Artificial Intelligence Based Demand Management In Smart Grid

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ABSTRACT
Smart grid is a technological innovation that improves efficiency, reliability, economics, and sustainability of electricity services. It plays a crucial role in modern energy infrastructure. The main challenge of smart grids is proper distribution of power. In this paper, we design and develop an artificial intelligence based demand management system by predicting the demand and dispatching the power according to the demands in a Distributed Power System. The introduction of new technologies and regulatory changes in the distribution systems of electric power, aims to present a methodology for the distribution of power based on demand. Demand prediction can be carried out using various Artificial Neural Network models. The results obtained in the simulations can say that the ANFIS network predict and distribute the power based on demand in smart grids.

KEYWORDS: Smart Grid; ANN; Distribution Networks; Demand.

INTRODUCTION
The amount of electricity demand is increasing day by day. Power plant converts the energy stored in the fuel or hydro into electric energy. The energy is supplied through step-up transformers to the electric network. Power systems are comprised of 3 basic electrical subsystems: Generation subsystem, Transmission subsystem, Distribution subsystem. Power distribution systems are responsible for generating, transmitting and distributing the electric power to the customer at their demand level. Power grid failures due to faults or attacks could paralyze a city, region or—in the worst case—an entire country. Generation subsystem includes all the hard- and software used to generate and distribute electrical power to the payload. The transmission subsystem connects the high-voltage substations to the distribution substations. The typical voltage of the transmission subsystem is between 138 and 69 kV. In high load density areas, the transmission subsystem uses a network configuration that is similar to the high voltage network. In medium and low load density areas, the loop or radial connection is used. The distribution subsystem has two parts, primary and secondary. The primary distribution system consists of overhead lines or underground cables, which are called feeders. The feeders supply the distribution transformers that step the voltage down to the secondary level. The secondary distribution system contains overhead lines or underground cables supplying the consumers directly by single- or three-phase power. Smart grid has brought renewed interest in enhancement of all parts of power systems. Challenge focused in moving to smart grid: The smart grid can be viewed as a digital upgrade of the existing electricity infrastructure to allow dynamic optimization of current operations as well as incorporate dynamic gateways for alternative sources of energy. Electric distribution networks come with problems and challenges-
the uncertainty in the forecast of power generation from grid connected renewable and distributed energy sources. The power flow management would need to be distributed, flexible, and intelligent in order to cope with these challenges. Electricity demand prediction is a central and integral process for planning periodical operations to distribute the power according to the demand.

**Literature Survey:**

Predicting electricity demand plays an important role in inventory planning and management, it can be achieved by an accurate prediction model. Also it helps in better management of resources for the utility companies or distributors or investors and so it has to be aimed first. Various methods have been proposed to solve the demanding task of load forecasting, especially over the past few decades. Previous research shows that neural networks have been successfully used for many types of forecasting problems and in different fields such as in financial applications, psychology, medicine, mathematics, engineering, tourism and energy sector; Did a comparative study on performance of the three approaches such as ARIMA, ANN and MLR and found that artificial neural networks using Multilayer perceptrons method for predicting electricity demand was superior to other approaches in terms of error measurement. In the same lines, did a case study by comparing Neural Networks with Traditional forecasting methods and results showed that forecasting with Neural networks offers better performance.

According to, it is mentioned that NN approach is able to provide a more accurate prediction than expert systems or statistical counterpart. As per the above examples, when compared to the other traditional methods like statistical models or time series methods, we knew that ANN is a clear winner and in one of his research papers mentioned the below reasons on why/how ANN is a better method for forecasting. ANN’s are data driven self-adaptive methods, which means that they learn from examples and capture subtle functional relationships among the data even if the underlying relationships are unknown or hard to describe. Thus ANNs are well suited for problems whose solutions require knowledge that is difficult to specify but for which there are enough data or observations. ANN’s can generalize, even after learning the data presented to them, ANNs can often correctly infer the unseen part of a population even if the sample data contain noisy information. ANN’s are universal functional approximators as they have more general and flexible functional forms than the traditional statistical methods can effectively deal with due to the limitations in estimating the underlying function due to the complexity of the real system. Finally, ANNs are nonlinear which are best suitable for real world problems as they are often non-linear. ANN’s are generally non-linear data driven approaches as opposed to model-based non-linear model, which makes it much better for forecasting.

**Proposed System:**

**A. Demand Forecasting:**

Traditional forecasting models such as multiple linear regression based, Average Trend and Naïve forecast. Multiple linear uses change in past demand to find the future demand. Naïve Forecast makes use of latest value of interest to predict the future value. Average Trend forecast using a function of time.

