DANA OMAR QADER

VOLTAGE CONTROL OF DISTRIBUTION GRIDS WITH MULTI-MICROGRIDS USING REACTIVE POWER MANAGEMENT

NEU 2019

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCE

OF

NEAR EAST UNIVERSITY

By

DANA OMAR QADER

In Partial Fulfilment of the Requirements for the Degree of Master of Science

in

Electrical and Electronic Engineering

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Approval of Director of Graduate School of

Applied Science

Prof. Dr. Nadire CAVUS

We certify this thesis is satisfactory for the award of the degree of Masters of Science in Electrical and Electronic Engineering

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I herewith assure that ethical behaviors and academic rules was considered in the whole knowledge gained and demonstrated in this thesis. In addition, based on the necessary rules and conduct, I had cited and referenced all the information and outcomes, which is not authentic in this document.

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Date:

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First and foremost, Glory to the Almighty God and My parent, for protecting me, granting me strength and courage to complete my study and in all stages during my life. I deeply thank and appreciate to my supervisor Prof. Mehrdad Trafdar Hagh for his kind instruction. I would like to thank him not only for abetting me on my Thesis but also for encouraging me to look further in the field my career development. His advice on the Thesis as well as on the career I chose has been splendid. In addition, my family and friends was very supportive all along my working time on my thesis, and they deserve very special thanks and sincerely for their kind help and backing me all the time, so they make my life easier.

To my parents…

ABSTRACT

This research presents how reactive power generation and/or absorption can be utilized to partake voltage control in medium voltage distribution through multi microgirds. Nowadays, only in high voltage substations and large power plants, reactive power is controlled. In this research, we aim to control reactive power near consumption points by integrating mult-microgrids in our distribution grids. One of the essential advantage of the MG integration to the grid is changing the system networks from the unidirectional to bidirectional. This piece of work shows how the MG on the buses contribute to control the voltage on the buses during the fault or line disconnected, and how the system losses will decrease by integrating active power.

Keywords: Microgrid; voltage control; reactive power; renewable energy; load flow; distributed energy; distribution grid.

ÖZET

Bu araştırma, reaktif güç üretimi ve / veya absorpsiyonunun, çoklu mikrogruplar aracılığıyla orta gerilim dağıtımında voltaj kontrolü için nasıl kullanılabileceğini göstermektedir. Günümüzde sadece yüksek gerilim trafoları ve büyük enerji santrallerinde reaktif güç kontrol edilmektedir. Bu araştırmada, dağıtım şebekelerimizde mult-microgrids entegre ederek tüketim noktalarının yakınlarındaki reaktif gücü kontrol etmeyi hedefliyoruz. Şebekeye MG entegrasyonunun temel avantajlarından biri, sistem ağlarını tek yönlüden çift yönlü hale getirmektir. Bu çalışma, otobüslerdeki MG'nin, arıza veya hattın bağlantısı kesilirken, otobüslerdeki voltajın kontrol edilmesine nasıl katkıda bulunduğunu ve aktif güçleri entegre ederek sistem kayıplarının nasıl azalacağını göstermektedir.

Anahtar Kelimeler: Microgrid; voltaj kontrolü; reaktif güç; yenilenebilir enerji; yük akışı; dağıtılmış nesil; dağıtım şebekesi.

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LIST OF ABBREVIATIONS

DG:	Distributed Generation
DER:	Distributed Energy Resources
EV:	Electric Vehicle
PV:	Photovoltaic
WT:	Wind Turbine
CHP:	Combined Heat and Power
ESS:	Energy Storage System
VC:	Voltage Control
MG:	Microgrid
EMS:	Energy Management System
AC:	Alternative Current
Q:	Reactive Power
SVC:	Static Voltage Compensation
FACTS:	Flexible AC Transmission System
VAR:	Volt – Ampere Reactive
CVR:	Conservation Voltage Reduction
AVR:	Automatic Voltage Regulators
APU:	Auxiliary Power Unit
DC:	Direct Current
AND:	Active Distribution Network
DSO:	Distribution System Operator
PLL:	Phase lock loop
TL:	Transmission Line

CHAPTER 1

INTRODUCTION

1.1 Microgrid

The new distribution system has been founded by the researcher, which use the DG to produce power and designed from the idea of the smart grid.MG will increase the power reliability in the area because the MG can operate independently if anything happened to our system. There are three essential objectives, which achieved with the MG such as good impact on environment, increase system efficiency, and increase power quality. Always MG located near to the consumption point. Producing electricity with the help of the distributed generation will help to cancel the cost of energy production such as buying fuel, energy transmission such as transmission line cost, and power distribution such as transformer, poles, and conductor costs, and also the MG will help to the system in term of efficiency. In comparison the DG to the generators, we see the great advantage of the DG over this generator in term of environmental, power quality, and generation cost (Considine, 2012).

As we mentioned before the microgrid has the ability to work either independently or grid connected through having the many types of DG in the system such as photovoltaic, wind turbine, fuell cell, ESS. By the integrating microgrids to the distribution power system, the distributed system operator will face the new challenge such as how the control and manage this new energy. In the traditional distribution system there are the control room, which was responsible to manage and arrange for this, and it is now necessary to advance the EMS in order to tackle new challenges (Lasseter, 2002).

Figure 1.1: Distribution system with renewable energy (EPA, 2015)

1.1.1 Why we choose the MG?

There are many energy source of renewable energy, which have the good ability to produce the power, and as we now the energies of the renewable energy are environmental friendly, developed through the world quickly. By having this sources to generate energy, we can say that we use many type of fuels to generate power, have a difference type of energy that the costumer should choose among them, have a better power quality, and preserve the fossile fuel, which is harmful to the communities and going to be finish in some days. As we see from the Europe, especially Germany will take many advantage from the renewable energies, and there are some homes or villages, who can generate its demand with the renewable energy and even selling the power to the government. It is a small example of the benefits of the MG and the renewable energy (Nasiri, 2016).

1.1.2 The MG advantages

A. Better power deliver

With the emerging the new technologies such as MG the power deliver to the consumption point is much easier now because the power that produced by the MG, which contain the distributed generation is located near to the consumption point. In the old way the government should think how to deliver the power to the loads, and they have to build the necessary infrastructure for that. By having the MG in our system which enable the consumer to sell the active power to the power system and help the distribution system operator in the peak and valley point also we can take advantage from the MG as a backup energy. There are many homes who can supply its needs by having a roof top photovoltaic, boiler photovoltaic that help them also to save money (Interesting Engineering, 2015).

B. Improve power continuity

At the traditional distribution system, the reliability of system was good, but when the system faces the load fluctuation, which means the load variation, this load variation causes the voltage variation and decree the reactive power in the system and the grid will shut down due to the load fluctuation, but if we have the MG in the system we can use the power of the MG as a standby power to recover for the system load fluctuation and control the voltage also we can use the power of the MG independently. This will ameliorate the power reliability of the system and change the distribution system to AND (Bollen, 2011).

C. Decrease power cost

Most of the microgrids are owned by the private sector or normal people and some of them is owned by the system operators, and as we knew from the previous discussion the MG can work independently this will help this communities or homes to save money and even sometime sell the energy to the system and make money, and even if the system has a problem they can operate their MG independently (Cox, 2011).

D. Make money to the owner

As it described before the MG has many benefits to the distribution system and one of this benefits is that the owner of the microgrid can sell the power to the system and by which getting money instead of paying money to the system because it has the self-sufficient energy and can give energy to the system and make money instead giving money to the system.

E. Environmental friendly

The source of the renewable energies is the clean energy, as a result of that the MG have a very good impact on the environment, and by generating energy from the renewable energies will help the world to preserve the natural resources such as fossil fuel, which were used widely to produce the electrical energy and had a very harmful gas emission such as greenhouse gasses.

F. Increase the system flexibility

The traditional system was unidirectional, which means that from the loads side there is no contribution just absorbing active power from the system, but in the distribution system with the MG, which called the bidirectional system, which means from the load side, the system can get active and reactive power from the MG and this make the system more flexible and rise the reliability of the system.

G. Help the economy

As it described before, having the MG in the system will help the economy throughout in many areas. This new technology takes the interest of the international company and encourage them to invest money in it and make many job opportunities the country. For example, in my country the government will spend nearly 3 billion USD to generate the electricity from buying the heavy fossil fuels, but instead of this the government can take advantage from this new technology and produce most of our energy from the renewable energy which is environmental friendly.

1.1.3 Operation mode of the microgrids

Microgrid has the two operation mode such as connected mode or independent mode. Connected mode means the MG has binded to the distribution system grid and help the system to have power and it is a part of the system and the system operator will take benefits from their power and it is very useful to the system at the peak load demand time and lowest load demand time. Independent mode means that the MG is work independently and provide power, and this mode is used when the system has the problem or at the system shut down. As a result, the both mode operation can be chosen by the owner of the microgrids (Department of energy, 2014).

1.1.4 Microgrid connection to the grid system

The microgrid can connect to the system from the coupling point, which at this poing the voltage value is the same and if there are any problem in the system the microgrid can be disconnected from the system to operate independently. The distribution system can be disconnected from the MG through the swith. This switch can be worked in two modes such automatically or manually (Nakisa, 2014).

1.1.5 What are the advantage of MG to the community?

By having the microgrid in the distribution power system. The community can take advantage from the microgrid power as the standby or backup energy. The MG presence in the system will make the electricity cost to be decreased because the MG energy is provided through the renewable energy or distributed generation. The MG will help the community to provide their energy and this energy have a very good impact on the environment (Nakisa, 2014).

1.1.6 Power size of the microgrid

The MG is difference in the term of size and their size is different due to what size we need in this place. The microgrid can power from the entire building and small villages to the factory also the design of the microgrid is difference based on what we need in this place (Department of Energy, 2014).

1.1.7 Microgrid classifications

A. Utility Microgrids

In this type of the micogrid the consumers will invest in the microgrid and this participation will decrease the cost of the energy and make the new energy policy (Department of Energy, 2014).

B. Industrial microgrid

This type of microgrid is very important for the factories because this this microgrid will help them to decrease the required load, which make them to pay less for the electricity, and this MG is very useful during any electric outage from the system (Department of Energy, 2014).

C. Campus microgrid

This type of microgrid is very useful to the university because in the university we need the continuity of power for many things such as Security camera, heating, cooling, laboratories. In this type if we have more power from the microgrid beyond our expenses we can sell the power to the network system and make money instead paying more to the government (Department of Energy, 2014).

D. Military service microgrid

In this type of the microgrid, the most important this power continuity that any military services places have many devices that need the power in every second such as security camera and monitoring rooms, so the microgrid could be very useful in this aspect (Podlesak, 2012).

