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**INSTITUTE OF ENGINEERING**  
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**Thesis No: 073/MSPS/708**

**Reactive Power Reallocation for Loss Minimization, Voltage Profile  
Improvement, and Voltage Stability Enhancement Using Moth Flame  
Algorithm**

**By**

**PRAKASH BUDHA**

**A THESIS**

**SUBMITTED TO THE DEPARTMENT OF ELECTRICAL ENGINEERING  
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE  
DEGREE OF M.SC. IN POWER SYSTEM ENGINEERING**

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a progress report of thesis entitled “**Reactive Power Reallocation for Loss Minimization, Voltage Profile Improvement, and Voltage Stability Enhancement Using Moth Flame Algorithm**” submitted by **Prakash Budha**, in partial fulfillment of the requirements for the degree of Master of Science in Power System Engineering.

.....  
Prof. Dr. Nava Raj Karki  
Supervisor, Program Coordinator  
M.Sc. in Power System Engineering  
Department of Electrical Engineering  
Pulchowk, Campus

.....  
Er. Anup Kr Upadhyay  
Former Secretary  
Ministry of Energy, Government of  
Nepal

.....  
Assoc. Prof. Er. Mohammad Badrudoza  
Head of Department  
Department of Electrical Engineering  
Pulchowk, Campus

February, 2021

## ABSTRACT

The Power industry became the most vital part of the economic development of the nation. In modern century power system is the back bone of economic development and prosperity of the nation. The demand of electricity and the area of its utilization has been increasing day by day. Major portion of the electricity demand is still served by the conventional type of the fuel which is on the verge of depletion. Optimal use of energy has always been the matter of interest. Since, the power system has been back bone of the prosperity and economic development, the availability, security of the power system has been the factor to be augmented. So, economics and the security of the electricity system has been the center of concern. Optimal use of energy and the enhancing the stability of the system is the important features of power system operation. The major power system crisis occur in the system is because of the scarcity of the energy sources and the failure of the system due to instability. Most of the black out of the system is caused by Voltage instability.

In this thesis work, we have concerned about the economics of operation and the enhancement of the system Voltage stability and Voltage quality. The economics of the operation is concern with the reduction of the loss. The reduction of the loss and the Voltage profile improvement as well as Voltage stability enhancement is achieved by the reallocation of the reactive power dispatch for generation and the shunt compensation. The reallocation of reactive power causes to rearrangement of the reactive power flow pattern in the line and the loss, and Voltage profile and stability will be altered. The dispatch of the reactive power at which the loss is minimized, Voltage profile is improved and Voltage stability is enhanced is optimal dispatch. The Optimal reactive power dispatch solution is obtained through the moth flame optimization technique, which is newly developed and very effective in implementation. This algorithm is inspired by the nature moth movement with respect to light. The implementation of this optimization problem is done with the IEEE 57 standard bus. In the standard bus, the Optimal dispatch of 7 generator and 3 compensators is obtained.

The dispatch of reactive power of generator and shunt compensation is controlled by the AVR of Generator, the tap setting of transformers and the switching of static compensation. So, taking these as the control variable for the optimization problem, the optimized control value is obtained by the moth-flame algorithm, then later the respective dispatch of reactive power generation is calculated. The Voltage stability is measured by the L- index indices. It reflects the margin of the actual state from the point of Voltage collapse. Due to inbound nature of the L-index for 0-1, it became practical for optimization problem.

In our thesis work, the loss minimization, Voltage deviation minimization and Stability enhancement is three independent objectives. The control variable for the IEEE 57 bus, system consists of 7 generator Voltage, 15 transformers tap setting and 3 compensators. The optimal value of control variable is obtained after the optimization is done. The Optimal dispatch of reactive power is calculated through the load flow after the optimal value of control variable is obtained. Initially, At Base condition, the active power loss was 27.86 MWatt, Voltage Deviation index (VDI) = 3.814074, and L-index (max) was 0.3099. When the MFO is applied for the objective of Minimum Loss condition, the loss is reduced to minimum value of 24.09 MWatt, VDI is also changed to 2.7026, and L-index max is deducted to 0.3099. The Optimization is done for voltage profile improvement, the Voltage deviation index (VDI) is obtained at its minimum value of 1.469248, in this case, loss is also deducted to 26.99 MWatt, and stability is also enhanced to 0.2727 MWatt. When MFO is applied for voltage stability Enhancement, the L-index (max) value is reduced to 0.2653, and loss at that condition is 27.49 MWatt, Voltage Deviation index (VDI) = 2.897311. In all three cases, the Objective is minimized in respective aspects, and the operating scenario is better in all three aspect of loss, voltage profile and voltage stability than that at the base condition.

After conduction of moth flame methodology to the optimization problem for each independent objective, it is reflected that rearranging the reactive power flow in the line could reduce the impact of reactive power flow. After optimization the loss is reduced in significant value, and the Voltage profile and much improved and stability is enhanced. The moth flame shows very effectiveness on solving the non-linear optimization problem for the optimal reactive power dispatch.

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## CHAPTER 1 : INTRODUCTION

### 1.1 Background

In this Modern age, Energy has been paramount important in the lives of people, and has become must needed commodity from living to the comprehensive progression of modern world. It is unimaginable to have the world without harnessing the energy. Energy has become the potential to achieve vigorous growth of the national economy. Thus, it has also been the interest of politics. The Energy consumption rate of each nation as well as of the whole world is uprising. However, the most of energy demand is fulfilled by the conventional source of energy. Whatever be the source of energy, the most accessible way to convey the energy is in the form of electricity due to its flexibility of conversing into another form and vice versa. Electricity has been proven as most advanced and efficient way to convey energy to ultimate consumers. In the modern world, electricity and its network has played the important role in promising the continuity of supply of energy. The loss of power supply in the electricity network is due to loss of rotor angle stability or the Voltage stability, because of subsequent loss of adequate support. Most of Black out in system is occurred due the Voltage instability. In the current scenario, many parts of world are facing with energy deficit. Yet, Huge amount of energy has been loss lost to the surrounding. It is inevitable to have loss of some amount of energy through transmission and distribution of energy. Security and Reliability of Power network has always been the concern for power industry. Thus, the Loss Reduction (Energy Saving) and Improve the quality ness of supply has paramount importance.

The loss occurred in the system during the convey of the electrical energy in the power system network. In Practical the power delivery is done through the conductor in the different Voltage level depending upon the techno-economically design. The conductor is not 100% efficient on carrying the power, some energy loss is mandatory due the resistive nature of the conductor. Therefore, During Convey of electrical energy the loss is dissipated in the surrounding in the form of the heat. The amount of energy waisted as heat has the quadratic relation with the congestion of power to the network. Due to quadratic relation among congestion and the loss, it becomes more obvious to reduce the loss by managing the congestion. The congestion is power flow in the line of network.

The managing of power flow in the individual line, the total loss of the network can be managed.

The Voltage stability of the system depends upon the Voltage profile of the system and the network constraints. The Voltage profile of network is result of the operation scenario of the transmission network. The Voltage profile depends upon the power flow in the lines and the network constraints and the place of the sources and load. Thus, the Voltage stability as well as Voltage profile is can be managed through the managing the operation scenario in the network.

In our research, we have controlled the operation scenario and reactive power flow in the lines is altered so as the objective is achieved. The change is reactive power flow in the line is achieved by the changing the level of shunt compensation and the changing the reactive power dispatch through the sources. As the reactive power dispatch by the sources and the compensation level is altered the reactive line flow changes, so does the operation scenario.

The optimization sub-problem in the power system has non- linear characteristics involving the equality and inequality constraints. The optimization can be done by the numerous optimization techniques, there are conventional method as linear programming, non-linear programming quadratic programming, newtons method, gradient-Based algorithm and many more, however they are not efficient to deal with solving nonlinear optimization problem.

There are so-called stochastic search optimization methods such as genetic algorithm (GA), evolutionary programming (EP), evolutionary strategy (ES) and tabu search (TS) were also applied to overcome the ORPD problem. The key success of stochastic search methods is their ability in obtaining global optimum and handling non-convex as well as discontinuous objective functions. As per the NO Free Lunch Theorem [1], there is no specific technique that can solve all the optimization problem. Therefore, ORPD problem still can be solved by implementing new developed optimization algorithm.

In Our Research we have used the Novel Nature-Inspired heuristic techniques known as Moth flame algorithm. This algorithm is developed by the sydenjali Mirjalili [2] and it has already been popular and competitive among the many other stochastic optimization

method solving Non-linear Optimization problem due to simplicity and the efficiency. The Moth-flame Optimization algorithm is inspired by the navigation of moth at dark around the light source. In comparison with other techniques, it has much contribution in the algorithm which ensure to the global optimization.

## **1.2 Problem Statement**

The power industry has become the billion-dollar industry. Since, the economic growth of nation is also reflected by the energy consumption. And energy abundancy and network robustness become back bone of nation economic development. since, most portion electricity demand is full-filled by the conventional non-renewable energy sources and fossil fuel and gasses. There is huge need of energy saving and economic operation in order to procrastinate the future energy crisis. The losses caused by the transmission and distribution of electricity; the billion dollars of loss has been made each year. The economic operation of the power system is the very essential and beneficial for the power industry and society. The economic operation and security are always concerned for the power system. the major of the blackout is caused due to the Voltage instability result into billions of dollars of losses. The operation of the power system toward enhancing the Voltage stability and Voltage profile is also matter of concern for the power system operation and control. the Voltage profile, stability index and Loss depends upon the flow of power in the individual line of the power network. The power flow in line constituted of both reactive power and the active power. The reactive power can be compensated and the dispatch value can be managed in order to change operation scenario of the lines. The injection of reactive power from the generator is controlling through the generation Voltage magnitude. And switching mechanism can be controlled for injection from compensation.

## **1.3 Objectives and Scopes**

The main Objective of this thesis work is to find out optimal value of the dispatch of reactive power through generator and the value of reactive power of compensation of static compensation at pre-defined location and the Voltage ratio of the transformer, so as the following sub-objectives is achieved.

- Power Loss in the whole network is to be minimized
- The Voltage profile is improved
- The Voltage stability is enhanced

The above-mentioned sub-objective are optimized giving the operating scenario of reactive power flow and the transformer Voltage ratio. The optimization is to be done considering the constraint of the power system operation.

The Power System Operation Constraints for Optimization.

- The control variable values should be within limit
- The reactive flow dispatch should be within limit
- The Voltage at each bus should be with in limit

#### **1.4 Limitation of the Thesis**

The study is considered on the optimal allocation of the reactive power from the generation and the reactive power compensation. The value of allocation is evaluated for that location of compensation where it is already installed. It doesn't explore the more suitable location of the reactive power sources. It also doesn't consider the optimized size of the reactive power source at that location. it only allocates the reactive power of the compensation with in the already installed capacity of the compensation. The optimal allocation of reactive power is done to achieve the Minimum system loss, enhance stability and the Voltage profile at a once. It has not considered all the objective at once. The cost of reactive power compensation has not been considered for the optimization. The system has studies under the IEEE standard bus. It has not studied under the real-life system.

#### **1.5 Outlines of Thesis**

The remainder of the thesis is organized as follows:

**Chapter 2:** It includes detail description on Literature review, The power flow in the transmission line and evaluation of system loss, indices for the Voltage stability and Voltage profile improvement. it gives the understanding of the moth flame optimization method for solving the non- linear optimization problem



**Chapter 3:** Way to evaluate the system loss, stability indices and Voltage profile improvement indices and method to apply moth flame algorithm to obtain optimal allocation of reactive power.

**Chapter 4:** It includes the result of the optimization method is applied to obtain reactive power dispatch to minimize loss, enhance stability and Voltage profile

**Chapter 5:** Conclude the study achievement and contribution of the study and future scope of possibility.

## CHAPTER 2 : LITERATURE REVIEW

### 2.1 Power Loss

Power loss is inevitable in the network during convey of power in the work. It is due to imperfection of the element using for the power flow. i.e., Resistiveness present in the conductor. During the flow of the current in order to flow of power, there is certain loss in the conductor which is dissipated to surrounding as a heat.

Power loss is due to the current flowing in the conductor of transmission line. The flow of current to convey the power which is categories into two components.

- Active Power
- Reactive Power

The Active and reactive power flows in the networks to full fill the active and reactive power demand of the load connected to the network. The power flows from the source point to the load point through the different path in the transmission network.

#### 2.1.1 Loss Reduction:

The reactive power can be provided locally, and supplied to the load side through the compensation. By compensation to the load side, the amount of reactive power needs to be flowed from source to load is reduced, so does the value of reactive component of current is reduced and the power loss is reduced. However, the over compensation of reactive power act as the source of reactive power at that point, so over compensating doesn't always mean the reduce in the loss. it depends upon the operating scenario. There is always optimal value of compensation for reactive power so as the loss is minimized.

In the Transmission Network, some of line is overloaded comparison to the thermal capacity, some lines are lightly loaded with respect to thermal capacity. Since, loss is proportional to the square of power flow in the respective lines. So, we can redistribute the flow of the reactive power in the way that the heavily loaded became moderate loaded as a consequence, the lightly loaded became moderate loaded. However, the loss of overall system reduces.

That means, the redistribution of reactive power flow in the line can be done to reduce the overall loss. the redistribution of reactive power flow line led to change in the reactive power dispatch from the sources and the compensation. Hence, changing the dispatch of reactive power, it reduces the loss of the system.

Also, the Transformer Voltage ratio plays the controlling factor for the flow of reactive power in the line, hence, it is also another controlled factor for the reactive power dispatch.

## **2.2 Voltage Stability.**

Voltage stability is defined as the ability of a power system to maintain steady Voltages at all buses in the system after being subjected to a disturbance from a given initial operating condition [3]. Power system said to have entered into the Voltage instability when disturbances cause progressive and uncontrollable decline in the Voltage. Loss of synchronization is also be accompanied by the Voltage instability. Voltage instability led to Voltage collapse. As Per CIGRE

- Power System at give operation state and subject to a given disturbance is a Voltage Stable if the Voltages near to the loads approach post disturbance equilibrium.
- Voltage instability is the absence of the Voltage stability

The main factor contributing for the Voltage instability are

- Stressed in the power system,
- Inadequate reactive power support
- Transformer tap changer responding to the decreasing Voltage magnitude at the load bus
- Unexpected and unwanted relay operation during low Voltages and many more

The study of Voltage Instability has been analyzed under different approaches that can be basically classified into dynamic and static analysis.

The static Voltage stability method depends mainly on the steady state model in the analysis, power flow model or a linearized dynamic model described by the steady state

operation. The dynamic analysis implies the use of a model characterized by the non-linear differential and algebraic equations which includes generator dynamics, tap changing transformers etc. through transient stability simulation [4]. Stabilities studies will be in brief when the general dynamic behavior is studied, in this thesis work, we studies basis of static analysis. The Voltage stability Index is used to determine the state of Voltage instability. In our thesis work we used the L- index.

### **2.2.1 Stability Enhancement.**

The Voltage stability depends upon the Voltage profile and the network constraints. The Voltage profiles are the depends upon the operating scenario. That means The Voltage profile depends upon the power flow in the lines, the operating state of transformer ratio, and the level of compensation. Locally compensated reactive power causes to reduce the flow of reactive power in the lines, causing improvement in the Voltage profile. However, over compensation of reactive power just act as the source of reactive power. There is always optimal value of compensation. Voltage stability is often explained by the PV-Curves. The curve at Figure give below represents the PV-curves at different loading scenario. The Voltage stability depends upon the loading condition of the lines. The Voltage stability is more enhanced as the Power factor of loading is increased from lagging to leading. That mean reactive flow on lines in the system play the role in the Voltage stability. Altering the reactive flow of lines can enhance or worsen the Voltage stability of particular bus. Voltage stability is measured through the status of weak bus. The overall Voltage stability status is dictated by the weak bus.

The reactive power flow pattern in line is achieved in such a way that the Voltage stability status of weak bus is enhanced so that overall networks stability is enhanced. The change is the reactive loading of the line and the level of compensation leads to the change in the reactive power dispatch form the sources.

## Maximum loading point shifts with different power factor.

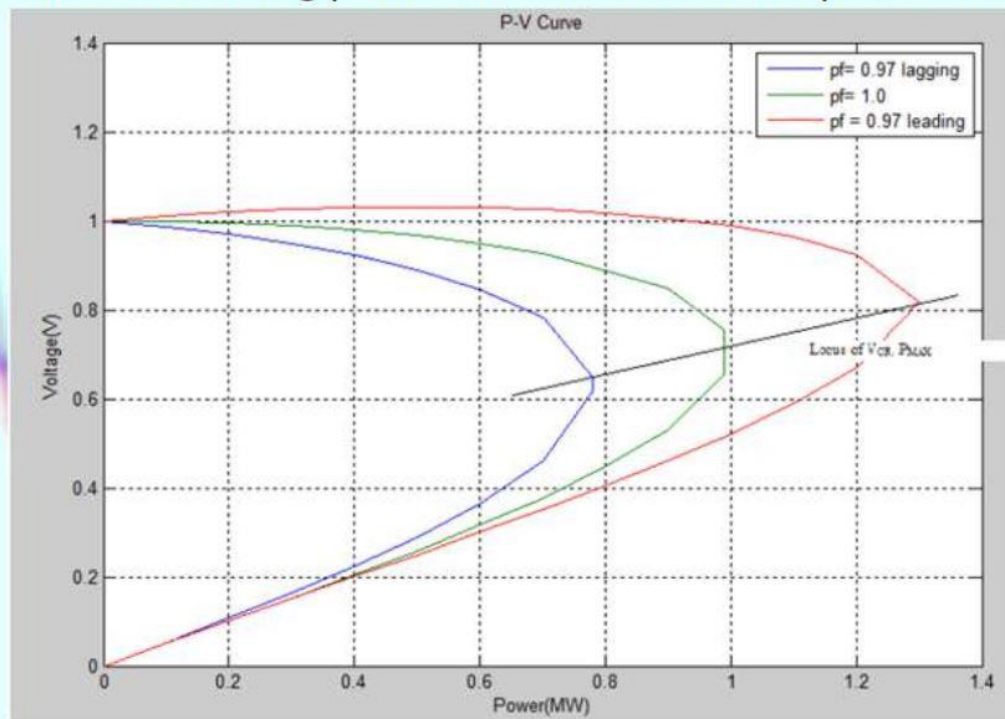


Figure 2.2-1: PV curves with loading at different power factor.

