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Prohibited Operating Zones Constraint with Economic Load Dispatch using Genetic Algorithm

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Abstract— This paper present an efficient and reliable GA method for solving Economic Load Dispatch (ELD) problem with considering prohibited operating zone limits of thermal units. The objective of ELD problem is to minimize total fuel cost of thermal generating unit while maintaining generator constraints. A is a stochastic global technique developed by john Holland for solving optimization problem and inspired by the biological evolution process. This paper present an application of GA to determine the optimal loading of generator in power system where some of the unit have prohibited operating zones for 15 generator test case system. The result obtained using GA are compared with conventional method. The simulation result sow that GA method is capable of obtaining optimum solution and show reliable convergence.

***Key words*—Genetic algorithms, Economic load dispatch, prohibited operating zones.**

I. INTRODUCTION

In modern power system, ELD is one of the most important highly constrained nonlinear optimization problem.ELD determine the optimal combination of output power of all generating unit in order to minimize total fuel cost of generator plant, while satisfying an equality constraint and a set of inequality constrained. A various investigation has been done in this area to improve solution quality, as better solution would result in significant economical benefits. Previously, various algorithms and optimization technique have been employed to solve ELD problem. These methods include gradient method, base point participation factor, lambda iteration method. For the solution of ELD problem, the incremental cost curve is assumed monotonically increasing in all these methods'. But in practice, due to valve point loading, ramp rate limit, prohibited operating zone and multi fuel option etc, the input output characteristic of modern generator unit are highly nonlinear and discontinuous. Some of these techniques may not be able to produce good solution in large practical thermal generation. Even in this case, the solution could be far from optimal and very time consuming. A simplified input-output curve of thermal unit known as heat-rate curve as shown in fig1. Converting the ordinate of heat rate curve from Btu/h to Rs/h by multiplying the fuel input by the cost of fuel in Rs/Btu which result in fuel cost curve as shown in fig 2. In practice, all the operating zone of generator unit is not always available for load allocation due to physical operation limitation. Fault in generation machine or their associated auxiliaries occasionally exist. So prohibited operating zones could be formed between maximum and minimum generation limits. A unit with these prohibited zones results in unavailable amplification of shaft bearing vibration.

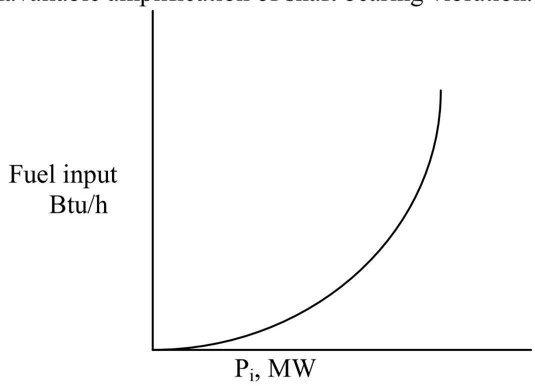

Fig. 1: Heart Rate Curve

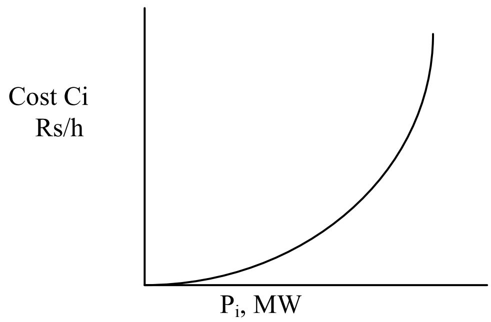

Fig. 2: Fuel Cost Curve

A unit with prohibited operating zones transforms the ordinary economic dispatch to a non convex optimization problem where the conventional based method cannot be applied. The discontinuous input output power generation characteristic provided by the unit with prohibited operating zones is shown in fig 3.

