Genetic Algorithm based Optimal Power Dispatch

B. Balaki[1] Dr. K. Yasoda[2]
[1,2]Department of Electrical and Electronics Engineering
[1,2]Government College of Engineering and Technology Coimbatore, India

Abstract— Optimization is a technique used for finding the best option among number of possible choices that are feasible solutions in a power system. Genetic algorithm is capable of being applied to an extremely wide range of problems. It is used to solve and analyze the optimal flow dispatch problem. The objective of the thesis is to minimize the power loss and generator fuel cost with greater efficiency and to give accurate results in optimal power flow problem. Economic power dispatch plays a major role in order to prove secure and economic operation in the power system. In this project, genetic algorithm is used to solve the optimal reactive power dispatch for a power system using MATLAB toolbox. The proposed method minimizes the active power loss in a standard IEEE 30 bus system.

Keywords: Genetic algorithm (GA), Economic dispatch (ED), Reactive power dispatch (RPD)

I. Introduction

Most power systems or networks are capital-intensive. It is therefore very important to ensure their operations are economic and efficient so as to guarantee a return and profits on the capital invested. Furthermore the need for efficiency is heightened when certain factors are brought into consideration; fuel costs, cost of provisions or supplies, maintenance cost as well as regulation or rates fixed by government or regulatory bodies. Maximum efficiency is achieved by minimizing both the cost of power to the consumer as well as the cost of generating and delivering power to the company. The economics of operations in a power system can be approached either by minimizing the losses during delivery of power to the consumer/loads and the other dealing with minimum cost of power production. The latter, is referred to as economic dispatch and works by calculating the power output of each generation unit within a given power system that will minimize the cost of fuel needed to serve the system loads.

Economic Dispatch (ED) is the optimization scheme of computing the best generation schedule to supply a predetermined load, with minimum cost while satisfying the essential constraints like power balance and generation limits. For any specified load condition economic dispatch determines the power output of each plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load. Thus, economic dispatch focuses upon coordinating the production costs at all power plants operating on the system.

Reactive power dispatch (RPD) or optimal RPD is one of the most important tasks for the proper operation and control of a power system. RPD is carried out to reduce power losses and to improve voltage profile, voltage stability and improved overall system operation. In the necessity of the reduction of the system losses, the RPD is made to work towards the improvement of the power factor of the system. Due to the unity power factor in the system, the reduction of losses is obtained, resulting in the maintenance of stability in the system. The RPO is used for the maintenance of stability and safe operating zone in the system in addition to reduction of power loss. For the optimization of reactive power in a system, the optimization is done on the basis of the voltage profile of the bus bar and power factor. By various optimization techniques the minimization of loss of power in a system is achieved. Real power generation constraint and reactive power generation constraints are taken into account in the reduction of the power loss. The quantity of reactive power depends on the phase shift between the voltage and current wave. Reactive power improves voltage stability and avoids voltage collapse. By regulating the reactive power, voltage stability, system efficiency, energy cost, and power losses of a power system network can be controlled effectively.

II. Optimization

Optimization means discovering one or more feasible solutions which correspond to extreme values of one or more objectives. The requirement for seeking such optimal solutions in a problem comes mostly from the extreme need of either plotting a solution for minimum possible value, or for maximum possible value, or others. Because of such extreme characteristics of optimal solutions, optimization processes are of high consideration in practice. When an optimization problem involves only one objective function, the work of discovering the optimal solution is defined as single objective optimization. When an optimization problem involves more than one objective function, the work of discovering single or multiple optimum solutions is stated as multi objective optimization. Most real world problems naturally involve multiple objectives.

The search technique is simple and takes small time to arrive at final solution. With the advent of the fast computation facilities, the sophisticated methods for higher accuracy can be the criterion for adjudging the 'best' solution.

Optimization methods can be broadly divided into two classes: trajectory-based and population-based methods. The main difference between these two classes relies in the number of tentative solutions used in each step of the (iterative) algorithm. A trajectory-based method (e.g. Hill Climbing, Tabu Search, Simulated Annealing and Explorative Local Search methods) starts with a single initial solution and, at each step of the search, the current solution is replaced by another (often the best) solution found in its neighborhood. It is not uncommon for trajectory-based metaheuristic methods to quickly find a local optimal solution.