The above figure portrait the shifting of the nose point with change in power factor of flow on line. Nose point is shifted to right and the load ability increases when the power factor is reach toward the leading form the lagging.

### 2.2.2 Voltage Stability Indices

The condition of Voltage stability in a power system can be known using Voltage stability indices. This index can either reveal the critical bus of a power system or the stability of each line connected between two bus in an interconnected network or evaluate the Voltage stability margins of a system. The indices used to examine the system stability are briefly described in this section

### 2.2.3 PV curve and QV curve:

The P-V curves are the most used method of predicting Voltage security. They are used to determine the loading margin of a power system. The power system load is gradually

increased and, at each increment, is necessary recompute power flows until the nose of the PV curve is reached. The margin between the Voltage collapse point and the current operating point is used as Voltage stability criterion [5].

With Q-V curve is possible, for the operators, to know which is the maximum reactive power that can be achieved or added to the weakest bus before reaching Minimum Voltage limit. The reactive power margin is the MVar distance from the operating point to the bottom of the Q-V curve. The Q-V curve can be used as an index for Voltage instability. The point where  $dQ/dV$  is zero is the point of Voltage stability limit [3].

#### 2.2.4 L-index:

Kessel et al. [6] developed a Voltage stability index Based on the solution of the power flow equations. The L index is a quantitative measure for the estimation of the distance of the actual state of the system to the stability limit. The L index describes the stability of the complete system and is given by:  $L_j = \left| 1 - \sum_{i=1}^{n_{pv}} F_{ij} \frac{v_i}{v_j} \right|$  where  $n_{pv}$  = no of generator bus,  $j$  = no varies from 1 to no of load bus. The  $L_j$  value represent the L-index of the individual load bus. The load bus having maximum value of  $L_j$  represent the critical node where the Voltage collapse may start. So,  $L_j$  (max) is represent the stability index for whole system.  $L_j$  is a local indicator that determines the busbars where Voltage collapse may originate. The L index varies in a range from 0 (for no-load condition) to 1 (Voltage collapse) as shown in figure below.

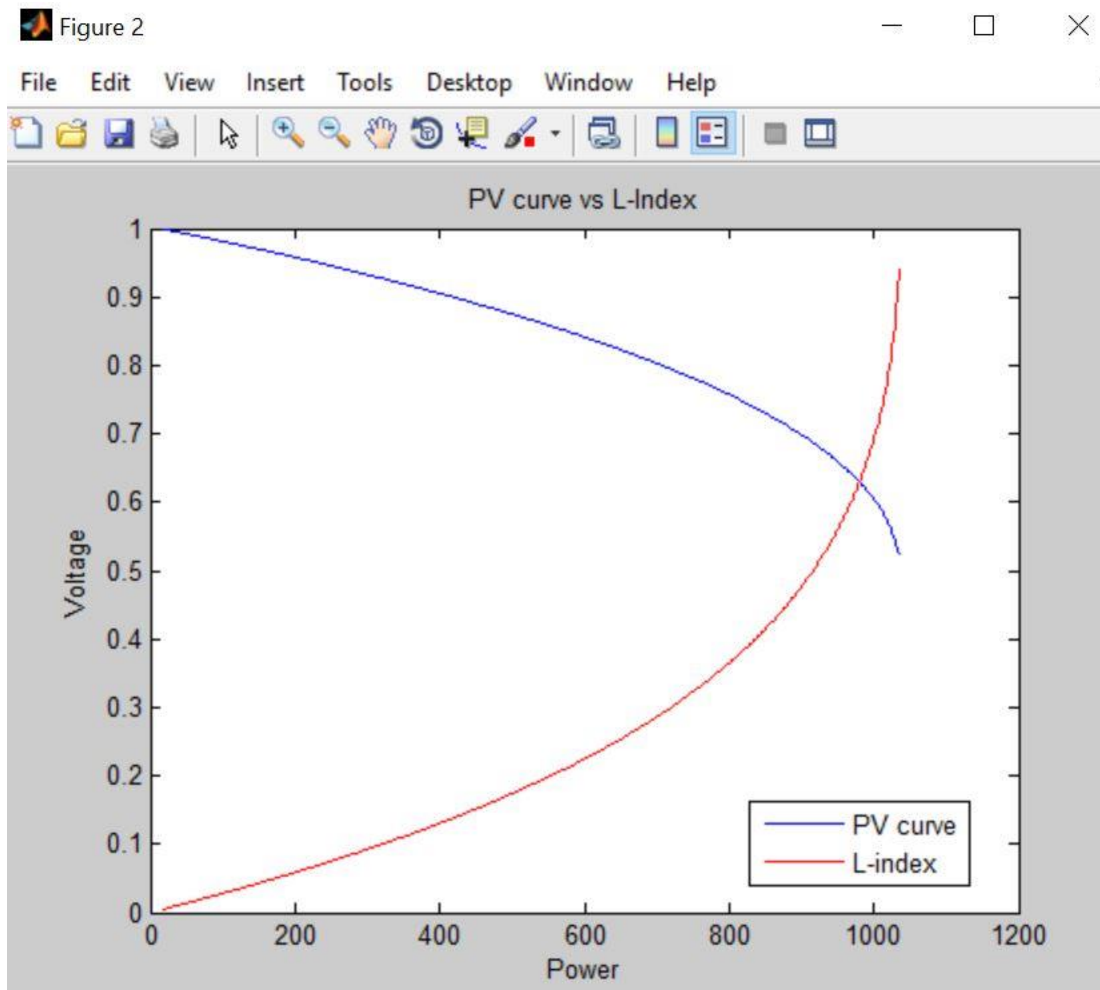


Figure 2.2-2: PV curve relationship with L-index

The above figure shows the relationship between the PV-curve and the L-index. It shows that L-index values is ranges from 0-1. Its value equal to 0 at no-load condition and 1at voltage collapse condition.

### 2.2.5 Modal analysis:

Gao et al. [7] proposed a method that computes the smallest eigenvalue and associated eigenvectors of the reduced Jacobian matrix of the power system Based on the steady state system model. The eigenvalues are associated with a mode of Voltage and reactive power variation. If all the eigenvalues are positive, the system is considered to be Voltage stable. If one of the eigenvalues is negative, the system is considered to be Voltage unstable. A zero eigenvalue of the reduced Jacobian matrix means that the system is on

the border Voltage instability. The potential Voltage collapse situation of stable system can be predicted through the evaluation of Minimum eigen values. Magnitude of each Minimum eigen value provides a measure of how close the system is to Voltage collapse. The participant factor gives the weakest bus, which is greatest contributing to the Voltage collapse.

## **2.3 Moth Flame Algorithm**

### **2.3.1 General**

Moth-Flame Optimization (MFO) algorithm. The main inspiration of this optimizer is the navigation method of moths in nature called transverse orientation. Moths fly in night by maintaining a fixed angle with respect to the moon, a very effective mechanism for travelling in a straight line for long distances. However, these fancy insects are trapped in a useless/deadly spiral path around artificial lights. This paper mathematically models this behavior to perform optimization [2]. This Method is already proven competitive among other optimization methods. The main contribution of this algorithm to the problem solving non- linear optimization, it has provision that guide the moth to search around the flame of worst merit to the best merit as the iteration reached to the its final, which enables this method to avoid the entrapment to local minima and ensure the global solution. since, the development of the its method, it has been popular among the many profession for solving optimization problem because of simplicity and effective ness of this algorithm.

Moth use transverse orientation for navigation, they use the moon light for navigation. They move the straight path keeping the fixed angle to the moon, since moon is far away. But the moth gets confused to the artificial light, and while trying to move keeping the fixed angle to the source of light, they get trapped in the spiral path because of relatively small distance for moth to source. They move around the artificial source of light which we call as flame and eventually converges to the flames and dies out.



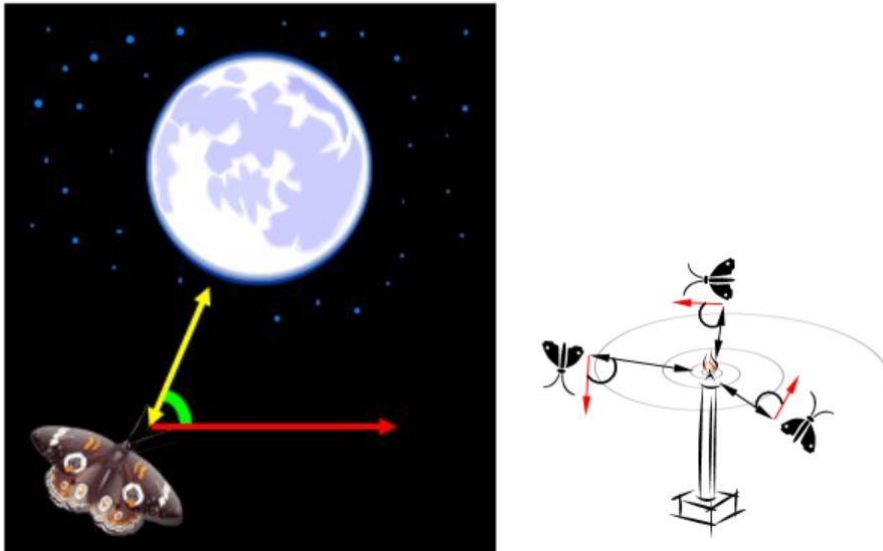


Figure 2.3-1 Movement of the moth to the moon light and artificial source of light.

The above figure represents the nature of movement of moth in a straight line by keeping the fixed angle with light of moon, but get trapped in the spiral path in artificial light because of relative short distance.

### 2.3.2 Moth, Flame, and Flame no

The moths are the candidate solution and the flame are the best solution found so far. The moth updates their position with respect to the distance from the flames and analyses the solution and update the flame. The flame no plays important role to avoid entrapment from local minima. The flame no varies from the worst position flame to best, so at starting some moths searching around the worst flame, as the iteration goes up, more no of moths searching around the better flame, and at final iteration most moths search around the best flame. So that it avoids entrapment form local minima.

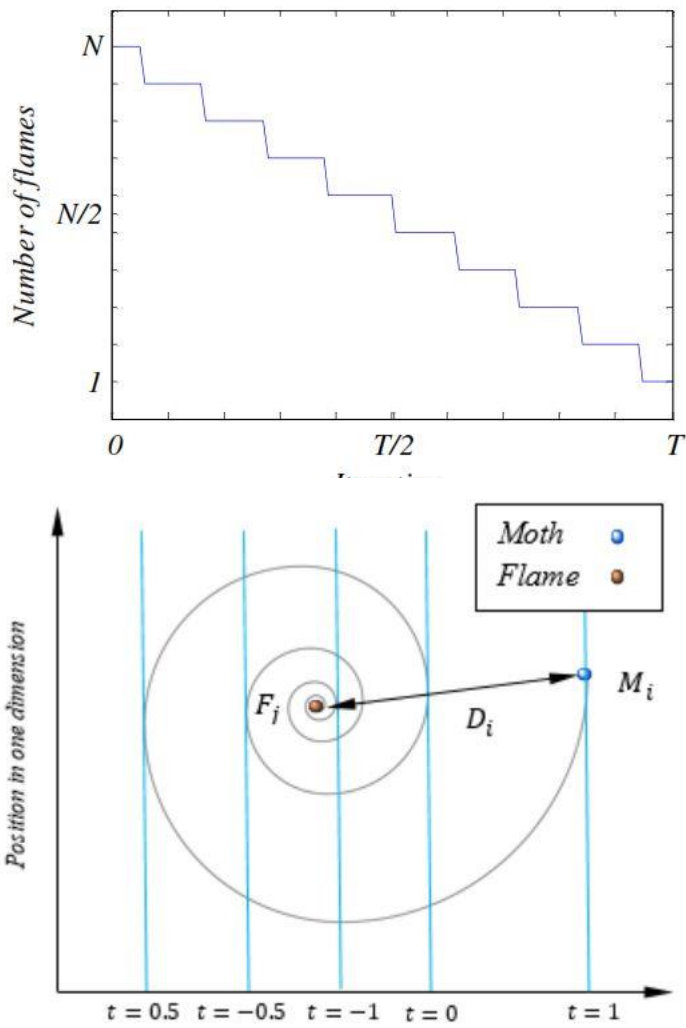


Figure 2.3-2 : Convergence of flame no(i) moth position update (ii)

This figure shows how the flame no values is decline, and moth updated their position with respect to distance from the flame.

## CHAPTER 3 : METHODOLOGY

### 3.1 Power-flow analysis in Transmission Network.

#### 3.1.1 Ac power flow

The commonly used methods for load flow analysis are Gauss Seidel method and Newtons-Raphson Method. The problem formulation in the gauss seidel is comparatively simple for each iteration, however the convergence rate is slow. Thus, much iteration is required to reach convergence. Newtons-Raphson method is used is comparatively much faster than Gauss-seidel, and each iteration require comparative much computation though. Hence, Due to high convergence rate, Newtons Raphson Method is taken in this thesis work.

In Power System load flow analysis, bus is categorized as the three type of bus: load bus, generator bus, and swing bus.

Load bus: the bus where the active power and reactive power injection is predefined.

Generator bus: the bus where the active power injection is predefined and magnitude of generator Voltage determines the reactive injection and the Voltage angle.

Swing bus: where neither active power is predefined nor reactive power. It compensates the shortage or excess of power. Voltage angle of this bus act as reference angle to determine for the Voltage angle for other bus. Voltage magnitude participate the reactive power injection of other bus, Technically Voltage of reference bus also plays role on reactive power dispatch

In Newtons-Raphson's Method the load flow is done as;

- Initially, Guess Voltage Magnitude of load bus is assumed as 1, and Voltage angle as zero. The Voltage magnitude of Generator bus kept constant over the iteration as the given value and the angle is assumed 0 initially
- The reference bus Voltage magnitude and angle are taken as given.
- The  $Y_{bus}$  is calculated for the given network.
- With initial guess the power flow at each load bus and the generator active power dispatch is calculated from load flow equation

$$S_i^* = V_i^* \left( \sum_1^{nbus} Y_{ik} * V_k \right)$$

- The Jacobian Matrix is calculated for the given Voltage solution.
- The mismatch of active and reactive power is calculated for load bus and mismatch active power is calculated for Voltage bus.
- The correction factor for Volage Magnitude and Angle is calculated from jacobian and mismatch power matrix.
- The Voltage magnitude and Angle is corrected and the process is repeated from point (iv) until the convergence is achieved.
- If final power flow violated the reactive power flow limit of generator, that bus is made to load bus limiting the reactive power flow at boundary

### 3.1.2 Active power loss computation

After the load flow gives the solution of each bus Voltage and magnitude, the active loss is calculated in each line, and total loss of system will be the summation of individual loss in the transmission line.

$$P_{Loss} = \sum_{i=1}^{NL} G_{i,j} (V_i^2 + V_j^2 + 2V_i V_j \cos \delta_{ij})$$

Where  $G_{ij}$  is the Conductance of the transmission line. NL is the no of transmission line.  $V_i$  and  $V_j$  is the Voltage magnitude of the node i and node j,  $\delta_{ij}$  is the Phase difference between  $i^{th}$  and  $j^{th}$  node.

### 3.2 Voltage Stability indices

There are no of Voltage indices to measure the Voltage stability. In this this L-index is taken for Voltage stability measurement. L-index is computed for Voltage stability index. L index value is computed for each load bus.

For each load bus. L index is calculated as 
$$L_j = \left| 1 - \sum_{i=1}^{n_{pv}} F_{ij} \frac{v_i}{v_j} \right|$$

Where 
$$F_{ij} = [F_{LG}] = -[Y_{LL}]^{-1} [Y_{LG}]$$

$[Y_{LL}][Y_{LG}]$  is obtained from Y bus Matrix.

$$\begin{pmatrix} I_G \\ I_L \end{pmatrix} = \begin{pmatrix} Y_{GG} & Y_{GL} \\ Y_{LG} & Y_{LL} \end{pmatrix} \begin{pmatrix} V_G \\ V_L \end{pmatrix}$$

Rearranging

$$\begin{pmatrix} V_L \\ I_G \end{pmatrix} = \begin{pmatrix} Z_{LL} & F_{LG} \\ K_{GL} & Y_{GG} \end{pmatrix} \begin{pmatrix} I_L \\ I_G \end{pmatrix}$$

Where,  $I_G, I_L, V_G, V_L$  are the Injected current and Voltages of the Generator and Load bus.  $Y_{GG}, Y_{GL}, Y_{LG}, Y_{LL}$  are the sub-matrix element of  $Y_{bus}$ . The Bus having maximum value of is critical bus from where Voltage instability may occur, and the  $L_{max}$  is the state of Voltage stability of whole system.

