MAJOR PROJECT REPORT

On

"PARTICLE SWARM OPTIMIZATION OBTAINING MAXIMUM LOADABILITY"

Submitted in
Partial Fulfillment of the Degree of
Master of Technology in Power System

DELHI TECHNOLOGICAL UNIVERSITY

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DECLARATION

I hereby declare that the work, which is being presented in the project report entitled, **"Particle Swarm Optimization obtaining maximum loadability"** submitted for partial fulfillment of the requirements for the award of the degree of Master of Technology (Power System) is an authentic record of my own work carried out under the able guidance of **Dr. Narendra Kumar.**

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CERTIFICATE

This is to certify that this major project "**Particle Swarm Optimization obtaining maximum loadability"** has been done by **Swati Yadav (2K12/PSY/21)** during fourth semester of Master of Technology in Power System (Electrical Department) from Delhi Technological University during the academic year 2013-14. The matter embodied in this project has not been submitted earlier for the award of any degree or diploma to the best of my knowledge and belief.

Date:

Dr. Narendra Kumar

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ABSTRACT

Due to increasing in demand power system becomes highly stressed. The work deals with efficient and reliable evolutionary based approach to obtaining maximum loadability. PSO algorithm is a robust, stochastic computational technique based on movement and intelligence of swarm. The work introduces a conceptual overview and detail of PSO Algorithm as well as shows how it can be used for obtaining maximum load ability. The maximum loadability is an important part of a power system. Voltage stability and security assessment is the part of maximum load ability. In this work, maximum load ability can be obtained by PSO. Optimization problem can be expressed as the problem to obtain maximum load ability. The load power factor is maintained corresponding to base power factor to that bus. From 2, 4, 6 and 14 bus, maximum load ability can be obtained for various standard systems. Both the continuous and the discrete variables are used as state variables in voltage/VAR control.

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LIST OF SYMBOLS AND ABBREVIATION

Symbol/Abbreviation	Meaning
Gbest	Global Best
Pbest	Personal Best
Lbest	Location best
SA	Simulated Annealing
ANN	Artificial Neural Network
GA	Genetic Algorithm
PSO	Particle Swarm Optimization

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CHAPTER 1
INTRODUCTION

1.1 Overview

In power system, voltage stability is an important part and it is stressed day by day due to increase in power demand. Voltage stability is explained as ability of maintaining acceptable voltages at all buses in system under normal condition and after being disturbance. The stress on system can be decreased by expansion of system. However, constraints which are affected by environment and economy can be limited by expansion of system. Voltage stability can bring by restricting of electrical power system. Voltage instability causes voltage collapse.

There is various reasons for voltage stability. Increase in load is one of them. Increase in load helps in reducing stability margin. The difference between current operating point and maximum loading point of system is called stability margin or load margin. There is various ways to find load margin, as they are sensitivity analysis, nodal analysis, interior point optimization methods etc.

To obtain maximum loadability, continuation power flow is used in which continuation parameterization technique, corrector and predictor step are used to draw PV curve at particular bus. The problem of divergence can be reduced by using parameterization technique near critical point. The critical point is then used to find load margin but mathematical formulation of continuation power flow is complex.

Here, particle swarm optimization helps to explore critical point without drawing PV curve in this work. Particle swarm optimization helps to work in both continuous and discrete variables in Voltage /VAR control by reducing real power losses.

1.2 Motivation

Complexity is present everywhere. We observe complexity in our daily lives like in traffic, due to weather changes, due to change in population, behaviors of organizational, changes in public views, stock markets, and urban developments. While it is very difficult to handle situation such as the components identification may be straightforward, interaction between components. A reductionist’s method is suggested for approximate and approach. When any decision is taken wrong, then these models become less effective while taking decision making. Many complex systems is specified by non additive nature. Scientific method handle non additive nature and say that complex system have non linear nature. The reaction of non linear system is not good as expected during growth. So for analyzing complex system reductionism method is less effective. Now, question rises, what are those methods used for analyzing complex system?

Now sciences have come and understand the behavior of complex systems. Complexity science is a made up of complicated components that interact in non linear ways. Complexity science has taught us that the dynamics of all complex system, whether they are biological or man-made, are very similar. Now the methodologies and tools are used for analyzing the complex system. Since complex systems are characterized in non linear ways, it is compulsory to detect the behaviors and changes of complex system. Complexity sciences have properties to detect behavior and where changes will occur. As we are able to identify phase transition, then desired result can be produced. Complexity science is method of finding global behaviors spring from a few simple rules. Simple example comes from birds flock. In real life, each bird has basic rules which they are following. A first rule is that moves without hitting other birds. Second is that fly in same way as other birds moves and fly with birds having own species. By these rules, we will able to get the behaviors of flocking. Complexity sciences have a property which will be used in business, government and military operation for improvement in next decades. Early adopters have already achieved significant results.

1.3 Literature Reviews:

In past decades, there are various salient mathematical approaches which has been suggested. As an analogy to conventional mathematical approaches, heuristic optimization technique such as genetic algorithm, tabu search, simulated annealing and recently introduced PSO are considered as realistic and powerful solution scheme to find global or optimum solution in power system.

Custem [1] reported on concept of voltage instability, its countermeasures and various analysis methods. He has discussed the voltage instability threats in which there is dramatic drop of transmission system voltages and due to this whole system is disrupted. In this paper its various analysis methods and countermeasures have been discussed more.

Atputharajah et al. [3] have given the report on stability in system, reliability and several major errors. They have explained basic cause, and from blackouts they took solutions.

Begovic and Phadke [4] have presented Jacobian matrix which have minimum singular value and total generated reactive power which corresponds to static bifurcation of load flow equations and sensitivity methods for reactive support allocation.

Gao et al. [5] have explained the analysis of voltage stability by using modal analysis technique. In this paper, by using steady state system model , the smallest Eigen values can be completed and corresponding Eigen values. Each Eigen values is related with voltage / reactive variation finding relative measure of proximity to voltage stability.

Irisarri et al. [6] have explored that to obtain maximum loadability in power system , non linear optimization interior point is discussed. They discussed pure primary dual and predictor corrector primal dual IP algorithms.

Mallick et al. [11] presented in which fuzzy logic along new formation of sparse constant array that help to explore maximum loadability. By using fuzzy controller, iteration methods can be started with random initialization. Then NR method technique and standard fuzzy logic controller compared with obtained results.

Ajjaraju and Christry [7] have explained continuum of power flow solutions and leads to steady state limits. It is well maintained at and near to critical point.

Chaing et al. [8] have discussed the continuous power flow for exploring steady state behavior by changing the parameter variations. The parameters variation are held due to bus real and reactive load, area real loads and real generation at PV buses

Kennedy and Eberharts [9] have presented optimization method for solving continuous non linear functions. They have explained the concepts of particle swarm optimization stages of its development from social simulation to optimizer.

Valle et al.[10] have explained basic concepts of particle swarm optimization . They also have explained the advantages from PSO nature. In this work, particle formulation and efficient fitness function is discussed here.

Alrashidi and Elhawary [12] have presented different type of PSO application for solving optimization in the different area of electric power system. They also discussed the various applications of PSO which will use in future and its theatrical studies.

Gnanambal and Babulal [14] have explained differential evolution PSO algorithm for finding the maximum loadability limit in power system. They have presented the comparison between DEPSO algorithms with other evolutionary algorithm such as multi agent hybrid PSO.

EL-Dib et al .[15] have explained the formulation of maximum loading point. They have discussed evolutionary PSO for finding optimization problem. The obtained results are compared with cpf technique.

Arya et al.[16] have discussed a methods i.e coordinated aggregation based PSO to explore loadability margin. There are two objective functions which is used to select load margin enhancement. One method is used to minimize total reactive power loss and second method is used to reduce incremental reactive power loss.

Shunmugalatha and Slochanal [17] have discussed about multiagent hybrid particle swarm optimization for obtaining maximum loadability limit. MAHPSO is a method in which genetic algorithm, PSO, and multiagent agent system is combined. The feature of MAHPSO and HPSO is a part of multiagent based hybrid PSO.

Shunmugalatha and Slochanal [18] have discussed in this paper is that optimum cost of generation is formulated for obtaining maximum loadability in electrical power system. They have discussed the hybrid PSO, which incorporates the breeding and subpopulation process in GA into PSO.

Althowibi and Mustafa [20] have presented sensitivity and modal analysis for the same.

Tomsovic [22] has designed many objectives and some constraint on voltage controller problem with the help of fuzzy sets. Here, piece wise is used and fuzzy sets of membership function are explained. With the help of this formulation of fuzzy problem is done again.

Ramos et al. [23] have designed tool of hybrid to guide voltage control optimization. Here numerical and heuristic methods have many advantages. One of is that it is able to find voltage violations or power losses is also reduced.

Chang et al. [24] have developed a method that is voltage/VAR control of sensitivity tree.

Swarp and Subhash[25] have suggested a method i.e called neural network for controlling voltage/VAR.

Wu et. al [26] have developed the control of voltage /VAR by particle swarm optimization method.

Liu et al. [27] have developed the problem of MOAPSO.

Mohan el at [28] explained that there are various method of designing the fitness function. The main concern of this function is smoothness .If it is not smooth then it may interrupt on search and disrupt algorithm .

