UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ASSESSMENT ON THE IMPACT OF DISTRIBUTED GENERATION ON GRID'S POWER FACTOR COMPENSATION BY USING POWER WORLD SOFTWARE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Industrial Power) (Hons.)

by

MUHAMMAD ADDEY BIN KAHAR

B071310783

FACULTY OF ENGINEERING TECHNOLOGY

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Assessment on the impact of Distributed Generation on grid's Power Factor compensation by using Powerworld Software**

SESI PENGAJIAN: **2016/17 Semester 2**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:

………………………………….

(Adlan bin Ali)

Lecturer

ABSTRAK

Penjanaan Teragih digunakan secara meluas di dalam industri utiliti kerana dapat mengurangkan kesan rumah hijau, mengurangkan kemelesetan elektrik, meningkatkan keselamatan grid dan mengurangkan bill utiliti. Panel photovoltaic, turbin angin dan roda tenaga adalah beberapa contoh penjanaan teragih. Penjanaan teragih boleh disalurkan melalui grid ataupun tidak melalui grid tetapi penyelidikan ini hanya menumpukan kepada saluran melalui grid. Malangnya, penjanaan teragih mempunyai kapasiti yang rendah berbanding penjanaan konvensional yang sedia ada. Tetapi penjanaan teragih sangat berguna untuk menyokong penjanaan ke kawasan yang jauh dari pusat penjanaan untuk mengurangkan kehilangan kuasa. Setiap penjanaan teragih mempunyai parameter tersendiri contohnya nilai regangan yang tentunya menghasilkan kuasa reaktif kepada pengguna. Terdapat 3 jenis kuasa elektrik iaitu kuasa sebenar, kuasa reaktif dan kuasa jelas. Kesemua kuasa tersebut berkait dengan sudut kuasa dan faktor kuasa yang menjadi penyukat kecekapan pengagihan tenaga. Semakin kurang faktor kuasa akan meningkatkan arus punca min persegi seterusnya menyebabkan peralatan utility menjadi panas. Kesemua parameter boleh di simulasi dengan menggunakan perisian Powerworld. Perisian tersebut boleh disimulasikan berdasarkan reka bentuk litar penjanaan, penghantaran dan beban grid kebangsaan. Simulasi tersebut akan mendedahkan dengan jelas tentang hubungan antara penjanaan teragih dan faktor kuasa. Oleh yang demikian, kajian in akan mencadangkan cara terbaik untuk pemasangan penjanaan teragih ke grid tanpa atau mengurangkan pembaikan faktor kuasa dengan simulasi.

ABSTRACT

Distributed Generation are widely used in utility industries due to not produce greenhouse gasses, less electricity loss, improves grid security and lower utility bills. Photovoltaic panels, wind turbines and flywheels are the example of distributed generation. Distributed Generation can be transmit on grid or off grid but in this research it mainly focused on the on grid transmission. Unfortunately, Distributed generation has small capacity rather than conventional generation but it really useful to support the generation in rural area that far from the generator to reduce power losses. Every distributed generation has different parameters such as reactance due to different actuators used that surely produce reactive power to the consumer. There are 3 types of electrical powers that is real power, reactive power and apparent power. All these power much related to the power angle and power factor that indicates the efficiency of power generation. It stated that the lower the power factor will increase the current RMS that will lead to overheat he utility equipment. All the parameter can be simulated easily by using Power World Software. The software simulates all parameters in generators, transmission lines and load by design the suitable circuit diagram of national grid. The simulation will provide a clear view about the relationship between distributed generation and power factor. Besides that, this research will suggest the best way to install the distributed generation without or decrease the power factor compensation of the grid with the simulation.

DEDICATION

I would like to present this research to my family
for giving me all the inspiration
and support I need.

ACKNOWLEDGEMENT

First and foremost, I humbly express my gratefulness to Allah s.w.t with praised for His blessing, kind and compassionate for giving me the opportunity to perform this research. Not forgettable, I would like to express my very great appreciation to my parents especially my father Mr. Kahar bin Sariaat for his support in all side as he have a lot of experience in electrical world and also my mother Mrs. Suriati binti Roslan for her prayer every day. Besides that, I would like to express my deep gratitude to my supervisor, Mr. Adlan bin Ali for his time and precious ideas in helping me to construct the journey to complete the Bachelor Degree Project I. He inspired me so much as he never stop to encourage and support me with his priceless knowledge, unforgettable experience and beautiful advices in success to run the research. I would like to thanks United Kingdom Generic Distribution System (UKGDS) as they provide guidance and examples parameters in a conventional grid. Next, I would like to thanks all staffs and lecturers of Faculty of Engineering Technology that participate for giving opportunity to contribute to this Bachelor Degree Project I. lastly I would like to thank to my fellow friends that directly and indirectly give support, guidance and encouragement. Without their guidance and continuous help, this Bachelor Degree Project will not meet the success.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AC	-	Alternating Current
ASEAN	-	Association of Southeast Asian Nations
ATE	-	Average Thermal Efficiency
BLDC	-	Brushless Direct Current Machine
CO_2	-	Carbon dioxide
DC	-	Direct Current
DFIG	-	Double Field Induction Generator
DG	-	Distributed Generation
DSP	-	Digital Signal Processor
EAF	-	Equivalent Availability Factor
EU	-	European Union
EUOF	-	Equivalent Unplanned Outage Factors
FIFA	-	Fédération Internationale de Football Association
FiT	-	Feed-in Tariff
GWh	-	Giga-Watt hour
Hz	-	Hertz
ICT	-	Information and Communication Technology
IEC	-	International Electrotechnical Commission
ITIF	-	Information Technology and Innovation Foundation
IGBT	-	Insulated-gate Bipolar Transistor
kg	-	kilogram
ktoe	-	kilo toe
LCL	-	Inductor-Capacitor-Inductor
LNG	-	Liquefied Natural Gas
MFO	-	Medium Fuel Oil
MHD	-	Magnetohydrodynamic
MW	-	Mega Watt
NaS	-	Sodium Sulphate

$PbSO_4$	-	Lead Sulphate
PCC	-	Point of Common Coupling
PEMFC	-	Proton Exchange Membrane Fuel Cell
PF	-	Power Factor
PMSM	-	Permanent Magnet Synchronous Machines
PV	-	Photovoltaic
PWM	-	Pulse Width Modulation
Q	-	Reactive Power
RE	-	Renewable Energy
rpm	-	revolution per minute
SCAG	-	Squirrel Cage Asynchronous Generator
TNB	-	Tenaga Nasional Berhad
V-A	-	Voltage-Ampere
VSC	-	Voltage Source Converter
WECS	-	Wind Energy Conversion System
+	-	Cathode
-	-	Anode

CHAPTER 1

INTRODUCTION

1.1 Introduction

This section provide the explanation about the background, problem statement, objective, scope and organisation of this project report.

1.2 Background of Project

For the next decades, world will see a big approaches to energy transition challenges to be faced by industrial country and developing country. In industrial countries, the tough challenge might be carbon reduction. This can be done with continuous effort to have greater penetration of energy with energy storage as back up. An aggressive step towards electricity should be continued since most of renewable energy nowadays are adopted as preferred energy source. Societies also must play their role to maintain a positive thinking for next generation to have a better quality of their lives. It is no longer the time for the present societies to steal nature resources of future generations. For developing countries, the challenge must be faced to have a better quality of life. The existing information worldwide continues to achieve these ambitions. It is accepted that improving the quality of life will provide better access to energy. Therefore, the challenge will be how to deal with the challenge without causing damage to environment.

The renewable energies are one of the distributed generation (DG) that can be defined as electric power generation within distribution networks or on the consumer side networked. Penetration of DG into an existing grid can result in a lot of benefits. The benefits are reduce line losses, reduce environmental damage, increased energy efficiency, reduce transmission and distribution crowding, voltage support, and produce smart investments to upgrade existing generation, transmission, and distribution systems. However there is less study has been done to investigate the power factor effect in transmission line after penetrating DG. This is important, since different type of DG using different type of machines as their actuator. Since the machines not only generates real power but also reactive power that effect drop of power angle. Therefore the impact of penetration of DG to grid's power factor need to be investigated and simulated. This report will explain the important of power factor in grid and potential effect if installing DG into grid.

1.3 Problem statement

Distributed generation (DG) is a small capacity power plants based on combustion based technologies, such as reciprocating engines and turbines, and non-combustion based technologies such as flywheels, photovoltaics, wind turbines, etc (P., K., Ganesh, 2013). Normally DG contributes small capacity generation about less than 100MW. According to Ke, Jiqing, Tong, Bo (2011), the penetration of DG into an existing utility can result in several benefits. These benefits include reduction of line loss, reduced environmental destruction, peak shaving, increased energy efficiency, relieved transmission and distribution congestion, voltage support, and lower investments to upgrade existing generation, transmission, and distribution systems.

In the other hand, power loss normally caused at distributed grid and transmission grid. This loss is depends by the current and the impedance of the grid (Wang,Lan, 2011). The location of penetration of DG also would be influence the power loss of the grid. Since DG has many types of sources, there must be different actuators to use and different way in causing decrease of power factor. There are conventional and non-conventional DG that usually use to connect to the grid according to Alka Yadav, Laxmi Srivastava (2014). Devices like Permanent Magnet Synchronous Machines (PMSM) is using as an actuator for micro turbine (Li, 2010). The machines itself contain an inductive load that produce reactive power to transmission line. Same goes to an asynchronous generator that being used in wind turbine (Haan, Frunt, Kling, 2010) and brushless DC machines (BLDC) in flywheels generation (Archana, Homi, 2013). Mostly past research state that there are some issues of the actuators used generates reactive powers as long as real powers.

The higher the reactive power, the higher the power angle thus power factor will drop. According to Suma, L., Usha (2014), power factor indicates how efficient the equipment generates power from the utility. When the power factor reduced in operation for a given voltage and power level, the current flow by the equipment will be large, thus utility requiring higher V-A ratings of the equipment such as transformers, transmission lines and generators. The efficiency of the distribution network is reduced by presence of reactive and distortion powers which produce high RMS currents. As the result, resulting extra losses lead will forced utility to use bigger size of copper area of the distribution power wires.

1.4 Objectives of Projects

The first objective of this project is to analyse the power factor compensation at the conventional grid without DG. The analysis must be made to have the initial condition of conventional grid's power factor and easily observe the different after adding DG.

The second objective of this project is to expose the impact of DG penetration such as photovoltaic (PV), wind turbine, batteries, micro-turbines and flywheel on grid's power factor compensation by referring to the conventional power generation and distribution. Since DG has no problem to be installed anywhere in the grid, the penetration of DG must be made in many ways to observe the different behavior of power factor.

The third objective is to suggest the suitable way for penetration of DG in maintaining the power factor compensation. This can be succeed by varies the capacity of DG or find the most suitable bus to penetrate the DG in the simulation.

1.5 Scope of Projects

This project will construct a grid system models as an example of grid system in Malaysia. Every parameters and devices use for simulation in the project are partly referring TNB Technical Guidebook on Grid-interconnection of Photovoltaic Power Generation, The Malaysian code(2012), renewable energy(technical & operational Requirements) Rules 2011 and IEC 61727. This is important for reference in future studies and improvement of Malaysian National Grid with DG compensation.

For the model of the power system, this project are referring the design of KLIA distribution grid since there use their own generators, transmission lines and substations. The parameters in this simulation mostly referring to United Kingdom Generic Distribution System (UKGDS) since there are limitation to find the parameter in Malaysia's Grid. This project only covers certain part of the power system due to software limitation. The Power world Software licensed only for evaluation and university educational use. The software is limited to 13 bus bars even though the real transmission is more than that, this project will cover until the maximum bus bar that the software support. This project also only cover the effect of power factor compensation by adding DG to the grid. This project not covered others effect of adding DG to existing grid such as high dispatch mode if their penetration and affect the load forecasting result as the writer states in previous studies. This project only cover the constant generation and load in steady state condition. This project not cover the comparison of generation with DG of working day and holiday. This project also not covering the difference of power factor when peak hours and normal. Other than that, this project also not covering the unexpected load from event such as FIFA world cup or other event that using high unexpected load. This projects will find the best place to install DG without interrupting power factor compensation.

1.6 Organisation of Report

The first paper of this project report will discuss about the background, problem statement, objectives and scope of work. For the next chapter that is chapter two, this paper will discuss on related references by doing some literature review. On chapter three, a simple flowchart is placed as a guide and explanation to achieve the objective of this project. However, the fourth chapter that is result will be collected, discussed and analyzed during Bachelor Degree Project II. It will present along with the conclusion and recommendation in chapter five in the next semester.

1.7 Summary

This chapter contains the background of this project where some information is stated about the latest phenomenon in electrical world. The problem statement is gain base on the related literature review about this project. Therefore, objective is discussed base on problem appeared. The scope of this project is stated where certain part is covered and not covered in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed the literature review of the related issue to this research. First, this chapter discussed about the performance and statistical information on electricity supply industry in Malaysia. Next, this paper will discussed about the awareness of renewable energy in Malaysia. Other than that, this paper will bring the type of DG and its impact to transmission and generation. Lastly, this paper will discussed about power factor with definition, advantage and importance.

2.2 Information and Statistics of Electrical Supply Industry in Malaysia

In 2013, Malaysian economy increasing by 4.7 percent due to continuous strong growth domestic consumption. Even though there is weak external environment at the first quarter, the domestic consumption remain the same throughout the year. Private sector consumption is favorable due to employment condition and wage growth.

2.2.1 Key Economic and Energy Data

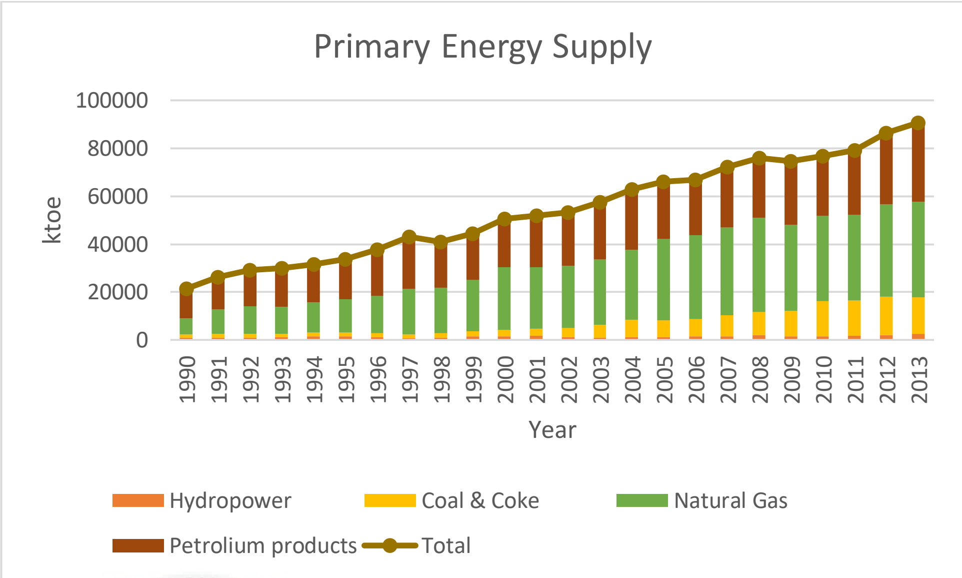

Figure 2.2.1(a) Primary Energy Supply in Malaysia in ktoe
(Source: National Energy Balance 2013)

Figure 2.2.1(a) shows the total energy used to converted into electrical energy in ktoe from 1990 to 2013. Based on the graph, the most energy source increase yearly is natural gas product while the least energy source increase yearly is hydropower. From the graph, it shows that Malaysia are focus in petroleum based product energy since the second highest increment yearly is petroleum. This is because Malaysia is the one of the oil-producing country in the world so that the source is easily to get. Last 10 years, the graph shows that the usage of coal in generation is increase rapidly since Malaysia start to focus in reducing the cost of generation source since coal relatively cheaper than petroleum source.

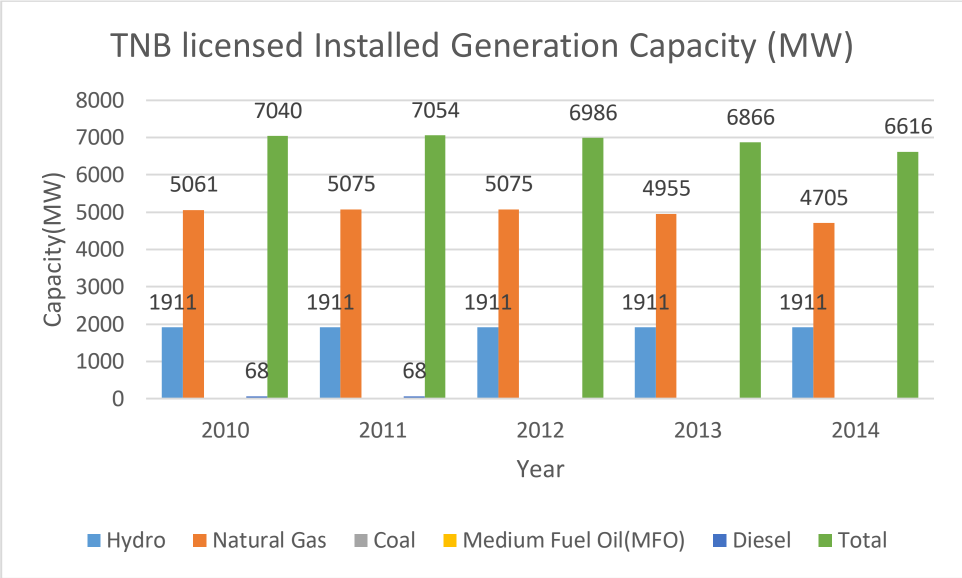

Figure 2.2.1(b) TNB Licensed Installed Generation Capacity (MW) in peninsular Malaysia
(Source: Performance and Statistical information on electricity supply industry in Malaysia 2014)

Figure 2.2.1(b) shows the capacity of TNB licensed installed generation. TNB reduce their total generation of electricity slowly by last five years from 7040 MW in 2010 to 6616 MW in 2014. TNB reduce the generation with natural gas based source from 5061MW in 2010 to 4705MW in 2014. The hydro plant generation is maintain it generation for 1911 MW in five years. TNB has stop the coal as the source of generation in peninsular Malaysia by 2011. There is no more generation by coal combustion after 2012 and last generation of coal source with 68MW in 2011. The figure also state that there is no generation of electricity by using medium fuel oil (MFO).

2.2.2 Energy Demand

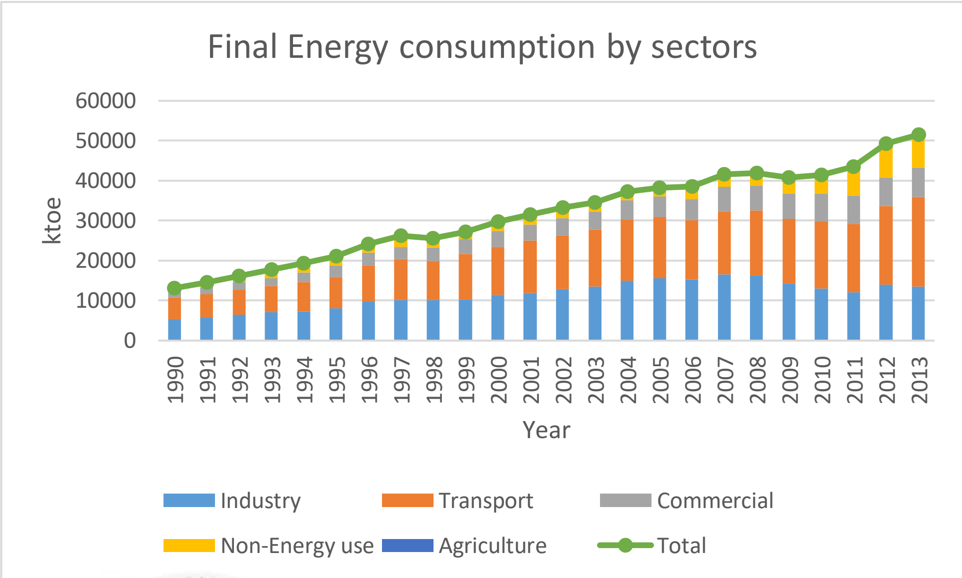

Figure 2.2.2 Primary Energy Supply in Malaysia in ktoe
(Source: National Energy Balance 2013)

Figure 2.2.2 shows the final energy consumption by sectors in Malaysia. There are five big sectors in Malaysia that is industry, transport, commercial, non-energy use and agriculture. The total energy demand increase 5 to 11 percent every year. On 1990, the total energy demand is 13146 ktoe. Since Malaysia is one of the developing country, the positive growth shows for thirteen years where the total energy demand in 2013 is 51584 ktoe. Eventually, industrial demand is the highest every year starting 1990. However, in early 2000's transport sector take place as the highest energy demand every year until 2014. Non-energy and commercial increase slowly through the years.

In peninsular, the grid system demand reach maximum increment to 16901 MW in 2014. It increase 2.05% compared to 16562 MW in 2013. The highest energy demand of the day is recorded on 24 June 2014 with 355.8 GWh. On 31 December 2014, the generation capacity increase to 20944 MW not including Sultan Iskandar Power Station with 240 MW capacity and Connaught Bridge Power Station with 116 MW capacity.

2.2.3 Performance of Electricity Supply Industry in Malaysia

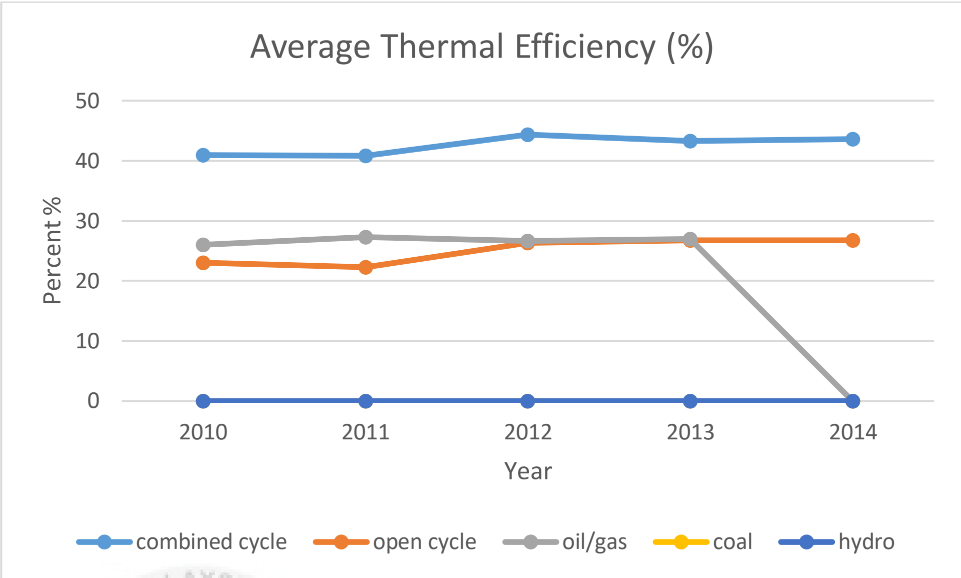

Figure 2.2.3(a) Peninsular TNB Average Thermal Efficiency

Source: Performance and Statistical Information on Electricity Supply Industry in Malaysia

Overall, the Average Thermal Efficiency (ATE) in peninsular by TNB generation is at satisfactory level. For TNB oil and gas generation on 2013 decrease to 0 because contribute in maintenance. For the five years stated above, hydro and coal plant has 0 thermal efficiency. Combined cycle and open cycle generation increase simultaneously the ATE by 2.5% during 2012.

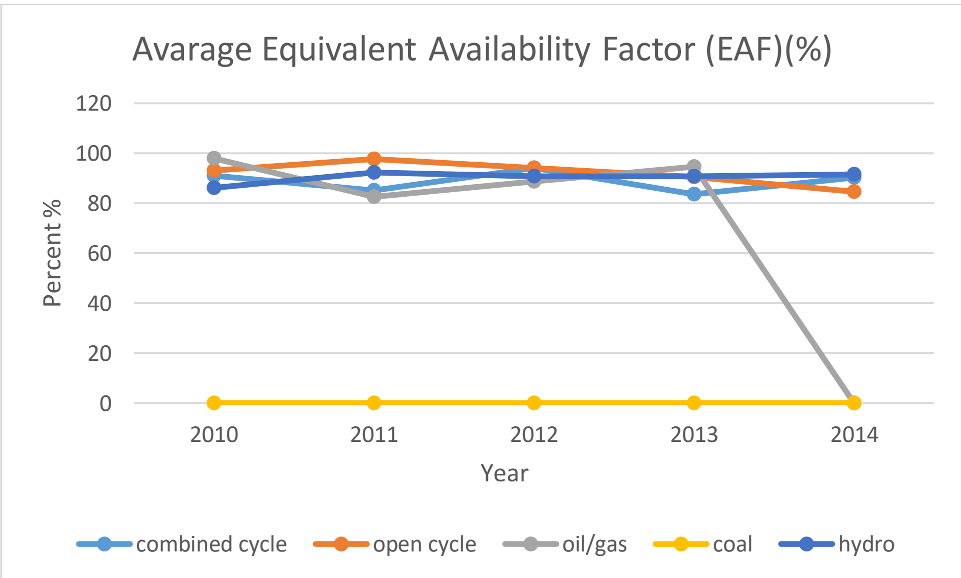

Figure 2.2.3(b) Peninsular TNB Average Equivalent Availability Factor (EAF) (%)

Source: Performance and Statistical Information on Electricity Supply Industry in Malaysia

Average equivalent availability factor (EAF) for combined cycle, open cycle, oil & gas and hydro is at between 80 to 100 percent. However, in 2014, oil & gas generation depleted drastically to 0 due to maintenance. For TNB coal generation is maintain at 0 while TNB has stop the coal based generation during 2011. In 2014, it has be seen the increase of EAF is due to liquefied natural gas (LNG) imported to meet domestic fuel supply.

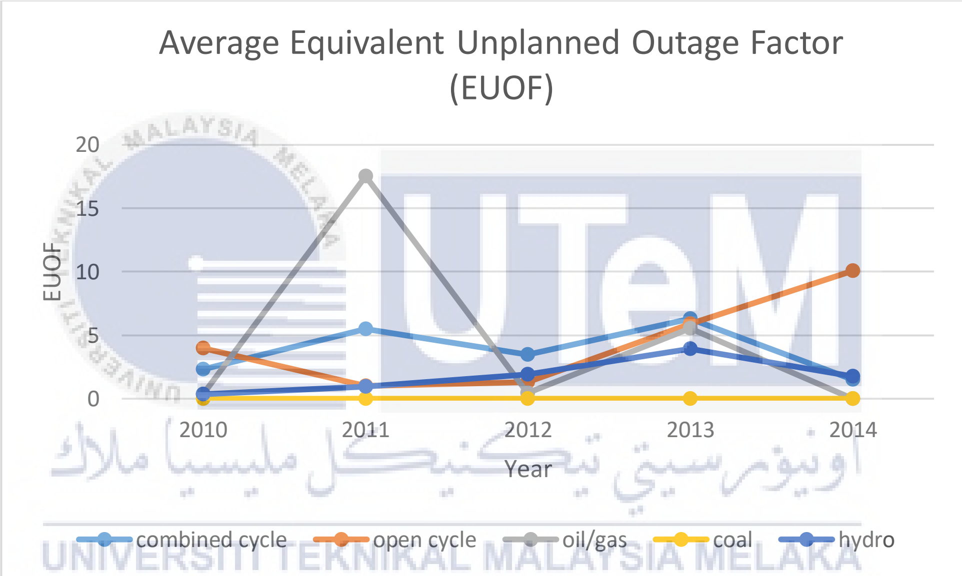

Figure 2.2.3 (c) Peninsular TNB Average Equivalent Unplanned Outage Factor (EUOF)

Source: Performance and Statistical Information on Electricity Supply Industry in Malaysia

Based on figure 2.2.3 (c) above, the highest Equivalent Unplanned Outage Factor (EUOF) is highest in 2011 with 17.53. This is because of condenser tube leak and condenser filter choke. After 2013, almost all generation source decrease in EUOF. The decreasing of EUOF indicates more stable in electric generation in peninsular Malaysia. Oil and gas generation show increment in EUOF starting 2012 because of poor condenser vacuum, hot gas leakage, vibration and aging.

2.3 Awareness of Renewable Energy in Malaysia

According to Wei-nee Chen (2012), renewable energy (RE) means any kind of inexhaustible resources and recurring that produce primary energy. Renewable energy development in Malaysia start during eighth Malaysia Plan (2001-2005) that provide renewable energy as the fifth fuel based generating in Malaysia. Other than that, the plan suggest to imply five percent of renewable energy in energy mix.

In ninth Malaysia Plan (2006-2010), renewable energy will be connected to power utility grid. As the first step, 300MW distributed generation is connected in peninsular Malaysia and 50MW in Sabah. Before reach 2010, the power generation mix is plan to be 51% natural gas, 26% coal, 9% hydro, 8% oil, 5% diesel and 1% biomass. The carbon intensity target was 40% lower than 2005 levels by 2020. As in 2010, there is 68.45 MW DG has been connected to grid. That's mean target from ninth Malaysia Plan has 20% achieved. There is more than 1GW off-grid DG has been set up by using private palm oil millers and solar hybrid.

A motion has been approved in Malaysian parliament on 2nd April 2010 about increasing the utilization of renewable energy resources to contribute towards national electricity supply security and maintaining socio-economic development. The objective of this policy statement are to increase contribution of renewable energy in the power generation mix and helping the growth of the renewable energy industry. Other than that, the policy statement is approved to monitoring reasonable renewable energy generation costs while conserve the environment for future generation. Last but not least, the motion approved to create awareness on the importance of renewable energy.

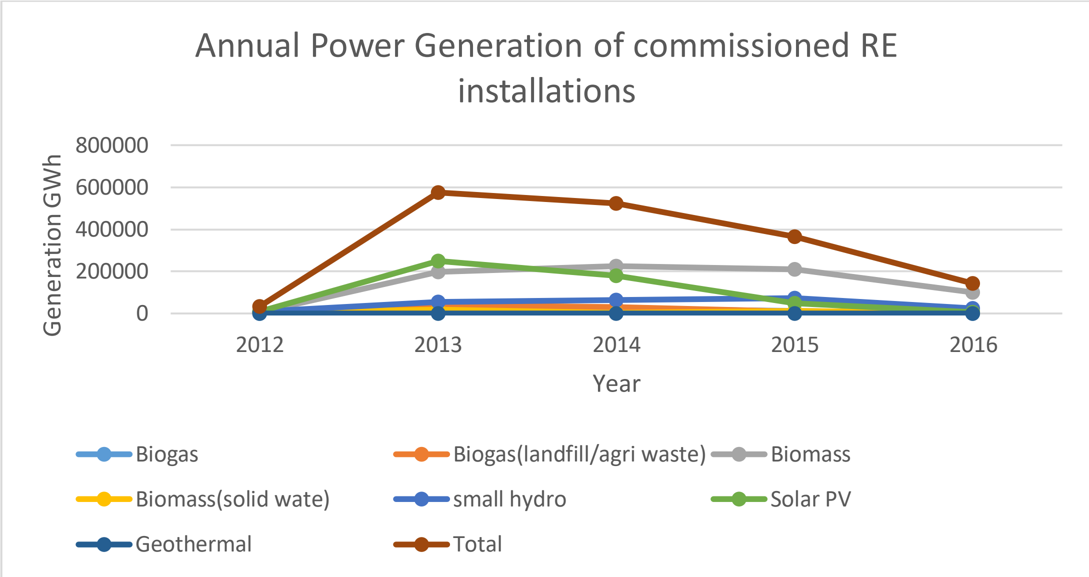

Figure 2.3 Annual Power Generation of commissioned RE installations

Source: Sustainable Energy Development Authority Malaysia

Based on figure 2.3 above, the amount of RE generated is under the Feed-in Tariff (FiT) system. The reading above based on amount of RE generated yearly. From the start RE generation penetrated to grid in 2010, the total RE generation is at maximum at 2013 about 575881 GWh. Unfortunately, the RE generation is decreasing slowly until 2016 by 142451 GWh. For the past five years, geothermal is not emphasized yet but the RE are focus on solar and biomass since the source of sunrays and palm husks can easily to get in this county.

2.4 Introduction of Distributed Generation

The penetration of distributed generation resources in distribution grids increasing worldwide, it gives a challenge and provide an opportunity for a variety of technologies and operating scenarios. Nowadays, it is important to generate an acceptable power quality and reliability as to create an encouragement to penetrate the distributed resources and operating practices innovation. Distributed resources is a term that involving both distributed generation and distributed energy storage. There are several benefit of penetration of DG to national grid. One of the benefit is customer will experience a better quality supply with lower cost. Other than that, penetration of DG will reduce the line losses according to Ke Dang, Jiqing Yu and Tong Dang (2011). According to Laxmi (2014), distributed generation is also known by other names like decentralized generation, dispersed generation, embedded generation, on-site generation, distributed energy or redistributed energy.

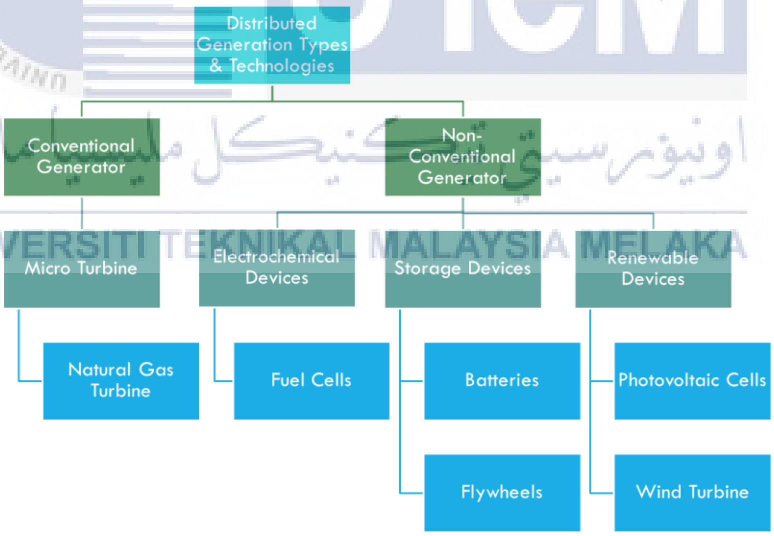

Figure 2.4 (a): Distributed Generation Types (Alka Yadav, 2014)

Recently, distributed generation produce electricity from many small energy sources. Almost all the countries generate electricity in large centralized generation. The central generation are using the non-renewable source such as fossil fuel and nuclear or hydropower plants and large plants by using renewable source. Theoretically, there are different types of DGs depend on the constructional and technological points of view. DGs may be spread categorized as conventional and nonconventional generators. As for conventional generators, micro turbines are a relatively new type of combustion turbine that produces both heat and Electricity on a small scale. Micro turbines offer a clean and efficient solution to direct Mechanical drive markets such as compression and air conditioning. The non-conventional generators include Electrochemical Devices such as fuel cell, Storage devices such as batteries and Renewable devices such as photovoltaic cell and wind turbine.

2.4.1 Conventional Generator

2.4.1.1 Micro Turbine (Natural Gas Turbine)

According to Li Jun (2010), there are two types of micro gas turbine designs. Firstly, a high speed single shaft design is embedded with the compressor. The turbine is mounted on the same shaft with the permanent magnet synchronous generator. The generator can generate high frequency three phase signals between 1500 to 4000 Hz. The second one is a split shaft design that uses a power turbine rotating at 3600 rpm with a conventional generator connected via a gearbox. The compressor turbine produce torque which drives PMSM for producing power, the high frequency signal is initially rectified and then transferred to load through LCL filter. Single shaft micro gas turbine system has higher efficient, more compact structure and higher stability compared to gearbox system.