E. Public microgrid

In this type of the microgrid, the continuity of the power is very important and in this type we have a heavy load, as a result of this we would like to decrease the energy usage. The power required for the police station, transportation, school, hospital, and fire station are very high and we would to decrease the power usage of them by having the microgrid (Department of Energy, 2014).

F. Rural microgrid

This places are far from the consumption load and sending the power through the transmission to them will be costly. Usually this place using the traditional generators to generate electrical power for them, which is not environmental friendly and have a harmful greenhouse gasses due to the fossil fuel that benn used to produce electricity, so the best choice here is to have the microgrid near this rural place to provide the suffiecient energy for them (Kirubi, 2009).

1.2 Reactive Power Management

1.2.1 Definition

In the power system we have three kinds of power one is apparent power (S), active power (P), and the last one is reactive power (Q), which we are talking about now. We don’t have the reactive power in DC power system. In the AC circuit, if the resistive load also the reactive power will be equal to zero, but if we have the inductive load or capacitive alone or with the resistive load then we have the reactive power, so the reactive power will produce when we have the difference between the voltage and current phase, and this power is not useful, which we cannot use it but it is also very important to the overall system. The reactive power unit is (VAR), and the reactive power is given by this equation

$$Q = V_{rms} I_{rms} \cos\theta \tag{1.1}$$

Reactive power is the power that disappear and we cannot use it. We can measure the voltage and current of the inductive or capacitive load (Parmar, 2011).

1.2.2 Benefits of reactive power

A. Voltage control in the system

Nowadays, voltage control is one of the biggest problem in the power system. Due to the very high demand on the power in this days the voltage will fluctuate, and we can control the voltage level by change the reactive power because if we have the high voltage will may blow or damage many electrical appliances in our home or if we have a low voltage, this will make the electrical appliances to have a lower performance. If in the distribution power networks, the generated power was less than the required amount then the voltage will drop because the system will take more current, and as we know the active is the multiplication of the voltage, current and the power factor. To solve this problem, we should provide the reactive power to the load via the capacitor bank or inductor in substation. If the voltage increase in the distribution system we should put more inductor to retrieve the voltage in the desired value, and if the voltage decreases in the distribution system we should put more capacitor in the system in order to bring back the voltage in the desired value. In conclusion, to keep the voltage in the desired level we should have the apparent power (Fakham, 2010).

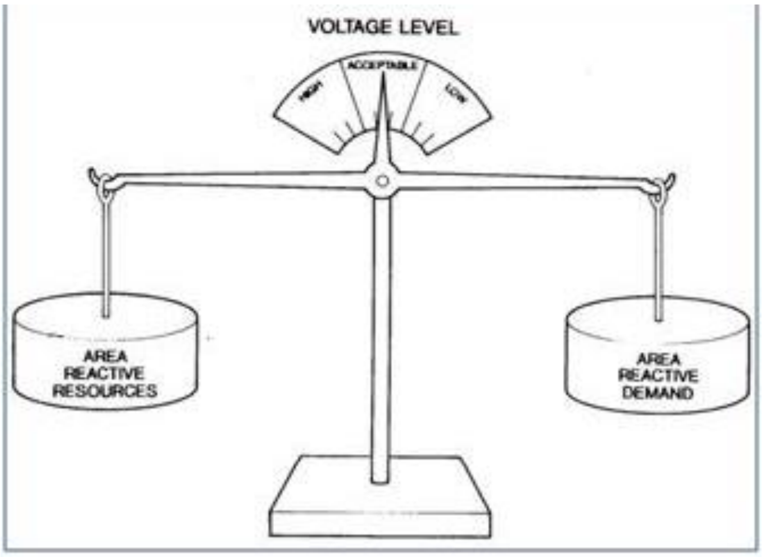

Figure 1.2: How Reactive Power maintain Voltage Level (ABB, 2016)

B. System outage

If in any distribution system, the value of the required load is increased then the value of the voltage will decrease, and if this continued and the value of the voltage is going down more and more, the system will shut down due to the absences of the desired value of the reactive power (Parmar, 2011).

C. Devices

There are many electrical tools that need the reactive power to their works such as generator, transformer because those devices will need the reactive power to produce their magnetic flux in order to work. In this devices there is an inductor, which we call it coil, this coil will produce the magnetic flux in its magnetic field due to this magnetic flux the generator can work properly.

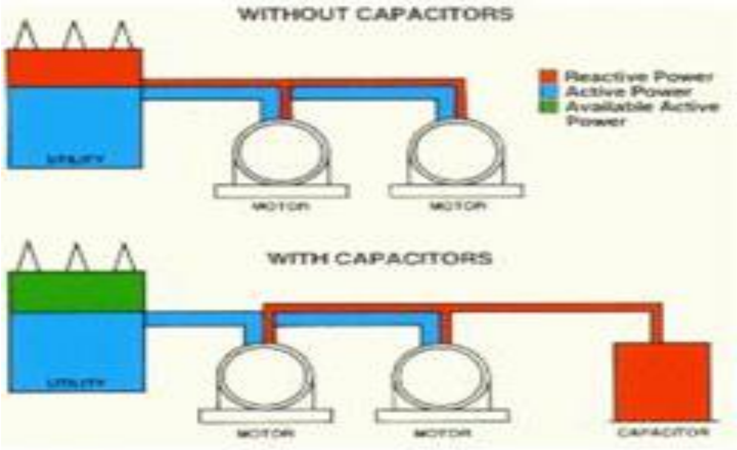

Figure 1.3: Motor working with and without Capacitor (ABB, 2016)

1.2.3 Why reactive power is important

As we describe before the reactive power is very important in the distribution system, and the importance of the reactive power increase due to the higher load demand in the power system. When the load demand will increase in the power system due to any reasons, we need the reactive power more and more to control the voltage in the system and prevent from the outage. Now, the best and efficient way to send the power from the power plant to the consumption point is the system with the power electronic converters such as FACTS and SVC. By using FACTS in transmission lines, this will increase the transmission capability and increase reliability in the system (Madureira, 2009).

1.2.4 Reactive power management in the distribution grids

The reactive power management is very important in power system due to the big work that done by the reactive power. Reactive power is the essential part in the distribution system, and the system operator should care about the reactive power management. If we face any problem such as load fluctuation and the voltage fluctuation, we can control this situation by reactive power management because in the power system the reactive power is responsible for the voltage and by changing the value of the reactive power the magnitude of voltage will be change due to this change in the reactive power magnitude (Stock, 2016).

1.3 Problem Statement

The literature has distinguished abundant indication of the necessary importance of access to a reliable supply of electricity for economic progression. However, a suitable and stable source of electricity is distant from a reality in developing states (Agalgaonkar, 2014).

The power outage is happened all over the world then it was known that is happened because of the low reactive power in the system. Reactive power management is very important for controlling the voltage in the distribution systems, and utilize of the distributed generation to shore the voltage in the system was necessary (Baran, 2007).

There is a new power grid system, which have the ability to achieve this day's requirements in a very sufficient way. This power grid is called the smart grid. The smart grid includes the very effective idea, which is the active distribution networks. Having renewable energies and distributed generation in distribution power system will change the system to the active distribution system, and active distribution system means bidirectional system. Active distribution system has many advantages over the traditional power system because in the active distribution system, we have a better power quality and less system losses due to having renewable energies and distributed generations. Also having DGs in the power distribution system will active the energy market because with the DGs we can produce electric power cheaper than using the fossil fuels. The object of this work is to survey the voltage can be controlled by contribution of the microgrids by only injecting or absorbing reactive power (Wlodarczyk, 2015).

In the active distribution networks, which that the system is the bidirectional power system, and having the distributed generation in the distribution networks has the negative effect and bring new operational problems to the system such as voltage violence and congested line, so in the recent years, the voltage control is the big issues that have to be solved (Biserica, 2011).

Loss of energy during the transmission of the electrical energy from production place to running down place is problem in power system, and we can use microgrids instead of this power to decrease the energy losses and having a better power quality especially for the rural place such as village which is so far from the production place, so we have to spend too much money to build the infrastructure for the transmission lines and losing energy due to the resistance of the conductor of the transmission lines as we now every conductor has the resistance, as a result of this we can solve this problem by having the microgrids and the renewable energies (Ju, 2014).

As we mention it before in the new distribution power systems voltage control was the big matters that have to be solved based on the reactive power management, and having the microgrids and the renewable energies as upholding power for helping the system power quality and keep the system away from the outage, and the load fluctuation is the main reason behind voltage violence (Zhou, 2007).

1.4 Objective of the Study

1.4.1 General objective

The main objective of this thesis work is to show how the reactive power of the microgrids can control the voltage of the distribution system, and how the microgrids contribute to control the voltage by using reactive power management.

1.4.2 Specific objectives

- To show the contribution of the microgrid
- To decrease the overall system losses
- To define the line sharing
- To increase the overall system active power, which makes the system more stable and improve the system power quality
- Decrease the energy cost and have a better effect on the environment

1.5 Significance of the Study

To ameliorate the quality of the energy and make the distribution power system more stable, we need the new sources for producing electric energy such as distributed generation and renewable energies. In addition, having the microgrids in the system will make the market of electric energy more competitive because the production cost of energy by the distributed generation is low and the distribution system operators can take advantage from this new sources of energy and use it, to solve their problem especially in the peak load time, valley load time, and form the faraway places such as rural place.

Having microgrids in the distribution system will help us to control the voltage of the distribution system, which is the big issue in the recent years due to the high demand on the electric energy, and having microgrids in the distribution system will make the energy market more competitive because the power that produce from the microgrids is cheap and environmental friendly. Furthermore, the distribution system operator can use the microgrid power as the backup power or the standby power.

1.6 Methodology

1.6.1 Source of data

In this thesis, we take advantage from the power flow system of part of the sulaimaniyah city in the Iraq, and we simulate it with have two microgrid in the system and how the microgrids share in to control the voltage and decrease the system losses. In my country our power system is the not stable owing to the lack of the power generation and power losses. In addition, we take advantage from this information and use data for our research and simulate the system.

In this thesis, we have the power flow system, which is interconnected very well, and it consist of 37 buses, 9 generation plants, and more than 50 transmission lines connected all this buses together, and we have two microgrids on the two busses to help the system stability and increase the power quality of the system. Suddenly, one of the main transmission line is disconnected from the system, so the system will face the voltage violence on the two busses under the names (Moro138, and Lynn138). Having microgrids in our system will help us to compensate for this voltage violence due to the line disconnected by altering the amount of the reactive power. Furthermore, we can take advantage from the active power of the microgrids at the high load demand times when the electric energy is very expensive, and we can use this power to decrease the load demand during the days.

