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Introduction to Load Forecasting

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Abstract

Load forecasting is a technique used by power companies to predict the power or energy needed to balance the supply and load demand at all the times. It is mandatory for proper functioning of electrical industry. It can be classified in terms of time like short-term (a few hours), medium-term (a few weeks up to a year) or long-term (over a year). In this paper, for medium and long term forecasting end use and econometric approach is used. Whereas for short term forecasting various approaches are used like regression models, time series, neural networks, statistical learning algorithms and fuzzy logic.

Key Words: Load forecasting, regression models, time series, neural networks, statistical learning algorithms and fuzzy logic.

1. Introduction

Electrical energy cannot be stored. It has to be generated whenever there is a demand for it. It is, therefore, imperative for the electric power utilities that the load on their systems should be estimated in advance. **This estimation of load in advance is commonly known as load forecasting**. It is necessary for power system planning. Power system expansion planning starts with a forecast of anticipated future load requirements. There is a growing tendency towards unbundling the electricity system. This is continually confronting the different sectors of the industry (generation, transmission, and distribution) with increasing demand on planning management and operations of the network. The operation and planning of a power utility company requires an adequate model for electric power load forecasting. Load forecasting succor an electric utility to make conclusions regarding decision on generating and purchase electric power, load switching, voltage control, network reconfiguration and infrastructure development. Electric load forecasting is the process used for forecasting future electric load, given historical load and weather information and current and forecasted weather information. In the past few decades, several models have been developed to forecast electric load more accurately. With an introduction of deregulation of power industry, many new challenges have been encountered by the participants of the electricity market. Forecasting of wind power, electric loads and energy price have become a major issue in power systems. Following needs of the market, various techniques are used to forecast the wind power, energy price and power demand. The market risk related to trading is considerable due to extreme volatility of electricity prices. Considering the uncertain nature of future prices in competitive electricity markets, price forecasts are used by market participants in their operation planning activities. In addition, to ensure the secure operation of the power system at some future time requires the study of its behavior under a variety of postulated contingency conditions. Demand prediction is an important aspect in the development of any model for electricity planning, especially in today's reforming power system structure [1]. The form of the demand depends on the type of planning and accuracy that is required. The objective of this paper is to provide a brief overview of various forecasting problems and techniques in power systems. Depending on the time zone of planning strategies the load forecasting can be divided into following three categories namely:

1. **Short term load forecasting**: this forecasting method is usually has period ranging from one hour to one week. It can guide us to approximate load flow and to make decisions that can intercept overloading. Short term forecasting is used to provide obligatory information for the system management of daily operations and unit commitment.
2. **Medium term load forecasting:** this forecasting method has its period ranging from one week to one year. The forecasts for different time horizons are important for different operations within a utility company.

Medium term forecasting is used for the purpose of scheduling fuel supplies and unit management.

3. **Long term load forecasting:** this forecasting method has its period which is longer than a year. It is used to supply electric utility company management with précised prediction of future needs for expansion, equipment purchase or staff hiring.

To execute different operations within a utility company, the forecast for different time horizon needed to be employed. The behavior of these forecasts is different as well. For instance, in a particular region it may be possible to predict coming day load with an accuracy of approximately 1-3%. Moreover, it is almost impossible to predict the peak load of next year with the similar accuracy since the prediction for long term forecasting may lack precision making this forecast unavailable. But, for the next year peak forecast, it is possible to produce the probability distribution load based on past weather observations. According to the industry practice, it is also possible to predict the so-called weather normalized load, which would take place for average annual peak weather conditions or worse than average peak weather conditions for a given area. The load calculated for the normal weather conditions which are the average of the weather is called weather normalized load. Further, the techniques employed by most of the forecasting methods are statistical techniques or artificial intelligence algorithms such as regression, neural networks, fuzzy logic, and expert systems. The two methods which are broadly used for medium-term and long-term forecasting are end-use and econometric approach. And for short-term forecasting, a variety of methods, which include the so-called similar day approach, various regression models, time series, neural networks, fuzzy logics and expert systems have been developed. A wide variety of mathematical methods and ideas have been used for load forecasting. The development and refinements of appropriate mathematical tools will lead to development of more accurate techniques for load forecasting. The accuracy is also the matter of forecasted weather scenarios; it doesn’t solely depend upon load forecasting techniques. Weather forecasting is the application of science and technology to predict the conditions if atmosphere for a given location and time.

