

## Hybrid Optimization of the Emission and Economic Dispatch by the Genetic Algorithm

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### Abstract

This paper presents an efficient and reliable technique of optimization with combined economic emission dispatch. This problem has been formulated as a multi-objective problem by considering both economy and emission simultaneously. The bi-objective problem is converted into single objective function using hybrid factor in the proposed approach. The optimal solution of problem is determined by genetic algorithm. This approach has been tested on Indian utility-62 bus systems consisting of 19 generators with line flow constraints. The solutions obtained are quite encouraging and useful in the present deregulated environment.

### Keywords

Nonlinear Programming; Genetic Algorithms; Load Flow; Combined Economic Emission Dispatch.

### Introduction

In traditional economic dispatch, the operating cost is reduced by the suitable attribution of the quantity of power to be produced by different generating units. However the optimal production cost can not be the best in terms of the environmental criteria. Recently

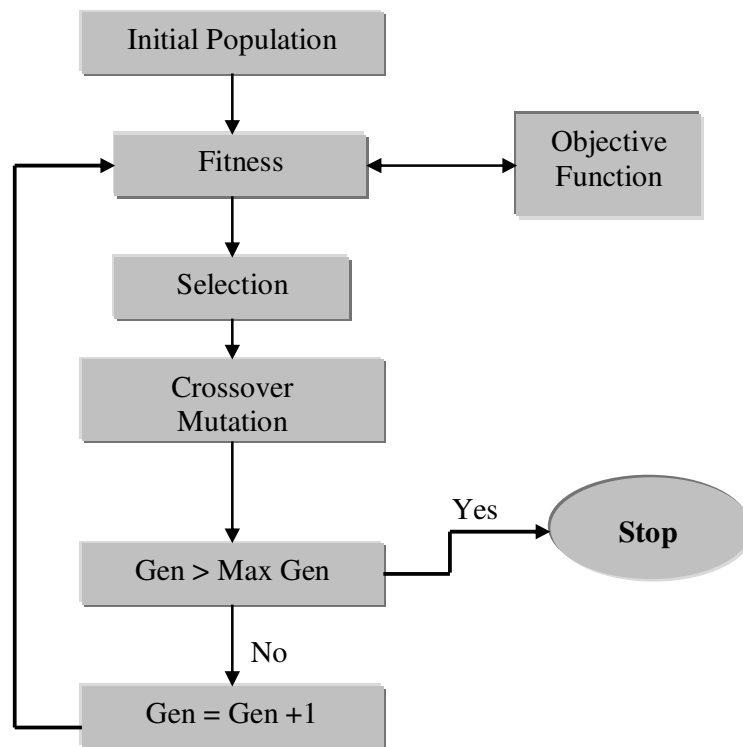
many countries throughout the world have concentrated on the reduction of the quantity of pollutants from fossil fuel to the production of electrical energy of each unit. The gaseous pollutants emitted by the power stations cause harmful effects with the human beings and the environment like the sulphur dioxide (SO<sub>2</sub>), nitrogen oxide (NO<sub>x</sub>) and the carbon dioxide (CO<sub>2</sub>), etc. Thus, the optimization of production cost should not be the only objective but the reduction of emission must also be taken into account. Considering the difference in homogeneity of the two equations, the equation of the cost of fuel given in \$/hr, and the equation of emission of gases to the production of electrical energy given in Kg/hr. In this approach, we optimize the two equations at the same time using a factor of hybridization (Hi). The genetic algorithms are more advanced to solve the problem of multi-objective optimization; the problem consists in combining the economic control system and the gas emission with the production of electrical energy.

### **Genetic Algorithm**

Genetic algorithms (GA) were developed after original work by Holland (1975). These consist of optimization procedures based on principles inspired by natural evolution. Given a problem for which a closed-form solution is unidentified, or impossible to obtain with classical methods, an initial randomly generated population of possible solution is created. Its characteristics are then used in an equivalent string of genes or chromosomes that will be later recombined with genes from other individuals. Each solution is assimilated to an individual, who is evaluated and classified in relation with its closeness to the best, yet still unknown, solution to the problem. It can be shown that, by using a Darwinian-inspired natural selection process, the method will gradually converge towards the best possible solution.

As in a biological system submitted to external constraints, the fittest members of the initial population are given better chances of reproducing and transmitting part of their genetic heritage to the next generation. A new population, or second generation, is then created by recombination of parental genes. It is expected that some members of this new population will have acquired the best characteristics of both parents and, being better adapted to the environmental conditions, will provide an improved solution to the problem. After it has replaced the original population, the new group is submitted to the same evaluation procedure,

and later generates its own offspring's. The process is repeated many times, until all members of a given generation share the same genetic heritage. From then on, there are virtually no differences between individuals. The members of these final generations, who are often quite different from their ancestors, possess genetic information that corresponds to the best solution to the optimization problem. A schematic outline of the GA used is presented in Figure 1.



