Optimized Distributed Generation Planning for Radial Distribution System Using Particle Swarm Optimization Algorithm

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A thesis submitted to the Department of Electrical and Electronic Engineering in partial
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Engineering.

Department of electrical and Electronic Engineering

BRAC UNIVERSITY

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DECLARATION

It is hereby declared that,

1. The thesis submitted is my/our own original work while completing degree at BRAC University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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ABSTRACT

Electrical generation and storage by a range of small grid-connected or distribution system-connected devices known as distributed energy resources is distributed generation. This paper presents the determination of the optimal position of a Distributed Generation (DG) Unit. There has been analysis of the radial distributed network. The placement of distributed generation and the size of the distribution generation is a prime factor here. The key motive of this paper is to minimize line losses and improve voltage profile. We have followed a robust technique called particle swarm optimization to achieve this objective. The application is illustrated on a 30 bus system of 132KV line Chittagong, Bangladesh power Grid system using Newton Raphson power flow method. Results presents the maximum reduction of real power loss in percentage and optimal location of Distributed Generation.

Keywords: Distributed generation (DG), particle swarm optimization (PSO), line loss, radial, voltage profile.

DEDICATION

We would like to devote our research to our parents who have always inspired us to aspire for achievement and have taken us so far with their never ending encouragement at all times. We would also like to dedicate this paper to our supervisor for his guidance and support in achieving the final work performance.

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LIST OF ACRONYMS

$ V $	Voltage Magnitude
n	Bus Number
δ	Angle $\Delta P(0)$ Real Power Mismatch $\Delta Q(0)$ Active Power Mismatch
C_1 and C_2	Acceleration factors;
r_1 and r_2	Randomly generated numbers
w	PSO momentum or inertia
swarm	Iteration index.
P	Real Power
Q	Reactive Power
P_{best}	Personal Best
G_{best}	Global Best
DG	Distributed Generation
PSO	Particle Swarm Optimization
LDWPSO	Linear decreasing weight particle swarm optimization

Chapter 1

Introduction

1.1 Background

Distributed Generation (DG) is a generation unit for electricity which is linked to or installed near to a distribution network consumers. In distributed generation, the technologies adopted different methods of small-scale generation of many renewable energies which include wind, solar energy, gas turbines, hydropower, and fuel cells etc.[1] DG is convenient, especially in countries, for both customers and utilities where it is difficult to centralize generations or where shortcomings can be found in transmission system. All the problems can be solved by the optimal allocation of DG units such as resulting in reduced losses in the power system, improved voltage profile, improve the capacity to transfer electricity, minimize emissions and cut generation cost for the consumers.[2]

DG can have alternatives that most power systems have, such as installing a computer at a non-optimal location. This can instead have the opposite effect on the system by considering the cost efficiency, such as increasing system losses followed by an increase in cost. With all that in consideration, selecting the most appropriate location for installation combined with the optimal size of a DG unit is of the greatest priority in a power system network. However, it is the highest concern to choose the most suitable position for installation paired with the optimum size of a DG in a power system.[3]

The most powerful and fundamental way to solve the problems of power system operation and planning is load flow analysis. Load flow analysis recognizes the consistent operation state with node voltages and branch power flow in the system. In optimization, numerous techniques are used in the power system to deal with the problem. This research work targets to use Particle Swarm Optimization for finding not only the optimal size but also the position of DG in the

power system network. Particle swarm optimization (PSO) is a population-based optimization technique first proposed in 1995 by Kennedy and Eberhart. The optimization technique is inspired by social behavior of bird flocking together or fish schooling in the nature[4]. In a PSO method, in a framework of multidimensional query, particles fly around. Each and every particle changes its location during the flight in accordance with experience of its own (known as Pbest) and, in accordance with the experience of the adjacent particle (known as Gbest), uses the optimal position found by itself and its neighbor.[4]

1.2 Problem Statement

Uncertainty in terms of sources of renewable energy and demand can be controlled in power systems by optimizing base point generator outputs to satisfy demand and projections for energy, while meeting constraints that ensure normal system activity regardless of the actual demand and performance of distributed generators. In order to generate sufficient power for customers, however, power losses and voltage magnitude must be taken into account. Non-optimal position and dimensioning of DG units can lead to an increase in losses, along with a poor impact on power losses and voltage magnitude.[2] Many methods of optimization are used by taking into account the optimum size and position of DG to minimize the loss as well as increases voltage profile. For this research work, an optimization method called Particle Swarm Optimization (PSO) is used in the 30 distribution bus system of Bangladesh to find the optimum size and location.

1.3 Objectives

The project's priorities include the following goals:

1. To learn the Generation of Distribution
2. To study load flow analysis and optimization method using Particle Swarm Optimization (PSO)
3. Using MATLAB programming to install the Distribution Generation with the Chittagong division's regular 30 bus installation in Bangladesh
4. To minimize the losses in a radial distribution network and increase the voltage profile
5. The minimization of active power loss in the radial distribution system is therefore considered the main purpose of this research proposed.

1.4 Literature review

The purpose of this section is addressing the key topics of this research which are Distribution Generation (DG), load flow analysis, optimization technique (Particle Swarm Optimization). Based on the research from the relevant publications and conferences, all the key topics referred to give us a decent understanding of how to approach our research work.

Previous Research on DG

A paper, titled by “Reliability based optimal DG planning for a meshed distribution network” has paved the way of our thinking in this research. The majority of the works in the writing concentrated on finding the ideal area and size for single or numerous DGs thinking about minimization of power loss, improvement of voltage profile, money saving advantage amplification, unwavering quality improvement, short circuit mega-volt amperes (MVA), and voltage strength. The methods of optimization that have been introduced include both conventional techniques such as linear programming and evolutionary algorithms like Particle

Swarm Optimization (PSO), Genetic Algorithm (GA), Artificial Bee Colony, and GA Unwavering quality. These optimization approaches are assessed utilizing an encoded Markov cut set calculation thinking about numerous practical boundaries like DG failures, probability of successful starting and switching of the DG, and probability of islanding during failures.[5]

Many significant researches have been done on distributed generation. Specifically mentioned one G. W. Ault, J. R. McDonald, and G. M. Burt, “Strategic analysis framework for evaluating distributed generation and utility strategies,” demonstrates that a system of strategic analysis is presented to analyze distributed generation and distribution utility method. The framework is built on the principle of analyzing all distributed generation problems through several cases in order to encompass the scope of unexpected situation arising from private distributed generation in controlled distribution networks. To allow distribution system planners and strategists to quantify the aggregate effect of distributed generation on all parts including its distribution sector, a distributed generation value feature is suggested. This helps the distribution company to formulate its response to distributed generation by using the spectrum of generation industry, power network and utility business models proposed to test prospective strategies. The findings of a test case reported on the UK situation show the possible benefits (both pros and cons) of distributed generation to distribution network operators. The case study also shows the implementation of the proposed framework for strategic analysis and the importance of the results obtained.[6]

Previous Research on Particle Swarm Optimization

The optimization approaches that have been applied in DG planning include both classical methods like linear programming and evolutionary algorithms like Particle Swarm Optimization (PSO). To dig into more into the PSO we came across several conference paper. A paper named “Center Particle Swarm Optimization Algorithm” spells out that PSO

calculation is a sort of strategy like social conduct and impersonate flying creatures and fish developed from technology. PSO algorithm has good convergence and good performance in nonlinear function optimization. It emphasize on linear decreasing weight particle swarm optimization algorithm and central particle swarm optimization algorithm. The exploratory outcomes show that the exhibition of the focal molecule swarm improvement calculation is superior to that of the LDWPSO calculation.[7]

