

# Combined Economic and Emission Dispatch by using Hybrid PSO-GA with Real and Reactive Power Constraints

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**Abstract** — This paper uses a hybrid PSO-GA for solving the combined economic and emission dispatch problems with real and reactive power constraints. The objective of Economic Load Dispatch is to minimize the overall cost of generation with required constraints. This paper concentrates on both the total production cost and total emission taken into account with satisfying constraints. Hybrid PSO-GA algorithm combines the advantage of PSO and GA. PSO algorithm can be used during the first stage of solving the optimization problem near the global optima. The last particle of the PSO is taken as the initial population of GA and it continues to further refine the optimized solution.

**Keywords** — GA, hybrid PSO-GA, Combined economic and emission dispatch (CEED).

## I. INTRODUCTION

Economic load dispatches is one of the most important functions in electrical power system operation, control and planning. In general, the main objective of economic load dispatch is to reduce the total production cost of the generating scheme while the necessary equality and inequality constraints must be satisfied, such as CEED [1]-[2]. At the present time thermal power plants account for the grand majority of generating installation in India. Thermal power plants discharge additional pollutants into the atmosphere. Because of the coal used in plant is of high ash and meager quality. Various pollutants from the thermal power plants include carbon dioxide (CO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>) and nitrogen oxide (NO<sub>x</sub>). Power sector is responsible for great part of total greenhouse emission in the world. This will cause bad effects on human being as well as on animals. Regulatory agencies on environmental protection are forcing energy system engineering to include environmental aspects along with economic consideration. In this paper both total production cost of generating unit as well as total emission is consider. Various researchers already done work in this field with real power equality and inequality constraints such as combined economic and emission dispatch (CEED) by using, GA [2], hybrid GA [6], SFLA [4], PSO [8].but this paper propose combined economic and emission dispatch with real and reactive power equality and inequality constraints.

This paper compare a GA and hybrid PSO-GA for solving combined economic and emission dispatch with real and reactive power constraints for IEEE 30 bus systems.

## II. PROBLEM FORMULATION

### A. Economic Dispatch

The economic load dispatch (ELD) problem is to find the best combination of power generation from each generating unit that minimizes the total fuel cost while satisfying the total demand and power system constraints [14]. The total fuel cost function of ELD problem is defined by following quadratic equation.

Let the net fuel input cost per hour be  $F_T$  which is the summation of fuel costs per hour of each of the units obtained by the generated power.

$$F_T = \sum_{i=1}^n F_i(P_i) = \sum_{i=1}^n a_i P_i^2 + b_i P_i + c_i \dots (1)$$

Where,  $F_i(P_i)$  is the cost of  $i^{\text{th}}$  generator in Rs/h;  $P_i$  is the real power output of generator  $i$  in MW,  $a_i$ ,  $b_i$  and  $c_i$  are the cost coefficients of the  $i^{\text{th}}$  generator.

Equality constraint of the problem Subject to the real power and reactive power balance as given below

$$\sum_{i=1}^n P_i - P_L - P_D = 'p$$

$$\sum_{i=1}^n Q_i - Q_L - Q_D = 'q$$

Where,  $P_i$  and  $Q_i$  is the real and reactive power output of generator  $i$  in MW.

$P_L$  And  $Q_L$  is the real and reactive power loss in MW it can be calculated by using load flow technique.

$P_D$  And  $Q_D$  is the real and reactive power demand in MW.

$'p$  And  $'q$  being the residual real and reactive power and should approach zero during steady state power system operation.

Inequality constraint of the problem Subject to the real power and reactive power limits of the generation outputs are

$$P_{i \min} < P_i < P_{i \max}$$

$$Q_{i \min} < Q_i < Q_{i \max}$$

Inequality constraints stress to generate real and reactive power from particular generating unit between its minimum and maximum value.

### B. Emission Dispatch

The amount of emission is not considered in pure ELD problem. The amount of emission from a fossil-fired generating unit depends on the amount of power generated by the unit. Total emission generated also can be approximated as sum of a quadratic function and an exponential function of the real power output of the generators.

