UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUE OF SCIENCE AND TECHNOLOGY

VERIFICATION AND MODIFICATION OF AN OPTIMAL PLACEMENT AND SIZING METHOD TO IMPROVE THE VOLTAGE STABILITY MARGIN IN DISTRIBUTION SYSTEM USING DISTRIBUTED GENERATION

MASTER THESIS

Layth Faeq KAMAL

The Department of Electrical and Electronic Engineering

The Program of Electrical and Electronic Engineering

DECEMBER 2017

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Layth Faeq Kamal, having student number 1406030025 and enrolled in the Master Program at the Institute of Science and Technology at the University of Turkish Aeronautical Association, after meeting all of the required conditions contained in the related regulations, has successfully accomplished, in front of the jury, the presentation of the thesis prepared with the title of "Verification and Modification of on Optimal Placement and Sizing Method to Improve the Voltage Stability Margin in Distribution System Using Distributed Generation"

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UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUE OF SCIENCE AND TECHNOLOGY

I hereby declare that all the information in this study I presented as my Master's Thesis, called: “Verification and Modification of on Optimal Placement and Sizing Method to Improve The Voltage Stability Margin in Distribution System Using Distributed Generation” has been present in accordance with the academic rules and ethical conduct. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

04.12. 2017
Layth Faeq Kamal

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In the name of ALLAH, the most Gracious, the Most Merciful for giving me the strength to complete this work in its final form. My Lord mercy and peace be upon our leader MOHAMMED peace be upon on him, who invites us to science and wisdom, and members of his family and his followers.

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ABBREVIATIONS AND NOMENCLATURE

DG	:	Distributed generation
VSM	:	Voltage stability margin
PF	:	Power flow
GA	:	Genetic algorithm
PMSM	:	Perpetual magnet synchronous machine
MTG	:	Micro-turbine generation
VSI	:	Voltage source inverter
PWM	:	Pulse width modulation
PCC	:	Common connection point
VSC	:	Voltage source convert
GS	:	Gauss Seidel
RDS	:	Radial distribution system
PU	:	Per unit values
FSWT	:	Fixed speed wind turbines
VSWT	:	Variable speed wind turbines
PVs	:	Photovoltaic system
RES	:	Electrical power storage
OLTC	:	On-Load Tap Changer
CB	:	Capacitors Banking
DC	:	Direct Current
AC	:	Alternating Current
CF	:	Capacity Factor
DER	:	Distributed Energy Resources
CHP	:	Combined heat and power
BSA	:	Backtracking search algorithm
RLF	:	Repeated load flow
PSO	:	Particle swarm optimization
FVSI	:	Fast voltage stability indicator

ABSTRACT

VERIFICATION AND MODIFICATION OF AN OPTIMAL PLACEMENT AND SIZING METHOD TO IMPROVE THE VOLTAGE STABILITY MARGIN IN DISTRIBUTION SYSTEM USING DISTRIBUTED GENERATION

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Recently, high penetration levels are used in distribution networks by the integration of distributed generation (DG) units. These high penetration levels have significant impact on improving the voltage stability margin (VSM) and decreasing the power losses. Interest in Distributed Generation (DG) in power system networks has been growing rapidly. This increase can be explained by factors such as environmental concerns, the restructuring of electricity businesses, and the development of technologies for small-scale power generation. DG units are typically connected so as to work in parallel with the utility grid; however, with the increased penetration level of these units and the advancements in unit's control techniques, there is a great possibility for these units to be operated in an autonomous mode known as a micro grid.

Integrating DG units in the distribution system causes several effects on power flow, power quality, reliability, protection and voltage stability margin. In fact, distribution systems typically don't have problems with stability because all real/reactive powers are guaranteed through substations. The utilization of modern optimization techniques aims to maintain the VSM and enhance power losses within an appropriate boundary. The aim of this thesis is to suggest a theory for determining the placement and size of DG units by using the genetic algorithm (GA) in order to improve the VSM in addition to minimize power losses through penetration level to the system that consists of 41-node radial distribution system which is used to display the performance of the proposed method at different levels.

Key Words: distributed generation; voltage stability margin; power flow; Genetic algorithm; optimal placement; voltage collapse.

ÖZET

DAĞITILMIŞ ÜRETİM KULLANILARAK DAĞITIM SİSTEMİ İÇERİSİNDEKİ GERİLİM DENGELEME SINIRINI GELİŞTİRMEK İÇİN EN UYGUN YERLEŞTİRME VE BOYUTLANDIRMA YÖNTEMİNİN DOĞRULAMASI VE MODİFİKASYONU

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Son yıllarda, dağıtılmış üretim (DG) birimlerinin birleştirilmesi ile yüksek giriş seviyeleri dağıtım ağlarında kullanılmaya başlamıştır. Bu yüksek giriş seviyeleri, gerilim kararlılığı marjını (VSM) geliştirmek ve güç kayıplarını azaltmak üzerinde önemli etkilere sahiptir. Güç sistemi ağlarında Dağıtılmış Üretime (DG) olan ilgi hızlı bir şekilde artmaktadır. Bu artış çevresel kaygılar, elektrik şirketlerinin yeniden yapılandırılması ve küçük ölçekli enerji üretimi için teknolojilerin geliştirilmesi gibi faktörler ile açıklanabilir. Dağıtılmış Üretim (DG) üniteleri tipik olarak tesisat şebekesi ile paralel olacak şekilde bağlanmaktadır; ancak, bu ünitelerin artan giriş seviyeleri ve ünitenin kontrol tekniklerindeki ilerlemeler ile, bu ünitelerin mikro şebeke olarak bilinen otonom modda çalışmaları için yüksek bir olasılık ortaya çıkmaktadır.

DG ünitelerinin dağıtım sistemine entegre edilmesi güç akışı, güç kalitesi, güvenilirlik, koruma ve gerilim kararlılığı marjı üzerinde çeşitli etkilere neden olacaktır. Aslında, dağıtım sistemleri tipik olarak kararlılık ile ilgili sorun yaratmazlar çünkü bütün gerçek/reaktif güçler yardımcı istasyonlar vasıtasıyla güvence altına alınırlar. Modern optimizasyon tekniklerinin kullanılması, VSM'yi korumayı ve güç kayıplarını uygun bir sınır dahilinde güçlendirmeyi amaçlamaktadır. Bu tezin amacı güç kayıplarını en aza indirgemenin yanı sıra gerilim kararlılığı marjını geliştirmek için genetik algoritmayı (GA) kullanarak, farklı seviyelerde önerilen yöntemin performansını göstermek için kullanılan 41 düğümlü radyal dağıtım sisteminden oluşan sisteme giriş seviyesi üzerinden DG ünitelerinin yerleştirilme ve boyutlarını belirlemek için bir teori önermektir.

Anahtar Kelimeler: dağıtılmış üretim; gerilim kararlılık marjı; güç akışı; Genetik Algoritma; en uygun yerleştirme; voltaj çökmesi.

CHAPTER ONE

INTRODUCTION

1.1 Presentation of The Work

In this work first, the method used and the result obtained in a previous work [1] about the optimal placement and sizing of the distributed generation to improve the voltage stability margin and reduce the power losses in a distribution system are examined and verified. The second part of this work deals with the addition of a modification to the method used to obtain the best results through the use of high penetration levels up to 75% of the total load. The system used consists of a 41 node-radial grid as a means to benefit from its results on the real practice. Distributed generation constitutes an approach that employs small-scale technologies to produce electricity close to the end users of power and often consist of modular and sometimes renewable-energy generators and they offer a number of potential benefits. In many cases, distributed generation can provide lower-cost electricity and higher power reliability and security with fewer environmental consequences than can traditional power generation. At the beginning, the study included demonstration the distributed generation definitions, their characteristics and different types which have been developed to enhance the voltage stability in the distribution system. After that, the problem and motivation are defined in this work in order to solve the matters when occurring in the electrical network resulting of installation of the generation units away from the consumer. The approach followed in this research is a high penetration level of the load in the power system. The main objective of this work is to improve the voltages stability margin in the power distribution network and adopted the allocation of distributed generation base on the best location optimization method (Genetic Algorithm), ultimately a proper allocation and sizing are lead to reduce the power losses of radial power distribution system.

The results indicate that using the penetration level in the system at 75% of total load give the best values which must be installed to improve the voltage stability margin and reduce the power losses. Moreover, ensuring economical and effective performance in the radial distribution system.

1.2 Overview of Power System

The electric power system consists of units for electricity production, devices that make use of the electricity and a power grid that connects them. The aim of power grid is to enable the transport of electrical energy from the production to the consumption, while maintaining an acceptable reliability and voltage quality for all customers (producers and consumers). These technologies are expected great benefit in terms of providing higher electrical power, energy reliability and environment-friendly and the most important benefit is a less expensive compared to the system that uses the distributed generation classical [1]. In contrast to the use of a few large-scale generating stations located far from load centers, the approach used in the traditional electric power paradigm. DG systems employ numerous, but small plants and can provide power onsite with little reliance on the distribution and transmission grid [2]. DG technologies yield power in limits that range from a small amount of a kilowatt [kW] to about 100 megawatts [MW]. Utility-scale generation units produce power in limits that frequently reach beyond 1,000 MW. The DG happens on two levels: the local level and the end-point level. local-level power generation plants often contain renewable energy technologies that are site particular, for example, wind turbines, geothermal energy production, solar system (photovoltaic and combustion), and some hydrothermal plants [3]. These plants have a tendency to be littler and less centralized than the conventional model plants. They additionally are oftentimes more energy and cost productive and more reliable. Since these local level DG producers often take into account the local context, they usually produce less environmentally damaging or disrupting energy than the larger central model plants. Phosphorus fuel cells produce a substitutional way to a DG technology. These are not as environmentally dependent on as the before mentioned technologies. These fuel cells can provide energy through a chemical process rather than a combustion process. This process creates few particulate waste [4]. The single power user can practice a large number of certain itself techniques together comparable results. A lot of time used by end-point consumers is the internal combustion engine unit. These internal combustion engines units can be employed to reinforcement RVs and places. As several of these well-known examples show DG technologies can work as isolated "islands" of electric power production or they can assist as small contributors to the power networkclients whose support this idea indicated to DG power to enhance an effectiveness to producing electricity [5]. The electric power from the generation station to client dissipates around (4.2% to 8.9%) from the energy as result of ageing transmission facilities, maladjusted implementation of reliability guidelines, and developing overcrowding. customers suffer from deteriorating power quality result voltage variations or power flow because of the diversity of factors, including weak converting processes in the power system. The place power use tools produce to shopper the inexpensive energy for a high-quality level. Also, possessor who produces energy regionally can probably to sell excess energy to the network [6].

1.3 Distributed Generation

1.3.1 The Importance of Distrubuted Generation and its Applications

Distributed generation technologies offer significant benefits that are most reliable especially for industrial plants that require continuous power service. The power shutdown and problems of quality disturbances cost American companies about 119 billion a year according to the Electrical Power Research Institute [7]. For this reason, some companies have installed distributed generation plants to ensure alternative energy to provide potential improvement and to enhance energy transmission. In addition, to reducing energy demand during the peak period and working to reduce overcrowding on the electrical grid. As a result of the construction of central power plants far from the load centers, DG units have delayed the modernization and additions to the network for a large number of these stations that use still restricted. Environmentalists and academics suggest that DG technologies can produce extra features to the community because of centralized power plants emit important large quantities of gases [8]. The Environmental Protection Agency. long time ago, mentioned the relationship between high levels of sulphur oxide emissions and the production of acid rain. Late studies have been proveded that point out the use of DG technologies significantly minimizes emissions: British reports evaluated that mixed heat and power technologies lowered carbon dioxide emissions by 41% in 2009. DG technologies remain independent of the network, they can present emergency power for a big number of public services, such as hospitals, airports, communications stations. Finally, the participation in the generation of electricity from several sources working on the recovery of the economy from the problems of prices and frequent interruptions in addition to the large losses of fuel.

1.3.2 Motivation

It is essential that the power system operators have sufficient knowledge to operate a state of equilibrium in the electricity generation and demand because the generated electrical energy is consumed at the same moment because it cannot be saved efficiently and in large quantities. Even though, the radial design of distribution system with the integration of distributed generation at the level was not considered in the design. This is due to serious fear entertained by the energy system operatives that safety and specificity of the network may be altered or not guaranteed. This makes the coordination of the integration of DGs essential to meet the system technical and economical demand by optimally placing and sizing DGs. Optimal allocation and sizing find a major application in this regard using algorithms for decision making.

1.3.3 Problem Definition

The efficiency and performance of power system while generation and distribution process are comprised a serious issue that makes many researchers study of these systems and suggests of many alternatives. The load increment by the time makes power network performance tends to critical. This performance is directly affected by the present of Watt power losses (real power) in a large amount as well as the present of high voltage profile degradation. Many types of research have been presented in this chapter for addressing this problem and making the power system more balanced according to the literature the most issues were faced by the researchers are the best place (point) to insert the DG into the mother network and also the size of that generator. The performance of power system will vary before and after the using of distributed generators. It is important to solve this issue by understanding the changes in the system after inserting the model.

1.4 Literature Survey

Once the demand is getting increased within power system, the necessity for developing a new technology becomes important to meet these rapid changes. The demand is recently expanded as the power systems extended and propagated to remote lands as well as the rapid revolution in the technology and electrical applications is dramatically widened. The distributed generators are one alternative to support the power grid. In order to demonstrate this technology, it is important to track the same over the previous years within their timeline. Following are the latest researches and studies in this regard:

In [1] the authors have dealt with distribution generator from the financial vision, hence they have characterized DG size and as smaller entity power generator as compared to the major plant. It is creating the amount of power in the range of 40 megaWatt and interconnected with main power system at a closer point to the consumers to bolster the mother power system.

In [2] the researcher defines distributed generation as “a small source of electric power generation or storage (typically ranging from less than a kW to tens of MW) that is not a part of a large central power system and is located close to the load.” It included the storage facilities in his definition.

In [3] author defines a distributed generation source as “an electric power generation source connected directly to the distribution network or on the customer side of the meter.” this definition is the most generic one because there is no limit of the size and capacity for the DG. The definition covers the location of the DG. Distributed generation is considered as an electrical source connected to the power system, at a point very close to/or at a consumer´s site, which is small enough compared with the concentrated power plants. As any other system, distribution generator is found with many technologies in the coming section the most of this techniques are being reviewed.

In [4] this research presents modeling and performance analysis of MTG system in grid connected and islanding modes of operation. The model developed in this work incorporates the individual components of prime mover like compressor, heat exchanger, burner, and turbine. The model of MTG system contains micro-turbine, perpetual magnet synchronous machine (PMSM) and power electronics interfacing circuit for generation and discussion from AC/DC/AC respectively. The MTG system uses a DC link voltage to control the micro turbine output power by fuel and air flow control methodology. The DC link power is delivered to the load through a voltage source inverter (VSI) with pulse width modulation (PWM) technique. The model simulation result shows the load following the performance of MTG system for various loads.

In [5]; the current trend towards miniaturization, portability and ubiquitous intelligence has led to the effective utilization of energy resources. The significance of Micro-turbine technology is increasing widely as energy sources have created major difficulties for the electrical business. Accordingly, MTG provides many benefits over conventional turbines, for example, high operating efficiency, ultra-low emission levels, low initial cost and small size. The integration of the increasing portion of MTG within the existing infrastructure requires a full understanding of its impact on the distribution network and its interaction with the loads and its location. This study combines designing and simulated of MTG system. Different research issues related to MTG size, location, operation, model, and applications have been discussed. Also, the model demonstrates the developed result along with the execution of the system.

In [6]; distributed generation is installed by a customer or independent electricity producer that is connected at the distribution system level of the electric grid. Distributed generation installed at sites possessed and worked by utility customers, for instance, micro turbine generator (MTG) serving a house or a co-generation facility serving an office. This exploration displays the insertion of modeling of the micro-turbine generator in distributed generation for grid connection and islanding operation. The presented study permits the power flow in both the directions that is in between grid and MTG. The control connection strategies are also offered during details.

In [7]; within hybrid energy system including renewable sources of energy, there has to be some storage facility to keep a continuity of supply to the load when renewable source alone is not adequate. The objective of this research is to present one of such generating system that is able to act as a reserve generator. This research presents the modeling and simulation of a micro turbine generation system, the nonrenewable source of energy appropriate for isolated thus grid-connected operation.

In [8]; the distributed generation based on micro-turbine technology is new and a fast increasing. These DG systems are quickly converting an energy administration solution that saves money, resources and the environment in one compact and capability package be it fixed or mobile, remote or interconnected with the utility network. In this study, the MTG system model appropriated for the network has been presented. The detailed modeling of a single-shaft MTG system suitable for network link has been developed in Simulink of the matlab. The three phase PLL construction represented in this research utilizes only positive sequence element of the voltage. Thus, gives an exact evaluation of the phase angle even under network disturbance situations. A seamless transfer design for MTG system operation between networks joined has been proposed. The exposed automatic mode exchanging system helps in providing continuous power supply to the consumer even during blackouts of the utility and is simple to implement without any additional hardware. The model displays excellent execution in both networks joined. Therefore, the improved model of MTG system will be utilized as a tool appropriate for studying and for performing accurate analysis of most electrical phenomena that happen when a micro turbine is attached to the network.

In [9]; to conquer the disadvantages of centralized generation, to enhance the quality of life and to minimize the gap between power request and supply, has become important to make use of available distributed generation because reduction in transmission loss as availability near to end clients, load sharing property and provides dependable and better quality of power. Among the different Distributed Energy Resources (DER), the micro turbine generation (MTG) has a good record of improving efficiency, system stability, reliability and power quality of network when operated in combined heat and power (CHP) mode with low emissions. This research explains the modeling and performance analysis MTG system when connected to load and grid under normal conditions, such that generated power should dynamically follow the power demand without wastage of power and no damage to the generating units.

In [10]; in this research, a solid oxide fuel cell for distribution generation application is introduced. The mathematical modeling of the fuel cell is studied and simulation study of the interfacing power electronics converters is done in this study. The physical model of fuel cell stack and power conditioning units are described also. The control design methodology for every component of the proposed system is also depicted. A MATLAB/Simulink simulation model is developed for the SOFC-DG system by consolidating the individual component models and the controllers designed for the power conditioning units. Simulation results are presented to demonstrate the general system performance including the real and reactive power compensation capability of the distribution system.

In [11]; the increments in power demand and limitation of transmission capacities have led to strong concern among electrical power industrials. This research presents a method to identify optimal DG location based on maximum power stability index while minimization of real power loss and also DG cost is considered in optimizing the DG size. A new developmental algorithm known as backtracking search algorithm (BSA) is selected in solving the optimization problem. The applicability of proposed method is verified utilizing the 30-bus distribution network.

In [12]; the integration of distributed generation in distribution systems places an important role for obtaining voltage stability margin and less power loss in the system. In this exploration, the results of 33, 41 and 69 bus radial distributed systems utilizing algorithms MINLP and BFO were obtained. This study involved method by test using the 33, 41and 69- bus systems. It can be reasoned from the above case studies the placement of the DG has the strong impact on the power loss and on the voltage profile of the system. Voltage sensitivity is the method used for selecting candidate buses for the purpose of integrating DG units. Research has been shown the voltage is clearly affected by the size and location of these units. There are many theories that are applied in order to determine the optimal locations and sizes DG units which achieve all the required goals.

In [13]; the increasing electricity demands, environmental concerns, and hike in fuel prices are the main factors which motivate the use of renewable energy in India. This study includes the study of combined biomass, biogas and solar hybrid system for generation of electric power. This system will help to conquer from global warming effect and the statistical effect on prosperity and reliance. In the hybrid system energy has a more consistency, can be cost effective and furthermore enhances services. Hybrid power system is to expand the system efficiency and the use of renewable energy based hybrid power system to meet the maintained load demands, diverse renewable energy sources require to be integrated. In this work, we will integrate biomass, biogas, and solar energy for generation of electricity, the composite delivered will be less and cost per unit of electricity created will be less relatively. The photovoltaic energy without cost, the installation cost of solar power plant is high however its operating cost is practically negligible. This research discusses the renewable biomass, biogas and solar PV combined power generation system in the village to conquer those issues which happened when they operate standalone.

In [14]; the modern power system introduces a new (DG) technology in restructured power system. It plays a vital part in the distribution system and participates in the market to provide ancillary services. The small power generation technologies are integrated into distribution system to compensate the load demand. In this manner, optimal (DG) installation must be found before its integration. In this study, distribution system load flow is performed using repeated load flow (RLF). These techniques are utilized to discover the optimal location and sizing of DG in distribution network which minimizes the power loss. The line loss reduction index (LRII) is also described which helps in lowering the power loss with the assistance of DG. With both techniques, the optimal location is bus-9 leads to a reduction in power loss up to 43.36% with RLF and 43.44% with PSO. These results are obtained using MATLAB and are found to be nurturing. The installation of DG unit in distribution system provides a higher power quality in an electrical distribution system.

