

Integration of DG and Capacitor in Radial Distribution Systems

A Dissertation

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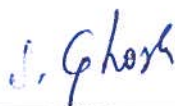
CERTIFICATE

I hereby declare that the thesis entitled “**Integration of DG and capacitor in radial distribution systems**” is an authentic record of my work carried out as requirements for the award of the degree of **Master of Engineering in Power Systems at Thapar University, Patiala** under the supervision of **Dr. Smarajit Ghosh**, Professor, Electrical and instrumentation Department, Thapar University, Patiala during July, 2016 to June, 2017. No part of the matter embodied in this report has been submitted to any other university or institute for the award of any degree.

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It is certified that the above statement made by the student is correct to the best of my knowledge and belief.



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(Bhavana Jangid)

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NOMENCLATURE

V_k	Voltage at k-bus
V_{kmin}	Minimum voltage limit for k th bus
V_{kmax}	Upper voltage limit for k th bus
P_{loss}	Total real power loss
Q_{loss}	Total reactive power loss.
$\sum P_{Di}$	Total real power demand.
$\sum Q_{Di}$	Total reactive power reactive.
$\sum P_{DGi}$	Total real power generated by DG.
$\sum Q_{DGi}$	Total reactive power compensated by capacitor
N	Total number of nodes in RDN
Br	Total number of branches in RDN
L	Total number of lateral lines in RDN
Sl	Total number of sub-lateral lines in RDN
M	Total number of minors in RDN
en_m	Main line ending node
Z_i	Impedance of i-branch
R_i	Resistance of i-branch
X_i	Reactance of i-branch
V	Voltage
S_N	Complex power at N-node
I_{IN}	Load current injected at N-node
I_{br}	Branch current
$I_{br,L}$	Branch current at L th lateral line
$I_{brs,s}$	Branch current from s sub-lateral line
$I_{br,m}$	Current in minor m
N_{mL}	Node number from where L th lateral line starts
N_{Ls}	Node number from where sub-lateral line starts
br_{ML}	Branch that connects main line to L lateral line
br_{Ls}	Branch that connects lateral line to sub-lateral line
br_{sm}	Branch that connects sub-lateral to minor line
sNL_L	Starting node of L th lateral line

sNS_L	Starting node of L th sub-lateral line
sNm_L	Starting node of m th minor line
eNs_{sL}	Ending node of sub-lateral line sL.
eNL_L	Ending node number of lateral line l
L	Number of lateral lines = 1,2,3,4,.....,n
Sl	Number of sub-lateral lines = 1,2,3,4,.....,sn
M	Number of minor lines = 1,2,3,4,.....m

LIST OF ACRONYMS

RDN	Radial Distribution Network
DG	Distributed Generation
GA	Genetic Algorithm
PSO	Particle Swarm Optimization
LSF	Loss Sensitivity Factor
VSI	Voltage Stability Index
NR	Newton Raphson
FDNR	Fast Decoupled Newton Raphson
KCL	Kirchhoff's Current Law
KVL	Kirchhoff's Voltage Law
HSA	Harmony Search Algorithm
AI	Artificial Intelligence
HPF	Harmonic Power Flow
FA	Firefly Algorithm

ABSTRACT

The requirement of reliable energy is increasing day by day. There is a need to set-up new infrastructure like generating stations, new transmission lines and utility to meet the demand. But installation of new infrastructure is very time consuming and costly. Also, more policies are buildup for the liberalization of the electricity market as more companies are emerging to enter the market. In addition, technical advancement in small-scale generation units popularly known as Distributed Generation enhances its role in today's market. The integration of Distributed Generation and Capacitors helps to decrease the losses and improves the voltage profile. It also provides grid reinforcement and more reliable supply to the consumer.

This dissertation presents an integrated approach for minimization of losses by installation of Distributed Generation and Capacitor unit in Radial Distribution Networks. The placement of an integrated system can provide number of advantages like line loss reduction, enhancement of system stability and voltage profile improvement. Focusing on the complex nature of the radial configuration and constraints, a nature-inspired meta heuristic approach is used. Particle Swarm Optimization is inspired from the social behavior of swarm members for survival in the eco-system. The efficiency of the following method is tested with 15-node and 118-node radial distribution networks.

For load flow analysis in radial distribution network backward-forward sweep based method is used in this thesis to emulate the losses under constant power loading condition. A nature inspired swarm based technique Particle Swarm Optimization technique is used to find out the optimal configuration. The sensitivity analysis is carried out using voltage stability index and loss sensitivity factor for finding the optimal location for DG and Capacitor installation. The conclusions are made based upon the obtained results.

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The energy demand is ever increasing. Presently, around 15-18% of total electrical energy generated in India is lost in distribution. Certainly, the reduction in distribution losses can minimize this discrepancy considerably. Due to the growing demand of electrical power, research works are being done to cope up with future demands and make the system more stable and reliable. A large number of infrastructure and system restructuring required for generation transmission and distribution to level up the mismatch between the generation and demand.

Due to economic, environmental and many other aspects addition of new centralized generation is not a feasible option as it has its own complications. Constraints are there due to line capacity for long distance transmission. All these restrictions have created increased interest in DG at the place of centralized generation. The capacitor and DG helps in grid reinforcement and loss reduction if strategically placed. At the same time the peak operating cost and voltage profiles can be improved. This provides a more efficient and reliable system. The principal purpose of the distribution system is to receive the mass power from transmission and meet the consumer's demand for power. The distribution system contributes about nearly 70% of the total losses occur in the power system. Substations are an indifferent part of electrical power system. Voltage levels are stepped up or down by the substation transformer and energy is dispatched from generating stations to consumers. The generated power may flow through many substations from generating station to the end user and voltage levels are changed in steps. The classification of substation is given below.

1.1.1 TRANSMISSION SUBSTATION:

Transmission substation incorporate the transmission line into a system having number of parallel interconnections so that, power for long distances can freely flow from the generating stations to the customers. Transmission system handles bulk power thus named bulk power system. Transmission system works at voltage above 132 kV.

1.1.2. SUB-TRANSMISSION SUBSTATION:

Sub-transmission substation usually operates at 400 kV to 132 kV voltage levels. From distribution system to further region, sub transmission system supplies the power. It transforms the high voltage used in transmission system over long distances, into sub

transmission voltages for cost-efficient transmission of bulk power. The lines connecting the substation to the distribution substation are radial express feeders.

1.1.3. DISTRIBUTION SUBSTATION:

It supplies the power directly to the consumers. It transfers power from distribution substation to the industrial and residential consumers. It has many branches from distribution substation to the local consumers. It constitutes transformers those transforms the distribution level voltage to service level voltage used for industrial and residential purposes ranges from 110 V to 600 V.

A simplified single-line diagram consisting all major electrical components from generation to a customer's service is shown in Figure 1.1

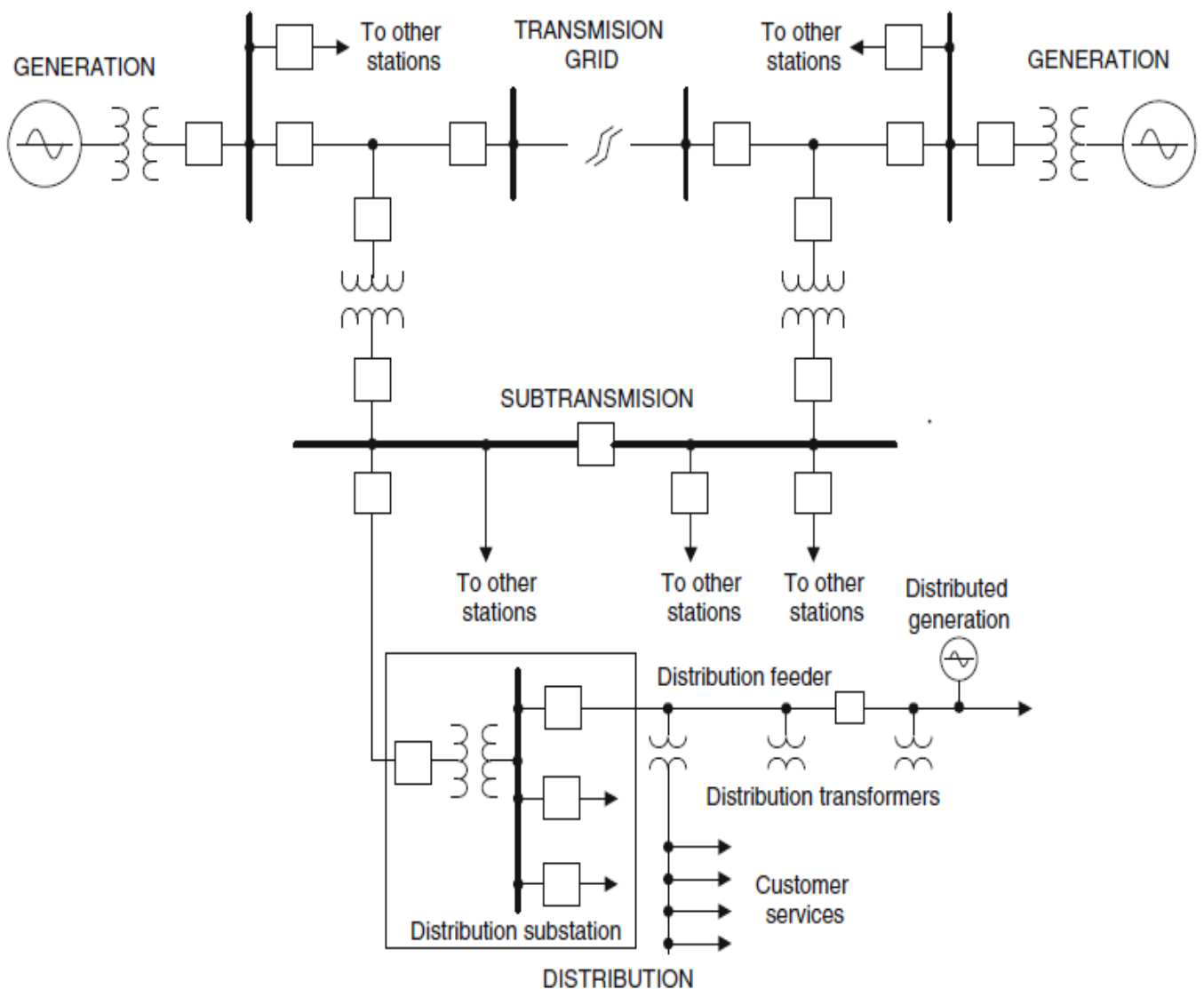


Figure1.1: Single line diagram of electrical power system.

1.2 CLASSIFICATION OF DISTRIBUTION SYSTEM:

On the basis of different aspects the distribution system is classified as shown in Figure 1.2

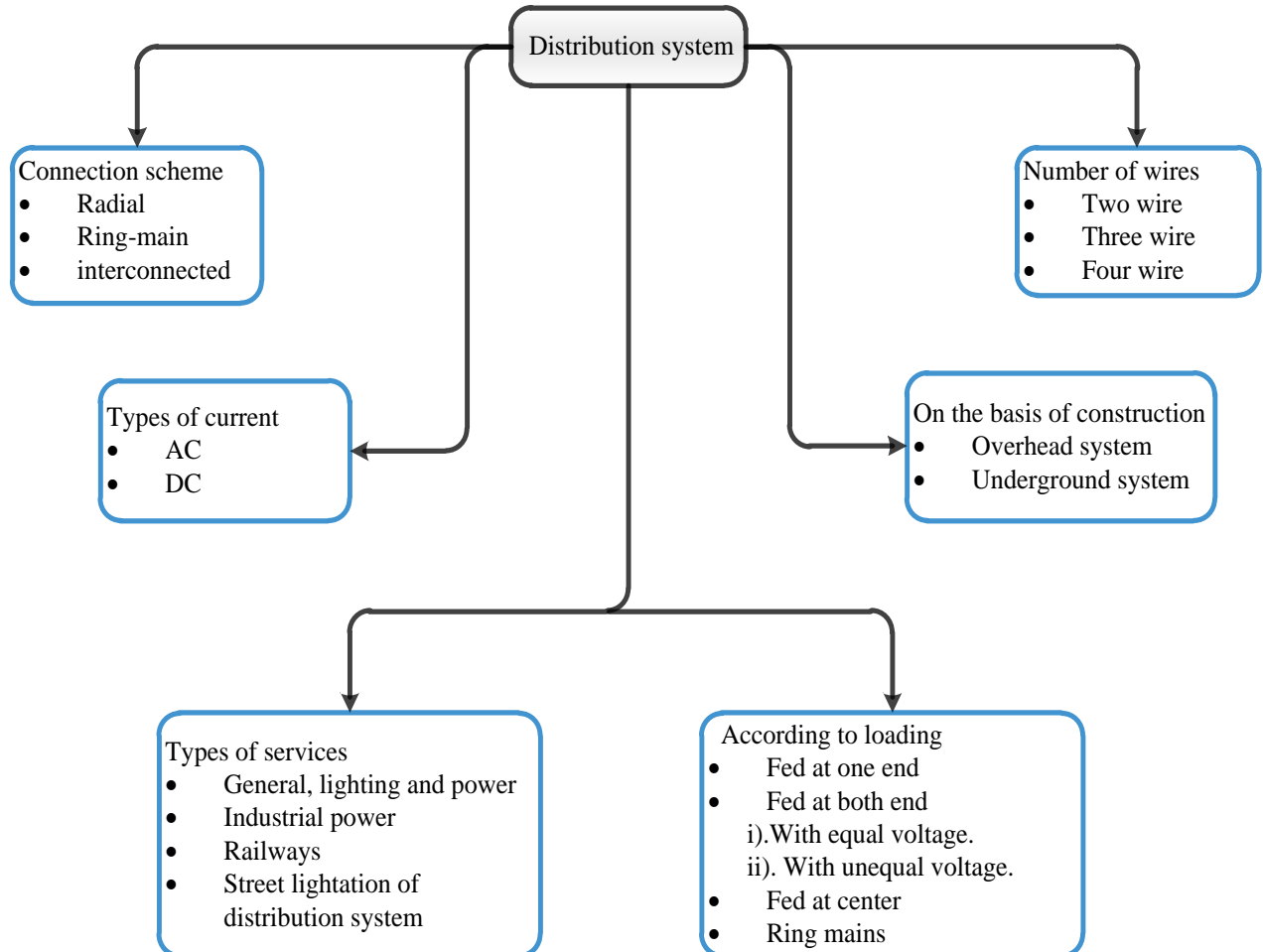


Figure 1.2: Classification of distribution system

1.2.1 CONNECTION SCHEME:

1.2.1.1 RADIAL DISTRIBUTION SCHEME

Radial distribution power is fed at one end only; there is only one way of power flow from each consumer to substation. In case of the occurrence of any contingency in the system the whole system disruption is there. This scheme is used only where the substation is located in the center and generated voltage is low.

Advantages of radial scheme

- The radial distribution scheme has low installation cost as well simple in design.

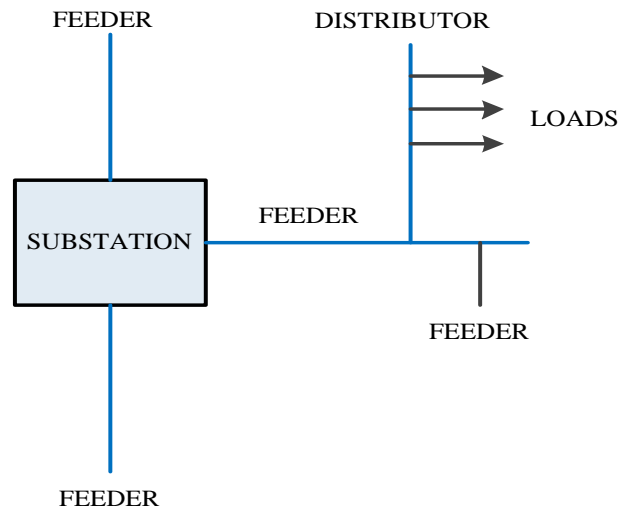


Figure 1.3: Radial distribution system

1.2.1.2 RING MAIN DISTRIBUTION

This scheme consists of more than one path for supplying electrical power from substation to consumers as shown in Figure 1.4. This system formulates a ring type structure by connecting the end lines back to the substation, the feeder is closed in itself.