**Figure 1.** Outline of a genetic algorithm

Most often, researchers encode individuals using bit string encoding called binary-coded GA. In this work, individuals are represented with floating point or real numbers. In real-coded Gas, an individual is coded as vector of real numbers corresponding to design variables. The real-coded Gas are robust, accurate and efficient because of floating point representation is conceptually closest to the real design space.

### ***Genetic Operators***

In this work, the following GA operators are used:

- ÷ ***Tournament selection***: The selection operator is intended to improve the average quality of the population by giving individuals of higher fitness a higher probability to be copied

into the next generation. Tournament selection works as follows; choose two individuals randomly from the population and copy the best individual into the intermediate population.

- ÷ **Whole linear crossover:** Crossover operator is intended to combine the genetic data of the existing population and generating offspring's. Pair of chromosomes is recombined on a random basis to form two new individuals. If according to a probability of crossover parameter, **pc**, there is crossover, then a whole linear crossover is used. From two parents p1 and p2, three offspring's are generated, namely  $0.5p1+0.5p2$ ,  $1.5p1-0.5p2$ , and  $-0.5p1+1.5p2$ . The best two of the three offspring's are then selected.
- ÷ **Non-uniform mutation:** Mutation operator plays a secondary role. It allows new genetic patterns to be formed, thus improving the search method. Occasionally, it protects some useful genetic material loss. During the process, a rate of mutation, **pm**, determines the possibility of mutating one of the design variables. If a variable is chosen to be mutated, its value is modified as follows:

$$V = \begin{cases} V + \Delta(t, UB - V) & \text{if tails} \\ V - \Delta(t, LB - V) & \text{if heads} \end{cases} \quad (1)$$

where t is the actual generation, UB and LB the upper and lower bounds for the variable, and  $\Delta(t,y)$  is given by

$$\Delta(t, y) = y \left( 1 - r^{\left(1 + \frac{t}{T}\right)^b} \right) \quad (2)$$

where r is a uniform random number between 0 and 1, T is the maximum generation, and b is a parameter determining the degree of dependency on the generation number (usually chosen between 1 and 5).

- ÷ **Elitist strategy:** In standard GA the best possible solution is not preserved, thereby increasing the chance of loosing the obtainable best possible solution. Elitist strategy overcomes this problem by copying the best member of each generation into the next one.

### Problem Formulation

The bi-objective combined economic emission dispatch problem is converted into single optimization problem by introducing prince hybridization factor.

Optimization of problem has been mathematically formulated is as follows.

$$f(P_{Gi}) = \text{Min} \sum_{i=1}^{nG} [F_i(P_{Gi}), E_i(P_{Gi})] \quad (3)$$

where  $f(P_{Gi})$  is the optimal cost of power generation.  $F_i(P_{Gi})$  and  $E_i(P_{Gi})$  are total cost and total emission of generators respectively.

$nG$  represents the number of generators connected in the network. The cost is optimized with the following constraints.

$$\sum_{i=1}^{nG} P_{Gi} = P_D - P_L \quad (4)$$

where  $P_{Gi}$  is the real power generation of  $i^{\text{th}}$  generator,  $P_D$  is the total load of the system and  $P_L$  is the transmission losses of the system. The inequality constraints on real power generation  $P_{Gi}$  of each generation  $i$  are:

$$P_{Gi}^{\min} \leq P_{Gi} \leq P_{Gi}^{\max} \quad (5)$$

where  $P_{Gi}^{\min}$  and  $P_{Gi}^{\max}$  are minimum and maximum value of real power allowed at generator  $i$  respectively.

The fuel cost of the production  $F_i(P_{Gi})$  (\$/hr) in terms of control variables generator powers can be expressed as,

$$F_i(P_{Gi}) = \sum_{i=1}^{nG} (a_i P_{Gi}^2 + b_i P_{Gi} + c_i) \quad (6)$$

where  $P_{Gi}$  is the real power output of an  $i^{\text{th}}$  generator.  $a_i, b_i, c_i$  are the fuel cost curve coefficients.

The total function of emission  $E_i(P_{Gi})$  (kg/hr) can be expressed as,

$$E_i(P_{Gi}) = \sum_{i=1}^{nG} (\alpha_i P_{Gi}^2 + \beta_i P_{Gi} + \gamma_i) \quad (7)$$

where  $\alpha_i, \beta_i$  and  $\gamma_i$  are emission coefficients.

