

## An Intelligent Approach for Cost Minimization of Power Generation

<sup>1</sup>Ahmed M.A. Haidar, <sup>2</sup>Ibrahim A. Ahmed and <sup>1</sup>Norazila Jaalam

<sup>1</sup>Faculty of Electrical and Electronics Engineering,  
University of Malaysia, Pahang, Malaysia

<sup>2</sup>Hodeidah University, Yemen, Saidi Arabia

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**Abstract:** Cost reduction is one of the main targets in power industry due to economic load dispatch problem and allocating loads to plants for minimum cost. The principal objective in economic dispatch of thermal generators in a power system is to determine the economic loadings of the generators so that the load demand can be met and the loadings are within the feasible operating regions of the generators. This study presents an optimization approach for fuel cost and power loss minimization based on genetic algorithm and particle swarm optimization methods. To demonstrate the global optimization power of the presented techniques, these methods are applied to the IEEE 30 bus test system with highly non-linear generator input/output cost curves and the results compared to those obtained using OPF method based on mathematical programming approaches. The results demonstrate that PSO and GA method show great promise for minimum cost when it contains highly non-linear devices.

**Key words:** Minimum cost, IEEE 30 bus test system, PSO method, GA method, OPF method, economic operation

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### INTRODUCTION

Economic operation is very important for a power system to return a profit on the capital invested. Rates fixed by regulatory bodies and the importance of conservation of fuel, place pressure on the power companies to achieve maximum possible efficiency. Maximum efficiency minimizes the cost of a kWh to the consumer and the cost to the company of delivering that kWh in the face of constantly rising prices for fuel, labour, supplies and maintenance. An intelligent energy management system based on the generation forecasting and the power flow optimization can be used to significantly reduce the operating cost (Chakraborty and Simoes, 2008). Economics operation involving power generation and delivery can be subdivided into two parts dealing with minimum cost of power production called economic dispatch which is focusing upon coordinating the production costs at all power plants operating on the system. While minimum cost of power transportation is dealing with minimum loss delivery of the generated power to the loads. Minimum cost problem of power production and delivery depending on how control of the power flow in the system is exercised. This problem can be solved using Optimal Power Flow method (OPF)

(Gao and Sheble, 2005). The conventional method of OPF is based on mathematical programming approaches to optimize the power flow solution by minimizing selected objective functions while maintaining an acceptable system performance in terms of generator capability limits and the output of the compensating devices. The objective functions also known as cost function, may present economic costs, system security or other objective (Kumari *et al.*, 2007), OPF is a nonlinear, nonconvex, large-scale, static optimization problem with both continuous and discrete control variables. OPF solution based on Mathematical Programming Approaches (MPA) are not guaranteed to converge to the global optimum of the general nonconvex OPF problem, although there exists some empirical evidence on the uniqueness of the OPF solution within the domain of interest (Kumari *et al.*, 2007). The conventional OPF solution does not take consideration of spinning reserves and ramp rates on the generating units. Many researchers solved the OPF problem with non-smooth fuel functions. Recent attempts to overcome the limitations of mathematical programming approaches include the application of simulated annealing methods and Genetic Algorithms (Gnanadass *et al.*, 2005) these approaches overcome the limitations of the conventional approaches

in the modeling of non-convex cost functions, discrete control variables and prohibited operating zones. Mostly, these techniques are suitable for off line application, i.e., the OPF algorithm is run in discrete instants of time for given sets of loading conditions. Then the system control variables are adjusted to match those obtained by OPF. Al-Awami and El-Sharkawi (2009), proposes the use of feedback control concepts for real time OPF. Feedback control based OPF is based on the gradient method. In order to solve the OPF problem using the gradient method, an initial solution is first selected. Then, the gradients of the Lagrangian are evaluated at that solution. A new optimization technique called Particle Swarm Optimization (PSO) is also used to solve OPF (Abido, 2002). PSO has a flexible and well-balanced mechanism to enhance and adapt the global and local exploration abilities. The GA and PSO become particularly suitable for the problem posed here.