M.A.Abido [29] describe advantage of particle swarm optimization .In this work , it describes that PSO is simple , easy ,take less computational time ,robust and gives more efficiency as compared to other optimization technique.

S.Naka and T.Genji [30] explained that particle swarm optimization is applied to any field like power system stabilizer design.

1.4 Objective of the work:

The objective of work is to find the maximum loadability using PSO and compare its effectiveness with the existing known algorithms.

CHAPTER 2

VOLTAGE STABILITY AND CONTINUATION POWER FLOW

This chapter describes the definitions and classification of voltage stability. Voltage instability is due to many reasons. One of them is due to the increase in load. The continuation power flow is well defined method to find critical load when system become unstable.

2.1 Voltage Stability

The voltage stability is also called as load stability, however is most important part of concerning in planning and operating electrical power system as the transfer of power is increasing , there is an also increasing . There is also increase in interconnection of networks due to obvious advantages and there is need for more intense use of available transmission facilities.

In power system, voltage stability involves generation, transmission and distribution. Voltage stability influences voltage control, reactive power compensation and management, rotor angle (synchronous) stability, protective relaying and control center operations.

In general, voltage stability is defined as the ability of maintaining preferable voltage at all buses in power system under normal conditions even after being subjected to disturbance. It refers large disturbance voltage stability, small disturbance voltage stability, short term voltage stability, and long term voltage stability.

The transfer of reactive power from source to sink during steady operating conditions is major aspect of voltage stability. It should be noted that the maximum power limit which to be transferred is not necessarily the voltage stability limit.

Some definition of power system in which voltage stability are described below:

- A power system at operating state subjected to small disturbance voltage stability, predisturbance values are almost equal to voltage near loads.
- When power system subjected to disturbance is voltage stable if voltage near loads approach posts disturbance equilibrium.
- A power system subjected to disturbance undergoes voltage collapse if voltage (post disturbance) lies below prescribed limit.

Voltage collapse may be total or partial. Voltage stability results in increase or decrease of voltage progressively.

Transient voltage stability:

The time period between transient voltage stability and angle stability is almost same and it lies between 0 to 10 seconds. It is very difficult to differentiate between transient voltage stability and transient angle stability due to this overlap of period. Therefore, angle rotor instability led to voltage instability or vice versa is also not cleared due to this period of overlapping.

Longer term voltage stability:

The time period is a few minutes typically two three minutes and hence, it is not possible for operation intervention.

High loads , high power imports from remote generation and a sudden large disturbance which is in form of large generators in load area or a loss of major transmission line comes under longer term voltage stability. The system is transiently stable. The main causes of disturbance are high reactive power loss and voltage sags in loads areas.

Longer term voltage instability:

The time period is of tens of minutes and involves a very rapid built up of load in term of MW/min and hence there is increase in large power transfer.

The time overload limit of transmission line (tens minutes) and loss of load diversity due to low voltage are the most important factor which affecting the voltage stability.

2.2 Critical voltage and maximum power:

The voltage varies with the variation in load power at receiving end. The graph representing the variation of load voltage with demand power is called as PV curve. At given bus, the increase in load results in decrease of voltage at that bus. Voltage becomes critical at certain maximum power. Thus maximum power transfer results voltage instability.

At the receiving end the voltage is given by:

$$V_R = V_S - jXI_L \qquad (2.1)$$

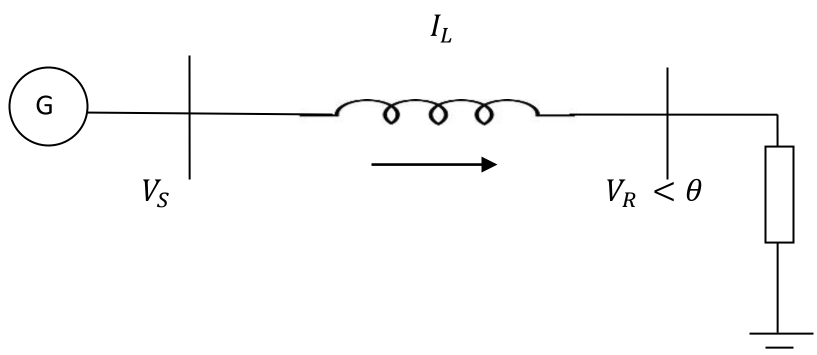


Fig 2.1 A generator connected to load

And the line current is given by

$$I_L = \frac{V_S - V_R}{JX} \tag{2.2}$$

The complex power is given by

$$S = V_R I_L^* \tag{2.3}$$

$$S = V_R \left(\frac{V_S - V_R}{JX}\right) \tag{2.4}$$

$$S = V_R \left(\frac{V_S - V_R}{-JX}\right) \tag{2.5}$$

$$S = V_R < \theta (\frac{V_S - V_R < -\theta}{-JX}) \tag{2.6}$$

$$S = -\frac{V_S V_R \sin\theta}{X} + J\left(\frac{V_S V_R \cos\theta}{X} - \frac{V_R^2}{X}\right) \tag{2.7}$$

The real and imaginary parts of complex power are separated and correspond to real and reactive power which is shown in below equation (2.8):

$$S = P + JQ \tag{2.8}$$

$$P = -\frac{V_S V_R}{X}\sin\theta \tag{2.9}$$

$$Q = \frac{V_S V_R}{X} \cos\theta - \frac{V_R^2}{X} \quad (2.10)$$

Above two equations (2.8) and (2.9) are to be substituted in given equation (2.11)

$$\sin^2 + \cos^2 = 1 \quad (2.11)$$

$$\left(\frac{-PX}{V_S V_R}\right)^2 + \left(\frac{QX + V_R^2}{V_S V_R}\right)^2 = 1 \quad (2.12)$$

By solving equation (2.11), obtain equation

$$\frac{V_R^4}{V_S^4} + \frac{V_R^2}{V_S^4}(2QX - V_S^2) + \frac{X^2}{V_S^4}(P^2 + Q^2) = 0 \quad (2.13)$$

Let σ be the power factor angle of the load and then Q is given by equation (2.14)

$$Q = P \tan\sigma \quad (2.14)$$

$$\frac{V_R^4}{V_S^4} + \frac{V_R^2}{V_S^4}(2XP \tan\sigma - V_S^2) + \frac{X^2}{V_S^4}\,(P^2 + P^2 tan^2\,\sigma) = 0 \quad (2.15)$$

By putting an eq(2.14) into above eq(2.15) and rearrange them , then we have an equation

$$\frac{V_R^4}{V_S^4} + \frac{V_R^2}{V_S^4}(2XP \tan\sigma - V_S^2) + \frac{X^2P^2}{V_S^4}\sec^2\sigma = 0 \quad (2.16)$$

$$\frac{V_R^4}{V_S^4} = \frac{V_R^2}{V_S^2}\left(\frac{2XP \tan\sigma}{V_S^2} - 1\right) + \frac{X^2P^2}{V_S^4}\sec^2\sigma = 0 \quad (2.17)$$

$$\frac{V_R^4}{V_S^4} = -\left(\frac{2XP \tan\sigma}{V_S^2} - 1\right) \pm \sqrt{\frac{\left(\frac{2XP \tan\sigma}{V_S^2} - 1\right)^2 - 4\frac{X^2P^2}{V_S^4}\sec^2\sigma}{2}} \quad (2.18)$$

Above equation (2.18) has four solutions in which two of them have meaningful results. There is one point where only one solution exists and this is called critical point. The critical point represent maximum power point and critical voltage.Maximum power and critical voltage is given by

$$\mathrm{P_{max}} = \frac{\mathrm{V_S^2}\cos\sigma}{2\mathrm{X}(1+\sin\sigma)} \tag{2.19}$$

$$\mathrm{V_{crit}} = \frac{\mathrm{V_S}}{\sqrt{2*\sin\sigma}} \tag{2.20}$$

2.3 Continuation Power Flow

At load bus, the increase in load give result in decrease in voltage at same bus & beyond a point known as critical point system loses equilibrium. The power transferred on critical point is the maximum power which can be transferred. The maximum power relates to voltage instability for constant power loads.

By using power flow equation and Jacobian matrix PV curve can be drawn for particular load. But, at maximum power, Jacobian become singular and thus conventional methods fail to converge at this point. There are many computational technique to avoid these problem based on bifurcation and continuation methods. The one of them is continuation power flow.