To solve the problem of the optimum distribution system location and scale of DG. The goal of this paper is to reduce reactive power losses in the network and improve the operating system voltage control and the safety constraints of radial distribution systems. On the 33 bus system, the study is performed. The use of the DG in the distribution system results in many advantages as a result of this analysis, such as enhanced performance of all processes, better time and losses in the system voltage profile.[8]

Previous Research on Load Flow Analysis

Load flow analysis is the most significant and basic way to resolve the issues of power system operation and planning. In view of a predetermined producing state and transmission network structure, load flow analysis understands the consistent activity state with node voltages and branch power flow in the power distribution. To learn more and be enlightened about load flow analysis we have gone through several papers and journal. Among them, a conference paper named “Determining the Optimal Location and Sizing of Distributed Generation Unit using Particle Swarm Optimization Algorithm” paved our way into this research work.[3] Load flow analysis can be done by solving a bunch of equations of power flow. In radial network, a path of a single direction is used for power flowing from supply point to loads. This technique emphasizes on the determination of:

- i. Real power loss

- ii. Reactive power loss
- iii. Voltage magnitude with angle.

It should be stated that power flow investigation depends on load flow analysis and the calculation of load flow analysis is likewise the base for dynamic investigation techniques. In this way, experience with the hypothesis and calculations of load flow are fundamental to understanding the methodology of modern power system analysis.

1.5 Overview of the thesis

This thesis has been divided into 6 chapters consisting of the basic knowledge descriptions of the distributed generation (DG), load flow analysis and particle swarm optimization (PSO). The results obtained from simulations and a detailed overview of all the research work carried out with future objectives and scopes. The MATLAB programming for load flow analysis of Newton Raphson method and particle swarm optimization was generated and the corresponding convergence graph is provided in result analysis. The simulation results are shown for 4 different transparent substrates Active power loss comparison with and without DG, optimal location and reactive power loss for With DG and Without DG ,voltage magnitude for with DG PSO Optimized and without DG, voltage profile at optimal Location.

Chapter 1

Here, the writing provides the motive of conducting this research work and the objectives of our work. Our inspiration and goals for this research work, a brief literature review, problem statement is mentioned in this chapter.

Chapter 2

In this chapter, a clear idea about distributed generation, its application and the benefits of using DG has been stated in brief. Functions of DG and what will be the effect on distribution networks and system has been focused in this particular chapter.

Chapter 3

We get a clear understanding of the load flow analysis of radial distribution system in this chapter. A knowledgeable perception of power flow and why did we choose Newton Raphson method in load flow analysis all that has been discussed here.

Chapter 4

Here, the optimization method particle swarm optimization has been discussed. Its uses and why we have approached this method has been described properly. The functions and formulas of PSO are described in this chapter vividly.

Chapter 5

The simulation results are shown for 4 different transparent substrates- active power loss comparison with and without DG, optimal location and reactive power loss for With DG and Without DG ,voltage magnitude for with DG PSO Optimized and without DG, voltage profile at optimal Location. The parameters of PSO has also been stated here.

Chapter 6

What we finally concluded after simulating is explained here. There was discussion of the overall benefit and efficiency inferred from the research work. Furthermore, in the future scope, the works that we still plan to do and the editions that need to be completed are listed.

Chapter 2

Distributed generation (DG)

Distributed generation is the method of generating and directly connecting electricity from several small energy sources to the distribution network or on the customer's side of the meter. It can also be referred to as generation on site, dispersed generation, decentralized generation, decentralized electricity or distributed energy.

Distributed Generation (DG) is a small generator spotted throughout a power system network, providing the electricity locally to the customer site of the meter.[9] For automotive, commercial and residential uses, DG can be an option. DG uses the latest advanced technology that is powerful, reliable and easy enough to compete in many areas with conventional large generators.[2] DG will reduce system losses and delay investment in the expansion of transmission and distribution. The keys to achieving it are optimal size and ideal locations.[3]

Figure 1: Distribution network reconfiguration with distributed generation

2.1 Distributed generation forms

In this period several types of DG are being used, such as solar photovoltaic, wind turbines and Turbine hydro. For the solar form, directly or indirectly, the most renewable energy comes from the sun. It is widely used for cooking, house lighting and various commercial industries. Then with the natural use of wind, the wind turbine form is created where it converts kinetic energy to electric energy. The water from the river is collected in a reservoir for the hydro turbine facility. Figures given here are showing some types of DG are used to generate the renewable energy.

Figure 2: Solar photovoltaic

Figure 3: Hydro turbine

According to supply duration, generated power, capacity and technology DG can be classified in different sections also. Those have been shown through the figure of classification of distributed generation (DG). Distribution generation combines renewable energy sources close to the consumers. Generally power plants generate the electricity and then through the transmission lines the electricity is carried long distances directly to the customers or through the substations in some areas.

Figure 4: Distributed generation classifications

2.2 Benefits of distributed generation

DG renders a group of advantages, such as, economic, environmental and technical. The economic advantages are reduction of transmission and distribution cost, electricity price and savings of fuel. Environmental advantages entail reductions of sound pollution and emission of greenhouse gases[2]. Technical advantages cover wide varieties of benefit, like, line loss reduction, peak shaving, increased system voltage profile and hence increased power quality. The relieved transmission and distribution congestion as well as grid reinforcement are also beneficial. It can also provide the stand-alone remote applications with the required power. So,

optimal placement of DGs and optimal sizing attract active research interests.[10] Specifically benefits of distributed generation can be described as follows:

- a. Helps to advance the efficiency of the electrical power. It can be used on both off grid and on grid
- b. Global distributed generation market has three type of end users. These are residential, commercial and industrial end users. DG's more dependable power for industries that require continuous service
- c. Energy cost saving
- d. Saving in transmission and distribution losses
- e. Improves the performance of system stability and efficiency.[2]

2.3 Effect on Distribution Networks and System and Losses

Historically, the function of distribution networks was mainly limited to the interconnection between, on the one hand, the generating and transmission systems and, on the other, the load centers. Therefore, such networks are known as "passive" networks. In recent years, however, the introduction of distribution generation into distribution networks has converted them from passive to active networks.[11]

Therefore, Distribution Generation may affect the whole range of activities already in place to deal with the preparation of future expansion and redevelopment of the distribution network. The productive and successful operation of a Distribution Generation distribution network will also assist in the prospective extension of the reconstruction of a distribution network.