In [15]; distributed generator (DG) is now commonly used in the distribution system to reduce the losses and enhance level energy and reliability network. The main undertaking of connecting DG is to recognize their optimal placement, also quantities energy produced. By considering this objective, a hybrid technique utilizing Genetic algorithm and Neural-network is proposed in this research. By placing DG at the optimal location and by evaluating generating power based on the load requirement then the number of generators in the network increases and so that different generator states are possible for a particular load condition. Reliability is an old concept and a new discipline. The LOLP and EENS evaluations are based on peak load consideration with load model is considered as a straight line. The probability of load surpassing the producing capacity has also been considered in LOLP evaluation. The proposed technique is tested on IEEE 30 bus system, by connecting appropriate size of DG at the optimal location of the system. The outcomes demonstrated a considerable reduction in the total power loss in the system, enhanced voltage profiles of all the buses and reliability parameters.

In [16]; the voltage stability issue is happening while raising the loading parameters on power system network buses. One of the reasons for growing the loading parameter is exhaustion of reactive power. The distributed generator has the ability for absorbing and injecting both active and reactive power in the distribution grid and so many other features from DG unit. By putting the DG in the system on the right bus, there would exchange the voltage stability margin and voltage profile in every load bus. Continuation power flow method is used and obtains the more sensitive bus for voltage deterioration by the help of PV bend. IEEE 14 bus system is employed for study and analysis in MATLAB toolbox PSAT.

In [17]; the use of renewable energy on the basis of distributed generation has an important advantage compared to conventional systems. The major aim of sites these units near from customers is to provide stability in the system including voltage, power loss and reliability. Therefore, the best locations and sizes of these units should be chosen so that all constraints must be observed and cannot be exceeded. The voltage stability margin is significantly affected by the integration of DG units. Therefore, this stability in voltage is of great importance to the quality of the power system. In this research, the theory of the modified voltage indicator was selected in order to select the best positions and sizes for the DG units. The purpose of this technique is to improve the voltage and reduce the loss of power. The study of the nature of the relationship between load and generation by selecting buses that are nominated and which are characterized by high sensitivity to the effort to install units of renewable energies. The applicable constraints are considered the limits of the penetration level of these units, the feeder capacity and the voltage of the system.

In [18]; Compared to previous years, distributed generation has been increasing, especially in distribution networks. The high demand for energy is the main cause of this growth in addition to exceeding all constraints on the power system with unlock of overcrowding on the distribution network. Putting DG units in the right places with their optimal sizes makes them very interesting. These things made the system enjoy better performance than before it was put DG units and worked to reduce the resulting losses and energy loss and improve the voltage level. This research provides an overview of DG the possibility of placing these units in the best locations and sizes, in addition to explaining all the obstacles and difficulties faced by these units.

In [19]; between transmission systems and distribution systems may occur several phenomena, including voltage instability. The result of this instability is the result of increasing and sudden loads on the electrical grid. The voltage instability in the distribution networks leads to the collapse of the electrical system and thus produces a general shutdown in all areas. Recently, the integration of distributed generation into distribution networks has led to high penetration levels. This penetration has a number of effects on some things, including load flow and voltage profile stability. This study discussed static voltage stability through the performance of the 15-bus distribution system by using a fast voltage stability indicator (FVSI) with loads and a different penetration level. Wind turbines and photovoltaic have been used in this work.

In [20]; based on two strategies of examination, power loss and weakest voltage buses and lines are calculated and then the optimal size of distributed generation is resolved. After that, by considering the minimum power losses and the maximization of voltage stability, the proposed index determines and ranks positions to decide the optimally distributed generation location in the system. This method allows us to find the best places and size to connect a number of distributed generation units by optimizing the objective functions. The simulation results were gotten utilizing a 33-bus radial distribution system to decide the location and size of the distributed generation units. The results show the effectiveness of voltage profile improvement, loading factor improvement, and power loss reduction. Further, the problems of a single objective function and the placement of the distributed generation unit using analytical methods have solved this approach.

In [21]; the researcher presents a method using particle swarm optimization (PSO). A simple and effective cumulative performance index, using voltage profile improvement, loss decrease, and voltage stability index (VSI) improvement is considered in this work. The system loss is minimized utilizing PSO considering steady power also voltage dependent load models. The three strategy results are compared with the traditional optimization strategies.

In [22]; the integration of distribution generators into the power system has been steadily increasing to high penetration levels. Therefore, this penetration has a significant impact on both the voltage profile and power losses in distribution systems. The techniques used for the purpose of improvement are tools capable of finding the locations of those (DGs) units in the power system. The objective is to select the optimal location and sizes of those units within specific limitations and constraints. This research is based on a study to find a method to select the best locations and sizes for (DGs) units. This system consists of 41 buses was used and the selection theory of the buses to which the candidates in order to install units in the power system. This process is carried out by (mixed-integer nonlinear programming) with the inclusion of objective function whose purpose is to improve the voltage by placing limits for the voltage of the system and the penetration level (DG).

In [23]; In this research, several objectives were studied in the follow-up of planning in distribution systems in case of uncertainty in the request for load and the integration of distributed generators DGs. A radial and tangled system have been used. This case was clearly modeled using (a fuzzy triangular number). The most important goals achieved in this research are: - Installation and operation are low cost as well as reduce the risk factor to the minimum possible. The risk factor (CLLI) used in this research is a contingency load-loss index. The tool used in optimal management is based on a multi-objective particle swarm optimization (MOPSO), which determines the location and sizes of DG units in the planning stages. The results that emerged between the load models and the planning approach were compared to demonstrate advantage and disadvantage, also the proposed planning approach was verified using three distribution systems.

In [24]; there are many advantages achieved as a result of the integration of distributed generation (DG) in power systems. The most important of these features is to improve the voltage level in addition to reducing losses in the distribution networks. This includes achieving and enhancing interest when choosing locations and optimal sizes for this units. This thesis presented a theory in the choice to improve the voltages as well as reduce losses by using the genetic algorithm (GA). The goal of this theory is to maintain the voltage profile in the network and reduce the loss of real power within certain restrictions cannot be exceeded. Two systems of distribution were used in this first research, consisting of 69 node and the other consists of 52 node and done to compare the results between these two systems in terms of voltage and loss of power.

In [25]; in this research, three main cases were examined in relation to the genetic algorithm. The first is based on the basic genetic algorithm (GA). The second includes the development software (EP). The last is the development strategy (ESs). The comparison of these cases was done by evaluating both the mutation, the selection operator, the variable schematics, and the recombination as well as the model work to improve the single standard algorithm. Finally, all the results were presented and the study of the similarity and the difference between these algorithms in order to improve the level of performance.

1.5 Significance of the Study

In this research, it is aimed at developing a method for finding the optimum location of distribution for placing and sizing the distribution generators (DG) and it depends on [1]. This method is ensuring an economical and efficient functioning distribution system. By employing the approach of distribution generator in our work and planning to fulfill the following steps in the power grid:

Efficient utilization of energy resource by reducing the losses of distribution network and enhancing the voltage stability margin.

1. Employing the distribution generator as a smaller power plant to be installed at a point close to the consumers in somewhere ensure the system reliability.
2. Designing a smart system to determine the best location of distribution generator in power grid.
3. Design a smart system to find out optimum size (capacity) of that generator.
4. Determine the effect of the foreign model on the power flow, voltage stability margin and the power losses.

5. According to the mentioned steps, final conclusions and results will be discussed to state the required recommendations which are ensuring the best location and proper finest size of distribution generator with its positive outcomes and effects on the main power network.

1.6 Thesis Organization

This dissertation is consisting of seven chapters to describe the entire procedure of employing the distribution generator approach for enhancing the power grid.

Chapter one "*Introduction*" is entitled to describe the main concept of distribution generator and its impact on the power performance and about most recently conducted studies in the domain of performance efficiency and the methods used to insert the distribution generator into power grid with the optimum size.

Chapter two "*Distributed Generation (DG) & system stability*" are different definitions of distributed generation were addressed with mention the energy sources and distributed generation technologies, types of DG units and ways of connecting these units to the electrical grid, as well as studying the impact of these DG units on the power system. The second part is devoted to stability system with its classifications. In addition to the effect of the DG units on voltage stability margin.

Chapter three "*Load Flow Techniques & Genetic Algorithm*" the Gauss-Seidel Method in distributed generators planning was described for the power load flow in distribution grids. The second part is entitled to describe the proposed algorithm (*Genetic Algorithm*) by highlighting the details of this algorithm and the setup to specify best location and sizing of DG and its impact on the network.

Chapter four "*Practical Module*" is involving a complete simulation and design of our proposed model. Chapter five "*The results"* are given.

Chapter six "*Conclusion and Recommendations*", where the interpretation of the gained results will carry out and accordingly the recommendations will be set.

Finally "*References*", where the related articles about the entire work will be stated and the publications which were done in the same regard will be mentioned as well.

CHAPTER TWO

DISTRIBUTED GENERATION AND SYSTEM STABILITY

2.1 Introduction

There are many names related to distributed generation which are mentioned in previous work and practice. This diversity in these names leads to misunderstanding and confusion. Use of vocabulary which are an integral part of decentralization and random DG. The result is Ackerman's analysis of this fact "Distributed generation is an electric power source connected directly to the distribution network or on the customer side of the meter".

This expression of distributed generation is not exhaustive in the classification of generation sources which must determine the maximum local distribution network conditions and voltage levels. In addition to this description of DG didn't mention any types of this technology.

2.2 Classification Distributed Generation

The two main parts of distributed generation are: (a) - DG units that are fully dependent on non-renewable sources (b) - DG units that rely on renewable sources. The first type is directly dependent on fuel fossil or biofuels and limits energy production. As for the second type, it depends on other sources and the principle of its work based on renewable primary engines and the resulting energy are random and difficult to make power electricity generation for the required loading purposes. Compared to the size, the distributed generation units are smaller than the conventional generating units so they can be placed near the desired load and it is connected with the distribution network at any voltage level. Thus, these DGs increase the efficiency and quality of the power system while minimizing the loss of power in the transmission networks. These units are different sizes and varied as they generate electricity from few KVA's to MVA's. Synchronous generating units such as (synchronous generators) have a good quality and usually used to control the generation outside of them for the purpose of providing the reactive power of the excitation operation processing. Recently, wind power units have been using induction generators or asynchronous generators as well as a transformer interface in generating electricity. The power is derived from the network and DG units are interconnected by electronic converter devices can control to produce a reactive power. Criteria for DG units explained in the Figure (2-1).

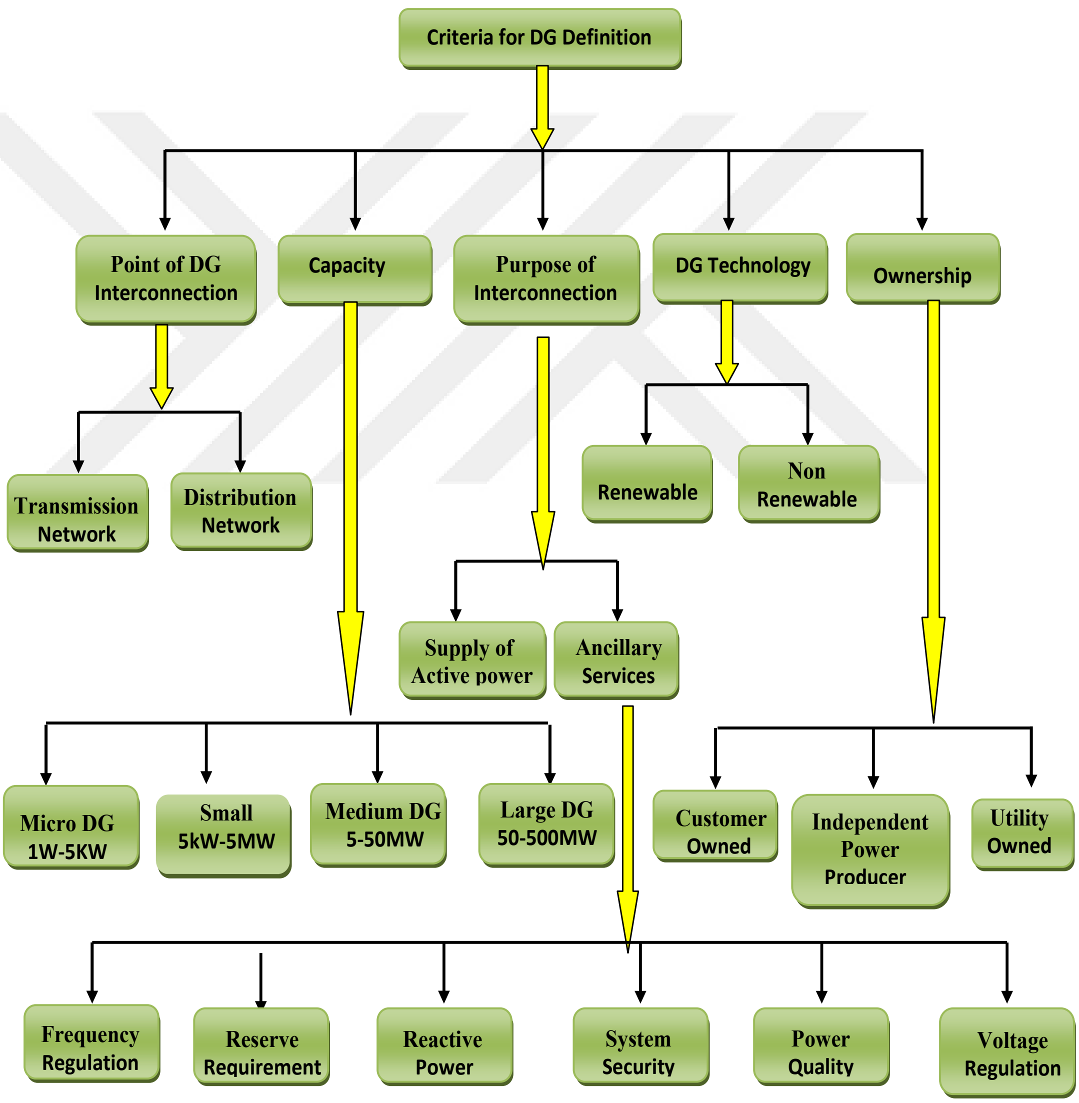


Figure 2.1: criteria for classification of (DGs).

2.3 Distributed Generation Technologies

Environmental issues related to climate and global warming as well as the high fuel associated with diesel generators always attracted attention. These diesel generators are identical to long-term distribution generators because of the high reliability and low cost. Over time, the development with another modern DGs technologies, the system becomes better improved and more stability. These modern technologies can be classified as in Fig (2-2).

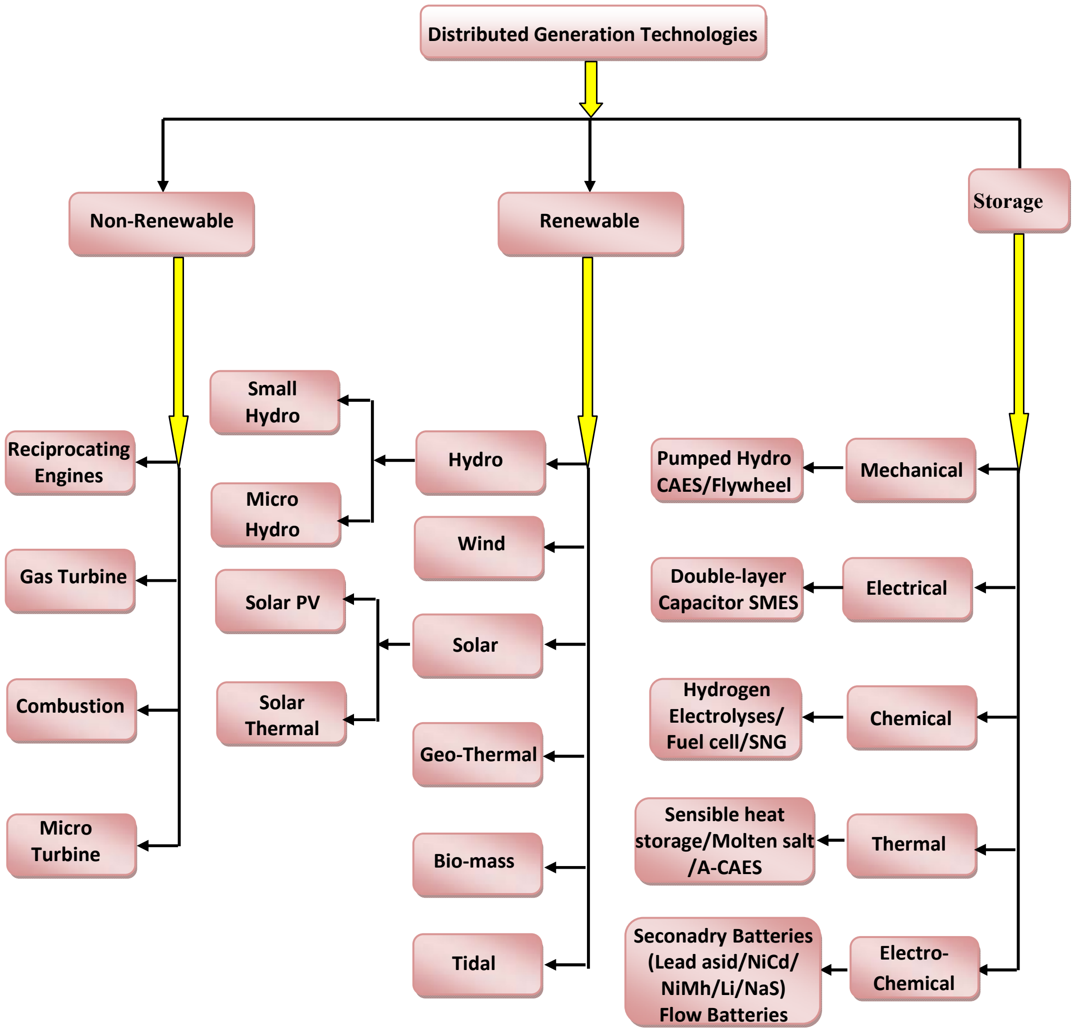


Figure 2.2: distributed generation technologies.

Many types of DGs are found on the market. The main contrasts can be remarked as the cost and economic value related to prosperities, as well as the installation and maintaining method can be done in addition to decrease the cost. All DGs are participating to enhance the efficiency of the power network. This aspect is popular for all generators. Two major categories are existed within this domain (renewable and none renewable) from the distributed generation.

2.4 Non-Renewable DGs Sources

Diesel generators are non-renewable energy sources and more popular in DGs. These units belong to the class of reciprocating engines making the electrical system more stable. The principle of its work is the result of a process of opening and closing automatic due to low voltage so it is a preferred option in some applications. In the past decade, the technology developments are forced to devise two new ways to rely on fossil fuels - Micro turbines and fuel cells. Natural gas is the main fuel, a high-speed and simple mechanically turbines. One of the most important features of these turbines are high efficiency and low operational cost but it does not environmentally friendly because of a large number of harmful emissions. Therefore, the emissions of natural gas in the air are less effective compared to other emissions of fossil fuels. The second type the fuel cell, it is very suitable for distributed generation applications, very popular and widespread because it is environmentally friendly and efficient.

2.5 Renewable DGs Sources

There are different types of renewable energy sources used to produce electricity.

2.5.1 Geothermal Energy

Geothermal energy is the warmth generated by earth's crust through aquifers or through the injection of groundwater flowing in the case of dry inflamed rocks. This geothermal energy is used from the ground and can be converted either by means of mechanical or utilize directly.There is a large abundance of this energy in the ground, but in practice can be used in specific areas only.Ground steam is extracted naturally in these sites which are treated easily and flexibly. Over time, the production of this steam is reduced in some thermal power plants very dramatically because the speed of using the ground heat is more than the heat recovery from the ground.

2.5.2 Tidal Energy

The strength of the disparity among low tide and high tide or sea movement among low tide and high tide is called tidal force. The process of drops water into the high tide only allows it to flow again in this low tide, one of the possible schemes. Therefore, it is worked to take advantage of this difference in sea level between low tide and high. This phenomenon usually occurs in areas with strong water flow. Energy is always produced around the low tide according to the tidal schemes about once every 12 hours. There is a system known as " tidal current " to generate electricity at the high and low tidal water flow. The mixture of these two designs together gives energy production 6 times a day. The tidal wave resulting from the difference in an interval of one month because around the earth the moon turns. Therefore, the energy resulting from the tidal scheme fluctuates strongly with the passage of time but the expectation is very difficult.

