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New Optimization Algorithms for Application to Environmental Economic Load Dispatch in Power Systems

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ABSTRACT

The determination of the most economical generation dispatch in an electrical power system has become a very important issue globally. However, economical dispatch can no longer be considered alone because of environmental problems that are derived from emissions such as nitrogen oxide, carbon dioxide, and sulfur dioxide. In this study, the problem of environmental economic load dispatch (EELD) in a power system of six generators is addressed both by neglecting and including line transmission losses using a modified genetic algorithm and a modified artificial bee colony optimization method. The results of these modified algorithms are compared with those of the unmodified versions. The results demonstrate that the proposed new methods have better economic and environmental distribution performances. Accordingly, it can be concluded that the new methods are more effective and should be adopted.

Keywords: Environmental economic dispatch, optimization, power systems, genetic algorithm, artificial bee colony.

Introduction

Energy is the infrastructure of industrialization and an indispensable factor of daily life and as such it has become increasingly important in a world of fast population growth and ever-developing technology. The need to generate secure, cheap, clean, and sufficient energy has become more and more important due to the progressive reduction of resources, external dependence and environmental impacts. Economic operation and planning of power generation systems are necessary to make the most efficient use of electrical energy. In this way, electricity demand will be met and power generation at minimum fuel cost and reduced environmental pollution will be provided. Economic load dispatch (ELD) is one of the most important problems that is necessary to be solved in the power system operation. The purpose of economic load dispatch is the sharing of power demand among generation units at minimum cost by considering physical limitation of system [1]. The economic dispatch model minimizes generation cost over time by meeting the generator operating conditions and fuel price [2]. In the days in which we live the whole world is exposed to environmental pollution, energy shortage and climate change [3]. The general use of fossil fuel resources for electrical energy generation causes environmental pollution. Fossil fuel power plants spread waste gases such as CO_2, SO, SO_2, NO_x into the air. The effects of an increase in environmental pollution will cause global warming which will have negative consequences on human health. Air pollutants mainly affect the area surrounding the source, and negatively affect health, materials, crops and visibility [4]. Therefore, it is important to generate power in a way which reduces damage to the environment, and environmental pollution must be considered at the same time as economic load dispatch [5]. Environmental economic load dispatch is an optimization problem that minimizes both fuel cost and quantity of emission. It aims at keeping the environment clean by reducing the amount of emissions generated by generator units. Units that generate minimum emissions are used more to do this. The required load is dispatched via various generator units using environmental economic load dispatch in order to provide minimum emission and keep fuel costs down [5].

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Many research groups have proposed a lot of methods to decrease emissions. Song et al. [6] used fuzzy logic controlled genetic algorithm to provide environmental economic dispatch on a six-generator system. Pandit et al. [7] proposed an improved differential evolution method for EELD in a multi-area power system by studying three test case systems. Sivasubramani and Swarup presented a new multi-objective harmony search algorithm for EELD problem and tested it on the standard IEEE 30 bus and 118 bus systems [8]. Güvenç et al. [9] proposed Gravitational Search Algorithm (GSA) to provide the optimal solution for Combined Economic and Emission Dispatch (CEED) problems and it was applied on four different test cases, taking into consideration no valve point effect without transmission loss and valve point affect with transmission loss. Bhattacharya and Chattopadhyay presented the combination of Biogeography-based Optimization (BBO) algorithm and differential evolution (DE) to solve complex EELD [10]. Abdelaziz et al. [11] implemented Flower Pollination Algorithm (FPA) to analyze ELD and Combined Economic Emission Dispatch problems. Chen et al. [12] used a nonlinear fractional programming approach in thermal systems to deal with the problem of EELD. Singh and Kumar used a new particle swarm optimization technique to create both economic and environmental emission dispatch at a thermal power system [13]. Gherbi et al. [14] used the firefly algorithm and bat algorithm to minimize the generation cost and the emission of NO_x for a 3-unit, 6-unit, and 14-unit system. Liu et al. [15] applied a novel CMOQPSO algorithm to solve multiobjective EELD problems. In this algorithm, they introduced cultural evolution mechanism into quantum-behaved particle swarm optimization.