The impact of system losses is focused on the power flow of the network. The generation of distribution is bound to impact the power flow of the corresponding distribution network, and the losses of such networks are also influenced in turn. Recent studies have shown that the Generation of Distribution can either help reduce or increase the magnitude of losses of devices. This relies on variables such as distribution generation size and position, the relative magnitude between the generation and the total linked load to the generator, whether the network is radial or interconnected. [12]

2.4 DG allocation in radial distribution system

Radial is a type of distribution network.[13] A radial system is structured like a tree where one source of supply is available to each customer. There are several supply sources running in parallel on a network infrastructure. For focused loads, spot networks are used. Radial devices in rural or suburban areas are widely used.[14]

A radial system is a system with a single path through which current may flow from the distribution substation or substations to the primary of any distribution transformer for a portion or all of the way.[15] The electricity generated from the power plants is transferred to the grid and then transmitted via overhead systems and substations to the end consumers. It is well known that the total power produced in power plants is not equal to the total power consumed in distribution load centers by consumers because of a certain amount of power dropped during the power dispatch. Distribution lines account for the highest percentage of power losses in a power grid.[16] In general, actual and reactive components compose the total power loss in an AC system. Due to the nature of the radial distribution networks' very high resistance/reactance ratio.[17] It is more important and difficult to minimize the actual power loss in a radial distribution system. Since the real power loss of a distribution network is a function of line

resistance and square line current flows, by minimizing the current drawn from the main distribution feeder, a distributed generation (DG) that delivers real power (such as an integrated grid photovoltaic system or fuel cell) incorporated at the appropriate location will minimize real power loss. A fresh approach towards selecting the most appropriate location and optimal size of DG in the radial distribution network has been proposed to solve this problem. This technique uses the principle of an optimization technique inspired by nature called PSO for minimizing the loss due to distribution of power by determining the most preferable size and location of real power infusing DG.

Chapter 3

Load flow analysis

Power-flow or load-flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. The key information obtained from the power flow analysis is the voltage magnitude and phase angle of each bus and the actual and reactive power flowing on each line.[18]

Load flow analysis is the most significant and basic way to resolve the issues of power system operation and planning. In view of a predetermined producing state and transmission network structure, load flow analysis understands the consistent activity state with node voltages and branch power flow in the force framework. Load flow analysis can give a decent consistent activity condition of the power system operation, without thinking about framework transient cycles. Henceforth, the mathematical model of load flow issue is a nonlinear arithmetical condition framework without differential conditions. Power system dynamic investigation examines framework consistency under some given unsettling influences. Its mathematical model incorporates differential conditions. It should be stated that power flow investigation depends on load flow analysis and the calculation of load flow analysis is likewise the base for dynamic investigation techniques. In this way, experience with the hypothesis and calculations of load flow are fundamental to understanding the methodology of modern power system analysis.

Load flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. It generally works on normal, steady-state operation. It helps us to understand the information of a power system. Load flow analysis is essential for whatever you do in a power system, regardless of whether you do fault studies, stability studies, economic operation and so forth. The principal information obtained from the

load flow analysis is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line with power losses.

Required input data for power flow analysis:

- Bus data :
 - For PV buses:
 - Real power (generation and demand),
 - Reactive power (demand),
 - Voltage magnitude.
 - For PQ buses:
 - Real power (generation and demand),
 - Reactive power (generation and demand).
 - For slack bus:
 - Voltage magnitude (usually 1 per unit),
 - Voltage angle(specified to be zero),
 - Real power (demand),
 - Reactive power (demand).
 -
- Line data:
 - Transmission lines:
 - Resistance,
 - Reactance,
 - Capacitance (can be negligible).
- Load data:
 - Active power

- Reactive power

Results which can be obtained from Power flow analysis for each branch are:

- Voltage magnitude
- Voltage angle
- Power flow in every branch (Real and reactive power)
- Power losses (Real and reactive power)

Figure 5: Inputs and Outputs of Load Flow Analysis[19]

Types of Load Flow Analysis Technique:

There are three commonly used iterative techniques for solving load flow problems which are:

1. Gauss-Seidel method
2. Newton-Raphson method
3. Fast Decouple method

3.1 Overview of the Techniques:

Gauss-Siedel Method:

In the beginning, based on the programming method and utilities, to solve power system load flow problems, the widely used method was the Gauss–Seidel iterative method based on a nodal admittance matrix [20]. The guideline of this strategy is fairly basic and its memory necessity is moderately little. These properties made it suit the degree of computer and power system theory around then. But later on, at the point when the framework scale expands, the quantity of iterations increases strongly and in some cases the iteration process can not satisfy its principles. Thus, it starts to lose its significance on solving larger and complex load flow problems.

Newton-Raphson Method:

The other way to solve the detriments of the impedance technique is to apply the Newton–Raphson technique. The Newton-Raphson strategy is a common technique used to solve nonlinear equations with truly ideal convergence. However long the sparseness of the Jacobean grid is used in the iterative cycle, the processing effectiveness of the Newton strategy can be extraordinarily improved [1]. The Newton-Raphson strategy has outperformed the admittance technique in the parts of combination, memory interest, and computation speed. It is as yet the supported strategy and is broadly utilized in load flow analysis.

Fast Decoupled Method:

The load flow analysis strategy has evolved with the passing of time and technology. Besides previous techniques, another method of load flow analysis emerged with its effectiveness which is called fast decoupled method, also known as P-Q decoupled method [1]. Comparing

with the Newton strategy, this technique is a lot more straightforward and more proficient algorithmically and subsequently well known in numerous applications.

	Gauss-Seidel	Newton-Raphson	Fast-decoupled
Complexity	Easy	Complex	Less complex
Convergence	Linear	Quadratic	Geometric
Sensitivity	Not available	Available	Available
System size	Problematic with large systems	Appropriate for any system size	Appropriate for any system size
Type of system	May have a convergence problem with ill-condition system	No problem with ill-condition system	No problem with ill-condition system
Accuracy	Good	The Best	Average

Table 1: Comparison between load flow analysis techniques

3.2Methodology

Nomenclature:

P_i is real power flows from (the sending end) bus i

Q_i is reactive power flows from (the sending end) bus i

V_i is bus voltage magnitude at bus i

r_i is resistance of branch, connected to (the receiving end) bus i

x_i is reactance of branch, connected to (the receiving end) bus i

P_{Li} is real power loads at bus i

Q_{Li} is reactive power loads at bus i

μ_P is real power multiplier

μ_Q is reactive power multiplier

P_{gi} is active Power magnitude injected at bus i

Q_{gi} is reactive Power magnitude injected at bus i

Newton-Raphson Technique:

The primary objective of our thesis work is to reduce the power losses and improve the voltage profile in power system network. To compute the power loss and voltage profile at each bus, Newton-Raphson strategy is utilized to take care of that issue in this venture. The basic equation, formation and calculation of Newton-Raphson method are discussed for solving voltage magnitude $|V|$ and angle δ , real (P) and reactive (Q) power injections. It consists of two sets of equation.

The Newton-Raphson procedure is as follow:

Step 1: Choose the initial values of the voltage magnitudes $|V|^{(0)}$ of all n_p loads buses and $n-1$ angles $\delta^{(0)}$ of the voltages of all the buses except the slack bus.

Step 2: Use the estimated $|V|^{(0)}$ and $\delta^{(0)}$ to calculate a total n-1 number of injected real power $P_{calc}^{(0)}$ and equal number of real power discrepancy $\Delta P^{(0)}$.

Step 3: Use the estimated $|V|^{(0)}$ and $\delta^{(0)}$ to calculate a total np number of injected reactive power $Q_{calc}^{(0)}$ and equal number of real power discrepancy $\Delta Q^{(0)}$.

Step 4: Use the estimated $|V|^{(0)}$ and $\delta^{(0)}$ to formulated the Jacobian matrix $J^{(0)}$.

Step 5: Solve the load flow problem for $\delta^{(0)}$ and $\Delta|V|^{(0)} \div |V|^{(0)}$.

Step 6: Obtain the updates from:

$$\delta^{(1)} = \delta^{(0)} + \Delta\delta^{(0)} \quad (1)$$

$$|V|^{(1)} = \Delta|V|^{(0)} + \left[\frac{\Delta|V|^{(0)}}{|V|^{(0)}} \right] \quad (2)$$

Step-7: Check if all the mismatches are below a small number. Terminate the process if yes. Otherwise go back to step-1 to start the next iteration with the updates given by (1) and (2).

