GENETIC ALGORITHM FOR THE REDUCTION OF REACTIVE POWER LOSSES IN RADIAL DISTRIBUTION SYTEM

By

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FINAL YEAR PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

LO THIN THIN

ABSTRACT

Power losses in distribution system have become the most concerned issue in power losses analysis in any power system. In the effort of reducing power losses within distribution system, reactive power compensation has become increasingly important as it affects the operational, economical and quality of service for electric power systems. Hence, the objective of the project is to perform a study and analysis on the power losses in radial distribution network by applying genetic algorithm approach for reduction of the reactive power losses. In this project, IEEE 34-bus Standard Test System is used together with the MATLAB and ERACS as powerful tools for the analysis and simulation work. Necessary literature reviews and research are conducted extensively in order to achieve the objectives of the project. The total loss saving for both single and multiple capacitor placements is 22.52% and 22.07% respectively. Single capacitor insertion is more cost effective as compare to multiple capacitor insertion because it have higher kW/kVAR ratio which is 2.696 and 2.163 respectively. Heuristic Search Strategies has total loss saving of 24.18% and 23.82% respectively for single and multiple capacitor insertions while GA has 22.52% and 22.07%. However, Genetic Algorithm is identified to be more cost effective because it has higher kW/kVAR ratio which is 2.696 and 2.163 for single and multiple capacitor insertion respectively for while 1.9885 and 2.158 for Heuristic Search Strategies. The objective and goal towards the end of the project is to achieve the reduction of reactive power loss using genetic algorithm. The final results of the project successfully provide solutions to the reduction of reactive power losses, which eventually further contribute to the entire electrical power system in achieving superior performance in the context of operational, economical and quality of service.

ACKNOLLEDGEMENT

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With deepest love and gratitude,
Lo Thin Thin
June 2006

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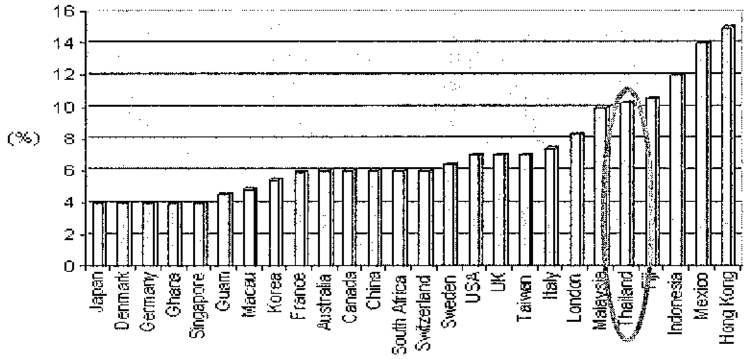
CHAPTER 1
INTRODUCTION

1.1 Background of Study

Power losses in distribution system have become one of the most concerned issues in the analysis of power losses in any power system. In the effort of reducing power losses within distribution system, reactive power compensation has become increasingly important as it affects the operational, economical and quality of service for electric power systems. Consumer loads impose active and reactive power demand, depending on their characteristics. Active power is converted into useful energy whereas reactive power must be compensated. This is to guarantee efficient delivery of active power to loads, thus releasing system capacity, reducing system losses and improving system power factor and bus voltage profile. The achievement of these aims depends on the sizing and allocation of capacitors. [1]



Source: World Development report 1997, and London Electricity of UK

Figure 1.1.1 Transmission and Distribution Losses

From the figure shown, it is noticed that Malaysia has a relatively high power losses as compared to other developed countries. Hence, in this project, ***Genetic algorithm*** has been considered as an approach to tackle the problem of optimal capacitor placement in radial distribution systems. In this optimal capacitor placement algorithm, two considerations namely minimizing capacitor installation cost and minimizing system losses need to be taken into account in order to achieve the objective.

1.2 Problem Statements

1.2.1 Problem Identifications

The resistance and reactance of the cable in the transmission line results in high power losses. These losses affect the efficiency of the overall electric power system. These losses also incur high monetary expenses in the operation of power delivery. Many previous efforts have been made to develop various methods and algorithms. These methods and algorithms are targeted to reduce the power losses in transmission system. However, these methods and algorithms greatly focus on mathematical model of the power system which requires complex computations and tedious iterations. A more effective method utilizing an accelerated process will be highly desired to generate the optimal parameters for the reduction of power losses. This project's intent is to perform reduction of reactive losses in radial distribution using the genetic algorithm principle.

1.2.2 Significance of the Project

The project developed will enable the identification of optimal node where capacitor insertion is needed. The size of capacitor inserted is determined by the result computed via genetic algorithm. The project is also able to deliver the amount of saving achieved via the insertion of capacitor. The amount of reactive power losses reduced will further contribute to achieving superior performance of the entire electrical power system in the context of operational, economical and quality of service.

1.3 Objective and Scope of Study

The objectives of the project are as the following:

a) Perform a study and analysis on the power losses in radial distribution network.
b) Apply genetic algorithm approach for reduction of the reactive power losses.
c) Evaluate the performance of the genetic algorithm.

The scopes of study of the project are as the following:

a) The reduction of losses is limited to reactive power.
b) The reduction of power losses is only limited to radial distribution network.
c) Genetic algorithm is used to compute the minimization of power losses.

1.3.1 The Relevancy of the Project

The project outcome can be used to tackle the real life problem in the radial distribution system, which helps to identify the location of capacitor insertion and sizing of capacitor. The results from the project will be able to enhance the operational, economical and quality of performances of power distribution system. Fundamental principles of power system could be utilized in performing study and analysis in the reduction of reactive power losses. This project involves simulation tool using genetic algorithm with the consideration of power system parameters.

1.3.2 Feasibility of the Project within the Scope and Time Frame

The project is highly feasible within the scope and time frame. It is being organized into two semesters whereby the first semester will be invested heavily on the literature review and analysis of reactive power reduction technique. The second semester greatly emphasize on the simulation work using genetic algorithm.

CHAPTER 2
LITERATURE REVIEW

2.1 Radial Distribution System

Radial distribution network is the most widely used network in Malaysia. In this network, the distributor connects to the supply system on one end only and it is noticed that the end of the distributor nearest to the generating station would be heavily loaded. The main advantage is that it is cost effective. However, its disadvantage is that the entire network will be affected if power interruption occurs at the nearest distributor. [2]

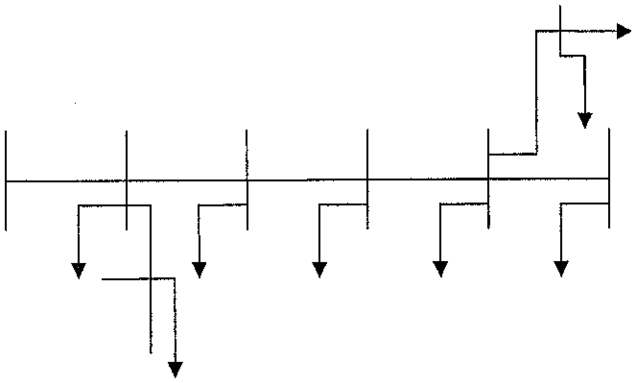


Figure 2.1.1 Radial Distribution Network

2.2 Reactive Power Losses

Reactive power is needed for inductive load, such as motor, compressor to generate and sustain a magnetic field in order to operate [2]. It is a non-working power with the unit KVAR. However, too much of reactive power is undesirable because it will lower the power factor, which in turn will incur more cost and cause ineffectiveness to the system. With the lowering of power factor, the distribution capacity will be reduces due to the increasing of the current flow and thus, cause voltage drop. [2]

Causes of Power Losses:

- a) Feeder length
- b) Inadequate Size of Conductor
- c) Location of Distribution Transformers
- d) Low Voltage
- e) Low Power Factor

2.3 Reactive Power Reduction

There are various devices, techniques and methods used for the purpose of the reduction of reactive power losses in distribution networks. [2]

- a) Reactive power compensation Devices
    - i) Static VAR compensators (SVC)
    - ii) Static Synchronous Compensator (STATCOM)
    - iii) Series Capacitors and Reactors
    - iv) Shunt Capacitors compensation
- b) Construction of new Substation
- c) Reinforcement of the Feeder
- d) Grading of Conductor
- e) Network Reconfiguration
- f) Shunt Capacitor Insertion

In this project, the technique that is emphasized on is the shunt capacitor insertion.

2.4 Overview of Genetic Algorithm

Genetic algorithm is a search algorithm based on the mechanics of natural selection and natural genetics [3], provides a global optimal solution for non-linear problems [4]. It considers a population of chromosomes as potential solution to a given problem. In genetic algorithm model, chromosomes are composed of genes for various characteristics to be optimized and can be binary strings of fixed length. Each chromosome represents a point in the search space and offers convenient way of handling constraints.

2.4.1 Background of Genetic Algorithm

Genetic algorithms have been developed by John Holland, his colleagues and his students at the University of Michigan.

The goals of their research have been twofold:

a) To abstract and rigorously explain the adaptive process of natural system.
b) To design artificial system software that retains the important mechanism and properties similar natural systems. [3]

This approach has led to important discoveries in both natural and artificial system science, which lead to the publication of Adaptation in Natural and Artificial System in 1975. [3]
Holland method is especially effective because he not only considered the role of mutation (mutations very seldom improve the algorithms), but he also utilized genetic recombination, (crossover): this recombination, the crossover of partial solutions greatly improves the capability of the algorithm to approach, and eventually find, the optimum.

2.4.2 Concepts of Genetic Algorithm

The genetic algorithm is a method for solving optimization problems that is based on natural selection, the process that drives biological evolution. The genetic repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals at random from the current population to be parents and uses them produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. You can apply genetic algorithm to solve a variety of optimization problems that are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, non-differentiable, stochastic, or highly non-linear [4].