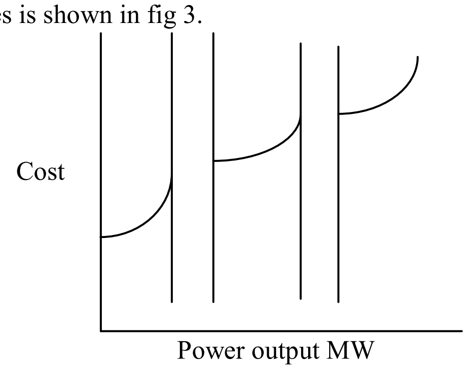

Fig. 3: Unit input/output characteristic

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Fan and McDonald and Lee and Breiphol solve the problem by performing a lambda iteration dispatch first, they dispatch the generation using some heuristic rules to search the neighborhoods of optimum solutions for feasibility, if some unit fall in infeasible region.

The paper explores the use of genetic algorithms techniques for solving such constrained economic dispatch problem with some unit having prohibited operating zones. This new optimization technique was first introduced by john Holland. GAs are optimization method employing search process imitated from the mechanism of biological selection and genetics[5].The GA optimization method has been employed to estimate the generation to be shared by each unit for a given plant load.

The remainder of this paper is organized as follow-section 2 provides a brief description and mathematical formulation of different type of ELD problem. In section 3, the concept of genetic algorithms is discussed. The section 4 shows the result. Finally, the conclusion and future work of research are outlines in section 5.

II. Problem Formulation

The economic load dispatch may be formulated as a non linear constrained problem. Both convex and non convex ELD problem have been modeled in this paper. The convex ELD problem assumes quadratic cost function along with system power demand and operational limit constraint. The practical non convex ELD problems, in addition, consider generator non linearity's as prohibited operating zones. The objective function F_t of ELD problem may be written as

$$Min\ F_t=\sum_{i=1}^{m} Fi(Pi) \qquad (1)$$

In (1), the fuel cost function Fi(Pi) of the ith generating unit is usually expressed as a quadratic polynomial:

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \qquad (2)$$

Where ai, bi, and ci, i=1, 2, 3…., m, are the fuel cost coefficient of ith generating unit, Pi is the power output of the ith generating unit. m is the total number of generating units .

Subjected to the constraints:

1. *Real Power Balance Constraint:*

$$\sum_{i=1}^{m} Pi = P_D + PL \qquad (3)$$

Where P_D is the total system demand and P_L is the total transmission loss and sit's expressed as

$$P_L=\sum_{i=1}^{m} \square * \sum_{j=1}^{m} P\ {}_iB_{ij}P_j + \sum_{i=1}^{m} B\ {}_{0i}P_i + B_{00} \qquad (4)$$

1. *Generator Capacity Constraint*: the power generated by each generator will be within their lower limit P_i^{min} and upper limit P_i^{max}. so that

$$P_i^{min} \le P_i \le P_i^{max} \qquad (5)$$

2. *Prohibited Operating Zones:* The Prohibited Operating Zones in the input–output performance curve for a typical thermal unit are because of a steam valve operation or vibration in the shaft. For unit i with POZs, the feasible operating zones can be described as follows:

$$P_i^{min} \le P_i \le P^l_{i,1} \qquad (6)$$

$$P^u_{i,j-1} \le P_i \le P^l_{i,j} \quad j=2,3,\dots\dots n_i \qquad (7)$$

$$P^l_{i,ni} \le P_i \le P_i^{max} \qquad (8)$$

Where j represents the number of prohibited operating zones of unit i. Pli,j is the lower limit of jth prohibited operating zone and Pui,j-1 is the upper limit of (j-1)th prohibited operating zone of ith unit. ni is the total number of POZ of ith unit.

It is noted that unit i with ni prohibited zones will have ni +1 disjoint operating regions. These disjoint regions form a non convex set.

