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Static And Dynamic Economic Load Dispatch Using Neural Networks

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***Abstract*— This paper presents a static and dynamic economic dispatch study in electrical power systems using the artificial intelligence, or more précising: the neural networks. Starting first of all by the load flow study to get an idea about the total :demand, generation and losses, moving to the optimization of the power flow using the gradient method and the neural network as an modern option. Of course system constraints are included such as line losses and generators limits. Furthermore, a comparison between the results using the above mentioned methods is carried out at the end of this paper.**

Index Terms— Economic Load Dispatch, Neural networks, Artificial Intelligence, Load flow.

I. INTRODUCTION

The economic dispatch problem is the determination of generation levels, in order to minimize the total generation cost for a defined level of load. It's a kind of management for electrical energy in the power system in way to operate their generators as economically as possible [1].

In the other side we know that the factors having effects on the power generators cost are:

- Operating efficiencies of generators.
- Fuel cost.
- Transmission line losses.

Initially Neural networks objective was: patterns recognition, classification. Then it becomes very interesting in all domains.

II. LOAD FLOW STUDY -NEWTON RAPHSON-

The system of equations we need to study is the following [2]:

$$P_i = V_i \sum_{j=1}^{n} V_j \left(G_{ij} \cos \delta_{ij} + B_{ij} \sin \delta_{ij}\right)$$
$$Q_i = V_i \sum_{j=1}^{n} V_j \left(G_{ij} \sin \delta_{ij} - B_{ij} \cos \delta_{ij}\right) \quad (1)$$

The aim is to get the phase and the magnitude of the voltage at any bus of generation. This can be obtained by using the jacobian matrix

$$\begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \vdots \\ \Delta P_n \\ \Delta Q_{m+1} \\ \Delta Q_{m+2} \\ \vdots \\ \Delta Q_n \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \frac{\partial P_2}{\partial \delta_3} & \cdots & \frac{\partial P_2}{\partial \delta_n} & \frac{\partial P_2}{\partial |\bar{V}_{m+1}|} & \frac{\partial P_2}{\partial |\bar{V}_{m+2}|} & \cdots & \frac{\partial P_2}{\partial |\bar{V}_n|} \\ \frac{\partial P_3}{\partial \delta_2} & \frac{\partial P_3}{\partial \delta_3} & \cdots & \frac{\partial P_3}{\partial \delta_n} & \frac{\partial P_3}{\partial |\bar{V}_{m+1}|} & \frac{\partial P_3}{\partial |\bar{V}_{m+2}|} & \cdots & \frac{\partial P_3}{\partial |\bar{V}_n|} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial P_n}{\partial \delta_2} & \frac{\partial P_n}{\partial \delta_3} & \cdots & \frac{\partial P_n}{\partial \delta_n} & \frac{\partial P_n}{\partial |\bar{V}_{m+1}|} & \frac{\partial P_n}{\partial |\bar{V}_{m+2}|} & \cdots & \frac{\partial P_n}{\partial |\bar{V}_n|} \\ \frac{\partial Q_{m+1}}{\partial \delta_2} & \frac{\partial Q_{m+1}}{\partial \delta_3} & \cdots & \frac{\partial Q_{m+1}}{\partial \delta_n} & \frac{\partial Q_{m+1}}{\partial |\bar{V}_{m+1}|} & \frac{\partial Q_{m+1}}{\partial |\bar{V}_{m+2}|} & \cdots & \frac{\partial Q_{m+1}}{\partial |\bar{V}_n|} \\ \frac{\partial Q_{m+2}}{\partial \delta_2} & \frac{\partial Q_{m+2}}{\partial \delta_3} & \cdots & \frac{\partial Q_{m+2}}{\partial \delta_n} & \frac{\partial Q_{m+2}}{\partial |\bar{V}_{m+1}|} & \frac{\partial Q_{m+2}}{\partial |\bar{V}_{m+2}|} & \cdots & \frac{\partial Q_{m+2}}{\partial |\bar{V}_n|} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial Q_n}{\partial \delta_2} & \frac{\partial Q_n}{\partial \delta_3} & \cdots & \frac{\partial Q_n}{\partial \delta_n} & \frac{\partial Q_n}{\partial |\bar{V}_{m+1}|} & \frac{\partial Q_n}{\partial |\bar{V}_{m+2}|} & \cdots & \frac{\partial Q_n}{\partial |\bar{V}_n|} \end{bmatrix} \begin{bmatrix} \Delta \delta_2 \\ \Delta \delta_3 \\ \vdots \\ \Delta \delta_n \\ \Delta |\bar{V}_{m+1}| \\ \Delta |\bar{V}_{m+2}| \\ \vdots \\ \Delta |\bar{V}_n| \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} [\Delta \delta^{(k)}] \\ [\Delta |\bar{V}|^{(k)}] \end{bmatrix} = [J]^{-1} \begin{bmatrix} [\Delta P^{(k)}] \\ [\Delta Q^{(k)}] \end{bmatrix} \quad (4)$$