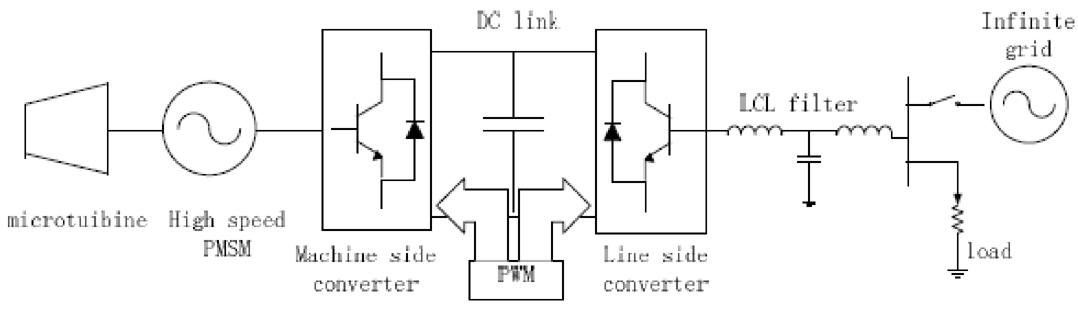

Figure 2.4 (b): Schematic diagram of Micro-turbine (Li Jun Jun, 2010)

According to P K Nag (2015), the advantages of micro turbine is once the turbine is spinning at the rated speed by starter motor, the micro turbine will accelerate to full load without warmup time. Other than that, micro turbine usually low weight and size since it preferable to be use at sea land and air. Therefore, the floor space is save since it is smaller in size. Micro turbine has high efficiency because it can consume a high inlet temperature as high as 1300°C thus the thermal efficiency is about 37% high. Micro turbine can be located at consumer side to reduce transmission line loss. The cost of installation is much lower than installing thermal plant.

However, there always some disadvantage using this micro turbine. Part load efficiency is low and the efficiency depends on the ambient condition. Micro turbine commonly sensitive to component efficiency. High quality air and gas filters must be use so that no dust will enter and corrode turbine blades.

2.4.2 Non-conventional Generator

2.4.2.1 Electrochemical Devices (Fuel Cell)

The fuel cell converts chemical energy straightforwardly into electrical energy in a reaction that dispenses burning of the fuel. Dissimilar to a heat engine that works on a thermodynamic power cycle, the performance of the fuel cell is not limited by the second law of thermodynamics. The sign conversion for the cathode(+) and the anode (-) is the same for batteries and fuel cells and for thermoelectric, thermionic and MHD generators; negative ions or electrons flow from the cathode to the anode inside the device, so that conventional current flow is from the cathode to the anode in the external circuit (P K Nag, 2015). The elemental particles are referred to as charge carriers. The negative charge carriers may consist of electrons or of atoms or molecules with negative charges or electrons. The positive charge carriers may comprise of atoms or molecules that have lost some of their electrons or might an electron hole (space left by the takeoff of an electron).

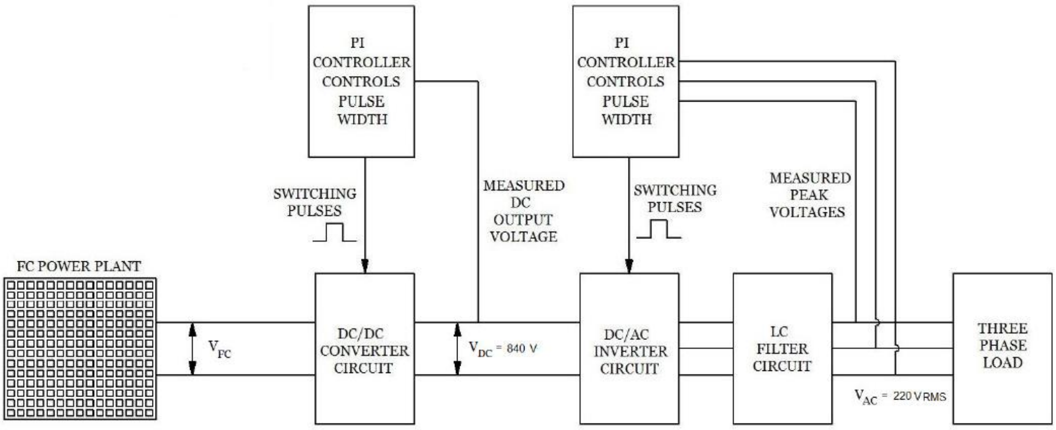

Figure 2.4 (c): Fuel cell Block Diagram (Ghareeb, Bendary, Saied, 2010)

The DC output from fuel cell power plant need to be converted to three phase AC before transferred it to grid. Based on figure 2.3 (c), there are two phase level in converting DC to AC by using controller that controls pulse width. This close loop system is needed to achieve standard demand by the system.

2.4.2.2 Storage device (Batteries)

Rechargeable electrochemical batteries have a long history of utilization in electrical power systems. At the beginning of the 20th century, in small rural area are using diesel engines for generation, local DC power system usually shut down at night and the demand was replaced by lead-acid batteries which were charged during the day. These batteries were also used in several US towns to support DC electricity to electric street cars during rush hour. The growth of large centralized AC power systems and cheap coal and oil generated electricity relegated batteries to emergency standby duty for DC auxiliaries.

The lead-acid battery invented by Plante is still dominated in market in 1859. This battery is the oldest chemical storage device. The battery comprises of alternate pairs of plates, one pure lead in spongy form and the other lead coated with lead dioxide, immersed in dilute solution of sulphuric acid which serves as an electrolyte. During discharge both lead electrodes are converted into lead sulphate($PbSO_4$). Charging restores the positive electrode to lead dioxide and the negative electrode to metallic lead. The battery decays steadily in execution due to irreversible physical changes in the electrodes and last comes up short after 1000-2000 cycles.

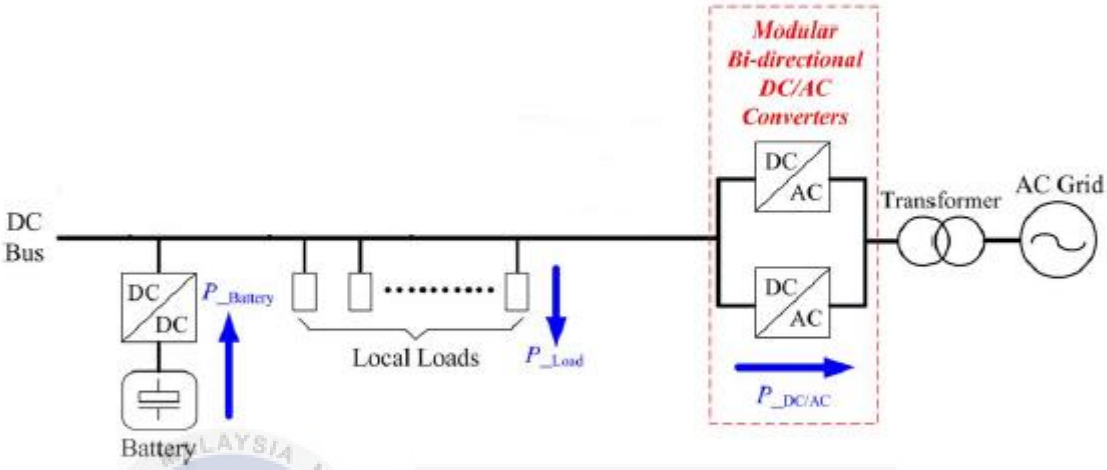

Figure 2.4 (d): Schematic diagram of battery storage (Yan Xing 2015)

2.4.2.3 Storage Device (Flywheel)

Storing energy in the form of mechanical kinetic energy(for comparatively short periods of time) in flywheels has known for centuries and is now being considered for a more extensive field of utilization, competing with electrochemical batteries. In inertial energy storage system, energy is stored in the pivoting mass of a flywheel. In order to maintain the flywheel rotation, an energy input is injected by kick at the lower wheel of the rotating table. The rotating mass stores the short energy input so that rotation can be maintained at a fairly constant rate. Flywheels have been applied in steam and combustion engines for the same purpose since the time they were invented. The application of flywheels for longer storage times is much recently and has been made possible by continuous developments in materials science and bearing technology.

More recently, interest in flywheel energy storage has been generated by automobile designers. It is also called hybrid automobile, the flywheel stores some of the energy of the gasoline engine during period of low vehicle demands and used it during high demands, such as during acceleration, hill climbing, and etc. Thus flywheel operates the engine at a more steady and hence more efficient output.

Flywheel has been tried recently for energy storage by utilities based on figure 2.3 (e). The flywheel is connected to motor generator set usually a brushless DC machines. In the charge mode, during off-peak hours, the machine adds energy to the flywheel. In the discharge or generator mode, during peak hours the flywheel drives the generator to supply electricity.

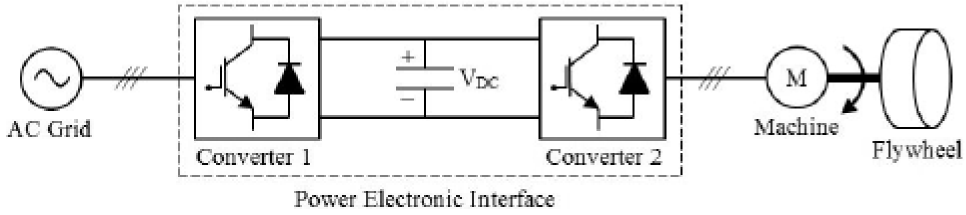

Figure 2.4 (e): Schematic diagram of basic flywheel (Mohamed, Awadallah, Bala 2015)

2.4.2.4 Renewable Device (Photovoltaic Cell)

In photovoltaic conversion, solar radiation falls on semi-conductor devices called solar cells which convert the sunlight directly into electricity. It depends on the effect that sunlight has big role on the junction between two types of semiconductor called p-type and n-type. N-type has an excess of electrons and p-type has a shortage of electrons. When a bright light shines on a semiconductor cell, energy from the light (photons) enable the one valence electrons to break free from the junction between them. The process called the photoelectric effect. For single-crystal silicon (4 valance electron), ‘p’ is obtained by doping silicon with boron (3 valance electron); ‘n’ is obtained by doping with arsenic or phosphorus(5 valence electron). The sun’s photons strike the outermost cell on the microthin p-side and penetrate to the junction to generate electron-hole pairs at n-side. When the cell is connected to a load, the electrons produce will diffuse from n to p. The direction of current will opposite to the direction of electrons (Mohamed, Bala, 2015).

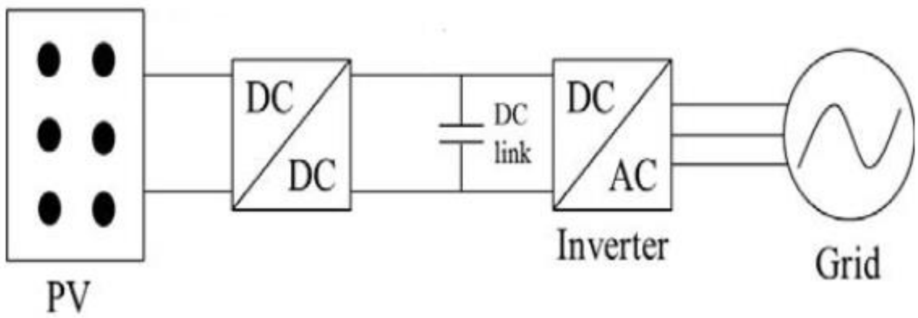

Figure 2.4 (f): Diagram of photovoltaic cell power generation
Source : TNB Guidebook on Grid-interconnection of Photovoltaic Power Generation System to LV and MV Networks 2011)

2.4.2.5 Renewable device (Wind Turbine)

Wind is present primarily by the uneven heating of the earth's crust by the sun. Consequently, wind energy is appropriately an indirect form of solar energy. Winds can be classified as planetary and local. Planetary winds are caused by high intensity solar heating of the earth's surface near the equator rather than near the north or south poles. This cause warm tropical air to rise and flow through the upper atmosphere towards the poles and cold air from the poles to flow back to the equator nearer to the earth's surface.

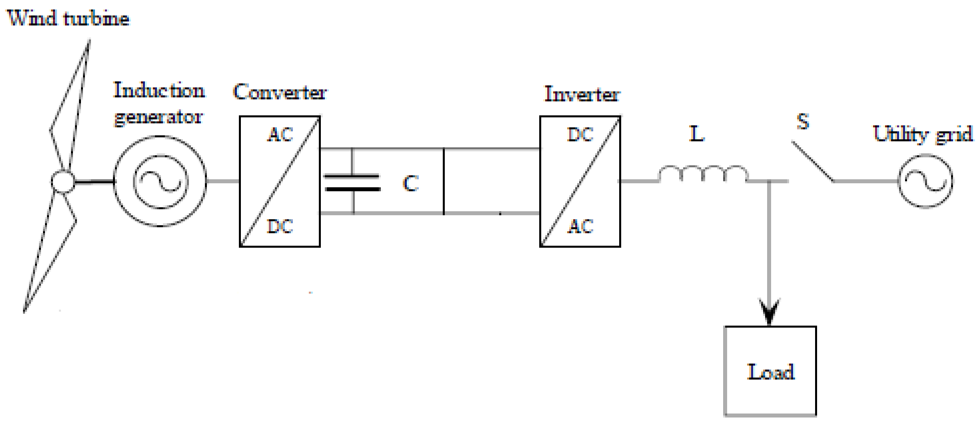

Figure 2.4 (g) : Schematic diagram of wind turbine generation (Sanjeev, Gaonkar, 2013)

The function of a windmill is to extract energy from the wind to produce mechanical energy which than converted to electricity. Many types of wind mill has been design. However, only a few have been found to be practically suitable and useful. Some of them are multiblade type, sail type, propeller type, savonious type and darrieus type.

2.5 Impact of Penetrating Different Types of Distributed Generation on Grid.

2.5.1 Permanent Magnet Synchronous Generator (PMSM)

According to Li Jun (2010) micro gas turbine distributed generation system adapts generally high PMSM based on past studies. Usually, a 2 pole PMSM with non-salient machine is use as generator. When the generator is at 1600Hz, the output power is 30KW and its terminal line-to-line voltage is 480V. When grid supply insufficient power to load, micro gas turbine system must provide dump power to allow the bidirectional power flow between grid and micro turbine distributed generation system. Conversely, DC-link capacitor stored grid power that converted by bidirectional PWM converter. Therefore, bidirectional PWM converter is used as a voltage source converter (VSC) for interfacing with respectively micro gas turbine and grid. VSC has low harmonic distortion rate and its control method is flexible, micro gas turbine output power can be quickly regulated, at the same time system response time is shortened by using suitable algorithm for VSC. This PMSM usually embedded with the single shaft with natural gas turbine.

2.5.2 Proton Exchange Membrane Fuel Cell (PEMFC)

PEMFC usually use a proton conductive polymer membrane as electrolyte. This innovation is standout amongst most widely used because of its simplicity, feasibility and quick start-up capabilities. According to William (2014), the voltage is typically reduced by 33% from minimum output power to maximum output power. Therefore, DC-DC converter is needed to condition the output of the fuel cell stack to allow it to be use with batteries and powered equipment. DC-DC converter topology used in a 5kW PEM cell to ensure that the PEM membrane fuel cell is generate maximum output power to a load during a power outage bridging the startup time as well as to optimize the health of the fuel cell membrane stack. General electrical efficiency of the fuel cell is shown to deliver over 90% of the electrical power produced by PEMFC stack. The DC-DC converter increase the system electrical efficiency by achieving over 97% efficiency. The PEM model is usually set and validated for an air cooled 5 kW 47 cells Ballard Nexa stack supplied by compressed air and pure hydrogen. The whole fuel cell stack is modeled by stacking N single-cell models together.

2.5.3 Sodium-Sulphur (NaS)

According to Majid, Mahdi, Masoud (2015), NaS batteries have been developed by NGK Insulators and Tokyo Electric Power since 1987. The batteries are one of the most successful electrochemical storage technologies in MW scale, with projected total installations of 606 MW by 2012. NaS batteries have shown their abilities in power quality applications and power time shift, with relative proficiency between 75 to 85 percent, 2500 to 4500 life cycles, expected lifetime of 15 year and discharge time up to 7 hours. The biggest project of NaS with 70 MW power has been developed in Italy, 2014. The NaS batteries have provided the boost for more fascinating work in solid state chemistry and electrochemistry in recent years. The original disclosure was the observation of very high sodium ion mobility above room temperature in sodium beta-alumina. The beta-alumina was thought to be isomorph of aluminum oxide, and its crystal structure was resolved before the Second World War. When the electrical conductivity of beta alumina was measured at 300°C, it turn out to be clear that the charge carriers were only sodium ions and not electrons. In the NaS battery, protected by Ford, rather than solid electrodes isolated by a liquid electrolyte, as in the conventional lead-acid car battery, sodium beta-alumina is used as a solid electrolyte, specifically conducting sodium ions between liquid electrodes of sodium metal and Sulphur.

2.5.4 Brushless Direct Current Machine(BLDC)

The complete flywheel system has been built using a BLDC machine, IGBT inverter and a mechanical flywheel. Motorola make digital signal processor (DSP) chip DSP56F805 to use as the controller. Motor current, rotor position and dc bus voltage are sensed using Hall Effect sensors and fed back to the DSP. The output power is 5kW with 15000rpm of 3phase 4 pole BLDC. Weight of flywheel is 42kg.the moment of inertia is 0.681Kg-m^2 . However, the device like flywheel electrical machine and bidirectional power converter and their sources of losses before penetrate into transmission lines. As example, flywheel will produce windage losses and bearing losses. BLDC itself is the source of hysteresis loss, eddy current and copper losses. The example of losses produce by bidirectional converter is conduction loss and switching losses. Those losses may lead to reduce the efficiency of the electricity generation (Gurumurthy, Archana, Satyabrata, 2013).

2.5.5 Photovoltaic Cell with Power Converters

Regardless of the many advantages of PV resources there are few challenges making them difficult to spread widely. The power source intermittency is one of the complex difficulties facing the integrating of the PV sources. To achieve a good controlling, the controller has to consider the input and output power disturbance into account when a PV distributed source connected to a public grid. According to bilal, nasirudin, jeyraj (2014) normally the two stage power conversion systems are executed between the PV source and the public grid to convert and control the power and voltage. The first stage is the DC-DC converter which step up the voltage and monitor the maximum power point, the second stage is the DC-AC inverter which synchronizes the PV source with the conventional grid and control the active and reactive power exported to the grid, all the previously considerations have to take into account when implement a power conversion system. One stage power conversion system has been studied in the past studies. System cost can be reduce and increase the power efficiency by expelling the DC-DC converter. As the DC-AC inverter is only used in the past research, so its function is to monitor the DC link voltage value which extract the maximum power from the PV and dispatch zero reactive power to the conventional grid. By following the IEEE standards, it applicable to all distributed resources with aggregate capacity of 10 MVA or less.

2.5.6 Squirrel Cage Asynchronous Generator (SCAG)

Based on Haan, Frunt, Kling (2010), SCAG is a best choice for a variable speed Wind Energy Conversion System (WECS) if comparing their costs, simple construction and robustness to other machine such as Double Field Induction Generator (DFIG) and PMSM. The amount of energy captured from a WECS depends not only on the overall wind at the site, but also on the control strategy utilized for the WECS. In the past research, it is specified that power fluctuations can occur. In combination with the vulnerability of the power system, the impact of power fluctuations on frequency fluctuations is resolved. Currently, single wind turbines can achieve sizes up to 7MW and new installed offshore wind farms in general reach about 100MW. Therefore wind turbines are increasingly regarded as typical power plants. There are three essential data sets that is wind speed time series data set, Power – Wind speed curve and transfer function of the wind turbine and farm to determine wind power fluctuations. The next approach is only valid if the wind turbines are equal in size, concept and control. In relation, the qualification is made between a single wind turbine and a complete wind farm. Due to the fact that within a wind farm not every single wind turbine confronts precisely the same wind speed, higher frequency power smoothing occurs.

2.6 Power Factor

At present, distribution networks with distributed generation (DG) are worked in a passive way. Most DGs operate at steady reactive power (Q), which is typically set at Q = 0 MVar. In this manner, can’t take an interest in either voltage control or power factor correction. The conventional solution to improve power factor (PF), is the utilizing of capacitor banks. However, this methodology has limitation when dealing with the leading power factor due to the capacitor can only infuse the reactive power into the system. The modern DG technologies which associate with the networks via the power converter, for example, large photovoltaic (PV) plant and small wind farms can give the active power factor correction similar to the utilization of power conditioners (e.g. active power filter). The reactive power support from DG interfaced-converter is already authorized by Grid Codes in few nations such as Malaysia, which converter-connected DG must be able to set no less than power factor of 0.90 (both leading and lagging) for distribution level. The Q output of DG is adjusted to take after the change of Q that flows through the point of common coupling (PCC).

The Q compensation from DG will control the total Q that flows through the PCC to at specific value or to be zero for making the unity power factor (PF = 1). The DG can either inject or absorb Q from the network to deal with both leading and lagging power factor. The Q output of DG can be controlled by DG's grid-side converter that interfaces with the primary grid. The grid-side converter is executed using the voltage source converter (VSC) which the output signals are generated by pulse wide modulation technique (PWM). The capacitor banks will inject Q into the network to prevent the lagging power factor at the pee is underneath the statutory limit (PF < 0.9). However, using only capacitor banks cannot support inductive Q to deal with the change of PF in case of PF is leading. Hence, the extra shunt reactors are required for absorbing Q from the network.

2.7 Industrial Review

i) "Portugal ran on renewable energy alone for four days" – geek

16th May 2016 by geek - Portugal hit a noteworthy point of reference in its progressing push to move to renewable energy. The whole nation kept running for more than a large portion of a week without resorting to fossil fuels. In the late '80s, Portugal brought a monstrous new coal-burning power plant online in Sines, and under two decades later it was gotten out by the WWF as being one of the biggest makers of CO2 emanations in all of Europe. It positioned 13 on the 2007 "Dirty 30" list. Presently, be that as it may, the tables are turning. For four entire days, Portugal created enough spotless, supportable power to address the issues of its kin. That is on account of a major push toward sun oriented, wind, and hydro power and a little poke from the EU which issued an order expressing that part countries need to create no less than 31% from renewable sources. As indicated by reports, Portugal's green run kept going from 6:45 AM Saturday, May 7 until 5:45 PM the next Wednesday. That totaled 107 straight hours amid which the nation didn't need to hope to coal or regular gas to get a move on. This is the second enormous win we've seen for renewable vitality in the EU this month. Simply a week ago the German government reported that the nation created so much renewable vitality on an especially sunny, breezy Sunday that there was a power overflow. Gas plants naturally close down amid the surge, however coal and nuclear facilities couldn't switch off as quick — so Germans were basically paid to drain the additional power out of the matrix.

ii) "Romania's renewable energy capacity reaches 5163 MW at the end of Q1"- Romania insider

17th May 2016 by Romania insider - The renewable energy creation limits in Romania achieved an aggregate introduced power of 5,163 MW toward the end of March 2016, as indicated by neighborhood power network administrator Transelectrica. The capacity is 3.6 times higher than that of the Cernavoda nuclear power plant (1,412 MW), reports nearby Agerpres. The renewable energy limits included wind parks with an introduced force of 3,129 MW, sun powered plants with an aggregate limit of 1,343 MW, small hydro power plants totaling 588 MW, and biomass activities of 103 MW. Toward the end of a year ago, the renewable energy generation limits totaled 5,142 MW. The renewable vitality makers get green testaments that they offer on a specific business sector, for extra incomes other than the energy they offer. Every one of the consumers in Romania, including by the population, pay for the green endorsements in the last power bill. In 2016, the compulsory share for efficient power at national level adds up to 12.15% of the gross power utilization.

iii) Asian Utility Week 2016 to shine spotlight on smart city innovation

Asian Utility Week 2016 is a stage that unites the best of breed utilities utilizing computerized techniques to enhance client engagement, energy proficiency and operational fabulousness from crosswise over Asia, Europe and the United States. The multilateral establishment takes note of that somewhere around 2000 and 2010, exactly 200 million individuals in East Asia moved to urban territories - an assume that would be the world's 6th biggest populace for any single nation. This has in turn led an unyielding weight on existing transport, force and utility systems, and spurred a developing interest for these fundamental utilities. As the urban populace in Asian urban areas keep on swelling by 44 million consistently, issues identified with blockage, power blackouts and insufficient waste administration will probably happen, says the ADB. Taking care of Asia's developing vitality demand is no simple deed as it is slated to double in the following 15 years. Savvy urban communities to overcome urbanization hardships Acknowledging this potential issue, Asian economies, for example, Singapore, China, Japan, Indonesia and Malaysia have been laying the basis for keen city arranges, which will utilize data and correspondence advances (ICT) to deal with their utilities, says the US-based research organization IT and Innovation Foundation (ITIF). By outfitting the force of these huge information investigation, smart grid activities can make wise sensor system to minimize wasted energy, power blackouts, and unexpected jumps in demand. Principal changes in the way power and water administrations are appropriated and enhancing customer engagement are only a portion of the issues which will be tended to at Asian Utility Week 2016, which held in Bangkok from May 31 to June 1.

Its topic, "Building the Digital Utility", concentrates on the most recent developments in smart meters, smart sensors, communication systems, command system, information investigation, distributed generation, customer billing and storage solutions. Another region that Asian Utility Week 2016 is concentrating on enhancing the distribution and generation of utilities in Southeast Asia. As per the International Energy Agency's Southeast Asia Energy Outlook report in 2015, a more prominent mix of Asean's energy systems is expected to delivered strong advantages over the district.

CHAPTER 3
METHODOLOGY

3.1 Introduction

This chapter will discuss about the methodology of the research that have been plan earlier to achieve the objective stated in previous chapter. This methodology has been plan during Bachelor Degree Project I and the first objective of the work plan has been done and been recorded. The research will be continued during Bachelor Degree Project II to achieve the second and third objective.

3.2 Methodology of Research

i) Preliminary Research

This research might have many reading materials and research to observe the problems, complication, technologies and development in electrical industry. By help of modern technologies, surfing internet about browsers and sites related to the research. IEEE explore is the best place where can find the previous study about related topics in this research. We can see the problem faced and things to be improve by reading the past studies. Industrial review also one of the originator of the idea because they share problem solving materials and information about technology achievement to encourage the research

ii) Calculation

Some calculation need to be done to verify the circuit whether it valid or not to be simulated for the next objective simulation. For this research the calculation of power factor must be done neatly because it is the main objective to get the circuit with power factor compensation correctly. The power factor calculation has been attached at the appendices of this report.

iii) Simulation of Circuit by using Power World Simulation

This research need only software based work station. Not like other research that need to be done at site or working on making a hardware for their project. To achieve the first objective, this paper will design the suitable and supported circuit to be simulated by power world software. The software must simulate the circuit with power factor compensation. After that, for the second objective the simulation will simulate the design with penetration of DG. All the DG parameters is varies such as reactance and resistance value to observe the behavior of power factor compensation in the simulation. The third objective can be done by simulate the best way to penetrate the DG to the designated circuit. DG penetration will be varies on every busses one in a time and observe the power factor compensation behavior.

The power world software is suitable to use in this research because it designed to simulate high voltage power system operation. The software consist of Optimal Power Flow (OPF), Transient stability, PV/QV curve tool and etc. as add on simulation in solving electrical problems. The simulation also easily to run in Microsoft Windows operating system XP minimum and have 32-bit and 64-bit editions that suitable for all types of laptop nowadays. The software initially very effective to simulate power flow analysis up to 250000 buses. However in this research, the software use is for university studies and it is limited to 13 busses. The power world software is preferred because it has been used in Power System and Advance Power System syllabus for Bachelor of Electrical Technology (Power Industry) students thus it easily to be use by experience from past studies.

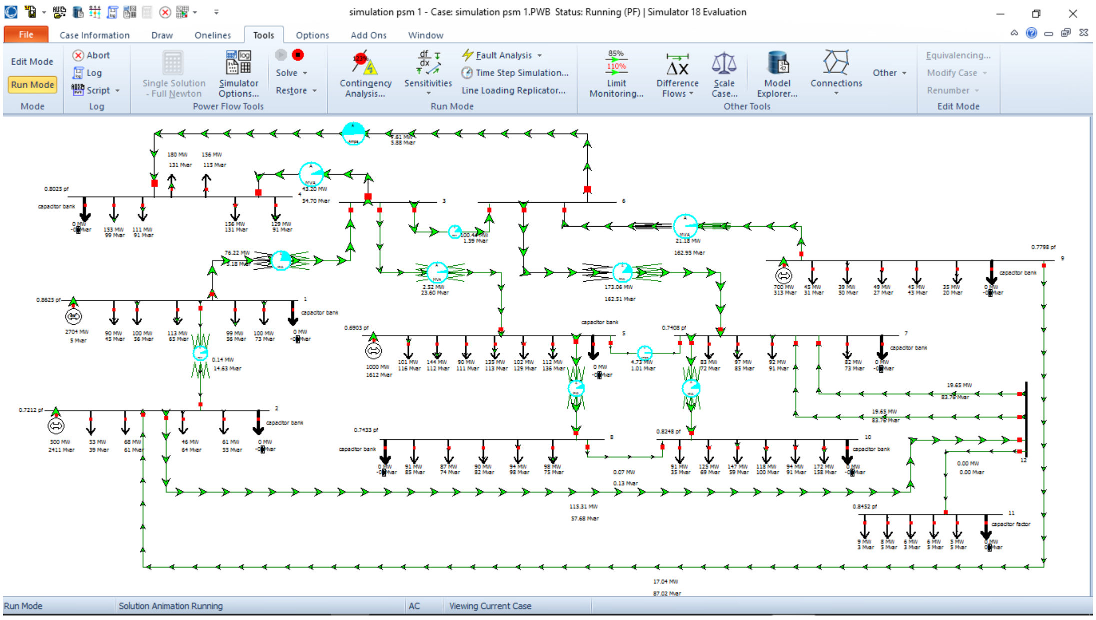

Figure 3.2: Example of simulation in Power World

3.3 Flow chart

By using a suitable flow chart, it shows the work flow from start of this research until the end of the session research. The step is organize systematically in order to have a guide during the research work is running to avoid skipped step and missing important information that will delay and interrupt the working process. Based on figure 3.3 (a) below, this research will start with literature review by related past studies have been down in five years back. The past research is reviewed to find the problem and connection between DG and power factor. Next, this research start to design power line generation and transmission by using power world software. This research circuit design consist of 4 generators, 55 loads, and 12 buses. Next, the design with power factor compensation is simulated by power world software. Then, the simulated power factor compensation is compared to calculated power factor compensation value to verification of design. If the different is out of the range, the circuit design and parameter must be monitored to have a valid simulation with calculation. This following step is repeated when simulating power factor compensation to achieve the first objective clearly.

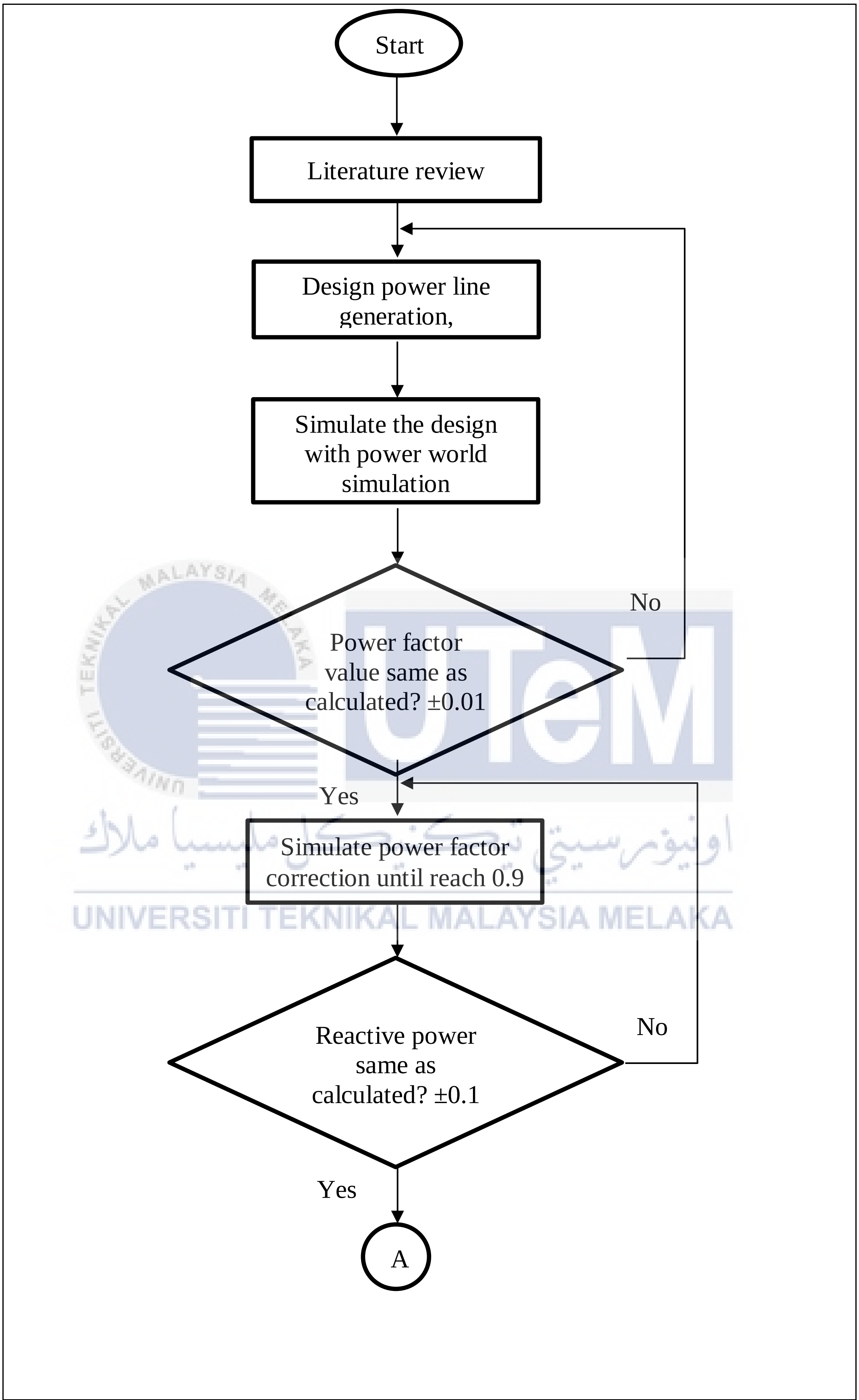

Figure 3.3 (a) : Flow Chart

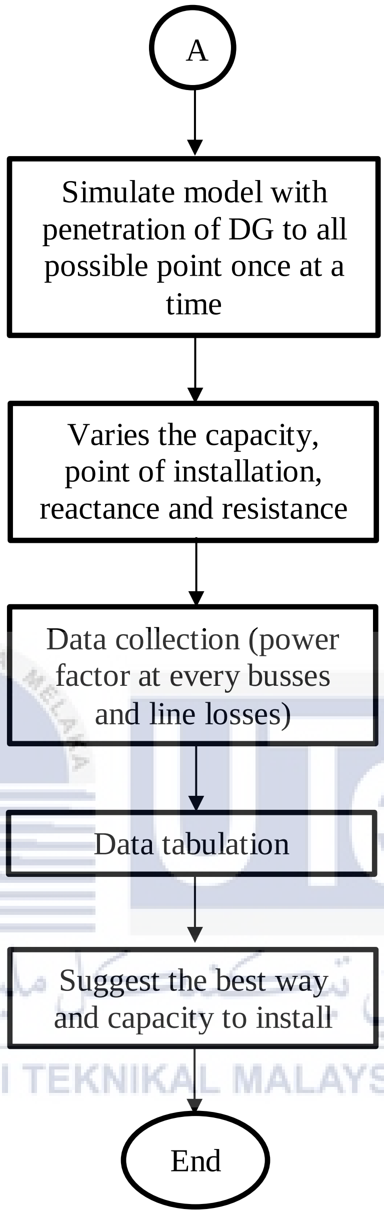

Figure 3.3(b) : Flow chart

Based on figure 3.3(b) above, it continues the research process by simulating the design with penetration of DG. The data can be collected by varies the capacity, point of installation, reactance and resistance value of DG. Data collected is then tabulate and ready to be analyses. After all the information is gain and collected, this research will suggest the best way and suitable capacity to install DG.

3.4 Theory in Designing National Grid with Generators and Load

Based on the studies that have been made in previous chapter, a theoretical design circuit must be built to have an exactly construction to the real grid. This is important where this research will see the problem faces or unexpected scenario that have a tendency to happen in real transmission. Other than that, when there is a penetration of DG, it can easily observe the real situation to the grid behaviors by just using the simulation. Therefore, some calculations and logic parameters value must be consider in every utility devices.

