CHAPTER 1

INTRODUCTION

1.1 General

Electricity is the basic prerequisite for the economic development of a country. In India, energy crisis is one of the biggest problems, not only in industrial development, but also in agriculture, etc. Looking to the current energy scenario of the electricity sector, 233.929 GW in December 2013 [1], the world's fifth largest. Out of total energy generation contribution of coal is largest after it, renewal hydropower accounts for 19%, renewable energy for 12% and natural gas for about 9%. India currently suffers from a significant lack of electricity generating capacity, although it is the world's fourth largest energy consumer after the U.S., China and Russia. The International Energy Agency estimates that India needs an investment of atleast 135 billion to provide universal access to electricity to its population. Over 300 million Indian citizens had no access to electricity. Over a third of India's rural population lacked electricity, and 6% of the urban population. Of those who had access to electricity in India, the supply was intermittent and unreliable. In 2010, blackouts and power shedding interrupted irrigation and production in the country.

Keeping in view of the above situation proper energy planning and efficient use of energy is very important aspect in distribution system it is the most visible part of the supply chain, and as such most exposed to the critical observation of its users. It is often the biggest investment, maintenance and operating costs, a subject of interest to the government, financial organizations and associations of concerned citizens. About 30 to 40% of the total investment in the electric sector goes to distribution systems, but nevertheless they have not received any technological effect in the same way as the generation and transmission systems. Many of the distribution network works with minimum monitoring systems, primarily with local and manual control of capacitors, breakdown switches and controls, and without adequate calculation support for system operators. Yet there is a growing trend to automate distribution systems to improve their reliability, efficiency and service quality. Ideally, the losses in an electrical system, be about 3 to 6 %. In developed countries, it is not more than 10, but in developing countries, the proportion of active power loss is about 20%. There for, utilities in the electric sector is currently interested in reducing it to be more competitive as electricity prices in liberalized markets is related to the loss of the system [2]. The benefits obtained from DG placement are site specific and hence DG's should be placed strategically in power system in order to obtain the maximum benefits for example improving the voltage profile in the system, reducing power losses, improving the system reliability, transmission and distribution system congestion management and on-peak operating costs and for better quality of power [3].

Currently, the trend for the production of electricity from DG sources grows through the world because of energy security, environmental protection, energy efficiency and security of supply. DG sources connected to the distribution network, which is basically designed to carry power from the generation site to load. The distribution voltage profile depends on the active and reactive power injected by DG source and load. Solar photovoltaic (SPV) systems are well suited to be used as DG in the SPV systems can be places of electricity very close to the place where power is required. Therefore, it reduces the transmission and distribution costs and losses. Further, many SPV power generation sources designed for small, medium and large use depending on the demand of consumption.

An inappropriate placement of incoming DG source in the distribution system with respect to location and size will lead to increase in the power losses and voltage profile of the system can also violates the limits. Hence DG source should be properly placed and sized to ensure that the voltage profile of distribution system should remain within the acceptable limits and also to reduce the system losses.

1.2 Distribution Generation

Distributed generation, for the moment loosely defined as small-scale electricity generation, is a fairly new concept in the economics literature about electricity markets, but the idea behind it is not new at all. In the early days of electricity generation, distributed generation was the rule, not the exception. The first power plants only supplied electricity to customers in the close neighborhood of the generation plant. The first grids were DC based, and therefore, the supply voltage was limited, as was the distance that could be used between generator and consumer. Balancing demand and supply was partially done using local storage, i.e. batteries, which could be directly coupled to the DC grid. Along with distributed generation, local storage is also returning to the scene. Later, technological evolutions, such as the emergence of AC grids, allowed for electricity to be transported over longer distances, and economies of scale in electricity generation lead to an increase in the power output of the generation units. All this resulted in increased convenience and lower per unit costs and massive electricity systems were constructed, consisting of huge transmission and distribution grids and large generation plants. Balancing demand and supply was done by the averaging effect of the combination of large amounts of instantaneously various loads. Security of supply was increased as the failure of one power plant was compensated by the other power plants in the interconnected system. In fact this interconnected high voltage system made the economy of scale in generation possible.

In the last decade, technological innovations and a changing economic and regulatory environment have resulted in a renewed interest for distributed generation. This is confirmed by the IEA (2002), who lists five major factors that contribute to this evolution, i.e. developments in distributed generation technologies, constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity, the electricity market liberalization and concerns about climate change.

1.3 Losses in Distribution Systems

There are many methods of loss reduction techniques used like feeder reconfiguration, capacitor placement, high voltage distribution system, conductor grading, DG unit placement. All these methods are involved with passive element except DG unit placement. Both DG units and capacitors reduce power loss and improve voltage regulation. But with DGs loss reduction almost double that of Capacitors [4].

1.4 Necessity of DG Placement in Distribution System

Distributed resources can improve the efficiency of the supply of electrical energy. They often emphasize that the transmission of electricity from a power plant to a typical user wastes about 4.2 to 8.9 percent of the electricity as a result of the aging of the transmission technology, inconsistent enforcement of reliability standards and increasing congestion. At the same time, customers often suffer from poor power quality voltage fluctuations or power flow, which results from a variety of factors, such as poor switching operations in the network, voltage dips, interruptions, transients and Network disturbances at loads. The uses of on-site energy systems can potentially consumers affordable performance at a higher level of quality. In addition, residents and businesses to generate energy locally, have the potential excess energy into the grid, the substantial income can sell arise in times of peak demand. DG facilities offer potential benefits for improving the power transmission. Because they produce electricity locally for users, they support the entire network by reducing demand at peak times and congestion by minimizing the power on the network, one of the causes of the blackout of 2003. And by building a large number of local energy generation plants rather than a few large power stations are only removed from load centers, DG can shift transmission upgrades and expansions at a time when investment in such investments contribute remains limited. Perhaps most important in the 11th after the September period, the DG technologies can improve the security of the network.

Environmentalists and scientists suggest that DG technologies can create additional benefits for society. Large, centralized power plants emit significant amounts of carbon monoxide, sulfur oxides, particulate matter, hydrocarbons and nitrogen oxides. Finally, DG can help the nation's to increase it's diversity of energy sources. Some of the DG technologies, such as wind turbines, solar photovoltaic panels and hydroelectric turbines, consume no fossil fuels, while others, such as fuel cells, Micro turbines, and some combustion unit’s burn natural gas, many of which are produced in the United States. The increasing diversity helps insulate the economy from price shocks, interruptions and lack of fuel.

1.5 Developed Methodology for DG Placement

Various methods for finding the location and size of DG in distribution systems are available in the literature. The problem with DG location in the distribution system as of shunt capacitor placement in distribution. Therefore method similar to that given for location of the capacitor is given for placement of DG [4-5]. Various technique use are

1. *2/3 Rule*

This method often used in proper placement of shunt capacitors in distribution systems. This was presented in [3] to find DG optimal location on a radial feeder with uniformly distributed load. It was proposed for minimizing the losses and voltage impacts and for using in feeders with uniform loads. This approximate and useful approach has presented that the best capacitor size is 2/3 of the load which is located 2/3 of the distance out the feeder. It also can be extended to the "2/(2N+l) Rule" for N capacitors. For instance, the optimal locations for two units with approximately 2/5 capacity for each of them, might be located at 2/5 and 4/5 length of line [10].

2. *Analytical Method*

It is basically based on theoretical and mathematical analysis and calculations. The placement of DG are entailed the theoretical optimal locations for adding DG owing to types of loads in radial feeders. Also, they may be extended to network systems to find the optimal bus for placing DG in these networks regarding to generation information, bus admittance matrix and load profile [13].

3. *Genetic Algorithm (GA)*

The optimal location and sizing of DG for minimization of the power loss and cost of DG is found using GA. One compromised solution satisfying both objectives is obtained according to the choice of the decision maker. The Multi objective optimization algorithm (NSGA-II) is used to solve these two objectives to get a set of pare to optimal solutions [24].

4. *Sequential Quadratic Programming (SQP)*

SQP is applied to solve Optimal Distributed Generation Placement (OPDG) without considering fault level constraints and a programming is use to find out the optimal size of DG [14].

5. *Particle Swarm Optimization(PSO) and HBMO*

Particle Swarm Optimization (PSO) is applied for the placement of Distributed Generators (DG) in the radial distribution systems to reduce the real power losses and to improve the voltage profile [20].

6. *Evolutionary Programming(EP)*

It cover a wide range of Artificial Intelligence (AI) techniques such as Genetic Algorithm [12-16], Fuzzy Systems [24,32-34], Tabu Search [18-20] etc. which have been applied in most optimization problems as well as DG optimal placement. The applications and goals of these techniques vary owing to their great potentials to optimize technical and economical DG challenges. The optimal DG locations are computed based on incremental bus voltage sensitivities and the optimal DG sizes are calculated by evolutionary programming [25].

7. *Heuristic Techniques*

Heuristic Techniques is applied to find out the optimal location for DG placement. In it at first find out critical node, named sensitive node, is selected for installing. The sensitive nodes are selected based on the power loss caused in the system by the active components of the load (bus) currents [12,25-30].

8. *Fuzzy Logic Based Methods*

Fuzzy Logic based methods use membership functions for Fuzzy Modelling of the actual system. A fuzzy inference system (FIS) containing a set of rules is then used to determine the DG placement suitability of each node in the distribution system [20,32-34].

In this discussion, two types of methodologies are used which are given below

a. *Heuristic Techniques*

b. *Fuzzy Logic Based Methods.*

1.5.1 Heuristic Search Approach

Heuristic method is used for find out critical node, named sensitive node, is selected for installing DG in order to achieve a large overall loss reduction in the system. This is based on the idea that the number of sensitive nodes is relatively small compared to the total number of nodes, which will considerably reduce the size of the problem. The sensitive nodes are prime locations for installing DGs. The sensitive nodes are selected based on the power loss caused in the system by the active components of the load (bus) currents.

1.5.2 Fuzzy Logic Based Methods

Fuzzy logic based methodology for optimal sizing of solar photovoltaic based DG system for loss reduction in distribution systems. The methodology ensures that power losses in the system should be minimised while maintaining voltage within the specified limits. Since distribution systems have low voltage as compare to high voltage transmission system and hence high currents therefore the power losses are significantly high. In the proposed work a radial distribution system is taken because of its simplicity. Fuzzy logic based methods use membership functions for fuzzy modelling of the actual system. In fuzzy logic based solutions developing appropriate membership functions is the most crucial task, assigning proper membership function depends upon developers experience and intuition. Node voltage in the distribution system and active power loss reduction index in the branches of the system are taken as indicators for placing the SPV based DG system at the concerned node then the size of the incoming DG to be placed at the appropriate node is determined using the exact loss formulae [10]. Fuzzy logic is a generalization of the usual Boolean logic used for digital circuit design. An input under Boolean logic takes on a value of “True” or “False”. Under fuzzy logic an input is associated with certain qualitative ranges. For instance the temperature of a day may be "low", "medium" or "high". Fuzzy logic allows one to logically deduce outputs from fuzz inputs. In this sense fuzzy logic is one of a number of techniques for mapping inputs to outputs.

Among the advantages of the use of fuzzy logic are the absences of a need for a mathematical model mapping inputs to outputs and the absence of a need for precise inputs. With such generic conditioning rules, properly designed fuzzy logic systems can be very robust when used for forecasting.

1.6 Organization of Dissertation

The dissertation is organized as follows: Chapter 1 is the introduction of present work. Literature review is prescribed in Chapter 2. Chapter 3 present load flow study and it's implementation in distributed systems. Chapter 4 Heuristic search strategies to determine the optimal distributed generation placement and size for distributed system. Chapter 5 presents application fuzzy logic in DG placement. The conclusion and the future scope of the work presented in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter includes the literature review related to optimal DG placement for maximum loss in distribution system. Various books and research paper related to DG implementation have been studied, which form the back bone of the present work undertaken by me.

2.2 Literature Review

2.2.1 Load Flow Study

In a three phase ac power system active and reactive power flows from the generating station to the load through different networks buses and branches. The flow of active and reactive power is called power flow or load flow. Power flow studies provide a systematic mathematical approach for determination of various bus voltages, there phase angle active and reactive power flows through different branches, generators and loads under steady state condition. Power flow analysis is used to determine the steady state operating condition of a power system. Power flow analysis is widely used by power distribution professional during the planning and operation of power distribution system. logic based approach for that various research papers are taken as reference.

