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Artificial Neural Network Approach for Economic Load Dispatch for varying Loads

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Abstract

The objective of the present paper is to know the distribution of load out of the total load arriving upon the generating plant for economic load dispatch. The plant consists of ten generating units each 250 MW. The estimation of load allocations to generators for every specific load has been carried out using mathematical approach as well as with the help of artificial neural network (ANN). After proper training of the artificial neural network when it is tested, it gave the load allocations for specific load which resulted in economic load dispatch. The results as obtained by mathematical modeling & artificial neural network show a good agreement. Thus it could be established that corresponding to certain load demand the ANN provides the loads to be taken up by the individual generators in the plant for ensuring economic load dispatch for every value of load demand.

Keywords: load demand, mathematical modeling, economic load dispatch, load allocations, artificial neural network

Introduction

The aim of present work is to develop an artificial neural network which works as a source to provide the load allocations to each of the generators so that the plant gives economic load dispatch for every value of load arriving on the plant. In this paper a generating plant having ten generating units each with a generation capacity of 250MW has been considered. It is aimed that all the units dispatch economically for every load demand. The artificial neural network has been deployed to provide load allocation to individual units as certain % of the total load appearing on the generating plant. Further these load allocations always satisfy the condition of economic dispatch. Thus the rate of change of fuel with power (dF/dP) remains same [1] in all the generators under every state of load demand from no load to full load. A mathematical model has been developed to obtain the size of load allocations to the units for a specific size of load on the plant.

Though the load allocations can be found for every value of load, yet the loads which are found to be repetitive in the duration of 24 Hrs.[3] every next day have been used to obtain a generalized data set for training the ANN. The ANN when tested for new load values, it gave the desired load allocations which agree to provide economic load dispatch.

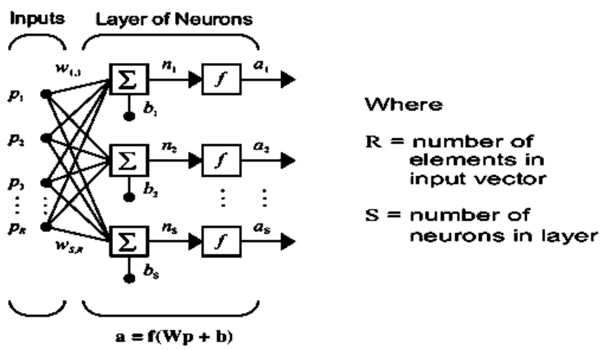
Thus it has been found that the results of ANN & mathematical model show a reasonably good agreement. Thus the ANN helps to give the load allocations for any new value of load such that optimal power flow or economic load dispatch is ensured. However this would require a specific fuel rate to be given to the turbine so that it generate power as desired by load allocation for given load demand. The paper however restricts the role of ANN to provide load allocations which ensure economic load dispatch and not upon the adjustment & control of fuel rate to agree with power demand.

The Feed Forward Network

In this type of networks, signal flow only in one direction from input to output. Their types include viz single layer and multilayer feed forward networks [11]

Single Layer Feed forward Networks

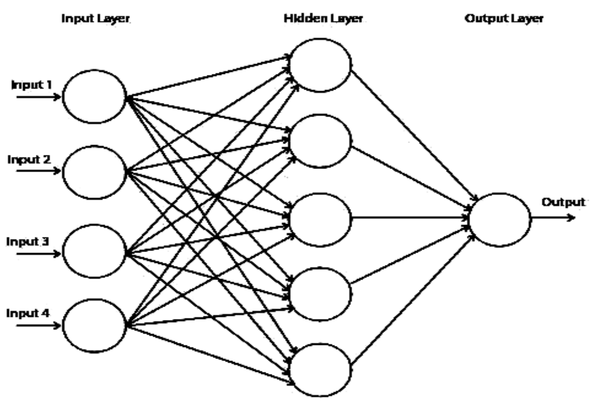
The networks in which signal flows from input layer to output layer neurons, but not vice versa are feed forward or acyclic type. It is illustrated in figure for the case of R input node and S output node. Perceptron is the simplest form of single layer network used for the classification of pattern said to be linearly separable.



