A Real Coded Genetic Algorithm For Solving Combined Economic Emission Dispatch (CEED) With Practical Constraints

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***Abstract* –Due to the continual awareness program of society about the global warming and due to the alarming rate of raise in the pollutants in the atmosphere people raise questions concerning environmental protection. So there arises the necessity to reduce the amount of pollutants released from the power generating units. This paper introduces an efficient evolutionary programming based algorithm to solve a Bi-objective (fuel cost and emission objectives) optimization problem. The proposed method has been employed to handle the Equality (Power balance constraints) constraints, Inequality constraints(generator capacity constraints) and also practical constraints such as transmission losses, valve point loading and ramp rate limits and prohibited operating zones. These salient features make the proposed algorithm to be attractive in practical generator operation/large scale highly non-linear and complex systems. The feasibility of the proposed method is tested for various power demands on 3-generator test system, 6-generator test system and also with IEEE-30 bus system for various power demand. The solutions obtained are quite encouraging and useful in the practical economic emission environment.In the proposed work a real coded genetic algorithm is used to solve the problem of Combined Economic Emission Dispatch.**

***Index terms*-Multi-objective optimization problem, Combined Economic Emission Dispatch, Real Coded Genetic Algorithm, Valve Point Loading, Ramp Rate limits, Prohibited Operating Zones.**

I INTRODUCTION

Scheduling of power plant generation is of great importance for electric utility systems which is carried out in the power plants on the basis of least fuel cost strategies without considering pollutants released from the thermal generation.One of the prime concerns from social and environment aspects is that both human and non-human life forms are severely affected by the atmospheric pollution caused during generation of electricity from fossil fuels. This may give rise to the problem of global warming. Due to increasing concern over the environmental consideration [1],society demands adequate and secure electricity not only at the cheapest possible price, but also at minimum level of pollution. So the optimal scheduling of generation in a thermal power plant involves the allocation of generation so as to optimize the fuel cost and emission level simultaneously. The remote location of power plant from the load centre has been identified as one of the reasons which caused high cost. The increase in fuel cost these days has also contributed to this phenomenon. Therefore, economic load dispatch is implemented in order to determine the output (generation) of each generator so that the total generation cost will be minimized. The generator's output has to be varied within limits so as to meet a particular load demand and losses with minimum fuel cost [2].Thus, Economic load dispatch (ELD) is one of the important topics to be considered in power system engineering.

In addition, the increasing public awareness of the environmental protection and passage of clean Air Act Amendments of 1990 have forced the utilities to modify their design or operational strategies to reduce pollution and atmospheric emission of thermal plants such that the electricity using industry must decrease its SO2 emission by 10 million ton/year and the NOX by 2 million ton/year[3]. Apart from heat, power utilities using fossil fuel as primary energy source, produces harmful gasses such as CO2, SO2 and NOx, which cause detrimental effect on human being.

Different methods are offered for reducing emissions such as switching to fuels with low emission potential, installing post-combustion cleaning system e.g. electrostatic precipitators etc. This method of reduction of pollutants increases the total operating cost of the entire thermal power plant. To minimize the overall operating cost the CEED problem seems to be the preferred choice which is an excellent power management approach because it is easily implemented and requires minimal additional costs [4].

The solution of economic power dispatch or minimum emission problems, when attempted in isolation will be different and conflicting with each other. Therefore in order to solve these two objectives (economic and emission) simultaneously, the problem is formulated into multiobjective problem that concurrently reduce both fuel cost and total emissions. While the emission is reduced the fuel cost may be inappropriately increased or while the fuel cost is reduced the emission may be increased. This difficulty of Multi-objective CEED problem is overcome by changing the multi-objective into a single objective function with the help of a price penalty factor and linear weighted sum method. The Price penalty factor blends the fuel cost and emission output. Many researchers propose the price penalty algorithm based CEED problem. K.Srikrishna and C.Palanichamy have proposed a method for Combined Emission and Economic Dispatch (CEED) using price penalty factor**[5].**

Recently price penalty approach is presented for solving emission, reserve and economic load dispatch (ERELD) problem with non-smooth and non-convex cost functions problem[6]. Over the past decade, the later approach has attracted many researchers' interests due to the new development of multi-objective evolutionary search techniques. Multi-objective evolutionary algorithms like Evolutionary programming (EP)**[7]**, Particle swarm optimization (PSO)**[8]**, Binary coded GA**[9]** have been introduced to solve the CEED problem. In addition, some other optimization approaches, such as fuzzy satisfaction maximizing technique **[10]**and genetic and evolutionary programming based hybrid approaches have been proposed [11],[12],[13].

