Analysis and Comparison of Various Methods Available for Load Forecasting: An Overview

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***Abstract*—Accurate load forecasting is essential for power system planning and operation. As the electricity end uses expand, load forecasting technique becomes more complicated. Depending on the nature of load variations, one particular method may not be suitable in each case. Before choosing a particular method, an overview of different techniques is required. This paper presents the analysis of various techniques for load forecasting. A comparative analysis is presented to understand the performance of each technique. None of them is found to be perfect alone; the trend is towards hybrid models.**

Keywords—load forecasting, short term load forecast, long term load forecast.

I. INTRODUCTION

Load forecasting came in the picture with the introduction of power system. The primary objective of an electric power system is to supply the various types of customer i.e. commercial, industrial, military, agricultural and domestic customers at minimum overall cost. The consumption of electricity is totally dependent on human activities and any electrical appliance had to be installed and turned on/off according to user's will. Therefore load forecasting is important for proper planning and operation of power system. The electric forecasting becomes complicated as its end uses expand and require efficient methodology. Figure 1 gives an overview of available forecasting techniques.

II. CATEGORIZATION OF LOAD FORECASTING

Samuel Insull, an innovator and investor of electric utility industry, introduced the concept of load forecasting in 1894. He analyzed that different load consumption pattern e.g. domestic and commercial end use has maximum consumption at day time whereas industries during nights. To my knowledge first time Reyneau [1] worked on this. It is not stopped here but careful planning and research for specific forecast of specific need [2] is continued. With the sky rocking growth of power system networks and the increase in there complexity load forecasting [3] is one of the influential critical factors for economic operation of power system. A number of techniques and models have been developed by researchers to solving the load forecasting problem. Diversity in different modelling techniques is because of nature of data sets in hand, type of load forecasting and nature of influencing factors on load variation [4]. Based on time horizon load forecasting is classified as:

- Long term load forecasting: This is longer than a year.
- Medium term load forecasting: This is usually from a month to a year.
- Short term load forecasting: valid for a few hours to few weeks.

III. LONG TERM LOAD FORECASTING

An efficient long term load forecasting is essential for power system planning and operation. It has long lead time enough for planning long term maintenance, for developing new generation, transmission and distribution systems. The future generation and distribution is influenced by accurate long term forecast. For longer time horizon precise load forecasting is very difficult task because of uncertainty of consumption. In general, long term load forecasting can be classified into Conventional and Artificial Intelligence methods [46]:

A. Parametric or conventional methods

These methods are dependent on mathematical expression between consumption and its influencing factors. A number of affecting factors has been discussed in [5,6] which may be responsible for uncertainty in long term forecast. Due to these uncontrollable factors long term forecast is inaccurate. Extrapolation is one of the techniques discussed in literature [7] in which trend curve is formed based on available past data. These trend curves, once extended, are utilized to forecast future load. Another technique for long term forecasting is correlation, [8] where load consumption is correlated with various demographic and economic factors such as population, industrial development, weather conditions etc. Three types of parametric models are discussed: trend analysis, end use models and econometric models

1) Trend analysis or Statistical Techniques: This technique based on previous changes in load consumption to predict changes in future load consumption. Trend analysis is simple, quick and cheaper technique. However this techniques only forecast the future and is unable to analyze the cause of these changes in load. Also this technique does not incorporate the economical and demographic changes.

