UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **PLACEMENT IMPACT OF DISTRIBUTED GENERATION IN DISTRIBUTION NETWORKS**

SESI PENGAJIAN: **2007/2010**

Saya **NURUL IMAN BT MAT YATIM (860531-56-5634)**
(HURUF BESAR)

mengaku membenarkan tesis (Sarjana Muda/~~Sarjana~~ /~~Doktor Falsafah~~)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

[ ]	**SULIT**	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
[ ]	**TERHAD**	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
√	**TIDAK TERHAD**	

Disahkan oleh:

(TANDATANGAN PENULIS) (TANDATANGAN PENYELIA)

Alamat Tetap:

NO. 531 KG BARU SG BAKAU,
48000 RAWANG,
SELANGOR DARUL EHSAN.

OMAR ALIMAN
(Nama Penyelia)

Tarikh: **24 NOVEMBER 2009**

Tarikh: : **24 NOVEMBER 2009**

CATATAN:
* Potong yang tidak berkenaan.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai atau TERHAD.
♦ Tesis dimaksudkan sebagai tesis bagi Ijazah doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

PLACEMENT IMPACT OF DISTRIBUTED GENERATION IN DISTRIBUTION NETWORKS

NURUL IMAN BT. MAT YATIM

This thesis is submitted as partial fulfillment of the requirement for the award of the

Bachelor Degree of Electrical Engineering (Power System)

Faculty of Electrical & Electronics Engineering

Universiti Malaysia Pahang

NOVEMBER 2009

“All the trademark and copyrights use herein are property of their respective owner.

Reference of information from other sources is quoted accordingly: otherwise the information

presented in this report is solely work of the author.”

Signature :

Author : NURUL IMAN BT. MAT YATIM

Date :

Specially dedicated to

My beloved family, my friends and those people who have guided inspired me throughout my journey of education

ACKNOWLEDGMENT

In the name of God, The Most Beneficent The Most Gracious

I would like to express my sincere gratitude and appreciation to En. Omar Aliman, my PSM Supervisor, for his advices, suggestions, patience and encouragement throughout the project. His invaluable support, understanding and expertise have been very important in completing my project

Sincere thanks to all the faculty and staff of Electric and Electronic Engineering for their encouragement and help.

I want to thanks Petronas for providing data to be test case to completing my Degrees program.

I would also like to thank my friends under supervise Encik Omar Aliman for the suggestions, support and sharing the knowledge together. Without them, I wouldn't be able to complete my project.

Not to forget, special thanks to my classmate, roommates and all my friends that gives invaluable supports, suggestions and advices for me from time to time until I complete the project.

Last but not least, I would like to thank my beloved parents who had given me a lot of moral support while I was struggling to finish this project.

ABSTRACT

The Distributed Generation (DG) penetration in distribution network has been slowly increasing for the last few years due to advancement of technologies and institutional changes in the electric power industry. DG has gained popularity as it seen to be the reliable option for solving major problem in electric power industry such as reduce high loss, decrease line losses, improving voltage profile at feeders and environmental effect. As the DG was popular, it is in the best interest of all players to allocate the DG to minimize the system losses thus improving voltage profile. This paper aims to find the optimal location for placing DG in distribution network to minimize the total power losses in distribution network, to propose the network improvement based on the presence of DG. The methodology starts with running the distribution load flow program to find the state of the bus systems. The base case load flow was simulated in DigSILENT PowerFactory to find the potential location for placing the DG. The proposed methodology in this paper is using Loss Sensitivity analysis which been applied at the feeder in test systems to find the potential location to place DG in terms minimizing the total power losses in the distribution network.

.

ABSTRAK

Dalam masa beberapa tahun ini, penggunaan Penjana Pembahagi atau dikenali sebagai ‘Distributed Generation’ (DG) ke dalam penyebaran jaringan telah meningkat. Ini adalah kerana kemajuan teknologi DG dan juga keadaan semasa dalam industri sistem kuasa. DG semakin dikenali kerana ia dianggap sebagai penyelesaian kepada masalah-masalah utama dalam industri sistem kuasa seperti mengurangkan kehilangan tenaga yang tinggi, mengurangkan kehilangan tenaga di jaringan, membaiki nilai voltan pada bus. Tesis ini bertujuan untuk mencari tempat sesuai untuk meletakkan DG didalam penyebaran jaringan untuk mengurangkan keseluruhan kehilangan tenaga dalam sistem, untuk mencadangkan pembaikan jaringan berdasarkan kewujudan DG. Cara untuk mencari lokasi yang sesuai untuk meletakan DG bermula dengan memulakan simulasi tentang penyebaran aliran beban bertujuan untuk mengetahui keadaan pada setiap bus dalam sistem. Simulasi dilakukan dengan menggunakan software DigSILENT PowerFactory untuk mencari lokasi sesuai untuk diletakkan DG. Cara yang dicadangkan untuk mencari lokasi sesuai untuk diletakkan DG adalah analisis Loss Sensitivity yang digunakan dibus yang boleh diharapkan untuk mencari tempat yang sesuai untuk diletakkan DG di dalam sistem untuk mengurangkan keseluruhan kehilangan tenaga pada sistem kuasa

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

Energy can be defined as the capacity of doing work. There is many form of energy. One of them is electrical energy. Electrical energy is the energy in a useable form, which can be transformed to other energy forms. The electrical energy can be produced at one location and transmitted to another instantaneously. It been delivered by a system of wires and control. This whole system is called electrical power system. Electrical power system is a key infrastructure nowadays as it was the major source of the energy in the world. The good electrical power system will promote the highest technologies. Power system can be explained by dividing it into three major parts: generation, transmission and distribution. The power is generate at the generation plant and been transport through high voltage transmission line and been step down the voltage and distribute in distribution network.

1.1 New Interest in Distributed Generation

Conventionally, the power plant used to supply electricity in the close neighborhood. But as the demand rises, the electricity grid was invented to transport the electricity over the longer distances. The invention of electricity grid has leads to construction of massive electricity system such as huge transmission and distribution grids and larger generation plant as the electricity that been transport over longer distance has increased the power output of generation units [1] and indirectly has increased convenience and lower per unit costs. But this has causing increasing of transportation costs. Distributed Generator (DG) is an alternative way to reduce cost of transportation as it was installing near to the load.

Moreover with the rapid load growth demanding more flexible power system that suits their needs. The utility companies used to predict the load growth in certain place until the predetermine amount was reach. When the amount was exceed the predict amount, they usually expanding the new substation capacity or construct the new substation. This had driving to the development technologies DG that fits to the criteria of flexible system. For the utility companies, they see DG as the tool that can help them to survive in liberalized market.

At present, the environmental issues has been the major reasons DG been so popular. Customers want the energy that cleaner and has less impact to the environment. They tend to choose DG as alternative power generating because the DG not only use the fuel fossil but also can be generates electricity with renewable sources. Also it is accepted by many countries that reduction in gaseous emissions (mainly CO_2) offered by DG is a major legal driver for DG implementation [2]. It also allows the optimizing energy consumption of firms which has lager demand for both electricity and heat. For example, compared to fossil fuel generation, the CHP generation has result in a primary energy conversion, varying from 10% to 30%, depends on the size of the cogeneration units [1]. It has promotes less pollution by using the waste of flue gas to generate electricity. Also the energy such as sun and wind are free and absolutely clean.

Nowadays, the need for more quality of electric supply has become priority for consumer. They are aware of the value of reliable electric supply. There are several reliability problems that disturbing distribution networks. Apart from the large voltage drops to near zero, consumer can also suffered from smaller voltage deviations [1]. For example in radial networks, bus voltages happens to decrease as the distances from the distribution transformer increases and may become lower than the minimum voltage permitted by the utility [3]. By adding DG, the branches current were reduces which causing the reduction of losses and increasing of voltage through feeder.

In electric power systems, normally the energy losses occur in distribution networks. This is because the electricity supply has been transmitting in over longer distances. The longer the distances the more losses in electricity supply. In order to transmit the electricity over longer distances; the grid has been invented in a bulk and high voltage to reduce the loss that absorbs through the transmission. This has causing the transportation cost to increase. DG provides the most economic solution to reduce the transportation cost. Moreover, DG provides the most economical solutions to load variation. Under voltages or overloads that are created by load growth may only happens at the circuit for a small number of hours [4].

1.2 Placement Impact of Distributed Generation in Distribution Network

The electrical power system faces many problems when adding the DG in the existing networks, since the DG imposes many impacts on the distribution networks.

However, in order to get all the benefits, the DG must be put in strategically place. Finding the DG strategically allocation can result in a decrease in system losses which lead to decrease costs. DG affects the flow of power and voltage conditions at consumers and utility equipment [5]. The distribution system has been designed in passive network that is to operate in unidirectional power flow, from source to the loads. In the presence of DG, the distribution network becomes active networks with multidirectional power flow. The power flow can be reversed with the DG sending power in either direction from where it from. This has causing the disturbances of radiality. The strategically place of DG has been taken as priority due to this problem.

Although there are many advantages using the distributed generation, there are many issues that need consideration especially in technical issues such as the best allocation to install the distributed generation in order to get benefits from it. As the voltages to be within a specified limit, finding proper place to install DG is necessary as DG has greater effect on the voltage profiles along a feeder by changing the direction and magnitude of real and reactive power flows. DG can change the voltage where it is applied without having to change the voltage across the entire power system [6]. DG injected power has causing the voltage to be out of limits further downstream [7].

1.3 Thesis Organization

This paper proposes the analytical approaches to determine the optimal location for placing DG in network system. The process were observing at events, collecting data from the calculation and simulation, and analyzing information by comparing the result between calculation and simulation and reporting the result.

For this engineering project, the method that been proposed to find the strategically placement distributed generator (DG) in distribution networks is sensitivity analysis based on the voltage sensitivity and loss sensitivity. And also random technique that appropriate for the project also has been used as one of the method. For simulating the result that were obtain from the data, the DigSILENT Power Factory software were use as an analysis tool that combine reliable and flexible system modeling capabilities. The DigSILENT Power Factory software is an integrated power system analysis tool that combines both reliable factor and flexible system modeling capabilities to simulate the design.

This analysis study will focus on the presence DG which is the system losses, and power quality of the system. However, reliability, protection and economic impact are out of analysis study. The test system for this project is standard IEEE RS of 34 bus system been use to getting data from real utilities for the base case. For safety reasons, there is no testing and live measurement since the project was dealing with real high voltage system. The validation process is done by comparing with two different software or base comparison to tests recorded by the consultant.