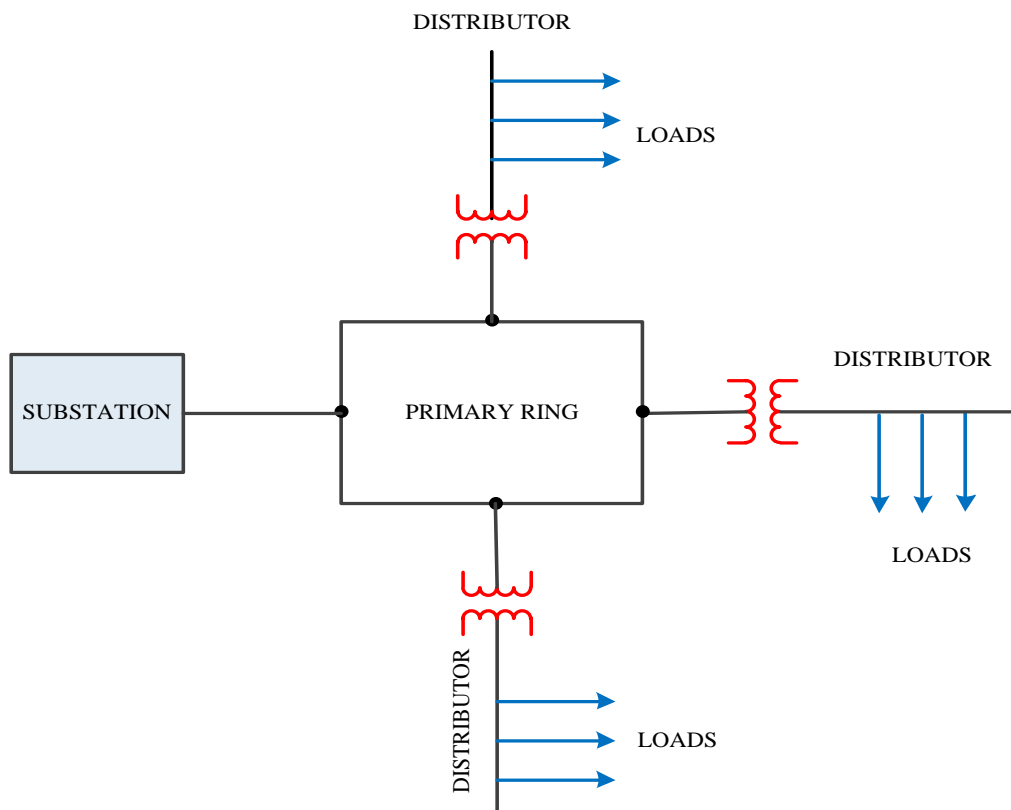


Figure 1.4: Ring main distribution system

The main advantages of such type of scheme is that it is

- It is more reliable.

- This scheme provides continuous supply of the power to the consumers in case of occurrence of contingency in any part of feeder. So, even in case of fault the supply is continued to the customers.

1.2.1.3 INTERCONNECTED DISTRIBUTION SYSTEM

In this scheme the feeder ring is energized by more than one generating stations, hence it is called interconnected system. This system has advantages like reliability of service, and during different loading conditions power can be fed from any one substation or from both at the same time during peak load hours.

Advantages of interconnected system

- Increment in system efficiency.
- Minimization of reverse power capacity.

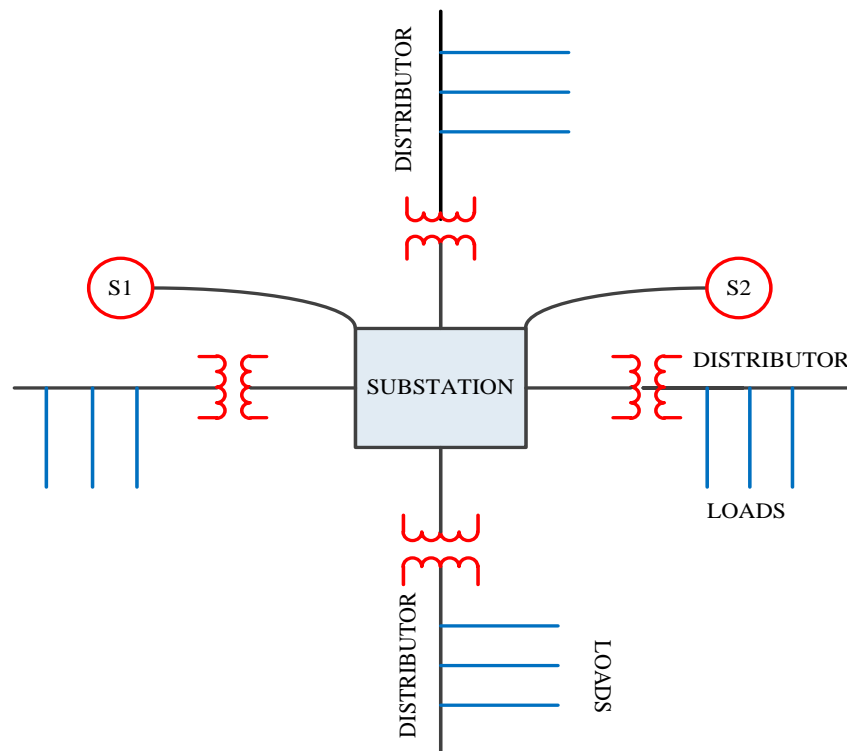


Figure 1.5: Interconnected distribution system.

1.3 NEED OF INTEGRATED SYSTEM

Advanced control of electric distribution feeder reconfiguration is used as planning tool and also as real time control tool. This has been possible with tremendous research and

development in microprocessors, minicomputer and telecom systems. By altering the on/off states of switches for transferring load from one feeder to another feeder with some modifications in real structure, the operating conditions for overall system can be improved.

The reconfiguration of feeder allows to transfer load from heavily loaded feeder to comparatively lightly loaded feeder. These kinds of systems techniques not only provides load level alteration but also are helpful in improvement of voltage profile along the feeder and reduction in system losses.

Power system faces problems like high power losses, poor power quality, surplus/ clogging in transmission line etc. DG is one of feasible option to few problems. Smaller DG size will be helpful in planning and installing shorter time frame as compared to the conventional generation units.

A step moving towards decentralized environment where, demand and supply uncertainty occur at large extent. It would stand beneficial to install DG in existing utility setup. Loss minimization can be achieved using various methods like system restructuring, placement of shunt capacitors and DG at optimal location with optimal ratings. Optimal ratings and positions are required. Otherwise, there is a chance of bus voltage exceed from pre described limits. Shunt capacitors installed on distribution primary feeders to improve feeder voltage profile via power factor correction. It has been also widely recognized that the application of shunt capacitors results in decrement of power and energy losses in the feeder.

Hence, full benefits from the use of DG and shunt capacitors can only be achieved through simultaneous consideration of the above-mentioned two effects [1].

1.4 DISTRIBUTED GENERATION:

Distributed power generation is a technology that accommodates a small scale generation at a site in the proximity of customers than the central generating station. Such unit can be connected directly to the consumer or to the distribution system.

1.4.1 TYPES OF DISPERSE GENERATOR

Disperse generators can be classified into four types

DG type 1 - supply real power only.

DG type 2 - supply reactive power only.

DG type 3 - supply real and reactive power.

DG type 4 - supply real power but absorbs reactive power from the system.

1.4.2 ADVANTAGES OF DISTRIBUTED GENERATION

Distributed generation serves many purposes along with loss minimization in the distribution system. Installation of DG unit has following benefits.

- DG can supply real power which improves power factor and voltage profile.
- DG located closer to the end user side aids reduction in transmission power losses.
- System becomes cost effective and cost corresponds to the power loss can be reduced upto large extent, thus cost minimization is there.
- As the power demand increases, generation has to increase. But every time it is not possible to increase the power generation due to limited generation and other aspects. So DG can serve a great purpose in such conditions and can supply the power without any alteration in the capacity of the generating system.
- For the installation of DG units geographical situations is not a key problem. They can be simply installed near consumer side. Thus, DGs are flexible devices.
- DG units are available in a wide range from a few kW to 15 MW, so can be used in small and medium distribution system.
- DG provides advantages to get start without any auxiliary power source and power can be restored during local area blackouts.
- Installation of DGs downturns the relying on the main grid. Thus, improve the stability and reduces the power losses.

1.4.3 ADVANTAGES OF SHUNT CAPACITOR

Most of the part of energy is lost in transmission and distribution of energy to remote or far locations. Hence, to remunerate these losses shunt capacitor may installed. This can be installed in the proximity of utility to compensate the losses in the system.

- Capacitors and DG units, if strategically installed, may contribute in compensation of the losses and remodeling the voltage profile. Loss reduction leads to improvement in efficiency of system.
- Efficiency improvement leads to cost reduction to the end consumers. Hence provides minimal overall cost and improves reliability.
- Shunt capacitor installation at or near to load improves the efficiency and reduces reactive power losses if they are optimally sized and located at appropriate locations.

1.5 THESIS OUTLINE:

The dissertation work is presented in five Chapters. Brief details about each chapter are as follows:

Chapter 1: Introduction

This chapter presents a brief introduction of distribution system, classification and radial distribution network.

Chapter 2: Literature Review

This chapter includes a concise explanation of relevant literature of the research carried out by different researchers. The requirement for improvement of the following methodology is highlighted.

Chapter 3: Objective Function and Constraints

The formulation of the objective function for loss minimization in radial distribution system along with the equality and inequality constraints are presented in this chapter.

Chapter 4: Methodology

This chapter explains the formulation of backward-forward sweep method for the development of an efficient load flow analysis. The method used for sensitivity analysis to find out the optimum place for the installation of DG and capacitor units is included in this chapter.

The chapter explains about the PSO algorithm and formulations for the application of the algorithm in order to achieve the objective.

Chapter 5: Results and Discussions

The proposed algorithms are tested on IEEE 15-node and 118-node test distribution system.

Chapter 6: Summary and Conclusions

This chapter brings out the summary of the work carried out and the prominent conclusions. The scope for future studies has also been included.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Distribution system has comparatively complex operation and control than the transmission system. The level of current is high in distribution system and the conductors used for distribution are highly resistive in nature with invariable resistance. In past decades, more focus is embarked on the reduction of the losses in distribution network.

2.2 LITERATURE SURVEY

An efficient and fast load flow technique is required to calculate the losses occurring in the distribution system. The distribution system has low X/R ratio and radial structure. Due to these factors the conventional methods used for transmission systems can not be used for distribution system because these methods fail to converge in case of distribution systems. Although modified NR method can be used for smaller distribution system but for a large distribution network sparsity of the Jacobian Matrices largely increases.

The methods represented in [2] and [3] were found to be slow and complicated.

Ghosh and Das [4] developed a method considering node beyond branches. With the consideration of the charging admittance they showed the reduction in losses and voltage profile improvement. They used simple algebraic expressions for voltage computation at receiving end. The current was calculated by adding the load currents at respective nodes. The method was quite efficient and simpler. The effectiveness of the method was tested through different examples. The shortcoming of this method was that it stored the nodes beyond every node for each branch.

Aravindhbabu et al. [5] developed a branch-node power flow method which uses upper triangular matrix for bus voltage calculations. This method was less complex than other because it doesn't require any matrix inversion. But, that method proved unsuitable in the presence of any sub lateral because it was complicated to form the matrix in that case.

Ranjan and Das [6] introduced a method, which involves simple algebraic equations. All the data was stored in vector form, which reduced the use of memory space. The methodology involved the calculation of the voltages for every bus using forward sweep. Thus losses were calculated for each node beyond the receiving end node.

Ghosh [7] presented a method to solve load-flow problem for RDN. The power flow through any branch can be easily computed using the algorithm exploring the radial feature of the

distribution networks. The suggested approach includes the assessment of simple receiving end voltages algebraic expression. The performance of the following method was analyzed with examples.

Ghosh and Sherpa [8] introduced a method, in which sequential numbering of the nodes and branches were not required. The proposed method was very efficient and used simple algebraic equations to compute the voltage magnitudes for different buses.

Grainger [9] presented a generalized procedure to realistic problems and to facilitate the immediate use by utility system designer. He presented an optimal method for the placement of shunt capacitors in RDN and presented ways to compute the effective size of capacitor for loss reduction.

Nara et al. [10] presented an Artificial Intelligence (AI) based method for the loss reduction in RDN. They presented a Genetic Algorithm (GA) based approach to minimize the losses. But this method was lengthy, as it involves different steps like mutation, crossover of the randomly generated population.

Row and Wan [11] proposed an approach to find out the optimum location using load flow algorithm. To locate the resources like fuel cell, battery storage, wind generation etc. a method was presented focusing on the maximization of the potential benefits. They computed the number of resources in candidate nodes using second order algorithm. This method was presented for transmission, sub transmission and distribution systems. But, as distribution system has different characteristics than transmission system, so this method was not efficient for all the cases.

Eberhart and Shi [12] presented a comparative study of GA and PSO. They showed that the problem space can affect search behavior of particles. They proposed a parameter named use-better, which is selected at runtime of PSO. This parameter causes the particles of PSO to continue in the same direction in which it finds maximum or better fitness function than the previous iterations. The particles having lower fitness values are eliminated from the population to obtain better global best in PSO. Thus, they incorporated some features of the GA in PSO to obtain better results.

Shi and Eberhart [13] presented a modified approach which uses PSO to find optimal size. They introduced a factor named 'inertia weight', which has significant impact. But the inertia weight factor had only a specific range in which it performed better.

Kim et al. [14] developed GA based algorithm to compute the optimal location for DG installation. The proposed method had been tested on different test systems along with the comparison of the results with the existing methods.

Acharya *et al.* [15] presented the interpretive way to shrink the losses with DG. Effect of DG sizing and location on losses was described comprising exhaustive load flow and loss sensitivity method. Exact loss formula was used to enumerate that approach.

Kruasukan and Ongsakul [16] presented a method for the computation of losses using exact loss formula. They emulated the effect of multiple DG in RDN and the optimal size of DG was found using PSO technique. The real and reactive power compensation using different types of DG was demonstrated.

Prakash and Sydulu [17] presented a sensitivity analysis to find most appropriate location for different standard bus systems and presented a novelistic approach for loss minimization using PSO for capacitor placement at different sensitive locations.

Singh and Goswami [18] proposed a new methodology which was based on nodal pricing to allocate multi DG units in an existing Indian rural distribution system for loss reduction and voltage profile improvement. The approach was realized for both time variant and invariant loads.

Koutroumpezis and Safigianni [19] presented a suitably modified and optimized approach by simulating an already installed DG unit with a real time network without any amendments in the already existing network structures.

Griffin *et al.* [20] demonstrated the critical importance of appropriate size and location of DG sets for loss reduction. Otherwise, it could cause adverse effect. They presented variation in losses depending on location of DG.

Kannan *et al.* [21] presented a new technology to identify weak nodes for capacitor placement using fuzzy expert system. The results of proposed approach were compared with other techniques to find out the optimal location and encouraging results were obtained.

Moradi and Abedini [22] proposed a novel Genetic Algorithm (GA) and PSO concerning the optimal size and location of DG units in a RDN. The prevalence of this approach was homogeneous solution having negligible value for variances along with the optimization of the system.

Jordehi and Jasni [23] presented an analytical study to solve discrete variable problems. Solving discrete variable problem is much more complex than solving the continuous variables. They showed that PSO stands good for discrete variable problem and provide optimal solution. The strategies to tackle discrete variables problem using PSO was presented.

Naik *et al.* [24] presented the systematic approach to reduce the losses in RDN, that enhanced voltage profile and economic aspect of the utility. The sensitivity analysis has

carried out to identify the optimal candidate locations for DG and capacitor placement. To find the optimal capacity of the DG and capacitor, the heuristic curve fitting technique was used. To authenticate the appropriateness of the proposed method, it has been applied on different test distribution systems. By comparing the different cases they proved that the allocation of DG and capacitor contributes significantly in reduction of power losses.

Kansal *et al.* [25] presented analytical approach for allocation of various DG using PSO to minimize the real and reactive power losses. They considered each bus of RDN to find the optimal location and size of DG. But, that was only limited to the smaller RDN. For larger systems this approach was not suitable as it was complicated and time consuming to analyze each and every node for larger RDN. The meta-heuristic approaches proved better for larger systems.

Michline and Ganesh [26] studied load flow in RDN using forward/backward sweep method. Using this method, power losses for bus branches and voltage for each node were determined.

Muthukumar *et al.* [27] presented method based on meta-heuristic search algorithm named Harmony Search Algorithm (HSA) to compute the size of the shunt capacitor in RDN. A backward-forward sweep based technique was adopted to compute losses and for optimal location VSI was used. This approach was more efficient in finding optimal solution.