Genetic Operators

a) Selection

   Select two parent chromosomes from a population according to their fitness. Chance for the better fitness individual will be selected is higher to produce the next generation with the higher fitness value. [6]

b) Crossover

   The crossover operator involves the exchange of genetic material between chromosomes (parents), in order to create new chromosomes (offspring). Various forms of this operator have been developed. The simplest form, single point crossover, is shown as Figure 2.4.2.1. This operator selects two parents, chooses random position in the genetic coding, and exchanges genetic information to the right of this point, thus creating two new offspring. [6]

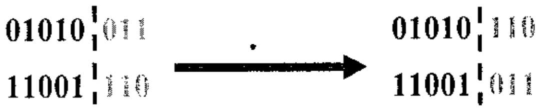


Figure 2.4.2.1 Single point crossover

c) Mutation

The mutation operator, in its simplest form, makes small, random, changes to a chromosome. For a binary encoding, this involves swapping gene **1** for gene **0** with small probability for each bit in the chromosome, as illustrated in Figure 2.4.2.2. [6]

01010110 → 01110110

Figure 2.4.2.2 Binary mutation operators

2.4.3 Application and Successful Story of Genetic Algorithm

Genetic algorithms have been used for difficult problems (such as NP-hard problems), for machine learning and also for evolving simple programs. They have been also used for some art, for evolving pictures and music. [7]

To get an idea about some problems solved by Genetic Algorithms, here is a short list of some applications: [7]

a) Nonlinear dynamical systems - predicting, data analysis
b) Designing neural networks, both architecture and weights
c) Robot trajectory
d) Evolving LISP programs (genetic programming)
e) Strategy planning
f) Finding shape of protein molecules
g) TSP and sequence scheduling
h) Functions for creating images

2.4.4 Advantages and Disadvantages of Genetic Algorithm

The advantages of genetic algorithm:

a) Parallelism

   Genetic algorithm is traveling in a search space using more individuals (and with genotype rather than phenotype) so that they are less likely to get stuck in a local extreme like the other methods. [7]

b) Easy to implement

   Once you have the basic genetic algorithm implemented, you have just to write a new chromosome (just one object) to solve another problem. With the same encoding you just change the fitness function - and you are done. However, for some problems, choosing and implementation of encoding and fitness function can be difficult. [7]

The disadvantage of genetic algorithm:

a) Computational time

   Genetic algorithm might be slower than other methods. However, genetic algorithm can terminate computation based on several criteria such as simulation reaches the number of generation specified. [7]

Besides considering the advantages and disadvantages of genetic algorithm, there are three main benefits of using Genetic Algorithm [6]

a) Suitability – It can be applied to a wide-range of problems without significant modification
b) Representation – It can include the representation of design parameters, inclusion of constraints, assessment of performance and method of coping with the likely properties of the fitness landscape.
c) Available Tools – A lot of toolbox have been developed for the technical computing package MATLAB.

2.4.5 Comparisons of Genetic Algorithm to Other Methods

In order for genetic algorithm to surpass their more traditional cousins in the quest for robustness, genetic algorithm must differ in some very fundamentals ways. Genetic algorithms are different from more normal optimization and search procedures in four ways: [3]

a) Use of the encoding of the parameters, not the parameters themselves.
b) Work on a population of points, not a unique one.
c) Use the only values of the function to optimize, not their derived function or other auxiliary knowledge.
d) Use probabilistic transition function not determinist ones.

CHAPTER 3

METHODOLOGY OF PROJECT WORK

3.1 Procedure Identification

The detail work and time frame is as shown in the gantt chart attached in Appendix 2. The flow chart below show the project work for two semesters.

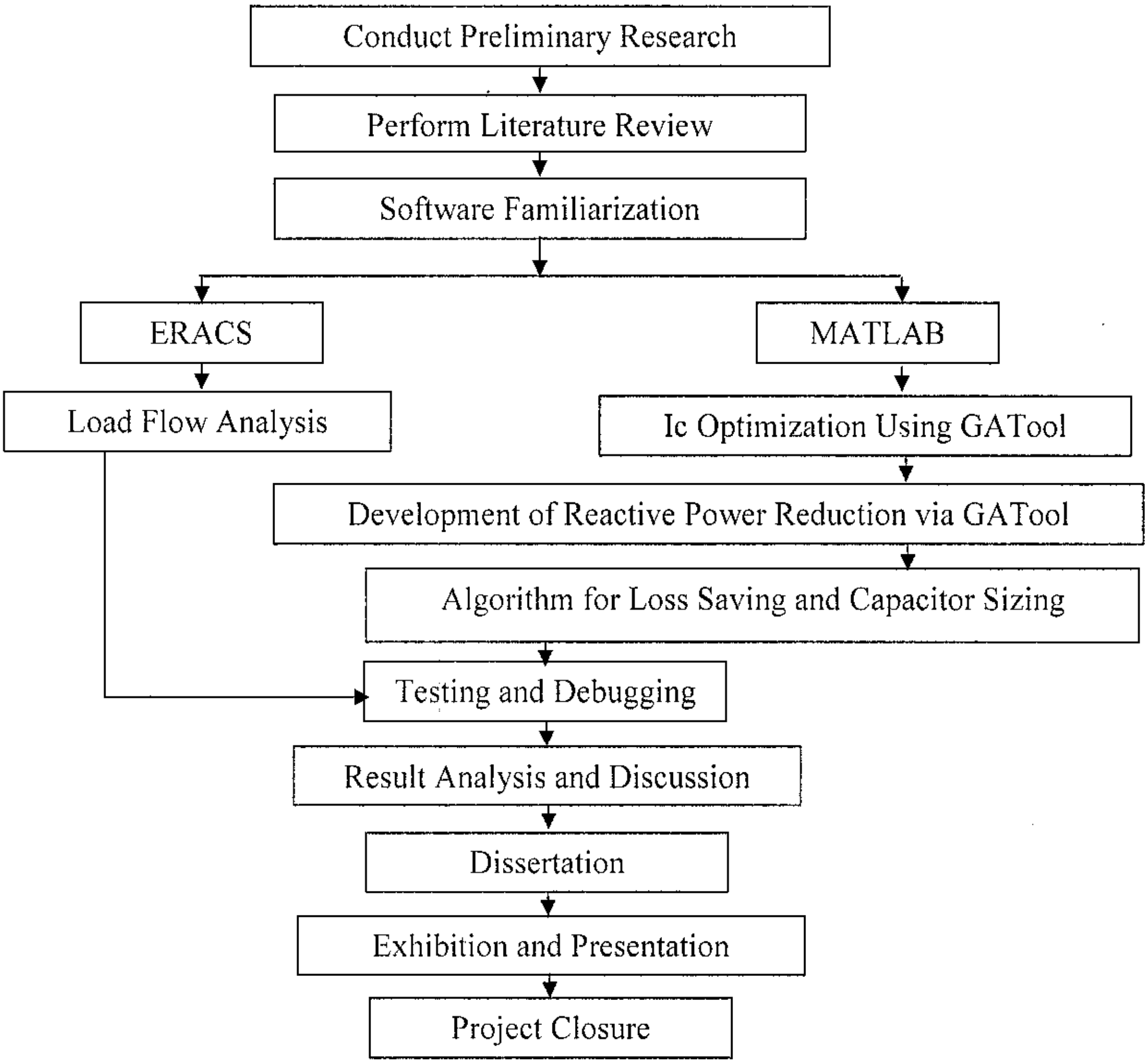


Figure 3.1.1 Project work flow chart

a) Preliminary Research

Preliminary research is the first step of the project. Understanding of the major concepts and fundamentals of reactive power reduction is achieved here. Preliminary research also assists the author by identifying the tools and software to be used in this project. Preliminary research yielded sufficient data and historic background on reactive power, the reduction method and algorithm. It is also very clear that MATLAB GATool will be used as the software platform to perform the reactive power reduction. In this project, it is also required to perform load flow analysis. ERACS is selected as the software platform to perform load flow analysis.

b) Literature Review

The project then continues with by performing a detail literature review. The literature review sources consist of study of journal, technical papers and books. Various past efforts and works on reactive power reduction technique are studied and investigated. The literature reviews greatly focus on the reduction of reactive power using integrated approach. Besides, a thorough understanding and literature review on the IEEE 34 bus and its system characteristic is achieved here. The insights are then gathered and consolidated to be applied in this project.

c) Software Familiarization.

This project utilizes several software in order to make the reduction of reactive power possible. The software used are ERACS for load flow analysis, GATool for parameters optimization and MATLAB for complex mathematical computations. This software are explored and familiarized in order to achieve the objectives of the project.

d) Parameter Identification

The reactive power reduction is achieved by the insertion of capacitor at a determined location in the IEEE 34 Bus branch. This involves finding the optimum point at which saving of power through reduction technique can be realized. In order to locate the optimum point, GA Tool is used to generate sets of capacitor current which is then used to calculate savings and capacitor size. The optimization method involves multiple variable using biological approaches. The parameters identified are as follow:

i) Crossover rates.
ii) Mutation rates.
iii) Population size.
iv) Selection.
v) Encoding.
vi) Crossover and mutation type.

e) Load Flow Analysis

Load flow analysis is a very important step in the entire project. Through load flow analysis performed by ERACS, the voltage profiles of IEEE- 34 Bus are obtained. The voltage profiles generated by ERACS need to be within an accepted per unit value before it can be used for analysis. Apart from the voltage values, ERACS also give the current values which will then be used for the computation of optimum capacitor current.

f) Optimization of Capacitor Current

The step after all the ground works have been performed is to optimize the capacitor current to achieve reactive power reduction. The very basic and fundamental algorithm is formulated by maximizing the savings through the size of capacitor inserted.

g) Development of Reactive Power Reduction using Genetic Algorithm.

Once the basic algorithm is formulated and approved, the next step is to realize the reactive power reduction via Genetic Algorithm. The algorithm developed is able of generating the optimized values of capacitor currents. These capacitor currents are used to compute the savings and capacitor size. The algorithm also identifies the location of the branch in IEEE- 34 Bus where the insertion of capacitor will produce the highest saving. The algorithm is also benchmarked and compared against the integrated approach method.

h) Testing and Debugging

It is very common to involve testing and debugging step in any project that involves software. The approach used in this project is to arbitrary selecting any value calculated by the software and this value is to be calculated manually. These two values are then compared. This step is repeated several times.

i) Result Analysis and Discussions

The results generated by GA Tool is compiled and formatted for the ease of analysis. Necessary charts and graphs are produced to analyze the results. The results are the discussed with respect to the theory of the capacitor insertion.

j) Dissertation

The final results and discussions are compiled in a clear and concise manner. This then produce the final dissertation for the project.

k) Presentation and Exhibition

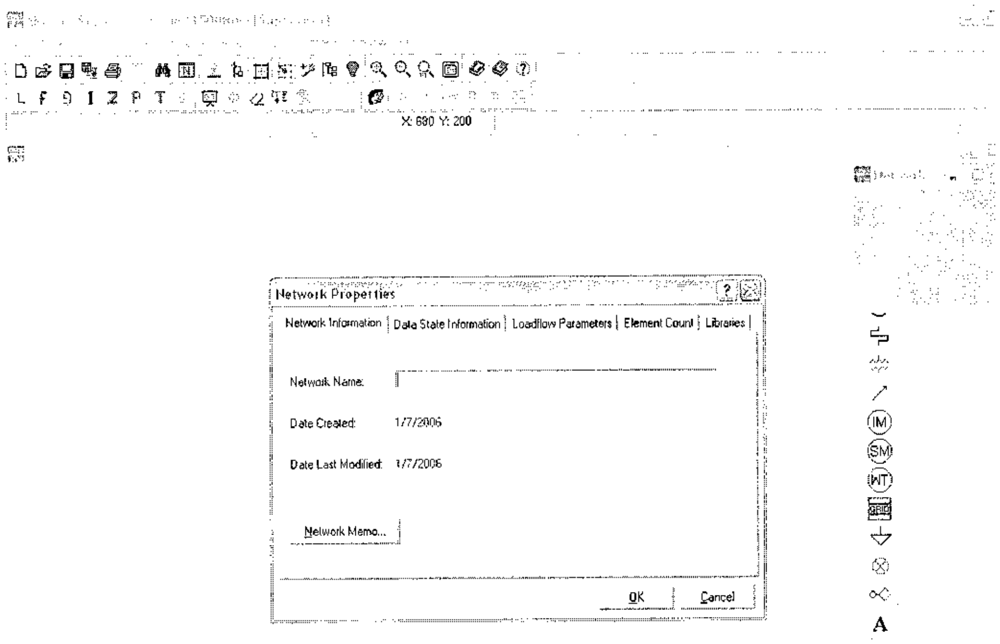
The project is wrapped up with a presentation to the supervisor and advisors. An exhibition is anticipated to be a knowledge sharing session.