### 3.3 Voltage profile improvement

Voltage profile is measured of the deviation of Voltage magnitude of each node from the node having maximum Voltage. The Voltage deviation index is measure of Voltage profile improvement. VDI is measured as.

$$VDI = \sum_{i=1}^n V_m - V_i$$

Where  $V_m$  = Maximum Voltage magnitude among buses.

$V_i$  = Voltage magnitude of  $i^{th}$  bus.

### 3.4 Moth flame algorithm:

The moth flame algorithm is the popular, simplest and efficient optimizer for the non-linear optimization problem. The moth flame algorithm is adapted in the many optimization problem. The contribution of this algorithm is the way moth are searching around the particular flame in each iteration, and the particular flame is changed from the worse to the best as the iteration goes on. At starting of flame some are searching around

the particular flame rest are searching around corresponding flame. But as iteration goes to be final, the most moth search around the particular flame denoted by flame no, at final iteration every moth will be searching around the particular flame, this allows to avoid entrapment from the local minima. the step for applying the moth-flame algorithm.

The flames are the best moth found so far, and the fitness function is the objective function for the optimizing problem.

- Set the population size of moth, and dimension of searching agent
- Set the maximum no of iteration
- Set the random value of the moth for initial iteration with in limit of its boundary value.
- Then compute the fitness values of each moth and compute the constraint introduce penalty value to fitness value if the moth violates the limiting constraint.
- Update the flame from the best moth found so far
- Calculate random variable and the flame no
- Update the moth from the corresponding flame if moth no is less than flame no, otherwise update moth from the particular flame denoted by flame no
- Check if the iteration is over? If yes show the result, else go for point no iv)
- This way the moth-flame algorithm is applied to find the optimal value of control variable of load for Minimum objective function.

### **3.5 Co-simulation of DigSilent and MATLAB.**

The DigSilent and MATLAB co-simulation is done through the features of file handling in both software. In the co-simulation, synchronization and data exchange is major part done during the processing. The parallel processing of both -software is done through the synchronization signal exchanged through some common file accessed by both of the software. In this thesis work, the csv file is used for the synchronization and the data exchange.

The main technique behind the synchronization is the sequential operation of each software is done, one software performs a work and send a single for completion of part of job and wait for the signal from another software to complete the remaining part send back green signal to repeat the performance.

The techniques to parallel work of both software for a common job is done by operating flag file as a common file by using read and write function by both software to synchronize. Other file is used to send or only to receive the data from each software.

### 3.5.1 DigSilent action for co-simulation

- i) DigSilent initial set the flag file of value 0;
- ii) Perform the operation and update data to write file and set value of flag file 1
- iii) Read the flag file until its value is 0
- iv) When flag value is 0 read the data from input file perform the rest operation and repeat to the point ii) until full job is complete.
- v) MATLAB action for co-simulation
- vi) Read the flag file until the value is 1;
- i) When flag is 1, read the data from write file send by DigSilent and perform the operation and update the result data to the read file and set the flag file 0
- ii) Again, repeat from point (i) unless full job is completed.

## 3.6 Project Implementation Features.

### 3.6.1 Test Bus

The thesis study is done on the IEEE 57 test bus. The features of IEEE 57 bus are

- 57 bus
- 42 loads
- 7 nos of generator
- 3 nos of shunt compensation
- 15 nos of transformer
- 65 lines

The reactive power injection from source is controlled by the Voltage level of generation, so the control variable is 7 Voltage magnitude, 3 shunt compensation, a and 15 transformers tap ratio.

### 3.6.2 Feature of the Moth flame algorithm.

- Population size=30;
- Dimension of searching agent(moth)=25;
- Maximum no of iteration: 300

### 3.6.3 The objective of the Optimization problem

- To Minimize Active power loss
- To Improve Voltage profile
- To Enhance Voltage instability

Subjected to the

- Equality constraint: Active and Reactive power balance.
- In Equality constraint: Voltage magnitude and Voltage angle with in limit.  
Control variable value with in limit.

### 3.7 Tools and software.

The DigSilent Power Factory and MATLAB tools is used for the Simulation and programming. This optimization problem has to be solved for the objective of active power loss reduction, the Voltage deviation reduction and the Voltage stability enhancement. The test bus modeling is done in DigSilent and MATLAB, and verified to be exact so that co-simulation is done without modeling error. The DigSilent Power Factory is used for the Simulation and programing in standalone mode and the co-simulation with the MATLAB. To limit the Voltage of bus with in boundary, the penalty factor is introduced and to limit reactive power dispatch limit, the load flow run in the reactive limit mode. For the loss reduction and the Voltage deviation reduction purpose, the DigSilent simulation and programming is done in standalone version for the Voltage stability enhancement optimization work, the co-simulation of DigSilent is done with the MATLAB software, because for the complex mathematical computation is required to evaluate the Voltage stability indices. For co-simulation the Y bus formation, L-index



calculation is done at MATLAB and the rest along with Optimizing algorithm and load flow simulation is done at the DigSilent power factory.

## CHAPTER 4 : RESULT AND DISCUSSION

### 4.1 General

The IEEE 57 test bus is taken as the study case for this thesis work. The IEEE 57 standard bus system has active power load of the 1250.80 MWatt and Reactive power load of 336.40 MVar. The 57- bus system is modeled in the DigSilent and the MATLAB. In DigSilent Simulation model is done, in MATLAB mathematical model is done. The Line and Data value of the network is tabulated in the ANNEX 1

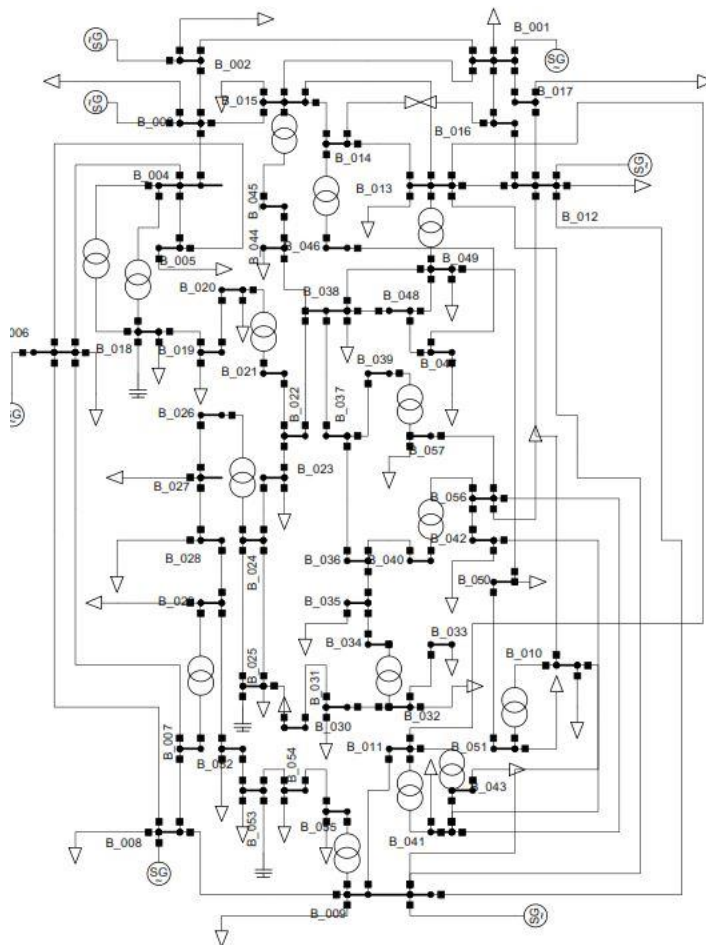


Figure 4.1-1 : The modeling of 57 bus on DigSilent power factory

The figure above is the simulation drawing of the IEEE 57 standard bus at the DigSilent Power Factory 15.1

## 4.2 Base Case Simulation

The Base case is Simulated on the DigSilent and mathematically modeled on the MATLAB. The both modeling is compared for exactness through the total net loss and the Voltage at each bus. The load flow is done by the newtons Raphson method. The load flow is done on both tools. The Voltage profile is as follows. The Voltage of power loss is same in both modeling at Base case; Therefore, exactness of modeling is verified.

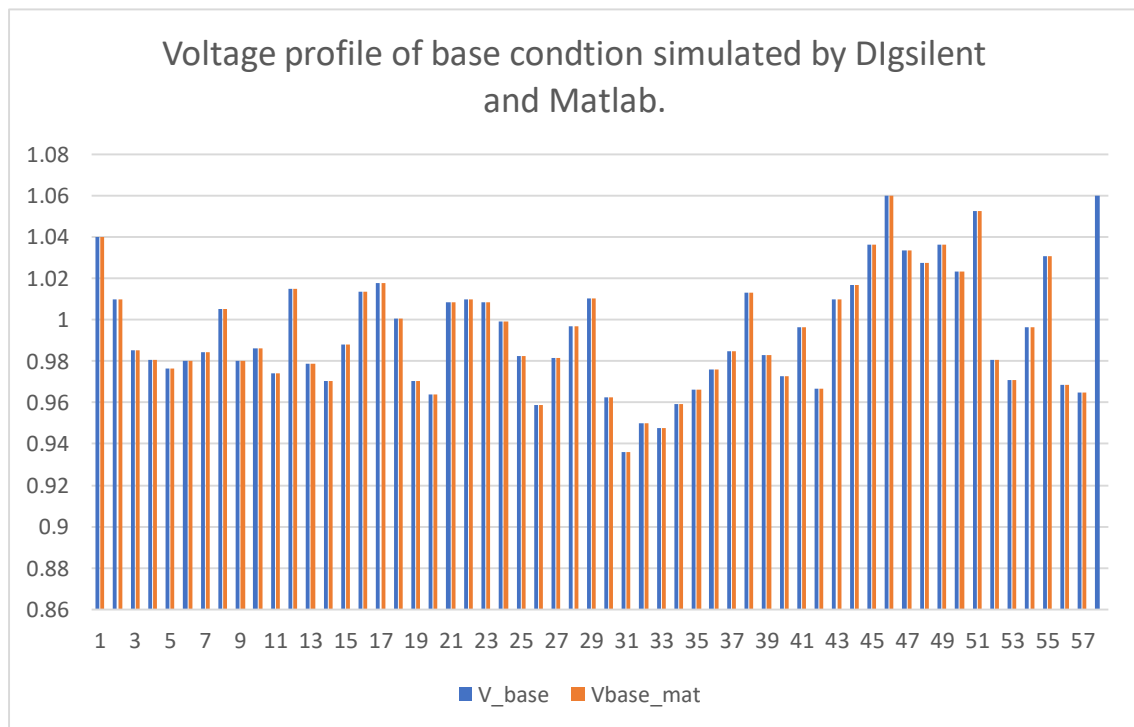


Figure 4.2-1 : The Voltage profile at Base condition simulated by DigSilent and MATLAB.

The Above figure represent the Voltage profile of 57 node of IEEE 57 bus, which is obtained after simulated at DigSilent and Mathematically modeled at MATLAB. The exactness of the voltage obtained from the Both tools verify the exactness of each model other. And synchronous operation can be done without modeling error.

The net loss, the Voltage deviation and Voltage stability indices, Reactive power dispatch and the reactive power flow in lines, active flow in lines, pf are evaluated for the Base case. At Base Case, System Loss= 27.86 MWatt. Voltage deviation summation= 3.8140.

The Voltage stability is measured by the L-index. The L-index is measured for each load bus. The bus having maximum value of L-index is known as critical bus, from where the Voltage collapses likely to originate if occurred. The maximum Value of L-index provide the Voltage stability status for the whole system.

Table 4.2-1 : The L-index value at Base case.

Load Bus No	L-index
4	0.011021
5	0.010429
7	0.026531
10	0.034682
11	0.032342
13	0.036135
14	0.050381
15	0.03224
16	0.025115
17	0.028564
18	0.094672
19	0.133547
20	0.140283
21	0.132506
22	0.130686
23	0.132869
24	0.148662
25	0.254627
26	0.142751
27	0.105957
28	0.081822
29	0.06431
30	0.278436
<b>31</b>	<b>0.309898</b>
32	0.280551

33	0.283197
34	0.183776
35	0.173879
36	0.161708
37	0.152633
38	0.126017
39	0.154126
40	0.162956
41	0.121274
42	0.169993
43	0.058342
44	0.111775
45	0.065771
46	0.080186
47	0.111616
48	0.115214
49	0.106497
50	0.110171
51	0.060253
52	0.099119
53	0.112858
54	0.073643
55	0.028125
56	0.183734
57	0.199236

The Above Table represent the L-index value of each load bus. L -index represent the margin of actual state from point of voltage collapse. L-index value is ranges from 0 to 1. Higher value of L-index means less margin of actual state from point of voltage collapse for that bus. The bus having high value of L-index have less margin from point of voltage collapse. So, L-index (max) is the voltage stability index of vulnerable bus, also the Stability index for whole system. In above table, Load bus at bus no 31 have high

value of L-index equals to 0.3099. that means, most unstable bus is bus no 31 from where voltage collapse may start if occurred.

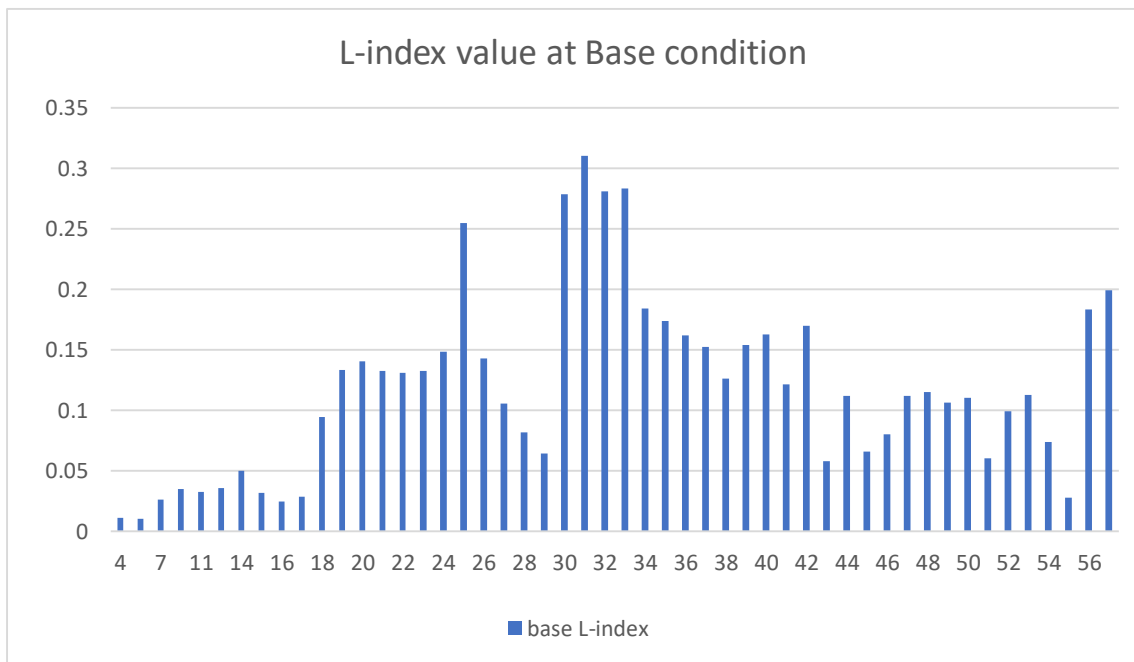


Figure 4.2-2 : L-index value of load bus at Base condition

The Above Figure represent the Graphical view of L-index value of the load buses. The bus no 31 is appeared to have maximum value of L-index. So, the critical bus is Bus no 31. The L-max value is 0.309898. the status of Voltage stability is measure by the L-max =0.309898.

Table 4.2-2 : The Reactive power dispatch by Generator and compensation by shunt compensator at Base case

QG1	128.8496
QG2	-0.755
QG3	-0.9049
QG6	0.8714
QG8	62.0996
QG9	2.2884
QG12	128.6309
QC18	10
QC25	5.9

QC53	6.3
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The Above Table is the value of reactive injection from the Generator and shunt compensator, at the base condition.