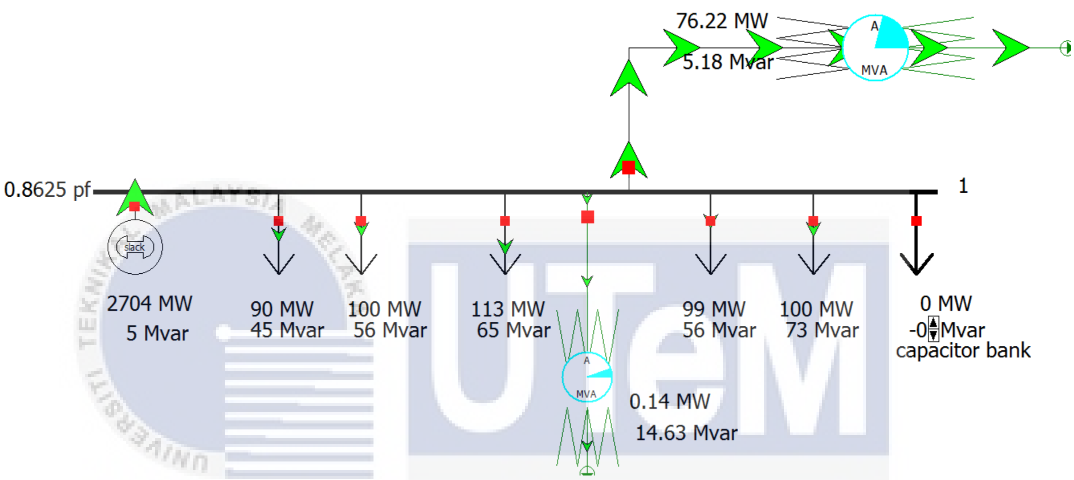

Figure 3.4: Diagram of first busbar

Based on figure 3.4, basically the first busbar model is set as system slack bus to balance and support the reactive power and real power throughout the system. This busbar consist of five simplified load with total 502 MW and 294.6MVar. There are two transformer that link to other busbars with real power and reactive power loss. The transformers has their own reactance and resistance value later will state in a table of every parameters.

As in real life, transformers and connecting line have their own reactance and resistive value due to its length, materials and weather condition. A capacitor bank is installed to the busbar to running the power factor compensation later. Initially, the power factor of the busbar is 0.8625. The capacitor bank need to increase the capacity of reactance in negative value as the capacitor bank absorb much reactance power to increase the power factor to 0.9. This step is repeated to all other eleven busbar.

Table 3.4 (a): Lines Parameters

Lines	Bus		Resistance, R	Reactance, X	Limit, MVA
	from	to			
1	1	2	0.00500	0.50501	100
2	3	1	0.00162	0.00011	3000
3	2	9	0.09745	0.49759	300
4	2	12	0.00247	0.00123	3000
5	4	3	0.00768	0.00972	1000
6	3	5	0.00166	0.01554	500
7	3	6	0.00575	0.00009	2000
8	4	6	0.00291	0.00225	1000
9	5	7	0.71463	0.15215	50
10	5	8	0.00980	0.02800	1500
11	6	7	0.00753	0.00707	2000
12	6	9	0.01493	0.11485	600
13	7	10	0.00980	0.00447	1500
14	7	12	0.00172	0.00735	1500
15	7	12	0.00172	0.00735	2000
16	8	10	0.00146	0.00256	100
17	12	11	0.08147	0.02691	100

Based on table 3.4(a), the line parameters is assume base on the line length in the design. Theoretically, the longer the distribution line the higher the intensity of inductive load thus increase the reactance load. The longest line was from bus two to bus nine. Even though a distribution line from bus one to two is to be short at design circuit but the line is assume to be old and rusty that cause high reactive load. Limits in every line load is determine by its capacity power transfer in MVA. The limit set to be closely the constant generation because it can be seen if there is limit exceeding when any unexpected behavior happen in line. The line from bus two to twenty and three to one has the highest limit and they trusted to transfer the highest reactive power to the load demand all over the circuit system.

Table 3.4(b): Bus load and generation capacity

Number	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
1	132	1	132	-98.21	502	294.6	2707.33	3.57
2	11	1	11	-113.87	228	219	500	2414.5
3	33	0.9655	31.861	-98.64				
4	132	0.87706	115.772	-100.43	885	658		
5	66	1	66	-101.58	684	717	1000	1612.58
6	132	0.8958	118.245	-100.53				
7	66	0.88381	58.331	-110.62	354	321		
8	33	0.7674	25.324	-109.08	460	414		
9	22	1	22	-74.67	213	171	700	313.15
10	33	0.76573	25.269	-109.18	747	512		
11	0.4	0.92802	0.371	-110.55	34	21.5		
12	0.4	0.96414	0.386	-111.09				

Table 3.4(b) shows the capacity of generations and loads at all twelve busses. The nominal voltage of busses is assume as the distribution and transmission line in Malaysia. The main generator is connected to the first bus with 2707.33 MW. The other three generator is acting like a co-generators that support the generation in the system.

Table 3.4(c) : Generator capacity and limit

Number of Bus	Gen MW	Gen Mvar	Set Volt	Min MW	Max MW
1	2707.33	3.57	1	0	3000
2	500	2414.5	1	0	1000
5	1000	1612.58	1	0	1500
9	700	313.15	1	0	1000

Based on table 3.4(c), the voltage set in every generator is 1 per unit with 0 degree. The limit of generator is set closely to the normal generation so that the generator will cut off when the circuit is overload.

Table 3.4(d): Load Capacity

Number of Bus	MW	Mvar	MVA		Number of Bus	MW	Mvar	MVA
1	90	45	100.62		**7**	82	73	109.79
1	100	56	114.61		**7**	0	0	0
1	113	65	130.36		**8**	0	0	0
1	99	56	113.74		**8**	91	85	124.52
1	100	73	123.81		**8**	87	74	114.21
1	0	-0.4	0.4		**8**	90	82	121.75
2	53	39	65.8		**8**	94	98	135.79
2	68	61	91.35		**8**	98	75	123.41
2	46	64	78.82		**9**	45	31	54.64
2	61	55	82.13		**9**	39	50	63.41
2	0	0	0		**9**	49	27	55.95
4	153	99	182.24		**9**	45	43	62.24
4	111	91	143.53		**9**	35	20	40.31
4	180	131	222.62		**9**	0	0	0
4	156	115	193.81		**10**	91	35	97.5
4	156	131	203.71		**10**	125	69	142.78
4	129	91	157.87		**10**	147	59	158.4
4	0	0	0		**10**	118	100	154.67
5	101	116	153.81		**10**	94	91	130.83
5	144	112	182.43		**10**	172	158	233.56
5	90	111	142.9		**10**	0	0	0
5	135	113	176.05		**11**	9	3	9.49
5	102	129	164.45		**11**	8	5	9.43
5	112	136	176.18		**11**	6	3	6.71
5	0	0	0		**11**	6	5	7.81
7	83	72	109.88		**11**	5	5	7.07
7	97	85	128.97		**11**	0	0.5	0.5
7	92	91	129.4					

Table 3.4(d) above shows the real and reactive power demand in every bus. The load has randomly set and assume as constant load consume without any unexpected load demand.

3.5 Simulation

3.5.1 Simulation of circuit without power factor compensation and DG

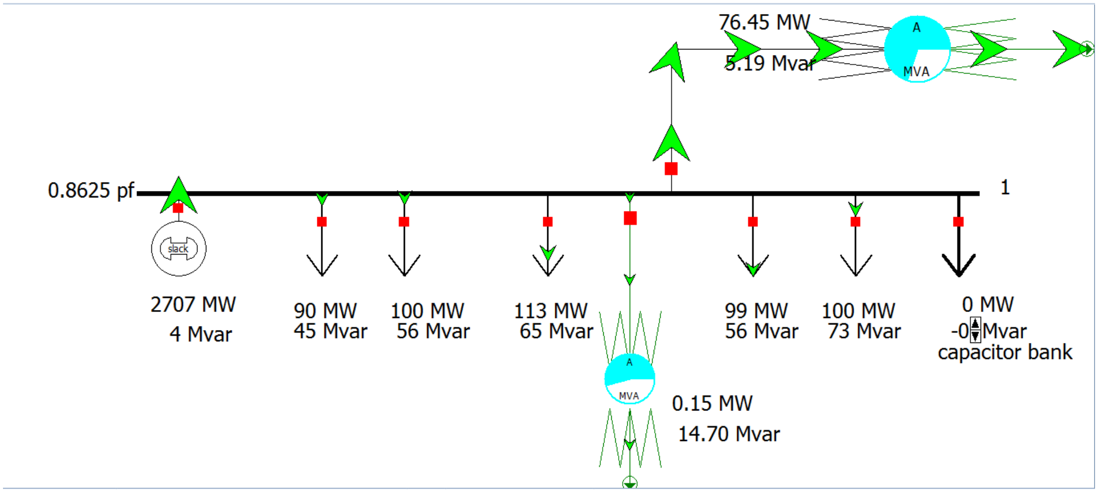

Figure 3.5(a): Simulation of circuit without DG and power factor compensation

Based on figure 3.5(a) above, it shows the simulation is running for simulate the circuit without DG penetration and power factor compensation. Even though there is capacitor bank, but it initially set to zero as the compensation not yet operates. As the initial situation, the power factor of the bus is 0.8625. The step is repeated to the other eleven busses and the data is collected and tabulated.

3.5.2 Simulation of the circuit with power factor compensation without DG

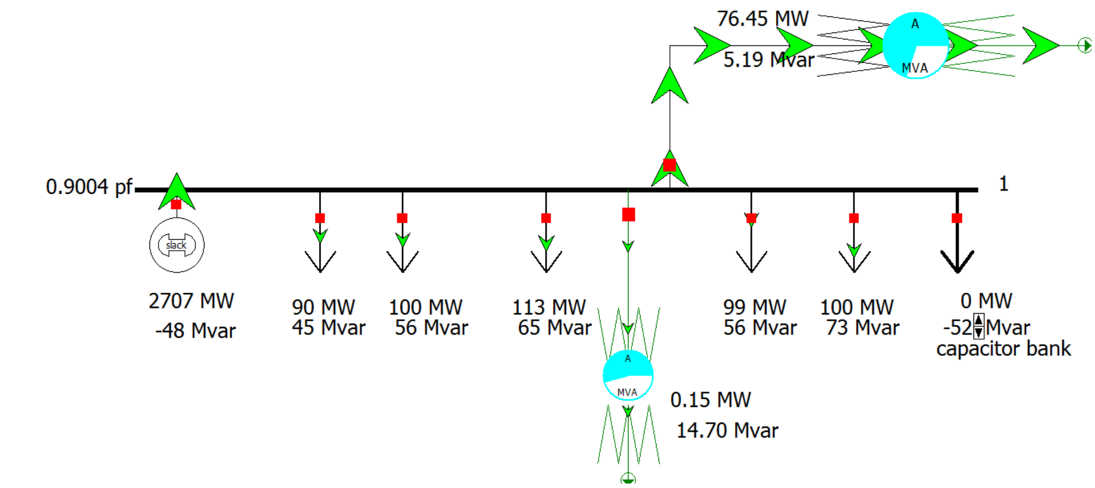

Figure 3.5(b): Simulation of circuit with power factor compensation without DG

Figure 3.5(b) shows the simulation of circuit with power factor compensation but without DG penetration. The capacitor bank absorbs 52 Mvar of reactive power from the bus to achieve the 0.9004 power factor which desired by Energy Commission. This step is repeated to all other eleven bus to simulate each of power factor. To determine the value is valid or not, calculation must be done and compared with simulated value.

Table 3.5(a): Table comparison between simulation and calculation

	Initial (before power factor compensation)		**Final (capacitor bank value when power factor = 0.9)**	
Bus bar	Simulated Power Factor	Calculated power factor	Simulated Reactive Power, Q (Mvar)	Calculated Reactive Power, Q (Mvar)
1	0.8625	0.8621	52	51.87
2	0.7212	0.7212	109	108.58
3	-	-	-	-
4	0.8025	0.8025	229	229.41
5	0.6903	0.6903	386	385.75
6	-	-	-	-
7	0.7408	0.7408	150	149.56
8	0.7433	0.7433	192	191.23
9	0.7798	0.7798	68	67.85
10	0.8248	0.8248	150	150.24
11	0.8508	0.8563	4	4.53
12	-	-	-	-

Based on table 3.5(a) above, it clearly show that the difference value between calculated and simulation is less than 1%.the calculation step and equation is stated at appendix at the back of this research report.

3.5.3 Simulation of circuit with Power Factor compensation and DG

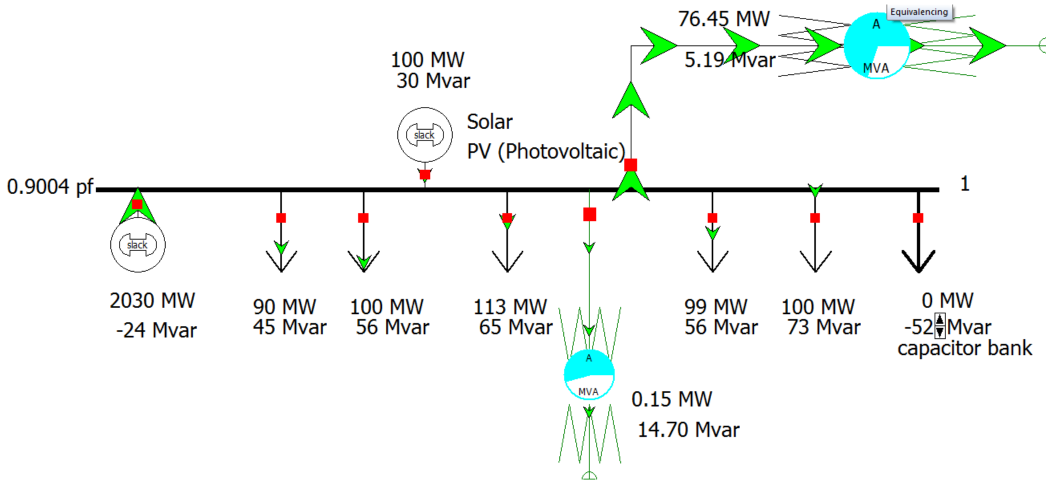

Figure 3.5(c): Simulation of circuit with power factor compensation and DG

Figure 3.5(c) shows the example of one of the bus is penetrate by a solar DG. The bus is connected with a DG with a certain parameter that will decide on next Bachelor Degree Project II. The penetration of DG will varies the capacity, reactance or number of DG penetrate to the bus. This step will be repeated for every bus in the circuit system. The data will be collected and tabulated to be analyses later. After the analysis have been made, the simulation of the most suitable point to penetrate the DG to the system must be run. The best point mean the point that not or least interruption to the power factor compensation.

3.6 Summary

As conclusion, all the methodology stated in this research is appropriately arrange to achieve all the objective stated in the previous chapter. The method involving simulation, calculation and parameters are based on preliminary reading and studies such as literature review, industrial review, trusted government website and some reference books before start the research simulation. Even though the first objective was achieved, the following objective will be focused in Bachelor Degree Project II next semester by following the methodology. This research will expose the impact of penetration of DG to the power factor compensation and this research will expose the best way to penetrate the DG into the system.

3.7 Conclusion

In the nutshell, the first objective have been achieve during Bachelor Degree Project I that is analyse the power factor compensation at the conventional grid without DG as stated at chapter I. A theoretical circuit has been design and simulated with power factor compensation in every bus in the system. The calculation also has been made to compare the calculated value power factor whether the circuit design is valid or not to be use for the next circuit simulation. As the result, the simulated value and calculated value has different only 1% between each other and the circuit was proved its validity to use for penetrate the DG for the next objective. As the early result, without penetrate DG to the system, the power factor compensation operates as expected and theoretically accepted. Based on the studies has been made, the penetration of DG might be some effect to power factor compensation. This is because the actuator use to drive the DG are normally have at least small amount of reactance due to inductive load inside the actuator. When there is reactance, the generator will produce reactive power that trusted to lower the power factor. Furthermore, usually DG produce DC voltage output. In order to transfer the power through conventional AC grid, DC-AC converter is needed to convert DC to AC voltage. The converter usually using a power diode as a bridge that will produce Harmonic Distortion. Harmonic Distortion will increase the angle between current and voltage from DG that will lead to much legging. Therefore, the conversion DC to AC and prime mover use is the main contribution to power factor degradation. As the next step that this research will done is to achieve the following objectives by Bachelor Degree Project II to assess the effect of DG penetration to power factor compensation and suggest the best way to install DG at the system. On Bachelor Degree Project I, this research has achieve the first objective from three that is simulating the system with power factor compensation and comparing with calculation value.

CHAPTER 4

RESULT & DISCUSSION

4.1 Introduction

This chapter will discuss about the result of this research based on the objectives stated in second chapter. The result will show the initial state of a busbars and transmission lines power factor from the simulation in power world software. Next, this section will show the result of DG penetration to the existing conventional grid's power factor especially busbars and transmission lines. Lastly, this section will expose the best way to install DG by considering least or none power factor depletion at transmission lines and busbars.

4.2 Experimental result using Power World Software

The result is recorded based on several way of simulation by using power world software. First simulation is about simulating the initial power factor compensation at all existing transmission lines. Secondly, a simulation of the transmission line power factor with the penetration of DG at buses respectively. Thirdly, transmission line capacity is simulated with the penetration of DG to observe the power quality of transmitting electricity. Fourthly, the same simulation to determine transmission line power factor with the DG penetration while changing the slack bus from bus 1 to bus 2. Fifth, the same step repeated to gain the transmission line capacity with DG penetration while slack bus changed from bus 1 to bus 2. Lastly, the data of power factor in each transmission lines are being compared to find the best way to install DG at the conventional grid

4.2.1 Power Factor compensation of grid without DG penetration

To achieve the first objective of this report that is to simulate the initial power factor compensation at the constructed conventional grid without penetration of DG, power factor value is collected at 16 transmission lines of the simulated grid.

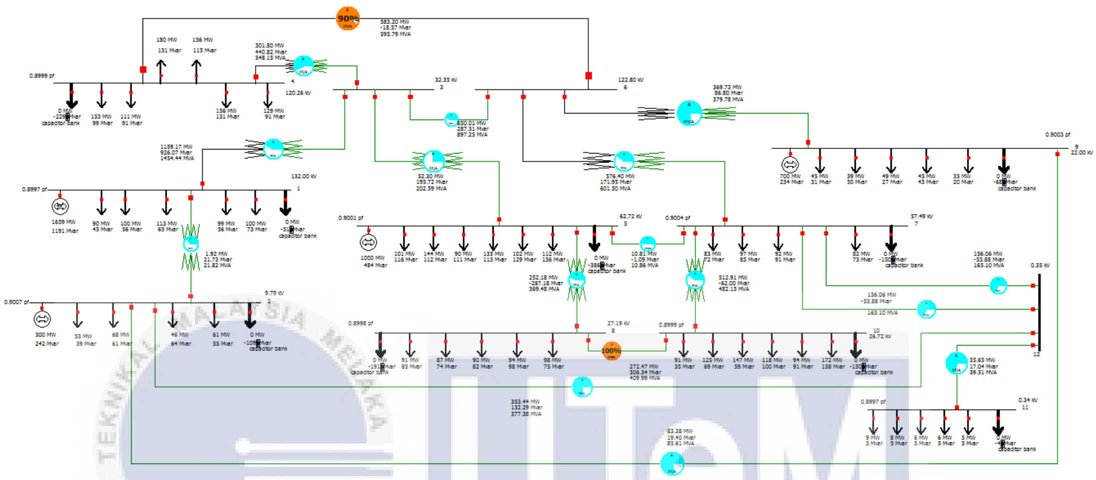

Figure 4.2.1(a) Construction of a conventional grid without DG

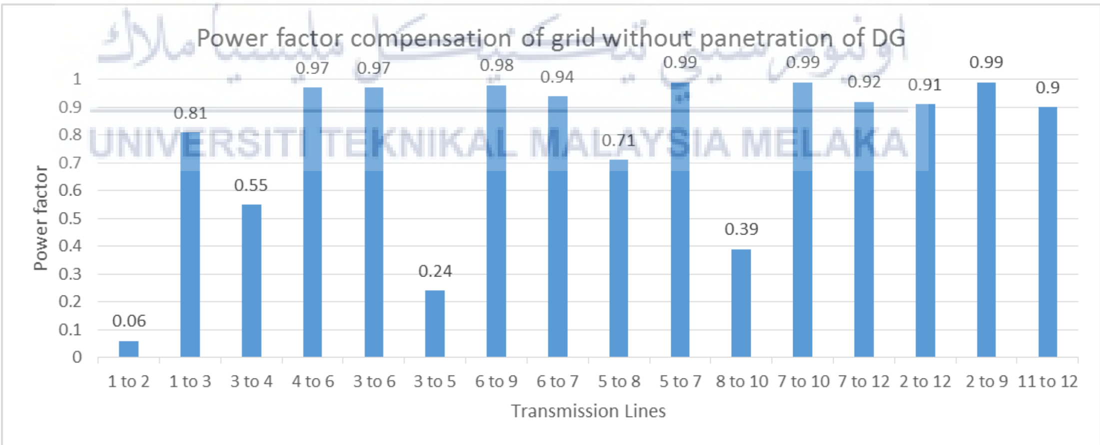

Figure 4.2.1(b) Bar graph of initial power factor compensation based on simulated conventional grid without DG penetration

4.2.2 Power Factor compensation of grid with DG penetration

This subtopic show the simulation result of conventional grid power factor compensation with DG penetration. The simulation is done by placing a DG to a busbar. Then, the conventional grid is tested with DG capacity from 0 MW to 500MW. The process were repeated for other 11 bus bars of the conventional grid.

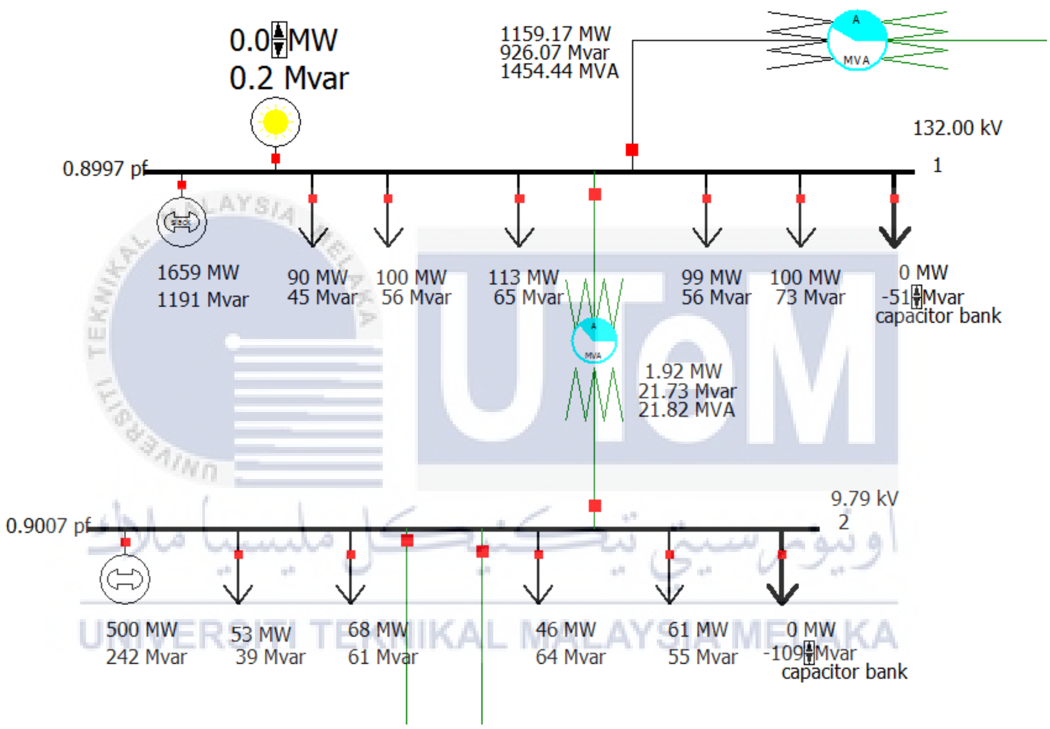

Figure 4.2.2(a) Figure of DG installed at bus 1

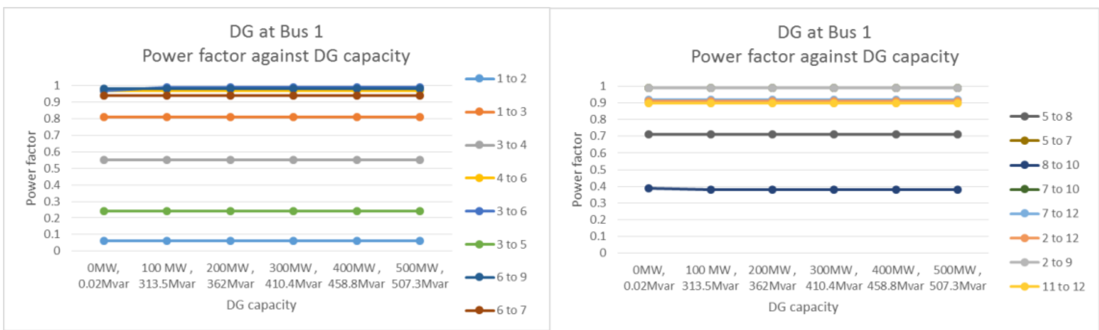

Figure 4.2.2(b) Figure of power factor compensation with DG installed at bus 1

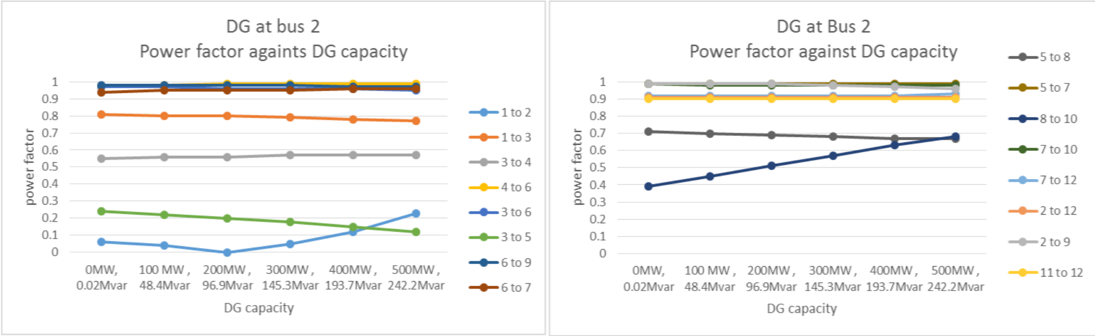

Figure 4.2.2(c) Figure of power factor compensation with DG installed at bus 2

Figure 4.2.2(d) Figure of power factor compensation with DG installed at bus 3

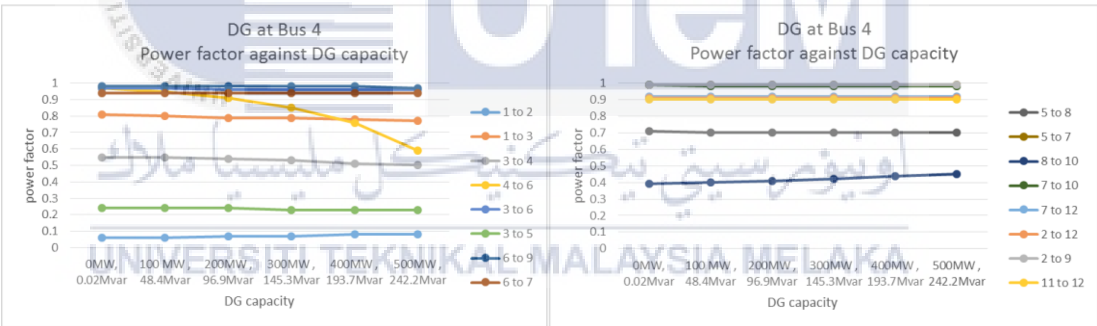

Figure 4.2.2(e) Figure of power factor compensation with DG installed at bus 4

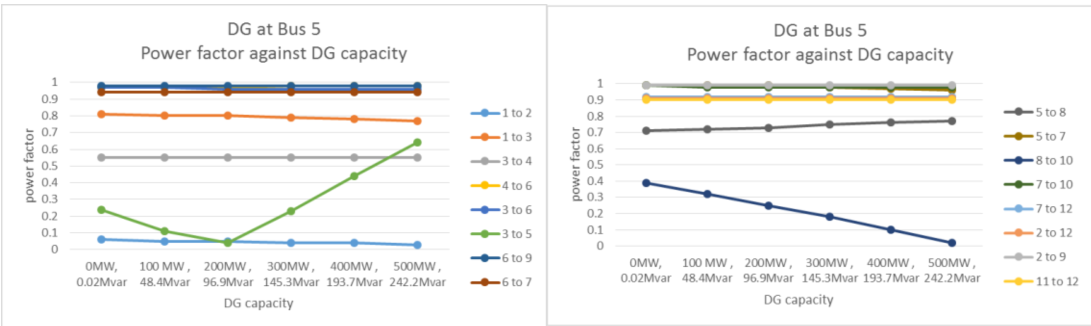

Figure 4.2.2(f) Figure of power factor compensation with DG installed at bus 5

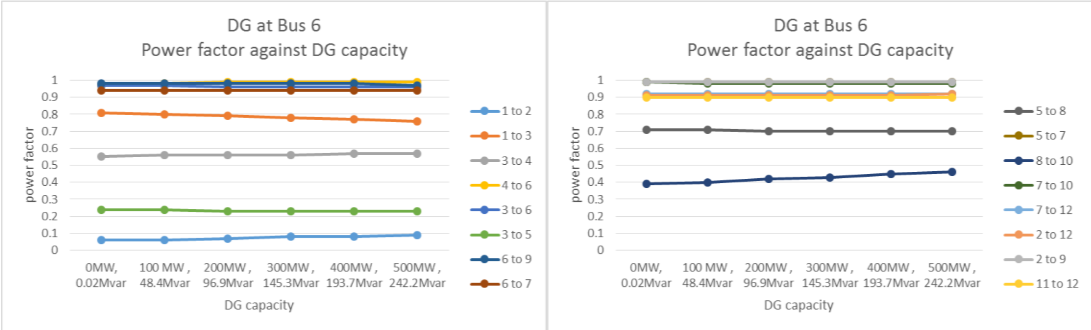

Figure 4.2.2(g) Figure of power factor compensation with DG installed at bus 6

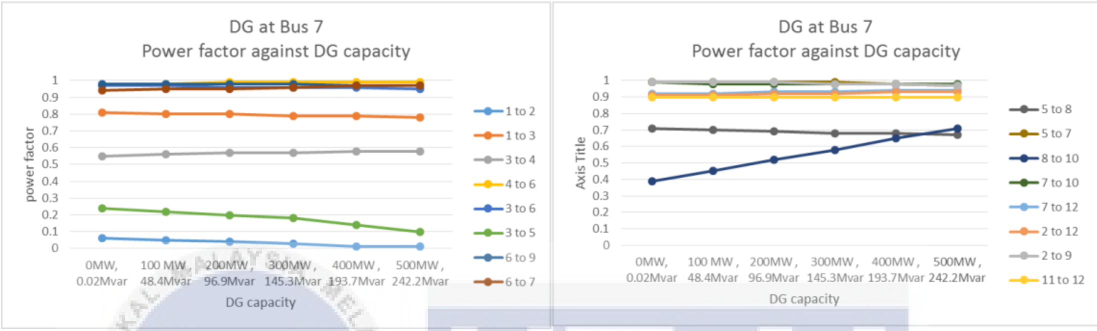

Figure 4.2.2(h) Figure of power factor compensation with DG installed at bus 7

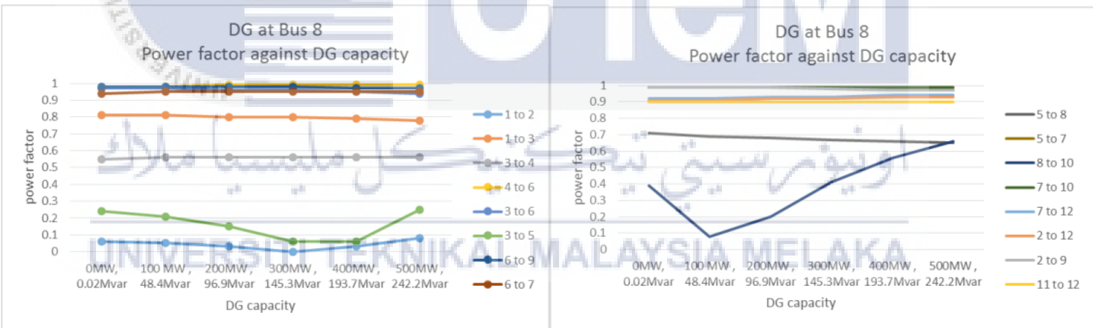

Figure 4.2.2(i) Figure of power factor compensation with DG installed at bus 8

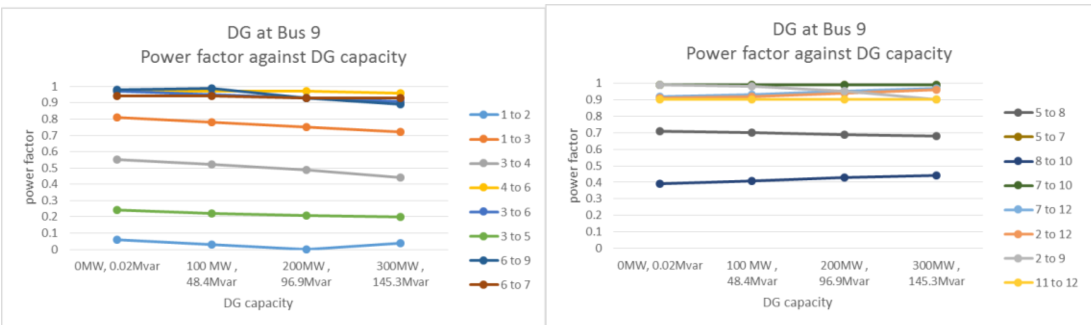

Figure 4.2.2(j) Figure of power factor compensation with DG installed at bus 9

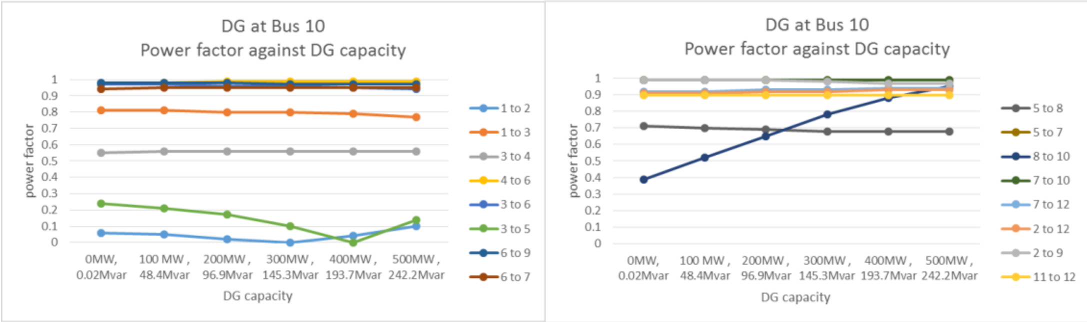

Figure 4.2.2(k) Figure of power factor compensation with DG installed at bus 10

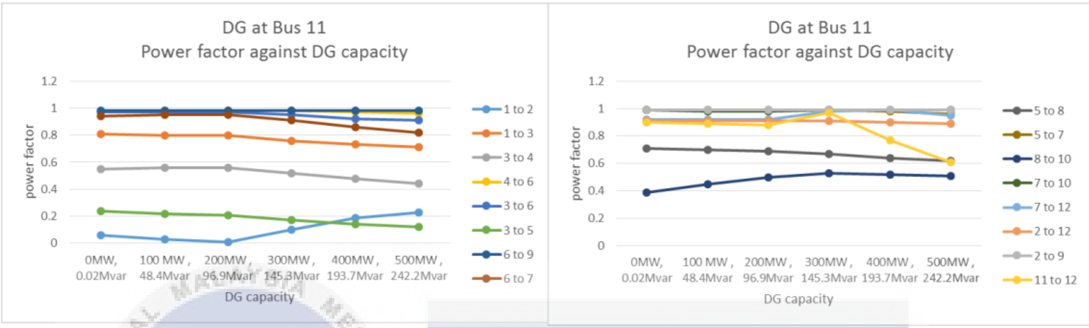

Figure 4.2.2(l) Figure of power factor compensation with DG installed at bus 11

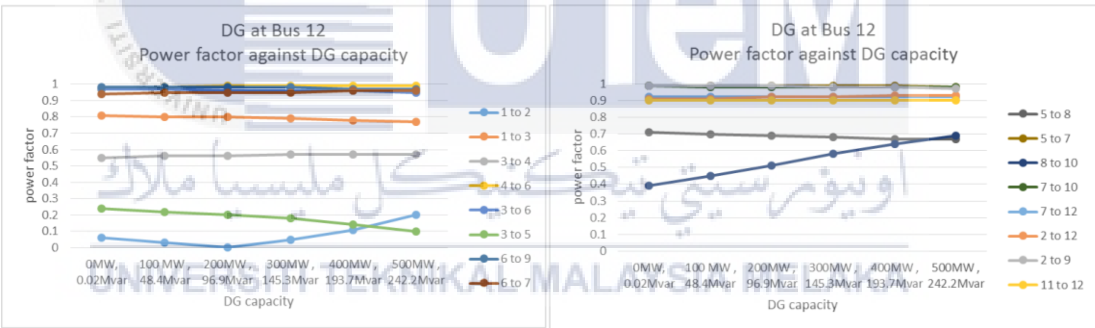

Figure 4.2.2(m) Figure of power factor compensation with DG installed at bus 12

4.2.3 Line capacity of grid with DG penetration

This subtopic shows the result of transmission line power capacity (MVA) after penetration of DG. The important of this simulation is to determine the power quality of the transmission line after penetration of DG. A DG is place at a busbar and simulated with capacity installed from 0MW to 500MW. The process were repeated for other 11 bus bars.

