Distribution loss minimization using an optimization technique

Major Project Report

Submitted in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Electrical Power Systems)

By

VISHAL PANCHAL

13**MEEE**13

NIRMA UNIVERSITY

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Undertaking for Originality of the Work

I, **Vishal Panchal** (**Roll.No.13MEEE13**), give undertaking that the Major Project entitled "**Distribution loss minimization using an optimization technique**" submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in Electrical Power Systems of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Certificate

This is to certify that the Major Project Report entitled "**Distribution loss minimization using an optimization technique"** submitted by **Mr. Vishal Panchal** (**Roll No:13MEEE13**) towards the partial fulfillment of the requirements for the award of degree in Master of Technology (Electrical Engineering) in the field of Electrical Power Systems of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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Abstract

One of the purpose of power system analysis to identify loading conditions of electrical system. Also the determination of transmission and distribution losses is important for any electrical system. In this thesis, Genetic Algorithm technique is used to optimize the distribution losses of large power system network.

The determination of power losses (active and reactive power) is performed for a typical industrial distribution network data. To obtain the losses, the system load flow solution is performed by using Newton-Raphson method. The Genetic Algorithm based results are compared with the solution obtained by using ETAP software. The results obtained by Genetic Algorithm can be used to identify the probable solutions for reducing the distribution losses and increase the system efficiency.

Abbreviations/Nomenclatures

ETAP .... Electrical Transient Analyzer Program

GA .... Genetic Algorithm

OPF .... Optimal Power Flow

NR .... Newton Raphson

pu .... Per Unit Value

S .... Complex Power

P .... Active Power

Q .... Reactive Power

Δ δ .... Change in Voltage Vngle

Δ V .... Change in Voltage Magnitude

J .... Jacobian Element

GA set .... Active and Reactive Power Value in Per Unit

P_{Loss} .... Active Power Loss

Q_{Loss} .... Reactive Power Loss

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Chapter 1

Introduction

1.1 Background

This project focuses on studying the method of load flow calculation and to solve optimal power flow problem in large electrical distribution system. Load flow study belongs to efficient mathematical method to calculate system bus voltages, phase angles, active and reactive power flow through various branches, loads on steady state condition and also in different loading condition. It is achieved by providing the compensation to different under voltage buses. This procedure is based on Newton-Raphson method, which is more accurate and resourceful. Power flow study plays important role in the large distribution electrical network to transmit active and reactive power and as well as constructing many other types of power system analysis. This project is meaningful for deciding the best solution and development of existing large power distribution systems.

1.2 History

According to the study of Alvarado and Thomas, the most primitive methodology was based on the Gauss-Seidel method, which made it possible that to solve the problem for large power distribution systems. But problem was that, it had poor convergence issues. After that, the Newton-Raphson method was studied to solve the convergence problem, but was initially developed to be impractical for solving computational problems with enormous power system. The result of a bus admittance matrix for multi-nominal dimensions is the essential problem for the iterative Newton-Raphson method. In 1960, Bill Tinney and his partners found that the important system matrix was very large, but it still had a very small ratio of nonzero values. This solution supported the development of sparsity methods. Due to the concept, it is possible to apply the Newton-Raphson method to systems of arbitrary size, and to achieve both efficiency and convergence issues. Since the '60s, large quantities of advanced methods have been used in solving power flow problem. Power flow study are the representation of components such as high-voltage direct-current transmission lines, better methods for loss calculation, solution of the optimal power flow and statement of estimation problems, and of course, the development of better ways of visualizing and presenting load flow results.

1.3 Aim

In this project, the aim is to focus on the problem of Load flow calculation and actual understanding of active power loss and reactive power loss in electrical distribution network. Therefore, load flow analysis with single line diagram is done in ETAP with Newton-Raphson method. The proposed GA is done to improve the losses available from load flow analysis.

1.4 Theoretical Foundation

1.4.1 Bus Classification

In the power system network, there are three kinds of busses consider for load flow calculation.

- Slack Bus - This bus is distinguised from the remaining types by the fact that real and reactive powers at this bus are not specified. Instead, voltage magnitude(normally set equal to 1 pu) and voltage phase angle (normally set equal to zero) are specified. Usually, there is only one bus of this type in given power system network. The slack bus is numbered 1, for convenience.

- Load Bus - (P-Q Bus) At this type of bus, the net powers active and reactive are known. The unknown are voltage magnitude and voltage phase angle. A pure load bus is which has no generating facility.
- Voltage Controlled Bus - (P-V Bus) The bus that the voltage magnitude and the injected real power are specified can be defined as a voltage controlled (or P-V) bus.

1.4.2 Power Flow

The definition of Power Flow is the rate at which energy is transported across a surface by an electromagnetic field. Power flow study is usually uses the simple equivalent circuit such as a one-line diagram, per unit system and focuses on various forms of AC power which are voltages, voltage phase angles, real and reactive power. To start, the power system as being a collection of buses, connected together by lines. At each of the buses, which may regard as nodes, transformers and equipments which are supply power to or remove power from the system. Basically power is mainly refer to complex power S, which is,

$$S = P + jQ \tag{1.1}$$

Where, P is real power, and Q is reactive power. Correspondingly, the voltage and current values are also in complex value, which can be represented with magnitude and phase. The load flow equations can be formed using either the mesh or node basis equations of a power system. However, from the view point of computer time and memory, the nodal admittance formulation using the nodal voltages as the independent variables is the most economic. The node basis matrix equation of n-bus system is given by,

$$Y_{Bus}V = I \tag{1.2}$$

Where,

Y_{Bus}=Bus admittance matrix of order(n×n),

V = Bus node voltage matrix of order,

I = Source current matrix of order(n×1).

There are multi variable, equation can be written as below in matrix foam:

$$\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_k \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{1p} & Y_{1n} \\ Y_{21} & Y_{22} & Y_{2p} & Y_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ Y_{k1} & Y_{k2} & Y_{kk} & Y_{kn} \\ \vdots & \vdots & \vdots & \vdots \\ Y_{n1} & Y_{n2} & Y_{np} & Y_{nn} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_k \\ \vdots \\ V_n \end{bmatrix} \tag{1.3}$$

Let,

I_k = Current injected to bus-k,

V_k = Voltage of bus-k.

