A Novel Approach towards Electrical Load Forecasting Conditions

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Abstract

This paper presents a study on load forecasting which is very important for energy supplying companies and all the other players of electric energy generation, transmission and distribution who are commonly known as the Utility companies. Load forecasting is extremely important as electricity cannot be stored and has to be used instantaneously. The Load forecasting can be broadly classified into three different sections: short-term load forecasting ranging from one hour to one week, medium term load forecasts that range from a week to a year, and long-term load forecasting which is done for a duration longer than a year. Various algorithms are classified under these three sections based on their applicability and suitability.

Keywords- Electricity; Utility; Short Term Load; Regression Methods; Genetic Algorithms

I. INTRODUCTION

In India and in other developing nations, there has been continuous failure in achieving the target capacity addition and that has led to continuous deficit situation in terms of load generation. This has paved the path of Load forecasting. Load forecasting helps an electric utility company to take important decisions including decisions on purchasing and generating electric power, load switching and infrastructure development and effective load generation for the future needs. The subject of load forecasting has been in existence for a long time to forecast the future demand as it is beneficial for mankind as well as the electric generating companies. Electricity demand forecasting is considered as one of the most important factors from the economic perspective, that accurate load forecasting holds a great saving potential for electric utility corporations and simultaneously enabling them to achieve the required business goals. Thus, load forecasting is used to achieve maximum savings. According to economists, the main reason for the increase in operating cost is due to positive or negative forecasting errors, both of which incur a loss. This paper focuses on the research work that is necessary to establish the statistical relevance of the proposed research work, establish a generalized research question, analyzing existing methods, and explore the areas of improvements. This research covers the analysis of various existing load forecasting techniques along with their mathematical descriptions in each of the sections. The effectiveness of each study is discussed in this article.

II. Different Load Forecasting Methods

Forecasting methodologies came into existence due to the emerging needs. Various types of differentiations based on duration of forecasting and forecasting methods are suggested over a long time. Demand forecasting methods can be also classified in terms of their degrees of mathematical analysis used in the accurate forecasting model. These are presented into two basic types which are: quantitative and qualitative methods. In most cases historical data is not sufficient or not available at all. Load forecasting has some dependent and some independent variables that need to be taken into account for efficient load forecasting. The forecasting changes for different weather conditions of different regions. This has paved the way for Short term load forecasts. The load forecasting techniques may be grouped broadly in three major groups: 1.Short Term Load Forecasting, 2.Medium Term Load Forecasting and 3.Long Term Load Forecasting respectively.

III. SHORT TERM LOAD FORECASTING

3.1 Regression Analysis

Regression is one of the most widely used statistical techniques and it is often easy to be implemented not only for load forecast but also for other statistical processes and their analysis. It is one of the conventional methods. The regression methods are usually employed to model the relationship of load consumption and other factors such as weather conditions like temperature, humidity, day types and customer types, weather conditions and special seasons. This method assumes that the load can be divided in a standard load trend and a linear trend that is dependent on some factors that influence the load. The mathematical equation can be written as:

$$L(t) = Ln(t) + \Sigma\, bi\, yi(t) + c(t) \qquad (1)$$

Where, $Ln(t)$ is the normal or standard load at time t, bi is the estimated slowly varying coefficients, $yi(t)$ are the independent influencing factors such as weather effect, c(t) is a white noise component, n is the number of observations, usually 24 for a day observed in an hourly basis or 168 depending on a weekly basis. The method accuracy relies on the adequate representation of possible future conditions by historical data but a measure to detect any unreliable forecast can be easily constructed. The proposed procedure requires few parameters that can be easily calculated from historical data by applying the cross-validation technique. In order to forecast the load precisely throughout a year, one should consider seasonal load change, annual load growth and the latest daily load change. To deal with these characteristics in the load forecasting, a transformation technique is presented. This technique consists of a transformation function with translation and reflection methods. The transformation function is estimated with the previous year's data , in order that the function converts the data points into a set of new data points with preservation of

the shape of temperature-load relationships in the previous year. Thus, Regression is a method to predict load based on past data.
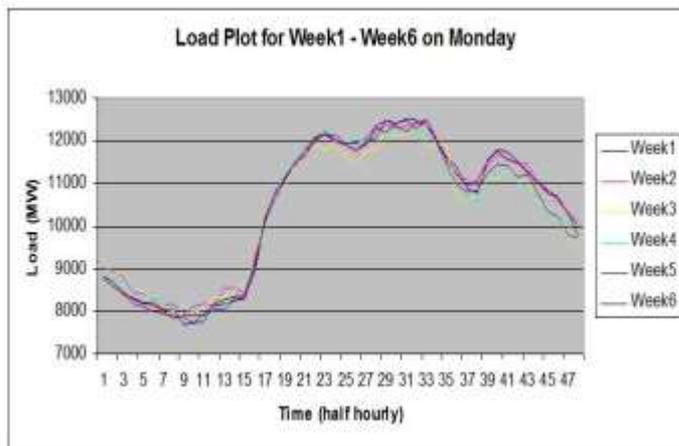

Figure 1. Weekly Load Forecasts

3.2 Multiple Regressions for Load Forecasting

Multiple Regressions is one of the most popular methods for forecasting as it takes many parameters such as growth in market, cost and other factors into consideration. Multiple Regression analysis for load forecasting uses the technique of least-square estimations. Mathematicians have used the following load model for applying this analysis:

$$L(t) = V(t)b(t) + c(t) \qquad (2)$$

Where,

t is sampling time,

L(t) is total measured load system,

V(t) is vector of variables such as time,

Temperature, light intensity, wind speed, humidity, day type (workday, weekend), etc., at is transposed vector of regression coefficients and c(t) is model error at time t.

