OPTIMAL ECONOMIC DISPATCH USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT – This paper present optimal economic dispatch by using back propagation neural networks. The optimal economic dispatch for each generating units must have total fuel cost at minimum point. For this problem, the total load is varied and the losses for generating units are ignored. There are many conventional method to solve economic dispatch such as Lagrange multiplier method, Lambda iteration method and Newton Raphson method. This paper present the back-propagation neural networks model to carry out instead the conventional Lambda iteration method.

I. INTRODUCTION

An important daily activity in power system operation is the economic load dispatch. Economic dispatch is a computational process whereby the total required generation is distributed among the generating units in operation, by minimizing the selected cost criterion, subject to load and operational constraints.

In the area of economic dispatch, several methods have been proposed. Recent advances were achieved by using gradient method, the recursive method, the Newton Raphson method. These methods are required more time to converge to the correct results [1].

In this paper, an application of neural networks is proposed to solve this problem. The method used a feed forward back propagation type of neural network. This method was trained to learn the different condition in operation of each unit. By changing the total load, the minimum cost operation should be selected. The minimum operation condition is selected with less iteration and time.

II. ECONOMIC DISPATCH PROBLEM

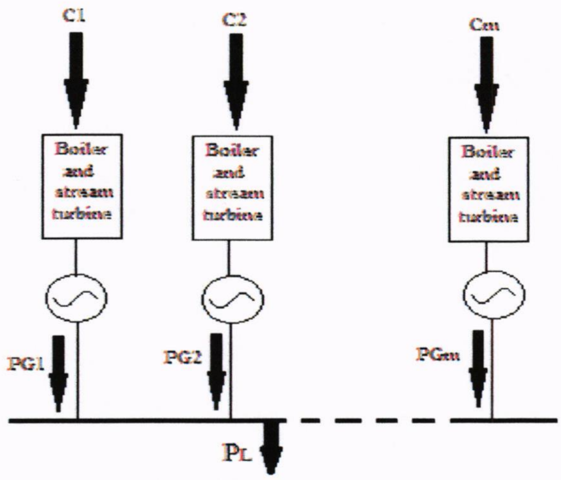

Figure 1: Generator unit committed to serve a load

Figure 1 shows the system that will discuss in this section. The system consist *m* generating units connected to single bus bar. C represents the cost rate of each generating units. PG is generating output of each unit and PL is load demand. The essential constraint on the operation of this system is that the sum of output power must be equal to load demand. The total cost of this system is the sum of the cost of individual generating units.

When load forecast is made, the objective of economic dispatch is to minimize the total generation cost throughout the target time interval. The economic dispatch problem can be mathematically described as follows [1]-[2]:

$$C_T = C_1 + C_2 + \dots + C_m = \sum_{i=1}^{m} Ci\ (PGi) \quad (1)$$

$$PG_T = PG_1 + PG_2 + \dots + PG_m = \sum_{i=1}^{m} PGi \quad (2)$$

$$\phi = 0 = P_D - \sum_{i=1}^{m} PGi \quad (3)$$

$$Min_{PGi} \sum_{i=1}^{m} Ci\ (PGi) = Min_{PGi} \sum_{i=1}^{m} (a_i + b_i PG_i + c_i\, PG_i^{\,2}) \quad (4)$$

Where:

m : The number of generating units

i : Index of dispatchable units

C_i : The fuel generation of unit I [$/h]

C_T : The total fuel cost generation in system

PG_i : The generated power of unit i [MW]

PG_T : The total power generation in system

a_i, b_i, c_i : Coefficients for power generation cost of unit i

(i) Power balance

$$\sum_{i=1}^{m} PG_i = P_D + P_L \qquad (5)$$

Where:

P_D = Total load demand [MW]

P_L = Power losses [MW]

(ii) Generation limit of each unit

Each generation units has its own minimum and maximum generation limits.

$$PG_{imin} \leq PG_i \leq PG_{imaax} \qquad (6)$$

Where:

PG_{imin} : The minimum generation limit of unit i

PG_{imax} : The maximum generation limit of unit i

III. ECONOMIC DISPATCH USING MATLAB SIMULATION.

Economic dispatch is solved using power toolbox developed in Matlab program by Hadi Saadat in chapter seven example six to get the power generated for each generating unit. This program requires total load demand and the generator limit is declared. For this system, the losses are ignored. The process to carry out the economic dispatch as a flow charts that shown in figure 2. They are used to determine the generating power of generators for each unit.

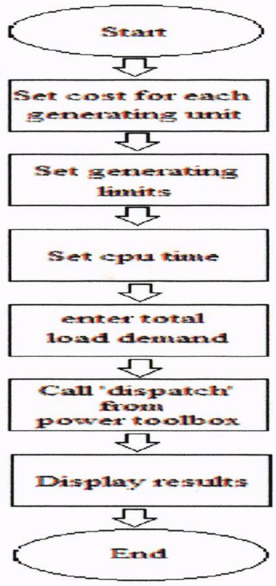

Figure 2: flow chart for Matlab program

IV. ARTIFICIAL NEURAL NETWORK

The theory of artificial neural networks (ANNs) is mainly motivated by the application of neural concepts for innovative technical problem solving [4]. ANNs are a wide class of flexible nonlinear regression and discriminant models, data reduction models, and nonlinear dynamical system. They consist of an often large number of "neuron," i.e. simpler linear or nonlinear computing elements, interconnected in often complex ways and often organized into layers.[5]

Artificial neural networks are use in three main ways:

i. As models of biological nervous systems and "intelligence"
ii. As real time adaptive signal processors or controllers implemented in hardware for applications such as robots
iii. As data analytic methods

The most popular used so far in real industrial problems is feed-forward multilayer perceptron. It is because the performance is better over a large set of different problems. This type of ANN consists of one input layer, one or more hidden layers and one output layer. Each layer employs several neurons and each neuron in a layer is connected to the neuron in the adjacent layer with different weights. Signal flow into input layer pass through the hidden layers and arrive at the output layer. In feed-forward network, neurons are not allowed to have feedback connection or connections from neuron within the same layer [4].