Certain evolutionary programming based hybrid optimization methods have some problems like more time for optimization, operation complexity, etc.. To overcome this problem real coded (continuous) genetic algorithm is proposed to solve the CEED in addition to loss minimization. In this optimization method, the output of each generating unit is represented by a floating point number, instead of binary coding, resulting in absolute precision. Hence dependence of accuracy on string length (number of bits) is eliminated. However, when the variables are continuous, it is more logical to represent them by floating-point numbers due to which it requires less space, inherently faster and also reduces the chances of error occurrence.

For convenience in solving the ED problem, the unit generation output is usually assumed to be adjusted smoothly and instantaneously. Practically, the operating range of all online units is restricted by their ramp rate limits for forcing the units operation continually between two adjacent specific operation period. In addition, the prohibited operating zones in the input-output curve of generator are due to steam valve operation or vibration in the shaft bearing. Because it is difficult to determine the prohibited zone by actual performance testing or operating records. The best economy is achieved by avoiding operation in areas that are in actual operation. Hence, the nonlinearconstraints (valve point loading and ramp rate limits and prohibited operating zones) of generator operation must be taken into account to achieve true economic operation.

II PROBLEM FORMULATION

2.1*Mathematical Model for Combined Economic Emission Dispatch*

The economic dispatch and emission dispatch are considerably different. Because of this conflicting nature of these two objectives it is necessary to find an operating point that makes a balance between fuel cost and emission which is possible by means of CEED problems. The Combined Economic Emission Dispatch problem is to minimize simultaneously the two competing objective functions fuel cost and emission while satisfying all equality, inequality and practical/non-linear constraints.

Since CEED problem deals with two single objectives,the mathematical model for the above problem is described as follows:

$TC = \mathrm{Min}\left(\sum_{i=1}^{Ng}[\,F_i\,(P_i), E_i(P_i)]\right)$Rs/hr2.1Where

$F_i(P_i) = \ a_i{*}P_i^{\,2} + b_i * P_i + C_i$ [fuel objective]

$E_i(P_i) = \ d_iP_i^{\,2} + e_i * P_i + f_i$[Emission objective]

TC-the total operating cost objective function

Ng - the total number of generators in operation

$F_i(P_i)$ - the fuel cost of i^th^ generating unit in Rs/h

$E_i(P_i)$ - the Emission output of i^th^ generating unit in Kg/hr

a_i, $b_i$and c_i - fuel cost co-efficient of i^{th}generating unit

d, e_i and f_i- Emission co-efficient of i^{th} generating unit

Subject to

$$\sum_{i=1}^{ng}(P_i) = P_D + P_{Loss} \qquad 2.2$$

$$P_{i,min} \leq P_i \leq P_{i,max} \qquad 2.3$$

Where

P_D -Power Demand in MW

$P_{i,min}$ -Minimum power generation limit of the i^{th}unit in MW

$P_{i,max}$ -Maximum power generation limit of the i^{th}unit in MW

The first constraint given by equation(2.2) represents the equality constraint of power balance conditions. Constraint equation(2.3) represents

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inequality constraints of generation real power limits.

2.2 Transmission Loss Constraints

Since there is no electrical network without loss, the transmission losses between two generating units must be accounted in order to have an exact CEED problem. In this proposed method transmission loss is calculated using B-Coefficient's method which can be expressed as

$$P_{Loss} = \sum_{i=1}^{Ng}\sum_{j=1}^{Ng} P_i B_{ij} P_j + \sum_{j=1}^{Ng} B_{0i} + B_{00} \quad \text{in MW}$$

Where

P_i -power generation of the i^{th} unit in MW
P_j -power generation of the j^{th} unit in MW
B_{ij} -the loss coefficientsbetweenith and jth generating unit in MW
P_{Loss} -the power loss in MW

The B-loss coefficients are constant under certain assumed conditions. The above loss formula is called as George's formula[21].

2.3.CEED Problem Considering Practical Operation Constraints Of Generator

As all the thermal generating units are having some non-linear characteristics in their operation, inorder to make the solution to be practical those non-linearities such as valve point effect, generator ramp-rate limits and prohibited operating zones must be considered while solving problem.Here those non-linearities are presented as follows.