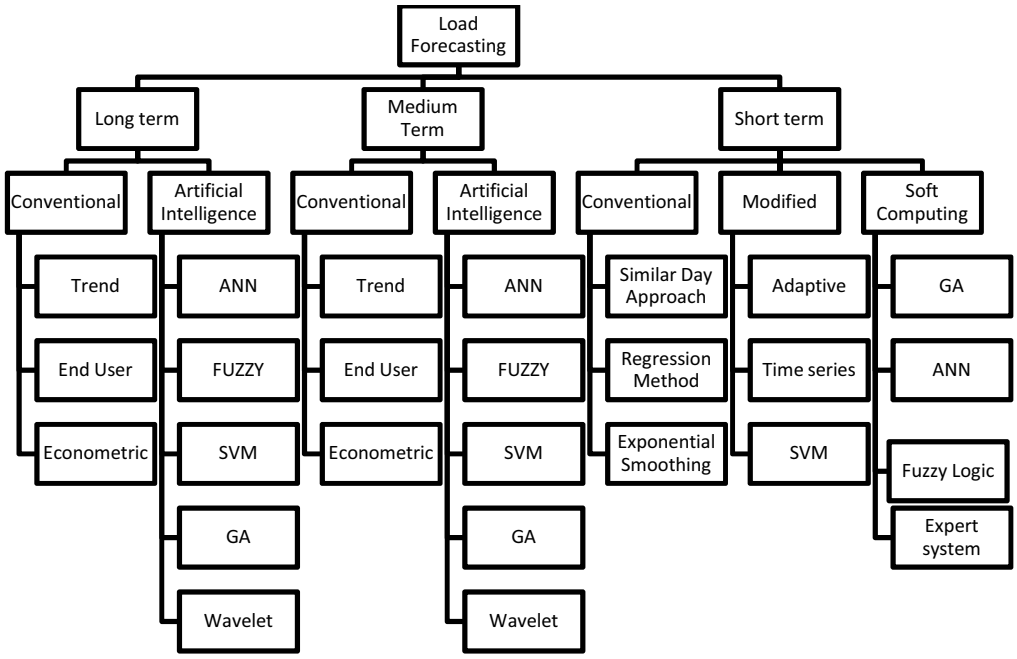

Fig. 1 Overview of Forecasting

2) End use models: The end-use approach assumes that energy consumption is totally dependent on end use and end users,. These models focus on the consumption of load in residential, commercial, industrial and agricultural usage [9]. In general this technique is very efficient. End used models are advantageous for planning purpose.

3) Econometric models: This model establishes the relationships between load consumption and factors affecting load. In this approach, load of different customer class (residential, commercial, industrial, etc) is estimated as functions of different affecting factors and finally past historical data is utilized for proper load forecast [10,11,12].

B. Artificial intelligence Based Methods

In the previous subsection we have discussed conventional methods for long term load forecasting. With the advent of artificial intelligent techniques these methods are modified [46] to get accuracy and speed. These methods are neural networks, support vector machines genetic algorithms, wavelet networks, fuzzy logic and expert system:

1) *Artificial Neural Network:* Artificial neural networks (ANNs) is successfully applied in solving power system problems, such as planning, control, analysis, protection, design, load forecasting etc. ANN has excellent ability to map complex non-linear relationships and attracting the researchers to utilize in load prediction [13,14]. Literature shows that ANN has been applied mainly for short term. But it is also used for long-term load forecasting [15,16,17,18].

2) *Wavelet Networks:* Wavelet theory is a powerful and flexible tool for solving load forecasting problems in comparison to conventional methods available. Thereby receiving wide attention of researchers. Wavelet theory decomposes load consumption into components of different frequency level. Literature indicates that lots of researchers are incorporating the wavelet analysis in load forecasting [19,20].

3) *Genetic Algorithm:* GAs is attracting researchers to solve attention for load forecasting problem. GA works on the survival of best fitness which combines the process of natural selection and natural genetics. GAs is found to be promising robust and suitable for load forecasting [21,22].

4) *Support Vector Machine:* SVM [47,48] is a powerful technique used for data classification and regression. It is easier to apply SVM in comparison to ANN. The support vector machines works on the principle of structural risk minimization which is a powerful technique that incorporates all useful information present in the data. SVM is computationally slower than ANN; however it is a promising non linear regression technique for load forecasting.

5) *Fuzzy Logic Model*: Fuzzy logic is introduced by Dr. Lotfi Zadeh in 1960 [23]. Fuzzy logic models are based on the degrees of truth. This concept incorporates a simpler rule based approach, for solving the load forecasting problems. It represents an inaccurate but rule based language just like skilled human operator. The goal of fuzzy logic system is to minimize this human operator's experiences. In long term forecasting the fuzzy rule based is formed that can be easily generated by observing available past data [24]. Fuzzy logic proved to be precise for load forecasting.