In contrast, population-based algorithms use a set of solutions (that is: a population of solutions). The initial population is randomly generated, and then enhanced through an iterative process. At each iteration, some members of the population are replaced by newly generated individuals (often those whose characteristics are better suited to the problem at hand), yielding a new generation. These techniques are called exploration-oriented methods, since their main ability resides in the diversification in the search space. Population-based methods have better performance for global optimization. Among these methods are Evolutionary Algorithms, Swarm Intelligence and Neural Networks, which have received enormous attention in recent years, primarily because of the rapid progress in computer technology, and the development of user-friendly software. It has been observed that memetic algorithm that combines both local and global population based algorithms may be the future to solve optimization problems.

Particle swarm optimization (PSO) is an optimization algorithm for dealing with nonlinear optimization problems. It has the advantages of fast convergence, simple calculation and easy global optimization.

Genetic algorithm is capable of being applied to an extremely wide range of problems. It is used to solve and analyze the optimal reactive power dispatch for a power system.

Optimization problems have the following characteristics:

1) Different decision alternatives are available.
2) Additional constraints limit the number of available decision alternatives.
3) An evaluation function defined on the decision alternatives describes the effect of the different decision alternatives.

It trade-off between tractability and specificity of optimization methods. If optimization methods are to perform well for the problem at hand, they usually need to be adapted to the problem. This is typical for modern heuristics but also holds for classical optimization methods like branch-and-bound approaches. Modern heuristics can easily be applied to problems that are very realistic and near to real-world problems but usually do not guarantee finding an optimal solution.

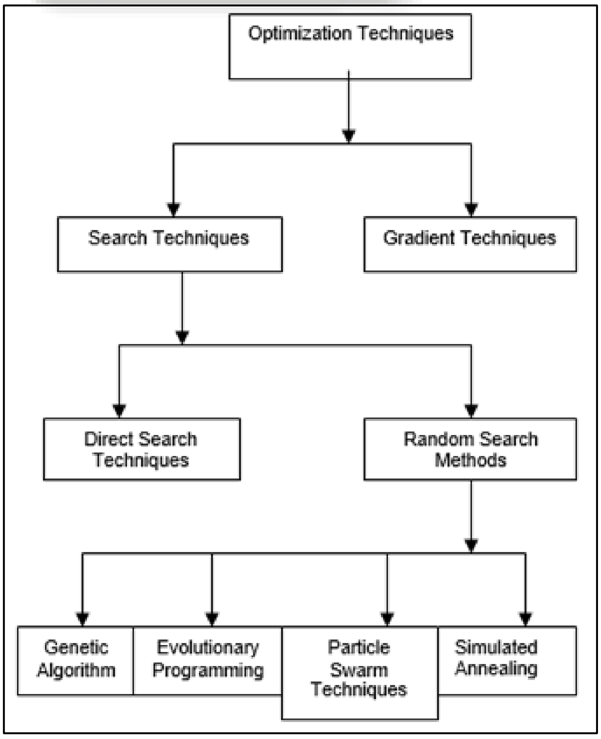

Fig. 1: Flowchart of Optimization types.

A. *Optimization Purposes and problem difficulties*

The purpose of optimization algorithms is to find high-quality solutions for a problem. If possible, they should identify either optimal solutions $x*$, near-optimal solutions $x \in X$, where $f(x) - f(x*)$ is small, or at least locally optimal solutions. Problem difficulty describes how difficult it is to find an optimal solution for a specific problem or problem instance. Problem difficulty is defined independently Properties of Optimization Problems of the optimization method used. Determining the difficulty of a problem is often a difficult task as we have to prove that that there are no optimization methods that can better solve the problem.

Statements about the difficulty of a problem are method independent as they must hold for all possible optimization methods. A globally optimal solution for an optimization problem is defined as the solution $x* \in X$, where $f(x*) \leq f(x)$ for all $x \in X$ (minimization problem). For the definition of a globally optimal solution, it is not necessary to define the structure of the search space, a metric, or a neighborhood.