Chaturvedi [2] discussed about the various soft computing techniques including fuzzy logic, which a capability of handling uncertainty arising from, say, vagueness, incompleteness, overlapping concepts; neural networks providing machinery for adaptation and learning, genetic algorithms for optimization and learning, and probabilistic reasoning for inference were considered to be the basic ingredients of soft computing. The ability to accurately forecast load is vitally important for the electric industry in a deregulated economy. F.Gonzalez-longatt [3] discussed bibliography review of the distributed generation concepts provided for international and regional institutes over worldwide and also summarize the most important and relevant characteristic of all concepts showed. It presents the most known concepts of international and regional institution, and summarizes and characterizes all concepts to make an inclusive concept like results and conclusions of this paper. G.rechberger [5] determine load flow cases with load and generation data in a meshed transmission grid, which cover all critical power line loading situation in a given time frame. Load flow method that use by rechberger give an objective and represent the picture of expected situation and can be used for power system planning in view of increasing demand and new generation capacity installations.

M.H.Haque [6] analyze and compare the load flow results of a distribution system for various voltage dependent load models. The load flow problem of a distribution system is also formulated in terms of three sets of recursive equations so that very sophisticated voltage dependent load models can easily be incorporated in these equations. and also explain the effect of various load models on the convergence pattern of the load flow method. Martinez [7] reviews models and solutions technique of load flow method for distribution system with DR penetration. On the behalf of his work author conclude that the distribution system structure is basically radial, and it's calculation is done by advanced load flow packages that will consider the random nature of some input (load, generation) and the time step will, on the other hand depend on the type of DR devices.

2.2.2 Developed Methodologies for DG Placement

Several techniques have been proposed in determining the optimal location of DG [8-32]. The major objective of DG placement techniques is to minimize the losses of power systems. However, other objectives like improving the voltage profile, reliability, maximizing DG capacity, cost minimization etc. have also been considered in different studies. Some of the methodologies used are given below.

M. Hamada [8] present a new approach based on the total reactive loss in a distribution system to decide the optimal locations and sizes of the compensation shunt capacitors in radial distribution feeder. According to this approach to determine the amount of compensation required for any feeder is equal to total reactive loads in addition to the total reactive losses in all sections of this feeder. It will find out with the help of load flow study. Author use optimization technique is use to find out the optimal or candidate bus at which the capacitor should be connected and result of this compared with the given result. Ravi Kumar [11] implement heuristic search strategies to determine the optimal size of SPV based Distributed Generation (DG) and optimal location for maximum loss reduction. The main objective is to apply heuristic search strategies to determine the node for the appropriate placement of DG. Ilyas [8] implements the identification of optimal DG locations by single DG placement algorithm he first evaluates the voltage profile using Newton-Raphson method and then it calculates the total I^2R loss of the system and then by placing the DG at each bus, it evaluates the corresponding total I^2R losses and obtained the optimal placement of DG for loss reduction and best suited voltage profile evaluation. Choi and Kim [9] work on the distribution automation. Due to many attractive aspects of DG in the future power distribution system. Author work on the distribution automation. Distribution automation will we a central hub of integration of the distribution system. Author present various operation strategies which are use network reconfiguration of the automated distributed system with DG as a real time operation tool for loss reduction and services restoration from the view of distribution operation.

Singh [12] Present an analytical expression based method is proposed for finding the optimal size of DG and location is found where loss is minimum. Size and location of DG are fundamental factors in the application of DG for loss minimization. Show that voltage profile is significantly improved by placing DG in Distribution system and the losses have been reduced by 47.28%. In practice, The choice of the best site may not be always possible due to many constraints. However, the analysis that he have done suggests that the losses arising from different placements vary greatly and hence this factor must be taken into consideration while determining appropriate location. Georgilakis [12] present a thorough description of the state of the art models and optimization methods applied to the optimal distributed Generation Placement. The main aim of georg is to provide the best location and size of DG to optimize electrical distribution network operation and planning taking into account DG capacity constraints.

It present an overview of the state of the art models and applied methods to the ODGP problem, analyzing and classifying current and future research tends in this field. Sharma [13] Present a heuristic approach for determination of DG allocation incorporating the constraints to arrive at a feasible solutions. Sharma present that with the help of Network Performance Enhancement Index (NPEI) we able to select the optimum solution satisfying all the constraints. The developed approach is tested on different test system and results obtained have shown that the technique gives the better and economical solution for the system improvement.

Wang [14] presents an analytical method to determine the optimal location to place a DG in radial as well as networked systems to minimize the power losses of the system. Presented approach is not iterative algorithms, like power flow programs and result will we obtain very quickly.

Chis [16] also present heuristic search strategies to determine the optimum capacitor placement and ratings for distribution systems and the applied approach is suitable for large distribution system and can be useful in online implementation. Rizwan [20] present a methodology for determining the optimum size and location for installing the solar photovoltaic (SPV) based system for supplying the active power at the node in radial distribution system for loss reduction. A heuristic approach is applied to determine the node for appropriate placement of DG.

Mekhamer [22] introduce heuristic techniques for reactive power reactive power compensation in radial distribution feeders. The methods can be considered as generalization ideas that emerged from recent heuristic search strategies and lead to better results. Dasan [25] present an approach to find out the optimal location for placing DG. Location is identify through loss sensitivity factors and L index and an evolutionary programming is use to find out the optimal size of distribution network. Lalitha [27] present a methodology using Particle Swarm Optimization (PSO) for the placement of Distributed Generators (DG) in the radial distribution systems to reduce the real power losses and to improve the voltage profile. DG placement method is proposed to find the optimal DG locations and PSO algorithm is propose to find out the optimal DG sizes.

Reddy [32] presents a methodology using Fuzzy and Artificial Immune System (AIS) for the placement of Distributed Generators (DGs) in a radial distribution system to reduce the real power losses and to improve the voltage profile. In this two-stage methodology for the optimal DG placement. At first use the fuzzy set approach is to find the optimal DG locations and Clonal Selection algorithm of AIS is used to find out the size of DGs in second stage. Fzalan [34] present a hybrid algorithm PSO and HBMO to determine optimal placement and sizing of distributed generation (DG) in radial distribution system to minimize the total power loss and improve the voltage profile. Lin, Zhou and Wang [33] presented the optimal planning scenario when capacities of distributed generators (DG) when capacities are known at different locations. The methodology used is to build a multi-objective function model considering installation cost, power supply reliability and line loss rate, then to normalize and assign weight to the multi-objective function to build optimal objective function to minimize cost of distribution network, finally, to apply electromagnetism-like mechanism to resolve the function. The proposed method has also been compared to GA in optimizing placement of DG and the results yielded that the former has significant advantages in speed, accuracy and error tolerance.

Allam and Shatla [21] proposed an optimal proposed approach (OPA) to determine the optimal sitting and sizing of DG with multi-system constraints to achieve a single or multi-objectives using genetic algorithm (GA). The authors report that the linear programming (LP) is used not only to confirm the optimization results obtained by GA but also to investigate the influences of varying ratings and locations of DG on the objective functions. A real section of the West Delta sub transmission network, as a part of Egypt network, has been used to test the capability of the OPA. The results demonstrate that the proper sitting and sizing of DG are important to improve the voltage profile, increase the spinning reserve, reduce the power flows in critical lines and reduce the system power losses.

CHAPTER 3

LOAD FLOW STUDY AND ITS IMPLEMENTATION IN DISTRIBUTED SYSTEMS

3.1 Introduction

Distributed Resources (DR) provide several challenges for the analysis of the distribution system due to the models and solution techniques are required for the representation and the right solution. Load Flow Analysis is used to determine the voltage magnitude and phase angle at each bus system, the power flow in each branch of the system, power injected by each source of generation, and system losses. The formulation of the power flow for distribution systems can be both single and three-time. The models and techniques developed to calculate load flow in distribution systems.

3.2 Load Flow Study

In a three phase ac power system active and reactive power flows from the generating station to the load through different networks buses and branches. The flow of active and reactive power is called power flow or load flow. Power flow studies provide a systematic mathematical approach for determination of various bus voltages, there phase angle active and reactive power flows through different branches, generators and loads under steady state condition. Power flow analysis is used to determine the steady state operating condition of a power system. Power flow analysis is widely used by power distribution professional during the planning and operation of power distribution system.

3.2.1 Objective of Load Flow Study

- Power flow analysis is very important in planning stages of new networks or addition to existing ones like adding new generator sites, meeting increase load demand and locating new transmission sites.
- The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels.

- It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines.
- It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances.
- System transmission loss minimizes.
- Economic system operation with respect to fuel cost to generate all the power needed
- The line flows can be known. The line should not be overloaded, it means, we should not operate the close to their stability or thermal limits.

3.2.2 Load Flow Solutions

For planning the operation of a power system, its improvement and also its future expansion require following studies such as load flow studies, short circuit studies and stability studies. Load flow studies are used to ensure that electrical power transfer from generators to consumers through the grid system is stable, reliable and economic. Load flow studies are most important of all power system analysis, because these are used in planning studies of power system network to determine if and when specific elements will become overloaded. This is important, as the magnitudes of voltages at every bus are required to be held within a specified limit. The objective of any load flow study is to provide the following information.

- Voltage magnitude and phase angle at each bus.
- Real and Reactive power flowing in each element.

Once the bus voltage magnitudes and their angles are computed using the load flow, the real and reactive power flow through each line can be computed. Also based on the difference between power flow in the sending and receiving ends, the line losses in any particular line can also be calculated. It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines. In the power flow problem, it is assumed that the real power P and reactive power Q at each Load Bus are known. For this reason, load buses are also known as PQ Buses. For Generator Buses, it is assumed that the real or active power generated P and the voltage magnitude V is known. For the Slack Bus, it is assumed that the voltage magnitude V and voltage phase angle of the buses are known. In this work Newton-Raphson method for load flow is used, because of its reliability towards convergence and not sensitive nature to the starting solution. In large-scale power flow studies, the Newton-Raphson has proved most successful because of its strong convergence characteristics.

3.2.3 Methods of Load Flow Solution

To study of power system analysis, three methods are given as follows

a. Gauss Siedel Method

b. Newton Raphson Method

c. Fast Decoupled Method

3.2.4 Bus Classification

A bus is a node at which one or many lines, one or many loads and generators are connected. In a power system each node or bus is associated with 4 quantities, such as magnitude of voltage, phage angle of voltage, active or true power and reactive power in load flow problem two out of these 4 quantities are specified and remaining 2 are required to be determined through the solution of equation. Depending on the quantities that have been specified, the buses are classified into 3 categories. Buses are classified according to which two out of the four variables are specified.

a) *Load Bus*

No generator is connected to the bus. At this bus the real and reactive power are specified. It is desired to find out the voltage magnitude and phase angle through load flow solutions. It is required to specify only Pd and Qd at such bus as at a load bus voltage can be allowed to vary within the permissible values.

b) *Generator Bus or Voltage Controlled Bus*

Here the voltage magnitude corresponding to the generator voltage and real power Pg corresponds to its rating are specified. It is required to find out the reactive power generation Qg and phase angle of the bus voltage.

c) *Slack (swing) Bus*

For the Slack Bus, it is assumed that the voltage magnitude |V| and voltage phase Θ are known, whereas real and reactive powers Pg and Qg are obtained through the load flow solution.

3.3 Losses in Power System

In India, average transmission and distribution losses have been officially listed as 23% of the electricity generated. However, according to studies conducted by independent agencies samples, these losses have been estimated to be as high as 50% in some states. In a recent study conducted by SBI Capital Markets for DVB, the transmission and distribution losses have been estimated as 58%. With the creation of state regulatory commissions in the country, accurate estimation of Transmission and Distribution Losses has gained importance as the level of losses directly affect the needs of power purchase and sales and therefore has an impact on the determining the electricity tariff by a utility commission.

3.3.1 Transmission and Distribution Losses

3.3.1.1 Losses in Transmission Lines

Losses in the transmission lines can be determined less complicated compared to transformers and distribution systems. The basic computation of it usually surrounds to the fundamentals of ohm‘s law. Due to the simplicity of the transmission lines configuration, solving for its line losses requires no advance knowledge in any electrical principles. However, there are also portion of these line losses that better understanding is necessary. Total transmission lines losses can be broken down into three relevant parts namely; conductor losses, dielectric heating & radiation losses, and coupling & corona losses. It is because current flows through a transmission line and a line has a finite resistance there is an un-avoidable power loss. This is sometimes called conductor loss or conductor heating loss and is simply a power loss. Conductor loss depends somewhat on frequency because of a phenomenon called the skin effect. In an AC system, the flow of current in the cross section of the wire is not uniformly distributed. Skin effect tends to make the current flow concentrated more in the outer layer of the conductor. Since a very small area of the wire carries that current, line resistance increases at the same time increases the dissipated power. Corona is luminous discharge that occurs between the two conductors of a transmission line, when difference of potential between them exceeds the breakdown voltage of the dielectric insulator. Generally when corona occurs the transmission line is destroyed. If the separation between conductors in a metallic transmission line is appreciable fraction of wavelength. The electrostatic and electromagnetic fields that surround the conductor. Cause the line to act as if it were an antenna and transfer energy to any nearby conductive material. The energy radiated is called radiation loss and depends on dielectric material conductor spacing and length of transmission line. It reduces by properly shielding the cable e.g. STP and coaxial has less radiation loss. It is also directly proportional to the frequency.

