A NEW APPROACH TO THE SOLUTION OF ECONOMIC DISPATCH USING GENETIC ALGORITHM

A.Q. Al-Shetwi[1*], M.I. Alomoush[2]

[1]Faculty of Electrical and Electronics Engineering, University Malaysia Pahang, Gambang, Pahang, 26300, Malaysia.
[2]Department of Electrical Power Engineering, Yarmouk University, Irbid, 21110, Jordan

ABSTRACT

Economic dispatch is the process of finding the optimal generation scheduling of a number of electricity generation facilities to meet the load of the system at lowest possible cost, subject to transmission and operational constraints of the system. The main idea of this paper focuses on the application of genetic algorithm in order to identify the best solution to an economic dispatch problem by using a new approach depending on B_{mn} coefficients and arithmetic crossover of the genetic algorithm. In this study, the proposed method solves the economic dispatch problem of three generator units whilst taking into consideration the coefficient losses to find the most important factors in electrical generation, which are output power and total cost. The results of this study are compared with the classical optimization calculation techniques, and it is found that the results were almost equal. The MATLAB simulation is run to demonstrate clearly the effectiveness of the new genetic algorithm approach as a very important method in the solution of economic dispatch problems.

KEYWORDS: *Economic Dispatch; Genetic Algorithm; power transmission losses; optimization*

1.0 INTRODUCTION

Nowadays, one of the important optimization problems in power system management is the economic dispatch problem. The main purpose of Economic Dispatch (ED) is to find the optimum generation from among the system units. For instance, the total generation cost is lessened while at the same time satisfying the power balance equations and various other constraints in the system to gives the customer sufficient and secures electricity.

Several techniques have been introduced to solve the optimization of ED. Meanwhile, as the complexity of dispatch problems increases, the conventional techniques become more complicated. The literature on the solution methods for the economic dispatch problem have been reviewed in Happ (1977) and in Chowdhury and Ramadan (1990); Mohammadi-Ivatloo, Moradi, and Rabiee, (2013).

*Corresponding Email: alialshetwi@yahoo.com

Genetic algorithms (GA) were developed by John Holland in the 1960s; they are optimization algorithms based on the mechanics of natural selection and natural GA (Holland, 2000). They are very good tools for solving ED, and another power system optimization is presented in Walters and Sheble, (1993) which presents an example with three generation units and uses a simple GA solution for the ED. This method was improved in Chiang, (2005) for multiple fuels.

Some studies have improved the solution of ED optimization by using a hybrid technique with GA, as proposed in Kherfane, Younes and Khodja, (2014), which solved the economic power dispatch problem using a new method combined in two meta-heuristic methods, the micro-genetic algorithm and the genetic algorithm. In addition, Song and Chou (1999) have proposed a hybrid genetic algorithm that is a combination strategy involving local search algorithms and a genetic algorithm. In most of the above papers, binary representation was utilized in solving the economic dispatch problems.

In this paper, the solution of the economic dispatch problem using a new approach that depends on B_{mn} coefficients by equal incremental cost using a genetic algorithm is proposed. The proposed approach has been applied to find the optimal dispatch of the generation and total generating cost of a three-unit system considering system losses.

2.0 METHODOLOGY

2.1 The Genetic Algorithm

GA is defined as a search algorithm or resolution algorithm essentially based on the mechanics of natural selection and natural genetics, thereby giving a more realistic simulation of a real power system. The basic theory of this algorithm is very simple, in which a series of binary strings (chromosomes or genes) is generated in a random way, while some of these chromosomes or genes are taken to represent variables. These binary strings are used as parameters in a system (real or simulated) and the relative success of that system is compared to a desired goal. The above step is re-iterated using each of the binary chromosomes and is sorted to determine the two best ones. From this point, an optimization cycle begins. The two most suitable chromosomes are taken from the previous run and the rest are erased (killed). These two chromosomes are divided at random points and recombined to create a new generation of chromosomes. A small percentage of genes are randomized (changed) to ensure that new solutions can arise. This new generation is then run through the system to evaluate the suitability of each one (Ouiddir, Rahli & Abdelhakem, 2005; Walters & Sheble, 1993; Yaşar & Özyön, 2012).

