

AN APPLICATION OF ENVIRONMENTAL ECONOMIC DISPATCH USING GENETIC ALGORITHM

Özge Pınar ARSLAN
Kırıkkale University
Electrical and Electronics
Engineering
Kırıkkale, Turkey
pozge.arslan@gmail.com

Yağmur ARIKAN
Kırıkkale University
Electrical and Electronics
Engineering
Kırıkkale, Turkey
yagmurarikan@gmail.com

Ertuğrul ÇAM
Kırıkkale University
Electrical and
Electronics Engineering
Kırıkkale, Turkey
camertugrul@gmail.com

İbrahim EKE
Kırıkkale University
Electrical and
Electronics Engineering
Kırıkkale, Turkey
eke@kku.edu.tr

Abstract: In the economic load dispatch, power plants are operated at minimum cost, but environmental pollution caused by fossil-fueled electric power plants is not considered. Therefore, new solution suggestions have come up due to the growing environmental problems in recent years. One of these suggestions is environmental economic load dispatch which aims to both operations of plants at minimum cost and trying to minimize the amount of emissions. In this study, 6-generator system with three load demands 500, 700 and 900 MW is tested to solve environmental economic load dispatch problem. Genetic algorithm from heuristic optimization methods is preferred for this problem. The results which transmission losses are considered are compared with the other studies in the literature. These results show the effectiveness and superiority of the method over economy and reduction of the emission.

Keywords: Environmental Economic Dispatch, Genetic Algorithm, Optimization, Emission.

Introduction

Economic load dispatch is one of the important problems in operation of power systems. It minimizes the generation cost while meeting demand and satisfying equality and inequality constraints. However, operation at minimum cost cannot be the only basis for dispatching electric load when the pollution is considered. Thermal power plants cause high concentration of pollutants. Therefore, emissions caused by electric power plants that use fossil fuel must be considered while operating electric power systems. Environmental economic dispatch, (EED), is the problem which takes into consideration the environmental pollution and aims to reduce emissions with minimum cost. It minimizes both cost and emission together.

EED problem has two objectives consisting of minimum fuel cost and minimum emission. There are many methods that have been proposed to solve this problem in the literature. Song et al. have applied fuzzy logic controlled genetic algorithm to EED on a six-generator system (Song, 1997). Pandit et al. have proposed an improved differential evolution method for EED in multi-area power system by studying on three test cases (Pandit, 2015). Sivasubramani and Swarup have presented a new multi-objective harmony search algorithm for EED problem and tested on the standard IEEE 30 bus and 118 bus systems (Sivasubramani, 2011). Güvenç et al. have proposed Gravitational Search Algorithm to find the optimal solution for Combined Economic and Emission Dispatch problems and it has been implemented on four different test cases, having no valve point effect without transmission loss and valve point affect with transmission loss (Güvenç, 2012). Bhattacharya and Chattopadhyay have presented the combination of Biogeography-based Optimization algorithm and differential evolution to solve complex economic emission load dispatch problems (Bhattacharya, 2011).

Problem Formulation

EED problem can be formulated by adding emission to the economic dispatch problem. Economic dispatch, (ED), formula is shown in Equation 1.

$$F(P_g) = \sum_{i=1}^n (a_i P_i^2 + b_i P_i + c_i) \quad (1)$$

In Equation 1, a_i , b_i , c_i are the fuel cost coefficients of the i th unit, $F(P_g)$ is total generation cost in the system (\$/h), P_i is the power generated by i th unit and the n is the number of generating units.

Emissions can be expressed by a quadratic equation depending on the active power output of the generator. It can be formulated as Equation 2.

$$E(P_g) = \sum_{i=1}^n (d_i P_i^2 + e_i P_i + f_i) \quad (2)$$

In Equation 2, $E(P_g)$ is the emission amount (lb/h or kg/h), d_i , e_i , f_i are the emission parameters of the i th power plant.

While solving the problem, the following constraints must be satisfied.

Power Balance: The sum of the generated powers must be equal to sum of the total transmission loss and power demand.

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

In equation 3, P_D is the demanded power and P_L is the line loss. The line loss can be found by using B matrix and it can be expressed as (4).

$$P_L = \sum_{i=1}^n \sum_{j=1}^n P_i B_{ij} P_j \quad (4)$$

where B_{ij} is the loss coefficients.

Generator lower and upper constraint: The active power limitation of each unit is defined as follows.

$$P_{i(min)} \leq P_i \leq P_{i(max)} \quad i = 1, \dots, n_g \quad (5)$$

where $P_{i(min)}$ is the minimum power generated by i th unit and $P_{i(max)}$ is the maximum power generated by i th unit.