In this study, two new algorithms were proposed and tried out with the aim of dealing with the problem of environmental economic load distribution in a 6-generator power system. Since many optimization algorithms will require some predetermined parameters to obtain good results, the proposed Genetic Algorithm and the Artificial Bee Colony optimization methods were introduced in the study. The parameters of the proposed Genetic Algorithm such as population size, number of elite individuals with the best fitness values in the current generation that are guaranteed to survive to the next generation, crossover rate, number of generations and the parameters of the proposed Artificial Bee Colony algorithm such as colony size, number of food sources, limit, maximum cycle, run time were adjusted by simulation experiments to get the optimum result. The problem was solved both by ignoring transmission line losses and by taking them into account. The results of the proposed methods were compared with the unmodified versions of Genetic Algorithm and Artificial Bee Colony Algortihm. The results show that the proposed methods have better performance than unmodified Genetic Algortihm and unmodified Artificial Bee Colony Algorithm.

This paper is arranged as follows: Section 2 explains the formulation of EELD problem; Section 3 introduces the methods. Our simulation and results are shown in Section 4, and Section 5 concludes the paper.

Problem Description

In this section, the environmental economic load dispatch problem, which plays a crucial role in power systems, will be defined. For this purpose, the fitness function used in this study will first be explained . Then, the constraints of the power system will be explained.

Fitness function

Environmental load dispatch problem can be calculated by adding the emission parameters to the ELD problem. Economic load dispatch formula is shown in equation (1).

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

where F is the total fuel cost (Rs/h), a_i, b_i, c_i are the fuel cost coefficients of generator i, P_i is the power generated by i-th unit, and n is the number of generators [16].

In the ELD problem, the amount of active power that different units generate to meet load demand is established. Emission and emission cost are excluded in pure ELD. The quantity of emission that thermal generator units based on fossil fuel cause depends on the quantity of power generated by these units. Emission can be formulated by a quadratic function depending on the active power output of the generator. It is shown in equation (2).

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

where E is the total amount of emission (lb/h or kg/h), d_i, e_i, f_i are the NO_x emission coefficients of generator i [16].

Fuel cost and amount of emission formulas are used to get the formula of EELD problem. This formula is shown in equation (3).

$$T = w_1 * F + w_2 * h * E \tag{3}$$

where T is the total cost, w_1 and w_2 are weight factors, h is the price penalty factor [16].

When w_1 is 1 and w_2 is 0, the problem becomes pure economic dispatch, when w_1 is 0 and w_2 is 1, the problem becomes pure environmental dispatch, when w_1 is 1 and w_2 is 1, the problem becomes environmental economic dispatch [16].

The calculation of the price penalty factor h is explained in the following steps. It is discussed by Kulkarni et al. [17].

i. The average cost of the each generator at maximum power output is found as shown in equation (4).

$$F_{i,ave} = F(P_{i,max})/(P_{i,max}) \; ... \$/MWh \quad (4)$$

where $F_{i,ave}$ is the average cost of i-th generator.

ii. The average emission of each generator at maximum power output is found as shown in Equation (5).

$$E_{i,ave} = E(P_{i,max})/(P_{i,max}) \; ... kg/MWh \quad (5)$$

where $E_{i,ave}$ is the average emission of i-th generator.

iii. Average cost of each generator is divided by its average emission and it equals to price penalty factor h that belongs to each generator as shown in equation (6).

$$h_i = (F(P_{i,max})/(P_{i,max}))/(E(P_{i,max})/(P_{i,max})) \; \$/kg \quad (6)$$

iv. The value of hi of each generator is sorted in ascending order.

v. Maximum power output of each generator is added one at a time starting from the smallest h_i unit until equation (7) is satisfied.

$$\sum_{i=1}^{n} P_{i,max} \geq P_D \quad (7)$$

where P_D is the power demand.

vi. The value of h associated with the last unit in the addition process is taken as price penalty factor for the given load.

