FUZZY LOGIC AND NEURAL NETWORK APPROACH TO SHORT TERM THERMAL UNIT COMMITMENT

Maninder Kaur, Rajdeep Kaur Dhaliwal

ABSTRACT

A work on neural network and fuzzy logic based technique for solving the problem of unit commitment in any electric utility is presented in this paper. The effectiveness of economic dispatch is well understood when the objective is to schedule the committed generators to meet the load, maintain voltages and frequency within prescribed tolerances and minimize operating cost without unduly stressing the equipment. The objective of this paper is to commit the units with the AI techniques back propagation neural network and Fuzzy logic without violating the constraints and to compare the results in order to find the best suitable method. A three-unit system is considered as an example and the above mentioned values were computed.

KEYWORDS: Back propagation, Neural network, Fuzzy logic, Unit commitment, Economic dispatch, Optimization

I. INTRODUCTION

In any power system, the load is dynamic in nature. It is higher during the daytime and early evening when industrial loads are high; lights are on, and so forth and lower during the late evening and early morning when most of the population is asleep. The load variation is continuous and the load must be met with the available resources economically. This is done by committing (switching ON) and decommitting (switching OFF) of the units in power station. By running only the most economic units, the load can be supplied to the best efficiency of unit operators. Thus committing the correct number and kind of units such that the load is met at least operating cost [1, 13]. There have been many methods that are available to solve the unit commitment problem such that the Lagrangian method, Dynamic Programming (DP), branch and bound technique, simulated annealing, Priority listing and Advanced Priority listing method. The DP method based on priority list is flexible, but it computational time suffers from dimensionality. Lagrangian relaxation for UCP is superior to DP due to its higher solution quality and faster computational time. However, numerical convergence and solution quality of LR do not give satisfactory results in case identical units exit. These methods though may give results but does not give a qualitative interpretation of the results in terms of input variables. Hence a fuzzy logic technique is used in order to solve the problem of unit commitment. The use of fuzzy logic has received increased attention in recent years because of its usefulness in reducing the need for complex mathematical models in problem solving. Fuzzy logic employs linguistic terms, which deal with the casual relationship between input and output variables. Hence, it simplifies the approach for manipulating and solving many problems, particularly where the mathematical models are either not explicitly known or if known it is difficult to formulate them. It also attempts to quantify the linguistic terms so that the variables can be treated as continuous rather than discrete. Furthermore, Fuzzy logic is a technique, which approximates reasoning, while allowing decisions to be made efficiently [4, 5, 16, 17]. The growing application of artificial intelligence techniques to power engineering has the potential of using the state of art technology in scheduling the short term power generation. In recent years, the neural network supported systems have started a new era of engineering technology holding its integrity. Simulation of neural networks and various expert system shells via computer software has provided powerful tools for developing new systems [7, 10, 15]. The neural network computing enhanced by expert systems has opened up a new route for the optimization of generation scheduling. With proper and sufficient training, the information regarding the optimal operation of a system can be stored in the network as such, and the output can be obtained in a much shorter time. In the problem, multilayer feed forward network using back propagation error of learning determine variables corresponding to the operating level of generators and production cost. Load demand profile is input to the neurons in the input layer. Generation is the output to the neurons in the output layer [1, 6, 14, 15].

II. PROBLEM FORMULATION

A. Back Propagation Algorithm

1. Read the input values, \(X\), target values, \(T\), learning rate coefficient, \(\eta\), tolerance limit of error, \(\varepsilon\), maximum number of iterations, \(\alpha\), neurons in hidden layer, \(n\), input nodes, \(m\), output nodes, \(z\), maximum value of input, \(x_{\text{max}}\), maximum value of target, \(t_{\text{max}}\)

2. Normalize the input and target vector.
3. Activate the first node of the input by 1.0 and the rest by the normalized inputs.