Devi and Geetanjali [28] presented an optimization technique based on the principle of PSO algorithm to verdict optimal location and sizing of DG and Distributed STATCOM. They concluded that LSF reduced the processing time for placement of DG and Distribution STATCOM.

Anusha and Kumar [29] proposed a two stage approach for loss reduction in RDN. For the first stage, sensitivity analysis was carried out and in the second stage to size of Capacitor was computed. They used Firefly Algorithm (FA) for minimization of the cost of the capacitors. This approach provided better results than the conventional methods.

Elsheikh *et al.* [30] presented a study on optimal placement of capacitor in RDN. They showed that the improper size of the capacitor affect the losses of the system in a negative way. They tested the following on different test systems in order to minimize the real and reactive power losses. Sensitivity analysis was done using LSF. They presented better results than previously presented methods and proved that PSO did not get trap into local minima.

Shuaib *et al.* [31] proposed GSA for optimal location and sizing of capacitor banks. The optimal size was achieved by movement of agents and direction is decided or varied by the

force of other agents. So, for obtaining the optimal solution for any RDN, search, direction and route were followed.

Das et al. [32] presented simple method using sequential numbering for loss computation in a RDN and to find the optimal sizing. The method assured the convergence for any RDN with the realistic X/R ratios. Moreover, that method was quite efficient in handling different types of load characteristics. But, in case of large systems the complexity of the computation was increased.

Chen et al. [33] proposed a method for sensitivity analysis which consists formation of a sensitivity matrix to compute power flow. With that method an interface between DGs and RDN was introduced. The influence of different type of DG on the voltage stability index of the network was demonstrated.

Amanifar and Golshan [34] studied the problem of optimal allocation of DG for loss reduction and improvement in voltage profile of RDN. The heuristic optimization technique, PSO was used for computing the economic cost of the system. To find out the global optimal solution, power flow algorithm was used. A different approach was followed to calculate the presence of harmonics, which involves the integration of PSO with Harmonic Power Flow (HPF) algorithm. Improvement in voltage profile was found along with the reduction in THD and power losses.

Murthy and Kumar [35] presented a novel comparison among the combined loss sensitivity and voltage sensitivity methods. They presented a modified method to find out the optimal size of DG along with the appropriate locations. That method involved the comparison of the sensitivity methods and comparison of the cost of power obtained from DG at different power factors.

Kennedy and Eberhart [36] developed PSO, which shows the effect of social factors on the behavior of swarm members. They summarized the PSO to solve optimization problems and studied the control dynamics of PSO. They proved that PSO can be successfully implemented in different areas such as control, design and optimization problems.

Elsheikh et al. [37] proposed a methodology for optimal placement of capacitor in RDN for the improvement of voltage profile, power factor and to maximize the power flow through the cable and transformers. They used LSI to find out the sensitive nodes where capacitor can be installed. The results demonstrated the effectiveness of the method.

Sultana and Roy [38] addressed a method to analyze the effective location of shunt capacitor in RDN using teaching learning based optimization method. The two phases were presented namely teaching phase and learning phase. In teaching phase the teaching phase the teaching

methodology was adopted by the learner to enhance the knowledge. In learning part the learner improved their knowledge by interacting with other learner. The method was tested on difficult test systems to analyze the feasibility of the method.

CHAPTER 3

OBJECTIVE FUNCTION AND CONSTRAINTS

3.1 OBJECTIVE FUNCTION

The objective function is to minimize the real and reactive power losses by real power and reactive power compensation. Due to high R/X ratio, mainly resistive losses occur in the distribution system.

Thus the objective function is stated as:

$$\text{Min (f) = Min (Ploss)}$$

Active and reactive power losses are given as

$$\text{Here , Ploss} = \sum_{i=0}^n |I(i)|^2 \times R(i) \quad (3.1)$$

$$Q_{\text{loss}} = \sum_{i=0}^n |I(i)|^2 \times X(i) \quad (3.2)$$

n= Total number of branches in RDN

I(i) = Current through i th branch

R(i) = Resistance of i th branch

X(i) = reactance of i th branch

Subjected to inequality and equality constraints

3.1.1 INEQUALITY CONSTRAINTS

Bus voltage constraints:

$$V_{kmin} \leq |V_k| \leq V_{kmax} \quad k= 1, 2, 3, \dots, N \quad (3.3)$$

Where,

N = Total no. of nodes in RDN

V_k = Voltage at k-bus

V_{kmin} = Minimum voltage limit for k th bus

V_{kmax} = Upper voltage limit for bus-k

Branch current constraints:

$$|I_i| \leq |I_{i,max}| \quad (3.4)$$

Where,

$I_{i,max}$ = Max. current-carrying capacity of i th branch

I_i = Current from i th branch

3.1.2 EQUALITY CONSTRAINTS

The constraints related to flow of power are shown as

$$P_{\text{loss}} + \sum P_{Di} = \sum P_{DGi} \quad (3.5)$$

$$Q_{loss} + \sum Q_{Di} = \sum Q_{DGi} \quad (3.6)$$

Where,

P_{loss} = Total real power loss.

Q_{loss} = Total reactive power loss.

$\sum P_{Di}$ = Total real power demand.

$\sum Q_{Di}$ = Total reactive power reactive.

$\sum P_{DGi}$ = Total real power generated by DG.

$\sum Q_{DGi}$ = Total reactive power compensated by capacitor

CHAPTER 4

METHODOLOGY

4.1 INTRODUCTION

In electrical system the load-flow has become the back bone of any RDN because, it outturns the performance, real and reactive power losses as well the voltages at different nodes operating under stable operations. For stability analysis and selection of conductor during planning of the overall system an efficient load flow is required.

4.2 LOAD FLOW ANALYSIS

An efficient load flow is important for the study of distribution system to inspect the problems related to design, controlling, operation and planning. There are some classical methods like Gauss-Seidel, Newton Raphson used for load flow studies of transmission systems.

In presented report, load flow analysis is done for distribution networks. The distribution systems are weakly meshed and are operated with the consideration of radial nature. RDN are easy to compute and has simplicity in design. The distribution network have high R/X ratio, whereas the transmission networks have loop nature with high X/R ratio [35].

Distribution system characteristics are as follows:

- (i) Very high values of resistances and reactances.
- (ii) Consists large number of nodes, buses and branches.
- (iii) Nature of the system is meshed or radial.
- (iv) Loads are unbalanced and distributed.

If, for any system the amount of power generated and power consumed are known then the other unknown quantities can be easily calculated with the help of load flow analysis. Voltage is a determining quantity as it consists magnitude and phase angle. If voltage is known than current can be calculated. A power flow study uses p.u. notation and single line diagrams for simplification.

4.2.1 BACKWARD-FORWARD SWEEP METHOD

A methodology is contemplated by Ghosh and Das[9] known as backward forward sweep method to solve weak RDN. In this method, loads are assumed to be constant and voltages

are calculated using simple algebraic equations. This method stands better than other conventional methods.

There are two subsequent sweep forward sweep and backward through which values of current are calculated and respective voltages are updated. For backward sweep, the far end bus voltages are computed with the help of simple KVL and KCL. In forward sweep, starting from source towards voltages of subsequent nodes are calculated. The process is repeated until tolerance is less than or equal to the difference of specific voltage and the calculated voltage. After computing voltages and current real and reactive power can be calculated.

To calculate real and reactive power losses occurring in the system

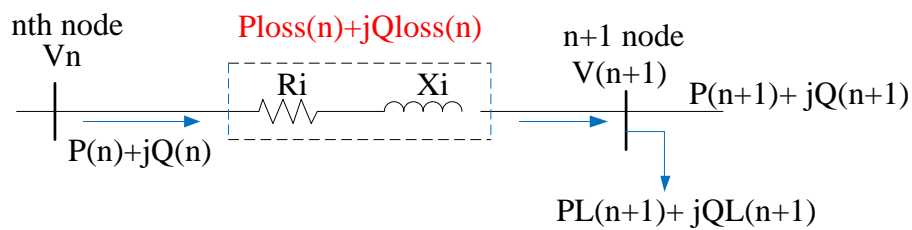


Figure 4.1 single line diagram of power flow from nth node to (n+1) node

$$P_{n+1} = P_n - P_{loss,n} - P_{Ln+1} \quad (4.1)$$

$$Q_{n+1} = Q_n - Q_{loss,n} - Q_{Ln+1} \quad (4.2)$$

Here ,

P_n = Real power flow out of bus.

Q_n =Reactive power flow out of bus.

P_{Ln+1} = Power loss at (n+1) bus.

Q_{Ln+1} = Reactive power loss at (n+1) bus.

The real and reactive power loss between n and n+1 bus

$$P_{loss}(n, n + 1) = R_n \left(\frac{P_n^2 + Q_n^2}{V_n^2} \right)$$

$$Q_{loss}(n, n + 1) = X_n \left(\frac{P_n^2 + Q_n^2}{V_k^2} \right)$$

Here,

$P_{loss}(n, n + 1)$ is real power loss between n and (n+1) buses .

$Q_{loss}(n, n + 1)$ is reactive power loss between n and (n+1) buses.

So, the total power loss will be

$$P_{loss}(n, n + 1) = \sum_{n=1}^t P_{loss}(n, n + 1) \quad (4.3)$$

$$Q_{loss}(n, n + 1) = \sum_{n=1}^t Q_{loss}(n, n + 1) \quad (4.4)$$

4.2.2 ALGORITHM AND FLOW CHART FOR LOAD FLOW ANALYSIS

Assumptions:

- Initial voltage is assumed to be 1p.u.
- Initial power losses both real and reactive are assumed to be zero.
- The three phase network is balanced in nature and can be represented by single line diagram.
- The effect of shunt capacitances and charging current is neglected.

For load flow

1. Assume flat voltage start

$$V_i = 1 + 0j, \text{ for } i = 1 \text{ to } n.$$

$$Pl_j = 0 \ \& \ Ql_j = 0, \text{ for } j=1 \text{ to } b$$

Where,

n= Total number of nodes,

b= Total number of branches.

Pl_j and Ql_j are real and reactive power losses.

2. Set iteration count IT= 1 where IT= 1 to ITMAX
3. Calculate current from each branch

$$I_j = \left\{ \frac{S_{i+1}}{V_{i+1}} \right\}^* \quad \text{for } i = 1 \text{ to } b$$

$$\text{Here, } S_{j+1} = (P_{i+1} + jQ_{i+1})$$

4. Backward sweep : update current starting from the end nodes

$$I_k = \sum_j I_j \quad \text{for } k = 1 \text{ to } b$$

$$\text{where } j \in C_j$$

Here , C_j is the set of next linked node beyond k branch.

5. Forward sweep: from branch currents update the nodal voltages starting from source node

$$V_{k+1} = V_k - (I_k \times Z_k) \quad \text{for } k = 1 \text{ to } n$$

6. Calculate Real and Reactive power losses

$$Pl_j = Il_j \times R_j$$

$$Ql_j = Il_j \times X_j$$

$$\text{Total real power loss} = \sum_{j=1}^b Pl_j$$

$$\text{Total reactive power loss} = \sum_{j=1}^b Ql_j$$

7. Check the deviation in values for real and reactive power losses from present and previous iteration.

If

Deviation is $< \epsilon$ then go to step 8.

else

go to step 3.

8. $IT = IT + 1$ until $IT = IT_{MAX}$
9. Return Pl_j, Ql_j, IT , total real and reactive power losses.

4.2.3 ILLUSTRATION OF LOAD FLOW ANALYSIS:

An example of radial network consisting root node, main line, lateral lines, sub-lateral lines and minor lines are as shown in figure:

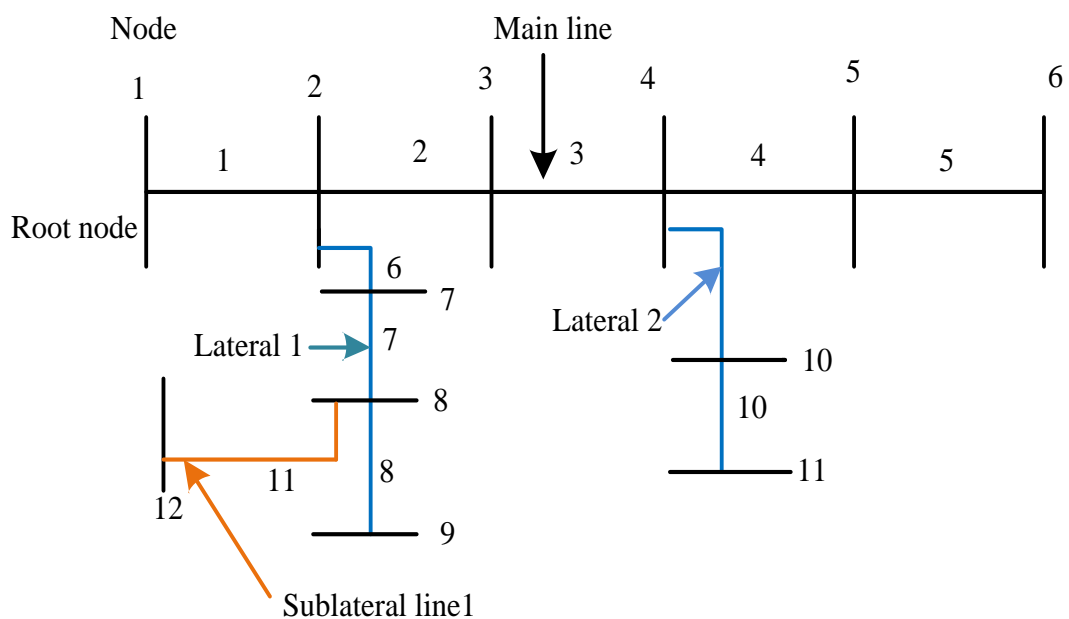


Figure 4.2 : An illustration of radial distribution system.

The details of the system are as follows:

$N = 12$; $br = 11$;

$L = 2$; $s = 1$; $m = 0$;

For lateral and lines:

Table 4.1 : Details of lateral lines

l	N_{ML}	br_{ML}	sNL_L	eNL_L
1	2	6	7	9
2	4	9	10	11

For sub-lateral lines:

Table 4.2 : Details of sub-lateral lines

sl	N_{LS}	br_{LS}	sNS_L	eNS_L
1	2	6	8	12

The steps involved in the load flow analysis using backward forward sweep is as follows:

(1). Injected current at node N is computed as

$$I_{L1}, I_{L2}, I_{L3}, \dots \dots \dots, I_{L12} \quad (4.5)$$

(2). The current through sub-lateral line-1 computed as

$$I_{11} = I_{12} + I_{L12} + \sum_{m=1}^{Nm} I_{br,m} \quad (4.6)$$

Here $I_{12} = 0$ as $(br + 1) = eNS_{SL} = 12$

$$\sum_{m=1}^{Nm} I_{br,m} = 0, \text{ as } N_m = 0$$

$$I_{brs,1} = I_{11} \text{ because } br = br_{L1} = 11$$

(3). The branch current in lateral line (L=1, 2) calculated using

For lateral L=2,

$$I_{10} = I_{11} + I_{L11} + I_{brs,1} \quad (4.7)$$

$$I_{11} = 0 \text{ as } (br + 1) = enS_2 = 11$$

$$i.e (br + 1) = 11 \text{ and } N_{L1} = 8$$

Branch current through 9th branch

$$I_9 = I_{10} \text{ where } I_{br,2} = I_9 \quad (4.8)$$

For lateral L=1

$$I_8 = I_9 + I_{L9} + I_{brs,1} \quad (4.9)$$

$$I_9 = 0 \text{ as } (br + 1) = enL_1 = 9$$

$I_{brs,1} = 0$, because $(br + 1) \neq N_{Ls} \forall sL$

i. e $(br + 1) = 9$ and $N_{L1} = 8$

Branch current through 7th branch is

$$I_7 = I_8 + I_{L8} + I_{brs,1} \quad (4.10)$$

$I_{brs,1}$ is calculated using equation (4.6)

Branch current through 6th branch

$$I_6 = I_7 + I_{L7} + I_{brL,1} \quad (4.11)$$

$I_{brL,1} = 0$, because $(br + 1) \neq N_{Ls} \forall sL$

i. e $(br + 1) = 7$ and $N_{L1} = 8$

$I_{br,1} = I_6$ where, $br = 6$

(4). The current through main-line

For 5th main line:

$$I_5 = I_6 + I_{L6} + I_{brL,1} + I_{brL,2} \quad (4.12)$$

$I_{brL,1} = I_{brL,2} = 0$ as $(br + 1) \neq N_{Ls} \forall sL$

i. e $(br + 1) = 6$ and $N_{m1} = 2$ & $N_{m2} = 4$

$I_6 = 0$ as $(br + 1) = eN_m = 6$

Similarly, for 4th main line:

$$I_4 = I_5 + I_{L5} + I_{brL,1} + I_{brL,2} \quad (4.13)$$

$I_{brL,1} = I_{brL,2} = 0$ as $(br + 1) \neq N_{Ls} \forall sL$

The current through branch 3rd :

$$I_3 = I_4 + I_{L4} + I_{brL,1} + I_{brL,2} \quad (4.14)$$

Where, $I_{brL,1} = I_9$ and $I_{brL,2} = I_6$

$I_{brL,1} = 0$ since $(br + 1) \neq N_{Ls} \forall sL$

The current through branch 2nd :

$$I_2 = I_3 + I_{L3} + I_{brL,1} + I_{brL,2} \quad (4.15)$$

$I_{brL,1} = I_{brL,2} = 0$ as $(br + 1) \neq N_{Ls} \forall sL$

because,

$$(br + 1) = 3 \text{ and } N_{m1} = 2 \ \& \ N_{m2} = 4$$

The current through 1st branch:

$$I_1 = I_2 + I_{L2} + I_{brL,1} + I_{brL,2} \quad (4.16)$$

$I_{brL,1}$ is calculated using equation (4.14)

$$I_{brL,2} = 0 \text{ since } (br + 1) \neq N_{m1}$$

Hence, the branch current are calculated.