The result can be found in a form of linear system of equations that can be expressed as [3]:

$$\begin{bmatrix} \Delta\theta \\ \Delta|V| \end{bmatrix} = -J^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \quad \text{Here, } \Delta P \text{ and } \Delta Q \text{ are called mismatch equation.}$$

Where,

$$\Delta P_i = -P_i + \sum_{k=1}^N |V_i||V_k|(G_{ik}\cos\theta_{ik} + B_{ik}\sin\theta_{ik})$$

$$\Delta Q_i = -Q_i + \sum_{k=1}^N |V_i||V_k|(G_{ik}\sin\theta_{ik} - B_{ik}\cos\theta_{ik})$$

and J is a matrix of partial derivatives known as a Jacobian Matrix:

$$J = \begin{bmatrix} \frac{\partial \Delta P}{\partial \theta} & \frac{\partial \Delta P}{\partial |V|} \\ \frac{\partial \Delta Q}{\partial \theta} & \frac{\partial \Delta Q}{\partial |V|} \end{bmatrix}$$

The sets of linear equations are solved to determine the next guess ($m+1$) of voltage magnitude and angles based on:

$$\theta^{m+1} = \theta^m + \Delta\theta$$

$$|V|^{(m+1)} = |V|^{(m)} + \Delta|V|$$

This iteration process continues until a stopping condition is met. A typical stopping condition is to end the iteration process if the standard of the iterative conditions is under a standard value.[20]

3.3 Load Flow Analysis without Distributed Generation (DG):

In our thesis project, we have applied the most generally used load flow analysis technique which is Newton-Raphson technique. It's a generalized method to compute the voltage magnitude and angle, real and reactive power flow of each bus and line losses of the power system. It is widely used for its simple conditions like combination, small memory requirement and computation speed. In this part of load flow analysis no distributed generation (DG) is connected with the system. The objective of this load flow analysis is to get an overview of the voltage profile and compute line losses of the power distribution system. After getting the results of the load flow analysis of the power distribution system, we will be able to understand the voltage profile of the system and how much line losses are occurring in this network.

First of all, we have to insert the Line data, Load data and Bus data of the Bangladeshi power system network as an input of the load flow analysis. The iteration process starts through

processing the input data through equations for Newton-Raphson technique. The iterations continues until a set of standard values of voltage magnitude and angle, real and reactive power flow of the system and line losses are obtained. After finishing the load flow analysis we will get a set of values of voltage magnitude and angle, real and reactive power flow and line losses of the system. This data is needed to be stored carefully as we have to compare this data with another set of data which can be obtained from load flow analysis of a distribution system with distribution generations.

3.4 Load Flow Analysis with Distributed Generation (DG):

Distributed generations are connected in the distribution network to give support to the network. It helps the system to in many ways. It improves voltage profile, reduces line loss and gives support in power generation. In order to take the benefits of the distributed generations, it needs to be placed in the right location of the distributed system. After connecting the DG's in the network another load flow analysis needs to be performed to determine the present voltage magnitude and angle, real and reactive power flow and line loss.[21] Again we have to insert the Line data, Load data and Bus data of the Bangladeshi power system network as an input of the load flow analysis. The iteration process starts through processing the input data through equations for Newton-Raphson technique. The iterations continues until a set of standard values of voltage magnitude and angle, real and reactive power flow of the system and line losses are obtained. After getting the results of the load flow analysis with DG connected to the network, it is needed to compare the both results. From the comparison, it can be seen that the DG helps to improves voltage profile, reduces line losses of the system and also helps in power generation. Furthermore, load flow analysis is a method of analyzing the power distribution system to get the overview of the distribution system. Newton-Raphson

technique is a method of performing the load flow analysis. It is an iterative process. The iterations continues until a set of standard values of voltage magnitude and angle, real and reactive power flow of the system and line losses are obtained for the distribution system.[20]

Equations for power flow solution [4] in Load flow analysis with DG:

$$P_{i+1} = P_i - P_{Li} - r_{i+1} \times \frac{[P_i^2 + Q_i^2]}{V_i^2} + \mu_P P_{gi}$$

$$Q_{i+1} = Q_i - Q_{Li} - x_{i+1} \times \frac{[P_i^2 + Q_i^2]}{V_i^2} + \mu_Q Q_{gi}$$

$$V_{i+1}^2 = V_i^2 - 2(r_{i+1}P_i + x_{i+1}Q_i) + r_{i+1}^2 + X_{i+1}^2 \times \frac{[P_i^2 + Q_i^2]}{V_i^2}$$

$$P_{Loss_i} = r_i \times \frac{[P_{i-1}^2 + Q_{i-1}^2]}{V_{i-1}^2}$$

$$Q_{Loss_i} = x_i \times \frac{[P_{i-1}^2 + Q_{i-1}^2]}{V_{i-1}^2}$$

$$P_{0,new} = P_{0,old} - P_n$$

$$Q_{0,new} = Q_{0,old} - Q_n$$

Chapter 4

Particle swarm optimization (PSO)

A new evolutionary algorithm developed by J. Kennedy and R. C. Eberhart is Particle Swarm Optimization (PSO).[22] Centered on the swarming social behavior of flocking birds and fish schooling in nature where they have their own point of view of seeking food and ultimately moving only in one direction only to move in groups for the best food. [23]

In addition, it has the flexibility to integrate with other technologies and not be affected by the nature of the objective function. It also has a few elements which need to be adjusted. Easy implementation and programming with mathematical operations. It Does not require a good initial values began in the solution process[24]

The PSO algorithm is a kind of evolutionary algorithm which because of its benefits of easy implementation, high accuracy and quick convergence, has drawn the attention of the academic circle.[25] . Swarm means population in PSO, with particles representing each member of the population. By randomly moving in various directions, each particle searches through the entire space and remembers the previous best solutions of that particle and also the locations of its neighboring particles.[26] Swarm particles dynamically change their location and velocity by communicating the best positions of all particles to each other. Finally, all the particles in the swarm continue to shift to better locations before the swarm finds an appropriate solution. Thus, all swarms are randomly initialized in the PSO technique and the fitness value is determined by updating personal best (best value of each swarm) and global best value (best value of all swarms in the entire search space). The loop will begin by assuming the particles' initial position values as the personal best and then updating each particle position using the updated velocity[10] . When the stop condition is met, the loop is stopped.

4.1 PSO in Algorithm

The optimization method of PSO which we have used in our research is given below:

Figure 6: PSO flowchart

The PSO techniques for general flow chart are shown in Figure 6 and is explained with step by step.

Step 1: The PSO parameters and the constraints used for their project are given as input in the initialization.

Step 2: The functions of fitness are calculated

Step 3: For an iteration equal to zero, the personal best (pbest) and global best (gbest) are found in this stage.

Step 4: For this step, the value of velocity and position are calculated by using the formula from equation (4.0) and (4.1) below.

Step 5: By transmitting the best locations of all particles to each other, swarm particles change their location and velocity dynamically. Finally, until the swarm finds an acceptable solution in this process, all the particles in the swarm begin to move to better locations.

Step 6: Step 3 is continued until the iteration criterion is fulfilled.

Step 7: The result will show the global best, ultimate position for placing DG.

