Differential Evolution Based Solution for Combined Economic and Emission Power Dispatch with Valve Loading Effect

K. Balamurugan, R. Muralisachithnndam and Sandeep R. Krishnan

Assistant Professor III, EEE Department, Associate Professor, EEE Department and PG Student, EEE Department, SASTRA University, Thanjavur, India
kbm@eee.sastra.edu, zenmurali@gmail.com and sandeep_rk87@yahoo.co.in

Abstract: In this work, a combination of Economic and Emission power dispatch optimization is solved by differential evolution technique using MAT-lab programming technique. The crux of the objective is to find the economic scheduling of the generation, such that the required load demands of the generation can be satisfied and the operation such as equality and inequality constraints of the generators including the total emissions within the allowable emission limit for satisfactory operation of the thermal power plant. In this work only one emission of Nitrogen oxide is considered for analysis. The economic / environmental load dispatch is analyzed in two cases. Case one deals excluding transmission losses and case two deals including transmission losses in the system. The standard data of IEEE Thirty Bus System and Indian Utility Sixty Two Bus Test System has been taken into account and simulated with aid of MAT-lab software and results are obtained. An apposite program has been developed using differential evolution technique and which has been verified for various load demand.

Keywords: Economic and Emission Dispatch, Valve Point Effect, Differential Evolution Technique, Indian Utility Sixty Two Bus System, IEEE Thirty Bus system, Mat Lab.

1. Introduction

Optimal generation dispatch represents one of the vital issues in power systems engineering. The optimal operating state reduces cost and improves overall system efficiency. For dispatching the electrical power by operating the units at minimum cost is not only the consideration, because of increasing environmental hazards. The main objective function of the environmentally constrained economic power dispatch problem is to reduce the emission rate and cost of generation. An efficient and reliable Differential Evolution programming based algorithm for finding the economic/environmentally power dispatch problem is presented. It is defined as a dual objective optimization problem with both equality and inequality constraints. The number of iterations is performed in a typical IEEE thirty bus systems and Indian utility sixty two bus system to achieve the objective function [1] & [2].

2. Economic Dispatch

A. Introduction

The primary requirement of power system optimal generation scheduling is to generate, at the possible lowest cost adequate quantity of power to satisfy the power demand. The problem of optimal generation scheduling can be formulated as minimization of the production cost function subjected to the various power system constraints along with power balance relation [3], [4], [5], [6] & [7].

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B. Objective Function

The traditional economic power dispatch problem is to reduce the total production cost by controlling the unit output of the each unit connected to the network. The overall production cost of the network is the summation of the fuel cost function of each generator as given in equation (1).

$$Min \sum F_i(P_{Gi}) \tag{1}$$

The overall \$/hr production cost function with valve loading effect of the generator can be expressed in equation (2) [8].

$$F_1 = \sum_{i=1}^{N} (a_i + b_i P_{Gi} + c_i P_{Gi}^2) + \left| d_i sin\big(e_i (P_{i\,min} - P_i)\big) \right| \$/h \tag{2}$$

Where

F_1 = Total fuel cost
a_i, b_i, c_i, e_i & d_i= Constants Coefficients of the i[th] unit
N = Number of generating units
P_i = Power output of i[th]generator
$P_{i.min}$= minimum power constraint for i[th] unit in MW

C. Equality Constraint

Equality constraint is also known as Power Balance Constraint. It is considered in two ways. Case one deals excluding transmission losses and case two deals including transmission losses in the system. In case one, balance is met when the sum of generation (ΣP_{Gi}) equals the sum of load, considering the system network as loss less as in equation (3).

$$\sum_{i=1}^{N} \boldsymbol{P_{Gi} - P_D = 0} \tag{3}$$

In case two, balance is met when sum of generation (ΣP_{Gi}) equals the sum of load (P_D) and total power losses (P_{Loss}), considering the power system network as including loss as stated below (4).

$$\sum_{i=1}^{N} \boldsymbol{P_{Gi} - P_D - P_{Loss} = 0} \tag{4}$$

The losses can be determined by using loss formula as function of the system generators outputs, as given (5).

$$P_L = \sum_{i=1}^{N_o} \sum_{j=1}^{N_o} P_{Gi} B_{ij} P_{Gi} + \sum_{i=1}^{N_o} P_{Gi} B_{io} + B_{oo} \tag{5}$$

Where

B_{ij}, B_{i0}, B_{00} = Loss Coefficients
N = Number of Generators

P_{Gi}= Power output of i[th]generator
P_D = Total demand
P_L = Power loss

D. Inequality Constraint

Inequality constraint is also known as power generator capacity constraint. Each generating units have minimum (P_{Gimin}) and maximum (P_{Gimax}) generation capacity according to its machine ratings. This can be constructed as an inequality constraint in equation (6).