3.3.1.2 Losses in Distribution Lines

The term distribution line losses refer to the difference between the amount of energy delivered to the distribution system from the transmission system and the amounts of energy customers are billed. Distribution line losses are comprised of two types: technical and non-technical. It is important to know the magnitude and causality factors for line losses because the cost of energy lost is recovered from customers. As a result of the composition and scale of the Hydro One distribution system it is not economic to provide metering and the supporting processes capable of measuring line losses directly. Since energy meters do not total data for the same periods, and load varies over time, a direct measurement of actual losses is not feasible. Instead, Hydro One relies on studies which are designed to calculate the magnitude, composition and allocation of system losses based on annual aggregate metering information for energy purchases, sales and system modeling methods. These studies are conducted with the energy assistance of industry experts in this field to ensure appropriate scientific methods and modeling techniques are utilized in establishing the magnitude, composition and allocation of losses.

3.3.1.3 Components of Transmission and Distribution Losses

Energy losses occur in the process of supplying electricity to consumers due to technical and commercial losses. The technical losses are due to energy dissipated in the conductors and equipment used for transmission, transformation, sub-transmission and distribution of power. These technical losses are inherent in a system and can be reduced to an optimum level. The losses can be further sub grouped depending upon the stage of power transformation and transmission system as Transmission Losses (400kV/220kV/132kV/66kV), as Sub transmission losses (33kV /11kV) and Distribution losses (11kV/0.4kv). The commercial losses are caused by pilferage, defective meters, and errors in meter reading and in estimating unmetered supply of energy.

3.3.1.4 Reasons for Transmission and Distribution Losses

Experience in many parts of the world demonstrates that it is possible to reduce the losses in a reasonably short period of time and that such investments have a high internal rate of return. Technical and commercial losses are the first step in the direction of reducing T&D losses. This can be achieved by putting in place a system for accurate energy accounting. This system is essentially a tool for energy management and helps in breaking down the total energy consumption into all its components. It aims at accounting for energy generated and its consumption by various categories of consumers, as well as, for energy required for meeting technical requirement of system elements. It also helps the utility in bringing accountability and efficiency in its working.

3.3.1.5 *Reasons for High Technical Losses*

The following are the major reasons for high technical losses in our country

1. Inadequate investment on transmission and distribution, particularly in sub-transmission and distribution. While the desired investment ratio between generation and T&D should be 1:1, during the period 1956 -97 it decreased to 1:0.45. Low investment has resulted in overloading of the distribution system without commensurate strengthening and augmentation.

2. Haphazard growths of sub-transmission and distribution system with the short-term objective of extension of power supply to new areas.

3. Large scale rural electrification through long 11kV and LT lines

4. Too many stages of transformations.

5. Improper load management.

6. Inadequate reactive compensation.

7. Poor quality of equipment used in agricultural pumping in rural areas, cooler air conditioners and industrial loads in urban areas.

3.3.1.6 Reasons for commercial losses

Burglary and theft account for a substantial part of the high transmission and distribution losses in India. Theft pilferage of Energy is committed mainly by two categories of consumers non-users and consumers of good faith. Anti-social elements take advantage of the offer unauthorized /unregistered engaging or touching bare conductors or cables LT feeder service handled. Some consumers in good faith intentionally commit theft by adverse alterations or creating equipment installed in facilities measuring.

Some of the modes of abstraction or illegal consumption of electricity is as follows

1. Making unauthorized extensions of loads, especially those having ―H.P.‖ tariff.

2. Tampering the meter readings by mechanical jerks, placement of powerful magnets or disturbing the disc rotation with foreign matters

3. Stopping the meters by remote control.

4. Willful burning of meters.

5. Changing the sequence of terminal wiring.

6. Bypassing the meter and changing C. T. ratio and reducing the recording.

7. Errors in meter reading and recording.

8. Improper testing and calibration of meters.

3.4 Application of Load Flow Study in DG

3.4.1 Algorithm for load flow study in DG

The computational steps in finding the optimal size distribution generator (DG) and able to participate in order to minimize the loss in a radial distribution system are summarized in the following:

1. First run the load flow analysis using Newton-Raphson method to determine the voltage profile and total loss of radial distribution system.

2. Second In load flow analysis will get the branch current I_{ij} between two buses by using,

$$I_{ij} = \frac{V_i - V_j}{R_{ij}}$$

Where, V_i = voltage of bus i

V_j = voltage of Bus j

R_{ij} = resistance between bus i and j

3. Obtain the active component I_a and reactive component I_r, of the branch currents I_{ij}.

4. We calculate total $I^2_a R$ loss by using,

$$P_L = \sum_{i=1}^{n} I_i^2 R_i$$

Where, $P_{La} = \sum_{i=1}^{n} I_{ai}^2 R_{ij}$ Due to active component of the current,

$P_{La} = \sum_{i=1}^{n} I_{ai}^2 R_{ij}$ Due to reactive component of current,

5. We calculate the power loss P_{La} (new) associated with the active component of branch current when DG is connected. it is given by

$$P_{La}^{new} \sum_{i=1}^{n} (D_i I_{ai} + D_i I_{DG})^2 R_i$$

where D_i=1;if branch $i \in \alpha$
=0,otherwise
'α' is the set of branches connected between the source and the bus m where DG is placed.

6. Repeat steps 1 through 5 steps and calculate P_{La} (new) by DG at each bus.

7. Calculate the energy savings by applying the following formula

$$s = P_{La} - P_{La}^{new}$$

8. The DG current IDG, the maximum saving offers can be obtained from,

$$\frac{\partial s}{\partial I_{DG}} = -2 \sum_{i=1}^{n} (D_i I_{ai} + D_i I_{DG})R_i = 0$$

9. Calculate DG power for maximum energy savings is given by,

$$I_{DG} = -\frac{\sum i \in \alpha \; I_{ai} \; R_i}{\sum i \in \alpha \; R_i}$$

10. Calculate be placed on each bus, the corresponding DG size is given by

At bus m,

$$P_{DG} = V_m I_{DG},$$

Where Vm is the Voltage Magnitude of Bus 'm'

11. Update the active power component,

$$P_{new} = P_{GEN} + P_{DG} - P_{LOAD}$$

12. Perform load flow analysis with upload active power component obtain in Step 11.

13. Perform the Step 10 and Step 12, and record the voltage profiles and total line loss.

14. Obtain the optimal location of Distributed Generation(DG) for total line loss minimization and voltage profile improvement.

3.4.2 Flow Chart for load flow study in DG

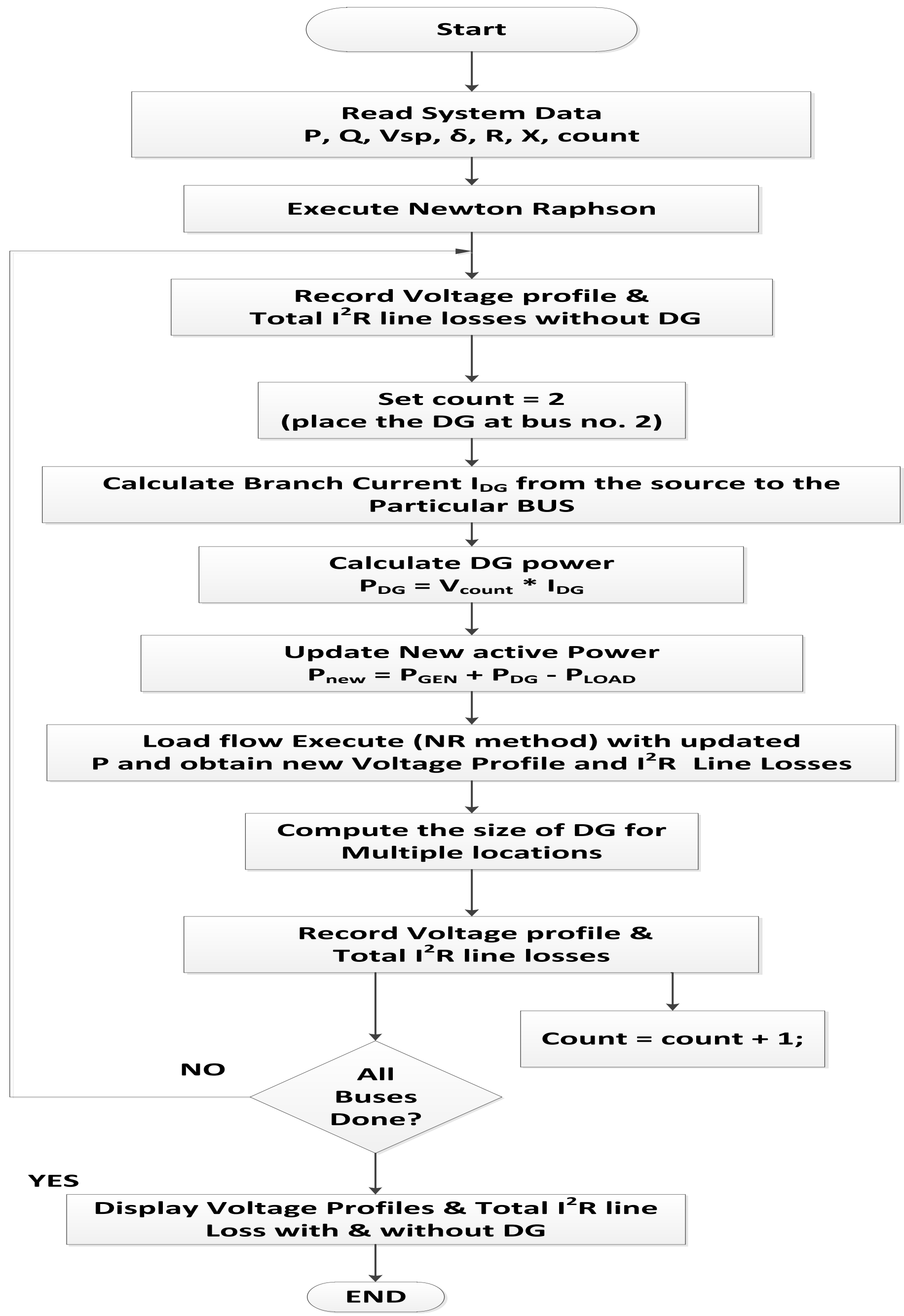

Figure 3.1 Flow chart for load flow study in DG

3.5 Result and Discussion

Newton-Raphson method has found wide applications in the field of power systems, it does not perform satisfactorily for systems with high R/X ratios. The application of the Newton-Raphson method in such situations either results in drastic increase of the number of iterations required for the system to converge or the maximum power mismatch of the system increases. For distribution systems, the increase in the R/X ratio increases the level of maximum power mismatch over a wide range of values. The number of iterations required for convergence also increases but it is not as pronounced as that in case of transmission system. In this thesis after applying Newton-Raphson method the result are given below. The power loss in base case system is 221.72 kW. The losses due to active component of current in the system are 162.71 kW and the losses due to reactive component of current in system are 59.017 kW. It is concluded that the performance of Newton-Rapson method is better as compared to other methods available in literature.

CHAPTER 4

HEURISTIC SEARCH APPROACH FOR DG PLACEMENT

4.1 Introduction

Reliability, accuracy and flexibility of the DG solution algorithm are influenced by the power flow analysis. It can be said that the power flow analysis is the heart of the DG solution algorithm. The power sources in the form of DG will be connected to the distribution network which has been designed to carry power from the generation side to load. Size and location of DG is reported to have considerable impact on the distribution system. So to find the appropriate location and size of DG Heuristic Search Strategies have been used and presented in this Chapter.

