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Short Term Load Forecasting: A Review of Improved Exponential Grey Smoothing Method, Ann & Fuzzy Logic Methods

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Abstract:
Short term load forecasting techniques have been used extensively over the years, and have produced effective results. Generation, transmission and the distribution companies make use of load forecast data to plan their day to day operation. This paper takes a look at the improved exponential grey smoothing method, artificial neural network (Ann), and the fuzzy logic method. Some of the works under this method were also reviewed, and the uniqueness of each method was described.

Keywords: *Power system planning, short term load forecasting, improved exponential grey smoothing method, artificial neural network, fuzzy logic*

1. Introduction

With the power system been deregulated and a rise in power demand, there is need for electric power utilities to be estimated. power is generated when there is a demand for it, the generated power should be equal to the power demanded, i.e. PG=PD + PL. Load forecasting can be said to be the estimation of load in advance [1]. Estimating the amount of power supply needed for the demand side is necessary for system planning. As demand increases, power system expansion starts with the forecast of future load requirements. Load forecasting helps generation, transmission and distribution to plan for future generation power required [2]. Electric utility will have to make decisions on generating and purchase of electric power, load switching, voltage control.

The power system planning and operation is a very essential aspect of generation, transmission and utility companies. Network reconfiguration and infrastructure development [3]. Also, the uncertain nature of future prices in the energy market, market participants use price forecast in their operation and planning activities.

Load forecasting entails estimating future consumptions based on various data and information available and as per consumer behavior. it involves the process of forecasting future electric load, given historical load and weather information and current forecasted weather information. Over the years many method and techniques has been used to forecast electric load more accurately. The behavior of a power system under a variety of contingency conditions over a period of time needs to be studied to ensure secure operation of the power system at future time.

1.1. Why Load Forecasting?

Load forecasting is important for power system operators and planners because, system operational planning such as unit commitment and economic dispatch, spinning reserve, maintenance scheduling, and expansion planning are usually performed based on the forecasted load;

- It helps in making decisions for the future in terms of size, location and type of the future generating plants. By determining the areas or regions with high or growing demand, the utilities will most likely generate the power near the load. This minimizes the transmission and distribution infrastructure as well as the associated losses.

By understanding the demand, the utility can know when to carry out the maintenance and ensure that it has the minimum impact on consumers. For example, they may decide to do maintenance on residential areas during the day when most people are at work and demand is very low.

- It increases the efficiency and revenues for the electrical generating and distribution companies.

- It helps utility companies to plan on their capacity and operation in order to reliably supply all consumers with the required energy.
- Helps to determine the required resources such as fuels required to operate the generating plants as well as other resources that are needed to ensure uninterrupted and yet economical generation and distribution of the power to the consumers.

2. Short Term Load Forecasting

Short term load forecasting deals with the forecasting of loads on hourly to weekly to meet the day to day needs of the GENCOS. The hourly load forecast with lead time up to one week in advance is necessary for one line one-line solution of scheduling problems [4].Short load forecasting involves general decomposition of load into components. The load decomposed reflects a trend component concerning the seasonal growth in load and a weather sensitive component reflecting the deviation in load due to weather fluctuations. Statistical analysis is done on this random error using to obtain stochastic error estimation method.

Five components are used for representing the expected hourly load forecast;

$$Y(I, j) = ADP(j) + AWP(k, j) + WSC(I, j) + TR(i) + SEC(I, j) \quad (1)$$

Where;

Y(I,j)= load forecast for jth hour of ith day ADP(j)= average daily load pattern at jth hour

AWP (k ,j) = average weekly load increment pattern at jth hour kth day of the week (k=1,2…7)

WSC (I, j)= weather sensitive component at jth hour of ith day TR (i) = trend component of load on ith day

SEC (I,j) = stochastic error component which is assumed to be normally distributed. The average daily pattern, which is an average of the daily load pattern over an optimal number of past days represents the hour the day effect.

The day of the week effect is represented by the average weekly pattern, which is calculated as the average of the weekly cycles over certain number of past weeks [3].

3. Techniques Used for Short

3.1. Term Load Forecasting

Previous works have been done on load forecasting using exponential method. Many researchers have also improved on previous works in attempt to develop a more efficient and reliable load forecasting technique.

3.1.1. Improved Exponential Smoothing Grey Model

In order to improve the prediction accuracy in load forecasting, M. Jianwi et al, carried out a research on short term load forecasting method based on improved exponential smoothing grey method (2018). His work uses the grey correlation analysis to determine the main factor affecting the power load. The second step was using the smoothed sequence which agrees with the exponential trend to establish the optimized background value of the grey prediction model.

Lastly, the method employs the inverse exponential smoothing method to restore the predicted value. His work was an improvement on the exponential smoothing method and the traditional grey prediction model [5]. The method made use of the combination of the grey correlation analysis, the exponential smoothing method and the 0.618 technique.