2. Basics of Forecasting

Forecasting is a Stochastic Problem

Forecasting, by nature, is a stochastic problem rather than being deterministic in nature. There is no "certain" in forecasting. Since the forecasters are dealing with randomness, the output of a forecasting process is supposed to be in a probabilistic form, such as a forecast under this or that scenario, a probability density function, a prediction interval, or some quantile of interest. In practice, probabilistic inputs cannot be taken in many decision making processes, so the most commonly used forecasting output form is still point forecast, e.g., the future expected value of a random variable.

All Forecasts are Not Accurate

The response variable to forecast is never 100% predictable due to the stochastic nature of forecasting. Bad data, inappropriate methodologies, and crappy software, etc are some other factors that may lead us to wrong forecasts. It's the forecaster's job to apply best practices to avoid these preventable issues.

Some Forecasts are Useful

The two most common aspects of usefulness in the utility industry are accuracy and defensibility. Accuracy can be calculated based on various peaks (i.e., monthly, seasonal or annual peaks), energy or the combination of them. Defensibility may include interpretability, traceability, and reproducibility. The points above needs to be prioritized differently depending upon the exact business need. For example, for regulatory compliance purpose, we would emphasize defensibility more than the accuracy. As a consequence, statistical approaches such as multiple linear regressions are usually preferred over black-box approaches like Artificial Neural Networks.

Forecasts can be Improved

Since all forecasts are not always correct, there is always way for improvement, at least from the accuracy point of view. Generally speaking, the objective of forecast improvement is to enhance the utility. For potential improvement there are some more specific directions which can be adopted:

a) **Spread of errors.** Nobody wants to have surprisingly big errors. Reducing the variance or range of the errors means reducing the uncertainty, which consequently increases the utility of the forecasts. Sometimes the business may even give up some central tendency of the error (e.g., MAPE), to gain reduction in the spread (e.g., standard deviation of APE).

b) **Interpretability of errors.** For instance, due to uncertainty in long term weather and economy forecasts in long term load forecasting, the load forecasts may result in some significant errors from time to time. Then the forecasters should help the business users to understand how much of the error is contributed by modeling error, weather forecast error and economy forecast error. Breaking down the error to its sources increases the interpretability as well as the utility of forecasts.

c) **Requirement of resources.** In reality, we always have limited resources like data, hardware and labor to build a forecast. If we can enhance the simplicity of the forecasting process by reducing the requirements on these resources, it can be of use for the business side.

Accuracy is Never Guaranteed

Due to the unpredictable nature of forecasting, the future will never redo the history in exactly the manner described by our models. Sometimes, the deviations are large; sometimes, they are small. Even if a forecaster could maintain a stable accuracy during the past a few years, there is still no guarantee that the similar accuracy can be attained going forward. Sometimes the consultants and vendors promise impractical accuracy to the clients in order to vend the services or solutions. This is one of the worst practices, because eventually the clients will realize that the error is not as low as what's been promised.

Having the Second Opinion is Preferred

There is never a perfect model. If only one model is being used, the forecaster will experience ”bad” forecasts from time to time and the predictions and outcomes will become worse. If multiple models are available, the situation can be completely different. The forecaster will have good outcomes when the models will agree to each other. Forecaster will be able to focus on the periods when these models disagree with each other significantly. Factually, combining forecasting techniques usually does a better job than each individual, offering more robust and accurate forecasts. Therefore, one of the best practices is to run multiple models and combine the forecasts.

3. Important Issues in Load Forecasting

Forecasting Load

Forecasting electricity loads has reached the state of maturity. Short-term (a few minutes, hours, or days ahead) to the long term (up to 20 years ahead) forecasts have become increasingly important since the restructuring of power systems. Many countries have recently follow isolationism and privatized their power systems, and electricity has been turned into an important commodity available at market prices. Load forecasting is an arduous task. First, because the load series is complex and exhibits several levels of seasonality like the load at a given hour is dependent not only on the previous hour loads, but also on the load at the same hour on the previous day, and on the same hour load on the day with the same value in the previous week. Secondly, because there are many important exogenous variables that must be considered, specially weather related variables [1] [2]. These issues can be resolved by using various models and methodologies like autoregressive models, dynamic linear or nonlinear models, fuzzy inference, fuzzy-neural models, Box and Jenkins transfer functions ARMAX models, , neural network (NN) etc.