Figure 7: Concept of a searching by PSO [27]

4.2 Problem formulation of PSO

Nomenclature

p^{old} is the older particle value

p^{new} is the new updated particle value

v^{old} is the old velocity of the particle

v^{new} is the new velocity of particle

r_1, r_2 -uniformly distributed random number between 0 and 1

c_1, c_2 weighting factors=1.2 and 0.12

p^{local} is the personal best of a given particle

p^{global} is the global best value of the group

Using the following information, each particle attempts to change its location: the current position, the current velocity, the distance between the current position and pbest, the distance between the current position and gbest. The modification of the particle's position can be mathematically modeled according the following equation:

$$\mathbf{V}_{\text{new}} = \mathbf{V}_{\text{old}} + c_1 * r_1 * (\mathbf{p}^{\text{local}} - \mathbf{p}^{\text{old}}) + c_2 * r_2 * (\mathbf{p}^{\text{global}} - \mathbf{p}^{\text{old}}) \dots \dots \dots (4.1)$$

$$\mathbf{p}^{\text{New}} = \mathbf{p}^{\text{Old}} + \mathbf{V}^{\text{New}} \dots \dots \dots (4.2)$$

Optimization of particle swarms is an extremely simple algorithm that appears to be efficient in optimizing a wide variety of functions. We see it as an A-life mid-level or biologically derived algorithm, occupying the space in nature between eons-requiring evolutionary search and neural processing, which takes place in the order of milliseconds. In the time frame of ordinary experience, social optimization happens - in fact, it is ordinary experimentation.[23]

Chapter 5

Result Analysis

In our work, Particle Swarm Optimization (PSO) is used for finding the optimal solution of DG. We have used a 30-bus radial distribution system. The minimum DG size is considered 3MW and the maximum DG size is considered 100MW. It is taken into consideration that, DG is operated at unity power factor. The first bus is considered as the feeder of electric power from the generation/transmission network. The remaining buses are considered for the placement of DG. Here we considered 2 conditions for our analysis, one is PSO optimized With DG and other one is Without DG Condition. The optimization method has been applied on the data retrieved from PGCB (Power Grid Company of Bangladesh), Dhaka, Bangladesh.

5.1 Active Power Loss

Figure 8: Active power loss comparison with and without DG

Active power loss comparison have been done on basis of two condition. One is With DG condition and the other one is Without DG condition.

Power loss that takes place in the resistive element is known as active power loss. In Figure 8, we showed the result for PSO optimized With DG and Without DG condition. With the DG condition, we used the PSO algorithm. By this PSO algorithm, we will be able to know about the position of DG which has been shown in the final result part. Without DG condition, we used Newton-Raphson load flow techniques. In Figure 8, we can see that the active power loss has been reduced in with DG condition compare to the without DG condition except for some buses.

Active Power Loss in Optimal Location

Bus No	Active Power Loss PSO optimized With DG	Active Power Loss Without DG
3	2.2	20.26072
6	3.201731	5.958435
9	3.033231	3.643688
10	3	5.664932
12	1.12	2.728706
20	2.4	22.90575
22	3.2	22.49807
25	3.2	26.56266
27	3	11.54865

28	3	8.006845
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Table 2: Optimal location and active power loss for With DG and Without DG

In Table 2, the optimal location of DG and the active power loss have been shown for With DG and Without DG. These locations we found by implementing the PSO algorithm. In the table, we can see that for 12 no. Bus active power loss with DG is minimum. For 12 no. Bus the loss has been reduced for with DG condition is 58.95% compare to without DG Condition.

Parameters of PSO that has been used in our algorithm is provided here-

Parameters	value
Number of the swarm, n	20
Maximum number of swarm step	50
PSO parameter C2	1.2
PSO parameter C1	0.12
PSO inertia weight, w	0.3

Table 3: Parameters of PSO

Figure 9: Active Power loss comparison in optimal Location With and Without DG

Figure 9 is the graphical representation of table 2. From Figure 9, we can see 10 optimal locations which has been found from PSO algorithm for the placement of DG by the active power loss. We can see that active power loss has been reduced in those locations when we used DG.

5.2 Reactive Power Loss

Figure 10: Reactive Power Loss comparison for With DG and Without DG

In Figure 10, Reactive power loss comparisons have been shown on basis of DG and Without DG conditions for each of the buses. Here we did similar work that has been done in the active power loss comparison part. From Figure 10, we can see, reactive power loss also decreasing for PSO optimized with DG condition compare with without DG conditions except for some buses.

Reactive Power Loss in optimal location

Bus No	Reactive Power Loss with DG	Reactive Power Loss Without DG
3	1.071	9.694411
6	1.42	1.635768
9	1.12	3.187294

10	0.698133	0.897
12	0.293	0.982405
20	1.33233	2.589235
22	1.292	4.149036
25	0.761245	1.731599
27	1.002	6.975374
28	1.085	2.028359

Table 4: Optimal location and Reactive power loss for With DG and Without DG

In Table 4, the optimal location of DG and the reactive power loss have been shown for With DG and Without DG. These optimal locations we found by implementing the PSO algorithm. In the above table, we can see that for 12 no. Bus reactive power loss with DG is minimum. For 12 no. bus, reactive power loss is the minimum which is 0.293V. On 12 no bus, the loss reduction rate is 70.28%.

Figure 11: Reactive Power loss comparison in optimal Location With and Without DG

Figure 11 is the graphical representation of table 4. In this figure, we can see the optimal location of the DG which has been found by the PSO algorithm. In bus no 12, the value of reactive power loss is the minimum value.

5.3 Voltage profile

Figure 12: Voltage magnitude for each bus

In Figure 12, the voltage magnitude for each bus has been shown. Here, two types of the result have been shown in Figure 12. One is without DG and another one is PSO optimized with DG. From the graph, we can see that the voltage magnitude is improving for the PSO optimized DG condition compare to without DG conditions.

Bus No	PSO Optimized With DG Voltage Magnitude	Without DG Voltage Magnitude
1	1.0400	1.0400
2	0.9730	0.9730
3	0.9819	0.9042
4	1.0100	1.0100
5	0.9600	0.9600
6	1.0127	1.0006
7	0.9700	0.9700
8	1.0300	1.0200
9	1.0536	1.0392
10	1.0341	1.0152
11	1.0820	1.0820
12	1.0308	1.0201
13	1.0710	1.0710
14	1.0128	0.9995
15	1.0076	0.9930
16	1.0312	1.0157
17	1.0300	1.0100
18	1.0035	0.9867

19	0.9977	0.9790
20	1.0151	0.9947
21	0.9840	0.9643
22	1.0251	1.0007
23	0.9967	0.9778
24	1.0092	0.9844
25	1.0287	0.9925
26	1.0112	0.9744
27	1.0308	1.0063
28	1.0181	1.0026
29	1.0111	0.9861
30	0.9997	0.9744

Table 5: Voltage magnitude for with DG PSO Optimized and without DG

In Table 5, voltage magnitude for PSO Optimized with DG and without DG have been shown. From the table, voltage magnitude for PSO Optimized with DG are either increasing or equal with compare to without DG condition.

Voltage Profile at Optimal Location

Figure 13: Voltage Profile at optimal Location

In Figure 13, we can see that the voltage profile with DG is increasing compared with the voltage profile without DG. These optimal locations have been found by the PSO algorithm. Here, voltage magnitude is improving for each of the 10 optimal locations.