1.4 Objectives of Project

The objectives of project are:

i. To determine the optimal location for placing distributed generation in network system to minimize power losses.
ii. To study the characteristics with and without DG.
iii. To propose the network improvement based on the presence of DG

1.5 Background

Electrical energy is the main source of energy nowadays. The electrical power system delivers the electrical energy to consumers which they use for variety of purposes. In return they pay for the energy that they consume. The electrical power system consist of three major parts; generation, transmission and distribution.

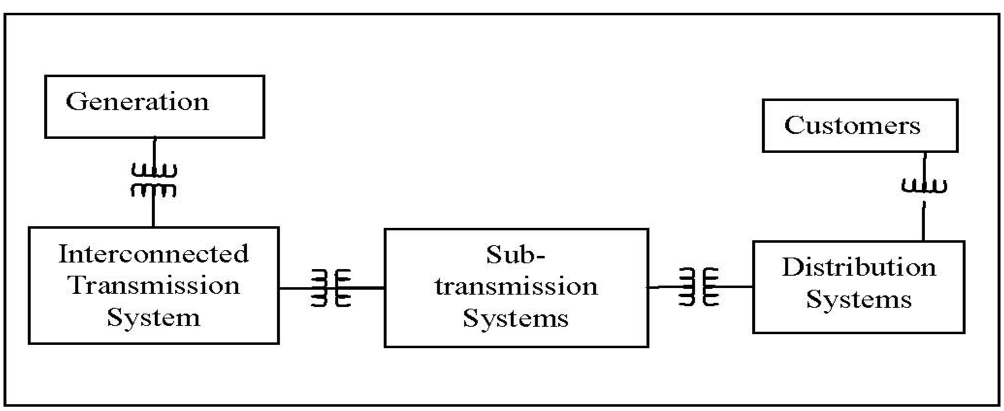


Figure 1.1 Typical Power System Components [8]

1.5.1 Generating Unit

The generation plant is used to convert the energy resources such as gas, coal and thermal into electrical energy in order to supply electricity requirements at all times. The electricity is produced in bulk at centralized station. The electricity is produced in remote place to avoid the pollution and construction of the huge structure require very large area as the generator very large and at times they are a group of two or more generators. The generation plant should be function in a reliable manner, involved maintaining the voltage and frequency stability of the network. It also should be avoid from disturbances which can jeopardize the correct functioning of the electrical power system.

1.5.2 Transmission Network

The electricity that been produced at remote area been transport via transmission line. The transmission system consists of three-phase transmission lines and connected to substation or switching stations. The transmission line usually installed in high voltage to decrease current amount thus reduces the cost of cable. There are 2 type of high-voltage transmission; high-voltage alternating current (HVAC) and high-voltage direct current (HVDC). The transmission line has three types; overhead, underground and submarine. A transmission network operates by a dispatching center or several regional dispatching centers. In general the transmission network is meshed. The power flow in each element of the networks can be calculated based on the inputs and the outputs of the electric power system.

1.5.3 Distribution System

The distribution system receives the voltages from high-voltage transmission lines and step down the voltage level to distribute to consumers according their needs. Distribution system operates either in radial or subnetworks to avoid overloading by the power flow coming from the electric transmission system mainly when some of the link failure to operate. Apart from the 3 major part of the electrical power systems, the distribution system plays the important role in the quality of serviced received by consumers. Good quality electric service requires acceptable range voltage level that suitable for their needs. The distribution system consist of passive electrical circuits which causing the active and reactive power fluxes flow from the high to low voltages. These fluxes are determined by loads. The voltage drops in the distribution networks are due to the active power circulation (R>>X) and the compensation of reactive power is mainly achieved at the consumer level because it forced by pricing [9].

1.5.4 Distributed Generation

Distributed generation or also known as embedded generation, on-site generation, dispersed generation, decentralized generation or distributed energy is a small plant generates electricity closed to the end user of power (connected to distribution network) and the capacity of DG is less than 100MW. It developed using the basis of cogeneration units, renewable energy system or traditional power generation. Some DG been installed at customer’s premise and connected to the customer’s side to directly supplied electricity. Others were connected to the distribution network to provide the electricity supply to multiple customers. The use of DG has helps providing power impacts on the design and operation of bulk supply system including ancillary services.

Since early 19th the demand for electricity has increased. Due to the increasing load and generators can't be overloaded and the emerging of new technologies. DG not only economical but it also easy to install as it was small, easier to find sites and take short installation times. It also energy efficiency as it reduces loss. The natural gas which often used in distributed generation seems to be available in most consumer areas and offer stable price. This new technologies also flexible, reliable and helps promote power quality of electric services. By adding DG has created problems to distribution systems such as reverse power flow, system voltage (steady-state and transient) and the system stability.

1.5.5 Distributed Generation Technologies

Type	Size Range (kW)	Electrical Efficiency (%)	Applications
Reciprocating Engines	5-7000	25-45	Backup power, base load, grid support and peak shaving.
Fuel Cells	1-10000	40-65	Co-generation, grid support

Photovoltaic Arrays	<1-100	5-15	Base load, peak shaving
Stirling Engines	1-25	12-20	Vehicles, Refrigeration, Aircraft, Space
Wind systems	Several kW-5000	20-40	Remote power, grid support
Micro Turbines	30-500	20-30	Stand-by power, power quality, reliability, peak shaving, and cogeneration
Biomass energy	5-10000	40-50	Co-generation, grid support

Table 1.1: Options for small scale distributed generation [8]

These are the latest form of distributed generation. They are other technologies beside the listed ones. These technologies are the result of intensive research and development.

1.5.6 Power losses

Transmission lines transmit electricity to generator unit to the customer. The long distance of transmission lines has causing the losses of the system due to many factors such as thermal resistance, line impedance and many more.

The high voltage will reduce the fraction of energy loss to resistance. This is because for the given amount of power, a higher voltage reduces the current thus reducing the resistive losses.

CHAPTER 2

LITERATURE REVIEW

For this chapter, the literature review was mainly because the major policy issues that popular the DG. And also this chapter will discussing about the DG technologies that helps to popular back the DG and the placement techniques that been used to find optimal placement to allocate DG to minimize the power losses in the system.

2.1 Major Policy Issues of DG

Nowadays, with the emerging of new technologies has indirectly growth many industries that demand much of electricity. This growth has demands for more flexible electric system, energy savings, changing regulatory and cleaner energy. This growth has leading to the development of distributed generation or DG. DG has cope the growing demand of electricity and render the certain activities sell-sufficient in terms of power productions thus savings energy [10]. Distributed generation (DG) defined as small scale electricity generation. DG is an alternative for expanding the new substations capacities and their associated new feeder or constructs the new substations [2] when the growths demand higher than existing demand of electricity. The utilities companies no longer have to predict about the load growth in certain places.

DG is expected to grow in the future. DG supplied the electricity to customer either by using the distribution networks or without distribution networks as DG normally was installing near to the loads. According to the M. Gandomkar, the main reasons for the increasing of DG is [7]; DG units are closer to customer so that the transmission and distribution costs are reduced, the latest technology has made available plants ranging in capacity from 10kW to 15kW, It is easier to find sites for small generators, usually DG plants require shorter installation times and the investment risk is not so high, CHP(Combined Heat and Power) groups do not require large and expensive heat network, natural gas, often used as fuel in DG stations is distributed almost everywhere and stable prices are to be expected, DG plants yield fairly good efficiencies especially in cogeneration and combine cycles, and lastly DG offers great values as it provides a flexible way to choose a wide range of combinations of cost and reliability.

By adding DG into the existing networks have impacts on the electric power system as the power system was not designed to existence of DG. According to Umar Nassem Khan there are few data that been need to consider before evaluating the impacts of DG in distribution networks. The data is size rating of the processor DG, type of DG power converter (static or rotating machine), type of DG prime energy source (such photovoltaic, wind or fuel cell), operating cycles, fault current contribution of DG, harmonics output content of DG, DG power factor under various operating conditions, locations and setting of voltage regulation equipment on distribution system, locations and settings of equipment for over current protection on distribution system. However, for this project, only potential locations of DG on the distribution system been taken to evaluate the impacts on the distribution systems.

Distribution networks been designed to transmit the electricity from high voltage transmission networks, which is generating plant to the customers. But, in the presence of DG has changed this thought. DG has change the passive networks of distribution networks that used to operate in unidirectional power flows to active networks with multidirectional power flows depending on the higher sources [7].

DG is an alternative option for solving major problems of distribution companies such as load growth, overload lines, quality of supply and reliability. DG applications can potentially be the investment as it could be the upgrade the assets of distribution system, extend equipment maintenance, reduce line loss and improve system reliability.

2.2 DG Technologies

DG technologies is one of the reason that popular back the DG. Before the DG was seldomly use due to the high cost and inefficient. With the DG technologies, the renewable energy was been used resulting cheaper choice energy for DG. The DG technologies have 4 basic technologies other than renewable energy that is reciprocating engines sets, gas turbine generators, microturbines, and fuel cells. According to Michael A. Devine, the journalist who wrote the 'The Case for Natural-Gas-Fueled Distributed Power Generation' reciprocating engine generators sets deliver the most reliable operating characteristics and the lowest cost of electricity[11]. The figure below shows the types and technologies of DG.

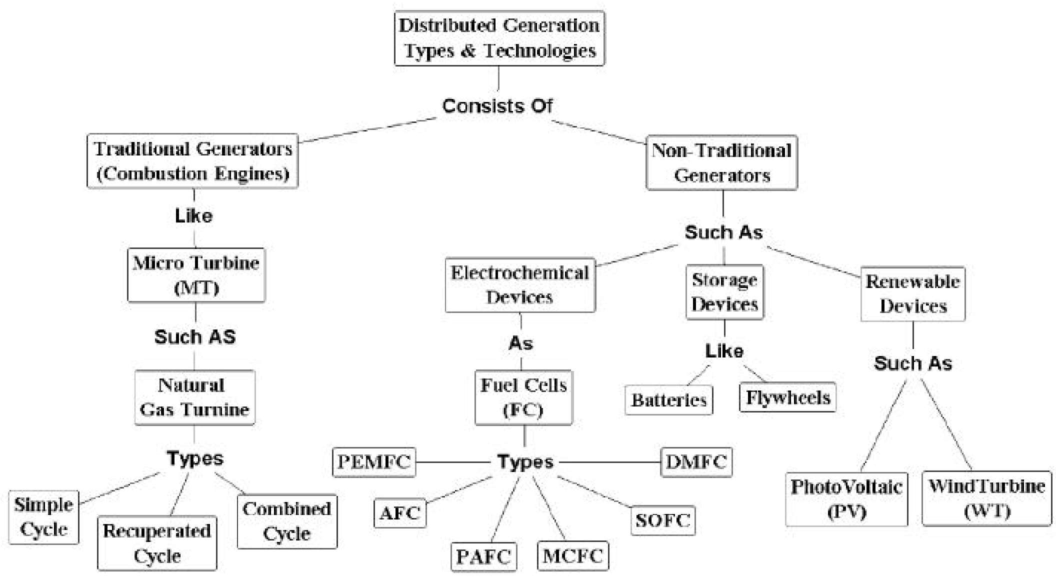


Figure 2.1 DG Types and Technologies

The next subtopic will be briefly discussing about the types of DG technologies.

