Optimal Reconfiguration of Distribution Network for Voltage Profile Improvement and Power Loss Minimization Using Distributed Generation (Sizing & Placement)

BY

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CERTIFICATE

We accept the work contained in this report as a confirmation to the required standard for the partial fulfilment of the degree of MS (EE).

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Internal Examiner	External Examiner

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DEDICATION

I dedicate this small Piece of the effort to my parents & supervisor as well as my colleagues, who encouraged and supported me during the whole tenure. Without their support and sincere advise, it could not possible to complete within a given time period.

Dedicated to my beloved grandparents, parents, wife and all family members.

DECLARATION OF AUTHORSHIP

I hereby declare that content of this thesis is my own work and that it is the result of work done during the period of registration. To the best of my knowledge, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgement has been made in the text.

Parts of this thesis appeared in the following publications, to each of which I have made substantial contributions:

- Publication…

(Student Signature)

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It is customary to thank those, who have delivered particularly useful support, technical or otherwise, during the thesis. The supervisor will evidently be contented to be acknowledged as he will have devoted quite a lot of time overseeing your evolution.

DECLARATION

It is declared that this is an original piece of my own work, except where otherwise acknowledged in text and references. This work has not been submitted in any form for another degree or diploma at any University or other Institution for tertiary education and shall not be submitted by me in future for obtaining any degree from this or any other University or Institution.

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ABSTRACT

Electrical power systems are multifaceted, and distribution networks are the most wide-ranging part of them. Minimum level of voltage of distribution system is the main cause of significant power losses in system overall. The development which targets at reconfiguring the distribution systems is generally called "Power System Reconfiguration". To attain minimum power losses, stability enhancement and voltage profile enrichment of the system, an optimized operating arrangement is designed by reconfiguration of the distribution network. A different approach is presented that is centered on the Strawberry Plant Algorithm (SPA), towards the solution of distribution reconfiguration of the given network and distributed generator (DG) optimal situation problems for the betterment of profile of voltage and for reduction of loss of power in the network. The recommended technique SPA was executed for IEEE 69 and IEEE 33 bus networks to reconfigure networks and to place the DGs on the optimal locations. The performance of SPA was also compared with particle swarm optimization (PSO) to authorize effectiveness of the running system. The simulation results reveal that SPA could offer better results as compared to PSO in correspondence with reconfiguration of network and DGs location for voltage profile improvement of buses and significant reduction in active power losses. Therefore, introducing SPA as operational algorithm as the ideal troubleshooter for the problems like reconfigurations of network on field and DG placement of networks of Distribution in the field of power.

Keywords: power loss 1; voltage profile 2; strawberry plant algorithm 3; distributed generation 4; reconfiguration

TABLE OF CONTENTS

List of Figures

ABBREVIATIONS

AI	Artificial Intelligence
DG	Distributed Generation
PSO	Particle Swarm Optimization
APSO	Accelerated Particle Swarm Optimization
ED	Economic Dispatch
PPA	Plant Prorogation Algorithm

CHAPTER 1: INTRODUCTION

1.1 Overview

The electrical systems of power contain distribution systems, generating systems and transmission systems. A generating system converts the fuel energy to electric current; a transmission system links generating station and distribution substation whereas a distribution system distributes powers to the customers. As per the network structures, distribution and transmission system varies. In general, transmission systems carry loop structures while distribution systems contain radial structures.

1.1.1 Distribution System

A system for Distribution is used with radial structures for obtaining operational feasibility. Through connected transmission networks, the primary distribution substation gets powers from the generating station. The radial distribution system (RDS) remains passive transferring powers to the customers via the substations. Hence, the power flows in RDS are always one directional. Because of the higher R/X ratio and higher voltage drop, larger losses of power occur within supply line. These distribution systems experience various alterations within the loads. In a majority of nodes, RDS experiences sudden collapses within voltage during the time of crucial load condition owing to lower voltage stability indexes. This research work proposes an RDS voltage stability index (VSI) for every node. This can be seen that the node having the least VSI value tends to be more sensitive leading to a collapse in the voltage.

In the earlier years, various techniques were used by situating scattered resources and injecting reactive powers such as capacitor bank for obtaining improvements in voltages and reducing the power loss. Though the capacitor situating method seems to be reliable, the improvements in voltage profiles was lesser than desired voltage levels i.e. 1.0 p.u. Because of the passivity of RDs, it is not reliable. Various solutions are put forward in the recent years to incorporate electric resources on the basis of renewable energy sources for overcoming the passivity of RDS and to improving the feasibility of the systems along with voltage profiles. The embedded RDS generation is mentioned as Dispersed or Distributed generation (DG).

1.2 Literature Review

The R/X ratio in the system of distribution is comparatively higher than the ratio of a transmission system, with indication of the power loss in distribution network is higher as compared to the transmission network. 13% of the total power produced and transmitted is lost to I^2R factor in the Distribution Network [1]. And it directly impacts in the increment of cost of energy with the imbalance along distribution feeder in terms of voltage levels. It is commonly known that in the network of distribution, significant amount of energy is lost, so to maintain them economically these losses must be restricted to minimum [1]**.** In the meantime, a rapid increase in load requirement generates more voltage instability in the network. While there are several methods to reduce or overcome the losses such as higher voltage levels, induction of capacitors, reconductoring and reconfiguration of networks. Generally a method is used called Network reconfiguration as there, additional installation of equipment is not involved and is effective according in terms of cost [2]. Main objective of distribution system reconfiguration (DSR), to optimize the present working framework which helps to overcome power losses and not affecting efficiency in terms of output. The reconfiguration of networks and DG installation, these two are best approaches for overcoming the losses of power and to improve the stability of voltage magnitude, that expands the total efficiency of the distribution network [3].It is important point to note here that the network configuration, DG unit's size and location must be ideal in order to get the maximum outcomes and decrease their influence on the system. Hence the optimal amalgamation among these two issues gets to be an important and complex problem.

A procedure of adjusting the opening and closing position of sections and in-line controls of the distributing network in order to alter the systems configuration is the Network reconfiguration. And this method can upgrade the efficiency of the network by considering the various specific objectives and limits [4]. Generally, the main objectives for reconfiguration of network are improvement in the voltage magnitude level, drop in power loss, balancing of load and voltage stability enhancement [5]. From the last two decades, many different methods have been used by the researchers in order for the solution of the reconfiguration of network problems [6]. For example, A.M. Imran concluded in his research work that performing the reconfiguration of network reduces the loss of power and enhance the maturity of voltage level in the system [7].

The reconfiguration of the network of distribution systems was initially introduced by 2 researchers i.e. Merlin and Back [8] using a bound and branch optimization scheme. An unusual working centred network was established by closing the switches altogether primarily, before the connections were unlocked one by one. The technique by Merlin entails excessive time to execute the process which was altered by Shirmohammadi and Hong after some time, the connections were opened one by one leaving the instantaneous interchanging the reconfiguration of feeder and reshape ideal strategy for flow of the system as a whole [8]. Later on, numerous optimization techniques have been established for the voltage level enhancement and to reduce the losses.

The Algorithm applied was Artificial Bee Colony (ABC), on distribution network to figure out the maximum load-ability problem, and also employed the continuation of the flow of power side by side the graph theory technique for smooth flow of power [9]. In [10], Bacterial Foraging Optimization Algorithm (BFOA) is given by the researchers in order to solve the problem of reconfiguration of the network by considering the series fault at different buses. Usage of this technique, honey bee mating optimization, in a modified form, was identified due to the solution of problem of reconfiguration of Network [11]. in the [12], the authors were presented a unique for explaining the issue of reconfiguration via non-revisiting.

Now, another effective technique to the betterment of maturity of voltage in network in order to minimize the loss of power is to install the DG unit in the network. Units of DG are minute power producing plants that are linked either on the customer meter or in the distribution network directly. The application of these units of DG allocation in distribution network has grown to a significant level, and ecological, technical, and economic effects of them, on the whole system are being investigated. Important parameters that can be impacts on the economic and technical factors are the ideal location, size of DG elements and its type in the existing power network. In recent times, numerous researches have executed on effect of DG entities. In [13, 14] authors were proposed a logical and enhanced analytical approach to know the size DG units and its location to limit the power loss in the network. Particle Swarm Optimization (PSO) approach was presented to find the ideal place of separate kinds of DGs for the minimization of loss of power problem [15]. New better way for the solution of ideal location and size of DGs, based on teaching and learning [16]. A hybrid population-based approach was introduced alongside the integration of PSO to set the right size of DGs and their placement in the said networks and gravitational search is also part of it [17]. Recently, to examine the DG installation issue at different load percentages a new approach named as BFOA had been presented [18].

All the above-mentioned researches [9–18] considered only the idealization of either location if DG in distributing network. However, the target was to reduce losses of power and enhance voltage profile, the configuration of said network normally never took DG instalments to attention and vice versa. But for maximum efficiency from the whole network of Distribution, mandatory thing is the incorporation of both, DG installation and reconfiguration of whole system issues [19, 20]. Authors have utilized Harmony Search Algorithm (HSA) to identify the DG ideal location and reconfiguration of the network on the same time keeping in lieu the power loss minimization as only objective function [21].

Therefore, this study is representing a doable and authentic, recently developed strawberry plant optimization algorithm (SPA) for the solution of reconfiguration of these networks of distribution. And to overcome losses of power and voltage profile enhancement DGs are placed along it. This procedure creates use of voltage violation VV for selection of bus locations for the installation of DGs before-hand. The Actual working phenomenon is supervised by this method on every stage with the help of creation of an exact and accurate path for parent node-child node on the time of power flow from the network. Two Standards IEEE 69- and 33-bus test systems cross checks validation of this method. Obtained virtual outcomes from SPA are also equated with PSO to authorize performance and effectiveness of this unique and innovative scheme.

1.3 Problem Statement

To find the ideal configuration of switches while reconfiguring the system of Distribution. Meanwhile Distributed Generators (DGs) are used usually in the systems of distribution to overcome the power disruption in the whole network of power system. Reconfiguration and installing DGs in distribution network, the voltage profile of buses and the loss of power can be reduced of the system. On the other hand optimization of reconfiguration and power allocation through DGs can result in the better solution than the separate optimization of every task. Previous work in this area normally focused on a single optimization, which may not be adequate for total improvement of the distribution network. So, for the above mentioned reason there must be an optimization method that can indicate best solution for network of distribution , that will be much help for planning of system engineer.

In Pakistan most fragile connection is dissemination arrange in the entire force part. The framework bears roughly 17% power is lost during transmission whereas losses among distribution are about inexact 20% of the total System of Power Distribution Network. Fundamental quantity of intensity framework losses are conceived due to essential as well as optional conveyance links. Major causes includes specialized losses, lengthy conveyance links, low influence factor of essential and optional dissemination system and low voltage in circulation organize. For the reason to remain serious, it is turning out to be increasingly more authoritative for power conveyance organizations to have the option to meet the prerequisites of their clients effectively. This implies one of their objectives is finding a working state for a huge, adjusted, three-stage, circulation organize which limits the cost for the force organization providing the force, while fulfilling the requests of the client. The fast populace development is one of the reasons for expanding interest for the power. The distribution framework has gotten increasingly unpredictable. The expansion in flow draw during the appropriation of power brings about the unsteadiness that frequently is the reason for power losses. This issue can be comprehended by composed reconfiguration and updating of the distribution framework.

1.4 Significance

The proposed research will enable engineers to monitor and analyse distribution network on real time basis. As the research is aimed at applications of electrical engineering, so the project will have an effective scope in distribution industries as well. As such work has not been done in Pakistan so the research will open a new dimension of study and its application will also contribute in improving the line losses in Pakistan. Sensitive loads which are at load bus are more secured from voltage sag/swell problems. This also results in reduction of distribution network losses and results in optimum flow of power in the dispersion framework.

The proposed research will empower engineers to monitor and investigate distribution system on real-time basis. As the research is focused for uses of electrical engineering, so the venture will have a powerful scope in distribution industry too. In that capacity work has not been done in Pakistan so the research will open another field of study and its application will likewise contribute in enhancing the line losses in Pakistan. Sensitive loads which are at load bus are more secured from voltage droop/swell issues. This additionally results in decrease in distribution network losses and results in ideal power flow in the Dispersion framework.

1.5. Purposes:

This project has following purposes:

1. The development of the optimum way to manage real and reactive powers and to improve voltage of nodes with RDS through DG. Implementing VSI (voltage stability index) techniques to optimally place the DG unit.
2. To achieve an ideal configuration for the network of power distribution.
3. To Implement SPA algorithm to obtain ideal space & location for DG and ideal reconfiguration to reduce the loss.
4. Carrying out a thorough analysis of method performance on IEEE-69 and 33 bus system for explaining the efficiency of the suggested technique.

1.6 Outlines of Dissertation

This exploration contains subsequent six subdivisions:

- ❖ Chapter 1 evaluations introduction of the power system, the literature evaluation, motivation and problem declaration, objectives, & association of thesis
- ❖ Chapter 2 describes power flow analysis, mathematical mode of radial distribution, voltage stability index
- ❖ Chapter 3 explains the Distributed generation, sizing and placing of Distributed generation, and reconfiguration.
- ❖ Chapter 4 particulars the examination scheme and the consequences gained after the employment of algorithm.
- ❖ Chapter 5 recapitulates the conclusions and endorsements.