The continuation power flow is based on continuation methods. The continuation method is mathematical path following methodology. It involves predictor, corrector, step length control, parameterization strategy and so is the continuous power flow. Most of non linear equation can be solved and near critical point, it can be find appropriate solution. For that, it uses local parameterization continuation technique.   Let have power flow equation at bus 2 system

$$P(V,\delta) = 0 \tag{2.21}$$

$$Q(V,\delta) = 0 \tag{2.22}$$

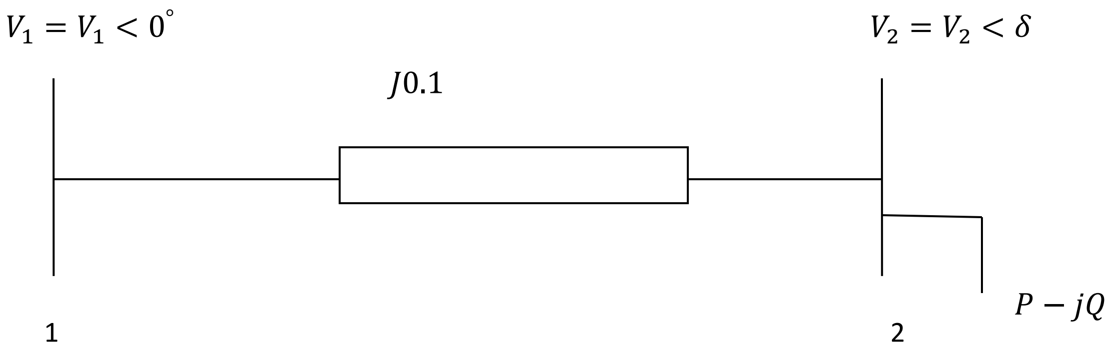


Fig 2.3 Two bus system

If load parameter λ is added to these equation (2.18)& (2.19) then modified equation are

$$P(V, \delta, \lambda) = 0 \qquad (2.23)$$

$$Q(V, \delta, \lambda) = 0 \qquad (2.24)$$

$$P = P_0 * (1 + \lambda K) \qquad (2.25)$$

$$Q = Q_0 * (1 + \lambda K) \qquad (2.26)$$

$$Q_0 = P_0 \tan \varphi \qquad (2.27)$$

where ,

P_0 = real power of load

Q_0 = reactive power of load

K= rate of change of load

Ψ= power factor angle of load

Original Jacobian matrix for this system is given by equation

$$J_0' = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V_2} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V_2} \end{bmatrix} \qquad (2.28)$$

Now Jacobian matrix is added by one column. New Jacobian matrix is given by an equation (2.29)

$$J_0 = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V_2} & \frac{\partial P}{\partial \lambda} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V_2} & \frac{\partial Q}{\partial \lambda} \end{bmatrix} \qquad (2.29)$$

A row vector ,e with all elements equal to zero except one element chosen properly which is equal to one , is appended to augmented Jacobian to normalize the tangent vector , t. the tangent vector is the vector of differentials. The value of one of the variables is mentioned as either +1 or -1 . This particular variable is the continuation parameter as shown in equation (2.30)

$$\begin{bmatrix} J_0 \\ e \end{bmatrix} * t = \begin{bmatrix} 0 \\ \pm 1 \end{bmatrix} \quad (2.30)$$

$$T = [\partial\delta \quad \partial V_2 \quad \partial\lambda] \quad (2.31)$$

The tangent vector is found using equation and prediction is made using by eq (2.32)

$$\begin{bmatrix} \delta^{n+1} \\ V_2^{n+1} \\ \lambda^{n+1} \end{bmatrix} = \begin{bmatrix} \delta^{n} \\ V_2^{n} \\ \lambda^{\mathrm{n}} \end{bmatrix} + \sigma \begin{bmatrix} d\delta \\ dV_2 \\ d\lambda \end{bmatrix} * \sigma \quad (2.32)$$

where ,

n is the number of iteration

σ is specified step length

Now modified iteration is given by equation

$$\sigma_{New} = \frac{\sigma_{old} N_{opt}}{N_j}$$

N_{opt} is corrector iteration number

N_1 is iteration number used to correct pervious predicted solution

Now solution will not exist at particular maximum value of the continuation parameter. So at this time, continuation parameter is changed. It will choose one of state variable as continuation parameter. That's why this is called as locally parameterized continuation. The process to choose parameter correctly is to start from λ. For stopping criteria it has to be checked out that whether critical point has been achieved or not.

CHAPTER 3

OPTIMIZATION TECHNIQUE

3.1 Introduction

Now-a-days, Optimization algorithm is popular among research communities of power system. This field of optimization algorithm is a interrelated area of research because these algorithm can help to find approximately solution to problems where analytical method does not exists for solution like non linear wide range of application in power system since many problem can be formulated as an to minimize task , where the main task is to minimize and maximize objective function f. in other words , in a search space the objective is to obtain solution of such possible solutions such as function is minimized or maximized for example the quality of generation can be improved by such algorithm , it also help in reducing the production cost or also helps in improving efficiency of transmission system and scheduling related problems.

Hence the technique used in optimization is an important key to success in comparison with such algorithm technique, the manual work for obtaining the optimum solution is quiet difficult, If not impossible because in manual optimization it requires a great deal of patience.

Alternately optimization algorithm will automate search and gives better solutions. The method of finding good approximately solution and real world optimization problems have lead to great variety of optimization technology.

3.2 Categories of optimization

Optimization algorithms are categorized into six parts and neither of these is mutually exclusive.

a) One dimensional and multi dimensional
b) Static and dynamic
c) Discrete and Continuous
d) Constrained and non Constrained
e) Trial and error method

One dimensional and Multi dimensional:

In one dimensional, it has only one variable while in multi dimensional it has more than one variable.

Constrained and multi constrained:

It refers to variable, equalities and inequalities in terms of cost functions while in multi constraint, the variable can be put into any values.

Static and dynamic:

In Static, the output does not depend upon the function of time while in dynamic the output depends upon the function of time.

Discrete and Continuous:

In discrete only finite values are possible where in Continuous optimization, only infinite number of values is possible.

Trial and error optimization:

It helps to adjust variables in which it does not know about process and produce output.

3.3 Nature optimization methods

3.3.1 Evolutionary Algorithms:

The iterative and stochastic technique is the part of evolutionary algorithm and these concepts is inspired by Darwinian evolution theory. The purpose of EA is to find the best possible solution to optimization problem by simulating an evolutionary process from population of individuals. There are three operations in simulation cycle that are recombination, mutation and selection. Recombination and mutation find new candidate solution whereas selection finds out candidate with low fitness, which is evaluated by objective function. The initialization and iterative cycle in EA is shown in fig 3.1. EA was first suggested by Lawrence Fogel Rechenberg and Hans Paul Schwefel Holland.

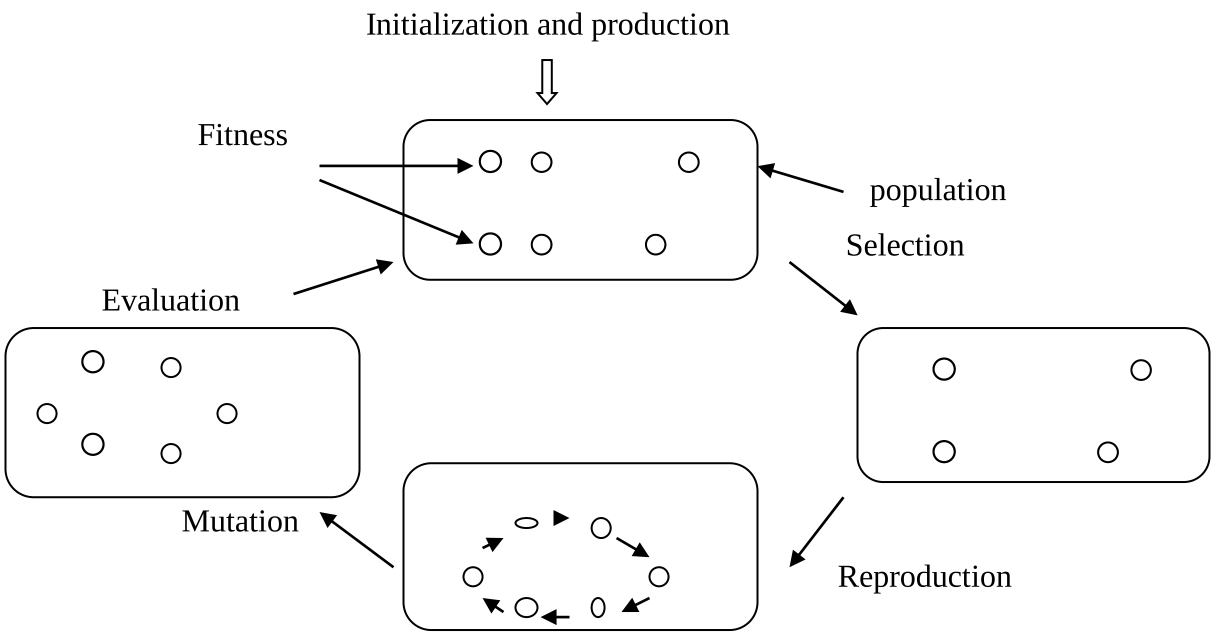


Fig 3.1 Initiative cycle in Evolutionary algorithm

3.3.2 Genetic Algorithm:

The concept of genetic algorithm as well as that of Evolutionary computing was a kind of result of Darwin theory of natural selection and survival of fittest. The concept of genetic algorithm was proposed by John Hallord . They are problem solving program which help to try to minimize large population way through processes such as reproduction, mutation and natural selection. By using genetically based processes, Genetic Algorithm provides evolution of solutions. Alternatively natural evolution, in a fraction of seconds, programs is able to produce and measure thousand of generations. Genetic Algorithm is a technique which is used to compute for finding and search true or approx solution to optimization. Genetic algorithms are defined as global search heuristics. Genetic algorithm is that algorithm in which population of candidate solution are implemented in computer simulation which moves towards better solutions.

In GA, solution are in binary solution 0's and 1 s. but other encoding is also done here. The method of searching usually initiates from group of randomly generated individuals. The fitness of every individual is checked in each generation and based on their fitness multiple individual is chosen from current location. After that they are modified to form a new population. When maximum no. of solution has developed or satisfactory fitness value is formed, then algorithm terminates.