2.2.1 Reciprocating Engine Generator Sets

Reciprocating engines was the first among the DG technologies. It was fastest selling, lowest-cost distributed generation due to that it reliable, low maintenance, and good durability [12]. The type range in size from less than 5 to 5000kW and their fuel source was diesel, natural gas, or waste gas. The installation is fast and simple which it was in mobile packaged generator sets can be delivered and install within hours [11]. Reciprocating engine generator sets are proven in a wide range of distributed power applications such as standby, prime mover, cogeneration and peaking.

2.2.2 Microturbines

Microturbines are small capacity combustion turbines which operate using either natural gas, propane, and fuel oil. This type generally sized from 25-500kW. The basic technology in micrturbines is derived from aircraft auxiliary power systems, diesel engine turbochargers, and automotive designs [13]. Microturbines consist of a compressor, combustor, turbine and generator. The advantages of using microturbines is they can be installed on-site especially if there are space limitations since they are compact in size and light in weight with respect to traditional combustion engines, very efficient and have lower emissions with respect of large scale, start-up easily, less maintenance and small number of moving parts with small inertia not like a large gas turbine with large inertia [14].

2.2.3 Fuel Cells

Fuel cells are using the technology which combines oxygen and hydrogen to generate electricity with water and heat being produced as by product. It can be considered as a battery supplying electric energy as long as its fuels are continued to supply. But unlike batteries, the fuel cells do not need to be charged for the consumed material during electrochemical process since these materials are continuously supplied [15]. The development stages of fuel cells are phosphoric acid, molten carbonate, solid oxide and proton exchange membrane. Fuel cells capacities vary from kW to MW for portable and stationary units. It clean power and heat for several applications and operates at different pressures and temperatures which varies from atmospheric to hundreds of atmospheric pressure and from 20 to 200˚C [16].

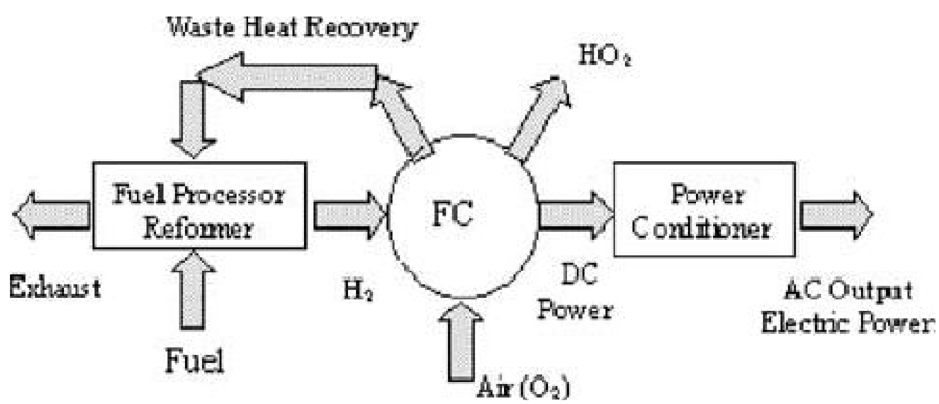


Figure 2.2 Fuel cells construction, operation, and products

2.2.4 Photovoltaic System

Photovoltaic (PV) solar panels are made of cells that may be square or round in shape, made of doped silicon and connected to form a module or panel which connected to form an array to generate the required power. It converts the light radiation into DC electrical power. The operation of PV is the cells absorb solar energy from the sunlight, where the light photons force cell electrons to flow, and convert it into dc electricity [14]. It’s been use widely for both commercial and domestic use. This type size is range from less than 5kW and units can be combined to form a system of any size. PV panel produce no emissions, and require minimal maintenance. However they are quite costly [17].

2.2.5 Wind Turbines

Wind turbines is not new form as it has been used for decades and it been considered as DG due to size and location of some wind farms has made them suitable for connection at distribution voltages [18]. It consists of a rotor, turbine blades, generator, drive or coupling device, shaft and nacelle drive that contains the gearbox and the generator drive [14]. The size of wind turbines are range from less than 5kW to over 1000kW. They provide a relatively inexpensive (compared to other renewable) way to produce electricity, but as they depends on wind which is unpredictable, are unsuitable for continuous power needs [17]. With the new development has pair the wind turbines with battery storage systems that can provide with power when the turbine is not running.

2.3 DG Placement Techniques

The DGs has been used widely around the world and it is important to place it properly with jeopardizing the power systems. Proper placement of DGs will lead to the reduction of system loss thus improving voltage profiles at feeder. Meanwhile the improper placement of DGs will result increasing of overall system loss. The proper placement also will free available capacity for power transmission of power system and reduce equipment stress. By allocate DG at proper place, we can defer investment in transmission line expansion as well as improve overall efficiency of the power delivery. There are more power quality can be improved by placing DG at proper place.

A near placement technique to reduce the system loss has been presented in [19]. Transmission losses are being calculated using 'B' loss coefficient. This method has been widely used by power utility to find loss. Based on this, loss sensitivity of load bus was calculated. First, the buses are ranked based on their loss sensitivity and size of DG in that bus is kept increasing until loss start to increase. Then the DG is placed at the bus that has most loss reduction. In this study, four feeders are chosen according to the transmission system and size of DG. This method was only finding the location of DG and does not find the size of DG and hence loss sensitivity of buses changes when the size of DG increase.

Genetic algorithm (GA) was another method to find allocation of DG.GA is suitable for multi-objective problem and gives near optimal solution but is computationally intensive and suffers from excessive convergence and premature convergence. And it was presented in [20]. For this study, the B-loss coefficient is used to find the system loss. This method uses Genetic Algorithm Toolbox and both optimal location and size can be found from it. Another genetic algorithm based DG placement was presented in [21]. This algorithm finds optimal size and place where we can install DG to reduce system loss. This technique was used to solving the DG placement problem in medium voltage distribution system.

Another method that been used is Hereford Ranch Algorithm. It was used to find the optimal location for DG in distribution networks to reduce power loss under constraint of the total injection of installed DG in [22]. This method quite similar to GA as it was computationally intensive though it addresses the issue of premature convergence. It also has ability to search for better optimal solution.

In [23], the DG placement problem was solved when the optimal location to place DG with unity power factor in radial or networked system while minimizing the loss. This method based on the bus admittance matrix, generation information, and load distribution of the system. Again, this technique also focuses on the optimal placement of DG while ignoring the optimal sizing of DG in the system. The strong point of this method is it considers time varying load.

The proposed methodology in [24] was two Lagrangian based approach to determine the location, taking system cost and stability limit under consideration. By using Lagrangian multipliers associated with real and reactive power load flow equations, the optimal location can be found in the system. Traditional pool based Optimal Power Flow (OPF) and Voltage Stability Constrained OPF has been used to place DGS to reduce the system costs and enhance stability. In another technique, the DG is placed at the bus which has greatest effect on the overall system cost. In another technique, DG is placed in the bus that has the greatest effect on stability margin of the system. This solves the location problem but does not find the size of DG.

CHAPTER 3

METHODOLOGY

The penetration of distributed generators (DG) in the electric power system has been slowly increasing in the last few years. Many institutes predict that DG will become more popular in the future as DG can be considered as one of the best options to solve some problems faced by electric power system such as high loss, poor voltage profiles, low reliability, and congestion in transmission system and meeting with energy demand with unpredictable growing loads. In addition, DG was small and modular had facilitated planner to install DG in short time compare to the conventional generating units. However, the DG needs to be placed at proper place in order to receive all the benefits.

The proper placement of DG in distribution system plays an important role in reducing system loss. If the DG been allocated at optimal placement it will decrease system loss thus improving system losses. However if the DG been put at inappropriate place it will lead to greater losses compare the system without penetration of DG. The utilities had already facing the problem of high losses and poor voltage profile and cannot tolerate with any action that bring down more losses. That why it's important to find the optimal placement of DG in distribution system.

3.1 Analysis of Base Case Load Flow

For the base case load flow data, the data was obtained from the petrochemical place. The data contains various sizes of cables, 15 transformers, 13 static loads and 12 motors. The data was simulated using the DigSILENT Power Factory software. From the simulation, the total loss of the system was obtained which will be used to find the proper place to locate DG. The result of base case:

Grid: Grid	System Stage: Grid	Study Case: Study Case	Annex:

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
0.41	0.00	1.50	0.92	0.00	0.00			0.01	0.01	0.00
	0.00	1.43	0.40	0.00	0.00			0.03	0.03	-0.00
						11.00 kV	-2.43	0.03	0.01	0.02
							-1.86	0.05	0.05	0.00
3.30	0.00	0.00	0.72	0.00	0.00			0.00	0.00	0.00
	0.00	1.23	0.54	0.00	0.00			0.00	0.00	-0.00
						11.00 kV	-0.72	0.01	0.00	0.01
							-1.77	0.04	0.02	0.02
11.00	0.00	3.50	0.80	0.00	0.00			0.00	0.00	0.00
	0.00	3.31	-0.00	0.00	0.00			-0.03	0.00	-0.03
						0.41 kV	2.46	0.03	0.01	0.02
							1.91	0.05	0.05	0.00
						3.30 kV	0.73	0.01	0.00	0.01
							1.82	0.04	0.02	0.02
						33.00 kV	-7.49	0.04	0.01	0.04
							-7.01	0.22	0.13	0.08
33.00	0.00	25.00	8.00	0.00	0.00			0.00	0.00	-0.00
	0.00	22.90	6.00	-0.86	0.00			-0.19	0.01	-0.20
						11.00 kV	7.53	0.04	0.01	0.04
							7.22	0.22	0.13	0.08
						132.00 kV	-40.54	0.15	0.12	0.03
							-35.07	4.07	4.02	0.05
132.00	0.00	0.00	0.00	0.00	40.76			0.07	0.07	-0.00
	0.00	0.00	0.00	0.00	39.24			0.10	0.15	-0.05
						33.00 kV	40.69	0.15	0.12	0.03
							39.14	4.07	4.02	0.05