3.2 Tools and Software

3.2.1 ERACS

ERACS is used as power system simulation and analysis software as it will be able to perform the calculations faster and more accurate. ERACS is specifically used in performing load flow analysis for the network after new capacitor value is computed. Furthermore, this software is more user-friendly and reliable.

The construction of the network involves the following steps:



Network Name:

Date Created: 1/7/2006

Date Last Modified: 1/7/2006

Figure 3.2.1.1 At ERACS Start-up with new network properties

At the start up of the ERACS software, the Network Properties need to be filled in the following field:

a) Network Information
b) Data State Information
c) Loadflow Parameter and
d) Libraries

To Create the Network use the toolbars below to insert the element needed.

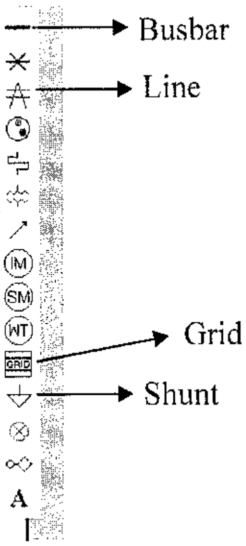
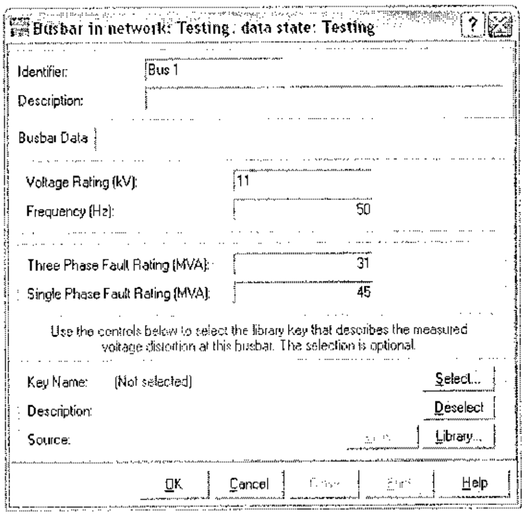


Figure 3.2.1.2 Toolbars

For each insertion of busbar the identifier and the voltage rating need to be filled. Voltage Rating for all busbar is 11kV.


Busbar in network: Testing, data state: Testing

Identifier: Bus 1
Description:

Busbar Data

Voltage Rating (kV): 11
Frequency (Hz): 50

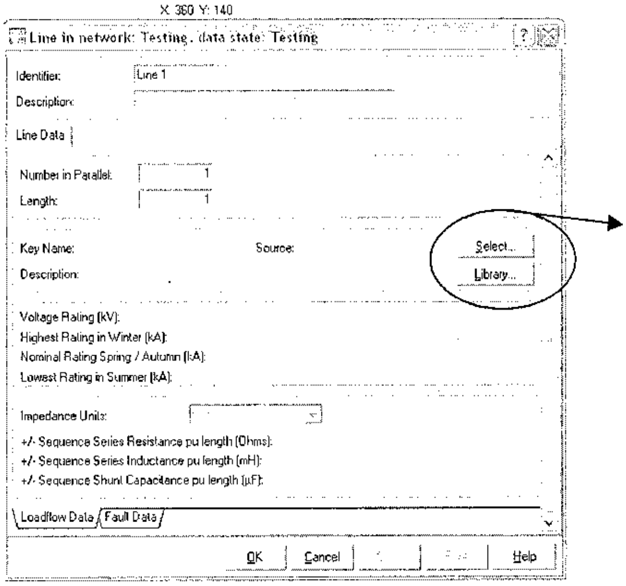
Three Phase Fault Rating (MVA): 31
Single Phase Fault Rating (MVA): 45

Use the controls below to select the library key that describes the measured voltage distortion at this busbar. The selection is optional.

Key Name: (Not selected)
Description:
Source:

Figure 3.2.1.3 Busbar Data

For Line and Shunt, individual libraries need to be created to fill in all the parameters needed as follow:



Identifier: Line 1

Description:

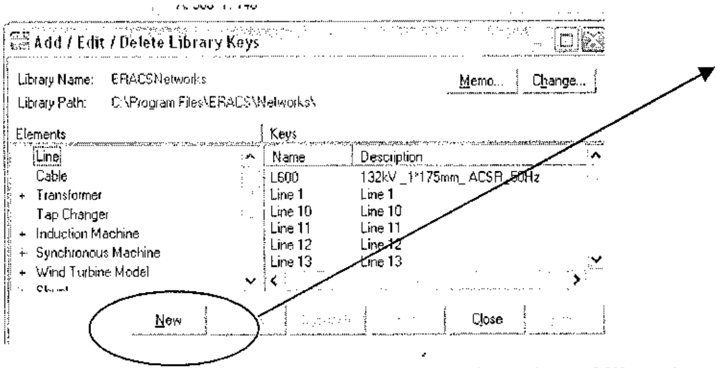
Number in Parallel: 1

Length: 1

The Library Button is pressed.

Figure 3.2.1.4 Insert Line data

Then, the following window will appear.



Library Name: ERACSNetworks

Library Path: C:\Program Files\ERACS\Networks\

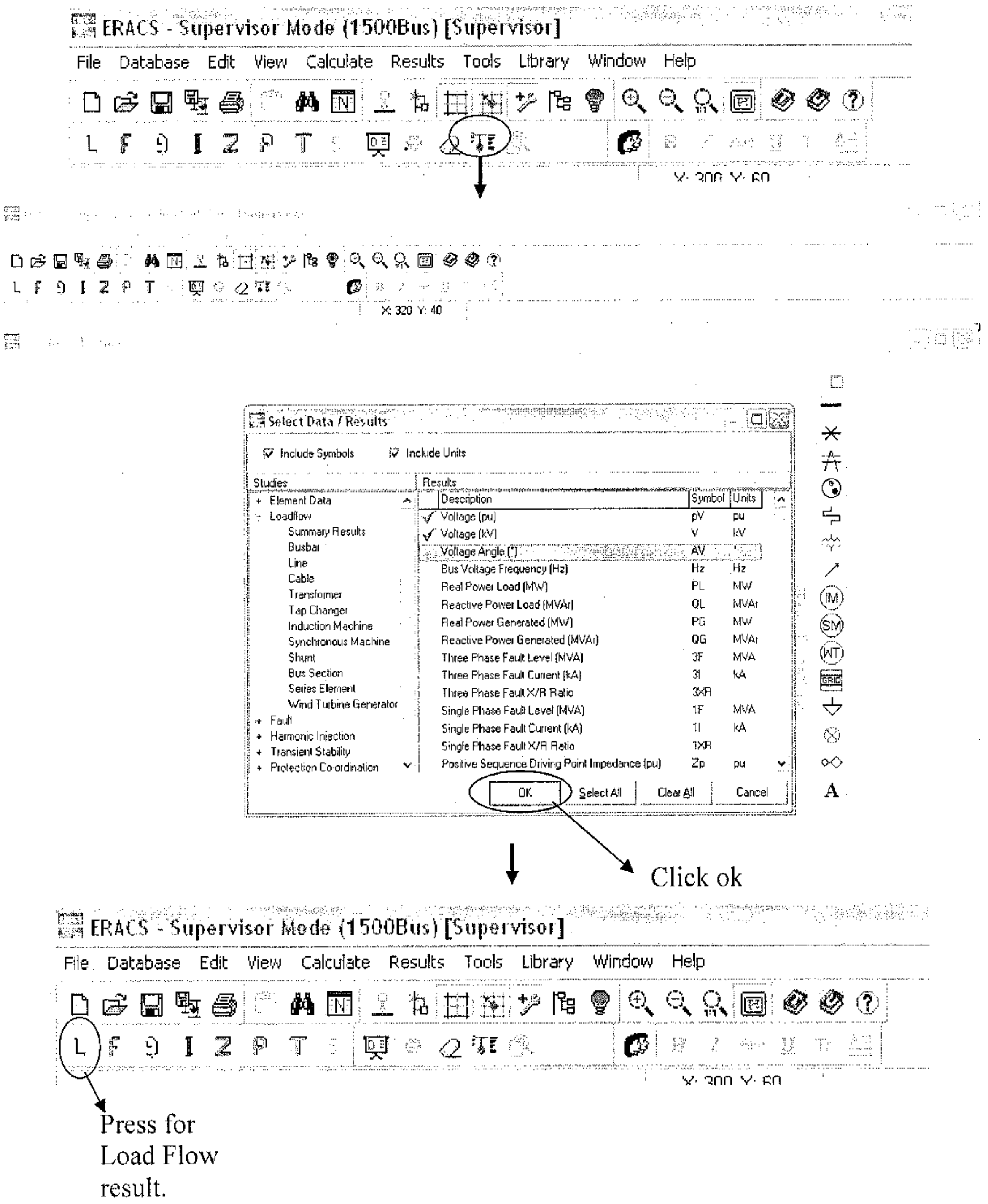
Name	Description
L600	132kV _1*175mm_ ACSR_50Hz
Line 1	Line 1
Line 10	Line 10
Line 11	Line 11
Line 12	Line 12
Line 13	Line 13

New Button is pressed to create new library according to each line and shunt that is inserted

Figure 3.2.1.5 Creation of libraries

For line, the resistance and reactance value need to be inserted. As for shunt, the Reactive Power and Real Power Value need to be inserted.

For result, the following is selected:



☑ Include Symbols ☑ Include Units

Studies
- + Element Data
- − Loadflow
  - Summary Results
  - Busbar
  - Line
  - Cable
  - Transformer
  - Tap Changer
  - Induction Machine
  - Synchronous Machine
  - Shunt
  - Bus Section
  - Series Element
  - Wind Turbine Generator
- + Fault
- + Harmonic Injection
- + Transient Stability
- + Protection Co-ordination

Results

	Description	Symbol	Units
✓	Voltage (pu)	pV	pu
✓	Voltage (kV)	V	kV
	Voltage Angle (°)	AV	°
	Bus Voltage Frequency (Hz)	Hz	Hz
	Real Power Load (MW)	PL	MW
	Reactive Power Load (MVAr)	QL	MVAr
	Real Power Generated (MW)	PG	MW
	Reactive Power Generated (MVAr)	QG	MVAr
	Three Phase Fault Level (MVA)	3F	MVA
	Three Phase Fault Current (kA)	3I	kA
	Three Phase Fault X/R Ratio	3XR	
	Single Phase Fault Level (MVA)	1F	MVA
	Single Phase Fault Current (kA)	1I	kA
	Single Phase Fault X/R Ratio	1XR	
	Positive Sequence Driving Point Impedance (pu)	Zp	pu

OK | Select All | Clear All | Cancel

Figure 3.2.1.6 Sequence of getting results of load flow

3.2.2 MATLAB

MATLAB is used in computing the algorithm replacing the more conventional types of programming languages. MATLAB provide Genetic Algorithm toolbox which ease the programming and no declaration is needed. Genetic algorithms greatly accelerate the simulation cycle.

