Journal of Energy and Natural Resources
2014; 3(1): 1-5
Published online February 20, 2014 (http://www.sciencepublishinggroup.com/j/jenr)
doi: 10.11648/j.jenr.20140301.11

Economic load dispatch with the proposed GA algorithm for large scale system

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To cite this article:
Hamed Aliyari, Reza Effatnejad, Ardavan Areyaei. Economic Load Dispatch with the Proposed GA Algorithm for Large Scale System. *Journal of Energy and Natural Resources.* Vol. 3, No. 1, 2014, pp. 1-5. doi: 10.11648/j.jenr.20140301.11

Abstract: Economic load dispatch (ELD) have been applied to obtain optimal fuel cost of generating units. Genetic Algorithm (GA) is a global search technique based on principles inspired from the genetic and evolution mechanism observed in natural biological systems. This paper presents a novel stochastic Genetic Algorithm approach to solve the Economic Load Dispatch problem considering various generator constraints and also conserves an acceptable system performance in terms of limits on generator real and reactive power outputs bus voltages, shunt capacitors/reactors, transformers tap-setting and power flow of transmission lines. The ELD problem in a power system is to determine the optimal combination of power outputs for all generating units which will minimize the total fuel cost while satisfying all practical constraints. To show its efficiency and effectiveness, the proposed GA algorithm is applied to some types of ED problems containing non-smooth cost functions of 13 and 40 generating units systems (large scale systems). The experimental results show that the proposed GA approach is comparatively capable of obtaining higher quality solution.

Keywords: Non-Smooth Cost Functions, Genetic Algorithm, Economic Dispatch, GA, IEEE Tests Systems

1. Introduction

Conventionally, economic load dispatch problem allocates loads to plants at minimum cost while meeting the constraints. It is an optimization problem which minimizes the total fuel cost of all committed plants while meeting the demand and losses. The optimal power system operation is achieved when both the objectives of power systems i.e. cost of generation and system transmission losses simultaneously attain their minimum values. Economic load dispatch reflects the optimal electrical output of generation facilities, to fulfill the system load demand, at the lowest possible cost, while providing power in a robust and reliable way. Economic load dispatch problem is one of the fundamental matters in power system operation. In essence, it is an optimization problem and its main objective is to cut-down the total generation cost, without breaching any constraints [1]. Preceding efforts on solving ELD problems have made use of various mathematical programming and optimization techniques [2]. Numerous techniques have been established to help solve the ELD problems, such as Particle Swarm Optimization [3], Artificial Bee Colony Algorithm [4], Genetic Algorithm [5], Pattern Search Algorithm [6], Neural Networks [7], Evolutionary Programming [8], and Harmony Search Algorithm [9]. Each of the employed techniques may have some advantage and disadvantages. For instance, Particle Swarm Optimization (PSO) is well recognized for its capability to permit each particle to maintain a memory of the best solution it has discovered in the particle's neighborhood swarm. Furthermore, PSO is easy to device, and effective [10]. However, the algorithm might experience inequality constraints difficulties. Recently, Ant Colony Optimization (ACO)[11] has turn into a candidate for many optimization applications [12] such as the combinatorial optimization travelling salesman problem (TSP), quadratic assignment problem (QAP), and optimal design and scheduling problem of thermal units [13].

This paper presents an innovative approach based on Ant Colony Algorithm was chosen for solving the load-flow problem.

2. Economic Load Dispatch

The objective of Economic Load Dispatch is to minimize the operating cost of each generating unit in the system. Thus, an optimal generated output can be acquired from the solution. Economic Load Dispatch can be calculated by using the following equations[15-19]

$$optimum\ \cos t = \sum_{i}^{Ng} Fi(Pi) \tag{1}$$

Where *cost* is the operating cost of power system and the objective function is to minimize the cost. Ng is the number of units. $Fi(Pi)$ is the cost function and Pi is the power output of the unit i. $Fi(Pi)$ is usually approximated by a quadratic function of its power output Pi as:

$$Fi(Pi) = a_i + b_i P_i^2 + b_i P_i + c_i \tag{2}$$

Where ai, bi, and ci are the cost coefficients of unit i. The above equation is subjected to both the equality and inequality constraint as follow:

Real power balance constraint is given by:

$$\sum_{i}^{Ng} Fi(Pi) = P_D + P_L \tag{3}$$

Real power generation limit is given by:

$$P_{i\,\min} \le P_i \le P_{i\,\max} \tag{4}$$

Where PD is the total load demand in MW, PL is the total transmission loss of the system in MW; $Pimin$ and $Pimax$ are the minimum and maximum generation limit of Pi. Next, The search of the optimal control vector is performed using into account the real power flow equation which present the system transmission losses (PL). These losses can be approximated in terms of B-coefficients as [20]:

$$Pf = \left(1 - \frac{\partial P_L}{\partial P_g}\right)^{-1} \tag{5}$$

These losses are represented as a penalty vector [21-24]given by:

$$P_L = \sum_{i}^{N}\sum_{j}^{N} P_i B_{ij} P_j \tag{6}$$

The transmission loss of a power System PL can be calculated by the B-Coefficients method [25] and given by:

$$P_L = \sum_{i}^{N}\sum_{j}^{N} P_i B P_j + \sum_{i}^{N} B_{oi} + B_{oo} \tag{7}$$

Where B is an $ng{\times}ng$ coefficients matrix, $B0$ is an ng-dimensional coefficient column vector and $B00$ is a coefficient.