$$V_i^{k+1} = V_i^k + \Delta V_i^k$$
$$\delta_i^{k+1} = \delta_i^k + \Delta \delta_i^k \quad (5)$$

III. ECONOMIC DISPATCH STUDY

III.1. *The cost function*

$$F_i\,(P_{Gi}) = a_i + b_i\,P_{Gi} + c_i\,P_{Gi}^2 \quad (6)$$

$F_i\,(P_{Gi})$: is the function we need to optimize.

Where:

P_{Gi} = the real generated power in per unit on a common power base.
F_i = the operating cost of unit in \$/h.
a_i ,b_i and c_i are the cost coefficients of the generator i.
Expressed in dollars per hour (\$/h). [3][4][5][6]

III.2. Equality constraints

$$\sum_{i=1}^{N} P_{Gi} = P_D + P_L \quad (7)$$

P_D : total system demand.
P_L: total system loss.
N: total number of generators. [5][6][7]

III.3. Inequality constraints

$$P_{i(min)} \leq P_i \leq P_{i(max)} \quad i = 1, \dots, N \quad (8)$$

$P_{i(max)}$: The maximum output of generator i.
$P_{i(min)}$: The minimum output of generator i. [5][6][8].

III.4. Losses formula

$$P_L = \sum_{\substack{i=1 \\ j=1}}^{N} B_{ij} \, P_{Gi}{}^2 \qquad (9)$$

B_{ij} are called the loss coefficients, which are assumed to be constant for a base range of load.

III.5.Condition on the generated power

The Lagrange function can be constructed as shown bellow [10][11]:

$$L = F_{Total} + \lambda(P_D + P_L - \sum_{i=1}^{N} P_{Gi}) \qquad (10)$$

Where: λ is called Lagrange multiplier. Or mathematically the incremental cost.

$$\left(\frac{\partial L}{\partial P_{Gi}} = 0 \; and \; \frac{\partial L}{\partial \lambda} = 0\right) \qquad (11)$$

We can find the iterative compact form to get the minimum cost:

$$P_i^{(K)} = \frac{\lambda^{(k)} - b_i}{2(c_i + \lambda^{(k)} B_{ii})} \qquad (12)$$

IV. NEURAL NETWORKS

IV.1. Neuron Model

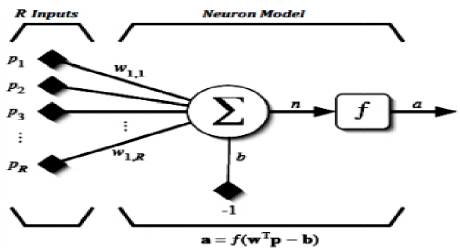

Fig.1 Artificial neuron model [11]

$$n = \sum_{j=1}^{R} w_{1,j} p - b \qquad (13)$$

$$a = f(\sum_{j=1}^{R} w_{1,j} p - b) \qquad (14)$$

IV.2. Error correction learning

$$Error_{\,global} = \frac{1}{2P} \sum_{P=1}^{P} \sum_{K=1}^{N} \left(y_k^{(p)} - d_k^{(p)}\right)^2 \qquad (15)$$

$$\Delta w_{kj} = -\eta \nabla_{w_{kj}} \left(\text{Error}_{\text{global}}\right) \Rightarrow \Delta w_{ki} = \eta y_j (d_k - y_k) \qquad (16)$$