Steps involves while utilizing the GA tool.

To start the Genetic Algorithm Toolbox, first click on <START> button, then Toolboxes, Genetic Algorithm and Direct Search, Genetic Algorithm Tool as shown in Figure 3.2.2.1. Then, the window as shown in Figure 3.2.2.2 will appear. [5]

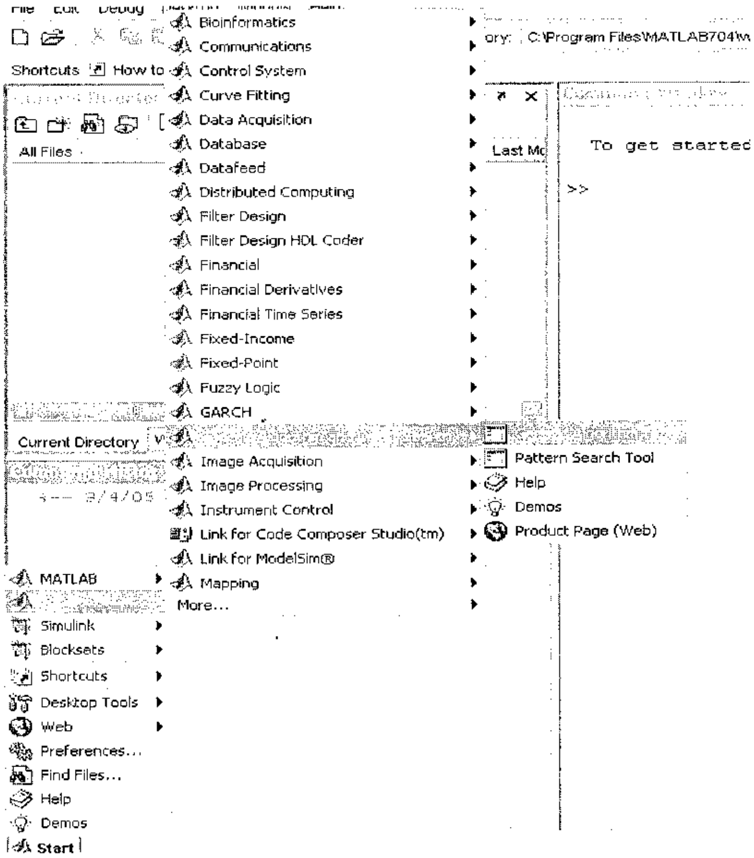


Figure 3.2.2.1 Start Genetic Algorithm Toolbox

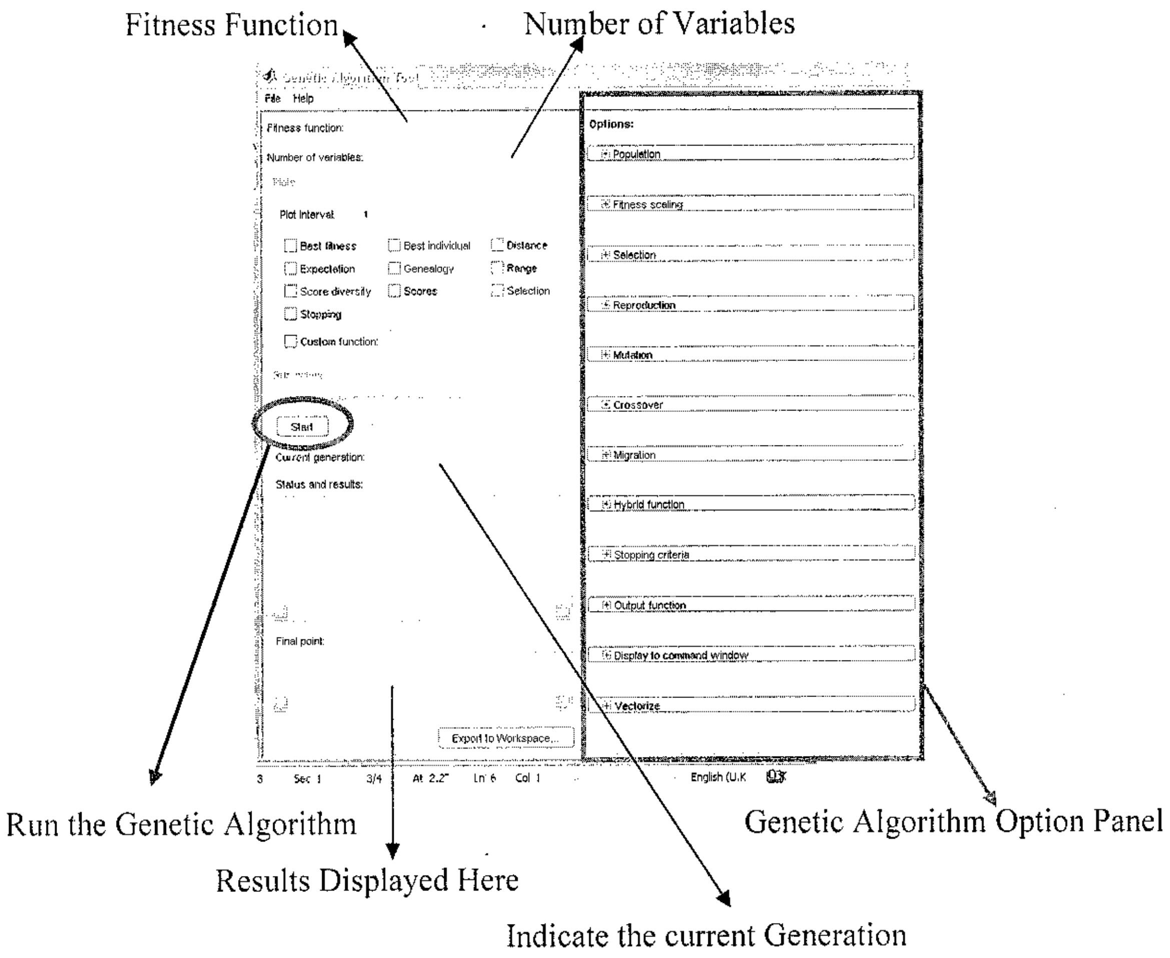


Figure 3.2.2.2 Genetic Algorithm Toolbox Window

To start the Genetic Algorithm Tool, the following must be entered (with referring to Figure 3.2.2.1).

a) Fitness Function – The objective function you want to minimize. Enter function in the form @fitnessfun, where fitnessfun.m is an M-file that computes the fitness function.

b) Number of variables -- The length of the input vector to the fitness function.

When the START button in Figure 3.2.2.2 is clicked, it runs Genetic Algorithm. The result will then display at the Status and Results Panel. To view and change the Genetic Algorithm options, click on the categories listed at the panel.

3.2.3 IEEE 34-Bus Standard Test System

IEEE 34-Bus Standard Test System is a model that is able to represent the real distribution system. The significance of it is that when the algorithm works on the model, it will be able to works well in the real world condition. The IEEE 34- bus system is used as the test bed for this project in order to generate the load flow analysis. Using ERACS, the IEEE- 34 bus system network is constructed and load flow analysis is performed. The line data consists of resistance and reactance. The load data for the IEEE- 34 bus system consists of active and reactive power losses with respect to individual busbar.

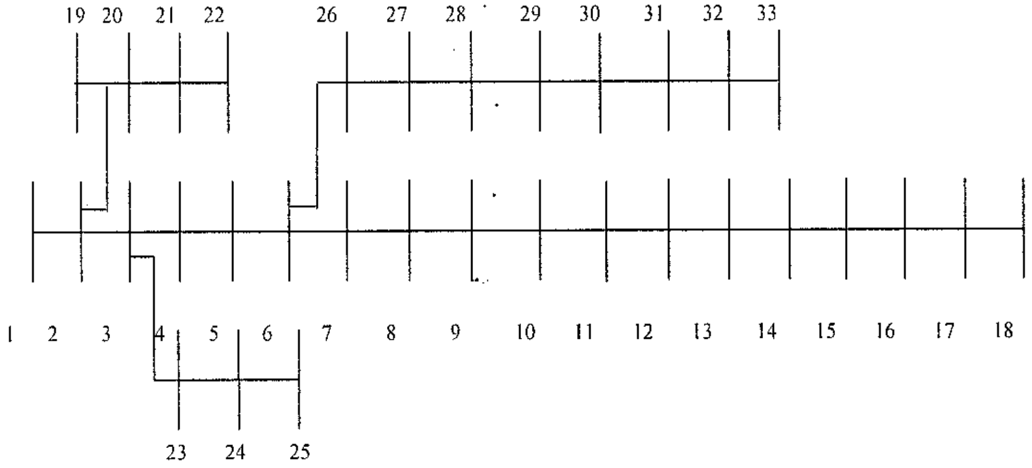


Figure 3.2.3.1 IEEE 34-Bus Standard Test System

Table 3.2.3.1 Line Data

Line	Sending End Node	Receiving End Node	Resistance (Ω)	Reactance (Ω)
1	1	2	0.1170	0.0480
2	2	3	0.1073	0.0440
3	3	4	0.1645	0.0457
4	4	5	0.1495	0.0415
5	5	6	0.1495	0.0540
6	6	7	0.3144	0.0540
7	7	8	0.2096	0.0360
8	8	9	0.3144	0.0540
9	9	10	0.2096	0.0360
10	10	11	0.1310	0.0225
11	11	12	0.1048	0.0180
12	12	13	0.1572	0.0270
13	13	14	0.2096	0.0360
14	14	15	0.1048	0.0180
15	15	16	0.0524	0.0090
16	16	17	0.1749	0.0498
17	17	18	0.1645	0.0457
18	18	19	0.2079	0.0473
19	19	20	0.1890	0.0430
20	20	21	0.1890	0.0430
21	21	22	0.2620	0.0450
22	22	23	0.2620	0.0450
23	23	24	0.3144	0.0540
24	24	25	0.2096	0.0360
25	25	26	0.1310	0.0225
26	26	27	0.1048	0.0180
27	27	28	0.1572	0.0270
28	28	29	0.1572	0.0270
29	29	30	0.1572	0.0270
30	30	31	0.1572	0.0270
31	31	32	0.2096	0.0360
32	32	33	0.1572	0.0270
33	33	34	0.1048	0.0180

Table 3.2.3.2 Load Data

Busbar	PL(kW)	QL(kVAR)
2	230	142.5
3	0	0
4	230	142.5
5	230	142.5
6	0	0
7	0	0
8	230	142.5
9	230	142.5
10	0	0
11	137	142.5
12	72	84
13	72	45
14	72	45
15	13.5	45
16	230	7.5
17	230	142.5
18	230	142.5
19	230	142.5
20	230	142.5
21	230	142.5
22	230	142.5
23	230	142.5
24	230	142.5
25	230	142.5
26	230	142.5
27	137	85
28	75	48
29	75	48
30	75	48
31	57	34.5
32	57	34.5
33	57	34.5
34	57	34.5

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 System Functionality

4.1.1 Stopping Criteria

The genetic algorithm uses five criteria to decide when to stop the algorithm automatically. By setting the stopping criteria, the algorithm will stop if any one of the conditions is met. [5]

a) Generations - The algorithm reaches the specified number of generations.
b) Time -- The algorithm runs for the specified amount of time in seconds.
c) Fitness limit -- The best fitness value in the current generation is less than or equal to the specified value.
d) Stall generations -- The algorithm computes the specified number of generations with no improvement in the fitness function.
e) Stall time limit -- The algorithm runs for the specified amount of time in seconds with no improvement in the fitness function.