4. Generate the random weights.

5. Set all the elements of error weight matrices \(dW_1\) and \(dW_2\) equal to zero.

6. Set \(epoch = 0.0\).

7. Set \(serr = 0.0\).

8. Calculate output \(Y_1\) using

\[
Y_1(k) = X(1,i)W_1(i,k)
\]

where \(i = 1,2,\ldots,m, k = 1,2,\ldots,n\) (1)

Process output of hidden layer through a non linear activation function (positive sigmoid function) to produce output of hidden layers.

\[
Y_1(k) = 1/(1+\exp(-Y_1(k))\)
\]

where \(k = 1,2,\ldots,n\) (2)

Calculate the final output using

\[
Y_2(j) = Y_1(1,k)W_2(k,j)
\]

where \(j = 1,2,\ldots,z, k = 1,2,\ldots,n\) (3)

11. Process again through sigmoid function to find output of network.

\[
Y_2(2,j) = 1/(1+\exp(-Y_2(j))\)
\]

where \(j = 1,2,\ldots,z\) (4)

12. Calculate square error as

\[
e(s,1) = T(s,1) - Y_2(1,1)
\]

\[
serr+ = e(s,1) + e(s,1)T
\]

where \(s = 0.0\) (5)

13. Adjust the weight of output layer

\[
d12(j) = Y_2(j)(1-Y_2(j))e(s,1)T
\]

\[
dW_2(j,1) = \eta d12(j)(Y_2(2,j) + \alpha dW_2(j,1)
\]

\[
W_2(j,1) = dW_2(j,1)
\]

(6)

14. Adjust the weight of hidden layer

\[
s_{\text{sum}_w} = 0;
\]

\[
s_{\text{sum}_w} = d12(j)W_2(j,1)
\]

\[
d11(k) = s_{\text{sum}_w} = Y_1(k)(1-Y_1(k))
\]

\[
dW_1(i,k) = \eta d11(k)x(i) + \alpha dW_1(i,k)
\]

\[
W_1(i,k) = dW_1(i,k)
\]

(7)

15. Check for tolerance, if \(serr > \varepsilon\) then go to step 7.

16. Test the stopping condition.

The stopping condition may be the minimization of errors, number of epochs, etc.

**B. Fuzzy Logic Algorithm**

1. Identify fuzzy input and output variables.

The identified fuzzy input and output variables are load demand, incremental cost and power generation of three units.

2. Relate the fuzzy input and output variables using fuzzy rules (If-then) like if the load demand is low and incremental cost is low then the power generation of unit 1 is low, power generation of unit 2 is low and power generation of unit 3 is low.

3. Observe the results that satisfy more than one rule.

4. Defuzzify the output variable (power generation).

5. Then from the output variable cost is obtained

6. Repeat steps 2 to 5 for all the possible applied rules.

**C. Fuzzy Sets Associated With Unit Commitment**

After identifying the fuzzy variables associated with unit commitment, the fuzzy sets defining these variables are selected and are normalized between 0 and 1. This normalized value can be multiplied by a selected scale factor to accommodate any desired variable.

The sets defining the load demand as follows:

\[LD, MW = \{\text{Low, below average, Average, above average, High}\}\]

The incremental cost is stated by the following sets:

\[IC, Rs = \{\text{Zero, Small, large}\}\]

The power generation, chosen as the objective function, is given by:

\[PG, Rs = \{\text{Low, below average, Average, above average, High}\}\]

Based on the aforementioned fuzzy sets, the membership functions chosen for each input and output variables. For convenience, a triangular shape is used to illustrate the membership functions considered here. Once these sets are established, the input variables are then related to the output variable by IF-THEN rules [4, 11, 18].

**IV. EXAMPLE PROBLEM AND SIMULATION RESULTS**

The above mentioned approach is applied to a system comprised of 3 generating units whose input data like Load Pattern of 24 hr, Cost functions and Unit Characteristics [1] are listed in Table I and II. A MATLAB code developed for solving back propagation neural network and fuzzy logic based unit commitment problem is used to solve the above problem. The results obtained using the back propagation neural network and fuzzy logic approach is tabulated against that obtained using the conventional dynamic approach in Table III.