The emission dispatch problem can be described as the optimization of total amount of emission being released defined by as:

$$E_T = \sum_{i=1}^n (\alpha_i P_i^2 + \beta_i P_i + \gamma_i) \quad \dots (2)$$

Where,

$n$  is the total number of generating units

$E_T$  is the total pollutant emission (lb/h)

$P_i$  is the power output of generating unit  $i$

$\alpha_i$ ,  $\beta_i$  And  $\gamma_i$  are emission coefficients of unit  $i$

### C. Combined Economic and Emission Dispatch (CEED)

The economic dispatch and emission dispatch are two distinct problems. Emission dispatch can be included in conventional economic load dispatch problems by the adding of emission cost to the normal dispatch cost. Actually, CEED problem have two objectives. But CEED can be converted into single objective optimization problem by introducing a price penalty factor  $h$  (Rs/lb) as follows:

$$h = \frac{F_T(P_{i,max}) / P_{i,max}}{E_T(P_{j,max}) / P_{j,max}} \quad \dots (3)$$

Where,

$h$  is the price penalty factor

$i$  is the highest fuel-cost unit

$j$  is the highest pollutant-emission unit

The combined objective function of the economic and emission dispatch is assigned by the following expression.

$$\phi_T = F_T + hE_T \quad \dots (4)$$

Where,

$F_T$  Is the total fuel cost and  $E_T$  is the total emission cost.

## III. GENETIC ALGORITHM

Genetic algorithm is introduced in the 1970 by John Holland. It is a universal search technique based on the means of natural choice and natural genetics-like operator [9]. There are mainly three operators in genetic algorithm like reproduction; crossover; and mutation they described in details in [10]. They search a global optimum by moving from a previous population of individuals to a novel population by using its operators.

### A. Functioning Of GA Is Finished By Performing The Following Assignment.

#### a) Coding

In order to use genetic algorithm to solve optimization problem variable of the problem are primary coded in some string structure. The span of the string is usually determined according to the desired solution correctness. After coding of the variable individual string are selected and this string can be found to represent a point in the search space according to fixed mapping rule

$$X_i = X_i^l + \frac{X_i^u - X_i^l}{2^\beta - 1} \sum_{j=0}^{\beta} \gamma_j 2^j \quad \dots (5)$$

In the above equation, the variable  $x_i$  is coded with sub-string  $s_i$  of length  $\beta$ . The decoded value of a binary sub-string  $s_i$  is calculated as

$$\sum_{j=0}^{\beta} \gamma_j 2^j$$

Where,  $S = (s_{\beta-1} s_{\beta-2} \dots \dots s_2 s_1 s_0)$

#### b) Fitness Function

Genetic algorithm is suitable for solving the maximization problem but minimization problem are also solve by GA by converting a minimization problem to maximization by using suitable transformation. For maximization problem fitness function equal to objective function.

$$F(x) = O(x)$$

In case of minimization problem fitness function can be obtained by using a suitable transformation one of them is given below.

$$F(x) = \frac{1}{1 + f(x)} \quad \dots (6)$$

Where  $F(x)$  the fitness is function and  $f(x)$  is the objective function.

#### c) GA operators

There are mainly three operators in genetic algorithm.

##### i. Reproduction

Reproduction is an operator that makes more copies good string in a new population and form a mating pool. Individual string is selected for mating pool its probability depends upon its fitness.

The probability for selecting the  $i^{\text{th}}$  string is

$$P_i = \frac{F_i}{\sum_{i=1}^n F_i} \quad \dots (7)$$

##### ii. Crossover

A crossover operator is used to recombine two strings to obtain an improved string. It is important to note that two strings is taken from the mating pool it is called parent string and some portion of the parent string is exchange and get a new string known as children string. In a crossover operator random number (between 0 and 1) is generated for individual bit of the string .whenever random number is less than the crossover probability after that bit whole information is exchange and gets a new string. Crossover probability is always greater than 0.5.

##### iii. Mutation

Mutation is an operator that adds new information in a random way to the genetic search process and finally helps to keep away from getting trapped at local optima. Due to repeated use of selection and crossover operator the population becomes homogenous after that search process trapped at local optima. To avoid these problem mutation add new information in a random way and maintain diversity in the population. They operate at the bit level. There is a probability that individual bit may become mutated called a mutation probability and it is always less than 0.5. If random number (between 0 and 1) is less than mutation probability the bit is mutated so that one becomes zero and zero becomes one.