2.3.1 Valve Point Loading

For more rational and precise modeling of economic and emission function, the above expression of cost function is to be modified suitably. Modern thermal power plants are designed to have generating units with multi-valve steam turbines to incorporate flexible operational facilities but it gives a very different cost curve and exhibits a greater discrepancy in the fuel cost curves. Typically, ripples are introduced in the fuel cost curve as each steam valve starts to operate.

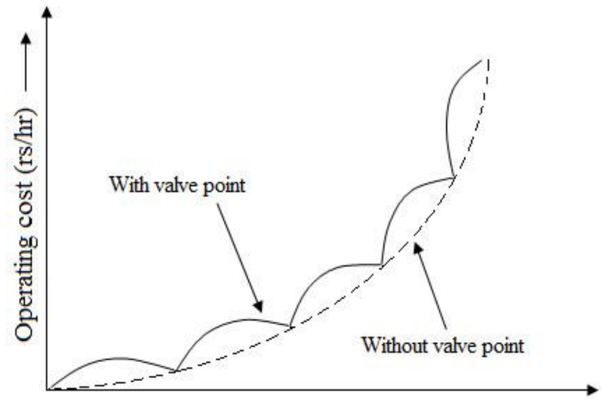


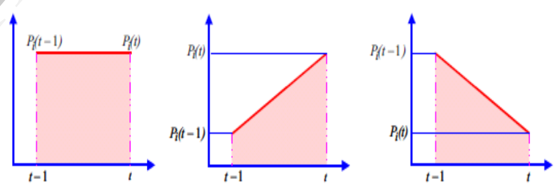
Fig.1. Valve point loading curve

The valve-point effect may be considered by adding a sinusoidal function to the quadratic cost function described above. Hence, the problem described is revised as follows:

$$F_i(P_i) = a_i * P_i^2 + b_i * P_i + c_i + |d_i * \sin(e_i * P_i^{min} - P_i)|$$

Where $F_i(P_i)$ is total fuel cost of generation in ($/hr) including valve point loading, d_i ,$e_i$are fuel cost coefficients of the ith generating unit reflecting valve-point Effect.

2.3.2 Ramp Rate Limit



The inequality constraints due to ramp rate limits for unit generation changes are given in terms of

1) as generation increases

$$P_i - P_i^0 \leq UR_i$$

2) as generation decreases

$$P_i - P_i^0 \leq DR_i$$

Fig.2 Generator ramp rate limit curves

Where P_i^0 is the power generation of uniti at previous hour and $UR_i$and$DR_i$are the upper and lower ramp rate limits respectively. The inclusion of ramp rate limits modifies the generator operation constraints as follows[22],

$$\text{Max}(P_i^{min}, P_i - P_i^0) \leq P_i \leq \text{Min}(P_i^{max}, P_i - P_i^0)$$

2.3.3 Prohibited Operating Zone

Due to steam valve operation or vibration in a shaft bearing there are some restricted zones identified in the input-output curve. Because it is difficult to determine the prohibited zone by actual performance testing or operating records, the best economy is achieved by avoiding operation in areas that are in actual operation. Symbolically, for a generating unit i, where *j* is the number of prohibited zones of unit[8]

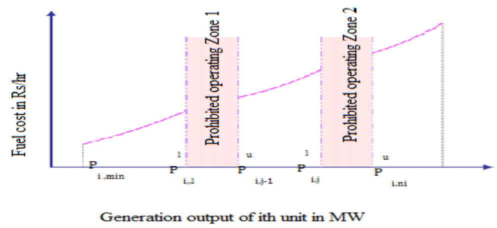


Fig.3Two Prohibited Operating Zones Function cost Curve

$P_{i,min} \leq P_i \leq P^l_{i,1}$
$P^u_{i,j-1} \leq P_i \leq P^l_{i,j}$ j=1,2, n
$P^u_{i,ni} \leq P_i \leq P_{imax}$
Where *j* is the number of prohibited zones of unit.

2.4 Modified Price Penalty Factor Algorithm

Since the CEED problem is of conflicting in nature(i.e Minimization cost increases emission and vice versa), a price penalty factor(PPF) method has been chosen as a suitable method to convert a bi-objective problem into a single objective. A practical way of determining PPF is discussed by Palanichamy and Srikrishan[14]. Since the above price penalty factor algorithm provide an approximate value of price penalty factor for the power demand, an accurate method of determining price penalty factor called as Modified Price Penalty Factor(MOPPF) Algorithm is used in this work. Determination of MOPPF is gives as follows.