IV. MEDIUM TERM LOAD FORECASTING

Medium term load forecast is also important as its application is in maintenance schedule. The difference between long and medium term forecast is of time horizon. The time range for medium forecast is from a couple of

months to a year [8]. The various available methods can be classified in [10]:

- Conventional Methods: These methods require mathematical representations i.e. Regression models, statistical learning model etc.
- Artificial Intelligence Methods (ANN, Expert system etc.): These techniques for medium term load forecasting are same as long term forecasting. But the trend is towards integrated techniques which combined two or more techniques to give hybrid model.

V. SHORT TERM LOAD FORECASTING

Short term forecasting is the most preferable type of load forecasting as it is valid for a few hours to few weeks. Generally it is performed on daily basis for the day ahead with hourly or below it. Various conventional techniques [25] are available in literature and most popular technique is defined as statistical technique [26]. The emergence of artificial intelligence technologies [27] has modified these conventional techniques over the last decades. The load forecasting is influenced by several factors, i.e.: economics, times, weather, and random effects [4]. One of the difficult tasks with STLF is that these factors influences different areas with different contribution and therefore a specified prediction algorithms [28, 29] is needed. The diversity in usage area and generation will lead to various forecasting techniques [30]. Based on the various types of studies present in literature, [31,32,33] the load forecasting techniques may be classified into Conventional, Modified and Soft computing based Forecasting Techniques [46]:

A. Conventional Forecasting Techniques:

In early days, the load forecasting was carried out using conventional mathematical techniques. The conventional forecasting techniques are as follows:

1) Similar Day Approach: Similar day approach [46] is based on avialable past data of days for few years having the similar characteristics to the day of forecast. These characteristics are similar weather, similar day of the week. Load forecasting is done by linear combinations or regression procedures by identifying several similar days. The trend analysis of the previous years is also utilised for forecast.

2) Regression Methods: Regression technique for load forecasting is based on the mathematical relationships between electric load and its influencing prameters weather, holiday, temperature, wind condition, humidity, day type, and customer class etc. There are several regression models available in literature [4,34,35,38] .

3) Exponential Smoothing: Exponential smoothing is also used for predicting future load where a model is developed based on previous data. Due to its robustness and accuracy Exponential smoothing is used in variety of applications. Christiannse [36] developed an exponential smoothing model for the hourly load forecast over an interval of one week instead of separate weekday or weekend model.

B. Modified Forecasting Techniques:

The conventional forecasting techniques can improve the accuracy of forecasting model under different conditions. Some of the modified load forecasting techniques are

1) Adaptive Load Forecasting: Load forecasting model parameters are automatically corrected according to changing weather conditions. Hence it is adaptive in nature. Literature shows that lots of models based on adaptive demand forecasting [37] are available.

2) Stochastic Time Series Approach: The time series approach is most popular [38]. Due to accuracy of its results. it is still used by many utilities companies. To forecast present load the time series observes the actual load pattern. Characteristics of the added linear filter make it capable of into Auto Regressive (AR), Moving-Average (MA), and Auto regressive Integrated Moving Average (ARIMA) and Autoregressive Moving Average (ARMA) processes. This is a very popular class of forecasting models..

3) Support Vector Machines: Support Vector Machines (SVM) is the most powerful and latest technique for solving classification and regression problems. This approach was introduced by Vapnik's, statistical learning theory. The SVM transforms the input space into a high dimensional feature space by nonlinear mapping and then solves a linear separable classification problem in this space feature. A number of SVM based models [47,48] are proposed

C. Soft Computing Based Forecasting Techniques:

Conventional methods still have problem of uncertainty and variations. Hence a soft computing approach which is capable of removing these drawbacks has been emerged out. This flexible approach had a remarkable ability of human mind to analyze in uncertain and imprecise environment. Soft computing techniques consist of following techniques:

1) Genetic Algorithm: The genetic algorithm (GA) approach [21,22] is very effective optimization algorithm and capable to obtain global minima and maxima. Therefore best suitable for calculating minimum and maximum load leading to improved accuracy of load forecasting model.

2) Fuzzy Logic: Fuzzy logic is a technique which do not involve mathematical expression of inputs and outputs. In the fuzzy logic forecaster past load data are used to train input and output pattern will be generated after defuzzification. References [39,40,41] gives applications of fuzzy logic to electric load forecasting.

