



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: VII Month of publication: July 2018

DOI: <http://doi.org/10.22214/ijraset.2018.7070>

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Applications of Artificial Neural Networks in Power Systems: A Review

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Abstract: A standout amongst the most energizing and potentially productive ongoing developments is expanding use of Artificial Intelligence techniques like artificial neural networks, expert system, genetic algorithms and fuzzy logic. Artificial neural networks in particular, have gained enormous attention due to the variety of advantages they offer over the conventional method. Among these advantages the self-adaptive, flexible computational tool, fast speed, and robustness are the most profound. This paper presents an overview of ANNs in power system subjects like load forecasting, transient stability analysis and economic load dispatch.

Keywords: Neural network; load forecasting; economic dispatch; power system and transient stability.

I. INTRODUCTION

Artificial Intelligence is based around the idea that human knowledge can be characterized in such exact terms that a machine can mimic it. The goals of artificial intelligence include learning, reasoning and perception, and machines are wired using a cross-disciplinary approach based in mathematics, computer science, linguistics, psychology and more. Following three fields of AI techniques that are majorly considered to be applied in power systems are:

- A. Expert Systems
- B. Fuzzy Logic
- C. Artificial Neural Networks

An Artificial Neural Network (ANN) is an information processing paradigm that is stimulated the way as the biological nervous systems process information. Large number of interconnected processing units called neurons work together to solve specific problems. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in a biological system, or specifically a brain, is due to the adjustments of synaptic connections that exists between the neurons. This paper is an overview of applications of ANNs in power system operation and control. It is to be noted that the following areas have attracted the most attention in the past eight years:

- D. Economic load dispatch
- E. Load forecasting
- F. Security assessment
- G. Fault Detection
- H. Transient stability

The key element of this paradigm is the structure of the information processing system. In this paper we will discuss the applications of ANNs in Load forecasting, Transient stability analysis, and Economic load dispatch.

II. ARTIFICIAL NEURAL NETWORK

A. An Artificial Neuron

An artificial neuron is a connection point in an artificial neural network. Like the biological neural network in human's artificial neural networks also have a layered architecture and each neuron (connection point) has the ability to process input and forward output to other nodes in the network. The connections between the nodes (or neurons) are characterized by synaptic weights, which represent the significance of the connection. As new data is received and processed the synaptic weights change and this is how learning occurs. An example of an artificial neuron is shown in Fig. 1.

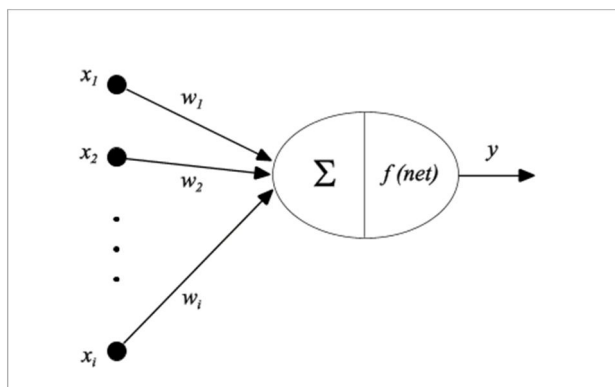


Figure1. An Artificial Neuron.

B. Architecture Of Neural Network

Networks are formed from trillions of neurons (nerve cells) exchanging brief electrical pulses called action potentials. Artificial neural network consists of a large number of computer algorithms that mimic the biological structures in humans. Neural network research is used to develop computers that can deal with abstract and poorly defined problems. For examples, tasks like understanding a particular speech or recognizing faces is very easy for humans in comparison to conventional computers. A number of neural network structures have been studied earlier. This neural network is formed in three layers, called the input layer, hidden layer, and output layer. A neural network can consist of a number of hidden layers. Each layer consists of one or more nodes, represented in this diagram by the small circles. The flow of information from one node to the next is indicated by the lines between the nodes (neurons). In this type of neural network, the information flows only from the input to the output i.e. from left to right. In contrast, many neural network also consists of feedback paths.

