	-0.106
Q1	-0.204	-0.2042	***0.2042***	-0.2042	-0.209	0.056	-0.204
Q2	0.561	0.5607	***-0.5607***	0.5607	0.539	0.06	0.561
Q5	0.357	0.3565	0.3565	0.3565	0.356	0.425	0.357
Q8	0.361	0.361	0.361	0.361	0.362	0.364	0.361
Q11	0.161				0.162	0.161	0.161
Q3	-0.105				-0.104	-0.105	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.009	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.012	0.065	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0.002	0.074	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.107	-0.104	-0.109
Q10	0	0	0	0	0.002	0	0
Q12	-0.02	-	-0.0197	-	-0.02	-0.02	-0.02

		0.0197		0.0197			
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.074	-0.075	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.006	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0.001	0	0
Q28	0				0.001	0.002	0
Q29	-0.009				-0.011	-0.009	-0.009
Q30	-0.019				-0.016	-0.019	-0.019
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.668	1.692	1.733
P1-3	0.876	***-0.8767***	0.8767	0.8767	0.864	0.875	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.446	0.435	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.822	0.822
P2-5	0.824	0.8236	0.8236	0.8236	0.829	0.822	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.614	0.6	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.725	0.722	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.144	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.379	0.381	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.295	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.286	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.162	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0.003	0	0

P9-10	0.277	0.2774	0.2774	0.2774	0.278	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.45	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0.002	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.08	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.18	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.073	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.015	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.068	-0.067	-0.067
P10-20	0.09				0.091	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.159	0.158	0.158
P10-22	0.076				0.077	0.076	0.076
P21-22	-0.018				-0.018	-0.018	-0.018
P15-23	0.05				0.051	0.051	0.051
P22-24	0.057				0.058	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.047	-0.048	-0.047
P28-27	0.181				0.186	0.181	0.181
P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.073	0.071	0.071
P29-30	0.037				0.04	0.037	0.037
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.189	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.62	-1.643	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.834	-0.844	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.435	-0.425	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.799	-0.792	-0.794
P6-2	-0.584	-	-0.5844	-	-0.594	-0.58	-0.584

		0.5844		0.5844			
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.718	-0.716	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.146	0.15	0.15
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.375	-0.377	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.295	-0.294	-0.295
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.286	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.162	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	-0.003	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.278	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.45	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	-0.002	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.079	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.178	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.015	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.09	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.018	0.018	0.018
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035

P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.186	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.072	-0.07	-0.069
P30-29	-0.037				-0.04	-0.037	-0.037
P28-8	0.005				0.005	0.005	0.005
P28-6	-0.186				-0.189	-0.186	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.246	0.013	-0.247
Q1-3	0.043	***-0.0429***	0.0429	0.0429	0.037	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.043	-0.035	0.048
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.038	-0.038	-0.039
Q2-5	0.028	0.0277	0.0277	0.0277	0.026	-0.041	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.01	-0.066	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.112	0.111	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.027	-0.029	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.073	-0.075	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.083	-0.082	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.001	0.001	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.157	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.058	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.143	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.067	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.033	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.007	0.006	0.007
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037

Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.03	0.031	0.031
Q23-24	0.012				0.012	0.012	0.013
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.049	0.05	0.051
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.015	0.016	0.017
Q29-30	0.006				0.004	0.006	0.006
Q8-28	-0.005				-0.006	-0.006	-0.005
Q6-28	0.001				-0.001	-0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.332	0.076	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.029	0.026	0.027
Q4-2	-0.055	- 0.0549	-0.0549	- 0.0549	-0.05	0.027	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.054	0.054
Q5-2	0.052	0.0521	0.0521	0.0521	0.054	0.124	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.012	0.087	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	- 0.1312	-0.1312	- 0.1312	-0.129	-0.127	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.024	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.068	0.069	0.066
Q9-6	0.097	0.0974	0.0974	0.0974	0.1	0.098	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.012	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.162	0.161	0.161
Q10-9	-0.051	- 0.0507	-0.0507	- 0.0507	-0.051	-0.05	-0.051
Q12-4	-0.097	- 0.0971	-0.0971	- 0.0971	-0.096	-0.096	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.105	0.104
Q14-12	-0.022	- 0.0222	-0.0222	- 0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-	-0.0634	-	-0.063	-0.063	-0.064

		0.0634		0.0634			
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.007	-0.006	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.028	-0.029
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.019	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.005	0.004	0.004
Q27-28	-0.037				-0.036	-0.037	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.012	-0.013	-0.014
Q30-29	-0.005				-0.004	-0.005	-0.005
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.011	-0.01	-0.012

Table B-52: 30 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.046	1.043	1.045
V2	1.045	1.0539	1.0539	1.0539	1.045	1.044	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.02	1.021
V4	1.012	1.0135	1.0135	1.0135	1.012	1.011	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.009	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.01	1.011

V7	1.003	1.0054	1.0054	1.0054	1.003	1.002	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.009	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.05	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.044	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.081	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.042	1.043
V15	1.038				1.038	1.037	1.038
V16	1.045				1.045	1.044	1.045
V17	1.04				1.04	1.039	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.024	1.026
V20	1.03				1.03	1.029	1.03
V21	1.033				1.033	1.031	1.033
V22	1.034				1.034	1.033	1.034
V23	1.027				1.027	1.026	1.027
V24	1.022				1.022	1.02	1.022
V25	1.018				1.018	1.017	1.018
V26	1				1	0.999	1
V27	1.024				1.023	1.022	1.023
V28	1.007				1.007	1.005	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.003	1.003
V30	0.992	0.989	0.989	***-0.989***	0.992	0.991	0.992
P1	2.61	2.6096	***-2.6096***	2.6096	2.609	2.629	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.4	0.365	0.4
P5	0	0.0002	0.0002	0.0002	0	-0.009	0
P8	0	0.0001	0.0001	0.0001	0	0.033	0
P11	0				0	-0.007	0
P3	0				0	0.006	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.016	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.074	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0.012	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.207	-0.228

P10	0	0.0002	0.0002	0.0002	0	0.016	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.083	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.113	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.068	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.078	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.026	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.087	-0.09
P18	-0.032				-0.032	0.002	-0.032
P19	-0.095				-0.095	-0.146	-0.095
P20	-0.022				-0.022	0.001	-0.022
P21	-0.175				-0.175	-0.235	-0.175
P22	0				0	0.079	0
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.101	-0.087
P25	0				0	0.004	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0.008	0
P28	0				0	-0.06	0
P29	-0.024				-0.024	-0.014	-0.024
P30	-0.106				-0.106	-0.118	-0.106
Q1	-0.204	-0.2042	***0.2042***	-0.2042	-0.204	-0.184	-0.204
Q2	0.561	0.5607	***-0.5607***	0.5607	0.561	0.554	0.561
Q5	0.357	0.3565	0.3565	0.3565	0.357	0.359	0.357
Q8	0.361	0.361	0.361	0.361	0.361	0.36	0.361
Q11	0.161				0.161	0.161	0.161
Q3	-0.105				-0.104	-0.105	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.025	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	-0.001	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.112	-0.109
Q10	0	0	0	0	0	0.001	0
Q12	-0.02	-	-0.0197	-	-0.02	-0.012	-0.02

		0.0197		0.0197			
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.063	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.013	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.031	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.023	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.06	-0.058
Q18	-0.009				-0.009	-0.01	-0.009
Q19	-0.034				-0.034	-0.03	-0.034
Q20	-0.007				-0.007	-0.01	-0.007
Q21	-0.112				-0.112	-0.116	-0.112
Q22	0				0	-0.006	0
Q23	-0.016				-0.016	-0.017	-0.016
Q24	-0.067				-0.067	-0.063	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0
Q28	0				0	0	0
Q29	-0.009				-0.009	-0.014	-0.009
Q30	-0.019				-0.019	-0.012	-0.019
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.733	1.755	1.733
P1-3	0.876	***-0.8767***	0.8767	0.8767	0.876	0.875	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.437	0.43	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.828	0.822
P2-5	0.824	0.8236	0.8236	0.8236	0.824	0.821	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.598	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.723	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.159	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.372	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.278	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.277	0.275	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.159	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0.007	0