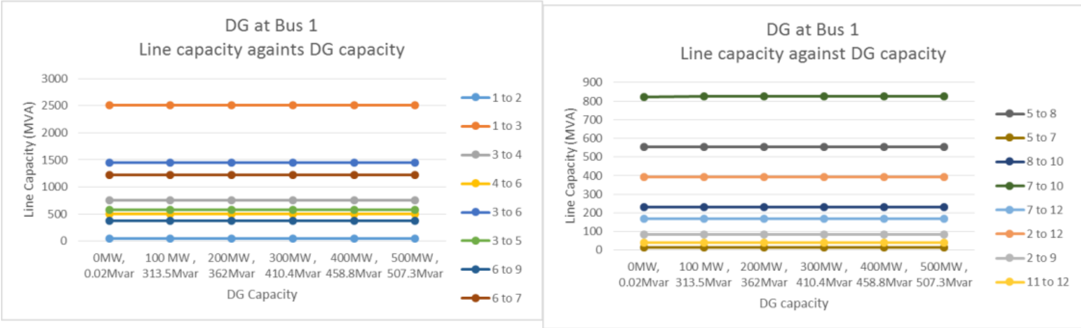

Figure 4.2.3(a) Figure of Line capacity (MVA) with DG installed at bus 1

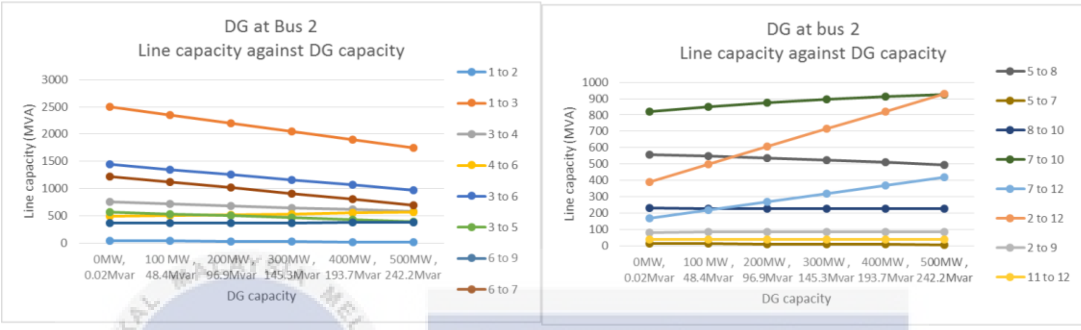

Figure 4.2.3(b) Figure of Line capacity (MVA) with DG installed at bus 2

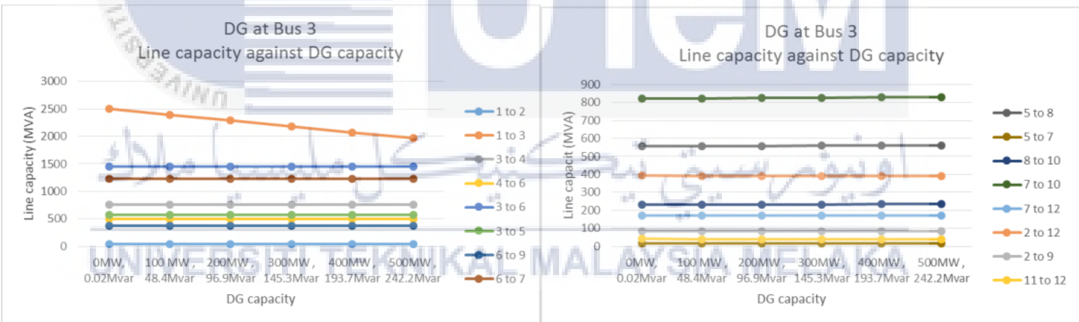

Figure 4.2.3(c) Figure of Line capacity (MVA) with DG installed at bus 3

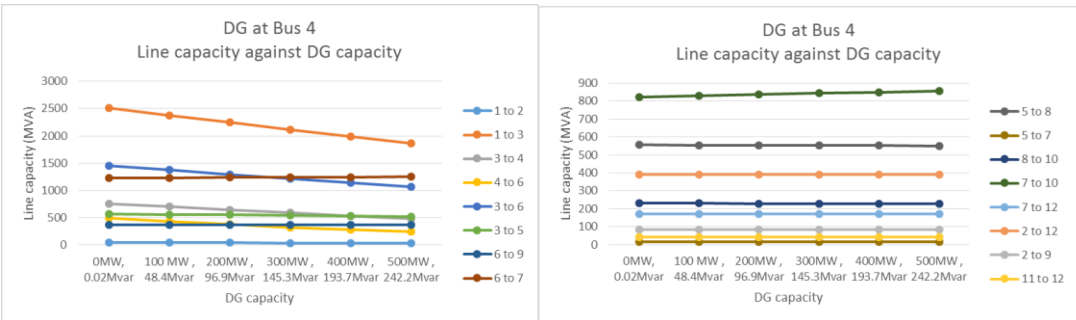

Figure 4.2.3(d) Figure of Line capacity (MVA) with DG installed at bus 4

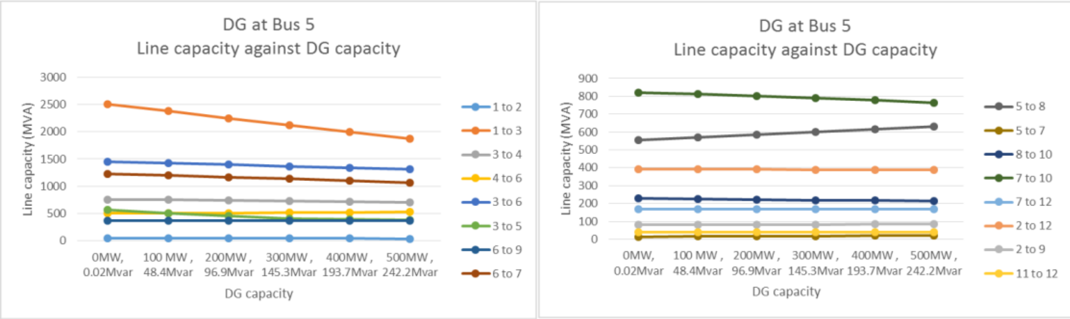

Figure 4.2.3(e) Figure of Line capacity (MVA) with DG installed at bus 5

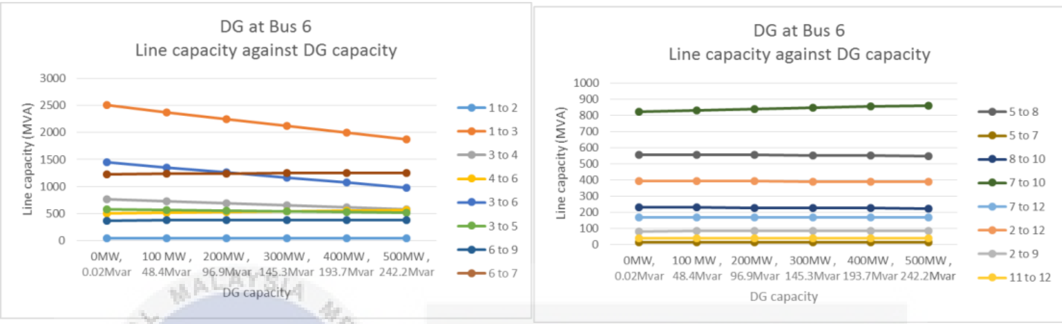

Figure 4.2.3(f) Figure of Line capacity (MVA) with DG installed at bus 6

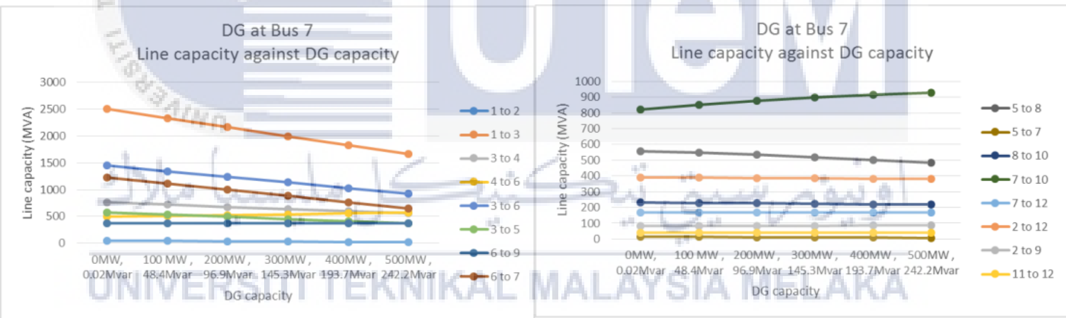

Figure 4.2.3(g) Figure of Line capacity (MVA) with DG installed at bus 7

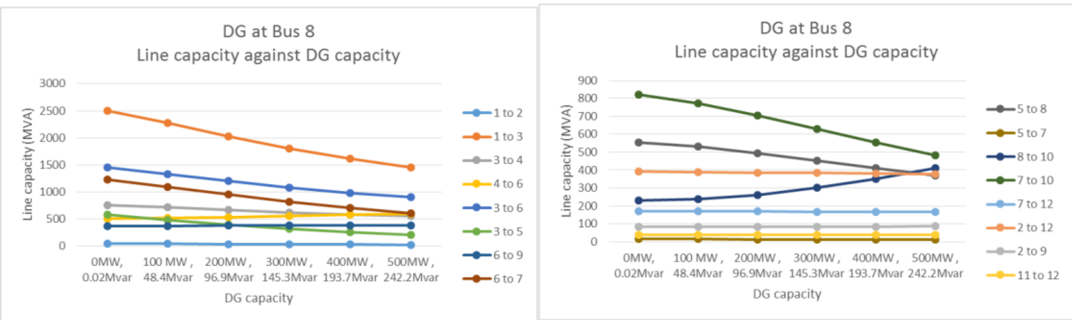

Figure 4.2.3(h) Figure of Line capacity (MVA) with DG installed at bus 8

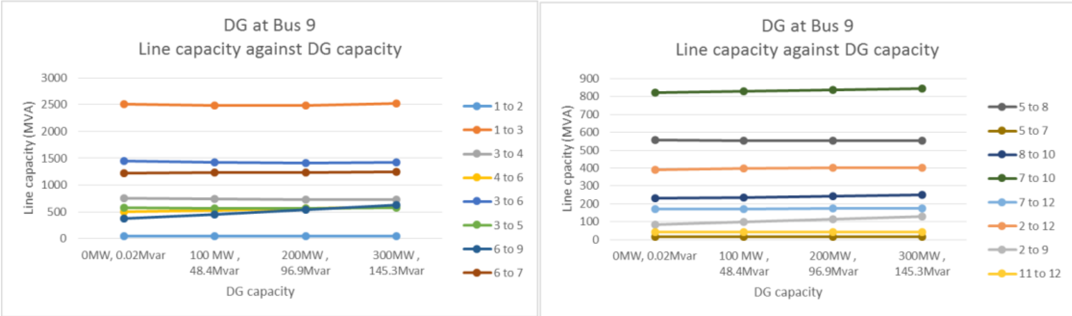

Figure 4.2.3(i) Figure of Line capacity (MVA) with DG installed at bus 9

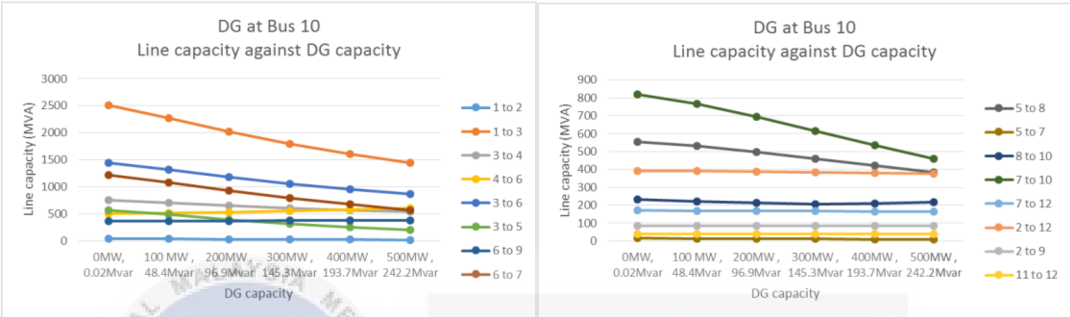

Figure 4.2.3(j) Figure of Line capacity (MVA) with DG installed at bus 10

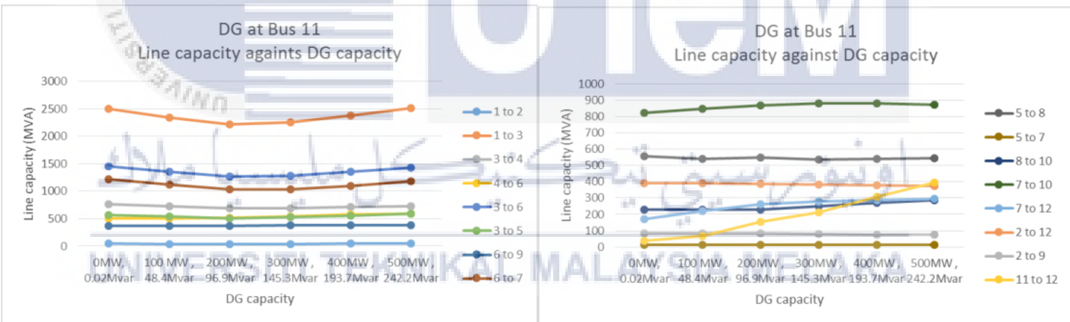

Figure 4.2.3(k) Figure of Line capacity (MVA) with DG installed at bus 11

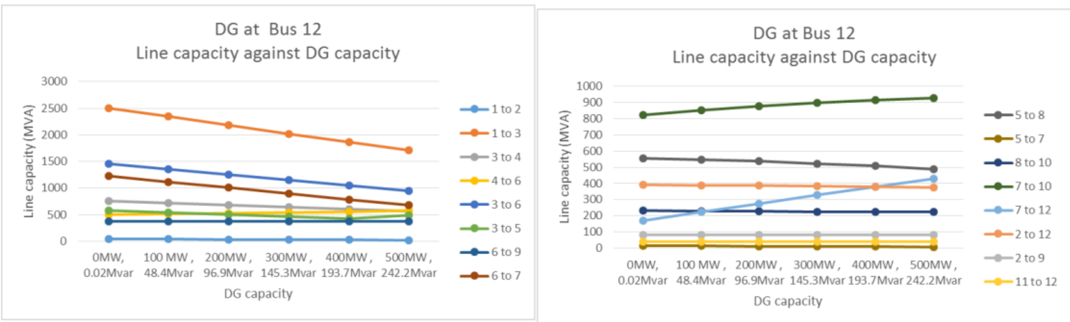

Figure 4.2.3(l) Figure of Line capacity (MVA) with DG installed at bus 12

4.2.4 Different slack bus power factor compensation of grid with DG penetration

This is the part of simulation where the slack bus from the same grid is change from bus 1 to bus 2. This simulation is to determine the power factor compensation of the conventional grid if the slack bus is varied. DG is install with capacity of 0MW until 500MW and simulated with the power world software at a busbar. The process were repeated for other 11 bus bars.

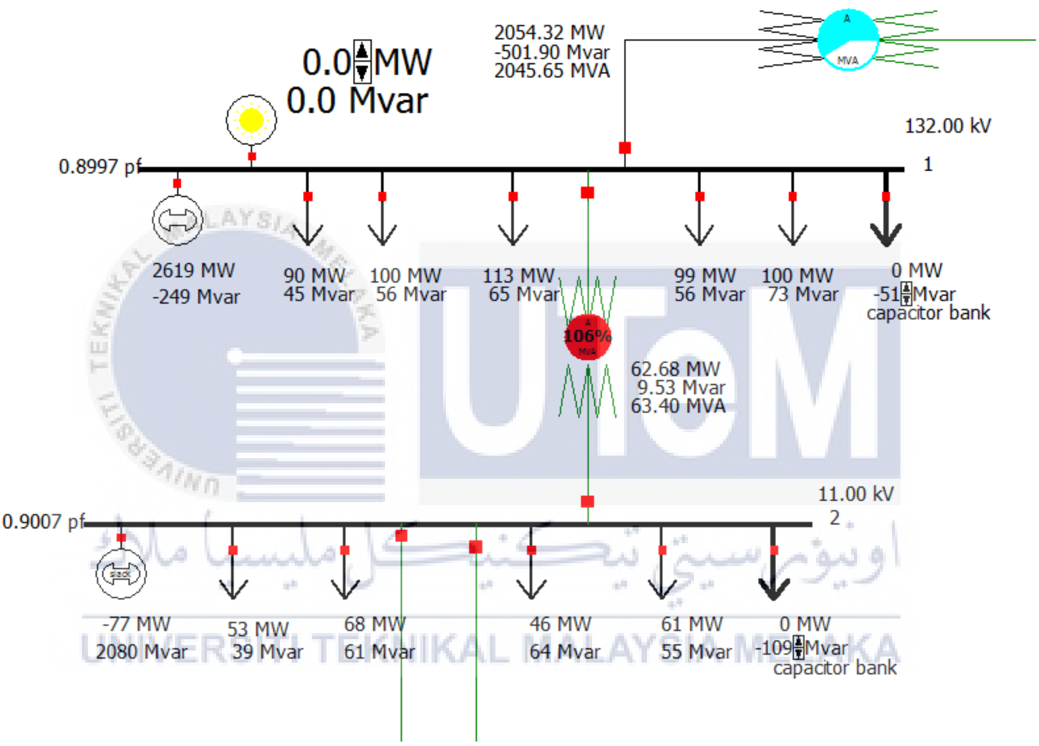

Figure 4.2.4(a) Figure of DG installed at bus 1 with slack bus 2

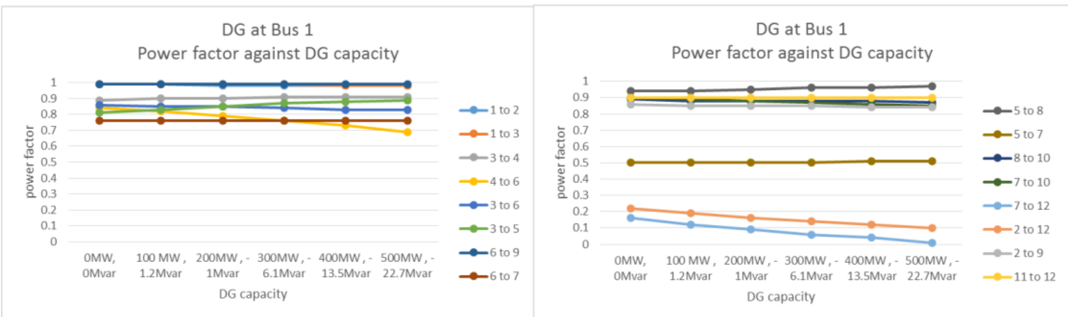

Figure 4.2.4(b) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 1

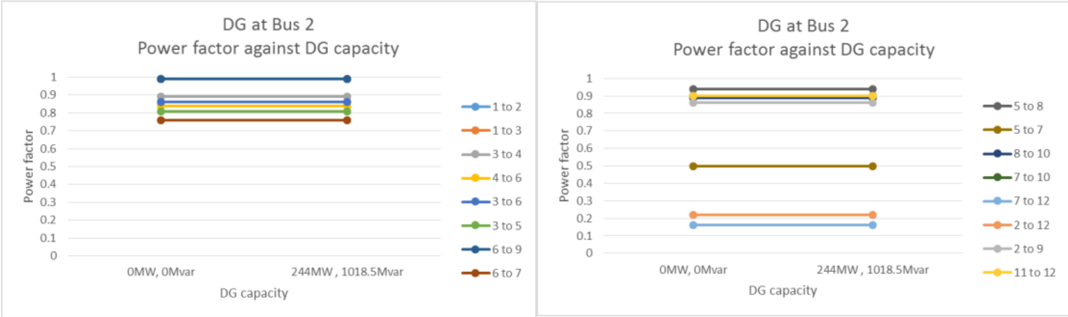

Figure 4.2.4(c) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 2

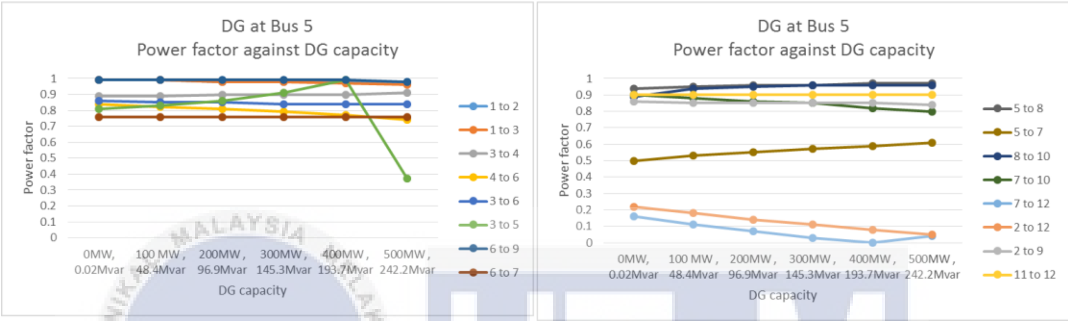

Figure 4.2.4(d) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 5

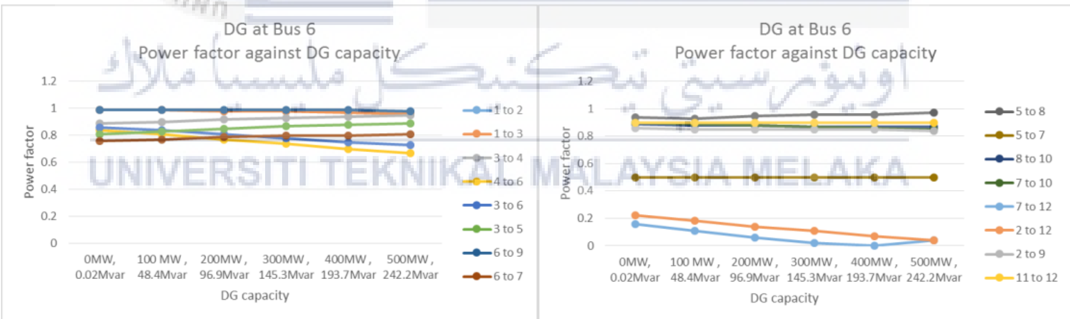

Figure 4.2.4(e) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 6

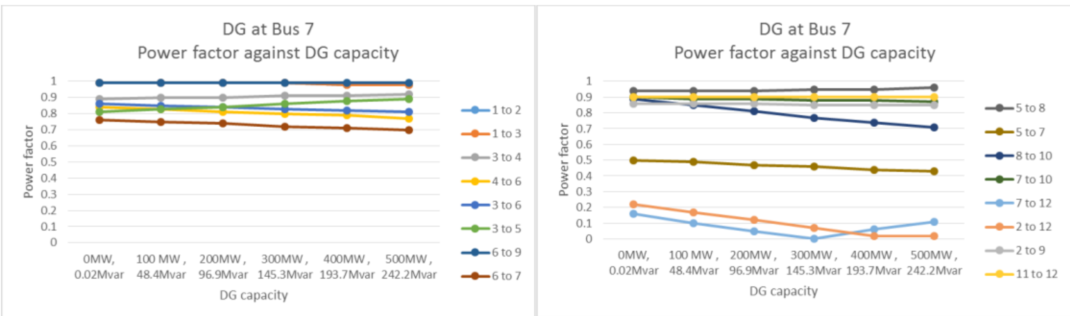

Figure 4.2.4(f) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 7

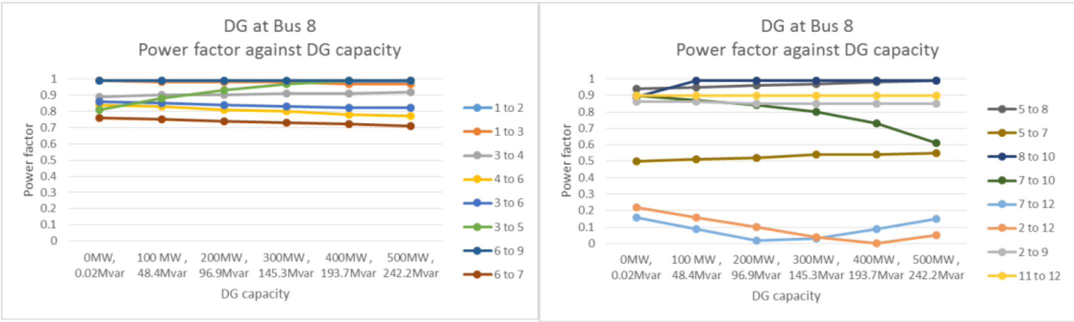

Figure 4.2.4(g) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 8

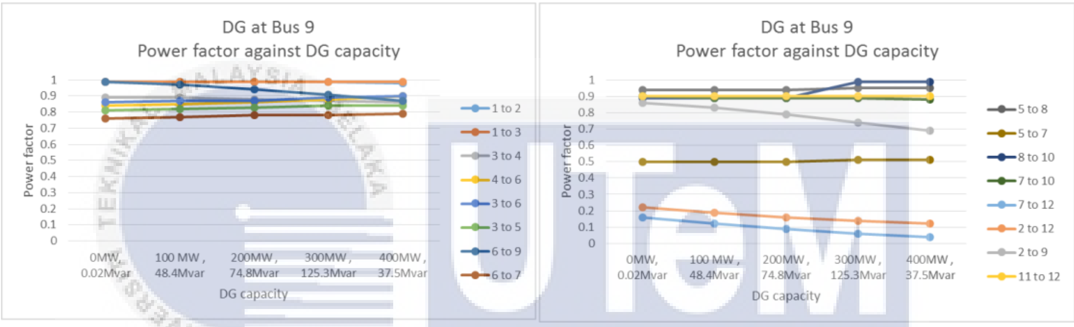

Figure 4.2.4(h) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 9

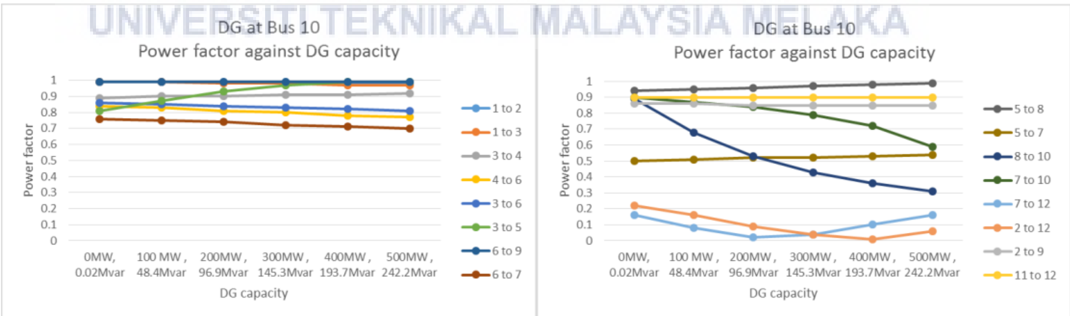

Figure 4.2.4(i) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 10

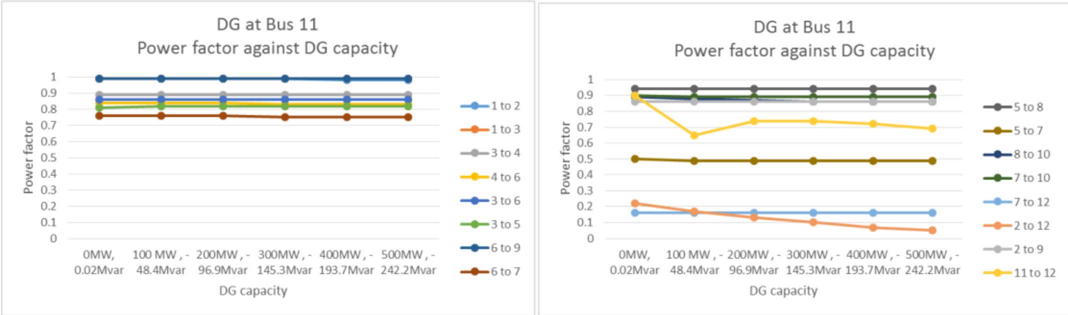

Figure 4.2.4(j) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 11

Figure 4.2.4(k) Figure of power factor compensation when slack bus change to bus 2 with DG installed at bus 12

4.2.5 Different slack bus line capacity of grid with DG penetration

This is the part of simulation where the slack bus from the same grid is change from bus 1 to bus 2. This simulation is to determine the line capacity (MVA) of the conventional grid if the slack bus is varied. DG is install with capacity of 0MW until 500MW and simulated with the power world software at a transmission line. The process were repeated for other 15 transmission lines of each 11 bus bars.