The calculated h value is used in equation (3), the value of w_1 and w_2 weight factors are taken as 1 and environmental economic dispatch is formulated.

Constraints

In the environmental economic dispatch problem, there are some constraints that must be taken into consideration while solving the problem and they are listed below [16].

i. When transmission line losses are not included in the problem, equation (8) must be satisfied. The sum of the all generated powers must be equal to power demanded by the load.

$$\sum_{i=1}^{n} P_i = P_D \quad (8)$$

When transmission line losses are included in the problem, equation (9) must be satisfied. The sum of the all generated powers must be equal to power demand by the load and total line losses.

$$\sum_{i=1}^{n} P_i = P_D + P_L \quad (9)$$

where P_L is the transmission loss power [18].

ii. Power output of the generators must be above or below a certain limit value. Therefore, use of the generators is limited to the minimum and maximum powers. Thus inequality constraint is expressed as shown in equation (10).

$$P_{i(min)} \leq P_i \leq P_{i(max)} \quad (10)$$

where $P_{i(min)}$ is the minimum power output of the generator i and $P_{i(max)}$ is the maximum power output of generator i.

Methods

Power flow analysis has an important place in solving ELD and EELD problems. The voltage amplitude and the phase angle of each bar are computed in power flow analysis. Different methods are used for this [18]. Gauss-Seidel, Newton Raphson, Fast Heterogeneous (Fast-Decoupled) are traditional methods that are widely used in power flow analysis. However, it is not benefitial to use traditional methods in the solution of such problems because of high cost, slow convergence and more computational time. Therefore, heuristic methods are preferred for these problems. While heuristic methods have a better ability to reach near global optimal solution compared to traditional methods, the results can be improved by modifying them. Thus, more optimal solution can be obtained. Various techniques can be applied to improve the results. In this study, Genetic Algorithm and Artificial Bee Colony Algorithm from heuristic methods are modified and new optimization methods are proposed for the problem. They are modernized by generating an initial population with some prior knowledge and choosing the parameters properly. The parameters were chosen with the aim of getting the optimal solution. These optimization methods are explained below.

Genetic Algorithm

Genetic Algorithm (GA) is an heuristic algorithm based on evolutionary ideas of natural selection and searches for the best solution at the complex multi-dimensional space. John Holland formally presented Genetic algorithms in the 1970s in the United States [19].

Genetic algorithms search very large problem spaces and while doing this, they evaluate a small number of the total possibilities [19]. In genetic algorithm, random initial population is created by chromosomes. The fitness value of each chromosome is calculated separately. If the termination criterion is met, the algorithm is finished. Otherwise, new solutions are generated for future generations by applying genetic algorithm operators. These operators are elitism, selection, crossover, and mutation. Fitness values are calculated again and the algorithm continues to search until a stopping condition is satisfied and an optimal solution is found. When the condition is met, the program is stopped and the best solution in the population is collected. The process of genetic algorithm is explained as follows [20].

- Step 1. Establish the count of chromosomes and generation.
- Step 2. Establish the value of mutation rate and crossover rate.
- Step 3. Initialize the population with a random value.
- Step 4. Do steps 5-9 until the termination criteria is met.
- Step 5. Evaluate the fitness value of individuals by calculating objective function.
- Step 6. Select individuals.
- Step 7. Crossover.
- Step 8. Mutation.
- Step 9. New individuals.
- Step 10. Take the best individuals.

These steps are shown in Figure 1 [20].