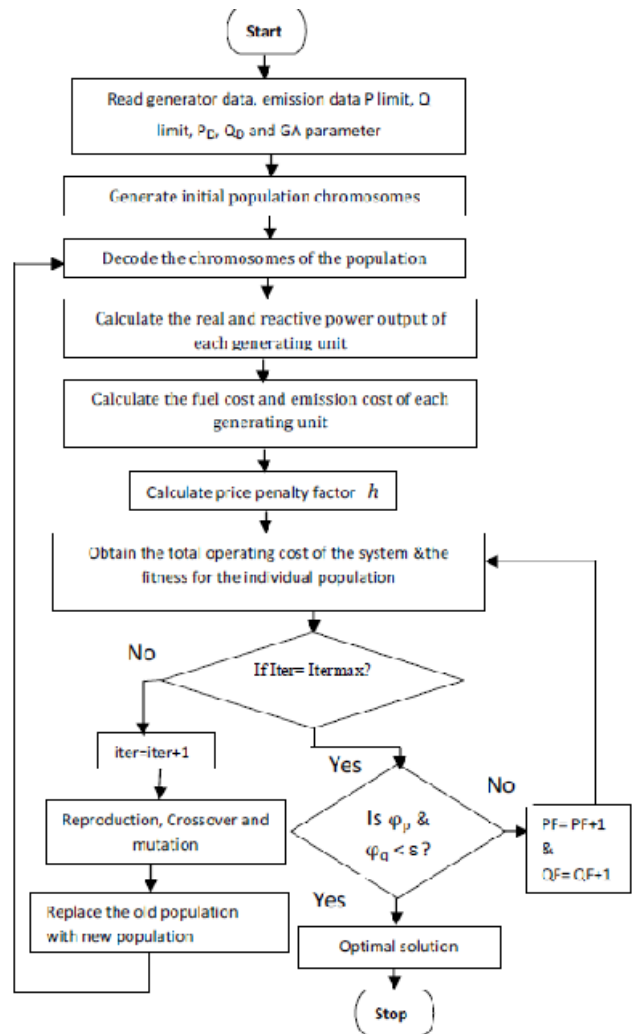
### B. ALGORITHM

Step by step algorithm of GA is given below.

- Step1.** Generate initial chromosomes.
- Step2.** Decode the chromosomes.
- Step3.** Evaluate fitness value for each individual.
- Step4.** Apply reproduction, crossover and mutation.
- Step5.** Replace old chromosomes with new chromosomes.
- Step6.** If  $Iter = Itermax$  then go to next step else go to step 2.
- Step7.** Stop

### IV. CEED BY USING GENETIC ALGORITHM

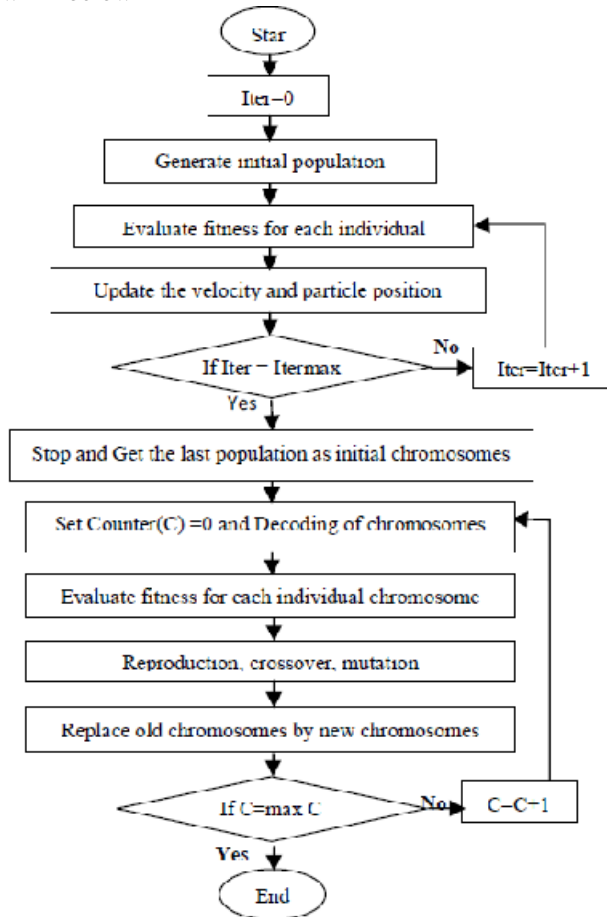
Genetic algorithm is one of the modern search algorithm used in find the exact or approximate solution to optimization problem. GA is motivated by the study of its operator. In the case of GA initially we generate the initial population and compute the total cost. After that we have find the fitness value for individual population according to its fitness value form a mating pool. Genetic algorithm operators applied to this mating pool and replace the old population to new population. This process repeat until the convergence criteria can be satisfied [1, 2, 5, and 6