Although in most studies binary representation is applied to power optimization problems, in this study, a real-value representation scheme is used for solving the ED problem by using crossover GA and taking into account the B_{mn} coefficient where the use of real-value representation in the GA offers a number of benefits in numerical function optimization over binary encoding. The k-th chromosome C_k, for the real-value representation can be defined as in Equation (1):

$$C_k = \left[P_{k1}, P_{k2} ......P_{kn}\right] \text{ where } k = 1, 2, ..., \text{up to population size} \quad (1)$$

where P_{ki} is the generation power of the ith unit at kth chromosome. The reproduction will yield a new offspring from the mating of two selected parents. The operator responsible for the global search property of the GA is mainly the crossover operator. This study used an arithmetic crossover operator that defines a linear combination of two chromosomes, which takes two individuals and produces two new individuals, as shown in Figure 1.

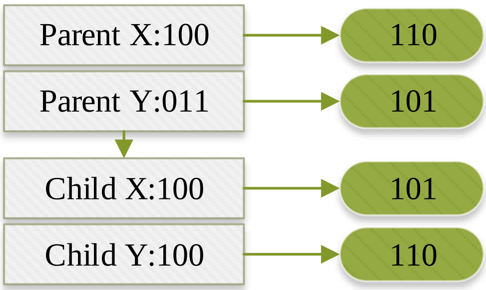


Figure 1. A diagram of a very simple crossover

The two chromosomes or children, C_x^{child} and C_y^{child}, of the crossover, which was selected randomly, may produce two offspring, $C_x^{child+1}$ and $C_y^{child+1}$, which are considered a mix of their parents, as shown in Equations (2) and (3), respectively.

$$C_x^{child+1} = aC_x^{child} + (1-a)C_y^{child} \quad (2)$$

$$C_y^{child+1} = (1-a)C_x^{child} + aC_y^{child} \quad (3)$$

where (a) is a random number in the range of 0 and 1, whereas child represents the new generation. For the purpose of injecting new genetic material into the population, the mutation operator should be utilized, which is applied to each new structure individually. In the case of the recombining of existing chromosomes or a crossover search, they do not create any new genetic material in the population. The mutation operator is capable of solving this shortcoming (Yalcinoz,Altun, & Uzam, 2001). The fitness function, which is also called an evaluation function, assigns a fitness value to each individual within the population. This function is also used to measure the quality and relative fitness of an individual. The fitness function is defined as stated in Equation (4).

$$Fit(x) = g(f(x)) \quad (4)$$

where f (x) represents the objective function and g transforms the value of f(x) to a non-negative number. A typical GA cycle includes four main processes: fitness evolution, selection, recombination or crossover, and creation of a new population. Figure 2 shows the general flow chart used in this study.

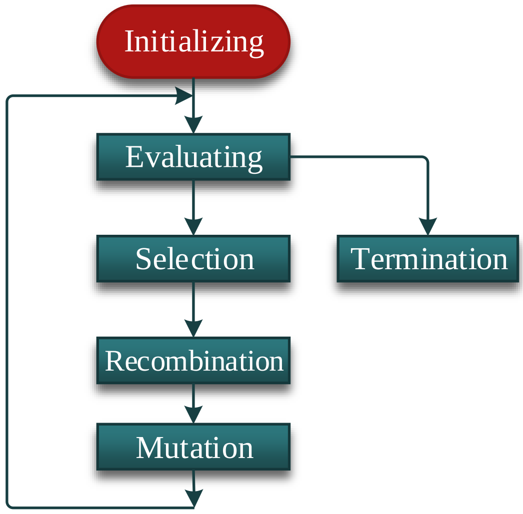


Figure 2. The general flow chart

2.2 Economic Dispatch Problem

One of the biggest challenges for all power utilities is not only to meet the consumer demand for power, but also to work at minimal cost. A reliable power system consists of many generating units, each of which has its own characteristic operating parameters.