2.5.3 Thermal Energy Plants

Thermal power plants produce huge quantities of electricity in the world today and this energy is produced by large units ranging in size from (100 -1000) MW. The fuel user in these units is often either fossil fuels or uranium. This fuel is usually transported from distant areas around the world. That the actual locations of electricity production units are not necessarily present close to the fuel. Therefore, it is can be built near the consumption centers. Knowing that fuel sites may sometimes affect the locations of those units. Thermal power plants always need to be cooled by water, so it is best to selection these units near the edges of rivers or coast. Therefore, this property of these units limits the choice of sites. This does not prevent its location near consumption. The efficiency of thermal power plants is limited in the production of electricity according to the laws of thermodynamics. This process is called Carnot. The process of producing 1 MW of electricity needs 2-2.5 MW hours of primary energy.

2.5.4 Hydro Energy

Hydropower is " the result of the flow of water towards the sea for the purpose of producing electricity ". The use of giant dams and the establishment of large water tanks are the most traded in this case. The potential energy of water generated from upstream and downstream levels can be effectively used to produce electricity. The rate of these units ranges from (10 – 100) MW.Hydropower is located which be large reservoirs in very remote areas. This energy needs a solid system for transportation. In addition to further strengthening the system by extending hydropower. Hydropower has a long-term difference in properties ranging from days to months. This makes them a leader and very attractive in the electricity market and operating the transportation system. Small hydropower from the flow water or river near the consumer can be located in large hydropower. Typically, mountain areas are limited and it can be used this energy to enhance and improve the distributed generation system in mountainous highlands.

2.5.5 Combined Heat-and- Energy (Biomass)

Co-generation is defined as a combination of heat and energy and means the reuse of waste heat from any production unit for the purpose of other requirements of the processes, thereby enhancing use energy unit. This increases the overall heat efficiency of the unit from 40%-50% to 70-90% while maintaining a higher limit of large units that have a very good thermal demand. Biomass is a source of heat and energy sources and is a scalable model by burning some organic material directly to provide vapor and power. This process of heat and energy is considered the operation of burning under controlled conditions to make the operation more efficient away when the output of power electronic above the desired limit and impossible to transfer heat over long distances.

2.5.6 Solar Energy

The earth receives a huge amount of energy from the sun. For example, 1 m^2 of energy varies greatly between sites. The amount of energy is the highest level when approaching the equator and the lowest value when approaching the poles (North Pole, Antarctica) in the absence of clouds and can tilt the solar panels always at an optimal angle to the sun to compensate for bending the earth and reduce the impact of clouds. The amount of energy that reaches the solar panels is estimated between 1000 to 2000 kWh/m^2.Solar energy can be used in several ways, but the most common use is solar panels, which are often installed on rooftops. Electricity is used in buildings mainly by transferring part of its solar energy to electricity. The highest amount of solar energy production in the daily peak usually falls at noon. At the annual peak, especially when consumption rises, it often occurs in summer in countries with a hot climate and energy consumption due to cooling. The Direct radiation is defined as the electrical power produced by solar cells (solar panels) directly proportional to the amount of radiation reaching those plates because solar panels often use semiconductor cells that generate light when exposed to solar radiation, so-called photovoltaic cells. PV modules generate current and voltages that differ because variations at solar insulation used and heat level. The maximum power produced by the optical system is transferred by an inverter algorithm that converts photovoltaic energy into electrical power.

2.5.7 Wind Energy

The kinetic energy resulting in the movement of the wind horizontally turns into dynamic energy from through turbines by way the blades directly attached to the shaft. The dynamic energy of turbines can be converted to electrical power by the use of an electric generator. The amounts of energy generated over a full year by wind turbines are entirely dependent on the locations of those wind turbines. Thus its installation on the basis of wind changes and appropriate conditions but it does not necessarily have to be put in suitable place for the grid. The strong difference with the time-period of the wind and solar energy is called intermittent interference. It is possible to expect this difference. In distribution network depends mainly on real differences. Whereas in transmission lines depends primarily on differences and significance predictable. Wind turbines divided into two main parts:

a) Fixed speed wind turbines (FSWT)
b) Variable speed wind turbines (VSWT)

2.6 Energy Storage Technologies

This power resulting from RES, for example, PV and the wind turbines are dependent on meteorological conditions at that time. Electrical power storage can bridge the gap between power from these sources and load by providing power during the times of unavailability. In addition, storing the surplus power during high times of wind and sun. A wide scale of storage technologies basically adopts mechanical, chemical and physically available.

2.7 Interface With the Grid

There is a common connection point (PCC) between the power source and the network. The technology of contact is a tool that connects the power source PCC and often refers to the converter.

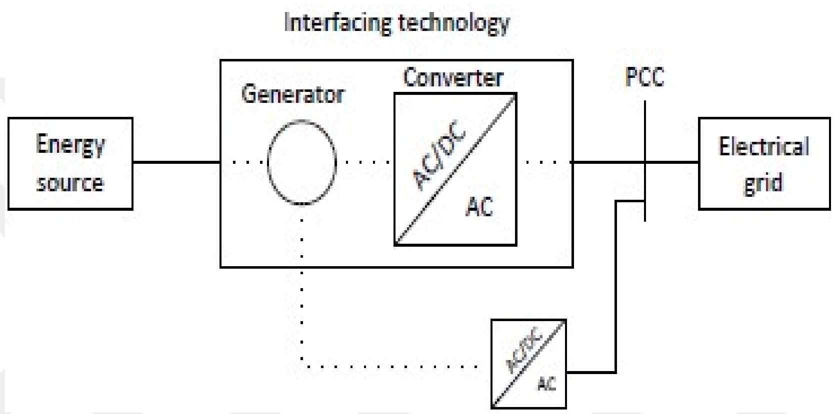


Figure 2.3: link between the power source and network.

The generators and transformers electric are considered electric electronics devices of the various techniques for joint contact as in the figure above. The purpose of this linked communication to constrain the power provided by this contact to the specifications of a network. The process of describing interfacing techniques is divided into four levels coupling: distributed power electronics, partial power electronics, full power electronics, and direct machine.

2.7.1 Distributed Power Electronics

Distributed power electronics interfaces are defined as distributed generation numbers which are directly connected to the local network by means of devices called electrical electronics transformers on the foundation that these units are part of a system belonging to the same system (owner). Controlled and coordinated with them for the purpose of achieving several benefits which reduce the power losses and organization of local voltage.

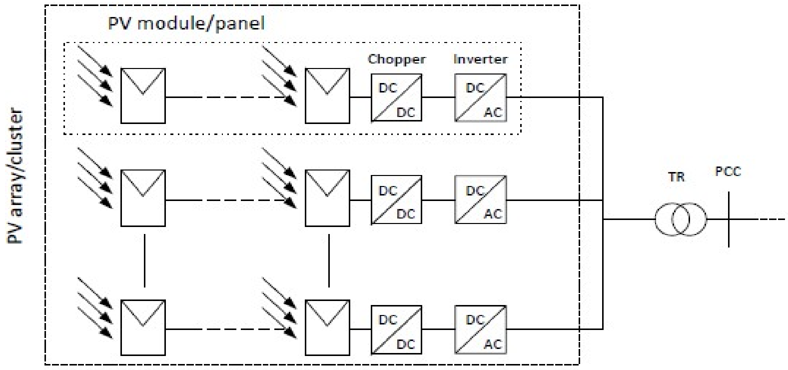


Figure 2.4: Solar cells array interface with conversion units.

The incorporated solar cells system is a module as shown in the above diagram of distributed generation, a type of interface structure of the active distributor has been recently improved for the purpose of increasing the reliability and efficiency of solar cells. This is true because the solar cells are different in order of arrangement or irradiation are irregular. All the integrated adapter are operated at several different points relate to with the efficiency of the MPP. It is better when compared to the central conversion.

For example, wind farms use wind turbines with full electrical power. Implementation of appropriate control devices to make this performance reliable when using a distributed control of the converters as well as reconfiguration.

2.7.2 Partial power electronics

The figure below shows a link to the double-fed induction generator in a network. Other procedures are sometimes applied to connect the power electronics to the network, which is smaller than the converter, the transformer is estimated to the purpose to providing the real/reactive power of the DG.

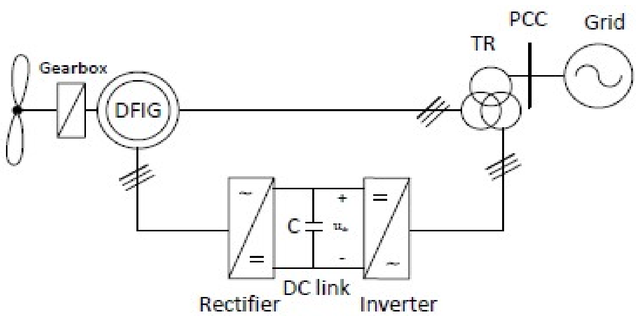


Figure 2.5: Double-fed induction generator connection of a wind turbine.

Typically, when the variable speed turbines are connected with induction generators related by dual feeding, the converter supports winding the rotor. A fixed coil is connected directly to the grid. This conversion is done by separating the mechanical frequency from the electrical frequency, which makes the change of a certain speed by vary the electric rotor frequency. It is not possible for these turbines to operate as a complete the scale of (0 - fixed speed). Therefore, this scale of speed is more adequate. The real reason for selecting this range in speed to the converter is much less than the measured energy by the device. The losses are low in same a full conversion system. Usually, in the wind farm, it is necessary to need a generator with a partially rated power electronics. The purpose is to improve the voltages on the grid by capacitance. This feature is essential in supporting the reactive power and the various network elements. The main technology in enabling all power sources to be connected directly to the network is "voltage source convert" (VSC). It usually linked either to the full or to partial electrical electronics. The self-commutating switch use in order to convert the power generated by the network as appropriate, in addition to the presence of a capacitor in the DC circuit and this is an important feature in the reconfiguration. The injection is a different type of energy at the common connection point.

2.7.3 Direct Machine Coupling With the Grid

This type of kinds is enough efficient to convert mechanical power into electrical energy by direct integrating mechanical in the network without any step intermediate. The quality of the mechanical power supply resulted in the choice of the type of device intended to obtain a fixed mechanical power. This leads us to the fact that the speed of rotation becomes continuous. Therefore, the synchronous generator is considered as the most likely candidate while the inductive machine is more suitable for the variable power.

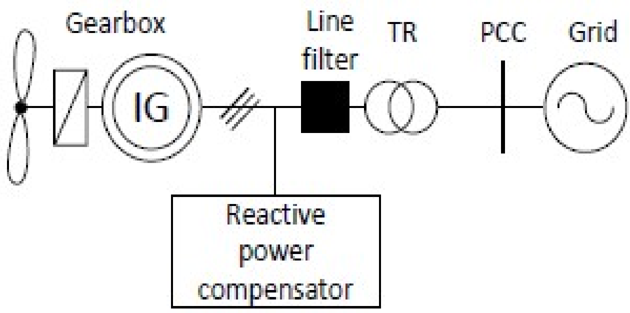


Figure 2.6: Direct induction generator coupling for a wind turbine.

Examples of these machines are wind power generators. These synchronized machines are equipped with both the real and reactive power of the electrical system. The reactive power in the system and the high start currents are among the most important problems experienced by the induction machine, so when being connected to the network, it needs to be compensated for the extra reactive power. Thus, a capacitor bank can be used. The size of these machines, when used as a distribution generator is considered limited generally.

2.7.4 Full Power Electronics

A process the converting (DC/AC) is compatible with conditions of the network is done by the power electronics converter. These converters are referred to as (DC/AC) transformer. These are sometimes DC sources and sometimes these transformers can consist of only one transformer (DC/DC) or by adding another transformative step, its purpose to complete a particular objective. For example, photovoltaic systems process the outward voltage regulation makes the output power as far as possible as shown in Fig (2-7).

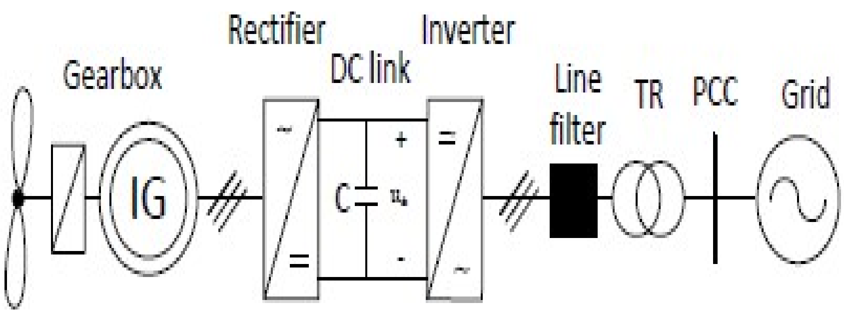


Figure 2.7: wind turbine interfaced by the induction generator.

Steps resulting from the converter (AC/DC/AC) are usually indicated to frequency converters because it is connected to between two different AC systems, as well as the possibility of having two different frequencies together in the form of a back-to-back overlay. The frequency converter can be transformed by the connection of the DC Directly both Transformers.

2.8 System Stability

Any operating system in the world during its operation have to be balanced among the power produced and the consumption of this energy demand." The property of any system of ability to enable it to maintain the state of balance in any normal operating conditions or restore the state of equilibrium acceptable after exposure to any disturbance "is called the stability of power system [9]. Depending on the physical quantities applied to the operating systems, the state system was described both of real/reactive power in the network, (phase angle/voltage buses). If these quantities are not fixed at all times, the system will be in disturbance state. There are two kinds of disturbances that occur in the power system. First type; small disturbances are resulting from changes in load and generation. Either the second type is due to faults, and the exit of generating units from operating [9-10]. Therefore, these disturbances measured according to their magnitude and origin. The stability system is divided into three types (frequency stability, voltage stability, rotor angle stability). Because the installation of the DG units in the distribution system, all the real/reactive power will be in reverse directions.

Stability, in this case, becomes a very important issue as the penetration level increases. Distribution systems are an integral part of the DG units. Most of the major factors that affect instability are the inertia constant of the motor, site of the fault, load system types, energy storage systems, and control strategies in DG units [10].

2.9 Voltage Stability

Voltage stability was defined as a measuring the ability of power system to keep the stability of the voltage value and make it acceptable in all buses in the power system after are encountered these voltages more disturbance in the initial operating conditions. The inability to provide reactive power is one of the main factors which cause voltage instability [10-11]. Depending on the disturbance that suffers by the power system, voltage stability was classified into couple types (small or large).

Small voltage stability: It is defined as the ability of the system to fix (control) the voltage when any small disturbances occur, such as sudden changes in the load.

Large voltage stability: It is defined as the ability of the system to stabilize the value of the voltage after the system is subjected to such large disturbances such as: shut down, faults, large sudden change in the loads. Voltage stability analysis was classified into couple types. Static and Dynamic.

2.9.1 Static Analysis

This method examines the feasibility of the equilibrium point in case the energy system operates during the specified conditions. Therefore, this theory examines large situations of the system under different conditions. The process of the manufacture of electrical facilities depends mainly on these curves to decide voltage in buses. In addition, there is being evaluated from a variety of techniques such as: P-V and Q-V curves**.**

a) P-V and Q-V curves

Through of applying the theory of continuous power flow, the curves of P-V and Q-V are formed. This theory works on modeling the power system often with nonlinear equations [11].

$$\dot{X} = f(X, \lambda) \tag{2.1}$$

The parameter vector is λ subject to several changes due to differences in loads. Therefore, the power flow can be vary by λ. The power flow is the power system as in [11-12].

$$0 = f(X, \lambda) \tag{2.2}$$

The following example explains the P-V curve when looking at the figure (2.8) which represents a single-machine PV bus. These buses can provide the system with a load for each P-Q bus with a constant power factor by the transmission line. The state vector (X) in Equation (2.2) represents the voltage (V) and the power angle (δ) and the parameter vector λ represent real power and reactive power respectively. The power flow from Equation (2.2) gives two balancing options: one is a low voltage value and the other is a high voltage value. The stable solution is the optimal solution with high voltage values [12], when increase loading with increase low voltage and decrease high voltage values. These points for this solution can be move along the path of the P-V curve until accumulate and cluster at the critical load point and then disappear. After this critical point, the load flow can decrease.

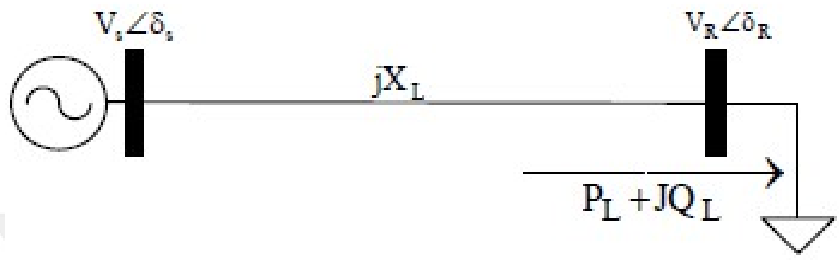


Figure 2.8: P-Q load bus.

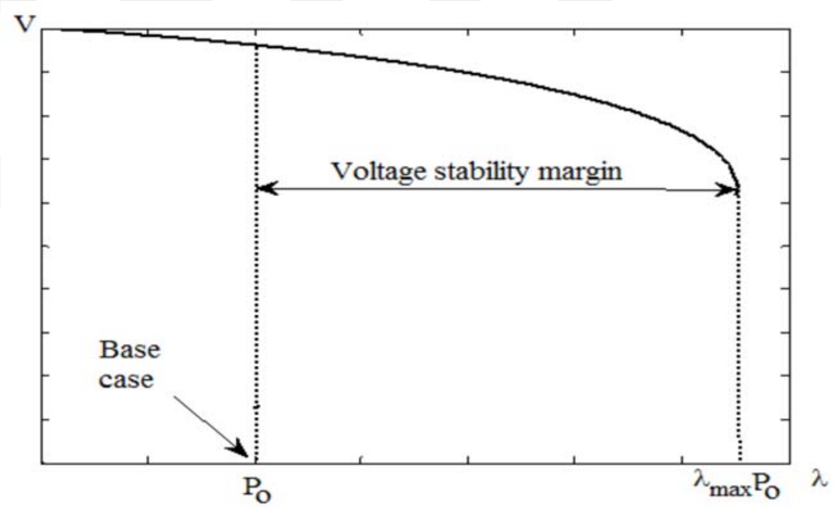


Figure 2.9: Nose curve.

b) V-Q sensitivity analysis

In this way can be represented the electrical network by the power flow equation from during a linear equation as in equation (2.3) [12].

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{P\theta} & J_{PV} \\ J_{Q\theta} & J_{QV} \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \Delta V \end{bmatrix} \tag{2.3}$$

Where

ΔP: The incremental change in bus real power.

ΔQ: The incremental change in bus reactive power.

ΔV: The incremental change in bus voltage magnitude.

$\Delta\theta$: The incremental change in bus voltage angle.

J: The Jacobian matrix.

Taking into consideration load real power (P) is fixed. Thus, the gradual alteration of produce real power of bus (ΔP) equal zero. Then using the partial inversion method of equation (2.3) produce:

$$\Delta Q = \left(J_{QV} - J_{Q\theta}\, J_{P\theta}^{-1}\, J_{PV}\right) \Delta V \tag{2.4}$$

Or

$$\Delta V = \left(J_{QV} - J_{Q\theta}\, J_{P\theta}^{-1}\, J_{PV}\right)^{-1} \Delta Q \tag{2.5}$$

By solving the equation (2.4) can calculate the sensitivity Q-V that represents a slope at a certain point of operation in the Q-V curve (2.10). The steady state of operation indicates the positive sensitivity of the Q-V curve. As a result, the unstable state of the operation indicates the negative sensitivity [12-13].

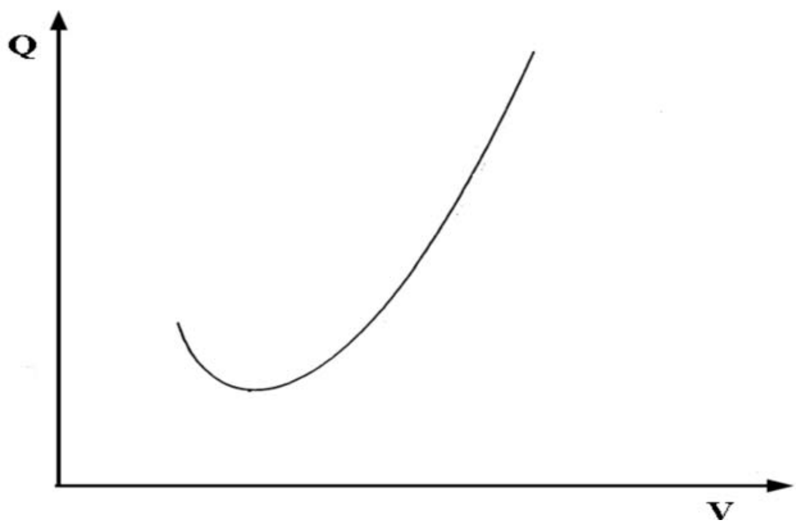


Figure 2.10: Q-V characteristic curve.