Single Layer Feedforward Network

2.1.2 Multilayer Feed Forward Networks

Feed forward network with at least one hidden layer, whose computation nodes are correspondingly called hidden neurons or hidden units. These networks are used to implement higher order statistic. So it can deal with the nonlinear classification problem, system identification and control problems.



Multilayer Feed forward Network

Consider a generating plant having "n" no. of generators in order that it operates economically,

$$\frac{dF_1}{dP_1} = \frac{dF_2}{dP_2} = \cdots \ldots \ldots \ldots \ldots .. \frac{dF_n}{dP_n} = \lambda \ldots \ldots \ldots . (1.1)$$

Here

$$\lambda = \frac{change\ in\ fule\ supply}{change\ in\ power\ output} \ldots \ldots \ldots \ldots \ldots (1.2)$$

The cost of fuel/unit power F Rs/MW is given by

$F= a+ bP + cP^2$ Rs/MW… … … … … … … … … .. (1.3)

Thus the cost of fuel/MW depends on the size of power being generated by the generating unit. Also the cost of fuel depends on the certain design and operating constant a, b and c. These constant are different for different generating units. It is therefore even if the generators give equal power output 'P' it would cost differently to each of them. Also for all the generators to operate economically with varying values of constant a, b and c the ratio ($\frac{dF}{dP}$) should be equal for all the generating units i.e. equal to 'λ' It therefore requires Eqn. (1.1) to be satisfied.

Illustration:

Consider a generating plant with ten generators. If (F_1, P_1), (F_2, P_2), (F_3, P_3) ... (F_{10}, P_{10}) are pairs for fuel input and power output for generators G_1, G_2, G_3 ... G_{10}.

(i) Give the condition for economic load dispatch and

(ii) Obtain load allocation to individual Units for a given load on the plant.

Also let 'X' be the load at certain time "t"

if P_1, P_2, P_3 ..., P_{10} are the load allocations then

$P_1 + P_2 + P_3 + \ldots\ldots\ldots + P_{10} = X$ … … … … . (1.4)

For load demand 'X'.

3.1 Economic Load Dispatch

The condition for economic load dispatch in plant with "10" Generating units would be as given in Eqn. (1.1)

$$\frac{dF_1}{dP_1} = \frac{dF_2}{dP_2} = \cdots \ldots .. \frac{dF_{10}}{dP_{10}} = \lambda \ldots \ldots \ldots \ldots \ldots \ldots (1.5)$$

Let the fuel costs for each generators be,

$F_1 = a_1 + b_1P_1 + c_1P_1^2$

$F_2 = a_2 + b_2P_2 + c_2P_2^2$

. . . .

. . . .

. . . .

$F_{10} = a_{10} + b_{10}P_{10} + c_{10}P_{10}^2$

Here, when

$$\frac{dF_1}{dP_1} = \frac{dF_2}{dP_2}$$

gives.

$$P_2 = \left(\frac{b_1 - b_2}{2c_2}\right) + \frac{c_1}{c_2}.(P_1)$$

Similarly

$$P_3 = \left(\frac{b_2 - b_3}{2c_3}\right) + \frac{c_2}{c_3}.(P_2);$$

. . .

. . .

. . .

$$P_{10} = \left(\frac{b_9 - b_{10}}{2c_{10}}\right) + \frac{c_9}{c_{10}}.(P_9)$$

$$P_1 = \left(\frac{b_{10} - b_1}{2c_1}\right) + \frac{c_{10}}{c_1}.(P_{10})$$

Again

$$P_{10} = \left(\frac{b_1 - b_{10}}{2c_{10}}\right) + \frac{c_1}{c_{10}}.(P_1)$$

If the power generated by generator G_1, is P_1, and if P_1 & Non P_1 constants are then m_1& n_1

$P_2 = m_1 + n_1 P_1$

$P_3 = m_2 + n_2 (m_1 + n_1 (P_1))$

. . . .

. . . .

