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Solution of Economic Load Dispatch problem in Power System using Lambda Iteration and Back Propagation Neural Network Methods

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Abstract: Economic load dispatch is the process of allocating the required load demand between the available generators in power system while satisfying all units and system equality and inequality constraints. Economic Load Dispatch solutions are found by solving the conventional methods such as lambda iteration, Gradient search method, Linear Programming and Dynamic Programming while at the same minimizing fuel costs, but convergence is too slow, so in order to get fast convergence and accurate results we are using artificial neural network. Artificial neural network is well-known in the area of power systems. It is a very powerful solution algorithm because of its rapid convergence near the solution. This property is especially useful for power system applications because an initial guess near the solution is easily attained. In this paper a three generator system is considered and by using lambda iteration method Economic Load Dispatch is determined and 150 patterns for different loads will be derived from same method to train neural network. As it is too slow method, we proposed a soft computing based approach i.e. Back Propagation Neural Network (BPNN) for determining the optimal flow. This method provides fast and accurate results when compared with the conventional method.

Keywords: Load Dispatch, Economic Load Dispatch, Lambda Iteration, Back Propagation Training Algorithm, Neural Network and Artificial Neural Network.

1. Introduction

The optimal system operation, in general, involved the consideration of economy of operation, system security, emission at certain fossil-fuel plants, optimal releases of water at hydro generation, etc. All these consideration may make for conflicting requirement and usually a compromise has to be made for optimal system operation [1]. The main aim in the economic dispatch [2] problem is to minimize the total cost of generation real power (production cost) [3] at various stations while satisfying the load and the losses in transmission line. The major component of generation operating cost is the fuel input/hour. The fuel cost is meaningful in case of thermal and nuclear stations, but for hydro station where the energy storage is 'apparently free'. The operating cost as such is not meaningful.

Since an engineer is always concerned with the cost of products and services, the efficient optimum economic operation [4] and planning of electric power generation system have always occupied an important position in the electric power industry. With 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. A saving in the operation of the system of a small percent represents a significant reduction in operating cost as well as in the quantities of fuel consumed. The classic problem is the economic load dispatch of generating systems to achieve minimum operating cost.

This problem area has taken a subtle twist as the public has become increasingly concerned with environmental matters, so that economic dispatch now includes the dispatch of systems to minimize pollutants and conserve various forms of fuel, as well as achieve minimum cost. In addition there is a need to expand the limited economic optimization problem to incorporate constraints on system operation to ensure the security of the system,

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thereby preventing the collapse of the system due to unforeseen conditions. However closely associated with this economic dispatch problem is the problem of the proper commitment of any array of units out of a total array of units to serve the expected load demands in an 'optimal' manner. For the purpose of optimum economic operation of this large scale system, modern system theory and optimization techniques are being applied with the expectation of considerable cost savings.

2. Economic Load Dispatch

The economic load dispatch (ELD) is an important function in modern power system like unit commitment, Load Forecasting, Available Transfer Capability (ATC) calculation, Security Analysis, Scheduling of fuel purchase etc. A bibliographical survey on ELD methods reveals that various numerical optimization techniques have been employed to approach the ELD problem. ELD is solved traditionally using mathematical programming based on optimization techniques such as lambda iteration, gradient method, Newton's method, Piecewise linear cost functions, Linear programming , Dynamic programming.

The Economic Load Dispatch (ELD) problem is one of the fundamental issues in power operation. The ELD problem involves the solution of two different problems. The first of these is the Unit Commitment or pre-dispatch problem wherein it is required to select optimally out of the available generating sources to operate, to meet the expected load and provide a specified margin of operating reserve over a specified period of time.

The second aspect of economic dispatch is the on-line economic dispatch wherein it is required to distribute the load among the generating units actually paralleled with the system in such manner as to minimize the total cost of supplying the minute-to-minute requirements of the system. The main objective is to reduce the cost of energy production taking into account the transmission losses. While the problem can be solved easily if the incremental cost curves of the generators are assumed to be monotonically increasing piece-wise linear functions, such an approach will not be workable for nonlinear functions in practical systems. In the past decade, conventional optimization techniques such as lambda iterative method, linear programming and quadratic programming have been successfully used to solve power system optimization problems such as Unit commitment and Economic load dispatch. Lambda iteration, gradient method can solve simple ELD calculations and they are not sufficient for real applications in deregulated market. However, they are fast.

There are several Intelligent methods among them genetic algorithm applied to solve the real time problem of solving the economic load dispatch problem. Whereas some of the works are done by Evolutionary algorithm. Few other methods like tabulation search are applied to solve to solve the problem. Artificial neural network[5] are also used to solve the optimization problem. However many people applied the swarm behavior to the problem of optimum dispatch as well as unit commitment problem are general purpose; however, they have randomness. For a practical problem, like ELD, the intelligent methods[6][7] should be modified accordingly so that they are suitable to solve economic dispatch with more accurate multiple fuel cost functions and constraints, and they can reduce randomness.