P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.284	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0.006	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.081	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.175	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.068	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.013	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.042	0.037
P15-18	0.06				0.06	0.055	0.06
P18-19	0.028				0.028	0.056	0.028
P19-20	-0.067				-0.067	-0.09	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.046	0.053
P10-21	0.158				0.158	0.157	0.158
P10-22	0.076				0.076	0.066	0.076
P21-22	-0.018				-0.018	-0.079	-0.018
P15-23	0.05				0.05	0.053	0.05
P22-24	0.057				0.057	0.066	0.057
P23-24	0.018				0.018	0.021	0.018
P24-25	-0.012				-0.012	-0.015	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.047	-0.046	-0.047
P28-27	0.181				0.181	0.174	0.181
P27-29	0.062				0.062	0.06	0.062
P27-30	0.071				0.071	0.076	0.071
P29-30	0.037				0.037	0.045	0.037
P8-28	-0.005				-0.005	0.01	-0.005
P6-28	0.187				0.187	0.225	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.701	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.844	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.42	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.819	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.792	-0.794
P6-2	-0.584	-	-0.5844	-	-0.584	-0.579	-0.584

		0.5844		0.5844			
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.717	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.15	0.161	0.15
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.377	-0.368	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.295	-0.277	-0.295
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.275	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.159	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	-0.007	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.284	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	-0.006	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.08	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.173	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.067	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.013	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.042	-0.037
P18-15	-0.06				-0.06	-0.054	-0.06
P19-18	-0.028				-0.028	-0.056	-0.028
P20-19	0.067				0.068	0.09	0.068
P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.046	-0.053
P21-10	-0.157				-0.157	-0.156	-0.157
P22-10	-0.076				-0.076	-0.066	-0.076
P22-21	0.018				0.018	0.079	0.018
P23-15	-0.05				-0.05	-0.053	-0.05
P24-22	-0.057				-0.057	-0.066	-0.057
P24-23	-0.018				-0.018	-0.021	-0.018
P25-24	0.012				0.012	0.015	0.012
P26-25	-0.035				-0.035	-0.035	-0.035

P27-25	0.048				0.047	0.046	0.047
P27-28	-0.181				-0.181	-0.174	-0.181
P29-27	-0.061				-0.061	-0.059	-0.061
P30-27	-0.069				-0.07	-0.074	-0.07
P30-29	-0.037				-0.037	-0.044	-0.037
P28-8	0.005				0.005	-0.01	0.005
P28-6	-0.186				-0.186	-0.224	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.247	-0.234	-0.247
Q1-3	0.043	***-0.0429***	0.0429	0.0429	0.043	0.05	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.048	0.049	0.047
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.039	-0.044	-0.039
Q2-5	0.028	0.0277	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.015	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.16	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.118	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.072	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.06	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.141	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.072	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.038	0.034
Q14-15	0.006	0.007	0.007	0.007	0.007	0.01	0.007
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.015	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.005	0.006
Q19-20	-0.028				-0.028	-0.025	-0.028
Q10-20	0.037				0.037	0.038	0.037

Q10-17	0.044				0.044	0.046	0.044
Q10-21	0.1				0.1	0.105	0.1
Q10-22	0.046				0.046	0.048	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.03	0.029
Q22-24	0.031				0.031	0.028	0.031
Q23-24	0.012				0.012	0.012	0.012
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.051	0.049	0.051
Q27-29	0.017				0.017	0.018	0.017
Q27-30	0.017				0.017	0.014	0.017
Q29-30	0.006				0.006	0.002	0.006
Q8-28	-0.005				-0.005	-0.006	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.345	0.335	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.019	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.058	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.055	0.06	0.055
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.051	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.004	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.173	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.134	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.067	0.066	0.066
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.161	0.161	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.052	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.094	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.105	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.023	-0.022
Q15-12	-0.064	-	-0.0634	-	-0.063	-0.068	-0.063

		0.0634		0.0634			
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.037	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.006	-0.01	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.016	-0.015
Q19-18	-0.006				-0.006	-0.005	-0.006
Q20-19	0.028				0.028	0.026	0.028
Q20-10	-0.035				-0.035	-0.036	-0.035
Q17-10	-0.044				-0.044	-0.046	-0.044
Q21-10	-0.098				-0.098	-0.102	-0.098
Q22-10	-0.045				-0.045	-0.047	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.029	-0.029	-0.029
Q24-22	-0.03				-0.03	-0.027	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.005	0.004
Q27-28	-0.037				-0.038	-0.037	-0.038
Q29-27	-0.015				-0.015	-0.016	-0.015
Q30-27	-0.014				-0.013	-0.011	-0.014
Q30-29	-0.005				-0.005	-0.001	-0.005
Q28-8	-0.038				-0.038	-0.037	-0.038
Q28-6	-0.012				-0.012	-0.011	-0.012

Table B-53: 30 Bus-WLS Estimated values for partial redundancy with SCADA & PMU having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	1.0135	1.012	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011

V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.027	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.024	1.024	1.024
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.004
V30	0.992				0.992	0.992	0.992
P1	2.61	2.6096	2.6096	2.6096	2.61	2.61	2.61
P2	0.4	0.4001	0.4001	0.4001	0.399	0.399	0.4
P5	0	0.0002	-0.0002	0.0002	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112

P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.176	-0.176	-0.176
P22	0				0.001	0.001	0.001
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	0
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.024
P30	-0.106				-0.106	-0.106	-0.106
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.204	-0.204	-0.204
Q2	0.561	0.5607	0.5607	0.5607	0.56	0.56	0.56
Q5	0.357	0.3565	-0.3565	0.3565	0.357	0.357	0.357
Q8	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Q11	0.161				0.16	0.16	0.16
Q3	-0.105				-0.104	-0.104	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	0	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109
Q10	0	0	0	0	0.001	0.001	0.001
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.021	-0.021	-0.021
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.075	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007

Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0
Q28	0				0	0	0
Q29	-0.009				-0.009	-0.009	-0.01
Q30	-0.019				-0.019	-0.019	-0.019
P1-2	1.733	1.7333	1.7333	1.7333	1.733	1.733	1.733
P1-3	0.876	0.8767	0.8767	0.8767	0.876	0.876	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.436	0.436	0.436
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.822	0.822
P2-5	0.824	***-0.8236***	0.8236	0.8236	0.824	0.824	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.381	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158

P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.019	-0.019	-0.019
P15-23	0.05				0.05	0.05	0.05
P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.048	-0.048	-0.048
P28-27	0.181				0.181	0.181	0.181
P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.037
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.149	0.149	0.149
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.378	-0.378
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.294	-0.294	-0.294
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028

P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.019	0.019	0.019
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.037
P28-8	0.005				0.005	0.005	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	-0.2473	-0.2473	-0.2473	-0.247	-0.247	-0.247
Q1-3	0.043	0.0429	0.0429	0.0429	0.043	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.047
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.038	-0.038	-0.038
Q2-5	0.028	***-0.0277***	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.014	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.072	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.034	0.034

Q14-15	0.006	0.007	0.007	0.007	0.006	0.006	0.006
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.012	0.012
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.05
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0.006
Q8-28	-0.005				-0.005	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.345	0.345	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.054	0.054
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.067	0.067	0.067
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.16	0.16	0.16
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097

Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.064	-0.064
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.006	-0.006	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.028	-0.028
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.037	-0.037	-0.037
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.014	-0.014	-0.014
Q30-29	-0.005				-0.005	-0.005	-0.005
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.012	-0.012
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.131
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.193
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.224
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.206

Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246
Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274
Va11	-0.2461	-14.1335	-14.1335	-14.1335	-0.246	-0.246	-0.246
Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261
Va13	-0.2606				-0.261	-0.261	-0.261
Va14	-0.2762				-0.276	-0.276	-0.276
Va15	-0.2778				-0.278	-0.278	-0.278
Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.292
Va30	-0.3079				-0.308	-0.308	-0.308

Table B-54: 30 Bus-IRLS Estimated values for partial redundancy with SCADA & PMU having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	1.0135	1.012	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003

V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.027	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.024	1.024	1.023
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.001
V30	0.992				0.992	0.992	0.992
P1	2.61	2.6096	2.6096	2.6096	2.61	2.61	2.61
P2	0.4	0.4001	0.4001	0.4001	0.399	0.399	0.4
P5	0	0.0002	-0.0002	0.0002	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062

P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.176	-0.176	-0.175
P22	0				0.001	0.001	0
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	-0.002
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.021
P30	-0.106				-0.106	-0.106	-0.107
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.204	-0.204	-0.204
Q2	0.561	0.5607	0.5607	0.5607	0.56	0.56	0.561
Q5	0.357	0.3565	-0.3565	0.3565	0.357	0.357	0.357
Q8	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Q11	0.161				0.16	0.16	0.161
Q3	-0.105				-0.104	-0.104	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	0	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109
Q10	0	0	0	0	0.001	0.001	0
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.021	-0.021	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.075	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112

Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0.007
Q28	0				0	0	0
Q29	-0.009				-0.009	-0.009	-0.022
Q30	-0.019				-0.019	-0.019	-0.013
P1-2	1.733	1.7333	1.7333	1.7333	1.733	1.733	1.733
P1-3	0.876	0.8767	0.8767	0.8767	0.876	0.876	0.877
P2-4	0.437	0.4364	0.4364	0.4364	0.436	0.436	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.822	0.822
P2-5	0.824	***-0.8236***	0.8236	0.8236	0.824	0.824	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.381	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158
P10-22	0.076				0.076	0.076	0.076

P21-22	-0.018				-0.019	-0.019	-0.018
P15-23	0.05				0.05	0.05	0.05
P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.048	-0.048	-0.047
P28-27	0.181				0.181	0.181	0.181
P27-29	0.062				0.062	0.062	0.06
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.038
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.149	0.149	0.15
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.378	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.294	-0.294	-0.295
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068

P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.019	0.019	0.018
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.06
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.038
P28-8	0.005				0.005	0.005	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	-0.2473	-0.2473	-0.2473	-0.247	-0.247	-0.247
Q1-3	0.043	0.0429	0.0429	0.0429	0.043	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.048
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.038	-0.038	-0.039
Q2-5	0.028	***-0.0277***	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.014	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.072	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.006	0.006	0.006

Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.012	0.013
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.051
Q27-29	0.017				0.017	0.017	0.024
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0
Q8-28	-0.005				-0.005	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.345	0.345	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.054	0.055
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.067	0.067	0.067
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.16	0.16	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.104

Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.064	-0.063
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.006	-0.006	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.028	-0.029
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.037	-0.037	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.022
Q30-27	-0.014				-0.014	-0.014	-0.013
Q30-29	-0.005				-0.005	-0.005	0.001
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.012	-0.012
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.131
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.193
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.224
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.206
Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246

Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274
Va11	-0.2461	-14.1335	-14.1335	-14.1335	-0.246	-0.246	-0.246
Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261
Va13	-0.2606				-0.261	-0.261	-0.261
Va14	-0.2762				-0.276	-0.276	-0.276
Va15	-0.2778				-0.278	-0.278	-0.278
Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.291
Va30	-0.3079				-0.308	-0.308	-0.308

Table B-55: 30 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having single error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	1.0135	1.012	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051

V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.028	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.024	1.024	1.023
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.003
V30	0.992				0.992	0.992	0.992
P1	2.61	2.6096	2.6096	2.6096	2.61	2.61	2.61
P2	0.4	0.4001	0.4001	0.4001	0.399	0.4	0.4
P5	0	0.0002	-0.0002	0.0002	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0.001	0	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035

P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.176	-0.176	-0.176
P22	0				0.001	0.001	0.001
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	0
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.024
P30	-0.106				-0.106	-0.106	-0.106
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.205	-0.204	-0.205
Q2	0.561	0.5607	0.5607	0.5607	0.56	0.561	0.56
Q5	0.357	0.3565	-0.3565	0.3565	0.357	0.356	0.357
Q8	0.361	0.361	0.361	0.361	0.36	0.361	0.361
Q11	0.161				0.16	0.16	0.16
Q3	-0.105				-0.104	-0.104	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.011	-0.012	-0.011
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0.001	0	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109
Q10	0	0	0	0	0.001	0	0
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.02	-0.02	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.074	-0.075	-0.074
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.015
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016

Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0.001	0	0
Q28	0				0	0	0
Q29	-0.009				-0.009	-0.009	-0.009
Q30	-0.019				-0.019	-0.019	-0.019
P1-2	1.733	1.7333	1.7333	1.7333	1.733	1.733	1.733
P1-3	0.876	0.8767	0.8767	0.8767	0.876	0.876	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.436	0.436	0.436
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.821	0.822
P2-5	0.824	***-0.8236***	0.8236	0.8236	0.824	0.824	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.382	0.381	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.078	0.079	0.078
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158
P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.019	-0.019	-0.019
P15-23	0.05				0.05	0.05	0.05

P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.036	0.036	0.035
P25-27	-0.048				-0.048	-0.048	-0.048
P28-27	0.181				0.181	0.181	0.181
P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.037
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.15	0.15	0.149
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.378	-0.378
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.295	-0.294	-0.295
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.09	-0.089	-0.09
P17-10	-0.053				-0.053	-0.053	-0.053

P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.019	0.019	0.019
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.037
P28-8	0.005				0.006	0.005	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	-0.2473	-0.2473	-0.2473	-0.247	-0.247	-0.247
Q1-3	0.043	0.0429	0.0429	0.0429	0.042	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.047
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.038	-0.039	-0.038
Q2-5	0.028	***-0.0277***	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.013	0.014	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.071	-0.072	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.102	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.033	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.007	0.007	0.007
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016

Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.013	0.012
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.051
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0.006
Q8-28	-0.005				-0.006	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.002
Q2-1	0.345	0.3447	0.3447	0.3447	0.345	0.345	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.054	0.054
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.066	0.066	0.066
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.16	0.16	0.16
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.063	-0.064

Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.007	-0.006	-0.007
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.029	-0.029
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.038	-0.038	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.014	-0.014	-0.014
Q30-29	-0.005				-0.005	-0.005	-0.005
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.013	-0.012	-0.013
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.131
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.193
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.224
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.206
Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246
Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274

Va11	-0.2461	-14.1335	-14.1335	-14.1335	-0.246	-0.246	-0.246
Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261
Va13	-0.2606				-0.261	-0.261	-0.261
Va14	-0.2762				-0.276	-0.276	-0.276
Va15	-0.2778				-0.278	-0.278	-0.278
Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.292
Va30	-0.3079				-0.308	-0.308	-0.308

Table B-56: 30 Bus-WLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.046
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.024
V4	1.012	1.0135	1.0135	***-1.0135***	1.012	1.012	0.991
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.013
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045

V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.058
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.027	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.024	1.024	1.024
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.004
V30	0.992				0.992	0.992	0.992
P1	2.61	2.6096	2.6096	2.6096	2.61	2.61	2.64
P2	0.4	0.4001	***-0.4001***	0.4001	0.4	0.399	0.421
P5	0	0.0002	0.0002	0.0002	0	0	0.004
P8	0	0.0001	***-0.0001***	0.0001	0	0	-0.005
P11	0				0	0	0.001
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.024	0.049
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.331
P7	0	-0.0003	-0.0003	-0.0003	0	0	0.132
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.231
P10	0	0.0002	0.0002	0.0002	0	0	0.003
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.056
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.1
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.063
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.084
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.036
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.089