3.1.2. Artificial Neural Network (Ann)

The use of artificial neural network has been applied in short term load forecasting over the years. The back propagation is the most popular artificial neural network architecture used for electrical load forecasting [5]. The artificial neural network can be a hardware or software model inspired by the structure and behavior of neurons and nervous systems. The basic unit is a neuron that is artificial, and it receives information from multiple input nodes, processes it and gives an output [6]. For the processing, there is a combination of the input value linearly, and the result gotten, represents the argument of a non-linear activation function.

The neurons are connected together, the internode connection strength stores the processing ability and are called weights. When developing an ANN, set of systematic steps are followed which are called 'learning rules' [7]. For the processing, there is a combination of the input linearly, and the result produced is used as the argument of a non-linear activation function.

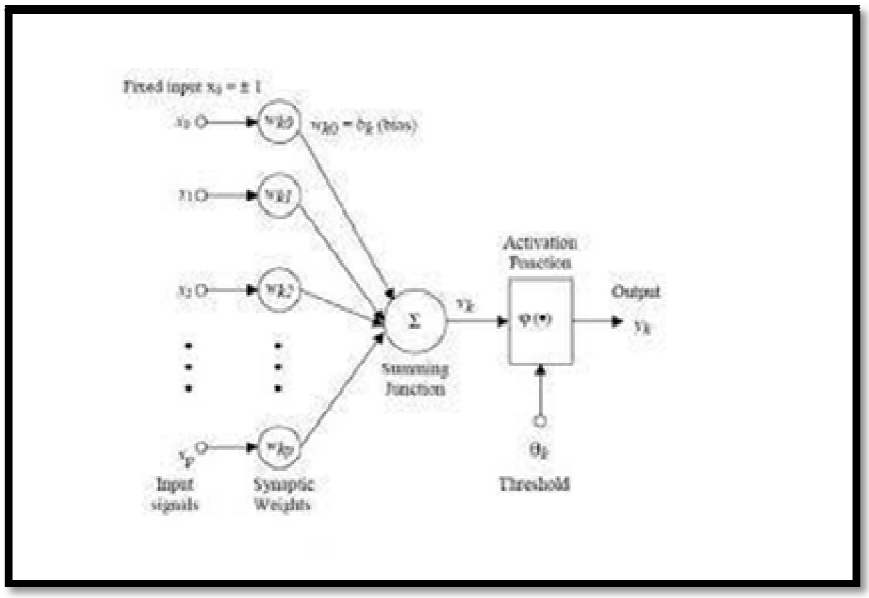

Figure 1: Artificial Neural Network Model

Artificial neural network (ANN) has advantage, due to the fact that no precise relationship between the input variable and the output is required to be specified before the process of prediction [8].

ANN can be divided into Multi- Layer Perceptron (MLP), Self-Organizing Maps (SOM), Deep Learning (DL), and Extreme Learning Machine (ELM). The MLP is a class of feed forward artificial neural network. The MLP is made up of at least three layers of nodes, consisting of an input, a hidden layer and an output layer [9]. It uses a supervised learning technique known as back propagation for training. This method can distinguish data that is not linearly separable.

In 2012, S.A. Ilic wrote a paper on 'Hybrid Neural Network System for Short Term Load Forecasting'. His work used an MLP which functioned as an integrate load predictor (ILP) for the day forecasting. The ILP gives an output that is inputted in a more complex MLP, which acts as an hourly load predictor (HLP). The system was tested by the data gotten form Serbian electricity utility company. The use of two separate ANN provided additional information to the actual forecasting (HLP) and a more accurate prediction.

Muhammad Buhari and Sanusi, 2012 developed an ANN based short term load forecasting model for a 132KV/33KV substation

Kano, Nigeria. The data for the daily load profile was gotten from the utility company. They used the Levenberg-Marquardt optimization technique for a back-propagation algorithm using MLP [10]. 70% of the input data set was used as training set, while 15% each was for the network output result testing and validation. The neural network error was about 5.84e-6 of any input figure. The technique produced a robust result for planning of the daily operations for the substation.

In 2014, A. Indira et al in 2014 presented paper on short term load forecasting of an interconnected grid using neural networks. The work compared short term load forecasting using neural network with the conventional exponential smoothing technique. The study used the daily load data of an interconnected grid as data sets for training and comparing. The results evaluation was done using Mean Absolute Percentage Error (MAPE) and Mean Absolute Deviation (MAD). Prediction of the neural network was very robust and effective more than the conventional smoothing technique [11]. Artificial neural network method is fault tolerant, extremely powerful and very efficient [12].

3.1.3. Fuzzy Logic Load Forecasting Method

According to A. Hesham et al (2002), 'a fuzzy logic system with centroid defuzzification can identify and approximate any unknown dynamic system on the compact set to arbitrary accuracy' [13]. It is a logical system that uses if- then rules and human like uncertainties. it transforms human knowledge base into mathematical formulas. A set of rules represents the mechanism of control decision. The fuzzy uses algorithm that will convert the linguistic variable [14].