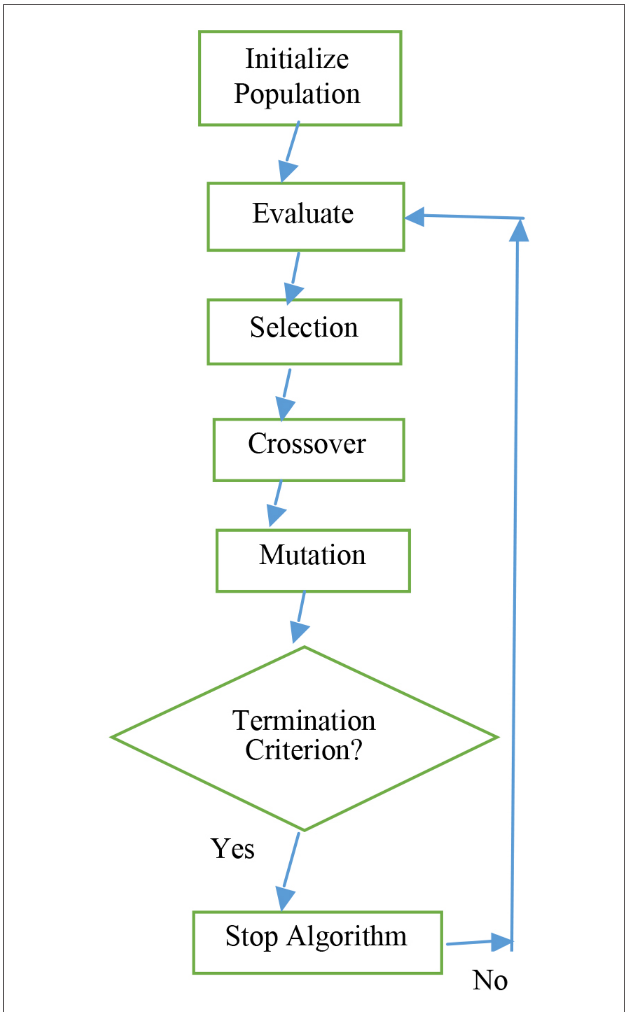

Figure 1. Genetic algorithm process

Initialization of population

Initial population of genetic algorithms is usually created by a random number generator. However, if some solutions for problems are roughly known, the initial population can be formed using them. It is also necessary to determine the population size. If there is a large population, genetic algorithm reduces the chance of getting local minimum and searches broader solution areas but it slows the working of the algorithm. In a small population, although the algorithm works quickly, the area of search space narrows and the chance of obtaining an efficient solution declines.

Calculation of fitness value

Every problem with solution has a fitness function. A fitness value is calculated for each individual by using fitness function and identifies the quality of the solution. If a fitness value of the solution is better, its chance of survival, reproduction and rate of representation in the next population is high.

Elitism

This is the process of transferring the best individuals to the next population without any change. The best individuals enter the new generation with the help of these elite individuals that are transferred to the population so improved results can be caught.

Selection

High quality individuals ensure survival and the number of them increases with selection in genetic algorithm. However, the number of low quality individuals decreases and thus they become lost. Genetic algorithm has different types of selection.

Crossing

Crossing is the process of producing new individuals from two individuals that are selected from the new population which is obtained at the end of multiplication process. It is used to create new individuals that have better quality than the previous generation.

Mutation

This is the process of changing the bits in the chromosomes. According to mutation rate, bits are convert so 1 becomes 0, 0 becomes 1. Mutation gives diversity to the population.

In this study, a new Genetic Algorithm is proposed by forming some parameters to get optimal results. These parameters are population size, number of elite individuals, crossover rate, and number of generations that stop the algorithm (criterion). They are important parameters of the algorithm providing an optimal result. The suitable values of parameters are set using simulation experiments.

Artificial bee colony algorithm

Artificial Bee Colony (ABC) is an algorithm inspired from the clever behaviour of bees and it is described by Derviş Karaboğa in 2005 [21]. In the ABC algorithm, there are three groups of bees in the colony. They are employed bees, onlookers and scouts. The first half of the colony consists of employed artificial bees and the second half consists of the onlookers. One employed bee is responsible for each food source. Therefore, the number of food sources and the number of employed bees are equal to each other. If the food source of the employed bee has been discarded by the bees, it becomes a scout [22].