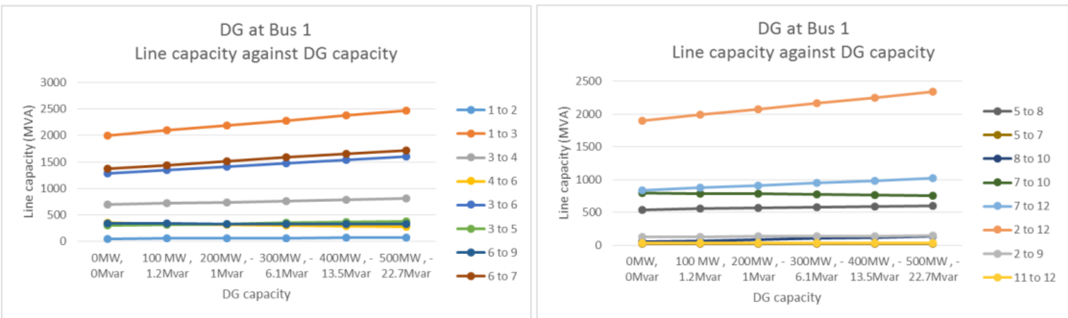

Figure 4.2.5(a) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 1

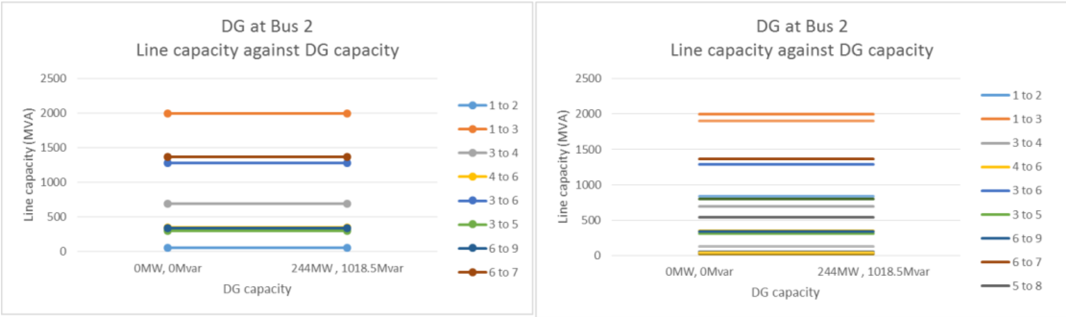

Figure 4.2.5(b) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 2

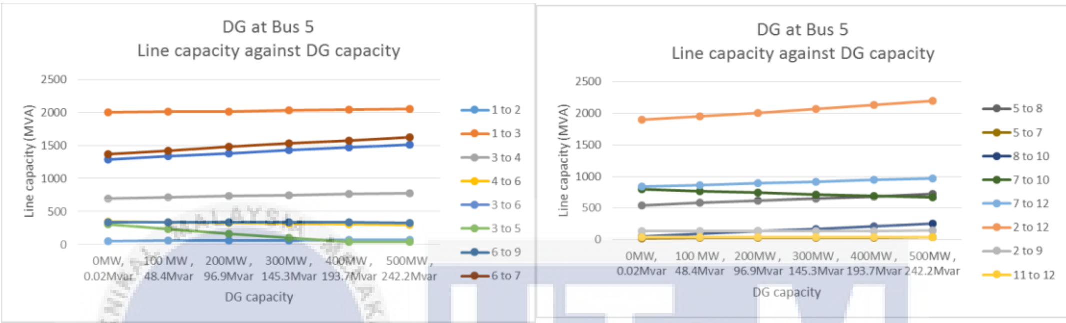

Figure 4.2.5(c) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 5

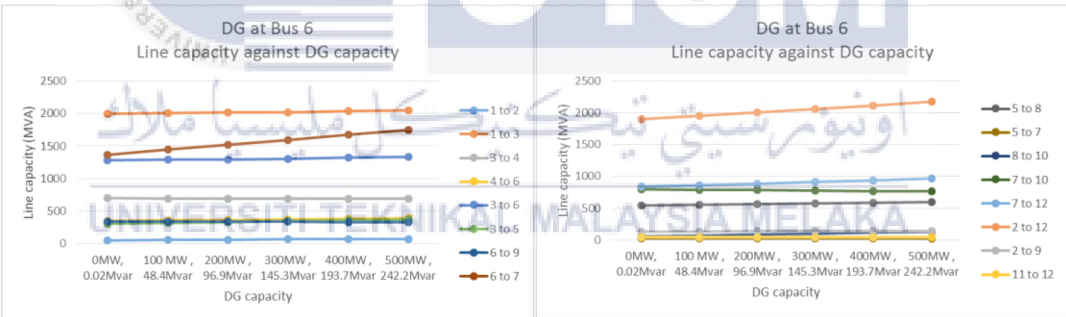

Figure 4.2.5(d) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 6

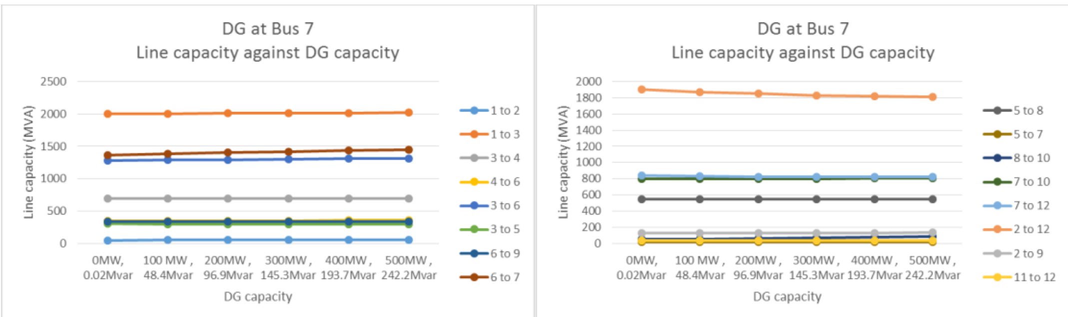

Figure 4.2.5(e) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 7

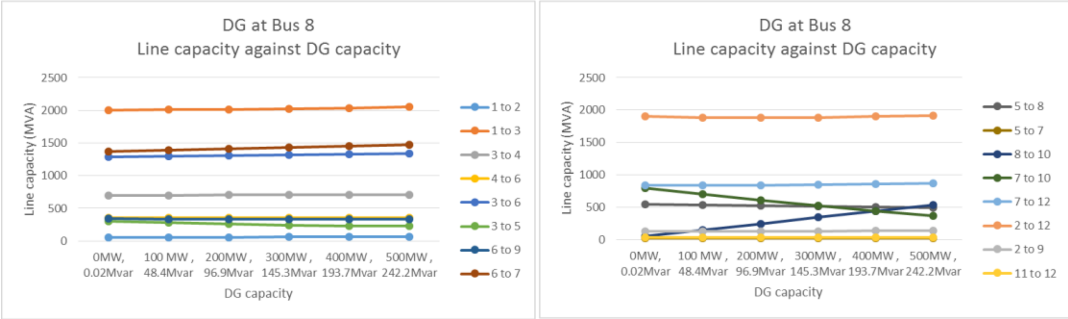

Figure 4.2.5(f) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 8

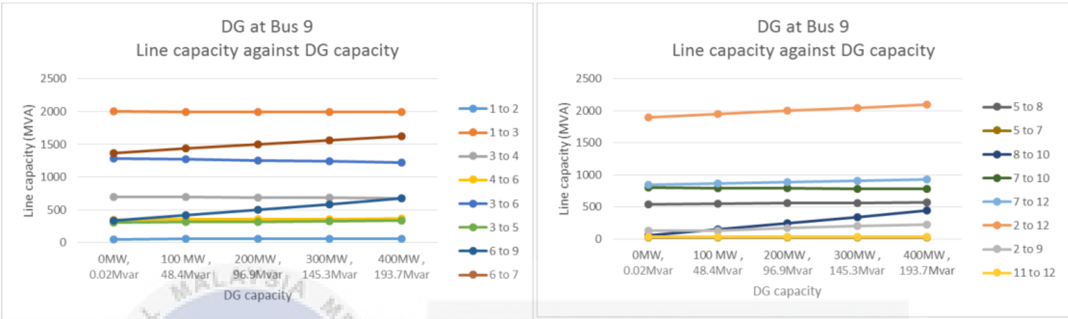

Figure 4.2.5(g) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 9

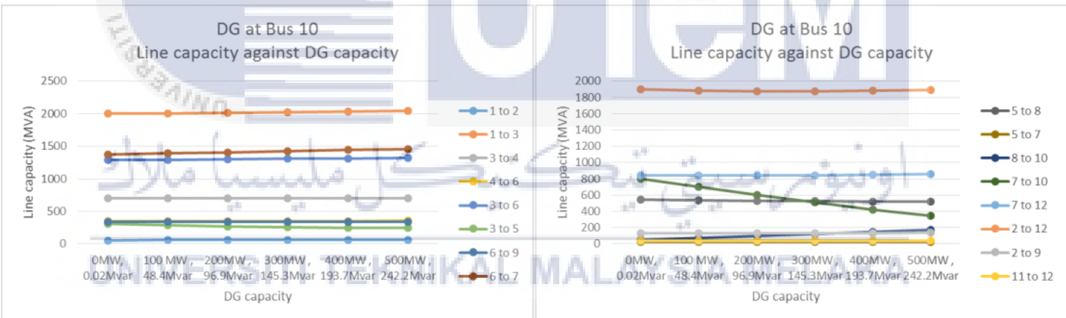

Figure 4.2.5(h) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 10

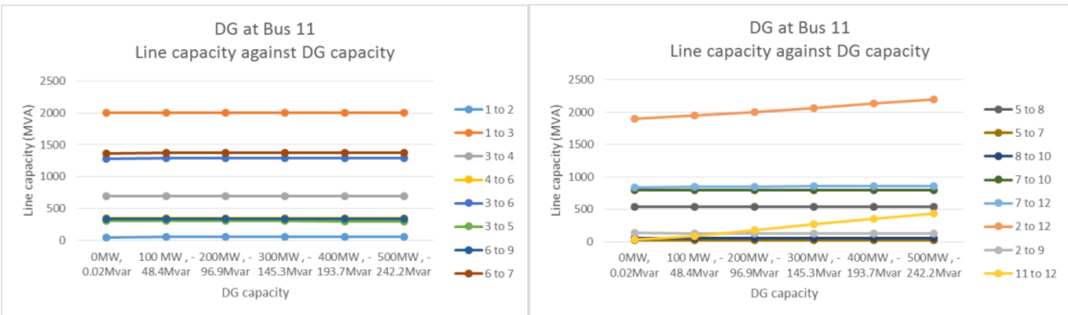

Figure 4.2.5(i) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 11

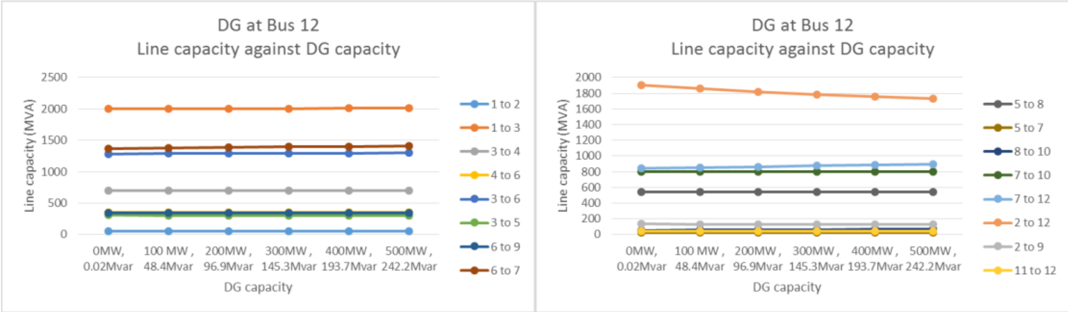

Figure 4.2.5(j) Figure of line capacity when slack bus change to bus 2 with DG installed at bus 12

4.2.6 Power factor behaviour in each line at simulation with DG penetration

The results shows the power factor behavior of all transmission lines after penetration of DG. Each transmission line is simulated with DG varies its capacity of 0MW until 500MW. Then, DG is installed to other 11 bus bars respectively and the data is recorded. This step will repeated the same to other 15 transmission lines. The simulation is done to find the best way to installed DG at existing conventional grid without or least interrupting the power factor of existing transmission line.

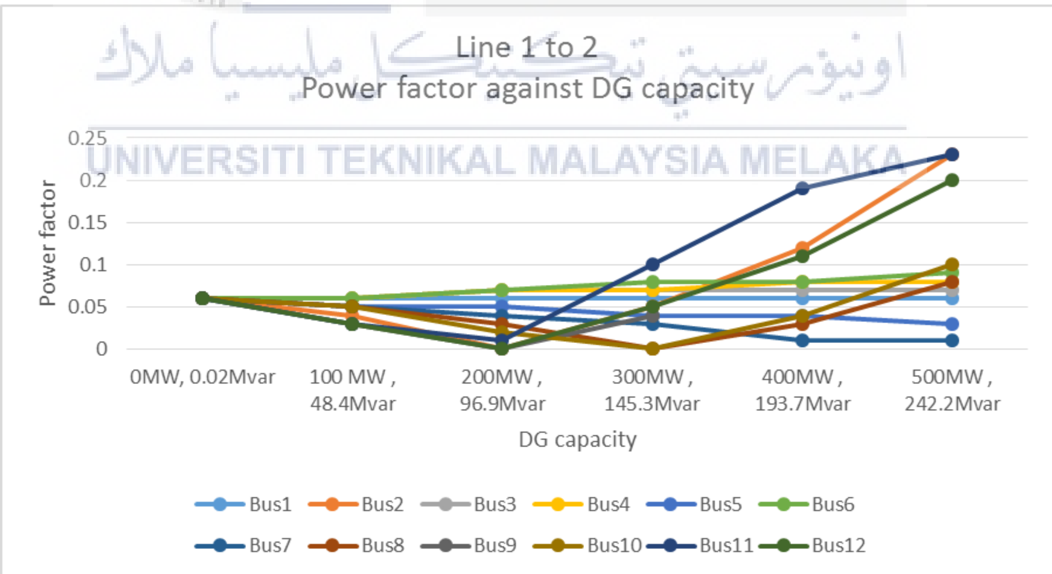

Figure 4.2.6(a) Figure of power factor behavior at transmission line 1 to 2 with penetration of DG

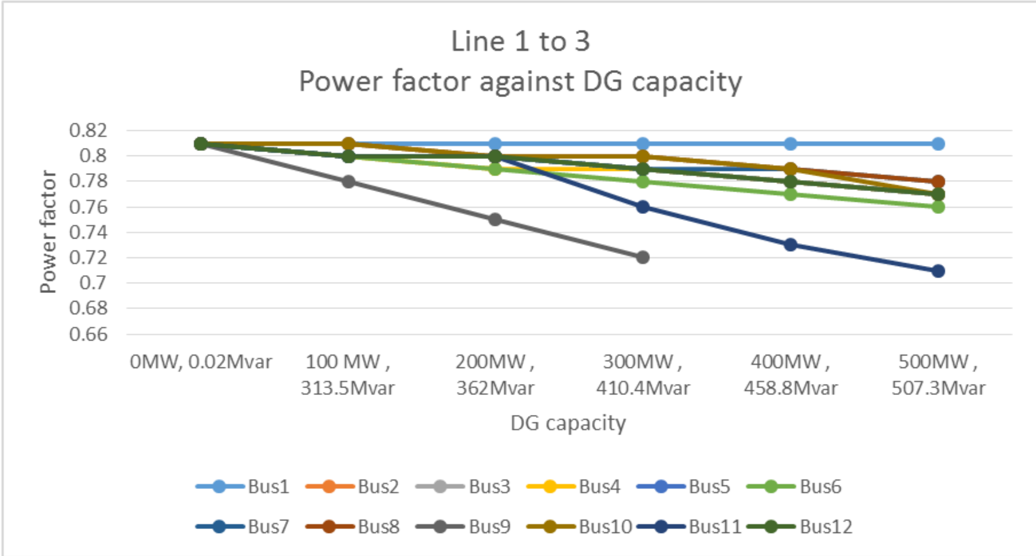

Figure 4.2.6(b) Figure of power factor behavior at transmission line 1 to 3 with penetration of DG

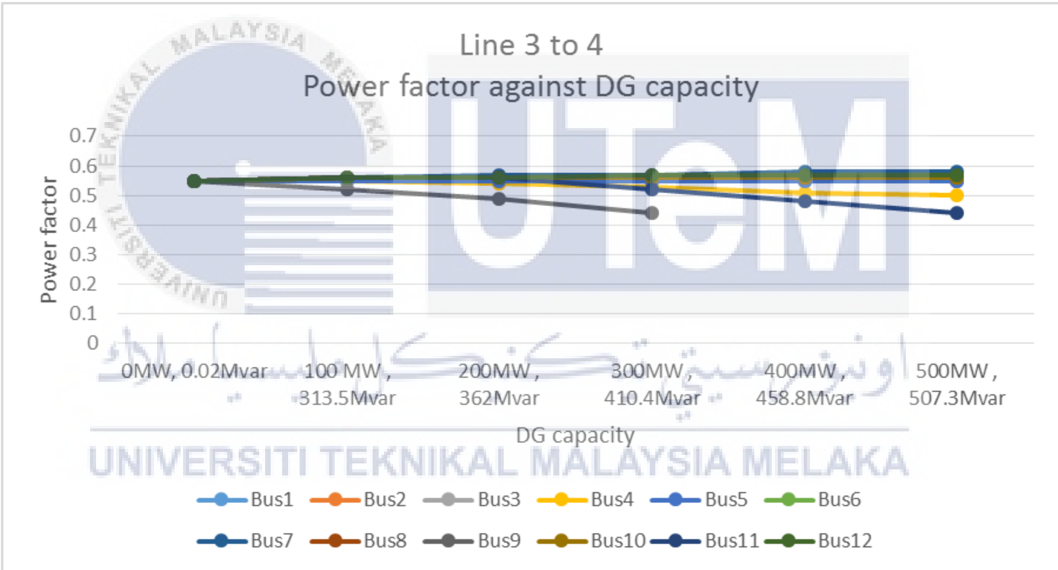

Figure 4.2.6(c) Figure of power factor behavior at transmission line 3 to 4 with penetration of DG

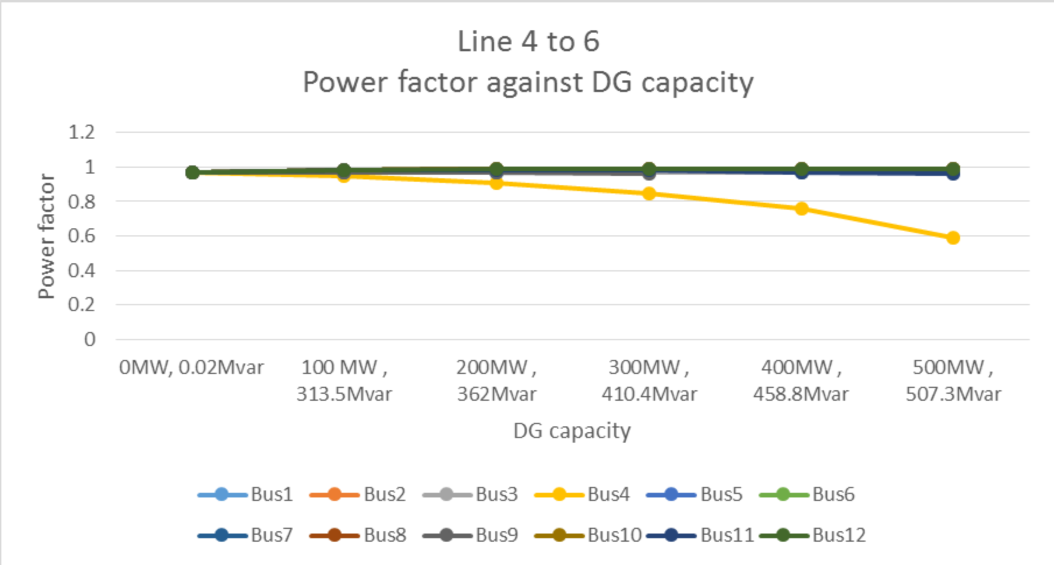

Figure 4.2.6(d) Figure of power factor behavior at transmission line 4 to 6 with penetration of DG

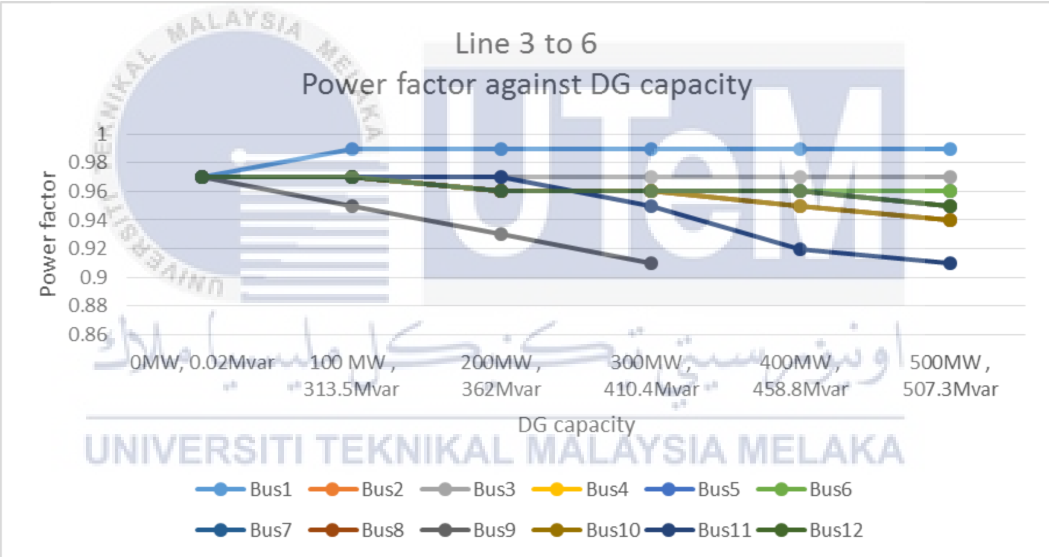

Figure 4.2.6(e) Figure of power factor behavior at transmission line 3 to 6 with penetration of DG

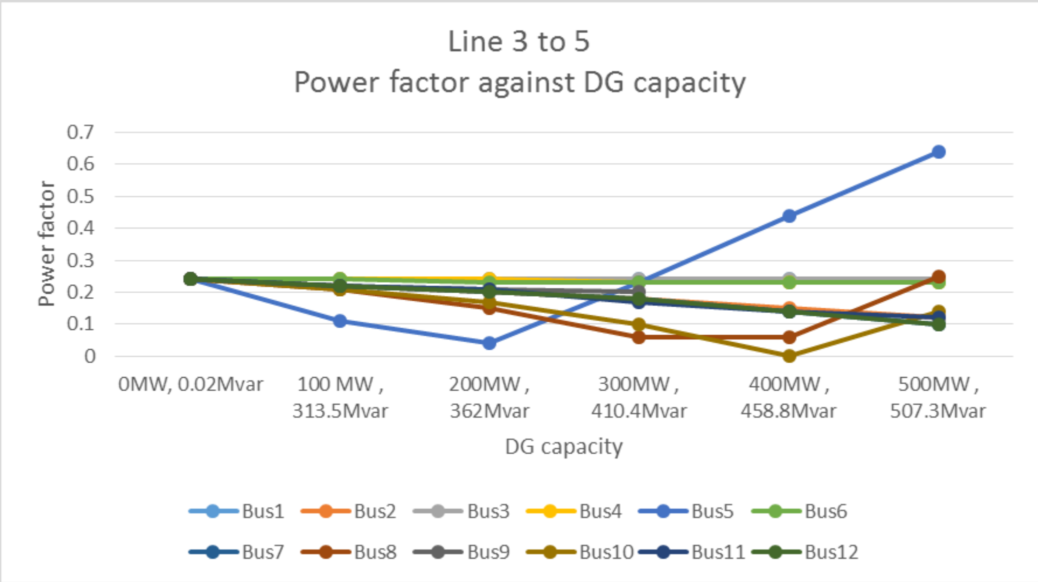

Figure 4.2.6(f) Figure of power factor behavior at transmission line 3 to 5 with penetration of DG

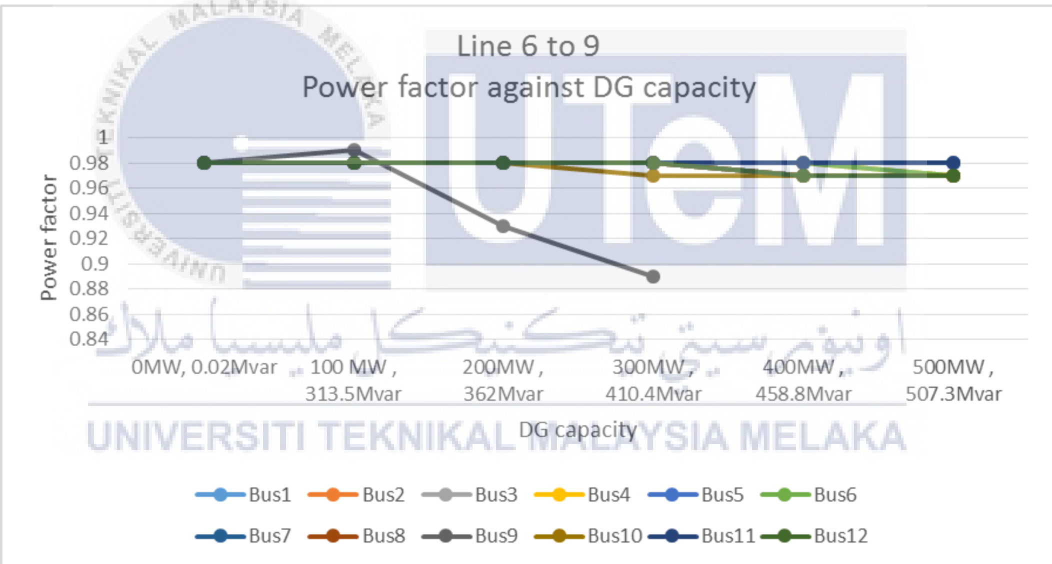

Figure 4.2.6(g) Figure of power factor behavior at transmission line 6 to 9 with penetration of DG

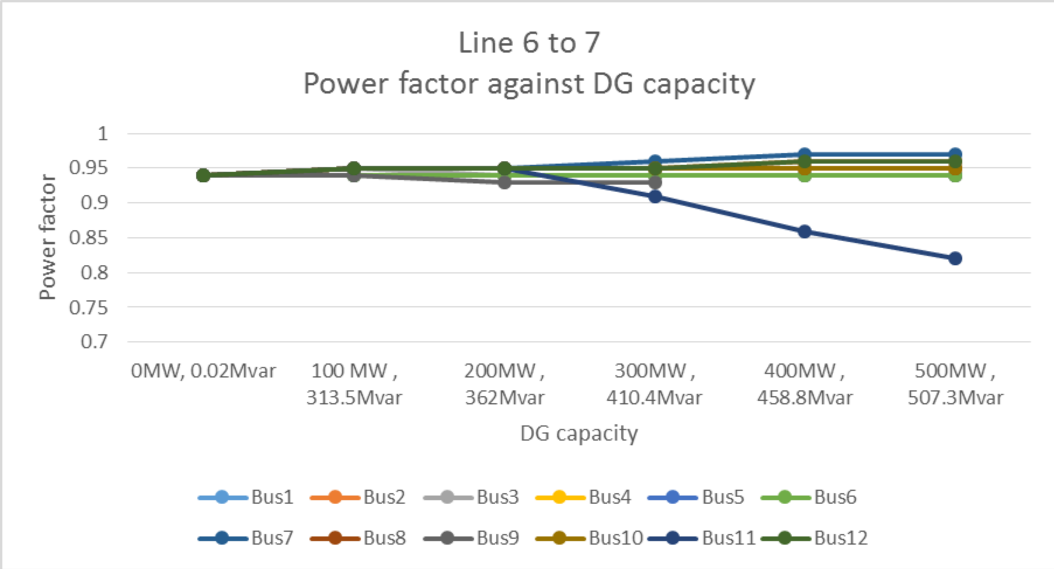

Figure 4.2.6(h) Figure of power factor behavior at transmission line 6 to 7 with penetration of DG

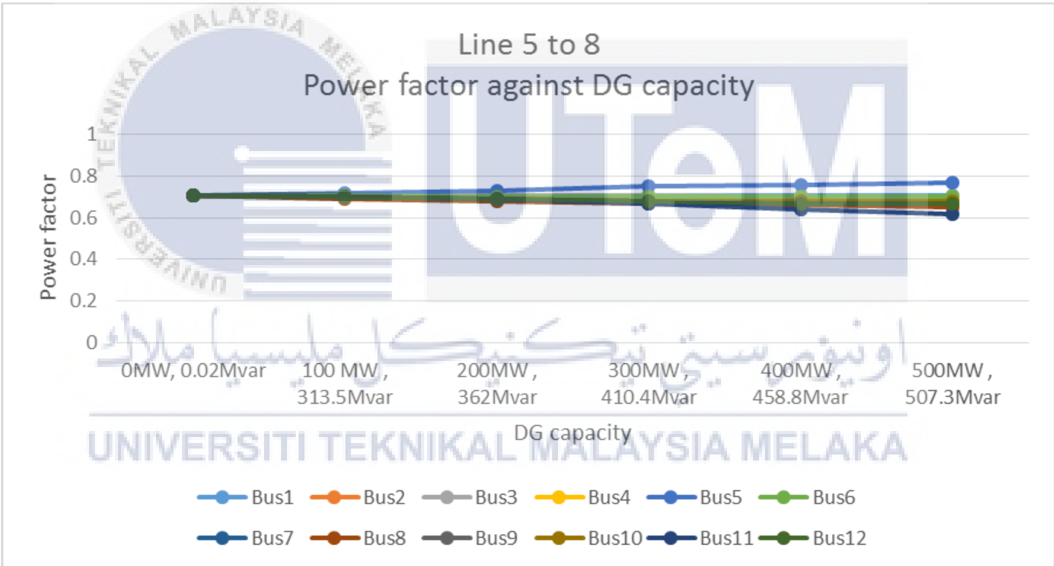

Figure 4.2.6(i) Figure of power factor behavior at transmission line 5 to 8 with penetration of DG

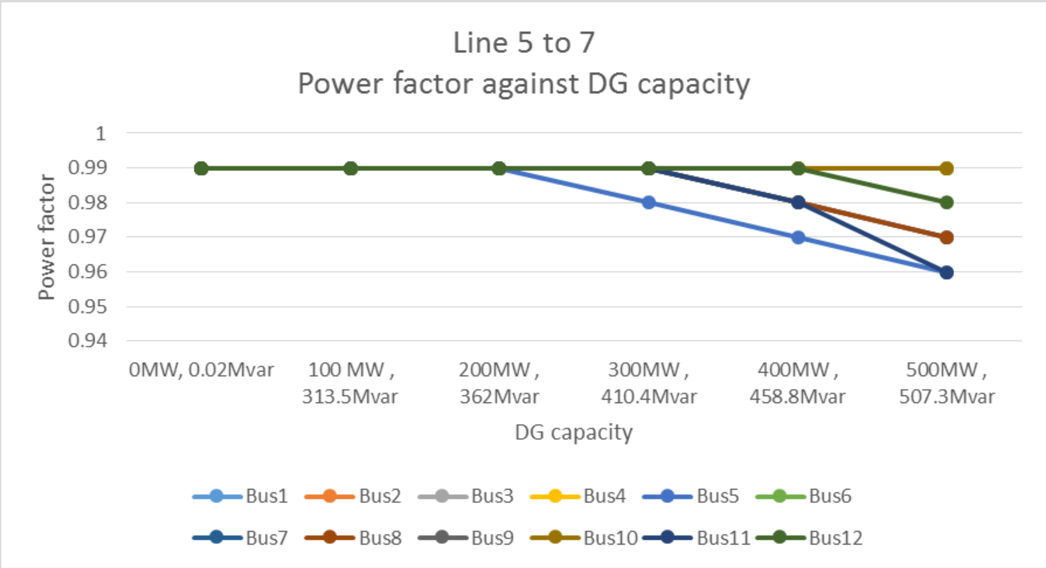

Figure 4.2.6(j) Figure of power factor behavior at transmission line 5 to 7 with penetration of DG

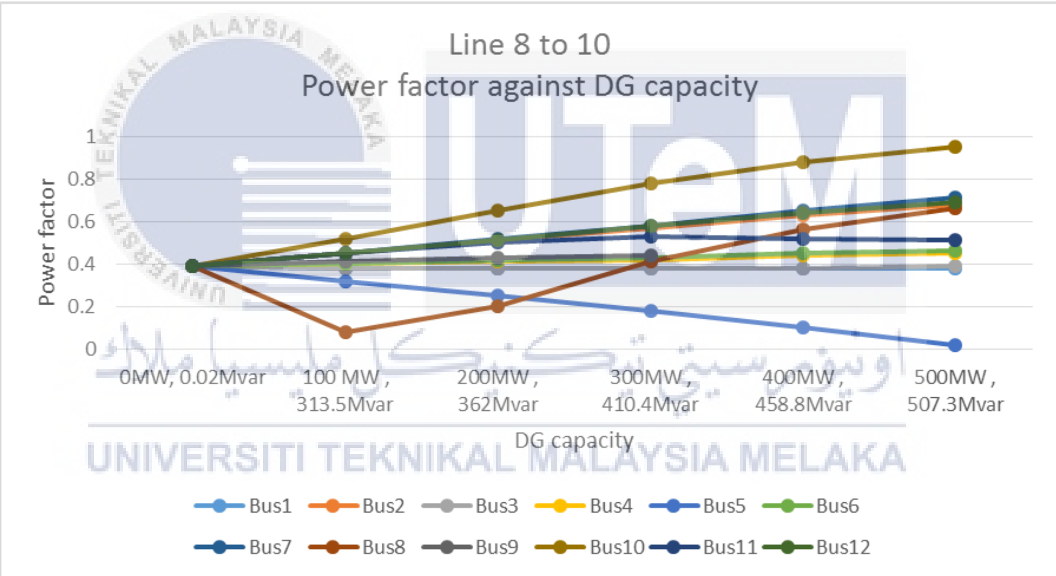

Figure 4.2.6(k) Figure of power factor behavior at transmission line 8 to 10 with penetration of DG

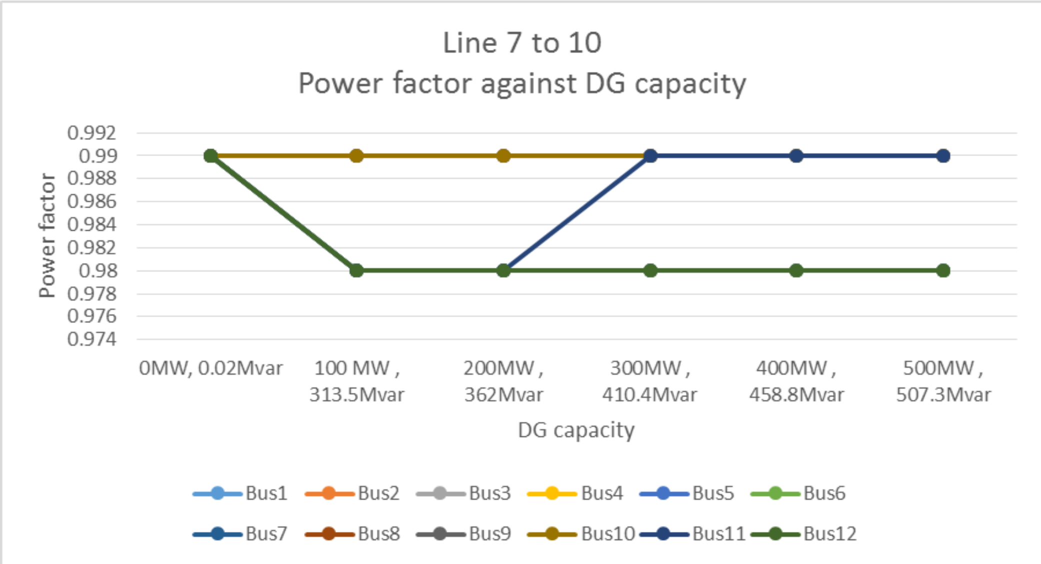

Figure 4.2.6(l) Figure of power factor behavior at transmission line 7 to 10 with penetration of DG

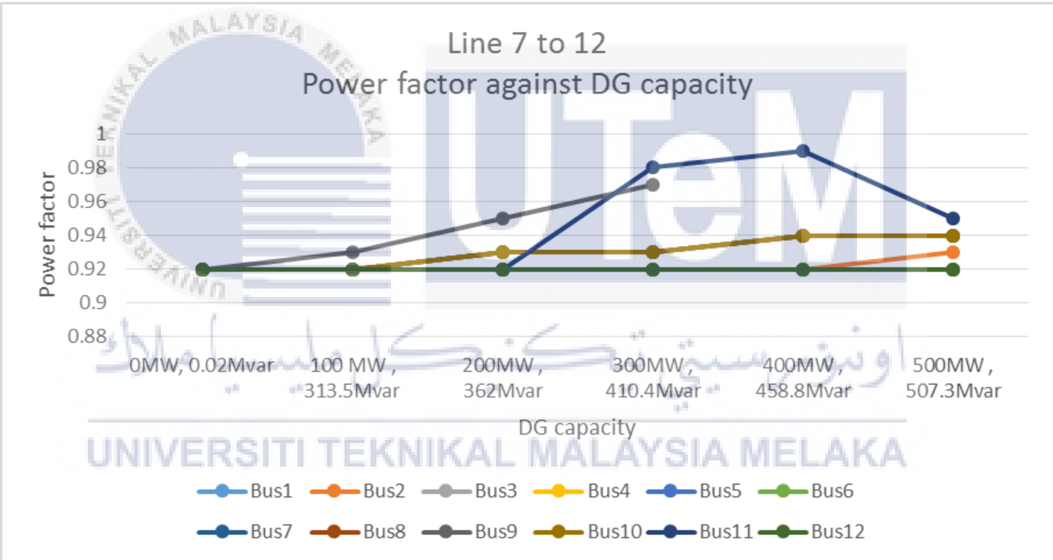

Figure 4.2.6(m) Figure of power factor behavior at transmission line 7 to 12 with penetration of DG

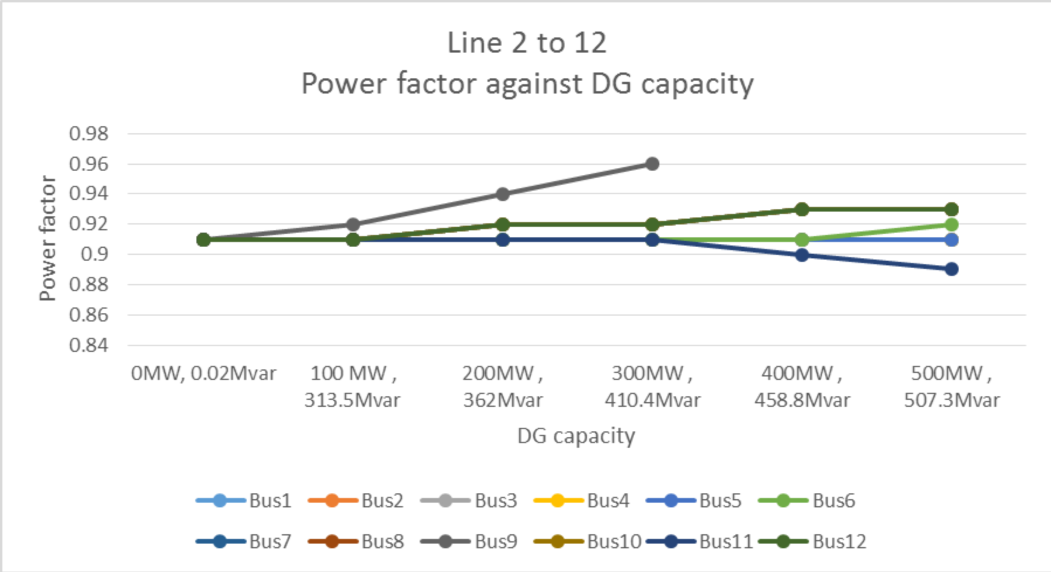

Figure 4.2.6(n) Figure of power factor behavior at transmission line 2 to 12 with penetration of DG

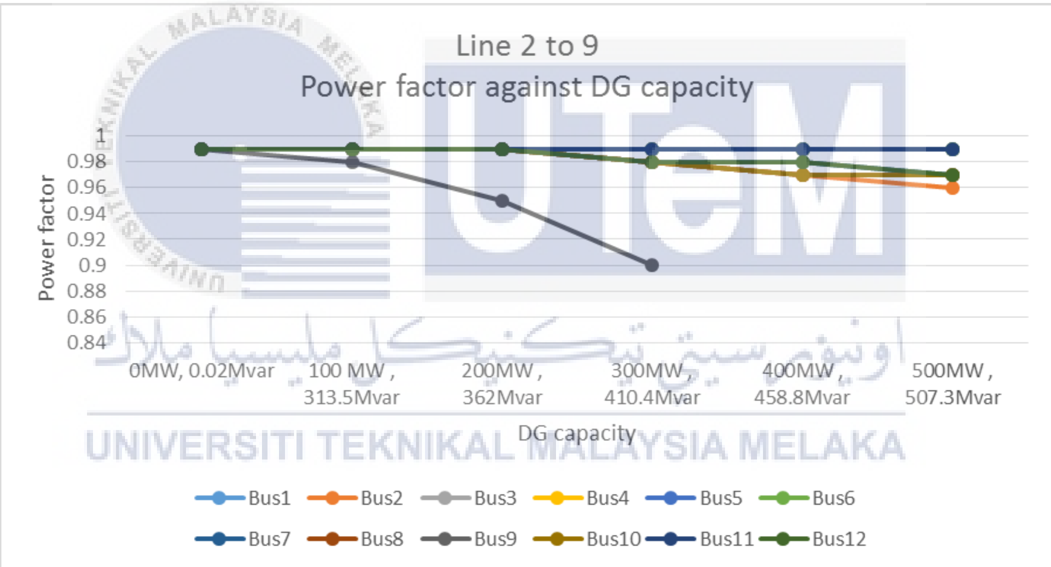

Figure 4.2.6(o) Figure of power factor behavior at transmission line 2 to 9 with penetration of DG

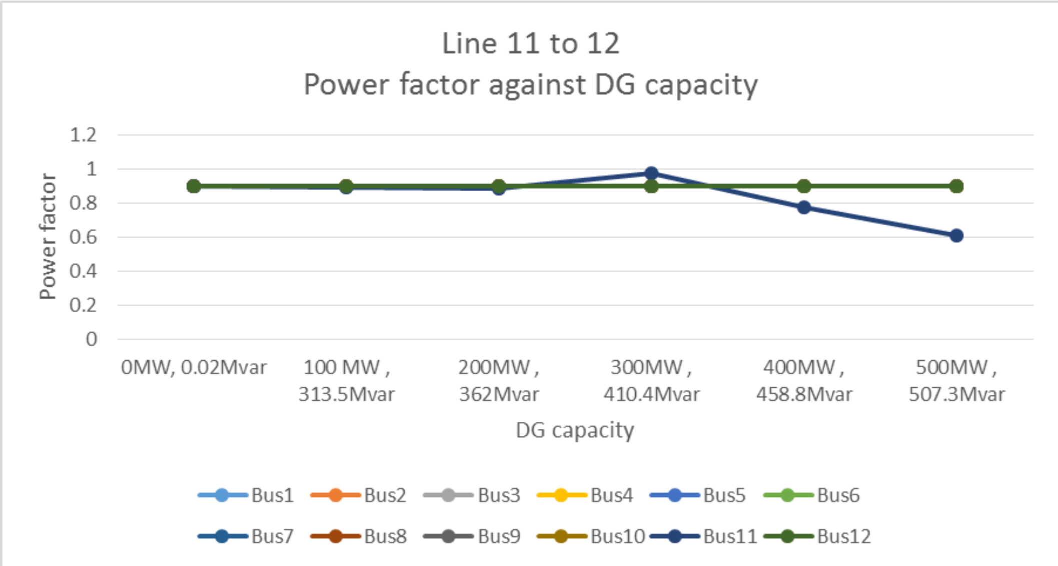

Figure 4.2.6(p) Figure of power factor behavior at transmission line 11 to 12 with penetration of DG

4.3 Analysis results of the power factor compensation of the grid without DG

Based on the result shows at Figure 4.2.1(b), the initial power factor of all 16 transmission lines has been shown. As we can see, the transmission line from 1 to 2 has very least amount of power factor by 0.06. This indicates the transmission line has high intensity of current flow and might be harmful to competent person to do services. This is because there are main generators at each buses. So, the power will not supply to each other buses and feed more power supply to other buses. This transmission line can be seem not relevant because it supply high reactive power rather than real power from slack bus 1 to bus 2. This power transfer activity has almost the same situation with transmission line 3 to 4, 3 to 5 and 5 to 8 where they are already have enough power supply to be transferred to the involved buses. This less power is transferred that lead to increase the power factor of the transmission line. Other transmission line such as line 4 to 6, 3 to 6, 6 to 9, 6 to 7, 5 to 7, 7 to 10, 7 to 12, 2 to 12, 2 to 9 and 11 to 12 has met Malaysia standard transmission line power factor that is 0.9.