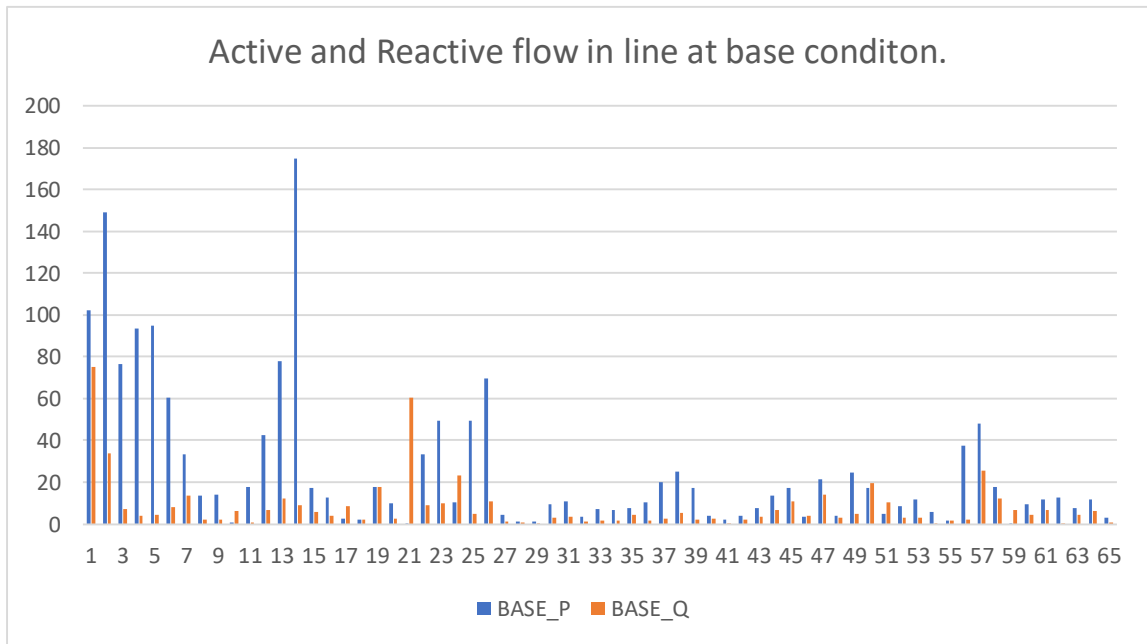


Figure 4.2-3 Active and Reactive power flow in the Line at Base Condition.

### 4.3 Optimization for the loss reduction.

The optimization for the loss reduction is done through reactive power dispatch, and reactive power compensation. The control variable for the reactive power dispatch and shunt compensation are the Voltage magnitude of generator, the value of shunt compensation, and transformer tap ratio.

The control variable values as the results of moth flame algorithm implication.

Table 4.3-1 : The Control variables values are as the output for this optimization of Minimum power loss.

Control Variable Name	Control variable value
PG01	1.059999

PG02	1.050708
PG03	1.044838
PG06	1.033593
PG08	1.06
PG09	1.026822
PG12	1.033906
TR04-18(1)	0.994608
TR04-18(2)	0.9
TR07-29	0.937356
TR09-55	0.931289
TR10-51	0.928505
TR11-41	0.9
TR11-43	0.914917
TR13-49	0.900139
TR14-46	0.918907
TR15-45	0.93278
TR20-21	1.0097
TR24-26	1.007482
TR32-34	0.973475
TR39-57	0.979395
TR40-56	1.00679
SC18	8.343411
SC25	5.9
SC53	6.299452

The Above Table is the value of the control variable that is obtained after the moth flame optimization is applied for the objectives of loss minimization. The control variable values are used to update the IEEE 57 bus system and load flow is done to evaluate other power system results.

Table 4.3-2 : Reactive power dispatch from Generator and value of shunt compensation



QG1	27.7363
QG2	50
QG3	60
QG6	-8
QG8	84.03201
QG9	8.99982
QG12	72.64819
QC18	8.343411
QC25	5.9
QC53	6.299452

The above table gives the value of the reactive power allocation from generation and the compensator to achieve the active power loss minimization.

After the optimization, the active power is loss reduced to the 24.09 MWatt from the 27.86 MWatt at Base condition, which is more than 13 percentage in reduction. The Voltage deviation value is also reduced from 3.814047 to 2.702691. The Voltage stability index is also improved. i.e., L-max is reduced to 0.2695 from the L-max=0.309898.

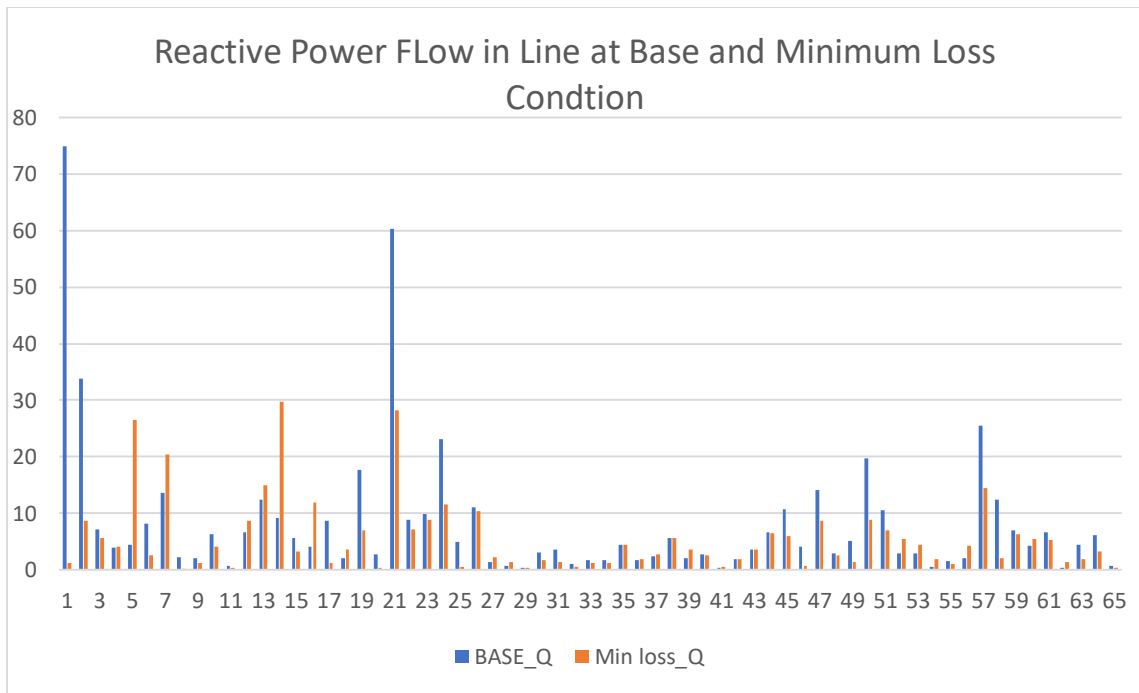


Figure 4.3-1: Comparison of Reactive power flow in the line at Base condition and Minimum Loss condition.

The above diagram is for the comparison of the reactive power flow in the transmission lines, at the base condition and at the minimum loss condition after reactive power is reallocated.

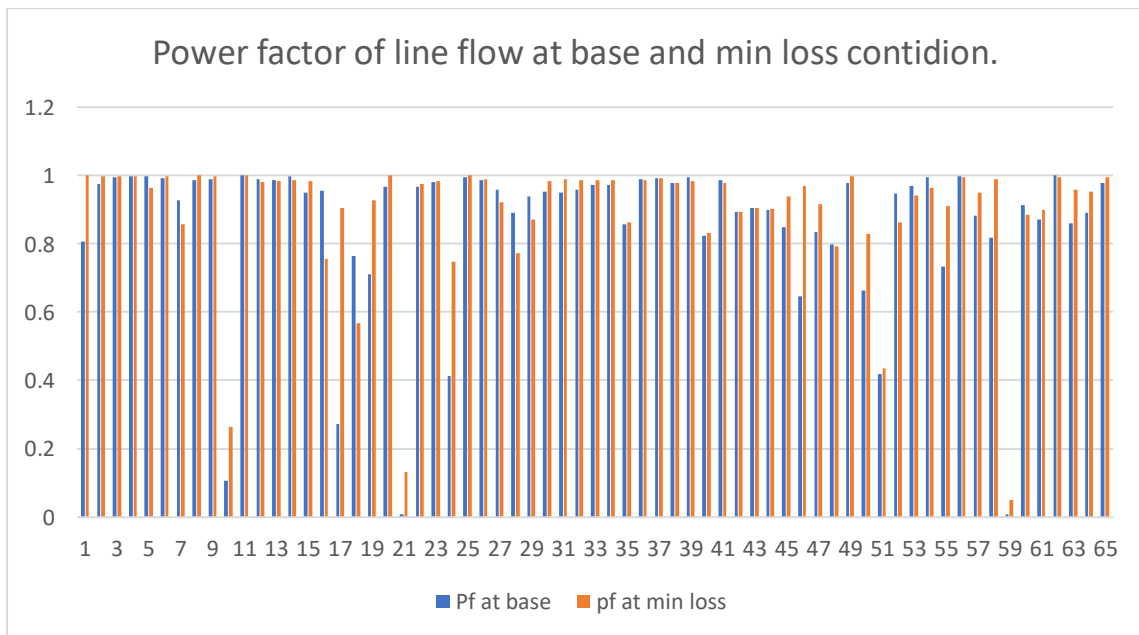


Figure 4.3-2 : Comparison of Power factor of line flow at the Base and min loss condition.

The above figure is the comparison of the power factor of the flow of line at the base condition and the loss minimization condition. it is seen that power factor in the line is changed when it is operated in the loss minimization condition.

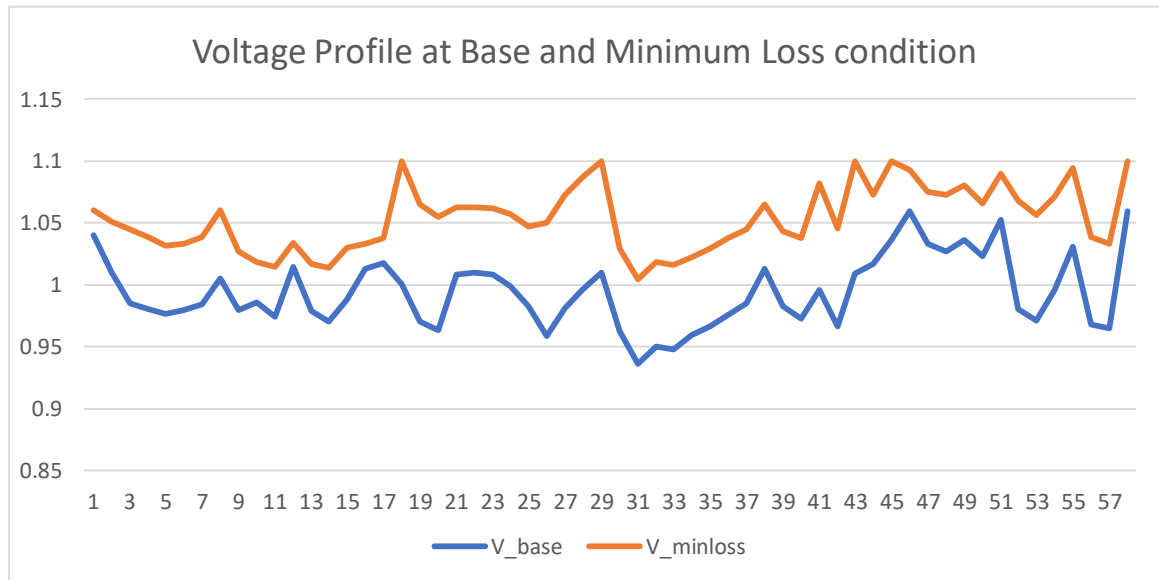


Figure 4.3-3 : Voltage profile of bus at Base condition and Minimum loss condition

The above figure shows the voltage profile of nodes, at base condition and the optimized condition for loss minimization. It seems voltage profile is also improved than the base condition when the reactive power reallocation is done for loss minimization.

#### 4.3.1 Comparison of Active power loss with other method

When the Loss reduction evaluated through the moth flame algorithm, the system loss is compared with value obtained from another similar type of search algorithm. The loss reduction in the system through moth flame is more than that is reduced through another algorithm. Therefore, the moth flame algorithm show is very effectiveness and competitiveness on exploring the global minima, compared to another type of methods. The comparative value of loss is given below.

Table 4.3-3 :Comparison of Real power loss among Different Method [8]

Methods	Real Power loss
CSA	24.2619
GWO	24.7523

GSA	24.4922
FA	24.49587
MFO	24.09

The above table is comparison of active power loss reduction is achieved with different optimization method. It is clearly seen that the loss reduced by the moth flame algorithm is appeared much than that is reduced using other methods. The MFO algorithm therefore proved the competitiveness with other type of algorithm.

#### 4.4 Optimization for Voltage profile Improvement.

The objective is, to Minimum the Voltage deviation of each bus Voltage from the maximum Voltage of the system. the control variable the reactive power dispatch of generator, the value of compensation of shunt compensation and transformer tap ratio.

Table 4.4-1 : The Control variables as the output for this optimization of Minimum Voltage deviation.

Control Variable Name	Control variable value
PG01	1.06
PG02	1.031033
PG03	1.020991
PG06	1.037241
PG08	1.057739
PG09	1.031689
PG12	1.06
TR04-18(1)	0.998533
TR04-18(2)	0.949353
TR07-29	0.966124
TR09-55	0.965103
TR10-51	0.981906
TR11-41	0.900398

TR11-43	0.953782
TR13-49	0.9
TR14-46	0.956861
TR15-45	0.972902
TR20-21	0.954955
TR24-26	1.1
TR32-34	0.900074
TR39-57	1.1
TR40-56	1.005113
SC18	9.99973
SC25	5.9
SC53	6.118675

The Above Table is the value of the control variable that is obtained after the moth flame optimization is applied for the objectives of voltage deviation minimization. The control variable values are used to update the IEEE 57 bus system and load flow is done to evaluate other power system results.

Table 4.4-2 : Reactive power dispatch from Generator and value of shunt compensation

QG1	87.91713
QG2	-17
QG3	-10
QG6	25
QG8	67.34808
QG9	9
QG12	142.9747
QC18	9.99973
QC25	5.9
QC53	6.118675

The above table gives the value of the reactive power allocation from generation and the compensator to achieve the voltage deviation minimization.

After optimization is done for Voltage profile improvement, the Voltage deviation summation is reduced to 1.469248 from 3.8140. the loss is reduced to the 26.99 MWatt from 27.76 at Base condition. the Voltage stability index is also improved compared to the Base condition. L-max value is reduced to the 0.2699 from the 0.309898 at Base condition.

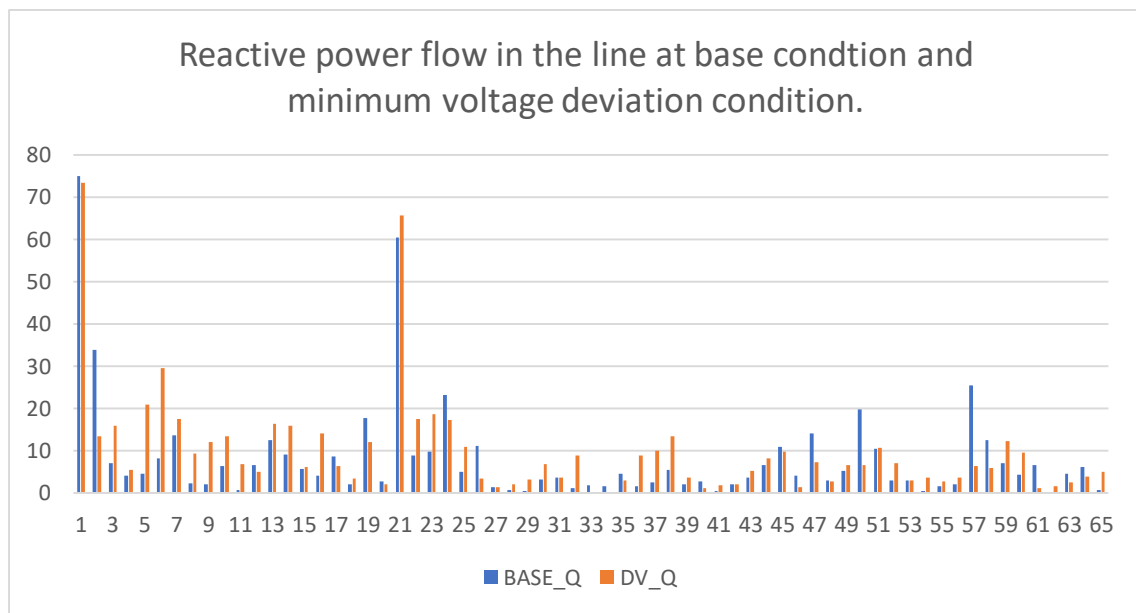


Figure 4.4-1 : Comparison of Reactive power flow in the line at Base condition and Minimum Voltage deviation condition

The above diagram is for the comparison of the reactive power flow in the transmission lines, at the base condition and at the minimum voltage deviation condition after reactive power is reallocated.