Given a problem instance (X, f) and a neighborhood function N, a feasible solution of $x' \in X$ is called locally optimal (minimization problem) with respect to N if $f(x') \leq f(x)$ for all $x \in N(x')$. Therefore, locally optimal solutions do not exist if no neighborhood is defined. Furthermore, the existence of local optima is determined by the neighborhood definition used as different neighborhoods can result in different locally optimal solutions.

The modality of a problem describes the number of local optima in the problem. Unimodal problems have only one local optimum (which is also the global optimum) whereas multi-modal problems have multiple local optima. In general, multi-modal problems are more difficult for guided search methods to solve than unimodal problems.

B. *Objective*

The Objective of the thesis is minimization of power loss and performance of generator cost in the analysis of an optimal power flow problem. To provide better economic dispatch, greater convergence in GA.

In existing system many algorithms and optimization techniques are used to test the IEEE bus systems for converging the optimal results. Particle swarm optimization is chosen to solve the reactive power dispatch problem and results are taken for the effectiveness of the particle swarm algorithm in considering the IEEE 30 Bus system.

In proposed system, simple genetic algorithm is used to show the standard optimum values with better effectiveness in results. Optimization of fitness function in genetic algorithm is analyzed and performance of cost efficiency, losses in the real and reactive power are characterized. The analysis and performance of the economic dispatch using genetic algorithm are considered in the IEEE 30 bus system data.

III. GENETIC ALGORITHM

Genetic algorithms are an approach to optimization and learning based loosely on principles of biological evolution, these are simple to construct, and its implementation does not require a large amount of storage, making them a sufficient choice for an optimization problems. Optimal scheduling is a nonlinear problem that cannot be solved easily yet, a GA could serve to find a decent solution in a limited amount of time Genetic algorithms are inspired by the Darwin's theory about the evolution "survival of fittest", it search the solution space of a function through the use of simulated evolution (survival of the fittest) strategy. Generally the fittest individuals of any population have greater chance to reproduce and survive, to the next generation thus it contribute to improving successive generations However inferior individuals can by chance survive and also reproduce, Genetic algorithms have been shown to solve linear and nonlinear problems by exploring all regions of the state space and exponentially exploiting promising areas through the application of mutation, crossover and selection operations to individuals in the population. The development of new software technology and the new software environments (e.g. MATLAB) provide the platform to solving difficult problems in real time. MATLAB has a wide collection of functions useful to the genetic algorithm practitioner and those wishing to experiment with the genetic algorithm for the first time.

It is an optimization technique influenced by the process of natural selection. It utilizes the operators of selection crossover and mutation. It combines survival of the fittest aiming string, structures with a structural information exchange. In every generation a new set of artificially developed strings is produced using elements of the fittest of the old; an occasional new element is experiment with for enhancement. A shorting population is built with random gene values and if involves through several generations in which selection, crossover and mutation are respected until a satisfactory solution is arrived at or a maximum number of iterations have reached. This algorithm selects the individuals with optimizing fitness values and discards those with lower fitness.

The goal of the genetic algorithm (GA) is to optimize the structure of power distribution network by multiple criteria in order to minimize unsupplied energy and to minimize losses caused by supply interruptions to users.

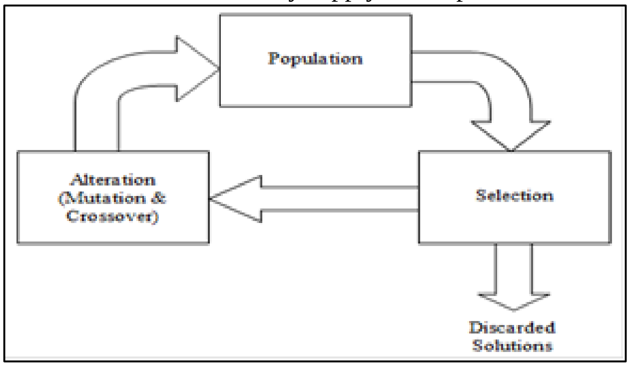

Fig. 2: Block diagram for GA.