The operational cost of these generators is not always proportional with their outputs, so the challenge for power plants is to try to balance the total load between generators that are working efficiently as much as possible. Therefore, the objective of ED is to minimize the overall cost of the power system generation. The ED problem minimizes the cost rate and at the same time meets the load demand of the power system, which is comprised of *n* generating units that are already linked to the system. The load of each unit is in the range of 3 to 5 minutes (Yalcinoz et al., 2001; Balakrishnan, Kannan, Arvandian & Subathra 2003). The ED problem can be written in mathematical form (Saadat, 1999; Wood & Wollenberg, 1984) as expressed in Equation (5):

$$\text{Minimize} \sum_{i=1}^{ng} C_i\left(P_{Gi}\right) \tag{5}$$

Subject to the following set of constraints:
Power balance constraint, which can be expressed as in Equation (6):

$$P_D + P_L - \sum_{i=1}^{ng} P_{Gi} = 0 \tag{6}$$

Inequality constraints of each generating unit's active power output ranging between its lower and upper limits to ensure stable operation, as given in Equation (7):

$$P_{Gi}^{\min} \leq P_{Gi} \leq P_{Gi}^{\max} \tag{7}$$

where n =Total number of online thermal units in a power system.
P_{Gi}=Power produced (output power) by generator i.
P_D =Total system demand (load).
P_L=Total system loss.
$P_{Gi}^{\min}$, $P_{Gi}^{\max}$ represent the minimum and the maximum limits of generator i, respectively.
$C_i(P_{Gi})$ is the operating cost or production cost of generator I; consequently, the quadratic cost function of unit i can be given by Equation (8):

$$C_i\left(P_{Gi}\right) = \alpha_i + \beta_i P_{Gi} + \gamma_i P_{Gi}^2 \tag{8}$$

where α_i, β_i, γ_i are respectively constant, linear and quadratic cost coefficients of unit i.

Using the B-coefficient method, the total system loss is expressed as in Equation (9):

$$P_L = \left[P_{Gi}\right]^T \left[B\right]\left[P_{Gi}\right] + \left[B_{io}\right]\left[P_{Gi}\right] + B_{oo} \tag{9}$$

The loss formula can be expressed in Kino's loss formula as in Equation (10):

$$\sum_{i=1}^{NG}\sum_{j=1}^{NG} P_{Gi} B_{ij} P_{Gj} + \sum_{i=1}^{NG} B_{io} P_{Gi} + B_{OO} \tag{10}$$

where B_{ij}, B_{io}, B_{oo} are the loss coefficient depending on system topology and online parameters.

3.0 SOLUTION TO PROBLEMS VIA GENETIC ALGORITHM (GA)

The way to use a genetic algorithm mainly depends on the problem mapping, which includes the conversion of the problem solution to a chromosome representation and the design of the fitness function as an estimation of the quality of a solution. Every chromosome inside the population is considered as a candidate solution. Each single chromosome should represent a generation scheduling with a view to solving the ED problem by using a GA process.

The main decision variable in an economic dispatch problem is the output of the power unit, while the loading range for every single unit is represented by a real number. The representation takes care of the unit maximum and minimum limits of the load, since the real representation is made to cover only the values between the limits. The following three steps describe the GA method used to solve the economic dispatch problem:

STEP 1: Selecting the reference unit or plant. For better convergence, a reference plant should be chosen which has maximum range and capacity. In this study, plant number one was selected as the reference. The reference plant distribution is fixed by Equations (6) and (10).

STEP 2: Converting the constrained optimization problem to an unconstrained problem by the penalty function method, as described in Equation (11).

Minimize:

$$\sum_{i=1}^{n} C_i(P_{Gi}) + 10^3 \times abs\left[\sum_{i=1}^{n} P_{Gi} - P_D - \sum_{i=1}^{n}\sum_{j=1}^{n} B_{ij} P_i P_j\right] \tag{11}$$

STEP 3: Programing the code according to the above information; by running the program the minimum fuel cost and transmission losses can be determined.

4.0 RESULTS AND DISCUSSION

The proposed method has been applied for a system consisting of three generating units in a power system. The example is taken from Haadi Sadat's book, Power System Analysis (Saadat, 1999). This approach solves the economic dispatch with B_{mn} coefficients by using the Genetic Algorithm toolbox in MATLAB, as illustrated in Figure 2. By running the programs, the allocation of minimum fuel cost and transmission losses has been determined. The system has three units, and details of this test system are given as follows:

$$C_1(P_{G1}) = 200 + 7.0P_{G1} + 0.008P_{G1}^2 \quad \$/h$$
$$C_2(P_{G2}) = 180 + 6.3P_{G2} + 0.009P_{G2}^2 \quad \$/h$$
$$C_3(P_{G3}) = 140 + 6.8P_{G3} + 0.007P_{G3}^2 \quad \$/h$$

where P_{G1}, P_{G2} and P_{G3} are in MW. On the other side, the plant output is subject to the following limits:

$$10 \text{ MW} \le P_{G1} \le 85 \text{ MW}$$
$$10 \text{ MW} \le P_{G2} \le 80 \text{ MW}$$
$$10 \text{ MW} \le P_{G3} \le 70 \text{ MW}$$