(5). After calculating current for each branch voltage is to be computed as follows:

$$V_N = V_{N-1} - I_{br}Z \quad (4.17)$$

V_{N-1} = the voltage at (N-1) node

$$br = V_{N-1}.$$

I_{br} = is the branch current through any branch.

Z = the impedance of the branch.

The calculated voltages are compared with the reference voltage. By comparison the deviation of the voltage is calculated.

If, the deviation is more than the specified tolerance value *i.e* 0.0000001 then iteration count is increased by one and all the steps shown above are repeated for that next iteration

(6). The losses are calculated using respective voltage values

The active power loss is computed as,

$$P_{loss} = \sum_{br=1}^{Nbr} |I_{br}|^2 R_{br} \quad (4.18)$$

The reactive power loss is computed as,

$$Q_{loss} = \sum_{br=1}^{Nbr} |I_{br}|^2 X_{br} \quad (4.19)$$

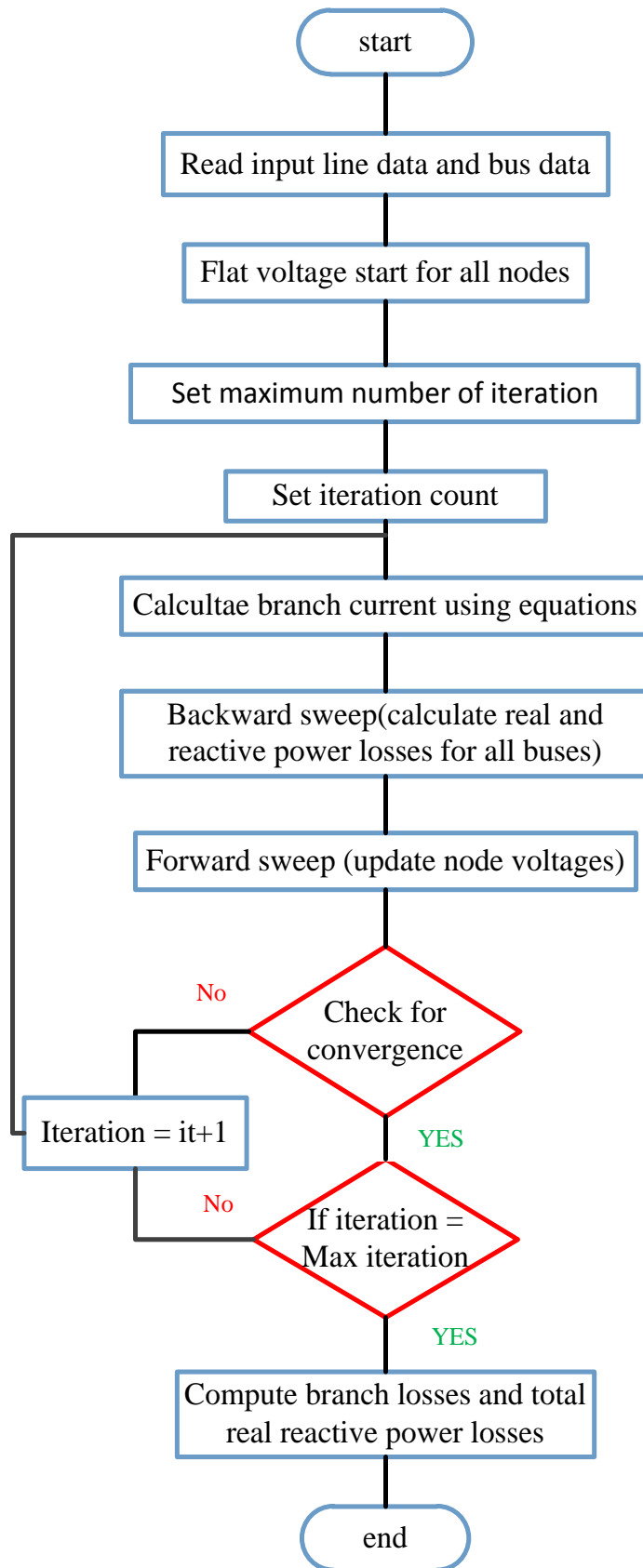


Figure 4.3 : Flow chart for load flow using backward- forward sweep method.

4.3 SITING OF DG AND CAPACITOR

To find out the accurate size of DG and capacitor a thorough evaluation of the system is required. To analyze the most sensitive to place DG and capacitor for loss reduction, different parameters and indexes are used for different networks.

4.3.1 SENSITIVITY ANALYSIS [36]

The objective is to minimize the active and reactive power losses in the system hence, the methodology to find the optimal location or node for the placement of DG and capacitor must be chosen accurately.

Here, VSI and LSF are used to find the location of sensitive node for shunt capacitor and DG placement respectively.

4.3.2 VOLTAGE STABILITY INDEX

The system stability can be found by calculating the VSI for each node. The index value for stable node must be nearly equal to 1.0. The node having stability index with lower value taken as sensitive or weak node and has chances of voltage collapse compared to other nodes having value nearly equal to 1.0 or stable nodes. So, the node with low VSI is best suited for the installation of shunt capacitors.

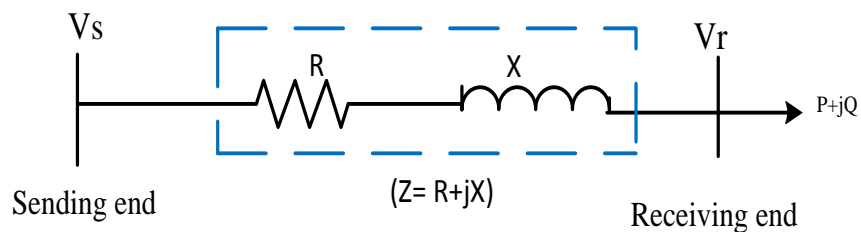


Figure 4.4 : Single line diagram of power flow from sending end to receiving end.

Where,

r: Receiving end node.

s : Sending end node.

Vs : Sending end voltage.

Vr : Receiving node voltage.

X : Effective reactance.

R : Effective resistance.

Using Eq.(4.20) the VSI of receiving node r can be calculated as,

$$VSI(r) = \{|V(s)|^4 - 4.0 |V(s)|^2 \{P R + QX\} - 4.0\{PX - QR\}^2\} \quad (4.20)$$

For steady operation of n number of nodes

$VSI(r) \geq 0$, for $r = 2, 3 \dots n$.

4.3.3 LOSS SENSITIVITY FACTOR

For the identification of the sensitive nodes for the placement of DG units, LSF technique is used. On the basis of LSF the prominent buses are selected for the installation of DGs. Loss sensitivity method needs less computational time and search space is reduced for such kind of problems, thus optimization can be carried out faster. This method linearize the nonlinear equations so that number of iterations required for optimization reduces.

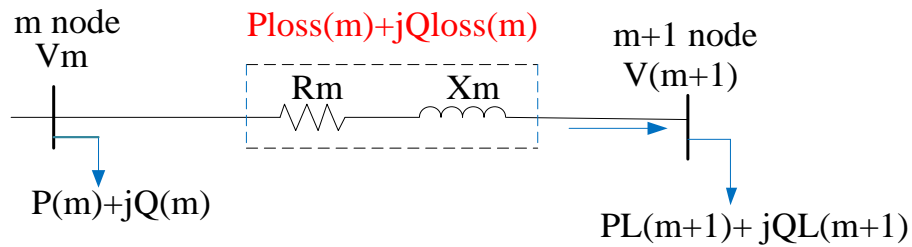


Figure 4.5 Single line diagram of power flow from m node to (m+1) node.

For m th line the real power loss is given as (4.21)

$$P_{loss(m)} = \frac{\{(P^2(m) + Q^2(m))R(m)\}}{\{V(m)^2\}} \quad (4.21)$$

Similarly reactive power for m th line (4.22)

$$Q_{loss(m)} = \frac{\{(P^2(m) + Q^2(m))X[m]\}}{\{V(m)^2\}} \quad (4.22)$$

Now differentiating the above equations with respect to real and reactive powers

$$\frac{\partial P_{loss(m, m+1)}}{\partial P_{m, m+1}} = \frac{2P_{m+1, eff} \times R_m}{|V_{m+1}|^2} \quad (4.23)$$

$$\frac{\partial P_{loss(m, m+1)}}{\partial Q_{m, m+1}} = \frac{2Q_{m+1, eff} \times R_m}{|V_{m+1}|^2} \quad (4.24)$$

Where,

$P_{m+1,eff}$ = The effective real power beyond the (m+1) node

$Q_{m+1,eff}$ = The effective reactive power beyond the (m+1) node

Using load flow solutions LSF are calculated here and then the values are arranged in descending orders for all the buses. The ordering of the LSF will conclude the ranking order in which allocation is considered for the buses. This ranking is purely evaluated using LSF. Hence, the proposed technique proved to be an effective and useful method for allocation of DG.

Here, the base case voltage profile given as (norm $V[i] = V[i]/0.95$), which governs the normalize voltage profile. The buses having the normalize values less than 1.01 are considered as candidate buses needs DG installation, and if normalized voltage is greater than 1.01 no DG allocation is required for those buses. Hence norm $V[i]$ decides the candidate buses for DG allocation whereas, the LSF decides the ranking in which buses are to be considered for DG installation.

4.4 A BRIEF INTRODUCTION TO PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is nature inspired optimization technique based on the social behavior of the birds flocking or fish schooling. In search of food and for survival birds travel from one place to other the movement depends upon their own knowledge as well the knowledge of the neighbors. It was developed by Kenney and Eberhart in year 1995[37]. It is a population based technique whose solution can be represented in n-dimensional space. It uses quasi-stochastic manner for search. A population with some random number of particles is initiated. For every iteration the particles perceive the best-suited value and observe the fitness of the particles. The particles observe their own fitness as well the fitness value of the neighbourhood particles whose current position is better suited for the defined problem.

In this technique, each solution is like a bird, flying in free space. It is called “particle”. The particles in PSO learn from their past experience and uses this knowledge to solve the optimization problem. The particles have fitness values which are calculated by using the fitness function and velocities in search space.

Some random particles are generated which searches for the optimal solution by changing their velocities and positions. For each iteration, the particles update their best value.

There are two best values personal best and global best. Personal best is the individual best solution reached/attained so far by the particle and it is called “Pbest”.

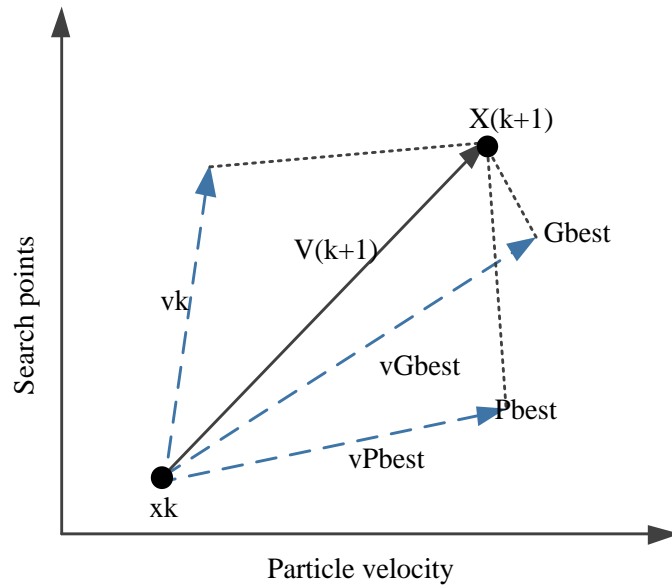


figure 4.6 : Graphical presentation of particle swarm optimization.

The main factors of PSO are:

1. **Particles:** It is an n-dimension vector, which shows the size of capacitor or solution. For mth particle at any time t. It is denoted as

$$X_{m,1}(t) = \{X_{m,1}(t), X_{m,2}(t), \dots \dots X_{m,n}(t)\}$$

2. **Population :** It is a set of m number of particles and represented as

$$\{X_1(t), X_2(t), X_3(t) \dots \dots X_m(t)\}$$

3. **Swarm :** it is a group of randomly generated particles or disorganized population which tends to move in particular direction.

4. **Particle velocity $V(t)$:**

$$V_m(t) = \{V_{m,1}(t), V_{m,2}(t) \dots \dots V_{m,n}(t)\}$$

Where, m is dimension of the vector

n is number of particles.

5. **Inertia weight:** It is the controlling vector that used to control the effect of previous velocity on present velocity.
6. **Personal best :** As the particle travels in search space in order to discover the best solution, it remembers all the values attained so far by that particle. If the fitness value of the present value is better than the values attained so far than the previous individual best is replaced by the current individual best. So, for each particle Pbest is updated during search.

7. **Global best** : The another best value is global best, it is the overall best value obtained so far by any particle among the whole population this is called “Gbest”. After the computation of the Pbest and Gbest particles update their velocity and position as per following equation [38].

Velocity update:

$$V_j^{k+1} = wV_j^k + c_1rand_1(P_{bestj}^k - X_j^k) + c_2rand_2(G_{bestj}^k - X_j^k) \quad (4.25)$$

Position update:

$$X_j^{k+1} = X_j^k + V_j^{k+1} \quad (4.26)$$

Where,

V_j^k = particle velocity.

X_j^k = current position of the particle.

$rand_1$ and $rand_2$ = random values between 0 to 1.

c_1 and $c_2 = 2$ = learning factors[38].

W = inertia weight.

Here $w_{min} < w < w_{max}$

$$w_{max} = 0.9$$

$$w_{min} = 0.4$$

Equation for inertia weight is

$$w_j = w_{max} - \frac{w_{max} - w_{min}}{j_{max}} \times j$$

Pbest() and Gbest() are defined as stated before. rand () is a random number between (0,1). c_1, c_2 are learning factors. usually $c_1 = c_2 = 2$.

Implementation :-

For the implementation of PSO various parameters need to be defined. In this dissertation following values have been taken:

- c_1 and $c_2 = 2$
- $0.9 < w < 0.4$
- $0 < rand1 < 1$
- $0 < rand 2 < 1$
- Max iteration = 200

Step 1: Run the load flow and compute the real and reactive power losses of the bus system.

Step 2: Using the sensitivity factors identify the sensitive nodes where the DG and capacitor units needed to place.

Step 3: Generate a random population having m number of particles

Step 4 : Initialize the particles with certain velocity that lies between the minimum and maximum limits.

Step 5: Start the iteration count $It=1$

Step 6 : Compute the active and reactive power losses by placing the particle 'i' at selected candidate bus.

Step 7 : Calculate the value of the fitness function for the particle 'i' and check for the P_{best} . If the current value of P_{best} is better than assign the value to P_{best} .

Step 8 : Compute the overall best i.e G_{best} . If the current value is better than previous G_{best} then assign the value to G_{best} .

Step 9: Make velocity updates using equation (4.25).