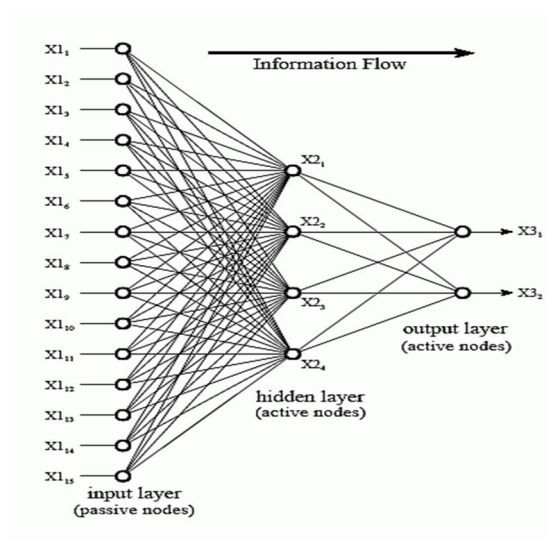


Figure2. Architecture of a Neural Network.

The nodes of the very first layer or input layer are passive meaning they do not modify the data. They receive a single value on their input, and duplicate the values to their multiple outputs. In comparison, the nodes of the hidden and output layer are active. This means they modify the data. The variables: X_1, X_2, \dots, X_{15} holds the data to be evaluated. Each value from the input layer is duplicated and sent to all the nodes of the hidden layer. This is called a fully interconnected structure. The values entering a hidden layer node are multiplied by weights. The weight assigned to a node is a set of predetermined numbers stored in the program. The weighted inputs are then added to produce a single number. Before leaving the node, this number is passed through a nonlinear mathematical function called a sigmoid. The input to a sigmoid function is a value between $-\infty$ and $+\infty$, while its output can only be between 0 and 1. The outputs from the hidden layer are represented in the flow diagram by the variables: X_{21}, X_{22}, X_{23} and X_{24} .

Again, each of these values is duplicated and applied to the next layer. The active nodes of the output layer combine and modify the data to produce the two output values of this network, X_{31} and X_{32} . Neural networks can have any number of layers, and any number of nodes per layer. Most applications use the three layer structure with a maximum of a few hundred input nodes. The hidden layer is usually about 10% the size of the input layer. In the case of target detection, the output layer consists of a single node. The output of this node is functioned to provide a positive or negative indication of the target's presence or absence in the input data. This basic architecture of neural network is shown in Fig 2.

ANN can be classified as supervised ANN or unsupervised ANN. The supervised ANN requires the sets of inputs and the outputs for its training. During the training, the output from the ANN is compared with the desired output (target) and the difference (error) is reduced by employing some training algorithm. This training is repeated till the actual output acquires an acceptable level. Supervised ANN may be a feed forward or non-recurrent network such as Multi Layer Perceptron (MLP), Functional Link Net (FLN). On the other hand, the artificial neural network which does not require a supervisor or teacher for training is known as unsupervised ANN. In competitive or unsupervised learning units of the output layer compete for the chance to respond to a given input pattern. Kohonen's Self-Organizing Feature Map (SOFM) and Adaptive Resonance Theory (ART) are examples of unsupervised learning.

III. APPLICATIONS OF NEURAL NETWORKS IN POWER SYSTEMS

This section deals with applications of ANN in power systems. Areas like security assessment, transient stability, fault detection and diagnosis, control analysis includes the major use of ANN. Most popular problems are: (i) Load Forecasting (ii) Transient stability analysis and (iii) Economic load dispatch. Fig 3 shows the distribution of use of ANN in the various areas of power systems.

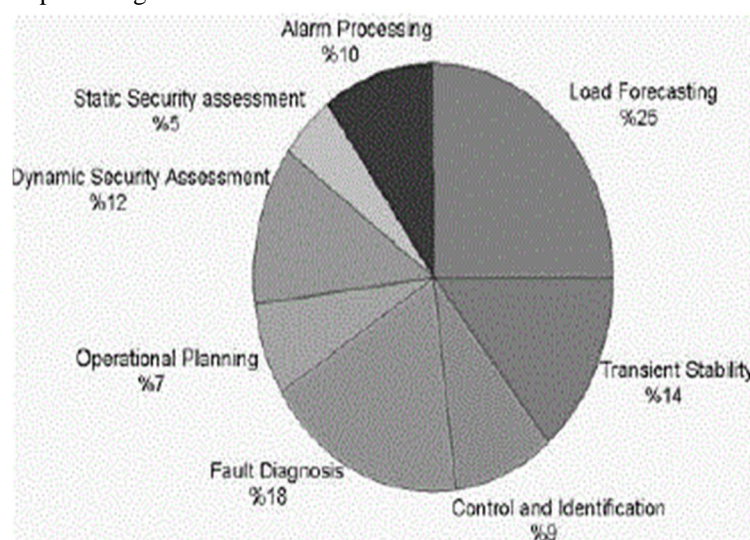


Figure3. Distribution on the basis of use of ANN.