2.9.2 Dynamic Analysis

The following factors, protection systems, control equipment for frequency, an automatic voltage in addition loads (dynamic and static) all of them reflect the actual performance an energy system. DG units are represented by dynamic analysis. This system is generally represented by the first-order differential equations as in the following equation (2.6).

$$\dot{X} = f(X, V) \tag{2.6}$$

And a set of algebraic equations

$$f(X, V) = Y_N V \tag{2.7}$$

With a set of known initial conditions (X^0, V^0)

Where

X : state vector of the system.

V : bus voltage vector.

I : current injection vector.

$Y_{N:}$ network node admittance matrix.

Equations (2.6) and (2.7) by numerical integration techniques at time domain was solved. This study provides time domain results. Thus, the system can be modeled and simulated with the help from during diverse simulation software such as MATLAB [13].

2.10. Voltage Instability State

All of the above, the using of the relationship between (P) and voltage (V) at a certain point in the system can be analyzed by a fixed technique. This is called the nose curve (2.9) or curve (P-V). The continuous load flow method is applied to obtain this curve. The maximum loading of the system is measured at the critical point λ_{max} (saddle-node bifurcation point) in the (P-V) curve. The Jacobian matrix of the power flow equations is considered to correspond with the singularity. The penetration level for these units may be increasing or decreasing the voltage stability margin of depends mainly on the operation of the DG units when working with a unity, lead or lag power factors. In addition to the locations of these units and the amount of their penetration level in network. It can be expressed the (P-V) curve by the figure (2.9). Where the x-axis represents λ and the value of λ varies (0 - maximum loading (λ_{max})). Equation (2.8) is called a scaling factor.

$$P_i = \lambda P_{0,i}$$

$$Q_i = \lambda Q_{0,i} \quad (2.8)$$

the ways of the voltage instability able to use for the purpose of identifying different issues the static analysis cannot determine the control and interaction procedures between the integrated these units. The dynamics unit's impacts by using small-signal stability analysis have been analyzed in the literature [13-14].

2.11 İmpacts of the DG Sizes on Voltage Stability

The majority of DG units installed are connected to the different power factor [14]. As a result of this proposal in this thesis, all DG units installed on the vary power factor can be operated. Figure (2.11) shows the effect these units on maximum loadability and voltage. The x-axis often is called λ, which is called the scaling factor when the load is requested at a given point of operation as in equation (Equation (2.8)). The value of λ ranges from zero to λ_{max} due to bus injection. Normal operating point is increasing of the voltage from V1 to V2 at the same time increases the maximum load from λ_{max1} to λ_{max2}.

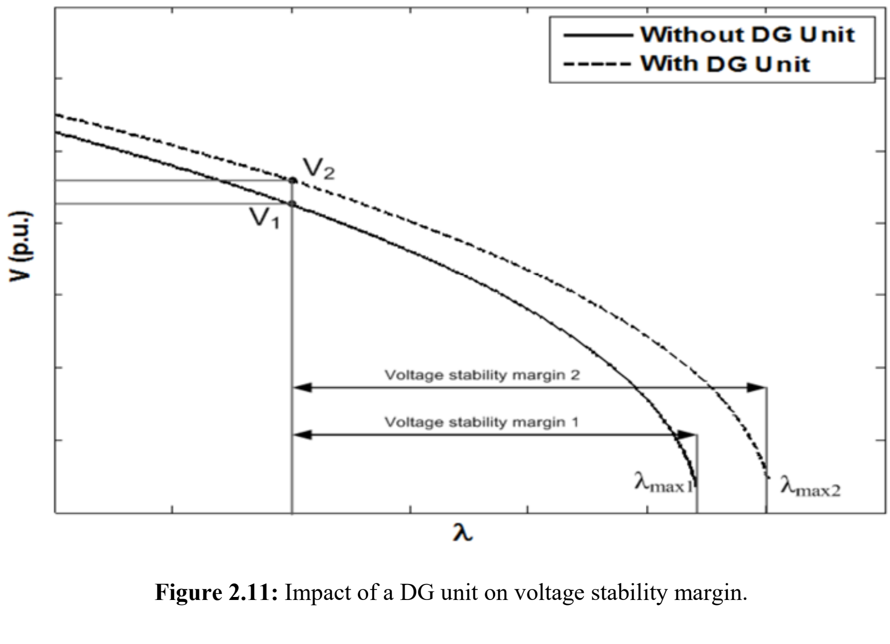


Figure 2.11: Impact of a DG unit on voltage stability margin.

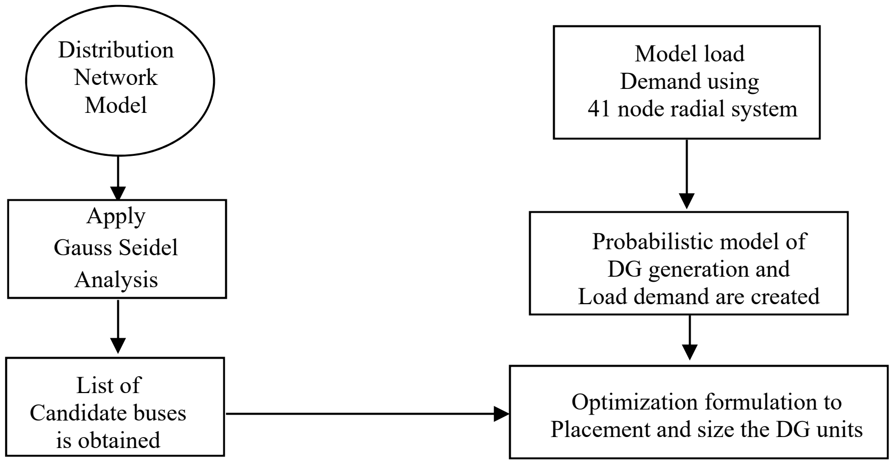


Figure 2.12: A diagram improve the VSM.

2.12 Summary

All mentioned in this chapter show the installation of DG units are capable of affecting in the distribution system either deteriorate or improve system stability. Previous studies have been shown extent impact DG units on voltage stability in the distribution systems. The presented work is focused on renewable and non-renewable energy units with their pre-defined capacities and constant loads. The capacity of both generation and loads for these units should be considered after use to improve the voltage. Most likely installing the DG units in the distribution system maybe cause some kind of resonance. It is necessary studied this issue when integrating the distributed generation because this phenomenon (resonance) maybe has a significant impact on the stability of the system.

CHAPTER THREE

POWER FLOW AND GENETIC ALGORITHM

3.1 Introduction

Power systems can always be analyzed by using steady state conditions because these systems usually operate under slow and variable status. This analysis imposes several conditions, including any disturbances are occurred in these systems have been stabilized with the assumption situation either steady state or unchanging system. The analysis of power flow is expressed as a preliminary analysis tool for the steady state process. The stable operating state of any electrical power system consists of power flow analysis. The load conditions for real / reactive powers across the entire electrical grid and value of phase angles and voltage in all buses determine the steady state of the system.This information is very important in providing an appropriate and continuous assessment of the performance of any power system. As a result, the analysis of alternative effective plans is working to expand this system to be able to meet the increased load required. It is an application that represents a particular tool or process (subroutine) within the most complex processes, for example (optimization problems, training simulations, stability analysis, etc.)

The power flow allows planning engineers to schedule all the different future scenarios that will be formed as a result of the expected load required through continuous network operation and observe all the immediate deviations that are unacceptable to the voltage due to the unexpected overload of normal load. As well as sudden changes in the structure of the network. Therefore, power flow is the main performance of security analysis [14-15].

Power flow method solution by five principal features:

1. The simplicity.
2. Accuracy of solution.
3. The versatility.
4. Maximum to the computational speed
5. Minimum computer storage.

3.2 Principle Form

Through the writing of mathematical equations that represents steady-state system, which represents a procedure to determination and addition of generation in the bus given to the load and the changing powers through the components of the transmission line that are connected to the bus to zero. Both the real /reactive power are applied to this system. These mathematical equations were given as express:-

$$\Delta P_k = P_{Gk} - P_{Lk} - P_k^{cal} = P_k^{sp} - P_k^{cal} = 0 \tag{3.1}$$

$$\Delta Q_k = Q_{Gk} - Q_{Lk} - Q_k^{cal} = Q_k^{sp} - Q_k^{cal} = 0 \tag{3.2}$$

These variables should be known in advance, where:

ΔP_k : The mismatch active power at bus *k*.

ΔQ_k: The mismatch reactive power at bus *k*.

P_{Gk} : The active power injected by a generator at bus *k*.

Q_{Gk}: The reactive power injected by a generator at bus *k*.

P_{Lk} : The real power drawn

Q_{Lk} : The imaginary power drawn

P_k^{cal}: Real power transmitted.

Q_k^{cal}: Reactive powers transmitted.

Through equations, it possible calculate the value of the production & loading at the bus *k* by the electricity unit, which gives its optimal values with the special real/reactive powers as follows:

$$P_k^{sp} = P_{Gk} - P_{Lk} \tag{3.3}$$

$$Q_k^{sp} = Q_{Gk} - Q_{Lk} \tag{3.4}$$

The real/reactive powers transmitted describe both of all nodal voltages and the grid impedance and are calculated by power flow equations. However, the transmitted powers are quickly and accurately determined because of the scientific purpose. The equivalent powers equal 0, in addition to the balance of power at any node in the network is acceptable if the node voltages are not known in advance, the calculated transmitted powers have approximate values and therefore corresponding mismatch powers are not equal to zero. Typically, the sequential correction approach to calculating nodal voltage is achieved by resolving the power flow. Therefore, the purpose is to reach the transmitted powers to the exact values sufficiently. This makes the disparity powers near to 0. When applying the mathematical equations in modern software applications, the iterative solution can be considered as successful at narrow tolerance as in 1e -12 before applied to all the mismatch equations. When approximating these values are shown useful and good results for the voltage angles values for all the stable working requirements in power system as the case variables [15].

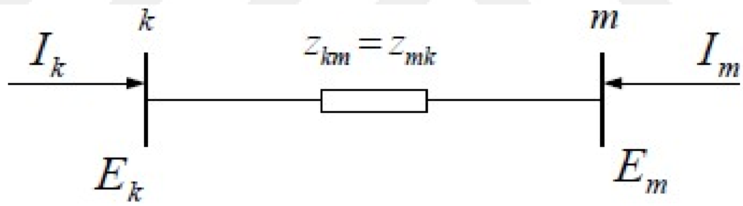


Figure 3.1: Equivalent impedance.

A relationship can be found between the injected buses currents and bus voltages through the development of appropriate power flow equations. Thus, it is possible to express the injected current complex I_k on the bus k based on Figure (3-1) as well as the expression of complex buses voltages E_k and Em as follows:

$$I_k = \frac{1}{z_{Km}} \, (E_k - E_m) = y_{km} \, (E_k - E_m) \tag{3.5}$$

Similarly for bus m,

$$I_m = \frac{1}{z_{mk}} \, (E_m - E_k) = y_{mk} \, (E_m - E_k) \tag{3.6}$$

The above equations can be written in matrix form as,

$$\begin{bmatrix} I_k \\ I_m \end{bmatrix} = \begin{bmatrix} y_{km} & -y_{km} \\ -y_{mk} & y_{mk} \end{bmatrix} \begin{bmatrix} E_k \\ E_m \end{bmatrix} \tag{3.7}$$

Or

$$\begin{bmatrix} I_k \\ I_m \end{bmatrix} = \begin{bmatrix} Y_{kk} & Y_{km} \\ Y_{mk} & Y_{mm} \end{bmatrix} \begin{bmatrix} E_k \\ E_m \end{bmatrix} \quad (3.8)$$

The bus voltages and admittances can be expressed more explicit in the design:

$$Y_{ij} = G_{ij} + jB_{ij} \quad (3.9)$$

$$E_i = V_i\, e^{j\theta_i} = V_i\,(cos\theta_i + jsin\theta_i) \quad (3.10)$$

Where i = k, m and j = k, m.

The function of nodal voltage, as well as the injected currents in the bus *k* can be expressed by the complex power injected that is composed of both an active and a reactive component.

$$S_k = P_k + jQ_k = E_k I_k^* = E_k\,(Y_{kk}E_k + Y_{km}\,E_m\,)^* \quad (3.11)$$

Where I_k^* the current conjugate injected in bus k.

By modifying equations (3.9) and (3.10) produce us the equation (3.11), which expresses both P_k^{cal} andQ_k^{cal}, by isolating the real and imaginary parts, as shown in the following equations:

$$P_k^{cal} = V_k^2\, G_{kk} + V_k V_m\, [\, G_{km}\cos(\theta_k - \theta_m] + B_{km}\sin(\theta_k - \theta_m)] \quad (3.12)$$

$$Q_k^{cal} = -\,V_k^2\, B_{kk} + V_k V_m\, [\, G_{km}\sin(\theta_k - \theta_m] - B_{km}\cos(\theta_k - \theta_m)] \quad (3.13)$$

The equations (3.12) and (3.13) are only related to the power injected into the *k* bus. As a result, the efficient systems consist of a large number of buses. in addition to many transmission elements. Therefore, the system expressed in equations (3.12) and (3.13) is the most general terms, with the flow of power in the bus *k* resulting from the power flow summation at each end of the bus. The states of active and reactive powers can be forms (3-2 a) and (3-2 b) respectively as in Fig.

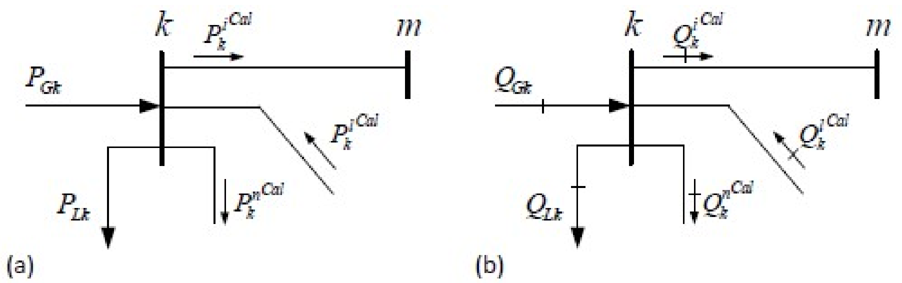


Figure 3.2: (a) & (b) active/reactive powers balance in k bus respectively.

Real & imaginary powers injected can be expressed as follows:

$$P_k^{cal} = \sum_{i=1}^{n} P_k^{i\ cal} \tag{3.16}$$

$$Q_k^{cal} = \sum_{i=1}^{n} Q_k^{i\ cal} \tag{3.17}$$

Where $P_k^{i\ cal}$ and $Q_k^{i\ cal}$ are computed by using equations (3.12) and (3.13) respectively. As an extension, the generic power mismatch equations at bus k are:

$$\Delta P_k = P_{Gk} - P_{Lk} - \sum_{i=1}^{n} P_k^{i\ cal} = 0 \tag{3.18}$$

$$\Delta Q_k = Q_{Gk} - Q_{Lk} - \sum_{i=1}^{n} Q_k^{i\ cal} = 0 \tag{3.19}$$

3.3 Bus Classification

There are two equations of power flow for the power system that contains n buses. So 6 items are available on the bus ($V_k, \theta_k, P_{Lk}, Q_{Lk}, P_{Gk}$ and Q_{Gk}). Therefore, four of these variables will be selected for each bus. Rely the quality on a bus with the exemption two unknown elements on each bus. Therefore, Buses will be classified accordingly [15-16].

3.3.1 Load Bus (P-Q Bus)

It is defined as any bus system in power system which determines the real/reactive powers is the load bus. In other words, they ensure that generators have real and reactive powers specific outputs. So, it does not necessarily have the necessary to the processing of the imaginary power to limit voltage value in particular values. This bus, both reactive energy (Q_{Gk}-Q_{Lk}) and the real energy (P_{Gk}-P_{Lk}) will be determined as a result, V_k and θ_k will be calculated. The net load bus (without bus generation,$P_{Gk} = Q_{Gk} = 0$) is known as (PQ).

3.3.2 Slack (Swing) Bus

The bus that determined the voltage value V_{slack} and the angle θ_{slack} was described as the slack buses. The " swing slack "method means that bus chosen to be the slack buses have to be the exporter real/reactive powers injection during this bus. As a result, the voltage phase angle is determined in the slack Buses and considered a (basic) by every voltage is measured for other voltages in this system. In fact, the value of fix must be zero.

3.3.3 Voltage Controlled Bus (PVT Bus)

The power flow analysis, in this case, is applied by the transformer with load tap changer. It is used to enter a bus controlled by termed PVT Bus. Therefore, similar to a bus PV due to voltage control on the bus PVT which is controlled by an adapter equipped with a LTC. In this case, the LTC tap *(Tk*) is treated as an unknown variable and therefore the voltage value (V_k), net active power (P_k) and net reactive power (Q_k) are determined. Controlled bus residue PVT gave that T_k is within the boundaries, namely, $T_{k\,min} < t_k < T_{k\,max}$, that means particular voltage is achieved if T_k outside of boundaries in addition, the $T_k > T_{k\,max}$ or $T_k < T_{k\,min}$, T_k is fixed at the break boundary and the bus becomes *PQ*.

3.3.4 Voltage Controlled Bus (P-V Bus)

The voltage controlled bus is defined as each bus that determines a voltages value and active power injection. Variables for the load (P_{Lk}) and (Q_{Lk}) was recognized variables. When generation makes Q_{Gk} and θ_k not clear bus components if design limits of the reactive power of the generators are not exceeded, the continuous voltage operation is possible. That is, $Q_{Gk\,min} < Q_{Gk} < Q_{Gk\,max}$. If Q_{Gk} becomes between $Q_{Gk\,max}$ and $Q_{Gk\,min}$. The Q_{Gk} put specified values between $Q_{Gk\,max}$ or $Q_{Gk\,min}$. Thus, bus k will change from bus (PV) to bus (PQ) because Q_{Gk} will be a recognized variable and therefore both voltages (V_k) and angle (θ_k) are calculated.

3.4 Power Flow Solution Methods

The solutions of a series of nonlinear algebraic mathematical equations through the description of the electrical network under the steady state in all conditions through the mathematical modeling from the point of view is the power flow solution. There are several types of ways solutions at the same time to use iterative techniques even for the simplest power system, these different ways are:-

1. Gauss-Seidel Method
2. Newton-Raphson Method
3. Fast Decoupled Power Flow Method

3.5 Gauss-Seidel Method

The Gauss-Seidel (GS) technique consider a repeated algorithm to resolving nonlinear equations. There is a planner series to wipe every node and refreshed the voltage node by terms the voltages from at the side of buses. Normally, getting the vector X appropriate of a nonlinear system.

$$f(x) = 0 \quad (3.20)$$

The fixed-point problem can be rewritten like as,

$$x = F(x) \quad (3.21)$$

The process of the solution is carried out through the initial values of the sequence, which begins with the initial value of(x^0), which was determined through statistical data, past experiences or practical considerations:

$$x_k^{i+1} = F_k \; (x_1^{i+1}, \dots , \; x_{k-1}^{i+1}, x_k^i, \dots, x_k^n) \qquad \boldsymbol{k = 1, 2, \dots, n} \quad (3.22)$$

This can be rewritten Equation (3.11)

$$S_k^* = E_k^* \, (Y_{kk} E_k + Y_{km} \, E_m) \quad (3.23)$$

By compensation $S_k^* = P_k - \; jQ_k$ in the equation above.

$$\frac{P_k - \; jQ_k}{E_k^*} = \; (Y_{kk} E_k + Y_{km} \, E_m) \quad (3.24)$$

By focusing on resolving the power flow problem, the terms used in the equations can be rearranged (3.22), (3.24).

$$E_k^{i+1} = \frac{1}{Y_{kk}}\left[\frac{P_k - \ jQ_k}{(E_k^i)^*} - \sum_{m=1}^{k-1} Y_{km} - \sum_{m=k+1}^{n} Y_{km}\, E_m^{i+1}\right] \tag{3.25}$$

If this condition is applied, the operation can cease.

$$max_k \ = \ \left|E_k^{i+1} - \ E_k^i\right| \ \leq \ \varepsilon \tag{3.26}$$

The results of this theory are closer to linear in addition to that calculation of the voltage in the iterative process is logical. As a result of the number of iterations will notice that load is decreasing slightly or quite linearly. Thus, the time required to solve large-scale systems will increase significantly in addition to the total accounting cost consider as a constraint for huge systems. At the beginning, the power flow will be processed by calculating all voltages buses excluding a slack bus because will be a fixed value from the particular voltage. There are two main reasons why Equation (3.24) cannot be applied directly to PV buses. First, the value of Q_k is not known in advance. Second, after each repeat, voltage values will be generated that differ from the specified values. For the solution of the first problem is done by substitute Q_k by the best value of the existing voltages. As for the second problem, it can be solved by refreshed the phase angle θ_k by measuring the output voltage while maintaining the specified voltage value V_k [15-16].