. . . .

$P_{10} = m_9 + n_9 (m_8 + n_8 (m_7 + n_7 (m_6 + n_6 (m_5 + n_5 (m_4 + n_4 (m_3 + n_3 (m_2 + n_2 (m_1 + n_1 (P_1)))))))))$

On generalization the load allocation to i^{th} generator is given by

$P_{i+1}= m_i+n_i (m_{i-1}+n_{i-1} (m_{i-2}+n_{i-2} (m_{i-3}+n_{i-3}(m_{i-4}+n_{i-4} (\ldots\ldots\ldots\ldots m_{i-j}+n_{i-j}(P_1))$ … … … … . … … … … . (1.6)

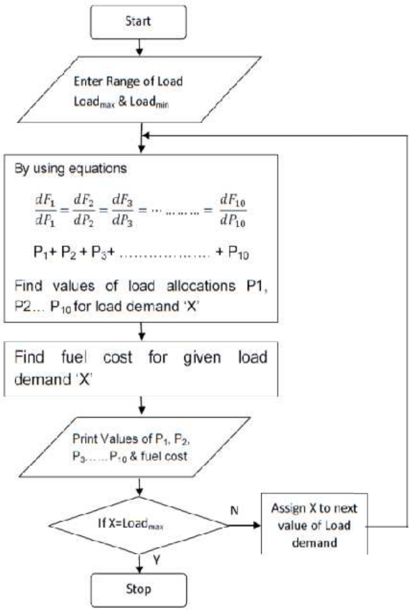
Also

$$\left.\begin{aligned} m_i &= \left(\frac{b_i - b_{i+1}}{2c_{i+1}}\right) \\ n_i &= \left(\frac{c_i}{c_{i+1}}\right) \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots (1.7)$$

Where i = 1, 2, 3, 4, 5 ... 9 and j = i-1

For Economic Load Dispatch

The Flowchart to determine load allocations to individual units in a generating plant having ten units is as

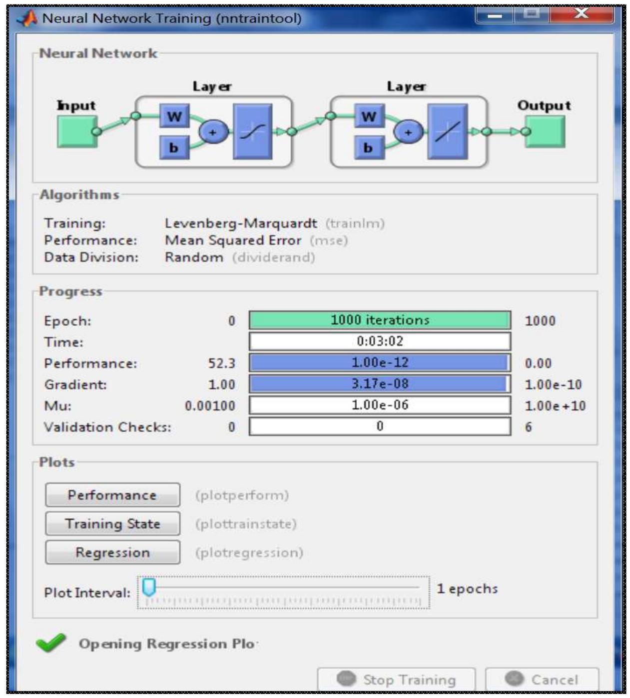


Mathematical Approach for Determination of Loads

A computer program whose algorithm is as given in appendix-1 has been developed on the basis of formula for load allocation given by Eqn (1.4), (1.5), (1.6) & (1.7). The results for load allocation as obtained by above equation [4] is given as under. Though the load is varying from no-load to full load. The data corresponding to some specific loads are given in table 1.

Determination of load allocations using ANN approach.