With regards to the system load, P_D was 150MW, whereas, the estimated loss formula coefficients are given as in the matrix illustrated below:

$$B = \begin{bmatrix} 0.0218 & 0.0093 & 0.0028 \\ 0.0093 & 0.0228 & 0.0017 \\ 0.0028 & 0.0017 & 0.0179 \end{bmatrix}$$
$$B_o = \begin{bmatrix} 0.0003 & 0.0031 & 0.0015 \end{bmatrix}, B_{oo} = 0.00030523$$

Table 1 represents the result for the above example by using a normal solution (calculations).; in other words, the solution without using a genetic algorithm, according to Saadat (1999).

Table 1. The result without using a genetic algorithm

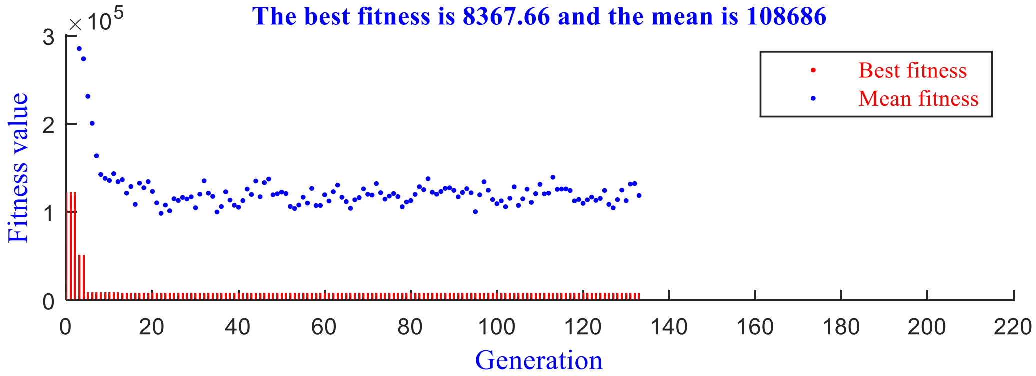
Power Output (MW)			Total Cost ($/h)
P_{G1}	P_{G2}	P_{G3}	
33.4701	64.0974	55.1011	1599.98

Table 2 illustrates the result for the same example by using the proposed new genetic algorithm approach.

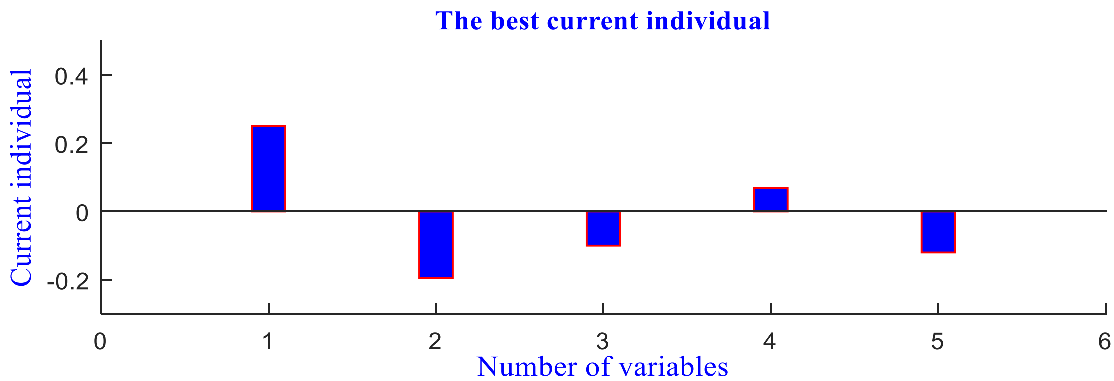
Table 2. The result when using a genetic algorithm

Power Output (MW)			Total Cost ($/h)
P_{G1}	P_{G2}	P_{G3}	
34.0089	64.0272	54.6342	1600

A comparison between the two tables indicates that the results are very close to each other. Therefore, the proposed approach is suitable for solving ED using a GA instead of the long-used traditional method (Mohammadi-Ivatloo et al., 2013; Saadat, 1999).