P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.176	-0.176	-0.175
P22	0				0.001	0.001	0.001
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	0.002
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.024
P30	-0.106				-0.106	-0.106	-0.106
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.204	-0.204	-0.237
Q2	0.561	0.5607	***-0.5607***	0.5607	0.56	0.56	0.684
Q5	0.357	0.3565	0.3565	0.3565	0.357	0.357	0.352
Q8	0.361	0.361	***-0.361***	0.361	0.361	0.361	0.299
Q11	0.161				0.16	0.16	0.16
Q3	-0.105				-0.104	-0.104	-0.1
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	0.629
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-1.352
Q7	0	-0.0001	-0.0001	-0.0001	0	0.001	0.713
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.141
Q10	0	0	0	0	0	0	-0.013
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.021	-0.021	-0.025
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.075	0.033
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.018
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.029
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.021
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067

Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0
Q28	0				0	0	-0.045
Q29	-0.009				-0.009	-0.009	-0.01
Q30	-0.019				-0.019	-0.019	-0.019
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.733	1.734	1.741
P1-3	0.876	0.8767	0.8767	0.8767	0.876	0.876	0.899
P2-4	0.437	0.4364	0.4364	0.4364	0.437	0.436	0.464
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.821	0.915
P2-5	0.824	0.8236	0.8236	0.8236	0.824	0.823	0.822
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.606
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.587
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.145
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.382	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.3
P6-9	0.277	***-0.2772***	0.2772	0.2772	0.277	0.277	0.272
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.156
P9-11	0	0.0001	0.0001	0.0001	0	0	-0.001
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.276
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.433
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.181
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.073
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.157
P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.019	-0.019	-0.019
P15-23	0.05				0.05	0.05	0.05
P22-24	0.057				0.057	0.057	0.057

P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.048	-0.048	-0.048
P28-27	0.181				0.181	0.181	0.179
P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.037
P8-28	-0.005				-0.005	-0.005	-0.006
P6-28	0.187				0.187	0.187	0.186
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.689
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.866
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.451
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.901
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.793
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.586
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.578
P7-5	0.15	0.1496	0.1496	0.1496	0.149	0.149	0.147
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.378	-0.378
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.294	-0.295	-0.299
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.272
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.156
P11-9	0	0.0001	0.0001	0.0001	0	0	0.001
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.276
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.433
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.079
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.179
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.073
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.156

P22-10	-0.076				-0.076	-0.076	-0.075
P22-21	0.018				0.019	0.019	0.019
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.179
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.037
P28-8	0.005				0.005	0.005	0.006
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.247	-0.247	-0.258
Q1-3	0.043	0.0429	0.0429	0.0429	0.043	0.043	0.021
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.168
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.038	-0.039	0.576
Q2-5	0.028	0.0277	0.0277	0.0277	0.028	0.028	0.031
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.013	0.001
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.689
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.114
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	0.005
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.071	-0.01
Q6-9	-0.081	***0.0807***	-0.0807	-0.0807	-0.081	-0.081	-0.068
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.007
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.045
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.099
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.026
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.072
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.034	0.036
Q14-15	0.006	0.007	0.007	0.007	0.006	0.006	0.006
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006

Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.045
Q10-21	0.1				0.1	0.1	0.101
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.012	0.012
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.05
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0.006
Q8-28	-0.005				-0.005	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.046
Q2-1	0.345	0.3447	0.3447	0.3447	0.344	0.344	0.358
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.053
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.166
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.054	-0.542
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.048
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.019
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.715
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.13
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	-0.011
Q8-6	0.067	0.0665	0.0665	0.0665	0.066	0.066	0.004
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.083
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.006
Q11-9	0.161	0.1608	0.1608	0.1608	0.16	0.16	0.16
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.002
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.1
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.024
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.064	-0.067
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.035

Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.006	-0.006	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.028	-0.028
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.037	-0.037	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.014	-0.014	-0.014
Q30-29	-0.005				-0.005	-0.005	-0.005
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.013	-0.057
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.135
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.194
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.225
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.207
Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246
Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274
Va11	-0.2461	-	-14.1335	-	-0.246	-0.246	-0.246

		14.1335		14.1335			
Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261
Va13	-0.2606				-0.261	-0.261	-0.261
Va14	-0.2762				-0.276	-0.276	-0.276
Va15	-0.2778				-0.278	-0.278	-0.278
Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.292
Va30	-0.3079				-0.308	-0.308	-0.308

Table B-57: 30 Bus-IRLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	***-1.0135***	1.012	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082

V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.033
V23	1.027				1.027	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.017
V26	1				1	1	1
V27	1.024				1.024	1.024	1.023
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.001
V30	0.992				0.992	0.992	0.992
P1	2.61	2.6096	2.6096	2.6096	2.61	2.61	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.4	0.399	0.4
P5	0	0.0002	0.0002	0.0002	0	0	0
P8	0	0.0001	***-0.0001***	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032

P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.176	-0.176	-0.175
P22	0				0.001	0.001	0
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	-0.002
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.021
P30	-0.106				-0.106	-0.106	-0.107
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.204	-0.204	-0.204
Q2	0.561	0.5607	***-0.5607***	0.5607	0.56	0.56	0.561
Q5	0.357	0.3565	0.3565	0.3565	0.357	0.357	0.356
Q8	0.361	0.361	***-0.361***	0.361	0.361	0.361	0.361
Q11	0.161				0.16	0.16	0.161
Q3	-0.105				-0.104	-0.104	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	0.001	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109
Q10	0	0	0	0	0	0	0
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.021	-0.021	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.075	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0

Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0.007
Q28	0				0	0	0
Q29	-0.009				-0.009	-0.009	-0.022
Q30	-0.019				-0.019	-0.019	-0.013
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.733	1.734	1.733
P1-3	0.876	0.8767	0.8767	0.8767	0.876	0.876	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.437	0.436	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.821	0.822
P2-5	0.824	0.8236	0.8236	0.8236	0.824	0.823	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.382	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.296
P6-9	0.277	***-0.2772***	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.073
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158
P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.019	-0.019	-0.018
P15-23	0.05				0.05	0.05	0.05
P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018

P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.048	-0.048	-0.047
P28-27	0.181				0.181	0.181	0.181
P27-29	0.062				0.062	0.062	0.06
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.038
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.149	0.149	0.149
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.378	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.294	-0.295	-0.295
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076

P22-21	0.018				0.019	0.019	0.018
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.059
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.038
P28-8	0.005				0.005	0.005	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.247	-0.247	-0.247
Q1-3	0.043	0.0429	0.0429	0.0429	0.043	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.048
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.038	-0.039	-0.039
Q2-5	0.028	0.0277	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.013	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.071	-0.072
Q6-9	-0.081	***0.0807***	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.006	0.006	0.006
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028

Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.012	0.013
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.051
Q27-29	0.017				0.017	0.017	0.024
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0
Q8-28	-0.005				-0.005	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.344	0.344	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.026
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.054	0.055
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.066	0.066	0.067
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.16	0.16	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.064	-0.063
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.006	-0.006	-0.006

Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.028	-0.029
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.037	-0.037	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.022
Q30-27	-0.014				-0.014	-0.014	-0.014
Q30-29	-0.005				-0.005	-0.005	0.001
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.013	-0.012
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.131
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.193
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.224
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.206
Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246
Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274
Va11	-0.2461	-14.1335	-14.1335	-14.1335	-0.246	-0.246	-0.246

Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261
Va13	-0.2606				-0.261	-0.261	-0.261
Va14	-0.2762				-0.276	-0.276	-0.276
Va15	-0.2778				-0.278	-0.278	-0.278
Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.291
Va30	-0.3079				-0.308	-0.308	-0.308

Table B-58: 30 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having double non-interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	***-1.0135***	1.012	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.046	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.058	1.057

V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.029	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.027	1.028	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.024	1.024	1.023
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.004
V30	0.992				0.992	0.992	0.992
P1	2.61	2.6096	2.6096	2.6096	2.61	2.61	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.4	0.399	0.4
P5	0	0.0002	0.0002	0.0002	0	0	0
P8	0	0.0001	***-0.0001***	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.023	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.077	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0.001	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.057	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.061	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.083	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095

P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.176	-0.176	-0.176
P22	0				0.001	0.001	0.001
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	0
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.024
P30	-0.106				-0.106	-0.106	-0.106
Q1	-0.204	-0.2042	-0.2042	-0.2042	-0.205	-0.205	-0.204
Q2	0.561	0.5607	***-0.5607***	0.5607	0.56	0.559	0.561
Q5	0.357	0.3565	0.3565	0.3565	0.357	0.357	0.357
Q8	0.361	0.361	***-0.361***	0.361	0.361	0.359	0.361
Q11	0.161				0.161	0.16	0.161
Q3	-0.105				-0.104	-0.103	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.009	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.017	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	0.001	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109
Q10	0	0	0	0	0	0.001	0
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.02	-0.02	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.074	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.015	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023

Q27	0				0	0	0
Q28	0				0	0	0
Q29	-0.009				-0.009	-0.009	-0.009
Q30	-0.019				-0.019	-0.019	-0.019
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.733	1.733	1.733
P1-3	0.876	0.8767	0.8767	0.8767	0.876	0.876	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.436	0.436	0.436
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.822	0.821
P2-5	0.824	0.8236	0.8236	0.8236	0.824	0.824	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.722	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.382	0.381	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.296
P6-9	0.277	***-0.2772***	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.078	0.078	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158
P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.019	-0.019	-0.019
P15-23	0.05				0.05	0.05	0.05
P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012

P25-26	0.035				0.035	0.036	0.035
P25-27	-0.048				-0.048	-0.048	-0.048
P28-27	0.181				0.181	0.181	0.181
P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.037
P8-28	-0.005				-0.005	-0.006	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.814	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.149	0.149	0.149
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.378	-0.378
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.295	-0.295	-0.294
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.09	-0.09	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.019	0.019	0.019

P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.037
P28-8	0.005				0.005	0.006	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.247	-0.247	-0.247
Q1-3	0.043	0.0429	0.0429	0.0429	0.042	0.042	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.047
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.036	-0.039	-0.039
Q2-5	0.028	0.0277	0.0277	0.0277	0.028	0.027	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.013	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.158	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.07	-0.072
Q6-9	-0.081	***0.0807***	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.155	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.102	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.033	0.034
Q14-15	0.006	0.007	0.007	0.007	0.007	0.007	0.007
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.015	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037

Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.012	0.013
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.051
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0.006
Q8-28	-0.005				-0.005	-0.006	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.345	0.345	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.052	0.055	0.054
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.171	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.023	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.066	0.065	0.067
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.098	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.161	0.16	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.103	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.064	-0.063
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.007	-0.007	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014

Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.029	-0.029	-0.029
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.037	-0.038	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.014	-0.014	-0.014
Q30-29	-0.005				-0.005	-0.005	-0.005
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.013	-0.013
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.131
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.193
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.224
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.206
Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246
Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274
Va11	-0.2461	-14.1335	-14.1335	-14.1335	-0.246	-0.246	-0.246
Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261

Va13	-0.2606				-0.261	-0.261	-0.261
Va14	-0.2762				-0.276	-0.276	-0.276
Va15	-0.2778				-0.278	-0.278	-0.278
Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.292
Va30	-0.3079				-0.308	-0.308	-0.308

Table B-59: 30 Bus-WLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	1.0135	1.012	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071

V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.027	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.024	1.024	1.024
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.004
V30	0.992	0.989	0.989	***-0.989***	0.992	0.992	0.992
P1	2.61	2.6096	***-2.6096***	2.6096	2.609	2.609	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.4	0.401	0.4
P5	0	0.0002	0.0002	0.0002	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.023	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022

P21	-0.175				-0.176	-0.176	-0.176
P22	0				0.001	0.001	0.001
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	0
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.024
P30	-0.106				-0.106	-0.106	-0.106
Q1	-0.204	-0.2042	***0.2042***	-0.2042	-0.204	-0.204	-0.204
Q2	0.561	0.5607	***-0.5607***	0.5607	0.56	0.559	0.56
Q5	0.357	0.3565	0.3565	0.3565	0.357	0.357	0.357
Q8	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Q11	0.161				0.16	0.16	0.16
Q3	-0.105				-0.104	-0.104	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.015	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	0	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109
Q10	0	0	0	0	0.001	0	0.001
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.021	-0.021	-0.021
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.075	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0

Q28	0				0	0	0
Q29	-0.009				-0.009	-0.009	-0.009
Q30	-0.019				-0.019	-0.019	-0.019
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.733	1.733	1.733
P1-3	0.876	***-0.8767***	0.8767	0.8767	0.876	0.876	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.437	0.437	0.436
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.822	0.822
P2-5	0.824	0.8236	0.8236	0.8236	0.824	0.824	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.382	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158
P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.019	-0.019	-0.019
P15-23	0.05				0.05	0.05	0.05
P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035

P25-27	-0.048				-0.048	-0.048	-0.048
P28-27	0.181				0.181	0.181	0.181
P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.037
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.149	0.149	0.149
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.378	-0.378
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.294	-0.295	-0.294
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.019	0.019	0.019
P23-15	-0.05				-0.05	-0.05	-0.05

P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.037
P28-8	0.005				0.005	0.005	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.247	-0.246	-0.247
Q1-3	0.043	***-0.0429***	0.0429	0.0429	0.043	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.047
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.039	-0.039	-0.038
Q2-5	0.028	0.0277	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.014	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.072	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.006	0.006	0.006
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.044

Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.012	0.012
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.05
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0.006
Q8-28	-0.005				-0.005	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.344	0.344	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.055	0.054
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.067	0.066	0.067
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.16	0.16	0.16
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.064	-0.064
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.006	-0.006	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015

Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.028	-0.028
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.037	-0.037	-0.037
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.014	-0.014	-0.014
Q30-29	-0.005				-0.005	-0.005	-0.005
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.012	-0.012
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.131
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.193
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.224
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.206
Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246
Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274
Va11	-0.2461	-14.1335	-14.1335	-14.1335	-0.246	-0.246	-0.246
Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261
Va13	-0.2606				-0.261	-0.261	-0.261

Va14	-0.2762				-0.276	-0.276	-0.276
Va15	-0.2778				-0.278	-0.278	-0.278
Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.292
Va30	-0.3079				-0.308	-0.308	-0.308

Table B-60: 30 Bus-IRLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	1.0135	1.012	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043

V15	1.038				1.038	1.038	1.038
V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.027	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.024	1.024	1.023
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.003
V30	0.992	0.989	0.989	***-0.989***	0.992	0.992	0.992
P1	2.61	2.6096	***-2.6096***	2.6096	2.609	2.61	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.4	0.4	0.4
P5	0	0.0002	0.0002	0.0002	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.176	-0.175	-0.175

P22	0				0.001	0	0
P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	0
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.024
P30	-0.106				-0.106	-0.106	-0.106
Q1	-0.204	-0.2042	***0.2042***	-0.2042	-0.204	-0.203	-0.204
Q2	0.561	0.5607	***-0.5607***	0.5607	0.56	0.559	0.561
Q5	0.357	0.3565	0.3565	0.3565	0.357	0.357	0.357
Q8	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Q11	0.161				0.16	0.16	0.161
Q3	-0.105				-0.104	-0.104	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	0	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109
Q10	0	0	0	0	0.001	0	0
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.021	-0.021	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.075	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0
Q28	0				0	0	0