$$P_{Gimin} \leq P_{Gi} P_{Gimax} \quad i = 1, \dots \dots N \tag{6}$$

Where

P_{Gimin} = Min power generated in i[th] generation
P_{Gimax}= Max power generated in i[th]generation

3. Environmental Load Dispatch

A. Introduction

According to the 1990 Clean Air Amendment, environmental considerations have regained considerable attentions in the power system industry due to the significant amount of emission and other pollutants derived from fossil based power generation. So there is a necessity of economic and emission power dispatch to reduce generation cost and emission rate. As the traditional the economic generation scheduling problem is to reduce the production cost without considering emission rate. The emission power dispatch problem is to reduce the emission output without considering economic constraints. So in order to overcome the above mentioned problem the new method of combination of economic and emission power dispatch technique is developed [9], [10], [11], [12] & [13].

The production of power from the fossil fuel generating units discharges several harmful gases, such as Sulfur Oxides (SO_2), Nitrogen Oxides (NO_x) and Carbon Dioxide (CO_2) into the environment. The combination of economic and emission power dispatch problem can be constructed as an optimization problem. The SO_2 and NO_x are the two major gases that are released from generating unit. So these two gases are considered for the emission dispatch. During the combustion process in a power station, some of the sulfur unites reacts with the oxygen in the fuel and combustion air to form SO_2 and that are released through the stack as an emission. The nitrogen combines with oxygen from the fuel to form fuel $NO_{x,}$ it also combines with oxygen from the air to form thermal NO_x. The total NO_x emission is a combination of the thermal and fuel NOx.

B. Multi-objective Economic/Environmental Dispatch Formulation

One of the techniques used to minimizing the emission production in a power station is the Economic and emission Power Dispatch. This dispatch finds the power allocation that reduces the generation cost of the system considering the amount of emission produced. Sulfur dioxide and NO_x emission is dependent on the power consumption. It is formulated as the traditional fuel cost function equation that comprises of polynomial and exponential terms as below

$$F_2 = \sum_{i=1}^{N} \left[10^{-12}\left(\alpha_i + \beta_i P_{Gi} + \gamma_i P_{Gi}^2 + \eta_i \, exp(\delta_i P_{gi}\right)\right] tons/hr \tag{7}$$

Where,

α_i, β_i, $\gamma_i \boldsymbol{\eta_i}$, $\boldsymbol{\delta_i}$= i[th] generation unit emission rate coefficients
F_2 = Total emission
N = Number of Generators

P_{Gi}= Power output of i[th]generator

The nature of cost and emission production allows the economic and emission dispatch problem which is constructed as a dual objective optimization problem.

C. Objective Function

The combination of economic and emission dispatch problem is to reduce the cost function and the emission function including penalty factor as in equations (8) and (9).

$$h = \frac{F_T(P_{i.min})/P_{i.min}}{E_T(P_{i.min})/P_{i.min}} \tag{8}$$

Where $P_{i.min}$is minimum power constraint for i_{th} unit in MW, Price penalty factor h (\$/lb)

Minimize $\emptyset_T = F_T(P) + h.E_T(P)$ (9)

Where

F_i (P_{Gi}) is a cost function

E_i(P_{Gi})is an emission function.

4. Differential Evolutiontechnique (DE)

A. Introduction

The differential evolution technique (DE) is a population based algorithm. The main stages are initialization, crossover, mutation and selection. In initialization stage the populations are generated. In the mutation process mutant vector are created based on difference of the randomly chosen target vector and added up with another target vector. In cross over stage cross over operator does the selection process. The final selection is done by calculating the fitness of the vector by the selection operator [14] & [15].

B. The Main Stages of the DE Technique

- *Initialization*

In this process initial population of candidates are generated by assigning values to the parameter of the each individual of the population as shown in equation (10). The assigning values should be within the lower and upper boundary limits.

$$X_{j,i}^{(0)} = X_j^{min} + \eta_j\left(X_j^{max} - X_j^{min}\right)\forall i,j \tag{10}$$

Where

$\eta_j$is a random uniformly distributed number.

X_j^{min}&X_j^{max} are lower and upper boundary constraints.

For certain problems, information might be available that would favors exploration in certain areas. In this case the population can be seeded around these areas of interest.

- *Mutation*

The mutation operation is performed on the each target vector to obtain the new parameter vectors called mutant vectors, as given in equation (11).

$$V = X_{r1,G} + F\left(X_{r2,G} - X_{r3,G}\right) \tag{11}$$