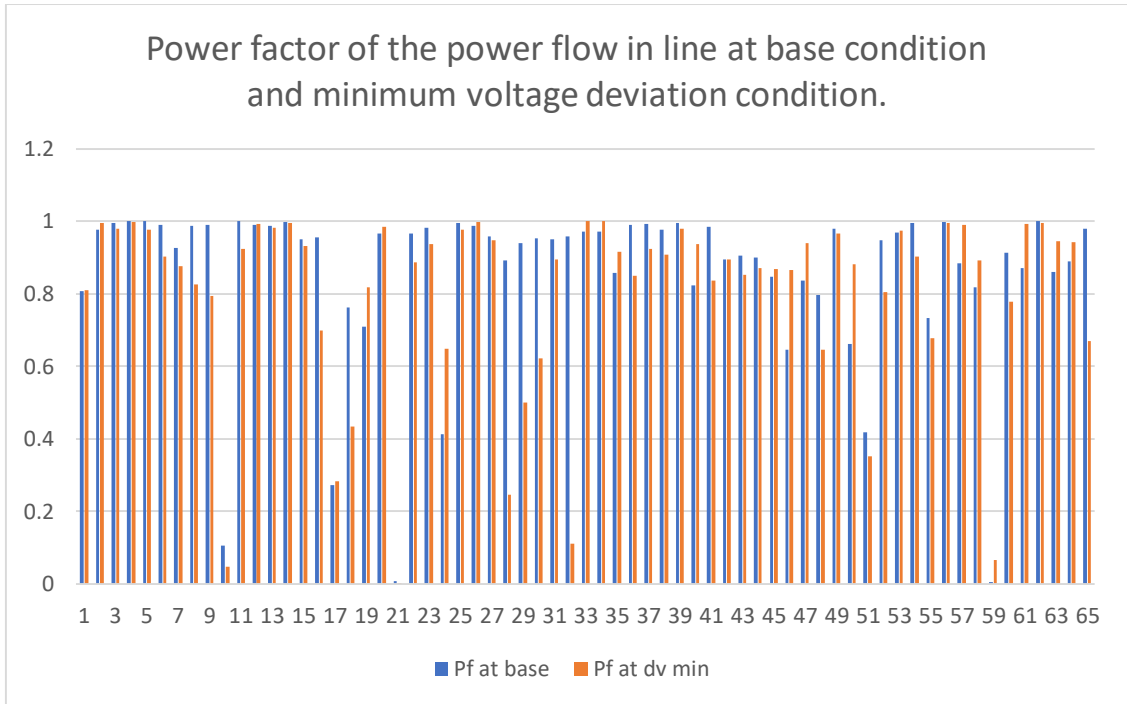


Figure 4.4-2 The comparison of Power factor of the power flow in line at Base condition and the Minimum Voltage deviation condition.

The above figure is the comparison of the power factor of the flow of line at the base condition and the voltage deviation minimization condition. it is seen that power factor in the line is changed when it is operated in the voltage deviation minimization condition.

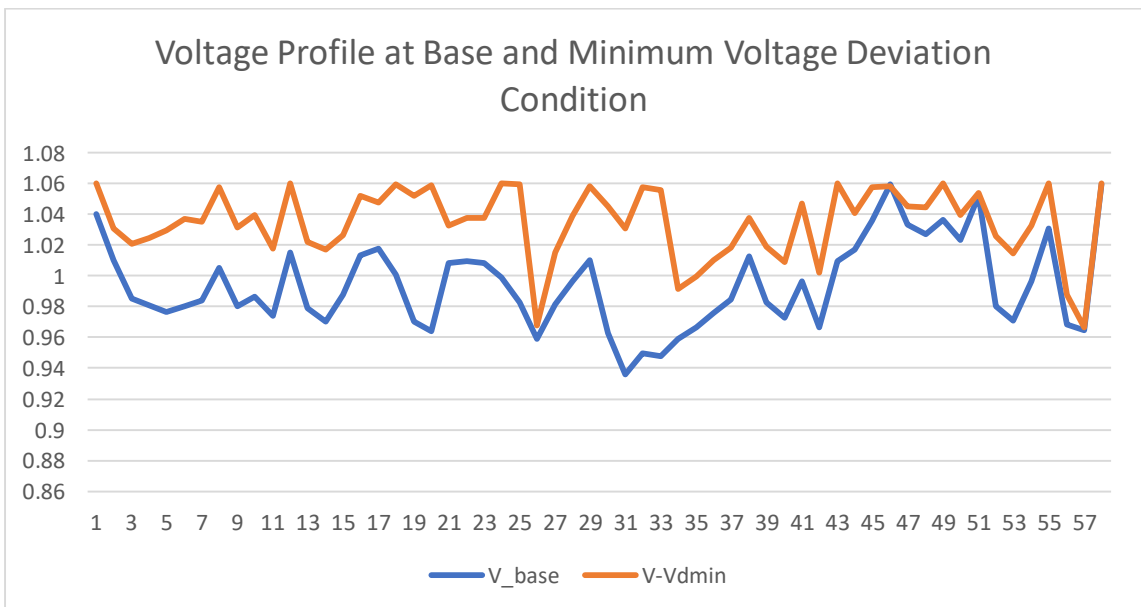


Figure 4.4-3 The Voltage profile of bus at Base and Minimum Voltage deviation condition.

The above figure shows the voltage profile of nodes, at base condition and the optimized condition for voltage deviation minimization. It seems voltage profile is also improved than the base condition when the reactive power reallocation is done for voltage deviation minimization.

#### **4.5 Optimization for Voltage stability Enhancement (Minimization of L-index Max)**

The Voltage stability enhancement is denoted by the L-index. Each load bus has L-index value. The bus having high value of L-index is the critical bus from where Voltage collapse originated if occurred. The L-max value dictate the Voltage stability states of the system. the optimization is done to reduce the value of L-max.

Table 4.5-1 : The Control variables as the output for this optimization of Minimum L-index max.

Control Variable Name	Control variable value
PG01	1.0598
PG02	1.0275
PG03	1.0075
PG06	1.0119
PG08	1.06
PG09	1.0237
PG12	1.037404
TR04-18(1)	0.911599
TR04-18(2)	0.9
TR07-29	0.911684
TR09-55	0.997148
TR10-51	0.914858
TR11-41	0.9
TR11-43	0.910999



TR13-49	0.938807
TR14-46	0.903044
TR15-45	0.922625
TR20-21	1.085164
TR24-26	1.088453
TR32-34	0.9
TR39-57	1.1
TR40-56	1.065009
SC18	6.762335
SC25	5.9
SC53	0

The Above Table is the value of the control variable that is obtained after the moth flame optimization is applied for the objectives of Voltage instability minimization. The output as control variables is used for the further load flow to evaluate the power system power flow results.

Table 4.5-2 : Reactive power dispatch from Generator and value of shunt compensation for Voltage stability enhanced condition.

QG1	127.7671
QG2	-17
QG3	-10
QG6	-8
QG8	130.6624
QG9	-2.96161
QG12	93.89898
QC18	6.762335
QC25	5.9
QC53	0

The above table gives the value of the reactive power allocation from generation and the compensator to achieve the voltage instability minimization.

After optimization is done for Voltage stability enhancement, the L-max value is reduced to 0.2653 from 0.3098 at Base condition. the loss is reduced to the 27.49 MWatt form 27.86 at Base condition. the Voltage deviation summation is also reduced 2.897311 form the 0.2699 from the 3.814047 at Base condition.

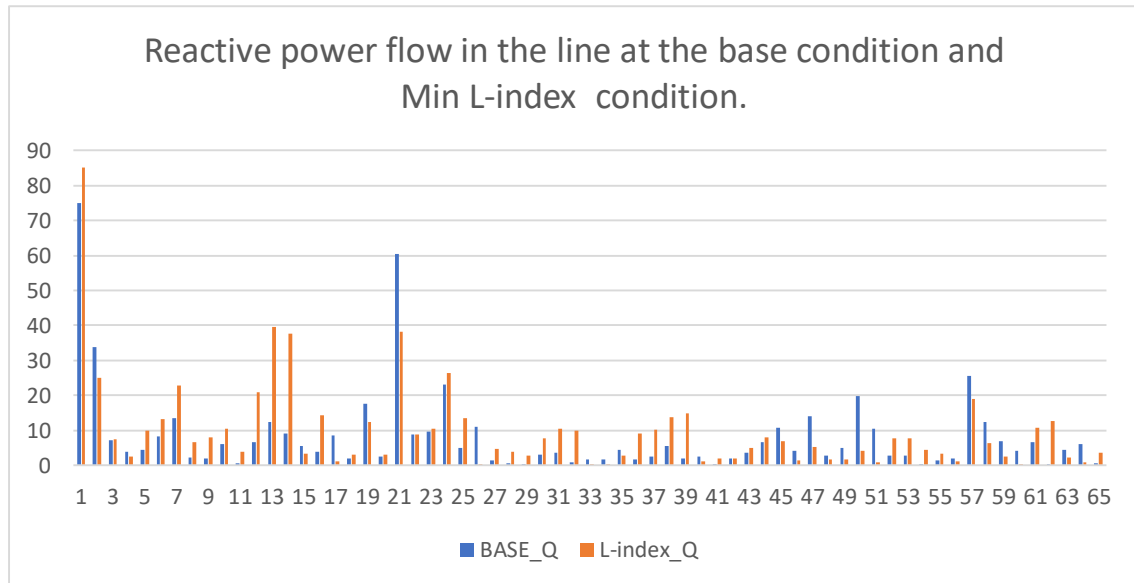


Figure 4.5-1 : The Comparison of Reactive power flow in the line at Base condition and Minimum L-index condition.

The above diagram is for the comparison of the reactive power flow in the transmission lines, at the base condition and at the voltage stability enhancement condition after reactive power is reallocated.

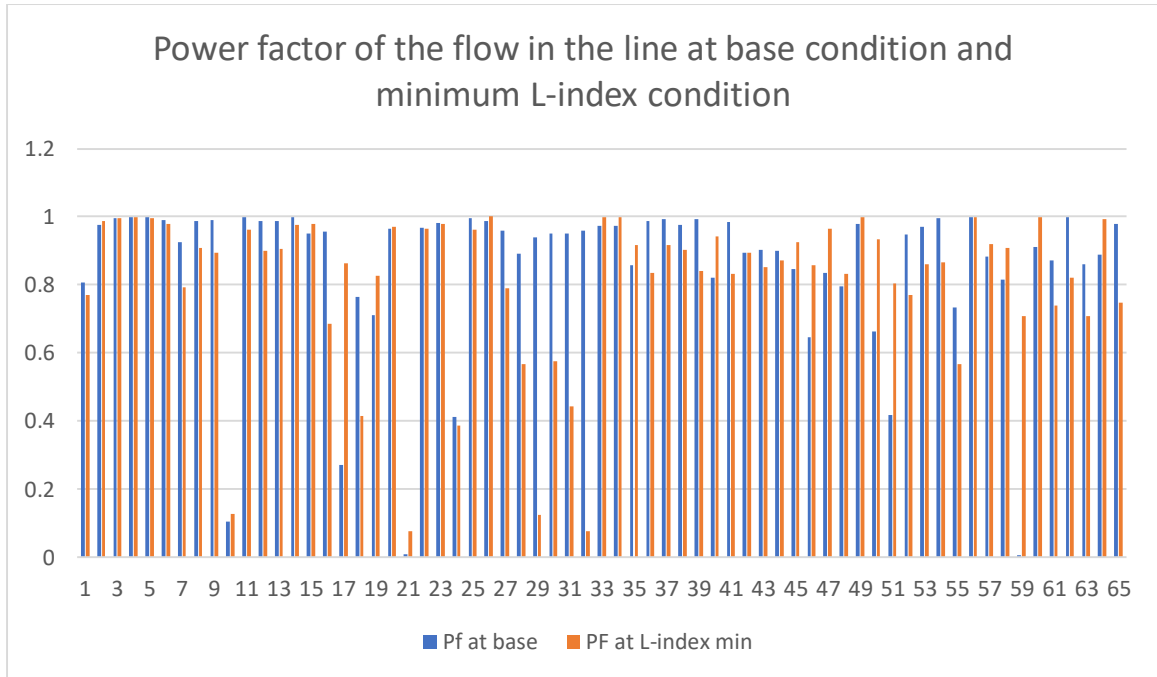


Figure 4.5-2: The comparison of the Power factor at Base condition and the Minimum L-index condition.

The above figure is the comparison of the power factor of the flow of line at the base condition and the voltage stability enhancement condition. it is seen that power factor in the line is changed when it is operated in the voltage stability enhancement condition.

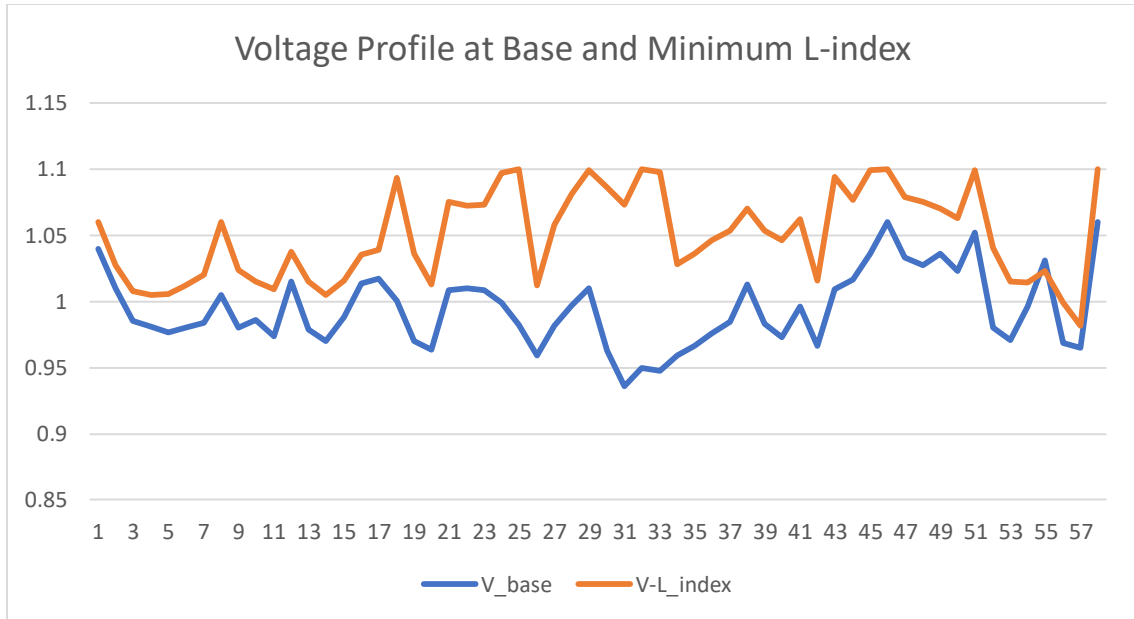


Figure 4.5-3 : 3 Voltage Profile at Base and Minimum L-index condition

The above figure shows the voltage profile of nodes, at base condition and the optimized condition for voltage deviation minimization. It seems voltage profile is also improved than the base condition when the reactive power reallocation is done for voltage deviation minimization.

#### 4.6 Other Comparative Result.

Table 4.6-1: comparison of the objective value at different scenario.

	Base Condition (initially)	Minimized Loss	Minimum Voltage deviation	Minimum (max L-index)
System loss (MWatt)	27.86	<b>24.09</b>	26.99	27.49
Voltage deviation index	3.814047	2.702691	<b>1.469248</b>	2.897311
Voltage stability index (Max L -index)	0.3099	0.2695	0.2727	<b>0.2653</b>

QG1 (MVar)	128.8496	27.7363	87.91713	127.7671
QG2 (MVar)	-0.755	50	-17	-17
QG3(MVar)	-0.9049	60	-10	-10
QG6 (MVar)	0.8714	-8	25	-8
QG8 (MVar)	62.0996	84.03201	67.34808	130.6624
QG9 (MVar)	2.2884	8.99982	9	-2.96161
QG12 (MVar)	128.6309	72.64819	142.9747	93.89898
QC18 (MVar)	10	8.343411	9.99973	6.762335
QC25 (MVar)	5.9	5.9	5.9	5.9
QC53 (MVar)	6.3	6.299452	6.118675	0

The above table give the operation scenario for different objectives condition and the reactive allocation values for generation and shunt compensator to operate in respective condition.

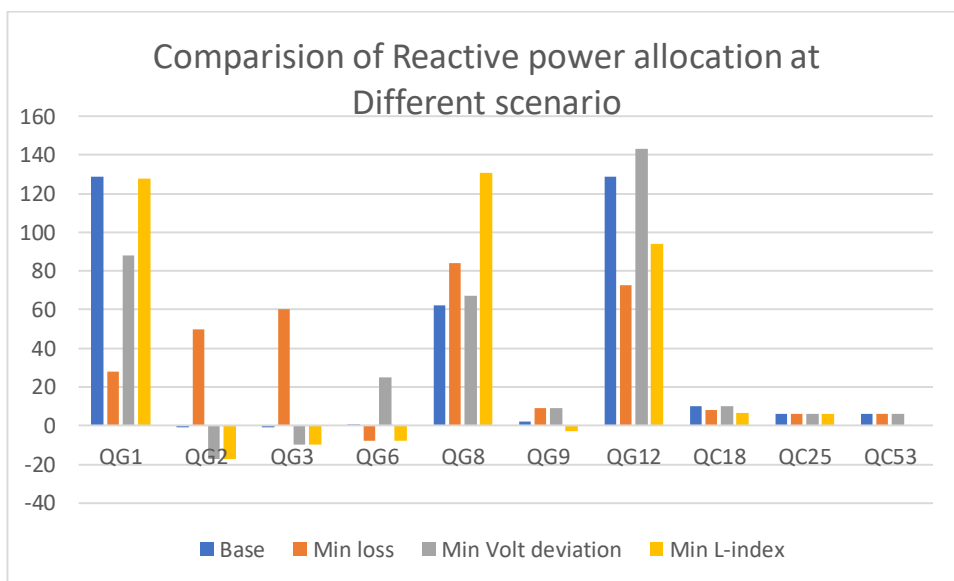


Figure 4.6-1: Comparison of Reactive power dispatch at different scenario.

The above figure gives the pictorial view of the reactive power allocation from the generator and the compensator at the different case scenario of Base condition, active power loss, voltage profile improvement and voltage stability enhancement condition.