CHAPTER 2: DISTRIBUTION SYSTEMS

2.1. Introduction

The real time applications including optimizing networks, switching, estimating the states and others need an effective and standardized power flow technique. Owing to the specialized aspects of distribution system like radial structures, higher ratio of R/X along with far-reaching reactance and resistance value is observed. As a result, Gauss Seidel (GS) and Newton Raphson (NR) approaches no longer remain efficient. Particularly, within standardized rapidly decoupled NR process, techniques utilized to simplify the process do not remain effective in RDS; thus, making the transmission system power flows computational system varied from the distribution system. Therefore, an effective power flow algorithm is required for the distribution network.

For carrying out both instable and well-adjusted RDS examination, different techniques are used. Generally, they are categorized into two different types. First type comprises of modifying the conventional technique including GS and NR while the second type includes forward and backward sweep processes utilizing Kirchhoff's law. In the network of Distribution, power flows analysis, to and fro sweep-based processes have become more popular due to their higher computation effectiveness, lower memory needs and stronger convergence attribute. This research thesis carries out load flow analysis utilizing regressive and advancing sweep technique.

Within this method, the bus-branch data is regarded as only input. Key aims of this chapter include solving power flow for RDS in a direct way and the development of the formulation including the benefits of topological attributes of distribution network. The new process does not perform advancing/regressive substitution of Jacobian matrices and the time-consuming LU breakdown as were achieved in the conventional NR and GS processes. This novice process performs the bus inoculation to subdivision current matrices and simple matrix operation for obtaining the load flow solutions. As compared with the traditional process, it is very effective and reliable process. Its results describe the reliability and sustainability of this method.

2.2. Mathematical Model for Radial Distribution Systems

Supposing that 3-phased RDS is composed presented in a solitary line diagram, a simplified radial dispersion network with sources on the one end and load on various nodes is given below in the figure 1:

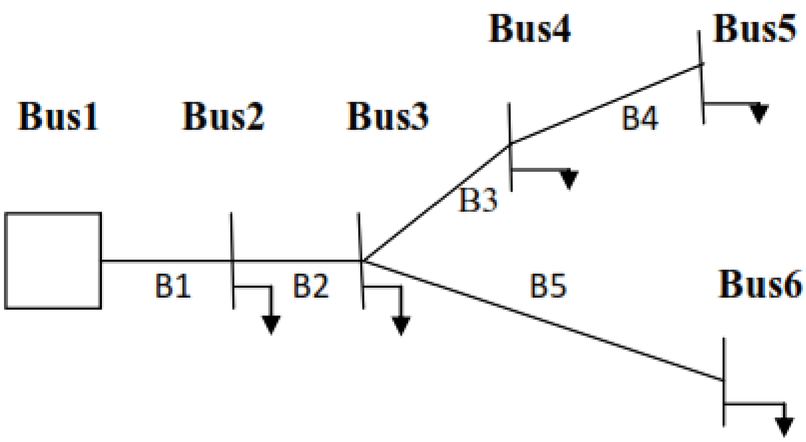


Figure 1Simple Distribution System

2.2.1CalculationofNodeCurrent

In the distribution network, current injection model has more practicality. For bus or node, load $S_i$is given below:

$$S_i = P_i + Q_i \quad i=1,2,3,...,N \qquad \textit{Eq (2.1)}$$

While the correspondent current on the m-th iteration remains:

$$I_I^M = \left(\frac{P_i + Q_i}{V_i^m}\right) \qquad \text{Eq (2.2)}$$

2.2.2 Calculation of Branch Current:

The instance of a basic RDS is given below in Figure2.1. The injected powers of the bus is converted into current injection by eq. (2.2). To apply KCL at the distribution systems, the relation between branches and bus currents are obtained. The branch current is shown as the purpose of current injection. For instance, the subdivision current I_{B1}, ***IB2, IB3, IB4***and$I_{B5}$are represented by

$$I_{B_1} = I_2 + I_3 + I_4 + I_5 + I_6$$

$$I_{B_2} = I_3 + I_4 + I_5 + I_6$$

$$I_{B_3} = I_4 + I_5$$

$$I_{B_4} = I_5$$

$$I_{B_5} = I_6 \qquad \text{Eq (2.3)}$$

Relationship among branches and current in bus injection is as follows

$$\begin{bmatrix} I_{B_1} \\ I_{B_2} \\ I_{B_3} \\ I_{B_4} \\ I_{B_5} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} I_2 \\ I_3 \\ I_4 \\ I_5 \\ I_6 \end{bmatrix} \qquad \text{Eq (2.4a)}$$

Branch current is calculated by:

$$[I_B] = [BIBC \mid I_n] \qquad \text{Eq (2.4b)}$$

In this equation, **BIBC** represents bus injections to branch current matrices. This matrix consists of 0's and1's.

2.2. Formulation of BIBC Matrix:

Within equation (2.3), the BIBC matrix's algorithm is represented by:

Step1. In RDS having ***n***-bus and ***m***-branch, the dimensions of the BIBC

The Matrix remains ***m***x***(n-1)***.

Step2. When the branch (**B_k**) is situated in the middle of ***i*** bus and the ***j*** bus column of ***i***-th bus and the column of ***j***-th bus and mark+1 at k-th row and jth column is copied.

Step3. Repeat step 2 till each branch section is involved in BIBC.

On the basis of the bus branches database, building algorithm is formulated. Therefore, integrations of suggested process within existing DA becomes easier where time for data preparation is lessened.

2.3. Calculations of Branch Voltage drop and Node Voltage drop

Assuming flat voltage for RDS as,

$$V_n = (1+j0) \text{ p.u}$$

Drop in voltage for every branch remains attained along with the voltage of other node is calculated by KVL as,

$$\Delta V = I_B \times Z$$

Consider branch**B_1**,

The receiving node voltage is shown as: $V_2 = V_1 - \Delta V$

$$V_2 = V_1 - I_{B_1} Z_1 \qquad \text{Eq (2.5)}$$

For the branch2, $$V_3 = V_2 - I_{B_2} Z_2 \qquad \text{Eq (2.6)}$$

Since voltage $V1$ is already known and if ***Ib1*** isknown already, then branch current, $V2$ is calculated from the eq.2.5. When $V2$ is already known, V3 is calculated from eq.2.6. In the similar way, calculations of voltage of new nodes 4, 5..., *NB* stays easier when current in the branch is already identified. Therefore, a normal eq. For voltage of received and sent-end, current in branch and impedance of branch is as follows:

$$V(n2) = V(n1) - I(kk)Z(kk) \qquad \text{Eq (2.7)}$$

Equation. (2.**7)** is considered as, kk=1, *2...NB.*After calculating subdivision current, reactive and real loss of power is attained by:

$Ploss(m) = I_{b(m)}^2 \; x \; R(m)$For m=1, 2, 3...N Eq (2.8)

$Qloss(m) = I_{b(m)}^2 \; x \; X(m)$For m=1, 2, 3...N Eq (2.9)

Total active and responsive power loss TPL, TQL is given as under:

$TPL = \sum_{k=1}^{NB} Ploss(m)$ Eq (2.10)

$TQL = \sum_{k=1}^{NB} Qloss(m)$ Eq (2.11)

Here,

N	number of busses
NB	number of branchesi.e. NB=N-1
Kk	branch number
n1	Sending end nodes
m2	receiving end nodes
I_n	Load currents at each bus
Z	Impedance for all branches
V_n	Voltage at receiving end node
V_s	Voltage at sending end node
ΔV	Voltage drops in each branch
TPL	Total active power loss
TQL	Total reactive power loss
Ploss(m)	Real power loss for branch k
Qloss(m)	Reactive power loss for branch k

In this part, a mathematical chart is shown by the consideration of the impacts of real static loads model and load growths model. Algorithm Load flow is cast-off in the research study comprises of forward sweeps and BIBC formulation method. Forward sweeps are voltage drop calculations from sent to receive ends of the lateral. BIBC refers to the current summation method on the basis of voltage update. Utilizing Kirchhoff's law, voltage drop is attained.

At the initial stage, consistent voltages of every node and computation of the load current by eq. 2.2 is assumed. After computation of the load current, the computation of branch current through eq. 2.4 is obtained. Node voltage using eq. 2.7 is calculated. Reactive and real power loss of every branch is computed through eqs. 2.8 and the other 2.9. Later, consuming of value of voltage, junction criteria need confirmation. Utilizing the latest value of voltage, current utilized by the load is considered repeating whole method until convergence is achieved. Convergence criteria of this process includes maximized voltage difference lesser than 0.00001P.U.

2.4. Voltage Violations (VV)

The VV shows numeric solutions for identifying sensitive nodes/buses within the systems. This assists the operators in checking systems for preventing from voltage collapses after initializing automated remedial action. The major goal of VV involves finding the sensitive buses for the implementation of remedial actions. Voltage collapses normally begin at the most sensitive nodes within the systems passing to other nodes that are equally sensitive. Below aspects shows sensitive node to voltage collapse :

1. High critical points
2. Lower margins of reactive powers
3. Major shortage of reactive powers

2.4.1. Mathematical Formulation

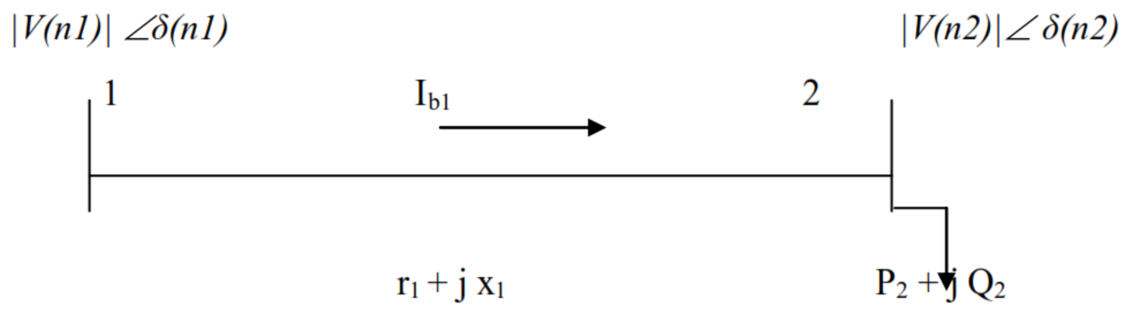


Figure 2Basic 2 bus system

As per the figure.

$$I(kk) = \frac{|V(n1) < \delta(n1) - |V(n2) < \delta(n2)}{r(kk) + x(kk)}$$ Eq (2.12)

$$P(n2) - jQ(n2) = V(n2)\ X\ I(kk)$$ Eq (2.13)

As per the eqs. (2.12)& (2.13), the following is obtained,

$$\frac{|V(n1) < \delta(n1) - |V(n2) < \delta(n2)}{r(kk) + x(kk)} = \frac{P(n2) - jQ(n2)}{V(n2)}$$ Eq (2.14)

After the solution of eq.(2.14),the below equation is obtained,

$$|V(n2)|^4 - \{|V(n1)|^2 - 2 \times P(n2)r(kk) - 2 \times Q(n2)x(kk)\}|V(n2)|^2 + \{P^2(n2) + Q^2\ (n2)\}$$

$$\{r^2(kk) + x^2(kk)\} = 0$$ Eq (2.15)

Let

$$b(kk) = |V(n1)|^2 - 2 \times P(n2)r(kk) - 2 \times Q(n2)x(kk)$$ Eq (2.16)

$$c(kk) = \{P^2(n2) + Q^2(n2)\}\{r^2(kk) + x^2(kk)\}$$ Eq (2.17)

After the eqs.(2.15),(2.16),(2.17)the following is obtained as,

$$|V(n2)|^4 - b(kk)|V(n1)|^2 + c(kk) = 0$$ Eq (2.18)

As per equation (2.18), received end voltage $V(n2)$consists of 4solutions including:

1. $0.707\ [b(kk) - \{b^2(kk) - 4c(kk)\}^{0.5}]^{0.5}$
2. $-0.707\ [b(kk) - \{b^2(kk) - 4c(kk)\}^{0.5}]^{0.5}$
3. $-0.707\ [b(kk) + \{b^2(kk) - 4c(kk)\}^{0.5}]^{0.5}$
4. $0.707\ [b(kk) + \{b^2(kk) - 4c(kk)\}^{0.5}]^{0.5}$

Where P,Q**,** ***r, x*** and ***V*** are represented as per unit, $b(kk)$ remains positive because the formula*2{P(n2)r(kk)+Q(n2)x(kk)}* is smaller as related to $|V(n2)|^2$ and the Formula***4c(kk)***is smaller as relative to $b^2(kk)$**.**

Hence,$\{b^2(kk) - 4c(kk)\}^{0.5}$Equals to$b(kk)$and Hence, the 2 results of $|V(n2)|$ equals to zero which is not reliable. 3rd explanation remains adverse and is cannot be relied upon. 4th explanation is reliable and is encouraging. Hence, the solution of equation (2.18) is *exclusive.*

I.e. $|V(n2)| = 0.707\ [b(kk) - \{b^2(kk) - 4c(kk)\}^{0.5}]^{0.5}$ Eq (2.19)

P(n2) denotes total of every actual power load for each node elsewhere n2 and to this node as well along with the sum of real power loss for every branch away from n2.

Q(n2) refers to total of every responsive power load at each node beyond n2 node and at this node as well along the total real reactive loss in every branch elsewhere n2 node.