ABC optimization algorithm tries to find the place that has the source of the most amount of nectar, thereby finding solutions that maximize or minimize the problem [23]. The steps of algorithm process may be as follows [24].

- Step 1. The count of employed bees and onlookers is generated by creating random food sources. Moreover, the limit value is determined and the counter variable is created for control.
- Step 2. The solution value of each food that belongs to created food sources is calculated based on the type of objective function.
- Step 3. The maximum number of cycles is determined and employed bees are sent to the food source. The employed bees head towards the food randomly and begin to exploit this food. After this, a new solution belonging to this food is calculated. If the new solution value is better than the previous one, this food and information about it are stored. If the solution value is improved, the limit value is reset. Otherwise, it is increased by one.
- Step 4. Onlookers are activated after the employed bees. The onlookers start to work on a food source that is selected based on the fitness value of the food. After it is treated, the new solution value of this food is calculated. Unlike the employed bees, they make a choice based on the fitness value. Whether or not the new solution value is better than the former solution, this food and information about it are stored. If the solution value is improved, the limit value is reset. Otherwise, it is increased by one.
- Step 5. At this stage, scouts that prevent algorithm to be in local minimum or maximum, which are the least or highest values that locate within a set of points which may or may not be a global minimum or maximum and may not be the lowest or highest value in the entire set, are activated. The resulting solution is eliminated completely, or limit values are reset, and it provides the generation of a new solution. The new solution and the value of the solution that was previously stored are compared. The best one of the two solution values is kept in the memory.
- Step 6. The algorithm continues to work until it reaches a maximum number of cycles. When the criteria for termination are met, the algorithm is terminated.

Initialization of food sources

A random value is generated for each parameter between the lower and upper limits. The location of food sources corresponding to solutions is found using equation (11).

$$x_{ij} = x_j^{min} + rand(0,1)\left(x_j^{max} - x_j^{min}\right) \quad i = 1, \dots, SN, \quad j = 1, \dots, D \tag{11}$$

SN represents number of food sources, D represents the number of variables that will be optimized, x_j^{min} is the lower limit of the parameter of j, x_j^{max} is the upper limit of the parameter of j in equation (11) [23].

Sending employed bees to food sources

A new food source is detected by the employed bees in the neighborhood of the food source where they work and the quality of it is appraised. If the new source is better than the previous source, they memorize the new source. The simulation of the specification of a new source in the available neighborhood is defined by equation (12) [23].

$$v_{ij} = x_{ij} + \emptyset_{ij}\left(x_{ij} - x_{kj}\right) \tag{12}$$

v_i source in the neighborhood of x_i is found with changing j that is the only parameter of the solution for each source that is indicated by x_i. j is an integer that is generated randomly between [1,D]. The randomly selected parameter j is changed and j. parameter of available source is differed from j. parameter of random x_k neighborhood solution (k ε {1,2,…SN}). It is weighed with $\emptyset_{ij}$ that takes a random value between [-1,1]. Then, it is added to j. parameter of available source [23].

If generated v_{ij} exceeds the limit of the parameter that is already determined, it is deferred to lower or upper limits of the parameter as shown in equation (13) [23].

$$v_{ij} = \begin{cases} x_j^{min}, & v_{ij} < x_j^{min} \\ v_{ij}, & x_j^{min} \le v_{ij} \le x_j^{max} \\ x_j^{max}, & v_{ij} \ge x_j^{min} \end{cases} \tag{13}$$

v_i represents the new source and its quality is calculated as shown in equation (14). A fitness value is calculated. Calculation of fitness varies depending on whether the problem is maximization or minimization [23].

$$fitness_i = f(x)\begin{cases} 1/(1+f_i) & f_i \ge 0 \\ 1+|f_i| & f_i < 0 \end{cases} \tag{14}$$

f_i is the cost value of the solution of v_i in equation (15). If the resulting solution is worse than the previous one, the limit value is increased by one. Otherwise, the limit value is reset.