Equation of current I_k can be written as shown below:

$$I_k = Y_{k1}V_1 + Y_{k2}V_2 + .. + Y_{kk}V_k + .. + Y_{kn}V_n \tag{1.4}$$

$$I_k = \sum_{j=1}^{k-1} Y_{kj}V_j + Y_{kk}V_k + \sum_{j=k+1}^{n} Y_{kj}V_j \tag{1.5}$$

1.5 Outline of Thesis

- **Chapter 1** introduces the power flow calculation of large distribution system and also classification of buses.Aim is describe in brief.
- **Chapter 2** gives literature survey which are refers to help in load flow calculation and programming.
- **Chapter 3** gives single line diagram calculation with using Newton-Raphson method and also shows the $MATLAB^{®}$ flowchart of N-R method.

- **Chapter 4** gives optimize calculation process of Genetic Algorithm. GA operators are explain in briefly using Can design problem.
- **Chapter 5** describes the $MATLAB^{®}$ coding algorithm with GA and process of how it is deal with power system network.
- **Chapter 6** presents the results which is based on specified range in loading condition for each bus. Also analyze voltage profile of each bus and at the last iteration optimize losses.
- **Chapter 7** includes conclusion.

1.6 Summary

This chapter includes the background and history of large distribution power network also introduce bus classification and power flow.

Chapter 2

Literature Survey

For the better understanding of project detail literature survey plays a very important role. Literature Survey consists of papers referred which gives fundamental knowledge of large distribution network model.

- **Jaswanti, Tilak Thakur**[1] The paper entitled "Loss Minimum Configuration of Power Distribution System" gives information about new method for loss minimum reconfiguration for radial power distribution system, in which the choice of the switches to be opened / close is based on the calculation of voltage at the buses, real and reactive power flowing through lines, real power losses and voltage deviation, using distribution load flow (DLF) program.

- **Ajit K. Hiranandani**[2] The paper entitled "A sensitivity approach to the sizing of insulated power cables in low and medium voltage electrical power distribution systems" discusses about the important factors influence the sizing of a cable from technical standpoint which are system voltage-present,ampacity, thermal condition rated temparature of surrounding medium,permissible voltage regulation.

- **V. Glamocanin, V. Filipovic** [3] The paper entitled "Open Loop Distribution System Design" discusses about the ability to supply consumers of an urban area, without any longer interruption during a feeder segment or substation transformer outage, is assured by a uniform cable size of the feeder segments along the entire loop. Based on the criterion of the uniform cable size, a loop configuration is obtained first by minimizing the installation costs, and then an open loop solution is find by minimizing the power losses.

- **W.D. Stevenson Jr.**[4] The book entitled "Elements of power system analysis" discusses depth of load flow analysis methods, McGraw-Hill, 4th edition, 1982.
- **Hadi sadat** [5] The book entitled "Power System Analysis " discusses about the different methods and gives the best operation in newton raphson method. It also gives the basic knowledge of $MATLAB^{®}$ programming which is useful for large distribution network.
- **Rana A. Jabbar Khan, Muhammad Junaid** [6] The paper entitled "Analyses and Monitoring of 132 kV Grid using ETAP Software" discusse about the detailed analyses and monitoring by using the most modern software ETAP, which performs numerical calculations of large integrated power system with fabulous speed besides, generating output reports.
- **Kitagawa,Ishihara**[7]The paper entitled "Implementation of genetic algorithm for distribution systems loss minimum re-configuration" , IEEE transactions on distribution, Vol.7,Issue.4, August 1992.

2.1 Summary

In this chapter gives brief description about the literature survey of distribution losses for large power network. It is also gives the programming in $MATLAB^{®}$.

Chapter 3

Methodology

3.1 Newton Raphson method

Method for solving simultaneous nonlinear algebraic equation is N-R method because, it is successive approximation procedure based on initial estimate of unknown and use of Taylor's series expansion.
For large distribution power systems, the N-R method is more efficient and practical. The number of iterations required to obtain a solution is independent of the system size and more functional evaluations are needed at every iteration. The power flow problem real power and voltage magnitude are specified for voltage-controlled buses, the power flow equation is formulated in polar form. In power system, current entering equation can be written in terms of bus admittance matrix as

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \tag{3.1}$$

In above equation, j includes bus i. and expressing the equation in polar form, we have

$$I_i = \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j \tag{3.2}$$

The complex power at bus i is

$$P_i - jQ_i = V_i^* I_i \tag{3.3}$$

Substituting from 3.2 for I_i in 3.3,

$$P_i - jQ_i = |V_i| \angle - \delta_i \sum_{j=1}^{n} |Y_{ij}| V_j| \angle \theta_{ij} + \delta_j \tag{3.4}$$

Separating real and imaginary parts we get,

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \tag{3.5}$$

$$Q_i = -\sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \tag{3.6}$$

Equations 3.5 and 3.6 constitute a set of nonlinear algebraic equations in terms of independent variables, voltage magnitude in per unit, and phase angle in radians. With help of two equations for each load bus, given by 3.5 and 3.6, and one equation for each load bus, given by 3.5. Expanding 3.5 and 3.6 Taylor's series about the initial estimate and neglecting all order terms results in following set of linear equations.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{ccc|ccc} \frac{\partial P_2}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial P_2}{\partial \delta_n}^{(k)} & \frac{\partial P_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial P_2}{\partial |V_n|}^{(k)} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial P_n}{\partial \delta_n}^{(k)} & \frac{\partial P_n}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial P_n}{\partial |V_n|}^{(k)} \\ \hline \frac{\partial Q_2}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial Q_2}{\partial \delta_n}^{(k)} & \frac{\partial Q_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial Q_2}{\partial |V_n|}^{(k)} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial Q_n}{\partial \delta_n}^{(k)} & \frac{\partial Q_n}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial Q_n}{\partial |V_n|}^{(k)} \end{array}\right] \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \hline \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix} \tag{3.7}$$

Here, Bus 1 is assumed to be as slack bus for the Jacobian matrix which gives the linearized relationship between small changes in voltage angle $\Delta\delta_i$ and voltage magnitude $\Delta|V_i|$ with small change in real and reactive power ΔP_i and ΔQ_i. The elements of jacobian matrix are the partial derivatives of 2.5 and 2.6, evaluated at $\Delta\delta_i$ and

$\Delta|Vi|$. In short form, it can be written as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \tag{3.8}$$