A. Load Forecasting

Electric load forecasting is an important aspect in electric power industry. It is a technique used to predict the future electric load. This is done with the help of historical and current load as well as weather information. In the past few decades, several models have been developed to forecast electric load more accurately. Load forecasting can be categorized as long term, medium term or short term. Long term load forecasting deals with leading time for more than a year. On the other hand short-term forecasting covers a time span of one hour to seven days.

While applying neural networks to load forecasting we need to select the architecture, the number of layers and elements, the connectivity between the various layers, use of bi-directional or uni-directional links, and the number formats. Many architectures such as Hopfield, back propagation, boltzman machine etc. have been studied. The most popular artificial neural network architecture for electric load forecasting is back propagation. Back propagation neural networks use continuously valued functions and supervised learning. In supervised learning, the actual numerical weights assigned to element inputs are determined by matching historical data (such as time and weather) to desired outputs.

B. Transient Stability Analysis

Transient stability is the ability of the system to stay in synchronism when subjected to a large disturbance. Due to large disturbances like faults, large load variations, generator outages etc. there will be large swings in the electrical power outputs, rotor angles, rotor speeds and bus voltages of the generators in the system. Due to this reason a power system cannot be linearized, like in the case of small signal stability analysis. The system cannot be linearized for large disturbances, hence Eigen value analysis cannot be used for assessing the stability as the system is nonlinear. One way of assessing the effect of large disturbances on the system stability is through numerical solution of differential algebraic equations (DAE). The time of interest for transient stability assessment is typically 2 to 10 seconds after a disturbance. During this time usually it is assumed that the turbine and its governors would not be acting as they are mechanical systems. Hence, for transient stability analysis usually the turbine and speed governor dynamics are not considered and the input mechanical torque is considered constant.

Many researchers have been working on the use of artificial neural networks in transient stability analysis. The Critical Clearing Time (CCT) is a very important parameter in order to maintain the stability of power systems. The CCT is the maximum time duration that a fault may occur in power systems without failure in the system so as to recover to a steady state operation. Some works have been carried out to determine the CCT of power systems using the feed forward multilayer perceptron (MLP) with back propagation learning. ANN method based on fuzzy ARTMAP architecture is also used to analyze TSA of a power system. Works have also been published for determining the transient stability using Probabilistic Neural Networks.

C. Economic Load Dispatch

The economic load dispatch is a phenomenon for determining the least-cost power generation to meet the total power demand at a given point of time. The generating unit cost and the network transmission losses are modeled as quadratic function of the power generation.

Several conventional methods have been used in past for solving economic dispatch problems. These methods include lagrange multiplier method, linear programming (LP) techniques, Beale's quadratic programming, Newton-Raphson's method, genetic algorithms and NNs. The main drawbacks of genetic algorithm for ED are difficult to define the fitness function, find the several sub-optimum solutions without guarantee that this solution isn't locally and longer search time. Neural networks and specially the Hopfield model, have a well-demonstrated capability of solving combinational optimization problem. This model can be used to solve the conventional ELD problems for units with continuous quadratic, piecewise quadratic, or cubic fuel cost functions.

IV. CONCLUSION

This paper gives a brief introduction about the Artificial Neural Network approach of Artificial Intelligence. ANN is nonlinear model that is easy to use and understand compared to statistical methods. ANN is non-parametric model while most of statistical methods are parametric model that need higher background of statistic. ANN with Back propagation (BP) learning algorithm is most popular and is widely used in solving various forecasting problems. Even though convergence in BP is slow but it is guaranteed. However, ANN is black box learning approach, cannot interpret relationship between input and output and cannot deal with uncertainties. To overcome this, several approaches have been combined with ANN. This paper further reviews the various applications of AI to power systems putting particular emphasis on load forecasting, economic load dispatch and transient stability analysis. The present day prime difficulties and their proposed solutions are reviewed finally; the integration of ANNs with other emerging technologies such as FS, GA etc. was discussed as a future research direction.

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