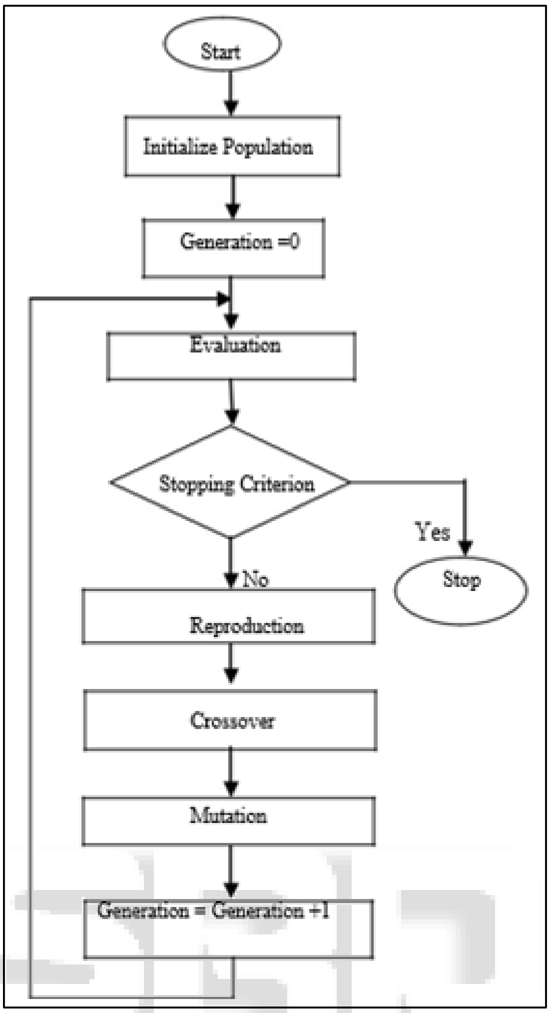

Fig. 3: Genetic Algorithm Flowchart.

The Genetic Algorithms are part of the evolutionary algorithms family, which are computational models, inspired in the Nature. Genetic algorithms are powerful stochastic search algorithms based on the mechanism of natural selection and natural genetics. GAs works with a population of binary string, searching many peaks in parallel. By employing genetic operators, they exchange information between the peaks, hence reducing the possibility of ending at a local optimum. GAs are more flexible than most search methods because they require only information concerning the quality of the solution produced by each parameter set (objective function values) and not lake many optimization methods which require derivative information, or worse yet, complete knowledge of the problem structure and parameters. There are some difference between GAs and traditional searching algorithms. They could be summarized as follows:

The algorithms work with a population of string, searching many peaks in parallel, as opposed to a single point.

GAs work directly with strings of characters representing the parameters set not the parameters themselves.

GAs use probabilistic transition rules instead of deterministic rules.

GAs use objective function information instead of derivatives or others auxiliary knowledge.

GAs have the potential to find solutions in many different areas of the search space simultaneously.

A. Objective Problem Formulation

The various kinds of objective function formulation are given below:-

1) Simplified Economic Cost Function:

Simplified economic dispatch problem can be represented as a quadratic fuel cost objective function.

2) Economic Cost Function:

The generating units with multiple control device in turbines are available. The opening and closing of these control device are helpful in maintaining the active power balance.

3) Economic Cost Function with Multiple Fuels:

The different type of fuels can be used in thermal generating unit, hence fuel cost objective function can be represented with piecewise quadratic function reflecting the effect of fuel type changes.

B. Implementation of GA in MATLAB

Genetic algorithms are search and optimization procedures that are motivated by the principle of natural genetics and natural selection. For higher precision, larger string length is required. The population size requirement is also large for large strings. Thereby the computational complexity of the algorithm increases. Since a fixed coding scheme is applied to code the decision variables. Variable bounds must be such that they bracket the optimum variable values. In many problems, this information is not usually known a priori then this may cause some difficulty in using binary-coded GAs in such problems.

The first thing must do in order to use a GA is to decide if it is possible to automatically build solutions on problem.GA requires an initial population P of solutions. Then must decide what "gene" representation will use we have a few alternatives like binary, integer, double, permutation, etc. The binary and double being the most commonly used since they are the most flexible. This algorithm selects the individuals with optimizing fitness values and discards those with lower fitness.