Step1:Evaluate the Maximum cost of each generator at its maximum output is

$$F_i\,(P_{imax}) = a_i * P_i^2 + b_i * P_i + C_i \text{Rs/hr}$$

Step2: Evaluate the Maximum No_x emission of each generator at its maximum output is

$$E_i\,(P_{imax}) = d * P_i^2 + e_i * P_i + f_i \qquad \text{Kg/hr}$$

Step3: Divide the Maximum cost of each generator by its average No_x emission, i.e

$$\frac{F_i\,(P_{i\,max})}{E_i\,(P_{i\,max})} = \frac{(a_i * P_i^2 + b_i * P_i + C_i)}{d * P_i^2 + e_i * P_i + f_i}$$

Recalling that

$$\frac{F_i\,(P_{i\,max})}{E_i\,(P_{i\,max})} = h_i \quad \text{Rs/kg}$$

Step4:Arrang h_i $(i = 1,2 \ldots \ldots . NG)$ in ascending order
h= $[h_1, h_2, h_3 \ldots h_n]$

Step5: Let P_m be the vector having the maximum values of the respective h Values
$P_m = [P_{m1}, P_{m2}, \ldots\ldots\ldots\ldots, P_{mn}]$
Let m be the vector having
$m = [m_1, m_2, \ldots\ldots, m_n]$
where$m_{i+1} = m_i + P_{mi+1}$

Step6: Add the maximum capacity of each unit,P_{mi} one at a time until

Case1:If the load demands $P_D = m_i$, then
$h_m = h_i$ is the modified price penalty factorRs/kg for the given load

Case2: If the load demand P_D is between m_i and m_{i+1}, then

$$h_m = h_i + \frac{(h_{i+1} - h_i)}{(m_{i+1} - m_i)} * (P_D - m_i)$$

Where h_m is the Modified Price penalty factor in Rs/Kg, which is fixed for a load demand.

2.5 Complete Optimization Problem

The complete CEED optimization problem using Modified Price Penalty Factor is determined by using the following equation.

$$\text{Minimize TC} = \text{Min}\left(\sum_{i=1}^{ng} [F_i\,(P_i) + hm * E_i(P_i)]\right) \quad \text{(Rs/hr)}$$

h_m is the Modified penalty factor in Rs/kg
TC isthe total operating cost objective function

III REAL CODED GENETIC ALGORITHM

3.1 An Introduction to Genetic algorithm

A Genetic Algorithm (GA) is an iterative procedure which begins with a randomly generated set of solutions referred as initial population. For each solution in the set, objective function and fitness are calculated. On the basis of these fitness functions, pool of selected population is formed by selection operators; the solution in this pool has better average fitness than that of initial population. The crossover and mutation operator are used to generate new solutions with the help of solution in the pool. The process is repeated iteratively while maintaining fixed number of solutions in pool of selected population. As the iteration progresses, the solution improves and optimal solution is obtained.

During the selection process of the GA, good solutions are selected from the initial generated population for producing offspring. Good solutions are selected randomly from the initial generated population using a mechanism which favors the more fit individuals. Good individuals will probably be selected several times in a generation but poor solutions may not be selected at all.

3.2 Structure of Real coded Genetic algorithm for solving CEED Problem formulation

In this paper, real coded genetic algorithm (RGA) is used as an optimization tool for solving the Combined Economic and Emission (CEED) problem formulation. Real coded genetic algorithm does not need any coding and decoding, where it seems to be faster and more accurate than binary GA. Similar to ordinary GA, RGA operators are: selection, crossover and mutation. These terms are explained in the following sections.

3.3 Crossover

The task of crossover is the creation of new individual, out of the two individual of the current population. Simple arithmetic blend crossover type is used in this paper, shown in equation(3.1).

$$O_1 = \lambda_1 P_1 + (1-\lambda_1)P_2$$
$$O_2 = \lambda_2 P_2 + (1-\lambda_2)P_1,\ \ \lambda_1, \lambda_2 \in [0,1] \quad 3.1$$

Where, P_1, $P_2$are the two parents, O_1, $O_2$are their two offspring and λ_1, λ_2 are the two random numbers.