If the algorithm has obsolete due to large number of generation, an ordinary solution then ordinary solution may or may not have been reached. The application of Genetic algorithm used in computer science engineering, economics, chemistry, biogenetics, mathematics, physics and other application etc.

3.3.4 Ant colony optimization:

Ant colony optimization was developed by Dorigo and Maria in 1997 ACO is also defined as group based on Meta heuristic which help to find approximate solution from difficult optimization. Ant colony is a multi agent system in which nature of each particle is followed by behavior of ants and it also called as ant algorithm. If the food source access has given to population of ant through multiple approaches paths. Most of ants will use smallest, shortest and optimum roots. To make this process fast , some ant species releasing a chemical substances (is called pheromones) on ground when travelling to food source

When process starts iteration, pheromones are collected at higher rate on the shorter path than longer paths. When the other ants reach at a decision path, they make decision based on the amount of pheromones which they smell. Due to higher concentration of pheromones, all of the ants are travelling on the shortest path. The deposition of pheromones is simulated by ant algorithm among various they travel upon. When the high concentration of ants travel on the path from which optimal path can be identified. The best example of ant algorithm is swarm intelligence system and trying to solving numerous optimization problems.

3.3.5 Particle Swarm Optimization

PSO is basically developed by Dr. Eberhant and Dr. Kennedy and it is biologically inspired method of search and optimization.

For example like a flock , swarm divert towards “leader” the current best known solution , accelerating and turning as better solution are found. From the research it has demonstrated that PSO provides efficiently best solutions in comparison with other technique for many complex problems.

PSO is stochastic optimization technique and it is developed by Dr. Eberhant and Kennedy in 1995 which is followed by social behavior of bird flocking or fish schooling. In PSO, particles are potential solution; go through the problem space by following current optimum particles. Each particle has records of its coordinates in problem space, which are linked with the best solution. The fitness value is also kept. This value is called pbest .

Another best is location best which is followed by particle swarm optimizer which is best value. When particle combines all groups, then that best value is called global best. At each step of time, PSO consists of changing velocity of each particle to its pbest and lbest .Acceleration is chosen by random term and in several past years, PSO is most successful technique and it is used in many research and application area. It is concluded that PSO gives better result in faster, cheaper way as compared to other methods.

Other beneficial of PSO is that it is attractive in which only few parameter are to be adjust.

3.3.6 Tabu Search:

It is iterative method for solving problems of optimization. It involves scheduling, time tabling and layout optimization in which is used to obtain optimal and near optimal solution for problem successfully.

The basic concept of Tabu search is to find search space of all feasible solution through various moves. Tabu steps are obtained from short term and long term history (past) of sequence of moves.

3.3.7 Fuzzy System:

Fuzzy system comprises variety of concepts and techniques for representing and proving knowledge i.e uncertain, unreliable. Fuzzy system develops rules which uses approximate values, also ambiguous data. Fuzzy system gives the meaning of handling such information by developing logic with defined imprecision. Other traditional programs that uses IF then rules, fuzzy system uses totally different statement and module the way of people thinking, which can be interpreted by computers as well as human experts.

3.4 Why PSO?

Now a day’s PSO has several challenging features. In other algorithm if there is number of local optima, in that case exact global optimum cannot found in prescribed time while it does not carry such problems . Other algorithms stagnate at local optimum, which gives less desirable solution while PSO seems to be particularly promising approach for several reasons. PSO algorithm can be applied to continuous and mixed integers etc. Furthermore PSO can handle easily many challenges such as local optima, multiple objectives, constraint and dynamic components.

As it has also many disadvantages. As many of candidate solution have to be evaluated in the optimization process after that they are rather computationally demanding. Furthermore, PSO cannot be applied blind folded to any optimization problem. As in power system there are many simpler and fast techniques but PSO should be applied first because PSO provides better solutions to optimization problem. Another advantages of PSO is that only few algorithm need to be tune.

CHAPTER 4
ECONOMIC LOAD DISPATCH

4.1 Introduction

Electrical energy id produced from natural sources and cannot be kept, as demand increases, it is delivered. The bulk of power is transferred by transmission lines over a long distance and for local deliveries, a distribution system is used. There are main three parts of interconnected power system that are generator which is used to generate electrical energy , second is transmission in which electrical energy is transmitted and third is load ,which uses it.

Few facility are there to store electrical energy, the net production of a utility must clearly track its load. The basic problem is one of minimizing cost. So the economic dispatch is used to minimize the cost of generation and transmission in prescribed loads. The economic dispatch problem consists of two parts:

- Unit commitment
- On line economic dispatch

Unit commitment is defined as the supply of load of system over a prescribed of time in order to minimize cost.

On line economic dispatch is defined as the supply of load in generating load as well as system over minute to minute.

Economic Dispatch neglecting losses and no generator limits

First case of economic load dispatch is that transmission losses are neglected in which line impedance and system configuration is not included. The models show that system have only one bus with many generator and load is connected in it .the addition of all power generation is total demand of demand. The cost function is defined by an equation for each plant

$$C_i = \sum_{i=1}^{n_g} C_i$$

$$C_I = \sum_{i=1}^{n_g} \alpha_i + \beta_i P_i + \gamma_i P_i^2$$

subject to constraint, and is minimum

$$\sum_{i=1}^{n_g} P_{gi} = P_D$$

where,

C_i is total cost of production

C_1 is the cost of production in i^{th} plant

P_i is the generation of power in i[th] plant

P_D is total demand of power and it is also equal to generating power.

4.2 Operating Cost of a thermal plant

At minimum cost, power generator is influenced by some factor

- Operating efficiencies
- Fuel cost
- Transmission losses

The generators have not security of minimum cost. The transmission losses gets higher , if plant away from load over a long distance and due to this plant may be uneconomical. hence , we need to calculate power generation of different plant in order to minimize the operating cost

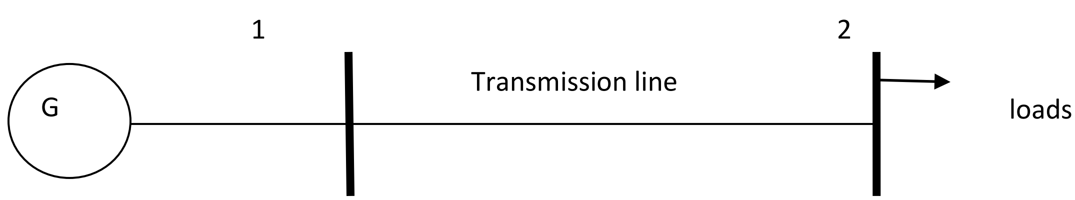


Fig 4.1 Simple model of power system

4.3 Economic Dispatch Neglecting Losses and including Generator limits

The generators have some limited values which should be lie within maximum and minimum limits. Finding of real power generation is our aim so that objective function should minimize.

Subject to constraint

$$P_{i(min)} \leq P_i \leq P_{i(max)}$$

$$i = 1 \dots\dots\dots n_g$$

where,

$P_{i(min)}$ $and P_{i(max)}$ are minimum and maximum genearting limits for plant i

4.4 Economic Load Dispatch Including Losses

In an interconnected power system, when power is transmitted over small distance with load low density, then power generation with all plant is equal to demand power with no transmission losses.

As transmission is long having low density ares, then the major factor is transmission losses. A total transmission loss is expressed as the quadratic function of generating power outputs and is given below:

$$P_L = \sum_{i=1}^{n_g} \sum_{j=1}^{n_g} P_i B_{ij} P_j$$

A general formula consists a linear term and constant term , called as Koron loss formula , is

$$P_L = \sum_{i}^{n_g} \sum_{j}^{n_g} P_i B_{ij} P_j + \sum_{i=1}^{n_g} B_{0i} P_i + B_{00}$$

The coefficient is expressed as loss coefficient or B- coefficient. B-coefficient is constant . the economic dispatch problem has a function of minimizing generating cost that is function of output of plant.

$$C_t = \sum_{i=1}^{n_g} C_i$$
$$= \sum_{i=1}^{n_g} \alpha_i + \beta_i P_i + \gamma_i P_i^2$$

Subject to constraint

$$\sum_{i=1}^{n_g} P_{gi} = P_D + P_L$$

Limits are expressed as follows

$$P_{i(min)} \leq P_i \leq P_{i(max)}$$

$$i = 1 \ldots \ldots n_g$$

These are generating limits for plant i.

4.5 Non linear cost function optimization

The important tool in computer aided design is non linear function optimization and it is group of optimization called non linear programming. Our basic aim is to minimize function of non linear objective with subject to nonlinear equality and in equality constraints.

Many of mathematical tools that have been used to help in solving unconstrained parameters optimization problems. With the help of derivative of f with respect to variable which is equal to zero, cost function can be reduced which is called as gradient vector.