**B. Artificial Neural Network:**

These are flexible non-linear models that can be used for prediction in various fields. The Electrical Power Load Forecasting is classified in terms of the planning horizon’s duration: up to 1 day/week ahead for short-term, 1 day/week to 1 year ahead for medium-term, and more than 1 year ahead for long-term [2,19]. Short-term forecasts are used to schedule the generation and transmission of electricity. Medium-term forecasts are used to schedule the fuel purchases. Long-term forecasts are used to plan the power supply and delivery system (generation units, transmission system, and distribution system). The ANN architecture proposed in this work for the day ahead forecasting demand has a multi-layer perceptron structure. This particular type of ANN consists of three parts: input layer, hidden layer, and output layer, as shown in figure 1. The input layer receives information from the outside world. The hidden layer does not have any connection to the outside world; it only connects to the input layer with and the output layer. The output layer will give the ANN output to the outside world after the incoming information is processed by the network. In this work it has been chosen to use only one hidden layer in order to have a good computational speed during training phase and not to complicate ANN architecture. The effectiveness of this choice was confirmed in all the simulation scenarios because the results have been satisfying. One of the most important factors for designing a good ANN architecture is choosing appropriate input variables. Since data is time series, the input can be a number of past demand values. Also the output it fed back together with its past values as inputs. If input is u(t), the output can be written as follows:

\[ y(t) = f(u(t-1), ..., u(t-d1), y(t-1), ..., y(t-d2)) \]

where \(d1\) is the time delay of the input and \(d2\) is the feedback delay.
In this paper two different types of ANN input are proposed: 1. Predicting and dispatching user demand management using ANN in a power grid where the number of energy sources is two. 2. Predicting and dispatching user demand management using ANN in a power grid where the number of energy sources is three.

Predicting and dispatching user demand management using ANN in a power grid where the number of energy sources is two: The load data of 24 hours is given as an input to the ANN with \( n=2 \). The inputs given are: Input 1 = week selection, Input 2 = Day selection. The output of the input layer is used as input of hidden layer which uses the activation function as tan-sigmoid. The outputs of hidden layer are given as input to output layer which uses, the activation function linear-sigmoid. The training of ANN is done by \( Q \) set of training data assumed to the available. Inputs \( \{ X_1, X_2 \} \) are imposed on the top layer. The ANN is trained to respond to the corresponding target vectors, \( \{ Y_1, Y_2 \} \) on the bottom layer. The output from neuron \( i \) of the input layer \( O_i \), is connected to the input of hidden layer neuron \( j \) through the interconnection weight \( W_{ij} \). The state of the neuron \( k \) is:

\[
O_k = f(\sum W_{ik} O_i)
\]

Where \( f(x) = 1/(1 + e^{-x}) \) and sum of all neurons in the adjacent layer. Let the target state of the output neuron be \( Y \). The error at the output neuron can be defined as:

\[
E = 1/2(Y_k - O_k)^2
\]

Where neuron \( k \), is the output neuron. According to the difference between the produced and target outputs, the network’s weights \( \{W_{ij}\} \) are adjusted to reduce the output error. The error at the output layer propagates backward to the hidden layer, until it reaches the input layer. To evaluate the result of ANN performance, the following percentage error measure is employed.

\[
\text{Error} = \left( \frac{\text{Actual Load} - \text{Forecast load}}{\text{Actual Load}} \right) \times 100
\]

The ANN trained by actual load data will predict the load for the upcoming weeks that is the future demand. Once the training of the network was complete the weights and bias terms were kept fixed for current year. To meet with the periodic load growth, the network is configured for automatic yearly training. The output of ANN controller is given to the dispatcher to distribute the power based on the prediction.

Again the results are verified using ANN with three energy sources. The proposed ANN based distributed power system uses DSTATCOM. Distributed Static Compensator (DSTATCOM) is a fast-compensating reactive power source in power distribution system. DSTATCOM reduces voltage variations such as sags, surges, and flicker, along with instability caused by rapidly varying reactive power demand. DSTATCOM can also help provide quick recovery for the transmission system after contingency events such as loss of part of the system or individual equipment. A grid feeding three loads and a distribution static synchronous compensator (DSTATCOM) connected to the point of common coupling (PCC).
Fig. 2: DSTATCOM

C. ANN Controller:
The DSTATCOM is used to intensify the achievement of accurate load forecasting in ANN controller.

Fig. 3: ANN Controller

The performance of ANN controller with respect to conventional based counterpart is reported for few power quality problems. So Simulation of DSTATCOM with ANN based controllers are carried out using MATLAB/Simulink for improving the power factor of the system or voltage regulation and load balancing.

Experimental Results:
The model proposed in this paper was implemented using Simulink. For MLP, the feed forward structure of the ANN was used and the activation functions are selected. The proposed model was tested over a data set, containing historical data of electrical load. ANN monitors the power among two sources power system and three sources power system.
The training of ANN is done with two energy sources first. When we eliminated the validation sets from the training samples, we opted to use a fix number of epochs to train. An epoch is one step of the training when all the available training samples are shown to the ANN. In this proposed method we fix the epochs to be 10000 and started training.

The sampling frequency adopted for sampling the voltage and current waveforms in this work is 1000 hz. From the figure 5, we observe that the training of neural network has achieved normalization by adjusting the weight and bias, thereby training is completed to predict the load correctly. Thus the trained ANN is able to predict the load for a week. Based on the prediction, the power can be distributed by the dispatcher to the substation. Again the results are verified using ANN with three energy sources.

**Conclusion:**

This paper presented a proposed ANN based demand management technique. ANN is trained in such a way that it is able to predict the continuous change in the demand. Experimental Results shows that the ANN is a reliable and effective method for an electrical power system to predict the load. Accurate prediction will provide a clear picture for power system operators to effectively dispatch the electricity generation, reduce power loses, and enhance the energy security.

**REFERENCES**