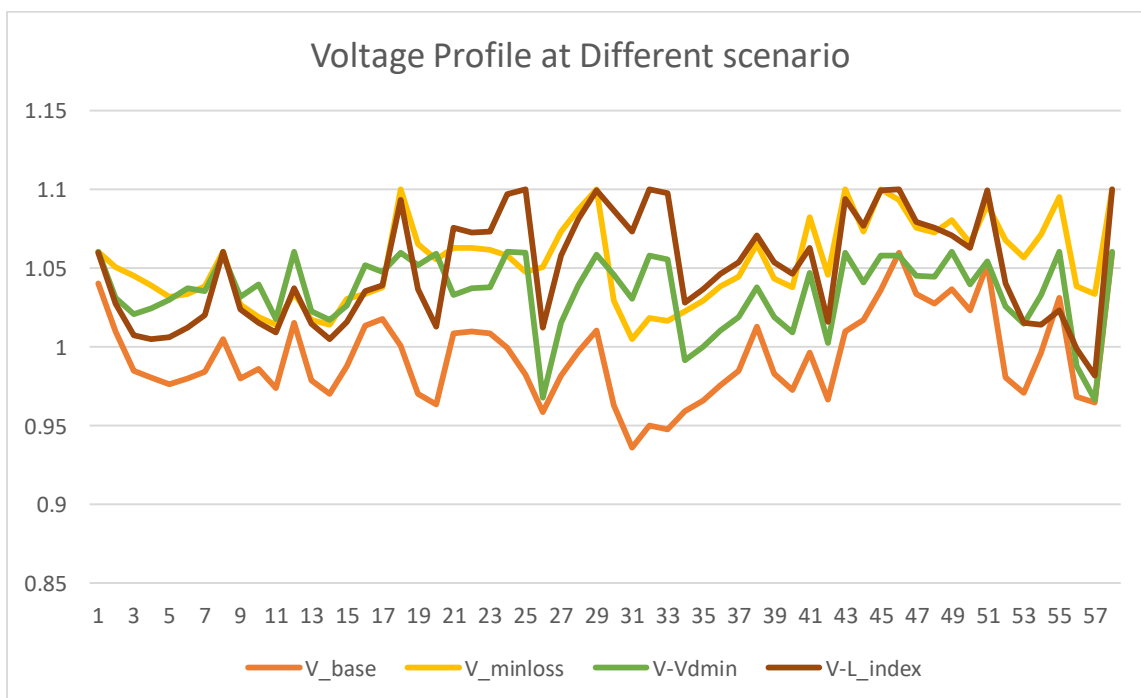


Figure 4.6-2: Voltage Profile of bus at different scenario.

The above figure gives the comparative view of the voltage profile for all the cases. It is clearly seen that voltage profile for minimum voltage deviation condition have less deviation among node voltage in comparison with the other cases.

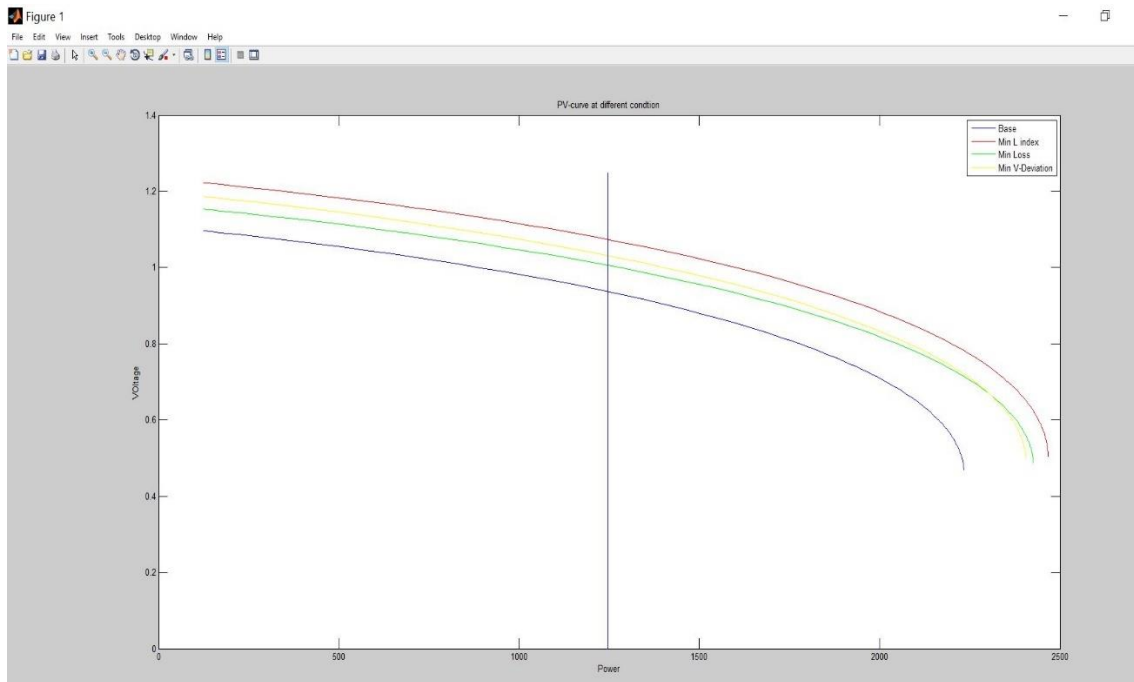


Figure 4.6-3: PV curve at the different operating scenario showing the enhancement of Voltage collapse point.

The above figure is about the enhancement of the voltage stability at different cases. It is reflected that the nose point for voltage collapse is enhanced than base condition and the voltage collapse point is maximum extended for the condition of Min L-index (max).

## CHAPTER 5 : CONCLUSION.

In this Thesis, the optimal values of reactive power injection from generation and the reactive power compensation from shunt compensators evaluated for the three objectives: Active power loss reduction, the Voltage deviation minimization, the Voltage stability enhancement. The reactive power flow in the line is another responsible factor for the loss in transmission, the deviation of Voltage and Voltage instability. The idea is to reduce the impact of the reactive flow in the line through optimization process by controlling the operation in a way that the effect due to the flow of reactive power in line is minimized by altering the reactive power flow in the lines where impact could be minimized. In this thesis, it is studied that the reactive power flow in the pattern could be changed with meeting reactive power demand, the effect on the loss, Voltage regulation and Voltage stability is also changed. By Proper rearrangement of reactive line flow, the overall system line loss could be reduced, or the Voltage deviation could be minimized and the Voltage stability could be enhanced. The proper value of the rearrangement of reactive line flow is optimized using moth flame algorithm. The rearrangement of reactive power line will be consequence of the altering the reactive power injection from the source and reactive power compensation. The MFO is applied for objective of loss minimization, the active power loss is reduced to minimum value of 24.09 MWatt, which was 27.86 MWatt before reactive power reallocation is done. When reactive power reallocation is done for voltage profile improvement, VDI (Voltage Deviation Index) is reduced to least value of 1.469248 from 3.814047 at Base condition. Similarly, When MFO is applied for voltage stability enhancement, L-index (max) is deduced to minimum value of 0.2653 after reactive power reallocation, from the value of 0.3099 at Base condition. Through reactive by reallocation, using MFO algorithm, the power loss, voltage deviation index and L-index (max) is reduced to minimum value. So, the active power loss reduction, voltage profile improvement, and voltage stability enhancement is achieved by reactive power reallocation using Moth flame algorithm. In this thesis, the optimal reactive power allocation from source and compensator is evaluated by optimization techniques, for three objective cases of active loss, Voltage deviation, and Voltage stability separately. In all three cases, the operation scenario is better than the Base cases in all three aspects of loss, Voltage deviation and the Voltage stability. So, power system should be operated economically and technically optimized.



## PUBLICATION

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### ANNEX 1: Bus Data, Line Data of IEEE 57 Bus Test System

Table: Bus Data of IEEE 57 Bus Test System

Base MVA=100

Bus	Bus Type	Voltage Magnitude	Voltage Angle	P Gen	Q Gen	P Load	Q Load	Bs
1	3	1.04	0	128.9	-16.1	55	17	0
2	2	1.01	-1.18	0	-0.8	3	88	0
3	2	0.985	-5.97	40	-1	41	21	0
4	1	0.981	-7.32	0	0	0	0	0
5	1	0.976	-8.52	0	0	13	4	0
6	2	0.98	-8.65	0	0.8	75	2	0
7	1	0.984	-7.58	0	0	0	0	0
8	2	1.005	-4.45	450	62.1	150	22	0
9	2	0.98	-9.56	0	2.2	121	26	0
10	1	0.986	-11.43	0	0	5	2	0
11	1	0.974	-10.17	0	0	0	0	0
12	2	1.015	-10.46	310	128.5	377	24	0
13	1	0.979	-9.79	0	0	18	2.3	0
14	1	0.97	-9.33	0	0	10.5	5.3	0
15	1	0.988	-7.18	0	0	22	5	0
16	1	1.013	-8.85	0	0	43	3	0
17	1	1.017	-5.39	0	0	42	8	0
18	1	1.001	-11.71	0	0	27.2	9.8	10
19	1	0.97	-13.2	0	0	3.3	0.6	0
20	1	0.964	-13.41	0	0	2.3	1	0
21	1	1.008	-12.89	0	0	0	0	0
22	1	1.01	-12.84	0	0	0	0	0
23	1	1.008	-12.91	0	0	6.3	2.1	0
24	1	0.999	-13.25	0	0	0	0	0
25	1	0.982	-18.13	0	0	6.3	3.2	5.9
26	1	0.959	-12.95	0	0	0	0	0
27	1	0.982	-11.48	0	0	9.3	0.5	0

28	1	0.997	-10.45	0	0	4.6	2.3	0
29	1	1.01	-9.75	0	0	17	2.6	0
30	1	0.962	-18.68	0	0	3.6	1.8	0
31	1	0.936	-19.34	0	0	5.8	2.9	0
32	1	0.949	-18.46	0	0	1.6	0.8	0
33	1	0.947	-18.5	0	0	3.8	1.9	0
34	1	0.959	-14.1	0	0	0	0	0
35	1	0.966	-13.86	0	0	6	3	0
36	1	0.976	-13.59	0	0	0	0	0
37	1	0.985	-13.41	0	0	0	0	0
38	1	1.013	-12.71	0	0	14	7	0
39	1	0.983	-13.46	0	0	0	0	0
40	1	0.973	-13.62	0	0	0	0	0
41	1	0.996	-14.05	0	0	6.3	3	0
42	1	0.966	-15.5	0	0	7.1	4.4	0
43	1	1.01	-11.33	0	0	2	1	0
44	1	1.017	-11.86	0	0	12	1.8	0
45	1	1.036	-9.25	0	0	0	0	0
46	1	1.05	-11.89	0	0	0	0	0
47	1	1.033	-12.49	0	0	29.7	11.6	0
48	1	1.027	-12.59	0	0	0	0	0
49	1	1.036	-12.92	0	0	18	8.5	0
50	1	1.023	-13.39	0	0	21	10.5	0
51	1	1.052	-12.52	0	0	18	5.3	0
52	1	0.98	-11.47	0	0	4.9	2.2	0
53	1	0.971	-12.23	0	0	20	10	6.3
54	1	0.996	-11.69	0	0	4.1	1.4	0
55	1	1.031	-10.78	0	0	6.8	3.4	0
56	1	0.968	-16.04	0	0	7.6	2.2	0
57	1	0.965	-16.56	0	0	6.7	2	0

Table: Line Data of IEEE 57 Bus Test Systems

From Bus	To Bus	R (p.u.)	X (p.u.)	B(p.u.)	Ratio
1	2	0.0083	0.028	0.129	0
2	3	0.0298	0.085	0.0818	0
3	4	0.0112	0.0366	0.038	0
4	5	0.0625	0.132	0.0258	0
4	6	0.043	0.148	0.0348	0
6	7	0.02	0.102	0.0276	0
6	8	0.0339	0.173	0.047	0
8	9	0.0099	0.0505	0.0548	0
9	10	0.0369	0.1679	0.044	0
9	11	0.0258	0.0848	0.0218	0
9	12	0.0648	0.295	0.0772	0
9	13	0.0481	0.158	0.0406	0
13	14	0.0132	0.0434	0.011	0
13	15	0.0269	0.0869	0.023	0
1	15	0.0178	0.091	0.0988	0
1	16	0.0454	0.206	0.0546	0
1	17	0.0238	0.108	0.0286	0
3	15	0.0162	0.053	0.0544	0
4	18	0	0.555	0	0.97
4	18	0	0.43	0	0.978
5	6	0.0302	0.0641	0.0124	0
7	8	0.0139	0.0712	0.0194	0
10	12	0.0277	0.1262	0.0328	0
11	13	0.0223	0.0732	0.0188	0
12	13	0.0178	0.058	0.0604	0
12	16	0.018	0.0813	0.0216	0
12	17	0.0397	0.179	0.0476	0
14	15	0.0171	0.0547	0.0148	0

18	19	0.461	0.685	0	0
19	20	0.283	0.434	0	0
21	20	0	0.7767	0	1.043
21	22	0.0736	0.117	0	0
22	23	0.0099	0.0152	0	0
23	24	0.166	0.256	0.0084	0
24	25	0	1.182	0	0
24	25	0	1.23	0	0
24	26	0	0.0473	0	1.043
26	27	0.165	0.254	0	0
27	28	0.0618	0.0954	0	0
28	29	0.0418	0.0587	0	0
7	29	0	0.0648	0	0.967
25	30	0.135	0.202	0	0
30	31	0.326	0.497	0	0
31	32	0.507	0.755	0	0
32	33	0.0392	0.036	0	0
34	32	0	0.953	0	0.975
34	35	0.052	0.078	0.0032	0
35	36	0.043	0.0537	0.0016	0
36	37	0.029	0.0366	0	0
37	38	0.0651	0.1009	0.002	0
37	39	0.0239	0.0379	0	0
36	40	0.03	0.0466	0	0
22	38	0.0192	0.0295	0	0
11	41	0	0.749	0	0.955
41	42	0.207	0.352	0	0
41	43	0	0.412	0	0
38	44	0.0289	0.0585	0.002	0
15	45	0	0.1042	0	0.955
14	46	0	0.0735	0	0.9
46	47	0.023	0.068	0.0032	0

47	48	0.0182	0.0233	0	0
48	49	0.0834	0.129	0.0048	0
49	50	0.0801	0.128	0	0
50	51	0.1386	0.22	0	0
10	51	0	0.0712	0	0.93
13	49	0	0.191	0	0.895
29	52	0.1442	0.187	0	0
52	53	0.0762	0.0984	0	0
53	54	0.1878	0.232	0	0
54	55	0.1732	0.2265	0	0
11	43	0	0.153	0	0.958
44	45	0.0624	0.1242	0.004	0
40	56	0	1.195	0	0.958
56	41	0.553	0.549	0	0
56	42	0.2125	0.354	0	0
39	57	0	1.355	0	0.98
57	56	0.174	0.26	0	0
38	49	0.115	0.177	0.003	0
38	48	0.0312	0.0482	0	0
9	55	0	0.1205	0	0.94

Table: Boundary limit of control variable and operation limit of Generator reactive power

Control Variable	Lower Boundary	Upper Boundary
Generator Voltage	0.94	1.06
Transformer tap setting	0.9	1.1
Shunt capacitor at bus 18	0	10 MVAR
Shunt Capacitor at bus 25	0	5.9 MVAR
Shunt Capacitor at bus 53	0	6.3 MVAR

	Min (Q) MVAR	Max (Q) MVAR
Generator at Bus 1	-140	200
Generator at Bus 2	-17	50
Generator at Bus 3	-10	60
Generator at Bus 6	-8	25
Generator at Bus 8	-140	200



## ANNEX 2: Bus Voltage for the different scenario.

Table: Bus Voltage for different scenario.

<b>Bus No</b>	<b>Base condition</b>	<b>Loss Minimization</b>	<b>Voltage deviation minimization</b>	<b>Voltage stability enhancement</b>
1	1.04	1.059999	1.06	1.0598
2	1.01	1.050708	1.031033	1.027515
3	0.985	1.044838	1.020991	1.007537
4	0.98078	1.03868	1.024424	1.004773
5	0.976499	1.031801	1.029546	1.005964
6	0.98	1.033593	1.037241	1.011928
7	0.984202	1.038565	1.035039	1.020158
8	1.005	1.06	1.057739	1.06
9	0.98	1.026822	1.031689	1.023689
10	0.986242	1.018859	1.039333	1.015372
11	0.973962	1.014238	1.017527	1.009138
12	1.015	1.033906	1.06	1.037404
13	0.978887	1.016971	1.022357	1.01482
14	0.970177	1.013926	1.017143	1.005044
15	0.988032	1.03049	1.026324	1.015975
16	1.013369	1.033196	1.051786	1.035529
17	1.017454	1.037813	1.047391	1.038853
18	1.000659	1.099783	1.059755	1.093134
19	0.970158	1.065283	1.05186	1.036455
20	0.96379	1.055223	1.058856	1.012706
21	1.008498	1.062795	1.03258	1.075537
22	1.009744	1.062844	1.037405	1.072304
23	1.00833	1.061771	1.037881	1.072908
24	0.999233	1.057566	1.060137	1.096812
25	0.982521	1.047524	1.059779	1.099998
26	0.958818	1.050519	0.967998	1.011896
27	0.981541	1.072853	1.015178	1.057613

28	0.996678	1.087255	1.03922	1.08082
29	1.01022	1.099994	1.058182	1.099077
30	0.962661	1.029175	1.045467	1.086488
31	0.935933	1.004717	1.030585	1.072793
32	0.949875	1.018348	1.05756	1.099621
33	0.947581	1.016209	1.055501	1.09764
34	0.9592	1.022611	0.991442	1.028151
35	0.966212	1.029168	0.999854	1.036318
36	0.975828	1.038159	1.010318	1.046444
37	0.984887	1.044695	1.018584	1.053436
38	1.012812	1.064945	1.037715	1.070322
39	0.982823	1.043015	1.019053	1.053468
40	0.972811	1.037732	1.008959	1.0464
41	0.996217	1.08211	1.046974	1.062415
42	0.966526	1.045761	1.002267	1.015869
43	1.009564	1.099991	1.0599	1.093967
44	1.016799	1.072964	1.04081	1.076459
45	1.036005	1.099997	1.05787	1.099511
46	1.059797	1.093315	1.058103	1.099959
47	1.033251	1.075338	1.045111	1.079175
48	1.027351	1.072644	1.044413	1.075448
49	1.036246	1.080189	1.060155	1.07045
50	1.023336	1.065838	1.039363	1.062954
51	1.052262	1.090228	1.05395	1.099252
52	0.980369	1.067767	1.025638	1.040269
53	0.970946	1.056538	1.014467	1.015058
54	0.996319	1.071266	1.032791	1.014164
55	1.030786	1.094822	1.060148	1.023354
56	0.968369	1.038352	0.987666	0.998975
57	0.964826	1.033429	0.96653	0.981456

### ANNEX 3: Reactive line flow in different Scenario.

Table: Reactive line flow in line at different Scenario.