3.4 Mutation

Mutation is for introducing artificial diversification in the population to avoid premature convergence, which corresponds to a local optimum. In this work, simple real mutation type is used, as shown in the equation (3.2).Here it is assumed that for a given parent P, if the gene $O_k$is selected for mutation, then theresulting gene will be selected by using equation

$$O_k = a_k + (b_k - a_k) * r \quad 3.2$$

Wherea_k, b_k are lower and upper bands of $O_k$and r ∊ [0, 1].

3.5 Selection and Survival of fittest

As GAs depicts the natural phenomena, the best individuals survive by competing others. These individuals are selected using roulette wheel with slot sized according to fitness, so that the probabilities of selecting best strings are higher.

3.6 Fitness Evaluation

In the CEED problem of determining minimum operating cost considering the fuel cost and emission output, the goal is to minimize the objective function

$$TC = Min\left(\sum_{i=1}^{ng} [F_i(P_i) + h * E_i(P_i)]\right)$$

and with the equality constraints

$$\sum_i P_i - P_D - P_{Loss} = 0, \quad i = 1,2, \ldots .Ng.$$

is changed to an unconstrained optimization problem using the penalty functions (PF) as given in equation .This becomes the fitness function

$$\text{Fitness function} = TC + PF * \phi \quad 3.3$$

Where$\phi = \sum_{i=1}^{ng} P_i - P_D - P_{Loss} = 0$

The Second term ϕ in the equation (3.3) is the power balance equation. The Penalty function placed in the objective function penalizes any violation of the constraints and forces the unconstrained optima towards the feasible region. This second term becomes zero during the initialization of fitness function and it gets a non-zero value after mutation only if generator vector violate its limit. Therefore, only F1 becomes the fitness function and is computed for the offspring vector similar to the parent vector.

IV.REAL CODED GENETIC ALGORITHM FOR SOLVING CEED OPTIMIZATION PROBLEM

The real coded genetic algorithm has been structured as follows

Step1 : Read the Power Demand P_D
Step2 : Calculate the price penalty factor (h_m) using Modified price penalty factor algorithm
Step3 : Initialize the iteration iter =1
Step4 : Generate n population vector of generatorreal power based on ramp limit and prohibitedzone constraints
Step5 : Calculate the fitness function using (3.3)
Step6 : Select n population size of parent using Roulette wheel selection method
Step7 : Generaten population size child using equation (3.1)
Step8 :Non-repeated Mutated child formation equationusingequation(3.2)
Step9 : Increment the iteration iter =iter+1

Step10 : Checkiter is greater than maximum iter , If yes go to step 5 otherwise go to step11

Step11 :Print the Minimized operating cost and the corresponding Fuel cost, Emission output, Generator schedule

The flowchart of proposed real coded genetic Algorithm for solving the CEED problem is in Fig.4

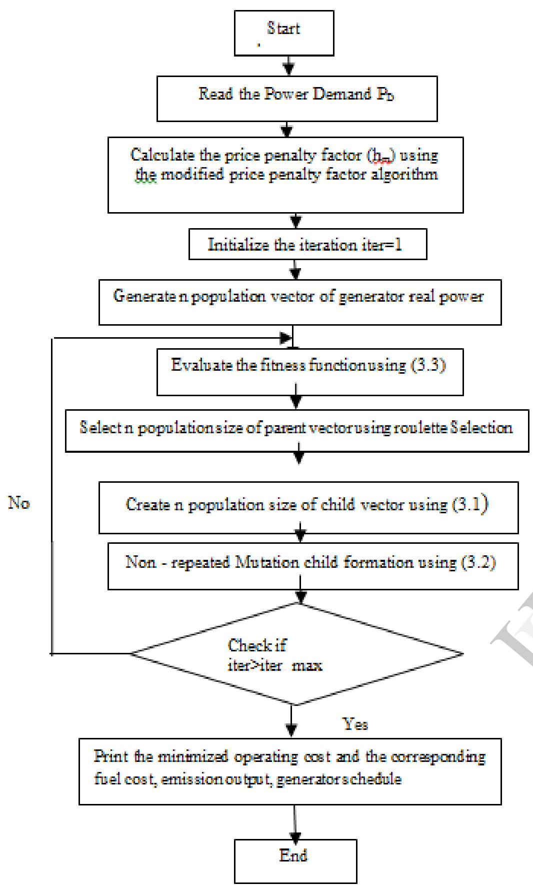


Fig.4 Flowchart of Real coded Genetic Algorithm for solving the CEED problem

V RESULTS AND DISCUSSION

The efficacy and viability of the proposed method is tested with 3-generator test system, 6-generator test system and IEEE 30 bus system respectively considering non linearity practical constraints such as transmission losses, ramp rate limits, prohibited operating zone and valve point effect. The performance of each system has been compared with other methods like PSO, GA etc. The coding has been written in MATLAB 7.10 and run on a 3.0 MHZ, 1GB RAM.