3.2 Procedure for Power Flow solution by N-R method

- For load buses, where P_i^{sch} and Q_i^{sch} are specified, voltage magnitudes and phase angles are set equal to slack bus voltage value. For $|V_i| = 1.0$ and $\delta_i^{(0)} = 0.0$

- For load buses, P_i^k and Q_i^k are calculated from

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \tag{3.9}$$

$$Q_i = -\sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \tag{3.10}$$

ΔP_i and ΔQ_i are calculated from

$$\Delta P_i^{(k)} = P_i^{(sch)} - P_i^{(k)} \tag{3.11}$$

$$\Delta Q_i^{(k)} = Q_i^{(sch)} - Q_i^{(k)} \tag{3.12}$$

- The elements of Jacobian Matrix are calculated from

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{j \neq i} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \tag{3.13}$$

$$\frac{\partial P_i}{\partial \delta_j} = |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) j \neq i \tag{3.14}$$

- The new voltage magnitudes and phase angles are computed from

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)} \tag{3.15}$$

$$|V_i^{(k+1)}| = |V_i^{(k)}| + \Delta|V_i^{(k)}| \tag{3.16}$$

- The procedure is continued until residuals $\Delta P_i^{(k)}$ and $\Delta P_i^{(k)}$ are less than specified accuracy, we take 0.0001 accuracy in this case

$$|\Delta P_i^{(k)}| \leq \epsilon \tag{3.17}$$

$$|\Delta Q_i^{(k)}| \leq \epsilon \tag{3.18}$$

3.2.1 Single line diagram for Load Flow Analysis

From given data, one line diagram of typical industrial distribution power network is to be developed in ETAP which is shown in figure and with the help of load flow analysis using N-R method, load flow summary including voltage magnitude, phase angles and active-reactive losses are obtained.

All real-time data (transformer detail,cable details,load current for every feeder and substation details)are as under. For case study, ETAP model is shown in figure 3.1.

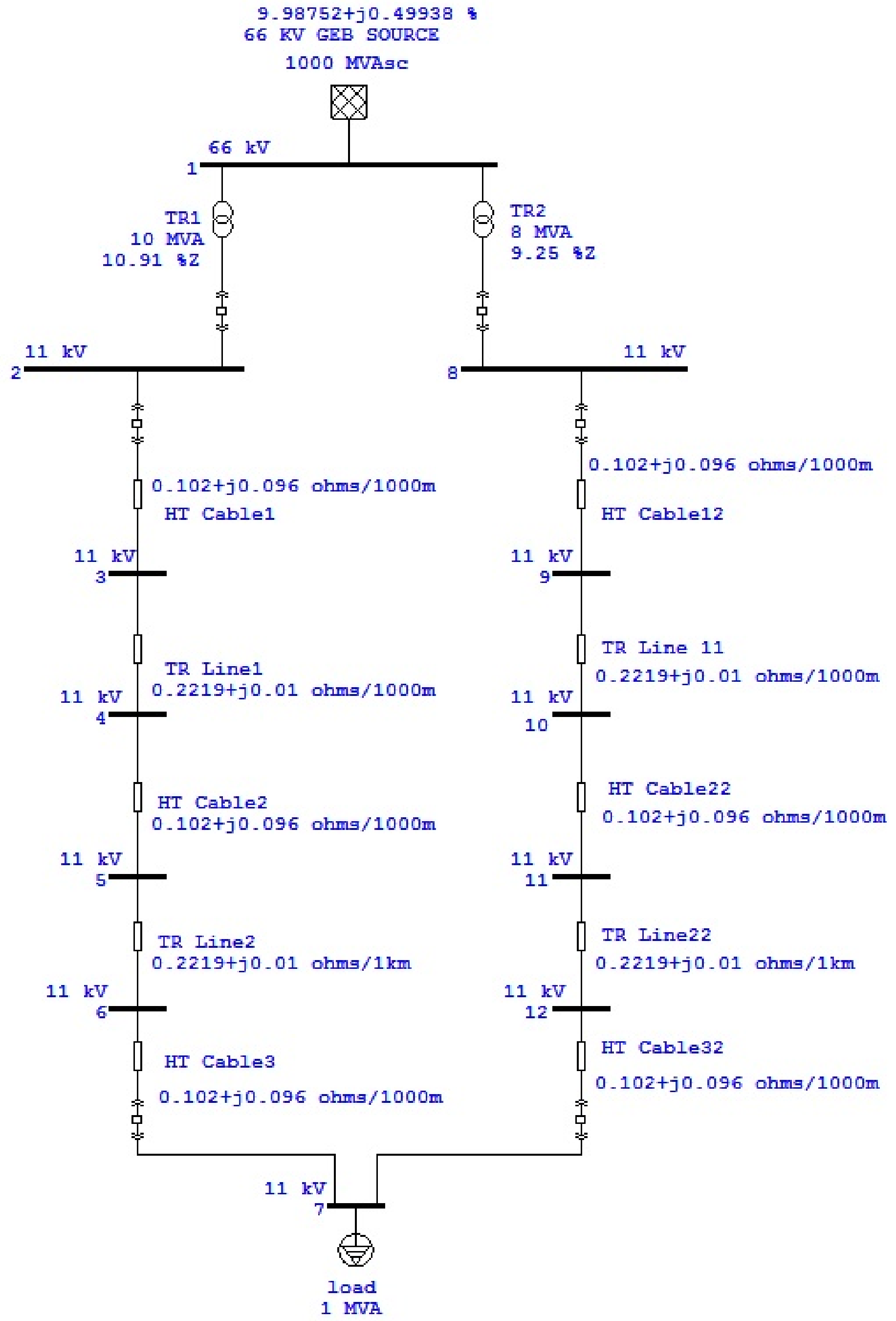

Figure 3.1: 12-bus ETAP model

Table 3.1: Line data

From bus	To bus	R in Pu.	X in Pu.	B/2(p.u.)	tapping
1	2	0.070	1.089	0.000	1.000
1	8	0.029	0.415	0.000	1.000
2	3	0.126	0.119	0.000	1.000
3	4	0.412	0.019	0.000	1.000
4	5	0.0170	0.016	0.000	1.000
5	6	0.367	0.017	0.000	1.000
6	7	0.013	0.012	0.000	1.000
8	9	0.126	0.119	0.000	1.000
9	10	0.412	0.019	0.000	1.000
10	11	0.017	0.016	0.000	1.000
11	12	0.367	0.017	0.000	1.000
12	7	0.013	0.012	0.000	1.000