4.2 Heuristic Search Strategies

Heuristic Search Strategies are methods in which only critical node, named sensitive node, is selected for installing DG in order to achieve a large overall loss reduction in the system. This is based on the idea that the number of sensitive nodes is relatively small compared to the total number of nodes, which will considerably reduce the size of the problem. The sensitive nodes are prime locations for installing DGs. The sensitive nodes are selected based on the power loss caused in the system by the active components of the load bus currents. Also, the variations of the load during the day are taken into consideration for the purpose of achieving a higher reduction of the overall losses during the year. This study presents a heuristic approach to determine the suitable locations for DG placement. The objectives considered for identifying the optimal DG location is to minimize the real power loss while maintaining voltage within permissible limits. The DG unit can be placed on the nodes where the active load currents are causing the highest power losses. The problem of DG unit placement consists of determining the size, location and number of DG units to be installed in a distribution system such that maximum benefits are achieved while operational constraints at different loading levels are satisfied. The branch current has two components, active component and reactive component. For a given configuration of a single source radial distribution network, the losses associated with the active component of branch current cannot be minimized because all the active power must be supplied by the source at the root bus. This is not true if DG units are to be placed at different locations for loss reduction that is real power can be supplied locally by using DG units of optimum size to minimize active power loss associated with the active component of branch current. However there is significant change in reactive power loss with DG unit in distribution system. The method for obtaining the optimal DG size and location is outlined and also presented in Figure 4.1.

Step I

The peak power losses caused by the active load currents that flow through the feeder are computed by first, a load flow program calculates the power loss reduction.

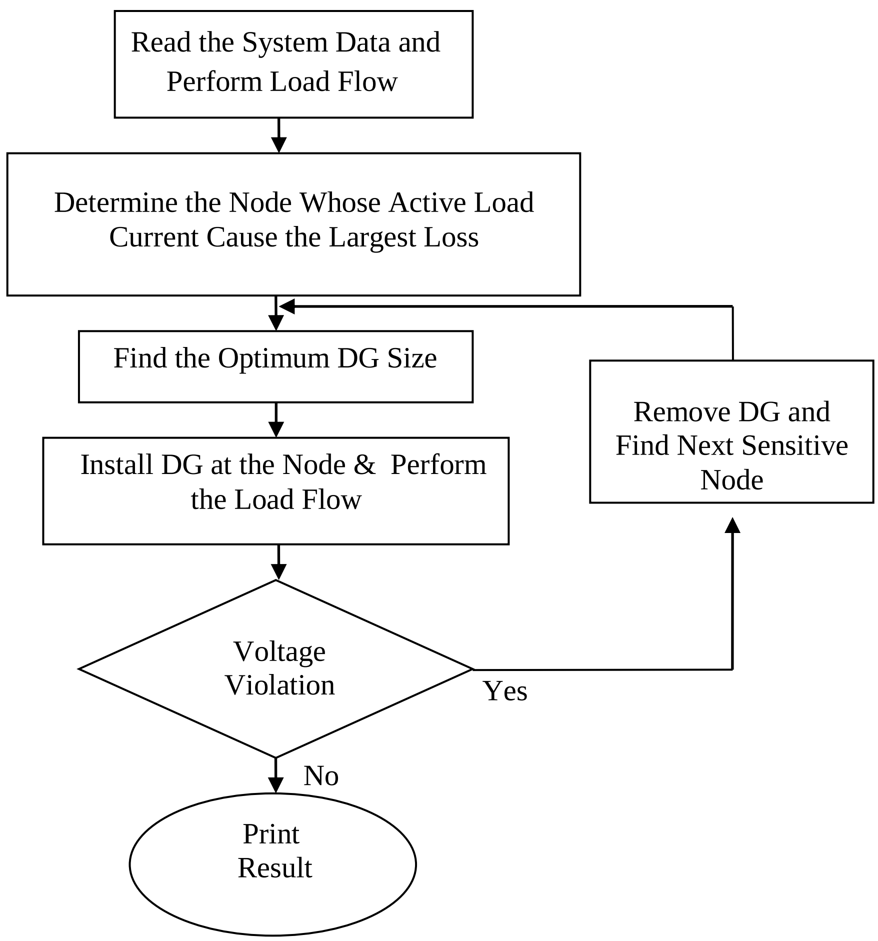

Figure 4.1 Flowchart of algorithm for finding the optimal DG location

by compensating the total active load current at every node of the distribution system. The loss reductions are then linearly normalized into a (0 - 1) range called as Power Loss Reduction Index (PLRI) with the largest loss reduction having a value of 1 and the smallest one having a value of 0. The node whose active load current has the largest impact on the power loss in the system is then selected for compensation and is called a sensitive node. Suppose this node is ‘k’

Step 2

Secondly, the optimal size of the compensating DG to be placed at node 'k' has to be determined. The idea is to place a DG unit with a proper size and location such that the system loss reduction is maximized. For system loss reduction to be maximum the DG unit must be placed at node ’k’, such that the rate of change of losses with respect to the injected bus power becomes zero [14]

Step 3

A load flow is performed in order to get the new values of the load currents and to check if the voltage constraints are met. If there is any violation of the voltage constraints, the DG is removed and the next largest loss node is selected as the next sensitive node and the procedure is repeated starting from Step 2.

4.3 Implementation of Heuristic Approach for DG Placement

In this dissertation, 33-bus system has been selected for analysis. Distribution network configuration of 33 bus system is presented in Figure 4.2. The details of feeding characteristics and capacities are given in Table of Appendix A. The total installed peak power is 5.4 MVA average power factor of 0.85. The software implementation the procedure was done using the MATLAB environment for the user to operate with complex numbers. All calculations were carried out in the unit-system with three basic phases S = 100 MVA, VB = 11 kV.

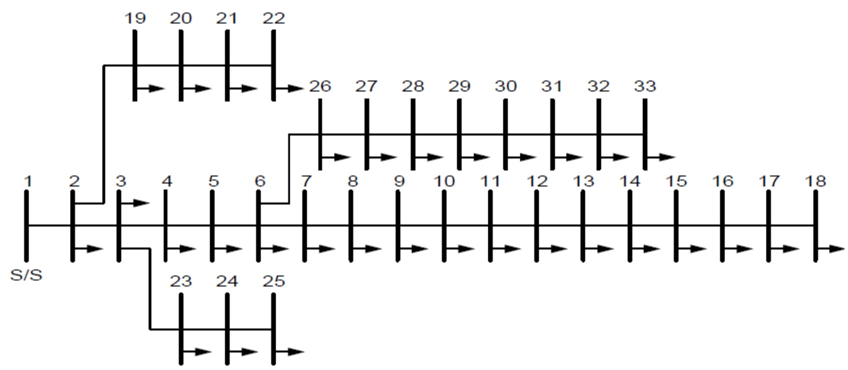

Figure 4.2 Distribution network configuration

4.4 Result and Discussion

Before the placement of DG the power loss in the system is 221.72 kW. The loss due to the active component of the current in the system are 162.71 kW and the loss due to the reactive component of the current in the system are 59,017 kW. The implementation of the proposed method to the system produces the following results. The Figure 4.3 shows the rate of reduction of normalized power losses reduction index after offsetting the total active power on each node in the distribution system, AS shown in Figure 4.3 that the node 26 is causing the highest losses in the system and is identified as the most sensitive node for the placement of DG.

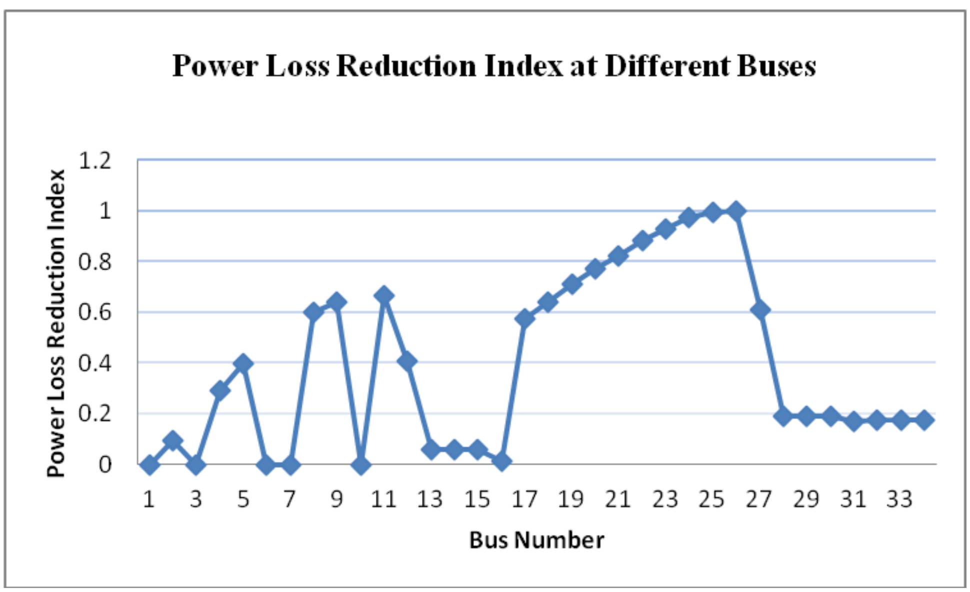

Figure 4.3 Power Loss Reduction Index at Different Buses

The optimal DG size is obtains 2.2801MW by applying the algorithm. This SPV type DG size gives the maximum loss reduction at the node 26 which is shown in Figure 4.3. The total active power losses in the system placement of DG at node 26 is 131.490KW and the losses due to active component of current are 73.992KW and the losses due to reactive component of the current is 57.498KW.

Figure 4.4 show the voltage profile of the system before and after placement of the DG at node 26 and in figure shown that placement of DG also significantly improves the system profile.

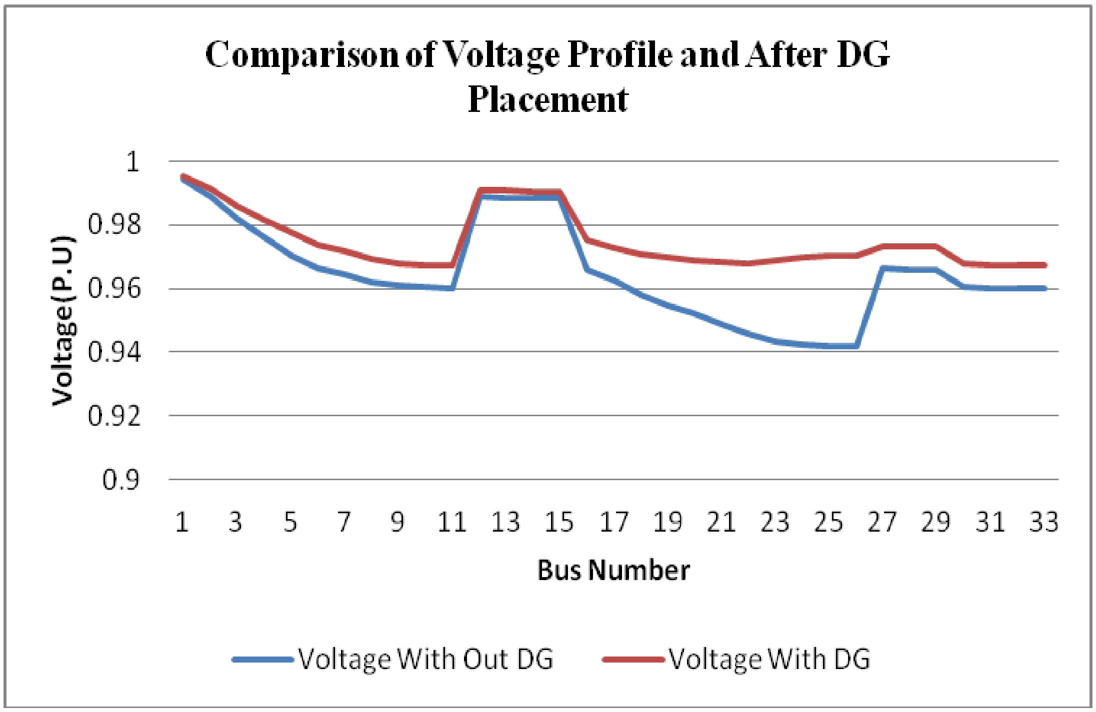

Figure 4.4 Comparison of Voltage Profile Before and After Placement of DG

Heuristic search strategies is used to determine the optimal distributed generation placement and size for distribution systems. The solution to the distributed generation placement problem using heuristic technique involves a set of rules and according to that possible solutions. This is achieved by examining the solution at a critical node named sensitive node. The sensitive node is selected based on the losses caused in the system by the active components of the load currents. It is proved that the proposed method can save huge amount of power and achieve significant improvement in voltage profile.

Since the number of sensitive nodes is relatively small compared to the total number of nodes in the distribution system, the size of the problem is considerably reduced. So we easily deal with large distribution system.