1.6.2 Data analysis

In this thesis we use the power world simulator to simulate and analyze how the microgrids can contribute in distribution grid so as to control the voltage and decrease the power losses, and MATLAB and Microsoft excel for the tables. For this simulation we have two microgrids in our system which contribute to control the voltage in the busses, and the voltage of the busses have the voltage violence, one of them is facing the low voltage and the second bus will face the high voltage, and we have the microgrids in connection with those busses, so by the microgrid contribution we can control the voltage of the busses and bring them in desired voltage range which is decided by the system operators.

1.7 Ethical Considerations

Considering the preparation of design requirements and standards ethical features of design procedures is implemented during the thesis work. All of the preparation of this thesis is done by myself, regarding taking advantage from the power flow. The other Ethical consideration is using the ideas or words of another person with giving appropriate credit.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Theory of the System

Having the distributed generation in the distribution networks has the negative effect and bring new operational problems to the system such as voltage violence and congested line. The old control actions are not good enough to decrease the voltage violence problem, so the distributed system operator will face the problem and with using this old techniques, which not economical to operate the distribution networks. Elastic and harmonious work is necessary to overcome this problem (Gustavo, 2013).

One of the proposed idea was an intra-day scheduler in order to modify the output power to decrease the voltage violence and control variables based on the previous scheduler. This controller was not very accurate because it depends on the previous scheduler and the voltage and power variation is not known in practice, the prediction may be wrong or the predicted value is not the same as the practical value (Borghetti, 2010).

There is a new power grid system, which have the ability to achieve this day’s requirements in a very sufficient way. This power grid is called the smart grid. The smart grid includes the very effective idea, which is the active distribution networks. The distribution network, which contain the high number of distributed generation such as PV, WT, fuel cell, storage system is called the active distribution networks. This distributed generation will make the network grid to be bidirectional distribution system, which means that we can give active and reactive power to the network grids and take the active and reactive power from the network grid system. Even though having the distributed energy resources in our distribution system had a many benefits to our system. For example, having a better power quality, minimizing the system power losses, and active the energy market. The object of this work was to investigate the voltage can be controlled by contribution of the microgrids by only injecting or absorbing reactive power (Wlodarczyk, 2015).

Growth of the distributed energy resources in the distribution system will challenge the distribution system in the term of voltage violence. As, we know in the new distribution systems voltage problem is one of the hot topics, which have to be solved because the voltage violence will make the system unstable and decrease the quality of the delivered energy. Having distributed energy resources and renewable energy in distribution system have the financial benefits to the system operators and the consumer, and the system operator can take advantages from distributed energy resources to decrease the energy usage in the peak load demands time, which the energy price is very high in comparison to the normal time. By having the distributed energy resources in the distribution system this will make the system to be bidirectional which is mean, we can inject or absorb reactive power and active power to the system in the load side, and also have the very good impact on the environment and will decrease the greenhouse gas emissions to the atmosphere and decrease the energy cost and increase the competition between energy markets (Zhang, 2014).

Microgrids as its clear from its name is a tiny grid, which can work distinctly or in the connection with the distribution systems. Microgrids has many benefits which we are going to discuss about such as increase voltage control, reduce system losses, improve power quality, and lower power price (Considine, 2012).

2.2 Voltage Control

In the distribution system when we face the voltage violence due to any reason, we try to compensate it through the adding more capacitor to our system through the capacitor bank, by this operation we increase the reactive power in the system. Having distributed energy resources in our system also increase the active power in our system which we can take advantages from this to decrease the system overall losses. Having renewable energy in our system means that in our system we use a fuel diversity to generate our power, which also have a very good impact on the environments. One of the factors which made the old network system suffer was the load fluctuation, which it means voltage fluctuation, but by integrating DG to our system we can compensate to this problem. There a significant distinction between the characteristic of active distribution network, which means bidirectional distribution system and conventional distribution network, which means the unidirectional distribution networks, and we have to know how to choose the suitable size of microgrid for our system and its effect on our system (Li, 2017).

In the distribution system when active and reactive injection or absorbing by distributed generation and load is varied, this cause the lower power quality and voltage violation, so using of the traditional tools for mitigate the voltage violence will not be accurate and respond fast to the changing of the voltage. Moreover, we need the new control part to respond to this problem based on the new technologies and the old technologies to make the respond faster and keep the voltage in the desired level (Di Fazio, 2018).

2.3 Reactive Power

Reactive power management in the distribution power system with the integration of the distributed generation is very important task for now and the future. By integrating distributed generation to the distribution system will help us to control the reactive power because in the old concept of the distribution systems the reactive power is managed only in the very big substation and power plants (Morais, 2013).

2.3.1 Reactive power compensation methods

In this part we are going to talk about how the reactive power is compensating in the power system, and the reactive power is produced by having the phase shifting between the voltage and current which is means having inductor or capacitor in the power system circuit (Dudhe, 2015).

A. Parallel connection compensation

In this connection the capacitor or inductor is connected in the parallel with the transmission lines. In addition, if we connect the capacitor to the system that means we have added the reactive power to the system, and, if we connect the inductor to the system that means we have removed the reactive power from the system. (Dudhe, 2015).

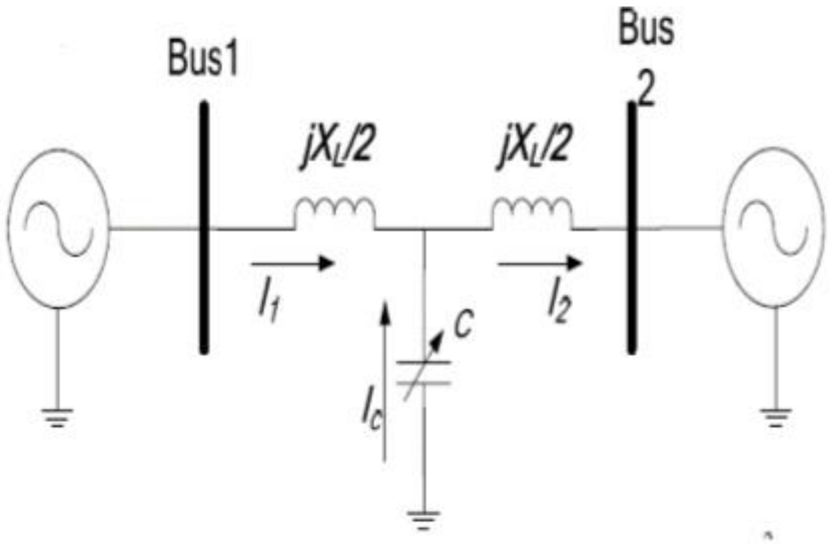

Figure 2.1: parallel connection of capacitor with TL (Dudhe, 2015)

B. Series connection compensation

Series connection compensation means that either capacitor or inductor is connected in series with the transmission line. Moreover, for increasing reactive power in the system we connect capacitor in series with the transmission line and to decrease the reactive power we connect the inductor in series with the transmission line (Dudhe, 2015).

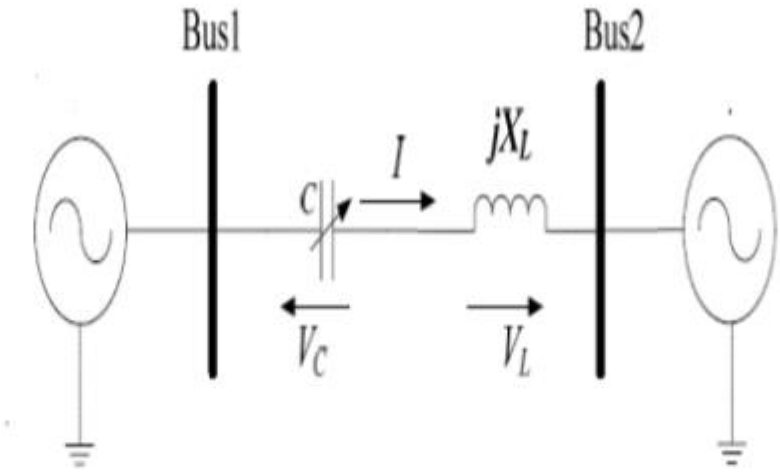

Figure 2.2: Series connection of capacitor with TL (Dudhe, 2015)

C. FACTS

Flexible ac transmission system is the other type of reactive power compensation, and FACTS devices such as SVC, STATCOM, TCR, TCS etc. In addition, the FACTS technique is new and have a faster response to any change in the system in comparison to the other two types and the thyristor is used in the FACTS. STATCOM can be emploied as both the source of the reactive power and sink of the reactive power.

2.4 Distributed Generation

2.4.1 Definition

Distributed generation is the new technologies to generate electricity in the specified range from the (1KW to 50MW), and usually the consumers are the owner of the distributed generators, or the system operator is the owner of this distributed generator. The consumers take as much as power that they need from the distributed generators and if they have more power, they will give it to the distribution power system, and in some cases the distributed generators are giving all of their power to the distribution power systems. There are types of the distribution generator, which used the renewable energy to produce electricity, or use the fossil fuels to produce the electricity, but fortunately the energy that we get from the distributed generators has a good quality, very low cost, and this energy doesn't have any bad impacts on the environments (Tuleixuan, 2015).

Table 2.1: DG Technical information

Types	Application Range	Electricity Conversion Effeciency	Application	Fuel
Reciprocating Engines	Diesel 20KW Gas 5KW	Diesel 36% to 43% Gas 28% to 42%	Emergency or standby and CHP	Diesel: Heavy fuel oil / Gas: Natural Gas
Gas Turbine	20MW	21% to 40%	CHP and Peak Power supply	Gas or Kerosene
Micro Turbine	35KW to 1MW	25% to 30%	Power Generation with CHP	Natural Gas
Fuel Cell	250KW to 5MW	35% to 60%	CHP AND UPS	Hydrogen or Natural Gas
Photovoltaic	1KW to every range is available	Not Applicable	Household and Small commercial	Sun
Wind	200W to 3MW	Not Applicable		Wind
Other Renewables		Not Applicable		

2.4.2 The importance of distributed generation

1. Regulation in the market

In the past and before emerging of the distributed generation, the consumer will buy the electricity from the system at a specified price, but with the emerge of the distributed generators and applying it to the distribution grid, this make the system operator to revise the power market, and now the consumer can get the power from the system cheaper than before. Even in some cases, the consumer may have distributed generator like photovoltaic and have the energy more than its needs so that he can sell its power to the system and get money from the system that's why emerging the distribution grid will change the power market and force the system operator to regulate their power police and prices, and the system operator can take advantage s from the distributed generators power (Wu, 2016).

A. Backup power

The system operator can take advantages from the power of the distribution generators and use whenever the system need it, and the size of the distributed generators are different from each other. The system operator can use this power at the peak load time or at the valley load time because the distributed generator energy is cheap energy and its costly to bring the power from the central power plants (Tanaka, 2010).