As per the equation (2.19), this is detected that reliable load flow answer of working distributions network exists only when,

$$b^2(kk) - 4c(kk) \geq 0 \qquad \text{Eq (2.20)}$$

After simplifying, it is obtained,

$$|V(n2)|^4 - 4\{P(n2)r(kk) + Q(n2)x(kk)\}^2 - 4\{P(n2)r(kk) + Q(n2)x(kk)\}|V(n1)|^2 \geq 0$$

Eq (2.21)

Let

$$SI(n2) = |V(n2)|^4 - 4\{P(n2)r(kk) + Q(n2)x(kk)\}^2 - 4\{P(n2)r(kk) + Q(n2)x(kk)\}|V(n1)|^2$$

Eq (2.22)

In which

SI(n2)= Voltage Steadiness Index of Node *n2*. (*n2*=2, 3, 4....., *NB*)

Forgetting steady operations of RDS,

SI(n2) ≥ ***0***; for n 2=2,3,4.....,*NB*

Utilizing VSI, firmness levels of working network of distribution is calculated where a reliable step is taken in case VSI shows poorer stability levels. The modal voltage and branch current is attained after studying load flow; thus, P(n2) and Q(n2) are measured. Hence, an individual calculates VSI of every node. Nodes having minimized VSI values are sensitive and can collapse within voltages. The efficiency of this process is described through 33&69-nodeRDS.

CHAPTER 3: SIZING AND PLACMENT OF DG AND RECONFIGURATION

3.1. Introduction

System of Distribution makes the major component of electrical energy network system. For the improvement of efficiency of the distribution network various activities have been done. Network reconfiguration is the most fundamental, the commonest means for enhancement of the recital of network of distribution. By opening and closing switches i.e. sectionalizing and tie, of the network the system's feeders are reconfigured. There are different ways to setup the distribution network, here under only three of them are discussed.

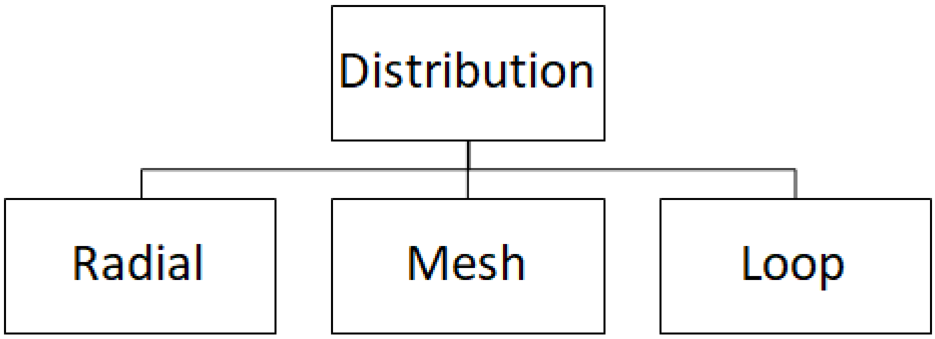


Figure 3 : Power Distribution Structure

a. **Radial:** For radial setup of distribution network, there is solitary single way between substation or service transformer and client. This single path carries the flow of current from substation to the customer. Additionally, circular is inexpensive and foreseeable to practice and simple to analyze. Besides, it is easy to analyze and minimize power losses.
b. **Mesh:** For mesh, as obvious from the name, there are multiple paths between all points in the network. This setup splits the flow of power between 2 points in multiple ways. This is a trustworthy procedure for dispersing power flow. If fiasco happens at any path, the power immediately redirects itself. Other than that, it is frequently implemented in highly populated municipal zones where preservation and conservations are hard and expensive.
c. **Loop:** For loop, there exist two paths amongst substation transformer and client. Electricity travels generally from mutual sides to the center point. The hardware is evaluated with the goal that the services can be preserved if an open point happens in the network.

3.2. Importance of DG

The fundamental thought process behind applying DGs in the power dissemination are vitality effectiveness or judicious utilization of vitality, deregulation or rivalry arrangement, expansion of vitality sources, accessibility of measured creating plant, simplicity of discovering areas for littler generator, short development time and low capital expenses for littler plant, and nearness of the age plants to overwhelming burdens, that can diminish the transmitting cost. The DG when associated with system can give various advantages. A portion of the advantages are control misfortunes lessening, vitality undelivered costs decrease, averting or postponing system extension. Different advantages are crest stack working costs lessening, enhanced voltage profile and enhanced load factor. Notwithstanding giving advantages, DG can likewise greatly affect arrange. These effects incorporate recurrence deviation, voltage deviation and music on arrange. The expansion of energy misfortunes is another impact that may happen. In this manner watchful contemplation should be taken when estimating and finding DGs in dispersion frameworks.

3.3. DG placement and sizing

Distributed Generation (DG), little scale control age that is generally associated with dissemination framework. The Electric Power Research Institute (EPRI) characterizes DG as an age since a couple of kilowatts about 50MW [6]. CIGRE characterizes DG as an age having attributes (CIGRE, 1999): that isn't midway arranged; it isn't halfway dispatched at introduce; it is normally associated with the conveyance systems; which is littler to 50-100MW. Ackermann et al. provide the latest meaning of DG as: "DG refers to the electrical power age resource associated specifically to the dispersion arrange or on the client sides of the meter."

Within a majority of power frameworks, an expansive bit of power request is provided by huge scale generators. This is a direct result of monetary points of interest of the unit against the little one. Notwithstanding, within the most recent decades, mechanical developments and a varying financial and administrative condition has brought about a recharged enthusiasm for the DG unit. An investigation by Electric Power Research

Institute (EPRI) showed the results, that in the year 2010, 25% of the latest age was disseminated. Petroleum gas establishment inferred that it may be higher as about 30%. Distinctive innovations that are utilized for DG resources, for example, photograph voltaic cell, wind age, ignition motors, energy units and different sorts of age from the assets that are accessible in the geological zone.

During the past few years, alternative solution to the conventional power station has been great priority because of the restricted presence of fuel resource for meeting the electrical energy demand. These renewable energy sources are regarded as the alternate solutions for existing fuel. Compared to larger fossil fuels power plant, the renewable energy generator size is smaller. These are very suitable for lower voltages RDS.

Traditionally, power system is devised on the basis of power flows in singular direction; however, the concept of DG leads to the new research on distribution network. The dispersed generation penetration affects the operation of distribution systems beneficially by enhancing line loss which creates negative impact. The positive features of DG include provision of voltage support and the reduction in power losses while its negative features include protection coordination and versatile stability. In order to adopt DG within distribution networks, special care must be taken for its technical constraint and penetration level to maximize its advantages.

Generally, stack development is gauged by appropriation organizations until the point that a foreordained sum is come to, whereby another limit is included to the system. The recent limit is generally the expansion of the latest substation or growing current substation limits and their related latest feeder or both. Be that as it may, the adaptability, innovations, specialized and money related advantages and ideas of DG arranging is testing this condition of issues and picking up validity as an answer for the conveyance arranging issues within the restrictively higher costs of influence shortening in the changed administrative and financial situations. It improves DG as an alluring conveyance arranging alternative that abstains from causing debasement of energy quality, dependability and control of the utility frameworks. In [19] revealed that the circulation framework arranging issue is to distinguish a blend of development ventures for the minimum cost organize speculation that fulfills stack development necessities without disregarding any framework and operational limitations.

More often than not, DGs are coordinated with the current conveyance framework and loads of research work is carried out to discover the most feasible area and sizes of DG to deliver most extreme advantages. The principle qualities that are considered for the ID of an ideal DG area and size are the minimization of transmissions losses, expansion of supplies dependability and boost of benefit of the circulation organizations (DISCOs). Because of broad charges, DGs ought can be dispensed legitimately through ideal scope to upgrade framework execution considering the final target to limit the framework misfortune and in addition to get a few changes in the voltage profiles by keeping up the strength of the framework. The impact of setting a DG on organize parameter normally varies on the premise of its sort, area and load at the association point. In this way interconnection arranging of DG to electrical system must think about various variables. The variables incorporate DG innovation; limit of DG unit; area of DG associated and arrange association sort.

Figure 3 demonstrates a 3D plot of run of the mill control misfortune against the sizes of DG at every transport in a specific conveyance testing framework. In the given figure, clearly for a specific transport, as the measure of DG is expanded, the misfortunes are lessened to a base esteem and expanded past sizes of DG (that is, the ideal DG estimate) at the area. In the event that the span of DG is additionally expanded, the misfortunes begins to increment and it is probable that it might overshoots the misfortunes of the base cases. Additionally, see the area of DG assumes an imperative part in limiting the misfortunes.

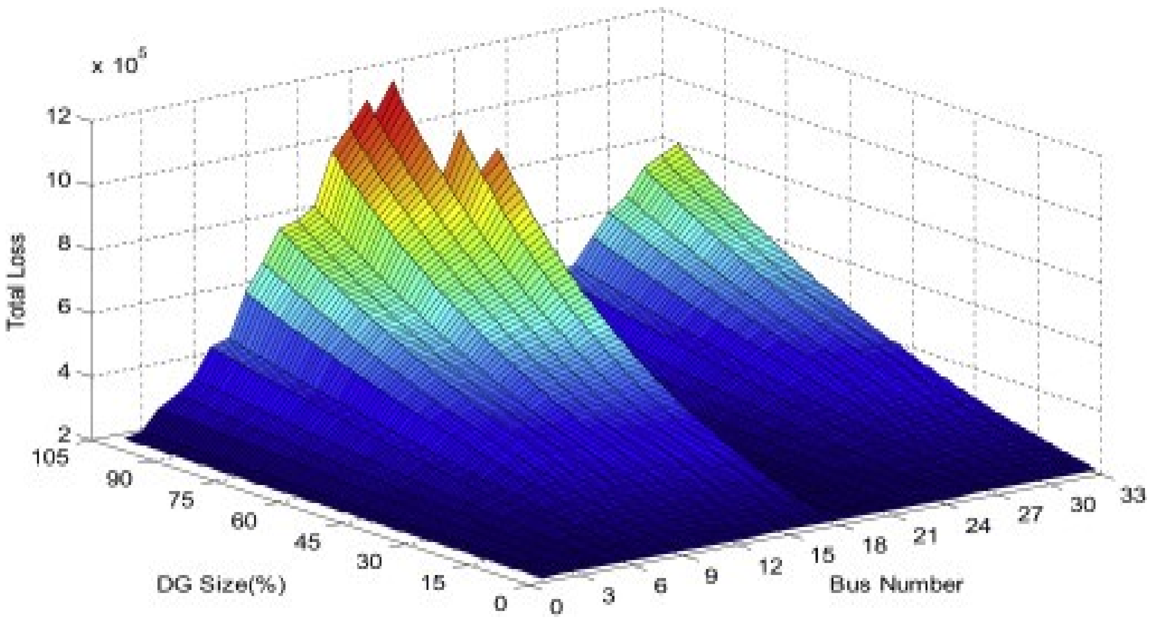


Figure 4Effects of sizes and locations of DG on the systems' loss

The basic and foremost result that is obvious from the above given figure, that qualities of appropriation of framework, that isn't fitting to build too higher DG within system. The sizes ought to be to an extent that it is useable inside the circulation substations' limit. An endeavor to introduce higher limit DG with the reason for sending out power past the substation (switch stream of energy however dissemination substation), will prompt high misfortunes. Along these lines, the measure of conveyance framework as far as load (MW) will assume a vital part in choosing the extent of DG. The purpose behind higher misfortunes at high limit of DG can be clarified by the way that the appropriation framework was at first composed with the end goal that influence streams alongside sending ends (cause substations) to heap and electrode sizes, bit by bit diminished from the substations to customer points. In this way, with the absence of the support of the framework, the utilization of higher limit DG prompts extreme power course via little measured conductor and thus brings about higher misfortunes.

Dispersed generation refers to a power resource installed in direct connection to customer sites or the distribution networks. This mainly has two features:

1. The location of DG on client side or in direct connection to the dispersion networks.

2. The demand-side source including energy effectiveness option and load managing system.

The interesting aspects of the DG source are that it is used as fulfilling customer demands plus generates powers on customers' sides. In modern days, distribution capacity contains every impact of DG and distributed source by reserving capacities to minimize the needs for the over dimensions of transmission/distribution systems.

Several methodologies are suggested to place and size the dispersed generator. In this research study, an easier technique to enhance voltage profile and to overcome the losses of power is proposed. Power flow analysis is undertaken after utilizing forward-backward sweeping techniques. Within RDS, optimal location to place DG unit is analysed through VSI method.

For finding the optimal position to place DG unit, various processes are devised. In the current research study, a method on the basis of VSI is devised to optimally place DG unit. Nodes with minimized values of VSI are regarded as the optimal position to place DG.

For obtaining optimum DG sizes, the following steps are used:

1. Nodes having minimized VSI are to be found initially whereby DG is situated at these nodes.
2. Supposing distributed generation power factors as consistent, sizes can be different within consistent steps from minimized value to maximized value (feeder load capability) until minimized loss is attained.
3. Sizes of DG producing minimized loss is regarded as the optimum sizes.