CHAPTER 5

APPLICATION OF FUZZY LOGIC IN DG PLACEMENT

5.1 Introduction

The distributed generation (DG) sources are added to the network to reduce the power losses in distribution system by supplying a net amount of power. In order to minimize line losses of power systems, it is equally important to define the size and location of local generation. There are many studies to define the optimal position of distributed generation. In this Chapter, we used fuzzy logic based approach to find the optimal locations of DG units and Real Coded Genetic Algorithm (RCGA) for optimal size of DG units. The proposed model is simple, accurate and incorporates the uncertainties in the input variables.

5.2 Basics of Fuzzy Logic

The concept of Fuzzy Logic was introduced by Professor Lotfi A. Zadeh at the University of California at Berkeley. His goal was to develop a model that could more closely describe the natural language process. This model was intended to be used in situations when deterministic and/ or probabilistic models do not provide a realistic description of the phenomenon under study.

5.2.1 Fuzzy Sets

The fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. But in order to say anything useful, we need to make complete sentences. The condition statements, IF-THEN rules, are things that make fuzzy logic useful. The fuzzy logic IF-THEN statements are used to characterize the state of a system and truth value of the proposition is a measure for how well the description matches the state of the system. The fuzzy set can be defined as follows:

Let X, be a universal set. The characteristic function μA of a subset of X takes its values in the two element set {0, 1} and is such that $\mu A(x) = 1$, if $x \in A$ and zero otherwise.

A fuzzy set A has a characteristic function taking its values in the interval {0, 1}. μA is the also called a membership function and μA (x) is the grade of membership of x ϵ X in A. In fuzzy set, the transition between membership and non membership is gradual rather than abrupt. The union and intersection of two fuzzy subsets A and B of X having membership function μA and μB respectively is defined as.

Union: $$\mu_{A\cup B}(x) = \max[\mu A(x), \mu B(x)] \tag{5.1}$$

Intersection: $$\mu_{A\cap B}(x) = \min[\mu A(x), \mu B(x)] \tag{5.2}$$

Fuzzy logic describes the vague concepts such as fast runner, hot weather, weekend days etc. It is convenient way to map an input to an output space. The concept of fuzzy provides a natural way dealing with the problems in which source of impression is the absence of sharply defined criterion rather than the presence of random variables. Prof. Zadeh also introduced linguistic as variables whose values are sentences in natural or artificial language.

5.2.2 Fuzzy Inference Systems

Fuzzy inference systems have been successfully applied in the various fields of engineering such as automatic control, power system analysis, circuit theory, electrical machines and drives etc. It is actual process of mapping from a given input to an output using fuzzy logic. In the fuzzy inference method sets of corresponding input and output measurements are provided to fuzzy system and it learns how to transform a set of inputs to corresponding set of outputs through fuzzy associative map or memory.

5.2.3 Fuzzy Membership Function

The literature is rich enough with references concerning the ways to assign membership values or functions to fuzzy variables. Among them ways are intuition, inference, rank ordering, angular fuzzy sets, neural networks, genetic algorithm, generalized neuron etc. The commonly used approach in fuzzy system is intuitive approach because it is derived from the capacity of humans to develop membership functions through their own innate intelligence and understanding. Intuition involves contextual and semantic knowledge about an issue; it can also involve linguistic truth values about this knowledge. Fuzzy membership is a curve that defined how each point in the input space is mapped to membership value or degree of membership between 0 and 1. Fuzzy membership functions may take many forms, but in practical applications simple linear functions are preferable. In particular, triangular functions with equal base width are the simplest possible choice.

5.2.4 Fuzzy Random Variable

a) Random variable

If an experiment is performed in which one or more variables behave randomly, then the outcome of the experiment will be random. In such a situation, it is not possible to specify in complete detail the outcome of the experiment in advance. Thus the theory of probability can be used to predict the outcome of an experiment affected by random variation in the variables. Moreover, the outcome of such an experiment is clearly defined; that is, the event corresponding to the experiment will either occur or will not occur at all. Let Ω be the set of all outcomes of a random experiment. The set Ω is also known as probability space. Then each element ω in Ω specifies exactly what happened; that is, ω is an outcome. A random variable Y is a function from Ω into the set R of real numbers; that is, Y: Ω R →. If Y is a random variable, each outcome will specify the value of Y. In other words, associated with each ω ϵ Ω, there is a number Y (ω).

b) Fuzzy variable

Fuzziness does not harbour the concept of clearly defined success (or failure) of outcome of an experiment. Rather it proposes to model the behaviour of the outcome of an experiment by allowing the concept of partial success (or partial occurrence). Let U be a universal set. A fuzzy subset F of U can be defined as a function: fF: U→[0, 1]. The membership function fF of F takes its value in the interval [0, 1]. Let γ be an element in U; then fF(γ) is the degree (or grade) of membership of γ in F. In a fuzzy set, the transition between membership and non membership is gradual rather than abrupt. The universal set U is not fuzzy.

The union of two fuzzy subsets F1 and F2 of U can be defined as

$$fF1\cup F2\ (\gamma) = \max\ [fFA\ (\gamma),\ fF2\ (\gamma)] \qquad (5.3)$$

The intersection of two fuzzy subsets F1 and F2 of U can be defined as fF1∩F2 (γ) = min [fFA (γ), fF2 (γ)] (5.4)

where fF1 and fF2 are membership functions of the fuzzy subsets F1 and F2, respectively, and γ is an element in U.

c) *Fuzzy random variable*

Let Γ be the collection or space of all fuzzy subsets and suppose (F1, . . . , Fn) are n unrelated fuzzy subsets (or variables) on Γ. Let γ be an element in Γ; then the membership of γ in a fuzzy subset Fi is determined by the membership function fF1 (γ) of Fi. Here fF1 (γ) is the degree of membership of γ in Fi. Suppose that **Ω** is a probability space. Further, suppose A1. An are the events that are the subsets of the probability space **Ω**.Let XAi be a random variable associated with event Ai , and each outcome ω ϵ Ai in **Ω** specifies the value of XAi , that is, XAi (ω). The random variable XAi can be described by any discrete probability distribution to provide the value of XAi (ω). Then a fuzzy random variable Y is a function from the probability space **Ω** into a space of fuzzy subsets Γ; that is, Y: **Ω** → Γ. In other words, Y can correspond to any one of n possible events (i.e., A1. . . An) corresponding to the fuzzy subset (i.e., F1, . . . , Fn) and can have a value from the membership range of the membership function (i.e., fF1 , . . . , f Fn).

If [0, 1] is considered as a non suitable membership scale for a fuzzy variable Fi , the points on the real line correspond to the range (a specified subinterval within the interval [0, 1]) of a membership function Fi rather than the domain [0, 1].

5.3 Data Collection and Normalization

A 33-bus three-phase radial distribution system as shown in Figure 4.2 in a single line diagram. Details of the feeder and the load data characteristics is given in Appendix. The total peek power is 5.4MVA with an average power factor of 0.85. The calculate value of the node voltage and active power loss reduction is presented in Table 5.1. The input is normalized and scaled in the range of 0 - 1 to avoid the convergence problem during the rules formation. The actual data is scaled by using the following expression and presented in Table 5.2

$$L_s = \frac{(Y_{\max} - Y_{\min})}{(L_{\max} - L_{\min})}(L - L_{\min}) + Y_{\min} \tag{5.5}$$

L_s =Normalized Value

L =Input Value from table
L_{min} =Min. Value in the table
L_{max} =Max. Value in the table
Y_{min} =Min. value of range (0)
Y_{max} =Max. Value in the range (1)

Table 5.1 Per Unit Bus Voltage and Active Power Loss at Every Node

S. No.	Active Power Loss	Node Voltage
1	221729.66	0.99413701
2	219501.05	0.98900776
3	221729.66	0.98204034
4	214651.42	0.97604872
5	212145.24	0.97040112
6	221729.66	0.96657316
7	221729.66	0.96447021
8	207306.14	0.96200241
9	206326.92	0.96081589
10	221729.66	0.96035825
11	205739.94	0.96022166
12	211949.68	0.98867392
13	220356.79	0.98836851
14	220325.12	0.98828568
15	220318.67	0.98827920
16	221460.24	0.96594009
17	207886.80	0.96223143
18	206323.24	0.95813618
19	204552.13	0.95484259
20	203130.13	0.95197944
21	201900.53	0.94871031
22	200471.14	0.94602351
23	199316.87	0.94349958
24	198266.51	0.94228467
25	197791.85	0.94181783
26	197636.72	0.94167839
27	206968.52	0.96623729
28	217151.16	0.96601336
29	217126.13	0.96590139
30	217117.79	0.96047527
31	217597.49	0.96013462
32	217564.60	0.95996429
33	217549.79	0.95990752
34	217546.50	0.99413701

Table 5.2 Normalized Input Data

S. No.	Input 1	Input 2
1	0.000	1.005
2	0.093	1.000
3	0.000	0.904
4	0.294	0.768
5	0.398	0.651
6	0.000	0.540
7	0.000	0.464
8	0.599	0.422
9	0.639	0.373
10	0.000	0.349
11	0.664	0.340
12	0.406	0.337
13	0.057	0.898
14	0.058	0.891
15	0.059	0.890
16	0.011	0.890
17	0.575	0.454
18	0.639	0.383
19	0.713	0.305
20	0.772	0.242
21	0.823	0.189
22	0.882	0.128
23	0.930	0.079
24	0.974	0.034
25	0.994	0.013
26	1.000	0.006
27	0.613	0.003
28	0.190	0.457
29	0.191	0.453
30	0.191	0.450
31	0.172	0.342
32	0.173	0.335
33	0.173	0.332
34	0.174	0.331

5.4 Application of Fuzzy Logic in DG Placement

5.4.1 Developed Model

The fuzzy logic model for determine the optimal dg location is developed and presented. The developed model contains a set of rules which are developed from qualitative descriptions. This study presents a Fuzzy Expert System (FES) based approach for appropriate location of DG in radial distribution systems. The problem considered is the identification of appropriate location for DG placement so that the total power losses in the distribution system are minimised at the same time voltage in the system should be maintained within the specified limits. The DG unit can be placed on the nodes where the DG suitability is maximum based on FES approach. The problem of DG placement also consists of determining the DG size once the location of the incoming DG to be placed is determined using the FES approach. FES contains set of rules which are designed with certain degree of accuracy based upon experience, probabilistic approach and intuition of the developer. For DG placement, the output of the rules is DG placement suitability. FES rules can be expressed in the following form. IF premise (antecedent), THEN conclusion (consequent).

5.4.2 Rule Base

To determine if a particular node is suitable for DG placement some fuzzy rules have been established and is mentioned in Table 5.3. For framing the rules the two inputs are node voltage and active power loss reduction index (APLRI) and the output is DG placement suitability. The consequent of the rules is given in the shaded portion of the Table 5.3. The input variables APLRI and node voltage and the output voltage DG placement suitability is defined by Fuzzy terms Low, Low-Med, Medium, Medium-high, High etc and are represented by membership functions. The development of membership function is based upon probalistic methods, experience and intuition of the developer. The fuzzy variables, APLRI, voltage, and DG placement suitability are described by the fuzzy terms.

These fuzzy variables described by linguistic terms are represented by membership functions as shown in Figures 5.1- 5.3. The fuzzy rules are implemented using the MATLAB, fuzzy logic tool box.