### V. HYBRID PSO-GA

PSO-GA algorithm combines the advantage of PSO and GA [11], [12]. For the purpose of increasing the number of well evaluated agents, while decreasing the number of poor evaluated agents at search process. The genetic algorithm is very sensitive to the initial chromosome because of the random nature of its operator like reproduction crossover and mutation. However if the initial chromosome not well selected the algorithm may not converge. On the other hand if the initial population are well selected the convergence characteristic of algorithm can be increased. As compare to GA, PSO is less sensitive to the initial population. One of the important characteristic of PSO is it's rapidly converge during the initial stage of search process and convergence is very slow near global optima. To avoid this problem this paper combined these two techniques PSO and GA and forms a PSO-GA algorithm in such a manner that the performance of newly recognized algorithm is better than individual algorithm. In this paper combined economic and emission dispatch is done with the help of PSO-GA algorithm. PSO algorithm can be used during the first

stage of solving the optimization problem near the global optima last particle of the PSO is taken as the initial population of GA. After that algorithm switch to GA and GA takes this initial population and continues to solve the optimization problem. Flow chart for hybrid PSO-GA shown in below



## VI. ALGORITHM FOR COMBINED ECONOMIC AND EMISSION DISPATCH BY USING HYBRID PSO-GA

This paper proposed a hybrid PSO-GA for solving combined economic and emission dispatch with real and reactive power constraints. Step by step algorithm is given below.

**Step1.**Generate real and reactive Power particles positions and velocity by using equation

$$X_k^i = X_{min} + rand * (X_{max} - X_{min}) / V_{max}$$

$$V_k^i = .4 * rand * V_{max}$$

Where,  $X_{min}$  and  $X_{max}$  are the minimum and maximum range of the particle.

$V_{max}$  is the maximum range of velocity.

**Step2.**Calculate fuel cost by using equation (1) and emission cost by using equation (2) after finding these two obtain a price penalty factor by using equation (3).

**Step3.**Calculate total operating cost  $\phi_T$  by using equation (4)

**Step4.**Evaluate fitness value by using equation

$$F = \phi_T + (PF * \dot{p}) + (QF * \dot{q})$$

Where,

$\dot{p}$  And  $\dot{q}$  are the real and reactive residual power, PF and QF are the real and reactive power penalty factor.

**Step5.** Obtain the global best and personal best value according to its fitness value.

**Step6.**Update the velocity and position by using  $pbest$  and  $gbest$ .

$$V_{ij}^{k+1} = w * V_{ij}^k + C1 * rand * [pbest_{ij}^k - X_{ij}^k] + C2 * rand * [gbest_{ij}^k - X_{ij}^k]$$

$$X_{ij}^{k+1} = X_{ij}^k + V_{ij}^{k+1}$$

Where,

$V_{ij}^{k+1}$  - Velocity of  $i^{th}$  individual at  $(k + 1)^{th}$  iteration;

$V_{ij}^k$  - Velocity of  $i^{th}$  individual at  $k^{th}$  iteration;

$w$  - Inertial weight;

$c1, c2$  - Positive constants called acceleration constants;

$rand$  - Generate random numbers within the interval  $[0, 1]$ .

$Pbest_{ij}$ - Best position of the  $i^{th}$  individual;

$W_i$  = the inertia weight at iteration  $i$ .

$gbest_{ij}$ - Best position among the individuals

(group best);

$X_{ij}$  - Position of  $i^{th}$  individual at  $k^{th}$  iteration;

$k$  - Position of  $i^{th}$  individual at  $k^{th}$  iteration;

$i$  - Particles index;

$j$  - Particles dimension;

**Step7.**Check if  $Iter = Iter\ max$  then go to next step else go to step 1.

**Step8.** Stop.

**Step9.** Get the last population as an initial chromosomes and set counter(C) = 0.

**Step10.** Decode the chromosomes by using equation (5).

**Step11.**Calculate fuel cost by using equation (1) and emission cost by using equation (2) after finding these two obtain a price penalty factor by using equation (3).

**Step12.** Calculate total operating cost by using equation (4).

**Step13.** Evaluate fitness value by using equation

$$F = \phi_T + (PF * \dot{p}) + (QF * \dot{q})$$

Where

$\dot{p}$  And  $\dot{q}$  are the real and reactive residual Power, PF and QF are the real and reactive power penalty factor.