Price Forecasting

Forecasting loads and prices in electricity markets are mutually intertwined activities, and error in load forecasting will propagate to price forecasting. Electricity price has its special characteristics. There are at least three main features that make it so specific. One of them is its non-storability of power, which means that prices are strongly dependent on the power demand. Another characteristic is the seasonal behavior of the electricity price at different level (daily, weekly and annual seasonality) and the third one is its questionable transportability. In today’s most competitive electricity markets, the hourly price series have the characteristics such as volatility, non-stationary properties, multiple seasonality, spikes and high frequency. A price spike can be caused by market power which is a randomized event, and also by unexpected events such as transmission congestion, transmission contingency and generation contingencies. It can also be affected by other factors such as fuel prices, generation unit operation costs, weather conditions, and probably the most theoretically significant factor, the balance between overall system supply and demand. Applications of electricity price forecasting fall into different time horizons which are short-term forecasting, medium-term forecasting and long-term forecasting. In order to maximize their profits in spot markets, market participants need to forecast short-term (mainly one day-ahead) prices. And for successful negotiations of bilateral contracts between suppliers and consumer, accurate medium term price forecasts are necessary. The decisions on transmission expansion and enhancement, generation augmentation, distribution planning and regional energy exchange are influenced by Long-term price forecasts. The models which are used to resolve these issues are statistical and non-statistical models. Time-series models, econometric models and intelligent system methods are the three main categories of statistical methods. Non-statistical methods include equilibrium analysis and simulation methods.

Forecasting Wind Power

Wind-generated power constitutes a noticeable percentage of the total electrical power consumed and in some utility areas it even exceeds the base load on the network. This indicates that wind is becoming a major factor in electricity supply and in balancing consumer demand with power production. To integration of wind power into the grid is its variability is its major barrier. Because of its dependence on the weather, the output cannot be guaranteed at any particular time. These issues can be solved by techniques with simple persistence approach, classical linear statistical models such as Moving Average (MA), Auto-Regressive Moving Average (ARMA) and the Box-Jenkins approach based on Auto-Regressive Integrated Moving Average (ARIMA) or seasonally adjusted ARIMA models, also known as SARIMA models.

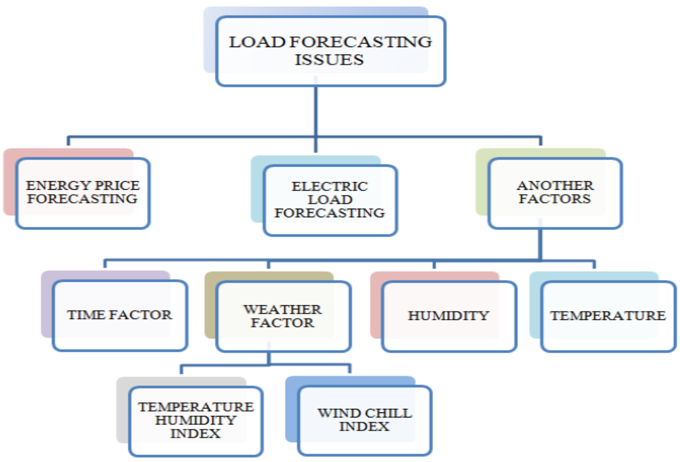

Fig. 1: Block Diagram of Load Forecasting Issues

4. Methodologies for Load Forecasting

Medium/Long-term Load Forecasting Methods

End-use and Econometric approach are two methodology used for medium- and long-term forecasting.

End-use Approach

The end-use approach directly estimates energy consumption by using extensive information on end use and end users, such as appliances, the customer use, their age, sizes of houses, and so on. End-use models focus on the various uses of electricity in the residential, commercial, and industrial sector. These models are based on the principle that electricity demand is derived from customer's demand for light, cooling, heating, refrigeration, etc. Thus end-use models explain energy demand as a function of the number of appliances in the market.

Econometric Approach

The econometric approach combines economic theory and statistical techniques for forecasting electricity demand. The approach estimates the relationships between energy consumption (dependent variables) and factors influencing consumption.

Short–term Forecasting Methods

Many methods which include the so-called similar day approach are various regression models, time series, neural networks, expert systems, fuzzy logic, and statistical learning algorithms, are used for short-term forecasting.

Similar-day Approach

This approach is based on searching historical data for days within one, two, or three years with similar characteristics to the forecast day. Similar characteristics include weather, day of the week, and the date.

Regression Methods

Regression is the one of most widely used statistical techniques. For electric load forecasting regression methods are usually used to model the relationship of load consumption and other factors such as weather, day type, and customer class.