3. Genetic Algorithm

3.1. Basic Principle of Genetic Algorithm

Genetic Algorithms (GA)[26,19] are direct, parallel, stochastic methods for global search and optimization, which imitate the evolution of the living beings, described by Charles Darwin. GA is part of the group of Evolutionary Algorithms (EA). The evolutionary algorithms use the three main principles of the natural evolution: reproduction, natural selection and diversity of the species, maintained by the differences of each generation with the previous. Genetic Algorithms works with a set of individuals, representing possible solutions of the task. The selection principle is applied by means of a criterion, giving an evaluation for the individual with respect to the desired solution. The best-suited individuals create the next generation.

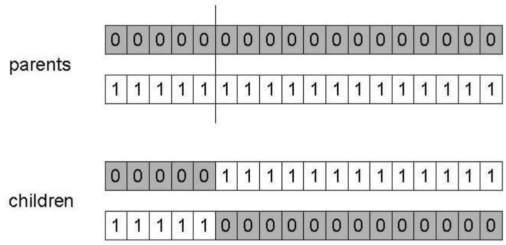

Fig 1. *Behavior of Genetic Algorithm.*

3.2. Genetic Algorithm with Arithmetic Crossover

In order to formulate the algorithm for economic/environmental ED problem, let the chromosome of the k-th individual Ck be defined as follows:

$$c_k = \left[P_{k1}, P_{k2}, \ldots, P_{kn}\right] \tag{13}$$

Where

k : 1, 2, . . . , popsize

n : 1,2….number_of_gene

popsize means population size, number_of_gene is the number of unit in our experiment

Pki is the generation power of the n-th unit at k-th chromosome

Reproduction involves creation of new offspring from the mating of two selected parents or mating pairs. It is thought that the crossover operator is mainly responsible for the global search property of the GA. We used an arithmetic crossover operator that defines a linear combination of two chromosomes [23]. Two chromosomes, selected randomly for crossover, C_i^{gen} and C_j^{gen} may produce two offspring, C_i^{gen+1} and C_j^{gen+1}, which is a linear combination of their parents i.e.,

$$C_i^{gen+1} = a.C_i^{gen} + (1-a)C_j^{gen} \tag{14}$$

$$C_j^{gen+1} = a.C_j^{gen} + (1-a)C_i^{gen} \tag{15}$$

where

C_i^{gen} : an individual from the old generation

C_i^{gen+1} : an individual from new generation

a : is the weight which governs dominant individual in reproduction and it is between 0 and 1

The mutation operator is used to inject new genetic material into the population and it is applied to each new structure individually. A given mutation involves randomly altering each gene with a small probability. We generate a random real value which makes a random change in the m-th element selected randomly of the chromosome.

3.3. Proposed GA Algorithm for Solving ED Problem

In this study, an innovative approach based on Genetic Algorithm was chosen for solving the load-flow problem, i.e. the two groups of genes are pretended in a parallel mood, in a way that one group moves in the values decreasing direction and the other one moves in the values increasing direction. After giving the primary values, the two groups converge to the minimum answer found.

The initialization method that is utilized in the following algorithm is an innovative method. The increasing primary amount is chosen in a way that at first, all the units should take their minimum amount and after that, we act according to the conditions 3 and 4 and the following algorithm:

A. A gene is chosen.
B. According to the probability function of one of the units, one of them is selected. Then the constant value (defined according to the accuracy and cpu time of the program, which can change based on the type of the operation), is added in accordance to the primary value that was defined for it previously. The amount of constant value should be selected in a way that it increases the power value of each unit, because each unit has already got its minimum power value. If this action does not violate condition "4" and that the amount of $\sum_{i}^{Ng} F(Pi)$ is less than P_D, then adding the constant value is accepted and proceeding to the level "C" is appproved, otherwise the constant value is not acceptable and this level should be repeated.
C. If the condition "3" is not violated, then proceeding to the next level is approved, otherwise going back to the level "B" is mandatory.
D. The primary amounting is done.
E. Chose another gene, i.e. go to level "A". (The number of genes is determined at first.)

We should do the same guess algorithm in a decreasing way, in which we give the maximum amount of units to them and we do the same steps in the decreasing route.