The Polynomial degree of influence of the variables from 1 to 5 can be selected by the data analysis program. Linear dependency often gives the best results. Analysts have compared it with other models for a 24-hour load forecast model that makes it good for short term predictions. Scientists have evaluated the regression model to fit data and check the seasonal variations that affects the load demands. They developed a model that produces an initial daily peak forecast and then uses this initial peak forecast to produce initial hourly forecasts. In subsequent step, it uses the maximum of the initial hourly forecast; the most recent initial peak forecast error and exponentially smoothed errors as variables in a regression model to produce an adjusted peak forecast. Trend estimation evaluates growth by the variable transformation technique, while Trend cancellation removes annual growth by subtraction or by division. A least-squares approach was used by scientists to identify and

quantify the different types of load at power lines and substations. To predict load demand for electricity in the late 20th century. Scientists have developed a weather-load model based on regression analysis of historical load and weather data. Lately they modified the developed model as an adaptable regression model for 1-day-ahead forecasts, which identifies weather-insensitive and sensitive load components. They used linear regressions of past data to estimate the parameters of the two components.

One of the most important topics for the planners of the nation is to predict future load demands for planning the infrastructure, development trends and index of overall development of the country etc. In early days, these predictions or forecasts were carried out using traditional/conventional mathematical techniques. With the development of advanced tools, these techniques have been augmented with the finding of researches for more effective forecasting in various fields of study and with technological advancements and the coming of Smart meters the accuracy has improved significantly. The traditional foresting techniques are as following: regression analysis and multiple regressions

IV. MEDIUM TERM LOAD FORECASTING

4.1 Autoregressive Moving-Average (ARMA) Model

In the statistical analysis of time series, autoregressive–moving-average (ARMA) models provide a parsimonious description of a (weakly) stationary stochastic process in terms of two polynomials, one for the auto-regression and the second for the moving average. ARMA model represents the current value of the time series y (t) linearly in terms of its values at previous periods *[y(t-1), y(t-2),..]* & in terms of previous values of a white noise components *[a (t), a (t-1),…]*. For an ARMA of order *(p,q)*, the model is written as:

$$y(t) = \varphi1y(t\text{ -}1)+...+ \varphi py(t\text{-}p)+a(t)\text{- } \varphi1a(t\text{-}1)\text{-}...\text{- } \varphi q(t\text{-}q).$$

A recursive scheme is used to identify the parameters, or using a maximum-likelihood approach. Scientists have presented a new time-temperature methodology for load forecasting. In this method, the original time series of monthly peak demands are decomposed into deterministic and stochastic load components, the latter determined by an ARMA model. Scientists used the WRLS (Weighted Recursive Least Squares) algorithm to update the parameters of their adaptive ARMA model. Others used an adaptive ARMA model for load forecasting, in which the available forecast errors are used to update the model. Using minimum mean square error to derive error learning coefficients, the adaptive scheme outperformed traditional ARMA models.

V. LONG TERM LOAD FORECASTING

5.1 Soft Computing Methods

It is a known fact that every system is complex, imprecise, uncertain and hard to be modeled precisely. A less rigid

approach called Soft Computing technique has emerged to deal such models effectively and most efficiently on research scenario. It has been very widely in use over the last few decades. Soft computing is an emerging approach which parallels the remarkable ability of the human mind to reason and learn in an environment of uncertainty and imprecision. It is fast emerging as a tool to help computer-based intelligent systems mimic the ability of the human mind to employ modes of reasoning that are approximate rather than exact. The basic theme of soft computing is that precision and certainty carry a cost and that intelligent systems should exploit, wherever possible, the tolerance for imprecision and uncertainty. Soft computing constitutes a collection of various disciplines which include fuzzy logic (FL), neural networks (NNs), evolutionary algorithms (EAs) like genetic algorithms (GAs) etc. Natural intelligence is the product of millions of years of biological evolution. Simulating complex biological evolutionary processes may lead us to discover, how evolution propels living systems toward higher-level of intelligence. One of the newer and relatively simple optimization approaches is the GA which is based on the evolutionary principle of natural selection. Perhaps one of the most attractive qualities of GA is that it is a derivative free optimization tool. The demand/ load forecasting techniques are also developed based on the following soft computing/ intelligent techniques. The Knowledge-based expert systems have been utilized for this purpose also.

