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Optimum Generation Scheduling for Thermal Power Plants using Artificial Neural Network

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Abstract

A simple method to optimize generation scheduling for thermal power plant using artificial neural network is presented. The optimal generation of generators is achieved considering operational and load constraints. The B- Coefficients are used to evaluate transmission loss in the system. The fuel cost of each unit in a plant is computed. The effectiveness of methodology is tested with six thermal power plants. A result of proposed method is compared with classical method. The artificial neural network method is quick. Hence, artificial neural network technique can be used in central load dispatch center.

Index Terms- Neural network, B-Coefficients, Fuel cost, Power loss, Real power

1. Introduction

With the large interconnection of the electric networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running charges of the electric energy. In developing countries like India, the cost of fuel is rapidly increasing. The main economic factor in power system planning, operation and control is the cost of generating real power. The size of electric power system is increasing rapidly to meet the energy requirements. A number of power plants are connected in parallel to supply the system load by interconnection of power stations. With the development of grid system, it becomes necessary to operate the plant unit most economically. The economic generation scheduling problem involves two separate steps namely the unit commitment and the on-line economic dispatch. The function of the on-line economic dispatch is to distribute the load among the generating units actually paralleled with the system in such a manner as to minimize the total cost of supplying the minute to minute requirements of the system and satisfying load and operating constraints. Thus, economic load dispatch problem is the solution of a large number of load flow problems and choosing the one which is optimal in the sense that it needs minimum cost of electric power generation. Accounting for transmission losses results in considerable operating economy. Further more, this consideration is equally important in future system planning and in particular, with regard to the location of plants and building of new transmission lines.

To calculate electric power generation of various units with different load demands, the usual Classical (Kirchmayer) method is used. These are generally solved by iterating the value of until the some of the generator outputs equals the system demand plus transmission losses. The incremental transmission losses are calculated using transmission loss coefficient called B co-efficient approach. As early as the mid 1930s economic dispatch of real power not considering the transmission losses was being performed. By the mid 1940's analysis techniques were sufficiently developed so that transmission losses could be taken into account. By the mid 1950s number of digital dispatch systems was available to the industry.

Economic dispatch programs which are installed today in the most modern control centers uses the classical methods to solve a well known exact co-ordination equations. The main difference between different techniques is the method used to solve the co-ordinations equations. The co-ordination equations are generally solved by interactively adjusting the load until the sum of the generator output matches the system load, pulse system loss. The transmission loss penalty factor have been implemented using one of the several loss formulas which are calculated off-line or on-line at periodic internal and on request.

In recent years, AI applications have received increasing attention in various areas of power systems such as operation, planning and control. A number of research articles appeared recently indicate applicability of AI techniques to power system for wider operating conditions under uncertainties. Artificial neural networks have attracted much attention due to their computational speed and robustness. A major advantage of the artificial neural network approach is that the domain knowledge is distributed in the neurons and information processing is carried out in a parallel distributed manner. Therefore, artificial neural network reaches the desired solution rather efficiently.

New graphical method for optimum power generation [1] with neglecting the mutual elements of B coefficient matrix is discussed. The analytical method to optimize generation schedule [2] neglecting the transmission losses is discussed. Simplified approach to solution of co-ordination equation for generation scheduling

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[3] is discussed. Quick method [4] to optimize generation scheduling is discussed. It eliminates the iterative steps and offers a good savings in computer time and computer memory.

2. Problem Formulation

To determine the economic distribution of load between the various units consisting of a turbine, generator, and stem supply, the variable operating costs of the unit must be expressed in terms of the power output. The variation of fuel cost of each generator with active power output P_{Gi} is given by a quadratic polynomial.

$$F_i = a_i P_{Gi}^2 + b_i P_{Gi} + c_i \text{ Rs / hr} \quad (1)$$

i=1,2,……..N

Where a_i is a measure of losses in the system, b_i is the fuel cost and c_i is the salary and wages, interest and depreciation. The optimal dispatches for the thermal power plants should be such that the load demands plus line losses, which can be written as:

$$\sum_{i=1}^{N} P_{Gi} - P_D - P_L = 0 \quad (2)$$

Where,
N= Total number of generating plants.
P_{Gi}= Generation of i^{th} plant.
P_L= Total system transmission loss.
P_D= System load demand

The transmission losses which occur in the line when power is transferred from the generating station to the load centers increases in distance between the two. The transmission losses may vary from 5 to 13 % of the total load. If the power factor of load at each bus is assumed to remain constant the system loss P_L can be shown to be a function of active power generation at each plants i.e.