**Step14.** Form a mating pool according to its fitness value.

**Step15.** Update the chromosomes by using reproduction crossover and mutation.

**Step16.** Replace the old chromosomes to updated chromosomes.

**Step17.** Check if counter(C) = max C then go to next step else go to step 10.

**Step18.** Check if  $p$  &  $q < \epsilon$  then go to next step else update the real and reactive power penalty factor and go to step 13.

$$PF=PF+1$$

$$QF=QF+1$$

**Step19.** Stop.

## VII. RESULT AND DISCUSSION

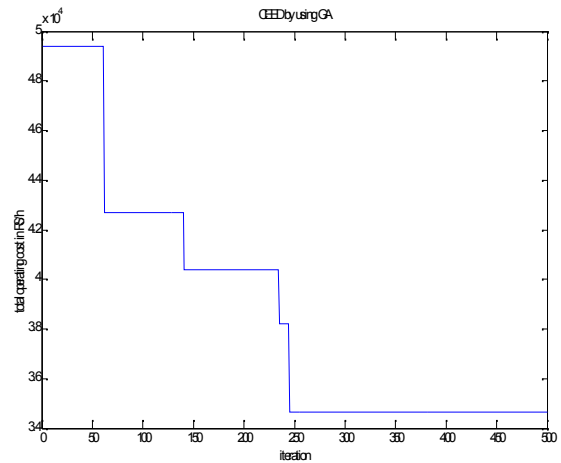
The proposed method GA and hybrid PSO-GA has been applied to power system on six generating system. The cost function of each unit is chosen as a quadratic function for the test systems. Fuel coefficients and emission coefficients and real and reactive power limits of six generating unit given below. In Table 1  $a_i, b_i$  and  $c_i$ , are the cost coefficients of the  $i^{th}$  generator. In Table 2  $\alpha_i, \beta_i$  and  $\gamma_i$  are emission coefficients of the  $i^{th}$  generator.

GENERATING UNIT	$a_i$	$b_i$	$c_i$	$P_{imi}$	$P_{imax}$
1	0.15247	38.539	756.79	10	130
2	0.10587	46.159	451.32	20	155
3	0.02803	40.396	1049.9	55	235
4	0.03546	38.305	1243.5	65	210
5	0.02111	36.327	1658.5	130	325
6	0.01799	38.270	1356.6	125	315

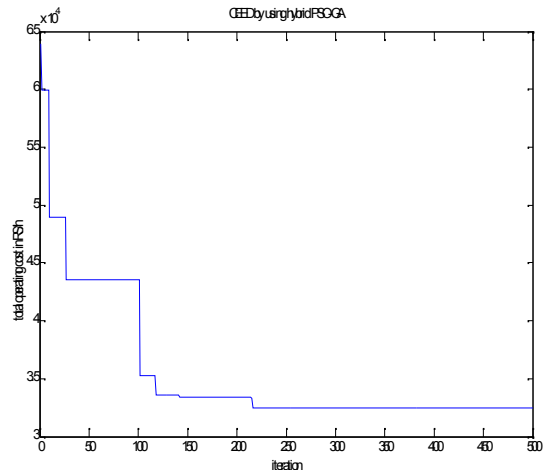
Table: 1 Generator real power operating limits and quadratic cost function coefficients.

GENERATING UNIT	$\alpha_i$	$\beta_i$	$\gamma_i$	$Q_{imin}$	$Q_{imax}$
1	0.0041	0.32767	13.85	5	300
2	0.0041	0.32767	13.85	5	50
3	0.0068	-0.54551	40.26	10	60
4	0.0068	-0.54551	40.26	8	25
5	0.0046	-0.51116	42.89	35	200
6	0.0046	-0.51116	42.89	25	155

Table: 2 Generator reactive power operating limits and quadratic emission function coefficients.



Plot (1) CEED by using GA for 400 M.W. load demand  
Total operating cost after 500 iteration = 3.4630e+004



Plot (2) CEED by using hybrid PSO-GA for 400 M.W. load demand  
Total operating cost after 500 iteration = 3.2455e+004

Total operating cost at various load demand is given below.

LOAD DEMAND IN (MW)	TOTAL COST BY USING GA IN (RS/h)	TOTAL COST BY USING HYBRID PSO-GA IN (RS/h)
400	3.4630e+004	3.2455e+004
500	3.8689e+004	3.7543e+004
700	5.0665e+004	4.6253e+004

Table: 3.Total operating cost by using GA and hybrid PSO-GA.

## VIII. CONCLUSION

In this paper the CEED problem with real and reactive power constraints is solved by using hybrid PSO-GA method to minimize the total operating cost of the system for a given load condition. Hybrid PSO-GA is applied to IEEE 30 bus 6 generator system. The result obtained in this paper clearly demonstrate that the hybrid PSO-GA converges fast and gives better results as compare to GA as shown in table 3. For example for 700 M.W. load demand the total production cost by using genetic

algorithm is  $5.0665e+004$  and by using hybrid PSO-GA is  $4.6253e+004$ . If we apply hybrid PSO-GA for 700 M.W. load demand in place of genetic algorithm save the total production cost 4430 RS/h.

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