Table 3.2: Bus data

Bus No.	Bus type	Voltage in Pu.	Theta	Load P	Load Q	Gen. P	Gen. Q	Gen. Min Q	Gen. Max Q	Shunt Mvar
1	1	1.000	0.00	0.000	0.000	0.590	0.365	0.000	0.000	0.000
2	0	0.998	-0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0	0.997	-0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0	0.996	-0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0	0.996	-0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0	0.995	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0	0.995	0.00	0.589	0.365	0.000	0.000	0.000	0.000	0.000
8	0	1.000	-0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0	1.000	-0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0	0.997	-0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0	0.997	-0.1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0	0.995	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000

3.2.2 Input Data

Technical details for all substations with impedance voltage of transformer,capacity of transformers, cable details and load current are shown in table as below:

Table 3.3: Data of Main substation

Sr. No.	Panel Name	Feeder Name	Max. current	Remarks
1	Main 11kV Panel	Line No.9	575 A	LT
2	Main 11kV Panel	Line No.10	575 A	LT
3	Main 11kV Panel	GC-2	575 A	LT
4	Main 11kV Panel	S/S-1	575 A	LT
5	Main 11kV Panel	PH-1	575 A	LT
6	Main 11kV Panel	S/S-2	575 A	LT
7	Main 11kV Panel	S/S-5	575 A	LT
8	Main 11kV Panel	ELL-1	575 A	LT
9	Main 11kV Panel	PH-2	575 A	LT
10	Main 11kV Panel	GC-1	575 A	LT
11	Main 11kV Panel	ELL-2	575 A	LT
12	Main 11kV Panel	S/S-4	575 A	LT
13	Main 11kV Panel	S/S-3	575 A	LT

Table 3.4: Data of substation 1

Sr. No.	Panel name	Feeder name	Max. current	Remarks
1	Transformer LT Panel	LT Main I/C	1098 A	LT
2	Transformer LT Panel	Compressor Panel	989 A	LT
3	Transformer LT Panel	Offshore	334 A	LT
4	Transformer LT Panel	Apfc	300 A	LT
5	Transformer LT Panel	Elgi Comp.	-	off
6	Transformer LT Panel	Store Lighting	1 A	LT
7	Transformer LT Panel	Fire Station	100 A	LT
8	Transformer LT Panel	Rolling Area	30 A	LT
9	Transformer LT Panel	220kV Gate	5 A	LT
10	Transformer LT Panel	Main Gate	2 A	LT

Table 3.5: Data of substation 2

Sr. No.	Panel name	Feeder name	Max. current	Remarks
1	Transformer LT Panel	LT Main I/C	575 A	LT

Table 3.6: Data of substation 3

Sr. No.	Panel name	Feeder name	Max. current	Remarks
1	11kV Panel	Transformer	50 A	HT
2	11kV Transformer	LT Main I/C	1295 A	LT
3	Transformer LT Panel	To Oxegen Plant	8 A	LT
4	Transformer LT Panel	To Technical-2	70 A	LT
5	Transformer LT Panel	To Technical-1	145 A	LT
6	Transformer LT Panel	To Admin Building	174 A	LT
7	Transformer LT Panel	To SS Lighting	12 A	LT
8	Transformer LT Panel	Tecon Supply	12 A	LT

Table 3.7: Data of substation 4

Sr. No.	Panel name	Feeder name	Max. current	Remarks
1	11kV Panel	Main IC	49 A	HT
2	11kV Panel	Transformer	97 A	HT
3	11kV Panel	Ell-1	28 A	HT
4	11kV Panel	Gc-1	18 A	HT
5	11kV Panel	Gc-2	16 A	HT
6	Transformer LT Panel	LT Main I/C	2494 A	LT
7	Transformer LT Panel	To P.E. Berth	419 A	LT
8	Transformer LT Panel	To Zig area	175 A	LT
9	Transformer LT Panel	To Apfc	557 A	LT
10	Transformer LT Panel	To Freq. Conv.	200 A	LT
11	Transformer LT Panel	To Gallery feeder	400 A	LT

Table 3.8: Data of substation 5

Sr. No.	Panel name	Feeder name	Max. current	Remarks
1	Transformer LT Panel	Main I/C(PCC1)	1192 A	LT
2	Transformer LT Panel	East Fob	1388 A	LT
3	Transformer LT Panel	West Fob	1908 A	LT
4	Transformer LT Panel	LT Main I/C(PCC2)	750 A	LT
5	Transformer LT Panel	60Hz(West Fob)	295 A	LT
6	Transformer LT Panel	60Hz(East Fob)	210 A	LT
7	Transformer LT Panel	Apfc-2	235 A	LT
8	Transformer LT Panel	Apfc-1	300 A	LT
9	Transformer LT Panel	Bore Well	350 A	LT
10	Transformer LT Panel	LT Main I/C(PCC3)	1000 A	LT
11	Transformer LT Panel	Osv	1000 A	LT
12	Transformer LT Panel	West P.E. Berth	300 A	LT
13	Transformer LT Panel	Capston	200 A	LT
14	Transformer LT Panel	Ell-2	293 A	LT

Table 3.9: Data of Cables

Sr. No.	From	To	Cable size	No. of run	Length in m
1	11kV Panel	Gc-2	11kV,3cx240sq.mm	1	705
2	11kV Panel	Gc-1	11kV,3cx240sq.mm	1	705
3	11kV Panel	PH1	11kV,3cx400sq.mm	1	1000
4	11kV Panel	PH2	11kV,3cx400sq.mm	1	1000
5	11kV Panel	S/S 1	11kV,3cx150sq.mm	1	45
6	11kV Panel	S/S 2	11kV,3cx95sq.mm	1	200
7	11kV Panel	S/S 3	11kV,3cx300sq.mm	1	1000
8	11kV Panel	S/S 4	11kV,3cx300sq.mm	1	705
9	11kV Panel	S/S 5	11kV,3cx300sq.mm	1	1000
10	11kV Panel	Ell-1	11kV,3cx95sq.mm	1	705
11	11kV Panel	Ell-2	11kV,3cx95sq.mm	1	1000
12	11kV Panel	Spare	11kV,3cx300sq.mm	2	0
13	S/S 4	Ell-1	11kV,3cx95sq.mm	1	20
14	S/S 4	Transformer	11kV,3cx300sq.mm	1	10
15	S/S 4	Gc-2	11kV,3cx300sq.mm	1	230
16	S/S 4	Gc-1	11kV,3cx300sq.mm	1	190
17	S/S 3	Transformer	11kV,3cx300sq.mm	1	20
18	S/S 3	Spare	11kV,3cx150sq.mm	1	0
19	S/S 3	Spare	11kV,3cx150sq.mm	1	0
20	S/S 3	Spare	11kV,3cx150sq.mm	1	0

3.2.3 Load Flow summary

From entering all data in model we get load flow summary which is shown in table.