EED can be formulated by using generation cost and amount of emission and converting them into the single optimization problem as seen in Equation 6.

$$T = w_1 * F(P_g) + w_2 * h * E(P_g) \quad (6)$$

In Equation 6, T is the total operation cost of the system, w_1 and w_2 are weight factor and h is the price penalty factor.

The price penalty factor h has some steps (Kulkarni, 2000):

(i) Firstly, h_i is calculated:

$$h_i = \frac{FC_i(P_{i(max)})/(P_{i(max)})}{EC_i(P_{i(max)})/(P_{i(max)})}, \quad i = 1, \dots, n \dots \$/kg \quad (7)$$

(ii) Secondly, arrange the values of h_i in ascending order.

(iii) Thirdly, add the maximum capacity of each generator one at a time starting from the smallest h_i until $\sum_{i=1}^n P_{i(max)} \geq P_D$.

(iv) And finally, h_i calculated from last generator becomes the price penalty factor h .

When $w_1=1$ and $w_2=0$, the problem becomes ED; when $w_1=0$ and $w_2=1$, the problem becomes emission dispatch; when $w_1=1$ and $w_2=1$, the problem becomes EED.

Genetic Algorithm

A genetic algorithm (GA) is a method for optimization problems and it solves both constrained and unconstrained problems. It is based on a natural selection process. The algorithm repeatedly develops a population of individual solutions. This method randomly selects individuals from the current population and produce the children for the next generation. The population move to an optimal solution over successive generations.

The genetic algorithm uses three operators to generate the next generation from the current population. These operators are selection, crossover and mutation. The individuals named as parents are selected. Crossover combines two parents to form children for the next generation. Random changes are applied to individual parents to form children by mutation.

The Study

GA is applied on the test system and its performance is compared to other optimization methods.

In the system, there are 6 generating units which have cost and emission functions with demand of 500, 700 and 900 MW. The data of this system is derived from study of Rughooputh (Rughooputh, 2003).

The value of h is calculated as 43.8983 for 500 MW demand, 47.8222 for 700 MW demand, and 43.1533 for 900 MW demand.

EED problem is solved by using GA with the help of MATLAB program. The dispatch results for 500, 700, and 900 MW demands are shown separately, see [Table 1].

Table 1: Results of EED problem by GA

Unit (MW)	Demand (MW)		
	500	700	900
P1 (MW)	55.3071	93.4380	123.2889
P2 (MW)	40.1529	66.9674	116.2879
P3 (MW)	66.5698	82.2116	98.4371
P4 (MW)	80.2377	111.7986	134.9396
P5 (MW)	147.4310	204.2191	263.0380
P6 (MW)	132.9505	179.6866	228.3156
Total generation (MW)	522.6490	738.3213	964.3011
Losses (MW)	22.6491	38.3213	64.3011
Fuel cost (Rs/h)	28475	39008	51139
Emission output (kg/h)	277.4178	472.5402	764.2358

According to results of EED for the system that has 6 generating units by using genetic algorithm; fuel cost is 28475 Rs/h, emission output is 277.4178 kg/h, transmission loss is 22.6491 MW for 500 MW load; fuel cost is 39008 Rs/h, emission output is 472.5402, transmission loss is 38.3213 MW for 700 MW load; fuel cost is 51139 Rs/h, emission output is 764.2358, transmission loss is 64.3011 for 900 MW load.

The results of GA are compared with other methods. These methods are Newton-Raphson, (NR), (Song, 1997), Fuzzy Controlled Genetic Algorithm, (FCGA), (Song, 1997), Biogeography based Optimization, (BBO), (Roy, 2010), and Non-dominated Sorting Genetic Algorithm, (NSGA), (Roy, 2010). The comparison results are showed, see [Table 2]. It is explicitly seen from Table 2 that GA is the best method in terms of emission output.

Table 2: Results of EED problem by methods

Load (MW)	Method	Total Cost (Rs/h)	Amount of Emission (kg/h)
500	GA	28475	277.4178
	NR [1]	28550.15	312.513
	FCGA [1]	28231.06	304.90
	NSGA [8]	28291.119	284.362
	BBO [8]	28318.5060	279.3092
700	GA	39008	472.5402
	NR [1]	39070.74	528.447
	FCGA [1]	38408.82	527.46
	NSGA [8]	38671.813	484.931
	BBO [8]	38828.266	476.408

900	GA	51139	764.2358
	NR [1]	50807.24	864.060
	FCGA [1]	49674.28	850.29
	NSGA [8]	50126.059	784.696
	BBO [8]	50297.271	765.087

Conclusions

Power systems have some serious environmental problems. EED problem aims to decrease fuel cost and also emission. In this paper, GA has been successfully applied to EED problem. It is tested on six generator system. The results of GA is compared with the other studies in the literature. It has seen that GA provides improved results at cost and emission output.

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