Where, Δw_{ki} is the weight variation of the connection between the neurons j from the anterior layer and the output layer node k.

d_k: The desired neuron output k.y_j and y_k are the output values produced in the neuron i and k respectively [11]

$$w_{kj}^{actual} = \Delta w_{kj} + w_{kj}^{anterior} \qquad (17)$$

V. APPLICATION AND COMPARISON

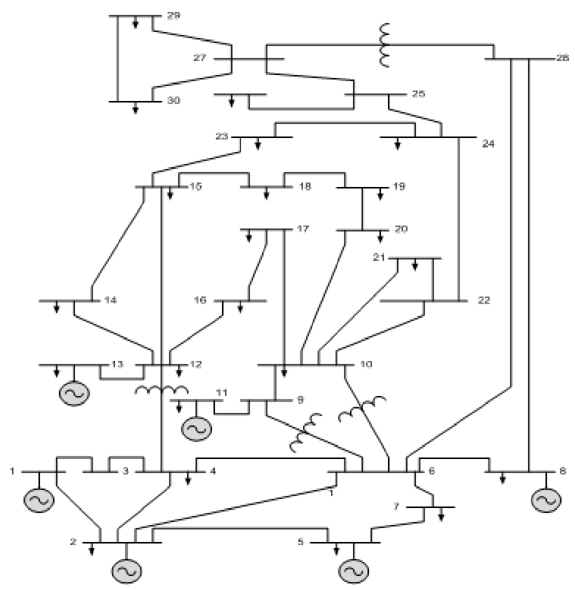

Fig .2 Single line diagram of IEEE-30bus [2]

V.1. *Results*

V.1.1. *Load flow*

n° jb	V(pu)	Delt (°)	Pg MW	Qg MVR	Pl MW	QlMVR
1	1,06	0,000	260,983	-20.498	0,000	0,000
2	1,04	-5,503	40,000	47,014	21,70	12,700
3	1,02	-8,039	0,000	0,000	2,400	1,200
4	1,01	-9,701	0,000	0,000	7,600	1,600
5	1,01	-14,335	0,000	32,648	94,2	19,000
6	1,01	-11,451	0,000	0,000	0,000	0,000
7	1,00	-13,160	0,000	0,000	22,800	10,900
8	1,02	-12,235	0,000	44,012	22,800	30,000
9	1,05	-14,451	0,000	0,000	0,000	0,000
10	1,04	-16,029	0,000	0,000	5,800	2,000
11	1,07	-14,451	0,000	11,121	0,000	0,000
12	1,06	-15,323	0,000	0,000	11,200	7,500
13	1,07	-15,323	0,000	0,000	0,000	0,000
14	1,04	-16,209	0,000	10,137	6,200	1,600
15	1,04	-16,293	0,000	0,000	8,200	2,500
16	1,04	-15,893	0,000	0,000	3,500	1,800
17	1,04	-16,195	0,000	0,000	9,000	5,800
18	1,03	-16,893	0,000	0,000	3,200	0,900
19	1,02	-17,058	0,000	0,000	9,500	3,400
20	1,03	-16,858	0,000	0,000	2,200	0,700
21	1,03	-16,474	0,000	0,000	17,500	11,200
22	1,03	-16,460	0,000	0,000	0,000	0,000
23	1,03	-16677	0,000	0,000	3,200	1,600
24	1,02	-16,846	0,000	0,000	8,700	6,700
25	1,02	-16,460	0,000	0,000	0,000	0,000
26	1,00	-16,875	0,000	0,000	3,500	2,300
27	103	-15,962	0,000	0,000	0,000	0,000
28	1,01	-12,120	0,000	0,000	0,000	0,000
29	1,01	-17,174	0,000	0,000	2,400	0,900
30	1,00	-18,043	0,000	0,000	10,600	1,900
Total			300,983	124,434	283,400	126,200

V.1.1. Static economic dispatch using classical method and neural networks.