Q29	-0.009				-0.009	-0.009	-0.009
Q30	-0.019				-0.019	-0.019	-0.019
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.733	1.733	1.733
P1-3	0.876	***-0.8767***	0.8767	0.8767	0.876	0.877	0.877
P2-4	0.437	0.4364	0.4364	0.4364	0.437	0.437	0.437
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.821	0.822
P2-5	0.824	0.8236	0.8236	0.8236	0.824	0.824	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.381	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158
P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.019	-0.019	-0.018
P15-23	0.05				0.05	0.05	0.051
P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.035	0.035	0.035
P25-27	-0.048				-0.048	-0.048	-0.047

P28-27	0.181				0.181	0.181	0.181
P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.037
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.149	0.15	0.15
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.378	-0.377
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.294	-0.294	-0.295
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.019	0.019	0.018
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057

P24-23	-0.018				-0.018	-0.018	-0.018
P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.037
P28-8	0.005				0.005	0.005	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.247	-0.246	-0.247
Q1-3	0.043	***-0.0429***	0.0429	0.0429	0.043	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.048
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.038	-0.038	-0.039
Q2-5	0.028	0.0277	0.0277	0.0277	0.028	0.028	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.014	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.072	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.006	0.006	0.006
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1

Q10-22	0.046				0.046	0.046	0.046
Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.012	0.012	0.013
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.051
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0.006
Q8-28	-0.005				-0.005	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.344	0.344	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.027	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.054	0.055
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.022	0.022	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.067	0.067	0.067
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.16	0.16	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.064	-0.064	-0.063
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.006	-0.006	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006

Q20-19	0.028				0.028	0.028	0.028
Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.028	-0.029
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.037	-0.037	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.014	-0.014	-0.014
Q30-29	-0.005				-0.005	-0.005	-0.006
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.012	-0.012
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.131
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.193
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.224
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.206
Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246
Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274
Va11	-0.2461	-14.1335	-14.1335	-14.1335	-0.246	-0.246	-0.246
Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261
Va13	-0.2606				-0.261	-0.261	-0.261
Va14	-0.2762				-0.276	-0.276	-0.276

Va15	-0.2778				-0.278	-0.278	-0.278
Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.293
Va30	-0.3079				-0.308	-0.308	-0.308

Table B-61: 30 Bus-WLAVIRLS Estimated values for partial redundancy with SCADA & PMU having double interacting error

		Measured Values			Estimated Values		
	Actual	Line	Injection	V mag	Line	Injection	V mag
V1	1.06	1.0562	1.0562	1.0562	1.06	1.06	1.06
V2	1.045	1.0539	1.0539	1.0539	1.045	1.045	1.045
V3	1.021	1.0207	1.0207	1.0207	1.021	1.021	1.021
V4	1.012	1.0135	1.0135	1.0135	1.012	1.012	1.012
V5	1.01	1.0178	1.0178	1.0178	1.01	1.01	1.01
V6	1.011	1.0003	1.0003	1.0003	1.011	1.011	1.011
V7	1.003	1.0054	1.0054	1.0054	1.003	1.003	1.003
V8	1.01	1.0116	1.0116	1.0116	1.01	1.01	1.01
V9	1.051	1.0546	1.0546	1.0546	1.051	1.051	1.051
V10	1.045	1.0316	1.0316	1.0316	1.045	1.045	1.045
V11	1.082	1.088	1.088	1.088	1.082	1.082	1.082
V12	1.057	1.0628	1.0628	1.0628	1.057	1.057	1.057
V13	1.071				1.071	1.071	1.071
V14	1.043				1.043	1.043	1.043
V15	1.038				1.038	1.038	1.038

V16	1.045				1.045	1.045	1.045
V17	1.04				1.04	1.04	1.04
V18	1.028				1.028	1.028	1.028
V19	1.026				1.026	1.026	1.026
V20	1.03				1.03	1.03	1.03
V21	1.033				1.033	1.033	1.033
V22	1.034				1.034	1.034	1.034
V23	1.027				1.027	1.027	1.027
V24	1.022				1.022	1.022	1.022
V25	1.018				1.018	1.018	1.018
V26	1				1	1	1
V27	1.024				1.024	1.024	1.023
V28	1.007				1.007	1.007	1.007
V29	1.004	1.003	1.003	***-1.003***	1.004	1.004	1.004
V30	0.992	0.989	0.989	***-0.989***	0.992	0.992	0.992
P1	2.61	2.6096	***-2.6096***	2.6096	2.61	2.61	2.61
P2	0.4	0.4001	***-0.4001***	0.4001	0.4	0.4	0.4
P5	0	0.0002	0.0002	0.0002	0	0	0
P8	0	0.0001	0.0001	0.0001	0	0	0
P11	0				0	0	0
P3	0				0	0	0
P4	-0.024	-0.0239	-0.0239	-0.0239	-0.024	-0.024	-0.024
P6	-0.076	-0.0761	-0.0761	-0.0761	-0.076	-0.076	-0.076
P7	0	-0.0003	-0.0003	-0.0003	0	0	0
P9	-0.228	-0.2278	-0.2278	-0.2278	-0.228	-0.228	-0.228
P10	0	0.0002	0.0002	0.0002	0	0	0
P12	-0.058	-0.0579	-0.0579	-0.0579	-0.058	-0.058	-0.058
P13	-0.112	-0.1121	-0.1121	-0.1121	-0.112	-0.112	-0.112
P14	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062	-0.062
P15	-0.082	-0.0819	-0.0819	-0.0819	-0.082	-0.082	-0.082
P16	-0.035	-0.0351	-0.0351	-0.0351	-0.035	-0.035	-0.035
P17	-0.09	-0.0901	-0.0901	-0.0901	-0.09	-0.09	-0.09
P18	-0.032				-0.032	-0.032	-0.032
P19	-0.095				-0.095	-0.095	-0.095
P20	-0.022				-0.022	-0.022	-0.022
P21	-0.175				-0.176	-0.175	-0.176
P22	0				0.001	0	0.001

P23	-0.032				-0.032	-0.032	-0.032
P24	-0.087				-0.087	-0.087	-0.087
P25	0				0	0	0
P26	-0.035				-0.035	-0.035	-0.035
P27	0				0	0	0
P28	0				0	0	0
P29	-0.024				-0.024	-0.024	-0.024
P30	-0.106				-0.106	-0.106	-0.106
Q1	-0.204	-0.2042	***0.2042***	-0.2042	-0.204	-0.202	-0.204
Q2	0.561	0.5607	***-0.5607***	0.5607	0.561	0.558	0.561
Q5	0.357	0.3565	0.3565	0.3565	0.357	0.357	0.357
Q8	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Q11	0.161				0.16	0.161	0.161
Q3	-0.105				-0.104	-0.104	-0.104
Q4	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012
Q6	-0.016	-0.0161	-0.0161	-0.0161	-0.016	-0.016	-0.016
Q7	0	-0.0001	-0.0001	-0.0001	0	0	0
Q9	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109	-0.109
Q10	0	0	0	0	0	0	0
Q12	-0.02	-0.0197	-0.0197	-0.0197	-0.02	-0.02	-0.02
Q13	-0.075	-0.0748	-0.0748	-0.0748	-0.075	-0.075	-0.075
Q14	-0.016	-0.0158	-0.0158	-0.0158	-0.016	-0.016	-0.016
Q15	-0.025	-0.0247	-0.0247	-0.0247	-0.025	-0.025	-0.025
Q16	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018	-0.018
Q17	-0.058	-0.0578	-0.0578	-0.0578	-0.058	-0.058	-0.058
Q18	-0.009				-0.009	-0.009	-0.009
Q19	-0.034				-0.034	-0.034	-0.034
Q20	-0.007				-0.007	-0.007	-0.007
Q21	-0.112				-0.112	-0.112	-0.112
Q22	0				0	0	0
Q23	-0.016				-0.016	-0.016	-0.016
Q24	-0.067				-0.067	-0.067	-0.067
Q25	0				0	0	0
Q26	-0.023				-0.023	-0.023	-0.023
Q27	0				0	0	0
Q28	0				0	0	0
Q29	-0.009				-0.009	-0.009	-0.009

