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Synchrophasor Technology: PMU Applications in Smart Grids

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Abstract: Synchrophasor technology was first introduced in 1980s. Since then, many electric utilities such as American Electric Power (AEP), Bonneville Power Administration (BPA), Southern California Edison (SCE), New York Power Authority (NYPA), as well as universities such as Virginia Polytechnic Institute (VPI), have been conducting R&D to explore and advance the application of synchrophasor technology. The R&D pace has accelerated recently, mainly due to active participation and leadership provided by US Department Of Energy (DOE) and North American Electric Reliability Corporation (NERC). These R&D efforts have shown that the synchrophasor technology has promise to greatly enhance the transmission planning, design & operations functions. This paper provides a brief description of synchrophasor technology and summarizes potential synchrophasor technology applications that can contribute towards the development of a smarter transmission grid.

Keywords: PMU, GPS, WAMS.

I. INTRODUCTION

At present SCADA systems is used for monitoring and control of power system. These SCADA systems provides only steady state view of the power system and takes minutes to deliver a snap shot of a system whose characteristics are changing very vast.

To monitor dynamic behaviour of power systems wide area measurements systems (WAMs) are introduced for monitoring, operation and control. These systems will enable the monitoring, operation and control of power systems in wide geographical area and facilitate the understanding and management of the increasingly complex behaviour exhibited by large power systems.

PMU or synchrophasor is a device which measures the electrical waves on an electricity grid, using a common time source for synchronization. Time synchronization allows synchronized real-time measurements of multiple remote measurement points on the grid. In power engineering, these are also commonly referred to as synchrophasors and are considered one of the most important measuring devices in the future of power systems. A PMU can be a dedicated device, or the PMU function can be incorporated into a protective relay or other device

II. WAMS DATA ACQUISITION SYSTEMS

Data acquisition system comprises of Phasor Measurement Unit (PMU), Phasor Data concentrator (PDC) and communication system.

A. *Phasor Measurement Unit (PMU)*

A phasor is a complex number that represents both the magnitude and phase angle of the sine waves found in AC system as shown in Figure 1.Phasor measurements that occur at the same time are called "synchrophasors" and can be measured precisely by the Phasor measurement units (PMUs).

A phasor measurement unit (PMU) is a microprocessor based device that uses digital signal processing technique to measure 50Hz signal (voltage & current phasor) at sample frequency of 25 or 50 samples per seconds.

Each measurement is time stamped with common time reference (GPS) thus allowing the phasor measurements from different geographical location to be time aligned and provide a comprehensive view of the entire grid at central location.

PMU exchange data on standard IEEE 37.118 protocol.

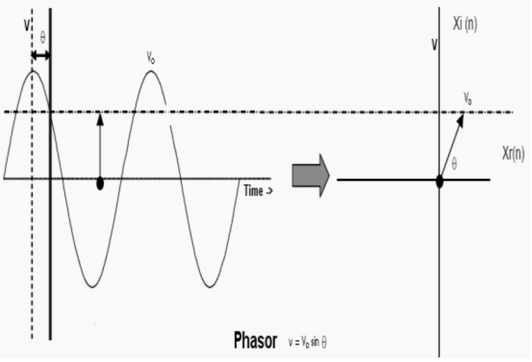

Figure 1 : Phasor representing magnitude & phase angle of sine wave of voltage or current

A typical PMU installation as a part of wide area monitoring system (WAMS) network consists of placement of phasor measurement units (PMU)

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throughout the electricity grid at strategic locations in order to cover the diverse footprint of the grid.

B. Phasor Data Concentrator (PDC)

Phasor data concentrator is placed at central location to gather data from several PMUs, reject bad data and time aligned the time stamped data to create a synchronised data set and transmit this data set to other information system.PDC can also filter the data so that it can be fed to applications that use slow sample data like SCADA/EMS etc. In a hierarchal set up PDCs can also be used to collect data from number of downstream PDCs.

C. Communication Systems

Communication systems in WAMs are responsible for data delivery from data resources to control centres. Therefore it is the main backbone of WAMs architecture. Due to high volume of continuously streaming phasor data communication bandwidth and latency are of high importance in selecting the communication system. Fiber Optic medium which offers high bandwidth & low latency are preferably used to connect PMUs installed at various locations in the network.