Total demand (MW)	Inc cost (λ) ($/MWh)	Generation (MW)						Total Gene (MW)	Total Cost ($)
		P1	P2	P3	P4	P5	P6		
300.98 Classic	8,1245	62,308	61,683	25,000	62,308	61,683	28,000	300,980	4.289,7
300 .98 ANN	8,1243	62,310	61,685	25,001	62,310	61,685	28,001	300,980	4.289,7

V.1. 2. Dynamic economic dispatch using neural networks

- *Training phase*

In our case we are studying a fitting problem this may explain the reason for which we are going to use Levenberg - Marquard algorithm.

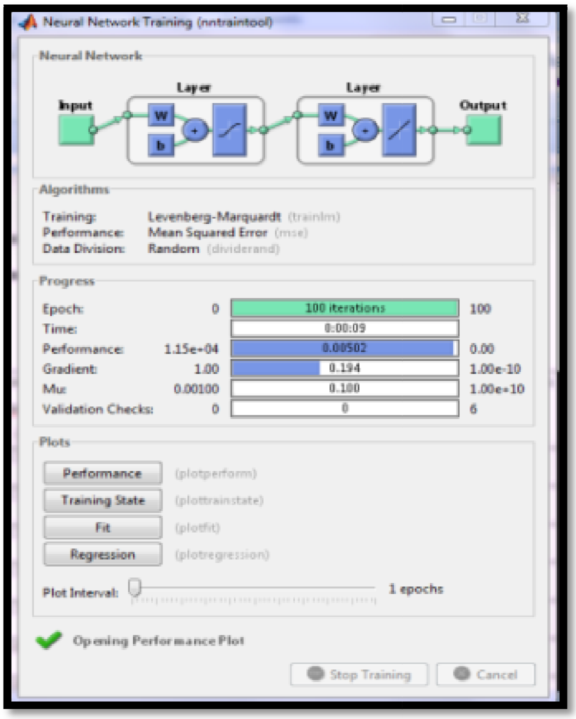

Fig.3 Architecture, training algorithm and cost function

This figure illustrates us:

1- The architecture of the neural network, so it contains two layers, the first one is hidden with two neurons and tangent sigmoid transfer function (tang). Whereas the second one is the output of the network containing seven neurons and a pure linear Transfer function (purelin).
2-The training algorithm is Levenberg-Marquard (trainlm) .
3-The performance is the mean squared error, on matlab (mse)
4-Data division: divide random.
5-The convergence is satisfied at the ninth second (9sec) and the iteration number100.

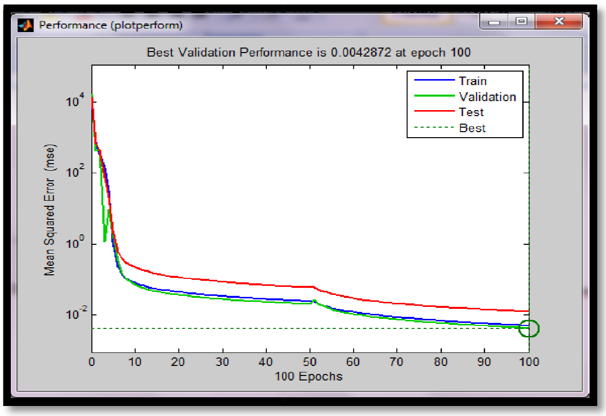

Figure.4. Performance

The best validation performance or the main squared error is about 0.0042872 at one hundred epochs. The total system (the training, validation and the test) is descending fast to reach the value mentioned earlier.