The second term which is associated with term is given by :

$$\frac{\partial f}{\partial x_{i=0}}$$

$$i = 1,2 \dots \dots \dots . . n$$

$$\nabla f = 0$$

$$\nabla f = \frac{\partial f}{\partial x_1} \; \frac{\partial f}{\partial x_2}, \dots \dots \dots \dots . \frac{\partial f}{\partial x_n}$$

$$H = \frac{\partial^2 f}{\partial x_i \partial x_j}$$

The above equation are symmetric matrix, called as hessian matrix of the jacobian . At local extreme$x_1 x_2 \dots \dots \dots x_n$, when derivative of f is finished for having minimum relative value, then Hessian matrix is calculated and it must have a positive definite matrix. The Eigen values of Hessian matrix which is calculated should come positive. Now it concludes here that when the partial derivative with respect variable parameter is done, then unconstrained function which having minimum value is found. Among the sets of parameters values obtained , those at the matrix of second partial derivative derivatives of cost function is positive definite are local minima. When a single local minimum is found here, it means that global minimum exists, otherwise at each local minima, the cost function is calculated which is equal to global minimum.

4.6 Constrained Parameter Optimization: Equality constraints

When the function are dependent among these parameter which is to be selected, is one of problem. The problem is minimized

$$f(x_1 , x_2 \dots \dots \dots . . x_n)$$

subject to equality constraint

$$g(x_1 , x_2 \dots \dots \dots . . x_n) = 0$$

$$i = 1,2 \dots \dots . k$$

Lagrange multiplier method is used to solve this problem which helps in providing augmented cost function by announcing K-vector.the unconstrained cost function becomes

$$£ = f + \sum_{i=1}^{k} \lambda_i g_i$$

Constrained local minima have following necessary condition which is given below:

$$\frac{\partial £}{\partial x_i} = \frac{\partial f}{\partial x_i} + \sum_{i=1}^{k} \lambda \frac{\partial g_i}{\partial x_i} = 0$$

$$\frac{\partial £}{\partial \lambda_i} = g_i = 0$$

The above equation shows original equality constraints.

4.7 Constraint Parameter Optimization: Inequality Constraints

Partial optimization problems include inequality constraint as well as equality constraint. The problem is to minimize the cost function .

$$f(x_1, x_2 \dots \dots \dots .. x_n)$$

subject to equality constraints

$$g(x_1, x_2 \dots \dots \dots .. x_n) = 0$$

$$i = 1,2 \dots \dots \dots . k$$

And when subject to inequality constraint

$$\mu_j (x_1, x_2 \dots \dots \dots \dots x_n) \leq 0$$

$$i = 1,2 \dots \dots \dots . m$$

This type of problem is solved by inequality constraint by announcing m–vector. The equation of unconstrained cost function is given by:

$$£ = f + \sum_{i=1}^{k} \lambda_i g_i + \sum_{j=1}^{m} \mu_j u_j$$

Constrained local minima have following necessary condition which is given below:

$$\frac{\partial £}{\partial x_i} = 0$$

$$i = 1,2 \dots \dots .. m$$

$$\frac{\partial £}{\partial \lambda_i} = g_i = 0$$

$$i = 1,2 \dots \dots ... k$$

$$\frac{\partial £}{\partial \lambda_i} = \mu_j \leq 0$$

$$j = 1,2 \dots \dots \dots . m$$

$$\mu_j u_j = 0 \qquad \& \quad \mu_j > 0$$

$$j = 1,2 \dots \dots \dots m$$

The above equation shows original equality constraints.

Table 4.1

Comparison of computational time by varying swarm size

S.No	Swarm Size	No. of Iteration	C.P.U Time
1.	1000	15	
2.	500	15	
3.	250	15	
4.	125	15	
5.	50	15	

CHAPTER 5

MAXIMUM LOADABILITY USING PARTICLE SWARM OPTIMIZATION

This chapter explains the basics concept of PSO, and the problem of maximum loadability is been formulated using PSO and also variable and algorithm is also discussed.

5.1 Particle Swarm Optimization

The concept of PSO depends on the behavior of different organism for example school of fish and group of bird.

Swarm intelligence's 5 basic principles:

Proximity principle: They must move easily in simple space and time computations.

Quality principle: They must be able to react on quality factors in the environment.

Diverse response principle: They should not respond its activities along very narrow channels.

Stability principle: As environment changes, it should not change behavior.

Adaptability principle: They must be able to change behavior mode when it's worth the computational price.

Stability and Adaptability principles are the opposite sides of the same coin. The particle swarm optimization concept and paradigm presented in this paper seems adhere to all five principles. Every agent clarifies its position in any dimensional space according to its own and neighbors experience. Each agent has its own best position which is called lbest while among the best position all position is again recorded that is called global best position.

vel – velocity of each agent

The modified velocity and position of each particle is given by eq (5.1) and (5.2)

$$\mathrm{vel}_{ij}^{n+1} = C_1 * \mathrm{vel}_{ij}^{n} + C_2 * \mathrm{rand} * \left(\mathrm{lbest}_{ij}^{n} - P_{ij}^{n}\right) + C_3 * \mathrm{rand} * \left(\mathrm{gbest}_{j}^{n} - P_{ij}^{n}\right) \quad (5.1)$$

$$P_{ij}^{n+1} = P_{ij}^{n} + \mathrm{vel}_{ij}^{n+1} \quad (5.2)$$

$$\mathrm{for}(i = 1,2 \ldots\ldots s), j = (1,2 \ldots\ldots m)$$

where

s = number of agent in population

m= number of members in a particle

C_1= inertia weight

C_2 and C_3 = acceleration constant

Rand= uniform random values

vel_{ij}^{n} = velocity of j^{th} member of i^{th} particle at n^{th}iteration

P_{ij}^{n}= current position of j^{th}member of i^{th}particle at n^{th}iteration

lbest= local best value of j^{th} member of i^{th}particle at n^{th}iteration

gbest = global best value of j^{th} member at n^{th} iteration

Velocity should be maintained properly for exploring not beyond local solution. It should not be too high or low. Thus velocity of each agent should lies between minimum and maximum velocities. Constant C2 and C3 help each agent to find local and global best positions. They are set equal to 2 . The inertia weight is set according to given an equation(5.3)

$$C_1 = C_1^{max} - \left(\frac{C_1^{max} - C_1^{min} * IT}{IT^{max}}\right) \tag{5.3}$$

5.2 Problem formulation

The critical point can be determined by an equation

Minimize

$$\frac{1}{1+(V_i-1)^2+Pd_i^2} \tag{5.4}$$

where

Pd_i is real power demand at load bus i

V_i is corresponding voltage at bus i

5.3 State Variable

At load bus real power demand is varied for which critical point is to be located. It is varied between a minimum and maximum value. Minimum value is equal to 0.0. Maximum value can be taken to high value ,say 20 or 30 pu . Ratio of reactive power and real power demand of i^{th} bus of base case data is determined.

5.4 Basic terminology

a) **Particle or agent :**

Each individual in a group is called particle or agent. Each particle should behave individually in a group and following same principle: they should move towards its best personnel and overall best location with observing their current position.

b) **Position:**

A bee's placed in a field is referred as position. this can be shown on coordinates plane. We can extend idea into any dimensional space according to problem. This dimensional space is a solution space for the problem being optimized. if optimization problem is reduced to any set of values then that could represent a position in solution space.

c) **Fitness:**

There are various method and function to find goodness of positioning all evolution technique. The fitness function should lie in solution space and give value of that position. Fitness function can be simply represented by density of flowers; as higher the density, betters the location. The antenna gain, weight gain, peak cross polarization represent fitness.

d) **Pbest :**

As every bee reminds their location in which they encountered personally the most flower. And those locations which is discovered personally by bee with highest fitness values is known as Pbest. Now every bees have their own pbest which is determined by path that is has flown. Now, bees compare their fitness value from their previous location at each node. If current location have higher fitness value than previous, then pbest is replied.

e) **Gbest :**

The way of knowing of higher concentration of flower may be different for each bees. Each bees is explored to one gbest for entire swarm. Now each bees compares their current location with gbest at each node. If bees have higher location , then gbest is replaced by current location of bees.

Key PSO Vocabulary

Particle	Single in the group
Location	In n-dimensional coordinates it is used to represent solution to optimization problem.
Swarm	Groups of particles

Fitness	Good solution in solution space
Pbest	The location in which best fitness will come back for specific particle in the parameter space.
Gbest	The location in which best fitness will come back for the entire group in the parameter space.
V_{max}	In a given direction , the maximum velocity travelled by agent

5.5 Basic Model of PSO

The canonical model of PSO has a group of particles in which they are moved with randomly generated solution from population. In simple model of PSO, initiation of each agent is done by two elastic forces. First one is to find fittest location which is explored by particles having random magnitude and second one is to find the best location which is explored by swarm.

Suppose, PSO is dealing with N-dimensional coordinates. The representation of each particle position, velocity and acceleration is represented by vector. It starts with acceleration vector

$$a = a_1 , a_2 \cdots a_n$$

And each component is given by a

$$a_i = \varphi_1 R_1 (x_{si} - x_i) + \varphi_2 R_2 (x_{pi} - x_i) \quad (5.5)$$

Where ,

x_{si} is best node represented by swarm in i^{th} component

x_i is current location find by agent's i^{th} component

x_{pi} is personnel best of agent in i^{th} component

R_1 *and* R_2 are random component which are balancing the diversity of population and they are lied in between the range if [0,1]. $\varphi_1$and φ_2 are rate of learning , which is used to maintain the proportion of cognition and social interaction of swarm.

$\varphi_1$is self recognition coefficient

φ_2 is component of social coefficient.