A. Cost Function

The total cost incurred to generate electrical energy is the sum of the cost of individual generator[8][9]. Cost function is given by

$$C = \sum_{i=1}^{N} C_i (P_{gi}) \tag{1}$$

B. System Constraints

Broadly speaking there are two types of constraints

i) Equality constraints

ii) Inequality constraints

i) Equality Constraints

From observation we can conclude that cost function is not affected by the reactive power demand. So the full attention is given to the real power balance in the system. Power balance requires that the controlled generation variables P_{Gi} abbey the constraints equation.

$$P_D = \sum_{i=1}^{n} P_{gi} \qquad (2)$$

ii) In-Equality Constraints

Inequality constraints consists of generator constraints such as active power and reactive power constraints as below

Active Power Constraint: $P_{\min} \leq P \geq P_{\max}$

Reactive Power Constraint: $Q_{\min} \leq Q \geq Q_{\max}$

The inequality Constraints also consists of Voltage Constraints, Running Spare Capacity Constraints, Transmission Line Constraints, Transformer taps settings, Network security constraints.

3. Lambda iteration method

Algorithm for Lambda Iteration method [10][11] :

1. Read data, namely cost coefficients, a_i, b_i , c_i : B-coefficients , b_{ij}, b_{i0} , b_{00} (i=1,2,……..NG; j=1,2,………NG) ITMAX, ε,α
2. Compute
$$\lambda = \frac{\dfrac{\partial F(P_{gi})}{\partial P_{gi}}}{1 - \dfrac{\partial P_i}{\partial P_{gi}}} \qquad (3)$$
$$P_{gi} = \frac{\lambda - b_i}{2a_i} \qquad (4)$$
3. Assume no generator has being fixed at either lower limit or at upper limit
4. Set iteration counter, IT=1
5. Compute
$$P_{gi} = \frac{\lambda(1 - B_{i0} - \sum_{\substack{j=1 \\ j\neq i}}^{N_G} 2B_{ij}P_{gj}) - B_i}{2(a_i + \lambda B_{ii})} \qquad (5)$$
6. Compute transmission losses $P_L = B_{00} + \sum_{i=1}^{N_G} B_{i0}P_{gi} + \sum_{i=1}^{N_G}\sum_{j=1}^{N_G} P_{gi}B_{ij}P_{gj}$ (6)
7. Compute $\Delta P = P_D + P_L - \sum_{i=1}^{N_G} P_{Gi}$ (7)
8. Check $|\Delta P| \leq \varepsilon$, if yes then goto step 11
Check IT≥ ITMAX, if yes then GOTO step11
9. Modify $\lambda^{new} = \lambda + \alpha\Delta P$, where α is the step size used to increase or decrease the value of λ in order to meet the step 7
10. IT=IT+1, $\lambda = \lambda^{new}$ and GOTO step 5 and repeat
11. Check the limits of generators if no more violations then GOTO step13, else fix as following
If $Pgi < Pgi^{min}$ then $Pgi = Pgi^{min}$
If $Pgi > Pgi^{\max}$ hen $Pgi = Pgi^{max}$
12. GOTO step4
13. Compute the optimal total cost and transmission losses.
14. Stop

4. Back propagation neural network

Back Propagation is a systematic method for training multilayer artificial networks. It is a multilayer forward network using extend gradient-descent based delta-learning rule, commonly known as back propagation rule. Back propagation provides a computationally efficient method for changing the weights in a feed forward network, with differential activation function units, to learn a training set of input-output examples. Being a gradient descent method it minimizes the total squared error of the output computed by net. The network is trained by supervised learning method.

The aim of this network is to train the net to achieve a balance between the ability to respond correctly to the input patterns that are used for training and the ability to provide good responses to the input that are similar.

Algorithm:

The Total algorithm will be the combination of the following four groups (A,B,C &D)

A. Initialization of the weights

Step1:Initialize weights to small random values

Step2: While stopping condition is false do Steps 3-10

Step3: For each training pair do steps 4-9

B. Feed Forward

Step4: Each hidden unit receives the input signal xi and transmits the signals to all units in the layer above i.e. hidden units