5.1Three-Unit Thermal System

The system consists of three-thermal units. The generator cost coefficients, emission coefficients and generation limits, Bmn coefficient matrix are given in [15],[16]. The proposed Real Coded Algorithm for solving Combined Economic and Emission dispatch for the first test case is tested with the five load demandwhich is given in table 5.1

Table 5.1 Load Demand details for 3- Unit Thermal System

S.No	Load Demand
1	350 MW
2	400 MW
3	450 MW
4	550 MW
5	600 MW

Table 5.2 CEED Solution of Three-Generator System

	Power Demands (MW)				
	350`	400	450	550	600
P1 (MW)	88.4275	102.5864	115.6740	142.0743	155.6327
P2 (MW)	135.1281	153.6839	173.0219	212.1404	231.7087
P3 (MW)	132.0988	151.1419	170.7305	210.0032	229.6589
Fuel cost (Rs/h)	18587.07	20836.92	23139.27	27903.67	30368.08
Emission (Kg/hr)	158.5442	199.4818	249.8745	379.7289	459.4187
PPF(Rs/K)	43.4265	43.6865	43.9465	44.4665	44.7265
Total ystem loss (MW)	5.6545	7.4122	9.4264	14.2179	17.0001
Total Cost (Rs/h)	25472.09	29551.68	34121.08	44788.89	50916.27

The CEED Solution of Three-Generator System for all the power demand considered is given in Table 5.2. First row shows the optimal scheduling of the three-Generator units for each power demand. Second row and third row shows the minimized fuel cost in Rs/hr and emission output level in kg/h. Fourth row shows price penalty factor obtained from modified price algorithm in Rs/kg for different power demand. Fifth row shows system loss in MW. Sixth row shows the optimal total cost in Rs/hr at which the system fuel cost and emission level is minimized. The convergence characteristics of minimum total cost obtain using real coded Genetic algorithm for the power demand of 350MWconsidered is shown in Fig.5.1 From the table, it can be observed that the cost required for generating the required power increases as the power demand rises. Also, the emission output rises as the power demand rises.

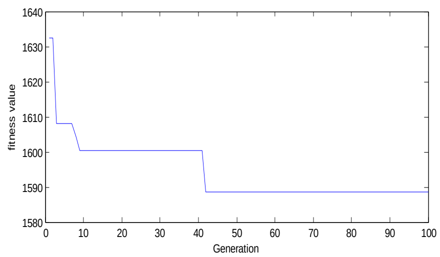


Fig.5.1Convergence characteristics for350MW load demand

The proposed Real coded genetic algorithm (RGA) technique is evaluated with the results of optimization techniques like Particle Swarm Optimization (PSO) and Binary Genetic Algorithm (GA) proposed by Lakshmi et.al [17].The fuel cost required by various techniques is provided in table 5.3. From the result, it can clearly suggest that the proposed technique is better which required lesser cost for the system operation when compared to other technique .The emission resulted for using PSO, GA and RGA for various power demands is provided in table 5.4. The emission resulted for using the proposed optimization technique is very much reduced when compared to the other techniques. This case is true not only for particular power demand rather it is true for all cases. By considering the overall result, it can be suggested that the usage of proposed technique will reduce the fuel cost as well as the emission output; Hence the total operating cost of the system is minimized and its comparison with other techniques is given in Table 5.5

Table 5.3 Fuel Cost (Rs/hr) for Different Optimization Techniques

Optimization Techniques	Power Demand (MW)				
	350`	400	450	550	600
GA	18591.8	20840.1	23142.6	27905.4	30372.3
PSO	18589.2	20838.3	23140	27904.1	30368.2
RGA	18587.0	20836.9	23139.2	27903.6	30368.0