After the employed bees have completed the research and returned to the hive, they transfer the information about the amount of source of nectar and its location to the onlookers in the dance area. The onlookers select an area with the probability that is proportional to the amount of nectar. The probabilistic selection process that is performed depending on the fitness value is done with a roulette wheel. The ratio of the fitness value of one source to the sum of all fitness values of sources gives the ratio of the selection of this source according to other sources as shown in equation (15) [23].

$$p_i = fitness_i \;/\; \sum_{j=1}^{SN} fitness_i \qquad (15)$$

$fitness_i$ represents the quality of i. source, SN indicates the number of employed bees in equation (15). When the nectar amount of the source increases, the probability of its election rises also [23].

Sending onlookers to food sources

After the onlookers leave the hive, they tend to go to food sources that are related to the calculated fitness value and they then calculate the new value of solution. The new value of the solution is compared with the old value. If the new one is better than the old one, the limit value is reset. Otherwise, it is increased by one. When all onlookers go to the food source, the process is finished.

Leaving of food source and generation of scouts

At this stage, if the value of the solution cannot be improved, thus meaning that the value of the limit exceeds the maximum value, the scouts take on the task. The new food source is composed thanks to the scouts and the solution value of this source is calculated. The value of the new food source is compared with the value of the old one. If the new one is better than the old one, it is memorized. Otherwise, it is ignored. All these stages continue until the criteria for stopping the process are satisfied, at which point the algorithm stops working and leaves the cycle.

In this study, a new Artificial Bee Colony algorithm is proposed by modifying the parameters of the algorithm. These parameters are the size of the colony (employed bees + onlooker bees), the number of food sources, the limit (a food source that could not be developed through "limit" trials is left by its employed bee), maximum cycle (the number of cycles for foraging-stopping criteria) and run time. These are important parameters of the algorithm in terms of reaching the optimal solution. The suitable values of parameters are set with simulation experiments.

Simulations and Results

Environmental economic dispatch is applied on a 6-generator test system with 3 load demands 500, 700, and 900 MW. Fuel cost coefficients, generator limits and NO_x emission coefficients are taken from the study [25].

The value of h used in the solution of environmental economic dispatch problem is calculated as 43.8983 for 500 MW load, 44.7880 for 700 MW load, 47.8222 for 900 MW load.

In this paper, both transmission line without losses and transmission line with losses are solved. The proposed Genetic Algorithm and Artificial Bee Colony algorithm are applied to two different situations, and the results are explained below.

Results of Environmental Economic Dispatch Without Losses Using the Proposed Genetic Algorithm

Environmental economic load dispatch problem is solved using the proposed Genetic algorithm with the help of MATLAB program. The parameters of the proposed Genetic Algorithm and their values are shown in Table 1. The transmission line losses are neglected. The results for 500, 700 and 900 MW load conditions are shown in Table 2.

Results of Environmental Economic Dispatch without Losses Using the Proposed Artificial Bee Colony Algorithm

Environmental economic load dispatch problem is solved using the proposed Artificial Bee Colony algorithm with the help of MATLAB program. The parameters of proposed Artificial Bee Colony algorithm and their values are shown in Table 3. The transmission line losses are neglected. The results for 500, 700 and 900 MW load conditions are shown in Table 4.