Table 5.3 Decision Matrix for the determination of DG suitability

AND		Voltage				
		Low	Low-Nor	Nor	High-Nor	High
APLRI	Low	Low-Med	Low-Med	Low	Low	Low
	Low-Med	Med	Low-Med	Low-Med	Low	Low
	Medium	High-Med	Med	Low-Med	Low	Low
	Med-High	High-Med	High-Med	Med	Low-Med	Low
	High	High	High-Med	Med	Low-Med	Low-Med

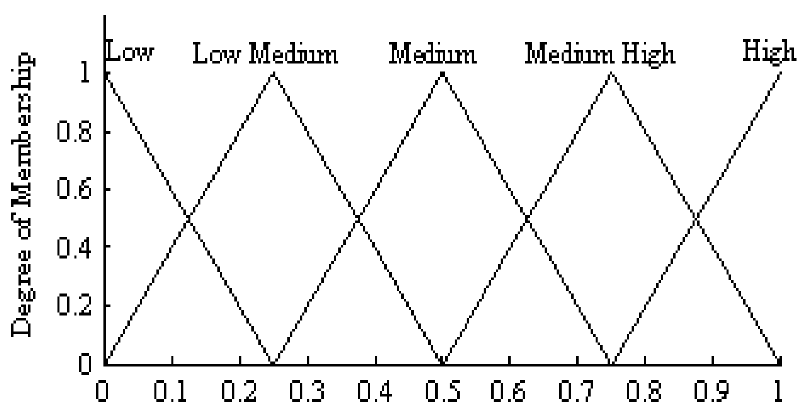

Figure 5.1 Fuzzy Subsets Membership Functions for Active Power Loss Reduction Index (APLRI)

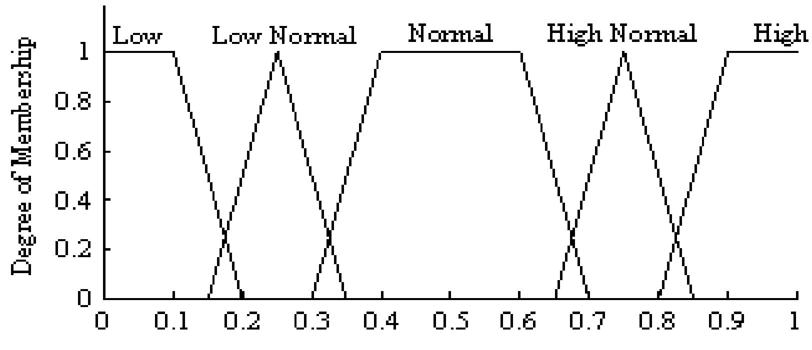

Figure 5.2 Fuzzy subsets membership functions for voltage

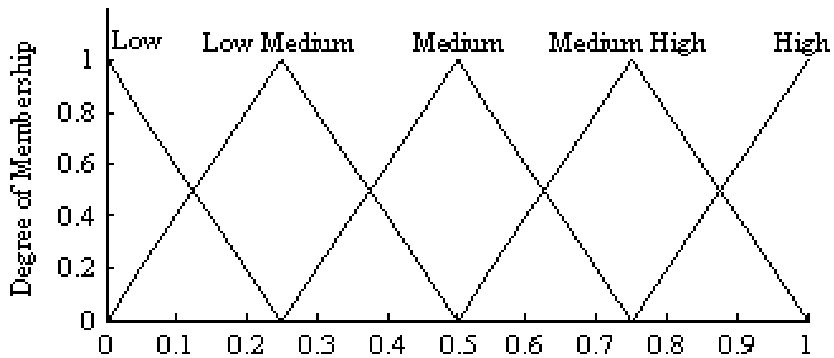

Figure 5.3 Fuzzy subsets membership functions for DG suitability

5.4.3 Components of Fuzzy Tool Box (FTB)

5.4.3.1 Fuzzy interface system(FIS) Editor

The FIS Editor displays information about a fuzzy inference system. The FIS Editor handles the high-level issues for the system such as how many input and output variables, their names etc. Fuzzy Logic Toolbox software does not limit the number of inputs. However, the number of inputs may be limited by the available memory of your machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other GUI tools.

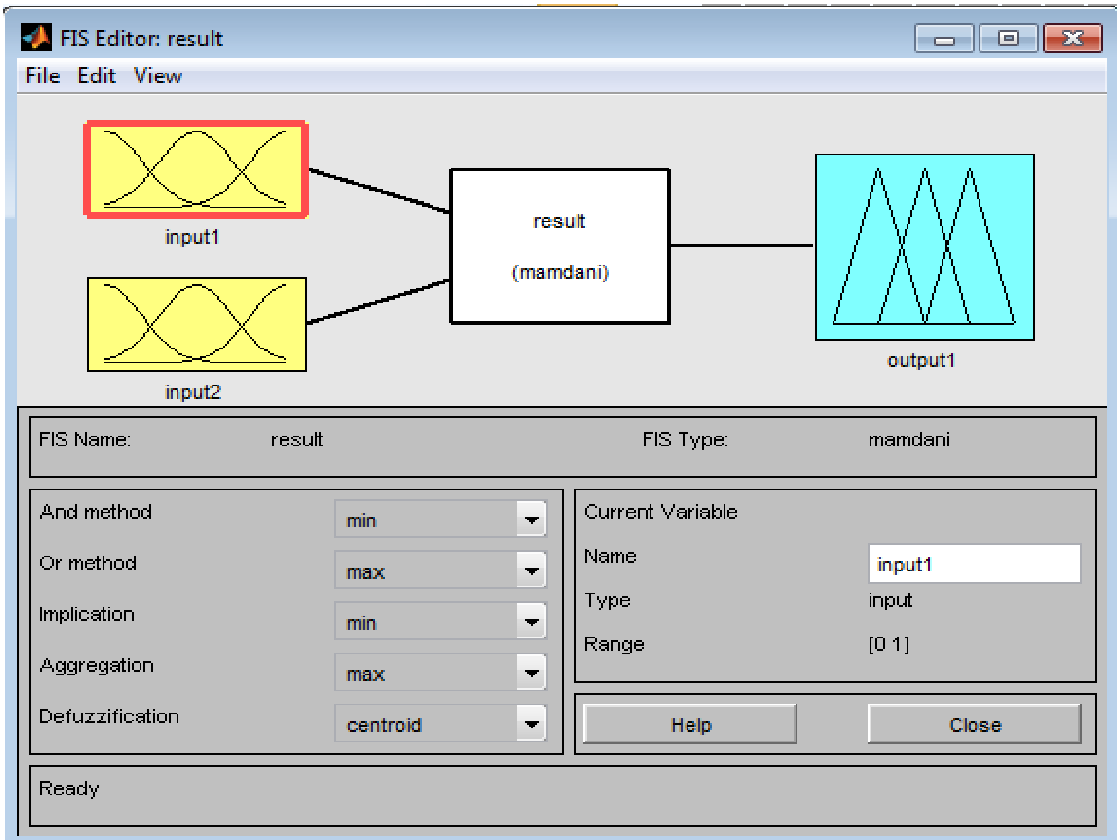

Figure 5.4 MATLAB Model of FIS

5.4.3.2 Membership Function

The membership function editors is the tool that lets you display and edit all of the membership functions associated with all of the input and output variables for the entire fuzzy inference system. The membership function editor shares some features with the FIS Editor, as shown in the figure. When we open the membership function editor to work on a fuzzy inference system that does not already exist in the workspace, there are no membership functions associated with the variables that you defined with the FIS Editor, so basically membership function editor is used to define the shapes of all the membership functions associated with each variable.

In Figure 5.5, four input and outputs are provided corresponding to which membership function is formed. The input data is provided in normalized form to avoid problem of convergence.

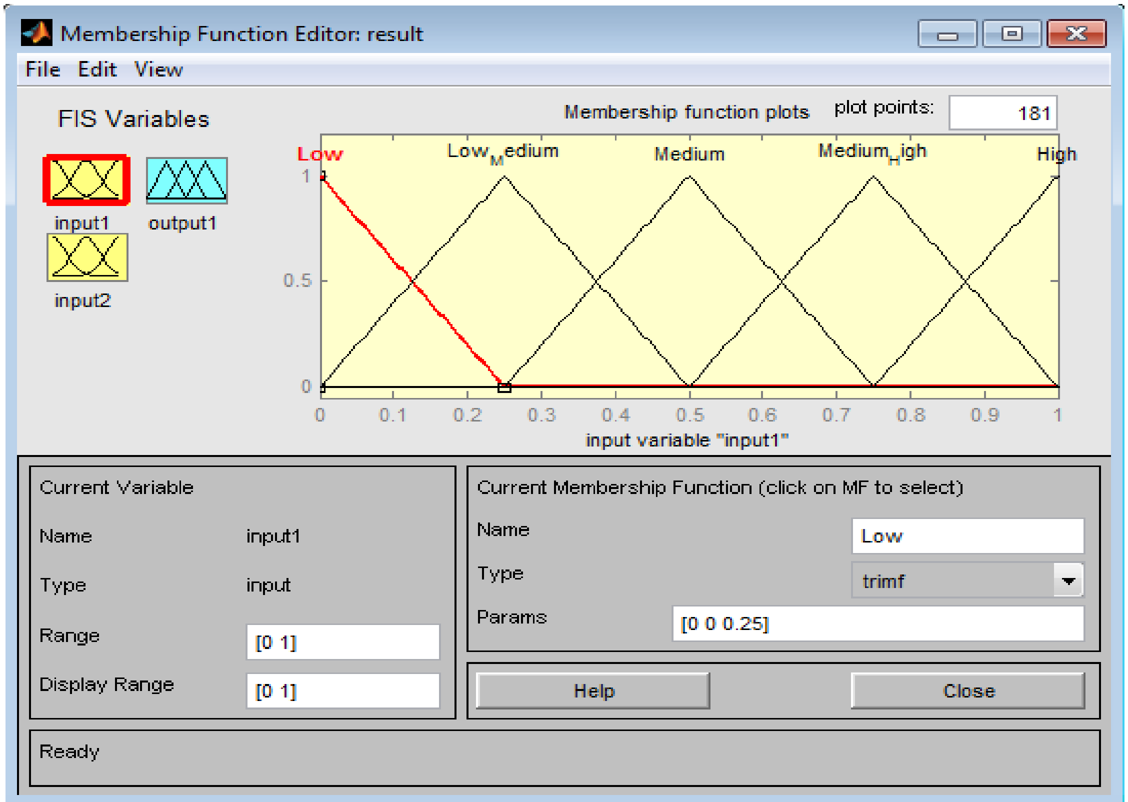

Figure 5.5 MATLAB Model of Membership function in FTB

5.4.3.3 Fuzzy Rule Editor

The rule editor is for editing the list of rules that defines the behavior of the system. Based on the descriptions of the input and output variables defined with the FIS editor, the rule editor allows you to construct the rule statements automatically. It also facilitate to change the fuzzy rule base, for calculating the fuzzy output corresponding to actual output it has linguistic variable which define mathematical value into non mathematical or linguistic value.

The Figure 5.6 shows the rule base of the fuzzy logic model. The fuzzy variable are defined or modified as per the requirement in the fuzzy rule editor. It provide both AND and OR connection, along with this It also provide function of add, delete and changing the rule base.

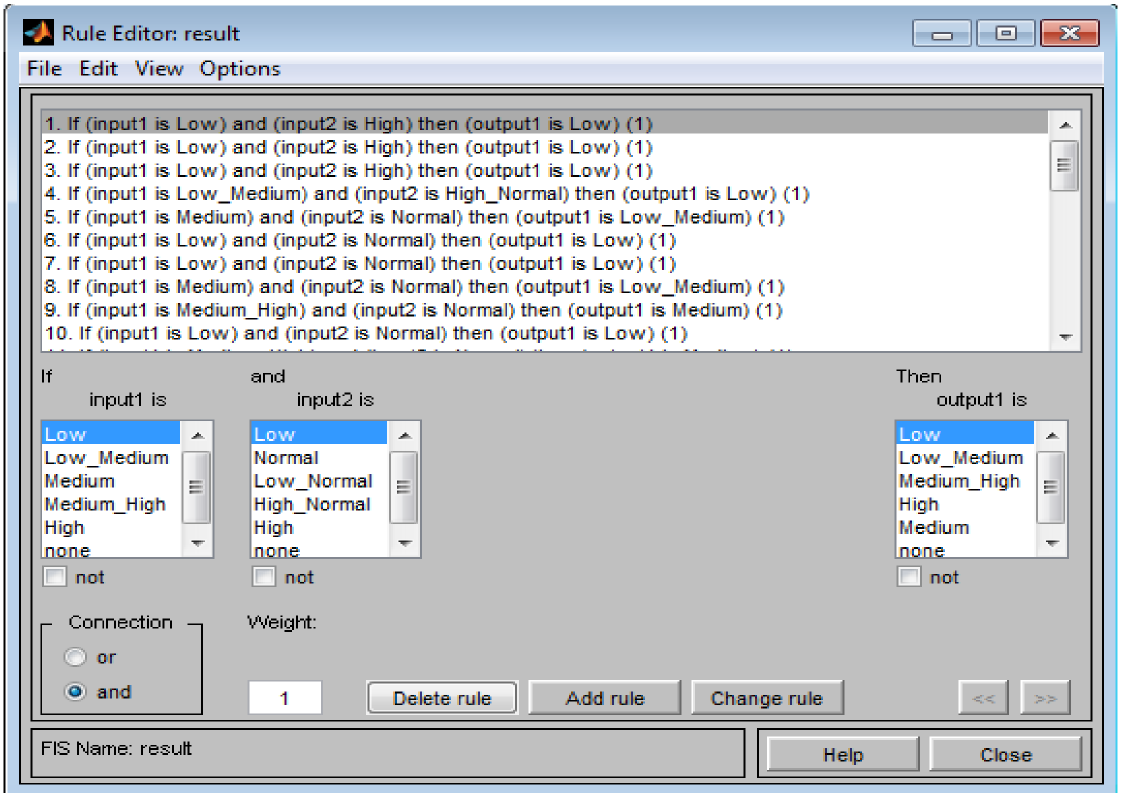

Figure 5.6 MATLAB Model of Rule Editor

5.4.3.4 Rule Viewer

The rule viewer displays a roadmap of the whole fuzzy inference process. It is based on the fuzzy inference. The rule viewer and the surface viewer are used for looking at, as opposed to editing, the FIS. They are strictly read-only tools. The rule viewer is a MATLAB technical computing environment based display of the fuzzy inference diagram shown at the end of the last section. Used as a diagnostic, it can show (for example) which rules are active, or how individual membership function shapes are influencing the results. The surface viewer is used to display the dependency of one of the outputs on any one or two of the input that is, it generates and plots an output surface map for the system.

