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Economic Load Dispatch with Multiple Fuel Options Using GA Toolbox in Matlab

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Abstract : *This paper presents the solution of Economic Load Dispatch with multiple fuel options (ELDMFO) using Genetic Algorithm (GA). Finding the global optimum solution for Economic Load Dispatch (ELD) problem with nonlinear cost function is cumbersome using traditional approaches. Few generators utilizes multiple fuels, there arises a problem of determining economic fuel among the number of available fuels. Many Evolutionary algorithms were proposed to solve ELD problem. In this paper a more heuristic approach known as Genetic algorithm (GA) is proposed to solve ELDMFO. This method is applicable for solving non smooth and non linear functions like cost characteristics of fossil fuel fired plants. A test system of four generating units with three fuel options has been considered and applied GA. The simulation is carried out with MATLAB software and the obtained results are compared with the conventional equal incremental cost criteria and also with PSO.*

Keywords - *Economic Load Dispatch, Genetic Algorithm (GA), and multiple fuel options*

I. Introduction

The main objective of a power system operation is to minimize the total fuel cost. It is to determine optimal combination of the generating units, which reduces the total fuel cost by satisfying the imposed constraints on them. If there is no limitation on fuel availability, the ELD can be solved with only the present conditions as data [1]. However in practical, generating units utilizes more than one fuel such as coal, gas, Oil, nuclear or water which limits the power plant operation. In such cases the ELD problem should be carried out in different way. There arises a concept of economic load dispatch with multiple fuel options. The cost function of a generator is much nonlinear and with more discontinuous. Conventional lambda iteration method, PSO, Evolutionary programming yields good results. But the rate of convergence is slow [15], and there is no guarantee for global optimum. Hence in this paper Genetic Algorithm was proposed to solve the ELDMFO. GA was already proved that it leads to global optimum results.

II. Mathematical Problem Formulation

In ELDMFO problem it is more realistic if we consider the piece wise quadratic cost function. For the generator with k fuel options, the cost curve is divided in to k discrete areas as shown in Fig. 1.

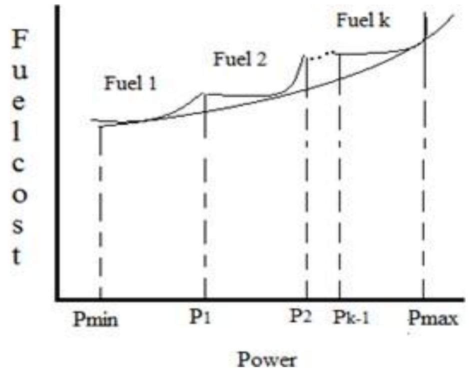

Fig. 1. Multiple fuel cost curves

The objective of ELDMFO is

Minimize $C_T = \sum_{i=1}^{N} C_i(P_i)$ Rs/hr (1)

and

$C_1(P_{i1}) = a_{i1}P_{i1}^2 + b_{i1}P_{i1} + c_{i1}$ for fuel 1, subjected to $P_{min} \le P_{i1} \le P_1$.

$C_2(P_{i2}) = a_{i2}P_{i2}^2 + b_{i2}P_{i2} + c_{i2}$ for fuel 2, subjected to $P_1 \le P_{i2} \le P_2$.

Similarly for k^{th} fuel

$C_i(P_{ik}) = a_{ik}P_{ik}^2 + b_{ik}P_{ik} + c_{ik}$ for fuel k, subjected to $P_{k-1} \le P_{ik} \le P_{max}$. (2)

Where C_T is the total cost with n number of generators and k number of fuel options, $C_i(P_{ik})$ is the total fuel cost of i^{th} generator by using k^{th} fuel option, a_{ik}, b_{ik} *and* c_{ik} are cost coefficients for i^{th} plant with k^{th} fuel option [9]. The fuel cost minimization is subjected to the following constraints [7].

A. Power Balance Equation

The total generation of all the units by using available fuel options should be equal to the sum of system demand and the power losses in a transmission system. Mathematically it is expressed as in equation (3).

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

Where P_D= the total demand of the system, P_L=the transmission power loss of the system. For the considered problem Transmission loss was neglected.

B. Power Generation Capacity Limit

$$P_{imin} \le P_i \le P_{imax} \quad (4)$$

Where P_{imin} = the minimum possible generation of i^{th} generator, P_{imax} .= the maximum possible generation of i^{th} generator.