Table 1. Parameters of the proposed genetic algorithm and their values

Parameters of the proposed Genetic Algorithm	Values
Population size	100
Number of elit individuals	10
Crossover rate	0.4
Number of generations that stop the algorithm (criterion)	55

Table 2. Results of environmental economic dispatch problem without losses and using the proposed genetic algorithm

	Demand (MW)		
Unit (MW)	500	700	900
P1 (MW)	31.6061	59.6819	89.4139
P2 (MW)	23.6848	56.1309	89.7192
P3 (MW)	88.0526	116.4225	143.9294
P4 (MW)	89.2854	116.7638	145.1156
P5 (MW)	134.9353	176.5053	215.1937
P6 (MW)	132.4359	174.4956	216.6281
Total generation (MW)	500.0000	700.0000	900.0000
Fuel cost (Rs/h)	27187	36619	46806
NO_x emission (kg/h)	257.4830	423.1776	656.6952

Table 3. Parameters of the proposed artificial bee colony algorithm and their values

Parameters of the proposed Artificial Bee Colony algorithm	Values
Colony size (employed bees+onlooker bees)	20
Number of food sources	10
Limit	100
Maximum cycle (Stopping criteria)	2500
Run time	3

Table 4. Results of environmental economic dispatch problem without losses and using the proposed artificial bee colony algorithm

	Demand (MW)		
Unit (MW)	500	700	900
P1 (MW)	42.0642	38.3017	110.3992
P2 (MW)	32.8695	70.7661	71.9325
P3 (MW)	74.0628	125.8842	148.5211
P4 (MW)	94.3425	86.0948	154.5025
P5 (MW)	130.2502	179.7173	218.3618
P6 (MW)	126.4151	199.3042	196.3007
Total generation (MW)	500.0043	700.0683	900.0176
Fuel cost (Rs/h)	27330	36656	47026
NO_x emission (kg/h)	257.6095	438.4085	660.4282

Table 5. Parameters of the proposed Genetic Algorithm and their values

Parameters of proposed Genetic Algorithm	Values
Population size	100
Number of elit individuals	10
Crossover rate	0.4
Number of generations that stop the algorithm (criterion)	10

Results of Environmental Economic Dispatch with Losses Using the Proposed Genetic Algorithm

Environmental economic load dispatch problem including transmission line losses is solved using the proposed Genetic algorithm with using MATLAB program. The parameters of the proposed Genetic Algorithm and their values are shown in Table 5. The results for 500, 700 and 900 MW load conditions are shown in Table 6 [26].

Table 6. Results of environmental economic dispatch problem with losses and using the proposed genetic algorithm

	Demand (MW)		
Unit (MW)	500	700	900
P1 (MW)	57.2500	94.9434	124.3750
P2 (MW)	39.8750	67.2451	101.5482
P3 (MW)	68.0352	83.1904	101.9688
P4 (MW)	80.1084	112.1353	137.5000
P5 (MW)	143.5679	203.7607	266.5801
P6 (MW)	134.0322	177.0393	230.6904
Total generation (MW)	522.8687	738.3142	962.6624
Losses (MW)	22.8681	38.3135	62.6621
Fuel cost (Rs/h)	28510	39047	50766
NO_x emission (kg/h)	276.8340	471.7438	764.3676

Table 7. Results of environmental economic dispatch problem with losses and using the proposed artificial bee colony algorithm

	Demand (MW)		
Unit (MW)	500	700	900
P1 (MW)	57.4055	94.0712	125.0000
P2 (MW)	37.3212	67.2152	96.0000
P3 (MW)	65.0613	83.1354	104.1139
P4 (MW)	81.9516	110.9599	138.0000
P5 (MW)	147.0000	204.0000	273.0068
P6 (MW)	133.5921	179.0000	225.6305
Total generation (MW)	522.3317	738.3816	961.7512
Losses (MW)	22.3318	38.3789	61.8483
Fuel cost (Rs/h)	28456	39028	50637
NO_x emission (kg/h)	277.7753	472.1017	765.9759

Results of Environmental Economic Dispatch with Losses Using the Proposed Artificial Bee Colony Algorithm

Environmental economic load dispatch problem including transmission line losses is solved using the proposed Artificial Bee Colony algorithm with the help of MATLAB program. The values of the parameters of the proposed Artificial Bee Colony algorithm in Table 3 are used. The results for 500, 700 and 900 MW load conditions are shown in Table 7.