Step5: Each hidden unit sums its weihted input signals

$$Z_{-inj} = Voj + \sum_{i=1}^{n} (X_i x V_{ij}) \tag{8}$$

applying activation function for to get output

$$Z_j = f(Z_{-inj}) \tag{9}$$

Step6: Each output unit sums its weighted input signals

$$Y_{-inj} = W_{ok} + \sum_{j=1}^{p} (Z_j x W_{jk}) \tag{10}$$

and apply activation function to calculate output

$$Y_k = f(Y_{-inj}) \tag{11}$$

C. Back Propagation of errors

Each output unit receives a target pattern corresponding to an input pattern , error information term is calculated as

$$\Delta_k = (t_k - y_k) x\ f(Y_{-ink}) \tag{12}$$

Step8: Each hidden unit sums its delta from units in the layer above

$$\delta_{-\mathrm{inj}} = \sum_{k=1}^{m} \delta_j x W_{jk} \tag{13}$$

The error information term is calculated as

$$\delta_j = \delta_{-\mathrm{inj}}\ x\ f(Z_{-\mathrm{inj}}) \tag{14}$$

D.Updation of the weights

Step9: Each unit updates its bias and weights

The weight correction term is given by

$$\Delta W_{jk} = alpha\ x\ \delta_{k\ x} Z_j \tag{15}$$

And the bias correction term is given by

$$\Delta W_{ok} = alpha\ x\ \delta_k \tag{16}$$

Therefore

$W_{jk}(new)=W_{jk}(old)+ \Delta W_{jk},$ (17)

$W_{ok}(new)=W_{ok}(old)+ \Delta W_{ok}$

Each hidden unit updates its bias and weights.The weight correction term is given by

$\Delta V_{ij}=alpha \ x \ \delta_{j \ x} X_i$ (18)

And the bias correction term is given by

$\Delta V_{ok}=alpha \ x \ \delta_j$

Therefore $V_{ij}(new)=V_{ij}(old)+ \Delta V_{ij},$ (19)

$V_{oj}(new)=V_{oj}(old)+ \Delta W_{oj}$

Step10:Test stopping condition

5. Test system

The three generating units considered are having different characteristic. Their cost function characteristics are given by following equations

$$F1 = 0.00156x\,P_{g1}^2 + 7.92x\,P_{g1} + 561$$

$$F2 = 0.00194x\,P_{g2}^2 + 7.85x\,P_{g2} + 310$$

$$F3 = 0.00482x\,P_{g3}^2 + 7.97x\,P_{g3} + 78$$

According to the constraints considered in this work among inequality constraints only active power constraints are considered. Their operating limit of maximum and minimum powers are also different. The unit operating ranges are

$$100MW \le P_{g1} \ge 600MW$$

$$100MW \le P_{g2} \ge 400MW$$

$$50MW \le P_{g2} \ge 200MW$$

The transmission line losses can be calculated by knowing the loss coefficient. The B_{mn} loss coefficient matrix is given by

$$B_{mn} = \begin{bmatrix} 0.7 & 0.05 & 0.075 \\ 0.05 & 0.15 & 0.01 \\ 0.075 & 0.10 & 0.450 \end{bmatrix}$$

6. Result

Lambda iteration method is converged in 15 iterations and error is minimized below 0.001. The error versus iterations graph is as shown in figure 1

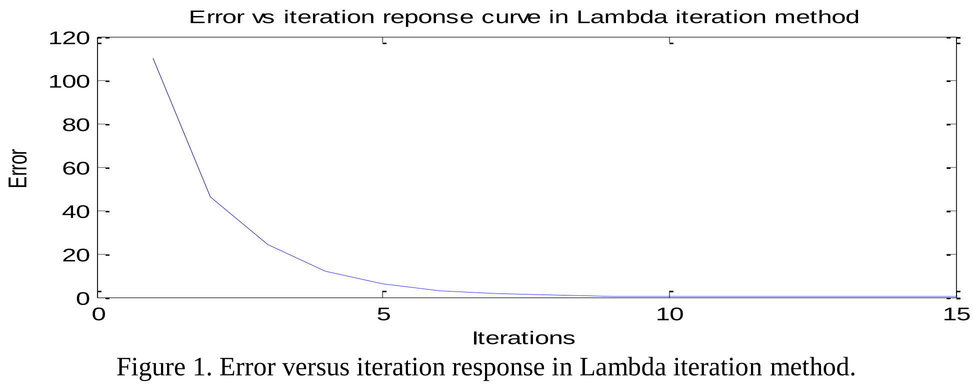

Figure 1. Error versus iteration response in Lambda iteration method.

Economic Dispatch using Lambda Iteration method is as given in the conclusion Table.

Using Lambda Iteration method for different input load demands different out puts were determined as a training set to the neural network. Neararly 150 training patterns were developed. But Neural Network accepts values between 0 and 1only, so all these patterns has to be normalised between 0and 1.

Normalization is done as follows.

- Select maximum and minimum values out of the total training patterns
- Now normalization of any value x is given by

Norm =(x-min)/ (max-min).

The architecture of the proposed Back Propagation Neural Network has been shown in fig.2.