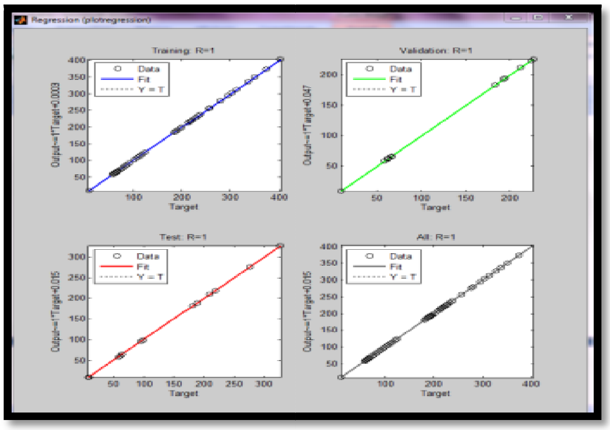

Figure.5 .Regression

The regression is best when it reaches the value (1); and this is illustrated in figure (3),for the training, validation and the test .

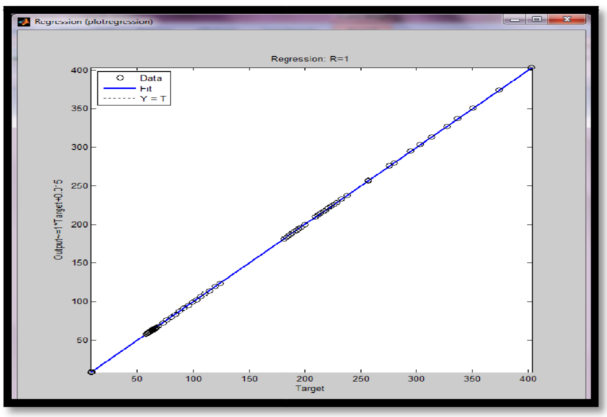

Figure.6. The regression for the total system

- *Real time*

After the training phase the network is ready to be used at real time.And this is the allocation of the generated power for a total demand varying from 909(MW) to 1589(MW).

Total demand (MW)	The generation					
	G1(MW)	G2 (MW)	G3 (MW)	G4 (MW)	G5(MW)	G6 (MW)
909	237.55	154.20	70.554	229.08	162.42	64.962
919	240.21	155.82	71.382	231.72	164.06	65.759
929	242.87	157.45	72.210	234.36	165.70	66.558
939	245.53	159.07	73.039	237.01	167.34	67.356
949	248.20	160.70	73.868	239.65	168.98	68.155
959	250.86	162.32	74.697	242.30	170.62	68.955
969	253.53	163.95	75.527	244.95	172.26	69.754
979	256.19	165.58	76.357	247.60	173.90	70.554
987	258.33	166.88	77.021	249.72	175.22	71.194
997	261.00	168.5	77.852	252.37	176.86	71.995
1006	263.40	169.97	78.600	254.76	178.34	72.715
1140	299.28	191.77	89.762	290.41	200.36	83.470
1280	336.96	214.54	101.48	327.84	223.37	94.752
1309	344.78	219.26	103.91	335.62	228.13	97.095
1430	377.54	238.9	114.08	368.16	247.98	106.890
1598	423.28	266.09	128.26	413.61	275.46	120.540

And we can see now the total losses, generation and cost.

Tlosses (MW)	T Generation (MW)	T Cost ($)
9.7627	918.76	9451.8
9.9543	928.95	9539.3
10.1500	939.15	9627.0
10.3490	949.35	9714.8
10.5520	959.55	9802.7
10.7590	969.76	9890.7
10.9690	979.97	9978.8
11.1820	990.18	10067.0
11.3560	998.36	10138.0
11.5750	1008.60	10226.0
11.7760	1017.80	10306.0
15.0460	1155.00	11502.0
18.9370	1298.90	12771.0
19.7940	1328.80	13036.0
23.5460	1453.50	14152.0
29.2380	1627.20	15724.0

VI. Conclusion

In this paper a static and a dynamic economic dispatch study's has been developed using the artificial intelligence or more précising the neural networks. This method has been tested on a test grid IEEE 30bus. Results obtained show that the neural networks method give better results than the classical method. Results shown previously illustrate us clearly the exactitude and the velocity of the neural network.This optimization on time is in another word an optimization on fuel.

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