3.6 Overview of Optimization

For getting an optimal solution from a set of the possible alternative must attempt to use the optimization process. The problem of the DG allocation such that it give most prudent, effective, in fact sound distribution system must be optimized at the DG locations and sizes. This is more difficult to discover the best DG placement and size by hand In general distribution system which has numerous nodes. In the research there are many optimization approaches were utilized. Population-based evolutionary algorithms were utilized as optimization approaches in most of the current works. It was utilized as the arrangement procedure in this work [16].

3.7 Genetic Algorithm

The varied exploratory research processes which concentrated around the development thoughts features selection and genetic are called Genetic algorithms. A heuristically controlled random hunt system that simultaneously estimates thousands of assumed answers is a genetic algorithm then verified in order to advance towards better solutions by biased random choice and mixing of the estimated searches. The operation of hereditary DNA and the determination strategy was gotten from Darwin's survival of the fittest was based on the coding and doctrinaire search data. Chromosomes are the Exploration data that normally coded as binary strings that collectively make populations. Includes the use of normally intricate 'fitness' capacities to the series of value (genetic) in every chromosome and Evaluation was executed over the entire population. Typically, in two chromosomes that are chosen from the entire population by mixing includes recombining the data that was grasped by I. Rechenberg in his work "Evolution strategies" Evolutionary computing was suggested in the 1960s. By other researchers, his purpose was then advanced by John Holland. Their research has been having double aims (1) the adaptive processes of natural networks are abstract and rigorously define and (2) the important technique of natural networks was designed by artificial networks software. Genetic algorithms have been rootedness to the center theme of research. The central theme of research on genetic algorithms has been rootedness, the balance between efficiency and efficacy necessary for survival in many different environments [16].

3.8 Traditional Algorithms & GAs

There are four ways which genetic Algorithms are diverse from traditional optimization and search techniques:

1. Deterministic rules not utilize in the GAs, just probabilistic transition rules.
2. The payoff (objective function) information uses from GAs, not another ancillary knowledge or derivatives.
3. From a population of points, GAs are searching rather than an individual point.
4. A coding of the parameter collection works by GAs, which is not the parameters themselves.

3.9 Description of Genetic Algorithm

The population is a collection of solutions (represented by chromosomes) that starts with the algorithm. To form a new population must utilize to obtain Solutions from one population. The desire in this motivated, that the old population will be worse than the new one. To frame new arrangements (offspring) as per their fitness must select suitable Solutions - The more opportunities to generate them, the greater their chances. In order to until some condition is convinced must be reproduced. One possible solution was described by every point in the search space. Discover the best solution amongst an amount of possible solutions by use GA. The search can be highly complicated and therefore it is a problem. From where to start or from where to look for a solution, one may not understand it. To find an appropriate solution there are several methods one can utilize but do not significantly provide the best solution of these techniques. The great results in various practical problems that produced by the simple genetic algorithm are composed of three operators [16-17].

Reproduction: In the light of Darwinian survival of the fittest among strong creatures through this administrator be able to choose an artificial version of natural. A number of ways can be achieved in algorithmic form by the reproduction operator.

Crossover: Expected to happen after reproduction or choice. From two present ones produce two new populace or strings from determination parts shaped by hereditarily recombining haphazardly by arbitrarily choice crossover point.

Mutation: Mutation generates another string by changing the worth of existing string thus it is considered an intermittent irregular alteration of the estimation of a string position.

The Fitness: There are two things that can be defined for the needs of a standard genetic algorithm: (1) Results of genetic representation (2) estimate of a fitness function. All the genetic exemplification and measures the quality of the represented solution are considered as the fitness function. The regular problem dependent a fitness function by described the genetic representation and the fitness function and then enhanced by the repeated application of select operators, mutations, and crossover [17].

3.10 GA Parameters

Crossover probability and mutation probability are two fundamental parameters of GA. population size is considered from anther parameters. How frequently crossover will be performed is called crossover probability. Offspring are exact duplicates of parents if there is no crossover. Offspring are framed from parts of both parent's chromosome, if there is a crossover. All offspring are formed by crossover if the percentage of crossover probability is 100%. All new generation is made from accurate copies of chromosomes from the old population if the percentage is 0%. The modern chromosomes consider preferable because of the mating is created with the expectation that new chromosomes will incorporate great parts of old chromosomes [18]. Regularly parts of the chromosome will be mutated is Mutation probability. Offspring are produced quickly after crossover (or directly copied) without any difference if there is no mutation. Performed the mutation, if the percentage of mutation probability is 100%, at least one sections of a chromosome are changed. On the off chance that the rate is 0% nothing is changed, the entire chromosome is changed. To keep the GA from dropping into local extremes must happen Mutation. The GA will in truth change to random search, therefore, the mutation should not happen so usually. How several chromosomes are in population (in one generation) is called Population size. Furthermore, GA slows down, if there are too many chromosomes [19].

3.11 GA Applications

Result by innate counts (genetic algorithms) join timetabling and scheduling matters give for the Problems an impression of being particularly suitable, and around GAs centered many planning programming packages. Therefore, GAs to engineering was joined. To take care of global optimization problems the Genetic algorithms are always joined as a methodology. It might be significant in matter region that have a muddled fitness scene as perplexity, when in doubt of thumb genetic algorithms, i.e., the mutation in consolidation with crossover, The optimization gives excellent performance mainly through its use in GAs [20]. The function optimizer results from treatment through GAs to view genetic algorithms in diverse areas, so there are various other ways such as:

1. GAs as guiding philosophy.
2. GAs is another innovative network as a mathematical model.
3. GAs are innovation and creativity as a computational model.
4. GAs as the reason for capable machine learning.
5. GAs is similar a difficult technical puzzle.
6. GAs as problem solvers.

Machine learning and also for developing simple programs utilized for complex issues, (for example, NP-difficult issues) by Genetic algorithms. For evolving pictures and music, they have been too worked for some art. For examples of the utilization of GAs are:

1. TSP and sequence scheduling.
2. Signal Processing.
3. Predicting, data analysis nonlinear dynamical networks.
4. Both architecture, weights, and Designing neural networks.
5. Finding the shape of protein molecules.
6. Strategy planning.
7. Evolving LISP programs (genetic programming).
8. Robot trajectory.

3.12 Optimization Objective Function

An objective function on the premise of that the enhancement will proceed ought to have in every advancement procedure. Objective functions were generally divided two sorts, single and multi-objective. Both of them streamlining issue were considered and ceaseless arranging choice factors through distribution system in planning problem. And can decide a practical yet reliable system with better specialized favorable advantages through the principal objective. Better node voltage profile, and lower power loss so as to reduce Waste of reactive power demand and excessive active from transmission networks. Therefore, there are two types of objective functions: minimization of (i) maximum node voltage variation (V_{dev}) ratio and (ii) the overall power (P_{loss}) in power system. Optimization of (i) produces highly efficient network and an economical and optimization of (ii) results in better technical features with a reliable network [20-21].

Single-objective optimization: single objective optimization has been considered as just the power loss of the radial distribution system (RDS). The objective function mathematically expressed as:

(i) Min $\varphi\ (\gamma_P) = (\sum_i^{N_L}\ P_{loss}^{with\_DG})$ (3.27)

(ii) Min $\varphi\ (\gamma_P) = (\frac{\sum_i^{N_L} P_{loss}^{with\_DG}}{\sum_i^{N_L} P_{loss}^{without\_DG}})$ (3.28)

Multi-objective optimization: both of them in multi-objective optimization to minimization of (a) most extreme node voltage deviation (V_{dev}) proportion has been considered. (b) The total power loss (P_{loss}) of the distribution network [21].

$$Min\ \ \varphi(\gamma_v,\gamma_p) = \left(k_v * \frac{max(V_{sub} - V_i^{with\_DG}}{max(V_{sub} - V_i^{with\_DG}} + k_p * \frac{\sum_i^{N_L} P_{loss}^{with\_DG}}{\sum_i^{N_L} P_{loss}^{without\_DG}}\right) \quad (3.29)$$

Where Min $\gamma_v = \frac{\max\left(V_{sub} - V_i^{with\_DG}\right)}{max\left(V_{sub} - V_i^{without\_DG}\right)}$ (3.30)

Min $\gamma_P = \frac{\sum_i^{N_L} P_{loss}^{with\_DG}}{\sum_i^{N_L} P_{loss}^{without\_DG}}$ (3.31)

3.13 DG Allocation by Basic GA Optimization

The major objective to be introduced into the distribution system improvement must perceive the sizing and position DG units. To characterize a temperate yet dependable system with better specialized points of interest in distribution system arranging issue streamlining is accomplished by genetic algorithm. Better node voltage profile, and lower power loss so as to reduce Waste of reactive power demand and excessive active from transmission networks. Starts with an initial population fundamentally which randomly generated after that discussing a GA which is an iterative procedure. Which depends upon the problem to be optimized through there are various diverse encoding methodologies for the initial populace. For each and every chromosome of the population are determined Objective function and fitness. The selection operators is a set of the chromosome chosen for the mating pool in populace premise. To protect similar number populace in the mating pool the chromosome [22]. In this case, chromosomes share in mating pool have greater medium efficiency than the primary status from through selection operator and to generate new offerings is used the crossover and mutation administrator on the chose chromosome. The optimal solution is obtained from the iteration progress, as this process is returned iteratively in most of the states the process find enhancement within arrangements. A basic Genetic Algorithm for DG distribution issue is examined in points of interest with the above description as follow:

3.14 Coding Sketch

The GA structure will success rest on the coding sketch. There are two different ways which can be completed coding in a genetic algorithm. (a) real number coding sketches and (b) binary coding sketch for enhancement process and used in the radial distribution systems is used the practical coding sketch is chosen.

3.15 Initialization

The generation of the initial population is considered as initialization. There are three optimization variables for the initial population is produced randomly which includes rating/settings and number of DG. All decisions variable are randomly generated from the created value. To be installed at the load node but without the substation bus must know the DGs of various sizes. There are some factors that influence the efficiency and execution of the algorithm including the generation size, population size, mutation probability, crossover probability. First, the better performance of optimization next stage if it considered randomly some numerical value. The diverse values of optimization parameters are discovered by a multi-run process [22-23].

3.16 Chromosome Encoding

As shown below, there are three choices factors that had been considered for every DG improvement.

State of DG optimization:

1. The number of DG in a string.
2. where DG is to be connected / placed have to know the node number in the networks.

3. DG power rating.

N_{DG}	ρ_1	ρ_2	ρ_3	ρ_4	- - - -	ρ_n	P1	P2	P3	P4	- - - -	Pn
No. DG	←		DG placements			→	←		DG setting			→

3.17 Fitness Function

The process of resolving the load flow is accompanied by the improvement of variables in diverse conditions, the purpose of which is to evaluate the target function $\varphi(\gamma_v,\gamma_p)$ on each chromosome. This is after the population is generated from the required size. The value of the objective function is directly correlated with fitness function '$f(\varphi)_i$' which is a huge application in the optimization problem. This is a reason to solve load flow repetitively in addition to assessing the objective function and fitness function of all chains in the population. Two different patterns can be used in the distribution generator location problem after the objective function and fitness function $f(\varphi)$ is calculated. The cost function can be reduced by objective function [23].

1- Single-objective optimization.

$$f(\varphi)_i = \frac{\varphi(\gamma_p)i}{\sum \varphi(\gamma_p)i} \qquad i = 1,2,3\ldots\ldots popsize \qquad (3.32)$$

2 - Single-objective and multi objective optimization.

$$f(\varphi)_i = \frac{1}{1+\varphi(\gamma_v,\gamma_p)i} \qquad i = 1,2,3\ldots\ldots popsize \qquad (3.33)$$

3.18 Elitism

There is a possibility of loss for the best chromosomes if generating a new population by crossover and mutation. The method that first copies the best chromosome (or few best chromosomes) to the new population is called the Elitism. To keep a lost the best-discovered solution, Elitism can quickly improve the performance of GA because it whatever remains of the populace is shaped by GA.

3.19 Parameter Selection for Genetic Control

The elements that assistance to tune the execution of the genetic algorithm are Genetic parameters. These parameters work an imperative part in getting an improve solution by the selection of values and could be taken after to arrive at improve values for these parameters by using some general guidelines. (Crossover probability and mutation probability) are considered the basic parameters of GA. population size and maximum generation they are Additional parameters [23-24].

3.20 Size Population

Since the populace creates an inadequate measure of test for mating the most optimal outcome and just a little search space is searched. The genetic algorithm gives a pretty poor performance with a very small population, therefore, it is various chromosomes comprise of the populace or in one generation. To include a representative from a large number of hyperplanes, a large population is more expected. Accordingly, a vast populace debilitates premature joining to the suboptimal solution, therefore, GAs can achieve a more informed search. However, perhaps bringing about an unsuitably slow rate of convergence. So a large population needs more evaluations per generation [24].

3.20.1 Probability of Crossover (Ω_c)

The crossover rate is extremely high if the greater crossover average for all the quickly modern chromosome occur within the populace selection to produce improvements when the high-performance chromosome is discarded faster. The search may disintegrate because of the lower investigation rate if the crossover rate is low. The child chromosome being the best fitness on the grounds that the Crossover is made with the expectation that new chromosomes will include best parts of parent’s chromosomes.

3.20.2 Probability of Mutation (Ω_m)

Offspring is produced instantly taking after crossover (or specifically duplicated) with no change If there is no mutation. The GA restricts from dropping into local extremes because Mutation to keep each small location from stalling outside solitary magnitude because of the low level of mutation. Moreover, the random research achieved by change the GA, therefore, the mutation must not happen [25].

3.21 Summary

This chapter reviewed a general introduction to power flow in the electrical system and the most important features to be used by applying power flow theories in different situations. The principal form of power flow was indicated by the representation of steady-state equations in power systems and classified of the buses used in the power system are listed in four types, which were summarized in detail. The commonly used methods of power flow were presented in three main theories. The theory of Gauss-Seidel used in this thesis was explained in detail in this chapter with all its equations mentioned. In addition, a general introduction to the genetic algorithm and the history of its origin and development through its applications in various fields with indicating to the parts and parameters of this algorithm.

CHAPTER FOUR

PRACTICAL MODULE

4.1 Network

The network used in this thesis included 41 bus test system which was applied in the reference [1]. The network is composed of a delta-linked feeder including three wires, considering that the voltage is measured by (p.u), this feeder unit may be either an overhead or an underground distribution line. The figure below illustrates a 41 bus test system.

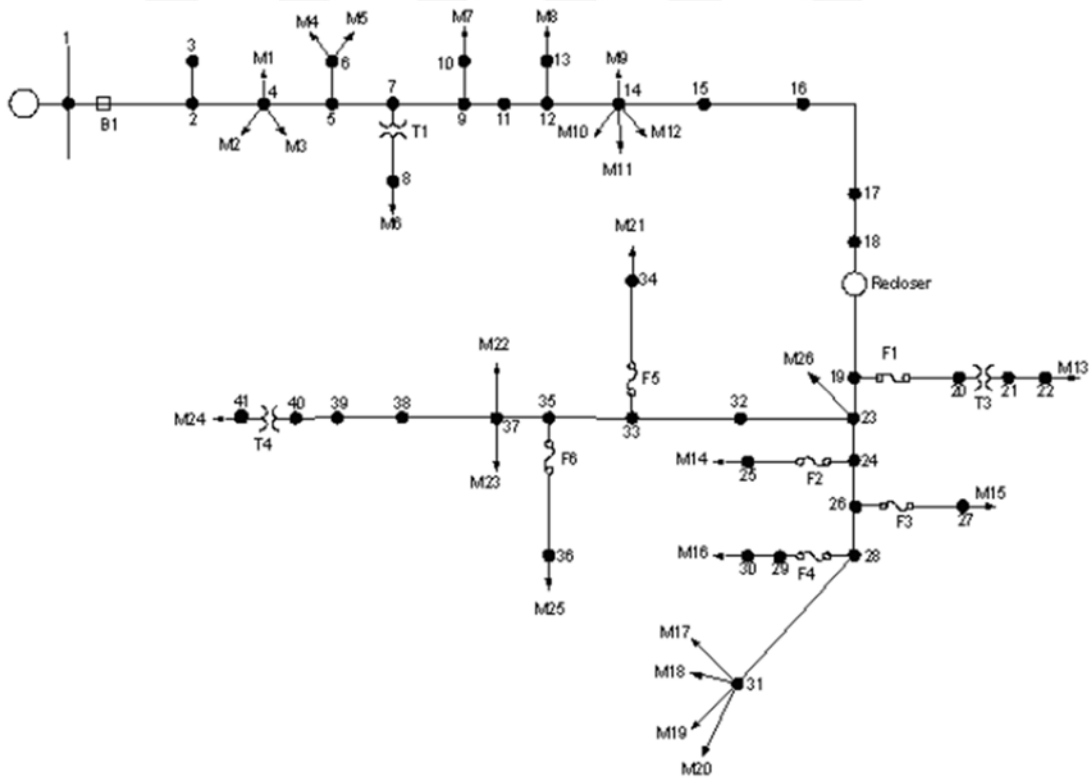


Figure 4.1: A distribution test system of 41 buses.

This system is more appropriate for all distribution systems because it is a radial distribution power system.In this thesis, the maximum peak load 16.18 MW obtained by this system is 300 Amper. The substation is often placed on bus No. (1), which is intended to feeder the entire electrical power system.

4.2 Per Unit Values

Most often, the power system has a diverse voltage level that connected through which is known as the power transformer. For the purpose of analyzing this system and making simpler. Therefore, the values of the basic parameters that are common for the evaluation of all quantities in this system was chosen by the per-unit system. Thus, the system has reduced the group of impedances and the voltage levels various have become hidden. Through this process, voltage values are identical for both primary and secondary transformer sides as well as for load buses. By way of the following equation for a per-unit system, possible display all basic quantities during energy system by:-

$$Quantity\ (per\ unit) = \frac{Quantity\ (normal\ units)}{base\ value\ of\ quantity\ (normal\ units)} \tag{4.1}$$

Where,

$$S_{pu} = \frac{S}{S_{base}} \qquad V_{pu} = \frac{V}{V_{base}} \qquad I_{pu} = \frac{I}{I_{base}} \qquad Z_{pu} = \frac{Z}{Z_{base}} \tag{4.2}$$

4.3 Proposed Work

In this chapter, the methodology and the study of all cases used in this thesis will be explained and clarified by analyzing the power system. Therefore, both power flow and optimization were programmed in the performance of this system. Gauss Seidel technique was used in the analysis of power flow as mentioned earlier. In addition, utilize of the GA by the Matlab (R2013a) to selecting better sites and sizes for DGs. Gauss Seidel method is an effective technique in achieving possible repetitive solutions dependent on the initial values appropriate for all variables that will be involved in this study. It is also known that the power flow solution begins with networks that only conventional power sources by giving values (p.u) for all type *PQ* buses. At the beginning, specific values were given for each type of the slack, *PQ* and PV buses. During DG injection, these values will be changed according to the iterative settling of the load flow also amounts injection in these buses cannot exceed the violation of the grid. All DG units used in this study was operated by a unity power factor system or near from the one.

4.4 Load

The database for loads of this system is shown in Table (A.1) . As done described these loads have been designed as a fixed power. As a result of this design, the system absorbs the real and reactive power that is described by the fixed power loads as buses that are positively injected by modeling so that constant injection of power is maintained. One of the most important features of these loads is interacting with all the changes for both voltages and current. The buses type PQ are considered model loads with real power and reactive power variable values, and the voltage in k bus does not exceed the agreeable boundaries. If the acceptable voltage has been exceeded, the loads in PQ bus in the network can be modified with a fixed impedance.

$$P_k^{\ *} = \frac{-P_{Lk}\,V_k^2}{\left(V_k^{lim}\right)^2} \tag{4.3}$$

$$Q_k^{\ *} = \frac{-Q_{Lk}\,V_k^2}{\left(V_k^{lim}\right)^2} \tag{4.4}$$

4.5 Line

The network line in this thesis is shown in the figure below and this line is considered as a model on the form π and the entire data of this line is given in Table [B.1].

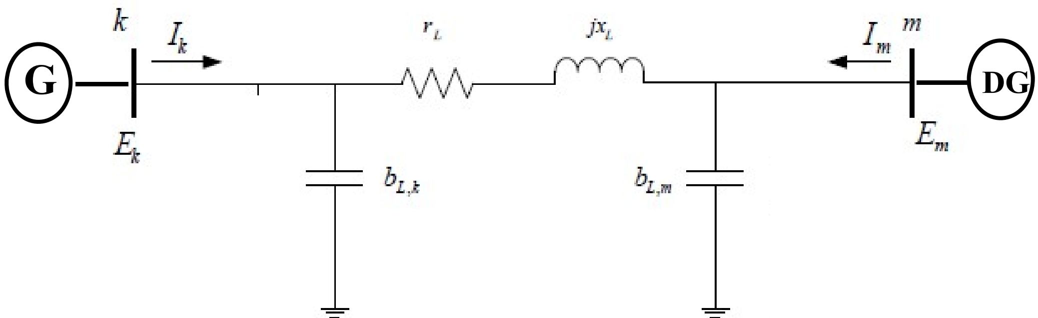


Figure 4.2: The penetration operation.