The ANN has been organized on MATLAB platform architecture and training [7] is for load solutions shown in the training window as below in figure



ANN Training Window

The training data for load near 1600MW, 1800MW, 2000MW, & 2200MW has been developed after training the testing of ANN has been done it gave results as shown in Table-I

TABLE I. **Comparison of mathematical & ANN outcomes of load allocation**

Sr. No.	Generator	Approach	Load on individual Generator			
			1600 MW	**1800 MW**	**2000 MW**	**2200 MW**
1.	**G1**	**Mathematical**	168.226339	189.217407	210.208475	231.199543
		ANN	168.226341	189.217412	210.208504	231.199547
		Error	2.34E-06	4.63E-06	2.94E-05	3.93E-06
2.	**G2**	**Mathematical**	152.023945	171.106734	190.189523	209.272312
		ANN	152.023947	171.106738	190.18955	209.272315
		Error	1.57E-06	4.01E-06	2.65E-05	3.16E-06
3.	**G3**	**Mathematical**	148.882754	167.295971	185.709189	204.122406
		ANN	148.882755	167.295975	185.709214	204.122409
		Error	1.43E-06	3.90E-06	2.54E-05	3.43E-06
4.	**G4**	**Mathematical**	170.128918	191.548375	212.967832	234.387289
		ANN	170.12892	191.548379	212.967862	234.387293
		Error	1.61E-06	4.43E-06	2.97E-05	3.98E-06
5.	**G5**	**Mathematical**	164.927783	185.507262	206.08674	226.666219
		ANN	164.927786	185.507266	206.086769	226.666222

		Error	2.60E-06	4.21E-06	2.91E-05	3.43E-06
6.	**G6**	**Mathematical**	149.487803	168.229828	186.971853	205.713878
		ANN	149.487805	168.229832	186.971879	205.713881
		Error	1.65E-06	3.77E-06	2.57E-05	3.12E-06
7.	**G7**	**Mathmatical**	153.842127	172.924916	192.007705	211.090494
		ANN	153.842128	172.92492	192.007731	211.090497
		Error	1.43E-06	3.95E-06	2.63E-05	3.20E-06
8.	**G8**	**Mathematical**	177.368446	199.699369	222.030293	244.361216
		ANN	177.368448	199.699374	222.030324	244.36122
		Error	2.17E-06	5.08E-06	3.09E-05	3.91E-06
9.	**G9**	**Mathematical**	140.188616	157.681173	175.173729	192.666286
		ANN	140.188618	157.681176	175.173754	192.666289
		Error	1.90E-06	3.23E-06	2.48E-05	3.10E-06
10.	**G10**	**Mathematical**	174.92327	196.788966	218.654662	240.520357
		ANN	174.9232723	196.7889704	218.6546922	240.5203612
		Error	2.32E-06	4.38E-06	3.02E-05	4.20E-06

Since the errors are within 5%, the results show good agreement hence the ANN-approach can suitably be used to determine the load allocation to ensure economic load dispatch.

Conclusion

- The developed ANN works successfully to obtain economic load dispatch.
- The load allocations as obtained by ANN Approach and the mathematical approach are closely placed. This gives strength to ANN approach to be used as a reliable tool for determining load allocations for economic load dispatch.
- A computer program has been developed to workout the outcomes of mathematical model.
- The error in mathematical & ANN approach is within 5%.

Future Scope

The exercise of determining load allocation for economic load dispatch at every state load cell be useful if the practical implementation to ensure supply of load demand by the generator could be made possible. This require the development of her real time controller for the purpose. This would be the next direction research.

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Appendix-1

The Algorithm to determine load allocations to individual units in a generating plant having ten units is as below

1. Start
2. Enter Range of Load ($Load_{min,}$ L_{max})
3. By using equation

$$\frac{dF_1}{dP_1} = \frac{dF_2}{dP_2} = \frac{dF_3}{dP_3} = \cdots \ldots \ldots \ldots \ldots .. \frac{dF_{10}}{dP_{10}}$$

   - P1+ P2 + P3+ ………………+ P10=X
   - Find values of P_1, P_2, …………P_n

4. Find fuel cost for given load X
5. Print Values of P1, P2, P3…… & fuel cost.
6. If X=Lmax
7. No Go for next value of load
8. Yes Exit