For each and every dimension, same formula is applied independently. The updation of velocity of agent and position is done by an equation

$$v_i(t) = \omega v_i (t - 1) + a_i \quad (5.6)$$

$$x_i(t) = x_i\,(t - 1) + v_i \quad (5.7)$$

From equation particles takes a decision to move forward having self experience. This experience is only last position taken by agent .in PSO model, particle finds solution having range of [-s,s] of problem space. If range is not symmetrical then it can be converted into symmetrical range. During one iteration, maximum distance must lie in between velocity$[-V_{max}, +V_{max}]$.

5.6 PSO Algorithm

Step 1: Solution Space

The space where solution exists is called solution space. Let us example bees has to find out the maximum density of lowers if there is no limitation for bees, they can move out of searching space.

Step 2: Find fitness function

This step provides a connection between optimization algorithm and physical world. Finding the optimum function is bit critical in no. of good solution. The fitness functional should have functional dependence which is interrelated to each characteristics being optimized. For each optimization, fitness function and solution space should develop specifically.

Step 3: Initiate random velocities and location

To start searching of positioning of solution space, each particle starts with own random location velocity (in terms of direction and magnitude). Since starting position is that location encountered by each agent and then each particle have position pbest and from initial position , first gbest is then selected.

Step 4 : Particles move towards solution space

The algorithm goes through each particle one by one, and circulating it by a fraction amount and cycling through entire swarm.

a) Evaluate the particle fitness, compares to gbest and pbest.

b) Update the particle’s velocity: particle velocity is the main element of entire optimization. To measure velocity, is key to understand the optimization. The velocity of the particle is changed by an equation below

$$vel_{ij}^{n+1} = C_1 * vel_{ij}^{n} + C_2 * rand * \left(lbest_{ij}^{n} - P_{ij}^{n}\right) + C_3 * rand * \left(gbest_{j}^{n} - P_{ij}^{n}\right)$$

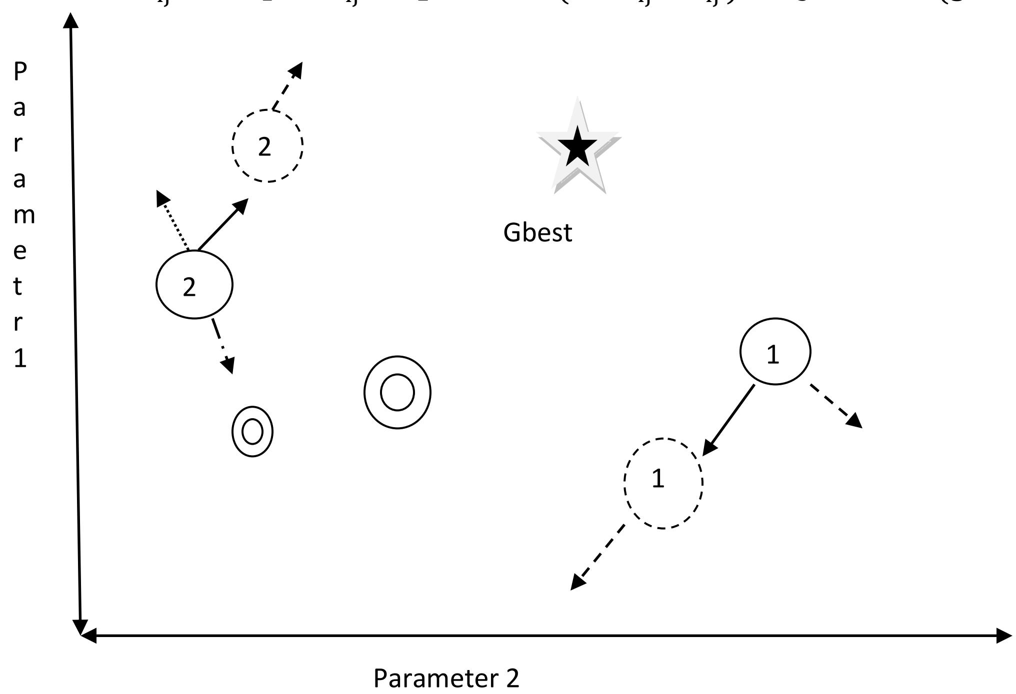


Fig 5.1 shows particle moves towards gbest and pbest

Each particles (1) and particle (2) are moved to best location solution and their own personnel best location, pbest 2-D parameter space. The new velocity is simply old velocity scaled by C_1 and for particular dimension, it is moved to its Gbest and pbest .C_1 and C_2 are acceleration factor which is used to determine the relative “PULL” of Gbest and Pbest. These are sometimes called as cognitive and social rates respectively. C_1 is a factor determines each particle is moved by his best locations. And C_2 is a factor which determines how much particle measures from rest of group. As C_1 is increased and it helps to increase in exploration of solution space as each agent accelerate towards its Pbest; C_2 is increased which is used to exploit of supposed global maximum.

The random number function lies in between 0.0 to 1.0.

c) **Move the particle:** the particle will move to its next location when velocity has been determined. The velocity is applied for some step time and usually taken to be one and new coordinated is calculated for each dimension according the following equation:

$$X_n = x_n + v_n * \Delta t$$

The particle is then accelerated to location is calculated by eq

Step 5 : Repeat :This process is repeated again and again until termination criteria are met .in this way particle lies in discrete time interval before being evaluated. Each agents position are being evaluated and correction changes of pbest and gbest before letting agent fly around for another second. Repetition of this cycle is continued until desire results will come out.there are various methods to find termination criteria.

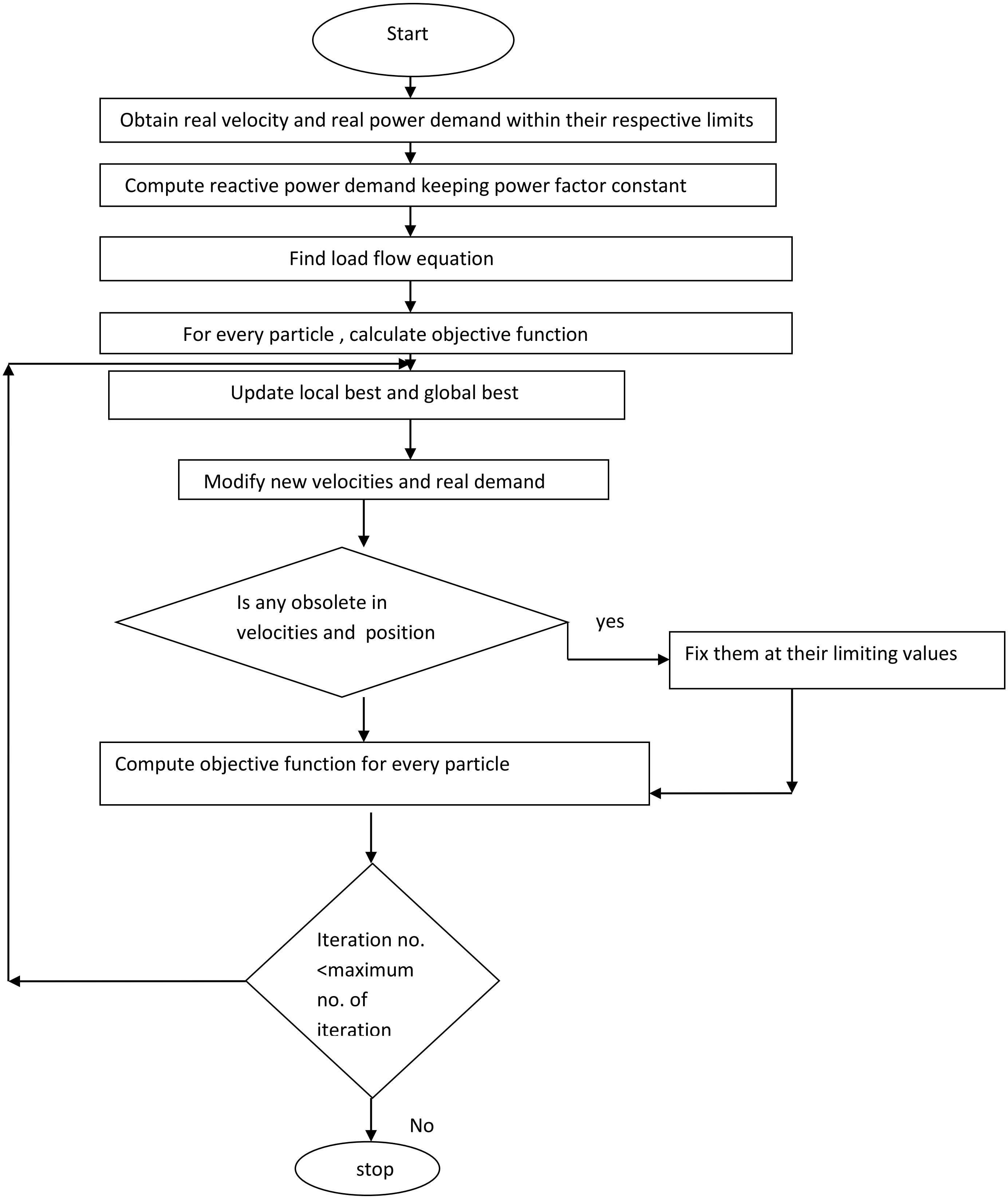


Fig A the flow chart to obtain max loadability using PSO algorithm

5.7 Boundary condition

It is very difficult that objective function will lie within solution space and also constriction factor, and inertial weights do not stop the particle within solution space. To address this problem, three boundaries are mentioned below:

a) Absorbing Walls
b) Reflecting walls
c) Invisible walls

Absorbing walls:

When an agent attracts the boundary of space in any one of dimension velocity will zero in that dimension and particle will come back in space. The energy of an agent will be absorbed by boundary “walls”.