The equivalent circuit shown in the figure above contains a set of resistors in addition to a set of reactors and four shunt components are the transmitter tip and the receiving station and between them are buses ready for transmission and buses ready for reception. The power flow through this network, which contains 41 buses has been analyzed under normal operating conditions so that all conditions applicable to the maximum load permitted for this line. These buses were injected by DGs units with different ratios of the total load. The best locations for these DGs will be chosen with optimal sizes after analyzing the results.

4.6 The Principle of Optimization

In this thesis, the genetic algorithm was used, which was considered as an optimization technique for all domains. This algorithm features several advantages that make desirable in many cases including:

1. Mathematically is very easy.
2. Simple application.
3. The final results are of high-quality values.

As the principle of its work is the result of the selection of the initial population, which is the first step to obtain a set of random solutions possible through continuous research, which express the writing of the corresponding coding of the situation. As previously mentioned, an individual can be expressed by a single chromosome, which is considered as one solution. These genes that were used in GA can be converted to a programming language by giving them binary values of 0 and 1. The purpose of applying the genetic algorithm is either to obtain maximum objective function or minimum objective function by guessing the fitness of each individual which is the best measure of performance for each chromosome. After this step, two individuals from the population will be selected to reproduce the new offspring by mating and preceding the last step which is the mutation as it will produce a generation that has excellent fitness and high performance. The following figure explains those steps where a random intersection will be selected at point (k) at a time interval along that string for individuals.

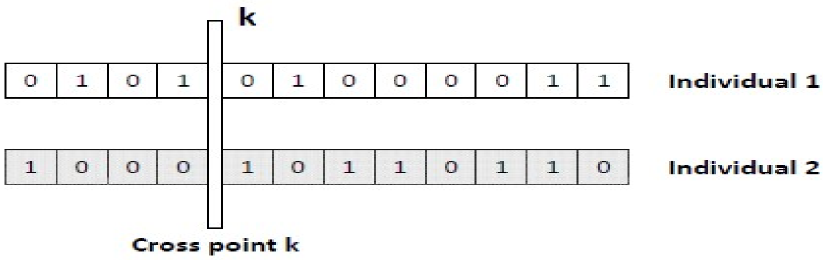


Figure 4.3: Description two individuals and the cross point k

Through the exchange of all symbols by the following form, two new strings are created.

l: The individual's string length.

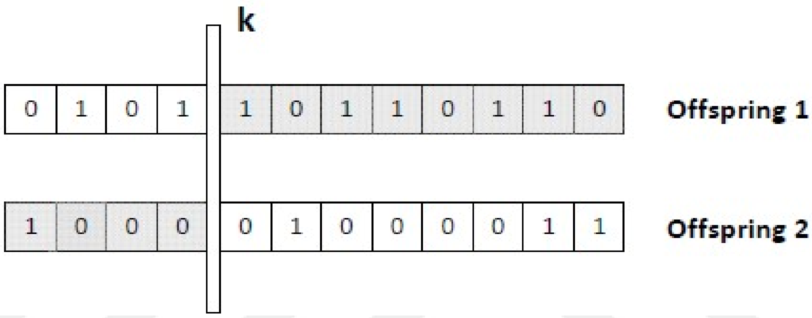


Figure 4-4: Two individuals after mating

Through the above figure, were observed the process of exchanging the elements between the strings for each parent through the first location of the crossover to the second site.The mutation is the one that ensures genetic variation. This change can be represented by a conversion from 0 to 1 and from 1 to 0 as in Fig.

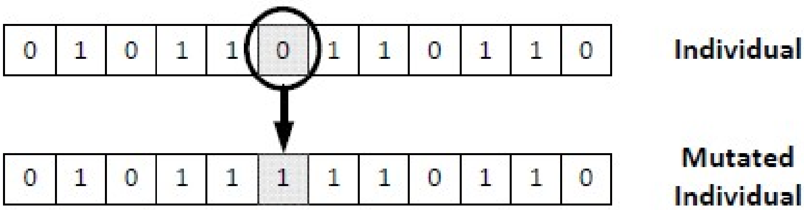


Figure 4.5: Result of the mutation.

A new population will be created by the three operators. This process is repeated until the best new population or maximum value is obtained from the objective function. The figure (4-6) describes the plan for implementing the genetic algorithm.

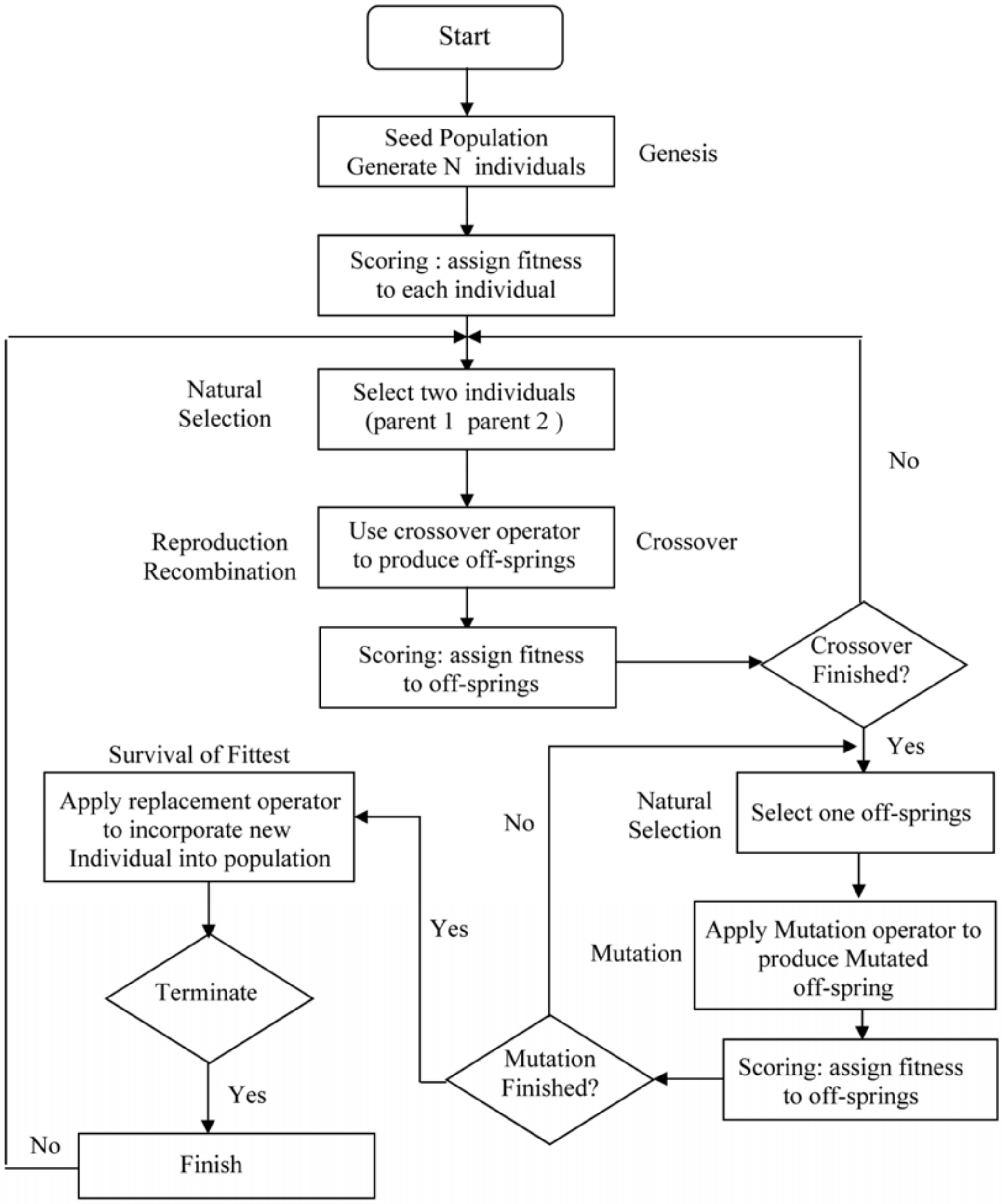


Figure 4.6: Implementing the genetic algorithm.

4.7 DG Placement Problem Formulation

After selecting the ideal values in part 4.3, the locations of these DG units must be allocated in this system, with emphasis on these units at unexpected loads at the most voltage drop buses which operate to breach the voltage limits or capacity the feeders. Through on the size of the DG units based on the load required, the proposed theory for the development of these units aims to improve the voltage stability margin of the system. This study was shown in four cases at different penetration levels.

The selected wind turbine is 1.1 MW, and the photovoltaic module is 75W, on the other hand, other wind and PV scores can be considered without loss of simplification. The features and classifications of these units were taken from [1]. The total penetration of the wind turbines can be an integer multiple of the selected rating. For example, if the result indications the penetration level at a convinced bus is 6.6 MW, it means six turbines of 1.1 MW are recommended to be installed at this bus. Solar generators can be modeled using photovoltaic modules (PV modules). Since the ratings of PV modules are small, they are unlike wind turbines, and the solar generators can be modeled to the required sizes. For example, if the required size of the solar generator is 1.55 MW, it requires 206667 modules of 75W. The dispatchable DG unit is selected to be 0.5 MW. It is assumed to generate a constant power at its rating. For example, if the required size is 4.5 MW, it requires nine dispatchable DG units. Since, the dispatchable generator generates constant power during the year, it does not have uncertainty.

4.8 Objective Functions

The main objective of my thesis is to improve the voltages stability margin during distribution grid and decrease the losses. Work is going to adopt the allocation of distribution generators base on the best location optimization method, ultimately a proper allocation and sizing will lead to enhance the reactive power and reduce the losses of radial power distribution system.

4.9 Constraints of Networks

a) All node voltage limits

$$\boldsymbol{V_{min} \leq V_i \leq V_{max}} \tag{4.5}$$

b) Real power loss

$$P_{i-loss}^{min} \le P_i \le P_{i-loss}^{max}$$

$$P_{Gn,1} + C(n,1) * P_{DG\,Di} + C(n,2) * P_{DG\,wi} + C(n,3) * P_{DG\,Si} - C(n,4) * P_{Di} = \sum_{j=1}^{m} V_{n,1} * V_{n,1} * Y_{ij} * cos\,(\theta_{ij} + \delta_{n,j} - \delta_{n,1}) \quad (4.6)$$

c) Reactive power loss

$$Q_i^{min} \le Q_i \le Q_i^{max}$$

$$Q_{Gn,1} - C(n,4) * Q_{D\,n,1} = -\sum_{j=1}^{m} V_{n,1} * V_{n,1} * Y_{ij} * sin\,(\theta_{ij} + \delta_{n,j} - \delta_{n,1}) \quad (4.7)$$

d) Maximum penetration on each bus:

$$P_{DG\ Di} + P_{DG\,Wi} + P_{DG\ Si} \le 10 \quad (4.8)$$

$P_{DG\ Di}$ /$Q_{DG\ Di}$ = Rated power / reactive power of the dispatchable DG connected at bus.

$P_{DG\ Wi}$ / $Q_{DG\ Wi}$ = Rated power/ reactive power of the wind-based DG connected at bus.

$P_{DG\ Si}$ / $Q_{DG\ Si}$ = Rated power/ reactive power of the solar DG connected at bus.

P_{Di} / $Q_{D\,i}$ = the peak active /reactive load at bus *i*.

$V_{n,1}$ = The voltage at bus i during state n.

4.10 Study Cases Definition

This part will clarify all the cases that have been addressed in this thesis:

4.10.1 Case 0

In this case, the system will be analyzed by the previously proposed method (Gauss-Seidel) by running the matrix Yn (network node admittance matrix) which represents both voltages and phase angles in each bus from this fact 41 voltage levels are there without penetration any bus at any levels or adding any distributed generation.The results are appeared explain both the voltages of the system at each node with real losses and reactive losses.

4.10.2 Case 1

Firstly, DG is added into bus 1 so the voltage of bus 1 will be changed as well as the voltage in the rest buses so we got new voltage magnitude and phase angle. Similarly adding the DG into bus 2 will result different voltages and losses, same concept will apply to all 41 iterations so that ultimately may get readings. Each bus is injected to by adding (DG) with a penetration level 30% of the load tied with the particular bus and thus will show the effect of the distributed generation on both voltages and losses.

4.10.3 Case 1 after modification

In this step, each bus is injected to by adding (DG) with a penetration level 50% of the load tied with the particular bus and thus will show the effect of the distributed generation on both voltages and losses.

4.10.4 Case 2 after modification

In this step, each bus is injected to by adding (DG) with a penetration level 75% of the load tied with the particular bus and thus will show the effect of the distributed generation on both voltages and losses. Setting the DG capacity into 75 % means that this generator is supplying 75 % of the load tied with the particular bus, this is meant as cost limitation and economic considerations. Adding generator with 75 % or more is not costing the same of 50% or 30% and so on.

4.10.5 Case 3

Finally, all above procedures are done, in order to explore the best location for DG must implement a genetic algorithm in the network (best locations with best losses and voltages). By running the program file "fnalfit" the readings obtained at three different locations in the network plotted in an individual graph and thus will see an improvement in voltages (high voltage with minimum losses).

CHAPTER FIVE

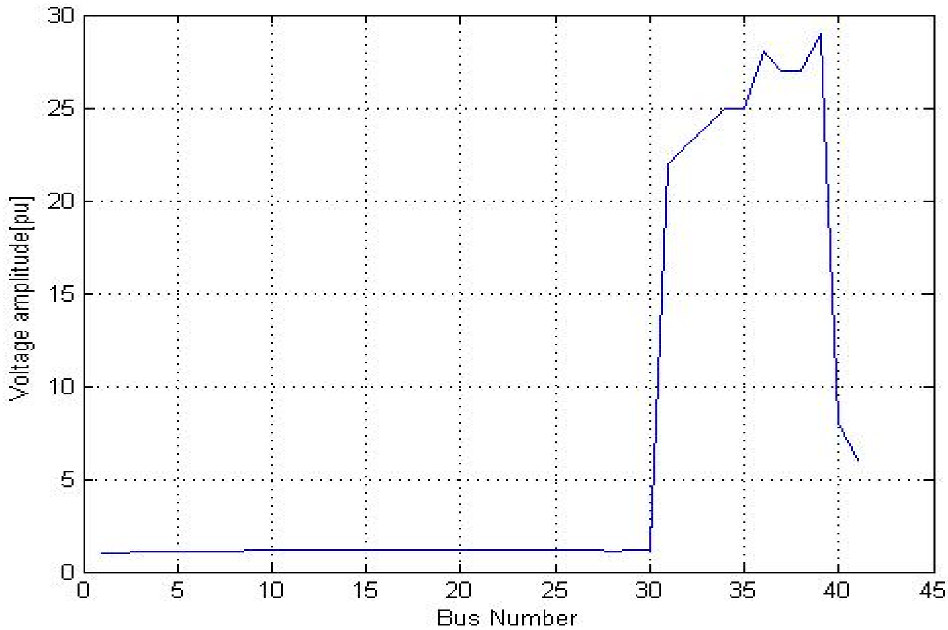
RESULTS OF THE WORK

5.1 Verification of the Results

In this chapter, all results are presented for different study cases.

5.1.1 Case 0

In this case, the power flow is simply analyzed without the addition of any distributed generation on the network. Therefore, the active / reactive power are generated of the main source. The voltage for all buses will be within the required limit Since the total power load is 300 Amper, the total real power loss is equal 970 KW and can be expressed by [pu] as in the form below for this situation.



Figures 5.1: Voltage in each bus before DG.

Figure 5.1 shows the voltages at each node of the grid without placing any distributed generation. These values for voltages are considered the basis for subsequent results after modification of the system through a high penetration level.

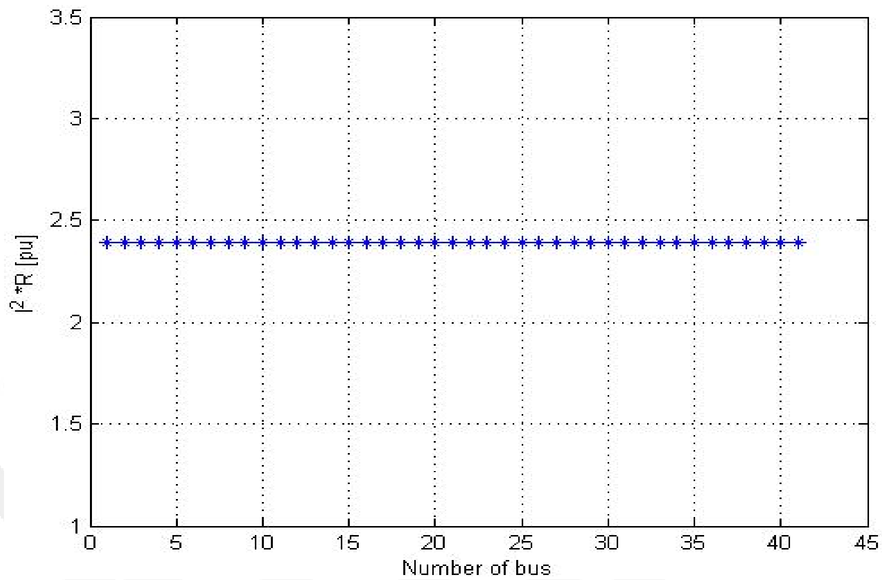


Figure 5.2: Active power losses in each bus.

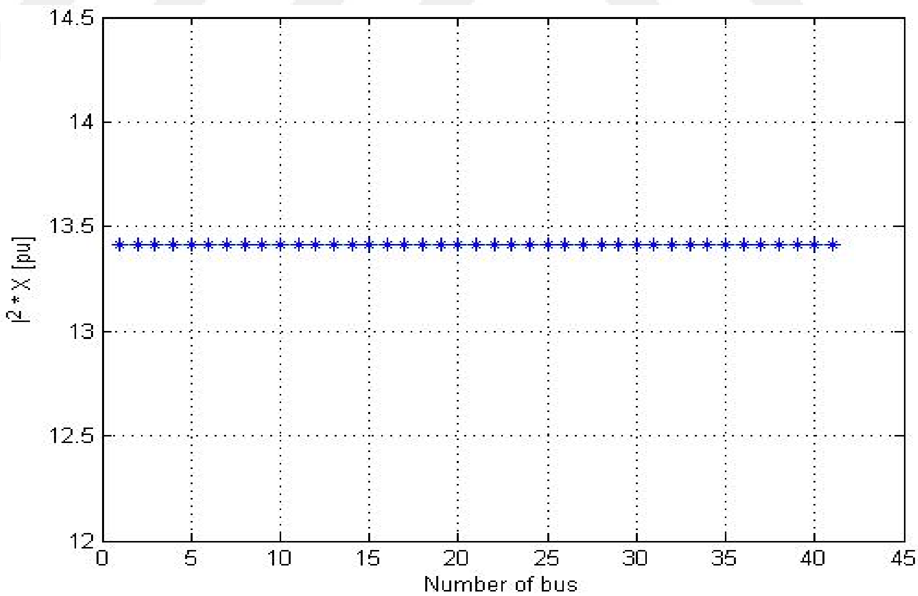


Figure 5.3: Reactive power losses in each bus.

Figures 5.2 and 5.3 show active and reactive power at each node of the grid without placing any distributed generation. These values for powers are considered the basis for subsequent results after the modification of the system through a high penetration level.

Table 5.1: Results of Case 0.

No. bus	Voltage value [pu]	Real power loss(MW)	Reactive power loss(MVar)	No. bus	Voltage value [pu]	Real power loss(MW)	Reactive power loss(MVar)
1	1.000	2.392	13.414	21	1.199	2.392	13.414
2	1.050	2.392	13.414	22	1.191	2.392	13.414
3	1.077	2.392	13.414	23	1.198	2.392	13.414
4	1.099	2.392	13.414	24	1.192	2.392	13.414
5	1.084	2.392	13.414	25	1.180	2.392	13.414
6	1.109	2.392	13.414	26	1.181	2.392	13.414
7	1.100	2.392	13.414	27	1.168	2.392	13.414
8	1.111	2.392	13.414	28	1.117	2.392	13.414
9	1.173	2.392	13.414	29	1.171	2.392	13.414
10	1.188	2.392	13.414	30	1.170	2.392	13.414
11	1.173	2.392	13.414	31	22.000	2.392	13.414
12	1.190	2.392	13.414	32	23.000	2.392	13.414
13	1.190	2.392	13.414	33	24.000	2.392	13.414
14	1.194	2.392	13.414	34	25.000	2.392	13.414
15	1.198	2.392	13.414	35	25.000	2.392	13.414
16	1.191	2.392	13.414	36	28.000	2.392	13.414
17	1.189	2.392	13.414	37	27.000	2.392	13.414
18	1.204	2.392	13.414	38	27.000	2.392	13.414
19	1.203	2.392	13.414	39	29.000	2.392	13.414
20	1.200	2.392	13.414	40	8.000	2.392	13.414
				41	6.000	2.392	13.414

Table 5-1 shows all values for both voltage, real and reactive power at each node represented by [pu] without inserting any distributed generation to the grid.