B. Improve system power quality

The distributed generators power is adding power to the overall system and we can use it at any time that we want, so this will increase the reliability of the system and improve the power quality, and keep the system away from the shut down and voltage fluctuation problem (Soroudi, 2010).

C. Power replacement

Emerging the distributed generation could be the replacement for the power form the central power plants because bringing the power from the central power plants needs the infrastructure, which has a very big cost. Especially for the far villages the distributed generator can be the very good choice to replace the power that bring from the central power plant which its very costly, and also in this days the system operators need many distribute generation in its system to prevent the system from the outages. Terrorists attack is another factor to having distributed generation in the system. If one large power plant is damaged or out of service due to any reason, this will lead to the big problem in the system or even system will collapse because if we remove very big amount of the active energy of the system, this will make the system to collapse (Lopes, 2007).

2. Good impact on the environment

Nowadays, environmental is the international problem and the very big and powerful countries in world had many meeting about the environment, and they started to take care to the environment. Some of the distributed generation types are used renewable energy to generate electricity which have a very good impact on the environment. Now, the distributed generation and renewable energies is a good replacement for generating electricity from fossil fuel, which has a very harmful gasses such as greenhouse gases. Now, in the world the use of distributed generation is started to grow because the government will encourage the people to generate their electricity needs from this sources (EPA, 2015).

A. CHP

CHP means producing electricity and heat together, which increase the overall efficiency of the power plant. CHP means combine heat and power, and is the new technologies that use to collect the heats, which already be wasted in the other power plant, then we can use this heats to get the “thermal energy” and use it to cooling or heating. By this operation the power plant efficiency will increase because beside the electricity we can produce another type of energy which is “thermal energy” (EPA, 2015).

B. Fuel diversity

As we know the distributed generation use many type of fuel to produce electricity, and some of them is renewable energy such as wind, photovoltaic, which use the light energy of the sun to change it to electricity through the solar cell, and fuel cell, which change the chemical energy to electrical energy (EPA, 2015).

2.4.3 Types of DG

1. Micro turbine

Micro turbine is one of the distributed generation type, and It can produce the power by combusting the natural gas, and the power that produce by the micro turbine is between 40KW to 1MW. Micro turbine relatively had a normal electrical conversion efficiency around 30%, and the micro turbine has a small size in comparison to the traditional generators. Also the micro turbine can produce both electricity and heat together, and the micro turbine is the environment friend because it has a good efficiency and can produce heat and electricity together. In addition, the micro turbine maintenance and operation cost is low, so the micro turbine is the very good way to produce electricity with the low cost (Capwhart, 2016).

2. Reciprocating engines

Reciprocating engines is one of the distributed generation types, which can produce electricity through producing rotation from the pistons by combustion of the natural gas and diesel. This piston will rotate the shaft of the generator, then we can produce the electricity. The power range of the reciprocating engines is low (5KW to 20KW), and we use its power for the emergency time. Its electric conversion efficiency is between 28% to 43% (Capwhart, 2016).

3. Gas turbine

Gas turbine is one of the distributed generations, which combust the natural gas and produce the mechanical energy, then this mechanical energy will rotate the generator turbine and produce electricity. The power range of the gas turbine is relatively high about 20MW and we can use it a power supply for the small villages or some small industrial factories. The electrical conversion efficiency of the gas turbine is between 20% to 40%, and also can be used to produce both heat and electricity together (Capwhart, 2016).

4. Fuel cell

Fuel cell is one of the distribution generations, which produce electrical energy from the chemical energy. Fuel cell contain catalyst, electrodes, and electrolyte, and each on of this elements has its job. In the electrodes the chemical reactions will be done, and the electrolyte will make the charges to moves from electrodes to produce electricity. Catalyst will make the reaction to be done faster, and this chemical reaction is happened by using either hydrogen or natural gas, and the fuel cell has a small emission (Capwhart, 2016).

5. Solar power

Solar power is one type of the distribution generation, which convert the light energy to the electrical energy through the solar cell. The solar power is totally renewable energy and have the very good impact on the environment, and the power range of the solar power is very high because we can connect the solar cell together and get more power. The solar power can be used to the household or the commercial projects, and there are types of the solar cell. Usually, solar cell will produce from the silicon (semiconductor), and the main source of the solar power is the sun (Capwhart, 2016).

6. Wind power

Wind power turbine is one of the distribution generations, which convert air motion into the mechanical energy and convert this mechanical energy to electrical energy through the generator. There are two types of the wind power turbine off shore and on shore. The wind turbine can produce electrical power up to 3MW, and the wind turbine cannot be installed in every place. Also the capital cost of the wind turbine is very high, but the operation cost of the wind power turbine is zero because the main source of the wind turbine is wind (Capwhart, 2016).

2.5 Electrical Power Grids

The electrical power grid consists of three part, the first part is generation part, which consist of the power plant, the palace where the power is generated, the second part is transmission part, which consist of the OHTL or underground cable that deliver the power from the power plant by increase its voltage throughout the transformer that increase the voltage and called “step-up transformer”. The “step-up transformer” will increase the voltage to the very high magnitude such as (132Kv or 400Kv) then in the substations the voltage will decrease to the (33Kv or 66Kv) by the transformer which is called “step-down transformer”. The final part is the power distribution part, this part is started from the main substation to the consumers. The second substation, which is known as “distribution substation”. This substation receives the power from the main substation with the high voltage value such as (33Kv or 66Kv), then this voltage will decrease through the second “step-down transformer” to the (11Kv) in the “distribution substation”. Also this power is transmitted to the consumer through the poles or a medium voltage underground cable, and the voltage will decrease again from the

(11Kv) to the (480v) phase to phase or (240) phase to neutral voltage, then the consumer can use this power in their homes. Usually the industrial factory or the residential complexes will take the power directly from the "distribution substation" or the main substation this will depend on the that how many (MW) need from this industrial factory and which substations is near the factory locations and have the ability to give the power to this industrial factory (ABB, 2016).

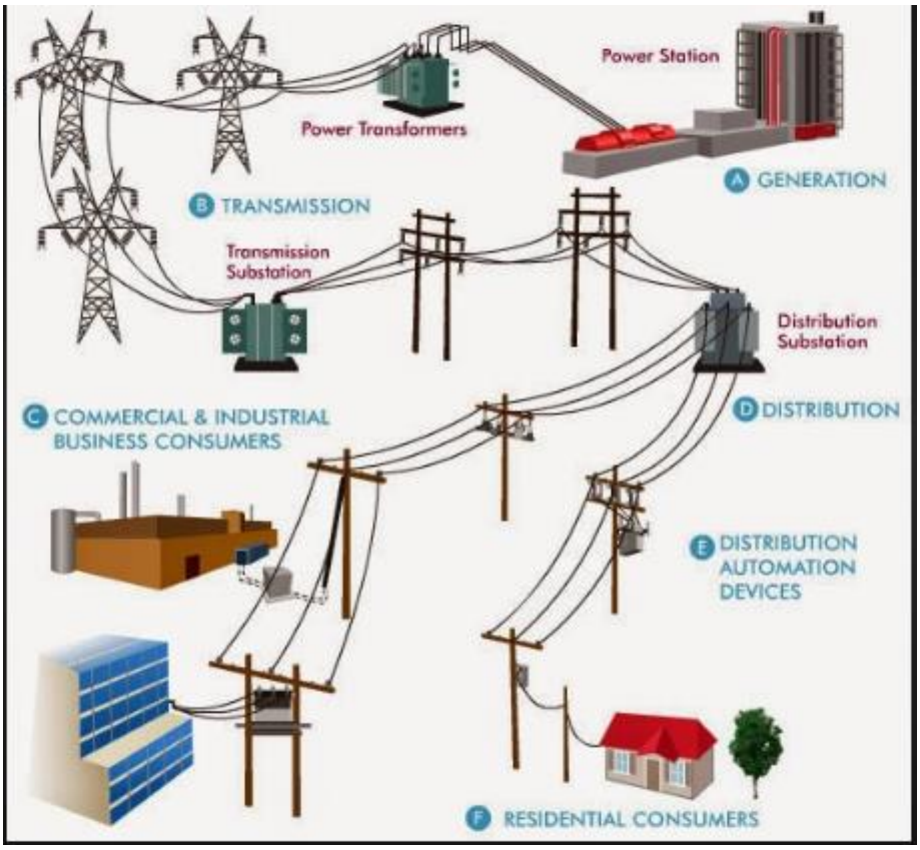

Figure 2.3: How the power delivered to the consumer (ABB, 2016)

2.5.1 Main Substation

There are many action that the main substation can do. The first action is that, the main substation had a transformer, which called “step-down transformer” that receive the power directly from the power plant to increase the voltage to the very high value such as (132KV or 400Kv), this step is done to decrease the power losses through the transmission lines because the transmission lines conductor or cable have the resistance and is transferred through a very wide distance. The second action is that, the main substation had the bus bar when we can send the power in the several lines to more than one “distributed substation” with the same voltage because the voltage of bus bar means the voltage of the substation. The final action that the main substation can do is that, as we mentioned before the main substation can deliver power to more than one “distributed substation”, and the substation can separate this lines from each other because of the circuit breakers that we have in the main substation. This action is done when one of the lines needs the maintenance, and we have to send power to the other lines or during the fault time on one of the lines (ABB, 2016).

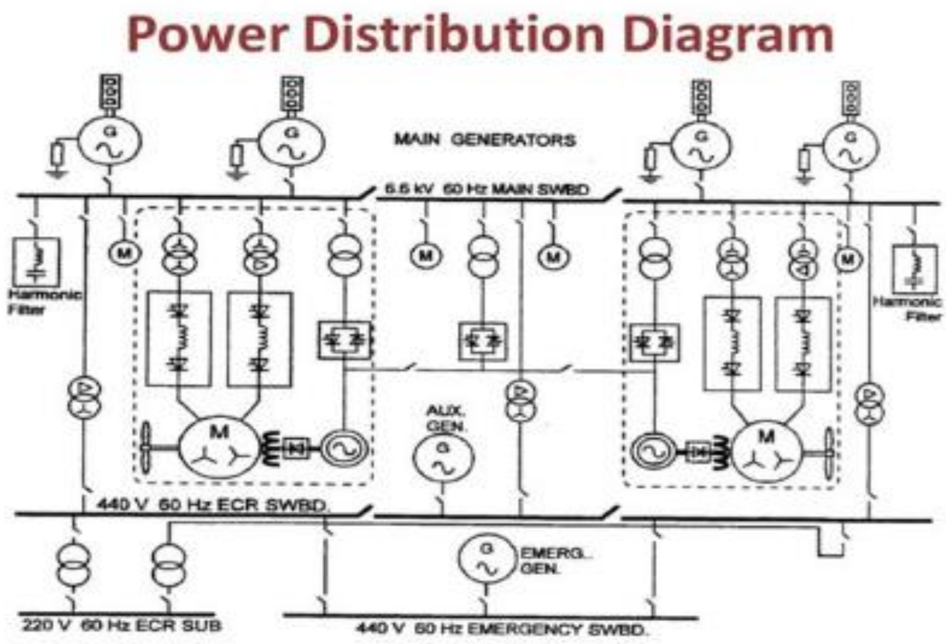

Figure 2.4: power distribution system diagram (EPA, 2015)

2.5.2 Advantages of the Q&V management

The Q &V management has two significant advantages one is the decreasing overall system power losses, and the second is keeping voltage under the control and in the desired place.