Reflecting walls:

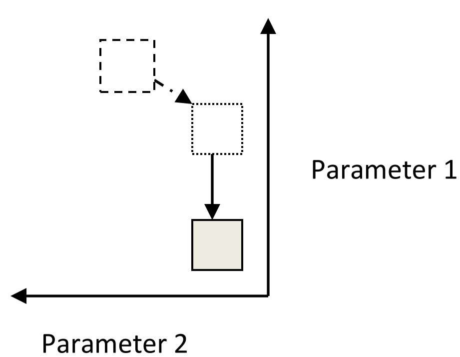
When an boundary is attracted by an agent in any one of dimension , then there will change in velocity sign and agent come back toward space.

Invisible walls:

When an agent are free to move without any condition. However agent which are move outside solution space, are not evaluated for fitness function.

The purpose of evaluating this is only to save computationally time in allowed solution space without disturbing with natural motion of swarm. Here, invisible walls gives better result than other technology.

- for “absorbing wall” velocity will zero when an agent go to boundary of parameter 2.
- for “ reflecting wall” when agent hits boundary , then there will change in velocity sign and agent come back toward space.
- For invisible wall fitness of agent is not computed when it goes outside solution space.



a) Absorbing wall

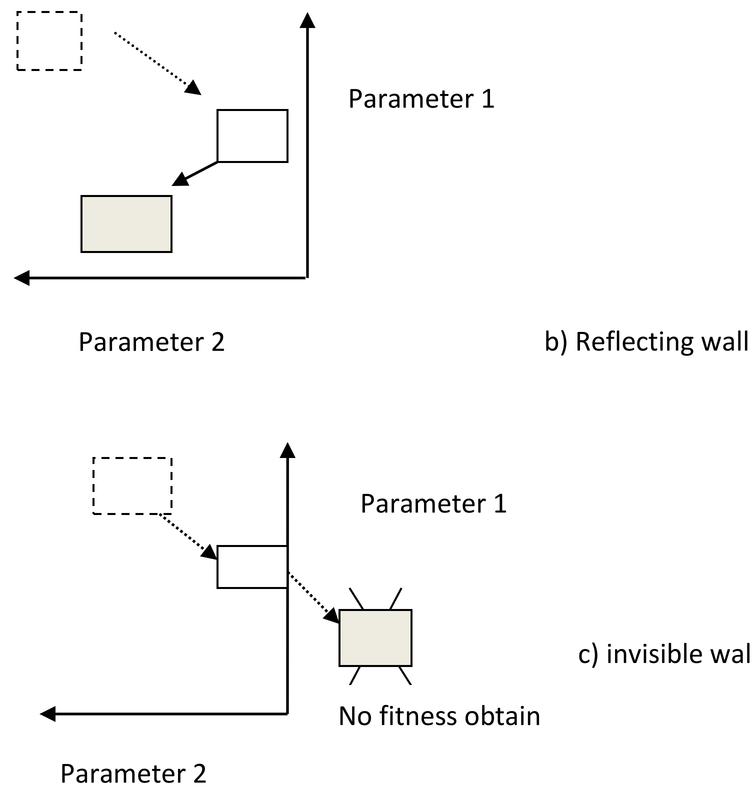


Fig 5.2 Type of walls

5.8 End Criterion

There is various methods to terminate criteria mentioned below:

a) Maximum iteration
b) Number of iteration without any improvement
c) Error of minimum objective function

Maximum iteration:

When the process has been repeated no. of times then PSO has stopped. Although, it not sure that best result may or may not come. But this method has property of simplicity and generality.

No. of iteration without any improvement:

In this case if there will not be any improvement in no. of iteration then optimization process is terminated.

Error of minimum objective function :

If the error between obtained objective function and most efficient fitness function is less than prescribed value then objective process is terminated. If solution obtained which is graeter or equal to fitness value then PSO is stopped at that point. In most of cases, if solution is obtained better than target fitness , then solution is good and no reason to continue to run.

5.9 Comparison with other techniques:

5.9.1 PSO Vs Genetic Algorithm:

As PSO and GA has very common property in the procedure. Both PSO and GA algorithm initiate from randomly generated population by evaluating group. Both PSO and GA have fitness function. PSO and GA try to update population, velocity and try to obtain optimum result. But optimum result may or may not be get, it is not guaranteed. As GA has property of mutation and crossover but PSO do not have such property. With the help of internal velocity, particle move themselves. This is very important advantages of Paso algorithm that is they have memory.

The share of information of PSO is different than GA. In GA, chromosomes share information with each other. In GA, total population will update to optimum result. While in PSO, only gbest share information that is the mechanism of sharing of one way information.

5.9.2 PSO Vs SA:

SA is basically based on the process of thermodynamics. SA is local search in which algorithm is allowed to escape local optimum. In SA , only those solution are accepted; those depends on temperature and gap between current solution and network candidate solution .The chance of accepting solution decrease as algorithm increase in steps.

The cooling procedure is same to SA in which there is gradual decrease in temperature and thus probability of solution is accepted.

SA initiate from generated solution and moves until there is no occurrence of improvement or some criteria is met (that is good solution obtain). There is one advantage of SA is simplicity. Multimodal performance landscape is the disadvantage of SA.

5.9.3 PSO Vs ANN

It is analysis paradigm. To run ANN, simple structure of brain and back propagation algorithm needs. Evolutionary computations have been suggested for ANN. The three main attribute of neural network is applied to Evolutionary computational.

- Network connection weight
- Network architecture
- Network learning algorithm

The advantage of evolutionary computational is that it can be applied to non- differential transfer function and it is also used on those places where no information is available.

Disadvantage of these technique is that no competition as compared to other for solving to optimization problem.

Secondly, to represent weight in algorithm is not easy and it should be observed by selecting the genetic operator. In many paper, it is shown that PSO comes forward to train ANN. And it is faster and gives better result.

5.10 Selection of PSO:

PSO has many challenging goal and one goal is that , PSO has to be maintain balance between global exploration and exploitation.

In PSO, first problem is that PSO has to be control on search space which is explored by PSO. If there is no boundary or restriction on velocity, agent will move out of solution space.

Earlier, Scientist suggested that the value of C2 and C3 is 2.0 for each. There are various values which have been selected for inertial weights, which is used to balance between global exploration and exploitation.

Inertial weight is larger which help to improve global exploration. Alternatively, inertial weight is small which represent exploration in which agent are moved towards gbest and pbest.

Eberhant and Shi suggested that inertial weight is varying from 0.9 to 0.4.for selecting number of iterations, some precaution should be taken. PSO will stagnate ,if there is maximum number of iteration or iteration is large , and then PSO will wait for inertial weight which to be decrease to begin exploration of maxima.

Similarly, if only less number of iteration takes place than PSO will also wait for the swarm which take time to explore space and find optimum. There are two basic methods as gbest and lbest suggested by Eberhant and Kennedy. In case of lbest model, agent has memory of previous move and has their own move and they are closed to neighbor best than swarm. In case of gbest, best node found by swarm. The agent which is best or having best node attracts the entire agent and all agents will change their position. In lbest model, each model is attracted by smaller number of members of population array.

Kennedy and Mendes studies the various population topologies on PSO performance. The communication abilities and thus group performance is affected by different topologies. Some different topologies are given below:

- Global topology
- Neumann topology
- Pyramid topology
- Circle topology
- Star topology

In global topology, the structure is fully joined connected network. Each agent has changed to other position which is best as shown in fig

In the von Neumann topology, dimensional lattice are connected to above, below and each side.

In pyramid topology, the formulation of 3 dimensional triangles is done.

In circle topology, each individual are not connected each other, have larger distance to each other but the connection of neighbors are closed.