3.3.1 Example of Sizing and placing DG

The System which is used for this research is IEEE-33 bus system, having voltage 12.66 kV with summation real power demands of 3.715 MW whereby responsive power demands is 2.3MVAr. Within first case, load flows in the absence of DG is studied where bus voltage magnitude and entire power losses of networks within RDS are computed. At this stage, VSI of several buses is measured. From this study, it is estimated that bus 18 has low VSI values i.e. 0.66721. Therefore, the bus 18 is regarded as the optimum position to place DG. In order to analyse, the two cases are regarded as given below:

Case1: Operational DG at0.9powerfactorslag

Case2: Operational DG at unity power factors

To find optimum size of DG within both cases, its sizes vary from 0.5MVAto 10.0MVAwithinsteps of0.005MVA. The test results show that power loss is non-linearly different having generator capacity. Initially, power loss is reduced to slight minimized value and later enhances along with DG capability increments. Therefore, the test result shows that within the base case without the presence of DG, entire real and reactive power loss remain 210.99kWand143.03kVAr.On the other hand, the loss obtained after the placement of DG having 1MVAof lag power factors at 0.9generates higher loss decrease as compared to DG sized 0.85MVAof the unity power factors. Therefore, optimum placement and size of DG reflect power losses decrease within radial distribution systems. It is also observed that substation capability releases higher in first case as compared with the second case. Since DG uses reactive and real powers for the local load centre, it assists to improve bus voltage by reducing load side loss. Comparing voltage variations of various cases through base case (in the absence of DG), case 1 and 2 show that enhancement in voltages in case 1 is greater than case 2.

In the same way, a study is undertaken for IEEE-69 bus systems. This contains voltage 12.66kV and the entire real power demands about 3.802MWwhile reactive power demands are2.694MVAr. This study shows that bus 65 has low VSI values. Therefore, bus 65 contains optimum position to place DG.

3.4. Distribution Network Reconfiguration (DNR)

Reconfiguration of networks was initially presented by Back and Merlin, utilizing discrete subdivision and limit optimisation procedure to reduce network loss. Firstly, the switches were altogether shut to build a interconnected network, and then for each and other step, one by one branches were till the time the working configuration was discovered. DNR refers to a process that involves changing the network topology at different conditions of operating by altering open/close status of switches as discussed previously. In fact, DNR can be used for planning and instantaneous procedure of distribution network. As presented in Fig. 2-5, the exposed/shut position of the switches determines the structure of network system. To achieve reconfiguration of system, the tie-switch 3 is shut, that creates a new hoop. For the purpose, to restore network again at a radial structure, a switch from 1, 2, 4 and 5 is selected and opened.

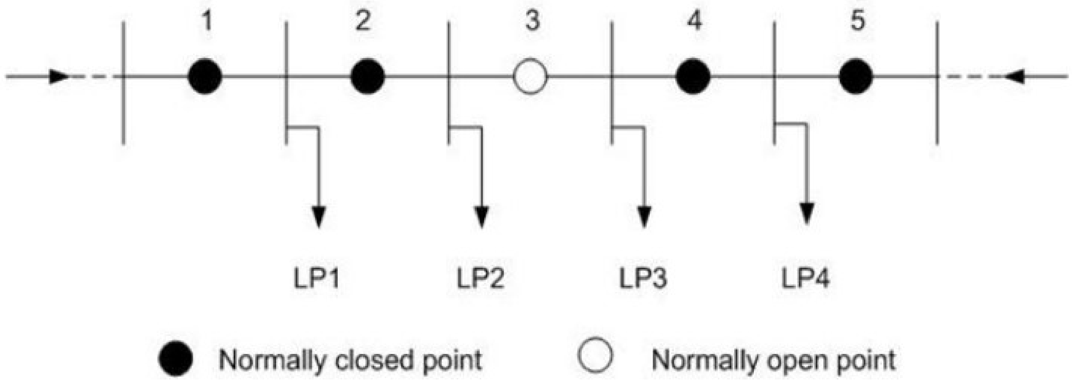


Figure 5 Radial test system

Since there are various combinations of switching, DNR is treated as a discrete and constrained optimisation problem. Recently, optimal DNR strategies, discussed in many literatures, have been implemented to achieve power loss reduction and reliability of system.

Network reconfiguration changes the basic structure of system of distribution by altering the status of switches, resulting in altering loads, i.e. from more burdened feeders to the lighter ones while, at one time maintains the working nature and structure of feeders of distribution. So, the difficulty of reconfiguration of network is in general to place the optimal switching configuration, which results in minimum losses. Reconfiguration of network is a challenging mission since there could be many probable combinations of 2 types of switches discussed earlier. But there are some conditions and rules that must not be violated during the process of optimization. All things considered, because of dynamic character of burdens, all out framework load is greater than its own age limit which causes assuaging the burden for feeders impractical including profile voltage of the framework will not be recouped at necessary side by side. So in order of getting together essential degree for burden request, DGs are joined for the dispersion system to improve profile of the given voltage, for giving dependable plus continuous force supplying, furthermore to attain gains in terms of money, as instance, minimum power loss, and strength effectiveness and to share burdens of feeders. However, arrange the configuration and DG position of distributed systems can be consider as freely [2].

Another early study for the reduction of loss via reconfiguration of network was done, which discussed how to achieve minimum power loss in distribution feeders through feeder reconfiguration. It is possible to determine loss variation by analysing the load flow results. This involved simulation of system configuration of previous and later feeder was reconfigure. It was based on a single pair switch operation per iteration. The relevant results showed that the loss was reduced only if the voltage across the tie-switch was significant and if the loads connected at the lower voltage side were transferred to the other side. This criterion was developed to eliminate undesirable switching options. The best switching option was then obtained from the results of load flow studies simulating all feasible feeder configurations.

It started with a feasible network operating in a radial configuration. The first step determined the loop that achieved maximum loss reduction by comparing the circle sizes for each loop. The largest circle indicated the maximum loss reduction. The second phase determined the switching options to be operated in that loop to provide maximum loss reduction. The smallest circle was identified for the best solution.

CHAPTER 4: METHODOLOGY

4.1. Overview and Introduction

Strawberry Plant algorithm (SPA) is a technique developed by Abdellah salih that is in nature similar to meta-heuristic optimization Algorithm [9]. The idea was took from the study of plant propagation routine. Its mathematical model demonstrates that the procedure of migration of SPA according to the suitable conditions according from a place to another, it also explains production to number of contenders and origins of the system, and SPA is a similar form of optimization. Similarly plants do the same activity by growing roots for firmness and runners for the external reach, to discover the resources like mineral and liquid. These parts, mentioned earlier are created randomly in strawberry plants, but when their these parts develop in a region, where a large quantity of resources are available, then the corresponding daughter plant develops more complex system of roots and runners at that place, which also impacts the overall growth.

So when an Algorithm is designed due to the inspiration of strawberry plant and suits the numerical algorithm optimization, then the algorithm formed is called strawberry plant algorithm (SPA). The following three facts help achieving the Strawberry plant Behaviour:

Every mother of said plant is developed through runners, due to random growth (global search for resources).

Roots and root hairs are developed arbitrarily in the mother of Strawberry Plant (local search for the needed resources).

The offspring plant that has reach to maximum resources grow rapidly and make itself stable by developing more roots and runners but the part which moves towards a place with less amount of resources is weak and eventually dies.

So, keeping in lieu the above given methods and processes, Following is a description of SPA:

pi plant is in place Xi in the measurement n. So, Xi = xi, j, for j= 1,……, n. Let NP the quantity of plants of strawberry used initially. Parameters used for process in SPA are the size NP are population that is equal to the number of strawberry plants, the maximum generations' gmax, and the maximum possible runners' nmax of every plant. This algorithm uses the independent function at different plant positions Xi = xi for i= 1,……, NP, in a normalized form Ni. The number of plant shoots n_{α}^{i} considered according to (1) below, has length dx^{i} measured with the help of the standardized form ofvalue Xi, each giving a $dx^{i}\epsilon(-1,1)^{n}$, as calculated with equation (2) below.

When all individual plants grow a standard amount of these parts then new population is calculated and sorted. Plants with low or zero growth are removed. So according to this number of plant runners are proportional to its fitness

$$n_{i}^{\alpha} = [n_{max}N_{i}\alpha], \qquad \alpha \in (0,1)$$

Every solution Xi produces minimum one runner and the length of that runner is inversely proportional to its growth as in 2 below,

$$dx_{j}^{i} = 2(1 - N_{i})(\alpha - 0.5), \quad forj = 1, \dots, n$$

Where dimension of problem is n. after the calculation of dx_{j}^{i}, the maximum point to which a runner can reach, so, the equation for its search will be:

$$y_{i,j} = x_{i,j} + (b_{j} - a_{j})dx_{j}^{i}, \qquad forj = 1, \dots, n$$

So by adjusting the search limits of domain the point will be in domain$[a_{j}, b_{j}]$, where $a_{j}, andb_{j}$lower and upper limits of the search space for the jth coordinate. Non-linear problems can be solved with this algorithm, non-continuous and non-differentiable space function as well. Time dependent objective functions, multi-dimensional and constraint optimization with penalty utilities can also be solved using this algorithm. So, due to above mentioned factors, the proposal is that, the said Algorithm is the best method of optimization for the explanation of problem which is under measured in this research work.

The general steps or phases of SPA can be explained in the following way:

Step 1: First of all, Read all parameters like line data and load data power flow is executed and calculate all system parameters for without DG case.

Step 2: Modify SPA Constraints population size, number of iterations and limits.

Step 3: Generate population by execution of power flow and calculate system parameters with DG case.

Step 4: Set Iteration=1

Step 5: Employed root' stage, for every employed root, produce a new position of water source. Compute the fitness value. Replacing positions old with new, if new position is better than old position.

Step 6: Compute the fitness function and the probability for solution.

Step 7: Onlooker runner' stage

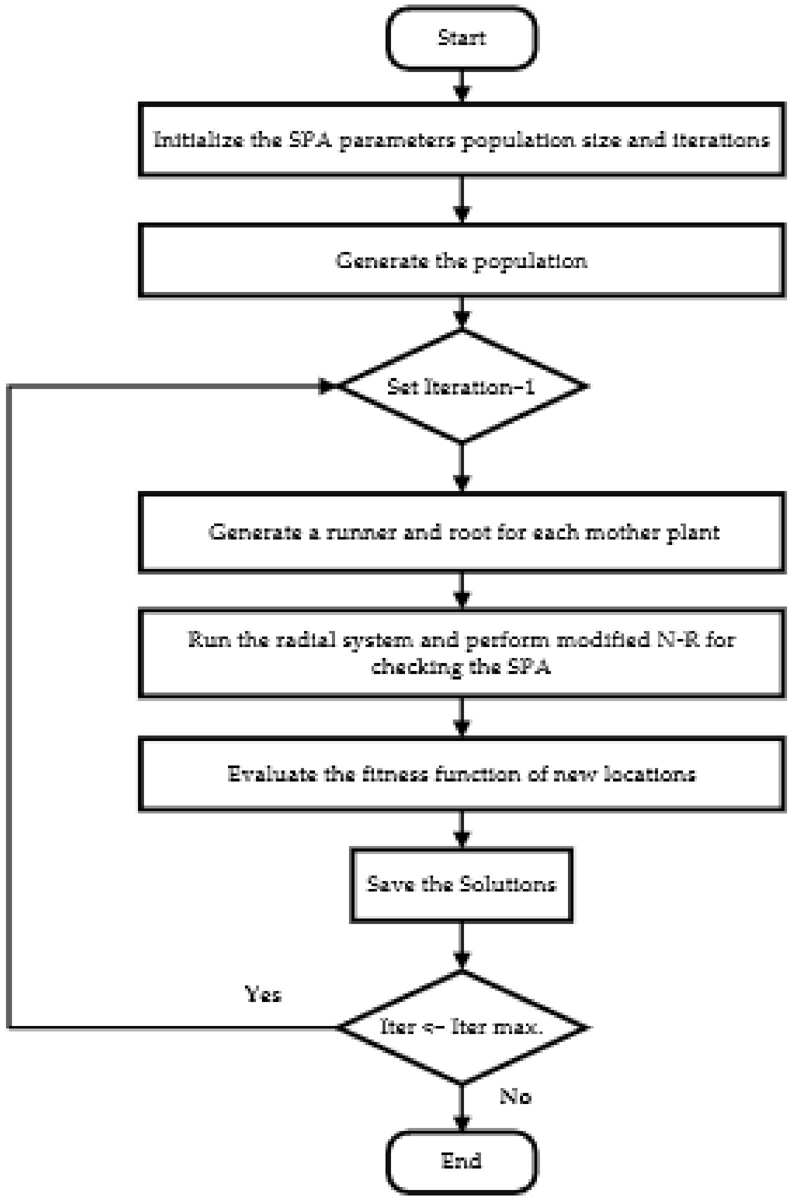
For every runner, select a water source depending on probability and produce a new position of water source.

Compute the fitness value. if new position is superior than old position then replace the positions.

Step 8: Scout root stage, Employed root is replaced with random source position if it becomes scout.

Step 9: Save the best solution in the memory.