Figure 3.1 Simulation result for the total losses at different voltage feeders

Grid: Grid	System Stage: Grid	Study Case: Study Case	Annex:	/ 5

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
Total:	0.00	30.00	10.44	0.00	40.76		0.00	0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24		0.00	4.29	4.42	-0.12

	DIgSILENT PowerFactory 13.2.336	Project: Date: 11/2/2009

Load Flow Calculation	Complete System Report: Voltage Profiles, Area Interchange

Balanced, positive sequence		Automatic Model Adaptation for Convergency	No
Automatic Tap Adjust of Transformers	No	Max. Acceptable Load Flow Error for	
Consider Reactive Power Limits	No	Nodes	1.00 kVA
		Model Equations	0.10 %

Total System Summary	Study Case: Study Case	Annex:	/ 6

	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Inter Area Flow [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
\iman\psm\Grid									
	0.00	30.00	10.44	0.00	40.76	0.00	0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24	0.00	4.29	4.42	-0.12
Total:									
	0.00	30.00	10.44	0.00	40.76		0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24		4.29	4.42	-0.12

Figure 3.2 Simulation results for the total losses in the system

3.2 Optimal DG Placement to Reduce Real Power Loss

The real power loss in the distribution system is very significant from the operation point of view. Losses increase the operating cost of a power system and determine the operation of various generating plants. In addition to that, thermal losses reduce the overall lifetime of electrical equipments. So loss in the system should be presented accurately. To find loss in the case is by running power flow. The difference between the generated power and load will give the loss. The loss in the system can be given by equation 3.1 [25], if the system operating condition was known.

$$PL = \sum_{i=1}^{N} \sum_{j=1}^{N} [\alpha ij\ (PiPj - QiQj) + \beta ij(QiPj - PiQj)] \quad (3.1)$$

$$\alpha_{ij} = \frac{Rij}{ViVj} \cos(\delta i - \delta j) \quad (3.2)$$

$$\beta ij = \frac{Rij}{ViVj} \quad (3.3)$$

Where,

P_i and Q_i are net real and reactive power injection in bus ‘i’

R_{ij} is the line resistance between bus ‘i’ and ‘j’

V_i and δ_i are the voltage and angle at bus ‘i’.

The objective of the placement technique is to minimize the loss. The objective function can be representing as:

$$P_L \quad (3.4)$$

$$P_G = P_D + P_L \quad (3.5)$$

Where, P_L is the real power loss in the system, and P_G and P_D are its power generation and demand, respectively.

Then to find the sensitivity factor, used the loss equation and equate its first derivative to zero. The sensitivity factors of real power loss with respect to real power injection from DG is given by

$$\alpha_{ij} = \frac{\partial PL}{\partial Pi} = 2 \sum_{i=1}^{N} (\alpha_{ij} P_j - \beta_{ij}) \quad (3.6)$$

3.3 System Modeling For Power Flow

To run a load flow, it is necessary to model the different parameters of the distribution system first. The following section will show how line, load, DGs can be modeled for load flow algorithm.

3.3.1 Line Modeling

Distribution feeders consist of three-phase underground cable or overhead transmission line. It can be representing by a single line π or T for balanced load.

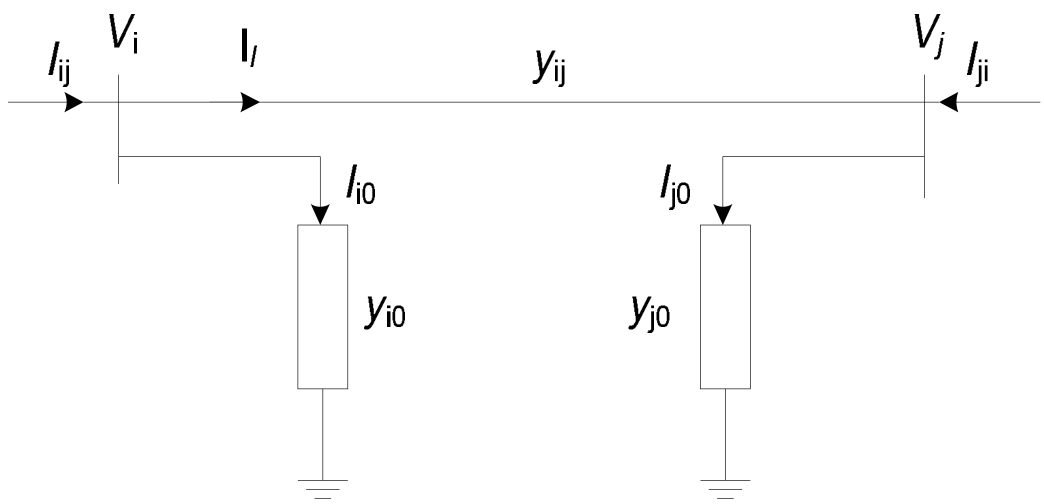


Figure 3.3 Modeling line for single phase π

The line impedance can represent by a 3x3 matrix as figure below:

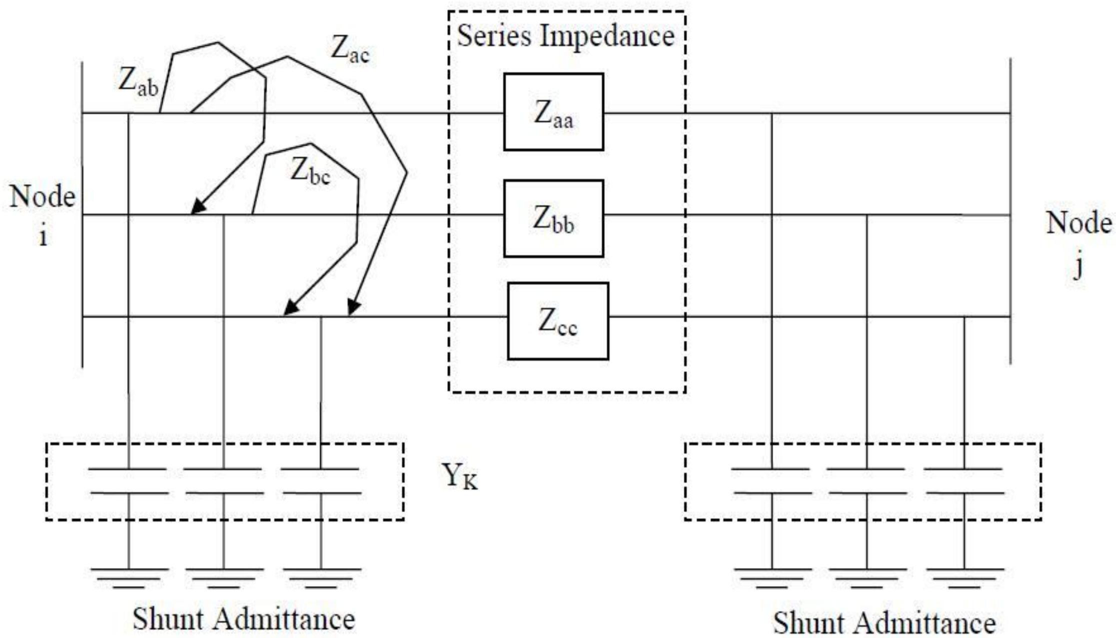


Figure 3.4 Model of a Line Section

$$Z_K = \begin{bmatrix} Zaa,k & Zab,k & Zac,k \\ Zba,k & Zbb,k & Zbc,k \\ Zca,k & Zcb,k & Zcc,k \end{bmatrix}$$

Zaa, Zbb, Zcc are the self impedance of phase A, B and C and Zab, Zbc, Zca are the mutual impedance between the phases.

3.3.2 Load Modeling

Three phase load can be representing as:

- Constant Power (P and Q constant)
- Constant Current (I Constant)
- Constant Impedance (Constant Z)
- Combination of all three

3.3.3 Feeder Modeling

For load flow technique, feeders are numbered in base case, layer of layer. It start will start only when all the branches in the previous are numbered. It illustrate like figure below:

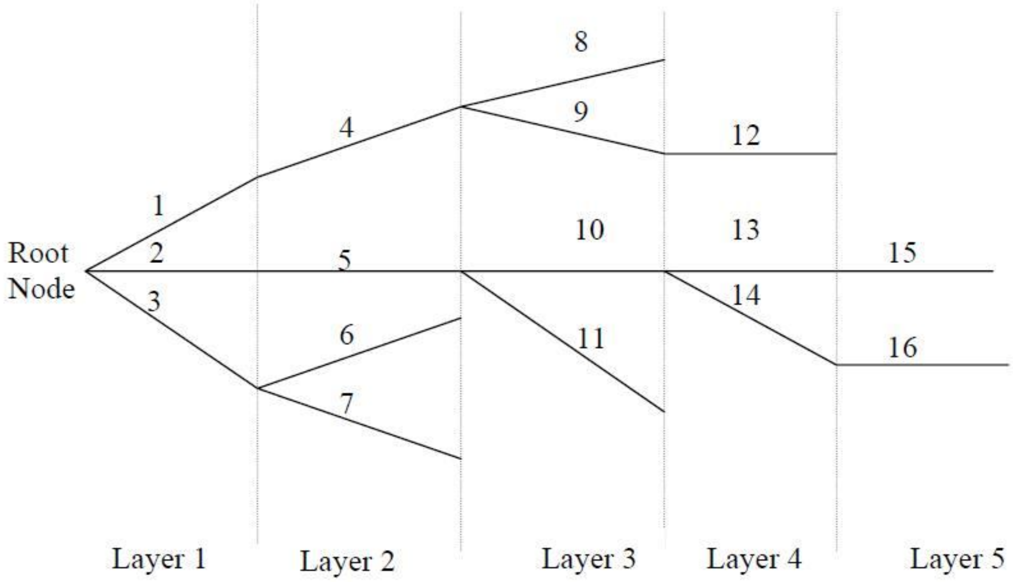


Figure 3.5 Numbering of Feeders

3.3.4 Distribution Generation Modeling

It is important to model DG in the distribution properly. This is because the characteristic of DG had biggest influence in distribution network. DG can be representing as:

- As a constant source of real or reactive power
- As a constant of real power and load of reactive power
- As a source that can maintain the bus voltage

At first case, the DG can be modeled as a negative real or reactive power load. For the second case, the DG can be modeled as the negative of real power with positive reactive power consumption which is the real power function. DG that produces in conventional way such as reciprocating engines and gas turbine will produce both real and reactive power. For DG technologies such as photovoltaic, it will supply real power but in turn it will consume reactive power.