Q30	-0.019				-0.019	-0.019	-0.019
P1-2	1.733	***-1.7333***	1.7333	1.7333	1.733	1.733	1.733
P1-3	0.876	***-0.8767***	0.8767	0.8767	0.876	0.876	0.876
P2-4	0.437	0.4364	0.4364	0.4364	0.436	0.436	0.436
P3-4	0.821	0.8213	0.8213	0.8213	0.822	0.822	0.821
P2-5	0.824	0.8236	0.8236	0.8236	0.824	0.824	0.824
P2-6	0.604	0.6042	0.6042	0.6042	0.604	0.604	0.604
P4-6	0.721	0.7211	0.7211	0.7211	0.721	0.721	0.721
P5-7	-0.148	-0.1479	-0.1479	-0.1479	-0.148	-0.148	-0.148
P6-7	0.381	0.3813	0.3813	0.3813	0.381	0.381	0.381
P6-8	0.296	0.2953	0.2953	0.2953	0.296	0.296	0.296
P6-9	0.277	0.2772	0.2772	0.2772	0.277	0.277	0.277
P6-10	0.158	0.1585	0.1585	0.1585	0.158	0.158	0.158
P9-11	0	0.0001	0.0001	0.0001	0	0	0
P9-10	0.277	0.2774	0.2774	0.2774	0.277	0.277	0.277
P4-12	0.442	0.4421	0.4421	0.4421	0.442	0.442	0.442
P12-13	0	-0.0002	-0.0002	-0.0002	0	0	0
P12-14	0.079	0.0789	0.0789	0.0789	0.079	0.079	0.079
P12-15	0.179	0.1788	0.1788	0.1788	0.179	0.179	0.179
P12-16	0.072	0.0727	0.0727	0.0727	0.072	0.072	0.072
P14-15	0.016	0.0159	0.0159	0.0159	0.016	0.016	0.016
P16-17	0.037	0.0372	0.0372	0.0372	0.037	0.037	0.037
P15-18	0.06				0.06	0.06	0.06
P18-19	0.028				0.028	0.028	0.028
P19-20	-0.067				-0.067	-0.067	-0.067
P10-20	0.09				0.09	0.09	0.09
P10-17	0.053				0.053	0.053	0.053
P10-21	0.158				0.158	0.158	0.158
P10-22	0.076				0.076	0.076	0.076
P21-22	-0.018				-0.019	-0.018	-0.019
P15-23	0.05				0.05	0.05	0.05
P22-24	0.057				0.057	0.057	0.057
P23-24	0.018				0.018	0.018	0.018
P24-25	-0.012				-0.012	-0.012	-0.012
P25-26	0.035				0.036	0.035	0.035
P25-27	-0.048				-0.048	-0.048	-0.048
P28-27	0.181				0.181	0.181	0.181

P27-29	0.062				0.062	0.062	0.062
P27-30	0.071				0.071	0.071	0.071
P29-30	0.037				0.037	0.037	0.037
P8-28	-0.005				-0.005	-0.005	-0.005
P6-28	0.187				0.187	0.187	0.187
P2-1	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681	-1.681
P3-1	-0.845	-0.8453	-0.8453	-0.8453	-0.845	-0.845	-0.845
P4-2	-0.426	-0.4263	-0.4263	-0.4263	-0.426	-0.426	-0.426
P4-3	-0.813	-0.8131	-0.8131	-0.8131	-0.813	-0.813	-0.813
P5-2	-0.794	-0.7943	-0.7943	-0.7943	-0.794	-0.794	-0.794
P6-2	-0.584	-0.5844	-0.5844	-0.5844	-0.584	-0.584	-0.584
P6-4	-0.715	-0.7151	-0.7151	-0.7151	-0.715	-0.715	-0.715
P7-5	0.15	0.1496	0.1496	0.1496	0.149	0.15	0.149
P7-6	-0.378	-0.3775	-0.3775	-0.3775	-0.378	-0.377	-0.378
P8-6	-0.295	-0.2946	-0.2946	-0.2946	-0.294	-0.295	-0.294
P9-6	-0.277	-0.2774	-0.2774	-0.2774	-0.277	-0.277	-0.277
P10-6	-0.158	-0.1582	-0.1582	-0.1582	-0.158	-0.158	-0.158
P11-9	0	0.0001	0.0001	0.0001	0	0	0
P10-9	-0.277	-0.2771	-0.2771	-0.2771	-0.277	-0.277	-0.277
P12-4	-0.442	-0.4419	-0.4419	-0.4419	-0.442	-0.442	-0.442
P13-12	0	-0.0001	-0.0001	-0.0001	0	0	0
P14-12	-0.078	-0.0778	-0.0778	-0.0778	-0.078	-0.078	-0.078
P15-12	-0.177	-0.1764	-0.1764	-0.1764	-0.177	-0.177	-0.177
P16-12	-0.072	-0.0718	-0.0718	-0.0718	-0.072	-0.072	-0.072
P15-14	-0.016	-0.0159	-0.0159	-0.0159	-0.016	-0.016	-0.016
P17-16	-0.037	-0.0367	-0.0367	-0.0367	-0.037	-0.037	-0.037
P18-15	-0.06				-0.06	-0.06	-0.06
P19-18	-0.028				-0.028	-0.028	-0.028
P20-19	0.067				0.068	0.068	0.068
P20-10	-0.089				-0.089	-0.089	-0.089
P17-10	-0.053				-0.053	-0.053	-0.053
P21-10	-0.157				-0.157	-0.157	-0.157
P22-10	-0.076				-0.076	-0.076	-0.076
P22-21	0.018				0.019	0.018	0.019
P23-15	-0.05				-0.05	-0.05	-0.05
P24-22	-0.057				-0.057	-0.057	-0.057
P24-23	-0.018				-0.018	-0.018	-0.018

P25-24	0.012				0.012	0.012	0.012
P26-25	-0.035				-0.035	-0.035	-0.035
P27-25	0.048				0.048	0.048	0.048
P27-28	-0.181				-0.181	-0.181	-0.181
P29-27	-0.061				-0.061	-0.061	-0.061
P30-27	-0.069				-0.069	-0.069	-0.069
P30-29	-0.037				-0.037	-0.037	-0.037
P28-8	0.005				0.005	0.005	0.005
P28-6	-0.186				-0.186	-0.186	-0.186
Q1-2	-0.247	***0.2473***	-0.2473	-0.2473	-0.247	-0.245	-0.247
Q1-3	0.043	***-0.0429***	0.0429	0.0429	0.043	0.043	0.043
Q2-4	0.047	0.0473	0.0473	0.0473	0.047	0.047	0.047
Q3-4	-0.039	-0.0386	-0.0386	-0.0386	-0.039	-0.039	-0.039
Q2-5	0.028	0.0277	0.0277	0.0277	0.028	0.027	0.028
Q2-6	0.014	0.0139	0.0139	0.0139	0.014	0.013	0.014
Q4-6	-0.159	-0.1592	-0.1592	-0.1592	-0.159	-0.159	-0.159
Q5-7	0.115	0.1151	0.1151	0.1151	0.115	0.115	0.115
Q6-7	-0.028	-0.0281	-0.0281	-0.0281	-0.028	-0.028	-0.028
Q6-8	-0.072	-0.0719	-0.0719	-0.0719	-0.072	-0.072	-0.072
Q6-9	-0.081	-0.0807	-0.0807	-0.0807	-0.081	-0.081	-0.081
Q6-10	0.002	0.0015	0.0015	0.0015	0.002	0.002	0.002
Q9-11	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156	-0.156
Q9-10	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Q4-12	0.144	0.1442	0.1442	0.1442	0.144	0.144	0.144
Q12-13	-0.103	-0.1031	-0.1031	-0.1031	-0.103	-0.103	-0.103
Q12-14	0.024	0.0242	0.0242	0.0242	0.024	0.024	0.024
Q12-15	0.068	0.0676	0.0676	0.0676	0.068	0.068	0.068
Q12-16	0.033	0.0336	0.0336	0.0336	0.034	0.034	0.034
Q14-15	0.006	0.007	0.007	0.007	0.006	0.007	0.006
Q16-17	0.014	0.0148	0.0148	0.0148	0.014	0.014	0.014
Q15-18	0.016				0.016	0.016	0.016
Q18-19	0.006				0.006	0.006	0.006
Q19-20	-0.028				-0.028	-0.028	-0.028
Q10-20	0.037				0.037	0.037	0.037
Q10-17	0.044				0.044	0.044	0.044
Q10-21	0.1				0.1	0.1	0.1
Q10-22	0.046				0.046	0.046	0.046