Step 10: iteration = iteration + 1 until iteration = MI



Flowchart of Proposed Algorithm based on SPA

CHAPTER 5 : CONCLUSION/RESULTS AND DISCUSSION

5.1. Introduction

For Simulation purposes MATLAB programs that are for SPA and N-R power flow algorithm are used with the integration of Network Reconfiguration and DGs allocation. MATLAB 2018b in 2.50 GHz, i5, personal computer is used for the given simulations. Initially we took two cases with five different scenarios each and applied SPA algorithm on the standard networks of IEEE to examine the efficiency of the scheme. IEEE 69-bus system and IEEE 33-bus systems are took as mentioned cases. The power systems data was taken from [31–33] for case studies of both, respectively. Now the standards which are used in the study of these cases are defined, and are same for both. 1 p.u is taken as the substation value. We installed five DGs at max, As for a fact, it is studied that improvement ratio and loss reduction value is decreased when the location of candidate is increased by five at all load levels [16, 23]. The given method is suitable to be tested for any number of DGs, we kept it five for the safe side.

Therefore, the six different scenarios for each test system are established and listed below to examine the efficiency of proposed technique.

Scenario 1: The system is considered as without network reconfiguration and DG installation, this is called the Base case scenario.

Scenario 2: In this the said system is considered with reconfiguration of network only.

Scenario 3: For this scenario, said system is tested with installation of DG only.

Scenario 4: Stated System is measured with connection of DG (rating and prime position) and after the reconfiguration of given network.

Scenario 5: Stated System is considered with reconfiguration of the given network after installation of DG.

Minimum 100 iterations were performed on the objective function just to minimize the loss of power and voltage violations, to collect results of these scenarios, as shown in Equation (8). 69-bus and 33-bus these systems of distribution showed best results that are presented as follows.

Case Study 1 (33-Bus Distribution System)

Required data for this case study with branches, tie lines and loads is extracted from [24]. It contains 32 sectionalize switches with five tie lines as mentioned. At start configuration of the arrangement comprised of 32 normally closed sectionalize switches i.e: (switch number 1 - 32) plus five generally opened switches which are: (switch number 33 - 37). The diagram of 33-bus network of distribution with respect to the tie switches is illustrated below in figure 4. The total active power and reactive power capacity demand of this system is 3.72 MW and 2.3 MVAR, respectively. The initial loss of power value for this network without implementation any technique is 208.4592 kW. In first part of the implementation of the problem, voltage violations analysis (VV) is Calculated through the analysis of flow of power of the system to track the applicant buses DG's location for the situations III, IV and V. And After Calculating the VV of the network buses, they are arranged and graded in ascending direction. According to this VV analysis, the most sensitive buses will be encountered for the placement of DGs. As in our research work, we have considered 5% DG allocation to the total network buses. Therefore, subjected to this condition there will be 2 DGs required for our 33-bus network. Then the two most sensitive locations are nominated for placement of DG units in the network from the VSI analysis. The selected locations for the cases III, IV and V are given in Table 2.The output of the anticipated strawberry plant algorithm (SPA) is shown in Table 2 withfive different scenarios for solvingthe system reconfiguration and DGs allocation problem.

As it is obvious obtained results that loss of active power was significantly concentrated from an original value in all the given cases as shown in table 3. Initial loss of power before the reconfiguration and DGs allocation of the network was 208.4592 kW. But an impressive improvement is there in the percentage reduction of active power loss while employing reconfiguration and DGs allocation techniques by using SPA and PSO algorithms. It is worth to note that the percentage of active power loss reduction for scenarios 2 (only reconfiguration) is 28.0225% by using SPA optimization technique. As in our research work, we have considered three different types of DGs, to be optimized for their optimal sizing and placement. Therefore, scenarios 3, 4 and 5 are further classified into 3 categories. And the power loss reduction percentage for the scenario 3 is 59.909 % (DG type 1), 70.768 % (DG type 2), and 59.00824 % (DG type 3) by using SPA respectively. For scenario 4 the percentage power loss reduction by using SPA is 70.889 % (DG type 1), 65.489 % (DG type 2) and 64.501 % (DG type 3) respectively. Similarly, the reduction in percentage of power loss is 66.686 % (DG type 1), 72.246 % (DG type 2), and 69.079 % (DG type 3) by applying SPA after considering the scenario 5 respectively. Similar, process is executed by using PSO technique and the derived results are established in table 2. The power loss comparison by employing SPA and PSO have been expressed in figures 5 and 7. The second part of objective function was to improve the voltage profile of buses in the network. It is obvious from table 2 that profile of voltage is alconsiderably enhanced by reconfiguring the network and by locating the DGs on optimal locations by employing the SPA and PSO techniques. The comparison graphs of voltage profile of buses by using SPA and PSO are shown in figures 4 and 6. Comparing outcomes of these (SPA, and PSO) optimization procedures for this case study 1, conclusion comes out to be, that performance of SPA is more efficient than PSO in both parts of objective function. The comparative analysis between SPA and PSO results are established in table 2.

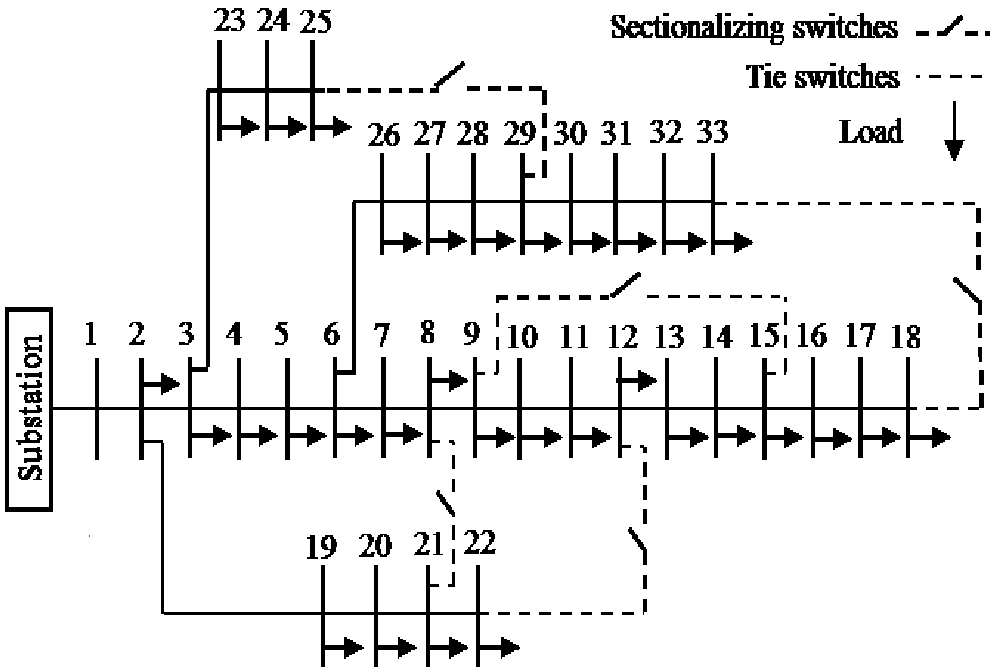


Figure 3. IEEE 33 bus distribution network

Table 3: Performance Analysis for 33 bus System

Scenario	Item	PSO		Proposed SPA	
Base Case (Scenario 1)	Opened switches	33, 34, 35, 36, 37		33, 34, 35, 36, 37	
	DG Placement	N/A		N/A	
	DG Size	N/A		N/A	
	Active power loss (kw)	208.4592 kW		208.4592 kW	
	Active power Loss Reduction (%)	N/A		N/A	
	Minimum voltage bus [p.u]	0.91075		0.91075	
Only Reconfiguration (Scenario 2)	Opened switches	7, 14, 32, 35, 37		7, 10, 14, 27, 31	
	DG placement	N/A		N/A	
	DG Size	N/A		N/A	
	Active power loss (kw)	150.8868 kW		150.133 kW	
	Active power loss reduction (%)	27.6642 %		28.0225 %	
	Minimum voltage bus (p.u)	0.932		0.939	
Only DG Installation (Scenario 3)	DG Type 1:				
	Open switches	N/A		N/A	
a) DG Type 1 (Inject	DG placement	3	6	3	6
	DG size MW	1.2781	2.2466	1.283	2.2429
	Active power loss (kw)	87.4674 kW		83.5724 kW	

active power)	Power loss reduction (%) Minimum voltage (p.u)	58.041 % 0.95187	59.909 % 0.97084
b) DG Type 2 (Inject active and reactive power)	DG Type 2: Open switches DG placement DG size (MW) DG size (MVAR) Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u)	N/A 3 6 1.234 2.2199 0.62811 1.5722 62.9239 kW 69.815 % 0.95735	N/A 3 6 1.2214 2.2354 0.62089 1.5492 60.9385 kW 70.768 % 0.9665
c) DG Type 3 (Inject active power but absorb	DG Type 3: Open switches DG placement DG size (MW) DG size (MVAR) Active power loss (kw)	N/A 3 6 1.2777 2.247 0 0 87.4671 kW 58.0411 % 0.95288	N/A 3 6 1.2729 2.2475 0 0 85.4511 kW 59. 00824% 0.9612

reactive power)	Power loss reduction (%) Minimum voltage (p.u)		

DG Installation After Reconfiguration (Scenario 4)	DG Type 1:		
	Open Switches	7, 9, 14, 27, 32	7, 9, 14, 27, 31
	DG placement	3 24	20 3
	DG size (MW)	0.97299 1.6716	1.5052 2.2461
	Active power loss (kw)	64.461 kW	60.6867 kW
	Power loss reduction (%)	69.0774 %	70.889 %
	Minimum voltage (p.u)	0.94932	0.95072
	DG Type 2:		
	Open Switches	7, 11,14, 32, 37	7, 10, 14, 27, 31
	DG placement	3 20	20 3
	DG size (MW)	2.4727 1.2599	1.4746 2.2276
	DG size (MVAR)	1.7104 0.61414	0.76559 1.6249
	Active power loss (kw)	79.1892 kW	71.9411 kW
	Power loss reduction (%)	62.0121 %	65.489 %
	Minimum voltage (p.u)	0.95697	0.96912
	DG Type 3:		
	Open Switches	7, 11, 14, 32, 37	7, 10, 14, 27, 31
	DG placement	3 20	20 3
		2.485 1.2649	1.5042 2.2369

	DG size (MW) DG size (MVAR) Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u)	0 0 79.2289 kW 61.9931 % 0.95597	0 0 74.002 kW 64.501 % 0.9615
Reconfiguration after DG Installation (Scenario 5)	DG Type 1: Open Switches DG placement DG size (MW) Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u) DG Type 2: Open Switches DG placement DG size (MW) DG size (MVAR) Active power loss (kw)	2, 3, 6, 8, 9 3 6 1.2776 2.2469 87.4671 kW 58.0411 % o.96171 14, 20, 35, 36, 37 3 6 1.234 2.2197 0.62519 1.5725 62.9235 kW 69.815 % 0.96474	7, 10, 14, 17, 24 3 6 1.2676 2.2516 69.447 kW 66.686 % 0.97574 5, 10, 14, 24, 31 3 6 1.1832 2.2158 0.66022 1.5563 57.855 kW 72.246 %

	Power loss reduction (%) Minimum voltage (p.u) DG Type 3: Open Switches DG placement DG size (MW) DG size (MVAR) Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u)	5, 11, 14, 27, 32 3 6 0.68273 0.70363 0.37782 0.02867 94.2782 kW 54.7738 % 0.95145	0.9788 7, 10, 14, 17, 24 3 6 1.2787 2.2432 0 0 64.457 kW 69.079 % 0.9629