<b>Line no</b>	<b>Q-flow at Base condition (MVar)</b>	<b>Q-flow at loss Minimum condition (MVar)</b>	<b>Q-flow at Voltage deviation Minimum condition (MVar)</b>	<b>Q-flow at Voltage stability enhancement (MVar)</b>
L01-02	74.99684	1.211121	73.25511	85.1911
L01-15	33.78674	8.618272	13.3786	24.98379
L01-16	7.082821	5.648053	15.77397	7.370881
L01-17	3.935669	4.051638	5.477962	2.685531
L02-03	4.464913	26.42046	20.90289	9.88933
L03-04	8.179274	2.587565	29.42047	13.26972
L03-15	13.65118	20.3089	17.49408	22.84501
L04-05	2.236179	0.06849914	9.295703	6.624852
L04-06	2.075005	1.142421	11.91216	8.033583
L05-06	6.236179	4.068499	13.2957	10.62485
L06-07	0.615746	0.3512598	6.713939	4.045339
L06-08	6.564333	8.577497	5.001387	20.80076
L07-08	12.41057	14.93234	16.27333	39.67246
L08-09	9.122892	29.69345	15.75301	37.54862
L09-10	5.576189	3.201538	6.003319	3.424554
L09-11	3.993753	11.93972	13.94313	14.30227
L09-12	8.643129	1.111747	6.265543	1.087637
L09-13	1.960113	3.523639	3.430205	3.178943
L10-12	17.65069	6.951624	11.91333	12.47554
L11-13	2.683989	0.394791	2.09339	3.164307
L12-13	60.35122	28.14021	65.53825	38.10411
L12-16	8.819144	7.148373	17.42913	8.936184
L12-17	9.767292	8.824864	18.69335	10.40796

L13-14	23.09684	11.56236	17.16613	26.49754
L13-15	4.913825	0.5286603	10.89409	13.51234
L14-15	10.98077	10.34719	3.449891	0.036607
L18-19	1.385186	2.150864	1.320403	4.868742
L19-20	0.625136	1.377805	2.022897	3.9093
L21-22	0.394571	0.3560814	3.126425	2.757006
L22-23	3.110455	1.660179	6.710001	7.864634
L22-38	3.543439	1.329216	3.551832	10.57797
L23-24	0.995119	0.4510296	8.820375	9.976878
L24-25	1.714037	1.164423	0.2644923	0.08214
L24-25(1)	1.647147	1.118981	0.2541706	0.078935
L25-30	4.464607	4.355778	2.935854	2.851144
L26-27	1.611387	1.862413	8.722154	9.155853
L27-28	2.425296	2.658066	9.968051	10.33821
L28-29	5.510793	5.655168	13.43268	13.70013
L29-52	1.950454	3.560691	3.672162	14.84182
L30-31	2.664607	2.555778	1.135854	1.051144
L31-32	0.352931	0.4441372	1.812591	1.890864
L32-33	1.9	1.9	1.9	1.9
L34-35	3.547663	3.500303	5.111562	5.118871
L35-36	6.547663	6.500303	8.111562	8.118871
L36-37	10.76926	5.919197	9.624691	6.869521
L36-40	4.088278	0.6219113	1.397041	1.319258
L37-38	14.15272	8.659753	7.118148	5.370267
L37-39	2.920557	2.544476	2.703342	1.635936
L38-44	5.081851	1.303875	6.591079	1.809479
L38-48	19.71006	8.742645	6.586571	4.234054
L38-49	10.44071	6.944188	10.67285	0.784173
L41-42	2.954713	5.346805	7.071633	7.830826
L41-43	2.951828	4.427457	2.972347	7.82322
L41-56	0.487554	1.887488	3.65423	4.474928
L42-56	1.462766	0.9299658	2.625526	3.371325

L44-45	2.086434	4.303801	3.658962	1.120199
L46-47	25.47109	14.4457	6.419464	18.94317
L47-48	12.43449	2.026333	5.907847	6.428313
L48-49	6.927855	6.24399	12.17764	2.685379
L49-50	4.296873	5.463269	9.490686	0.20855
L50-51	6.557915	5.306625	1.184467	10.75364
L52-53	0.249546	1.360691	1.472162	12.64182
L53-54	4.471734	1.779942	2.39646	2.197464
L54-55	6.062001	3.262851	3.916865	0.775601
L56-57	0.605676	0.3373529	4.901232	3.764074

## ANNEX 4: CODES

### A). CODE ON DIGSILENT

(i) **MAIN CODE** (mixed for Loss minimization, Voltage deviation minimization, Voltage enhancement)

```
int i,j,errs;
int Sn;
int Dim;
int Miter;
int Iter,tap;
int flag1,flag2,flag3,flag4,flag5,flag6,flag7,flag8;
int flag9,flag10,flag11,flag12,flag13,flag14,flag15,flag16;
string Str;
set con1,con2,con3;
double D,val,ttap,Penal,Lmax,Lsm;
string vel,ch;
object Ldf,SumGrid,Gens,obj;
EchoOff();
con1=control1.Get();
con2=control2.Get();
con3=control3.Get();
Sn=30;    ! NO of search agent
Dim=25;   !Dimension of control variable
Miter=300; ! maximum no of Iteration
ClearOutput();
M_double_pop.Init(2*Sn,Dim+1,1);
M_pos.Init(Sn,Dim+1,1);
M_fness_srt.Init(1,Sn,1);
M_bst_flame.Init(Sn,Dim+1,1);
M_prev_pop.Init(Sn,Dim+1,1);
M_temp.Init(Sn,Dim+1,1);
!M_pos.Resize(Sn,Dim+1);
Initialize.Execute(Dim,Sn);
for (Iter=1;Iter<=Miter;Iter+=1)
{

Limit.Execute(Dim,Sn);
for (i=1; i<=Sn;i+=1)
{
    obj=con1.First();
    j=1;           !counter for control varialbe
    while(obj)
    {
        Str=obj.loc_name;

        flag1=strcmp(Str,'PG01');
        flag2=strcmp(Str,'PG02');
```

```

flag3=strcmp(Str,'PG03');
flag4=strcmp(Str,'PG06');
flag5=strcmp(Str,'PG08');
flag6=strcmp(Str,'PG09');
flag7=strcmp(Str,'PG12');
flag8=flag1*flag2*flag3*flag4*flag5*flag6*flag7;

    if( flag8=0)

    {

        ! printf(' the oder %d and name is %s ',j,Str);
        val=M_pos.Get(i,j);
        obj:usetp= val;
        j+=1;

    }

    obj=con1.Next();
}

    obj=con2.First();
    while(obj)
{
    Str=obj:loc_name;
    flag1=strcmp(Str,'TR04-18(1)');
    flag2=strcmp(Str,'TR04-18(2)');
    flag3=strcmp(Str,'TR10-51');
    flag4=strcmp(Str,'TR11-41');
    flag5=strcmp(Str,'TR11-43');
    flag6=strcmp(Str,'TR13-49');
    flag7=strcmp(Str,'TR14-46');
    flag8=strcmp(Str,'TR15-45');
    flag9=strcmp(Str,'TR20-21');
    flag10=strcmp(Str,'TR07-29');
    flag11=strcmp(Str,'TR09-55');
    flag12=strcmp(Str,'TR24-26');
    flag13=strcmp(Str,'TR32-34');
    flag14=strcmp(Str,'TR39-57');
    flag15=strcmp(Str,'TR40-56');

    flag16=flag1*flag2*flag3*flag4*flag5*flag6*flag7*flag8*flag9*flag10*flag11*
flag12*flag13*flag14*flag15;
    if( flag16=0)

    {
        val=M_pos.Get(i,j);
        ! printf(' the oder %d and name is %s ',j,Str);

```

```

        ttap=(val-1)*100/0.01;
        tap=round(ttap);
        obj:nntap=tap;
        j+=1;
    }

    obj=con2.Next();
}
obj=con3.First();
while(obj)
{
    Str=obj:loc_name;
    flag1=strcmp(Str,'SC18');
    flag2=strcmp(Str,'SC25');
    flag3=strcmp(Str,'SC53');
    flag7=flag1 *flag2*flag3;
    if(flag7=0)
    {

        ! printf(' the oder %d and name is %s ',j,Str);
        val=M_pos.Get(i,j);
        obj:qcapn=val ;
        j+=1;
    }

    obj=con3.Next();
}

if (j<(Dim+1))
{
    printf(' " the control acess error');
    break;
}
SumGrid=SummaryGrid();
if(SumGrid)
{
    Ldf = GetCaseObject('ComLdf');
    errs=Ldf.Execute();
    if (errs=0)
    {
        D=SumGrid:c:LossP;
        !L_index.Execute(Iter,i,Dim,Lmax);          !note: D for Loss , D=Lmax from
L_index.Execute for L-index, D=Lsm for Voltage deviation
        !D=Lmax;
        penalty.Execute(Penal,Lsm);
        ! D=Lsm;
        D=D+Penal;
    }
    if (errs=1)

```



```

    {
        D=100000;
    }
    M_pos.Set(i,Dim+1,D);
}
}

moth_flame.Execute(Sn,Dim,Iter,Miter);
}
Set_val.Execute();
EchoOn();

```

(ii) Subcode To be Execute Inside main Code

**(1) Initialization.Execute()**

```

int i, j;
double d,du,db,rn,val;
for (i=1;i<=Sn;i+=1)
{
    for (j=1;j<=Dim;j+=1)
    {
        du=M_limit.Get(j,2)*1.2;
        db=M_limit.Get(j,1)*0.8;
        rn=Random(0,1);
        d=rn*(du-db)+db;
        M_pos.Set(i,j,d);
    }
}

```

**(2) Limit.Execute()**

```

int i,j;
double d,lb,ub;
for (i=1;i<=Sn;i+=1)
{
    for (j=1; j<=Dim;j+=1)
    {
        d=M_pos.Get(i,j);
        lb=M_limit.Get(j,1);
        ub=M_limit.Get(j,2);
        if(d<lb)
        {
            M_pos.Set(i,j,lb) ;
        }
        if(d>ub)

```

```

    {
        M_pos.Set(i,j,ub);
    }
}

```

```

}

```

### (3) Set\_Val.Execute()

```

object obj;
set con1,con2,con3;
string Str,ch;
double val,ttap;
int
j,tap,flag1,flag2,flag3,flag4,flag5,flag6,flag7,flag8,flag9,flag10,flag11,flag12,flag
13,flag14,flag15,flag16;
con1=control1.Get();
con2=control2.Get();
con3=control3.Get();
i=1 ;
obj=con1.First();
    j=1;          !counter for control variabe
    while(obj)
    {
        Str=obj:loc_name;
        flag1=strcmp(Str,'PG01');
        flag2=strcmp(Str,'PG02');
        flag3=strcmp(Str,'PG03');
        flag4=strcmp(Str,'PG06');
        flag5=strcmp(Str,'PG08');
        flag6=strcmp(Str,'PG09');
        flag7=strcmp(Str,'PG12');
        flag8=flag1*flag2*flag3*flag4*flag5*flag6*flag7;
        if( flag8=0)
        {
            val=M_bst_flame.Get(i,j);
            printf('\n the optimse control value for the %s = %f',Str,val);
            obj:usetp= val;
            j+=1;
        }
        obj=con1.Next();
    }
    obj=con2.First();

while(obj)

{
    Str=obj:loc_name;
    flag1=strcmp(Str,'TR04-18(1)');

```

```

flag2=strcmp(Str,'TR04-18(2)');
flag3=strcmp(Str,'TR10-51');
flag4=strcmp(Str,'TR11-41');
flag5=strcmp(Str,'TR11-43');
flag6=strcmp(Str,'TR13-49');
flag7=strcmp(Str,'TR14-46');
flag8=strcmp(Str,'TR15-45');
flag9=strcmp(Str,'TR20-21');
flag10=strcmp(Str,'TR07-29');
flag11=strcmp(Str,'TR09-55');
flag12=strcmp(Str,'TR24-26');
flag13=strcmp(Str,'TR32-34');
flag14=strcmp(Str,'TR39-57');
flag15=strcmp(Str,'TR40-56');

```

```

flag16=flag1*flag2*flag3*flag4*flag5*flag6*flag7*flag8*flag9*flag10*flag11*fl
ag12*flag13*flag14*flag15;
    if( flag16=0)
    {
        val=M_bst_flame.Get(i,j);
        printf(' \n the optimse control value for the %s = %f',Str,val);
        ttap=(val-1)*100/0.01;
        tap=round(ttap);
        obj:nntap=tap;
        j+=1;
    }
    obj=con2.Next();
}
obj=con3.First();
while(obj)
{
    Str=obj:loc_name;
    flag1=strcmp(Str,'SC18');
    flag2=strcmp(Str,'SC25');
    flag3=strcmp(Str,'SC53');
    flag7=flag1*flag2*flag3;
    if(flag7=0)
    {
        val=M_bst_flame.Get(i,j);
        printf(' \n the optimse control value for the %s = %f',Str,val);
        obj:qcapn=val ;
        j+=1;
    }

    obj=con3.Next();
}

```

```

val=M_bst_flame.Get(i,j);
printf( '\n the Minimum loss of the system is equal to the %f ', val);

```

#### 4. moth\_flame.Execute()

```

double val,val1,val2,rn;
double a,b,t,dtf,pie;
int Flame_no;
int i,j;
string ch;

pie=3.1415926535897932384626433832795028841971693993751058209749
44592307816406286;
copy.Execute(Sn,Dim); !copy the moth to another matrix
Flame_no=round(Sn-Iter*((Sn-1)/Miter)); !calculate flame no
a=-1+Iter*((-1)/Miter);
if (Iter=1) ! for first iteration
{
M_temp.SortToColumn(Dim+1); ! sort the moth as loss
for (i=1;i<=Sn;i+=1)
{
for (j=1;j<=Dim+1;j+=1)

{
val=M_temp.Get(i,j);
M_bst_flame.Set(i,j,val); ! copy the sorted moth
}

}

for(i=1;i<=Sn;i+=1)
{
val=M_temp.Get(i,Dim+1);
M_fness_srt.Set(1,i,val); ! sorted fnes
}

}

if(Iter>1) ! for second iteration
{

upd_double_pop.Execute(Sn,Dim); ! mix the previous and the best flames
M_double_pop.SortToColumn(Dim+1); !sort the mixed as per fitness

for (i=1;i<=Sn;i+=1)
{
for (j=1;j<=Dim+1;j+=1)

```

```

        {
            val=M_double_pop.Get(i,j);
            M_bst_flame.Set(i,j,val); !copy to best flame
        }

    }

    for(i=1;i<=Sn;i+=1)
    {
        val=M_double_pop.Get(i,Dim+1);
        M_fness_srt.Set(1,i,val); ! the best fitness sort
    }

}

for (i=1;i<=Sn;i+=1)
{

    for (j=1;j<=Dim+1;j+=1)

    {
        val=M_pos.Get(i,j);
        M_prev_pop.Set(i,j,val); ! saving into previous solution matrix
    }

}

for (i=1; i<=Sn; i+=1)
{

    for (j=1; j<=Dim; j+=1)

    {

        if (i<=Flame_no)
        {
            val=M_bst_flame.Get(i,j);
            val1=M_pos.Get(i,j);!Update the position of the moth with respect to
its corresponding flame

            dtf=abs(val-val1);
            b=1;
            rn=Random(0,1);

```

```

t=(a-1)*rn+1;
! output('the rn =rn the t is =t and valis =val and val2 is =val2');
!input(ch, 'wait dear');

val2=dtf*exp(b*t)*cos(t*2*pie)+val;
M_pos.Set(i,j,val2);

}

if (i>Flame_no)
{

val=M_bst_flame.Get(i,j);
val1=M_pos.Get(i,j);

dtf=abs(val-val1);
b=1;
rn=Random(0,1);

t=(a-1)*rn+1;
val=M_bst_flame.Get(Flame_no,j);

val2=dtf*exp(b*t)*cos(t*2*pie)+val;
M_pos.Set(i,j,val2);

}

}

}