Step 10 : Check for velocity whether it lies within specified limits or not. If not then set the violated limits.

Step 11: Update particle position using equation (4.26).

Step 12: With the obtained particle value run the load flow and find the losses.

Step 13: Again update P_{best} , G_{best} , velocity and position using above equations. Compute the losses for updated values.

Step 14: Repeat from step 6 to 12.

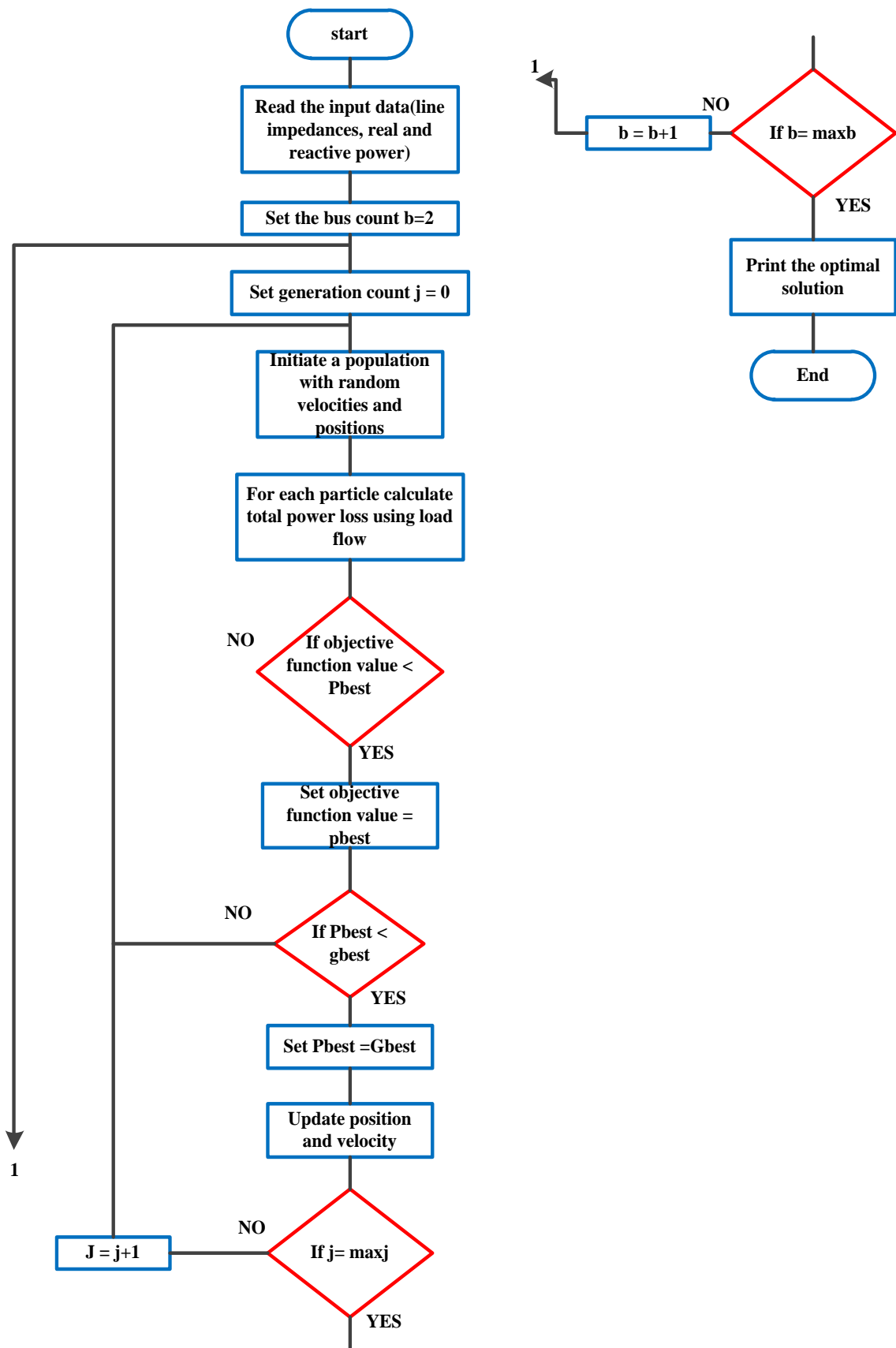


Figure 4.7: Flow chart for particle swarm optimization technique.

CHAPTER-5

RESULTS AND DISCUSSION

5.1 OVERVIEW

The performance analysis of the integrated system using DG and capacitor is presented in this chapter. The load flow analysis and the PSO is implemented to find optimal solution and tested on 15-node and 118-node radial distribution network. The following network is analyzed using three cases: using only DG, only capacitor and integrated system. The base values of voltage and MVA are taken as 11 kV and 10 MVA for 15-node system and 11 kV and 100 MVA for 118-node system.

5.2 15-NODE RDN

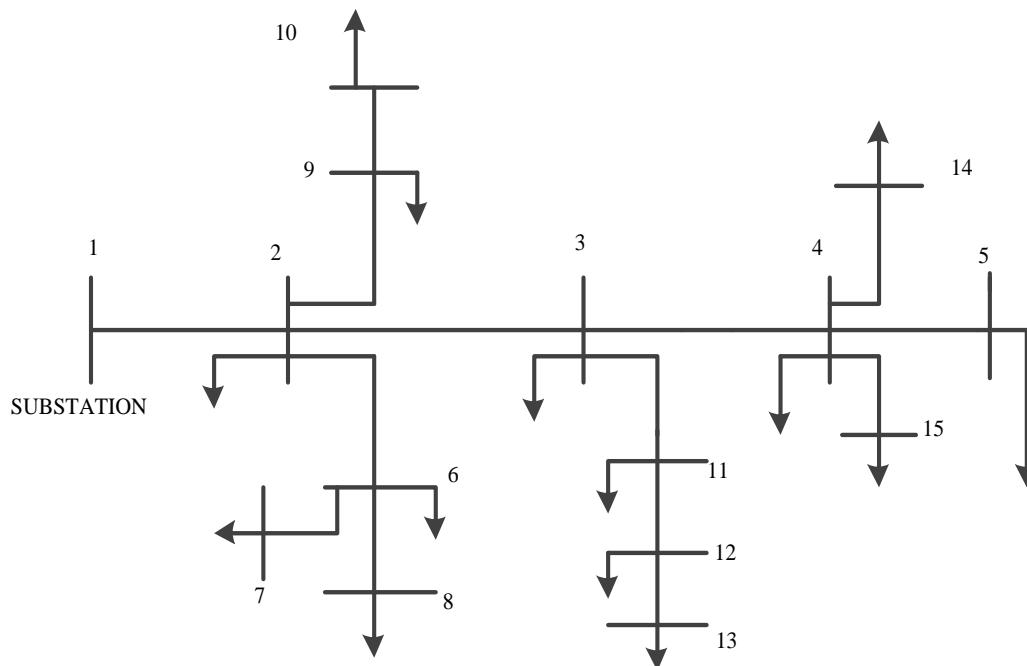


Figure 5.1: Single line diagram of 15 nodes RDN.

The 15 bus system is as shown in figure (5.1). The details of the network is as follows

Number of nodes: 15

Number of branches: 14

Base voltage: 11 kV

Base MVA: 10 MVA

Slack bus: bus -1

The real and reactive power losses are computed from load flow analysis by MATLAB platform using backward- forward sweep method.

The real and reactive power losses are:

Real power loss: 61.79 kW

Reactive power loss: 57.29 kVAr

Table 5.1. Performance analysis

Total real power losses (kW)	Total reactive power losses (kVAr)	Minimum Voltage (p.u.)
61.79	57.29	0.9445

Table 5.2 presents the magnitude of voltages in p.u before DG or capacitor placement at any nodes for 15-node RDN.

Table 5.2: Voltage magnitude for 15-node system.

Node No.	Voltage (p.u.)
1	1
2	0.9713
3	0.9567
4	0.9509
5	0.9499
6	0.9582
7	0.9560
8	0.9570
9	0.9680
10	0.9669
11	0.9500
12	0.9458
13	0.9445
14	0.9586
15	0.9484

The test system data is provided in Table A.1. The Table 5.3 shows the VSI for 15 node RDN and Table 5.4 shows the LSF obtained for the 15 node RDN.

Table 5.3: VSI at each node for 15-node RDN

Node No.	VSI
2	1

3	0.8867
4	0.8339
5	0.8062
6	0.8082
7	0.8349
8	0.8259
9	0.8310
10	0.8715
10	0.8697
12	0.7960
13	0.7928
14	0.7906
15	0.8053

Table 5.4 shows the LSF for each node of 15-node RDN without using the DG and capacitor.

Table 5.4 : Loss sensitivity factor for 15 node RDN.

Node no.	LSF
2	0.0009
3	0.0010
4	0.0036
5	0.0019
6	0.0026
7	0.0030
8	0.0015
9	0.0020
10	0.0021
11	0.0058
12	0.0024
13	0.0053
14	0.0028
15	0.0000

As shown in the Table 5.2 the VSI is found to be least at node number 14 and LSF is maximum at node number 11.

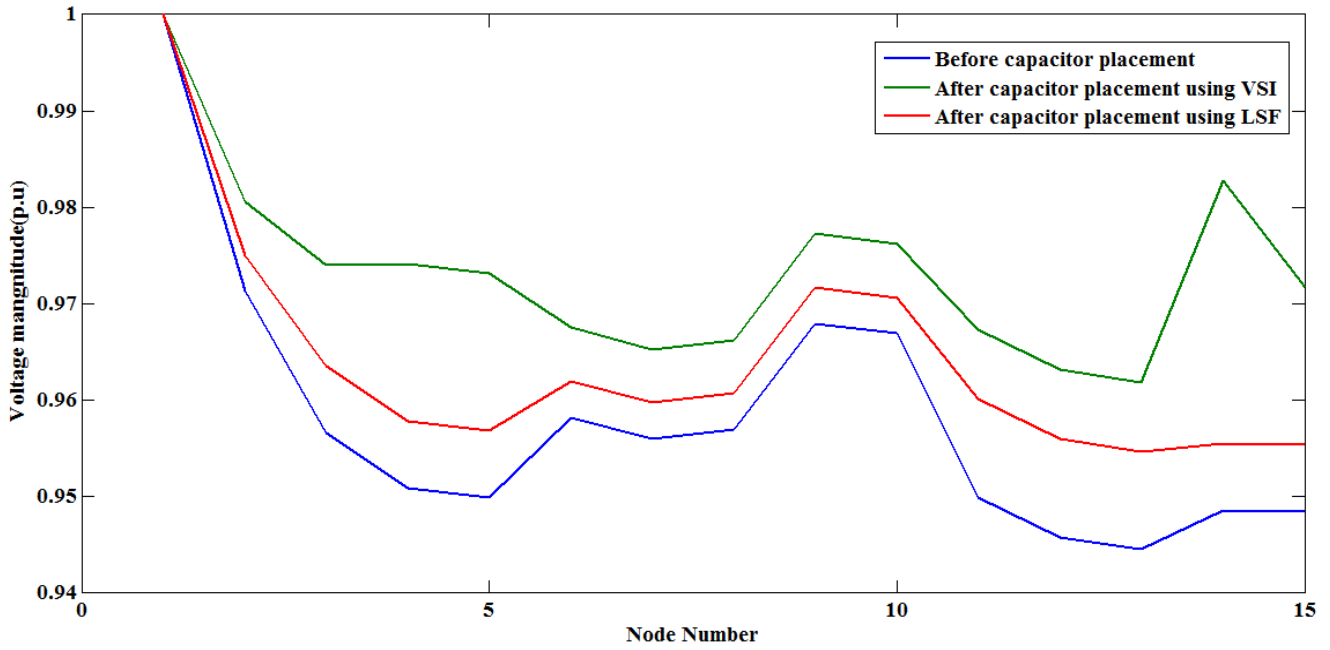


Figure 5.2 : Voltage profile comparison for capacitor using VSI and LSF

As shown in figure 5.2 three cases are taken first case is the voltage profile of the 15 node system without any DG or capacitor placement, second is the voltage profile improvement using VSI and third is voltage profile improvement using LSF. As shown in above figure VSI provides better voltage profile as compared to LSF for 15-node system.

Thus, for optimal results VSI is taken into consideration for sensitivity analysis for 15-node RDN.

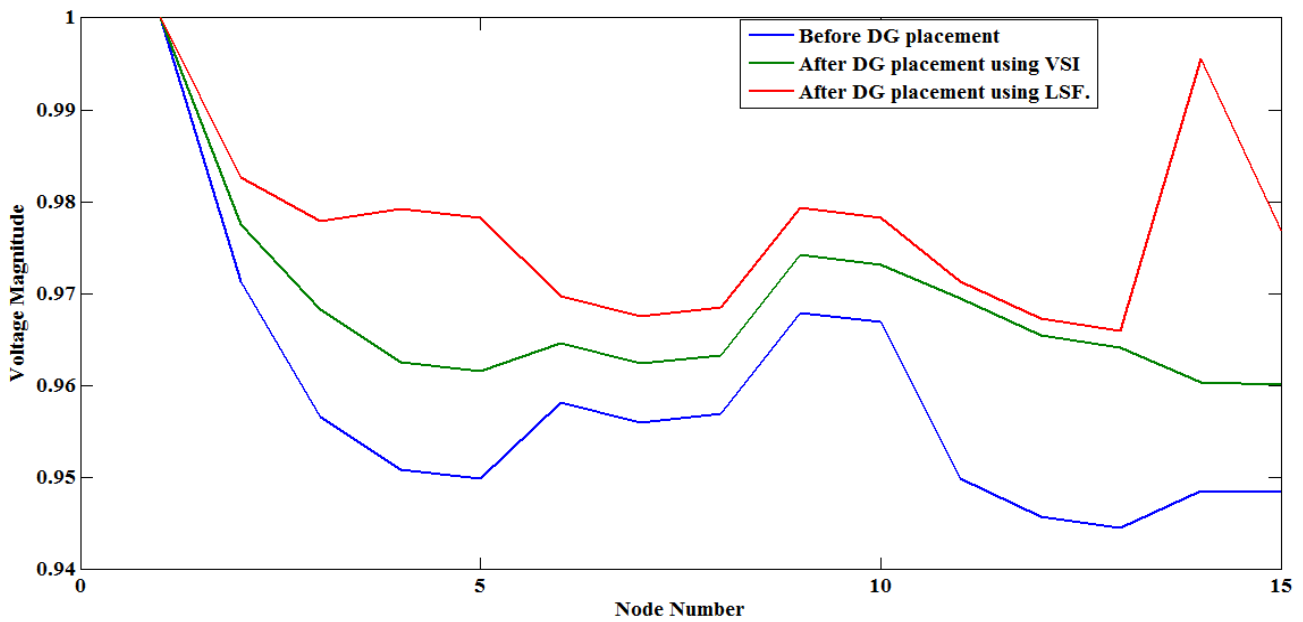


Figure 5.3 : Voltage profile comparison for DG using VSI and LSF

Case 1: CAPACITOR ALONE

As shown in figure 5.2 the voltage profile obtained using VSI prove better than the LSF for 15-node RDN. Thus the optimal location to place capacitor in 15 node system is considered using VSI. The performance analysis for 15- node system is as follows

Table 5.5 : Performance analysis with capacitor for 15-bus RDN

	Without Capacitor	With capacitor
Optimal node	-	14
Active power loss (kW)	61.79	49.945
Reactive power loss(kVAr)	57.29	42.4587
Minimum voltage node	0.9445 (13)	0.9680(15)
Minimum VSI	0.7906 (14)	0.8633(8)
Size of capacitor (kVAr)	-	455.26
% Real power loss reduction	-	19.61%
% Reactive power loss reduction	-	25.89%

Case 2 : DG ALONE

As shown in figure [5.3] the results obtained for voltage profile improvement from LSF are better than the results obtained from VSI. So, the LSF is taken into consideration for the optimal placement of DG in 15-bus RDN. The performance analysis for DG placement in 15-bus system is as shown below:

Table 5.6: Performance analysis with DG for 15-node RDN.

	Without DG	With DG
Optimal node	-	11
Active power loss (kW)	61.79	42.168
Reactive power loss (kVAr)	57.29	38.04
Minimum voltage in p.u (node)	0.9445 (13)	0.9619(15)
Maximum LSF (node)	0.0058(11)	0.0042(11)
Size of DG(kW)	-	419.82
% real power loss reduction	-	31.75%
% reactive power loss reduction	-	19.25%

reduction

Case 3: CAPACITOR AND DG BOTH

For loss minimization in RDN integration of DG and Capacitor is done which provides even better voltage profile and reduce losses up to a greater extent as compared to the DG or Capacitor installed alone. The analysis of the integrated system is presented below which shows the integrated system performs better than above two cases.