5.1.2 Case 1

In this case, all the buses will be injected by distributed generators at penetration level 30%. Setting the DG capacity into 30% means this generator is supplying 30 % of the load tied with the particular bus. The results show that an improvement has become in the voltage stability margin. In addition, decrease in real power losses where it became 962 KW with the decrease of some of the reactive power losses values and the increase of some of them as a result of inductance and capacitance loads. This phenomenon can be eliminated by adding capacitors bank on the network as in the following figures.

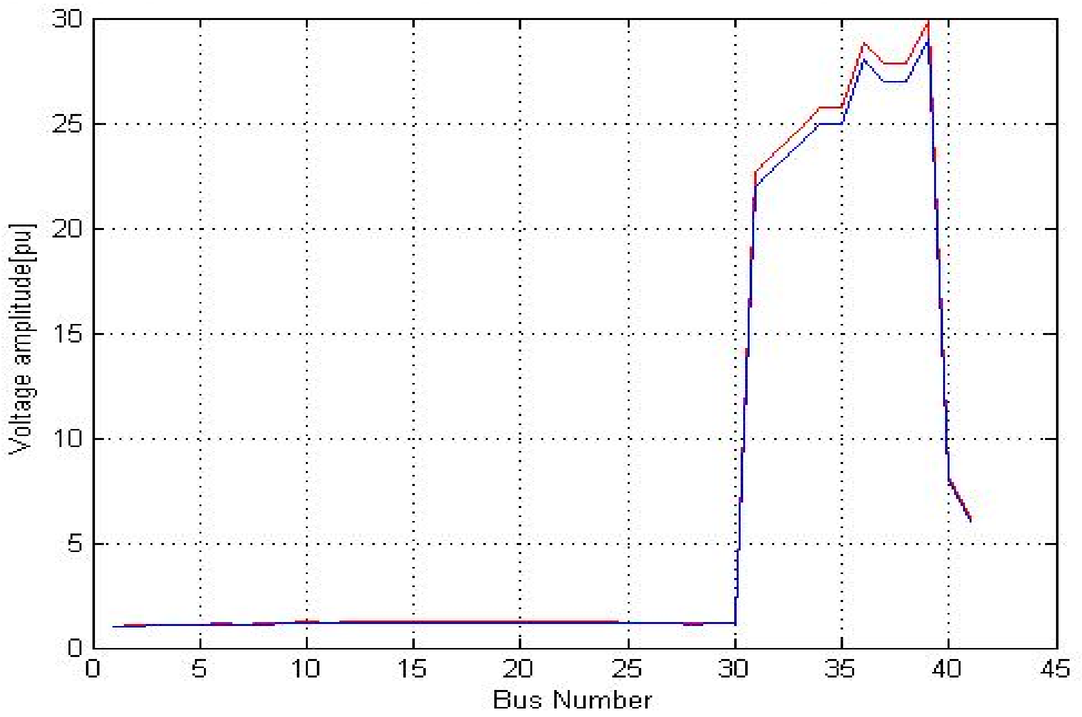


Figure 5.4: Voltage in each bus after penetration level 30%.

Figure 5-4 shows the impact of the DG units on voltage stability margin (V1 moves to V2). This result represents the improved voltages compared to the first case as a result of injecting DG units to the system through a value of the penetration level up to 30% of the total load.

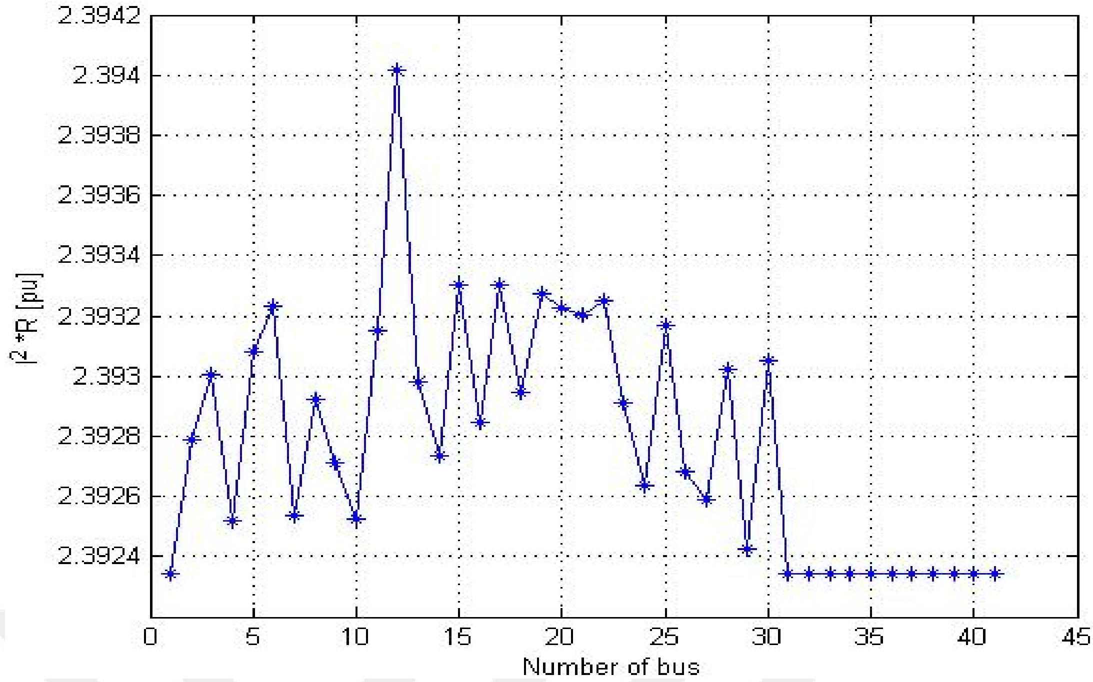


Figure 5.5: Active power losses after penetration level 30%.

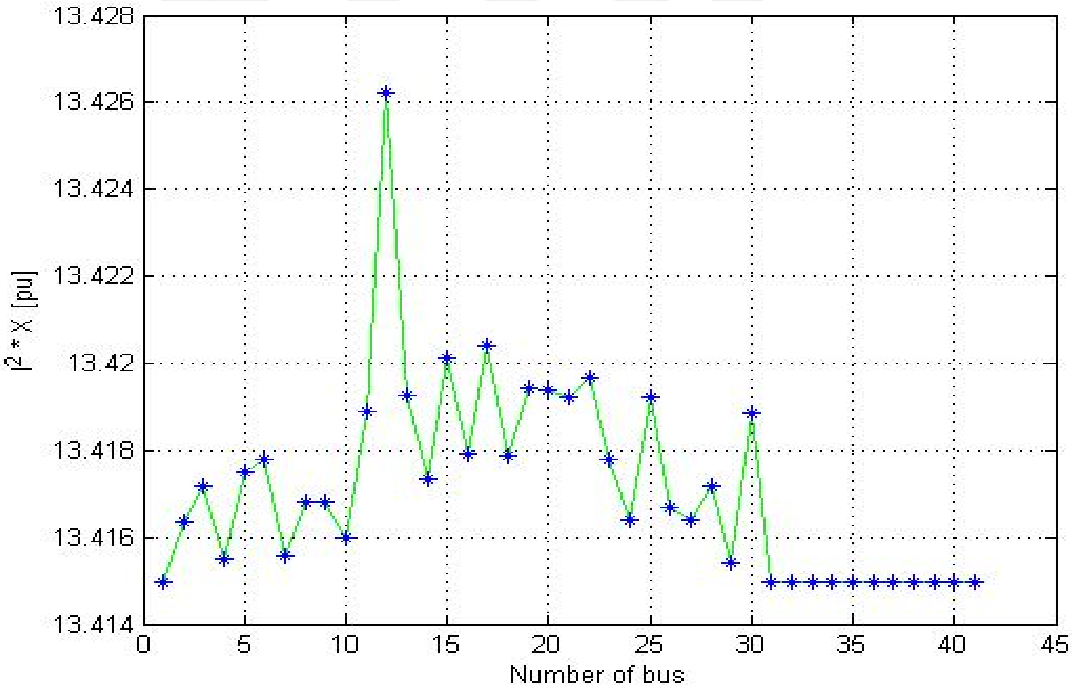


Figure 5.6: Reactive power losses after penetration level 30%.

Figures 5.5 and 5.6 show active and reactive power losses at each node of the grid after injecting DG units for the system in the rate of 30% of the total load. Where the effect of this injection can be observed to reduce losses both of them the active and reactive losses.

Table 5.2: Results of Case 1.

No. bus	Voltage value [pu]	Real power loss(MW)	Reactive power loss(MVar)
1	1.030	2.3923	13.4140
2	1.082	2.3925	13.4155
3	1.093	2.3926	13.4158
4	1.125	2.3924	13.4152
5	1.116	2.3926	13.4160
6	1.142	2.3927	13.4161
7	1.133	2.3924	13.4152
8	1.145	2.3926	13.4157
9	1.208	2.3925	13.4157
10	1.224	2.3924	13.4154
11	1.208	2.3927	13.4165
12	1.225	2.3930	13.4194
13	1.225	2.3926	13.4167
14	1.230	2.3925	13.4159
15	1.233	2.3927	13.4170
16	1.227	2.3925	13.4161
17	1.225	2.3927	13.4171
18	1.240	2.3926	13.4161
19	1.240	2.3927	13.4167
20	1.236	2.3927	13.4167

No. bus	Voltage value [pu]	Real power loss(MW)	Reactive power loss(MVar)
21	1.235	2.3927	13.4167
22	1.227	2.3927	13.4168
23	1.234	2.3926	13.4161
24	1.227	2.3925	13.4155
25	1.215	2.3927	13.4167
26	1.216	2.3925	13.4156
27	1.203	2.3924	13.4155
28	1.150	2.3926	13.4158
29	1.206	2.3924	13.4151
30	1.205	2.3926	13.4165
31	22.660	2.3923	13.4149
32	23.690	2.3923	13.4149
33	24.720	2.3923	13.4149
34	25.750	2.3923	13.4149
35	25.750	2.3923	13.4149
36	28.840	2.3923	13.4149
37	27.810	2.3923	13.4149
38	27.810	2.3923	13.4149
39	29.870	2.3923	13.4149
40	8.240	2.3923	13.4149
41	6.180	2.3923	13.4149

Table 5-2 shows all values for both voltage, real and reactive power at each node represented by [pu] after inserting distributed generation to the grid after injecting DG units for the system in the rate of 30% of the total load.

5.2 Results Obtained After Modification

In order to obtain the better results should make modification for the level of injections in the system by taking (50% and 75%) of the total load with a view to improve the voltage stability and reduce the power losses.

5.2.1 Case 1

In this case, all the buses will be injected by distributed generators at penetration level 50%. Setting the DG capacity into 50% means this generator is supplying 50% of the load tied with the particular bus. The results show that an improvement has become in the voltage stability margin. In addition, decrease in real power losses where it became 956 KW as in the following figures.

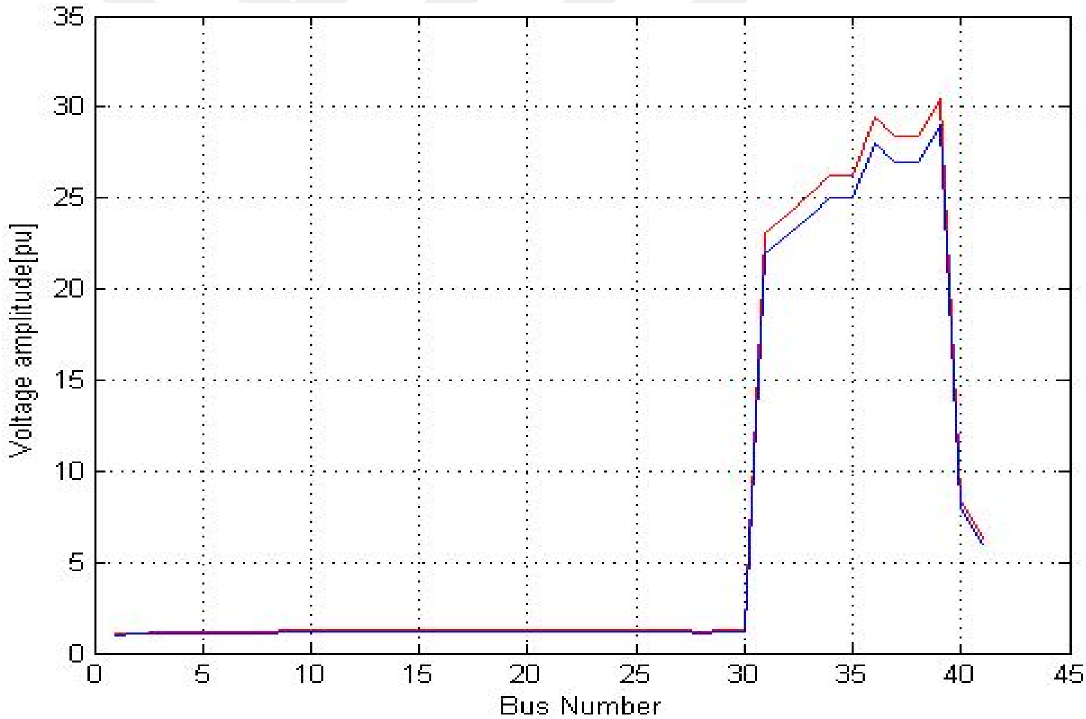


Figure 5.7: Voltage in each bus after penetration level 50%

Figure 5-7 shows the impact of the DG units on voltage stability margin (V1 moves to V3). This result represents the improved voltages compared to the first case as a result of injecting DG units to the system through a value of the penetration level up to 50% of the total load.

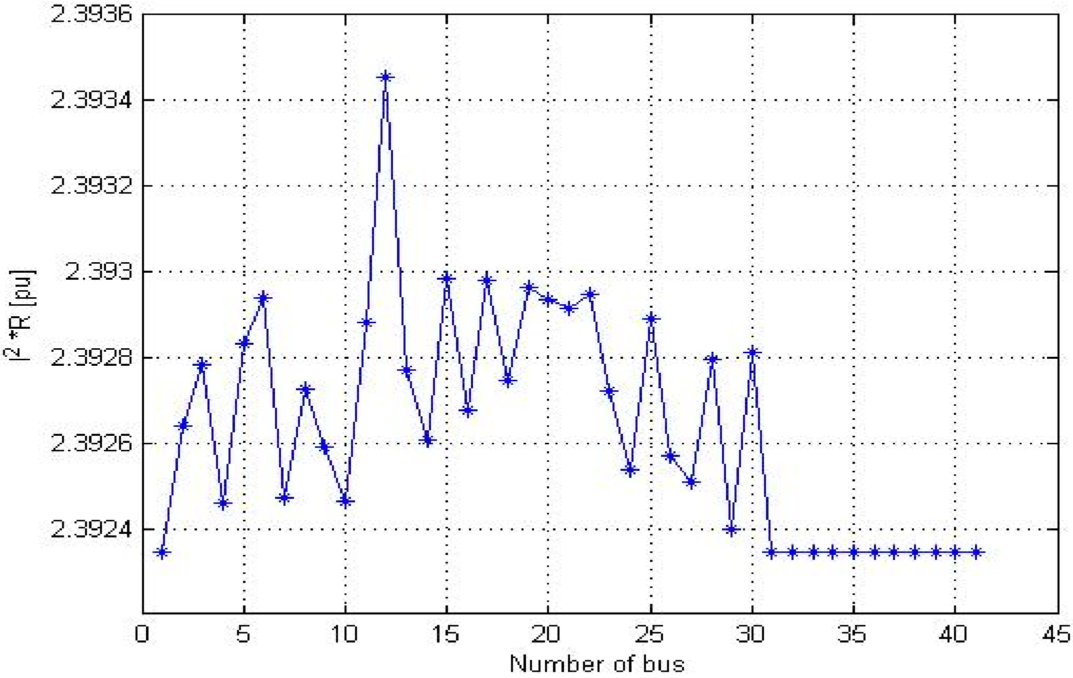


Figure 5.8: Active power losses after penetration level 50%.

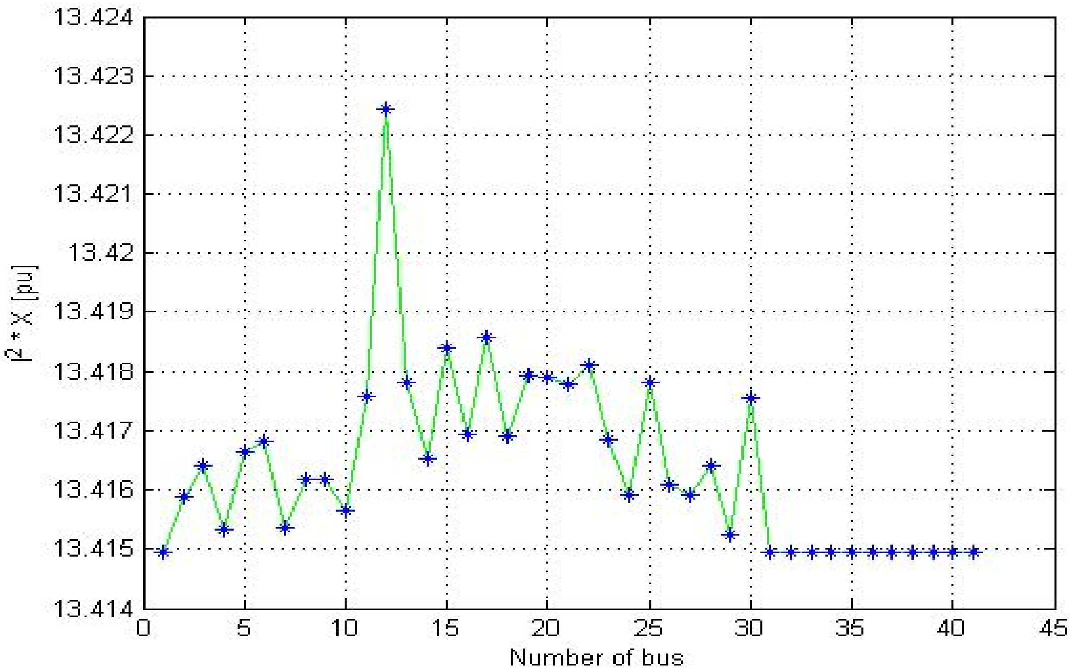


Figure 5.9: Reactive power losses after penetration level 50%.

Figures 5.8 and 5.9 show active and reactive power losses at each node of the grid after injecting DG units for the system in the rate of 50% of the total load. Where the effect of this injection can be observed to more reduce losses both of them the active and reactive losses.

Table 5.3: Results of Case 1 after modification.

No. bus	Voltage value [pu]	Real power loss(MW)	Reactive power loss(MVar)
1	1.050	2.3923	13.4149
2	1.103	2.3926	13.4159
3	1.131	2.3928	13.4164
4	1.147	2.3925	13.4153
5	1.138	2.3928	13.4166
6	1.164	2.3929	13.4168
7	1.155	2.3925	13.4154
8	1.167	2.3927	13.4162
9	1.231	2.3926	13.4162
10	1.248	2.3925	13.4156
11	1.231	2.3929	13.4176
12	1.250	2.3935	13.4124
13	1.250	2.3928	13.4178
14	1.254	2.3926	13.4165
15	1.257	2.3930	13.4184
16	1.251	2.3927	13.4169
17	1.249	2.3930	13.4186
18	1.264	2.3927	13.4169
19	1.264	2.3930	13.4169
20	1.260	2.3929	13.4179

No. bus	Voltage value [pu]	Real power loss(MW)	Reactive power loss(MVar)
21	1.258	2.3929	13.4179
22	1.251	2.3929	13.4178
23	1.239	2.3927	13.4181
24	1.251	2.3925	13.4168
25	1.239	2.3929	13.4159
26	1.240	2.3926	13.4178
27	1.227	2.3925	13.4161
28	1.173	2.3928	13.4159
29	1.229	2.3924	13.4164
30	1.228	2.3928	13.4176
31	23.100	2.3923	13.4149
32	24.150	2.3923	13.4149
33	25.200	2.3923	13.4149
34	26.250	2.3923	13.4149
35	26.250	2.3923	13.4149
36	26.400	2.3923	13.4149
37	28.350	2.3923	13.4149
38	28.350	2.3923	13.4149
39	30.450	2.3923	13.4149
40	8.400	2.3923	13.4149
41	6.300	2.3923	13.4149

Table 5-3 shows all values for both voltage, real and reactive power at each node represented by [pu] after inserting distributed generation to the grid after injecting DG units for the system in the rate of 50% of the total load.