4.1.2 Parameters of Genetic Algorithm

There are some basic recommendations in deciding to implement genetic algorithm. There is no general theory available that helps to tune Genetic Algorithms parameters for any specific problems. Recommendations are often results of empiric studies of genetic algorithms that were often performed on binary encoding only. [7]

a) Crossover rate. [7]

   Crossover rate should be high generally, about 80%-95%. (However some results show that for some problems crossover rate about 60% is the best.)

b) Mutation rate.

   On the other side, mutation rate should be very low. Best rates seem to be about 0.5%-1%. [7]

c) Population size.

   It may be surprising that very big population size usually does not improve performance of GA (in the sense of speed of finding solution). Good population size is about 20-30 [7]

d) Selection.

   Basic roulette wheel selection can be used, but sometimes rank selection can be better. There are also some more sophisticated methods that change parameters of selection during the run of GA. Basically, these behave similarly like simulated annealing. Elitism should be used for sure if you do not use other method for saving the best found solution. You can also try steady state selection. [7]

e) Encoding.

Encoding depends on the problem and also on the size of instance of the problem. [7]

f) Crossover and mutation type.

Operators depend on the chosen encoding and on the problem. [7]

4.2 Results and Analysis

4.2.1 Load Flow Analysis

Utilizing the ERACS software, the load flow analysis is conducted. The results are produced giving the values of total active and reactive power losses. Besides, the value interested from the load flow analysis is the bus voltage profile for further calculation and simulation of loss savings and capacitor sizing using the MATLAB.

The IEEE- 34 bus system network constructed for simulation of voltage profile is as shown in Figure 4.2.1.1 and its result of the voltage profile is as shown in Table 4.2.1.1.

From Figure 4.2.1.1, it is noticed that the active power losses is 0.222MW and the reactive power losses is 0.065MVar. From Table 1, it is noticed that the voltage profile is within the acceptable value.

a) Simulation Network

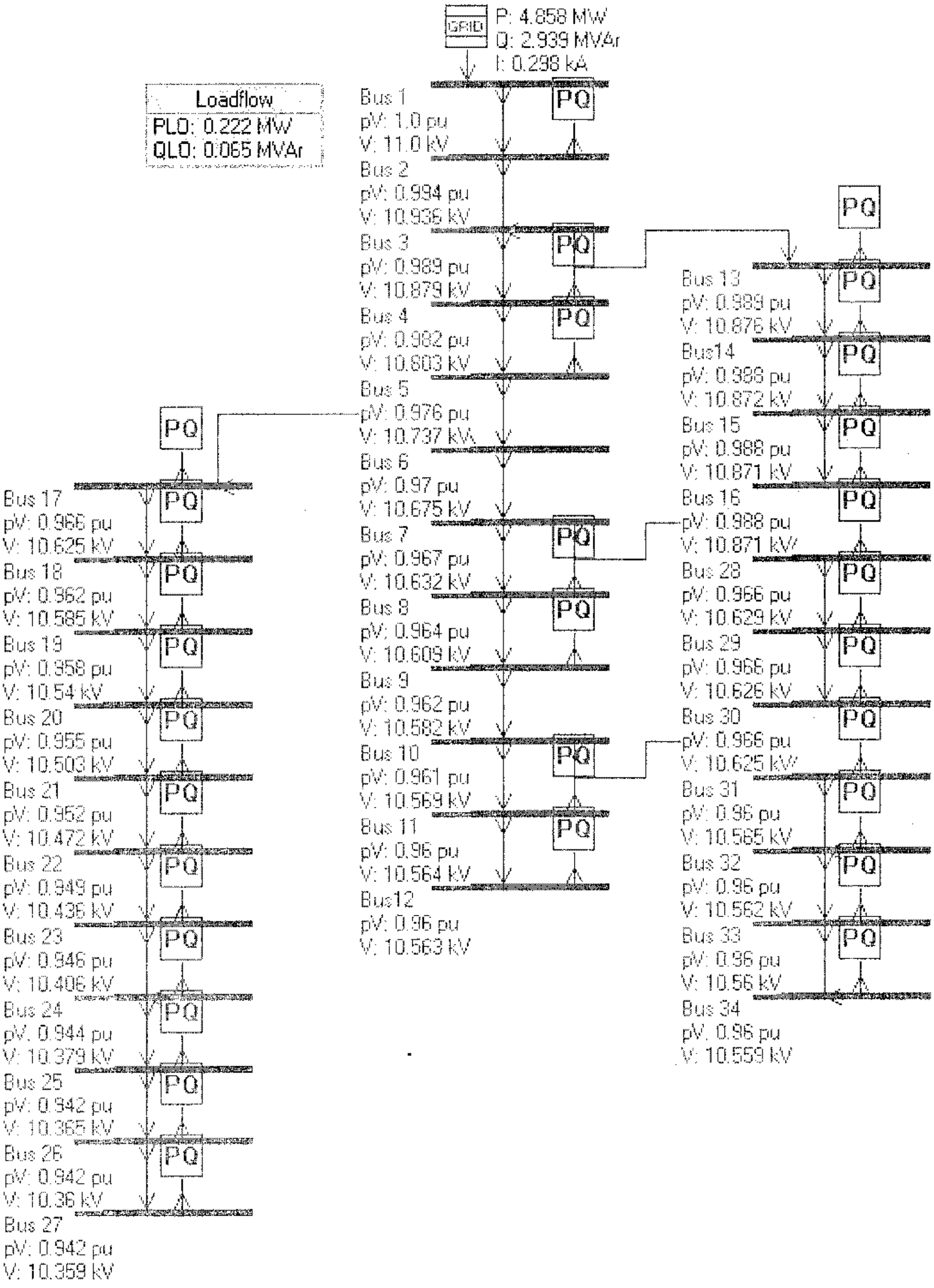


Figure 4.2.1.1 IEEE 34-Bus Test System simulation setup

b) The Summary of voltage profile is as follow:

Table 4.2.1.1: Summary of voltage profile

Busbar ID	pV (pu)	Voltage Profile V (kV)
Bus 1	1	11
Bus 2	0.994137	10.936
Bus 3	0.989020	10.879
Bus 4	0.982053	10.803
Bus 5	0.976061	10.737
Bus 6	0.970414	10.675
Bus 7	0.966586	10.632
Bus 8	0.964483	10.609
Bus 9	0.962015	10.582
Bus 10	0.960829	10.569
Bus 11	0.960371	10.564
Bus12	0.960235	10.563
Bus 13	0.988687	10.876
Bus14	0.988381	10.872
Bus 15	0.988298	10.871
Bus 16	0.988292	10.871
Bus 17	0.965953	10.625
Bus 18	0.962244	10.585
Bus 19	0.958149	10.54
Bus 20	0.954856	10.503
Bus 21	0.951993	10.472
Bus 22	0.948723	10.436
Bus 23	0.946037	10.406
Bus 24	0.943513	10.379
Bus 25	0.942298	10.365
Bus 26	0.941831	10.36
Bus 27	0.941692	10.359
Bus 28	0.966250	10.629
Bus 29	0.966026	10.626
Bus 30	0.965914	10.625
Bus 31	0.960488	10.565
Bus 32	0.960148	10.562
Bus 33	0.959977	10.56
Bus 34	0.959920	10.559

c) Decomposition of Branch Current

The branch current has two components, namely active and reactive components. Both the components can be calculated using equation (4.3). Loss associated with the branch current for the active component cannot be minimized as all the active power must be supplied by the source at the root bus. On the other hand, the loss associated with the branch current for the reactive component can be minimized by supplying part of the reactive power demand locally.

Table 4.2.1.2 shows the calculation of active and reactive branch current. Whereby, the reactive branch current need to be utilize in the MATLAB simulation later. This will eventually helps to produce the loss saving of the system in the later stage.

Table 4.2.1.2 Decomposition of Branch Current

(A)	(B)	(C)	(D) = (B)sin(C)	(E)=(B)cos(C)
Line	Current (kA)	Angle (°)	Current due to Reactive Component, I_{ri} (kA)	Current due to Active Component, I_{ai} (kA)
1	0.2980	-31.17	-0.15423	0.25498
2	0.2837	-31.14	-0.14671	0.24282
3	0.2694	-31.11	-0.13919	0.23066
4	0.2549	-31.08	-0.13160	0.21830
5	0.2404	-31.06	-0.12403	0.20593
6	0.0821	-31.20	-0.04252	0.07023
7	0.0676	-31.00	-0.03482	0.05794
8	0.0529	-30.94	-0.02719	0.04537
9	0.0381	-30.84	0.01953	0.03271
10	0.0236	-31.03	-0.01271	0.02022
11	0.0088	-30.86	-0.00451	0.00755
12	0.0143	-31.72	-0.00752	0.01216
13	0.0098	-31.64	-0.00514	0.00834
14	0.0053	-31.44	-0.00276	0.00452
15	0.0008	-28.94	-0.00039	0.00070
16	0.1582	-30.99	-0.08145	0.13562
17	0.1435	-30.96	-0.07382	0.12306
18	0.1288	-30.93	-0.06619	0.11049
19	0.1140	-30.90	-0.05854	0.09782
20	0.0991	-30.87	-0.05085	0.08506
21	0.0842	-30.84	-0.04317	0.07229
22	0.0692	-30.82	-0.03545	0.05943
23	0.0542	-30.80	-0.02775	0.04656
24	0.0391	-30.79	-0.02002	0.03359
25	0.0241	-30.79	-0.01234	0.02070
26	0.0090	-30.81	-0.00461	0.00773
27	0.0145	-32.11	-0.00771	0.01228
28	0.0097	-32.11	-0.00516	0.00822
29	0.0048	-32.10	-0.00255	0.00407
30	0.0146	-30.53	-0.00742	0.01258
31	0.0109	-30.53	-0.00554	0.00939
32	0.0073	-30.53	-0.00371	0.00629
33	0.0036	-30.53	-0.00183	0.00310