5.2 Fuzzy Logics

It is well known that a fuzzy logic system with centroid defuzzification can identify and approximate any unknown dynamic system (here load) on the compact set to arbitrary accuracy. Scientists have observed that a fuzzy logic system has great capability in drawing similarities from huge data and thus it is highly preferred in analytics. The similarities in input data *(N-i -N0)* can be identified by different first order differences *(M*k) and second-order differences (Ak), which are defined as:

Mk = (Nk – Nk-1)/T,   Ak = (Mk – Mk-1)/T

The fuzzy logic-based forecaster works in two stages: training and on-line forecasting. In the training stages, the metered historical load data are used to train a 2m-input, 2n-output fuzzy-logic based forecaster to generate patterns database and a fuzzy rule base by using first and second-order differences of the data. After enough training, it will be linked with a controller to predict the load change online. If a most probably matching pattern with the highest possibility is found, then an output pattern will be generated through a centroid defuzzifier. Several techniques have been developed to represent load models by fuzzy conditional statements.
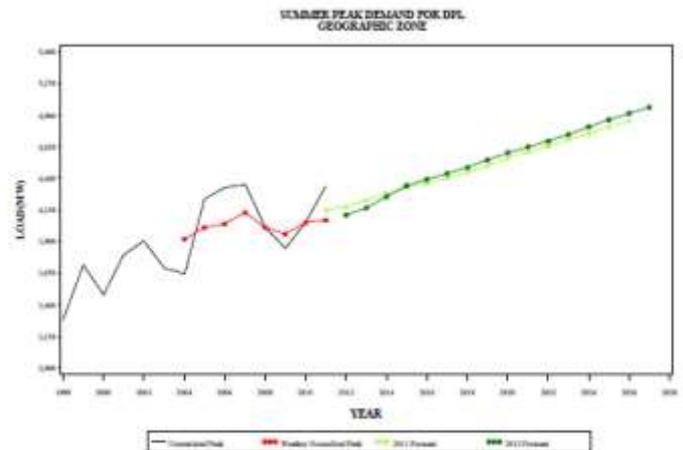

Figure 3. Long Term or Yearly Load Forecasting

5.3 Neural Networks

Neural networks (NN) or artificial neural networks (ANN) have very wide applications because of their ability to learn. In neural networks offer the potential to overcome the reliance on a functional form of a forecasting model. There are many types of neural networks: multilayer perceptron network, self-organizing network, etc. There are multiple hidden layers in the network. In each hidden layer there are many neurons. Inputs are multiplied by weights ωi and are added to a threshold θ to form an inner product number called the net function. The net function NET used by different analysts, for example, is put through the activation function y, to produce the unit's final output, y (NET). The main advantage here is that most of the forecasting methods seen in the literature do not require a load model. However, training usually takes a lot of time. Here we describe the method discussed by another researcher Liu, using fully connected feed-forward type neural networks. The network outputs are linear functions of the weights that connect inputs and hidden units to output units. Therefore, linear equations can be solved for these output weights. In each iteration through the training data (epoch), the output weight optimization training method uses conventional back propagation to improve hidden unit weights, then solves linear equations for the output weights using the conjugate gradient approach.
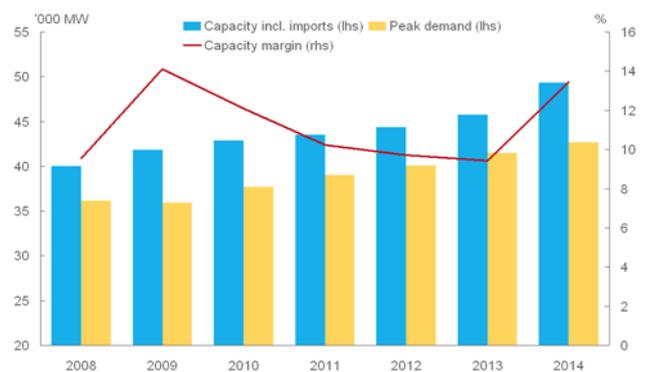

Figure 4. Long Term Load Forecasting Outcomes

VI CONCLUSIONS

The different techniques such as; regression analysis, multiple regression, linear regressions, stochastic time series analysis, fuzzy logic and neural networks etc. have been applied to the various load forecasting conditions depending upon their type. The advantages and disadvantages of these methods are presented method wise. From the research that is carried out till now, it can be said that demand forecasting techniques based on soft computing method is getting major advantages for their effective use. There is also a significant and lucid move towards hybrid methods that is observed as one particular methods falls short for accurate models, and therefore brings in the need for models which combine two or more of these methods. The research has been shifting and replacing the old approaches of load forecasting and coming up with newer and more efficient models. Load forecasting becomes more and more important with the upcoming resource limitations and thus it is necessary to make accurate load predictions. The load forecasting methods like short term, medium term and long term have been studied and the graphical representations have been shown and described in this paper. The discussions on the necessity of load forecasting has also been carried out thoroughly in this article.

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