In this study PSO and GA based fuel optimization technique is presented for allocating loads to plants for minimum cost while meeting the network constraints. For a given system network where in all branches between nodes are known and therefore evaluation of the objective function depends only on the size and location of power plant. Newton Raphson method has been used for computing power flow and economic dispatch on IEEE 30 bus, respectively. The best solutions obtained by PSO are quite encouraging and useful in optimal power flow environment.

## MATERIALS AND METHODS

**Basic approach (MPA) for economic dispatch:** The OPF problem is to optimize the steady state performance of the power system in terms of the objective function while satisfying several equality and inequality constraints. In general, OPF is formulated as a constrained optimization problem. The goal function that is to be minimized is highly nonlinear, discontinuous and of high dimensions. It is formulated as an optimization problem of minimizing the total fuel cost of all committed plant while meeting the network (power flow) constraints. The variants of the problems are numerous which model the objective and the constraints in different ways. The basic OPF problem can be described mathematically as a minimization problem for the total fuel cost of all committed plants subject to the constraints (Saadat, 2004; Kumar *et al.*, 2008) and given by:

$$\text{Minimize } \sum_{i=1}^n F_i(P_i) \quad (1)$$

$F(P_i)$  is the fuel cost equation of the  $i$ th plant. It is the variation of fuel cost \$ with generated power (MW). Normally it is expressed as continuous quadratic function of real power generation:

$$F_i(P) = a_i P_i^2 + b_i P_i + c_i, P_i^{\min} \leq P_i \leq P_i^{\max} \quad (2)$$

$a$ ,  $b$  and  $c$  are the cost coefficient of the  $i$ th. The total generation should meet the total demand and transmission loss. The transmission loss can be determined from power flow by Saadat (2004):

$$\sum_{i=1}^n P_i = P_d + P_l \quad (3)$$

$$P_i = \text{real} \left( \sum_j^n V_i Y_{ij} V_j \right) \quad i=1, 2, \dots, n \quad (4)$$

$$Q_i = \text{imag} \left( \sum_j^n V_i Y_{ij} V_j \right) \quad i=1, 2, \dots, n \quad (5)$$

**Particle swarm optimization:** Particle swarm optimization introduced is a population based evolutionary algorithm. In PSO, candidate solutions, called particles are associated with a velocity and a position. The particle velocity is constantly adjusted according to the experience of the particles and its companions. In a D-dimensional space the velocity and position of particle are adjusted as:

$$v_{id} = w_i * v_{id} + c1 * \text{rand}(\ ) * (p_{id} - x_{id}) + c2 * \text{Rand}(\ ) * (p_{gd} - x_{id}) \quad (6)$$

$$x_{id} = x_{id} + v_{id} \quad (7)$$

Where  $C1$  and  $C2$  are the positive constants known as constriction factors and  $\text{rand}(\ )$  and  $\text{Rand}(\ )$  are two random functions in the range of  $[0, 1]$ .  $P_{id}$  represents  $p$  best position of particle  $i$ , i.e., the best position of the particle in the current iteration and  $p_{gd}$  denotes the  $g$  best position of the particle  $i$ , i.e., the best position of the particle up to the present iteration.  $W_i$  is weight function for velocity of particle  $i$  (Eberhart and Kennedy, 1995; Eberhart and Shi, 2000).

**Genetic algorithm:** The genetic algorithm initiates the mechanism of the natural selection and evolution and

aims to solve an optimization problem with object function  $f(x)$  where  $x = [x_1, x_2, \dots, x_N]$  is the N-dimensional vector of optimization parameters. It has proved to be an effective and powerful global optimization algorithm for many combinatorial optimization problems, especially for those problems with discrete optimization parameters, nondifferentiable and/or discontinuous objective function (Hooshmand and Ataei, 2007).