III. Genetic Algorithm

Genetic algorithms are adaptive algorithms for finding the global optimal solution for an optimization problem. The genetic algorithms develop by john Holland is characterized by binary representation of individual solution, simple problem independent crossover and mutation operators and a proportional selection rule. Genetic algorithms operate on a population of potential solution applying the principal of survival of fittest to produce better and better approximation to a solution. At each generation, a new set of approximation is created by the process of selecting individual according to their level of fitness in problem domain. A flowchart for a genetic algorithm is shown in fig.4

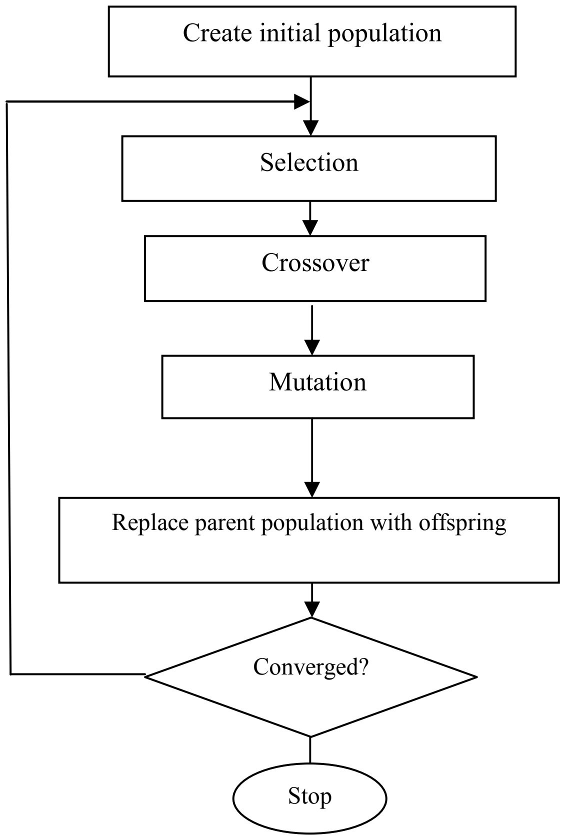

Fig. 4. Flow Chart

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Representation of parameter: In genetic algorithms, the parameters are represented as a string of binary number 0 and 1. So each parameter of given problem is coded with string of bits. The individual bit is called gene. The total string of such gene of all parameter written in a sequence is called chromosome. For example, if each parameter are x_i, i=1, 2, 3……n is coded in a string of length q, a parameter vector is represented using a string of total length nq. This string of total length nq is called chromosome. The general scheme of genetic algorithms starts from a population of randomly generated candidate solution (chromosome). If variable x is represented by a string of q binary digit and x_{max} and $x_{min}$are lower and upper bound of variable x, then its decimal value can be calculated by using this formula

$$X=x_{min}+ [b*(x_{max}-x_{min})/2^q-1] \quad (9)$$

Where b is a discrete value.

After selecting string representation, a random population of solution is generated. Then fitness is given to each population member, which represent the goodness of each solution .the string is evaluated in the context of objective function and constraints. If the constraint is absence, then objective function is treated as fitness function.

GA operator: - Genetic operators are used to generate new population from the previous population. These genetic operators are reproduction, crossover, and mutation.

Reproduction is the operator used to copy the old chromosome into matting pool according to their fitness. Chromosome with a high level of fitness is to be retained while the one with low level of fitness is discarded. The various method include roulette-wheel selection, tournament selection, rank selection, Boltzmann selection etc are used to select chromosome for parent to crossover. After reproduction, crossover operation is implemented. Crossover is the basic operator for producing new chromosome. In this, information is exchanged among string of matting pool to create new string. Crossover operator is proceeding in three steps. First, two individual string are selected from the matting pool generated by the reproduction operation. These are called parents chromosome. Then crossover sites are selected at random along the string length and then, the position value are swapped between two parents chromosome at crossover point. These are called child chromosome. This process is repeated until population is filled with new chromosomes. The final genetic operators are mutation. Mutation is a random process where one alley of gene is replaced by another to produce new genetic structure. Thus in mutation, 0 is changed to 1 and vice versa, at a random location.

Genetic algorithms is a very simple and straight-forward .reproduction select best string, cross-over operator recombine them to produce two better string and the mutation operator alter the string locally.

IV. ELD USING GENETIC ALGORITHM

For solution of ELD using GA, incremental fuel cost of the generators i.e. lambda is encoded in the chromosome. The algorithm for implementing ELD without losses using genetic algorithm is as follows.