Table 5.7: Performance analysis with DG and Capacitor for 15-node RDN.

	Without DG	With DG and Capacitor
Optimal node	-	11(LSF), 14(VSI)
Active power loss (kW)	61.79	27.36
Reactive power loss (kVAr)	57.29	21.27
Minimum voltage in p.u (node)	0.9445 (13)	0.9722 (7)
% Real power loss reduction	-	55.72%
% Reactive power loss reduction	-	62.87%

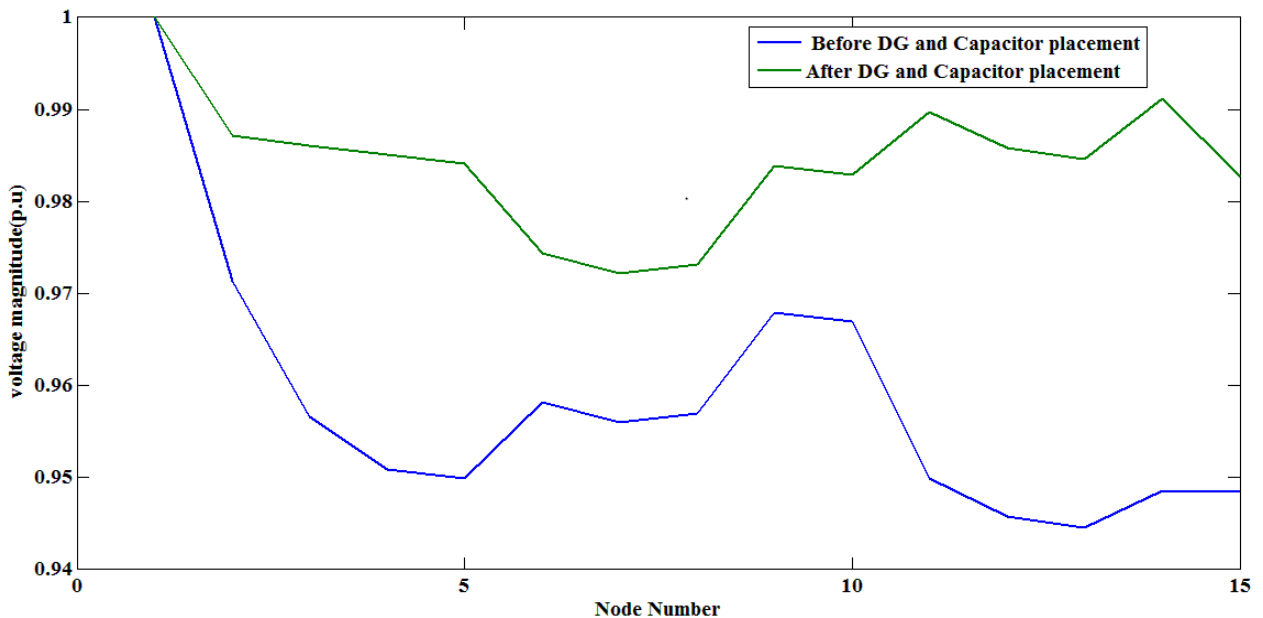


Figure 5.4: Voltage profile improvement after placing DG and Capacitor.

5.3 118-NODES RDN:

The 118 node system is as shown in figure (5.5). The details of the network is as follows

Number of nodes: 118

Number of branches: 117

Base voltage: 11 kV

Base MVA: 100 MVA

Slack bus: bus -1

The real and reactive power losses are:

Real power loss: 1298.10kW

Reactive power loss: 978.72 kVAr

Table 5.8 Performance analysis of 118-node RDN.

Total real power losses (kW)	Total reactive power losses (kVAr)	Minimum Voltage (p.u.)
1298.10 kW	978.72 kVAr	0.8688

Figure 5.6 shows the voltage profile for base case:

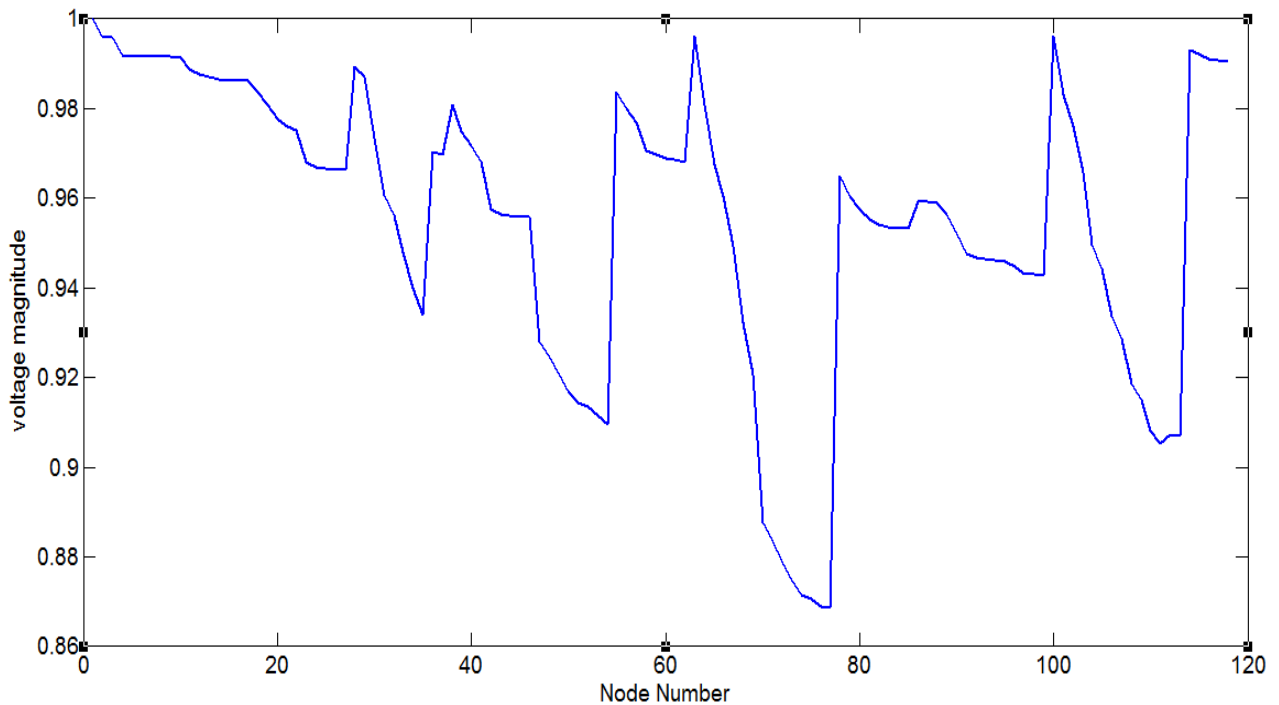


Figure5.5: Voltage profile before capacitor and DG placement

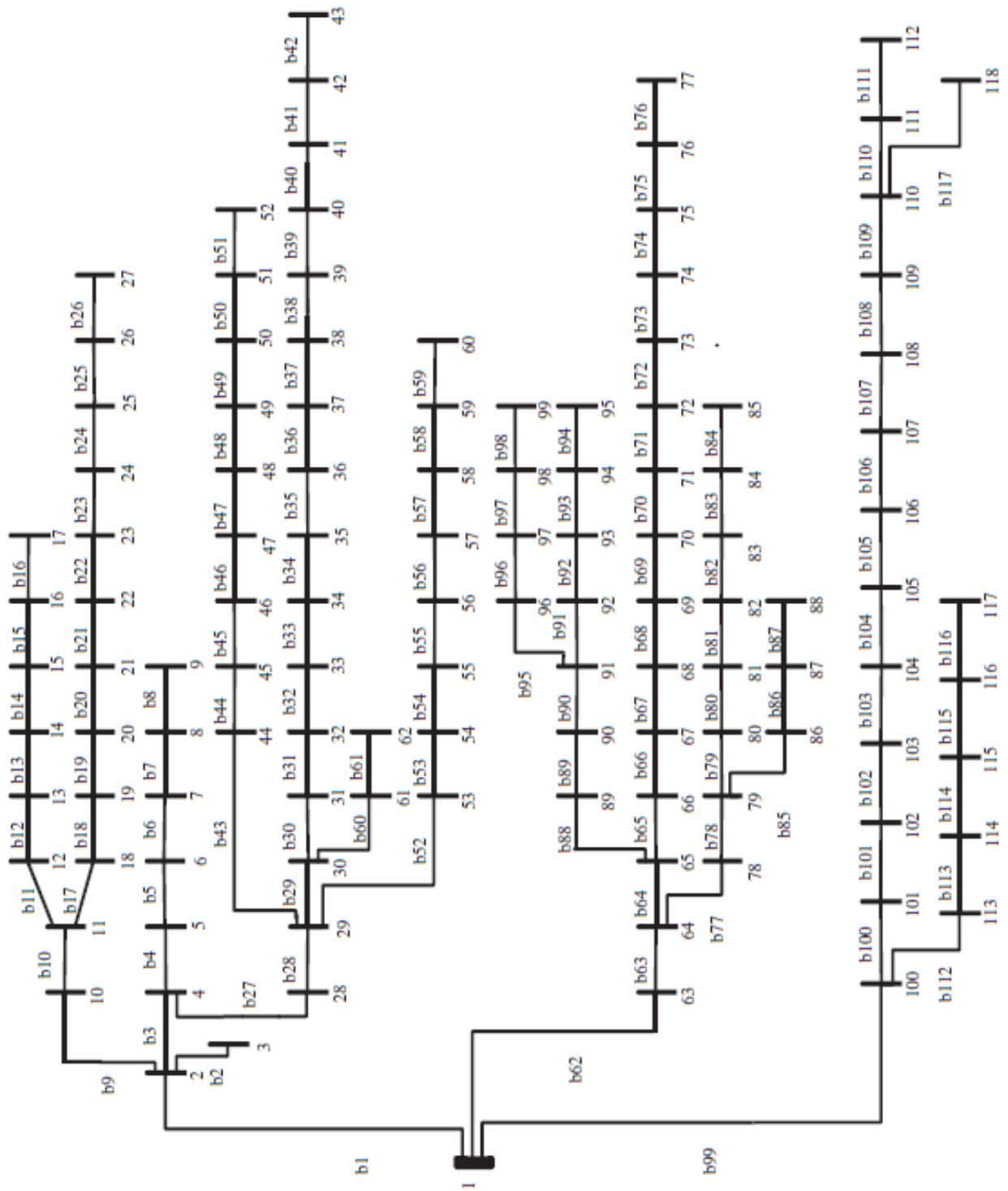


Figure : 5.6 Single line diagram of 118-bus RDN.

Table 5.9 presents the magnitude of voltages in p.u before DG or capacitor placement at any nodes for 118-node RDN.

Table 5.9 : Voltage magnitude for 118-node RDN.

Node	Voltage(p.u)
1	1
2	0.9959
3	0.9959
4	0.9918
5	0.9917
6	0.9915
7	0.9915
8	0.9915
9	0.9914
10	0.9914
11	0.9887
12	0.9876
13	0.9870
14	0.9865
15	0.9863
16	0.9861
17	0.9861
18	0.9837
19	0.9807
20	0.9776
21	0.9760
22	0.9752
23	0.9680
24	0.9669
25	0.9665
26	0.9664
27	0.9663
28	0.9893
29	0.9872

30	0.9733
31	0.9606
32	0.9562
33	0.9477
34	0.9397
35	0.9340
36	0.9704
37	0.9696
38	0.9807
39	0.9749
40	0.9716
41	0.9681
42	0.9576
43	0.9565
44	0.9561
45	0.9558
46	0.9557
47	0.9280
48	0.9247
49	0.9207
50	0.9168
51	0.9145
52	0.9136
53	0.9114
54	0.9094
55	0.9835
56	0.9799
57	0.9768
58	0.9707
59	0.9697
60	0.9688
61	0.9684
62	0.9679

63	0.9962
64	0.9807
65	0.9675
66	0.9605
67	0.9492
68	0.9322
69	0.9205
70	0.8876
71	0.8839
72	0.8791
73	0.8748
74	0.8714
75	0.8706
76	0.8688
77	0.8687
78	0.9650
79	0.9603
80	0.9574
81	0.9552
82	0.9541
83	0.9535
84	0.9533
85	0.9532
86	0.9593
87	0.9591
88	0.9590
89	0.9565
90	0.9520
91	0.9477
92	0.9468
93	0.9463
94	0.9461
95	0.9459

96	0.9448
97	0.9431
98	0.9430
99	0.9429
100	0.9962
101	0.9831
102	0.9758
103	0.9657
104	0.9497
105	0.9441
106	0.9336
107	0.9286
108	0.9186
109	0.9148
110	0.9080
111	0.9052
112	0.9072
113	0.9070
114	0.9929
115	0.9922
116	0.9911
117	0.9907
118	0.9878

Case 1: Capacitor alone

The voltage profile obtained using voltage sensitivity index stands better than the loss sensitivity index for 118-node RDN. Thus the optimal location to place capacitor in 118 node system is considered using VSI. The performance analysis for 118- node system is as follows

Table 5.10 : Performance analysis with capacitor for 118-node RDN

	Without Capacitor	With capacitor
Optimal node	-	77
Active power loss (kW)	1298.10	1161.5
Reactive power loss(kVAr)	978.72	635.54
Minimum voltage node	0.8688 (77)	0.8688(77)
Minimum VSI	0.5697 (77)	0.6625(84)
Size of capacitor	-	1207.3kVAr
% Real power loss reduction	-	10.52%
% Reactive power loss reduction	-	34.31%

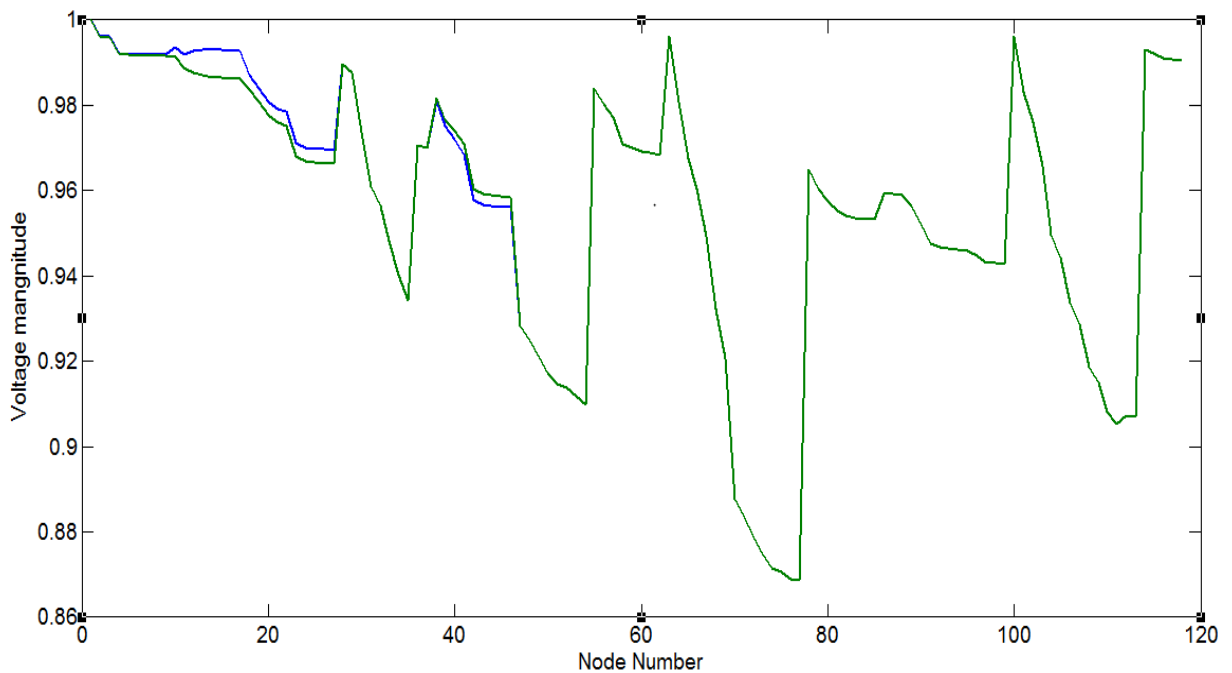


Figure 5.7: Voltage profile improvement after capacitor placement

Case 2 : DG alone

The results obtained for voltage profile improvement from LSF are better than the results obtained from VSI. So, the LSF is taken into consideration for the optimal placement of DG in 118-node RDN. The performance analysis for DG placement in 118-node system is as shown below:

Table 5.11: Performance analysis with DG for 118-node RDN.