All transmission has been installed with capacitor bank to feed in reactive power when power factor drop. Capacitor bank is the best and easiest way to compensate the power factor within load by install them at the busses. The power factor compensation will not involve the transmission lines since it installed at the distribution region.

4.4 Analysis results of the power factor compensation of the grid with DG

Results at figure 4.2.2(b) until figure 4.2.2(m) shows the power factor of transmission lines when DG installed at the busses repeatedly. When DG is installed at bus 1, bus 3 and bus 6, there is approximately no change in power factor of the transmission lines since DG is considered one of main generator at the slack bus. When DG installed at bus 2, we can see a large impact at line 1 to 2 and line 8 to 10. When the DG capacity increase, the transmission line 1 to 2 power factor decrease at first and increase back when DG start to supply 200MW capacity. This is because the higher the power capacity cause by increasing capacity of DG at bus 2 will change the direction of power flow that initially from bus 1 to 2. When DG at bus 4, transmission line 4 to 6 power factor drop continuously because the transmission line is a main feed in power to bus 4. So, if there is external supply attached to the bus, it will reduce the intake power from other source. Thus, it will increase the power factor at the line. This situation is same as transmission line 3 to5 when DG is installed at bus 5. Transmission line 8 to 10 also decrease in power factor since it has already new power feed in by DG at bus 5. When DG is installed at bus 7, transmission line 7 to 10 experience the power factor compensation as the DG capacity increase. This is because the higher the DG capacity, the higher the real power flow and lower reactive power flow. When DG is installed at bus bar 8, the power factor of the transmission line having some interruption while the power flow is changing from bus 10 to bus 8 initially. When DG installed at busbar 10, the power factor at transmission line 8 to 10 increase rapidly since real power gain from DG and DG absorb the reactive power at the transmission line. Transmission line 1 to 2 and 3 to 5 has some interruption in power factor compensation as the DG capacity increase. The power flow is reversible when DG capacity is at 300MW to 400MW. When DG installed at bus 11, there is an unusual behavior reaction on transmission line 11 to 12. Power factor of the line remain constant as the DG capacity increase until 300MW, it drop after the capacity keep increasing. Since bus bar 11 is a 400V bus, DG will contribute a large number of reactive power when the capacity is increasing continuously. This is one of the reason why TNB put some restriction of DG capacity can be installed at residential area. Lastly, when DG installed at bus 12, power flow at line 1 to 2 is reversed and may cause the power factor decrease at first place and increase as soon the power flow is reversed.

Figure 4.2.3(a) until figure 4.2.3(l) shows the line capacity of the simulation when installed DG at the busses respectively. From all these results, this research can conclude that by adding DG at a bus can support the generation of power. However, the caution must be aware at transmission line that feed the additional power to other bus bar. There always a capacity of each transmission line. If the capacity exceed the transmission line conducting properties, it may cause corona effect and may lead to transmission line breakdown due to high temperature and stress. Thus, line to ground fault will be occur. There is certain condition where a transmission line no longer become a feeder to the bus that installed a DG. This behavior will cause a power factor drop at transmission line. Increasing RMS current at the line may wound windings at transformer. Thus, an explosive substation will be occur.

Figure 4.2.4(b) until figure 4.2.4(k) shows the result of power factor of transmission lines when DG is installed. But this time, slack bus is change to bus 2. This simulation is to determine the effect changing slack bus to power factor compensation. Since the simulation is initially constructed for slack bus 1, there is some interruption cause by disagree parameters value of each transmission lines that may cause the simulation blackout at certain phase. Based on a past research by Priyadanai Pachanpan, he stated that, DG will either inject or absorb Q to maintain the flow of Q at the point of common coupling, PCC at the target value. This statement can be shown when DG is installed near to a conventional generator, there must be huge reactive power absorb or injected. This may be seen at the power factor behavior of nearest transmission line to the bus that installed DG.

Figure 4.2.5(a) until figure 4.2.5(j) show the line capacity of transmission line after adding DG when slack bus 2. The same conclusion can be made as the simulation for slack bus 1. When DG installed at bus 1, transmission line 4 to 6 has dropped the power factor when bus 4 has external capacity of power from bus 1 trough bus 3. Therefore, the power factor will drop since low power is transmit trough the line. So that, increase the RMS current. DG at bus 2 become fix and cannot be simulated. This is because DG has become one of conventional generator at the bus and provide fix capacity to meet the load demand. DG at bus 3 and 4 cannot be simulated as the simulation become blackout. This is due to parameter error that not suitable for slack bus 2 simulation. When DG installed at bus 5, transmission line 3 to 5 has reversed the power flow thus create an unstable power factor at the line. When DG is installed at bus 6, bus 7 and bus 8, transmission line 7 to 12 has been change the power flow due to increase of DG capacity. Power factor has been badly drop but increase as soon as possible. When DG installed at bus 9, there is no need a power supply from bus 2 because it can stand by their own. Then, the power factor slowly drop due to increase of reactive power at the transmission line. When DG is installed at Bus 10, transmission line 8 to 10 and 7 to 10 has decrease in power factor. Transmission 8 to 10 has increase in reactive power while transmission line 7 to 10 has decrease in real power. Thus, the power factor of transmission line will drop. When DG installed at bus 11, again it shows the unstable power factor behavior since bus 11 is 400V bus that is distribution region.

Figure 4.2.5(a) until figure 4.2.5(j) shows the capacity of transmission line when DG installed while slack bus 2. Almost all transmission line capacity increase with the DG capacity. This results shows the positive impact of installing DG to conventional grid that help to meet the consumer demand. However safety of the conventional grid must be monitored day by day so that, no interruption of power supply and tragedy will occur.

Based on figure 4.2.6(a) until 4.2.6(p), transmission line 1 to 2 has huge effect when DG is installed. This is because if DG installed near to the conventional generator, it will interrupt the power factor compensation. Transmission line 4 to 6 has almost uninterrupted from DG installation but when DG installed at bus 4, the power factor of the line is drop. Same goes to transmission line 6 to 7, this line almost least vulnerable to the existing DG in the grid but when DG is installed at bus 11 the power factor drop to 0.82. Line 11 to 12 only interrupted when DG is installed at bus 11. That mean the reactive power installed from the DG will cause the power factor drop and harmful to residence.

4.5 Discussion of results simulation

Based on the analysis that have been made from the results, even though the initial power factor is not in line with the regulation, simulation is keep run to see the behavior of power factor and line capacity of transmission line after adding DG. In Malaysia, the biggest solar plant provide 320MW which is quite small scale rather than other developed country. With this simulation, if the solar plant is installed at any busbar of the simulation, it still considered safe in power factor aspect. However, it may disobey Malaysia standard power factor regulation. The power factor might be corrected by using extra shunt reactors for absorbing Q from the network. The application of DG placement must be considered the issue that bring up by this research that is distance of DG and conventional generators and capacity of DG at distribution site.

4.6 The most suitable location and value of DG penetration to the grid

Based on the results, the most suitable location to install DG is at bus 3 and bus 6. As we can see there are no load at the busses. The busses also located at the middle of the conventional grid connection. If DG is installed at the busses, the DG additional supply is fairly transmitted to other load busses without interrupting or reduce the power factor of transmission line vigorously. Other than that, the DG will act as like shunt capacitor that inject or absorb Q besides generating real power. There is a complication when DG installed at the main generator section. DG will inject high reactive power thus it act like a shunt capacitor to the system. In the other hand, when DG is installed at residence site or distribution busbars, it will have a certain limit the DG can handle as a non-renewable generator feed in to the grid. In this project, the result shows DG can inject about 300MW to the distribution busbar before it produce a sudden reactive power to the grid. It drops power factor rapidly after inject over 300MW and continuously produce high reactive power. This will harm residence nearby because of transformer explosion hazard.

CHAPTER 5

CONCLUSION & FUTURE WORK

5.1 Introduction

This section will state the conclusion of this research and recap the objectives of this project. Other than that, this section will summarize this project in short and suggestion and future work will be stated.

5.2 Research conclusion

As a conclusion, this research as achieve the first objective very well that is to simulate the design conventional grid without penetration of DG. This aim is to get the initial condition of grid power factor and line capacity. Other than that, it make the research easier to make comparison and detect some working error while undergoing this research. This research also has simulate, analyses data of power factor compensation behavior and line capacity of the designed conventional grid with installation of DG. This part is the most important part that referring this topic and main aim of this research. Last but not least, this research has decide and suggest the most suitable way to place a DG plant in the conventional grid that is bus 3 and bus 6. Since the biggest capacity of DG plant in Malaysia is 320MW, the DG placement capacity may increase until 500MW as simulated in this research.

5.3 Significant research

The significant of this research is to create awareness of utility provider in Malaysia or anywhere else about the presence of reactive power in penetration of DG to the conventional grid. Commonly, people know by adding DG to grid is more compatible and relevant since DG mostly come from renewable sources but least people considering the safety and health of existing transformer. This research might expose and suggest the several other way to install DG without and least power factor reduction of the transmission line. Nothing else matter rather than taking good care of most important device in electrical grid that is transformer. Also, this research strongly agree that to reduce the fatality risk of competent person in Malaysia. As we know a person life is unreplaceable and once it gone, it will vanished forever.

5.4 Recommendations and future work for this research

This research initially use the parameter from UKGDS that referring to United Kingdom distribution system. This research recommend to use Malaysia grids parameters so that, the country transmission line system can be evaluate for further studies and long term grid planning. This is a good way to improve and maintaining the performance of the grid as we know the real condition of Malaysian conventional grid. Other than that, a field work can be done by visiting a site and collect information about the parameters, capacities and limits of the devices and load to be calculated and compared to the simulation.

For the future work for this research, the different types of DG installed to the conventional grid and the effect to the power factor of the conventional grid might be a continuation from this project. Other than that, identify the external factors that may interfere the conventional grid with DG installed.

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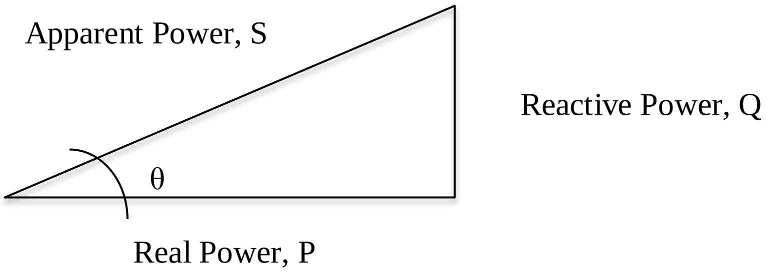
APPENDICES

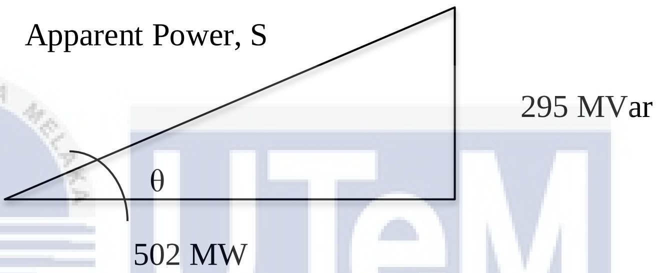
APPENDIX A

Calculation of Power factor compensation

Calculation of power factor before compensation in every busbar



Busbar 1



$\tan\theta = \dfrac{295\ MVar}{502\ MW}$

$\theta = 30.44°$

$\cos\theta = 0.8621$

Initial Power Factor = 0.8621

When power factor increased to 0.9,

$\cos\theta = 0.9$

$\theta = 25.84°$

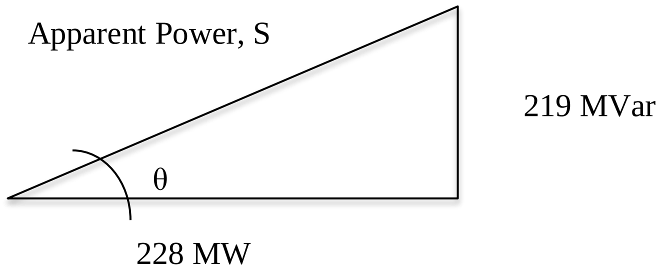
$\tan 25.84° = \dfrac{Qnew}{502\ MW}$

$Qnew = 243.13\ MVar$

$Capacitor\ Bank\ Value = Qold - Qnew\ = 295\ \text{MVar} - 243.13\ \text{MVar}$

$\mathbf{Capacitor\ Bank\ Value = 51.87\ MVar}$

Busbar 2



$$\tan\theta = \frac{219\ MVar}{228\ MW}$$

$\theta = 43.85°$

$\cos\theta = 0.7212$

Initial Power Factor = 0.7212

When power factor increased to 0.9,

$\cos\theta = 0.9$

$\theta = 25.84°$

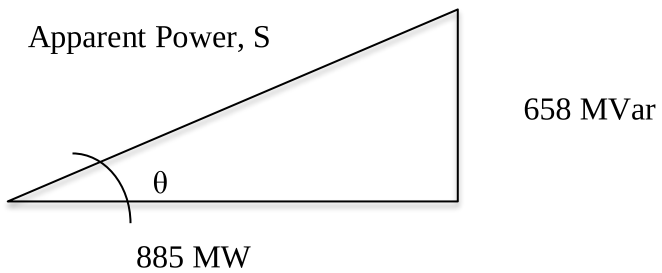
$$\tan 25.84° = \frac{Qnew}{228\ MW}$$

$Qnew = 110.42\ MVar$

$Capacitor\ Bank\ Value = Qold - Qnew\ = 219\ \text{MVar} - 110.42\ \text{MVar}$

$\textbf{Capacitor Bank Value} = \mathbf{108.58\ MVar}$

Busbar 4



$$\tan\theta = \frac{658\ MVar}{885\ MW}$$

$$\theta = 36.63°$$

$$\cos\theta = 0.8025$$

Initial Power Factor = 0.8025

When power factor increased to 0.9,

$$\cos\theta = 0.9$$

$$\theta = 25.84°$$

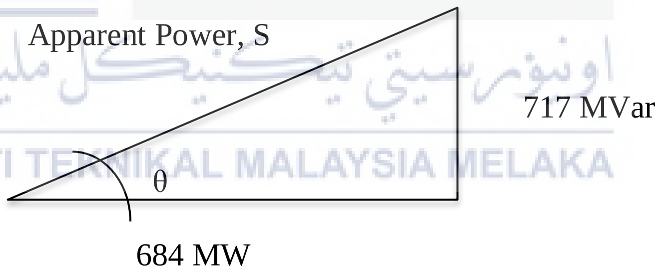
$$\tan 25.84° = \frac{Qnew}{885\ MW}$$

$$Qnew = 428.59\ MVar$$

$$Capacitor\ Bank\ Value = Qold - Qnew = 658\ \text{MVar} - 428.59\ \text{MVar}$$

Capacitor Bank Value = 229.41 MVar

Busbar 5



$$\tan\theta = \frac{717\ MVar}{684\ MW}$$

$$\theta = 46.35°$$

$$\cos\theta = 0.6903$$

Initial Power Factor = 0.6903

When power factor increased to 0.9,

$$\cos\theta = 0.9$$

$$\theta = 25.84°$$

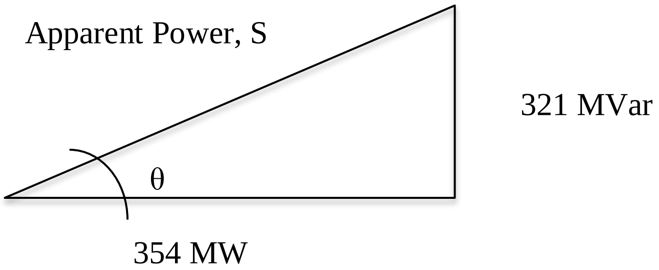
$$\tan 25.84° = \frac{Qnew}{684\ MW}$$

$$Qnew = 331.25\ MVar$$

$$Capacitor\ Bank\ Value = Qold - Qnew\ = 717\ \text{MVar} - 331.25\ \text{MVar}$$

$$\textbf{Capacitor Bank Value} = \mathbf{385.75\ MVar}$$

Busbar 7



$$\tan\theta = \frac{321\ MVar}{354\ MW}$$

$$\theta = 42.20°$$

$$\cos\theta = 0.7408$$

Initial Power Factor = 0.7408

When power factor increased to 0.9,

$$\cos\theta = 0.9$$

$$\theta = 25.84°$$

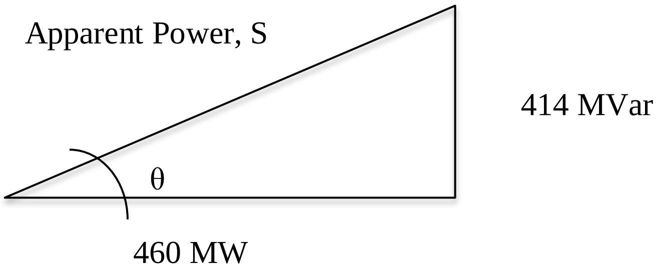
$$\tan 25.84° = \frac{Qnew}{354\ MW}$$

$$Qnew = 171.44\ MVar$$

$$Capacitor\ Bank\ Value = Qold - Qnew\ = 321\ \text{MVar} - 171.44\ \text{MVar}$$

$$\textbf{Capacitor Bank Value} = \mathbf{149.56\ MVar}$$

Busbar 8



$\tan\theta = \dfrac{414\ MVar}{460\ MW}$

$\theta = 41.99°$

$\cos\theta = 0.7433$

Initial Power Factor = 0.7433

When power factor increased to 0.9,

$\cos\theta = 0.9$

$\theta = 25.84°$

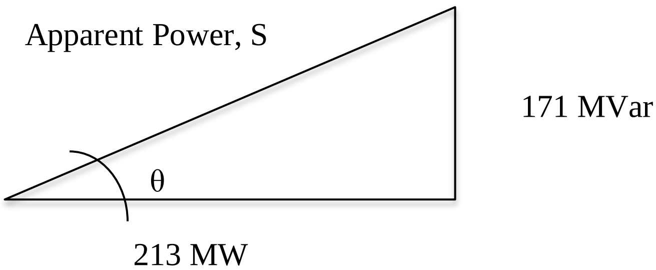
$\tan 25.84° = \dfrac{Qnew}{460\ MW}$

$Qnew = 222.77\ MVar$

$Capacitor\ Bank\ Value = Qold - Qnew = 414\ \text{MVar} - 222.77\ \text{MVar}$

$\mathbf{Capacitor\ Bank\ Value = 191.23\ MVar}$

Busbar 9



$\tan\theta = \dfrac{171\ MVar}{213\ MW}$

$\theta = 38.76°$

$\cos\theta = 0.7798$

Initial Power Factor = 0.7798

When power factor increased to 0.9,

$\cos\theta = 0.9$

$\theta = 25.84°$

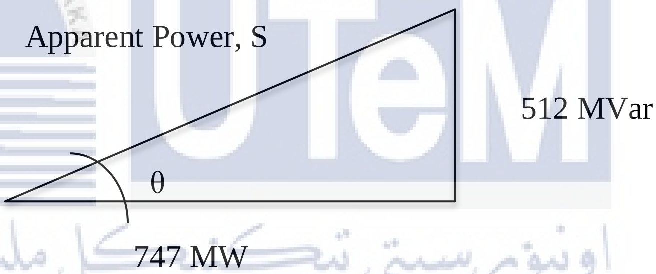
$\tan 25.84° = \dfrac{Qnew}{213\ MW}$

$Qnew = 103.15\ MVar$

$Capacitor\ Bank\ Value = Qold - Qnew\ = 171\ \mathrm{MVar} - 103.15\ \mathrm{MVar}$

$\mathbf{Capacitor\ Bank\ Value = 67.85\ MVar}$

Busbar 10



$\tan\theta = \dfrac{512\ MVar}{747\ MW}$

$\theta = 34.43°$

$\cos\theta = 0.8248$

Initial Power Factor = 0.8248

When power factor increased to 0.9,

$\cos\theta = 0.9$

$\theta = 25.84°$

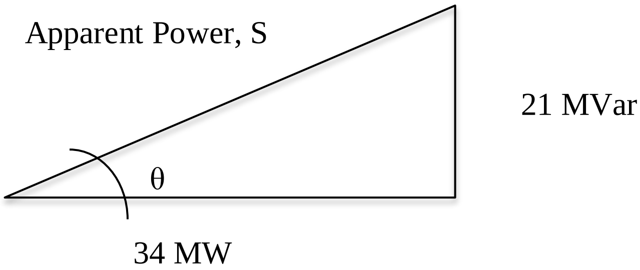
$\tan 25.84° = \dfrac{Qnew}{747\ MW}$

$Qnew = 361.76\ MVar$

$Capacitor\ Bank\ Value = Qold - Qnew\ = 512\ \mathrm{MVar} - 361.76\ \mathrm{MVar}$

$\mathbf{Capacitor\ Bank\ Value = 51.87\ MVar}$

Busbar 11



$$\tan\theta = \frac{21\ MVar}{34\ MW}$$

$$\theta = 31.70°$$

$$\cos\theta = 0.8508$$

Initial Power Factor = 0.8508

When power factor increased to 0.9,

$$\cos\theta = 0.9$$

$$\theta = 25.84°$$

$$\tan 25.84° = \frac{Qnew}{34\ MW}$$

$$Qnew = 16.47\ MVar$$

$$Capacitor\ Bank\ Value = Qold - Qnew = 21\ \mathrm{MVar} - 16.47\ \mathrm{MVar}$$