III. Genetic Algorithm (GA)

GA is a stochastic global search method [16]. GA uses the objective function of the problem without demanding its differentiability and linearity. The search process starts through a population of points not with a single point. The three basic pillars of GA are Selection, Crossover and Mutation operations. Initially chromosomes are selected to be parents randomly, which may not lead to global solution. The selection parameter selects the chromosomes which has high fitness value. There are many methods how to select the best chromosomes, for example Roulette wheel selection, rank selection, tournament selection and some others. Crossover is a process of taking two parents randomly and produces a new offspring solution. The idea behind the crossover is the new chromosome is better than their parents. This is analogous to reproduction. There are many methods for crossover, for example single point, two point and uniform crossover. The Mutation operator is to maintain diversity of solutions and to enlarge the information contained in the population. This is a random process where one allele of gene is replaced by another to produce the new genetic structure.

The following flowchart shown in Fig. 2. describes the implementation of GA to the engineering problems.

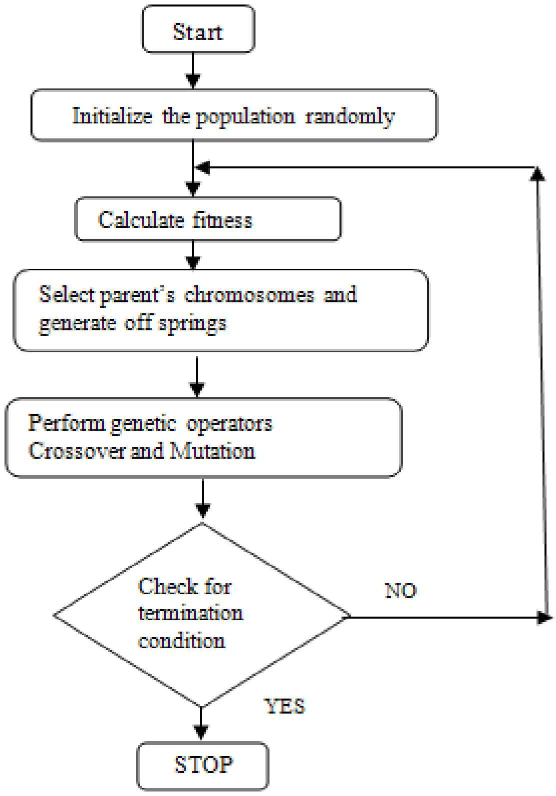

Fig 2 Flow Chart for Genetic Algorithm

IV. Implementation GA to ELDMFO Problem

Step1: Read all the data of the system, and initialize the population (Real powers) randomly.

Step2: Check for Power balance constraint and power limit constraints. Form a pooling mate which satisfies the above two conditions.

Step3: Calculate the fitness value for every single chromosome.

Step4: By using Roulette wheel selection procedure select those strings which have highest fitness value.

Step5: Apply GA operators Crossover and mutation.

Step6: Check for terminating condition. If the termination condition was satisfied stop the generations and print the cost else update the pooling mate and go to the Step3.

To describe the implementation of GA to ELDMFO two test systems were considered from ref [17].

Case a: The problem has four generating units and three fuel options. Generator1 has only first and second fuel options but the remaining units have all the three fuel options The cost coefficients for the three generators for fuel1 are illustrated in Table 1.. a_{ik}, b_{ik} and c_{ik} are cost coefficients. Where i indicate unit number and k indicates fuel option. Table 4 represents the power limits for the three units for the available fuel options. The total demand considered was 915MW

TABLE I

Cost Coefficients for Fuel 1

Units	a_{i1}	b_{i1}	c_{i1}
1	26.970	-0.39750	0.002176
2	118.400	-1.26900	0.004194
3	39.790	-0.31160	0.001457
4	1.983	-0.03114	0.001049

TABLE II

Cost Coefficients for Fuel 2

Units	a_{i2}	b_{i2}	c_{i2}
1	21.130	-0.30590	0.00186100
2	1.865	-0.03988	0.00113800
3	-59.140	0.48640	0.00001176
4	52.850	-0.63480	0.00275800

TABLE III

Cost Coefficients for Fuel 3

Units	a_{i3}	b_{i3}	c_{i3}
1	-------------	-------------	-------------
2	13.650	-0.19800	0.0016200
3	-2.876	0.03389	0.0008035
4	266.800	-2.33800	0.0059350

TABLE IV

Generation limits for various units for various fuel options.