3.4 Methodology for Optimal DG Placement to Reduce Real Power Loss System

The methodology starts with running the base case load flow to find the state of base case systems. Based on the system condition, we will find the power losses at feeders. Since the distribution networks in base case was in radial form, the loss sensitivity analysis was applied at 33kV and 11kV feeders only. The root node and 0.415kV buses was not been applied by loss sensitivity analysis. Then, place the DG at the place with high power losses. Then run the load flow to find the new power losses. There is another method which randomly injected the DG at 33kV and 11kV feeders. Then, run again the load flow to update the changes (DG) and the total power losses system were been observe.

When the DG been place at bus, there will be change in the state of the system. To find the new state of the system, the load flow needs to be run again. According to this point, the second method will give the accurate loss in the system. Hence, the calculation of loss was done to solve the placement problem.

The flow chart of method 1 and 2 are shown in Figure.

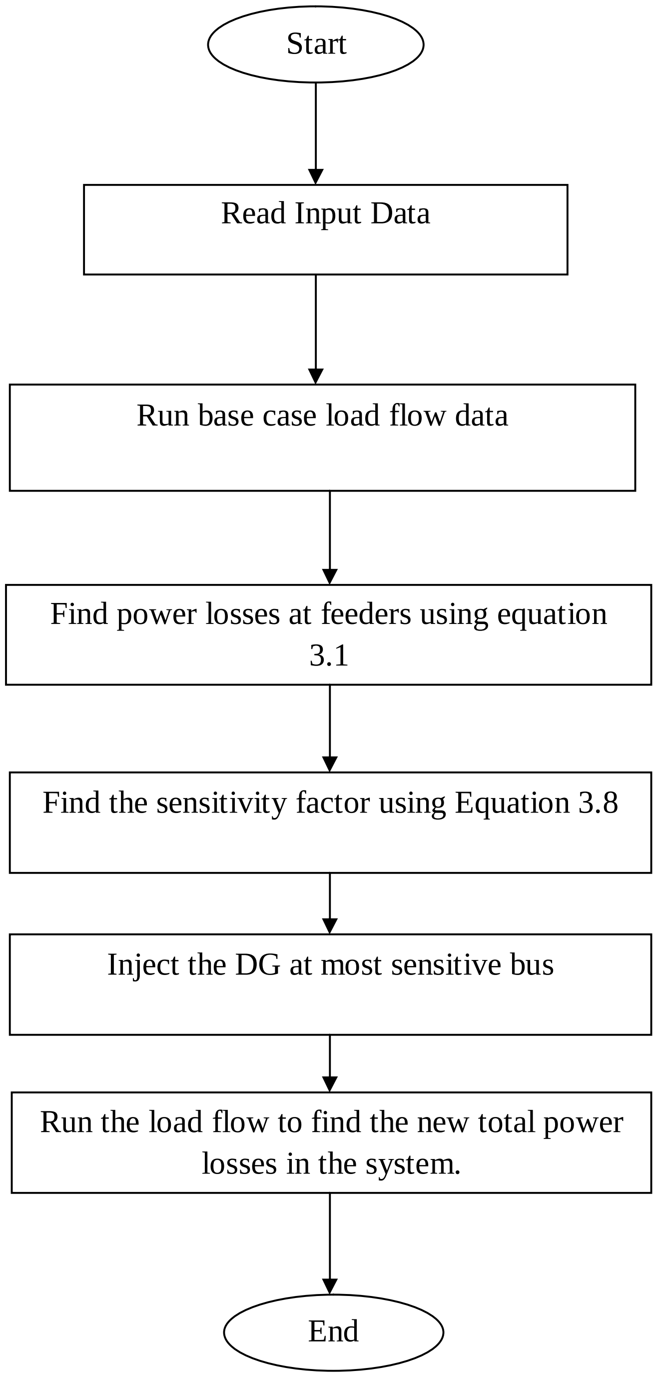


Figure 3.6 Flow Chart to Find the Optimal Placement of DG using Loss Sensitivity analysis to Reduce Loss in the System

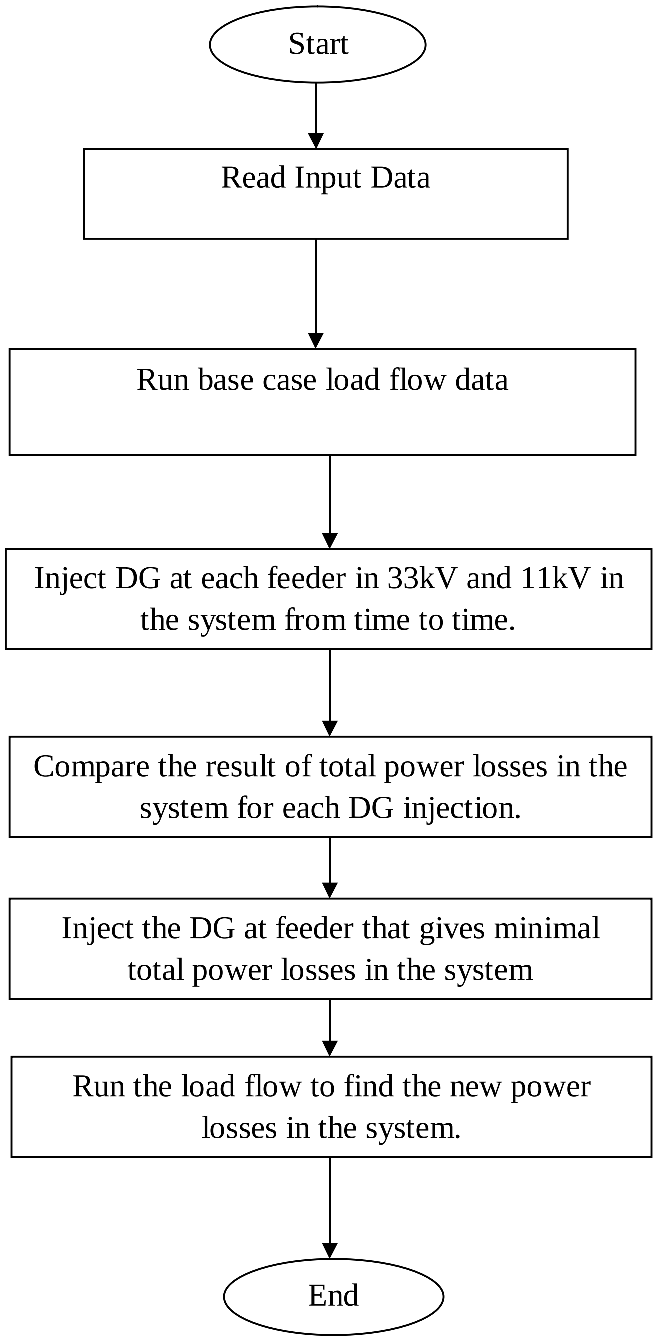


Figure 3.6 Flow Chart to Find the Optimal Placement of DG using Random analysis to Reduce Loss in the System

CHAPTER 4

RESULT AND DISCUSSION

Results from the simulation were presented here. First the result was obtained from base case load flow data. Then the result of base case load flow data was compared with the result of injection DG at each different voltage feeder to find the potential feeders that minimize the system losses.

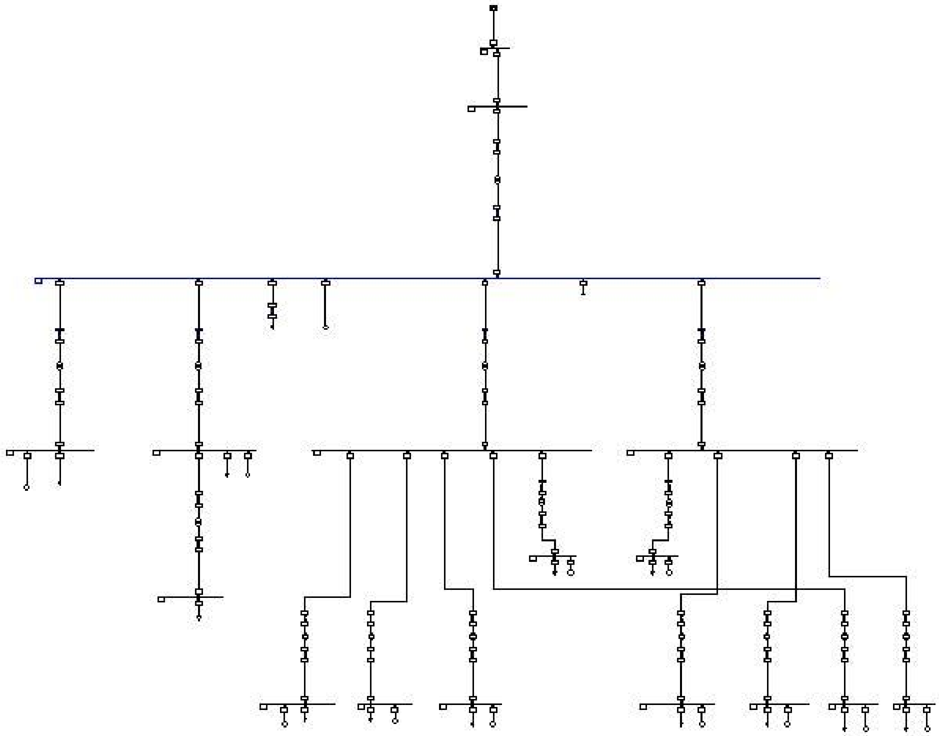


Figure 4.1 Base case load flow data diagram

Result of base case load flow data:

| Grid: Grid | System Stage: Grid | Study Case: Study Case | Annex:

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
0.41	0.00	1.50	0.92	0.00	0.00			0.01	0.01	0.00
	0.00	1.43	0.40	0.00	0.00			0.03	0.03	-0.00
						11.00 kV	-2.43	0.03	0.01	0.02
							-1.86	0.05	0.05	0.00
3.30	0.00	0.00	0.72	0.00	0.00			0.00	0.00	0.00
	0.00	1.23	0.54	0.00	0.00			0.00	0.00	-0.00
						11.00 kV	-0.72	0.01	0.00	0.01
							-1.77	0.04	0.02	0.02
11.00	0.00	3.50	0.80	0.00	0.00			0.00	0.00	0.00
	0.00	3.31	-0.00	0.00	0.00			-0.03	0.00	-0.03
						0.41 kV	2.46	0.03	0.01	0.02
							1.91	0.05	0.05	0.00
						3.30 kV	0.73	0.01	0.00	0.01
							1.82	0.04	0.02	0.02
						33.00 kV	-7.49	0.04	0.01	0.04
							-7.01	0.22	0.13	0.08
33.00	0.00	25.00	8.00	0.00	0.00			0.00	0.00	-0.00
	0.00	22.90	6.00	-0.86	0.00			-0.19	0.01	-0.20
						11.00 kV	7.53	0.04	0.01	0.04
							7.22	0.22	0.13	0.08
						132.00 kV	-40.54	0.15	0.12	0.03
							-35.07	4.07	4.02	0.05
132.00	0.00	0.00	0.00	0.00	40.76			0.07	0.07	-0.00
	0.00	0.00	0.00	0.00	39.24			0.10	0.15	-0.05
						33.00 kV	40.69	0.15	0.12	0.03
							39.14	4.07	4.02	0.05