Back propagation network is an example on nonlinear layered feed forward networks. The proposed neural network has one input layer, two hidden layers and one output layers. The input layer only has one neuron which is the number of total load. The hidden layer consist 15 neurons each layer. The output layer has m neurons represented the number of generated power of each generator. If the system has three generators, the output layer will have only three neurons.

Also a bias signal is coupled to all the neurons through a weight. All the layers of neural network have a hyper tangent sigmoid transfer function [1].

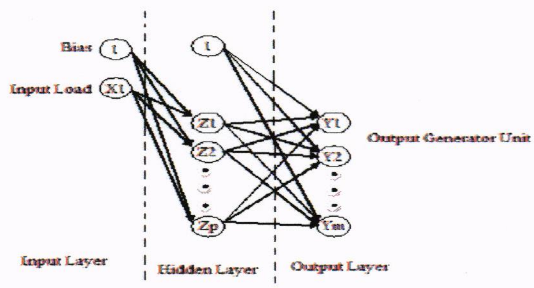

Figure 3: artificial neural networks structure

The back propagation training algorithm only needs the input and the desired outputs to adapt the weights. Back propagation is referred to as supervised training. The input for training neural network is variation of load and the optimal generated power of each generator as output which is calculated using power toolbox in Matlab program. And neural networks also were trained using Matlab program. Figure 4 below shows that the flow charts for training and testing algorithm for neural networks.

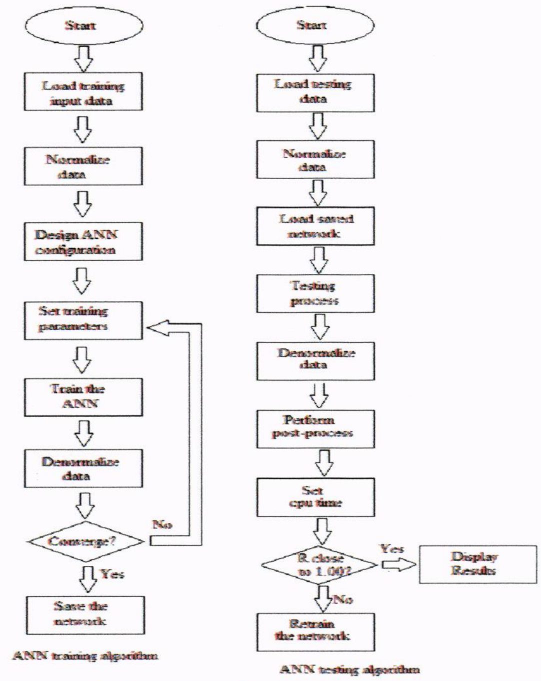

Figure 4: flow charts shows the ANN training and testing algorithm

V. SIMULATION RESULT

This section discusses the simulation of neural networks for economic dispatch. Generally, the fuel cost of each generator is represented as quadratic function as shown in equation below:

$$C_i(P_i) = a_i + b_iP_i + C_iP_i^2$$

where a_i, b_i and c_i are the coefficient of quadratic function.

In order to demonstrate the effectiveness of the proposed method, the test with three generators is compared between the neural network program and simulation using power toolbox. For the further study, it will test to ten unit generators and twenty unit generators in order to prove that this method is better than other method.

In this paper, the fuel cost of each generator is not considered the loss in transmission line and fault in generation. This program used computer Intel (R) Core (TM) i5 CPU M480, 2.67GHz and 2 GB Ram.

The fuel cost coefficient and generation limits for each unit generator is shown in table 1:

Unit (i)	Coefficient for power generation cost			Limit of generation	
	a_i	b_i	c_i	Min (MW)	Max (MW)
1	328	8.66	0.01	50	250
2	60	9.76	0.012	20	100
3	137	10.05	0.014	30	150

Table 1: Cost coefficient generator data of 3 unit system.

Result in table 2 only shows comparison of both methods at load 100, 150, 210, 290, 350, 430, 450 and 500MW. The optimal power generated by each generating unit will change when the total load is changing. The CPU time for computing of neural network is lesser than using power toolbox of Matlab program. In three generator system, the input matrix layer will have [1 X 99] neurons and the output matrix layer will have [3 X 99] neurons. The hidden layer will have 30 neurons and it train with trainlm function which has goal performance of MSE at 1e-8. The CPU time for computing to training is 53.8359sec.

Unit (i)	Power output using lambda iteration			Cpu time (sec)	Power output using Neural Network method			CPU time (sec)
	PG1	PG2	PG3		PG1	PG2	PG3	
100	50	20	30	0.44	50	20	30	0.016
150	90.5	29.5	30	0.28	90.5	29.5	30	0.016
210	119.9	54.1	36	0.27	119.9	54.1	30	0.016
290	151.3	80.3	58.4	0.17	151.3	80.2	58.4	0.016
350	174.9	99.9	75.2	0.19	174.9	99.9	75.2	0.016
430	221.5	100	108.5	0.19	221.4	100	108.5	0.016
500	250	100	150	0.13	250	100	149.9	0.016

VI. CONCLUSION

This paper has presented the application of neural networks for economic dispatch for 3 three generator units. This proposed method has simulated to verify the performance. The result shows that the proposed methods are similar to using power toolbox of Matlab program. However, the neural network used less time than using power toolbox. For further study, this proposed method will test for ten and twenty generator units.

VII. REFERENCES

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