Time Series

It has been used for decades in such fields as economics, digital signal processing, as well as electric load forecasting. In particular, ARMA (autoregressive moving average), ARIMA (autoregressive integrated moving average), ARM\AX (autoregressive moving average with exogenous variables), and ARIMAX (auto regressive integrated moving average with exogenous variables) are the most often used classical time series methods.

Neural Networks

Neural networks are essentially non-linear circuits that have the demonstrated capability to do non-linear network are some linear or nonlinear mathematical function of its inputs[20].The inputs may be the outputs of other network elements as well as actual network inputs. In practice network elements are arranged in a relatively small number of connected layers of elements between network inputs and outputs. Feedback paths are sometimes used. In applying a neural network to electric load forecasting, on must select one of a number of architectures (e.g. Hopfield, back propagation, Boltzmann machine), the number and connectivity of layers and elements, use of bi-directional or uni-directional links, and the number format (e.g. binary or continuous) to be used by inputs and outputs, and internally. The most popular artificial neural network architecture for electric load forecasting is back propagation.

Fuzzy Logic

Fuzzy logic is a generalization of the usual Boolean logic used for digital circuit design. Under fuzzy logic an input has associated with it a certain qualitative ranges. For instance a transformer load may be "low", "medium" and "high". Fuzzy logic allows one to deduce outputs from fuzzy inputs. In this sense fuzzy logic is one of a number of techniques for mapping inputs to outputs. Among the advantages of fuzzy logic is the absence of a need for a mathematical model mapping inputs to outputs and the absence of a need for precise or even noise free inputs [8][9].

Expert Systems

Expert systems are known to apply rules which have been generated by experts in the field. These procedures and rules are then transformed into software, which can automatically make forecasts about electricity demand. However, in order for the software to be efficient, expert forecasters will have to work hand in hand with software developers to include all expert information into the software. Here, software developers will be involved in coding all the information obtained from experts in forming software rules. The advantage of utilizing this method is that it is fast, accurate and easy to use when forecasting information about electricity demand. This is because it involves the use of software applications, which usually run at the click of a button.

5. Advantages & Disadvantages of Load Forecasting

Advantages

1) It enables the utility company to plan well since they have an understanding of the future consumption or load demand.
2) Useful to determine the required resources such as fuels required to operate the generating plants as well as other resources that are required to ensure uninterrupted and yet economical generation and distribution

of the power to the consumers. This is important for all short, medium, and long term planning.

3) Planning the future in terms of the size, location and type of the future generating plant are the factors which are determined by the help of load forecasting.
4) Provides maximum utilization of power generating plants. The forecasting avoids under generation or over generation.

Disadvantages

1) It is not possible to forecast the future with accuracy. The qualitative nature of forecasting, a business can come up with different scenarios depending upon the interpretation of the data.
2) Organizations should never rely 100 percent on any forecasting method. However, an organization can effectively use forecasting with other tools of analysis to give the organization the best possible information about the future.
3) Making a decision based on a bad forecast can result in financial ruin for the organization, so the decisions of an organization should never base solely on a forecast.

6. Future Research Directions

In this paper we have discussed several statistical and artificial intelligence techniques that have been developed for short-term, medium-term, and long-term electric load forecasting. Several statistical models and algorithms that have been developed though are operating ad hoc. The accuracy of the forecasts could be improved, if one would study these statistical models and develop mathematical theory that explains the convergence of these algorithms. Researchers should also investigate the boundaries of applicability of the developed models and algorithms. So far, there is no single model or algorithm that is superior for all utilities. Selecting the most suitable algorithm by a utility can be done by testing the algorithms on real data. In fact, some utility companies use several load forecasting methods in parallel. As far as we know, nothing is known on a priori conditions that could detect which forecasting method is more suitable for a given load area. An important question is to investigate the sensitivity of the load forecasting algorithms and models to the number of customers, characteristics of the area, energy prices, and other factors. There is also a clear move towards hybrid methods, which combine two or more of these techniques we think that the important research and development directions are:

i. Combining weather and load forecasting and
ii. Incorporating load forecasting into various decision support systems.

7. Conclusion

In this paper we have reviewed some statistical and artificial intelligence techniques that are used for electric load forecasting. We also discussed basics and factors that affect the accuracy of the forecasts. Different techniques are applied to load forecasting. It can be inferred that demand forecasting techniques based on soft computing methods are gaining major advantages for their effectual use. There is also a clear move towards hybrid methods, which combine two or more of these techniques. The research has been shifting and replacing old approaches with newer and more efficient ones.

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