Genes and chromosomes are the basic building blocks of the GA. The conventional standard GA (SGA) encodes the optimization parameters into binary code string. A gene in SGA is a binary code. A chromosome is a concatenation of genes that takes the form (Goldberg, 1989):

$$\text{Chromosome} = [g_1^1 g_2^1 \dots g_{L1}^1 g_1^2 g_2^2 \dots g_{L2}^2 \dots g_1^N g_2^N \dots g_{LN}^N] \quad (8)$$

$$= [x_1 x_2 \dots x_N]$$

$g_j^i$  is a gene and is the length of the code string of the optimization parameter and given as:

$$x_k = [g_1^k g_2^k \dots g_{Lk}^k] \quad (9)$$

**PSO and GA implementation:** In this research, PSO and GA are used to search points which are very close to the probable solutions. The input information are the collection of the bus data, line data and cost coefficient and there limits. Penalty function is used to transform a constrained optimization problem in to an unconstrained optimization problem.

Traditional calculus-based penalty methods gradually increase the penalty to obtain the optimal feasible value (Goldberg, 1989). The objective function given in (Goldberg, 1989) will minimize the total system costs and does not necessarily minimize the costs for a particular area within the power system (Osman *et al.*, 2004). The PSO being a very good search

method is used in estimating a close-in search point. Closeness of a point is measured by the overall mismatch value which is defined by Abido (2002). As for GA, the SGA parameters such as population size, the maximum number of generations, Uniform Crossover Probability, Mutation Probability and Elitism index are selected and can be readjusted and in order to get optimal fitness value. The algorithm is stopped when all chromosomes assume similar fitness values:

$$f(x) = C_t = \sum_1^{N_g} a_i + b_i P_{Gi} + c_i P_{Gi}^2 \quad (10)$$

$C_t$  is the total generation cost,  $P_{Gi}$  the real power generation of unit  $i$ th,  $N_g$  the total number of generation units and  $i = 1, 2, \dots, N_g$ .

## RESULTS AND DISCUSSION

The results have been determined for IEEE 30 bus test system. This network contains 6 generators, 21 loads and 41 branches (line plus transformers). The fuel cost variation, variation of total system real power loss, nodal prices real and reactive both have been obtained using OPF, PSO and GA. It is observed from Table 1 that different fuel cost pattern is obtained while using different optimization techniques. Comparing the fuel costs, minimum fuel cost is obtained by using PSO as an optimization method.

Thus, PSO has been proven as a good technique for fuel cost minimization. Referring to Table 1 the loss profile shows that the minimum real power loss is achieved by using PSO.

Comparing results for total fuel cost and total active system loss; it is observed that fuel cost and active system loss reduce when PSO used as an optimization method, it is important to locate loads to plants considering a minimum cost of power generation and lose reduction.

Table 1: Cost reduction using various minimization techniques applied on the IEEE 30 bus

Optimization technique system parameters	MPA, MW	PSO, MW	GA, MW
Generator 1	182.3159	176.7318	177.5356
Generator 2	33.0402	48.8280	48.5121
Generator 5	16.0919	21.4740	21.0620
Generator 8	32.4658	21.6500	21.2660
Generator 11	10.2095	12.0922	12.8809
Generator 13	18.7139	12.0000	11.5733
Total generation cost (total fuel cost) \$/h	810.8726	801.8436	801.8627
Maximum Voltage, p.u	1.0820 (bus 11)	1.0820 (bus 11)	1.0820 (bus 11)
Minimum Voltage, p.u	0.9956 (bus 30)	0.9957 (bus 30)	0.9957 (bus 30)
Total Active system loss, MW	9.4372	9.3760	9.4299

## CONCLUSION

This study explains the conventional OPF solution and compares several existing methods which can solve the Economic Dispatch problem. To demonstrate the validity of these methods, computer analysis with Matlab program are carried out on 30 bus test system and the results show that the performance of the two techniques PSO and GA is better than conventional approaches. Results showed that PSO is well suited for obtaining the best solution for real time power systems. With optimally located loads to plants, the consumers will get benefit paying lower cost of energy and there will be overall improvement in terms of technical and economical benefits in the energy market operation.

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