4.2.2 GAtool

GAtool is utilized to obtain the Ic values needed for the further simulation of the loss saving. Hence, the function below is written in the M-file format to obtain the simulation result utilizing population of 20.

```
function power = final03(x)        ───►        Function name

power= ((2*(-0.15423)*x(1) + x(1)^2)*0.1170)+
        ((2*(-0.14671)*x(2) + x(2)^2)*0.10725)+
        ((2*(-0.13919)*x(3) + x(3)^2)*0.16445)+
        ((2*(-0.1316)*x(4) + x(4)^2)*0.1495)+
        ((2*(-0.12453)*x(5) + x(5)^2)*0.14950)+
        ((2*(-0.04252)*x(6) + x(6)^2)*0.31440)+
        ((2*(-0.03482)*x(7) + x(7)^2)*0.20960)+
        ((2*(-0.02719)*x(8) + x(8)^2)*0.31440)+
        ((2*(-0.01953)*x(9) + x(9)^2)*0.20960)+
        ((2*(-0.01217)*x(10) + x(10)^2)*0.13100)+
        ((2*(-0.00451)*x(11) + x(11)^2)*0.10480)+
        ((2*(-0.00752)*x(12) + x(12)^2)*0.15720)+
        ((2*(-0.00514)*x(13) + x(13)^2)*0.20960)+
        ((2*(-0.00276)*x(14) + x(14)^2)*0.10480)+
        ((2*(-0.00039)*x(15) + x(15)^2)*0.05240)+
        ((2*(-0.08145)*x(16) + x(16)^2)*0.17940)+
        ((2*(-0.07382)*x(17) + x(17)^2)*0.16445)+
        ((2*(-0.06619)*x(18) + x(18)^2)*0.20790)+
        ((2*(-0.05854)*x(19) + x(19)^2)*0.18900)+
        ((2*(-0.05085)*x(20) + x(20)^2)*0.18900)+
        ((2*(-0.04317)*x(21) + x(21)^2)*0.26200)+
        ((2*(-0.03545)*x(22) + x(22)^2)*0.26200)+
        ((2*(-0.02775)*x(23) + x(23)^2)*0.31440)+
        ((2*(-0.02002)*x(24) + x(24)^2)*0.20960)+
        ((2*(-0.01234)*x(25) + x(25)^2)*0.13100)+
        ((2*(-0.00461)*x(26) + x(26)^2)*0.10480)+
        ((2*(-0.00771)*x(27) + x(27)^2)*0.15720)+
        ((2*(-0.00516)*x(28) + x(28)^2)*0.15720)+
        ((2*(-0.00255)*x(29) + x(29)^2)*0.15720)+
        ((2*(-0.00742)*x(30) + x(30)^2)*0.15720)+
        ((2*(-0.00554)*x(31) + x(31)^2)*0.20960)+
        ((2*(-0.00371)*x(32) + x(32)^2)*0.15720)+
        ((2*(-0.00183)*x(33) + x(33)^2)*0.10480);
```

M-files written to
obtain the Ic value of
each branch

After the M-file is run using the GAtools, the result is as follows:

Table 4.14.2: Result from GAtool

Branch	Ic
1	0.49638
2	0.15225
3	0.11944
4	0.19827
5	0.13652
6	0.055955
7	0.086621
8	0.066515
9	0.057581
10	0.1219
11	0.46336
12	-0.04725
13	-0.06779
14	0.002772
15	-0.09549
16	0.052641
17	0.34561
18	0.059504
19	0.12864
20	0.087313
21	0.064833
22	0.10196
23	-0.04405
24	-0.02661
25	-0.01053
26	-0.2013
27	0.03661
28	0.01896
29	-0.32078
30	-0.07023
31	-0.02971
32	0.21687
33	0.15259

4.2.3 MATLAB

The source code of the MATLAB programming for the calculation of loss saving at each branch and its capacitor sizing is attached in APPENDIX 3. The generated output of the program is attached in APPENDIX 4. From APPENDIX 4, the maximum loss saving is 14.92 kW when a shunt capacitor with a size of 914.34kVAR is placed at bus 21.

Figure 4.3.2.1 and Figure 4.3.2.2 summarizes the loss saving in kW at every bus and its corresponding capacitor size for insertion.

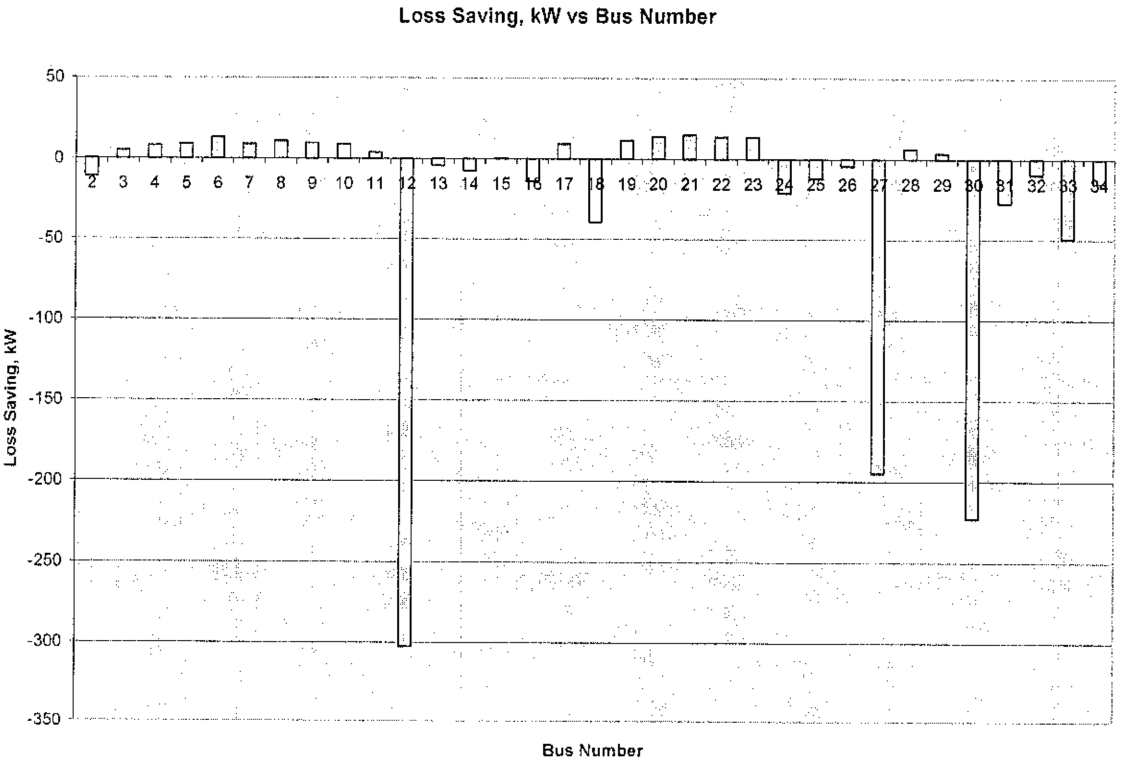


Figure 4.3.2.1 Loss Saving, kW vs Bus Number

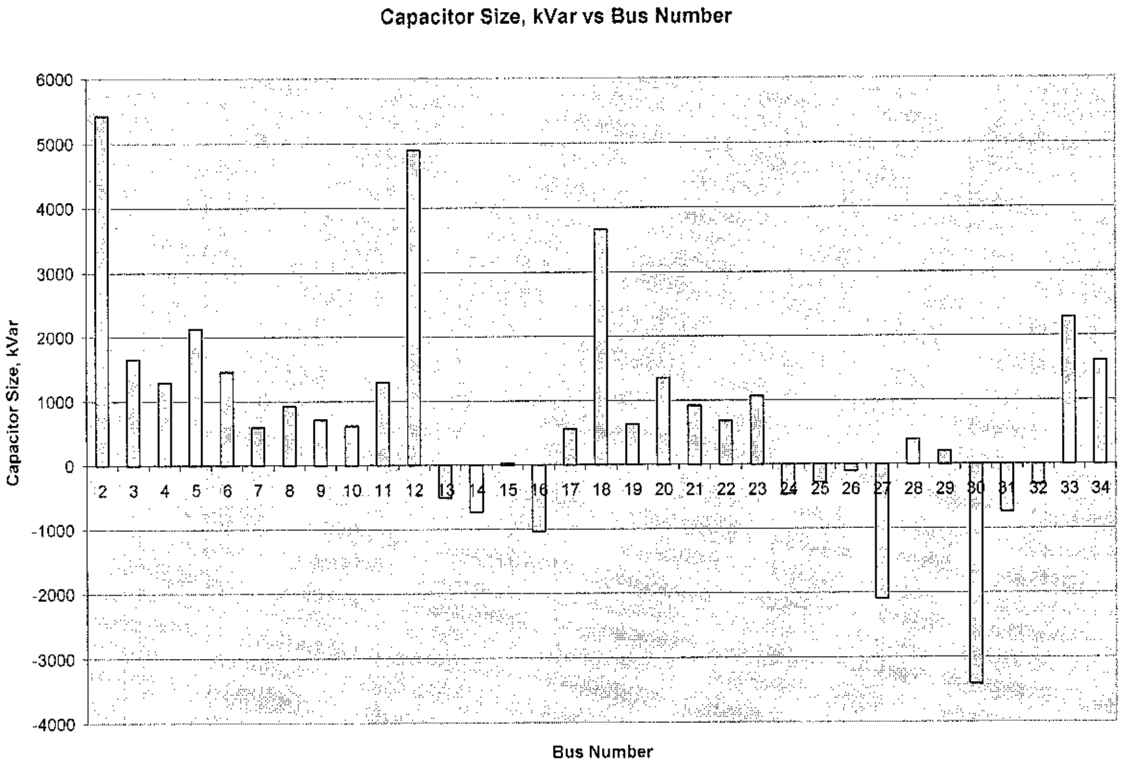


Figure 4.3.2.2 Capacitor Size, kVar vs Bus Number

4.2.4 Single Capacitor Insertion

For, single capacitor insertion, insert 1 capacitor, then the load flow is run again from the modified system to obtain the second bus where the second capacitor need to be inserted. From the figure 4.3.2.1 and figure 4.3.2.2, a 914.34kVAR capacitor is inserted at bus 21 in the original 34-bus system network. Then, run the load flow again to obtain new real and reactive power losses. Table 4.2.4.1 summarized the result of real and reactive power losses before and after compensation.

Table 4.2.4.1 Power Losses before and after compensation for 1 capacitor insertion

Type of Power Losses	Before Compensation	After Compensation
Total Real Power Losses, kW	222	185
Total Reactive Power Losses, kVar	65	54

From table 4.2.4.1, it is noticed that the total real power is saved by 37kW and the reactive power is saved by 11kVar.

The above method is repeated until the power losses cannot be saved. Hence, only 2 capacitors are to be inserted in the system. From Table 4.2.4.2, the total loss savings after the insertion of 2 capacitors is 50kW.

Table 4.2.4.2 Loss Saving after 2 Single Capacitor Insertions

No. of Capacitor	Bus Location	Capacitor Size kVar	Total Real Power Losses, kW	Total Reactive Power Losses, kVar	Total Loss Saving, kW	Total Saving, kW
0	-	-	222	65	-	-
1	21	914.34	185	54	37	37
2	20	940.17	172	50	13	50

The extra advantage of utilizing shunt capacitor insertion is that it helps to improve the voltage profile of the entire system. This is due to the current flowing in the line is decreased due to flow of less reactive component branch current, the voltage drop will decrease which in turn improve the voltage profile. Table 4.2.4.3 shows the voltage profile after compensation.