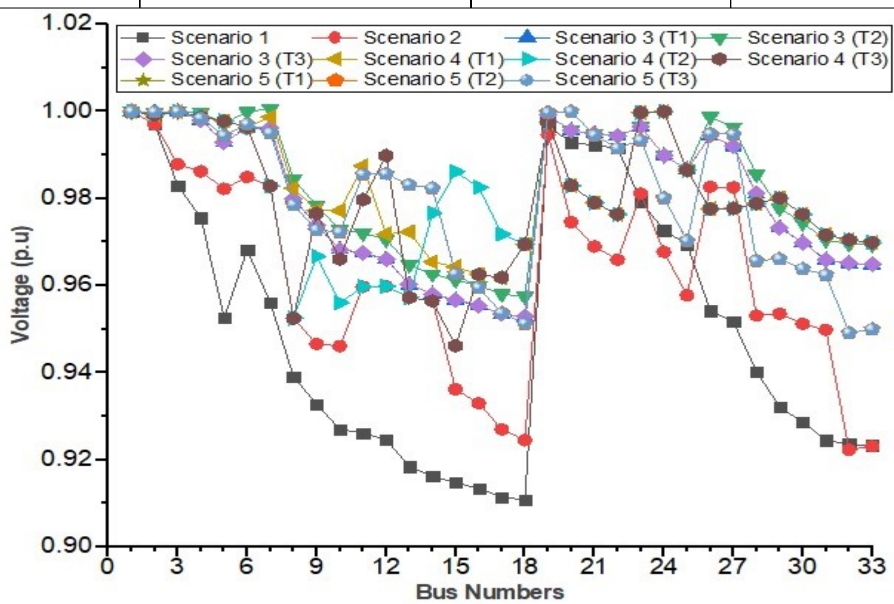


Figure 4. Comparison of voltage profile of buses in 5 scenarios by using SPA

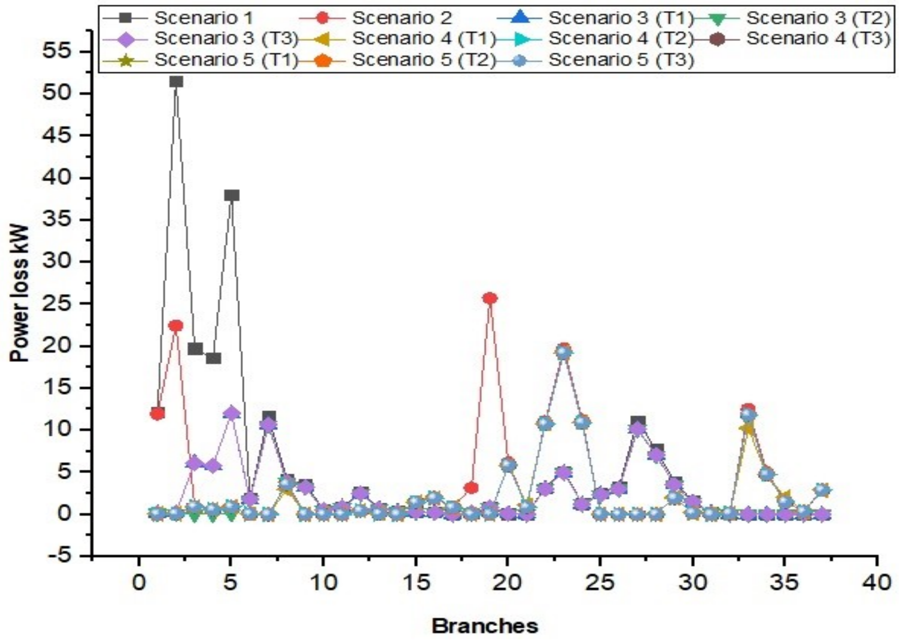


Figure 5. Comparison of power loss in 5 scenarios by using SPA

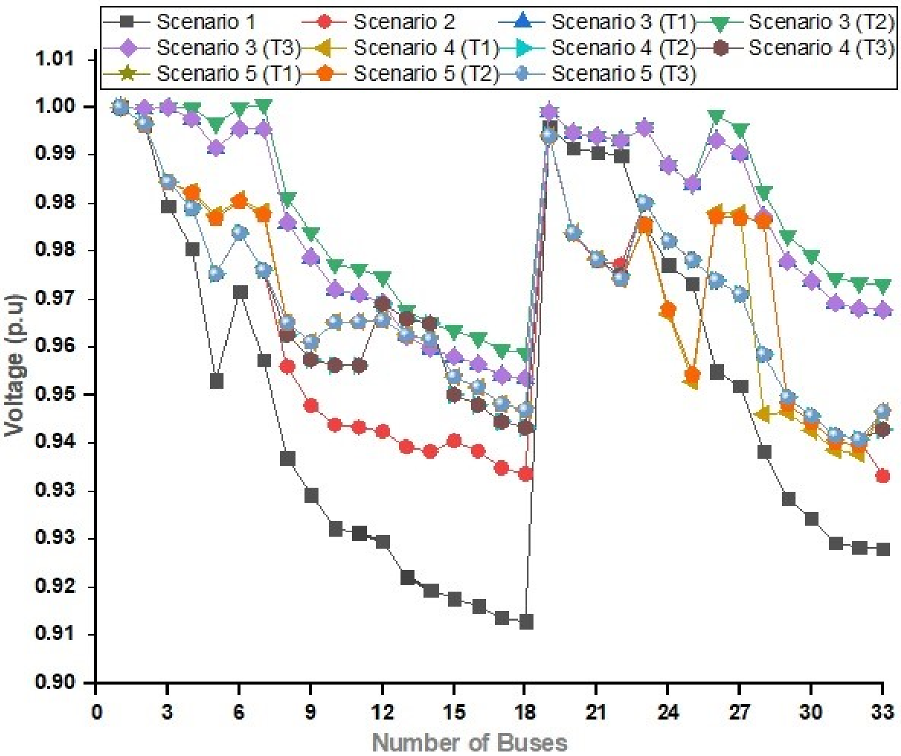


Figure 6. Comparison of voltage profile of buses in 5 scenarios by using PSO

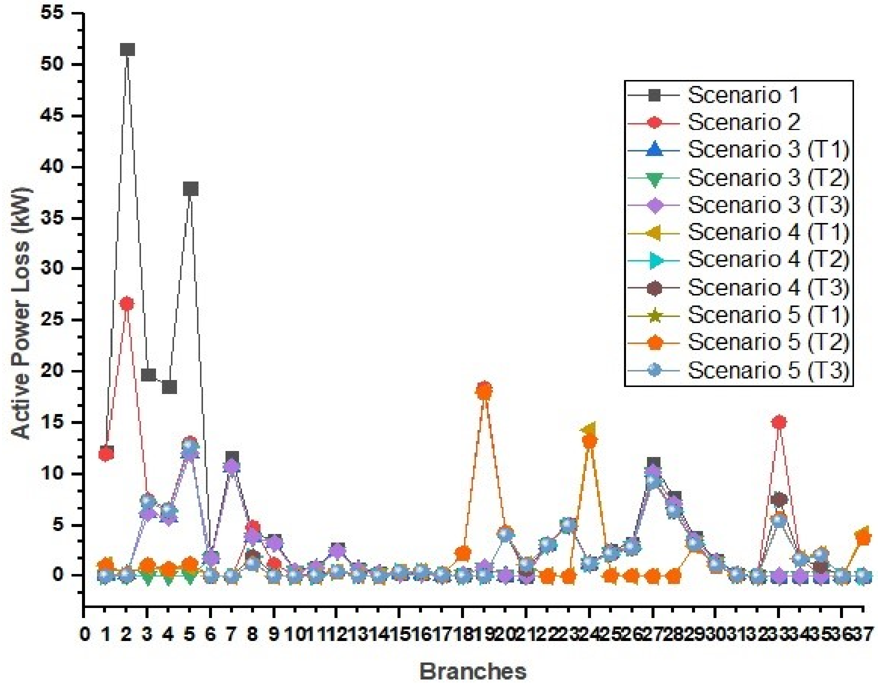


Figure 7. Comparison of power loss in 5 scenarios by using PSO

Case Study 2 (69-Bus Distribution System)

The mentioned IEEE trial network (radial system of Distribution) contains 69-buses and 73 branches which is shown in figure (4). There are 68 sectionalize switched with five open/tie switches in the structure. The initial arrangement has 68 generally closed switches i.e: (switch No 1 - 68), five typically tie switches that are (69 - 73). The sum of whole active and reactive power load demand is 3802 kW and 2696 kVAR, individually. In normal situation without reconfiguration and DGs allocations in this system the active power loss was 225.0007 kW. Similar to case study 1 (33 bus network), the simulation of said system for proposed five scenarios and the results are presented in Table 4. Firstly, VV analysis is performed from the power flow analysis of the system to figure out the Location of DGs for applicant bus for the scenarios III, IV and V. Later analysis of VV of the network buses, they are arranged and graded in ascending direction. According to this VV analysis, the most sensitive buses will be encountered for the placement of DGs. Therefore, subjected to the condition of 5% here 4 DGs will be required for the placement in 69-bus network. The size and selected locations of DGs for the scenario III, IV and V are shown in Table 4.

It is obvious from the derived results that the impact of DGs allocations and reconfiguration is different with respect to each scenario. It can be analyzed that the real power losses were significantly reduced from an original value (225.0007 kW) for all the respective scenarios as shown in table No 3. Preliminary power loss value was 225.0007 kW. However, there is notable improvement of the percentage decrease of active losses of power and voltage profile of buses (minimize voltage violations) while employing reconfiguration and DGs provision techniques of Using SPA and PSO algorithms. It can be analyzed that the real power loss percentage for scenarios 2 (only reconfiguration) is 57.325% by applying SPA optimization technique. Similarly, we have considered three different types of DGs for optimal location in the network like in case study 1. Thus, scenarios 3, 4 and 5 are further divided into 3 categories. If we examine the results of scenario 3, the percentage power loss reduction is 80.847 % (DG type 1), 80.437 % (DG type 2), and 79.86 % (DG type 3) by using SPA respectively. Similarly, the power loss reduction percentage by using SPA is 93.4724 % (DG type 1), 93.3955 % (DG type 2) and 93.3961 % (DG type 3) respectively for scenario 4. In scenario 5 it can be analyzed that the reduction in percentage of power loss is 84.62 % (DG type 1), 84.27 % (DG type 2), and 80.2712 % (DG type 3) respectively after the implementation of SPA. These all five scenarios are also executed by PSO technique. The detailed comparison of PSO outcomes are expressed in table 3. Power loss comparison by employing SPA and PSO have been expressed in figures 9 and 11. The second part of objective function was to improve the voltage profile of buses (minimization of voltage violations). Profile of voltage improvement according to each scenario is also shown in table 3 by expressing the minimum voltage at any bus in the network. It can also be seen from table 3 that the voltage profile is also significantly enhanced by reconfiguring the network and by locating the DGs on optimal locations by employing the SPA and PSO techniques. The comparison graphs of voltage profile of buses by using SPA and PSO have been shown in shown in figures 8 and 10. The Comparison of Results of these systems (SPA and PSO) techniques in this case study no 2, shows that the SPA produced more efficient, consistent and balanced results than the PSO method.

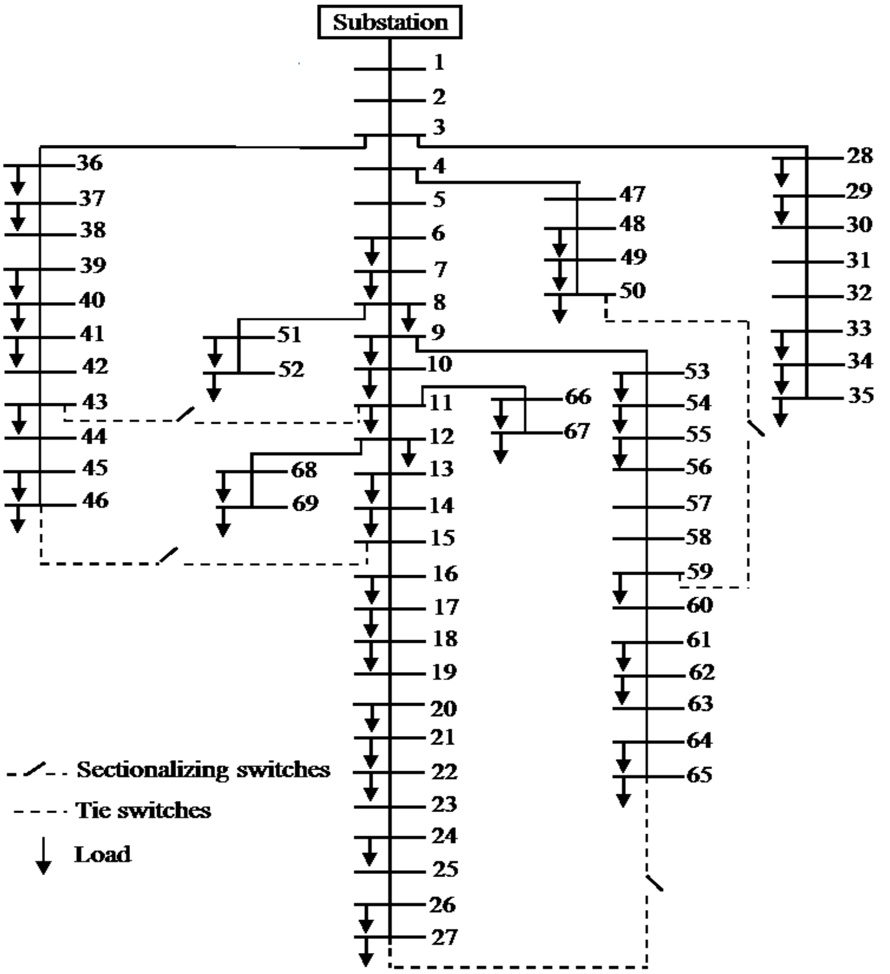


Figure 4.IEEE 69 bus distribution network

Table 4: Performance Analysis for 69 bus System

Scenario	Item	PSO	Proposed SPA
Base Case (Scenario 1)	Opened switches	69, 70, 71, 72, 73	69, 70, 71, 72, 73
	DG Placement	N/A	N/A
	DG Size	N/A	N/A
	Active power loss (kw)	225.0007 kW	225.0007 kW
	Active power Loss reduction (%)	N/A 0.90919	N/A 0.90919

	Minimum voltage bus [p.u]		
Only Reconfiguration (Scenario 2)	Opened switches DG placement DG Size Active power loss (kw) Active power loss Reduction (%) Minimum voltage bus (p.u)	14, 56, 61, 69, 70 N/A N/A 98.6039 kW 56.1762 % 0.94947	13, 19, 40, 52, 61 N/A N/A 96.021 kW 57.325 % 0.94995
Only DG Installation (Scenario 3) a) DG Type 1 (Inject active power only) b) DG Type 2 (Inject active and	DG Type 1: Open switches DG placement & DG size MW Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u) DG Type 2: Open switches	 N/A MW MVAR [57] 0.092484 0 [7] 1.017 0 [6] 0.027991 0 [58] 1.7328 0 46.8699 kW 79.169 % 0.97128 N/A MW MVAR	 N/A MW MVAR [57] 0.0695 0 [7] 1.073 0 [6] 0 0 [58] 1.75 0 43.0953 kW 80.847 % 0.97829 N/A MW MVAR

reactive power)	DG placement & DG size MW Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u)	[57] 0.061 0.046 [7] 0.97 0.681 [6] 0.012 0.007 [58] 1.72 1.209 46.0272 kW 79.5435 % 0.97829	[57] 0.126 0.135 [7] 0.981 0.608 [6] 0 0.125 [58] 1.653 1.178 44.0165 kW 80.437 % 0.9791
c) DG Type 3 (Inject active power but absorb reactive power)	DG Type 3: Open switches DG placement & DG size MW Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u)	N/A MW MVAR [57] 0.092 0 [7] 1.0176 0 [6] 0.028 0 [58] 1.74 0 49.8782 kW 77.832 % 0.9782	N/A MW MVAR [57] 0 0 [7] 1.064 0 [6] 0 0 [58] 1.84 0 45.31 kW 79.86 % 0.9850
DG Installation after Reconfiguration (Scenario 4)	DG Type 1: Open switches DG placement & DG size MW	14, 56, 61, 69, 70 MW MVAR	14, 18, 40, 52, 61 MW MVAR