$$P_L = (P_{G1}, P_{G2}, P_{G3}, \ldots\ldots\ldots P_{GN}) \quad (3)$$

One of the most important, simple but approximate method of expressing transmission loss as a function of generator power is through B- Coefficients as,

$$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} P_{Gi} B_{ij} P_{Gj} \quad (4)$$

where,
P_{Gi},& P_{Gj} are real power generation at i^{th} and j^{th} power unit. B_{ij} is loss coefficients.
The inequality constraints is given by

$$P_{GMin} \leq P_{Gi} \leq P_{GMax} \quad (5)$$

The maximum active power generation P_{GMax} of source is limited by thermal consideration and minimum active power generation P_{GMin} is limited by the flame instability of a boiler.

3. Methodololgy

The objective of optimum generation scheduling for thermal power plants is to allocate the generation to each and every units in a plant for a given load such that fuel cost is minimum subjected to equal and inequality constraints. Here, optimum generation scheduling is achieved by two techniques. The methods are presented below.

3.1 Artificial Neural Network Method

Artificial neural network based method is applied to the optimum generation scheduling problem. A multilayer feed forward neural network is selected. A neural network is constructed with one input layer, one hidden layer and one output layer. The input to the neural net contains load demand. The output from the network is generation of each generator. In the training process, load demand and active power generation which is input-output patterns Training set) are selected from data base to determine the weights for the neural network. The well known back propagation algorithm and the sigmoid transfer function are used in the model. Once the network trained, the network parameters (weights and bias terms) were kept fixed. The convergence criteria used for training is to have a tolerance and epochs. Once the network has been trained, the accuracy of the neural network can be evaluated by testing the neural network with another set of input-output data (testing set). To speed up the convergence, momentum and learning rate are selected. Selected input-output patterns are normalized between 0 and 1 to avoid the convergence. Since the variables, input to and outputs from ANN have very different ranges, the use of original data to the network will cause a convergence problem. The absolute percentage error (APE) of the generation scheduling is given below.

$$APE=\left|\frac{Load_{Scheduled}-Load_{caluclated}}{Load_{Scheduled}}\right|\times 100 \tag{6}$$

The mean percentage error (MAPE) is computed by

$$MAPE=\frac{1}{N}\sum_{i=1}^{N}APE \tag{7}$$

where N = Number of loads.

3.2 Classical Method

This is an iterative and an accurate method to determine output of generator. An algorithm for obtaining real power generation and fuel cost are iteratively solved on the following steps for a particular load demand.

1. Initially chose $\lambda=\lambda_0$
2. Assume $P_{GI}=0.0$; i=1,2,…………N
3. Solve below equation iteratively for P_G's

$$P_{Gi}=\frac{1-\dfrac{b_i}{\lambda}-\sum\limits_{\substack{j=1\\ j\neq i}}^{N}2B_{ij}P_{Gj}}{\dfrac{a_i}{\lambda}+2B_{ii}}$$

4. Calculate power loss using

$$P_L=\sum_{i=1}^{N}\sum_{j=1}^{N}P_{Gi}B_{ij}P_{Gj}$$

5. Check if power balance equation is satisfied, $\left|\sum_{i=1}^{N}P_{Gi}-P_D-P_L\right|\langle\,\varepsilon$

if yes, stop. Otherwise, go to step-6.

6. Increase λ by Δ λ; if $\left|\sum_{i=1}^{N}P_{Gi}-P_D-P_L\right|\langle\,0$ Otherwise, decrease λ by Δ λ ; if

$\left|\sum_{i=1}^{N}P_{Gi}-P_D-P_L\right|\rangle\,0$ Repeat from step-3.

4 Sample Sytem

A six plant system with the following cost equations is considered.

$F_1=0.005P_1^2+2P_1+100$ Rs/hr

$F_2=0.01P_2^2+2P_2+200$

$F_3=0.02P_3^2+2P_3+300$

$F_4=0.003P_4^2+1.95P_4+80$

$$F_5 = 0.01P_5^2 + 1.45_5 + 100$$
$$F_6 = 0.01P_6^2 + 0.95P_6 + 120$$

The inequality constraints are

$$10MW \leq P_{Gi} \leq 200MW \quad ;$$

i=1, 2 ,……….6

The transmission loss coefficient matrix B_{mn} is as given in Table1.