CHAPTER 3

DG INTEGRATION TO THE DISTRIBUTION SYSTEM

3.1 Voltage Control of Distribution Grid with MGs by using Reactive Power

There is a new power grid system, which have the ability to achieve this day's requirements in a very sufficient way. This power grid is called the smart grid. The smart grid includes the very effective idea, which is the active distribution networks. The distribution network, which contain the high number of distributed generation such as PV, WT, fuel cell, storage system is called the active distribution networks. This distributed generation will make the network grid to be bidirectional distribution system, which means that we can give active and reactive power to the network grids and take the active and reactive power from the network grid system. Even though having the distributed energy resources in our distribution system had a many benefits to our system. For example, having a better power quality, minimizing the system power losses, and active the energy market. This DER will help the DSO in the term of the power quality, voltage violence, and overloaded feeders. MG have the ability to work in connection with system or independently when the electric blackout happened also the MG have the ability to provide the electrical power to the village, factory or the residential area. In addition, MG can be very useful to the DSO in order to be used as a backup energy and help the distributed system operator in peak load time, which means maximum power needed and the valley point time, which means the minimum power needed, this will make the system efficiency to increase. In the distribution system when we face the voltage violence due to any reason, we try to compensate it through the adding more capacitor to our system through the capacitor bank, by this operation we increase the reactive power in the system. Having distributed energy resources in our system also increase the active power in our system which we can take advantages from this to decrease the system overall losses. Having renewable energy in our system means that in our system we use a fuel diversity to generate our power, which also have a very good impact on the environments. One of the factors which made the old network system suffer was the load fluctuation, which it means voltage fluctuation, but by integrating DG to our system we can compensate to this problem (Wlodarczyk, 2015).

There a significant variation between the characteristic of active distribution network, which means bidirectional distribution system and passive distribution network, which means the unidirectional distribution networks, and we have to know how to choose the suitable size of microgrid for our system and its effect on our system (Yu, 2012).

In this thesis, we did a great job and find many important information for the future work and do the object of the study on voltage control and the reactive power participation to control the bus voltage having distributed generation in the distribution system, which make the system to be active distribution network instead of old distribution network.

ADN means that the system is bidirectional system, which means that we can control the reactive power in the load side, but in the traditional power system the reactive power is controlled only in the power plant and very big substations.

In this thesis, we are controlling the voltage of the buses that we have microgrids on because this busses if facing voltage violence due to the transmission lines disconnection. Firstly, we have changing the reactive power and active power value of the microgrid one to know the its effect on the voltage, as we know the Moro bus face the voltage violence and its bus voltages is lower than the desired value, so we have to inject the reactive power and active power to the system in order to increase the voltage and bring it back to its desired value and put it in the desired value at its normal place, which is indicated by the system operator. In addition, this time for controlling the bus voltage of the Moro bus we have to vary the magnitude of the reactive power only and watch impact of the changing reactive power on the voltage violence and how the voltage is bringing back to its desired level. As we know by increasing reactive power in the power system the voltage of the system will increase and make the system more stable.

Moreover, the Lynn bus will face the voltage violence due to the line disconnection from the system and make this bus to suffer from the voltage violence and make the system unstable, as a result of this we have to decrease the reactive power from the system in order to fetch the voltage back to its desired place. Changing the value of the reactive power in the system will affect voltage in the system then to decrease the voltage of the system we have to absorb the reactive power from the system, and to compensate for the Lynn bus voltage which is greater than the desired value, so we have to absorb more reactive power from the system to bring this voltage back to its desired value. Firstly, we change the value of reactive power and active power of the microgrid two to control the voltage of this bus then we change only the value of the reactive power only.

In this thesis, also we calculate the system losses of our system and checking the overall system losses and try to decrease our power flow system loss and check how we can decrease our power flow system loss. By changing the value of the microgrids active power we can decrease the overall system losses, and every system is facing power losses due to many reason such transmission lines resistance and copper losses of the transformer. Firstly, we have changing the active power and reactive power of the microgrid one in order to decrease the system losses, and as we notice by injecting more active and reactive power to the system from microgrid one the system losses will decrease. Furthermore, we are changing only the active power of the system and we notice that the system losses will decrease with injecting more active power to the system, and putting in active power to the system it means that we increase apparent power in the system, so the system loss will decrease because the apparent power is the summation of the active and reactive power, and by increase active power means that we decrease the reactive power in the system, the angle between the voltage and current will be reduced and the power factor will increase and due to this formulation the power loss will decrease in the system .

Also the microgrids will changes the transmission lines power, which is transferred between the buses. By changing the active power of the microgrids, the power transferred by the transmission lines between busses will change due to the contribution of the microgrids. Firstly, we change the active power of the microgrid one on the Moro bus and we see the transferred power from the Moro bus and to the Moro bus changed which means that the power transferred by each transmission lines is changed also due to the microgrid one contribution. In addition, by changing the microgrid two active power, which is located on the Lynn bus, the power transferred from and to the Lynn buse will change which means that the power transferred by each transmission lines is changed due to the microgrid two contribution.

3.2 Limitations of the Microgrids

We decide as an operator the voltage of the desired buses should be between (0.98pu to 1.02pu), as a result of that we should keep the voltage between this level. Also the Microgrids have the limitation depend on their capability to inject and absorb the reactive power, so the limitation of MG1 ability is (20 MVAR to -60 MVAR), which means that we can absorb only the 15 MVAR from the network system because if we absorb more the voltage of this bus will be less than our limitation, so we should keep away from this, and also we can inject only the -55 MVAR from the network system because if we inject more the voltage of this bus will be more than our limitation, so we should keep away from this. The limitation of MG2 ability is (0 MVAR to 85 MVAR), which means that we cannot absorb less than the 8 MVAR from the network system because if we absorb less the voltage of this bus will be more than our limitation, so we should keep away from this, and also we can absorb only the 75 MVAR from the network system because if we absorb more the voltage of this bus will be less than our limitation, so we should keep away from this.

3.3 Per Unit

Per unit system means the mannar of the system magnitude according to the base value that we set previous and make the calculation easier because it reduces the very big value to a small value that we can deal with easily. In the power system we can use this per unit system for all variables such as voltage, current, etc and the base value will indicate accurately for the system variables. For example, for the base voltage we choose the rated voltage of the bus as the base value and the rated power as the base power in the system. Now, we define some formulas of the system:

For single phase

$$I_{base} = \frac{S_{base}}{V_{base}} = 1pu \tag{3.1}$$

$$Z_{base} = \frac{V_{base}}{I_{base}} = \frac{V_{base}^2}{I_{base}V_{base}} = \frac{V_{base}^2}{S_{base}} = 1pu \quad (3.2)$$

$$Y_{base} = \frac{1}{Z_{base}} = 1pu \quad (3.3)$$

For three phase

$$I_{base} = \frac{S_{base}}{V_{base}\, X\, \sqrt{3}} = 1pu \quad (3.4)$$

$$Z_{base} = \frac{V_{base}}{I_{base}\, X\, \sqrt{3}} = 1pu \quad (3.5)$$

$$Y_{base} = \frac{1}{Z_{base}} = 1pu \quad (3.6)$$

3.4 Why Injecting Active Power Decrease System Losses?

Every system has the power losses because of the resistance of the transmission line and transformer copper losses, and as we know by injection more active power to the system we see that the system losses will decrease because be injecting active power means that we increase the overall system apparent power. As we know the apparent power is consisting of active power and reactive power, so increasing active power more and more the angle between current and voltage will decrease and the $\cos\theta$ will increase this will decrease the overall system losses.

3.5 Power Flow Analysis

Power system usually include many generators, loads, transformer, which are connected by transmission lines together through the buses, and the power may include more than hundred buses or even more than thousands. If the number of the buses increase, solving the equation by manual will be tougher and need more time to solve. In the power system, power flow analysis is essential and substantial instrument, and the power system usually include many equations and solving this equation is very complex for manual solving and it take too much times to solve it, and all of the power flow equation is nonlinear, so we should use the computer base program to solve the equations such as MATLAB program (Dolan, 2013).

For calculating the power flow at any specific time, we should know the values of some variables such as bus voltage, generated voltage, and phase difference between these two voltages, and for computing this equation there are three techniques, which we can use to solve the power flow. At the beginning we have to assume some data in order to compute the voltage magnitude and if we find the difference between calculated value and assumed value then we have to calculate the another value and we use the calculated value as the input for this new value, and we have to calculate more value until we have the less divergence between the assumed amount and the generated value under the estimated value (Dolan, 2012).

3.6 Microgrid Synchronizations

Recently the world needs the energy with the high reliability, so we need the new ways to produce the electric energy such as renewable energies and distributed generations. Microgrids are the new idea that is used in the distribution system, and the microgrids consist of the different types of the distributed generation located at the same place. The microgrids can work in the two mode, which are independent mode and grid connected mode. To connected the microgrids to the grid system there are some condition that has to be done. Firstly, static switch has to do the phase estimation, and for the three phase system, static switch depend on the phase lock loop has been used for synchronizing the microgrid to the three phase systems. In addition, for the synchronizing microgrid with the power system phase angle estimation should be done by the static switch, then the synchronization will happen based on phase angle estimation, which is achieve by the phase lock loop.

In the static switch, phase lock loop does the phase detection, which is very important for synchronizing the microgrids to the main system, but for the tree phase system we use the special types of phase lock loop because it can find the phase angle of the tree phase voltage properly.

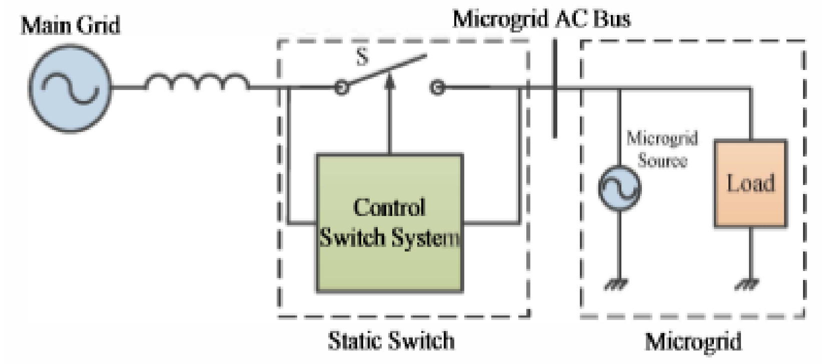

Figure 3.1: How MG connect to the main grid (Nakisa, 2014)

Static switch has the two states, the first one is connected state and the other one is disconnected state. When the phase angle of the microgrids and the system are the same the microgrid is connected to the main grid, and the best time for the linking between the microgrid and the power distribution system is the time in which current and the voltage fluctuation is the minimum (Nakisa, 2014).