In order to get to the optimum result in accordance to the guess algorithm, in the part that we are getting the best results, the more the number of these results (genes), the more the accuracy and the less the speed of running the code(CPU time), so the existing results give the prices of each unit.

Actually a large amount of data is obtained at the end of the process. We have to get to the most optimum level within the data, by means of GA algorithm based on arithmetic crossover and standard mutation separately.

Based on this method, the optimization was applied in 13 units [27], 40 units [28] systems (assuming power losses P_L to be zero). It should be mentioned that in all cases, constraints such as speed and the forbidden work zones of each generator is considered.

4. Simulation Results

To assess the feasibility of the PSO approach, the studies of ED were compared with many optimization methods such as GA, TS, PSO, and ACO, implemented in MATLAB (7.6.0.6324(2008a) version). These programs were run on a Pentium Dual core, 2.5 GHz personal microcomputer with 3 GB RAM under Windows XP. In each case study, 100 independent runs are carried out for each optimization method. In addition, 100 different initial trial solutions are used for each method.

The GPSO is applied to two ED problems with 13 and 40 generating units. The input data for 13 generating units system are given in [27] with 2520MW load demand. Also, the input data for 40 generating units system are given in [28] with 10,500MW load demand. The global solutions for these systems are not discovered yet. The best local solutions reported until now for 13 and 40 generating units are 24,169.92 $/h [29] and 121,741.98 $/h [30], respectively. After performing 100 trials, the best results for P_is, in the 13 units system and 40 units system, in order for the best answer to be found, are shown in the Tables 1 and 2 respectively.

Table 1. *Best result obtained by proposed GA for 13-unit system.*

unit	Pi(min) MW	Pi(max) MW	Pi MW
1	0	680	582
2	0	360	307
3	0	360	304
4	60	180	150
5	60	180	152
6	60	180	160
7	60	180	170
8	60	180	151
9	60	180	145
10	40	120	91
11	40	120	88
12	55	120	112
13	55	120	108
	Total power output	(MW)	2521.05807120690
	Total generation cost	($/h)	24167

Table 2. *Best result obtained by proposed GA for 40-unit system.*

unit	Pi(min) MW	Pi(max) MW	Pi MW
1	36	114	102.998723543689
2	36	114	48.8339865534452
3	60	120	81.9858291219816
4	80	190	184.910084237253
5	47	97	94.2352602174419
6	68	140	105.422756354223
7	110	300	276.389659153576
8	135	300	270.466620780899
9	135	300	298.060182246735
10	130	300	147
11	94	375	237.691701220395
12	94	375	206.462568526111
13	125	500	284.649567876062
14	125	500	299.585612037311
15	125	500	337.915510467145
16	125	500	276.073863005347
17	220	500	477.22822388695
18	220	500	498.847725762535
19	242	550	541.67218476475
20	242	550	420.642175667156
21	254	550	512.202032512945
22	254	550	530.777820055416
23	254	550	541.468907284464
24	254	550	521.954612690208
25	254	550	550
26	254	550	549.808717554535
27	10	150	18.4444706057755
28	10	150	17.5935208491752
29	10	150	12.786627396382
30	47	97	92
31	60	190	190
32	60	190	176.788840003834
33	60	190	186.052294384747
34	90	200	200
35	90	200	190.129452886447
36	90	200	200
37	25	110	102.62394666683
38	25	110	63.3481518226166
39	25	110	108.692272455022
40	242	550	543.705916841164
	Total power output	(MW)	10499.45
	Total generation cost	($/h)	121168.9255

In the Tables 3 and 4, there is a brief comparison between our suggested method and some other innovating methods proposed by other researchers and some standard methods based on the smart algorithms(that we discussed above) which are the results of other researchers.

Table 3. *Convergence results for 13-unit system.*

Method	Best Cost
Load demand	2520 MW
Propose GA	24167
[31]	24169.89
GA	24186.02
PSO	24171.70
ACO	24174.39
TS	24180.31

Table 4. *Convergence results for 40-unit system.*

Method	Best Cost
Load demand	10500 MW
Propose GA	121168.9255
[31]	121532.41
GA	121996.40
PSO	121800.13
ACO	121811.37
TS	122288.38

5. Conclusions

The problem of economic load dispatch with non-smooth cost functions has been investigated in this paper. We used GA algorithm with arithmetic crossover and standard mutation for arrived at this goal. A comparison analysis has been done for different intelligent techniques with respect to the total minimum generation cost that shown at the table 3 and the table 4. The present algorithm is able to solve the economic dispatch problem under partially deregulated environment. The performance of the developed algorithm has been demonstrated on an 13 units systems and 40 units systems test system.

According to the results of this research, and the comparison between other researches results, and the significant difference between them, it is obvious that this method can be a proper method for operating gigantic power systems.

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