Table 5.4 Emission Output (kg/h) for Different Optimization Techniques

Optimization Techniques	Power Demand (MW)				
	350`	400	450	550	600
GA	159.118	200.256	250.929	381.258	461.352
PSO	159.076	200.221	250.866	381.216	461.207
RGA	158.5442	199.4818	249.8745	379.7289	459.4187

Table 5.5 Total Operating Cost (Rs/h) for Different Optimization Techniques

Optimization Techniques	Power Demand (MW)				
	350`	400	450	550	600
GA	25481.6	29563.2	34138.2	44810	50948
PSO	25477.2	29559.2	34132.8	44806.8	50937.3
RGA	25472.1	29551.6	34121.08	44788.89	50916.2

5.2 Six-Unit Thermal System

The system consists of six-thermal units. The generator cost coefficients, emission coefficients and generation limits, Bmn coefficient matrix are given in Appendix. The proposed Real Coded Algorithm for solving Combined Economic and Emission dispatch for the first test case is tested with the three load demand is given in table

Table 5.6Load Demand details for 3- Unit Thermal System

S.No	**Load Demand**
1	700 MW
2	900 MW
3	1100 MW

The CEED Solution of Three-Generator System for all the power demand considered is given in Table 5.6. First row shows the optimal scheduling of the Six-Generator units for each power demand. Second row and third row shows the minimized fuel cost in Rs/hr and emission output level in kg/h. Fourth row shows price penalty factor obtained from modified price algorithm in Rs/kg for different power demand. Fifth row shows system loss in MW. Sixth row shows the optimal total cost in Rs/hr at which the system fuel cost and emission level is minimized. The convergence characteristics of minimum total cost obtain using real coded Genetic algorithm for the power demand of 900MW is shown in Fig.5.2. From the table 5.7, it can be observed that the cost required for generating the required power increases as the power demand rises. Also, the emission output rises as the power demand rises.

Table 5.7 CEED Solution of Six-Generator System

	Power Demand (MW)		
	700	900	1100
P1 (MW)	60.7202	88.2929	112.0472
P2 (MW)	61.5230	95.2998	133.9136
P3 (MW)	117.7257	151.5128	189.7779
P4 (MW)	120.6014	149.0817	178.7373
P5 (MW)	176.5699	225.7344	270.0510
P6 (MW)	179.9687	217.5239	257.3060
Fuel cost (Rs/h)	37481.41	48224.73	59872.05
Emission (Kg/h)	438.76	694.42	1034.244
PPF (Rs/Kg)	44.320	45.29	50.19
Totalsystemloss(MW)	17.1059	27.4455	41.8330
Total Cost (Rs/h)	56930.46	79678.46	111780.7

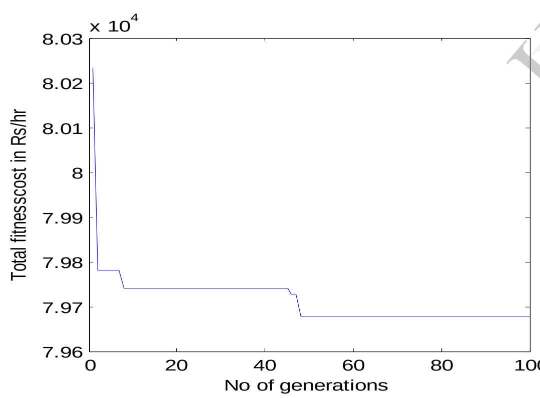


Fig.5.2. Convergence characteristics of RGA for the load demand 900 MW

The proposed Real coded genetic algorithm (RGA) technique is evaluated with the results of optimization techniques like Evolutionary Programming (EP) and Conventional Lambda iteration Method proposed by Venkatesh et al [18]. The fuel cost required by various techniques is provided in table 5.8. From the result, it can clearly suggest that the proposed technique is better which required lesser cost for the system operation when compared to other technique .The emission resulted for using Conventional Method, EP and RGA for various power demands is provided in table 5.9 and an illustration for power demand of 700 MW is shown in Fig.5.3 The emission resulted for using the proposed optimization technique is very much reduced when compared to the other techniques. This case is true not only for particular power demand rather it is true for all cases. By considering the overall result, it can be suggested that the usage of proposed technique will reduce the fuel cost as well as the emission output; Hence the total cost of the system is minimized and its comparison with other techniques is given in Table 5.10 .