		[59] 0.131 0 [49] 0.80 0 [61] 1.25 0 [60] 0.003 0	[59] 0.225 0 [49] 0.846 0 [10] 1.312 0 [61] 1.199 0
	Active power loss (kw)	26.3339 kW	14.6872 kW
	Power loss reduction (%)	88.2961 %	93.4724 %
	Minimum voltage (p.u)	0.96508	0.9773
	DG Type 2:		
	Open switches	14, 18, 40, 56, 61	14, 18, 40, 52, 61
	DG placement & DG size MW	MW MVAR [59] 0.117 0.077 [49] 0.774 0.556 [10] 1.326 0.917 [61] 1.243 0.894	MW MVAR [59]0.147 0.0682 [49]0.827 0.5394 [10]1.223 0.8726 [61]1.272 0.8879
	Active power loss (kw)	24.581 kW	14.86801 kW
	Power loss reduction (%)	89.075 %	93.3955 %
	Minimum voltage (p.u)	0.977	0.982
	DG Type 3:		

	Open switches DG placement & DG size MW Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u)	14, 18, 40, 56, 61 MW MVAR [59] 0.129 0 [49] 0.799 0 [61] 1.246 0 [60] 0.0097 0 26.3342 kW 88.2959 % 0.96508	13, 18, 40, 52, 61 MW MVAR [59] 0.2440 0 [49] 0.7279 0 [10] 1.3307 0 [61] 1.2583 0 14.8588 kW 93.3961 % 0.97746

Reconfiguration after DG Installation (Scenario 5)	DG Type 1: Open switches DG placement & DG size MW Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u) DG Type 2: Open switches DG placement & DG size MW Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u)	 6, 14, 64, 69, 70 MW MVAR [57] 0 0 [7] 1.034 0 [6] 0.028 0 [58] 1.81 0 39.8491 kW 82.2894 % 0.9829 14, 56, 64, 69, 70 MW MVAR [57] 0 0 [7] 0.991 0.694 [6] 0.011 0 [58] 1.77 1.244 39.8918 kW 82.2704 % 0.9829	 6, 14, 64, 69, 70 MW MVAR [57] 0.1084 0 [7] 1.0293 0 [6] 0 0 [58] 1.7104 0 34.6142 kW 84.62 % 0.9890 14, 18, 26, 40, 52 MW MVAR [57] 0.534 0.432 [7] 0.1161 0.223 [6] 0.9337 0.513 [58] 0.848 0.671 35.39 kW 84.27 %

	DG Type 3: Open switches DG placement & DG size MW Active power loss (kw) Power loss reduction (%) Minimum voltage (p.u)	14, 56, 64, 69, 70 MW MVAR [57] 0 0 [7] 1.039 0 [6] 0.028 0 [58] 1.805 0 47.1013 kW 79.0662 % 0.97829	0.9908 14, 19, 26, 40, 52 MW MVAR [57] 0 0 [7] 0.943 0 [6] 0.139 0 [58] 1.81 0 44.39 kW 80.2712 % 0.9808

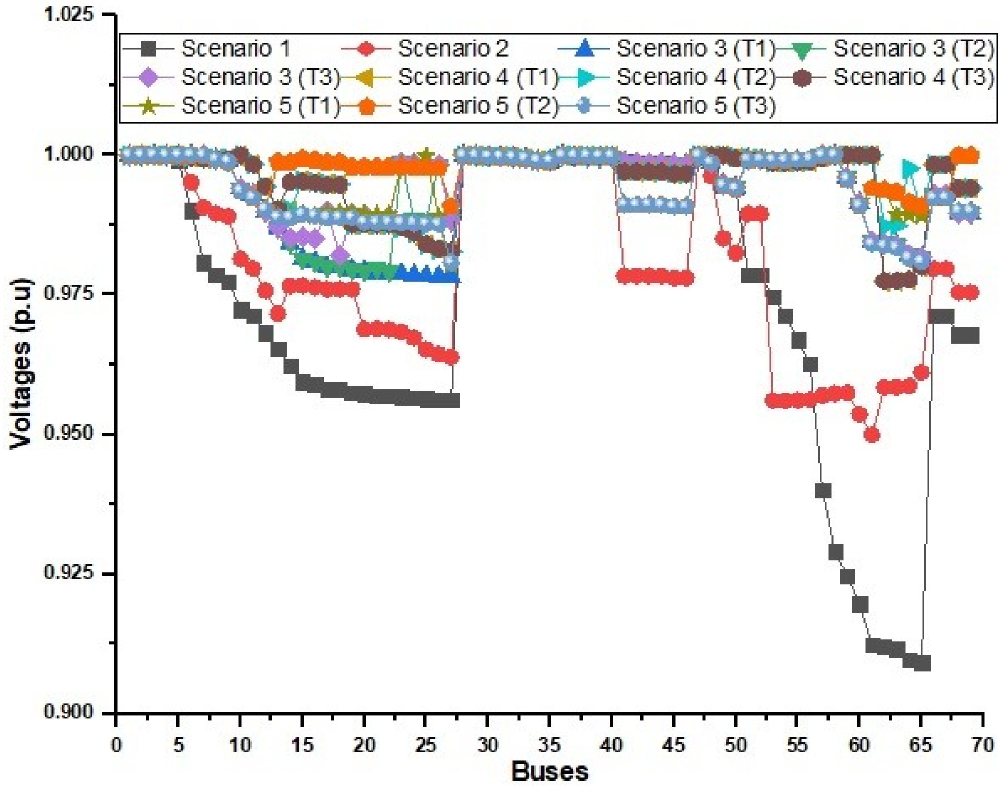


Figure 8. Comparison of voltage profile of buses in 5 scenarios by using SPA

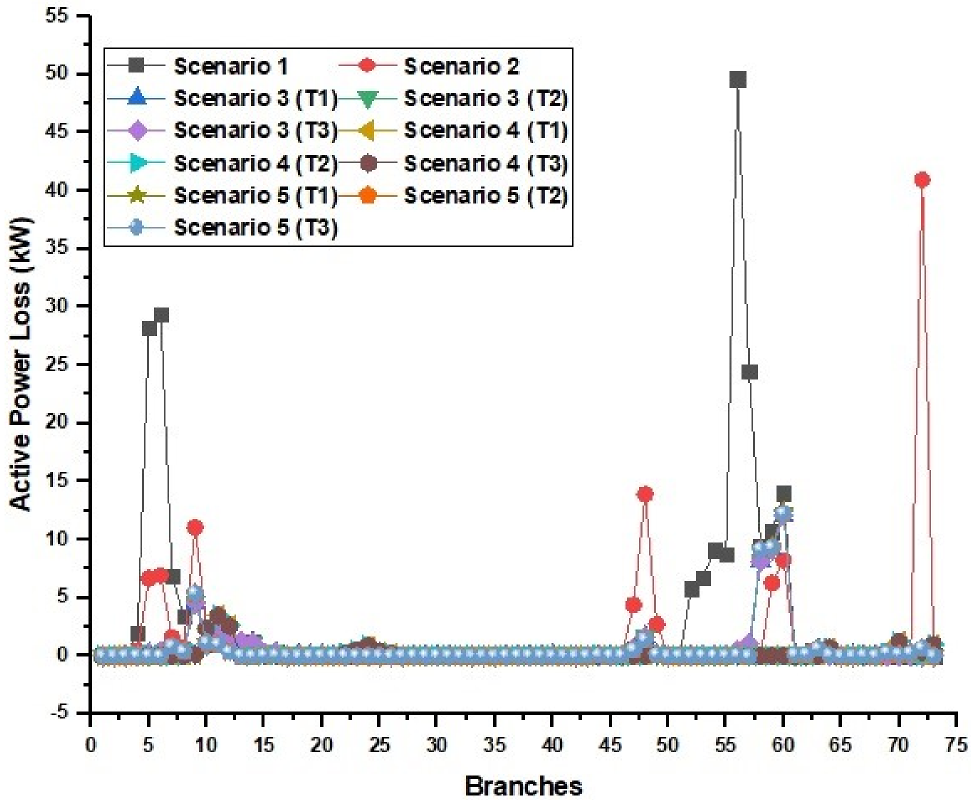


Figure 9. Comparison of power loss in 5 scenarios by using SPA

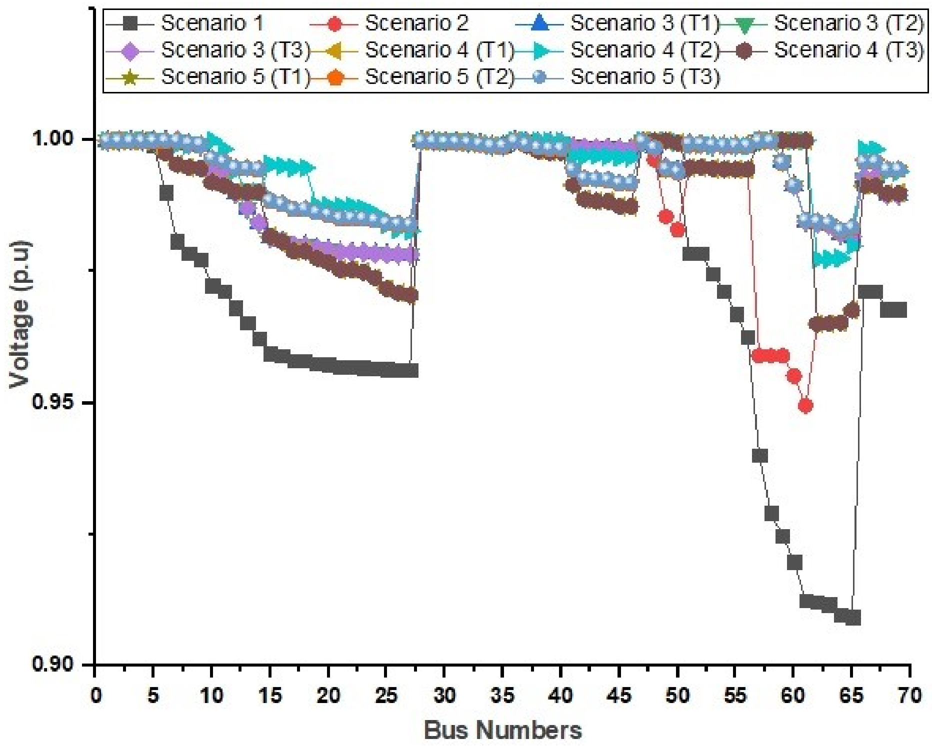


Figure 10. Comparison of voltage profile of buses in 5 scenarios by using PSO

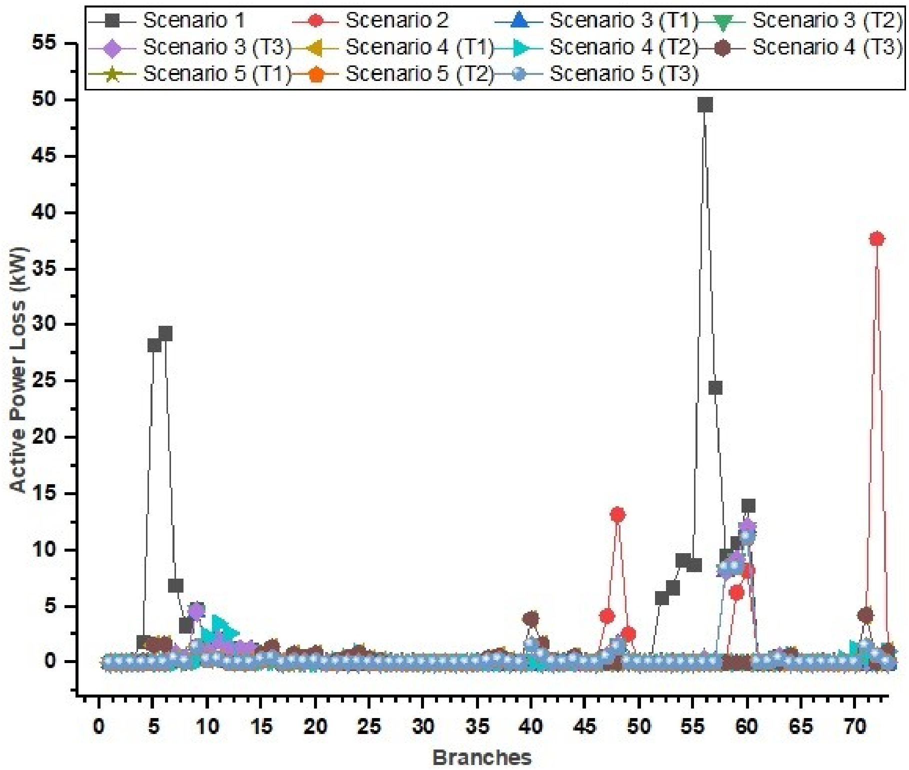


Figure 11. Comparison of power loss in 5 scenarios by using PSO

CHAPTER 6: CONCLUSION AND FUTURE WORK

6.1 Conclusion

The work of this conducted research comprises of investigation of application of integrating reconfiguration of network and for minimization of losses of power and violation in voltages, placement of DGs, using SPA. Method that is proposed maintains the actual working environment of the working network and flow of current in the proper course in whole system in phases of all reconfiguration of Network, due to the generation of an actual path between parent node and child node and doing so, forming BIBC matrix in the time of flow of power. This anticipated method is tested on the test system bus 69- and 33-, by considering five diverse scenarios. So the outcomes and results obviously prove that scenario IV (reconfiguration of Network with concurrent installation of DG) is more effective in solving the problem of reducing the loss of power and enhancing the profile of Voltage on the comparison to other different situations of similar nature. No doubt, that the method researched and proposed in this Study is ideal in solving all the situations and simulations that were tested. The results compiled after different situations and simulations clearly prove that SPA is much better than PSO. This Method can be applied to every large scale working Networks of Distribution and can easily be amended.