Unit	Fuel (1) , MW		Fuel (2) ,MW		Fuel(3) ,MW	
	Pmin	P1	P1	P2	P2	Pmax
1	100	196	196	250	---	---
2	157	230	50	114	114	157
3	200	332	388	500	332	388
4	99	138	138	200	200	265

From Table IV the maximum and minimum power limits for each unit are indicated below in Table V.

TABLE V
Generation limits for various units.

Unit	Pmin (MW)	Pmax (MW)
1	100	250
2	50	230
3	200	500
4	99	265

The initial starting of population i.e power generated are selected such that it should satisfy power balance and power limit constraints. On implementing GA to the ELDMFO using MATLAB toolbox the optimum value i.e fuel cost stabilizes by 53 generations which is shown in Figure 3.

TABLE VI
Results of he considered system

Unit	Present results		Results of ref.[9]		Results of ref.[8]	
	Power	Fuel	Power	Fuel	Power	Fuel
1	206.609	2	206.45	2	206.63	2
2	206.604	1	206.64	1	206.51	1
3	265.814	1	265.91	1	265.88	1
4	235.972	3	236.00	3	235.99	3
	Total Cost : 178.09517		Total Cost: 178.0957		Total Cost : 178.0954	

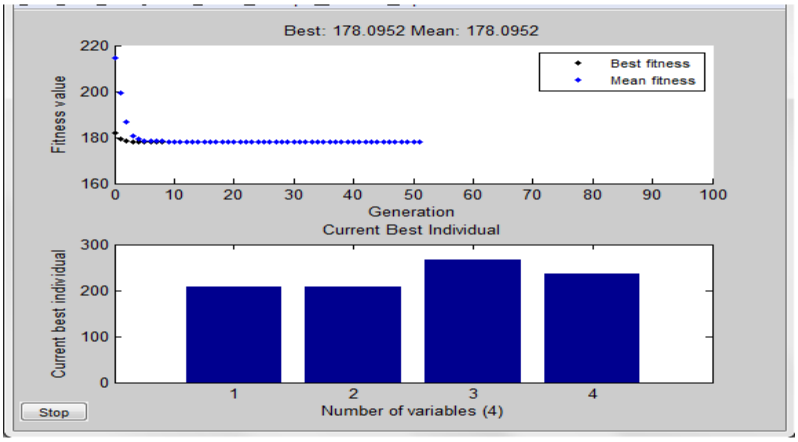

Fig. 3**.** Solution for ELDMFO

The result of the considered problem using GA was compared with the techniques explained in ref [9] and ref [8]. There is very small difference which can be neglected. The time taken to complete 53 iterations was 2 seconds.

Case b: Another test system consists of ten generating units was considered [17]. The cost coefficients for ten generators were given in Table 7, 8, 9. The load for this system is 2700Mw. Each generator has two or three fuel options. Table 10 indicates the power limits for each generator.

TABLE VII
Cost coefficients for Fuel 1

Units	a_{i1}	b_{i1}	c_{i1}
1	.2176e-2	-.3975e0	.2697e2
2	.4194e-2	-.1269e1	.1184e3
3	.1457e-2	-.3116e0	.3979e2
4	.1049e-2	-.3114e-1	.1983e1
5	.1066e-2	-.8733e-1	.1392e2
6	.2758e-2	-.6348e0	.5285e2
7	.1107e-2	-.1325e0	.1893e2
8	.1049e-2	-.3114e-1	.1983e1
9	.1554e-2	-.5675e0	.8853e2
10	.1102e-2	-.9938e-1	.1397e2

TABLE VIII
Cost coefficients for Fuel 2

Units	a_{i2}	b_{i2}	c_{i2}
1	.1861e-2	-.3059e0	.2113e2
2	.1138e-2	-.3988e-1	.1865e1
3	.1176e-4	.4864e0	-.5914e2
4	.2758e-2	-.6348e0	.5285e2
5	.1597e-2	-.5206e0	.9976e2
6	.1049e-2	-.3114e-1	.1983e1
7	.1165e-2	-.2267e0	.4377e2
8	.2758e-2	-.6348e0	.5285e2
9	.7033e-2	-.4514e-1	.1530e2
10	.4164e-4	.5084e0	-.6113e2

TABLE IX
Cost coefficients for Fuel 3

Units	a_{i3}	b_{i3}	c_{i3}
1	-	-	-
2	.1620e-2	-.1980e0	.1365e2
3	.8035e-3	.3389e-1	-.2875e1
4	.5935e-2	-.2338e1	.2668e3
5	.1498e-3	.4462e0	-.5399e2
6	.5935e-2	-.2338e1	.2668e3
7	.2454e-3	.3559e0	-.4335e2
8	.5935e-2	-.2338e1	.2668e3
9	.6121e-3	-.1817e-1	.1423e2
10	.1137e-2	-.2024e0	.4671e2

TABLE X
Generation limits for various units for various fuel options.