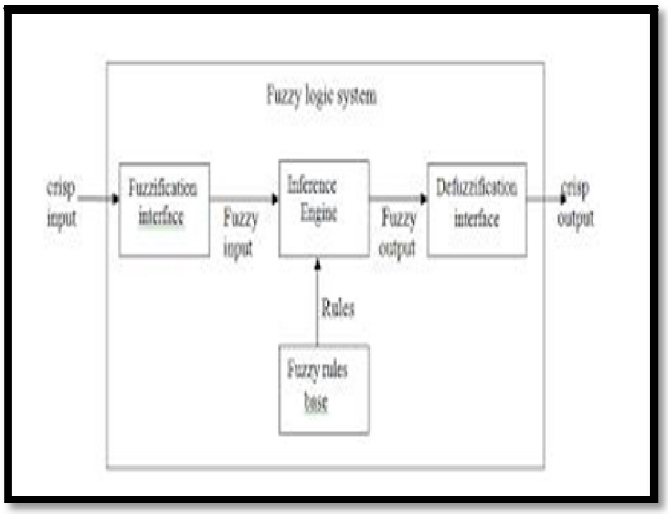

Figure 2: Block Diagram of a Fuzzy System

The fuzzy logic is made up of a set of fuzzy inference. It works on the basis of approximate reasoning that gives an output of a consequence action. Its approach involves decision making similar to humans that involves possibilities between digital values YES and NO. A fuzzy logic model maps out a set of input variable using the if-then statement. Over the years, fuzzy sets have been used for making decisions on electrical load data. One main advantage of the fuzzy logic approach is that it can produce a clear situation, out of an uncertain concept.

The fuzzifier changes crisp variables to linguistic variables or membership functions. The control algorithms are found in the rule matrix. When input is received by the fuzzifier, it is sent to the inference engine. The inference engine gets information from the rule matrix, processes the information and sends it to the defuzzifier. The defuzzifier changes the linguistic variable to the crisp values [15].

J. Kaur & Y.S. Brar in 2014, carried out a research on Short term load forecasting of a 220KV transmission line using fuzzy logic. The main aim of the work was to minimize error between the actual load value and the forecasted value of the available data. The data used was gotten from PSTCL, 220KV substation Pakhowal, Ludhiana, Punjab in India. The paper used absolute percentage error to evaluate the performance of the model. The proposed methodology could also solve forecasting problems with data ambiguity such as load pattern and temperature day. From the result obtained, the fuzzy forecasting was very close to the actual load [16].

In 2017, J. Jamaaluddin et al presented a paper on 'Very Short-Term Load Forecasting Peak Load Time using Fuzzy Logic'. The research was based on very short run time data at the same time for the previous 4 days in 3years. The work produced a MAPE of 0.6244%. in his work, Jamaaluddin suggested that an expansion of the membership function can increase the accuracy of the model [17].

K. D. Chawda et al in 2017, carried out an analysis of previous years load of a substation in India using Fuzzy logic-based load forecasting. The Mean Square Error (MSE) and Average Error (AE) showed that the fuzzy model with center of area (COA) defuzzification gave an improved performance more than other defuzzification method. The range of the error was in the range of 5-6% [18].

In 2017, P. Ganguly used historical data and the time of the day in designing a fuzzy rule-based model to predict the load curve of the day. The model was not able to consider any sudden change, so it would not be able to forecast load in case of any change [19].

L. Murat et al in 2018, carried out a study on short term fuzzy load forecasting model using genetic fuzzy and ant colony-fuzzy knowledge base optimization. The proposed system used historical hourly load consumption and temperature collected between 2011 and 2014, for its testing and training. The work produced a Mean Absolute Percentage Error (MAPE), of 3.9% for the monthly minimum of the forecasting model [20].

V. H. Hinojosa, 2010 applied Fuzzy Inductive Reasoning (FIR) to short term load forecasting in a power system for a day in advance. The FIR model used both past and future information of the load and temperature to achieve its result. The work applied the FIR model and simulated rebounding algorithm (SRA) to the Ecuadorian power system. The model incorporated weather, load, day and season without any complex formulation. The result showed that the model was intuitive and required minimal human intervention. it can be applied in problems that requires the consideration of both deterministic and stochastic variables [21].

4. Conclusion

The paper gave an overview of an improved exponential grey smoothing method, Artificial Neural Network (ANN) and Fuzzy logic methods for short term load forecasting.

Each method has its own unique characteristics. The improved exponential grey smoothing method reduces calculation quantities, while improving the prediction efficiency.

The ANN is a more robust method, is fault tolerant and extremely powerful and efficient.

The fuzzy logic method using genetic fuzzy and ant colony fuzzy knowledge-based information, produced the least MAPE of 3.9% of all the reviewed works. The fuzzy logic method is a special tool that is intuitive and can predict accurately with both deterministic and stochastic variables.

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