Table 3.10: Total loss summary of typical industrial distribution network

Power	P(MW)	Q(Mvar)
Swing bus	7.139	5.498
Generators	0.000	0.000
Total Demand	7.139	5.498
Total Motor Load	5.696	3.975
Total Static Load	0.888	0.659
Apparent Losses	0.555	0.864

3.3 N-R method for load flow calculation using $MATLAB^{®}$ program

3.3.1 Flowchart for N-R method

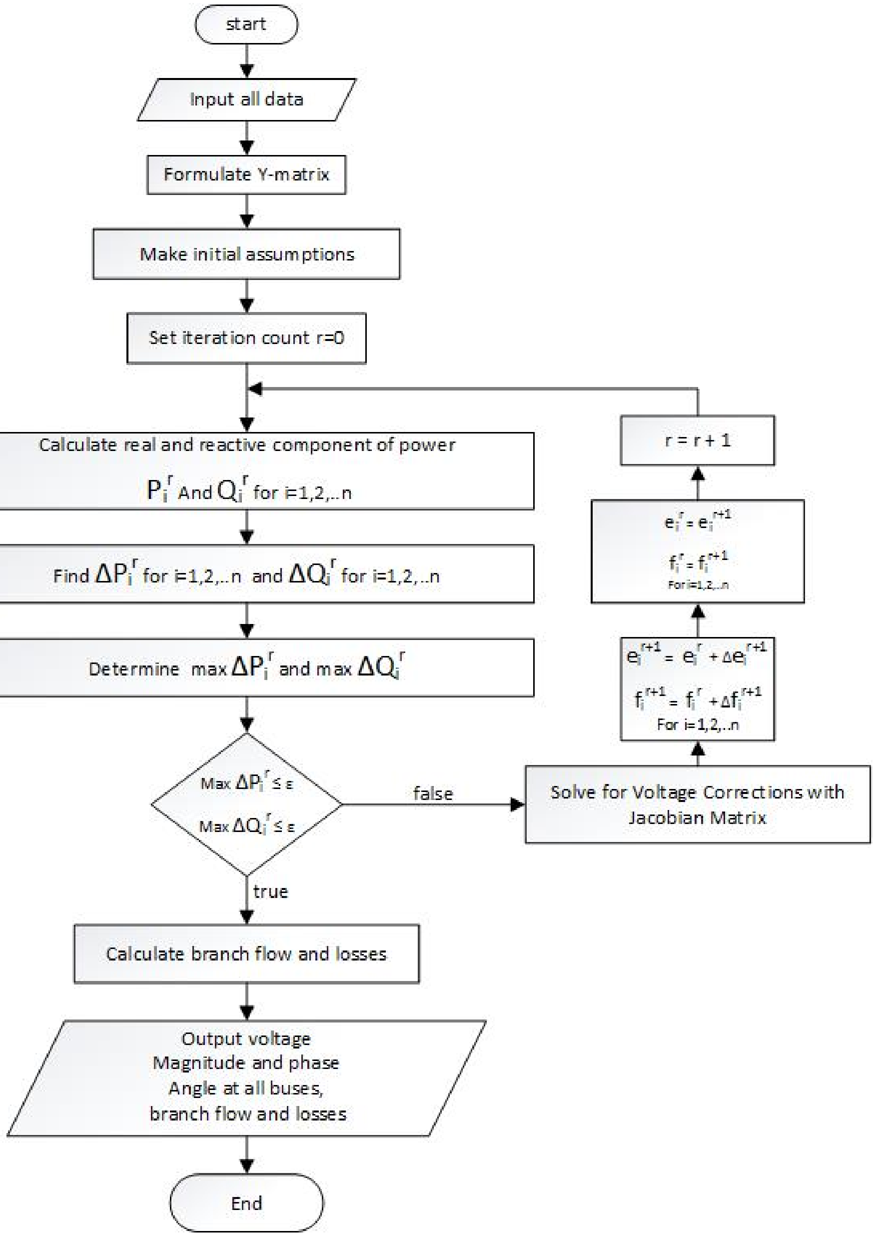

Figure 3.2: Flowchart of Newton Raphson method

3.4 Summary

This chapter is for complete input data which real time values and also gives the equation for calculate the load flow using Newton-Raphson method.

Chapter 4

Optimize Distribution Losses using GA technique

4.1 Introduction of GA

In an artificial intelligence, a genetic algorithm (GA) is a search heuristic that mimics the process of natural selection. Heuristic is routinely use to generate useful solution to optimize and search problems. It is belong to the larger class of evolutionary algorithms (EA), to generate solution for optimization problems with help of techniques from natural evolution, inheritance, selection, crossover, mutation.
Basically Genetic Algorithm works with a population of binary string, searching many peaks in parallel. With the help of Genetic operators, they exchange information between the peaks, hence reducing the possibility of ending at local optimum. GA is more flexible and reliable than most search methods because, it require only information by each parameter set which is objective function values.

4.2 Use of GA for Can design problem

First of all understand fitness function with Can design problem. Objective is to minimize the cost of Can material two deciding parameter which are diameter and height, assume the volume of Can is grater or equal to 300. Thus function for reducing the material use for making Can is depends on Min $F(d,h) = \lambda[\pi Dh + \pi D^2/2]$. Which is nothing but fitness function for Can design problem. And subject to $[\pi D^2 h/4 \geq 300]$ variable bounds are $d_{min} \leq d \leq d_{max}$ and $h_{min} \leq h \leq h_{max}$.