Table 4.2.4.3: Voltage Profile after Compensation for Single Capacitor Insertion

Busbar ID	pV (pu)	Voltage Profile V (kV)
Bus 1	1	11
Bus 2	0.994917	10.944
Bus 3	0.990514	10.896
Bus 4	0.984304	10.827
Bus 5	0.978997	10.769
Bus 6	0.974031	10.714
Bus 7	0.970217	10.672
Bus 8	0.968122	10.649
Bus 9	0.965664	10.622
Bus 10	0.964482	10.609
Bus 11	0.964026	10.604
Bus12	0.96389	10.603
Bus 13	0.990181	10.892
Bus14	0.989876	10.889
Bus 15	0.989793	10.888
Bus 16	0.989787	10.888
Bus 17	0.970377	10.674
Bus 18	0.967408	10.641
Bus 19	0.964083	10.605
Bus 20	0.961489	10.576
Bus 21	0.959325	10.553
Bus 22	0.956082	10.517
Bus 23	0.953416	10.488
Bus 24	0.950912	10.46
Bus 25	0.949706	10.447
Bus 26	0.949243	10.442
Bus 27	0.949105	10.44
Bus 28	0.969883	10.669
Bus 29	0.969659	10.666
Bus 30	0.969548	10.665
Bus 31	0.964142	10.606
Bus 32	0.963803	10.602
Bus 33	0.963633	10.6
Bus 34	0.963577	10.599

4.2.5 Multiple Capacitor Insertion

For multiple capacitor insertion, the capacitors are inserted simultaneously to reduce the reactive power losses. For this simulation, 2 capacitors are inserted simultaneously to the system, which are bus location 21 and 20 with the capacitor size of 914.34kVar and 1351.1kVar respectively. The total real and reactive power loss saved is 48kW and 15kVar respectively. Table 4.2.5.1 summarized the result after the multiple capacitor insertion. Table 4.2.5.2 shows the voltage profile after multiple capacitor insertion.

Table 4.2.5.1 Loss Saving after 2 Multiple Capacitor Insertions

Type of Power Losses	Before Compensation	After Compensation
Total Real Power Losses, kW	222	172
Total Reactive Power Losses, kVar	65	50

Table 4.2.5.2 shows the summary of the simulation result after the multiple capacitor insertion.

Table 4.2.5.2 Loss Saving after Multiple Capacitor Insertions

No. of Capacitor	Bus Location	Capacitor Size kVar	Total Real Power Losses, kW	Total Reactive Power Losses, kVar	Total Loss Saving, kW	Total Saving, kW
0	-	-	222	65	-	-
1	21	914.34	-	-	-	-
2	20	1351.1	173	50	49	49

Table 4.2.5.2: Voltage Profile after Compensation for Multiple Capacitor Insertion

Busbar ID	pV (pu)	Voltage Profile V (kV)
Bus 1	1	11
Bus 2	0.995088	10.946
Bus 3	0.990843	10.899
Bus 4	0.984797	10.833
Bus 5	0.97964	10.776
Bus 6	0.974824	10.723
Bus 7	0.971014	10.681
Bus 8	0.968921	10.658
Bus 9	0.966465	10.631
Bus 10	0.965283	10.618
Bus 11	0.964828	10.613
Bus12	0.964692	10.612
Bus 13	0.99051	10.896
Bus14	0.990205	10.892
Bus 15	0.990123	10.891
Bus 16	0.990116	10.891
Bus 17	0.971352	10.685
Bus 18	0.968551	10.654
Bus 19	0.965402	10.619
Bus 20	0.962971	10.593
Bus 21	0.960472	10.565
Bus 22	0.957233	10.53
Bus 23	0.95457	10.5
Bus 24	0.952069	10.473
Bus 25	0.950865	10.46
Bus 26	0.950402	10.454
Bus 27	0.950264	10.453
Bus 28	0.97068	10.677
Bus 29	0.970457	10.675
Bus 30	0.970345	10.674
Bus 31	0.964944	10.614
Bus 32	0.964605	10.611
Bus 33	0.964436	10.609
Bus 34	0.964379	10.608

4.2.6 Comparisons

The total loss saving contribute from both single and multiple capacitor insertions is 22.52% and 22.07% respectively. With that, the result is further compared to determine the cost effectiveness of each method utilizing the kilo-watt per kilo-volt-amps-reactive ratio (kW/kVAR). Utilizing the same method, the Genetic Algorithm will also be compared with the existing method namely, Heuristic Search Strategies. The higher the ratio, the more efficient the method would be. The higher the ratio, more saving is obtained by using the same capacitor size.

a) Single and Multiple Capacitor Insertions

Table 4.2.6.1 shows the comparison result for both single and multiple capacitor insertions. Single capacitor placement is identified to be more cost effective. It is because the kW/kVAR ratio is higher.for single capacitor insertion which is 2.696 as compared to 2.163 that of the multiple capacitor insertions. Hence, it indicates that less capacitor size, the system is able to contribute to the same amount of loss saving.

Table 4.2.6.1 Comparison of Single and Multiple Capacitor Insertions

No of Capacitor	Bus Number	Loss Savings (kW)		Capacitor Size (kVAR)		100(kW/kVAR)	
		Single	Multiple	Single	Multiple	Single	Multiple
0	-	-	-	-	-	-	-
1	21	37	-	914.34	914.34	-	-
2	20	13	49	940.17	1351.1	-	-
	Total	50	49	1854.51	2265.1	2.696	2.163

b) Genetic Algorithm (GA) and Heuristic Search Strategies (HSS)

Table 4.2.6.2 and Table 4.2.6.3 show the comparison result for both Genetic Algorithm and Heuristic Search Strategies with single and multiple capacitor insertions respectively. Although Heuristic Search Strategies is found to have total loss saving of 24.18% and 23.82% respectively for single and multiple capacitor insertions as compare to 22.52% and 22.07% respectively that of Genetic Algorithm. However, Genetic Algorithm is identified to be more cost effective. It is because the kW/kVAR ratio is higher for which 2.696 as compared to 2.163 for single and multiple capacitor insertion respectively for Genetic Algorithm as compare to 1.9885 and 2.158 of Heuristic Search Strategies. Hence, that shows that Genetic Algorithm is more cost effective in both single and multiple capacitor insertions.

Table 4.2.6.2 Comparison of Single Capacitor Insertion for GA and HSS

No of Capacitor	Bus Number	Loss Savings (kW)		Capacitor Size (kVAR)		100(kW/kVAR)	
		GA	HSS	GA	HSS	GA	HSS
1	21	37	41.07	914.34	1400	-	-
2	20	13	10.64	940.17	750	-	-
3	-	-	1.17		300	-	-
4	-	-	0.81		250	-	-
	Total	50	53.69	1854.51	2700	2.696	1.9885

Table 4.2.6.3 Comparison of Multiple Capacitor Insertions GA and HSS

No of Capacitor	Bus Number	Loss Savings (kW)		Capacitor Size (kVAR)		100(kW/kVAR)	
		GA	HSS	GA	HSS	GA	HSS
1	21	-	-	914.34	1400	-	-
2	20	-	-	1351.1	750	-	-
3	-	-	-	-	300	-	-
	Total	49	52.88	2265.1	2450	2.163	2.158

4.3 Discussions

Genetic algorithm is a very powerful in performing various simulation works due to its distinctive characteristics as discussed. This project focuses greatly in the development of genetic algorithm for the reduction of reactive power losses. The strategy behind the idea of reduction of reactive power is to capitalize the superior features of genetic algorithm in performing the mathematical simulation of a radial distribution network. The fundamental mathematical expressions of reactive power become the input to the genetic algorithm tool in this project. The mathematical expressions [2] involved in this project will be discussed in detail in the following section of the report.

The total power losses of a distribution system having n number of branches can be expressed as:

$$P_{LTOTAL} = \sum_{i=1}^{n} I_i^2 R_i \quad (4.1)$$

This power loss can be further associated into two components by separating the current, I into two namely the active branch, I_a and I_r reactive branch. The individual power losses namely the active power loss and reactive power loss are given by (4.2a) and (4.2b).

$$P_L = \sum_{i=1}^{n} I_{ai}^2 R_i \quad (4.2a)$$

$$Q_L = \sum_{i=1}^{n} I_{ri}^2 X_i \quad (4.2b)$$

The active and reactive components of branch currents are computed as:

$$I_a = I\cos\theta \quad (4.3a)$$

$$I_r = I\cos\theta \quad (4.3b)$$

Where

I = magnitude of current

θ = angle of current

Assume that a single source radial distribution system with n branches. A capacitor is to be placed at bus m with α is the set of branches connected between the source and capacitor bus.

Assume that a capacitor is inserted at bus 21, the set of α will then consists of braches 1, 2, 3, 4, 5, 16, 17, 18, 19, 20 and 21. The capacitor that is inserted draws a reactive current I_c. For a radial distribution system, the insertion of capacitor will only affect the reactive component of current of branch set α. Hence, the new reactive current I_{ri}^{new} of the ith branch is expressed as:

$$I_{ri}^{new} = I_{ri} + D_i I_c \quad (4.4)$$

Where

$$D_i = \begin{cases} 1, \, i \in \alpha \\ 0, \text{ otherwise} \end{cases}$$

The compensated reactive power is represented as the following:

$$Q_L^{com} = \sum_{i=1}^{n} (I_{ri} + D_i I_c)^2 Xi \quad (4.5)$$

Computing the overall saving as expressed.

$$\begin{aligned} S &= Q_L - Q_L^{com} \quad (4.6) \\ &= \sum_{i=1}^{n} I_{ri}^2 Xi - \sum_{i=1}^{n} (I_{ri} + D_i I_c)^2 Xi \\ &= \sum_{i=1}^{n} I_{ri}^2 Xi - \sum_{i=1}^{n} (I_{ri}{}^2 + 2 I_{ri} D_i I_c + D_i I_c{}^2) Xi \\ &= -\sum_{i=1}^{n} (2 I_{ri} D_i I_c + D_i I_c{}^2) Xi \quad (4.7) \end{aligned}$$

From expression 4.6, further simplification on the expression arrives at 4.7.