	Without DG	With DG
Optimal node	-	41
Active power loss (kW)	1298.10	948.23
Reactive power loss (kVAr)	978.72	684.51
Minimum voltage in p.u (node)	.8688(77)	0.9051(74)
Maximum LSF (node)	0.0054(41)	0.00526(32)
Size of DG(MW)	-	0.86304
% Real power loss reduction	-	26.95%
% reactive power loss reduction	-	29.99%

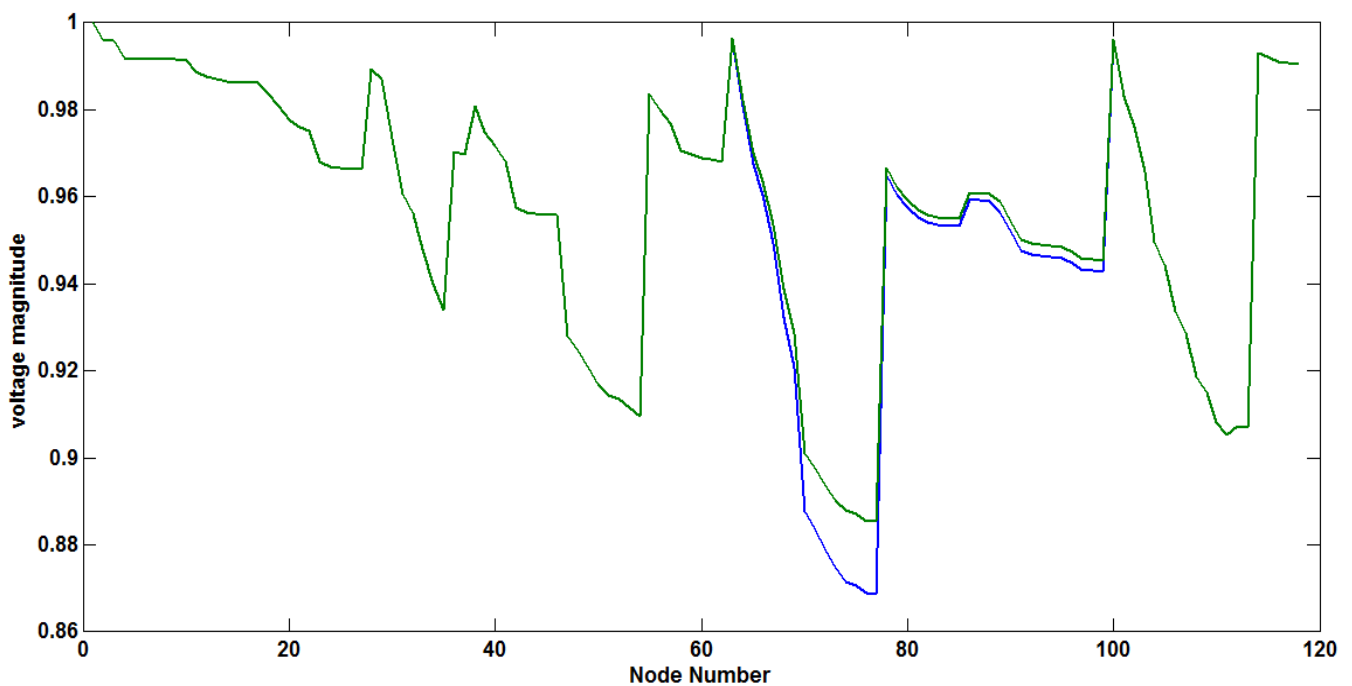


Figure 5.8 : Improvement in voltage profile before and after DG placement

Case 3: Capacitor and DG both

For loss minimization in RDN integration of DG and Capacitor is done which provides even better voltage profile and reduce losses up to a greater extent as compared to the DG or Capacitor installed alone. The analysis of the integrated system is presented below which shows the integrated system performs better than above two cases.

Table 5.12: Performance analysis with DG and Capacitor for 118-node RDN.

	Without DG	With DG and Capacitor
Optimal node	-	(LSF), (VSI)
Active power loss (kW)	1298.10	806.43
Reactive power loss (kVAr)	978.72	621.51
Minimum voltage in p.u (node)	0.8688(77)	0.8909(74)
% Real power loss reduction	-	37.87%
% reactive power loss reduction	-	36.49%

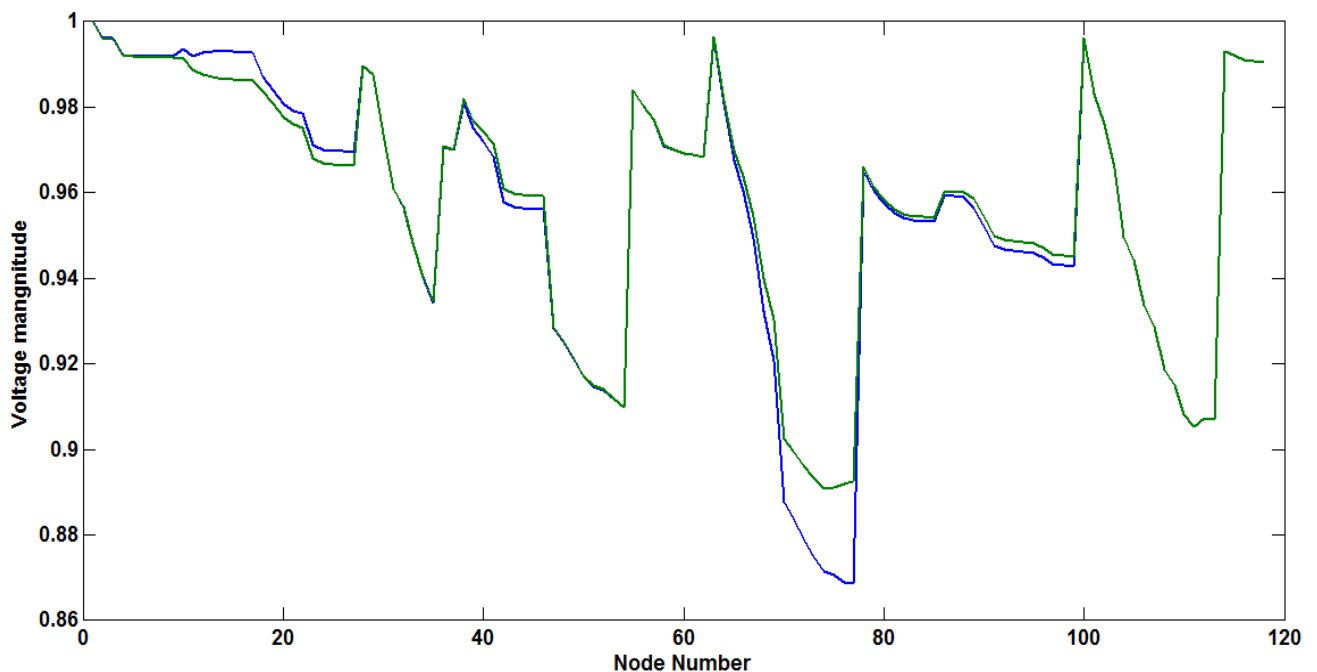


Figure 5.9: Improvement in voltage profile after DG and Capacitor placement.

CHAPTER 6

CONCLUSION

6.1 CONCLUSION

The distribution system contributes nearly 70% of the total losses occur in the power system. To minimize the losses some compensation devices such as capacitors and DG sets are installed in primary feeder distribution network. The correct location and sizing of the capacitors and DG are the main point of concern. In this dissertation load flow is done using backward/forward sweep method and optimum location found by using loss sensitivity factor and voltage stability index.

Optimal sizing is done using swarm based algorithm PSO. The obtained results are presented and it shows that the integrated system proves better than the single DG and capacitor for loss minimization in RDN. The performance of the presented methodology is tested on 15 and 118 node RDNs. The coding scheme was developed using MATLAB 2014.

6.2 FUTURE SCOPE

Along with the objective of minimization of power loss in RDNs many other objectives can be added like optimum conductor sizing, minimum cost, multi DG and capacitor placement etc.

The hybrid system can be extended from balanced system to unbalanced system.

Instead of placing only real power injecting DG resources, a modeling concept of DG can be established to incorporate the loss minimization.

LIST OF PUBLICATIONS

1. Bhavana Jangid and Smarajit Ghosh, “Load Flow Analysis Using Backward-Forward Sweep Method”, presented in International Conference on Advancements in Engineering and Technology held at Bhai Gurdas Institute of Engineering and Technology, Sangrur (Punjab), India. March 2017.

REFERENCES

- [1] S Kalambe, G Agnihorti, "Loss Minimization techniques used in distribution network", *Bibliographical Survey, Renewal Sustain Energy Rev.* Vol. 29, No. 4, pp.184-200, 2014.
- [2] S.Iwamoto, Y.A.Tamura, "Load flow calculation method for ill-conditioned power systems," *IEEE Transactions Power Apparatus and Systems*, Vol. 100, No. 4, pp.1706-1713,1981.
- [3] D. Rajicic, Y. Tamura, "A modification to fast decoupled load flow for networks with high R/X ratios," *IEEE Transactions on Power Systems*; Vol. 3, No.2, pp.743- 746, 1988.
- [4] S. Ghosh and D. Das, "Method for load-flow solution of radial distribution networks", *IEE Proceedings-Generation, Transmission and Distribution*, Vol. 146, No. 6, pp. 641-648, Nov. 1999.
- [5] P. Aravindhababu, S. Ganapathy and K.R. Nayar, "A novel technique for the analysis of radial distribution systems," *International Journal of Electric Power and Energy Systems*, Vol. 23, pp. 167–171, 2001.
- [6] R. Ranjan and, D. Das, "Simple and Efficient Algorithm to Solve Radial Distribution Networks," *International Journal of Electric Power Components and Systems*, Vol.31, No. 1, pp.95 -107, 2003.
- [7] S. Ghosh and K. S. Sherpa, "An efficient method for load flow solution in radial distribution network", *International Journal of Electrical*, Vol 2, No. 9, 2008.
- [8] S. Ghosh, "A New Technique for Load-Flow Analysis of Radial Distribution Networks," *International Journal of Engineering and Technology*, Vol. 1, No.1, April, 2009.
- [9] J.J Grainger, S.H Lee, "Optimum size and location of shunt capacitor for reduction of losses on distribution feeder", *IEEE Transaction on Power Apparatus and systems*, Vol. 100, No. 3, pp. 1105-1118, 1981.
- [10] K. Nara, A. Shiose, M. Kitagawoa and T. Ishihara, "Implementation of genetic algorithm for distribution systems loss minimum reconfiguraion ", *IEEE Transaction on Power system*, Vol.7 ,No. 3, pp. 1044-1051, Aug.1992.

- [11] N. S. Row , Y-H Wan “Optimum location of resources in distributed planning”, *IEEE Transactions on Power Systems*, Vol No. 4, pp. 2104-2120, 1994.
- [12] R. C. Eberhart and Y. Shi, “Comparison between Genetic Algorithms and Particle Swarm Optimization,” *Ep '98*, pp. 611–616, 1998.
- [13] Y. Shi, R.C. Eberhart, “A modified particle swarm optimizer”, *IEEE international conference on Evolutionary Computation, Anchorage , AK*, pp- 69-73, May 1998.
- [14] K-H Kim, Y-J Lee, S-B Rhee, S-K Lee, S-K You, “Dispersed Generator placement using fuzzy –GA in distribution systems”, *Proceedings of IEEE Power Engineering Society , Chicago, IL*, Vol 3, pp. 1148-53, July 2002.
- [15] N. Acharya, P.Mahat,N. Mithulananthan,“An analytical approach for DG allocation in primary distribution network”, *ELSEVIER*, Vol. 28, No 10, pp 669–678, 2006.
- [16] W. Krueasuk and W. Ongsakul, “Optimal placement of distributed generation using Particle Swarm Optimization,” *Australas.Univ. Power Eng. Conf. - AUPEC*, pp. 6, 2006.
- [17] K. Prakash and M. Sydulu, “Particle swarm optimization based capacitor placement on radial distribution systems”, *Proc. IEEE Power Engineering Society General Meeting*, Vol 31 No. 5, 2007.
- [18] R. K. Singh and S. K. Goswami, “Optimum allocation of distributed generations based on nodal pricing for profit, loss reduction, and voltage improvement including voltage rise issue,” *International Journal of Electric Power and Energy Systems*, Vol. 32, No 6, pp. 637-644, Jul. 2010.
- [19] G. N. Koutroumpezis and A. S. Safigianni, “Optimum allocation of the maximum possible distributed generation penetration in a distribution network,” *Electric Power System Research*, Vol. 80, No. 12, pp. 1421-1427, Dec. 2010.
- [20] T. Griffin , K Tomosovic, D Secrest, A. Law “Placement of dispersed generations systems for reduced losses ”, *Proceedings of the 33rd Hawaii international conference on sciences*, Hawii, 2011.
- [21] S.M.Kannan, P.Renuga , S.kalyani, E.Muthukumaran , "Optimal capacitor placement and sizing using Fuzzy-DE and Fuzzy-MAPSO methods.", *Applied Soft Computing*, Vol. 11 No.8,pp. 4997-5005, 2011.

- [22] M. H. Moradi and M. Abedini, "A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems," *International Journal of Electric Power Energy Systems*, Vol. 34, No. 1, pp. 66-74, Jan. 2012.
- [23] A. RezaeeJordehi and J. Jasni, "Particle swarm optimisation for discrete optimisation problems: a review," *Artif. Intell. Rev.*, Vol. 43, No. 2, pp. 243–258, 2012.
- [24] G. Naik, D. K. Khatod, M. P. Sharma, "Sizing and Siting of Distributed Generation in Distribution Networks for Real Power Loss Minimization using Analytical Approach," *International Conference on Power, Energy and Control*, pp. 740-45, 2013.
- [25] S. Kansal, V. Kumar, and B. Tyagi, "Optimal placement of different type of DG sources in distribution networks," *International Journal of Electric Power Energy Systems*, Vol. 53, No. 1, pp. 752–760, 2013.
- [26] J.A. MichlineRupa, S. Ganesh, "Power flow analysis for radial distribution system using backward/forward sweep method", *International Journal of electrical, Energetic, Electronic and communication engineering*, Vol 8, No.10, pp. 1537–1541, 2014.
- [27] Muthukumar, K. Dr. Jayalalitha, S. Dr. Ramasamy, M. and HaricharanCherukuri, S. "Optimal shunt capacitor allocation and sizing using harmony search algorithm for power loss minimization in radial distribution network" *IJDR*, Vol. 4, No. 3 , pp. 537-545, March, 2014.
- [28] S. Devi, M. Geethanjali, "optimal location and sizing determination of distributed generation and DSTATCOM using Particle Swarm Optimization algorithm," *ELSEVIER*, Vol 41. No 6, pp. 2772-2781, May 2014.
- [29] A. S. Anusha and M. R. Kumar, "The Sizing & Placement of Capacitor in a Radial Distribution System Using Loss Sensitivity Factor and Simulink," Vol. 9, No. 6, pp. 75–82, 2014.
- [30] A. Elsheikh, Y. Helmy, Y. Abouelseoud, and A. Elsherif, "Optimal capacitor placement and sizing in radial electric power systems," *Alexandria Eng. J.*, Vol. 53, No. 4, pp. 809–816, 2014.