1. Read population size, chromosome length, unit data, P_{demand}, Probability of Elitism, crossover and mutation.
2. Randomly generate population of chromosomes.
3. Decode the chromosomes using (6).
4. Lambda act=Lambda (min)+(Lambda (max-min)*Decoded lambda
5. Use the Lambda act and cost coefficients of the generators, and calculate real power output of the generators (P_{gen}).
6. Calculate the error of each chromosome as (SUM of P_{gen})-P_{demand}.
7. Fitness (i) of each chromosome is calculated as 1/ (1+error (i)/Pdemand).
8. Arrange the chromosomes in the descending order of their fitness.
9. Check if error (1), ≤0.0001*Pdemand
10. If yes STOP and calculate optimal fuel cost and P_{gen} of units Else
11. Check if Fitness (1) =Fitness (last chromosome)
12. If yes print 'All chromosomes have equal value', calculate optimal fuel cost and P_{gen} of units and STOP. Else.
13. Apply elitism, Reproduction (RWS), crossover and mutation and generate new population from old one.
14. Update generation count.
15. Check if Generation count>maximum generations?
16. If yes, print 'Problem not converged in maximum number of generations', STOP.
    Else
    Repeat from step 3.

V. SIMULATION RESULTS

The develop algorithm is tested on standard 15 generator. For every case the chromosome length, population size, probability of crossover, mutation considers with GA and conventional method. The test problem is based on a 15 unit power system [3] with 4of the unit having up to 3 prohibited operating zones. A 15 unit system is used to test the applicability of GA for solving the problem of constraint economic dispatch. The data are given in table 1 and Table 2 .Table 3 present results obtained for 15 generator system for power demand of 2630 & 2650 MW. The result obtained from proposed GA method has been compared with conventional method and Hopfield method. Their best solution is shown in table 4.

TABLE I: Unit characteristics

UNIT	A ($/H)	B ($/MWH)	C ($/MWH^2)	P_{MAX} (MW)	P_{MIN} (MW)
1	671.03	10.07	0.000299	150	455
2	574.54	10.22	0.000183	150	455

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3	374.59	8.80	0.001126	20	130
4	374.59	8.80	0.001126	20	130
5	461.37	10.40	0.000205	105	470
6	630.14	10.10	0.000301	135	460
7	548.20	9.87	0.000364	135	465
8	227.09	11.21	0.000338	60	300
9	173.72	11.21	0.000807	25	162
10	175.95	10.72	0.001203	20	160
11	186.86	10.21	0.003586	20	80
12	230.27	9.90	0.005513	20	80
13	225.28	13.12	0.000371	25	85
14	309.03	12.12	0.001929	15	55
15	323.79	12.41	0.004447	15	55

TABLE II: Unit prohibited operating zone

UNIT	PROHIBITED REGIONS		
	ZONE 1	ZONE 2	ZONE 3
2	[185,225]	[305,335]	[240,450]
5	[180,200]	[260,335]	[390,420]
6	[230,255]	[365,395]	[430,455]
12	[30,55]	[65,75]	

TABLE III: Output power generation

GENERATION IN MW	GA	
	LOAD DEMAND (MW) 2630	LOAD DEMAND (MW) 2650
PG1	415.31	452.4
PG2	359.72	455
PG3	104.42	130.963
PG4	74.98	129.1
PG5	380.28	337.1
PG6	426.79	428.5
PG7	341.31	466.4
PG8	124.78	60
PG9	133.14	27.6
PG10	89.25	27.1
PG11	60.5	25.7
PG12	49.99	54
PG13	38.77	25
PG14	41.94	15
PG15	22.64	15
FUEL COST ($/HR)	33113	32517
NO. OF GENERATION	1	1

VI. CONCLUSION

The application of GA method for the solution of economic load dispatch problem is demonstrated in this paper. The test result for the problem brings out the advantages of GA method. A 15 unit system with 4 units having prohibited operating zones was used for the application. The result is very good in the sense of accuracy and complexity. The method is attractive because there are few GA parameters to be set, result in less prior experimentation before application of the model. Best power output for 15 generator system wih prohibited operating zones.

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