The factor of hybridization is exposed like as:

$$H_i = \frac{\sum_{i=1}^{nG} F_i(P_{Gi}^{\max})}{\sum_{i=1}^{nG} E_i(P_{Gi}^{\max})} \quad (8)$$

where  $i = 1, 2, \dots, nG$ .

The function to minimize can be described as follows.

$$\text{Min} \left\{ f(P_{Gi}) = \sum_{i=1}^{nG} F_i(P_{Gi}) + H_i * \sum_{i=1}^{nG} E_i(P_{Gi}) \right\} \quad (9)$$

Subject to equality constraints,

$$\sum_{i=1}^{nG} P_{Gi} - P_D - P_L = 0 \quad (10)$$

and inequality constraints,

$$P_{Gi}^{\text{Min}} \leq P_{Gi} \leq P_{Gi}^{\text{Max}} \quad (11)$$

### ***Use of constraints***

Constraints may be handled by exterior penalty method; many alternatives are possible, simplest one is to square the violated constraints, multiply by a penalty coefficient and add to the fitness function.

Usually penalty coefficient is a large number.

*Min f(x)* Subject to  $g(x) \leq 0$   $h(x) = 0$  the constraints

The constrained function  $f(x)$  can be transformed to an unconstrained function  $F(x)$

$$\text{Min}F(x) = f(x) + r_p \left[ \max(0, g(x))^2 + h(x)^2 \right] \quad (12)$$

where  $r_p$  is the penalty coefficient.

For the application of the genetic algorithm, we transformed our problem of minimization with constraints has a minimization with not constraints by penalty method as follows.

$$F(P_{Gi}, r_p) = f(P_{Gi}) + r_p * \left[ \sum_{j=1}^m (h_j(P_{Gi}))^2 + \sum_{q=1}^k (g_q(P_{Gi}))^2 \right] \quad (13)$$

Equality constraints:  $h_j(P_{Gi}) = 0$ ,  $j = 0, 1, \dots, m$  and inequality constraints:  
 $g_q(P_{Gi}) \leq 0$ ,  $q = 0, 1, \dots, k$

### **Simulation Results**

The algorithm was applied to IEEE-30 bus system with 06 generating units and 41 transmission lines with four tap changing transformers. The total system load demand is 283.4 MW. The values of fuel cost and emission coefficients are given in Table 1 and the single-line diagram of this system is shown in Figure 2.

Table 1. Generator costs and emission coefficients.

N° Generator	$a_i$	$b_i$	$c_i$	$a_i$	$\beta_i$	$\gamma_i$
1	0.00375	2.00	0	0.0126	-1.1000	22.983
2	0.01750	1.75	0	0.0200	-0.1000	25.313
3	0.06250	1.00	0	0.0270	-0.0100	25.505
4	0.00834	3.25	0	0.0291	-0.0050	24.900
5	0.02500	3.00	0	0.0290	-0.0040	24.700
6	0.02500	3.00	0	0.0271	-0.0055	25.300

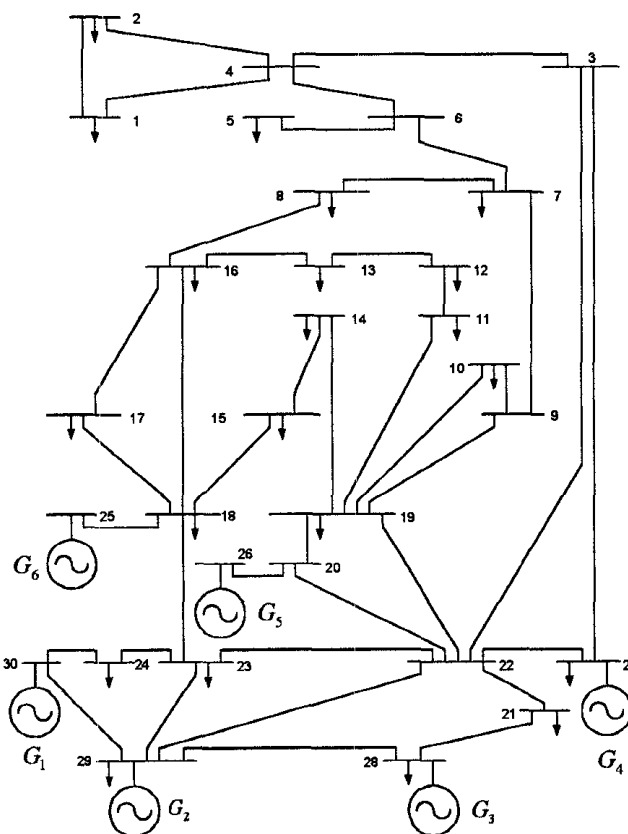


Figure 2. The single-line diagram of IEEE30-bus system

The factor of hybridization  $H_i$  for IEEE-30 bus system was explained as follows:

$$H_i = [h_1, h_2, h_3, h_4, h_5, h_6]; H_i = [1.792, 1, 734, 2.230, 2.053, 2.220, 2.338]$$