Table 8. Comparison resuls for environmental economic load dispatch

Demand (MW)	Method	Fuel cost (Rs/h)	NOx emission (kg/h)	Line losses (MW)
500	The Proposed Genetic Algorithm	28510	276.8340	22.8681
	The Proposed Artificial Bee Colony	28456	277.7753	22.3318
	Unmodified Genetic Algorithm	28551	283.9519	25.7529
	Unmodified Artificial Bee Colony	28613	282.2662	29.1090
700	The Proposed Genetic Algorithm	39047	471.7438	38.3135
	The Proposed Artificial Bee Colony	39028	472.1017	38.3789
	Unmodified Genetic Algorithm	39246	473.8901	40.9038
	Unmodified Artificial Bee Colony	39183	486.0955	47.0021
900	The Proposed Genetic Algorithm	50766	764.3676	62.6621
	The Proposed Artificial Bee Colony	50637	765.9759	61.8483
	Unmodified Genetic Algorithm	50775	772.4338	65.675
	Unmodified Artificial Bee Colony	51494	775.2970	79.9624

The results of environmental economic dispatch problem on six-generator test system are compared with the unmodified versions of Genetic Algorithm and unmodified Artificial Bee Colony Algortihm. The comparison is shown in Table 8.

Conclusion

When environmental economic load dispatch is applied on a 6-generator test system ignoring line losses and using the proposed Genetic Algorithm, the fuel cost is 27187 Rs/h, and the emission output is 257.4830 kg/h for a 500 MW load. For a 700 MW load the fuel cost is 36619 Rs/h, and the emission output is 423.1776 kg/h. For a 900 MW load the fuel cost is 46806 Rs/h, and the emission output is 656.6952 kg/h. Using the proposed Artificial Bee Colony algorithm, the fuel cost is 27330 Rs/h, and the emission output is 257.6095 kg/h for a 500 MW load. For a 700 MW load the fuel cost is 36656 Rs/h, and the emission output is 438.4085 kg/h, and for a 900 MW load the fuel cost is 47026 Rs/h, and the emission output is 660.4282 kg/h, . When the results are examined, it can be observed that the proposed Genetic Algorithm offers better results than the proposed Artificial Bee Colony algorithm in terms of providing greater reduction in fuel cost and emission output in the solution of EELD on a six-generator test system.

When environmental economic load dispatch is applied on a six-generator test system including line losses and using the proposed Genetic Algorithm, the fuel cost is 28510 Rs/h, the emission output is 276.8340 kg/h, and line losses are 22.8681 MW for a 500 MW load. For a 700 MW load the fuel cost is 39047 Rs/h, the emission output is 471.7438 kg/h, and the line losses are 38.3135 MW, and for a 900 MW load the fuel cost is 50766 Rs/h, the emission output is 764.3676 kg/h, and the line losses are 62.6621 MW.. the Using the proposed Artificial Bee Colony algorithm, the fuel cost is 28456 Rs/h, the emission output is 277.7753 kg/h, and the line losses are 22.318 MW for a 500 MW load. For a 700 MW load the fuel cost is 39028 Rs/h, the emission output is 472.1017 kg/h, and the line losses are 38.3789 MW , and for a 900 MW load the fuel cost is 50637 Rs/h, the emission output is 765.9759 kg/h, and the line losses are 61.8483 MW. When the results are examined, it can be seen that the proposed Genetic Algorithm is better than the proposed Artificial Bee Colony Algorithm in terms of emission output for all three cases.

Table 8 shows that the proposed Genetic Algorithm and Artificial Bee Colony algorithm optimization methods give better results than unmodified versions of Genetic Algorithm and unmodified Artificial Bee Colony algorithm. Comparison of results shows that using the proposed Genetic Algorithm and Artificial Bee Colony algorithm in the solving of environmental economic dispatch provides a reduction of fuel cost and NO_x emission.

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