4.2.1 Representing a solution

The first step to solve a problem by genetic algorithm is defining the structure of representation and the way to convert a chromosome to a solution. Representation is one of the most important subjects that influence the performance of GA. One known way to represent network problems is tree based representation. There are three ways for representing a tree: edge-based, vertex-based and edge-and-vertex based encoding. Now first we need to represent d and h in binary strings. For each variable 5 bits code is to be taken. Here, two variable are taken so overall string length will be equal to 10. Now, initial random set of solution:

Table 4.1: Initial random set solution

D	H	(d,h)	Objective function value
01101	00101	(13,5)	30
01010	00111	(10,7)	24
00101	01000	(5,8)	11
00100	01001	(4,9)	9
01000	01010	(8,10)	23
01110	00110	(14,6)	37

After creating a population of strings at random, is to be ready to apply genetic operation to such strings to find a better populations of solutions.

4.2.2 Fitness function

The fitness function shows the quality of the solutions with a numerical value and guides the searching process to better solutions. Fitness function in this problem consists of two parameters. For example the first parameter is diameter which is defined as the area from center. The second is height which is defined as the volume of Can and also depend on area. Now assigning fitness to a solution in binary GAs

work with strings. It is necessary to evaluate the solution.
Fitness of a string is assigned a value:

a. Which may be a function of solution's objective function value.

b. Equal to the objective function value.

In each generation, the chromosomes are evaluated by measuring their related fitness functions. The chromosomes of next to generation which are produced through two ways mentioned below are called offspring.

4.2.3 Crossover

Crossover, which is used to explore new solutions in search and it is responsible to exchange parts of chromosomes among selected particles. Crossover is nothing but one type of an operator to select the best value for require. Here in two point crossover operator is employed in which these two points is randomly selected among the corresponding parts of particles. Two strings are picked up from the mating pool at random and some portion of the strings are exchanged between the strings to create two new strings. There are different type of operator, single point crossover operator, two point crossover operator and N point crossover operator. Here single point crossover operator is shown:

$$\begin{array}{lll} (8,10) & 010 \mid 0001010 & \\ & & \longrightarrow \\ (14,6) & 011 \mid 1000110 & \end{array} \quad \begin{array}{ll} 101 \mid 1000110 & (10,6) \\ & \\ 011 \mid 0001010 & (12,10) \end{array}$$

4.2.4 Mutation

Mutation is another operator that is responsible for modifying genes within a chromosome at low rates and creates random combinations in some chromosomes. The main role of mutation is identify the some areas of the search space whose possibility of being explored is low. This operator reduces the probability of trapping populations in local optimal and prevents the premature convergence.

In the proposed algorithm, uniform mutation is employed and mutation probability is considered 0.1 in this operator which is depend on the user. The bitwise mutation operator changes a 1 to 0 and vice-versa with a mutation probability. First Create a Random Number belongs to [0,1]. The need of mutation is to keep diversity in the population. Mutation operator alters a string locally to hopefully create a better string.

4.3 Process to generate initial random number

In large distribution network loss are require to minimize by GA technique. For distribution system, it is basically one of complex combination to optimization, since switches must be sectionalizing to determine appropriately. GA is very useful to apply on distribution network for minimize the losses by reconfiguration. The fitness function consists of the total system losses and penalty value of voltage drop and current capacity violations. To minimize the loss in network is to reconfigure the parameters or by changing loading conditions and to solve problem by GA program. Distribution network design is one type of chain to supply the power from distribution side thus it is necessary to optimize the distribution losses by chain management. Thus Genetic Algorithm is give the best way to optimize power and reduction of losses. The location- allocation problem is studied under demand uncertainty. The aim is to specify the optimal number and location of distribution centers and to determine the allocation of customer demands to distribution centers. The main feature is to solving the model with unknown function which is suitable with the real time problems. To consider the uncertainty, a set of possible scenarios for customer demands is created based on the simulation. The co-efficient of variation of costs is mentioned as a measure of most stable structure for large distribution network. The best structure is identified using genetic algorithms and reduction in total supply chain costs. It imposes the least cost variation created by fluctuation in customer demands to the system.

4.4 Summary

This chapter is give the basic of GA optimization example for Can design problem with all GA operators.

Chapter 5

GA Programming using $MATLAB^{®}$

In this chapter GA programming flow is describe with entire process for given iteration values. Flow chart is as shown in figure 5.1. In MATLAB®, first *.m file is to be created in MATLAB® subroutines which makes independent package. Input and output files are placed in same dictionary where *.m file is to be exists. MATLAB® component runtime files are required to provide environment.

5.1 Flowchart for $MATLAB^{®}$ Programming

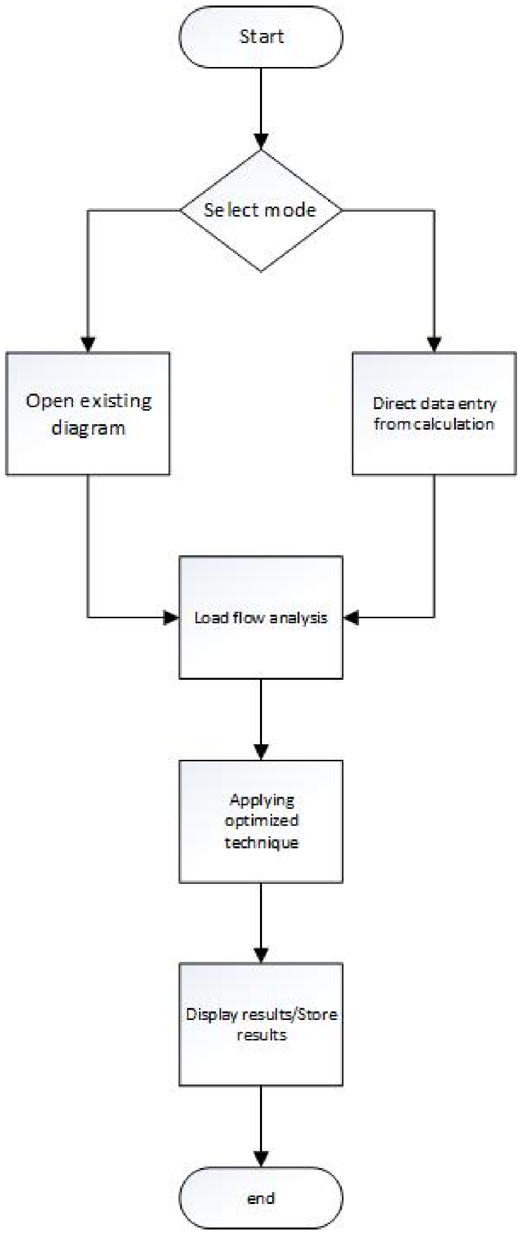

Figure 5.1: Flow Chart of GA Process

5.2 Load flow analysis

Here load flow analysis gives voltage value at each bus and total losses of system using N-R method MATLAB® programme. Capacitors is to provided to improve voltage profile or change on load tap change settings of entire system. Using load flow analysis loading condition is to be checked for different value from number of iterations and get minimum loss through GA programming.

