Application of Radial Basis Function Network for the Modeling and Simulation of Turbogenerator

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Abstract—In this paper, the applicability of Radial Basis Function (RBF) network for the modeling and simulation of turbogenerators is presented. It is expensive and time-consuming to do experimental work to predict the behaviour of Turbogenerators with changing all variables. The RBF network is developed with speed and excitation current as inputs and voltage, active power and reactive power as desired outputs. The proposed RBF model is developed and trained with MATLAB 7.8 software. To obtain the optimal RBF model several structures have been constructed and tested. The comparison between experimental and predicted values using the proposed RBF model shows that there is a good agreement between them. Moreover, the RBF model is compared with another model named Multi Layer Perceptron (MLP), which is another important architectures of neural networks. The results obtained show that the proposed RBF model is more accurate and reliable than MLP model.

Index Terms— Radial basis function, Modelling, neural network, Turbogenerator.

I. INTRODUCTION

A turbogenerator is a turbine directly connected to an electric generator for the generation of electric power [1]. Turbo generators are used on steam locomotives as a power source for coach lighting and heating systems [1]. Synchronous generators or alternators are synchronous machines used to convert mechanical power to AC electric power. The term synchronous refers to the fact that the electric frequency of the machine has been locked by a mechanical shaft. Generators are composed of two parts: moving parts, which are called rotor and the fixed part known as the stator. In [2] an artificial neural network (ANN) generalised inversion control strategy for a turbo-generator governor is proposed. The ANN generalised inversion, which can approach the dynamic inversion of the original controlled system, is composed of a single static ANN and several linear components. In [3] the characteristic of neural network to model bulb turbogenerators is presented. The results obtained from the nonlinear simulation demonstrate the adaptability and robustness of the control system based on the neural network. In [4] a novel algorithm called particle swarm optimization (PSO-BP) is proposed for ANN learning based on PSO to overcome the flaws of the traditional BP learning algorithm of its low convergence. The modeling and simulation of induction machines using vector computing technique in matlab/simulink is presented in [5], which provides an efficient approach for further research on wind generation system integration and control. A new wind turbine generator system is introduced, and its mathematical model, blade pitch control scheme, and nonlinear simulation software for the performance predication are presented [6]. A variable-speed induction generator, aimed at supplying an autonomous power system is presented [7]. The design of a fuzzy logic supervisor for the control of active and reactive power, which is generated by fixed speed wind energy conversion systems (WECS) is presented [8]. ANN [9] is used for multi-objective optimal reactive compensation of a power system with wind generators and after a training phase, the ANN model has the capacity to provide a good estimation of the voltages, the reactive productions and the losses for actual curves of the load and the wind speed, in real time. However, with regard to complexity and volume of calculations governing generator, the simulation of such a machine is time consuming. In this paper, radial basis function (RBF) network is used for modeling and simulation of turbogenerators. The schematic of the proposed RBF model is shown in Fig.1 where the RBF model is developed with speed and excitation current as inputs and voltage, active power and reactive power as desired outputs.
II. RADIAL BASIS FUNCTION

A RBF network is an ANN that uses RBFs as activation functions. RBFs can fit erratic data [10, 11]. They are used in function approximation, time series prediction, and control due to their good approximation capabilities, faster learning algorithms and simpler network structures. The RBF has a feed forward structure and typically has three layers: an input layer, a hidden layer with a non-linear RBF activation function and a linear output layer. Hidden unit implements a radial activated function. The input layer is made up of source nodes that connect the network to its environment. The hidden layer consists of a set basis function unit that carry out a nonlinear transformation from the input space to the hidden space. The transformation from input to hidden layer is nonlinear and from hidden to output layer is linear. The output from jth neurons of the hidden layer is given by:

\[ Z_j = k \left( \frac{\|x - \mu_j\|}{\sigma_j} \right) \quad j = 1, 2, \ldots, k \]

where \( K \) is a strictly positive radially symmetric function (kernel) with a unique maximum at its center \( (\mu_j) \), which drops off rapidly to zero away from the center. The number of neurons in the hidden layer is \( k \), and \( \sigma_j \) is the width of the receptive field in the input space from unit j. This indirectly indicate that \( Z_j \) has a desired value only when the distance \( \|x - \mu_j\| \) is smaller than the \( \sigma_j \).

The output of the mth neuron in the output layer is given by:

\[ y_m(x) = \sum_{j=1}^{k} w_{jm} z_j(x) \quad m = 1, 2, \ldots, M \]

where \( w_{jm} \) is the weighting factor.

III. RESULT AND DISCUSSION

For developing the proposed RBF model about 440 data were used. Total data are divided into two sets: training and testing. About 70% of the data were selected for training and 30% for testing the proposed RBF model. The best RBF network is obtained with 452 neurons in hidden layer. The comparisons between experimental and predicted values using the proposed RBF model are shown in Figs. 3-6. These figures compare the predicted values (RBF) and experimental values of voltage, active power and reactive power. From these figures, it is clear that the predicted values using the proposed RBF model are in good agreement with experimental data with least error. Also we have compared the proposed RBF model with MLP model [12] as shown in Table 1, where the mean relative error percentage (\( MRE\% \)) is evaluated as:

\[ MRE\% = \left( \frac{1}{N} \sum_{i=1}^{N} \left( \frac{X_{\text{Exp},i} - X_{\text{Pred},i}}{X_{\text{Exp},i}} \right) \right) \times 100 \]

Where \( N \) is the number of data and ‘\( X_{\text{Exp}} \)’ and ‘\( X_{\text{Pred}} \)’ stand for experimental and predicted values, respectively. It is observed from Figs. 3-6 and Table I that there is a good agreement between experimental and predicted values using RBF network and also the proposed RBF model is more accuracy in comparison with the MLP model [12].
TABLE I.
OBTAINED MRE% FOR THE PROPOSED RBF MODEL IN COMPARISON WITH MLP MODEL [12].

<table>
<thead>
<tr>
<th>Data</th>
<th>Output</th>
<th>MLP [12]</th>
<th>RBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train</td>
<td>Voltage</td>
<td>0.0492</td>
<td>0.0421</td>
</tr>
<tr>
<td></td>
<td>Active power</td>
<td>0.2116</td>
<td>0.193</td>
</tr>
<tr>
<td></td>
<td>Reactive power</td>
<td>0.186</td>
<td>0.169</td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

In this paper, an accurate RBF model is developed for the modeling and simulation of turbogenerator. The network is developed based on the experimental data. The comparison between experimental values and predicted values shows that there is a good agreement between them with MRE% less than 0.52%. Also the proposed RBF model is compared with the MLP model. The results obtained clearly demonstrate that RBF is more accurate in comparison with MLP model. With this ability, we can use our model as a tool in order to obtain turbogenerator outputs with different conditions with high computation speed and accuracy.

REFERENCES

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