**Table 1. Load Pattern**

<table>
<thead>
<tr>
<th>Hrs</th>
<th>Load (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-3</td>
<td>400</td>
</tr>
<tr>
<td>3-6</td>
<td>450</td>
</tr>
<tr>
<td>6-9</td>
<td>700</td>
</tr>
<tr>
<td>9-12</td>
<td>600</td>
</tr>
<tr>
<td>12-3</td>
<td>550</td>
</tr>
<tr>
<td>3-6</td>
<td>500</td>
</tr>
<tr>
<td>6-9</td>
<td>750</td>
</tr>
<tr>
<td>9-12</td>
<td>650</td>
</tr>
</tbody>
</table>
TABLE II. UNIT CHARACTERISTICS

<table>
<thead>
<tr>
<th>Unit no.</th>
<th>Max (MW)</th>
<th>Min (MW)</th>
<th>No load cost(Rs/hr)</th>
<th>Start up cost, Rs (hot)</th>
<th>Start up cost, Rs (cold)</th>
<th>Fuel cost (Rs/MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>600</td>
<td>150</td>
<td>213</td>
<td>250</td>
<td>400</td>
<td>1.1</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>100</td>
<td>175</td>
<td>175</td>
<td>300</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>50</td>
<td>115</td>
<td>100</td>
<td>200</td>
<td>1.2</td>
</tr>
</tbody>
</table>

TABLE III. RESULTS

<table>
<thead>
<tr>
<th>Load (MW)</th>
<th>Fuzzy logic approach</th>
<th>Neural Network Approach</th>
<th>Conventional dynamic approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>467.86</td>
<td>431.2306</td>
<td>909.524</td>
<td>504.55</td>
</tr>
<tr>
<td>517.86</td>
<td>486.2506</td>
<td>910.4743</td>
<td>557.43</td>
</tr>
<tr>
<td>767.86</td>
<td>761.6675</td>
<td>921.0281</td>
<td>1397.13</td>
</tr>
<tr>
<td>667.86</td>
<td>649.9988</td>
<td>920.9738</td>
<td>716.09</td>
</tr>
<tr>
<td>617.86</td>
<td>598.3325</td>
<td>913.9218</td>
<td>663.21</td>
</tr>
<tr>
<td>567.86</td>
<td>540.8338</td>
<td>910.4743</td>
<td>610.32</td>
</tr>
<tr>
<td>817.86</td>
<td>804.9975</td>
<td>921.0281</td>
<td>1506.96</td>
</tr>
<tr>
<td>717.86</td>
<td>704.9999</td>
<td>921.0281</td>
<td>2275.95</td>
</tr>
<tr>
<td>Total cost of operation (Rs)</td>
<td>4978.3103</td>
<td>7328.4525</td>
<td>8231.64</td>
</tr>
</tbody>
</table>

A comparison of results in table III indicates that neural network and fuzzy logic approach is comparable to the conventional dynamic approach. Neural network and fuzzy logic approach gives a lesser operating cost and dynamic approach gives more operating cost.

V. CONCLUSION

In a power system there is a large variation in load from time to time and it is not possible to have the load scheduling pattern for every possible load demand. As there is no general procedure for finding out the economical load scheduling pattern. This is where ANN plays an important role as we need small number of training data sets for the training of ANN. A trained ANN can then be applied to find out the economical load scheduling pattern for a particular load demand in a fraction of second.

Unit commitment is a problem where ambiguity exists and such problems can be easily addressed to using fuzzy logic. As the size of the system grows and more complicated constraints are imposed, it is often insufficient to rely on human intuition to achieve the optimal solution. Hence, fuzzy logic is implemented for solving the Unit Commitment problem. It was demonstrated that Unit Commitment problem can be solved using fuzzy logic and this method can be applied to any no. of units, each with different operating costs. From this approach, it can be concluded that the outcomes are easily understood in terms of the logical representation of the rules.

VI. FUTURE SCOPE

Due to flexibility in ANN several other practical constraints can also be easily incorporated as input-output information of the training sets. For future work, it is suggested to design a general ANN for such problems. Also, methods can be thought of which reduce the training time.

The proposed problem can also be solved with other artificial intelligence technique like Evolutionary programming and Genetic algorithm etc. The above problem can also be solved if the system complexity increases i.e. either by increasing the no. of units or adding the no. of constraints. We can also formulate the proposed technique by committing each unit separately.

REFERENCES


11. Mohammad Mohatram, Sanjay Kumar, “Application of artificial neural network in economic generation scheduling of thermal power plants”.