MATLAB provides an optimization toolbox that includes a GA-based solver. The toolbox can be start by typing optimtool in the MATLAB's command and pressing enter. As soon as the optimization window appears, we can select the solver ga – Genetic Algorithm and now MATLAB display the genetic algorithm toolbox.

Unlike in the binary-coded GAs, decision variables can be directly used to compute the fitness values. Since the selection operator works with the fitness value, any selection operator used with binary coded GAs can be used in real-parameter GAs.

C. Steps involved in GA

1) Run the GA with defined initial data set: population size, elite factor, maximum number of iterations, mutation factor, network models and the capital.
2) GA module records in database the network models of populations generated.
3) For the calculation of the population GA module runs the computer model with the following data: GA iteration - gen, structure number - ind and network model - simtype.
4) Computer model reads the network structure codenetcode, which corresponds to gen iteration and number ind.
5) Computer model reads existing modelling results with the code netcode and network simtype.
6) If the network with the code netcode and network model simtype has been already modelled and statistical number is greater than or equal to simmax, the network with the following code is not remodeled; otherwise the model is run to obtain the necessary statistical number of times.
7) Completes all of the same structure modelling times, computer model verifies if the number of tested individuals has been achieved. If it is not been achieved, then ind = ind + 1 and executes the Step 4.
8) GA completes the necessary operations and, if it has not reached the stop element, then repeats from Step 2, otherwise runs Step 9.
9) The last population with optimal calculation find is saved.

IV. ECONOMIC DISPATCH PROBLEM

Economic dispatch is defined as the process of calculating the power generation of the generating units in the system in such a way that the total system demand is supplied most economically. It has become a vital task in designing of power systems whose main objective is to schedule the committed generating units output to meet load demand at a greatly minimized cost. It aims to achieve this all the while meeting all unit and system requirements and constraints or limits.

Optimal reactive power dispatch (ORPD) is a nonlinear optimization problem and has both equality and inequality constraints. ORPD is defined as the minimization of active power loss by controlling a number of variables. Due to complex characteristics of ORPD, heuristic optimization has become an efficient solver.

A. Reactive Power Dispatch Problem

Reactive power improves voltage stability and avoids voltage collapse. By regulating the reactive power, voltage stability, system efficiency, energy cost, and power losses of a power system network can be controlled effectively. Over long distance power transmission, additional reactive power loss occurs due to the large reactive impedance. To avoid excessive reactive power transmission and consumption, it should be as close as possible to each other; if it is not compensated properly, then it will cause an inappropriate voltage profile.

The RPD problem has been formulated as,

1) Objective Function:

Real power loss minimization: The real power loss PL can be calculated as sum of real power loss occurring in various transmission lines of a power system and can be written as,

$F_1 = P_L = \sum_{K=1}^{NL} gk[V2i + V2j - 2ViVj \cos(di - dj)]$

where nl is the number of transmission lines, g_k is the conductance of the kth line, and $V_i\angle\delta_i$ and $V_j\angle\delta_j$ are the voltages at the terminal buses i and j of the kth line, respectively.

a) Real Power:

$$Minimize\, F(P_{gi}) = \sum_{i=1}^{NG} \left(a_i P_{gi}^2 + b_i P_{gi} + c_i\right)$$

Subject to:

1) Energy balance equation,

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

2) Inequality constraints.

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \quad (i = 1, 2, \dots\dots\dots, NG)$$

where a_i, b_i, c_i are the fuel cost coefficients.
P_D is the load demand.
P_{gi} is the real power generation.
NG is the number of generators
P_L is the transmission power loss.

b) Reactive Power:

$$Minimize\ F(Q_{gi}) = \sum_{i=1}^{NG} (a_{qi} Q_{gi}^2 + b_{qi} Q_{gi} + c_{qi})$$

where a_{qi}, b_{qi}, c_{qi} are reactive power cost coefficients
Q_{gi} is the real power generation
NG is the number of generators
NB:

$$a_{qi} = a_i sin^2\theta$$
$$b_{qi} = b_i sin\theta$$
$$c_{qi} = c_i cos\theta = 0.9\ or\ 085\ lagging$$

c) Combined Real and Reactive Power Objective Function:

Total fuel cost function for real and reactive power gives more weight to the real power component. The objective function for combined real and reactive power now becomes;

$$Minimize\ F_{Total} = \sum_{i=1}^{NG} WF(F_{gi}) + (1 - W)F(Q_{gi})$$

where P_{gi}, Q_{gi} are the active/real and reactive generations of i^{th} generator
P_{Di}, Q_{Di} are the active/real and reactive power demands
P_L, Q_L are the active/real and reactive power transmission losses
NB is the number of buses
NG is the number of generators

We shall set W to be 70% (1_W) and thus, becomes 30%. Therefore, the combined objective function becomes,

$$Minimize\ F_{Total} = \sum_{i=1}^{NG} 0.7F(F_{gi}) + 0.3F(Q_{gi})$$

V. IEEE 30 BUS SYSTEM

The standard IEEE 30-Bus 6 Generator test system is considered to investigate effectiveness. The IEEE 30-bus system has 41 transmission lines. The total load demand of the system should be optimum and 6 -Generators should share load optimally. Performance Analysis of best accuracy and results in network bus of IEEE 30 using GA is implemented in this thesis.

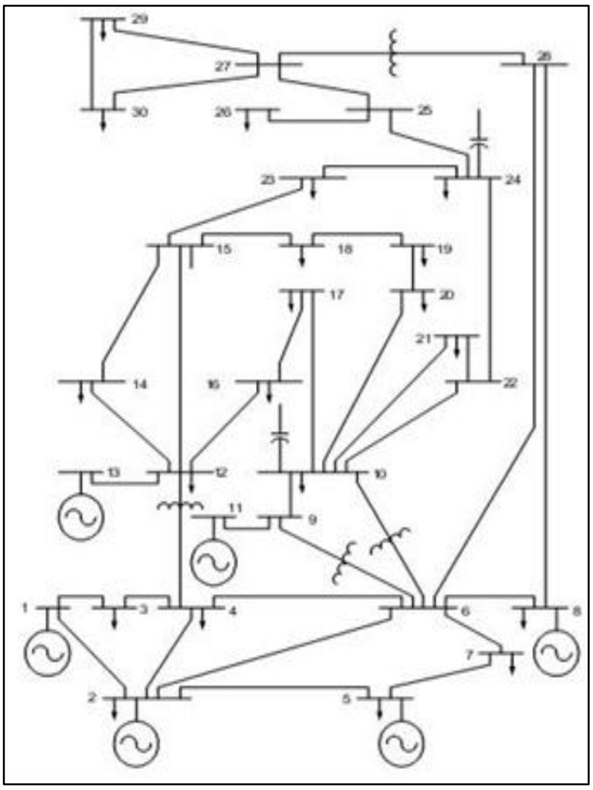

Fig. 4: Single line diagram for IEEE 30 bus system

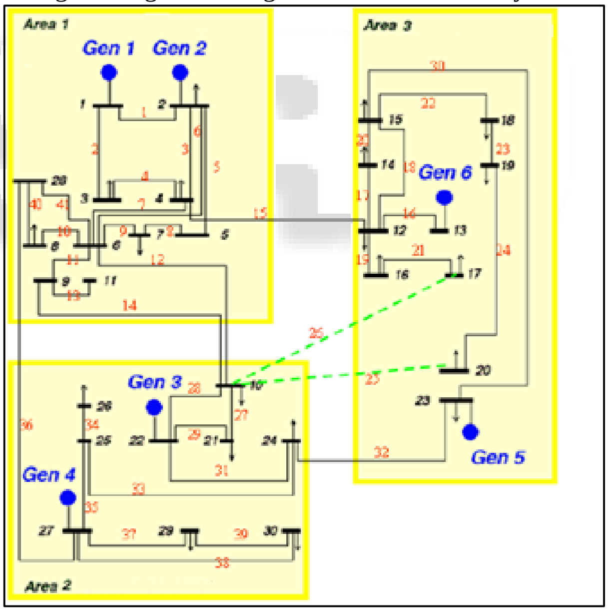

Fig. 5: IEEE 30 bus system Configuration.