$\mathbf{Capacitor\ Bank\ Value = 4.53\ MVar}$

APPENDIX B

Diagram of Simulation

DG INSTALLATION WHILE SLACK BUS 1

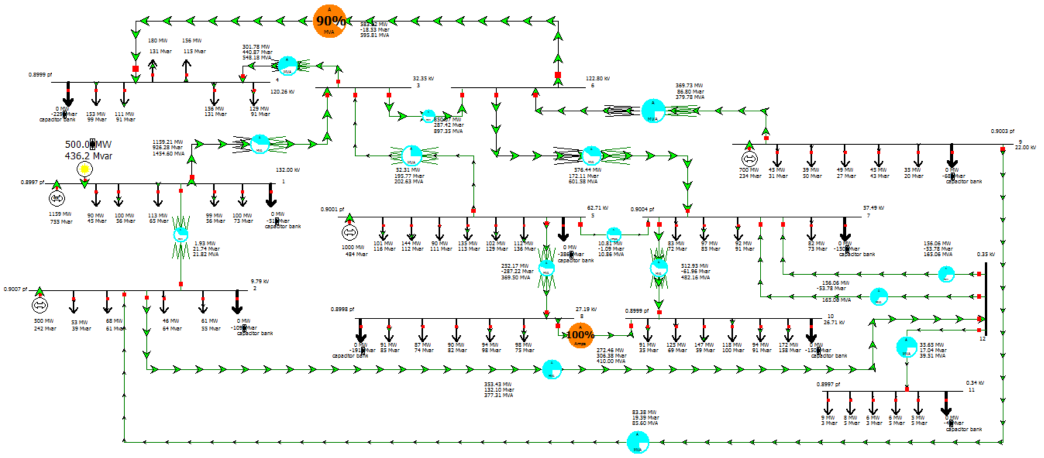


Figure of DG installed at bus 1

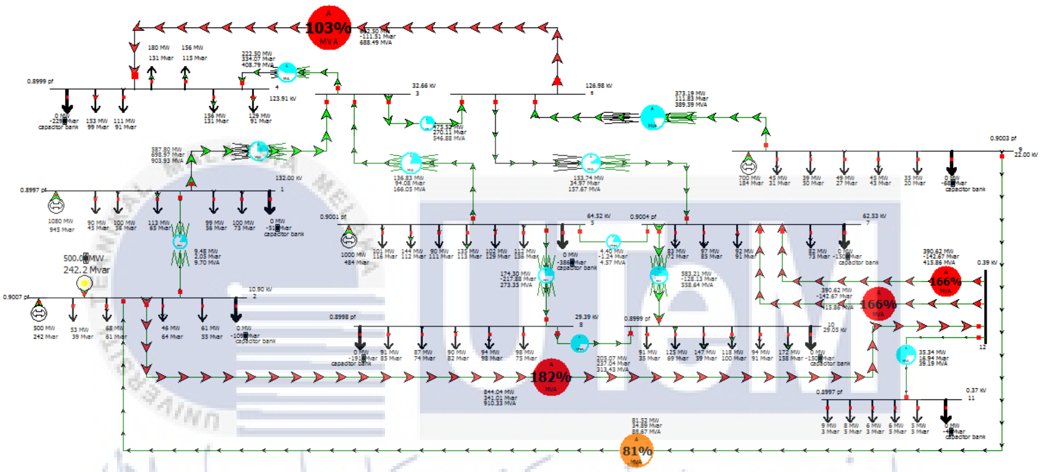


Figure of DG installed at bus 2

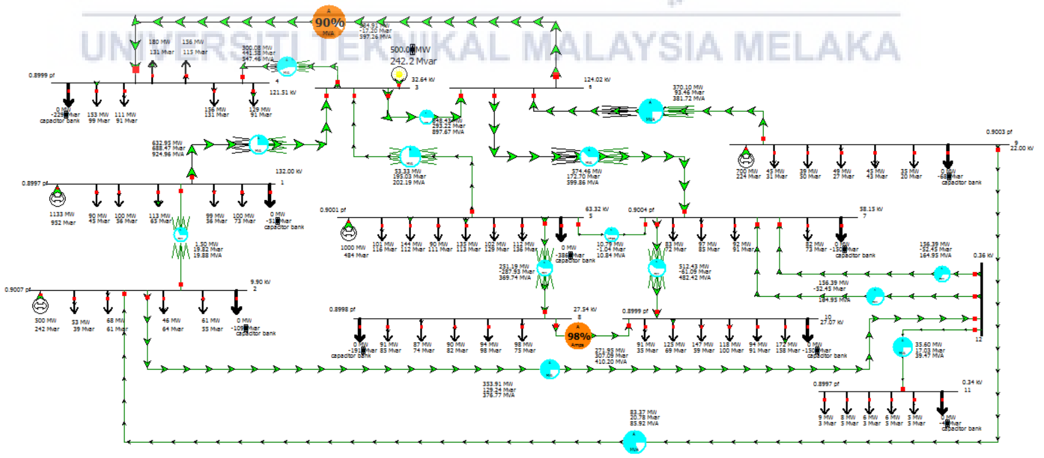


Figure of DG installed at bus 3

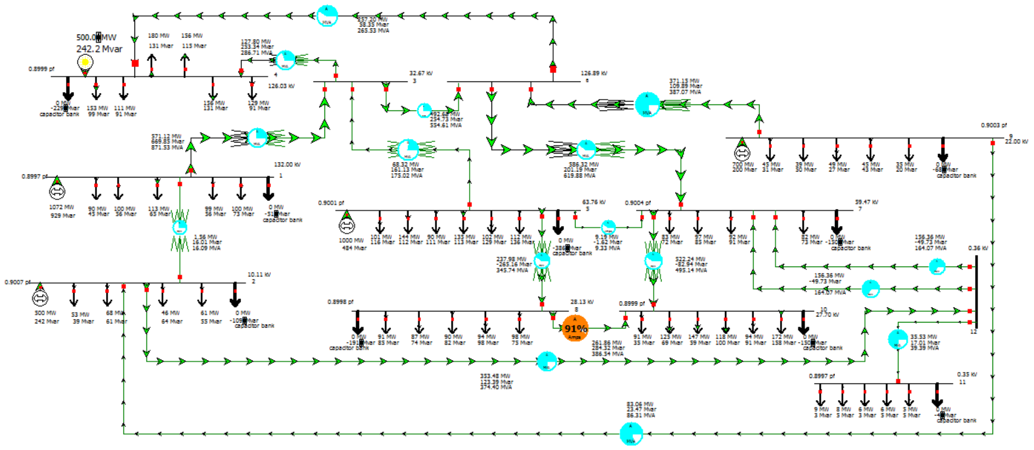


Figure of DG installed at bus 4

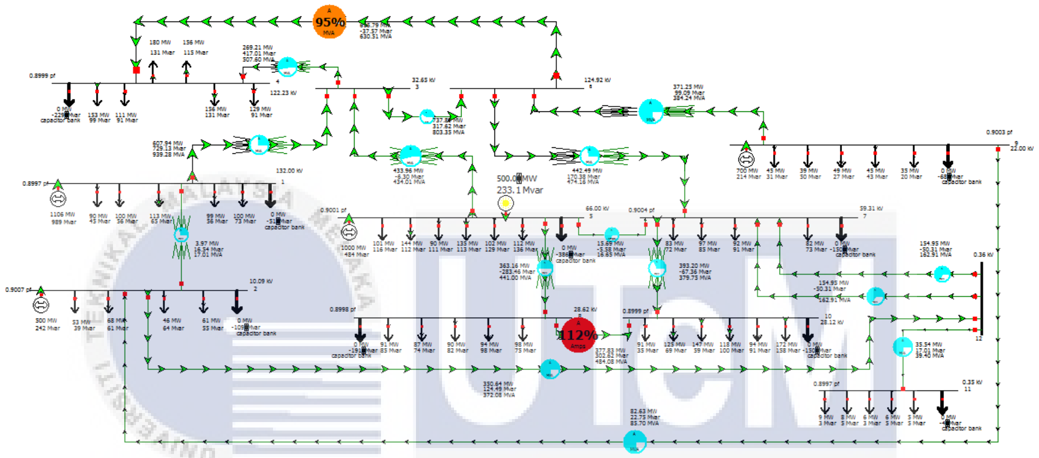


Figure of DG installed at bus 5

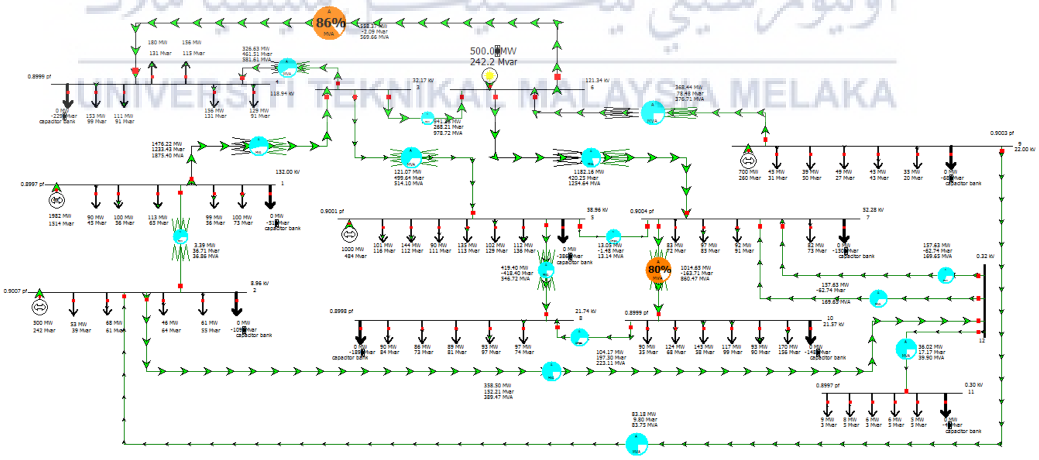


Figure of DG installed at bus 6

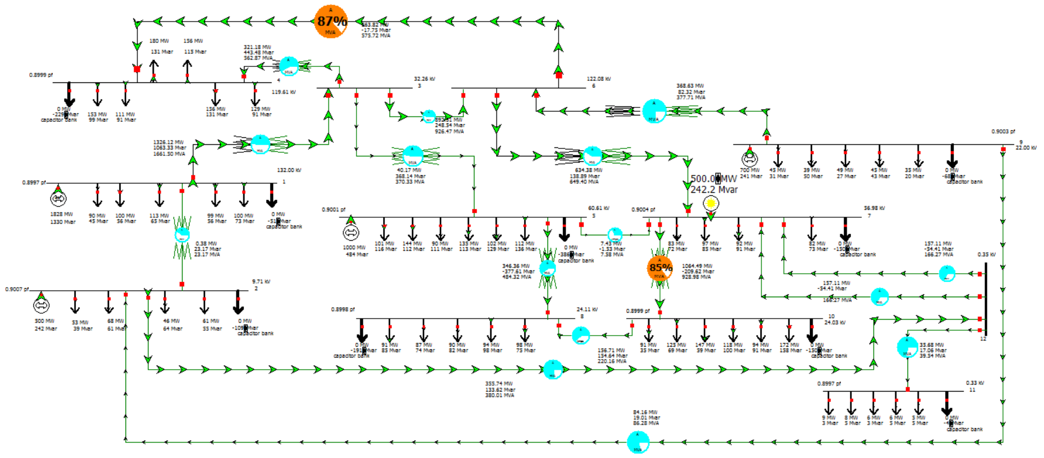


Figure of DG installed at bus 7

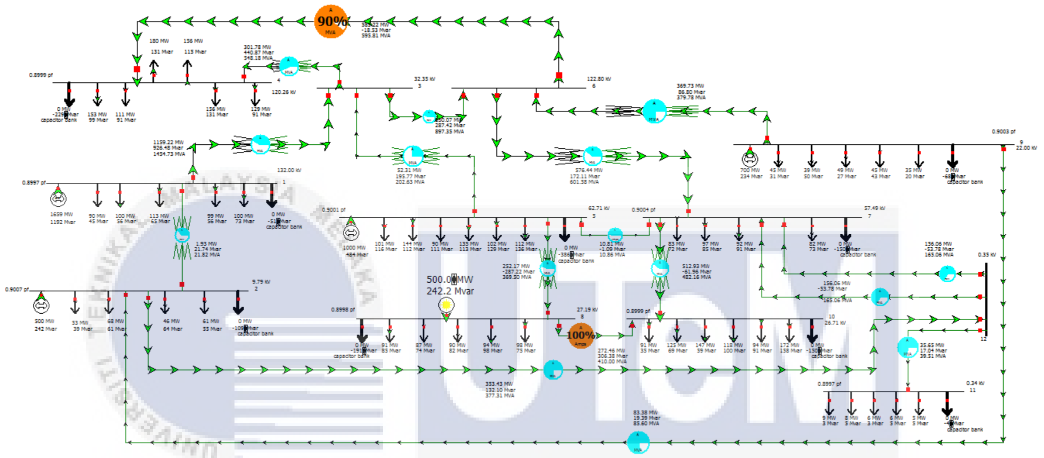


Figure of DG installed at bus 8

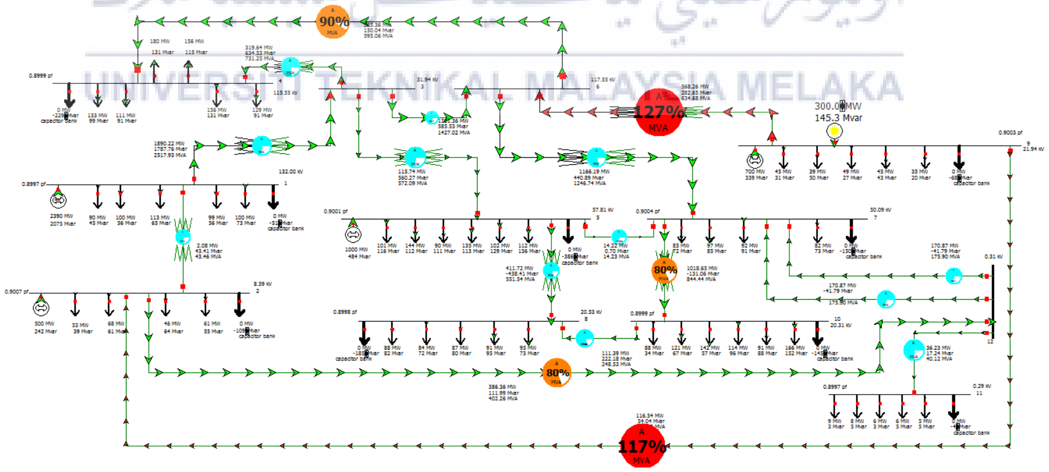


Figure of DG installed at bus 9

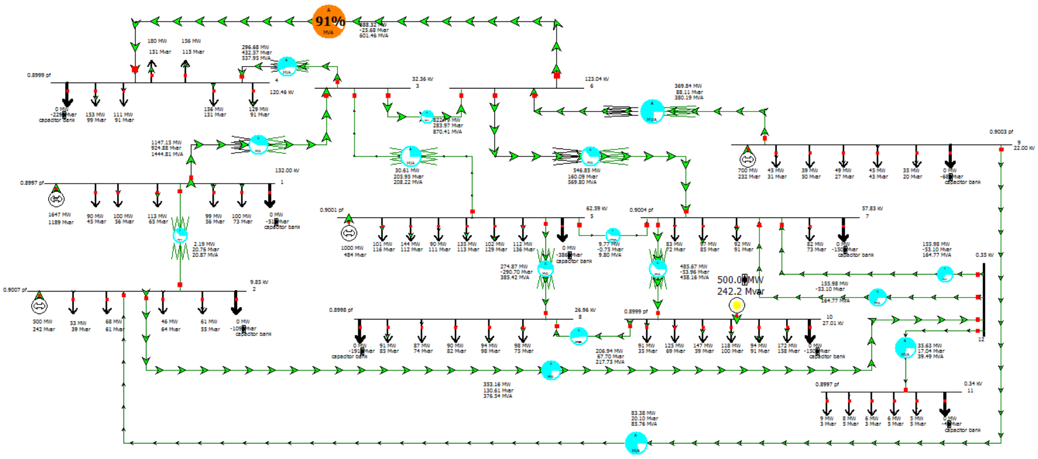


Figure of DG installed at bus 10

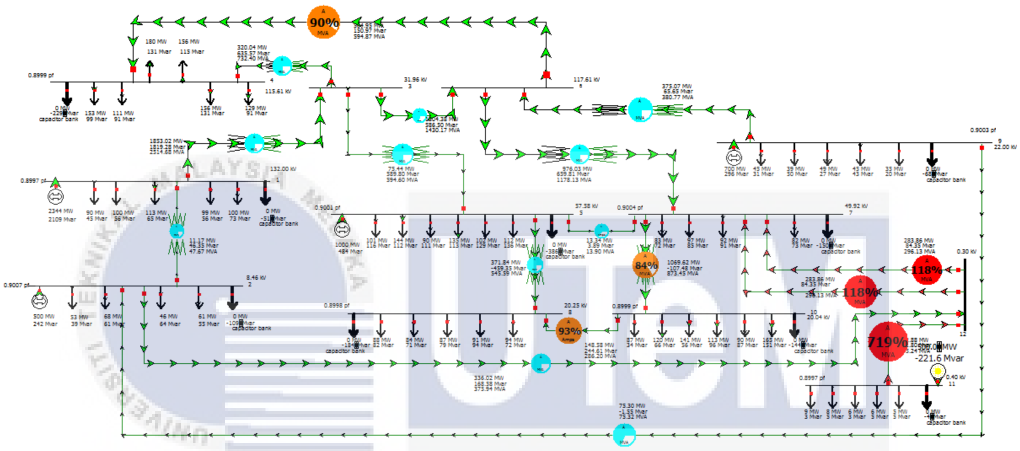


Figure of DG installed at bus 11

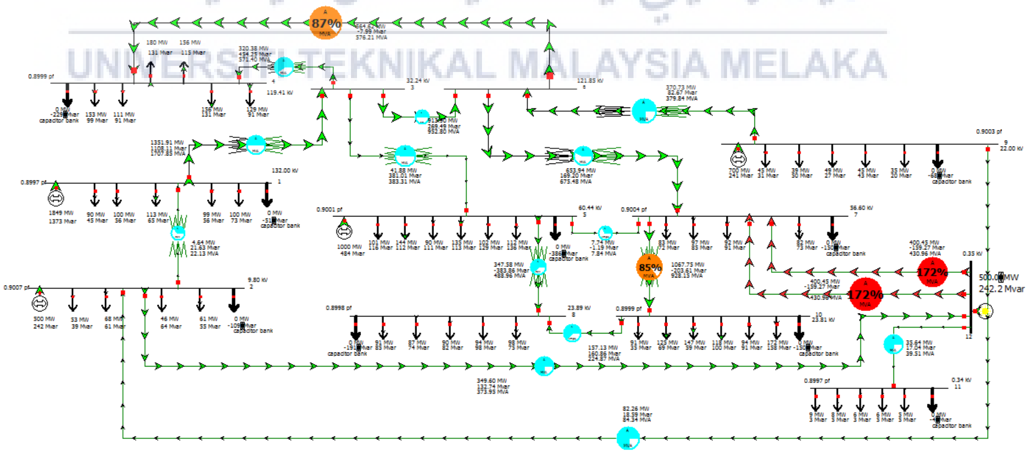


Figure of DG installed at bus 12

DG INSTALLATION WHILE SLACK BUS 2

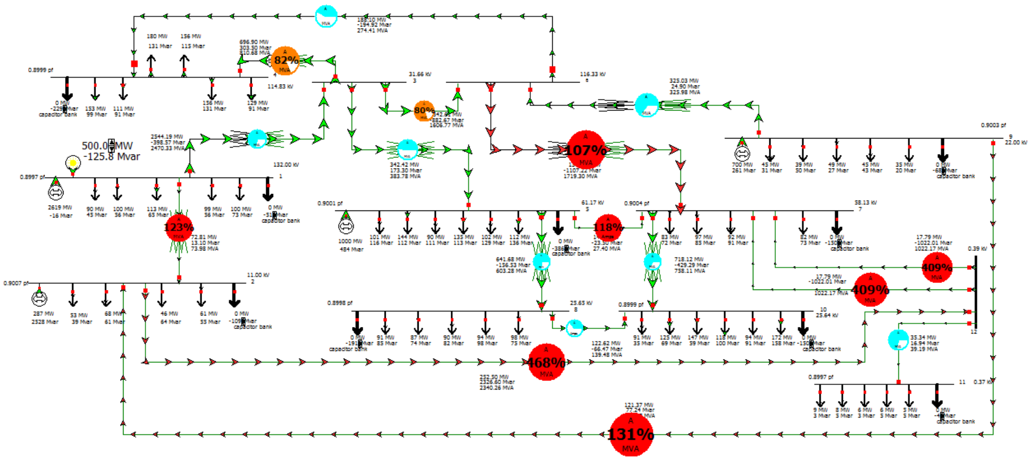


Figure of DG installed at bus 1

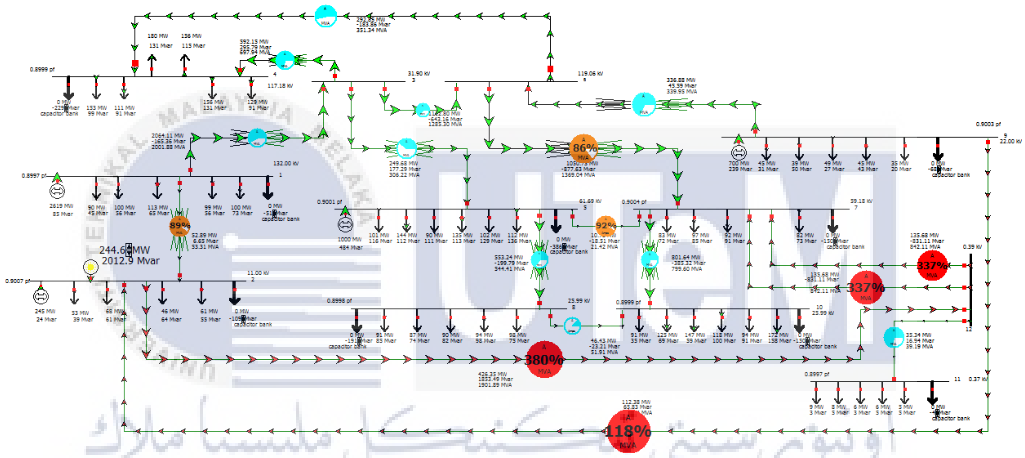


Figure of DG installed at bus 2

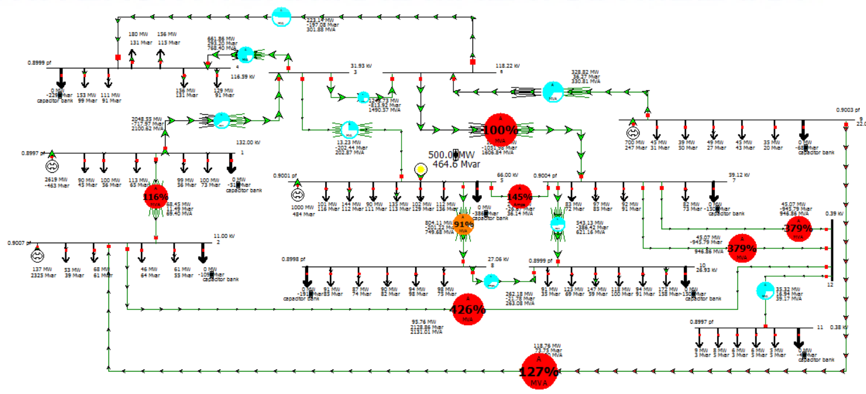


Figure of DG installed at bus 5

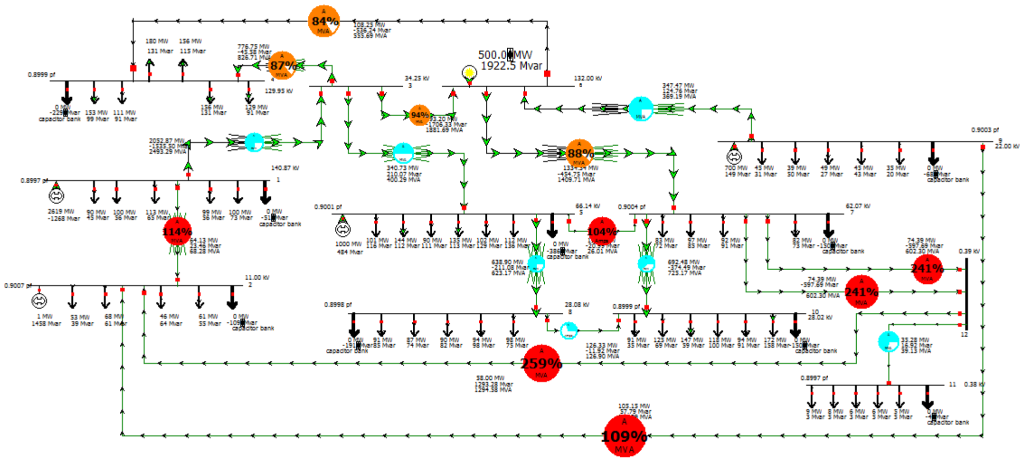


Figure of DG installed at bus 6

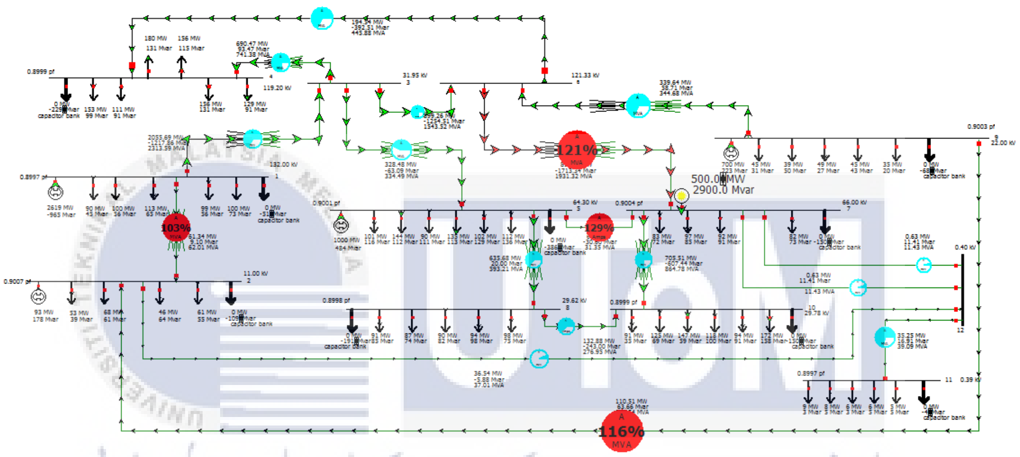


Figure of DG installed at bus 7

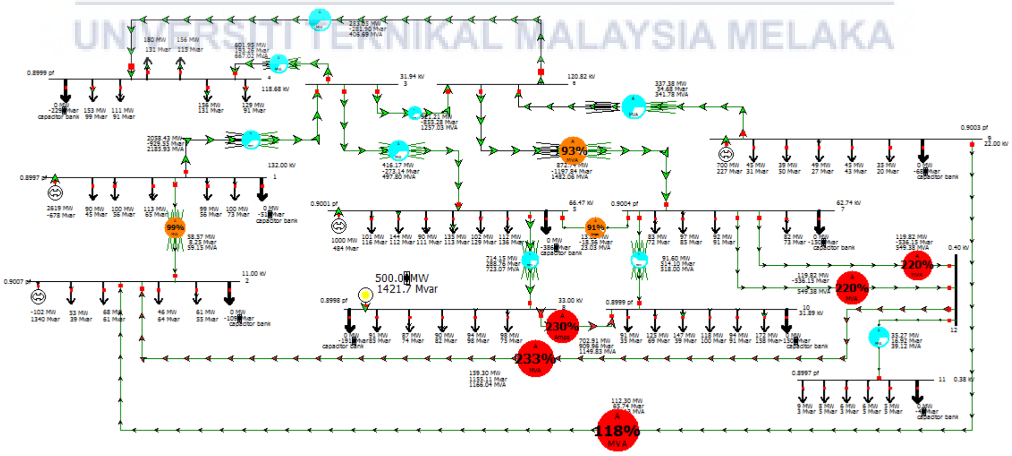


Figure of DG installed at bus 8

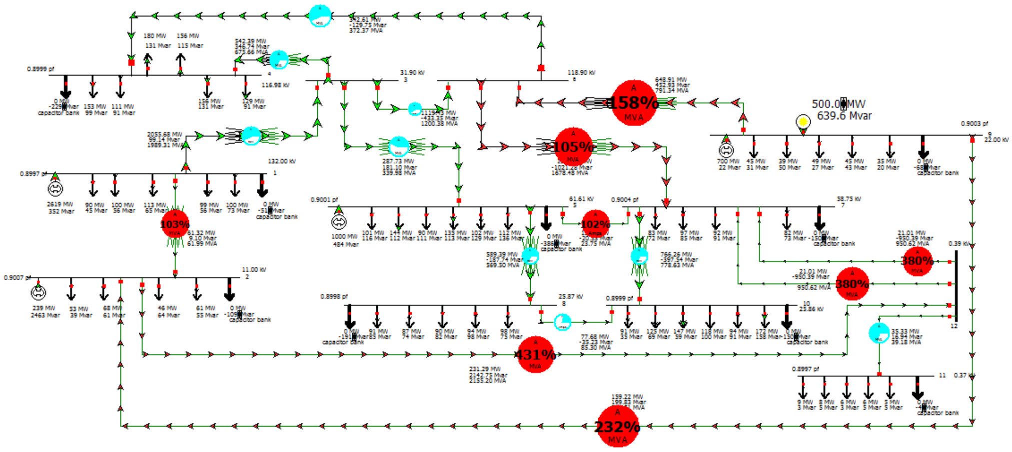


Figure of DG installed at bus 9

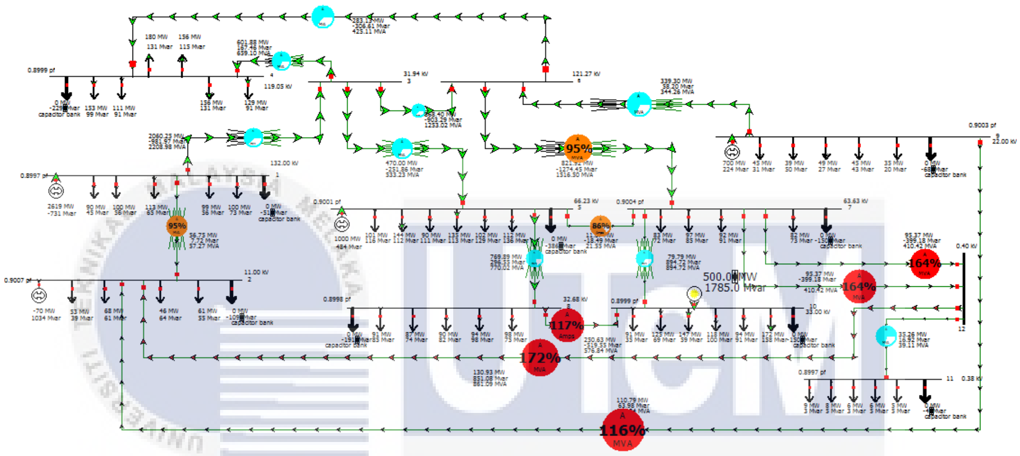


Figure of DG installed at bus 10

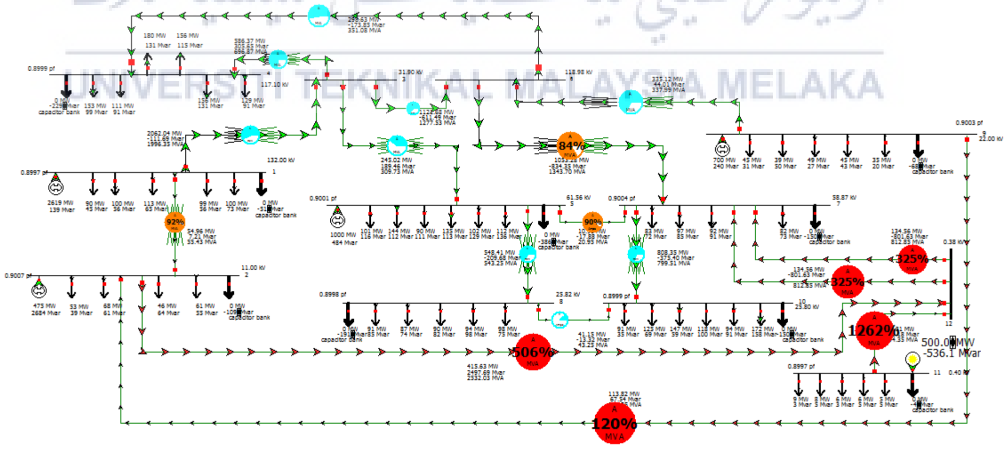


Figure of DG installed at bus 11

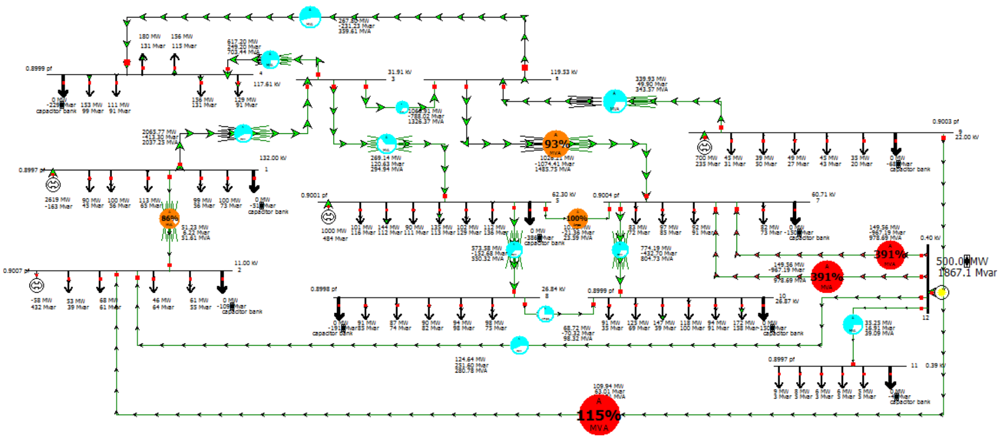


Figure of DG installed at bus 12

APPENDIX C

Table to record data simulation

Power factor of transmission lines when slack bus 1

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW , 3	0.06	0.81	0.55	0.97	0.99	0.24	0.98	0.94	0.71	0.99	0.38	0.99	0.92	0.91	0.99	0.9
200MW , 3	0.06	0.81	0.55	0.97	0.99	0.24	0.98	0.94	0.71	0.99	0.38	0.99	0.92	0.91	0.99	0.9
300MW , 4	0.06	0.81	0.55	0.97	0.99	0.24	0.98	0.94	0.71	0.99	0.38	0.99	0.92	0.91	0.99	0.9
400MW , 4	0.06	0.81	0.55	0.97	0.99	0.24	0.98	0.94	0.71	0.99	0.38	0.99	0.92	0.91	0.99	0.9
500MW , 5	0.06	0.81	0.55	0.97	0.99	0.24	0.98	0.94	0.71	0.99	0.38	0.99	0.92	0.91	0.99	0.9

Table of transmission lines power factor when DG at bus 1

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW , 4	0.04	0.8	0.56	0.98	0.97	0.22	0.98	0.95	0.7	0.99	0.45	0.98	0.92	0.91	0.99	0.9
200MW , 9	0	0.8	0.56	0.99	0.96	0.2	0.98	0.95	0.69	0.99	0.51	0.98	0.92	0.91	0.99	0.9
300MW , 1	0.05	0.79	0.57	0.99	0.96	0.18	0.98	0.95	0.68	0.99	0.57	0.98	0.92	0.91	0.98	0.9
400MW , 1	0.12	0.78	0.57	0.99	0.96	0.15	0.97	0.96	0.67	0.99	0.63	0.98	0.92	0.91	0.97	0.9
500MW , 2	0.23	0.77	0.57	0.99	0.95	0.12	0.97	0.96	0.67	0.99	0.68	0.98	0.93	0.91	0.96	0.9

Table of transmission lines power factor when DG at bus 2

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW , 4	0.06	0.8	0.55	0.97	0.97	0.24	0.98	0.95	0.71	0.99	0.38	0.99	0.92	0.91	0.99	0.9
200MW , 9	0.07	0.8	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.38	0.99	0.92	0.91	0.99	0.9
300MW , 1	0.07	0.79	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.38	0.99	0.92	0.91	0.99	0.9
400MW , 1	0.07	0.78	0.55	0.97	0.97	0.24	0.98	0.94	0.7	0.99	0.38	0.99	0.92	0.91	0.99	0.9
500MW , 2	0.07	0.77	0.55	0.97	0.97	0.24	0.98	0.94	0.7	0.99	0.39	0.99	0.92	0.91	0.99	0.9

Table of transmission lines power factor when DG at bus 3

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW , 4	0.06	0.8	0.55	0.95	0.97	0.24	0.98	0.94	0.7	0.99	0.4	0.98	0.92	0.91	0.99	0.9
200MW , 9	0.07	0.79	0.54	0.91	0.96	0.24	0.98	0.94	0.7	0.99	0.41	0.98	0.92	0.91	0.99	0.9
300MW , 1	0.07	0.79	0.53	0.85	0.96	0.23	0.98	0.94	0.7	0.99	0.42	0.98	0.92	0.91	0.99	0.9
400MW , 1	0.08	0.78	0.51	0.76	0.96	0.23	0.98	0.94	0.7	0.99	0.44	0.98	0.92	0.91	0.99	0.9
500MW , 2	0.08	0.77	0.5	0.59	0.96	0.23	0.97	0.94	0.7	0.99	0.45	0.98	0.92	0.91	0.99	0.9

Table of transmission lines power factor when DG at bus 4

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW , 4	0.05	0.8	0.55	0.97	0.97	0.11	0.98	0.94	0.72	0.99	0.32	0.98	0.92	0.91	0.99	0.9
200MW , 9	0.05	0.8	0.55	0.97	0.96	0.04	0.98	0.94	0.73	0.99	0.25	0.98	0.92	0.91	0.99	0.9
300MW , 1	0.04	0.79	0.55	0.98	0.96	0.23	0.98	0.94	0.75	0.98	0.18	0.98	0.92	0.91	0.99	0.9
400MW , 1	0.04	0.78	0.55	0.98	0.96	0.44	0.98	0.94	0.76	0.97	0.1	0.98	0.92	0.91	0.99	0.9
500MW , 2	0.03	0.77	0.55	0.98	0.96	0.64	0.98	0.94	0.77	0.96	0.02	0.98	0.92	0.91	0.99	0.9

Table of transmission lines power factor when DG at bus 5

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW , 4	0.06	0.8	0.56	0.98	0.97	0.24	0.98	0.94	0.71	0.99	0.4	0.98	0.92	0.91	0.99	0.9
200MW , 9	0.07	0.79	0.56	0.99	0.96	0.23	0.98	0.94	0.7	0.99	0.42	0.98	0.92	0.91	0.99	0.9
300MW , 1	0.08	0.78	0.56	0.99	0.96	0.23	0.98	0.94	0.7	0.99	0.43	0.98	0.92	0.91	0.99	0.9
400MW , 1	0.08	0.77	0.57	0.99	0.96	0.23	0.98	0.94	0.7	0.99	0.45	0.98	0.92	0.91	0.99	0.9
500MW , 2	0.09	0.76	0.57	0.99	0.96	0.23	0.97	0.94	0.7	0.99	0.46	0.98	0.92	0.92	0.99	0.9

Table of transmission lines power factor when DG at bus 6

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.0	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW ,	0.05	0.8	0.56	0.98	0.97	0.22	0.98	0.95	0.7	0.99	0.45	0.98	0.92	0.91	0.99	0.9
200MW ,	0.04	0.8	0.57	0.99	0.96	0.2	0.98	0.95	0.69	0.99	0.52	0.98	0.93	0.92	0.99	0.9
300MW , 1	0.03	0.79	0.57	0.99	0.96	0.18	0.98	0.96	0.68	0.99	0.58	0.98	0.93	0.92	0.98	0.9
400MW , 1	0.01	0.79	0.58	0.99	0.96	0.14	0.97	0.97	0.68	0.98	0.65	0.98	0.94	0.93	0.98	0.9
500MW , 2	0.01	0.78	0.58	0.99	0.95	0.1	0.97	0.97	0.67	0.97	0.71	0.98	0.94	0.93	0.97	0.9

Table of transmission lines power factor when DG at bus 7

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.0	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW ,	0.05	0.81	0.56	0.98	0.97	0.21	0.98	0.95	0.69	0.99	0.08	0.99	0.92	0.91	0.99	0.9
200MW ,	0.03	0.8	0.56	0.99	0.96	0.15	0.98	0.95	0.68	0.99	0.2	0.99	0.93	0.92	0.99	0.9
300MW , 1	0	0.8	0.56	0.99	0.96	0.06	0.98	0.95	0.67	0.99	0.41	0.99	0.93	0.92	0.98	0.9
400MW , 1	0.03	0.79	0.56	0.99	0.95	0.06	0.97	0.95	0.66	0.98	0.56	0.99	0.94	0.93	0.97	0.9
500MW , 2	0.08	0.78	0.56	0.99	0.94	0.25	0.97	0.95	0.65	0.97	0.66	0.99	0.94	0.93	0.97	0.9

Table of transmission lines power factor when DG at bus 8

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.0	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW ,	0.03	0.78	0.52	0.97	0.95	0.22	0.99	0.94	0.7	0.99	0.41	0.99	0.93	0.92	0.98	0.9
200MW ,	0	0.75	0.49	0.97	0.93	0.21	0.93	0.93	0.69	0.99	0.43	0.99	0.95	0.94	0.95	0.9
300MW , 1	0.04	0.72	0.44	0.96	0.91	0.2	0.89	0.93	0.68	0.99	0.44	0.99	0.97	0.96	0.9	0.9
Blackout																
Blackout																

Table of transmission lines power factor when DG at bus 9

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.0	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW ,	0.05	0.81	0.56	0.98	0.97	0.21	0.98	0.95	0.7	0.99	0.52	0.99	0.92	0.91	0.99	0.9
200MW ,	0.02	0.8	0.56	0.99	0.96	0.17	0.98	0.95	0.69	0.99	0.65	0.99	0.93	0.92	0.99	0.9
300MW , 1	0	0.8	0.56	0.99	0.96	0.1	0.97	0.95	0.68	0.99	0.78	0.99	0.93	0.92	0.98	0.9
400MW , 1	0.04	0.79	0.56	0.99	0.95	0	0.97	0.95	0.68	0.99	0.88	0.99	0.94	0.93	0.97	0.9
500MW , 2	0.1	0.77	0.56	0.99	0.94	0.14	0.97	0.95	0.68	0.99	0.95	0.99	0.94	0.93	0.97	0.9

Table of transmission lines power factor when DG at bus 10

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.0	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW ,	0.03	0.8	0.56	0.98	0.97	0.22	0.98	0.95	0.7	0.99	0.45	0.98	0.92	0.91	0.99	0.89
200MW ,	0.01	0.8	0.56	0.98	0.97	0.21	0.98	0.95	0.69	0.99	0.5	0.98	0.92	0.91	0.99	0.88
300MW , 1	0.1	0.76	0.52	0.98	0.95	0.17	0.98	0.91	0.67	0.99	0.53	0.99	0.98	0.91	0.99	0.97
400MW , 1	0.19	0.73	0.48	0.97	0.92	0.14	0.98	0.86	0.64	0.98	0.52	0.99	0.99	0.9	0.99	0.77
500MW , 2	0.23	0.71	0.44	0.96	0.91	0.12	0.98	0.82	0.62	0.96	0.51	0.99	0.95	0.89	0.99	0.61

Table of transmission lines power factor when DG at bus 11

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.0	0.06	0.81	0.55	0.97	0.97	0.24	0.98	0.94	0.71	0.99	0.39	0.99	0.92	0.91	0.99	0.9
100 MW ,	0.03	0.8	0.56	0.98	0.97	0.22	0.98	0.95	0.7	0.99	0.45	0.98	0.92	0.91	0.99	0.9
200MW ,	0	0.8	0.56	0.99	0.96	0.2	0.98	0.95	0.69	0.99	0.51	0.98	0.92	0.92	0.99	0.9
300MW , 1	0.05	0.79	0.57	0.99	0.96	0.18	0.98	0.95	0.68	0.99	0.58	0.98	0.92	0.92	0.98	0.9
400MW , 1	0.11	0.78	0.57	0.99	0.96	0.14	0.97	0.96	0.67	0.99	0.64	0.98	0.92	0.93	0.98	0.9
500MW , 2	0.2	0.77	0.57	0.99	0.95	0.1	0.97	0.96	0.67	0.98	0.69	0.98	0.92	0.93	0.97	0.9

Table of transmission lines power factor when DG at bus 12

Capacity (MVA) of transmission lines when slack bus 1

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW ,	44.55	2505.74	758.95	499.6	1451.52	573.01	376.32	1225.98	555.67	15.05	230.9	826.85	170.14	392.1	83.06	40.16
200MW , 3	44.55	2505.74	758.95	499.6	1451.52	573.01	376.32	1225.98	555.67	15.05	230.9	826.85	170.14	392.1	83.06	40.16
300MW , 4	44.55	2505.74	758.95	499.6	1451.52	573.01	376.32	1225.98	555.67	15.05	230.9	826.85	170.14	392.1	83.06	40.16
400MW , 4	44.55	2505.74	758.95	499.6	1451.52	573.01	376.32	1225.98	555.67	15.05	230.9	826.85	170.14	392.1	83.06	40.16
500MW , 5	44.55	2505.74	758.95	499.6	1451.52	573.01	376.32	1225.98	555.67	15.05	230.9	826.85	170.14	392.1	83.06	40.16

Table of transmission lines capacity when DG at bus 1

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	39.17	2351.17	722.41	510.03	1353.74	537.76	371.71	1121.97	547.17	13.63	229.37	848.7	220.89	499.79	83.6	40
200MW , 9	34.01	2198.26	686.37	522.66	1257.57	502.03	373.24	1017.78	536.76	12.23	228.13	873.1	271.06	607.19	84.09	39.86
300MW , 1	29.06	2046.02	650.57	537.39	1162.4	465.67	374.92	912.75	524.29	10.85	227.09	893.88	320.74	714.29	84.58	39.74
400MW , 1	24.32	1893.69	614.83	554.17	1067.76	428.61	376.75	806.27	509.56	9.49	226.2	910.83	370.02	821.11	85.08	39.63
500MW , 2	19.96	1745.55	579.94	572.42	975.9	392.66	378.7	700.83	493.18	8.15	225.8	925.14	418.95	927.72	85.62	39.53