III. WAMS ANALYTICS

Information about dynamic behavior of power system can be extracted from raw data obtained from field through PMU. This can be achieved by using computer aided tools that process the raw data and extract usable information from it for intelligent system operation control and planning. Historically these functions are provided by computer aided tools called energy management systems, state estimation, load flow, load forecast and economic dispatch. After introducing phasor measurement units to the power systems phasor data can be used to develop conventional applications and may facilitate development of new analytics/application due to availability of system information at 25 or 50 samples per sec. Some of these applications being developed in India under URTDSM project are:

i. Low frequency oscillation monitoring
ii. Line Parameter Estimation
iii. Online Vulnerability Analysis of Distance Relays
iv. Linear/Dynamic State Estimator
v. CT/CVT calibration
vi. Control Schemes for improving system security.(based on angular, voltage and frequency instability

A. Low frequency oscillation monitoring

Long distance bulk transfer of power may lead to low frequency oscillations. Effective monitoring and analyses are required to control low frequency oscillation. Wide area measurement systems measure all the physical variables of power systems at sub-seconds frequency. This sub-sec. data can be used to compute oscillation frequency using signal analysis technique to determine modes present in the frequency signal along with amplitude and damping ration to analyse the dynamic behaviour of power system.

B. Line Parameter Estimation

Availability of time synchronized data across wide area network has facilitated line parameter data estimation i.e. resistance, reactance and susceptance. Phasor measurement gives an opportunity to calculate positive sequence and zero sequence directly from the measurements. Least square and total least square techniques can be used to estimate line data using phasor measurements.

C. Online Vulnerability Analysis of Distance Relays

Relays in transmission lines are used to isolate line during fault conditions. However due to changing network conditions and over a period of time they become vulnerable to false tripping. WAMs data will enable the tracking of relay characteristic. The apparent impedance trajectory through online PMU data is superimposed on relay characteristic to identify the vulnerability of distance relays to tripping on Power Swing and Load Encroachment so that corrective measures can be taken accordingly.

D. Linear/Dynamic State Estimator

Traditionally, a state estimator uses asynchronous measurements of real and reactive power flows and voltage magnitudes. This makes the state estimator non-linear and hence iterative techniques are required. With PMUs in place, it is possible to synchronously measure voltage and current phasors. As a result, state estimation becomes a linear problem and hence can be solved in a single step. The application will help in determination of bad data, topological error, island in the network, inconsistencies in model, alarms for limit violations and early warnings.

E. CT/CVT Calibration

Instrument transformers, especially CVTs, suffer from drift in characteristics under different operating conditions and over a period of time. The accuracy of these instruments can be evaluated using highly accurate synchrophasor measurement. Bench mark CVT in network can act as reference for calculating other CVT in the network or residual error of State Estimation over a long period of time can be used to identify these errors.

F. Control Schemes for improving system security

Control schemes are fast and high impact schemes to ensure system integrity, or at least minimize the adverse

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effects of a disturbance. Global signals provided by synchrophasors allow for more reliable decision making. Controls, involve automatic actions taken in relatively short time (2-3 Sec) where direct operator intervention may not be feasible.

Trajectories of various parameter line voltage, current and status information of Circuit Breaker (CB) can be continuously monitored and analysed for stability and detect events which may harm the system stability.

Based on the analysis of the evolving trajectories a decision on whether to take an automatic control action and its quantum & location can to be taken by such a scheme.

IV. BENEFITS OF WAMS

Following are some of the benefits of synchrophasors technology:

(i)The Operators are additionally provided with online information at the right time for improved power system operation.

(ii) With real time information on angular separation between the buses and its voltages, transmission load ability in lines may be increased considerably,

Therefore more power can be transmitted on existing lines and construction of new lines can be deferred and also resulting in better utilization of the existing transmission system/assets.

(iii) Early detection of critical conditions in the grid and accordingly taking corrective operational measures to avert grid disturbance.

(iv) Detection of power system oscillation by Synchrophasor technology would enable tuning of PSS/ voltage stabilizer and thereby healthy operation of the machines for a longer period.

(v) Improved knowledge of the power system conditions and corrective actions prevents excessive or unnecessary load shedding.

(vi) The relay operation characteristic can be validated in real time.

(vii) According to the behaviour of the real time system dynamics measured & monitored by the technology, Defence Plan/ Islanding scheme(s) can be designed to avert grid collapse.

(viii) The technology will provide more intelligence on network security and help to improve and maintain the robustness of the grid.

(ix) Objectives of secure, safe, reliable and smart grid operation will be achievable through WAMs technology.