Fig 5 shows the system configuration of a 30 bus system. It consists of 6 generators, 41 transmission lines.

Parameters	Details
Generators	6 buses {1,2,5,8,11,13}
Transmission Lines	41
Transformers	4 locations {6 -9, 6 -10, 4 -12 and 27 -28}
Shunt Compensators	9 locations {10,12,15,17,20,21,23,24,29}

Table 1: IEEE 30 Bus Test System Details

Table 1 shows the effective parameter items of IEEE 30 bus system details configuration.

VI. SIMULATION RESULTS

In fig 6, the plot is drawn between best cost fitness function values of genetic algorithm and their iteration of population. Fig 7 and 8 shows during iteration the real and reactive power loss obtained in the IEEE system data which is considered. With Increase in iteration of buses the losses occurred in the system is plotted.

Maximum power loss and minimum power loss of both real and reactive power of the system data is obtained. After the iteration, the minimization of losses is created in the system with the help of genetic algorithm approach.

These are the simulation plot results on considering IEEE 30 bus data system using the genetic algorithm approach.

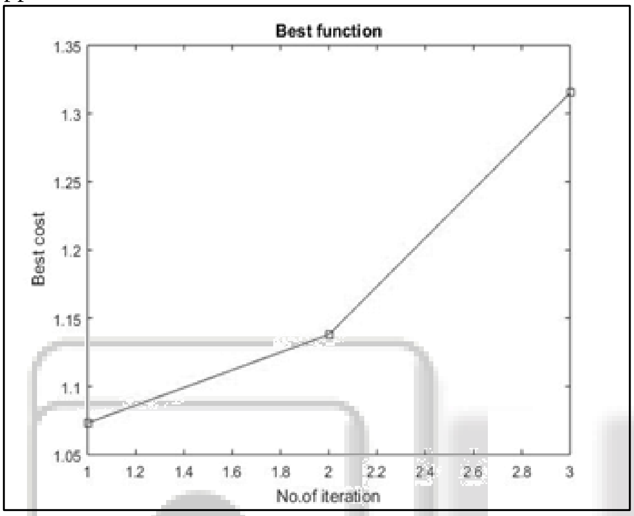

Fig. 6: Best cost fitness Plot of GA.