Figure 4.2 The total losses at every voltage feeder

Grid: Grid | System Stage: Grid | Study Case: Study Case | Annex: / 5

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
Total:	0.00	30.00	10.44	0.00	40.76		0.00	0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24		0.00	4.29	4.42	-0.12

DIgSILENT PowerFactory 13.2.336 | Project: | Date: 11/2/2009

Load Flow Calculation | Complete System Report: Voltage Profiles, Area Interchange

Balanced, positive sequence		Automatic Model Adaptation for Convergency	No
Automatic Tap Adjust of Transformers	No	Max. Acceptable Load Flow Error for	
Consider Reactive Power Limits	No	Nodes	1.00 kVA
		Model Equations	0.10 %

Total System Summary | Study Case: Study Case | Annex: / 6

	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Inter Area Flow [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
\iman\psm\Grid									
	0.00	30.00	10.44	0.00	40.76	0.00	0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24	0.00	4.29	4.42	-0.12
Total:									
	0.00	30.00	10.44	0.00	40.76		0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24		4.29	4.42	-0.12

Figure 4.3 The total losses system

4.1 Loss Sensitivity Analysis

The loss sensitivity analysis been applied at all feeder in the range of 33kV and 11kV. The feeder that involved to the loss sensitivity analysis is 21-SB1-01 (33kV), 21-SB2-01B, 25-SB2-01A and 25-SB2-01B (11kV). The result of sensitivity analysis is:

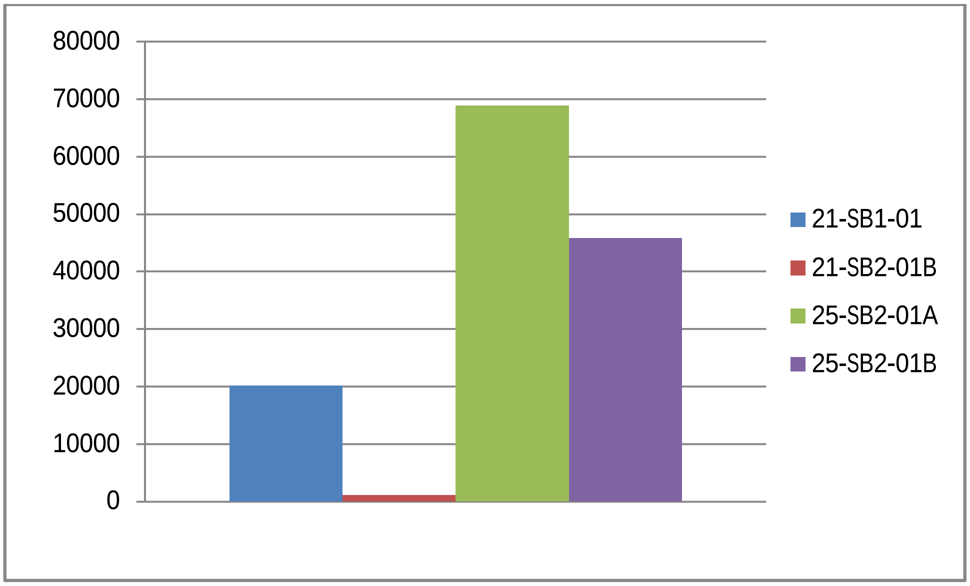


Figure 4.4 Real Power Losses at feeders

For real power losses in the system, the highest real power loss in the system is 25-SB2-01B bus with 68839.953MW. The result was been put in the table as shown below.

Bus	Power Losses (W)
21-SB1-01	20215.43
21-SB2-01B	1140
25-SB2-01A	68839.95
25-SB2-01B	45798.03

Table 4.1 Real Power Losses in at feeders

Then, the loss sensitivity factor was applied at the selected feeder to determine the optimal placement to locate the DG in distribution networks. The result was shown in the table below. The bus with value almost to zero was the optimal placement for DG in the test system.

Bus	Loss Sensitivity Factor
21-SB1-01	0.0065
21-SB2-01B	0.0127
25-SB2-01A	0.1549
25-SB2-01B	0.105

Table 4.2 Loss Sensitivity Factor at feeders

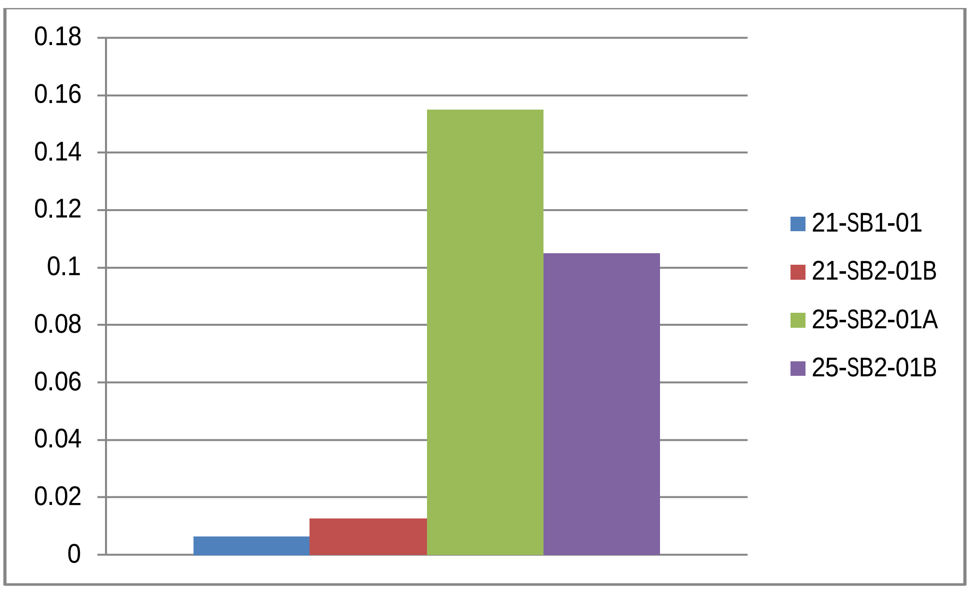


Figure 4.5 Loss Sensitivity Factor at feeders

Hence, the 21-SB1-01 bus was the optimal place to allocate the DG in the test system.

4.2 Random Analysis

In this method, the DG was been put at all feeder each at one time. Then the total power losses been obtained from load flow and been compared to each feeder. The one that has low power losses in the system was the best placement for DG in the test system. The result was shown in the table below and been illustrated at figure below.

Bus	Power Losses (MW)
21-SB1-01	0.29
21-SB2-01B	0.29
25-SB2-01A	0.29
25-SB2-01B	0.29

Table 4.3 Total Power Losses when DG was been injected at feeder

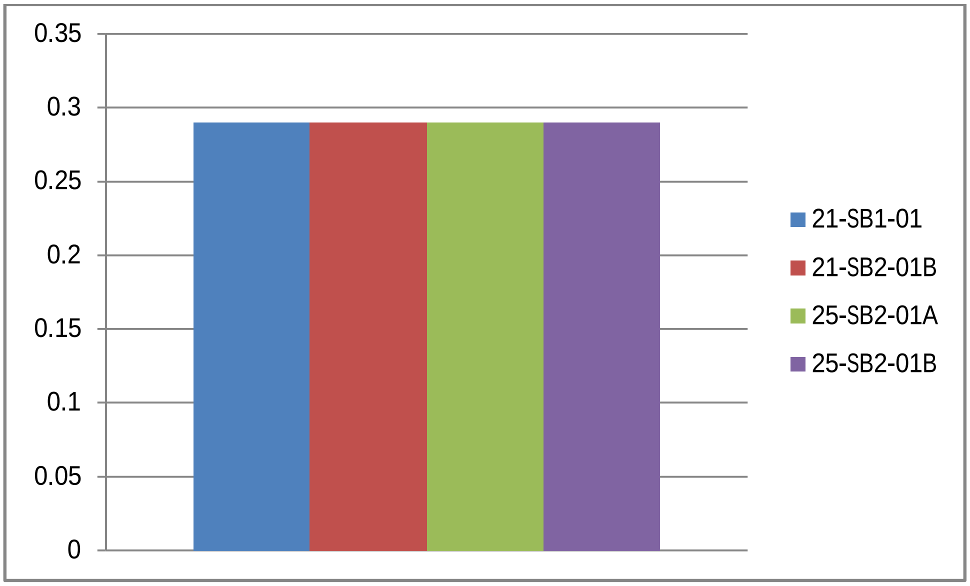


Figure 4.6 Total Power Losses when DG was been injected at feeder using DG sizing 5MVA

The result shown was obtained from size 5MVA. The power losses with respect of DG in each bus were same. Then, the random analysis was continuing with the size of 10MVA with power factor 0.85. The result was shown in the table and been illustrated using chart below.

Bus	Power Losses (MW)
21-SB1-01	0.26
21-SB2-01B	0.27
25-SB2-01A	0.27
25-SB2-01B	0.27

Table 4.4 Total Power Losses when DG was been injected at feeder

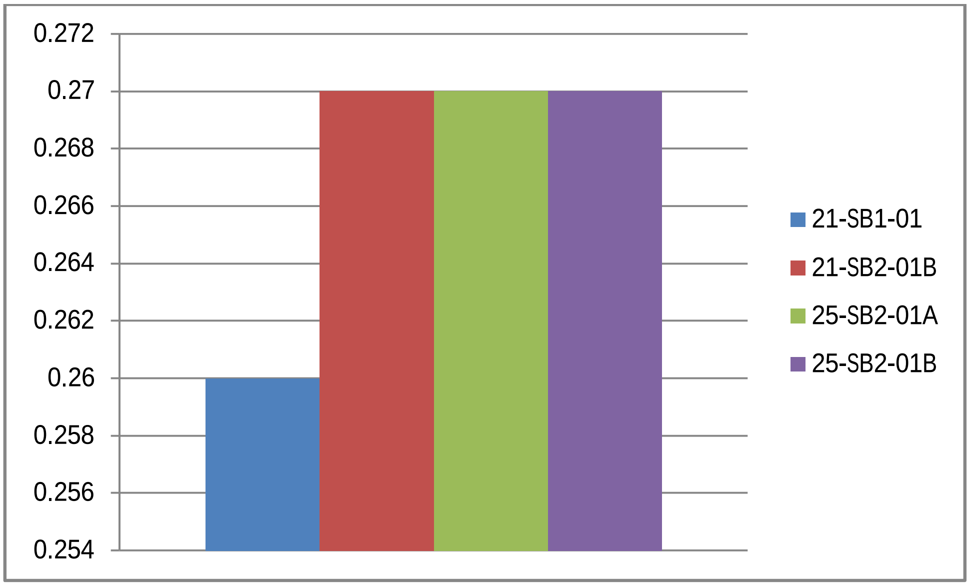


Figure 4.7 Total Power Losses when DG was been injected at feeder using DG sizing 10MVA

Hence, it has been proven that 21-SB1-01 bus was the optimal placement for DG in the test system.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

Proper location for DG placement is crucial to minimizing the total power loss in distribution network. It has been proven that by placing DG at wrong places will increase the total power loss in the distribution network. Hence the studies of finding the optimal placement in DG are very important.