Table 5.8 Fuel Cost (Rs/hr) for Different Optimization Techniques

Optimization Techniques	Power Demand (MW)		
	700	900	1100
Conventional	37781	48892	61208
EP	37519	48318	59929
RGA	37481.41	48224.73	59872.05

Table 5.9 Emission Output (kg/h) for Different Optimization Techniques

Optimization Techniques	Power Demand (MW)		
	700	900	1100
Conventional	442	701	1044
EP	439	695	1035
RGA	438.76	694.42	1034.244

Table 5.10 Total Fuel Cost (Rs/h) for Different Optimization Techniques

Optimization Techniques	Power Demand (MW)		
	700	900	1100
Conventional	57573	82413	61208
EP	56975	79749	111875
RGA	56930.46	79678.46	111780.77

5.3 CEED with Practical constraints on IEEE 30 bus system

The IEEE 30 bus system consists of six-thermal units and 41 transmission Lines. The generator cost coefficients, emission coefficients with valve point data and generation limits with ramp rate and prohibited zone data, Bmn coefficient matrix, are taken from [19].The proposed Real Coded Algorithm for solving Combined Economic and Emission dispatch for the above two case provide better results compared to other optimization techniques. Hence the proposed RGA method is used to solve the CEED for IEEE 30 bus system with practical constraints having the load demand of 283.4 MW. The CEED Solution of IEEE 30 bus system all the power demand considered is given in Table 5.11. First row shows the optimal scheduling of the Six-Generator units for each power demand. Second row and third row shows the minimized fuel cost in Rs/hr and emission output level in kg/h. Fourth row shows price penalty factor obtained from modified price algorithm in Rs/kg for different power demand. Fifth row shows system loss in MW. Sixth row shows the optimal total cost in Rs/h at which the system fuel cost and emission level is minimized. The convergence characteristics of minimum total cost obtain using real coded Genetic algorithm for the power demand considered is shown in fig 5.3

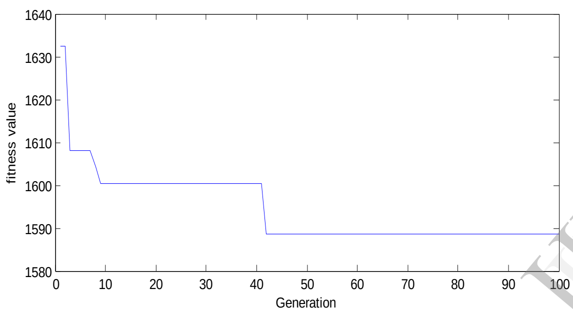


Fig .5.3. Convergence characteristics of RGA For the load demand 700 M

Table No.5.11 CEED Solution of IEEE-30 bus System for Demand of 283.4MW

	Power Demand (MW)
	283.4
P1 (MW)	145.0345
P2 (MW)	46.6183
P3 (MW)	27.0315
P4 (MW)	18.3124
P5 (MW)	23.9825
P6 (MW)	30.8432
Fuel cost ($/h)	864.8706
Emission (Kg/h)	364.3277
PPF ($/Kg)	1.9862
Total system loss (MW)	8.4224
Total Cost ($/h)	1588.4928

5.4 Determination of Parameters for ProposedAlgorithm

The parameter values are selected by trial and error method.Inorder to obtain the optimal solution for implementing this CEED problem using GA, the population size of 50, maximum generation of 100, Crossover Probability of 0.5, Survival Selection Probability of 0.8 has been taken for optimization problem. Programs are developed and simulated using MATLAB 7.10 software package tool.

VI. CONCLUSION

The Proposed RGA algorithm was tested on 3-generator test system and 6-generator test system for determining the minimum operating cost by minimizing the fuel cost and emission output of the Combined Economic and Emission dispatch problem (CEED) and the results were presented for comparison with various optimization techniques such as Binary coded GA, EP, PSO and Conventional lambda iteration method. Results showed that RGA method is well suited for obtaining the best solution for operating cost, fuel cost and Emission output. Savings of approximately 25 Rs/hr and above were obtained by the RGA method for six generator test system. The modified price penalty factor to solve CEED problem corresponding to the load demands was carried out to obtain exact best solution. The Proposed RGA is also tested with IEEE 30 bus system by considering the non-linearity practical constraints such as transmission losses, ramp rate limits, and prohibited operating zone and valve point effect. Practical generator operation has been modeled by this proposed methodology since more realistic constraints have been incorporated. The solutions obtained are quite encouraging and useful in the practical economic emission environment.

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