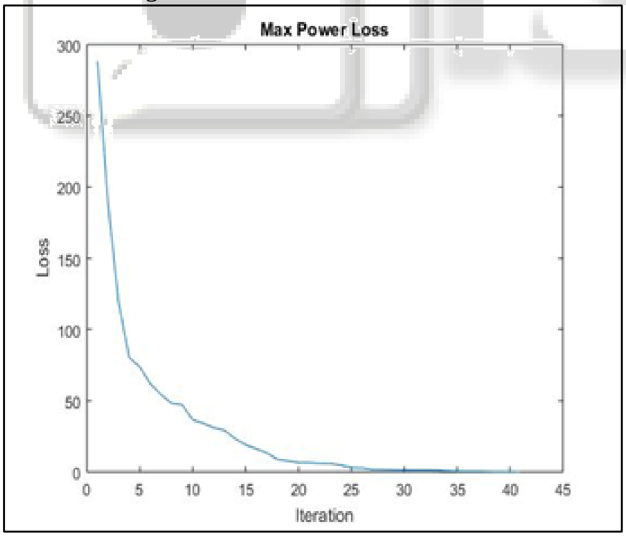

Fig. 7: Maximum power loss Plot

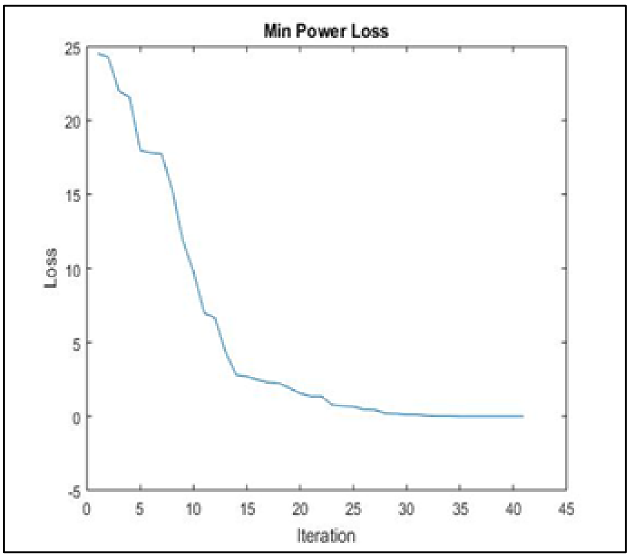

Fig. 8: Minimum power loss Plot

Attributes	PSO	HMPSO	GA
Power loss	0.164	0.9	0.0
Number of Population	30	30	30
Best Fitness Iteration	100	100	100
Average of time for convergence in sec	35	32	25

Table 2: Comparison Results

In the above table 2, particle swarm optimization (PSO), hybrid particle swarm optimization (HPSO), genetic algorithm (GA) are compared for power loss, iteration, best fitness and the time to take for convergence.

In GA, the fitness and power losses are optimized with less no of iterations and also with less no. of time.

VII. CONCLUSION

A novel method for the solution of Optimal Power Dispatch is proposed in this chapter. Genetic algorithm based approach has been presented and implemented to solve multi-objective RPD problem with real power loss minimization and cost functions as competing objectives to provide better accuracy in results. The thesis is implemented in IEEE 30 bus system for consideration of the optimal power values and the performance is analyzed using Genetic Algorithm. The analysis is carried out to obtain performance for minimum fuel cost and minimum power loss.

GA is used for many applications by providing optimal results. The thesis future work can be extended to multi dataset of IEEE bus system, more advanced algorithm can also be used to compare the results of accuracy.

REFERENCES

[1] Abou, El Ela, Abido, M.A., Spea, S.R., 2011,"Differential evolution algorithm for optimal reactive power dispatch", Electr. Power Syst. Res., 81, pp. 458–464
[2] Varadarajan, M., Swarup, K.S., 2008,"Differential evolutionary algorithm for optimal reactive power dispatch", Electr. Power Energy Syst., 30, pp. 435–441
[3] Badar Altaf, Q.H., Umre, B.S., Junghare, A.S, 2012, "Reactive power control using dynamic particle swarm

optimization for real power loss minimization", Int. J. Electr. Power Energy Syst, 41, pp. 133–136
[4] Singh, H., Srivastava, 2014, "Modified differential evolution algorithm for multi-objective VAR management", L.Int. J.Electr. Power Energy Syst., 55, pp. 731–740
[5] Ruiyang Yu, Bryan Man Hay Pong, Bingo Wing- Kuen Ling and James Lam, 2012, "Two-Stage Optimization Method for Efficient Power Converter Design Including Light Load Operation", IEEE Transactions on Power Electronics, vol. 27, pp. 1327-1337.
[6] Ruiyang Yu, Godwin Kwun Yuan Ho and Bryan Man Hay Pong, 2012, "Optimization methodology for efficient LLC resonant converter with power factor correction circuit", in 6th IET International Conference on Power Electronics, Machines and Drives (PEMD), pp. 1-6
[7] T. Goel and N. Stander, May 3, 2010, "A study on the convergence of multiobjective evolutionary algorithms," Conference on Multidisciplinary Analysis Optimization, pp. 1-18
[8] C. Blum and A. Roli, 2003, "Metaheuristics in combinatorial optimization: Overview and conceptual comparison," ACM Computing Surveys, vol. 35, pp. 268-308
[9] Boussaïd, J. Lepagnot and P. Siarry, 2013, "A survey on optimization metaheuristics," Information Sciences, vol. 237, pp. 82-117
[10] Edwin K.P. Chong and S. H. Zak, 2001, "Genetic Algorithms in an Introduction to Optimization", Wiley, Ed., 2nd.ed United States: WILEY-INTERSCIENCE, pp. 237-255.