This paper identified the bus that has decreased the total power losses due to injection of DG by using the DigSILENT PowerFactory software. This software calculates the total power losses in distribution network and voltage profiles at each bus by using the provided data from industry. However, this software has limitation. It's suitable for small bus system.

The proposed methodology of this paper is by Loss sensitivity analysis. This analysis helps to find the best place to install DG in terms of reducing real power losses. In reality, the best placement that been select might not always be the best sites due to many constraint. However, this analysis suggests that the losses arising from different placement varied greatly. Hence this factor must be taken into consideration when choosing the appropriate location.

5.2 Recommendations

DG has many advantages over it disadvantages. Nowadays the application of DG has been use widely due to increasing of load growth. It's not only energy efficient, improve voltage profile at feeders, reducing power losses but also the size of DG that small make it easy to install and find the suitable location to allocate the DG. Hence, the DG can be the power enhancer for the certain places with biggest loads.

The allocation of DG can be determined over many methods. There is advantage and disadvantage using the method. The sensitivity analysis has been selected as method to this study case. The sensitivity analysis can also be used to determine the placement of capacitor bank.

REFERENCE LIST

[1] G.Pepermans, J.Driesen, D.Haeseldonckx, W.D'haeseleer, R.Belmans (2003). *Distributed Generation: Definition, Benefits and Issues*. Preliminary Version

[2] T. N. Shukla, S. P. Singh, and K. B Naik. *Allocation of Optimal Distributed Generation using GA for Minimum System Losses.* Fifteenth National Power Systems Conference(NPSC), IIT Bombay, December 2008

[3] M. Begovic, A. Pregelj, A. Rohatgi, D. Novosel. *Impact of Renewable Distributed Generation on Power Systems.* Proceedings of the 34th Hawaii International Conference on System Sciences-2001

[4] Deependra Singh, Devendar Singh, and K.S Verma. *GA based Optimal Sizing & Placement of Distributed Generation for Loss Minimization*. Proceedings of World Academy of Sciences, Engineering and Technology Volume 26 December 2007 ISSN 2070-3740.

[5] A. Younes, Y. G. Hegazy, S. Tag Eldin, and M. El-Metwally. *Strategic Placement of Distributed in Distribution Networks*. 7th WSEAS International Conference on Electric Power Systems, High Voltages, Electric Machines, Venice, Italy, November 21-23 2007.

[6] Umar Naseem Khan. *Impact of Distributed Generation on Electrical Power Network.*

[7] *D. H Popovic, J. A Greatbanks, M. Begovic, A. Pregelj. Placement of distributed generators and reclosers for distribution network security and reliability. Electrical Power and Energy Systems 27 (2005) 398-408, 23rd March 2009, Citing Internet sources URL*

[8] Venkata Ramanujam Kanduri, *Distributed Generation Impact on a Fault Response of a Distribution Network.*

[9] Michel Crappe. Electric power systems.

[10] *M. Gandomkar, M. Vakilian, M. Ehsan. Optimal Distributed Generation Allocation in Distribution Network Using Hereford Ranch Algorithm.*

[11] Michael A. Devine. *The Case for Natural-Gas-Fueled Distributed Power Generation.*

[12] R. Fiskum. *Advanced Reciprocating Engine Systems (ARES)”*. Cogeneration and Distributed Generation Journal, Vol. 19, No 3, pp.75-79, June 2004.

[13] Resource Dynamics Corporation, “Technology”, November 2009, from http://www.distributed-generation.com/technologies.htm

[14] W. El-Khattam, M.M.A. Salama. *Distributed Generation Technologies, Definitions and Benefits.* Electric Power Systems Research, Volume 7, pp1 119-128, 2004.

[15] M.W Ellis, M.R. Von Spakovsky, D.J. Nelson. *Fuel cell systems: efficient, flexible energy conversion for the 21st century.* Proceedings of the IEEE, vol. 89, issues 12, December 2001, pp.1808-1818.

[16] Wm.L. Hughes. *Comments on the hydrogen fuel cell as a competitive energy source.* Proceedings of the Power Engineering Society Summer Meeting IEEE, vol. 1, 2001, 726-730

[17] Recources Dynamics Corporation, *Assessment of Distributed Generation Technology Applications.* Resource Dynamics Corporation, 8605 Westwood Center Drive, Vienna, February 2001.

[18] Pukar Mahat. *Optimal Placement of Distributed Generation in Distribution System.*

[19] T. Griffin, K. Tomosovic, D. Secrest and A. Law. *Placement of Dispersed Generations Systems for Reduced Lossess.* Proc. Of 33rd Hawaii International Conference on System Sciences, Hawaii, 2000.

[20] N. Mithulananthan, Than Oo, L.V. Phu. *Distributed Generation Placement in Power Distribution System Using Genetic Algorithm.* Thammasat Int. J. Sc., vol. 9, No. 3, July-September 2004.

[21] N.M Hung. *Genetic Algorithm for Optimal Distributed Generation Placement.* AIT Thesis, No. ET 02-16, Asian Institute of Technology, Bangkok Thailand, 2002.

[22] J.O. Kim, S.W. Nam, S.K. Park, C. Singh. *Disepersed Generation Planning Using Improved Hereford Ranch Algorithm.* Electric Power Research, Vol. 47, pp. 47-55, 1998.

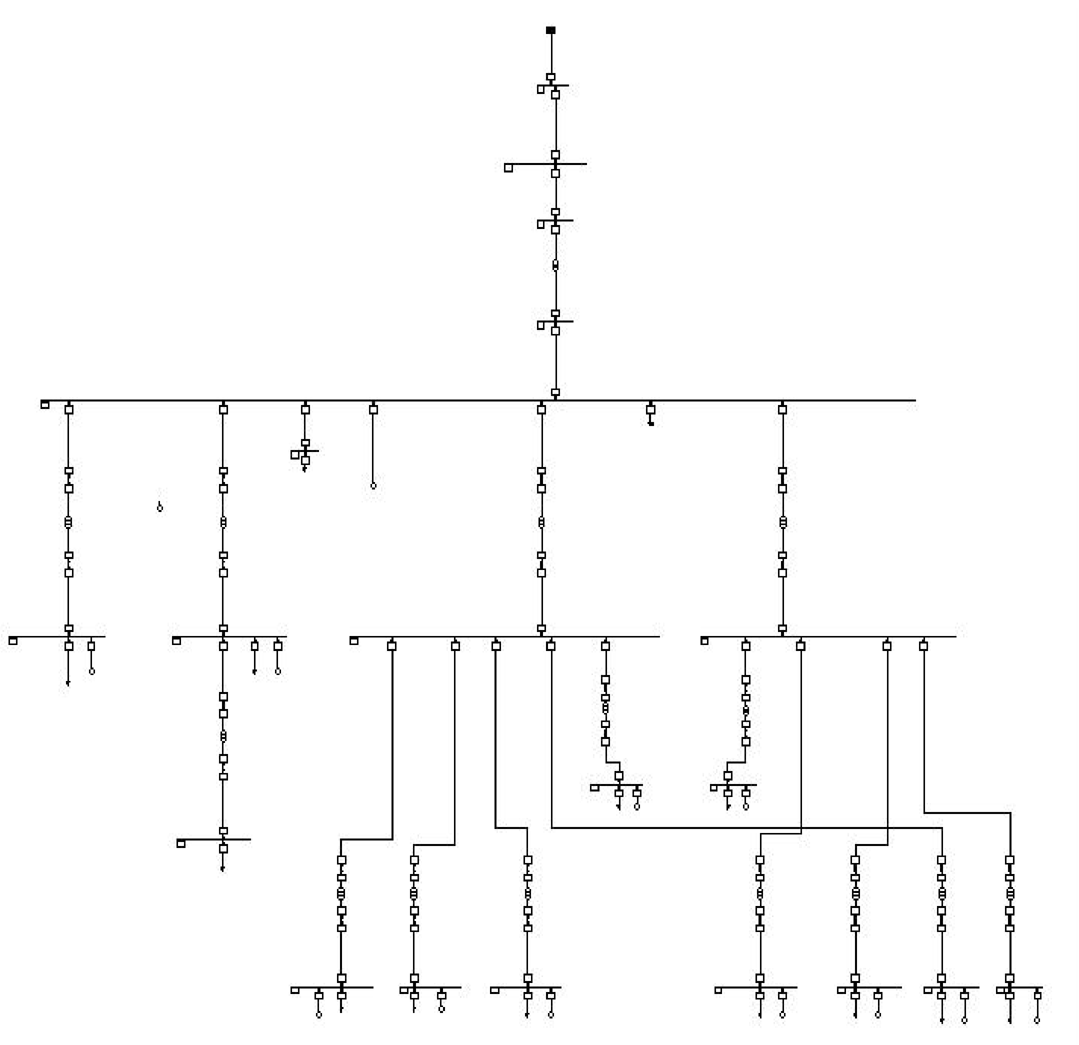
[23] C. Wang, N.H. Nehrir. *Analytical Approaches for Optimal Placement of Distributed Generation Source in Power System.* IEEE Transaction on Power System, Vol. 19.

[24] W. Rosehart & E. Nowicki. *Optimal Placement of Distributed Generation.* Proceedings of 14th Power Systems Computation Conference.