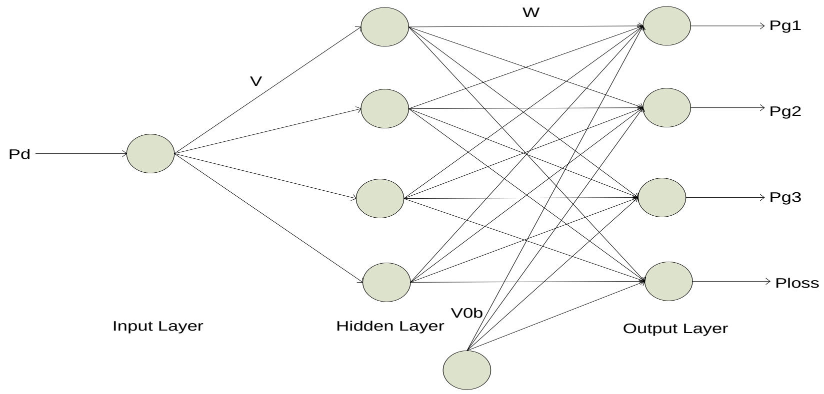

Figure2. Proposed Back Propagation Neural Network

The network considered is having 1 input neurons and 4 hidden layer neurons and 4 output layer neurons. 1 bias neuron is also connected to the output layer. The inputs to the neural network is active power demand and Outputs of the neural network are Economic Load Dispatch of the three generators and loses.

Neural Network is converged in 21430 iterations and the error versus iterations graph is as shown in fig.3 , eight iterations are picked randomly out of total iterations.

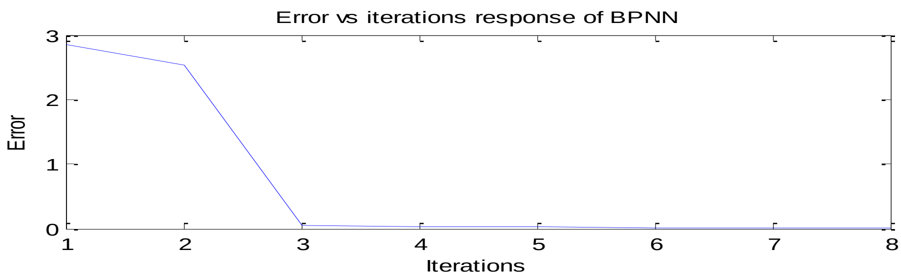

Figure 3. Error versus iteration response of BPNN

The finalized weights after complete training with 150 patterns are as follows

weihts between output and hidden layer

[-3.75094 -6.35845 3.44324 -6.3468
-3.79352 -5.1391 5.78377 -5.17903
-3.80224 -5.13058 5.78339 -5.17952
-3.77419 -5.2295 5.68096 -5.26371]

weihts between hidden and output layer

[-20.6266 -1.17142 1.16001 -1.17133]

bias weihts between output and hidden layer

[2.36679
0.00325223
0.00237995
0.00996728]

Table 1. Comparison

In the above comparison table for different load demands using Lambda iteration and Back Propagation Neural network Economic Load Dispatch [12] and losses are determined.

S.no	Input	Lambda iteration method					Artificial neural network				
---	PD	PG1	PG2	PG3	PL	TIME	PG1N	PG2N	PG3N	PLN	TIME
1	528	210.13	242.37	81.13	5.64	0.419	210.14	242.46	81.16	5.65	0.0142
2	534	212.57	245.05	82.15	5.77	0.456	212.32	244.76	82.04	5.76	0.0264
3	537	213.78	246.39	82.66	5.84	0.342	213.69	246.28	82.62	5.83	0.008
4	540	215.00	247.73	83.17	5.91	0.372	215.08	247.82	83.21	5.91	0.0175

Comparison is made in view of accuracy and time of execution. Load Demand in the above Table is randomly selected. For to calculate the Economic Load Dispatch different conventional methods such as Lambda iteration, Gradient Search methods, Linear Programming and Dynamic Programming and also evolutionary programming methods such as Genetic Algorithm, Particle swarm Optimization[13][14][15], Ant Colony and Bees optimization algorithm will be used. But Artificial Neural Network is a soft computing technique which can give accurate and fast results when compared to above methods.

7. Conclusion

Economic load dispatch problem here solved for two cases. One with transmission losses and other without transmission losses in three units generating station. This problem is solved by Lambda-Iteration method in the MATLAB environment. After solving economic load dispatch problem the total operating cost of power generation is low. This low operating cost is achieved by proper scheduling of each unit using lambda-iteration method. Optimal Dispatch of Power Generation for the given load patterns by using conventional method i.e. NEWTON method are determined. As this is too slow, we proposed a soft computing based approach i.e. Back Propagation Neural Network (BPNN) for determining the load dispatching. This method provided fast and accurate results when compared with the conventional method. By using this soft computing method we can also reduce the execution time, which plays a vital role in load sharing.

In future this project can be extended by using Radial Basis Function Neural Network (RBFNN).

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