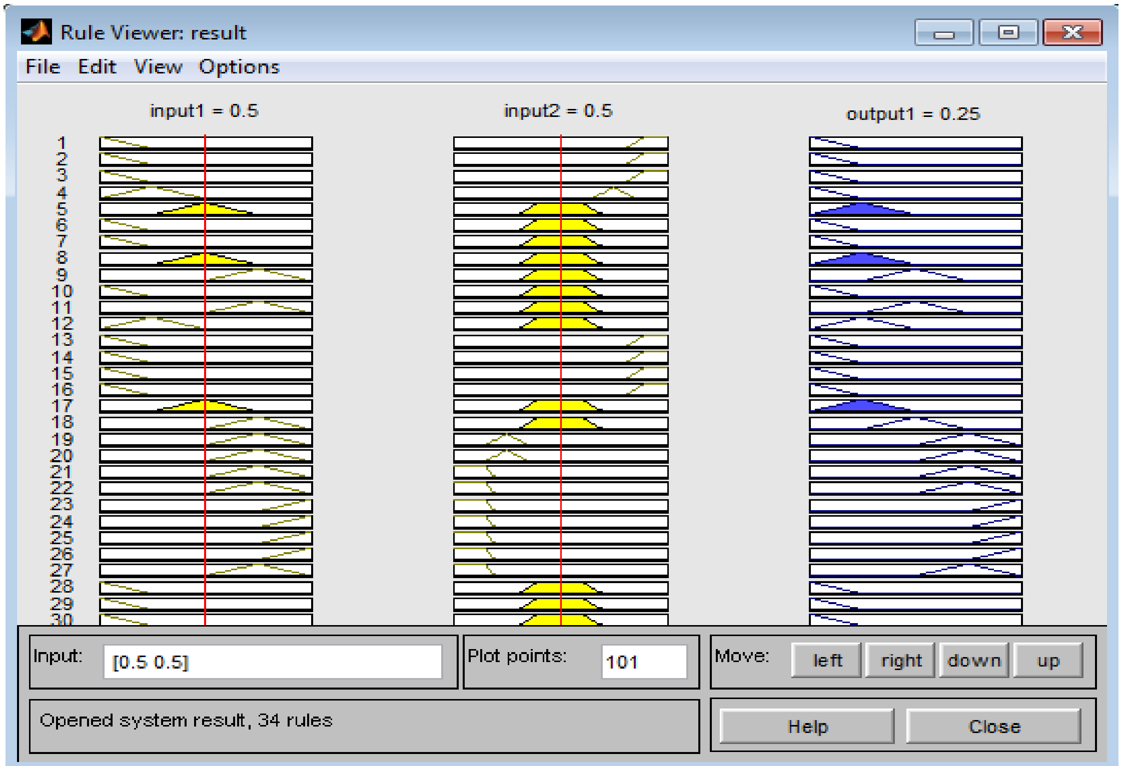

Figure 5.7 MATLAB Model of Rule Viewer Corresponding to Second Rule

With the help of load flow program total active power loss reductions are calculated at every node of the distribution system by compensating the total active power at every node of the distribution system. After calculation of active power loss reductions they are normalised in the range [0, 1] with larger of them having a value of 1 and smallest having a value of 0. These active power loss reductions and per unit node voltages are the inputs to the FES whose output is DG placement suitability determined by fuzzy inference. After determining the node at which DG unit is to be placed the size of the incoming DG is determined using the exact loss formulae as given in equation (5.6) and used in.

The algorithm followed for determining the optimal DG location and size is as follows.

1. Run the load flow program to calculate per unit bus voltages and active power losses at every node.
2. Linearly normalize active power loss reductions in the range [0, 1].

3. Find the membership functions corresponding to node voltages, active power loss and DG placement suitability.
4. Find the decision for the fuzzy sets corresponding to node voltages, active power loss and DG placement suitability.
5. Identify the node having highest DG placement suitability index.
6. Install a DG at optimal node. Select the DG size using equation (5.6)

$$\partial P_L/\partial P_i = 0 \tag{5.6}$$

   Means the rate of change of active power losses with respect to the injected bus power becomes zero.
7. Run the load flow to check if voltage constraint is satisfied [101]. If yes, go to next step, otherwise, go to step- 5
8. Get the results.

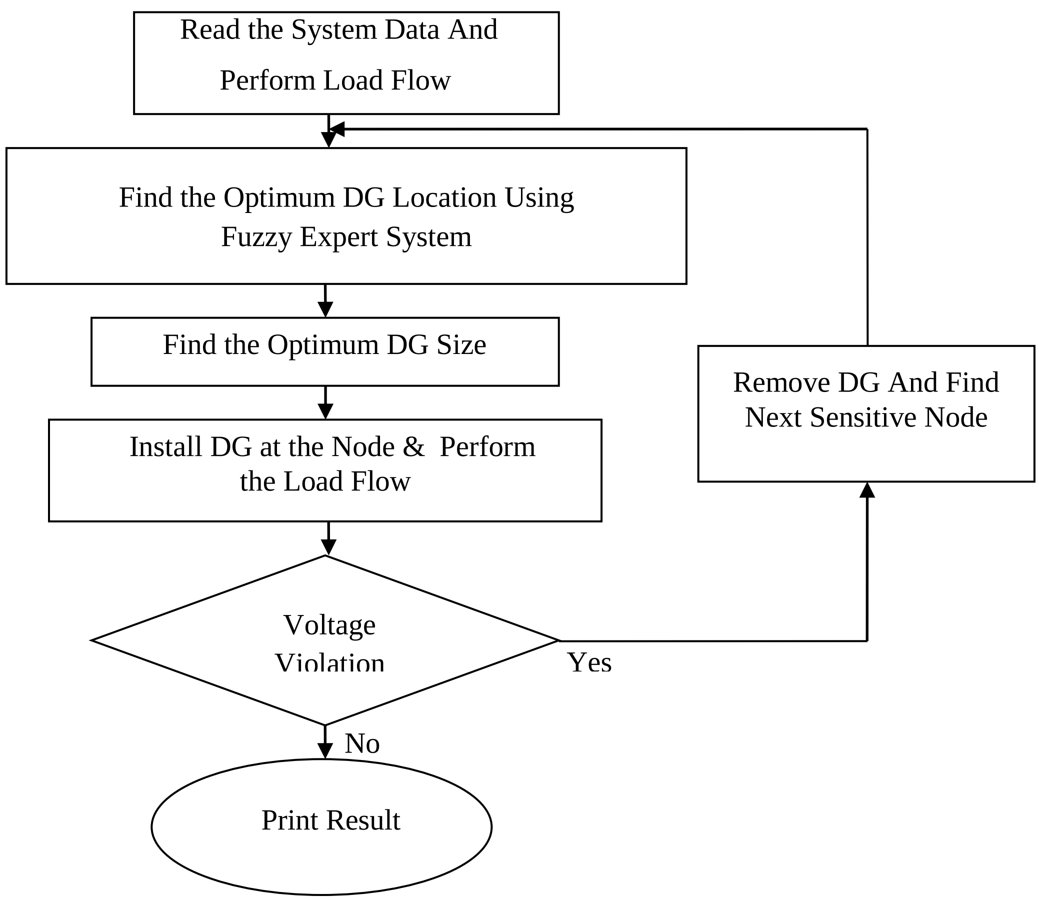

Figure 5.8 Flowchart of Algorithm for Finding The Optimal Location

5.5 Result and Discussions

The initial power loss in the system is 221.72 kW. The losses due to active component of current in the system are 162.71 kW and the losses due to reactive component of current in system are 59.017 kW. The application of the proposed method to the system yields the following results. Figure 5.9 shows the normalized power loss reduction index after compensating the total active power at every node of the distribution system, it is clear from Figure 5.9 that the node 26 is causing the highest losses in the system and it is identified as the most sensitive node for the placement of DG.

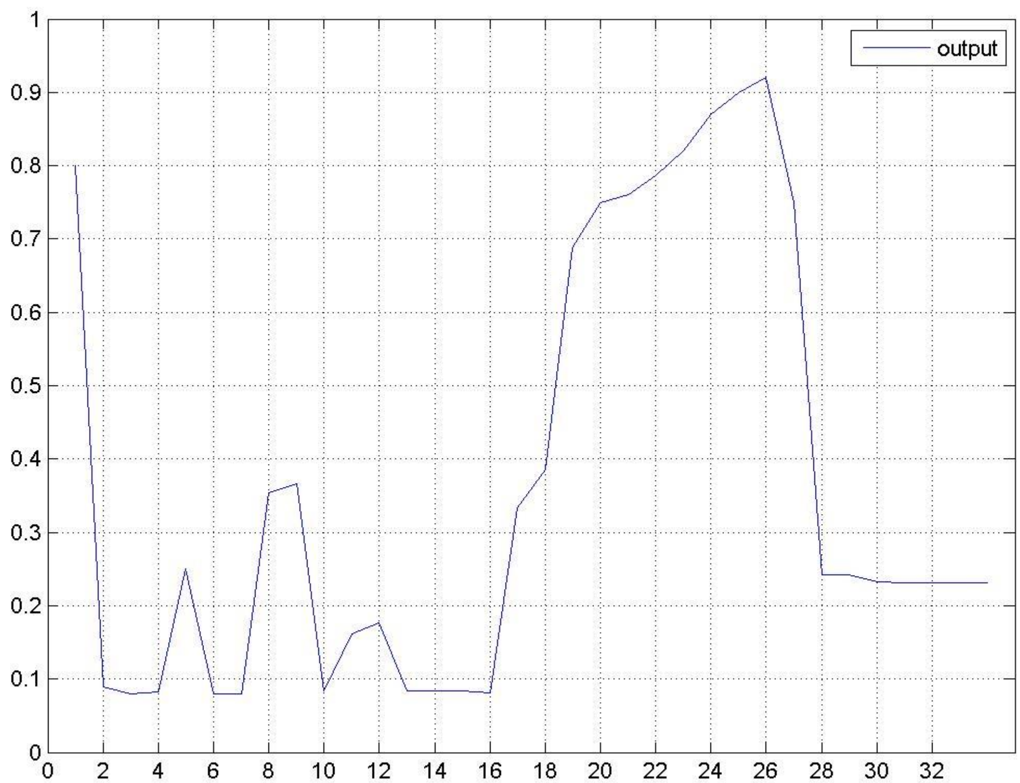

Figure 5.9 Fuzzy Based Approach to Find Out Optimal Node

If the voltage limits are taken into account, then the optimal size of DG is found to be 2.2801 MW at node 26, which gives the maximum loss reduction at this particular node. The total active power loss in the system after placement of DG at node 26 is 73.992 kW. Table 5.3 and Figure 5.10 show the voltage profile of the system before and after placement of the DG. It can be observed from the results that placement of DG in addition to reducing the losses also improves the voltage profile of the system significantly.

