Recent Developments on Applications of Neural Networks to Power Systems Operation and Control: An Overview

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Abstract. Artificial neural networks (ANNs) have found many potential applications in power systems operation and control recently. This paper presents a categorization of the main significant applications of neural networks, which includes power system controller design, power system security assessment and load forecasting. It is desired that they are helpful to the construction of more efficient, robust ANNs to solve a broader range of problems in power systems.

1 Introduction

Power system blackouts are rare events. However, when they occur, the effects on commerce, industry, and everyday life of the general population can be quite severe. In order to prevent a blackout, it is important to develop some strategies to meet the load demand and satisfy the stability and reliability criteria. Due to the increasing complexity of modern power systems, it is always attractive to employ intelligent system technology. The term "intelligent system" is often used to represent any combination of artificial neural networks (ANN's), expert systems, fuzzy-logic systems, and other emerging technologies, such as genetic algorithms. This paper concentrates on applications of ANNs to power systems and presents an overview on main significant applications of neural networks in recent years, which include power system controller design, power system security assessment and load forecasting.

2 An Introduction to Artificial Neural Networks

An ANN can be seen as a union of simple processing units, based on neurons that are linked to each other through connections similar to synapses. Many different types of ANN's are described in the technical literature. The main types of networks that have

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been used in power system applications are classified as: 1) Multilayer perceptrons; 2) Hopfield networks; 3) Kohonen networks; 4) Other networks. In this section, due to its very widespread application (over 80%), we concentrate on the overview of applications of the multi-layer perceptron (MLP) network. A multilayered perceptron (MLP) was used and trained with a supervised learning algorithm called back-propagation. A MLP consists of several layers of processing units that compute a nonlinear function of the internal product of the weighted input patterns. These types of networks can deal with nonlinear relations between the variables; however, the existence of more than one layer makes the weight adjustment process for problem solution difficult. In the original version, the back-propagation learning algorithm adjusts the weight of the connections one pattern at a time. The input patterns are represented by a vector $X_p = (x_{p1}, x_{p2}, \cdots, x_{pN})$ and are submitted to the ANN through the input layer that simply redistributes them to the following hidden layer. Each neuron of the following layer receives the weighted signals (signal multiplied by a weight) and generates an output signal to the following layer. This process is repeated until the output layer is reached, where the neurons will generate the output of the ANN for the given input vector. With the output of the ANN obtained, the weight adjustment of the connections will begin in the direction from output layer to input layer. The weight adjustments are realized in order to minimize the error function for a certain pattern. Equation (1) illustrates the error function

$$E_p = \frac{1}{2}\sum_j (d_{pj} - y_{pj})^2 , \tag{1}$$

where d_p is the desired output for input pattern *p* and y_p is the actual output pattern. Equation (2) mathematically defines how the connection weights of the network are modified

$$\omega_{ij}(t+1) = \omega_{ij}(t) + \eta\delta_j y_i , \tag{2}$$

where ω_{ji} is the weight of the connection between neurons *i* and *j*, and η is the learning rate. $\delta_j = (d_{pj} - y_{pj})$ if neuron *j* is an output layer unit and $\delta_j = \sum_k \delta_k \omega_{jk}$ if neuron *j* is a hidden layer unit. The choice of an appropriate learning parameter η will considerably influence the convergence rate of the algorithm [1]. For more details about neural networks, one can refer to [1].

3 An Overview on Recent Applications

ANN applications can be broken into two main categories: 1) curve fitting and regression and 2) pattern recognition and classification. While in many ways these two categories are the same, regression analyses often require some type of *a priori* knowledge of the general trends involved and the variables that significantly influence the trends. Examples of ANN applications to a variety of power system problems that are pertinent to industrial and commercial power systems can be found in