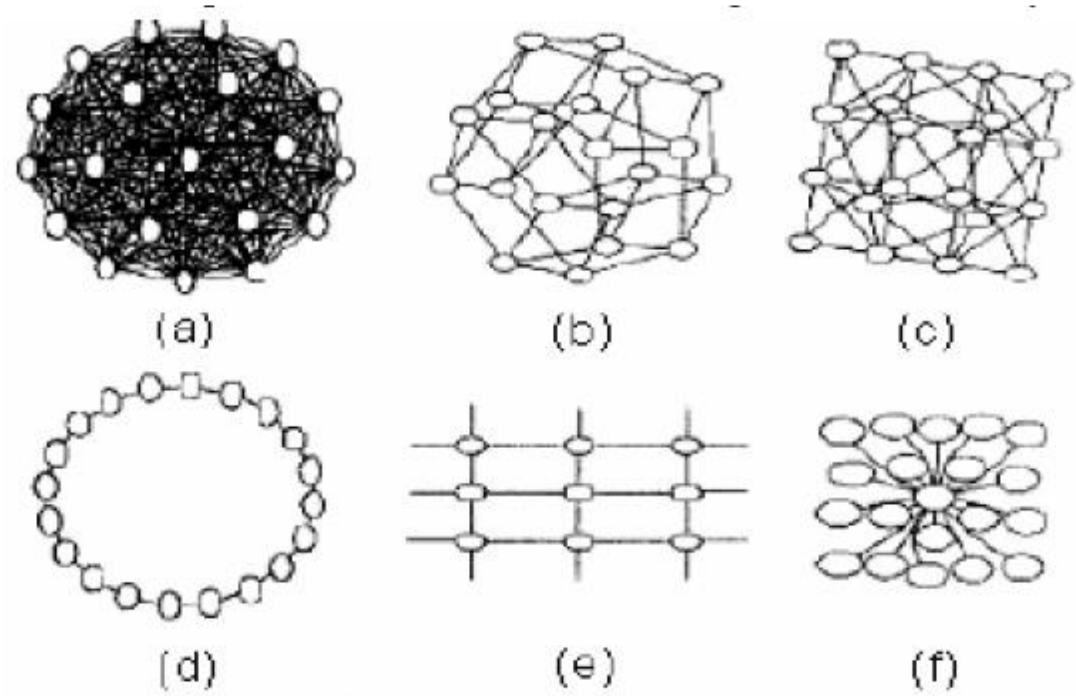


Fig 5.3 Some Neighbor Topologies

In star topology, all particles are attached to leader and whatever information they are getting, they has to share through leader and then compares the performance of all others.

CHAPTER 6

RESULT AND DISCUSSION

PSO algorithm is used to obtain maximum loadability which will be work on different power systems namely 2 –Bus, 4 – Bus, 6- Bus and IEEE 14 – Bus system.

6.1 Case 1

The work is carried out on 2- Bus system with one slack and one load bus. The maximum loadability can be understood by power factor i.e leading, lagging and unity power factor.

Table 6.1 by varying load bus, maximum loadability at different power factor

Power factor	**PSO**
0.8 Lagging	2.38
Unity	4.9426
0.8 leading	10.175

As shown in table, maximum loadability is obtained at different power factor. at leading power factor ,maximum loadability comes 10.175 which is maximum while it has minimum value at 0.8 lagging power factor. This shows that higher load can be obtained at leading power factor. And the corresponding voltage is 0.58789 at lagging power factor, 0.7229 at unity power factor and 1.1604 at leading power factor.

6.2 Case 2

This work is carried out on 4 bus data of one slack, one generator and two load buses. For getting maximum loadability, third and fourth load bus is varied and is analyzed at power factor.

Table6.2 by varying third load bus, maximum loadability at different power factor

Power factor	**PSO**
0.8 Lagging	7.018

Unity	17.289
0.8 leading	20

As seen from table, maximum loadability is in growing order. And corresponding voltage at unity power factor is 0.6587, at leading power factor, voltage is 1.2751 and at lagging power factor, corresponding voltage is 0.52999.when load bus -4 is varied, maximum loadability at unity power factor is 20 and corresponding voltage is 1.02.

6.3 Case 3

The maximum loadability is carried out by using PSO on 6 –bus data. 6-Bus data involves of two generators, three loads and one slack bus. Results obtained by varying load bus is shown in table 6.3

Table6.3 by varying fifth load bus, maximum loadability at different power factor

Power factor	**PSO**
0.8 Lagging	3.1366
Unity	5.0406
0.8 leading	6.4074

The corresponding voltage at lagging power factor is 0.58604 ,unity power factor have 0.70546 and leading power factor has 0.98113. the maximum loadability is higher at leading power factor.

Table6.4 by varying sixth load bus, maximum loadability at different power factor

Power factor	**PSO**
0.8 Lagging	3.8086

Unity	5.3713
0.8 leading	5.6314

6.4 Case 4

The proposed method is also tested on twelfth bus of IEEE 14 bus system. For leading power factor maximum loadability is greatest (2.6704) .

Table6.5 by varying 12 load bus, maximum loadability at different power factor

Power factor	**PSO**
0.8 Lagging	1.3492
Unity	2.1
0.8 leading	2.6704

6.5 Conclusion

For an interconnected power system, particle swarm optimization is used for finding the maximum loadability. The algorithm of particle swarm optimization will help agent or particle to choose not only from itself and also from best results. The procedure of findings global optimum can be increased by particle swarm optimization. The formulation of finding maximum loadability by using particle swarm optimization is simple and reliable and gives best value without any derivative methods.

6.6 Future Scope of Work

The maximum loadability can be obtained for different buses with help of PSO. PSO gives maximum loadability and then their results will compare to Continuation Power Flow.

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APPENDIX A

Table A.1 (a) Bus data 2-Bus system

Bus	Type	Voltage magnitude	Voltage Angle	Real Power Demand	Reactive Power Demand	Susceptance
1	1	1	0	0	0	0
2	3	1.004	0	100	0	0

Table A.1 (b) Generator data 2-Bus system

Bus	Real Power Generation	Reactive Power Generation	Qmax	Qmin
1	0	0	100	-100

Table A.1 (c) Branch data 2-Bus system

From Bus	To Bus	Resistance	Reactance	Line Charging Susceptance	Tap Setting
1	2	0.0	0.1	0	1

Table A.2 (a) Bus data 4-Bus system

Bus	Type	Voltage magnitude	Voltage Angle	Real Power Demand	Reactive Power Demand	Susceptance
1	1	1	0	50	30.99	0
2	3	1	0	170	105.35	0
3	3	1	0	200	123.94	0
4	2	1	0	80	49.58	0

Table A.2 (b) Generator data 4-Bus system

Bus	Real Power Generation	Reactive Power Generation	Qmax	Qmin
4	318	0	100	-100
1	0	0	100	-100

Table A.2 (c) Branch data 4-Bus system

From Bus	To Bus	Resistance	Reactance	Line Charging Susceptance	Tap Setting
1	2	0.01008	0.0504	0.1025	1
1	3	0.00744	0.0372	0.0775	1
2	4	0.00744	0.0372	0.0775	1
3	4	0.01272	0.0636	0.1275	1

Table A.3 (a) Bus data 6-Bus system

Bus	Type	Voltage magnitude	Voltage Angle	Real Power Demand	Reactive Power Demand	Susceptance
1	1	1.05	0	0	0	0
2	2	1.05	0	0	0	0
3	2	1.07	0	0	0	0
4	3	1	0	70	70	0
5	3	1	0	70	70	0
6	3	1	0	70	70	0

Table A.3 (b) Generator data 6-Bus system

Bus	Real Power Generation	Reactive Power Generation	Qmax	Qmin
1	0	0	100	-100
2	50	0	100	-100
3	60	0	100	-100

Table A.3 (c) Branch data 6-Bus system

From Bus	To Bus	Resistance	Reactance	Line Charging Susceptance	Tap Setting
1	2	0.1	0.2	0.04	1
1	4	0.05	0.2	0.04	1
1	5	0.08	0.3	0.06	1
2	3	0.05	0.25	0.06	1
2	4	0.05	0.1	0.02	1
2	5	0.1	0.3	0.04	1
2	6	0.07	0.2	0.05	1
3	5	0.12	0.26	0.05	1
3	6	0.02	0.1	0.02	1
4	5	0.2	0.4	0.08	1
5	6	0.1	0.3	0.06	1

Table A.4 (a) Bus data 14-Bus system

Bus	Type	Voltage magnitude	Voltage Angle	Real Power Demand	Reactive Power	Susceptance

					Demand	
1	1	1.06	0	0	0	0
2	2	1.045	0	21.7	12.7	0
3	2	1.01	0	94.2	19	0
4	3	1	0	47.8	-3.9	0
5	3	1	0	7.6	1.6	0
6	2	1.07	0	11.2	7.5	0
7	3	1	0	0	0	0
8	2	1.09	0	0	0	0
9	3	1	0	29.5	16.6	19
10	3	1	0	9	5.8	0
11	3	1	0	3.5	1.8	0
12	3	1	0	6.1	2.2	0
13	3	1	0	13.5	5.8	0
14	3	1	0	14.9	5	0

Table A.4 (b) Generator data 14-Bus system

Bus	Real Power Generation	Reactive Power Generation	Qmax	Qmin
1	232.4	-16.9	10	0

2	40	42.4	50	-40
3	0	23.4	40	0
6	0	12.2	24	-6
8	0	17.4	24	-6

Table A.4 (c) Branch data 14-Bus system

From Bus	To Bus	Resistance	Reactance	Line Charging Susceptance	Tap Setting
1	2	0.01938	0.05917	0.0528	0
1	5	0.05403	0.22304	0.0492	0
2	3	0.04699	0.19797	0.0438	0
2	4	0.05811	0.17632	0.034	0
2	5	0.05695	0.17388	0.0346	0
3	4	0.06701	0.17103	0.0128	0
4	5	0.01335	0.04211	0	0
4	7	0	0.20912	0	0.978

4	9	0	0.55618	0	0.969
5	6	0	0.25202	0	0.932
6	11	0.09498	0.1989	0	0
6	12	0.12291	0.25581	0	0
6	13	0.06615	0.13027	0	0
7	8	0	0.17615	0	0
7	9	0	0.11001	0	0
9	10	0.03181	0.0845	0	0
9	14	0.12711	0.27038	0	0
10	11	0.08205	0.19207	0	0
12	13	0.22092	0.19988	0	0
13	14	0.17093	0.34802	0	0