*3) Neural Network: A*rtificial neural networks has been introduced in electric load forecasting problem since 1992 [42]. Neural networks posses linear or nonlinear mathematical function between input and output variable. Usually ANN consists of a number of interconnected layers. Some time feedback are also utilized to increase the accuracy of model.

4) Knowledge Based Expert systems: Expert systems, replaces the rules and procedure used by human experts in to a software in a particular field to forecast load. Expert system was introduced in 1960's. These are rule-based techniques where the rules are derived from human experts. This approach was first developed by Rahman and Bhatnagar

[37,43] where algorithm has developed based on the logical relationships between weather and load. The developed algorithm performed better compared to the conventional Box-Jerkins Method.

D. Integrated Techniques or Hybrid Techniques:

It is very difficult for a forecaster to select a unique model for unique situations. Generally a number of models are proposed and one with the most accurate result or minimum error is selected. However, the final selected model may not necessarily be the best due to some other factors. But by combining two or more techniques these errors can be easily removed. The integrated model [44] of different techniques is known as Hybrid system, which utilizes combination of different techniques.

VI. Comparision Of Different Approaches

Long-term load forecasting is very complex because it is highly affected by the weather and social conditions. These factors are very difficult to forecast for time horizon. Whereas, short-term forecasting, can be done with higher precision irrespective of the fact that short term forecast affected by weather and daily social activities, as it is easy to forecast these factors for small time horizon.

Choosing a forecasting technique is very complicated task. One particular method can be superior to another depending on the nature of load forecast. Hence selecting best technique requires knowledge of advantages and disadvantages of various available methods. This section covers the comparison of different forecasting techniques. Wills and Northcotegreen [45] performed a comparison of fourteen load forecasting methods.

The methods used for long- and medium-term forecasting are trend analysis, end-use and econometric approach. The advantage of *trend analysis* is that it is quicker, simpler and cheaper and does not require much historical load data. The basic idea of the *end-use analysis* is that the load consumption depends on usage (the end-use). It identifies exactly how much electricity is consumed and for what purpose; The disadvantage is that most end-use models assume a constant relationship between load and end-use. This might work for few years, but after long period, with the change in different sectors and factors, the relationships will not remain constant. The advantages of *econometric methods* are that it provides detailed information on future load, how load increases or decreases, and is affected by various factors. The disadvantage is assumption that the changes in load must remain same in the forecast period as in the past.

The conventional methods for short term load forecasting include similar day approach, time series prediction methods and regression methods. *Similar day approach* is based on load data of days of past few years having the similar characteristics to the day of forecast. *Time series models* consider the extrapolation to predict load. *Time series* emphasizes the presence of large amount of previous data where as the *regression* emphasis on the relation load and influencing factors. The disadvantage is that heavy computational efforts are required for accurate load predictions.

The advent of artificial intelligence techniques has brought the concept of soft computing based load forecasting. Fuzzy logic, expert systems and neural networks have been proposed for electric load forecasting. *Knowledge based Expert system* utilizes the knowledge of skilled and technical human experts into a software to forecast the load. It is very difficult to transfer knowledge of human experts for developing rules. *The artificial neural network – based models* is the most popular for load forecasting due to its adaptable nature and supervised learning method for training the data set. The drawback is that it cannot identify the mathematical expression between dependent and independent variables. ANN model has better accuracy in comparison to conventional forecasting techniques. *Fuzzy logic system* provides reasoning logic and some of the uncertainty in input output curve is removed by fuzzy logic. Thereby increase the accuracy over ANN. *Genetic algorithms* works on principle of natural selection and genetics. GA proves to be promising approach for load prediction.

It has been discussed that parametric methods considers the relation between load and their influencing factors as input output relationship where as soft computing methods do not.

VII. Conclusion

Efficient and precise load forecasting is pre-requisite for power system planning and operation. In this paper different techniques available for electric load forecasting are discussed. It is concluded that the appropriate models in load forecasting will be achieved by better understanding of the load behaviour and its characteristics. Environment and situation has an important role in selecting accurate model. This paper compare various load forecasting techniques and it is concluded that none of them is perfect alone; the trend is towards hybrid models which utilizes integration of different techniques.

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