Unit	**Fuel (1), MW**		**Fuel (2) ,MW**		**Fuel(3) ,MW**	
	Pmin	P1	P1	P2	P2	Pmax
1	100	196	196	250	-	-
2	157	230	50	114	114	157
3	200	332	388	500	332	388
4	99	138	138	200	200	265
5	190	338	338	407	407	490
6	138	200	85	138	200	265
7	200	331	331	391	391	500
8	99	138	138	200	200	265
9	213	370	370	440	130	213
10	200	362	407	490	362	407

After applying GA to the ten generator test system, the optimum cost obtained was Rs 623.8092/-

V. Conclusion

An Economic dispatch problem with multiple fuel options has been considered and GA was applied to solve the problem. The procedure for solving has been explained in section 4. A test system was considered from ref [8] and [17] the results were compared. It has been found that the difference is very little. The time taken to reach the optimum solution also very less, that is 2 seconds. The advantage of this method is other types of non linearities also can be accommodating in a single objective function.

References

[1] A. J. Wood and B. F. Woolenberg, "Power Generation, Operation and Control", John Wiley & Sons, New York, (1984).
[2] O. I. Elgared, "Electric Power System Theory, An Introduction", Second Edition TMH, (1983).
[3] J. H. Park, "Economic Load Dispatch for Piece-wise Quadratic Cost Function using Hopfield Neural Networks", IEEE Trans. On PAS, vol. 8, no. 3, (1993) August, pp. 1030-1038.
[4] C. E. Lin and Viviani, "Hirarchical Economic Dispatch for Piece-wise Quadratic Cost Function", IEEE Trans. On PAS, vol. 103, no. 6, (1984) June, pp. 1170-1175.
[5] Barkirtzis, V. Petridis and S. Kazarlis, "Genetic algorithm Solution to the Economic Dispatch Problem", IEE Proceedings of Generation Transmission, Distribution, vol. 141, no. 4, (1994) July, pp. 377-382.
[6] R. Jabr, A. Coonick and B. Cory, "A Homogeneous Linear Programming Algorithm For the Security Constrained Economic Dispatch Problem", IEEE Trans. Power Syst., vol. 15, no. 3, (2000) August, pp. 930-936.
[7] H. H. Happ, "Optimal Power Dispatch – a Comprehensive Survey", IEEE Trans., (1977), PAS 96.
[8] P. K. Hota and S. K. Das, "Economic Load Dispatching of Generating Units with Multiple Fuel Options", Institution of Engineers India, vol. 88, (2007) June, pp. 22-28.
[9] S. Agrawal, T. Bakshi and D. Majumdar "Economic Load Dispatch of Generating Units with Multiple Fuel Options Using PSO" , International Journal of Control and Automation, Vol. 5, No. 4 (2012), December, pp. 79-92.
[10] D.C Walters and G.B. Sheble, "Genetic algorithm solution of economic dispatch with the valve point loading, " IEEE Trans. Power Systems, vol. 8, pp.1325-1332, Aug. 1993.
[11] N.Sinha, R. Chakrabarti, and P.K.Chattopadhyay, "Evolutionary programming techniques for economic load dispatch " IEEE Trans. Evol. Comput., vol. 7, pp.83-94, Feb. 2003.
[12] Chao-Lung Chiang, "Improved genetic algorithm for power economic dispatch of units wih Valve point effects and Multiple fuels", IEEE Trans. Power syst., vol.20, No.4, pp. 1690-1699.
[13] S.Baskar, P.Subbaraj, and M.V.C.Rao "Hybrid real coded genetic algorithm solution to economic dispatch problem," Paragmon, Computers and Electrical Engineering, vol. 29, 2003, pp. 407-419.
[14] D.Bhagwan Das, C.Patvardhan "Solution of economic load dispatch using real coded Hybrid stochastic search," Electrical Power Energy System, vol. 22, 1999, pp. 165-170.
[15] P. S. Manoharan, p. S. Kannan, v. Ramanathan, "A Novel EP Approach for Multi-area Economic Dispatch with Multiple Fuel Options," Turk J Elec Eng & Comp Sci, Vol.17, No.1, 2009, pp.1-19