Table 5.3 Comparison of Voltage Profile before and after Placement of DG

S.No.	Voltage Without DG	Voltage With DG
1	0.99413701	0.99535679
2	0.98900776	0.99134641
3	0.98204034	0.98609071
4	0.97604872	0.98165544
5	0.97040112	0.97756373
6	0.96657316	0.97376435
7	0.96447021	0.97167711
8	0.96200241	0.96922777
9	0.96081589	0.96805013
10	0.96035825	0.96759592
11	0.96022166	0.96746035
12	0.98867392	0.99101336
13	0.98836851	0.99070867
14	0.98828568	0.99062603
15	0.98827920	0.99061957
16	0.96594009	0.97495411
17	0.96223143	0.97294033
18	0.95813618	0.97098228
19	0.95484259	0.96962716
20	0.95197944	0.96869697
21	0.94871031	0.96809650
22	0.94602351	0.96806793
23	0.94349958	0.96871927
24	0.94228467	0.96960971
25	0.94181783	0.97045069
26	0.94167839	0.97031537
27	0.96623729	0.97343096
28	0.96601336	0.97320869
29	0.96590139	0.97309755
30	0.96047527	0.96771206
31	0.96013462	0.96737397
32	0.95996429	0.96720491
33	0.95990752	0.96714856

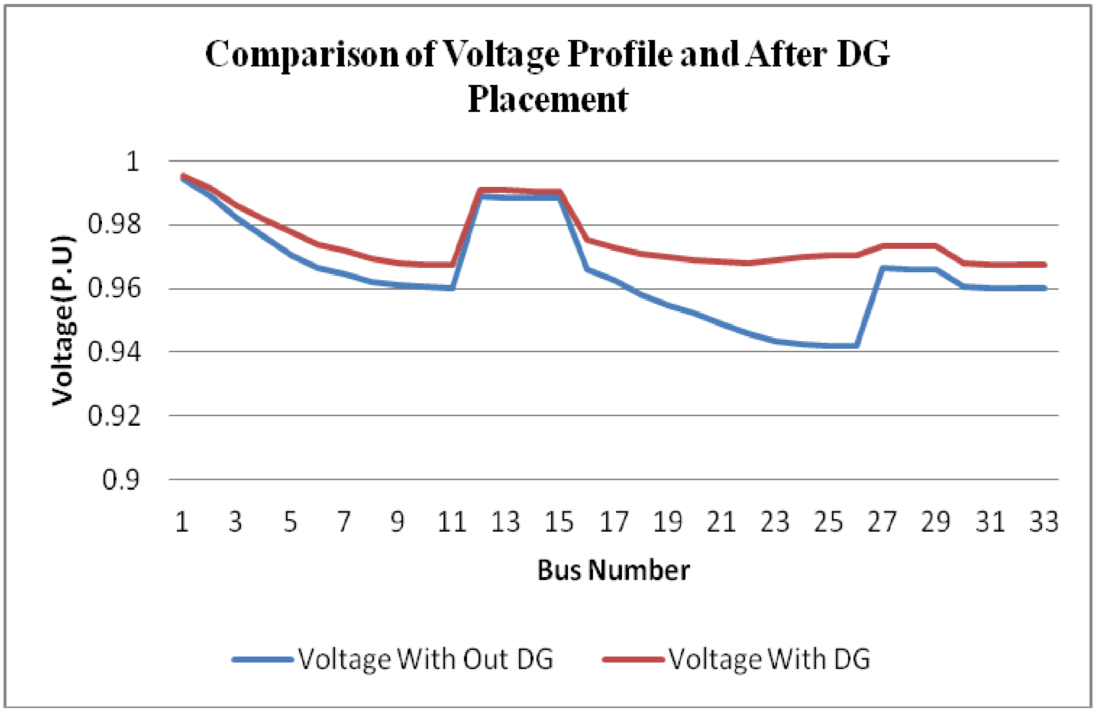

Figure 5.10 Comparison of Voltage Profile Before and After Placement of DG

Fuzzy Expert System has been used in this work to determine the optimal location of SPV based DG system in radial distribution system. The solution to the distributed generation placement problem using Fuzzy rules involves searching through a set of possible solutions. This method is easy to be implemented, more accurate reliable and faster than the analytical methods for accuracy.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

Heuristic Search Strategies and Fuzzy Logic based approach both are use to determine the optimal location of SPV based DG system in radial based DG system. Power losses and voltage profile of the system has been taken into consideration in determining the optimal DG location which minimizes the system power losses while maintaining voltage within the specified limits The proposed method is tested on IEEE 33 bus radial feeder system. The results of the study reflect the effectiveness of the proposed method in optimally locating the SPV based DG system for reduction of losses and in improving the voltage profile of the distribution system. The same procedure with some additional considerations can be successfully applied to complex systems having sub feeders or system with more buses.

6.2 Future scope

The following study based on the present research work can be extended in future. It helps to develop many other feed-forward and feedback neural structures which can be modeled for testing. Proposed algorithm can easily he extended for DG allocation in distribution systems operation, expansion and future planning.

Appendix

% BIBC-Bus injection to Branch current matrix - Upper Triangular Matrix

% BCBV-Branch current to Bus voltage matrix - Lower Triangular Matrix

% DLF-Distribution load flow= BCBV * BIBCBALANCED

% iter - iteration count

% m =No. of branches

% nob=Total No. of buses

% n=No. of Non source buses (total no of buses without considering the source buses(THREE FEEDER EXAMPLE)

% V0=initial voltages

% B=Branch current matrix455.5kvar 1055.4kvar 2983.5kvar

% I=injection current matrix

% line status=1-for sectionalizing branch

% line status=2-for Tie line branch

% bus_status =1 -for load bus

% bus_status =0 -for source bus

% a= No. of Tie lines in the network

% b=No. of Source buses in the network

% In this program i had taken such that no load at the source buses & 1.0 PU Voltage is maintained through out solution clc;

```
clear all;
%close all;
%*********************************************************************
*******************************
%                   TEST DATA-1  (one feeder radial line network - 10
Bus )
%            S.No.  from bus    To bus       Z=R+jX
line_status
  linedata=[ 1        1          2       (0.195+0.08i)*0.60          1;
             2        2          3       (0.195+0.081i)*0.55         1;
             3        3          4       (0.299+0.083i)*0.55         1;
             4        4          5       (0.299+0.083i)*0.50         1;
             5        5          6       (0.299+0.083i)*0.50         1;
             6        6          7       (0.524+0.09i)*0.60          1;
             7        7          8       (0.524+0.09i)*0.40          1;
             8        8          9       (0.524+0.09i)*0.60          1;
             9        9         10       (0.524+0.09i)*0.40          1;
             10      10         11       (0.524+0.09i)*0.25          1;
             11      11         12       (0.524+0.09i)*0.20          1;
```

```
              12       3          13        (0.524+0.09i)*0.30          1;
              13      13          14        (0.524+0.09i)*0.40          1;
              14      14          15        (0.524+0.09i)*0.20          1;
              15      15          16        (0.524+0.09i)*0.10          1;
              16       6          17        (0.299+0.083i)*0.60         1;
              17      17          18        (0.299+0.083i)*0.55         1;
              18      18          19        (0.378+0.086i)*0.55         1;
              19      19          20        (0.378+0.086i)*0.50         1;
              20      20          21        (0.378+0.086i)*0.50         1;
              21      21          22        (0.524+0.09i)*0.50          1;
              22      22          23        (0.524+0.09i)*0.50          1;
              23      23          24        (0.524+0.09i)*0.60          1;
              24      24          25        (0.524+0.09i)*0.40          1;
              25      25          26        (0.524+0.09i)*0.25          1;
              26      26          27        (0.524+0.09i)*0.20          1;
              27       7          28        (0.524+0.09i)*0.30          1;
              28      28          29        (0.524+0.09i)*0.30          1;
              29      29          30        (0.524+0.09i)*0.30          1;
              30      10          31        (0.524+0.09i)*0.30          1;
              31      31          32        (0.524+0.09i)*0.40          1;
              32      32          33        (0.524+0.09i)*0.30          1;
              33      33          34        (0.524+0.09i)*0.20         1];

%
%        s.no    bus no        S=P+jQ                        V0
Bus_status
busdata=[ 1       1             0+0j                         11000    0;
          2       2            (230+(142.5j))*1000           11000    1;
          3       3            (0+0j)*1000                   11000    1;
          4       4            (230+(142.5j))*1000           11000    1;
          5       5            (230+(142.5j))*1000           11000    1;
          6       6            (0+(0j))*1000                 11000    1;
          7       7            (0+(0j))*1000                 11000    1;
          8       8            (230+142.5j)*1000             11000    1;
          9       9            (230+142.5j)*1000             11000    1;
          10      10           (0+(0j))*1000                 11000    1;
          11      11           (230+142.5j)*1000             11000    1;
          12      12           (137+(84j))*1000              11000    1;
          13      13           (72+45j)*1000                 11000    1;
          14      14           (72+(45j))*1000               11000    1;
          15      15           (72+(45j))*1000               11000    1;
          16      16           (13.5+(7.5j))*1000            11000    1;
          17      17           (230+(142.5j))*1000           11000    1;
          18      18           (230+142.5j)*1000             11000    1;
          19      19           (230+142.5j)*1000             11000    1;
          20      20           (230+(142.5j))*1000           11000    1;
          21      21           (230+142.5j)*1000             11000    1;
          22      22           (230+(142.5j))*1000           11000    1;
          23      23           (230+142.5j)*1000             11000    1;
          24      24           (230+(142.5j))*1000           11000    1;
          25      25           (230+(142.5j))*1000           11000    1;
          26      26           (230+(142.5j))*1000           11000    1;
          27      27           (137+(85j))*1000              11000    1;
          28      28           (75+48j)*1000                 11000    1;
          29      29           (75+48j)*1000                 11000    1;
          30      30           (75+(48j))*1000               11000    1;
```

```
        31      31           (57+34.5j)*1000              11000    1;
        32      32           (57+(34.5j))*1000            11000    1;
        33      33           (57+34.5j)*1000              11000    1;
        34      34           (57+(34.5j))*1000            11000   1];

%   m=4;
%   n=5;
newlinedata=linedata;
a=find(newlinedata(:,5)==2);
newlinedata(a,:)=[];
m=length(newlinedata(:,4));
fprintf('\n No.of Tie lines are:\t  %d',length(a));
fprintf('\n Tie lines are:       ');
fprintf('\t %d',a);
fprintf('\n\n No. Of Branches:   %d',length(newlinedata(:,4)));
newbusdata=busdata;
b=find(newbusdata(:,5)==0);
newbusdata(b,:)=[];
n=length(newbusdata(:,3));
fprintf('\n \n No. of Sources Buses are: ');
fprintf('\t %d',length(b));
fprintf('\n Source buses are:       ');
fprintf('\t %d',b);

BIBC=zeros(m,n);
BCBV=zeros(n,m);
for k=1:m
    BIBC(:,newlinedata(k,3))=BIBC(:,newlinedata(k,2));
    BIBC(k,newlinedata(k,3))=1;
    BCBV(newlinedata(k,3),:)=BCBV(newlinedata(k,2),:);
    BCBV(newlinedata(k,3),k)=newlinedata(k,4);
end
% nob=max(max(newlinedata(:,2)),max(newlinedata(:,3)));
% nob-n  represents how many source buses in our network ( =length(b) )
for k=1:length(b) %nob-n
    BIBC(:,1)=[];
    BCBV(1,:)=[];
end
iter=1;
mismatch=1;
V=newbusdata(:,4);
while (mismatch>=0.01|iter==1)
    Vold=V;
    I=conj(newbusdata(:,3)./V);
    delV=BCBV*BIBC*I;
    V=newbusdata(:,4)-delV;
    mismatch=max(abs(V-Vold));
    iter=iter+1;
end
fprintf('\n\n Total No. of Iterations:%d',iter-1);
fprintf('\n\n The Voltage magnitudes of Given system are');
fprintf('\n %10.8f ',abs(V)/11000);
fprintf('\n\n The Voltage angles of Given system are');
fprintf('\n %10.8f',angle(V));
loss=0;
```

```
Rloss=0;
Iloss=0;
for k=1:m
    B=BIBC*conj(newbusdata(:,3)./V);
    loss=loss+abs(B(k))*abs(B(k))*real(newlinedata(k,4));
    Rloss=Rloss+real(B(k))*real(B(k))*real(newlinedata(k,4));
    Iloss=Iloss+imag(B(k))*imag(B(k))*real(newlinedata(k,4));

end
fprintf('\n\n The Total Losses in system (Base case) :
%16.8f',abs(loss));
fprintf('\n\n The Total Losses due to real current in system (Base
case) : %16.8f',abs(Rloss));
fprintf('\n\n The Total Losses due to imag current in system (Base
case) : %16.8f',abs(Iloss));


for k=1:m
    B=BIBC*conj(newbusdata(:,3)./V);
     sectionloss =abs(B(k))*abs(B(k))*imag(newlinedata(k,4));
 fprintf('\n\n The  Section Losses in system  : %16.8f',sectionloss);
 end
 z=abs(V)/11000;
 y=angle(V);
```

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