Q21-22	-0.014				-0.014	-0.014	-0.014
Q15-23	0.029				0.029	0.029	0.029
Q22-24	0.031				0.031	0.031	0.031
Q23-24	0.012				0.013	0.012	0.013
Q24-25	0.02				0.02	0.02	0.02
Q25-26	0.024				0.024	0.024	0.024
Q25-27	-0.004				-0.004	-0.004	-0.004
Q28-27	0.05				0.05	0.05	0.051
Q27-29	0.017				0.017	0.017	0.017
Q27-30	0.017				0.017	0.017	0.017
Q29-30	0.006				0.006	0.006	0.006
Q8-28	-0.005				-0.005	-0.005	-0.005
Q6-28	0.001				0.001	0.001	0.001
Q2-1	0.345	0.3447	0.3447	0.3447	0.345	0.343	0.345
Q3-1	0.027	0.0262	0.0262	0.0262	0.027	0.026	0.027
Q4-2	-0.055	-0.0549	-0.0549	-0.0549	-0.055	-0.055	-0.055
Q4-3	0.054	0.0547	0.0547	0.0547	0.054	0.055	0.054
Q5-2	0.052	0.0521	0.0521	0.0521	0.052	0.052	0.052
Q6-2	0.006	0.0062	0.0062	0.0062	0.006	0.006	0.006
Q6-4	0.172	0.1721	0.1721	0.1721	0.172	0.172	0.172
Q7-5	-0.131	-0.1312	-0.1312	-0.1312	-0.131	-0.131	-0.131
Q7-6	0.022	0.0224	0.0224	0.0224	0.023	0.022	0.022
Q8-6	0.067	0.0665	0.0665	0.0665	0.067	0.067	0.066
Q9-6	0.097	0.0974	0.0974	0.0974	0.097	0.097	0.097
Q10-6	0.011	0.0109	0.0109	0.0109	0.011	0.011	0.011
Q11-9	0.161	0.1608	0.1608	0.1608	0.16	0.161	0.161
Q10-9	-0.051	-0.0507	-0.0507	-0.0507	-0.051	-0.051	-0.051
Q12-4	-0.097	-0.0971	-0.0971	-0.0971	-0.097	-0.097	-0.097
Q13-12	0.105	0.1047	0.1047	0.1047	0.104	0.104	0.104
Q14-12	-0.022	-0.0222	-0.0222	-0.0222	-0.022	-0.022	-0.022
Q15-12	-0.064	-0.0634	-0.0634	-0.0634	-0.063	-0.063	-0.063
Q16-12	-0.032	-0.0324	-0.0324	-0.0324	-0.032	-0.032	-0.032
Q15-14	-0.006	-0.0062	-0.0062	-0.0062	-0.006	-0.006	-0.006
Q17-16	-0.014	-0.0138	-0.0138	-0.0138	-0.014	-0.014	-0.014
Q18-15	-0.015				-0.015	-0.015	-0.015
Q19-18	-0.006				-0.006	-0.006	-0.006
Q20-19	0.028				0.028	0.028	0.028

Q20-10	-0.035				-0.035	-0.035	-0.035
Q17-10	-0.044				-0.044	-0.044	-0.044
Q21-10	-0.098				-0.098	-0.098	-0.098
Q22-10	-0.045				-0.045	-0.045	-0.045
Q22-21	0.014				0.014	0.014	0.014
Q23-15	-0.028				-0.028	-0.029	-0.029
Q24-22	-0.03				-0.03	-0.03	-0.03
Q24-23	-0.012				-0.012	-0.012	-0.012
Q25-24	-0.02				-0.02	-0.02	-0.02
Q26-25	-0.023				-0.023	-0.023	-0.023
Q27-25	0.004				0.004	0.004	0.004
Q27-28	-0.037				-0.038	-0.038	-0.038
Q29-27	-0.015				-0.015	-0.015	-0.015
Q30-27	-0.014				-0.014	-0.014	-0.014
Q30-29	-0.005				-0.005	-0.005	-0.005
Q28-8	-0.038				-0.038	-0.038	-0.038
Q28-6	-0.012				-0.012	-0.012	-0.012
Va1	0	0.0212	0.0212	0.0212	0	0	0
Va2	-0.0939	-5.4137	-5.4137	-5.4137	-0.094	-0.094	-0.094
Va3	-0.1314	-7.4828	-7.4828	-7.4828	-0.131	-0.131	-0.131
Va4	-0.162	-9.255	-9.255	-9.255	-0.162	-0.162	-0.162
Va5	-0.2469	-14.1758	-14.1758	-14.1758	-0.247	-0.247	-0.247
Va6	-0.1929	-11.0392	-11.0392	-11.0392	-0.193	-0.193	-0.193
Va7	-0.2243	-12.7959	-12.7959	-12.7959	-0.224	-0.224	-0.224
Va8	-0.2059	-11.7405	-11.7405	-11.7405	-0.206	-0.206	-0.206
Va9	-0.2461	-14.0597	-14.0597	-14.0597	-0.246	-0.246	-0.246
Va10	-0.2738	-15.6919	-15.6919	-15.6919	-0.274	-0.274	-0.274
Va11	-0.2461	-14.1335	-14.1335	-14.1335	-0.246	-0.246	-0.246
Va12	-0.2606	-14.9201	-14.9201	-14.9201	-0.261	-0.261	-0.261
Va13	-0.2606				-0.261	-0.261	-0.261
Va14	-0.2762				-0.276	-0.276	-0.276
Va15	-0.2778				-0.278	-0.278	-0.278

Va16	-0.2708				-0.271	-0.271	-0.271
Va17	-0.2766				-0.277	-0.277	-0.277
Va18	-0.2885				-0.289	-0.289	-0.289
Va19	-0.2915				-0.292	-0.292	-0.292
Va20	-0.2881				-0.288	-0.288	-0.288
Va21	-0.2815				-0.282	-0.282	-0.282
Va22	-0.2813				-0.281	-0.281	-0.281
Va23	-0.2846				-0.285	-0.285	-0.285
Va24	-0.2877				-0.288	-0.288	-0.288
Va25	-0.2802				-0.28	-0.28	-0.28
Va26	-0.2875				-0.288	-0.288	-0.288
Va27	-0.2711				-0.271	-0.271	-0.271
Va28	-0.2038				-0.204	-0.204	-0.204
Va29	-0.2925				-0.292	-0.292	-0.292
Va30	-0.3079				-0.308	-0.308	-0.308

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