5.2.2 Case 2

In this case, all the buses will be injected by distributed generators at penetration level 75%. Setting the DG capacity into 75% means this generator is supplying 75% of the load tied with the particular bus. The results show that an improvement has become in the voltage stability margin. In addition, decrease in real power losses where it became 952 KW as in the following figures.

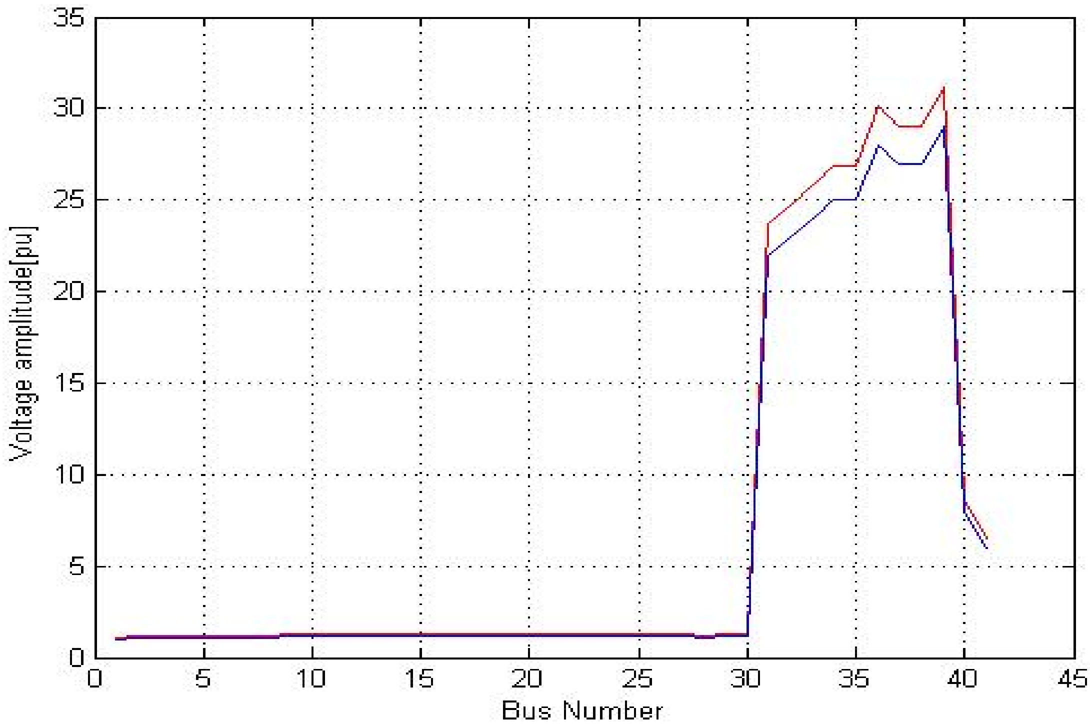


Figure 5.10: Voltage in each bus after penetration level 75%.

Figure 5-10 shows the impact of the DG units on voltage stability margin (V1 moves to V4). This result represents the improved voltages compared to the first case as a result of injecting DG units to the system through a value of the penetration level up to 75% of the total load. These results indicate that the penetration of the system at the level (75%) of total load gives the best values.

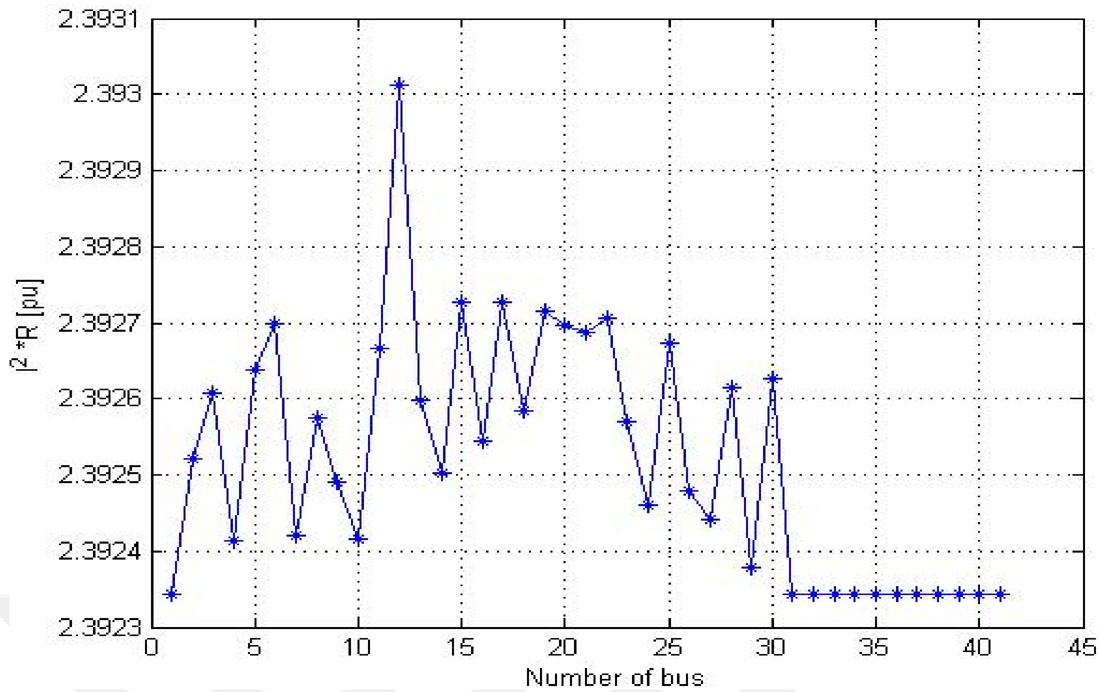


Figure 5.11: Active power losses after penetration level 75%.

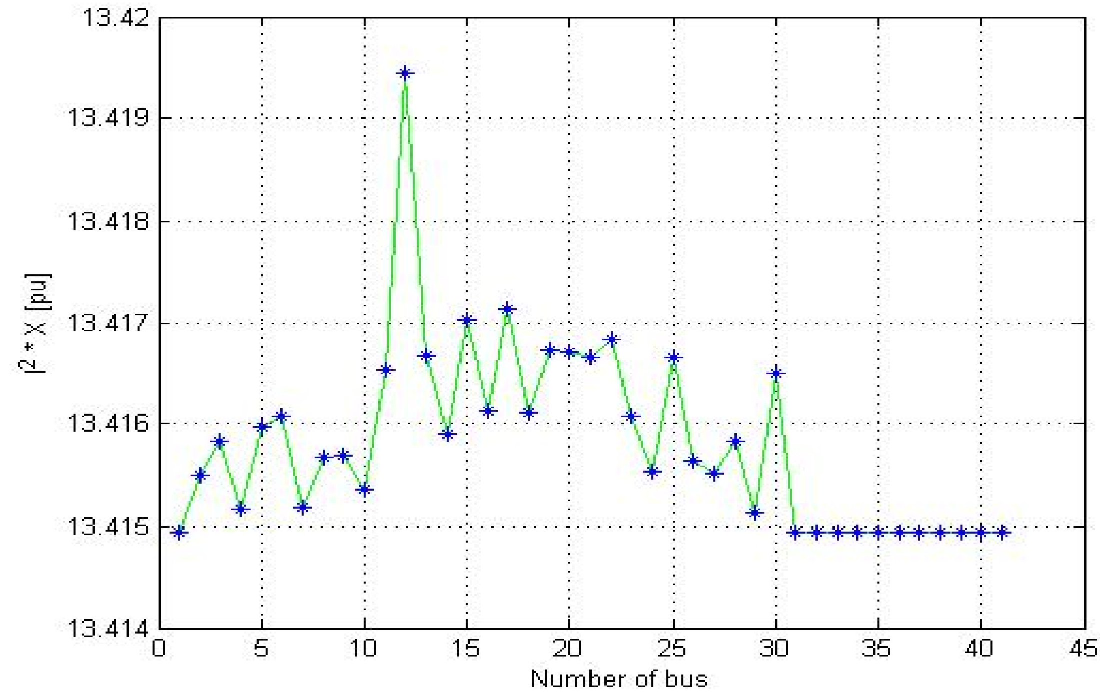


Figure 5.12: Reactive power losses after penetration level 75%.

Figures 5.11 and 5.12 show active and reactive power losses at each node of the grid after injecting DG units for the system in the rate of 75% of the total load. Where the effect of this injection can be observed to better reduce losses both of them the active and reactive losses.

Table 5.4: Results of Case 2 after modification.

No. bus	Voltage value [pu]	Real power loss(MW)	Reactive power loss(MVar)	No. bus	Voltage value [pu]	Real power loss(MW)	Reactive power loss(MVar)
1	1.075	2.3923	13.4149	21	1.288	2.3932	13.4192
2	1.129	2.3928	13.4164	22	1.281	2.3933	13.4197
3	1.157	2.3930	13.4172	23	1.288	2.3926	13.4178
4	1.174	2.3925	13.4155	24	1.281	2.3932	13.4164
5	1.165	2.3931	13.4175	25	1.268	2.3927	13.4192
6	1.192	2.3932	13.4178	26	1.269	2.3926	13.4167
7	1.182	2.3925	13.4156	27	1.256	2.3930	13.4164
8	1.195	2.3929	13.4168	28	1.201	2.3924	13.4172
9	1.261	2.3927	13.4168	29	1.258	2.3930	13.4154
10	1.278	2.3925	13.4160	30	1.258	2.3928	13.4189
11	1.261	2.3931	13.4189	31	23.650	2.3923	13.4149
12	1.279	2.3940	13.4162	32	24.725	2.3923	13.4149
13	1.279	2.3930	13.4193	33	25.800	2.3923	13.4149
14	1.284	2.3927	13.4173	34	26.875	2.3923	13.4149
15	1.287	2.3933	13.4201	35	26.875	2.3923	13.4149
16	1.281	2.3928	13.4179	36	30.100	2.3923	13.4149
17	1.279	2.3933	13.4204	37	29.029	2.3923	13.4149
18	1.294	2.3929	13.4179	38	29.025	2.3923	13.4149
19	1.294	2.3933	13.4194	39	31.175	2.3923	13.4149
20	1.290	2.3932	13.4194	40	8.600	2.3923	13.4149
				41	6.450	2.3923	13.4149

Table 5-3 shows all values for both voltage, real and reactive power at each node represented by [pu] after inserting distributed generation to the grid after injecting DG units for the system in the rate of 75% of the total load.

5.3 Case 3

The last case, after all values appear as a result of the injection of all nodes in percentages (0%, 30%, 50%, 75%) in the network. The genetic algorithm will be applied at each ratio so the distribution generators are optimally positioned to improve the voltage stability margin and reduce the losses in the electrical system. The first table shows the injection ratio and the generator position as well as power loss before and after DG.

Table 5.5: Results of the cases.

Penetration levels %	DG locations at bus	Power loss before DG [KW]	Power loss after DG [KW]
0	30	970	-
30	4	970	962
	19		
	28		
	40		
50	4	970	956
	19		
	28		
	40		
75	4	970	952
	19		
	28		
	40		

Table 5.6: Results of the DG location and size at 30%

Penetration levels %	No. bus	Wind (MW)	Solar (MW)	Dispatchable (MW)
30	4	0	0.85	0
	19	1.1	0.85	0
	28	1.1	0.85	0
	40	1.1	0.85	3.25

Table 5.7: Results of the DG location and size at 50%.

Penetration levels %	No. bus	Wind (MW)	Solar (MW)	Dispatchable (MW)
50	4	1.1	1.42	0
	19	1.1	1.42	0
	28	1.1	1.42	0
	40	2.2	1.42	5.7

Table 5.8: Results of the DG location and size at 75%.

Penetration levels %	No. bus	Wind (MW)	Solar (MW)	Dispatchable (MW)
75	4	1.1	2.15	0
	19	1.1	2.15	0
	28	2.2	2.15	0
	40	3.3	2.15	8.6

The results indicate that the penetration of the system at the level (75%) of total load gives the best locations that must be installed to improve the voltage stability margin and reduce the losses while ensuring economical and effective performance in the radial distribution system.

5.2 Discussion

This section shows the results obtained through this study. At the beginning, candidate buses are identified to installation DG units by power flow system analysis. Where the placements and sizes of DG units affect the voltage stability margin. Through the forms which are appeared, the changes in voltages are observed when DG units are installed in selected buses. The generation of the DG units depends on the penetration level and power factor unity with the assurance the load required for this system is taken at the peak load. Figure 5-13 represents the effect of change ($\Delta V / \Delta P$) on the selected buses, where the X-axis represents the number of buses and Y-axis represents the change in voltages due to injection of the DG unit.

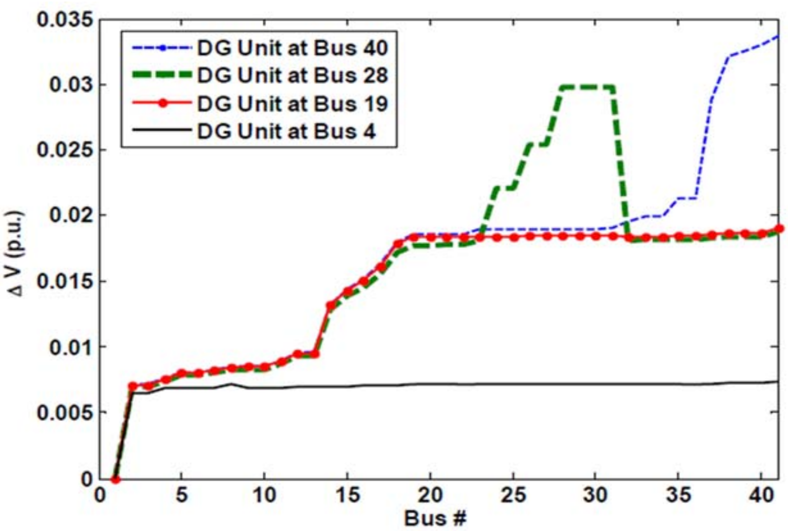


Figure 5.13: Results of voltage sensitivity analysis.

CHAPTER SIX

CONCLUSIONS AND CONTRIBUTIONS

The method used and the result obtained in a previous work [1] about the optimal placement and sizing of the distributed generation to improve the voltage stability margin and reduce the power losses in a distribution system are verified. After that, better results are obtained by modified the level of injections in the system by taking (50% and 75%) of the total load in order to improve the voltage stability and reduce the power losses. The high penetration levels has significant impacts on improving the voltage stability margin and decreasing power losses. Sometimes DG units consume the reactive power and cause the voltage collapse in the electrical grid. Several of the DG units were discussed in the second chapter with their most important effects on system stability. In the third chapter, the proposed theories like the Gauss-Seidel theory in the power flow, as well as the genetic algorithm used in order to select the best locations and sizes for DG units in a system consists of a 41 node. The constraints applied to this system have been taken into consideration, including the stability of the voltage, lowest and the high penetration level of each bus and the level of real and reactive power. The proposed methods have been applied in several different scenarios to read the results and the type at DG units in this work have been determined (renewable source energy and non-renewable source energy). These methods have been succeeded in selecting the best locations and sizes DG units based on the penetration level of each bus and the voltages collapse at each level. This thesis outlined the issue of voltage stability margin with power losses in distribution networks because lack of energy sources near consumers by the integration of distributed generation units through the high penetration levels (30%, 50%, 75%) of a radial distributed power system consisting of 41 nodes. The main objective of this thesis is to improve the level of voltage stability margin in the electrical network in addition to decreasing power losses in the system. The ultimately proper distribution and sizing are enhanced voltage stability margin and minimization of power losses and ensuring an economical and efficient functioning in the radial distribution system. The work was carried out by the Mathlab (2013a) program and collected all the results for all the cases used.

The results indicate that the penetration of the system at the levels (50% and 75%) of the total load gives the best values that must be installed to improve the voltage stability margin and reduce the losses while ensuring economical and effective performance in the radial distribution system. In addition, analyze the impacts of the DG units on the voltage stability margin and efficient utilization of energy resource by reducing the power losses of distribution network.

The completion of research thesis opens the avenues for work in many other related areas.The following areas are identified for future work:

The same work can be extended to more nodes in the network. Optimization process has been carried out on the basic genetic algorithm. The improved version of genetic algorithm can be applied in this network to obtain the better optimization.

The study has been carried out on balanced distribution networks. The DGs allocation problem can be extended to unbalanced distribution networks. The boundary conditions (tap change settings and DGs rating) can be modified and applied into the networks.

The DGs allocation problem can be extended for DGs reactive power optimization. The micro-turbines generation and fuel cell technology can be used to generate both electricity and thermal power.

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APPENDIX

APPANDIX A: 41-Node Radial Distribution Networks Load Bus Data

Table A.1: 41-Node radial distribution networks load bus data.

Bus No.	Min voltage [p.u]	Load		I_{min} (Amper)	I_{max} (Amper)
		P (MW)	Q (MVar)		
1	1	0	0	50	300
2	1.0300	21.7	12.7	80	100
3	1	2.4	1.2	0	0
4	1	7.6	1.6	0	0
5	0.9850	94.2	19	50	80
6	1.0071	0	0	0	0
7	1	22.8	10.9	0	0
8	1	30	30	35	0
9	1.0600	0	0	0	0
10	1	5.8	2	0	0
11	1.0800	0	0	30	50
12	1	11.2	7.5	0	0
13	1	0	0	40	60
14	1	6.2	1.6	0	0
15	1	8.2	2.5	0	0
16	1	3.5	1.8	0	0
17	1	9	5.8	0	0
18	1	3.2	0.9	0	0
19	1	9.5	3.4	0	0
20	1	2.2	0.7	0	0
21	1	17.5	11.2	0	0
22	1	0	0	0	0
23	1	3.2	1.6	0	0
24	1	8.7	6.7	0	0
25	1	0	0	0	0
26	1	3.5	2.3	0	0
27	1	0	0	0	0
28	1	0	0	0	0
29	1	2.4	0.9	0	0
30	1	10.6	1.9	0	0
31	1	9.5	3.4	0	0
32	1	2.2	0.7	0	0
33	1	17.5	11.2	0	0
34	1	0	0	0	0
35	1	3.2	1.6	0	0
36	1	8.7	6.7	0	0
37	1	0	0	0	0
38	1	3.5	2.3	0	0
39	1	0	0	0	0
40	1	0	0	0	0
41	1	2.4	0.9	0	0

APPENDIX B: System Lines Data

Table B.1: System lines data.

Bus line		Series impedance [p.u]	
From	To	R(Ω/Km)	X(Ω/Km)
1	2	0.019	0.0575
2	3	0.0452	0.1652
2	4	0.0570	0.1737
4	5	0.0132	0.0379
5	6	0.0472	0.1983
5	7	0.0581	0.1763
7	8	0.0119	0.0414
7	9	0.0460	0.1160
9	10	0.0267	0.0820
9	11	0.0120	0.0420
11	12	0	0.2080
12	13	0	0.5560
12	14	0	0.2080
14	15	0	0.1100
15	16	0	0.2560
16	17	0	0.1400
17	18	0.1231	0.2559
18	19	0.0662	0.1304
19	20	0.0945	0.1987
20	21	0.2210	0.1997
21	22	0.0820	0.1923
19	23	0.1073	0.2185
23	24	0.0639	0.1292
24	25	0.0340	0.0680
24	26	0.0936	0.2090
26	27	0.0324	0.0845
26	28	0.0348	0.0749
28	29	0.0727	0.1499
29	30	0.0116	0.0236
28	31	0.1000	0.2020
23	32	0.1150	0.1790
32	33	0.1320	0.2700
33	34	0.1885	0.3292
33	35	0.2544	0.3800
35	36	0.1093	0.2087
35	37	0	0.3960
37	38	0.2198	0.4153
38	39	0.3202	0.6027
39	40	0.2399	0.4533
40	41	0.0636	0.2000

APPENDIX C: Renewable Energy DG Units

Tables C-1and C-2 show the characteristics of the wind turbine and solar modules which are used in this study.

Table C.1: Wind turbine characteristics.

Features	Wind Turbine
Rated power (MW)	1.1
Cut-in speed (m/s)	4
Rated speed (m/s)	14
Cut-out speed (m/s)	24

Table C.2: Solar module characteristics.

Features	
Watt peak (W)	75
Open circuit voltage (V)	21.98
Short circuit current (A)	5.32
Voltage at maximum power (V)	17.32
Current at maximum power (A)	4.76
Voltage temperature coefficient (mV/°C)	14.4
Current temperature coefficient (mA/°C)	1.22
Nominal cell operating temperature (°C)	43

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