Table of transmission lines capacity when DG at bus 2

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	44.13	2397.25	758.88	499.69	1451.69	573.07	370.58	1226.44	556.84	15.05	231.55	822.76	170.15	392.02	83.11	40.14
200MW , 9	43.72	2288.85	758.78	499.8	1451.8	573.07	370.84	1226.82	557.99	15.06	232.2	824.63	170.16	391.95	83.17	40.13
300MW , 1	43.3	2180.58	758.66	499.92	1451.84	573.03	371.11	1227.11	559.11	15.06	232.84	826.45	170.16	391.87	83.22	40.11
400MW , 1	42.88	2072.47	758.51	500.04	1451.82	572.93	371.39	1227.33	560.21	15.06	233.46	828.23	170.17	391.79	83.28	40.1
500MW , 2	42.47	1964.56	758.34	500.18	1451.72	572.79	371.66	1227.46	561.29	15.06	234.08	829.96	170.18	391.71	83.33	40.08

Table of transmission lines capacity when DG at bus 3

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	43.19	2373.54	701.6	437.88	1373.05	564.05	371.32	1232.58	555.01	14.74	230.07	828.75	170.08	391.69	83.19	40.11
200MW , 9	41.85	2243.21	645.27	379.74	1297.17	554.88	372.36	1238.41	554.12	14.42	229.17	836.21	170.02	391.26	83.31	40.06
300MW , 1	40.52	2114.62	589.9	326.65	1221.45	545.48	373.44	1243.47	552.99	14.11	228.22	843.21	169.94	390.81	83.44	40.02
400MW , 1	39.19	1987.7	535.48	280.95	1146.6	535.85	374.56	1247.74	551.61	13.8	227.19	849.76	169.85	390.34	83.56	39.97
500MW , 2	37.86	1862.38	482.01	246.28	1072.57	525.98	375.72	1251.22	549.97	13.49	226.08	855.84	169.74	389.85	83.69	39.93

Table of transmission lines capacity when DG at bus 4

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	43.12	2377.27	748.38	504	1424.21	505.07	370.95	1196.57	571.19	16.15	226.27	812.08	169.91	391.31	83.16	40.11
200MW , 9	41.69	2249.93	737.6	508.74	1396.46	449.72	371.62	1166.38	586.38	17.27	222.22	802.13	169.66	390.47	83.24	40.06
300MW , 1	40.24	2123.63	726.61	513.83	1368.22	410.98	372.32	1135.35	601.22	18.41	218.87	790.93	169.37	389.58	83.32	40.01
400MW , 1	38.78	1998.32	715.38	519.3	1339.43	392.83	373.06	1103.4	615.72	19.55	216.33	778.43	169.06	388.64	83.4	39.96
500MW , 2	37.3	1873.97	703.87	525.15	1310.05	377.31	373.84	1070.46	629.86	20.69	214.74	764.53	168.72	387.64	83.47	39.92

Table of transmission lines capacity when DG at bus 5

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	43.01	2378.22	723.01	510.75	1355.74	561.95	371.48	1233.71	554.54	14.67	229.56	829.86	170.07	391.62	83.2	40.1
200MW , 9	41.48	2251.48	687.33	523.38	1260.63	550.55	372.69	1240.47	553.09	14.29	228.12	838.35	169.99	391.13	83.33	40.05
300MW , 1	39.94	2125.46	651.89	537.45	1166.13	538.78	373.97	1246.24	551.32	13.9	226.58	846.3	169.9	390.6	83.47	40
400MW , 1	38.4	2000.11	616.66	552.9	1072.17	526.64	375.3	1250.97	549.2	13.52	224.91	853.69	169.78	390.05	83.16	39.95
500MW , 2	36.86	1875.4	581.6	569.66	978.72	514.1	376.71	1254.64	546.72	13.14	223.11	860.47	169.65	389.47	83.75	39.9

Table of transmission lines capacity when DG at bus 6

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	40.17	2336.67	719.38	509.83	1345.06	534.07	371.5	1113.09	546.42	13.52	228.46	850.51	169.62	390.07	83.72	40.01
200MW , 9	35.84	2167.25	679.94	522.72	1239.15	493.93	372.83	998.77	534.72	12.01	226.12	876.16	168.96	387.83	84.36	39.87
300MW , 1	31.52	1996.45	640.38	538.25	1133.16	452.43	374.32	882.35	520.28	10.51	223.8	897.38	168.17	385.38	84.99	39.75
400MW , 1	27.21	1824.1	600.61	556.39	1026.93	409.74	375.99	763.58	502.87	9.01	221.48	913.82	167.24	382.71	85.64	39.64
500MW , 2	23.18	1661.71	562.92	575.68	926.6	370.4	377.71	649.55	484.35	7.58	220.16	929.01	166.27	380.02	86.28	39.55

Table of transmission lines capacity when DG at bus 7

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	39.34	2270.42	711.98	514.01	1326.22	483.55	371.93	1091.89	530.32	14.2	237.26	771.77	169.41	389.48	83.72	39.98
200MW , 9	33.99	2026.64	663.1	533.54	1196.64	393.03	373.91	949.35	494.21	13.25	261.7	704.41	168.4	386.32	84.32	39.82
300MW , 1	29.25	1807.39	619.07	554.82	1080.87	314.44	375.95	818.25	453.15	12.36	301.26	629.77	167.27	383.12	84.83	39.69
400MW , 1	25.27	1620.34	581.5	575.55	983.07	251.54	377.89	704.3	411.51	11.57	352.08	555.74	166.16	380.14	85.24	39.59
500MW , 2	21.82	1454.72	548.18	595.81	897.35	202.63	379.78	601.58	369.5	10.86	410	482.16	165.06	377.31	85.6	39.51

Table of transmission lines capacity when DG at bus 8

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	43.83	2483.81	744.08	529	1424.33	570.4	452.39	1230.41	554.1	14.71	235.84	829.64	172.57	396.71	97.12	40.14
200MW , 9	43.42	2484.44	734.06	560.38	1413.63	569.76	539.45	1236.9	552.68	14.43	241.59	837.6	174.58	400.31	112.15	40.12
300MW , 1	43.46	2517.92	731.25	595.06	1427.02	572.09	634.68	1246.74	551.54	14.23	248.53	844.44	175.91	402.26	128.46	40.12
Blackout																
Blackout																

Table of transmission lines capacity when DG at bus 9

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	39.08	2267.23	709.33	515.93	1319.24	487.36	372.03	1084.22	532.58	13.94	220.85	768.22	169.35	389.92	83.73	39.97
200MW , 9	33.49	2019.88	657.96	535.93	1183.09	399.23	374.1	934.13	499.17	12.76	211.67	695.9	168.26	385.95	84.37	39.81
300MW , 1	28.58	1799.36	612.09	558.32	1062.48	322.41	376.22	797.2	461.47	11.67	206.9	616.35	167.08	382.6	84.9	39.67
400MW , 1	24.45	1611.3	572.84	580.15	960.24	259.62	378.24	677.78	423.51	10.69	208.94	537.11	165.91	379.49	85.35	39.57
500MW , 2	20.87	1444.81	537.95	601.47	870.41	208.22	380.19	569.8	385.42	9.8	217.73	458.16	164.77	376.54	85.77	39.49

Table of transmission lines capacity when DG at bus 10

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	39.87	2350.02	722.23	509.8	1353.11	537.4	371.88	1121.56	538.85	13.62	229.13	848.71	221.07	389	83.35	67.11
200MW , 9	36.17	2224.39	692.89	519.1	1274.38	507.84	373.16	1036.97	547.15	12.5	227.46	868.45	261.78	386.46	83.61	153.5
300MW , 1	38.08	2258.78	691.01	548.54	1285.39	524.02	376.37	1034.79	537.43	12.22	248.37	881.07	276.65	381.6	80.74	212.97
400MW , 1	42.95	2385.32	709.84	575.37	1354.97	560.69	379.03	1100.54	541.45	12.93	270.61	880.89	285.68	378.03	77.61	307.56
500MW , 2	47.67	2514.68	732.4	594.87	1430.17	594.69	380.77	1178.13	545.59	13.9	286.2	873.45	296.13	375.94	75.32	395.24

Table of transmission lines capacity when DG at bus 11

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	44.54	2505.57	758.92	499.57	1451.42	572.96	370.31	1225.89	555.66	15.05	230.87	820.86	170.18	392.18	83.07	40.16
100 MW , 4	39.71	2344.39	720.87	510.34	1349.52	536.13	371.95	1117.66	546.78	13.57	229.16	849.73	222.97	388.87	83.34	39.99
200MW , 9	35.03	2183.95	683.12	523.53	1248.73	498.51	373.72	1008.57	535.75	12.11	227.69	874.93	275.42	385.42	83.59	39.85
300MW , 1	30.49	2023.46	645.48	539.09	1148.55	460.01	375.63	898.04	522.36	10.67	226.41	896.19	327.53	381.76	83.83	39.72
400MW , 1	26.12	1862.19	607.74	556.98	1048.54	420.58	377.69	785.48	506.37	9.23	225.26	913.19	379.36	377.89	84.08	39.61
500MW , 2	22.13	1707.84	571.4	576.21	952.8	484.31	379.84	675.48	488.96	7.84	224.87	928.15	430.96	373.95	84.34	39.51

Table of transmission lines capacity when DG at bus 12

Power factor of transmission lines when slack bus 2

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0M	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW ,	0.99	0.99	0.9	0.82	0.85	0.83	0.99	0.76	0.94	0.5	0.88	0.89	0.12	0.19	0.85	0.9
200MW , -	0.98	0.99	0.9	0.79	0.85	0.85	0.99	0.76	0.95	0.5	0.88	0.88	0.09	0.16	0.85	0.9
300MW , -	0.98	0.99	0.91	0.76	0.84	0.87	0.99	0.76	0.96	0.5	0.88	0.87	0.06	0.14	0.85	0.9
400MW , -	0.98	0.98	0.91	0.73	0.83	0.88	0.99	0.76	0.96	0.51	0.88	0.86	0.04	0.12	0.84	0.9
500MW , -	0.98	0.98	0.91	0.69	0.83	0.89	0.99	0.76	0.97	0.51	0.87	0.85	0.01	0.1	0.84	0.9

Table of transmission lines power factor when DG at bus 1

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0M	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
244MW , 1	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
DG Fix																

Table of transmission lines power factor when DG at bus 2

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW , 4	0.99	0.99	0.89	0.82	0.85	0.83	0.99	0.76	0.95	0.53	0.94	0.88	0.11	0.18	0.85	0.9
200MW , 9	0.98	0.98	0.9	0.81	0.85	0.86	0.99	0.76	0.96	0.55	0.95	0.86	0.07	0.14	0.85	0.9
300MW , 1	0.98	0.98	0.9	0.79	0.84	0.91	0.99	0.76	0.96	0.57	0.96	0.85	0.03	0.11	0.85	0.9
400MW , 1	0.98	0.97	0.9	0.77	0.84	0.99	0.99	0.76	0.97	0.59	0.96	0.82	0	0.08	0.85	0.9
500MW , 2	0.98	0.96	0.91	0.74	0.84	0.37	0.98	0.76	0.97	0.61	0.96	0.8	0.04	0.05	0.84	0.9

Table of transmission lines power factor when DG at bus 5

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW , 4	0.99	0.99	0.9	0.81	0.84	0.83	0.99	0.77	0.93	0.5	0.88	0.89	0.11	0.18	0.85	0.9
200MW , 9	0.98	0.98	0.92	0.77	0.81	0.85	0.99	0.79	0.95	0.5	0.88	0.88	0.06	0.14	0.85	0.9
300MW , 1	0.98	0.98	0.93	0.74	0.78	0.87	0.99	0.8	0.96	0.5	0.87	0.87	0.02	0.11	0.85	0.9
400MW , 1	0.98	0.97	0.94	0.7	0.75	0.88	0.99	0.8	0.96	0.5	0.87	0.86	0	0.07	0.85	0.9
500MW , 2	0.98	0.96	0.95	0.67	0.73	0.89	0.98	0.81	0.97	0.5	0.87	0.85	0.04	0.04	0.84	0.9

Table of transmission lines power factor when DG at bus 6

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW , 4	0.99	0.99	0.9	0.83	0.85	0.83	0.99	0.75	0.94	0.49	0.85	0.89	0.1	0.17	0.86	0.9
200MW , 9	0.99	0.99	0.9	0.81	0.84	0.84	0.99	0.74	0.94	0.47	0.81	0.89	0.05	0.12	0.86	0.9
300MW , 1	0.99	0.99	0.91	0.8	0.83	0.86	0.99	0.72	0.95	0.46	0.77	0.88	0	0.07	0.85	0.9
400MW , 1	0.98	0.98	0.91	0.79	0.82	0.88	0.99	0.71	0.95	0.44	0.74	0.88	0.06	0.02	0.85	0.9
500MW , 2	0.98	0.98	0.92	0.77	0.81	0.89	0.99	0.7	0.96	0.43	0.71	0.87	0.11	0.02	0.85	0.9

Table of transmission lines power factor when DG at bus 7

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW , 4	0.99	0.98	0.9	0.83	0.85	0.88	0.99	0.75	0.95	0.51	0.99	0.87	0.09	0.16	0.86	0.9
200MW , 9	0.98	0.98	0.9	0.81	0.84	0.93	0.99	0.74	0.96	0.52	0.99	0.84	0.02	0.1	0.85	0.9
300MW , 1	0.98	0.98	0.91	0.8	0.83	0.97	0.99	0.73	0.97	0.54	0.99	0.8	0.03	0.04	0.85	0.9
400MW , 1	0.98	0.97	0.91	0.78	0.82	0.99	0.99	0.72	0.98	0.54	0.99	0.73	0.09	0	0.85	0.9
500MW , 2	0.98	0.97	0.92	0.77	0.82	0.99	0.99	0.71	0.99	0.55	0.99	0.61	0.15	0.05	0.85	0.9

Table of transmission lines power factor when DG at bus 8

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW , 4	0.99	0.99	0.89	0.85	0.87	0.82	0.97	0.77	0.94	0.5	0.89	0.89	0.12	0.19	0.83	0.9
200MW , 7	0.99	0.99	0.88	0.86	0.87	0.83	0.94	0.78	0.94	0.5	0.89	0.89	0.09	0.16	0.79	0.9
300MW , 1	0.99	0.99	0.87	0.88	0.89	0.84	0.91	0.78	0.95	0.51	0.99	0.89	0.06	0.14	0.74	0.9
400MW , 3	0.98	0.99	0.86	0.9	0.9	0.84	0.87	0.79	0.95	0.51	0.99	0.88	0.04	0.12	0.69	0.9
Blackout																

Table of transmission lines power factor when DG at bus 9

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW , 4	0.99	0.99	0.9	0.83	0.85	0.87	0.99	0.75	0.95	0.51	0.68	0.87	0.08	0.16	0.86	0.9
200MW , 9	0.99	0.98	0.9	0.81	0.84	0.93	0.99	0.74	0.96	0.52	0.53	0.84	0.02	0.09	0.85	0.9
300MW , 1	0.99	0.98	0.91	0.8	0.83	0.97	0.99	0.72	0.97	0.52	0.43	0.79	0.04	0.04	0.85	0.9
400MW , 1	0.98	0.97	0.91	0.78	0.82	0.99	0.99	0.71	0.98	0.53	0.36	0.72	0.1	0.01	0.85	0.9
500MW , 2	0.98	0.97	0.92	0.77	0.81	0.99	0.99	0.7	0.99	0.54	0.31	0.59	0.16	0.06	0.85	0.9

Table of transmission lines power factor when DG at bus 10

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW , -	0.99	0.99	0.89	0.84	0.86	0.82	0.99	0.76	0.94	0.49	0.88	0.89	0.16	0.17	0.86	0.65
200MW , -	0.99	0.99	0.89	0.84	0.86	0.82	0.99	0.76	0.94	0.49	0.87	0.89	0.16	0.13	0.86	0.74
300MW , -	0.99	0.99	0.89	0.83	0.86	0.82	0.99	0.75	0.94	0.49	0.86	0.89	0.16	0.1	0.86	0.74
400MW , -	0.98	0.99	0.89	0.83	0.86	0.82	0.99	0.75	0.94	0.49	0.86	0.89	0.16	0.07	0.86	0.72
500MW , -	0.98	0.99	0.89	0.83	0.86	0.82	0.99	0.75	0.94	0.49	0.86	0.89	0.16	0.05	0.86	0.69

Table of transmission lines power factor when DG at bus 11

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	0.99	0.99	0.89	0.84	0.86	0.81	0.99	0.76	0.94	0.5	0.89	0.9	0.16	0.22	0.86	0.9
100 MW , 4	0.99	0.99	0.89	0.83	0.86	0.82	0.99	0.76	0.94	0.49	0.87	0.89	0.16	0.17	0.86	0.9
200MW , 9	0.99	0.99	0.9	0.83	0.85	0.83	0.99	0.75	0.94	0.48	0.84	0.89	0.15	0.12	0.86	0.9
300MW , 1	0.99	0.99	0.9	0.82	0.85	0.84	0.99	0.74	0.94	0.48	0.83	0.89	0.15	0.07	0.86	0.9
400MW , 1	0.99	0.99	0.9	0.81	0.84	0.85	0.99	0.74	0.94	0.47	0.8	0.89	0.15	0.01	0.86	0.9
500MW , 2	0.99	0.99	0.9	0.81	0.84	0.85	0.99	0.73	0.95	0.46	0.79	0.88	0.15	0.04	0.86	0.9

Table of transmission lines power factor when DG at bus 12

Capacity (MVA) of transmission lines when slack bus 2

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0MV	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	130.24	39.19
100 MW , 1	57.56	2095.46	720.51	334.26	1350.28	321.03	337.01	1442.6	556.24	22.66	70.22	790.09	877.46	1986.32	133.02	39.19
200MW , -	61.74	2189.35	743.1	318.01	1415	336.29	334.14	1514.37	568.07	23.88	88.13	781.19	913.32	2072.78	135.77	39.19
300MW , -	65.87	2283.17	765.67	302.61	1479.36	351.9	331.34	1584.36	579.87	25.07	105.64	772.91	949.5	2160.8	138.49	39.19
400MW , -	69.95	2376.88	788.2	288.07	1543.28	367.75	328.63	1652.65	591.62	26.25	122.75	765.22	985.82	2250.04	141.19	39.19
500MW , -	73.97	2470.3	810.67	274.41	1606.75	383.77	325.98	1719.28	603.28	27.4	139.47	758.11	1022.15	2340.23	143.86	39.19

Table of transmission lines capacity when DG at bus 1

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0MV	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	130.24	39.19
244MW , 1	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	130.24	39.19
DG Fix																

Table of transmission lines capacity when DG at bus 2

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	134.24	39.19
100 MW , 4	56.78	2007.25	714.05	338.93	1331.93	234.73	337.85	1422.93	578.91	24.14	91.17	769.11	865.18	1953.53	132.39	39.19
200MW , 9	60.16	2015.48	730.07	327	1378.13	165.08	335.8	1475.41	613.6	26.86	130.73	740.2	889.86	2009.18	134.5	39.18
300MW , 1	63.47	2026.09	746.01	315.51	1423.86	97.6	333.8	1526.55	648.4	29.59	170.15	712.99	915.91	2068.25	136.57	39.18
400MW , 1	66.71	2038.67	761.85	304.47	1469.14	36.2	331.84	1576.45	683.26	32.33	209.34	687.62	943.09	2130.28	138.61	39.18
500MW , 2	67.88	2052.85	777.62	293.84	1513.99	45.37	329.93	1625.21	718.1	35.07	248.25	664.21	971.21	2194.86	140.62	39.18

Table of transmission lines capacity when DG at bus 5

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	134.24	39.19
100 MW , 4	57.25	2006.11	695.83	356.9	1289.84	318.73	338.25	1445.7	555.25	22.56	69.14	790.96	864.07	1950.66	132.43	39.18
200MW , 9	61.12	2013.11	694.37	363.76	1297.02	331.68	336.59	1521.72	566.12	23.67	86	782.85	887.53	2003.04	134.57	39.18
300MW , 1	64.9	2022.61	693.53	371.79	1306.63	344.97	334.97	1597.12	577	24.76	102.49	775.25	912.26	2058.54	136.68	39.18
400MW , 1	68.61	2034.39	693.27	380.85	1318.48	358.51	333.38	1671.95	587.87	25.82	118.63	768.13	938.06	2116.71	138.76	39.18
500MW , 2	72.25	2048.24	693.56	390.82	1332.37	372.22	331.82	1746.25	598.72	26.87	134.43	761.49	964.76	2177.18	140.8	39.17

Table of transmission lines capacity when DG at bus 6

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	134.24	39.19
100 MW , 4	54.98	2004.07	698.26	352.37	1290.15	303.02	339.22	1385.15	544.82	21.74	58.52	800.38	833.17	1871.94	131.15	39.18
200MW , 9	56.62	2007.02	698.66	353.64	1295.36	300.17	338.5	1401.47	545.3	22.06	65.44	801.28	826.63	1847.58	132.05	39.17
300MW , 1	58.23	2010.68	699.16	355.14	1300.9	297.66	337.81	1417.98	545.8	22.38	72.54	802.31	822.55	1828.84	133.92	39.16
400MW , 1	59.81	2015.02	699.73	356.85	1306.75	295.49	337.12	1434.66	546.48	22.7	79.77	803.47	820.93	1815.7	133.78	39.16
500MW , 2	61.36	2020.81	700.38	358.77	1312.89	293.64	336.45	1451.49	547.17	23.02	87.08	804.74	821.8	1808.12	134.62	39.15

Table of transmission lines capacity when DG at bus 7

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	134.24	39.19
100 MW , 4	55.72	2007.69	700.27	350.79	1295.91	278.34	338.81	1391.38	533.4	22.35	145.69	705.17	840.41	1888	131.59	39.18
200MW , 9	57.97	2015.8	702.57	350.54	1306.22	256.67	337.74	1412.39	523.27	23.23	244.51	613.76	843.06	1884.1	132.85	39.17
300MW , 1	60.08	2025.7	704.83	350.52	1316.26	241.17	336.74	1432.28	514.13	24.08	343.62	526.1	849.18	1888.77	134.04	39.16
400MW , 1	62.07	2037.05	707.06	350.68	1326.04	231.76	335.79	1451.18	506.08	24.89	442.55	443.67	858.56	1900.56	135.16	39.16
500MW , 2	63.96	2049.57	709.25	350.98	1335.59	228.16	334.88	1469.23	499.22	25.67	541.23	369.26	870.14	1918.47	136.23	39.15

Table of transmission lines capacity when DG at bus 8

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	134.24	39.19
100 MW , 4	55.55	1998.32	693.58	354.44	1271.36	314.06	416.84	1433.61	550.7	22.04	145.69	794.33	862.53	1948.68	132.78	29.19
200MW , 9	57.61	1994.43	689.03	357.62	1255.67	321.63	497.84	1497.37	556.57	22.61	244.51	789.48	883.88	1997.99	175.96	39.19
300MW , 1	59.44	1990.7	684.39	361.14	1238.32	328.72	584.34	1559.87	561.88	23.1	343.62	785.14	905.89	2049.24	200.13	39.18
400MW , 1	60.97	1988.15	679.79	365.6	1219.56	335.05	679.75	1620.73	566.38	23.5	442.55	781.41	928.32	2102	226.09	39.18
Blackout																

Table of transmission lines capacity when DG at bus 9

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	134.24	39.19
100 MW , 4	55.6	2007.24	699.15	351.75	1292.91	283.94	338.9	1388.64	537.01	22.16	71.18	700.96	838.48	1882.81	131.51	39.18
200MW , 9	57.73	2014.66	700.35	352.44	1300.37	267.08	337.92	1407.17	530.55	22.86	94.61	604.61	839.02	1873.53	132.69	39.17
300MW , 1	59.73	2023.73	701.54	353.33	1307.67	255.41	337	1424.78	525.08	23.52	119.6	511.43	843.17	1873.24	133.81	39.16
400MW , 1	61.61	2034.1	702.73	354.4	1314.82	248.71	336.14	1441.61	520.66	24.16	145.22	423.16	850.44	1880.06	134.86	39.15
500MW , 2	63.4	2045.65	703.91	355.6	1321.83	246.54	335.31	1457.74	517.31	24.77	171.09	343.21	860.42	1893.18	135.85	39.15

Table of transmission lines capacity when DG at bus 10

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	134.24	39.19
100 MW , -	54.03	2002.14	697.96	351.63	1286.41	305.26	339.57	1372.96	544.46	21.5	53.57	799.84	847.8	1948.3	130.7	89.5
200MW , -	54.66	2002.23	697.96	351.86	1287.13	304.58	339.21	1375.52	544.48	21.56	54.71	800.03	851.7	2003.83	131.11	183.94
300MW , -	55.22	2002.18	697.93	352.05	1287.56	304.1	338.89	1377.08	544.47	21.59	55.44	800.18	854.25	2065.24	131.5	272.45
400MW , -	55.72	2002	697.88	352.18	1287.72	303.77	338.58	1377.8	544.43	21.61	55.85	800.29	855.71	2130.66	131.83	355.76
500MW , -	56.17	2001.71	697.82	352.28	1287.67	303.67	338.28	1377.78	544.37	21.61	55.96	800.38	856.2	2198.95	132.19	435.07

Table of transmission lines capacity when DG at bus 11

	1 to 2	1 to 3	3 to 4	4 to 6	3 to 6	3 to 5	6 to 9	6 to 7	5 to 8	5 to 7	8 to 10	7 to 10	7 to 12	2 to 12	2 to 9	11 to 12
0MW, 0.02	53.31	2001.85	697.93	351.34	1285.27	306.21	339.95	1369.02	544.41	21.42	51.9	799.61	842.1	1901.86	134.24	39.19
100 MW , 4	53.83	2003.3	698.17	351.77	1287.97	304.62	339.81	1377.78	544.69	21.59	55.36	799.91	853.46	1857.16	130.45	39.18
200MW , 9	54.34	2004.85	698.41	352.28	1290.69	303.11	339.67	1386.53	544.97	21.76	58.89	800.27	864.76	1817.57	130.65	39.17
300MW , 1	54.84	2006.59	698.68	352.86	1293.51	301.7	339.53	1395.33	545.27	21.93	62.5	800.67	876.01	1783.33	130.85	39.16
400MW , 1	55.34	2008.53	698.97	353.5	1296.41	300.37	339.4	1404.18	545.6	22.1	66.17	801.11	887.22	1754.63	131.04	39.15
500MW , 2	55.83	2010.66	699.27	354.2	1299.41	299.14	339.27	1413.09	545.94	22.27	69.89	801.58	898.4	1731.62	131.23	39.15

Table of transmission lines capacity when DG at bus 12

Power factor behaviour for each transmission lines when DG penetration

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
100 MW , 4	0.06	0.04	0.06	0.06	0.05	0.06	0.05	0.05	0.03	0.05	0.03	0.03
200MW , 9	0.06	0	0.07	0.07	0.05	0.07	0.04	0.03	0	0.02	0.01	0
300MW , 1	0.06	0.05	0.07	0.07	0.04	0.08	0.03	0	0.04	0	0.1	0.05
400MW , 1	0.06	0.12	0.07	0.08	0.04	0.08	0.01	0.03	Blackout	0.04	0.19	0.11
500MW , 2	0.06	0.23	0.07	0.08	0.03	0.09	0.01	0.08	Blackout	0.1	0.23	0.2

Table power factor behaviour of line 1 to 2 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
100 MW , 1	0.81	0.8	0.8	0.8	0.8	0.8	0.8	0.81	0.78	0.81	0.8	0.8
200MW , 3	0.81	0.8	0.8	0.79	0.8	0.79	0.8	0.8	0.75	0.8	0.8	0.8
300MW , 4	0.81	0.79	0.79	0.79	0.79	0.78	0.79	0.8	0.72	0.8	0.76	0.79
400MW , 4	0.81	0.78	0.78	0.78	0.78	0.77	0.79	0.79	Blackout	0.79	0.73	0.78
500MW , 5	0.81	0.77	0.77	0.77	0.77	0.76	0.78	0.78	Blackout	0.77	0.71	0.77

Table power factor behaviour of line 1 to 3 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
100 MW , 1	0.55	0.56	0.55	0.55	0.55	0.56	0.56	0.56	0.52	0.56	0.56	0.56
200MW , 3	0.55	0.56	0.55	0.54	0.55	0.56	0.57	0.56	0.49	0.56	0.56	0.56
300MW , 4	0.55	0.57	0.55	0.53	0.55	0.56	0.57	0.56	0.44	0.56	0.52	0.57
400MW , 4	0.55	0.57	0.55	0.51	0.55	0.57	0.58	0.56	Blackout	0.56	0.48	0.57
500MW , 5	0.55	0.57	0.55	0.5	0.55	0.57	0.58	0.56	Blackout	0.56	0.44	0.57

Table power factor behaviour of line 3 to 4 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
100 MW , 1	0.97	0.98	0.97	0.95	0.97	0.98	0.98	0.98	0.97	0.98	0.98	0.98
200MW , 3	0.97	0.99	0.97	0.91	0.97	0.99	0.99	0.99	0.97	0.99	0.98	0.99
300MW , 4	0.97	0.99	0.97	0.85	0.98	0.99	0.99	0.99	0.96	0.99	0.98	0.99
400MW , 4	0.97	0.99	0.97	0.76	0.98	0.99	0.99	0.99	Blackout	0.99	0.97	0.99
500MW , 5	0.97	0.99	0.97	0.59	0.98	0.99	0.99	0.99	Blackout	0.99	0.96	0.99

Table power factor behaviour of line 4 to 6 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
100 MW , 1	0.99	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.95	0.97	0.97	0.97
200MW , 3	0.99	0.96	0.97	0.96	0.96	0.96	0.96	0.96	0.93	0.96	0.97	0.96
300MW , 4	0.99	0.96	0.97	0.96	0.96	0.96	0.96	0.96	0.91	0.96	0.95	0.96
400MW , 4	0.99	0.96	0.97	0.96	0.96	0.96	0.96	0.95	Blackout	0.95	0.92	0.96
500MW , 5	0.99	0.95	0.97	0.96	0.96	0.96	0.95	0.94	Blackout	0.94	0.91	0.95

Table power factor behaviour of line 3 to 6 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
100 MW , 1	0.24	0.22	0.24	0.24	0.11	0.24	0.22	0.21	0.22	0.21	0.22	0.22
200MW , 3	0.24	0.2	0.24	0.24	0.04	0.23	0.2	0.15	0.21	0.17	0.21	0.2
300MW , 4	0.24	0.18	0.24	0.23	0.23	0.23	0.18	0.06	0.2	0.1	0.17	0.18
400MW , 4	0.24	0.15	0.24	0.23	0.44	0.23	0.14	0.06	Blackout	0	0.14	0.14
500MW , 5	0.24	0.12	0.24	0.23	0.64	0.23	0.1	0.25	Blackout	0.14	0.12	0.1

Table power factor behaviour of line 3 to 5 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
100 MW , 1	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.98	0.98	0.98
200MW , 3	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.93	0.98	0.98	0.98
300MW , 4	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.89	0.97	0.98	0.98
400MW , 4	0.98	0.97	0.98	0.98	0.98	0.98	0.97	0.97	Blackout	0.97	0.98	0.97
500MW , 5	0.98	0.97	0.98	0.97	0.98	0.97	0.97	0.97	Blackout	0.97	0.98	0.97

Table power factor behaviour of line 6 to 9 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
100 MW , 1	0.94	0.95	0.95	0.94	0.94	0.94	0.95	0.95	0.94	0.95	0.95	0.95
200MW , 3	0.94	0.95	0.94	0.94	0.94	0.94	0.95	0.95	0.93	0.95	0.95	0.95
300MW , 4	0.94	0.95	0.94	0.94	0.94	0.94	0.96	0.95	0.93	0.95	0.91	0.95
400MW , 4	0.94	0.96	0.94	0.94	0.94	0.94	0.97	0.95	Blackout	0.95	0.86	0.96
500MW , 5	0.94	0.96	0.94	0.94	0.94	0.94	0.97	0.95	Blackout	0.95	0.82	0.96

Table power factor behaviour of line 6 to 7 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
100 MW , 1	0.71	0.7	0.71	0.7	0.72	0.71	0.7	0.69	0.7	0.7	0.7	0.7
200MW , 3	0.71	0.69	0.71	0.7	0.73	0.7	0.69	0.68	0.69	0.69	0.69	0.69
300MW , 4	0.71	0.68	0.71	0.7	0.75	0.7	0.68	0.67	0.68	0.68	0.67	0.68
400MW , 4	0.71	0.67	0.7	0.7	0.76	0.7	0.68	0.66	Blackout	0.68	0.64	0.67
500MW , 5	0.71	0.67	0.7	0.7	0.77	0.7	0.67	0.65	Blackout	0.68	0.62	0.67

Table power factor behaviour of line 5 to 8 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
100 MW , 1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
200MW , 3	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
300MW , 4	0.99	0.99	0.99	0.99	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99
400MW , 4	0.99	0.99	0.99	0.99	0.97	0.99	0.98	0.98	Blackout	0.99	0.98	0.99
500MW , 5	0.99	0.99	0.99	0.99	0.96	0.99	0.97	0.97	Blackout	0.99	0.96	0.98

Table power factor behaviour of line 5 to 7 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
100 MW , 1	0.38	0.45	0.38	0.4	0.32	0.4	0.45	0.08	0.41	0.52	0.45	0.45
200MW , 3	0.38	0.51	0.38	0.41	0.25	0.42	0.52	0.2	0.43	0.65	0.5	0.51
300MW , 4	0.38	0.57	0.38	0.42	0.18	0.43	0.58	0.41	0.44	0.78	0.53	0.58
400MW , 4	0.38	0.63	0.38	0.44	0.1	0.45	0.65	0.56	Blackout	0.88	0.52	0.64
500MW , 5	0.38	0.68	0.39	0.45	0.02	0.46	0.71	0.66	Blackout	0.95	0.51	0.69

Table power factor behaviour of line 8 to 10 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
100 MW , 1	0.99	0.98	0.99	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98	0.98
200MW , 3	0.99	0.98	0.99	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98	0.98
300MW , 4	0.99	0.98	0.99	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.98
400MW , 4	0.99	0.98	0.99	0.98	0.98	0.98	0.98	0.99	Blackout	0.99	0.99	0.98
500MW , 5	0.99	0.98	0.99	0.98	0.98	0.98	0.98	0.99	Blackout	0.99	0.99	0.98

Table power factor behaviour of line 7 to 10 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
100 MW , 1	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.93	0.92	0.92	0.92
200MW , 3	0.92	0.92	0.92	0.92	0.92	0.92	0.93	0.93	0.95	0.93	0.92	0.92
300MW , 4	0.92	0.92	0.92	0.92	0.92	0.92	0.93	0.93	0.97	0.93	0.98	0.92
400MW , 4	0.92	0.92	0.92	0.92	0.92	0.92	0.94	0.94	Blackout	0.94	0.99	0.92
500MW , 5	0.92	0.93	0.92	0.92	0.92	0.92	0.94	0.94	Blackout	0.94	0.95	0.92

Table power factor behaviour of line 7 to 12 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
100 MW , 1	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.91	0.91	0.91
200MW , 3	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.94	0.92	0.91	0.92
300MW , 4	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.96	0.92	0.91	0.92
400MW , 4	0.91	0.91	0.91	0.91	0.91	0.91	0.93	0.93	Blackout	0.93	0.9	0.93
500MW , 5	0.91	0.91	0.91	0.91	0.91	0.92	0.93	0.93	Blackout	0.93	0.89	0.93

Table power factor behaviour of line 2 to 12 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
100 MW , 3	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.99	0.99	0.99
200MW , 3	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.95	0.99	0.99	0.99
300MW , 4	0.99	0.98	0.99	0.99	0.99	0.99	0.98	0.98	0.9	0.98	0.99	0.98
400MW , 4	0.99	0.97	0.99	0.99	0.99	0.99	0.98	0.97	Blackout	0.97	0.99	0.98
500MW , 5	0.99	0.96	0.99	0.99	0.99	0.99	0.97	0.97	Blackout	0.97	0.99	0.97

Table power factor behaviour of line 2 to 9 when DG is installed

	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6	Bus7	Bus8	Bus9	Bus10	Bus11	Bus12
0MW, 0.02	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
100 MW , 3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.89	0.9
200MW , 3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.88	0.9
300MW , 4	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.97	0.9
400MW , 4	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	Blackout	0.9	0.77	0.9
500MW , 5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	Blackout	0.9	0.61	0.9

Table power factor behaviour of line 11 to 12 when DG is installed