Bus No	Voltage Profile With DG	Voltage Profile Without DG
3	0.9819	0.9042
6	1.0127	1.0006
9	1.0536	1.0392
10	1.0341	1.0152
12	1.0308	1.0201

20	1.0151	0.9947
22	1.0251	1.0007
25	1.0287	0.9925
27	1.0308	1.0063
28	1.0181	1.0026

Table 6 : Voltage profile at optimal Location

Table 6 shows us the voltage profile at the optimal location. In those 10 optimal locations, voltage profile magnitude is increasing for with DG condition. This voltage profile magnitude satisfied one of our targets for using DG.

PSO Optimization

Figure 14: Voltage vs Time with PSO Optimization

In Figure 14, we can see that through PSO optimization Voltage is increasing with time. At one point, voltage reaches its highest point then it became constant. Voltage reaches its highest value by taking the lower time.

5.4 Total Active Power Loss

Figure 15: Final result of total active power loss

Figure 15 is the comparison of total power loss between with DG PSO optimized and the without DG. From this figure, we can see that total power loss have been reduced for PSO optimized with DG condition.

PSO Optimized with DG	Without DG
37.91 MW	84.7 MW

Table 7: Total power loss

This table shows us the total power loss comparison between PSO Optimized with DG and without DG condition. Here, we can see that, total power loss have been reduced in PSO optimized with DG condition compare to without DG condition. The rate of power loss reduction is 55.24%

5.5 Final Result

Condition	Active Power	Reactive Power	Voltage Profile
With DG	1.12	0.293	1.0308
Without DG	2.72871	0.98241	1.0201

Table 8: Condition at bus no 12

In Table 8, we showed the optimal best position that is 12 no. bus. Here, the active power loss, reactive power loss has been reduced after using DG. The voltage profile also has a significant improvement at the bus no 12.

Figure 16: Simulation scenario at BUS 12

Figure 16 is the graphical representation of Table 8. Here are shown the 3 parameters which have been considered for finding the best optimal location.

Optimal location	Power Loss PSO Optimized with DG(MW)	Power loss without DG(MW)	DG Size Range (MW)	% of loss reduction
12	37.91	84.7	3-100	55.24

By analyzing the 10 optimal locations with 3 parameters which are active power loss, reactive power loss, and voltage profile magnitude, bus no 12 is the best optimal location for the installation of DG. In our work, we considered the DG size range is 3-100 MW. The total power loss has been reduced to 55.24%.

Chapter 6

Conclusion

This paper proposed a technique for optimal placement of a distributed generation using particle swarm optimization technique in 30 bus radial distribution networks. By considering the 30 bus of 132KV Line of Chittagong division in BANGLADESH, where the cumulative losses in the bus are minimized up to 55.24%, the optimal position for the distributed generation placement has been obtained. The losses are found to be minimized if the distributed generation is placed in the system. The optimum position for the distributed generator placement has been found using the Particle Swarm Optimization algorithm. This technique is simple to implement and, compared to other traditional approaches, the time required for iteration is less.

6.1 Future scope of work

As a developing country, there will be always ample demand for electricity in our Bangladesh. Therefore, our research studies can be extended to solve the reliability of continuous power supply.

In future, we will extend our work which includes-

1. In future, work on multi objective particle swarm optimization technique (MPSO) can be done by using the knowledge which have been gathered from research work of PSO. The MPSO is used to minimize simultaneously economic cost and emission of thermal units by changing sitting and varying sizes of DG. Finding position of DG on power system network will be developed through PSO.[28]
2. There are ample scope of working with multiple DG in future from this point. Multiple Distributed Generation (DG) units could result in constraining the network, lowering

the utilization of its assets and minimizing the total DG capacity that can be accommodated.[29]

3. The similar optimization method can be applied on wireless meshed distribution network as well. With the fast development of wireless technologies, Wireless Mesh Networks (WMNs) are becoming an important networking infrastructure due to their low cost and increased high speed wireless Internet connectivity. [30]

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APPENDIX

We have collected line data and load data for 30 bus of Chittagong division from the following data sheet we got from PGCB (Power Grid Company of Bangladesh), Bangladesh.

Name of Substation		Number of Circuits	Voltage Level (kV)	Length (km)	Positive sequence impedances (ohm/km)		Zero sequence impedances (ohm/km)		Name of the conductor	Current carrying capacity (Amp)
					R1	X1	R0	X0		
From	To									
Hathazari	Kaptai	2	132	38.00	0.100852632	0.392868842	0.316841684	1.341648	Grosbeak	660.00
Hathazari	Baraulia	2	132	12.00	0.101616667	0.384691667	0.316536	1.341648	Grosbeak	660.00
Hathazari	Baroiarhat	2	132	67.60	0.101020	0.385090	0.316960	1.341650	Grosbeak	660.00
Hathazari	Madunaghat	2	132	9.00	0.100648889	0.385175556	0.315568	1.341648	Grosbeak	660.00
Hathazari	Raozan	2	132	22.50	0.0529	0.301647556	0.333387556	1.105727556	Twin 300 sq mm	750.00
Hathazari	GPH	1	230	17.00	0.05819	0.40204	0.13225	0.78292	Finch	1000.00
Hathazari	AKSML	1	230	18.50	0.05819	0.40204	0.13225	0.78292	Finch	1000.00
Hathazari	BSRM	1	230	47.92	0.05819	0.40204	0.13225	0.78292	Finch	1000.00
AKSML	Halishahar	1	132	13.50	0.100648889	0.411628148	0.378165333	1.235168	Grosbeak	660.00
Khulshi	Rampur	2	132	4.27	0.056	0.232042	0.23808	1.625173	Grosbeak	660.00
Khulshi	Madunaghat	2	132	12.70	0.101502362	0.411496063	0.377291339	1.234771654	Grosbeak	660.00
Khulshi	AKSPL	1	132	8.60	0.10127907	0.384860465	0.316063256	1.341242791	Grosbeak	660.00
Khulshi	Baraulia	1	132	12.90	0.10127907	0.384860465	0.316063256	1.341242791	Grosbeak	660.00
Khulshi	Modern Steel	1	132	3.04	0.100571465	0.383352714	0.317206786	1.341907354	Grosbeak	660.00
Khulshi	Bakulia	1	132	15.45	0.100571467	0.383352751	0.317207021	1.341907386	Grosbeak	660.00
Halishahar	Rampur	2	132	12.67	0.08298	0.34936	0.3023	1.3797	Grosbeak	660.00
Halishahar	Julda	1	132	6.22	0.048756395	0.393683598	0.152314893	1.240493556	AAAC	
Rampur	Agrabad	2	132	4.50	0.0316	0.126	0.18	1.847	XLPE, 800 sqmm	732.00
Baraulia	AKSPL	1	132	4.30	0.10127907	0.384860465	0.316063256	1.341242791	Grosbeak	660.00
Bakalia	Shikalbaha	2	132	3.80	0.067	0.367	0.174	0.833	ACCC	1220.00
Bakalia	Modern Steel	1	132	12.41	0.100571373	0.383352297	0.317206658	1.341900725	Grosbeak	660.00
Julda	Shikalbaha	1	132	7.39	0.101189	0.385276	0.317095	1.341432	Grosbeak	660.00
Julda	Shamirpur	2	132	5.70	0.101066561	0.385287614	0.278924615	1.179635368	Grosbeak	660.00
Madunaghat	Shikalbaha	1	132	16.10	0.100624845	0.385187578	0.317095155	1.340890435	Grosbeak	660.00
Madunaghat	T.K	1	132	8.75	0.100538286	0.385031771	0.317017234	1.340751909	Grosbeak	660.00
Madunaghat	Chandraghona	2	132	30.80	0.10123961	0.385162987	0.317139429	1.341308571	ACCC	1220.00
Dohazari	Shikalbaha	2	132	32.20	0.067	0.367	0.174	0.833	ACCC	1220.00
Dohazari	Cox's Bazar	2	132	86.60	0.101090155	0.384954921	0.317107772	1.341557719	Grosbeak	660.00
Chandraghona	Kaptai	2	132	11.50	0.08868	0.389301	0.34044	1.1856	Grosbeak	660.00
Chandraghona	Rangamati	2	132	27.68	0.08868	0.389301	0.34044	1.1856	Grosbeak	660.00
Shikalbaha	Shahmirpur	2	132	9.10	0.101079263	0.385288266	0.278324466	1.177439246	Grosbeak	660.00
Rangamati	Khagrachori	2	132	51.00	0.08868	0.389301	0.34044	1.1856	Grosbeak	660.00
Shikalbaha	T.K	1	132	8.59	0.10053828	0.38503177	0.31701723	1.34075191	Grosbeak	660.00
Shikalbaha	Anwara PP	1	230	17.33	0.037	0.281	0.248	0.87	Twin Mallard	1597
Shikalbaha	Intermediate GIS	2	230	2.2	0.027	0.162	0.455	0.655	Twin Mallard	1598
Intermediate	Baraka PP	2	230	0.80	0.041	0.265	0.311	0.73		
Intermediate	Anima	1	230	0.38	0.136	0.342	0.658	0.817		
GPH	BSRM	1	230	36.12	0.05819	0.40204	0.13225	0.78292	Finch	1000.00
Matarbari	tapping from Doha-Cox ckt-1(152 no. tower)	1	132	18.00	0.101090155	0.384954921	0.317107772	1.341557719	Grosbeak	660.00
Dohazari	Tapping point(Tower no. 152) for matarbari	1	132	48.00	0.101090155	0.384954921	0.317107772	1.341557719	Grosbeak	660.00
Baraulia	KSRM	1	132	4.20	0.101090155	0.384954921	0.317107772	1.341557719	Grosbeak	660.00
Baroiarhat	PHP	1	132	6.65	0.101020	0.385090	0.316960	1.341650	Grosbeak	660.00
Baroiarhat	Feni	1	132	23.60	0.101020	0.385090	0.316960	1.341650	Grosbeak	660.00