6.2 Recommendations and Scope of Future Work

This work done is important in the said field and is done on the basis of the idea of solving multiple problems simultaneously. These kind of problems are hard to solve as they include many acute aspects that need attention minutely. It helps in achieving maximum output while losing only a part of power that is being lost currently. DGs serve multi purposely, first in cutting cost and the other in the losses of line while transmission. So this is a solution to multiple problems and does affect any of it in any capacity. It serves multipurpose, in which all objectives optimized simultaneously. The future work is to solve multiple problems with simple yet comprehensive solutions and through this, an approach will prevail in which cost of DGs can be considered as another objective.

BIBLIOGRAPHY

[1] Merlin, A. (1975). Search for a minimal-loss operating spanning tree configuration for an urban power distribution system. *Proc. of 5th PSCC, 1975*, *1*, 1-18.

[2] Enacheanu, B., Raison, B., Caire, R., Devaux, O., Bienia, W., & Hadjsaid, N. (2008). Radial network reconfiguration using genetic algorithm based on the Metroid theory. *IEEE Transactions on Power Systems*, *23*(1), 186-195.

[3] Ochoa, Luis F., and Gareth P. Harrison. "Minimizing energy losses: Optimal accommodation and smart operation of renewable distributed generation." IEEE Transactions on Power Systems 26.1 (2011): 198-205.

[4] Acharya, Naresh, PukarMahat, and NadarajahMithulananthan. "An analytical approach for DG allocation in primary distribution network." International Journal of Electrical Power & Energy Systems 28.10 (2006): 669-678.

[5] Gozel, Tuba, et al. "Optimal placement and sizing of distributed generation on radial feeder with different static load models." International conference on future power systems. 2005.

[6] Celli, Gianni, et al. "A multi objective evolutionary algorithm for the sizing and siting of distributed generation." IEEE Transactions on power systems 20.2 (2005): 750-757.

[7] Ghosh, Sudipta, Sakti Prasad Ghoshal, and Saradindu Ghosh. "Optimal sizing and placement of distributed generation in a network system." International Journal of Electrical Power & Energy Systems 32.8 (2010): 849-856.

[8] Nara, K., Shiose, A., Kitagawa, M., & Ishihara, T. (1992). Implementation of genetic algorithm for distribution systems loss minimum re-configuration. *IEEE Transactions on Power systems*, *7*(3), 1044-1051.

[9] Jena, S., & Chauhan, S. (2016, May). Solving distribution feeder reconfiguration and concurrent dg installation problems for power loss minimization by multi swarm cooperative PSO algorithm. In *Transmission and Distribution Conference and Exposition (T&D), 2016 IEEE/PES* (pp. 1-9). IEEE.

[10] Flaihs, F. M., Lin, X., Abd, M. K., Dawoud, S. M., Li, Z., & Adio, O. S. (2017). A new method for distribution network reconfiguration analysis under different load demands. *Energies*, *10*(4), 455.

[11] A. Salhi and E. S. Fraga, “Nature-inspired optimization approaches and the new plant propagation algorithm,” in Proceedings of the The International Conference on Numerical Analysis and Optimization (ICeMATH '11), Yogyakarta, Indonesia, 2011.

[12] Celli, G., and F. Pilo. "Optimal distributed generation allocation in MV distribution networks." Power Industry Computer Applications, 2001. PICA 2001. Innovative Computing for Power-Electric Energy Meets the Market. 22nd IEEE Power Engineering Society International Conference on. IEEE, 2001.

[13] Graham, W., A. James and R. Mc-Donald, 2000. *“Optimal placement of distributed generation sources in power systems.”* IEEE Trans. Power Sys. 19(5): 127-134.

[14] EI-hattam, W. and M.M.A. Salma, 2004. “*Distributed generation technologies, definitions and benefits*.” Electric. Power Sys. Res., 71: 119-1283.

[15] H. Iyer, S. Ray, and R. Ramakumar, *“Voltage Profile Improvement with Distributed Generation*”, 0-7803-9156-X/05/ ©2005 IEEE

[16] C. L. Su, *“Comparative Analysis of Voltage Control Strategies in Distribution Networks with Distributed Generation*”, 978-1-4244-4241-6/09/ ©2009 IEEE

[17] Minnan Wang and JinZhong, *“A Novel Method for Distributed Generation and Capacitor Optimal Placement considering Voltage Profiles”,* 978-1-4577-1002-5/11/©2011 IEEE

[18] Pandi, V. Ravikumar, H. H. Zeineldin, and Weidong Xiao. "Determining optimal location and size of distributed generation resources considering harmonic and protection coordination limits." IEEE Transactions on Power Systems 28.2 (2013): 1245-1254.

[19] Bo Xing & Wen-Jing Gao Innovative Computational Intelligence: A Rough Guide to 134 clever Algorithms, Springer

[20] Jose, S., Singh, H. P., Batish, D. R., & Kohli, R. K. (Eds.). (2013). Invasive plant ecology. BocaRaton: Taylor & Francis Group, LLC, ISBN 978-1-7398-8127-9.

[21] Acharya, Naresh, PukarMahat, and NadarajahMithulananthan. "An analytical approach for DG allocation in primary distribution network." International Journal of Electrical Power & Energy Systems 28.10 (2006): 669-678.

[22] Mallahzadeh, A. R., Es'Haghi, S., & Hassani, H. R. (2009). Compact U-array MIMO antenna designs using IWO algorithm. International Journal of RF and Microwave Computer-Aided Engineering, 19, 568–576.

[23] Ghosh, A., Das, S., Chowdhury, A., & Giri, R. (2011). An ecologically inspired direct search method for solving optimal control problems with Bézier parameterization. Engineering Applications of Artificial Intelligence, 24, 1195–1203.

[24] Hajimirsadeghi, H., Ghazanfari, A., Rahimi-Kian, A., & Lucas, C. (2009). Cooperative

[25] Co-evolutionary invasive weed optimization and its application to nash equilibrium search in electricity markets. In World Congress on Nature and Biologically Inspired Computing (NaBIC), (pp. 1532–1535). IEEE.

[26] Pourjafari, E., &Mojallali, H. (2012). Solving nonlinear equations systems with a new approach based on invasive weed optimization algorithm and clustering. Swarm and Evolutionary Computation, 4, 33–43.

[27] H. Fudou, T. Genji, Y. Fukuyamam and Y. Nakanishi, "A genetic algorithm for network reconfiguration using three unbalanced load flow", Intelligent System Applications to Power System (ISAP"97), Seoul, Korea, 1997, pp. 1-5.

[28] Ray Daniel Zimmerman, Network Reconfiguration for Loss Minimization in Three Phase Power Distribution System, Cornel University, May 1992

[29] Ali Reza Fereidunian, Hamid Lesani and Caro Lucas "Distribution systems reconfiguration using pattern recognizer neural networks" IJE International: Applications Vol. 15, No. 2, July 2002 – 135

[30] H. Kim, "ANN based feeder reconfiguration for loss reduction in distribution system", IEEE Transaction on Power Delivery, Vol. 8,No. 3, 1993, pp. 1356-1366.

[31] Verma, H.K. and Singh, P., 2018. Optimal Reconfiguration of Distribution Network Using Modified Culture Algorithm. Journal of The Institution of Engineers (India): Series B, 2018, 6, pp.613-622.

[32] Sarfi, R.J., Salama, M.M.A. and Chikhani, A.Y., 1994. A survey of the state of the art in distribution system reconfiguration for system loss reduction. Electric Power Systems Research, 1994, 31(1), pp.61-70.

[33] Nguyen, T.T.; Truong, A.V. Distribution network reconfiguration for power loss minimization and voltage profile improvement using cuckoo search algorithm. Int. J. Electr. Power Energy Syst. 2015, 68, 233–242.

[34] Baran, M.E.; Wu, F.F. Network reconfiguration in distribution systems for loss reduction and load balancing. IEEE Trans. Power Deliv. 1989, 4, 1401–1407.

[35] Sultana, B.; Mustafa, M.W.; Sultana, U.; Bhatti, A.R. Review on reliability improvement and power loss reduction in distribution system via network reconfiguration. Renew. Sustain. Energy Rev. 2016, 66, 297–310.

[36] Kalambe S, Agnihorti G. Loss minimization techniques used in distribution network: bibliographical survey. Renew Sustain Energy Rev, 2014; 29:184–200.

[37] Imran, A.M.; Kowsalya, M. A new power system reconfiguration scheme for power loss minimization and voltage profile enhancement using fireworks algorithm. Int. J. Electr. Power Energy Syst. 2014, 62, 312–322.

[38] Shirmohammadi, D.; Hong, H.W. Reconfiguration of electric distribution networks for resistive line losses reduction. IEEE Trans. Power Deliv. 1989, 4, 1492–1498.

[39] Aman, M.M., Jasmon, G.B., Bakar, A.H.A. and Mokhlis, H. Optimum network reconfiguration based on maximization of system loadability using continuation power flow theorem. International journal of electrical power & energy systems, 2013, 54, pp.123-133.

[40] Kumar, K. Sathish, and T. Jayabarathi. Power system reconfiguration and loss minimization for an distribution systems using bacterial foraging optimization algorithm. International Journal of Electrical Power & Energy Systems, 2012, 36, pp. 13-17.

[41] Niknam, Taher, Abdollah Kavousi Fard, and Alireza Seifi. Distribution feeder reconfiguration considering fuel cell/wind/photovoltaic power plants. Renewable energy, 2012, 37, pp. 213-225.

[42] Wang, Chun, and Yuanhai Gao. Determination of power distribution network configuration using non-revisiting genetic algorithm. IEEE Transactions on Power System, 2013, 28, pp. 3638-3648.

[43] Acharya, Naresh, Pukar Mahat, and Nadarajah Mithulananthan. An analytical approach for DG allocation in primary distribution network. International Journal of Electrical Power & Energy Systems, 2006, 28, pp. 669-678.

[44] Hung, Duong Quoc, and Nadarajah Mithulananthan. Multiple distributed generator placement in primary distribution networks for loss reduction. IEEE Transactions on industrial electronics, 2011, 60, pp. 1700-1708.

[45] Kansal, Satish, Vishal Kumar, and Barjeev Tyagi. Optimal placement of different type of DG sources in distribution networks. International Journal of Electrical Power & Energy Systems, 2013, 53, pp. 752-760.

[46] García, Juan Andrés Martín, and Antonio José Gil Mena. Optimal distributed generation location and size using a modified teaching–learning based optimization algorithm. International journal of electrical power & energy systems, 2013, 50, pp.65-75.

[47] Tan, Wen Shan, Mohammad Yusri Hassan, Hasimah Abdul Rahman, Md Pauzi Abdullah, and Faridah Hussin. Multi-distributed generation planning using hybrid particle swarm optimization-gravitational search algorithm including voltage rise issue. IET Generation, Transmission & Distribution, 2013, 7, pp. 929-942.

[48] Kowsalya, M. Optimal size and siting of multiple distributed generators in distribution system using bacterial foraging optimization. Swarm and Evolutionary computation, 2014, 15, pp.58-65.

[49] Tan, Sicong, Jian-Xin Xu, and Sanjib Kumar Panda. Optimization of distribution network incorporating distributed generators: An integrated approach. IEEE Transactions on power systems 28, no. 3 2013, 28, pp.2421-2432.

[50] Georgilakis, Pavlos S., and Nikos D. Hatziargyriou. Optimal distributed generation placement in power distribution networks: models, methods, and future research. IEEE transactions on power systems, 2013, 28, pp. 3420-3428.

[51] Rao, R. Srinivasa, Kumudhini Ravindra, K. Satish, and S. V. L. Narasimham. Power loss minimization in distribution system using network reconfiguration in the presence of distributed generation. IEEE transactions on power systems, 2012, pp. 317-325.

[52] Thukaram, D. H. M. W., HM Wijekoon Banda, and Jovitha Jerome. A robust three phase power flow algorithm for radial distribution systems. Electric Power Systems Research, 1999, 50, pp. 227-236.