CHAPTER 4

SIMULATION STUDIES AND DISCUSSIONS

4.1 Simulation Study

In this part we are going to talk about the simulation of the our which is done by the power world simulator.

In figure (4.1) we have a gird which is consist of 37 bus and two microgrids which is connected to the buses (MORO138, LYNN138).

As it obvious from the (figure 4.1) that we have a line disconnected which force the voltage on the bus (MORO138) to decrease below the desired value, which is (1pu). As a result, we have to bring back the voltage of this bus to its desired value, and we have the MG1 on this bus, which contribute to bring back the voltage to its desired value.

As it is clarified from the table (4.1) we see that how the MG contribute to maintain the voltage control by changing the value of reactive power and active power, but in the table (4.3), MG contribute to increase the value of the bus voltage by only changing the reactive power magnitude. By injecting the reactive power, the voltage will increase, which it means giving the reactive to the network from the microgrid. In the table (4.1), we can plot the relation between active power and reactive power, which could be found in the figure (4.2). The positive sign of the reactive power means that the MG will insert the reactive power to the network system, and the negative sign of the reactive power means that the MG will absorb the reactive power from the network system. The positive sign of the active power means that the MG will absorb the active power from the network system, and the negative sign of the reactive power means that the MG will inject the active power to the network system.

In addition, the line disconnects also make the voltage of the bus LYNN 138 to increase over the desired value, which is (1pu). As a result, we have to bring back the voltage of this bus to its desired value, and we have the MG2 on this bus, which contribute to bring back the voltage to its desired value, and will increase the overall system losses because also the MG will absorb the active power to the system.

Varying the value of the active and reactive power, we are going to control the voltage violence and show how the voltage is controlled. Firstly, the bus voltage is facing voltage violence and have the magnitude more than the desired value and by putting in more reactive power to power system we can reduces bus voltage magnitude and put it in the desired level which is indicated by the system operator. Moreover, we change the reactive power of system from the microgrid two which help to maintain the voltage in the desires level.

In this thesis, we use the 37 bus system power flow and this system is interconnected together well and this system is facing voltage violence in two buses due to the transmission line disconnect, so we have to bring back the voltage to the desired level by integrating multi-microgrids in this transmission system and see its effect on the voltage violence and the voltage of the system is (132kv) and (66kv) and the active power of the system is 800 (MW) and reactive power of the system is 200 (MVAR). In addition, we have to react to this voltage violence, which happened on the bus (MORO138 AND LYNN 138) due to the line disconnection, and we put two microgrids on this two bus, and this two microgrids contribute to solve the voltage violence problem by using reactive power management only. This power flow, which is a part of Sulaymaniyah city in Iraq, and in the Sulaymaniyah power system we have the feeder overload problem in the most of the system, as a result of this problem I suggested to my government to put the microgrids on the system to solve the feeder overload problem. In this system, we have nine power plant and some of them is big and the other is small to provide the load demand for the consumers and we have many transmission lines between the buses. Moreover, this system is need some power as a standby power or backup power to support the system at the load peak time.

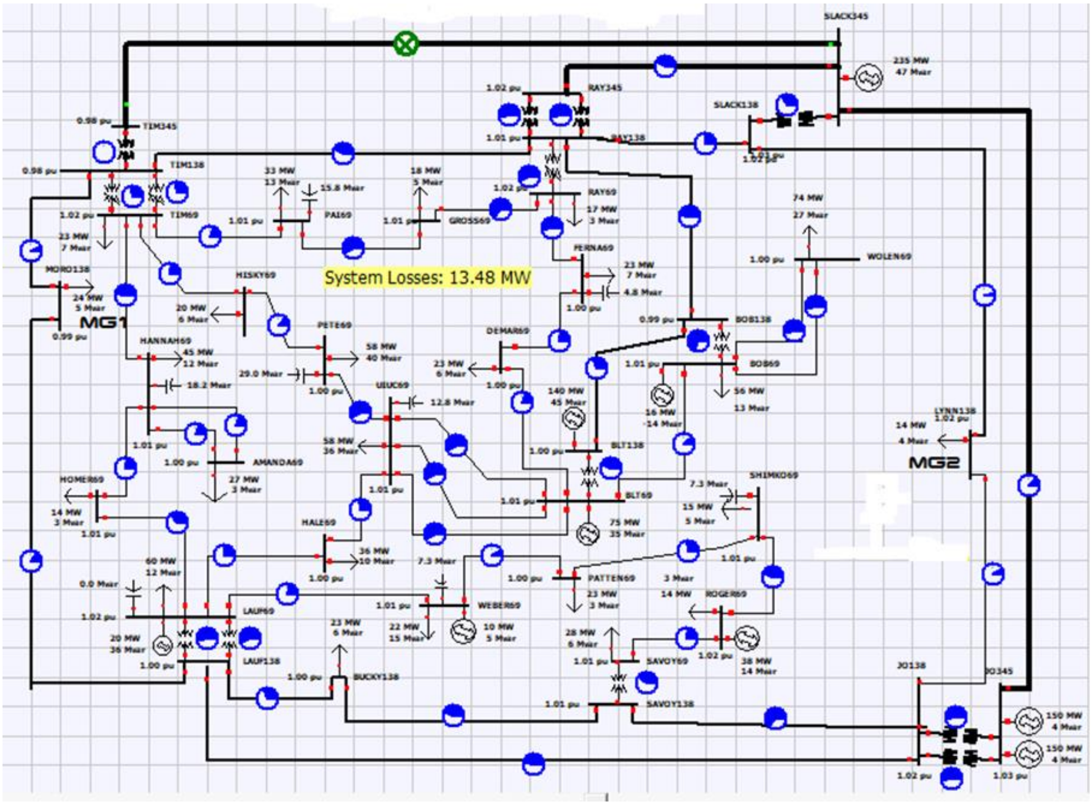

Figure 4.1: Power flow systems with two MGs

In this thesis we use the power world simulator to simulate and analyze how the microgrids can contribute in distribution grid to control the voltage and decrease the power losses. For this simulation we have two microgrids in our system which contribute to control the voltage in the busses, and the voltage of the busses have the voltage violence, one of them is facing the low voltage and the second bus will face the high voltage, and we have the microgrids in connection with those busses, so by the microgrid contribution we can control the voltage of the busses and bring them in desired voltage range which is decided by the system operators. In this section we are going to talk about the voltage control of the distribution system by using reactive power of microgrids and their impacts on the system and how the system will react to the microgrids contribution. In addition, by changing the values of the microgrids we will see that the system will directly react to the microgrid contributions, and now, we are concentrating on the microgrid contribution by changing the reactive power.

In the table (4.1), we see how by changing the value of the active and reactive power of the microgride number one, we can bring back the bus voltage to the desired level. In addition, as we see the bus voltage has the voltage violence and its voltage its less than the desired value, so we have by changing reactive power and active power to increase the voltage and we know that the reactive power is responsible for the voltage of the distribution system. As we can see from the table (4.1) injecting more reactive power to the system we can increase the voltage of the bus in this system.

Table 4.1: How MG1 contribute to increase voltage by changing P&Q

MG ON THE BUS MORO 138				
No.	P (MW)	Q (MVAR)	V (pu)	DEG
1	24	5	0.98423	-23.60
2	20	0	0.98663	-23.45
3	16	-5	0.98900	-23.31
4	12	-10	0.99137	-23.16
5	8	-15	0.99372	-23.02
6	4	-20	0.99941	-22.86
7	-5	-25	1.00212	-22.53
8	-15	-30	1.00485	-22.16
9	-25	-35	1.00755	-21.79
10	-32	-40	1.01335	-21.52
11	-38	-45	1.01575	-21.31
12	-44	-50	1.01812	-21.10
13	-49	-55	1.02040	-20.92

The figure (4.2) demonstrates the relation between the active power and reactive power of the microgrids one with a view to increase the bus voltage and bring it back to the desired level, this figure will show us that put in reactive power and active power to the system we can increase the voltage of the bus, and we can control the voltage of the bus and by injecting more reactive power and active power we can increase the voltage of the bus more.

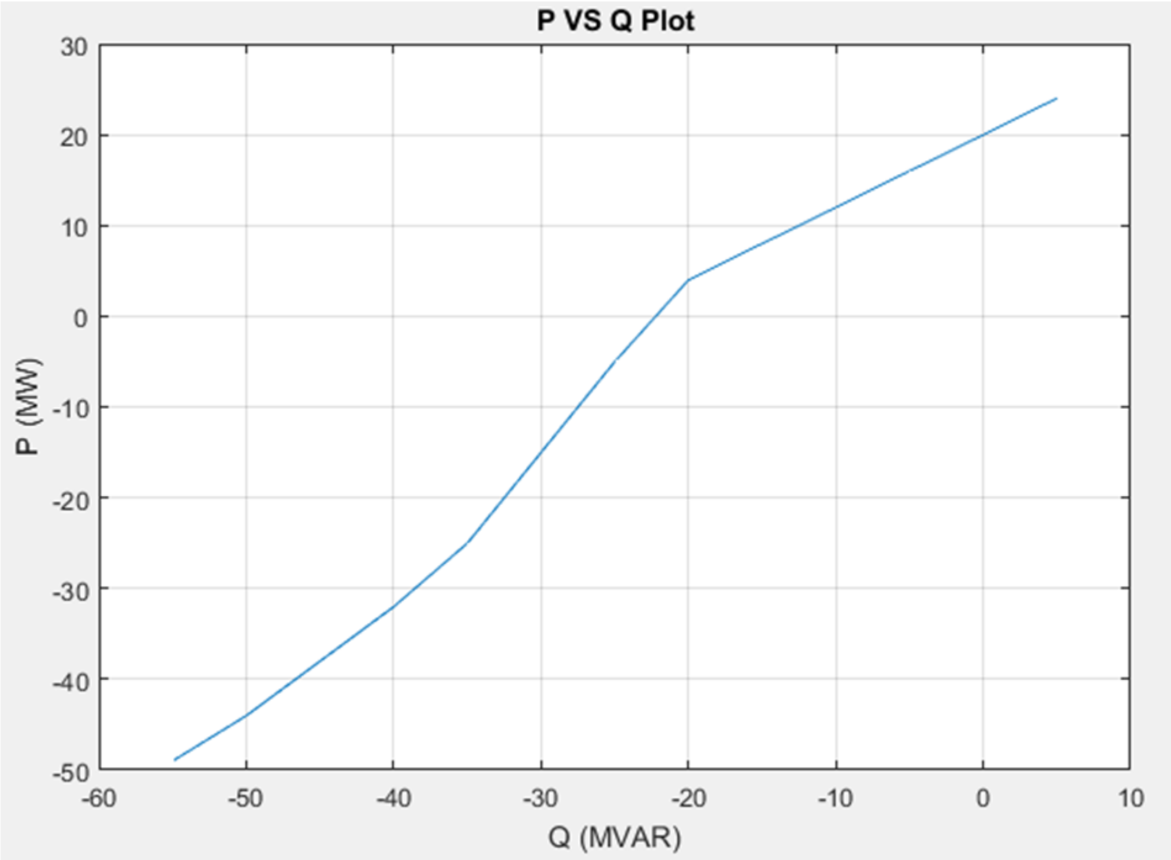

Figure 4.2: P vs Q plot

The bus voltage of the Lynn bus has a greater value than the normal value, and we have microgrid number two on this bus, so we have to decrease it. The table (4.2) describe our work how by absorbing more reactive power from the system the voltage will decrease and changing the reactive power magnitude have a good impact on the voltage value of the system, and in this system, we absorb the reactive power and inject active power to the system.