Table.1. Transmission loss Coefficient Matrix

2E-3	1E-5	15E-4	5E-5	0.0	-3E-4
1E-4	3E-3	-2E-4	1E-5	12E-4	1E-4
15E-4	-2E-4	1E-3	-1E-4	1E-4	8E-5
5E-5	1E-5	-1E-4	15E-4	6E-5	5E-4
0.0	12E-4	1E-4	6E-4	25E-3	2E-4
-3E-4	1E-4	8E-8	5E-4	2E-4	21E-3

The data required for the artificial neural network is as follows.

Learning Rate : 0.15
Momentum Constant : 0.8
Number of iterations (epochs) : 10000
Tolerance :0.001

5 Results

Generation scheduling for each load is obtained from three layer feed forward artificial neural network. The size of the artificial neural network is 1 / 2 / 6. ANN is trained with 42 different loads. Network is trained with back propagation algorithm. Once the neural net is trained, the accuracy of the neural net can be evaluated by testing the network with another 42 different loads. Log- sigmoid and pure linear transfer function is selected in the hidden and output layer respectively. Results are obtained by ANN method and classical method. The results of fuel cost for various load is given in Table2. From Table 2, it is found that the results obtained by the ANN method coincide with the accurate iterative method. The mean absolute percentage error is 2.577. Total fuel cost for each real power demand is presented in Table 3. The graph between fuel cost against real power demand is drawn and shown in Fig.1. The percentage deviation in the operating fuel cost for the ANN method with respect to classical method is calculated and given in Table 4. A graph between the received power and percentage deviation in the fuel cost for the ANN method is shown in Fig.2.

Table.2 Comparison of Results of ANN & Classical Method

Load MW	Generation (ANN)	Error
215	220.95	-0.890
355	342.77	3.445
598	608.5	-1.756
666	642.7	3.498
780	746.77	4.260
980	995.89	-1.621

Table.3 Comparison of Fuel Cost

Load (MW)	Fuel Cost (ANN)	Fuel Cost (Classical)
215	1333.0	1334.3
355	1642.8	1683.5
598	2453.9	2438.3
666	2475.6	2687.1
780	2983.1	3154.2
980	4176.8	4203.6

Table.4 % Deviation in Total Fuel Cost

Load (MW)	% Deviation of Fuel Cost
215	0.1
355	2.4
598	-0.6
666	7.9
780	5.4
980	0.6

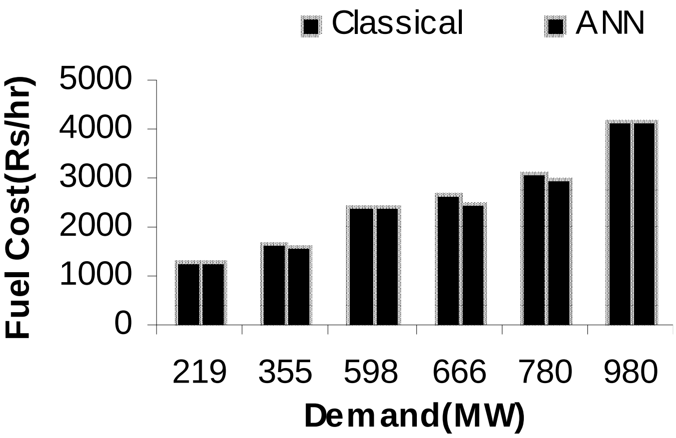

Figure.1 Fuel Cost and Real Power demand

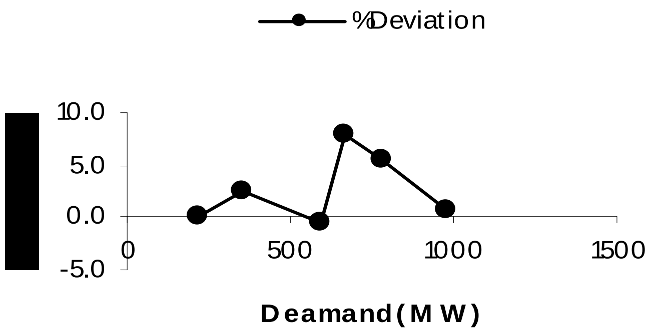

Figure.2 Percentage Deviation of Fuel Cost & Real Power

6 Conclusion

This paper deals with optimal generation scheduling in thermal power plant using artificial neural network. Three layer feed forward ANN is used to optimize generation scheduling. ANN is trained and tested with back propagation algorithm. The equality and inequality constraints are considered while optimizing generation scheduling. The constant B- Coefficients are used to find the transmission loss. The B- Coefficient method is simple and less time consuming method to find transmission loss when compared to load flow technique. The method is tested with six thermal power plants. Results are accurate and encouraging Results of ANN are compared with classical method.

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