The total load of this network is 283.4 MW. By using the method of Gauss-Seidel with the parameters of the lines, one finds the losses active of the network  $P_L = 14.10$  MW

$$\sum P_{Gi} - P_d - P_L = 0 \text{ (MW)} \Rightarrow \sum P_{Gi} - 297.5 = 0$$

Table 2. Generator operating limits

Bus	Pmin	Pmax
G1	50	200
G2	20	80
G3	15	50
G4	10	35
G5	10	30
G6	12	40

**Result of the application**

The optimal values of the generated powers, total cost of hybrid function, Fuel cost and Emission output are given by table 3.

Table 3. The best solution for fuel cost and emission gas optimized simultaneous.

N° Generator	GA method	EP method
PG1 Opt (MW)	139.202	118.770
PG2 Opt (MW)	54.792	62.246
PG3 Opt (MW)	25.618	34.462
PG4 Opt (MW)	29.560	24.289
PG5 Opt (MW)	23.989	21.621
PG6 Opt (MW)	24.340	28.072
Best Hybrid function	<b>1566.177</b>	2151.570
Fuel Cost. (\$/hr)	<b>769.677</b>	840.219
Emission (Kg/hr)	<b>353.404</b>	350.509

- EP: Evolutionary Programming [4]
- GA: Genetic Algorithm (Proposed approach).

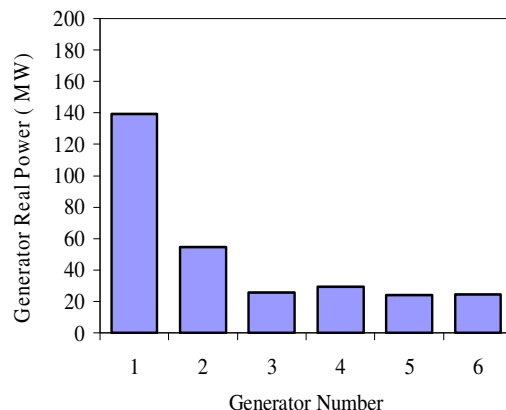
**Interpretations**

For the results of table 3, we calculated the optimum of the function combined between the fuel cost and the emission gas by introducing the factor to align dimensions of the two functions and we replaced the optimum power to find in both function.

In table 4, we optimized the two functions separately and one replaced the optimum power of the first in the second and conversely.

For our approach we can save 41.09 \$/hr of fuel and minimize 3.622 Kg/hr of toxic gas to liberate in the environment.





**Figure 3.** The best generator setting of GA

**Table 4.** The best solution for fuel cost and emission gas optimized individually.

	Best Fuel Cost	Best Emission Gas
$P_{G1}$ (MW)	178.954	117.516
$P_{G2}$ (MW)	046.703	052.192
$P_{G3}$ (MW)	020.790	032.167
$P_{G4}$ (MW)	025.763	033.362
$P_{G5}$ (MW)	010.042	027.147
$P_{G6}$ (MW)	015.248	035.114
Fuel cost (\$/hr)	<b>810.767</b>	876.403
Emission ( Kg/hr)	402.546	<b>357.026</b>

### Conclusion

In this article, an approach based on a genetic algorithm was presented and applied to the fuel cost and the function of emission gas in electric power network. The problem was formulated as multi-objective function environmental / economic dispatch, the problem is to optimize the fuel cost of the production and the emission gas on the environment at the same time.

For reason of the difference dimensioning of the two functions, we have to use the factor of hybridization for the first test (table 3), and for the second test (table 4) we have to optimize both separately function.

The genetic algorithm thus gave us well satisfactory results. This shows that it is much faster and more effective than the traditional techniques by dealing with the multi objective problems of optimization.

Certainly, we compared the minimal cost calculated in the first test with the minimal in the second test. We carried out in test 1 a reduction of 86.93 Kg/day pollutant gas (Nox, SO<sub>2</sub>, CO<sub>2</sub>, CO) emitted in the atmosphere and we have to gain has little close 987 \$/day.

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