- [31] Y. Mohamed Shuaib, M. Surya Kalavathi, and C. ChristoferAsirRajan, “Optimal capacitor placement in radial distribution system using Gravitational Search Algorithm,” *International Journal of Electric Power Energy Systems*, Vol. 64, pp. 384–397, 2015.
- [32] D. Das , D.P Kothari, A. Kalam, “ Simple and efficient method for load flow solution” , *Electrical Power & Energy Systems*, Vol. 17, No. 5, pp. 335-346, 1995.
- [33] O. Amanifar, M.E. Hamedani Golshan, “Optimal distributed generation placement and sizing for loss and voltage profile improvement in distribution system using particle swarm optimization and sensitivity analysis” ,*IJTPE*, Vol. 3, No.7 ,pages 47-53, 2011.
- [34] V.V.S.N. Murthy, Ashwani Kumar, “Comparison of optimal DG allocation methods in radial distribution systems based on sensitivity approaches” ,*ELSEVIER*, Vol. 53, No. 6, pp. 450-467, 2013.
- [35] J. Kennedy and R. Eberhart, “ Particle swarm optimization” ,*IEEE*, No. 3, 1995.
- [36] A. Elsheikh, Y. Helmy, Y. Abouelseoud , Ahmed Elsherif, “Optimal capacitor placement and sizing in radial electric power systems” , *ELSEVIER*, Vol 53, pp. 809-816, 2014.
- [37] S. Sultana and P. K. Roy, “Optimal capacitor placement in radial distribution systems using teaching learning based optimization,” *International Journal of Electric Power Energy Systems*, Vol. 54, pp. 387–398, 2014.
- [38] M. H. Mostafa “Power flow study and voltage stability analysis for distribution systems with distributed generation”, *International Journal of Computer Applications*, Vol. 137, No.9, March 2016.

2. APPENDIX: A

Table (A.1): Line Data and load data for 15-node Radial Distribution System

Line number	Branch		Impedances		Load	
	Sending end	Receiving end	Resistance(Ω)	Reactance(Ω)	Real power(kW)	Reactive power(kVAr)
1	1	2	1.35309	1.32349	44.1	44.9
2	2	3	1.17024	1.14464	70	71.41
3	3	4	0.84111	0.82271	140	142.83
4	4	5	1.52348	1.0276	44.1	44.9
5	2	9	2.01317	1.3579	140	142.83
6	9	10	1.68671	1.1377	140	142.83
7	2	6	2.55727	1.7249	70	71.41
8	6	7	1.0882	0.734	70	71.41
9	6	8	1.25143	0.8441	44.1	44.9
10	3	11	1.79553	1.2111	140	142.83
11	11	12	2.44845	1.6515	70	71.41
12	12	13	2.01317	1.3579	44.1	44.9
13	4	14	2.23081	1.5047	70	71.41
14	4	15	1.19702	0.8074	140	142.83

(Base voltage = 11 kV, Base VA = 10MVA)

Table (A.2) : Line Data and load data for 118-node Radial Distribution System

Line number	Branch		Branch impedance		Load	
	Sending end	Receiving end	Resistant (p.u.)	Reactance (p.u.)	Realpower (kW)	Reactive power(kVAr)
1	1	2	0.036	0.01296	133.84	101.14
2	2	3	0.033	0.01188	16.214	11.292
3	2	4	0.045	0.0162	34.315	21.845
4	4	5	0.015	0.054	73.016	63.602
5	5	6	0.015	0.054	144.2	68.604
6	6	7	0.015	0.0125	104.47	61.725

7	7	8	0.018	0.014	28.547	11.503
8	8	9	0.021	0.063	87.56	51.073
9	2	10	0.166	0.1344	198.2	106.77
10	10	11	0.112	0.0789	146.8	75.995
11	11	12	0.187	0.313	26.04	18.687
12	12	13	0.142	0.1512	52.1	23.22
13	13	14	0.18	0.118	141.9	117.5
14	14	15	0.15	0.045	21.87	28.79
15	15	16	0.16	0.18	33.37	26.45
16	16	17	0.157	0.171	32.43	25.23
17	11	18	0.218	0.285	20.234	11.906
18	18	19	0.118	0.185	156.94	78.523
19	19	20	0.16	0.196	546.29	351.4
20	20	21	0.12	0.189	180.31	164.2
21	21	22	0.12	0.0789	93.167	54.594
22	22	23	1.41	0.723	85.18	39.65
23	23	24	0.293	0.1348	168.1	95.178
24	24	25	0.133	0.104	125.11	150.22
25	25	26	0.178	0.134	16.03	24.62
26	26	27	0.178	0.134	26.03	24.62
27	4	28	0.015	0.0296	594.56	522.62
28	28	29	0.012	0.0276	120.62	59.117
29	29	30	0.12	0.2766	102.38	99.554
30	30	31	0.21	0.243	513.4	318.5
31	31	32	0.12	0.054	475.25	456.14
32	32	33	0.178	0.234	151.43	136.79
33	33	34	0.178	0.234	205.38	83.302
34	34	35	0.154	0.162	131.6	93.082
35	30	36	0.187	0.261	448.4	369.79
36	36	37	0.133	0.099	440.52	321.64
37	29	38	0.33	0.194	112.54	55.134
38	38	39	0.31	0.194	53.963	38.998

39	39	40	0.13	0.194	393.05	342.6
40	40	41	0.28	0.15	326.74	278.56
41	41	42	1.18	0.85	536.26	240.24
42	42	43	0.42	0.2436	76.247	66.562
43	43	44	0.27	0.0972	53.52	39.76
44	44	45	0.339	0.1221	40.328	31.964
45	45	46	0.27	0.1779	39.653	20.758
46	35	47	0.21	0.1383	66.195	42.361
47	47	48	0.12	0.0789	73.904	51.653
48	48	49	0.15	0.0987	114.77	57.965
49	49	50	0.15	0.0987	918.37	1205.1
50	50	51	0.24	0.1581	210.3	146.66
51	51	52	0.12	0.0789	66.68	56.608
52	52	53	0.405	0.1458	42.207	40.184
53	53	54	0.405	0.1458	433.74	283.41
54	29	55	0.391	0.141	62.1	26.86
55	55	56	0.406	0.1461	92.46	88.38
56	56	57	0.406	0.1461	85.188	55.436
57	57	58	0.706	0.5461	345.3	332.4
58	58	59	0.338	0.1218	22.5	16.83
59	59	60	0.338	0.1218	80.551	49.156
60	60	61	0.207	0.0747	95.86	90.758
61	61	62	0.247	0.8922	62.92	47.7
62	1	63	0.028	0.0418	478.8	463.74
63	63	64	0.117	0.2016	120.94	52.006
64	64	65	0.255	0.0918	139.11	100.34
65	65	66	0.21	0.0759	391.78	193.5
66	66	67	0.383	0.138	27.741	26.713
67	67	68	0.504	0.3303	52.814	25.257
68	68	69	0.406	0.1461	66.89	38.713
69	69	70	0.962	0.761	467.5	395.14
70	70	71	0.165	0.06	594.85	239.74

71	71	72	0.303	0.1092	132.5	84.363
72	72	73	0.303	0.1092	52.699	22.482
73	73	74	0.206	0.144	869.79	614.775
74	74	75	0.233	0.084	31.349	29.817
75	75	76	0.591	0.1773	192.39	122.43
76	76	77	0.126	0.0453	65.75	45.37
77	64	78	0.559	0.3687	238.15	223.22
78	78	79	0.186	0.1227	294.55	162.47
79	79	80	0.186	0.1227	485.57	437.92
80	80	81	0.26	0.139	243.53	183.03
81	81	82	0.154	0.148	243.53	183.03
82	82	83	0.23	0.128	134.25	119.29
83	83	84	0.252	0.106	22.71	27.96
84	84	85	0.18	0.148	49.513	26.515
85	79	86	0.16	0.182	383.78	257.16
86	86	87	0.2	0.23	49.64	20.6
87	87	88	0.16	0.393	22.473	11.806
88	65	89	0.669	0.2412	62.93	42.96
89	89	90	0.266	0.1227	30.67	34.93
90	90	91	0.266	0.1227	62.53	66.79
91	91	92	0.266	0.1227	114.57	81.748
92	92	93	0.266	0.1227	81.292	66.526
93	93	94	0.233	0.115	31.733	15.96
94	94	95	0.496	0.138	33.32	60.48
95	91	96	0.196	0.18	531.28	224.85
96	96	97	0.196	0.18	507.03	367.42
97	97	98	0.1866	0.122	26.39	11.7
98	98	99	0.0746	0.318	45.99	30.392
99	1	100	0.0625	0.0265	100.66	47.572
100	100	101	0.1501	0.234	456.48	350.3
101	101	102	0.1347	0.0888	522.56	449.29
102	102	103	0.2307	0.1203	408.43	168.46

103	103	104	0.447	0.1608	141.48	134.25
104	104	105	0.1632	0.0588	104.43	66.024
105	105	106	0.33	0.099	96.793	83.647
106	106	107	0.156	0.0561	493.92	419.34
107	107	108	0.3819	0.1374	225.38	135.88
108	108	109	0.1626	0.0585	509.21	387.21
109	109	110	0.3819	0.1374	188.5	173.46
110	110	111	0.2445	0.0879	918.03	898.55
111	109	112	0.2088	0.0753	305.08	215.37
112	112	113	0.2301	0.0828	54.38	40.97
113	100	114	0.6102	0.2196	211.14	192.9
114	114	115	0.1866	0.127	67.009	53.336
115	115	116	0.3732	0.246	162.07	90.321
116	116	117	0.405	0.367	48.785	29.156
117	117	118	0.489	0.438	33.9	18.98



**5th International Conference
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This is to certify that Dr./Ms./Mr. Bhavana Tangid
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Presented / Published paper titled Load Flow Analysis Using Backward Forward Sweep Method

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PUBLICATIONS

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STUDENT PAPERS

PRIMARY SOURCES

1 J. Grainger, S. Lee. "Optimum Size and Location of Shunt Capacitors for Reduction of Losses on Distribution Feeders", IEEE Transactions on Power Apparatus and Systems, 1981 % **1**
Publication

2 Sharma, Sharmistha, Subhadeep Bhattacharjee, and Aniruddha Bhattacharya. "Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine for optimal allocation of DG in radial distribution network", International Journal of Electrical Power & Energy Systems, 2016. % **1**
Publication

3 www.journalijdr.com % **1**
Internet Source

4 C. Lakshminarayana. "An improved load flow method for the analysis of pre / post fault distribution systems", 2006 India International Conference on Power Electronics, 12/2006 % **1**
Publication

5 M. Sydulu. "Particle Swarm Optimization

Based Capacitor Placement on Radial Distribution Systems", 2007 IEEE Power Engineering Society General Meeting, 06/2007

Publication

% 1

6

www.waset.org

Internet Source

<% 1

7

html.scirp.org

Internet Source

<% 1

8

www.ijareeie.com

Internet Source

<% 1

9

Devabalaji, K.R., K. Ravi, and D.P. Kothari. "Optimal location and sizing of capacitor placement in radial distribution system using Bacterial Foraging Optimization Algorithm", International Journal of Electrical Power & Energy Systems, 2015.

Publication

<% 1

10

Kansal, Satish, Vishal Kumar, and Barjeev Tyagi. "Composite active and reactive power compensation of distribution networks", 2012 IEEE 7th International Conference on Industrial and Information Systems (ICIIS), 2012.

Publication

<% 1

11

Zidan, Aboelsood, Rashid S. Al-Abri, and Ehab F. El-Saadany. "Load model effect on distributed generation allocation and feeders'

<% 1

reconfiguration in unbalanced distribution systems", 2015 IEEE 8th GCC Conference & Exhibition, 2015.

Publication

12

D. Kavitha. "Optimal Estimation of Harmonics in Power System using Intelligent Computing Techniques", 2007 International Joint Conference on Neural Networks, 08/2007

Publication

<% 1

13

Kaur, Manvir, and Smarajit Ghosh. "Network Reconfiguration of Unbalanced Distribution Networks using Fuzzy-Firefly Algorithm", Applied Soft Computing, 2016.

Publication

<% 1

14

Witoon Prommee. "Optimal multi-distributed generation placement by adaptive weight particle swarm optimization", 2008 International Conference on Control Automation and Systems, 10/2008

Publication

<% 1

15

Gnanasekaran, N.; Chandramohan, S.; Sudhakar, T. D. and Kumar, P. Sathish. "Maximum Cost Saving Approach for Optimal Capacitor Placement in Radial Distribution Systems using Modified ABC Algorithm", International Journal on Electrical Engineering & Informatics, 2015.

Publication

<% 1

16

Khyati. Mistry. "Enhancement of voltage

stability index of distribution system by network reconfiguration including static load model and daily load curve", ISGT2011-India, 12/2011

Publication

<% 1

17

Valdez, Fevrier, Juan Carlos Vazquez, Patricia Melin, and Oscar Castillo.

"Comparative study of the use of fuzzy logic in improving particle swarm optimization variants for mathematical functions using co-evolution", Applied Soft Computing, 2016.

Publication

<% 1

18

D.P. Kothari. "Distribution system planning using knowledge based expert system", Proceedings of International Conference on Power Electronics Drives and Energy Systems for Industrial Growth PEDES-96, 1995

Publication

<% 1

19

Esmaeili, Davar; Zare, Kazem; Mohammadi-Ivatloo, Behnam and Nojavan, Sayyad.

"Simultaneous Optimal Network Reconfiguration, DG and Fixed/Switched Capacitor Banks Placement in Distribution Systems using Dedicated Genetic Algorithm", Majlesi Journal of Electrical Engineering, 2015.

Publication

<% 1

20

""', IEEE Transactions on Dielectrics and

<% 1

21 Hien, Nguyen Cong, Nadarajah Mithulananthan, and R. C. Bansal. "Location and Sizing of Distributed Generation Units for Loadability Enhancement in Primary Feeder", IEEE Systems Journal, 2013. <% 1

Publication

22 www.ijsmdo.org <% 1

Internet Source

23 Sudha Rani, D., N. Subrahmanyam, and M. Sydulu. "Self Adaptive Harmony Search algorithm for Optimal Network Reconfiguration", 2014 Power and Energy Conference at Illinois (PECI), 2014. <% 1

Publication

24 Bompard, E.. "Convergence of the backward/forward sweep method for the load-flow analysis of radial distribution systems", International Journal of Electrical Power and Energy Systems, 20001001 <% 1

Publication

25 Hui, Jingxuan, Wenjia Cai, Can Wang, and Minhua Ye. "Analyzing the penetration barriers of clean generation technologies in China's power sector using a multi-region optimization model", Applied Energy, 2016. <% 1

Publication

Li, YanYan, and ChangZheng Qu. "Symplectic

26 invariants for curves and integrable systems in similarity symplectic geometry", Science China Mathematics, 2015. <% 1
Publication

27 Kayal, Partha, and C.K. Chanda. "Strategic approach for reinforcement of intermittent renewable energy sources and capacitor bank for sustainable electric power distribution system", International Journal of Electrical Power & Energy Systems, 2016. <% 1
Publication

28 www.inderscience.com <% 1
Internet Source

29 Thota, Purnachandrarao, and M. Venkata Kirthiga. "Optimal siting & sizing of distributed generators in micro-grids", 2012 Annual IEEE India Conference (INDICON), 2012. <% 1
Publication

30 Niu, Qun, Zhuo Zhou, Hong-Yun Zhang, and Jing Deng. "An Improved Quantum-Behaved Particle Swarm Optimization Method for Economic Dispatch Problems with Multiple Fuel Options and Valve-Points Effects", Energies, 2012. <% 1
Publication

31 waset.org <% 1
Internet Source

32

Novák, Pavel, Michal Šprlák, Robert Tenzer, and Martin Pitoňák. "Integral formulas for transformation of potential field parameters in geosciences", Earth-Science Reviews, 2016.

Publication

<% 1

33

Teaching Learning Based Optimization Algorithm, 2016.

Publication

<% 1

34

P. Ravibabu. "Implementation of Improved Genetic Algorithm in distribution system with feeder reconfiguration to minimize real power losses", 2010 2nd International Conference on Computer Engineering and Technology, 04/2010

Publication

<% 1

35

M. Sydulu. "A Novel Approach for Optimal Location and Sizing of Capacitors on Radial Distribution Systems Using Loss Sensitivity Factors and α -Coefficients", 2006 IEEE PES Power Systems Conference and Exposition, 2006

Publication

<% 1

36

Mondal, Abhisek, Deblina Maity, Sumit Banerjee, and Chandan Kumar Chanda. "Solving of economic load dispatch problem with generator constraints using ITLBO technique", 2016 IEEE Students Conference on Electrical Electronics and Computer

<% 1

37

Li Ping. "An adaptive binary particle swarm optimization for evolvable hardware", 2010 2nd International Conference on Industrial and Information Systems, 07/2010

Publication

<% 1

38

conferenceworld.in

Internet Source

<% 1

39

Lan, Wen Hao, Yi Hui Zheng, Li Xue Li, Xin Wang, Gang Yao, and Yang Zhang. "Fault Diagnosis of Grounding Grid Based on Self-Adaptive Particle Swarm Optimization", Applied Mechanics and Materials, 2013.

Publication

<% 1

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