Table 4.2: How MG2 contribute to decrease voltage by changing P&Q

MG ON THE BUS LYNN 138				
No.	P (MW)	Q (MVAR)	V (pu)	DEG
1	14	4	1.02158	-16.87
2	11	9	1.01957	-16.76
3	4	14	1.01778	-16.54
4	-12	19	1.01641	-16.05
5	-19	24	1.01458	-15.83
6	-25	29	1.01265	-15.64
7	-30	34	1.01067	-15.47
8	-36	39	1.00872	-15.28
9	-41	44	1.00668	-15.12
10	-46	49	1.00463	-14.95
11	-55	59	1.00046	-14.64
12	-61	66	0.99746	-14.44
13	-66	70	0.99571	-14.27

The relation between active power of the microgrid two and reactive power pf the microgrid two is given by the figure (4.3). By inserting more active power to the system and absorbing more reactive power to the system we can reduce the bus voltage of the Lynn bus, and this bus voltage face voltage violence and have the higher voltage value, so we have to decrease it.

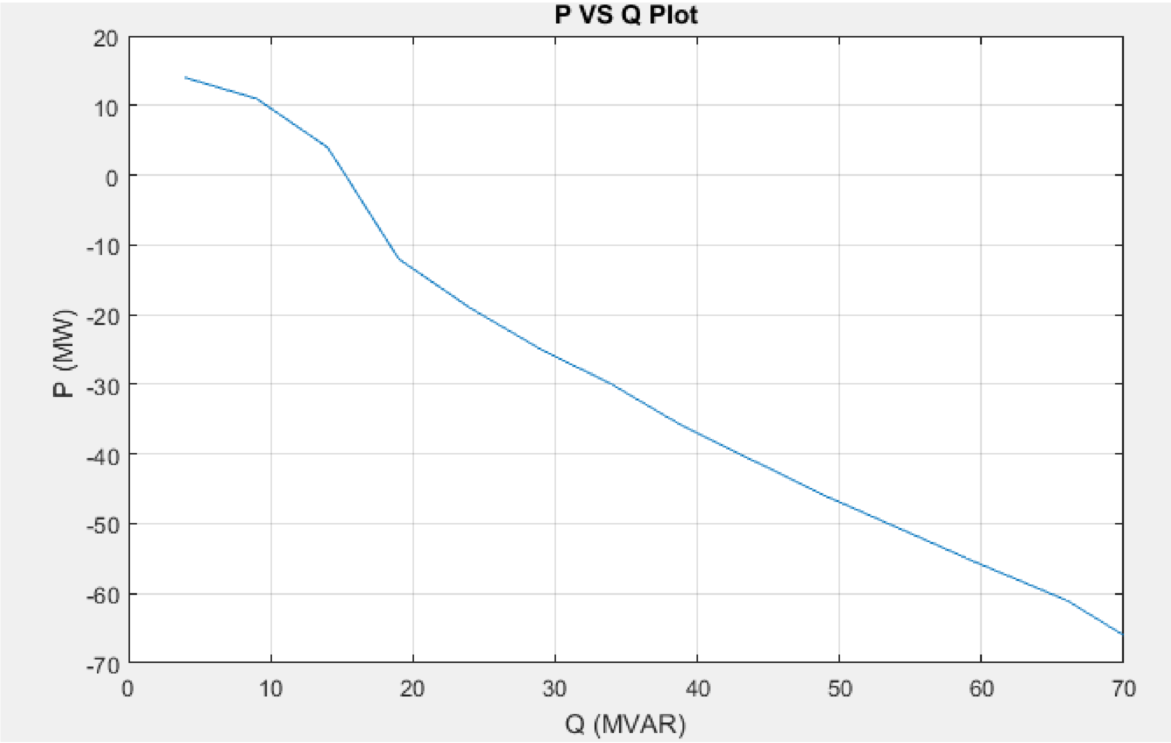

Figure 4.3: P vs Q plot

Table (4.3) defined the ways of improving bus voltage by injecting reactive power from the microgrid one to the system, and the data on the table shows that this bus voltage is less than desired, as a result by letting in more reactive power to the system and remain the active power as the same before the Moro bus voltage will increase slightly and by injecting more we can improve the bus voltage to the desired value.

Table 4.3: How MG1 contribute to increase voltage by changing only Q

MG ON THE BUS MORO 138				
No.	P (MW)	Q (MVAR)	V (pu)	DEG
1	24	5	0.98423	-23.60
2	24	0	0.98799	-23.60
3	24	-5	0.99006	-23.61
4	24	-10	0.99212	-23.62
5	24	-15	0.99417	-23.63
6	24	-20	0.99622	-23.65
7	24	-25	0.99825	-23.66
8	24	-30	1.00028	-23.67
9	24	-35	1.00230	-23.68
10	24	-40	1.00767	-23.67
11	24	-45	1.00967	-23.68
12	24	-50	1.01166	-23.69
13	24	-55	1.01365	-23.71

The data that we have in table (4.4) describe the system voltage situation which is unstable and higher than the common magnitude and in order to put it on the acceptable region we have to ingest more reactive power from the system by the microgrid one without changing the active power of the microgrid one. Absorbing reactive power reduce the bus voltage and positive sign of the reactive power means the absorbing and positive sign of the reactive power is injecting reactive power.

Table 4.4: How MG2 contribute to decrease voltage by changing only Q

MG ON THE BUS LYNN 138				
No.	P (MW)	Q (MVAR)	V (pu)	DEG
1	14	4	1.02158	-16.87
2	14	9	1.01940	-16.85
3	14	14	1.01721	-16.84
4	14	19	1.01501	-16.83
5	14	24	1.01279	-16.81
6	14	29	1.01057	-16.80
7	14	34	1.00834	-16.79
8	14	39	1.00608	-16.77
9	14	44	1.00380	-16.76
10	14	49	1.00151	-16.74
11	14	54	0.99921	-16.73
12	14	59	0.99691	-16.72
13	14	64	0.99458	-16.70

4.2 Calculating System Losses

In this section we can calculate the power losses of the system that we have and see how the microgrids can contribute to lowering power losses by injecting the active power to the system through the busses. As we know the active power is responsible to decrease the overall system power losses. As it is obviously shown from the table (4.5), we can easily see the contribution of the micrgrid1 on the MORO138 to decrease the overall system losses, and the system is interconnected well, so by injecting the active power to the bus we can decrease the value of overall system losses. In the table (4.6), we can see that we are changing either active and reactive power to decrease the overall system power losses, but we didn't see the significant change in comparison to the table (4.5), which in it we only change the value of the active power.

It's obvious from table (4.5), that microgrid one is contribute to decrease the overall system losses of the power flow, and as we know by injecting active power to the distribution system, the overall system losses will decrease because increasing active power in system means increasing of the apparent power of the system then this action will make the phase angle between voltage and current to decrease and the power factor will increase then the losses will decrease. As we see from the table injecting more active power to the system from the microgrid one will make the overall system losses to decrease more and more.

Table 4.5: MG1 contribution to decrease the system power losses by changing P

NO.	P (MG1) (MW)	system losses (MW)
1	0	13.48
2	5	13.29
3	10	13.11
4	15	12.92
5	20	12.75
6	25	12.57
7	30	12.41
8	35	12.25
9	40	12.09
10	45	11.94

The figure (4.4) will show the relationship between active power of the microgrid one and the overall system losses and by injecting active power to the distribution system, the overall system losses. We can draw the figure (4.4) from the data that we have from the table (4.5), and this figure will show us how injecting active power will decrease the system losses because increasing active power in system means increasing of the apparent power of the system then this action will make the phase angle between voltage and current to decrease and the power factor will increase then the losses will decrease.

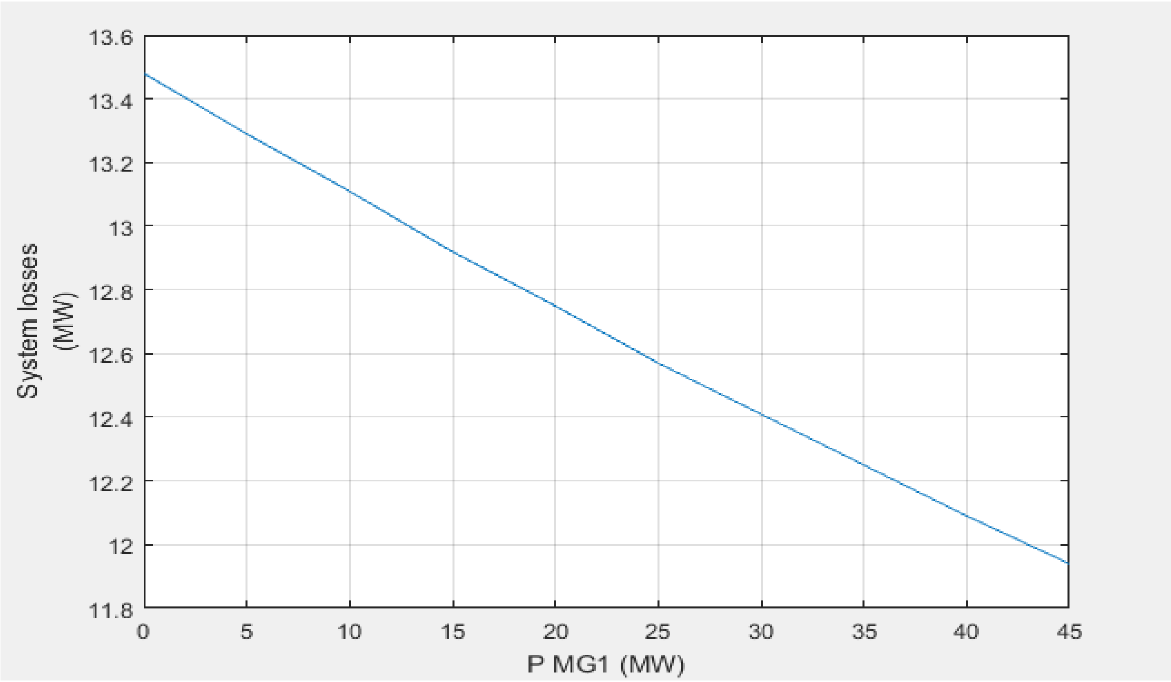

Figure 4.4: Changing P of MG1 to decrease the system losses

Injecting more active and reactive power from the microgrid one to the system will reduce the system power losses a few more than injecting reactive power alone, and the table (4.6) gives this information. Table (4.6) shows by injecting both active and reactive power from the microgrid one we can decrease the power system losses. Injecting more active power to the system means increasing apparent power and decreasing the angle between voltage and current as a result of this the system power loss will decrease.