The typical method of locating the optimum value of capacitor current I_c is achieved by performing a differentiation onto 4.7. The next step will be working on the differentiation of 4.7 to obtain an expression of the maximum saving per capacitor current.

$$\frac{\partial S}{\partial I_c} = -2\sum_{i=1}^{n}(D_i I_{ri} + D_i I_c)Xi = 0 \quad (4.8)$$

In order to obtain the individual capacitor current at each of the branches on IEEE- 34 bus, it is necessary to equate the maximum saving per capacitor current to zero

$$-2\sum_{i=1}^{n}(D_i I_{ri} + D_i I_c)Xi = 0$$

$$\sum_{i=1}^{n} D_i I_c X_i = -\sum_{i=1}^{n} D_i I_{ri} X_i \quad (4.9)$$

The following steps bring capacitor current I_c to one side in order to compute the new capacitor current new reactive current I_{ri}^{new} of the *i*th branch as in 4.4.

$$I_c = -\frac{\sum_{i=1}^{n} D_i I_{ri} X_i}{\sum_{i=1}^{n} D_i X_i} = -\frac{\sum_{i\in\alpha} I_{ri} X_i}{\sum_{i\in\alpha} X_i} \quad (4.10)$$

However by capitalizing the powerful features of MATLAB GATool, finding the optimum values of capacitor current I_c can be performed by using 4.7. MATLAB GATool is initially designed to locate the minimum value of any mathematical expression. In the case of interest, in order to locate the individual capacitor current I_c value at which maximum savings is achieved, the entire expression 4.7 need to be negated. This allows the computation of capacitor current I_c within the multidimensional expression of the total reactive power saving. The computed set of capacitor currents I_c are optimized to obtain the maximum saving of reactive power. The capacitor current I_c which produces the highest saving is then used to compute the optimal capacitor size. This capacitor is then inserted to the respective branch in IEEE 34 bus where the capacitor current I_c is calculated to produces the highest saving. The optimal capacitor size is computed using 4.11.

$$Q_c = V_m I_c \quad (4.11)$$

CONCLUSIONS AND RECOMMENDATIONS

The objective and goal towards the end of the project is to achieve the reduction of reactive power loss using genetic algorithm. The final results of the project successfully provide solutions to the reduction of reactive power losses, which eventually further contribute to the entire electrical power system in achieving superior performance in the context of operational, economical and quality of service. IEEE 34-bus Standard Test System is used together with the MATLAB, GATool in MATLAB and ERACS as powerful tools for the analysis and simulation work.

The total loss saving for both single and multiple capacitor placements is 22.52% and 22.07% respectively. Single capacitor insertion is more cost effective as compare to multiple capacitor insertion because it have higher kW/kVAR ratio which is 2.696 and 2.163 respectively.

Heuristic Search Strategies has total loss saving of 24.18% and 23.82% respectively for single and multiple capacitor insertions while GA has 22.52% and 22.07%. However, Genetic Algorithm is identified to be more cost effective because it has higher kW/kVAR ratio which is 2.696 and 2.163 for single and multiple capacitor insertion respectively for while 1.9885 and 2.158 for Heuristic Search Strategies

As recommendations for future work, the algorithm is suggested to be implemented in the real practical system to analyze the real cost-benefit and its impact to the reduction of the reactive power to a real system. The enhancement on the algorithm can be done by using the user interface program. For instance, the user can enter number of bus and branches which will ease the maintenance of the program written without constant change to the program which might lead to unnecessary errors while doing the modification.

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APPENDICES

APPENDIX 1 Gantt Chart for First Semester

	Final Year Project Gantt Chart for First Semester (July 2005)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Selection of Project Topic**	■													
2	**Preliminary Research Work**	■	■	■	■										
	Introduction														
	Problem Statements														
	Objectives														
	Literature Review														
	Project Planning														
	Genetic Algorithm Software Identification														
3	**Submission of Preliminary Report**				■										
4	**Project Work**					■	■	■	■						
	Review of Genetic Algorithm														
	Application of Genetic Algorithm														
	Familiarization of Software														
	Genetic Algorithm Parameters Identification														
5	**Submission of Progress Report**								■						
6	**Continution of Project Work**									■	■	■			
	Genetic Algorithm for Reactive Power Reduction														
	Testing and Debugging														
7	**Preparation of Interim Report**											■			
8	**Submission of Interim Draft**												■		
9	**Submission of Interim Report**													■	
10	**Preparation Oral Presentation**														■
11	**Oral Presentation**														

APPENDIX 2 Gantt Chart for Second Semester

Final Year Project Gantt Chart for Second Semester (Jan 2006)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Project Work**														
	Familiarization of ERACS Software	■	■												
	Building the IEEE 34-Bus Model			■											
	Performing the Load Flow Analysis				■										
2	**Submission of Progress Report 1**				■										
3	**Continution of Project Work**														
	Verifying the Load Flow Result					■									
	Running the Genetic Algorithm						■								
	Developing the Loss Saving Code in MATLAB							■							
4	**Submission of Progress Report 2**								■						
5	**Continution of Project Work**														
	Testing and Debugging								■						
	Performing Analysis from the Result									■					
5	**Preparation of Dissertation**										■	■	■		
6	**Submission of Dissertation Draft**													■	
7	**Oral Presentation**														■
8	**Submission of Technical Report**														■
9	**Submission of Dissertation Report**														■

APPENDIX 3 MATLAB Programming

```
% Program for the calculation of Loss Savings and the capacitor size
% Able to sort and identify the maximum loss saving and its branch

 % Define the D. V, Ir, R and Ic needed for the loss saving calculation

D=[ 1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0;
   1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0;
   1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0;
   1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0;
   1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0,0;
   1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0;
   1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0;
   1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0;
   1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1];


V=[10.936,10.879,10.803,10.737,10.675,10.632,10.609,10.582,10.569,10.564,10.563,10.876,10.872,10.87
1,10.871,10.625,10.585,10.540,10.503,10.472,10.436,10.406,10.379,10.365,10.360,10.359,10.629,10.626,
10.625,10.565,10.562,10.560,10.559];
 Ir=[-0.15423,-0.14671,-0.13919,-0.13160,-0.12403,-0.04252,-0.03482,-0.02719,-0.01953,-0.01217,-
0.00451,-0.00752,-0.00514,-0.00276,-0.00039,-0.08145,-0.07382,-0.06619,-0.05854,-0.05085,-0.04317,-
0.03545,-0.02775,-0.02002,-0.01234,-0.00461,-0.00771,-0.00516,-0.00255,-0.00742,-0.00554,-0.00371,-
0.00183];

R=[0.11700,0.10725,0.16445,0.14950,0.14950,0.31440,0.20960,0.31440,0.20960,0.13100,0.10480,0.1572
0,0.20960,0.10480,0.05240,0.17940,0.16445,0.20790,0.18900,0.18900,0.26200,0.26200,0.31440,0.20960,
0.13100,0.10480,0.15720,0.15720,0.15720,0.15720,0.20960,0.15720,0.10480];
```

```
 Ic=[0.49638,0.15225,0.11944,0.19827,0.13652,0.055955,0.086621,0.066515,0.057581,0.1219,0.46336,-
0.047245,-0.067792,0.0027715,-
0.095488,0.052641,0.34561,0.059504,0.12864,0.087313,0.064833,0.10196,-0.044049,-0.026612,-
0.010527,-0.2013,0.03661,0.01896,-0.32078,-0.070228,-0.029709,0.21687,0.15259];


%Segment for the calculation of Loss Saving for each branch

fprintf('\nLoss Saving When Corresponding Optimal Capacitor is Placed at:\n\n');

for i=1:33;
   total=0; S(i)=0;

      for j=1:33;

            total= -(2*D(i,j)*Ir(j)*Ic(i)+D(i,j)*Ic(i)*Ic(i))*R(j)*1000;
            S(i)=(S(i)+ total);
      end
end


%Display of the loss saving and capacitor size for all the branches

for k=1:33;

   fprintf('Bus %2d: \nLoss saving is %5.2f kW',k+1,S(k));
   fprintf(' with capacitor size. Qc of %7.2f kVAR \n\n', V(k)*Ic(k)*1000);

end


%Sorting for maximum loss saving, branch number and the calculation of Qc

max=0;
for p=1:33;
   if(max<S(p))
      max=S(p);
      no=p+1;
      Qc=V(p)*Ic(p)*1000;
   end
end

%Display of maximum loss saving, capacitor size and its branch

fprintf('\nThe maximum loss saving is %5.2f kW', max);
fprintf('when a shunt capacitor with a size of %8.2f',Qc);
fprintf('kVAR is placed at bus %2d \n\n', no);
```

APPENDIX 4 MATLAB Programming Result

```
Loss Saving When Corresponding Optimal Capacitor is Placed at:
Bus  2:
Loss saving is -10.91 kW with capacitor size, Qc of 5428.41 kVAR
Bus  3:
Loss saving is  5.09 kW with capacitor size, Qc of 1656.33 kVAR
Bus  4:
Loss saving is  7.99 kW with capacitor size, Qc of 1290.31 kVAR
Bus  5:
Loss saving is  9.12 kW with capacitor size, Qc of 2128.82 kVAR
Bus  6:
Loss saving is 13.09 kW with capacitor size, Qc of 1457.35 kVAR
Bus  7:
Loss saving is  8.98 kW with capacitor size, Qc of  594.91 kVAR
Bus  8:
Loss saving is 10.93 kW with capacitor size, Qc of  918.96 kVAR
Bus  9:
Loss saving is  9.76 kW with capacitor size, Qc of  703.86 kVAR
Bus 10:
Loss saving is  9.01 kW with capacitor size, Qc of  608.57 kVAR
Bus 11:
Loss saving is  3.90 kW with capacitor size, Qc of 1287.75 kVAR
Bus 12:
Loss saving is -302.57 kW with capacitor size, Qc of 4894.47 kVAR
Bus 13:
Loss saving is -4.15 kW with capacitor size, Qc of -513.84 kVAR
Bus 14:
Loss saving is -7.60 kW with capacitor size, Qc of -737.03 kVAR
```

Bus 15:

Loss saving is 0.20 kW with capacitor size, Qc of 30.13 kVAR

Bus 16:

Loss saving is -13.76 kW with capacitor size, Qc of -1038.05 kVAR

Bus 17:

Loss saving is 9.13 kW with capacitor size, Qc of 559.31 kVAR

Bus 18:

Loss saving is -39.14 kW with capacitor size, Qc of 3658.28 kVAR

Bus 19:

Loss saving is 11.72 kW with capacitor size, Qc of 627.17 kVAR

Bus 20:

Loss saving is 14.04 kW with capacitor size, Qc of 1351.11 kVAR

Bus 21:

Loss saving is 14.92 kW with capacitor size, Qc of 914.34 kVAR

Bus 22:

Loss saving is 13.80 kW with capacitor size, Qc of 676.60 kVAR

Bus 23:

Loss saving is 13.76 kW with capacitor size, Qc of 1061.00 kVAR

Bus 24:

Loss saving is -21.10 kW with capacitor size, Qc of -457.18 kVAR

Bus 25:

Loss saving is -11.98 kW with capacitor size, Qc of -275.83 kVAR

Bus 26:

Loss saving is -4.34 kW with capacitor size, Qc of -109.06 kVAR

Bus 27:

Loss saving is -194.74 kW with capacitor size, Qc of -2085.27 kVAR

Bus 28:

Loss saving is 6.46 kW with capacitor size, Qc of 389.13 kVAR

Bus 29:

Loss saving is 3.71 kW with capacitor size, Qc of 201.47 kVAR

Bus 30:

Loss saving is -222.65 kW with capacitor size, Qc of -3408.29 kVAR

Bus 31:

Loss saving is -27.51 kW with capacitor size, Qc of -741.96 kVAR

Bus 32:

Loss saving is -9.61 kW with capacitor size, Qc of -313.79 kVAR

Bus 33:

Loss saving is -49.41 kW with capacitor size, Qc of 2290.15 kVAR

Bus 34:

Loss saving is -14.99 kW with capacitor size, Qc of 1611.20 kVAR

The maximum loss saving is 14.92 kW when a shunt capacitor with a size of 914.34kVAR is placed at bus 21