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Figure 17 Collected line data from PGCB

Load data of Chittagong division collected from PGCB

Name of the Sub-station	Active Power (MW)	Reactive Power (MW)	Power factor
Madunghat	70	63	0.9
Hathazari	108	97.2	0.9
Khulshi	222	199.8	0.9
Halishahar	166	149.4	0.9
Baroaulia	199	179.1	0.9
Sikalbaha	39	35.1	0.9
Dohazari	106	95.4	0.9
Cox's Bazar	120	108	0.9
Chandraghona	42	37.8	0.9
Kaptai	20	18	0.9
A. Khaer Stl.	106	95.4	0.9
Bakulia	125	112.5	0.9
Julda	29	26.1	0.9
TK chemical	32	28.8	0.9

Modern Steel	24	21.6	0.9
Shahmirpur	47	42.3	0.9
Abul Khair	215	193.5	0.9
BSRM	165	148.5	0.9
Khagrachhari	34	30.6	0.9
Matarbari	41	36.9	0.9
Rangamati	14	12.6	0.9
Baroirhat	60	54	0.9

Table 9 Load data of Chittagong division from PGCB

Code for Load Flow

```
function result= nrloadflow(nbus,busd,linedata)

Y = ybusppg(linedata);

BMva = 100;           % Base MVA

bus = busd(:,1);      % Bus Number

type = busd(:,2);     % Type of Bus 1-Slack, 2-PV, 3-PQ

V = busd(:,3);        % Specified Voltage

del = busd(:,4);      % Voltage Angle

Pg = busd(:,5)/BMva;   % PGi

Qg = busd(:,6)/BMva;   % QGi

Pl = busd(:,7)/BMva;   % PLi

Ql = busd(:,8)/BMva;   % QLi

Qmin = busd(:,9)/BMva; % Minimum Reactive Power Limit

Qmax = busd(:,10)/BMva; % Maximum Reactive Power Limit

P = Pg - Pl;          % Pi = PGi - PLi

Q = Qg - Ql;          % Qi = QGi - QLi

Psp = P;              % P Specified

Qsp = Q;              % Q Specified

G = real(Y);          % Conductance

B = imag(Y);          % Susceptance


pv = find(type == 2 | type == 1); % PV Buses

pq = find(type == 3);    % PQ Buses

npv = length(pv);        % No. of PV buses

npq = length(pq);        % No. of PQ buses
```

```

Tol = 1;

Iter = 1;

while (Tol > 1e-5) % Iteration starting

    P = zeros(nbus,1);

    Q = zeros(nbus,1);

    % Calculate P and Q

    for i = 1:nbus

        for k = 1:nbus

            P(i) = P(i) + V(i)* V(k)*(G(i,k)*cos(del(i)-del(k)) + B(i,k)*sin(del(i)-del(k)));

            Q(i) = Q(i) + V(i)* V(k)*(G(i,k)*sin(del(i)-del(k)) - B(i,k)*cos(del(i)-del(k)));

        end

    end

    if Iter <= 7 && Iter > 2

        for n = 2:nbus

            if type(n) == 2

                QG = Q(n)+Ql(n);

                if QG < Qmin(n)

                    V(n) = V(n) + 0.01;

                elseif QG > Qmax(n)

                    V(n) = V(n) - 0.01;

                end

            end

        end

    end

```

```

        end

    end

    dPa = Psp-P;
    dQa = Qsp-Q;
    k = 1;
    dQ = zeros(npq,1);
    for i = 1:nbus
        if type(i) == 3
            dQ(k,1) = dQa(i);
            k = k+1;
        end
    end

    dP = dPa(2:nbus);
    M = [dP; dQ];

    %Jacobian

    J1 = zeros(nbus-1,nbus-1);
    for i = 1:(nbus-1)
        m = i+1;
        for k = 1:(nbus-1)
            n = k+1;
            if n == m

```



```

    for n = 1:nbus
        J1(i,k) = J1(i,k) + V(m)* V(n)*(-G(m,n)*sin(del(m)-del(n)) + B(m,n)*cos(del(m)-
del(n)));
    end

    J1(i,k) = J1(i,k) - V(m)^2*B(m,m);

else
    J1(i,k) = V(m)* V(n)*(G(m,n)*sin(del(m)-del(n)) - B(m,n)*cos(del(m)-del(n)));
end

end

end

end

J2 = zeros(nbus-1,npq);

for i = 1:(nbus-1)
    m = i+1;

    for k = 1:npq
        n = pq(k);

        if n == m
            for n = 1:nbus
                J2(i,k) = J2(i,k) + V(n)*(G(m,n)*cos(del(m)-del(n)) + B(m,n)*sin(del(m)-
del(n)));
            end

            J2(i,k) = J2(i,k) + V(m)*G(m,m);

        else
            J2(i,k) = V(m)*(G(m,n)*cos(del(m)-del(n)) + B(m,n)*sin(del(m)-del(n)));
        end
    end
end