V. CASE STUDIES

Case study-1

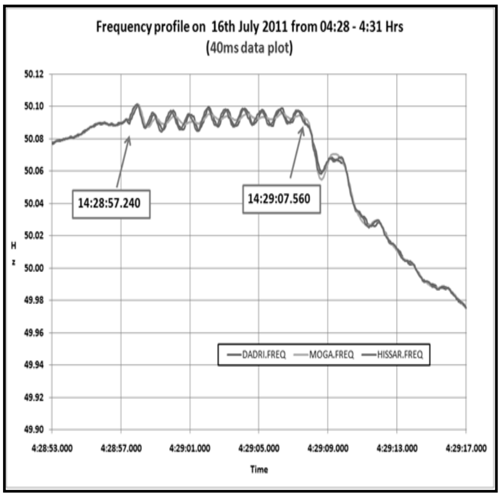

Figure 2: Delay in SPS operating settings at Karcham-Wangtoo unit

PMU pilot Project in Northern Region has helped a lot understanding the new technology and system operation in real time, protection co-ordination, disturbance analysis etc. Case study available to demonstrate better transmission system utilization with reliability for evacuation of Karcham-Wangtoo hydro generation along with Baspa and Jhakri Hydro generation during the monsoon season in 2011 with the help of PMU based measurements. Delay in SPS settings was identified and then rectified (Fig 2). This has facilitated full evacuation of power from Karcham-Wangtoo.

Case study-2

PMU also helped in detection of oscillations on 765kV Tehri-Meerut line (Charged at 400kV) [Figure 3]. Based on PMU data PSS tuning was done to avoid such oscillations.

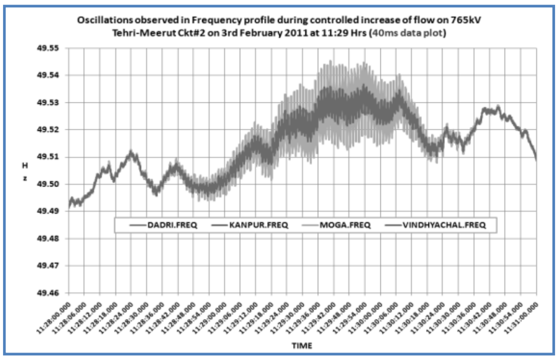

Figure 3: Oscillations in Tehri Unit

Case Study-3

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With the PMU data, operator at load dispatch centre can also know about fault clearing time facilitating to take necessary control action. As shown in Figure 4, double phase fault was cleared in 80 ms. Such information is helpful in preparing sequence of events even in the absence of information field. Better diagnosis of the events are possible.

Figure 4 Fault clearing time visualization through PMU

Case study-4

During foggy winter nights, large number of autoreclosure operation took place as shown in Figure 5and its detection in real time by system operator helped a lot in effective real time monitoring and control of the grid. PMU technology is a kind of Meta tool that will create new tools in future.

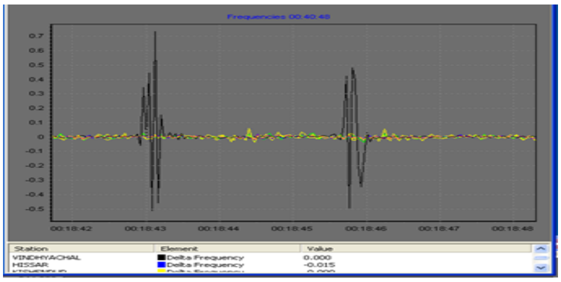

Figure 5: Auto-reclosure phenomena

REFERENCES

[1] "Smart Grid Technology and Applications" by Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, Nick Jenkins, John Wiley & Sons Publication, 2012.
[2] "Electrical Power Systems Quality", 3e, by Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, and H. Wayne Beaty, McGraw Hill Publication, 1996.
[3] "The Smart Grid : An Introduction", prepared for the U.S. Department of Energy by Litos Strategic Communication.
[4] CIGRE Technical Brochure 328 on "Modeling and Dynamic Behavior of Wind Generation as it Relates to Power System Control and Dynamic Performance", Working Group –C4.601, August 2007.
[5] Smart Grid – The New and Improved Power Grid : A Survey by Xi Fang, Satyajayant Mishra, GuoliangXue, and Dejun Yang, IEEE Communications Surveys & Tutorials, vol.14, no. 4, Fourth Quarter 2012.