5.3 GA programming

5.3.1 Initial random number generation

As discuss above to get best solutions, the random numbers are generated in specified range with number of buses. Input range of P_{max} and Q_{max} are load in between 0.1 to 1.0 because all load flow calculation bus data in per unit system. Active power and reactive power are the objectives to change the value in load flow analysis. In bus data, generation active and reactive power value at each buses are replace with initial random number. Number of GA iterations are also mentions in random number generation for getting best solution.

5.3.2 Change bus data with loading condition

For load flow calculation it is to be required bus data and line data which prepared in .txt file. In bus data column 5 and column 6 are taken as active load and reactive load respectively. These columns are replaced with initial generated random number. After replacing again load flow run with random numbers and different active and reactive losses are calculated.

5.3.3 Genetic operators

GA is an iterative process which has two steps at each iteration, one is evaluation and second is generation. Mostly GA is depends on the three basic operators: selection, crossover, and mutation. Selection operator is according to fitness of an unequal data, crossover and mutation operators are experimental data. GA combines the manipulation of previous results with the study of new generated areas of the search space. The efficacy of a GA depends on an appropriate mix of study and manipulation data. The following describe these three operators in detail.

Selection

Selection phase has an important role in GA which search towards better solution boundary from initial generation numbers. One of the set is select from lowest power loss through load flow calculation. This set of boundary is located from the position command and gives the set which has minimum loss. After selection process one integer set is to be selected but the problem is to convert it into binary set, thus from the floor command real number of set is to be converted into binary string. Which becomes fitness function of the optimize loss.

Crossover

In order to explore other points in the examination space, deviation is introduced into initial generated random number by means of some genetic recombination operators. The recombination operator is called crossover. Common method for crossover is one-point crossover method which is applied on binary string set using for-loop syntax in MATLAB® platform, The last string of binary data. Where '0' with '1' and '1' with '0' is to be replaced. And after this process convert binary string into decimal value. Hence previous set is replace with new set which has some minor changes.

Mutation

Mutation is defined with random bit value change in a chosen string with some new string value. The mutation adds a random set with define value in the genetic algorithm, it is require to avoid later on some generations. In this case it is to be select the set, which gives maximum loss from load flow calculation, and remove that maximum loss set with new generated set which is in specified range.

New population set is getting from GA operators, now as above discussed GA is an iterative process it is to be calculated load flow for given GA iterations and store the loss results for each iteration. When losses are optimized in some of condition than best solution results is to be achieved.

5.4 Summary

In this chapter, it is explain in detail how the GA is applicable in power system network to get optimize results.

Chapter 6

Results and Analysis

6.1 GA Algorithm

a. Clear all preloaded data.

b. Define input value with maximum active and reactive load.

c. Read all data of system from .txt file with same directory.

d. Find Active and Reactive losses from calculation of Newton-Raphson Load Flow method.

e. Make a loop for change power load data of each bus in (0.1 to 1.0) range and get the losses for given GA random number.

f. Find position of minimum losses and apply GA operator process with that GA set.

g. Find optimum set and calculate Active and Reactive losses.

6.2 Comparision of Results

ETAP and $MATLAB^{®}$ gives load flow calculation and with help of that active and reactive losses are shown in Table5.1. This calculations are at different loading conditions.Where active and reactive losses are everytime measured in ETAP and

$MATLAB^{®}$ simultaneously. Here error is very less thus load flow is converge in $MATLAB^{®}$ with same data of ETAP.

Table 6.1: Comparision of losses

% Loading	ETAP	ETAP	MATLAB	MATLAB	% Error	% Error
	P_{loss}	Q_{loss}	P_{loss}	Q_{loss}	P_{loss}	Q_{loss}
20	0.001	0.001	0.0006	0.0015	0.04	0.05
40	0.010	0.008	0.0062	0.0057	0.38	0.23
60	0.022	0.019	0.0235	0.0195	0.33	0.07
80	0.039	0.033	0.0423	0.0355	0.15	0.25
10	0.061	0.051	0.0667	0.0560	0.57	0.50

6.3 Load Optimization Results through GA

For the case study GA random number is 4 and number of iteration is taken 100 hence the result is optimized, which is shown in table.

Table 6.2: Iteration-1

Bus No.	GA set 1	GA set 2	GA set 3	GA set 4
1	0.7355	0.1351	0.6547	0.2662
2	0.1335	0.1030	0.2282	0.0672
3	0.3484	0.5785	0.5700	0.2643
4	0.3997	0.4721	0.4729	0.2113
5	0.1520	0.4569	0.8122	0.3113
6	0.3786	0.9116	0.1838	0.7636
7	0.8983	0.6917	0.7161	0.1443
8	0.2271	0.2271	0.2271	0.1421
9	0.8515	0.3926	0.4309	0.4578
10	0.1894	0.9566	0.1013	0.5430
11	0.1436	0.4985	0.8109	0.1453
12	0.5799	0.8237	0.6064	0.5719
P_{loss}	0.1198	0.1771	0.1286	0.2518

Table 6.3: Iteration-2

Bus No.	GA set 1	GA set 2	GA set 3	GA set 4
1	0.7355	0.6513	0.6547	0.2662
2	0.0672	0.5176	0.0672	0.0672
3	0.2643	0.1802	0.2643	0.2643
4	0.3997	0.7591	0.4729	0.2113
5	0.1520	0.3814	0.8122	0.3113
6	0.3786	0.4903	0.1838	0.7636
7	0.8983	0.4752	0.7161	0.1443
8	0.2271	0.1666	0.2271	0.1421
9	0.8115	0.7350	0.4309	0.4578
10	0.1894	0.4177	0.1030	0.5430
11	0.1436	0.0275	0.8109	0.1453
12	0.5799	0.3915	0.6064	0.5719
P_{loss}	0.1198	0.1680	0.1401	0.0667