[25] I.O. Elgerd. *Electric Energy System Theory: an Introduction.* McGraw Hill 1971

APPENDIX A

THE FIGURES OF BASE CASE SYSTEM



APPENDIX B

DATA OF BASE CASE SYSTEM

Bus	
ComponentName	Nom Volt (V)
BUS-0001	132000
132kV CUF 2M-SB0-01	132000
21-SB1-01	33000
BUS-0005	11000
BUS-0006	11000
BUS-0007	11000
BUS-0013	33000
BUS-0014	11000
BUS-0015	33000
BUS-0016	11000
21-SB2-01A	11000
21-SB2-01B	11000
BUS-0019	11000
BUS-0020	415
BUS-0021	11000
BUS-0022	415
21-MC4-01A	415
21-MC4-01B	415
BUS-0025	33000
BUS-0026	11000
BUS-0027	33000
BUS-0028	11000
25-SB2-01A	11000
25-SB2-01B	11000
BUS-0031	11000
BUS-0032	415
BUS-0033	11000
BUS-0034	415
BUS-0035	11000
BUS-0036	415
BUS-0037	11000
BUS-0038	415
BUS-0039	11000
BUS-0040	415
BUS-0041	415
BUS-0042	11000
BUS-0043	3300
BUS-0044	11000

BUS-0045	3300
BUS-0046	11000
BUS-0047	415
BUS-0048	11000
BUS-0049	415
BUS-0050	11000
BUS-0051	415
BUS-0052	11000
BUS-0053	415
BUS-0056	11000
BUS-0057	415
22-MC4-01A	415
22-MC4-01B	415
22-MC4-01C	415
25-SW4-01A	415
25-SW4-01C	415
25-SW4-01B	415
25-MC3-01A	3300
25MC4-01B	3300
25-MC4-01A	415
25-MC4-01B	415
23-MC4-01A	415
23-MC4-01B	415
23-MC4-01C	415
BUS-0079	132000
BUS-0080	33000
BUS-0081	33000

Cable							
ComponentName	CableSize	-	(Meters)	Rpos (Ohms/km)	Xpos (Ohms/km)	Rzero (Ohms/km)	Xzero (Ohms/km)
TNB Cable	300	3	5000	0.079	0.166	0.79	1.66
0M-1000-R1&2/Y1&2/B1&2	500	6	40	0.051	0.158	0.51	1.58
0M-0001-R/Y/B	400	3	15	0.063	0.162	0.63	1.62
CBL-0006	500	3	70	0.051	0.158	0.51	1.58
CBL-0007	630	6	60	0.0413	0.149	0.413	1.49
CBL-0008	500	3	70	0.051	0.158	0.51	1.58
CBL-0009	630	6	60	0.0413	0.149	0.413	1.49
CBL-0010	95	1	50	0.247	0.106	0.741	0.318
CBL-0011	400	7	50	0.065	0.15	0.26	0.6
CBL-0012	95	1	50	0.247	0.106	0.741	0.318
CBL-0013	400	7	50	0.065	0.15	0.26	0.6
CBL-0014	240	6	400	0.0979	0.169	0.979	1.69

CBL-0015	630	9	50	0.065	0.14	0.26	0.56
CBL-0016	240	6	400	0.0979	0.169	0.979	1.69
CBL-0017	630	9	50	0.065	0.14	0.26	0.56
CBL-0018	150	1	320	0.159	0.1	0.477	0.3
CBL-0019	400	11	50	0.065	0.15	0.26	0.6
CBL-0020	150	1	320	0.159	0.1	0.477	0.3
CBL-0021	400	11	50	0.065	0.15	0.26	0.6
CBL-0022	150	1	320	0.159	0.1	0.477	0.3
CBL-0023	400	11	50	0.065	0.15	0.26	0.6
CBL-0024	150	1	50	0.159	0.1	0.477	0.3
CBL-0025	400	11	50	0.065	0.15	0.26	0.6
CBL-0026	150	1	50	0.159	0.1	0.477	0.3
CBL-0027	400	11	50	0.065	0.15	0.26	0.6
CBL-0028	400	11	50	0.065	0.15	0.26	0.6
CBL-0031	240	1	50	0.0982	0.093	0.2946	0.279
CBL-0032	300	6	50	0.0791	0.151	0.791	1.51
CBL-0033	240	1	50	0.0982	0.093	0.2946	0.279
CBL-0034	300	6	50	0.0791	0.151	0.791	1.51
CBL-0029	150	1	50	0.159	0.1	0.477	0.3
CBL-0030	400	11	50	0.065	0.15	0.26	0.6
CBL-0035	150	1	50	0.159	0.1	0.477	0.3
CBL-0036	400	11	50	0.065	0.15	0.26	0.6
CBL-0037	150	1	300	0.159	0.1	0.477	0.3
CBL-0038	400	11	50	0.065	0.15	0.26	0.6
CBL-0039	150	1	300	0.159	0.1	0.477	0.3
CBL-0040	400	11	50	0.065	0.15	0.26	0.6
CBL-0043	150	1	300	0.159	0.1	0.477	0.3
CBL-0044	400	11	50	0.065	0.15	0.26	0.6
CBL-0053	400	5	50	0.0629	0.098	0.1887	0.294

2-Winding Transformer					
ComponentName	Size (kVA)	%Z (%)	X/R	Pri (V)	Sec (V)
TR-C	52000	12.00	31.185	11000	34500
TR-B	52000	12.00	31.185	11000	34500
TR-A	52000	12.00	31.185	11000	34500
21-TR2-01	20000	11.00	22.249	33000	11500
21-TR2-02	20000	11.00	22.249	33000	11500
21-TR4-01	1000	5.00	5.712	11000	433
21-TR4-02	1000	5.00	5.712	11000	433
25-TR2-01	31500	11.00	26.392	33000	11500
25-TR2-02	31500	11.00	26.392	33000	11500
22-TR4-01	1600	5.00	6.694	11000	433
22-TR4-02	1600	5.00	6.694	11000	433

22-TR4-03	1600	5.00	6.694	11000	433
25-TR4-04	1600	5.00	6.694	11000	433
25-TR4-05	1600	5.00	6.694	11000	433
25-TR3-01	6300	6.00	13.757	11000	3450
25-TR3-02	6300	6.00	13.757	11000	3450
25-TR4-01	1600	5.00	6.694	11000	433
25-TR4-02	1600	5.00	6.694	11000	433
23-TR4-01	1600	5.00	6.694	11000	433
23-TR4-03	1600	5.00	6.694	11000	433
23-TR4-02	1600	5.00	6.694	11000	433
2M-TR0-01	65000	15.00	33.341	132000	33000

General Load		
ComponentName	Rated kVA (kVA)	Rated kW (kW)
PDH - FEEDER A	400.0	400.0
PDH-FEEDER B	400.0	400.0
LOAD-21MC4A	100.0	85.0
LOAD-21MC4B	100.0	85.0
LOAD-22MC4A	100.0	90.0
LOAD-22MC4B	100.0	90.0
LOAD-25SW4A	100.0	90.0
LOAD-25SW4B	100.0	90.0
LOAD-MC3A	0.0	0.0
LOAD-MC3B	900.0	720.0
LOAD-25MC4B	100.0	90.0
LOAD-23MC4A	200.0	190.0
LOAD-23MC4B	200.0	190.0
LOAD-21SB1	10000.0	8000.0
TNB (Export)	60000.0	51000.0

Induction Motor				
ComponentName	(kVA)	PF (Lag)	Efficiency	LRCurrentRatio
MTRI-0004	3500	0.800	0.930	0.170
MTRI-0005	3500	0.800	0.930	0.170
MTRI-0008	600	0.800	0.930	0.170
MTRI-0009	600	0.800	0.930	0.170
MTRI-0010	400	0.900	0.930	0.170
MTRI-0011	400	0.900	0.930	0.170
MTRI-0012	1900	0.800	0.930	0.170
MTRI-0013	1900	0.800	0.930	0.170
MTRI-0014	400	0.800	0.930	0.170
MTRI-0015	300	0.800	0.930	0.170

MTRI-0016	300	0.800	0.930	0.170
MTRI-0017	50000	0.800	0.930	0.170

APPENDIX C

RESULT OF TOTAL POWER LOSSES IN BASE CASE SYSTEMS

Grid: Grid System Stage: Grid	Study Case: Study Case	Annex:

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
0.41	0.00	1.50	0.92	0.00	0.00			0.01	0.01	0.00
	0.00	1.43	0.40	0.00	0.00			0.03	0.03	-0.00
						11.00 kV	-2.43	0.03	0.01	0.02
							-1.86	0.05	0.05	0.00
3.30	0.00	0.00	0.72	0.00	0.00			0.00	0.00	0.00
	0.00	1.23	0.54	0.00	0.00			0.00	0.00	-0.00
						11.00 kV	-0.72	0.01	0.00	0.01
							-1.77	0.04	0.02	0.02
11.00	0.00	3.50	0.80	0.00	0.00			0.00	0.00	0.00
	0.00	3.31	-0.00	0.00	0.00			-0.03	0.00	-0.03
						0.41 kV	2.46	0.03	0.01	0.02
							1.91	0.05	0.05	0.00
						3.30 kV	0.73	0.01	0.00	0.01
							1.82	0.04	0.02	0.02
						33.00 kV	-7.49	0.04	0.01	0.04
							-7.01	0.22	0.13	0.08
33.00	0.00	25.00	8.00	0.00	0.00			0.00	0.00	-0.00
	0.00	22.90	6.00	-0.86	0.00			-0.19	0.01	-0.20
						11.00 kV	7.53	0.04	0.01	0.04
							7.22	0.22	0.13	0.08
						132.00 kV	-40.54	0.15	0.12	0.03
							-35.07	4.07	4.02	0.05
132.00	0.00	0.00	0.00	0.00	40.76			0.07	0.07	-0.00
	0.00	0.00	0.00	0.00	39.24			0.10	0.15	-0.05
						33.00 kV	40.69	0.15	0.12	0.03
							39.14	4.07	4.02	0.05

Grid: Grid	System Stage: Grid	Study Case: Study Case	Annex: / 5

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
Total:	0.00	30.00	10.44	0.00	40.76		0.00	0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24		0.00	4.29	4.42	-0.12

		DIgSILENT PowerFactory 13.2.336	Project:
			Date: 11/2/2009

Load Flow Calculation	Complete System Report: Voltage Profiles, Area Interchange

Balanced, positive sequence		Automatic Model Adaptation for Convergency	No
Automatic Tap Adjust of Transformers	No	Max. Acceptable Load Flow Error for	
Consider Reactive Power Limits	No	Nodes	1.00 kVA
		Model Equations	0.10 %

Total System Summary	Study Case: Study Case	Annex: / 6

	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Inter Area Flow [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
\iman\psm\Grid									
	0.00	30.00	10.44	0.00	40.76	0.00	0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24	0.00	4.29	4.42	-0.12
Total:									
	0.00	30.00	10.44	0.00	40.76		0.32	0.23	0.10
	0.00	28.88	6.94	-0.86	39.24		4.29	4.42	-0.12