```

#### 4a. Copy.Execute();

```

int i,j;
double val;
for (i=1;i<=Sn;i+=1)
{

```

```

        for (j=1;j<=Dim+1;j+=1)
        {
            val=M_pos.Get(i,j);
            M_temp.Set(i,j,val);
        }

    }
4b. upd_double_pop.Execute()
int i,j;
double val;

for (i=1;i<=2*Sn;i+=1)
{
    for (j=1;j<=Dim+1;j+=1)
    {

        if (i<=Sn)
        {
            val=M_prev_pop.Get(i,j);
            M_double_pop.Set(i,j,val);    }
        if (i>Sn)
        {
            val=M_bst_flame.Get(i-Sn,j);
            M_double_pop.Set(i,j,val);
        }
    }

}

```

#### **5. Penalty.Execute**

```

set con;
object obb;
int i,j;
double val,val1,sum;
con=Bus.Get();
i=1;
sum=0 ;
obb= con.First();
Penal=0;
while (obb)
{
    M_vol.Set(i,1,obb:m:u);
    i+=1;
    if (obb:m:u >1.1)
    {
        Penal=10;
    }
}

```

```

    }
    if (obb:m:u <0.9 )
    {
        Penal=10;

    }
    obb=con.Next();
}
M_vol.SortToColumn(1);
val=M_vol.Get(i-1,1) ;
for ( j=1;j<i;j+=1)
{
    val1=M_vol.Get(j,1);
    val1=val-val1;
    sum=sum+val1;
}
Lsm=sum;

```

```

6. L_index.Execute()
double Val,Val1,Val2;
int a,b,c,fg;
set SE;
string ch,name,address;
object objj;
int ct,fk;
int mp;
fk=1;
mp =i*Iter;
if (mp=4500)
{
    fk=0;
}

```

```

    !printf('the iter no %d and size on %d',Iter,i);

```

```

SE = Bus.Get();

```

```

objj= SE.First();
address='D:\study\thesis\project\matpower4.1 -Thesis\';

```

```

name=sprintf('%soutput.csv',address);
fopen(name,'w',1) ;

```

```

while (objj)
{
    Val1=objj:m:u;

```



```

! printf(' the name order %s', objj:loc_name);

fprintf(1,'%f',Val1);

objj=SE.Next();

}
objj= SE.First();
while (objj)
{
    Val1=objj:m:phiu;

    fprintf(1,'%f',Val1);

    objj=SE.Next();

}
for ( ct=1; ct<=Dim; ct+=1)
{
    Val1=M_pos.Get(i,ct);
    fprintf(1,'%f',Val1);
}
fprintf(1,'%d',fk);

fclose(1) ;
name=sprintf('%sflag.csv',address);
fopen(name,'r+',1) ;
fg=1;
fprintf(1,'%d',fg) ;
fclose(1) ;
while(1)
{
    name=sprintf('%sflag.csv',address);
    fopen(name,'r+',1) ;
    fscanf(1,'%d',fg) ;
    fclose(1);
    if(fg=0)
    {
        break;
    }
}

```

```

}

name=sprintf('%sinput.csv',address);
fopen(name,'r',1);

fscanf(1,'%f',Val);

fclose(1);

Lmax=Val;
printf('Matlab sync is going on, and returned value %f',Val);

```

**(B) Matlab code**

**(i) 57 bus model file**

**Case57.m IEEE 57 test bus modeling**

**(ii) Loadflow();**

```

function [V, del]=loadflow(temp, fg)
% fg==0 for the normol condition
%fg==1 for the reactive power limit
%temp= the matpower format
count=0;

MBase=temp.BaseMVA;

branch=data_branch(temp); %changing the branch data to
simple form
ybus=ybus_cal(branch); %calculate the ybus in the complex
form

G=real(ybus); %Real component of ybus
B=imag(ybus);

nbus=length(temp.bus(:,1));
pq=find(temp.bus(:,2)==1);
pr=find(temp.bus(:,2)==3);

```

```

pv=find(temp.bus(:,2)==2);

npq=length(pq);
npv=length(pv);
pg=zeros(nbus,1);
qg=zeros(nbus,1);
qmax=zeros(nbus,1);
qmin=zeros(nbus,1);
npg=length(temp.gen(:,1));

for i=1:npg

    a=find(temp.gen(i,1)==pv); %find the pv bus

        m=pv(a);

        pg(m)=temp.gen(i,2)/MBase; %set the generated
value

        qmax(m)=temp.gen(i,4)/MBase; % reactive limit of
generation
        qmin(m)=temp.gen(i,5)/MBase;

        a=find(temp.gen(i,1)==pq); %find the pq bus
        m=pq(a);
        pg(m)=temp.gen(i,2)/MBase; %set the generated
value
        qg(m)=temp.gen(i,3)/MBase; % reactive limit
of generation

end

while (1)

    fr=0; %flag for the convergence message

        %V=rand(nbus,1).*(1.05-0.95)+0.95; %initialize the
Voltage with in limit
        % del=rand(nbus,1).*-0.26; %initialize the Voltage
with in limit

```

```

        V=rand(nbus,1).*(0)+1; %initialize the Voltage with
in limit
        del=rand(nbus,1).*0; %initialize the Voltage with
in limit

        for i=1:npg

                a=find(temp.gen(i,1)==pv);
                m=pv(a);

                V(m)=temp.gen(i,6); %SET VOLTAGE OF THE
LOAD FLOW OF PV BUS AS PER THE GIVEN
                end

                ep=find(temp.gen(:,1)==pr);

                V(pr)=temp.gen(ep,6); %SET VOLTAGE OF THE SLACK
BUS AS GIVEN
                del(pr)=0;

                Ps=-temp.bus(:,3)/MBase+pg; %SPECIFIED POWER IS LOAD
SUBJECTED TO GENERATION.

                Qs=-temp.bus(:,4)/MBase+qg;

Tol=0.1;

while Tol>1e-5
        P=zeros(nbus,1);
        Q=zeros(nbus,1);
        for i=1:nbus
                for j=1:nbus
                        P(i)=P(i)+V(i)*V(j)*(G(i,j)*cos(del(i)-
del(j))+B(i,j)*sin(del(i)-del(j)));
                        Q(i)=Q(i)+V(i)*V(j)*(G(i,j)*sin(del(i)-del(j))-
B(i,j)*cos(del(i)-del(j)));
                end
        end

        dPa=Ps-P;
        dQa=Qs-Q;
        pp=[pv;pq];

```

```

pp=sort(pp);

dP=dPa(pp);

dQ=dQa(pq);

M=[dP;dQ];% delta Matrix
%% Formation Fo Jacobian Matrix[J1 J2;J3 J4]
%% Formation Of J1

J=Jacobian(nbus,npq,pq,V,G,B,del);

%% Formation Of J3
% Jacobian Matrix
X=inv(J)*M;
npp=length(pp);
dTh=X(1:(nbus-1));

% Change in angle
dV=X(nbus:end);

del(pp)=del(pp)+dTh; % Voltage angle update
% Voltage mag update
V(pq)=V(pq)+dV;

Tol=max(abs(M));
count=count+1;
if count==20
    disp(' the couldnt converge EVEN IN 20 ITERATIONIn
the load flow HAVE TO EXIT WITHOUT FURTHER PROCEDURE \n
');
    fr=1;
    break;
end
V;
del;

end
if fr==1
    break;
end

```

```

if fg==0
    break;
end

P=zeros(nbus,1);
Q=zeros(nbus,1);

for i=1:nbus
    for j=1:nbus
        P(i)=P(i)+V(i)*V(j)*(G(i,j)*cos(del(i)-
del(j))+B(i,j)*sin(del(i)-del(j)));
        Q(i)=Q(i)+V(i)*V(j)*(G(i,j)*sin(del(i)-
del(j))-B(i,j)*cos(del(i)-del(j)));
    end
end

flag=0;

for i=1:npv
    m=pv(i);
    Qgg=Q(m)+temp.bus(m,4)/MBase;
    if (Qgg>qmax(m))

        qg(m)=qmax(m);
        temp.bus(m,2)=1;

        flag=1;

    elseif Qgg<qmin(m)

        qg(m)=qmin(m);
        temp.bus(m,2)=1;

        flag=1;

    end
end
pq=find(temp.bus(:,2)==1);
pv=find(temp.bus(:,2)==2);

```

```

        npq=length(pq);
        npv=length(pv);

        if (flag==0)
            break;
        end
    end

    disp([' the iteration for convergence reached to  in the
', num2str(count), ' iteration']);

iii. data_branch();
function [branchh]= data_branch (mat)

branch(:,1)=mat.branch(:,1);
branch(:,2)=mat.branch(:,2);
branch(:,3)=mat.branch(:,3);
branch(:,4)=mat.branch(:,4);
branch(:,5)=0.5*mat.branch(:,5);

n=size(mat.branch);
b=n(1);
nbus=length(mat.bus(:,1));
for i=1:b
    if (mat.branch(i,9)==0)

        branch(i,6)=1;
    else
        branch(i,6)=mat.branch(i,9);
    end
end
end

for i=1:b

    branch(i,7)=0;
    branch(i,8)=0;

end

for i=1:nbus

    if (mat.bus(i,6)~=0)

```

```

        for j=1:b
            if (mat.branch(j,1)==i)

branch(j,7)=branch(j,7)+(mat.bus(i,6)/mat.BaseMVA);

                break;

            end

            if (mat.branch(j,2)==i)

branch(j,8)=branch(j,8)+(mat.bus(i,6)/mat.BaseMVA);
                break;
            end

        end

    end

    end

st=find(mat.branch(:,11)==1);
col=size(branch);
cl=col(2);
branchh=branch(st,[1:cl]);

end

iv. ybus_cal()
function YY=ybus_cal(branch)

fb=branch(:,1);
tb=branch(:,2);
r=branch(:,3);
x=branch(:,4);
b=branch(:,5);
a=branch(:,6);
ycap=branch(:,7);
ycap1=branch(:,8);
%z=r+i*x;
z=complex(r,x);
y=1./z;

```



```

%b=i*b;
b=complex(0,b);

%ycap=i*ycap;
ycap=complex(0,ycap);
ycap1=complex(0,ycap1);

nb=max(max(fb),max(tb)); %no of bus.
nl=length(fb); %no of branch.
Y=zeros(nb,nb);

for k=1:nl
    Y(fb(k),tb(k))=Y(fb(k),tb(k))-y(k)/a(k);
    Y(tb(k),fb(k))=Y(fb(k),tb(k));
end

% Formation of Diagonal Elements. { (ys) = y/a, Y1 = y*(1-
a)/(a^2), Y2 = y*(a-1)/a }
for m = 1:nb
    for n = 1:nl
        if fb(n) == m
            Y(m,m) = Y(m,m) + y(n)/a(n) + y(n)*((1-
a(n))/(a(n)^2)) + b(n) + ycap(n);
        elseif tb(n) == m
            Y(m,m) = Y(m,m) + y(n)/a(n) + y(n)*((a(n)-
1)/a(n)) + b(n)+ycap1(n);
        end
    end
end
YY=Y;
end

v. Jacobian()
function [J] = Jacobian(nbus,npq,pq,V,G,B,del)

% J1 - Derivative of Real Power Injections with Angles.
J1 = zeros(nbus-1,nbus-1);
for i = 1:(nbus-1)
    m = i+1;
    for k = 1:(nbus-1)
        n = k+1;
        if n == m
            for n = 1:nbus
                J1(i,k) = J1(i,k) + V(m)*V(n)*(-
G(m,n)*sin(del(m)-del(n)) + B(m,n)*cos(del(m)-del(n)));
            end
            J1(i,k) = J1(i,k) - V(m)^2*B(m,m);
        else

```

```

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

        end
    end
end

% J2 - Derivative of Real Power Injections with V.
J2 = zeros(nbus-1,npq);
for i = 1:(nbus-1)
    m = i+1;
    for k = 1:npq
        n = pq(k);
        if n == m
            for n = 1:nbus
                J2(i,k) = J2(i,k) +
V(n) * (G(m,n) * cos(del(m) - del(n)) + B(m,n) * sin(del(m) -
del(n)));
            end
            J2(i,k) = J2(i,k) + V(m) * G(m,m);
        else
            J2(i,k) = V(m) * (G(m,n) * cos(del(m) - del(n))
+ B(m,n) * sin(del(m) - del(n)));
        end
    end
end

% J3 - Derivative of Reactive Power Injections with
Angles.
J3 = zeros(npq,nbus-1);
for i = 1:npq
    m = pq(i);
    for k = 1:(nbus-1)
        n = k+1;
        if n == m
            for n = 1:nbus
                J3(i,k) = J3(i,k) + V(m) *
V(n) * (G(m,n) * cos(del(m) - del(n)) + B(m,n) * sin(del(m) -
del(n)));
            end
            J3(i,k) = J3(i,k) - V(m) ^2 * G(m,m);
        else
            J3(i,k) = V(m) * V(n) * (-G(m,n) * cos(del(m) -
del(n)) - B(m,n) * sin(del(m) - del(n)));
        end
    end
end

% J4 - Derivative of Reactive Power Injections with V.

```

```

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

J = [J1 J2; J3 J4];      % Jacobian Matrix.

```

End

```

v. cal_loss()
function LL=cal_loss(V, D, branch)
fb=branch(:,1);
tb=branch(:,2);
r=branch(:,3);
x=branch(:,4);
z=complex(r,x);

br_n=size(branch,1);
[r1, im]=pol2cart(D,V);
VV=complex(r1,im);

for i=1:br_n
    fbb=fb(i);
    tbb=tb(i);
    I(i)=(VV(fbb)-VV(tbb))/(z(i));
    [Im,Ia]=cart_pol(I(i));
    L(i)=(Im^2)*r(i);
end

LL=sum(L);

```

```

vi.cal_gen()
function [PG QG]=cal_gen(V,D,temp);
[r1 im]=pol2cart(D,V);
VC=complex(r1,im);
branch=data_branch(temp);
ybus=ybus_cal(branch);
S=cal_power(VC,ybus)*temp.BaseMVA;
P=real(S);
Q=imag(S);
PL=temp.bus(:,3);
QL=temp.bus(:,4);

pg=P+PL;
qg=Q+QL;
go=temp.gen(:,1);
PG=pg(go);
QG=qg(go);
end

vii. cal_power()
function S= cal_power(V,ybus)
    nbus=length(V);
    S=zeros(nbus,1);

    for o=1:nbus
        for j=1:nbus

            S(o)=S(o)+conj(V(o))*V(j)*ybus(o,j);

        end
    end
    S=conj(S);
End

```

```

vii.SYC_DIG_MAT57()

clear all;
clc;
miter=100;
Sn=30;
X=zeros(140,1);

```

```

t=[19 20 41 80 65 54 71 66 59 58 31 37 46 76 73]
vord=[50      51  52  44  45  53  46  54  55  47  48  56  49
41  42  43  4  5  6  7  8  9  10  11  12  13  14  15
16  17  18  19  20  57  21  22  23  24  25  26  27  28  29
30  31  32  33  34  35  36  37  38  3  39  40  2  1]

```

```

temp=loadcase('case57');
pv=find(temp.bus(:,2)==2);
pg=[1;pv];
pq=find(temp.bus(:,2)==1);

```

```

j=1;
while(1)

```

```

    while(1)
        ss=0;
        for p=1:1500;
            fprintf('\n Sync with Digsilent is
running');
            fprintf('\n Sync with Digsilent is
running');
            fprintf('\n Sync with Digsilent is
running');
            fprintf('\n Sync with Digsilent is
running');

```

```

        end

```

```

            fg=csvread('flag.csv');
            if(fg==1);

```

```

                break;
            end

```

```

        end

```

```

        j=j+1;

```

```

        X=csvread('output.csv');

```

```

V=X([1:57],1);

```

```

V=V(vord);

```

```

D=X([58:114],1);

```

```

D=D(vord);

```

```

x=X([115:139],1);

```

```

fg=X(140,1);

```

```

for i=1:7

```

```

    temp.gen(i,6)=x(i);

```

```

end

```

```

for i=1:15

```

```

        p=t(i);
        temp.branch(p,9)=x(7+i);
    end
    temp.bus(18,6)=x(23);
    temp.bus(25,6)=x(24);
    temp.bus(53,6)=x(25);
    branch=data_branch(temp);
    ybus=ybus_cal(branch);
    D=deg2rad(D);
    Lmax=L_index(pg,pq,ybus,V,D);
    Y=Lmax
    csvwrite('input.csv',Y);
    a=0;
    csvwrite('flag.csv',0);
    if(fg==0)
        break;
    end
end
end

```

viii.L\_index()

```

function mx=L_index(pg,pq,ybus,V,D)
ybus1=ybus(pg,pg);
ybus2=ybus(pg,pq);
ybus3=ybus(pq,pg);
ybus4=ybus(pq,pq);
F=-inv(ybus4)*ybus3;
size(F);

for j=1:length(pq)
    bsj=pq(j);
    sum=0;
    for i=1:length(pg)
        bsi=pg(i);

        [real1, imag1]=pol2cart(D(bsi),V(bsi));
        V1bsi=complex(real1,imag1);
        [real1, imag1]=pol2cart(D(bsj),V(bsj));
        V1bsj=complex(real1,imag1);
        sum=sum+F(j,i)*(V1bsi/V1bsj);

    end
    L(j)=1-sum;
    [de,ma]=cart2pol(real(L(j)),imag(L(j)));
    LL(j)=ma;

```

```
end  
LL;  
mx=max(LL);  
end
```