Table 6.4: Iteration-3

Bus No.	GA set 1	GA set 2	GA set 3	GA set 4
1	0.7355	0.6513	0.6547	0.2662
2	0.0672	0.5176	0.0672	0.0672
3	0.2643	0.1802	0.2643	0.2643
4	0.3997	0.7591	0.4729	0.2113
5	0.1520	0.3814	0.8122	0.3113
6	0.3786	0.4903	0.1838	0.7636
7	0.8983	0.4752	0.7161	0.1443
8	0.2271	0.1666	0.2271	0.1421
9	0.8115	0.7350	0.4309	0.4578
10	0.1894	0.4177	0.1030	0.5430
11	0.1436	0.0275	0.8109	0.1453
12	0.5799	0.3915	0.6064	0.5719
P_{loss}	0.0722	0.0836	0.0877	0.0614

Table 6.5: Iteration-4

Bus No.	GA set 1	GA set 2	GA set 3	GA set 4
1	0.7355	0.6513	0.6547	0.2662
2	0.0672	0.5176	0.0672	0.0672
3	0.2643	0.1802	0.2643	0.2643
4	0.3997	0.7591	0.4729	0.2113
5	0.1520	0.3814	0.8122	0.3113
6	0.3786	0.4903	0.1838	0.7636
7	0.8983	0.4752	0.7161	0.1443
8	0.2271	0.1666	0.2271	0.1421
9	0.8115	0.7350	0.4309	0.4578
10	0.1894	0.4177	0.1030	0.5430
11	0.1436	0.0275	0.8109	0.1453
12	0.5799	0.3915	0.6064	0.5719
P_{loss}	0.0557	0.0614	0.1399	0.0667

Table 6.6: Iteration-100

Bus No.	GA set 1	GA set 2	GA set 3	GA set 4
1	0.1226	0.1226	0.1226	0.1226
2	0.2981	0.2981	0.2981	0.2981
3	0.6344	0.6344	0.6344	0.6344
4	0.1506	0.1506	0.1506	0.1506
5	0.5645	0.5645	0.5645	0.5645
6	0.8153	0.8153	0.8153	0.8153
7	0.0221	0.0221	0.0221	0.0221
8	0.5843	0.5843	0.5843	0.5843
9	0.2548	0.2548	0.2548	0.2548
10	0.4853	0.4853	0.4853	0.4853
11	0.0226	0.0226	0.0226	0.0226
12	0.0061	0.0061	0.0061	0.0061
P_{loss}	0.0277	0.0277	0.0277	0.0277

6.4 Analysis and Outcome

GA algorithm is processed. From the results in various tables above, following observations are made.

- More random population generation per iteration occupies more computer memory; however overall processing time will be less. Ancient version of computers will not be able to allocate that much memory requirements hence atleast computers with 2 MB of RAM shall be used if random populations are created more than 15.

- Lesser random population with more no. of GA iterations takes more time to converge. Faster processing power is required to converge in lesser time.

- After application of GA for several times; it is observed that, every time new set of populations are generated hence final answer after GA iteration varies (Loss optimization). Optimized result is achieved after 10^{th} iteration with minimum 10 set of random population.

- For sake of understanding, 4 set of population per iterations are taken and GA was processed for 100 iterations. The results are indicated in table.
- It is presumed here to have batch process operation in the system under study, %loading selection at each bus is permitted. The same is achieve through GA which is indicated in above results.
- Reduction of losses, voltage profile can also be improved, this is permitted with buses with facilities of:
  - Transformer taps
  - Reactive power injection (capacitor bank)

In the system under study two buses where identified, random population generated with constrained of voltage variation permitted at (0.9 to 1.05). same is applied in GA results are as under.

Table 6.7: Voltage variation

No.	Bus-2	Bus-8	P_{loss}
1	0.9960	1.0000	0.0540
2	0.9889	1.0300	0.0412
3	0.9605	0.9986	0.0403
4	0.9994	0.9574	0.0368
100	0.9500	0.9915	0.0052

Result above indicates requirement of voltage improvement at this two buses, capacitor sizing and placement can be decided based on above results.

6.5 Summary

In this chapter GA code is gives optimize result,which is shown in table for change in loading and change in voltage condition.

Chapter 7

Conclusion

With the help of optimize technique distribution losses is optimized. To achieve fast convergence with less set of random populations, computer with fast processing speed to be used as it is required more no of iterations. Where in the case of more random number more accurate with lesser iterations convergence is achieved; computer with more memory is required.

Optimized % Bus loadings shall be implied in the system to achieve desired operations.

References

[1] **Jaswanti, Tilak Thakur**, "Loss Minimum Configuration of Power Distribution System".

[2] **Ajik K. Hiranandani**, "A sensitivity approach to the sizing of insulated power cables in low and medium voltage electrical power distribution systems" , IEEE transactions on power delivery, Vol.4,No.3,July 1989.

[3] **V.Glamocanin, V.Filipovic**, "Open Loop Distribution System Design",IEEE Transactions on Power Delivery. Vol. 8. No. 4. October 1993.

[4] **W.D.Stevenson Jr**, "Elements of power system analysis", McGraw-Hill, 4th edition, 1982.

[5] **Hadi Saadat**, "Power System Analysis", WCB McGraw-Hill.

[6] **Rana A. Jabbar Khan, Muhammad Junaid**, "Analyses and Monitoring of 132 kV Grid using ETAP Software" discusse about the detailed analyses and monitoring by using the most modern software ETAP, which performs numerical calculations of large integrated power system with fabulous speed besides, generating output reports.

[7] **Kitagawa,Ishihara**, "Implementation of genetic algorithm for distribution systems loss minimum re-configuration" , IEEE transactions on distribution, Vol.7,Issue.4, August 1992.

[8] **Arman Izadi, Ali Mohammad Kimiagari**, "Distribution network design under demand uncertainty using genetic algorithm"

[9] **Ying-Hong Liao, Chuen-Tsai**, "An Educational Genetic Algorithms Learning Tool".

[10] **M. Sasson**, "Nonlinear Programming Solutions for load flow, minimum loss, and economic dispatching problems",IEEE Transactions on Power Apparatus and Systems Vol.PAS.88,No. 4,April 1969.

Appendix A

Typical Industrial Distribution Power Network

Here is the complete one line diagram of typical industrial distribution network in ETAP model which is shown in Figure.