(a) Best and mean fitness



(b) Best current genes Individual

Figure 3. Using the GA approach to solve the ED problem

Figure 3 illustrates the generation way of the chromosomes. The mean fitness shows the average of fitness values across the entire population. Thus, in each generation, the population changes and produces average population fitness. the selected best fitness in this problem is five, so if the best offspring above five will not allow for parents to survive more than one generation as described in Section 2.0. After the specified maximum number of generations is reached, the best current individual is selected, as shown in the second part of Figure 3.

6.0 CONCLUSION

The economic dispatch problem is solved by using a new approach utilizing a genetic algorithm whilst considering system losses. The real-value representation scheme, arithmetic crossover, mutation and elitism are used in the GAto generate successive sets of possible operating policies, then select the best individual and fitness. In this paper, the proposed method has been applied to the ED problem with three generators to find output power and total cost. When the results from the presented approach were compared with the classical optimization technique and some new literature methods, it was found that the results were almost equal, and this indicates the efficiency of this new method. The MATLAB simulation results show clearly the effectiveness of the proposed approach as a solution to the economic dispatch problem.

ACKNOWLEDGEMENT

The authors are grateful to Universiti Malaysia Pahang for supporting this research project and Yarmouk University for the collaboration that make this research activity possible.

REFERENCES

Balakrishnan, S., Kannan, P., Aravindan, C. & Subathra, P. (2003). On-line emission and economic load dispatch using adaptive Hopfield neural network. *Applied Soft Computing,* 2(4)**:** 297-305.

Chiang, C.-L. (2005). Improved genetic algorithm for power economic dispatch of units with valve-point effects and multiple fuels. *IEEE Transactions on Power Systems,* 20(4)**:** 1690-1699.

Chowdhury, B. H. & Rahman, S. (1990). A review of recent advances in economic dispatch. *IEEE Transactions on Power Systems*, 5(4): 1248-1265

Happ, H. (1977). Optimal power dispatch- a comprehensive survey. *IEEE Transactions on Power Apparatus and Systems,* 96(3)**:** 841-854.

Holland, J. H. (2000). Building blocks, cohort genetic algorithms, and hyperplane-defined functions. *Evolutionary Computation,* 8(4)**:** 373-391.

Kherfane, R., Younes, M., Kherfane, N. & Khodja, F. (2014). Solving economic dispatch problem using hybrid ga-mga. *Energy Procedia,* 50**:** 937-944.

Mohammadi-Ivatloo, B., Moradi-Dalvand, M. & Rabiee, A. (2013). Combined heat and power economic dispatch problem solution using particle swarm optimization with time varying acceleration coefficients. *Electric Power Systems Research,* 95: 9-18.

Ouiddir, R., Rahli, M. & Abdelhakem-Koridak, L. (2005). Economic dispatch using genetic algorithm: Application to western Algeria's electrical power network. *Journal of Information Science and Engineering,* 21**:** 659-668.

Saadat, H. 1999. *Power system analysis*, Singapore: WCB/McGrawHill.

Song, Y., Chou, C. & Stonham, T. (1999). Combined heat and power economic dispatch by improved ant colony search algorithm. *Electric Power Systems Research,* 52 (2)**:** 115-121.

Walters, D. C. & Sheble, G. B. (1993). Genetic algorithm solution of economic dispatch with valve point loading. *IEEE Transactions on Power Systems,* 8(3)**:** 1325-1332.

Wood, A. J. & Wollenberg, B. F. (1984). Power generation, operation and control, New York, NY: John Wiley and Sons.

Yalcinoz, T., Altun, H. & Uzam, M. (2001). Economic dispatch solution using a genetic algorithm based on arithmetic crossover. *IEE Porto Power Tech Proceedings*, Portugal: 1-4.

Yaşar, C. & Özyön, S. (2012). Solution to scalarized environmental economic power dispatch problem by using genetic algorithm. *International Journal of Electrical Power & Energy Systems,* 38(1)**:** 54-62.