```

```

        end

    end

end

J3 = zeros(npq,nbus-1);

for i = 1:npq
    m = pq(i);
    for k = 1:(nbus-1)
        n = k+1;
        if n == m
            for n = 1:nbus
                J3(i,k) = J3(i,k) + V(m)* V(n)*(G(m,n)*cos(del(m)-del(n)) + B(m,n)*sin(del(m)-
del(n)));
            end

            J3(i,k) = J3(i,k) - V(m)^2*G(m,m);
        else
            J3(i,k) = V(m)* V(n)*(-G(m,n)*cos(del(m)-del(n)) - B(m,n)*sin(del(m)-del(n)));
        end
    end
end
end

```

```

J4 = zeros(npq,npq);

```

```

for i = 1:npq

```

```

m = pq(i);
for k = 1:npq
    n = pq(k);
    if n == m
        for n = 1:nbus
            J4(i,k) = J4(i,k) + V(n)*(G(m,n)*sin(del(m)-del(n)) - B(m,n)*cos(del(m)-del(n)));
        end
        J4(i,k) = J4(i,k) - V(m)*B(m,m);
    else
        J4(i,k) = V(m)*(G(m,n)*sin(del(m)-del(n)) - B(m,n)*cos(del(m)-del(n)));
    end
end
end

J = [J1 J2; J3 J4];

X = inv(J)*M;
dTh = X(1:nbus-1);
dV = X(nbus:end);

del(2:nbus) = dTh + del(2:nbus);
k = 1;
for i = 2:nbus
    if type(i) == 3

```

```

        V(i) = dV(k) + V(i);

        k = k+1;

    end

end

Iter = Iter + 1;

Tol = max(abs(M));

end

result.del=del;

[result.Pi, result.Qi, result.Pg, result.Qg, result.Pl, result.Ql,...

    result.Lpij, result.Lqij, result.V,result.I] =loadflow(nbus,V,del,BMva,busd,linedata);

power=[result.Pi result.Qi result.Pg result.Qg result.Pl result.Ql]'/BMva;

```

Code for PSO

```

function [bestsol,objval]=PSO(loadbusLocation,resultwithoutDG,nbus,dim,up,low)

n = 20;      % Number of the swarm

swarm_step = 50; % Maximum number of "swarm step"


c2 =1.2;      % PSO parameter C2

c1 =0.12;     % PSO parameter C1

w =0.3;      % PSO inertia weight

```

```
fitness=0*ones(n,swarm_step);
```

```
% initialize the parameter
```

```
R1 = rand(dim, n);
```

```
R2 = rand(dim, n);
```

```
current_fitness =0*ones(n,1);
```

```
% Initializing swarm and velocities and position
```

```
current_position = (up-low).*rand(dim,n)+low;
```

```
velocity = 0.03*rand(dim, n) ;
```

```
local_best_position = current_position ;
```

```
% Evaluate initial population
```

```
for i = 1:n
```

```
    current_fitness(i) = objf(current_position(:,i)',loadbusLocation,resultwithoutDG,nbus);
```

```
end
```

```

local_best_fitness = current_fitness ;

[global_best_fitness,g] = min(local_best_fitness) ;

for i=1:n

    globl_best_position(:,i) = local_best_position(:,g) ;

end

handl=waitbar(0,'Kindly Wait while PSO is Operating');

%% Main Loop

iter = 0 ;    % Iterations counter

while ( iter < swarm_step )

    iter = iter + 1;

    velocity = w *velocity + c1*(R1.*(local_best_position-current_position)) +
    c2*(R2.*(globl_best_position-current_position));

    save velocity velocity

    current_position = current_position + velocity;

    for i = 1:n

        current_position(:,i)=limitchk(current_position(:,i),up,low,nbus,loadbusLocation);

        current_fitness(i) = objf(current_position(:,i)',loadbusLocation,resultwithoutDG,nbus);

    end

    for i = 1 : n

```

```

    if current_fitness(i) < local_best_fitness(i)

        local_best_fitness(i) = current_fitness(i);

        local_best_position(:,i) = current_position(:,i) ;

    end

end

[current_global_best_fitness,g] = min(local_best_fitness);

if current_global_best_fitness < global_best_fitness

    global_best_fitness = current_global_best_fitness;

    for i=1:n

        global_best_position(:,i) = local_best_position(:,g);

    end

end

objval(iter)=global_best_fitness;

waitbar(iter / swarm_step)

end

close(handl)

[Jbest_min,I] = min(current_fitness);

bestsol=current_position(:,I);

```

Code for PSO Optimized DG

```
tic;

clc;

clear all;

close all

nbus = 30;

busdata = busdatas(nbus);

linedata = linedatas(nbus);

resultWithoutDG = nrloadflow(nbus,busdata,linedata);

dim = 10;

Pmin=3; %minimum power of solar DG unit

if nbus==30

    Pmax=30;

else

    Pmax=100; %maximum power of solar DG unit in MW

end

%% Optimal bus selection

R=linedata(:,3);

sourcbus=linedata(:,1);

destintnbus=linedata(:,2);

for ii=1:size(linedata,1)

    alpha(ii)=(R(ii)/(abs(resultWithoutDG.V(sourcbus(ii)))...

        *abs(resultWithoutDG.V(sourcbus(ii)))))...

        *cos(resultWithoutDG.del(sourcbus(ii))...

            -resultWithoutDG.del(destintnbus(ii)));
```



```

    beta(ii)=(R(ii)/(abs(resultWithoutDG.V(sourcbus(ii)))...
        *abs(resultWithoutDG.V(sourcbus(ii)))))...
        *sin(resultWithoutDG.del(sourcbus(ii))...
            -resultWithoutDG.del(destintnbus(ii)));
    SV(ii)=alpha(ii).*resultWithoutDG.Pi(destintnbus(ii))...
        -beta(ii).*resultWithoutDG.Qi(destintnbus(ii));

end

[sv,ind]=sort(SV,'descend');
po=destintnbus(ind);
[poo,ia,ic]=unique(po);
temp=po(sort(ia));
loadBusLocation = temp(1:dim);

%% PSO optimisation

[PSOx,objval]=PSO(loadBusLocation,resultWithoutDG,nbus,dim,Pmax,Pmin);
finalPSOresults= resultcalc(PSOx',loadBusLocation,resultWithoutDG,nbus);
FIG1 = figure('Name', 'PSO Optimization','NumberTitle','off');
figure(FIG1)
plot(1./objval)
grid on;
ylabel('VL (pu)');
xlabel('time (sec)');
title('PSO optimisation')

%% Result plotting
% volatge magnitude plot

```

```

FIG2 = figure('Name', 'BUS VOLTAGE','NumberTitle','off');

figure(FIG2)

bar([finalPSOresults.V,resultWithoutDG.V],'group')

xlim([0 nbus+1])

ylim([0.95,1.1])

grid on;

legend('PSO optimised With DG','Without DG')

xlabel('Bus number')

ylabel('Volatge Magnitude in p.u.')

title('Bus Voltage')

% power loss Comparison

FIG3 = figure('Name', 'Total Active Power loss','NumberTitle','off');

figure(FIG3)

bar([sum(finalPSOresults.Lpij);sum(resultWithoutDG.Lpij)])

grid on;

title('Total Active Power loss in MW')

ylabel('Active Power loss(MW)')

set(gca,'Xtick',0)

text(0.8,-0.2,'PSO tuned')

text(1.5,-0.2,'Without Optimisation')

toc;

```