Table 4.6: MG1 contribution to decrease the system power losses by changing P&Q

NO.	P (MG1) (MW)	Q (MG1) (MVAR)	system losses (MW)
1	0	0	13.48
2	5	5	13.29
3	10	10	13.09
4	15	15	12.90
5	20	20	12.72
6	25	25	12.55
7	30	30	12.39
8	35	35	12.12
9	40	40	11.98
10	45	45	11.84

System loss relation with the active and reactive power given by the figure (4.5), which represent the system reducing by injecting reactive and active power to the system by the microgrid one, and having microgrids in our system helps us to decrease the system losses by geberating more active power to the system from the microgrids. It is visibly notice from figure (4.5) that system losses will decrease by injective more active and reactive power to the system, and the X axis represent the active and reactive power and the Y axis represent the system loss.

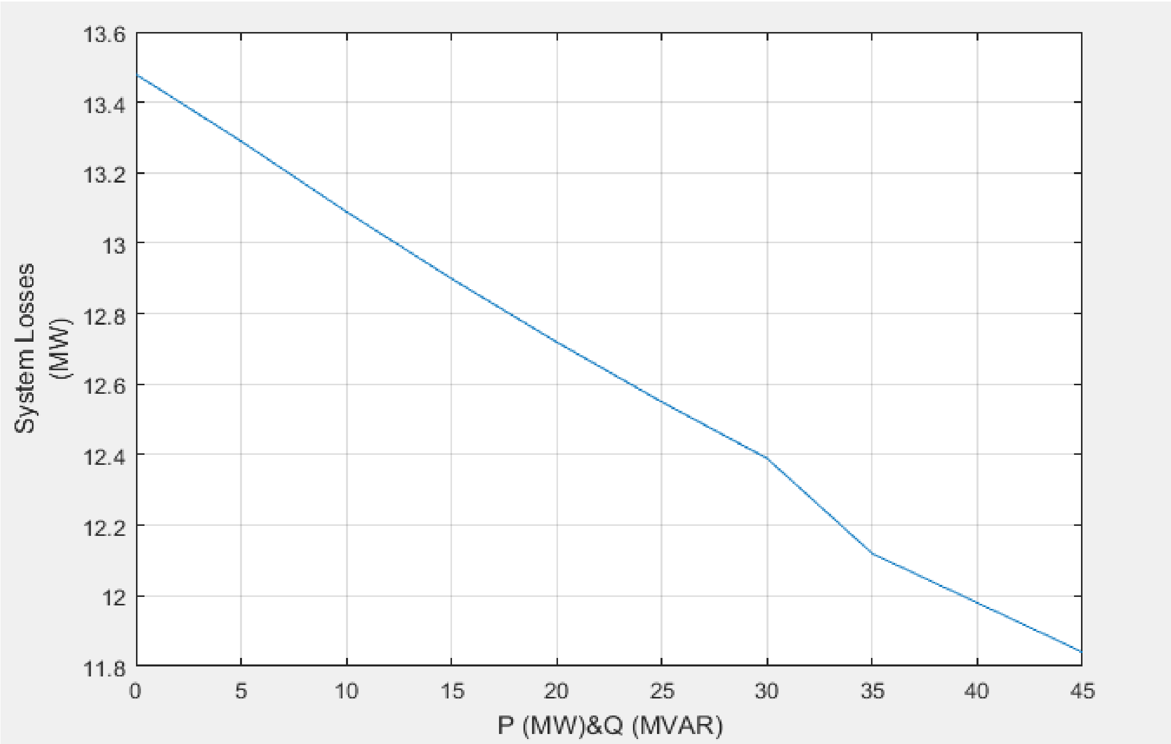

Figure 4.5: Changing P&Q of MG1 to decrease the system losses

4.3 Line Sharing

In this section, we are going to clarify how the MG contribution changes the power that transferred by each transmission between the desired bus and the other busses which connected to this bus, and the line sharing is very important for the system operators because the MG owner has to pay for using the transmission of the system to transfer its power, so the line sharing is the very important topic to study.

Table 4.7: Line Sharing Between Bus MORO138 and TIM138

Line Sharing Between Bus MORO138 and TIM138				
No.	Line power (MW)	Grid Power (MW)	MG Power (MW)	Difference (MW)
1	11	11	0	0
2	14.3	11	6	3.3
3	17.7	11	12	6.7
4	21	11	18	10
5	24.4	11	24	13.3
6	27.8	11	30	16.8
7	31.1	11	36	21.1
8	34.5	11	42	23.5

In the table (4.7) we see how the microgrid contribution will change the transmission line using by each buses, and there is a transmission line between the MORO138 bus and TIM 138 bus and as a result of the microgrid contribution the power that transferred by the transmission will change. In addition, by injectiong active power from the microgrids this transmission line will carry more power from the More bus to Tim bus, and the negative sign means that this transmission line will carry the power from the Moro bus to the Tim bus.

Table 4.8: Line sharing Between Bus MORO138 and LAUF138

Line sharing Between Bus MORO138 and LAUF138				
No.	Line Power (MW)	Grid Power (MW)	MG Power (MW)	Difference (MW)
1	-35	-35	0	0
2	-32.3	-35	6	2.7
3	-29.7	-35	12	5.3
4	-27	-35	18	8
5	-24.4	-35	24	10.6
6	-21.8	-35	30	13.2
7	-19.1	-35	36	15.9
8	-16.5	-35	42	18.5

Microgrid injection of the active power will change the line sharing of the transmission lines which is connected to the bus, so by injecting more active power from the microgrid one change the power that is transferred by the transmission line between Moro bus and Lauf bus, which is given by the table (4.8) because the Moro bus now inject active power to the system then it sends power by this transmission lines insread of getting power from this transmission line.

Table 4.9: Line sharing Between Bus SLACK138 and LYNN138

Line sharing Between Bus SLACK138 and LYNN138				
No.	Line Power (MW)	Grid Power (MW)	MG Power (MW)	Difference (MW)
1	2.2	2.2	0	0
2	-0.1	2.2	5	2.3
3	-2.4	2.2	10	4.6
4	-4.7	2.2	15	6.9
5	-7	2.2	20	9.2
6	-9.4	2.2	25	11.6
7	-11.7	2.2	30	13.9
8	-14	2.2	35	16.2

Microgrid two is located on the Lynn bus and changing active power of the microgrid two will affect the line sharing of connected transmission line to this bus, and from the table (4.9), transmission lines bring the power from the Slack bus to the Lynn bus, but when microgrid two start to inject active power to the system, then the transmission line tranfere power from the Lynn bus to the Slack bus as its seen from the sign of the line power.

Table 4.10: Line sharing Between Bus LYNN138 and JO138

Line sharing Between Bus LYNN138 and JO138				
No.	Line Power (MW)	Grid Power (MW)	MG Power (MW)	Difference (MW)
1	-11.6	-11.6	0	0
2	-9.1	-11.6	5	2.5
3	-6.4	-11.6	10	5.2
4	-3.7	-11.6	15	7.9
5	-1	-11.6	20	10.6
6	1.6	-11.6	25	13.2
7	4.3	-11.6	30	15.9
8	7	-11.6	35	18.6

Table (4.10) show the data of the line sharing between Lynn bus and Jo bus before and after injecting of the active power from the microgrid two. Injecting active power has impact on the line sharing and changes the value of the power that is transferred by the lines.As we see from the first reading when microgrid has no injection to the system then we transfer 11.6 MW from the Jo bus to the Lynn, but we the microgrid two stsrted o inject active power the transferred power from the Jo bus to the Lynn decreased until the power is transferred from the Lynn bus to the Jo bus.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main aim of this work is to show how the MG contribute to hold the voltage by only changing the reactive power. MG is the localized energy which can be connected to the network or work individually, and by integrating the MG to the system will change the system from unidirectional system to bidirectional system. Distributed generation is the recent technologies, which have a very good performance and efficiency, and also help in decreasing the energy price because from this sources we can give the energy to the system. As it shown in the power flow configuration by disconnecting lines from the power grid how the voltage of some buses will be affected directly and reduce its voltage value to below or over the desired value which is not to the overall system, and the system have to react to this undesirable condition. If we have the microgrids on this buses, we can react through the microgrids to control the voltage and keep it in desired level, which is decide by the operator of the system. Moreover, the consequence of this line, which disconnected from the network system will make some buses voltage to increase over the desired value and the other to decrease to below the desired value. As a result of that the MG has to contribute to make the bus voltage to be in desired value, which decide by the operator. The MG have to insert the reactive power to increment the voltage of the buses which is fallen to of the desired value and absorb reactive power from the grid system to decrease the voltage of the buses, which is over the desired value. In conclusion, MG is the essential part in the recent network system because MG will change the network system from unidirectional system to bidirectional system.

5.2 Recommendations

From the previous few decades until now, the distribution grid was unidirectional, which it means that only we take the reactive or active power from the power grid systems, and there was a big issue that have to be solved. But now there is a new concept of the distribution grid, which is integrated the microgrids to it. The microgrid will make the system to be bidirectional, which is mean now we can insert or soak up the active power and reactive power to the system and put in or imbibe the active power and reactive power from the power grid, and one of the big issues of distribution grid that is a voltage control can be solved by the microgrid integration to the system. We strongly recommend that the microgrid should connect to the distribution network to have a better voltage and saving money and have a less greenhouse gases.

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