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Issues, Challenges and Comparison of Electricity Demand Forecasting Techniques with ANN based Techniques

Gitika Sharma[1], Jaskaran Kaur[2]
[1]*Department of Computer Science & Engineering, Chandigarh university, gitika.cse@cumail.in*
[2]*Department of Computer Science & Engineering, Thapar University, jaskaran.kaur2012@gmail.com*

Abstract **Expansion of geographical boundaries of urban regions, increase in number of urban centres and growth in population size including increase in population, are major factors contributing towards rapid urbanization. This rapid urbanization creates various challenges in building smart cities. One of the major challenge is to forecast the electricity demand. This paper presents the various problems and challenges while forecasting electricity demand and also compares the various conventional techniques and comparison between ANN techniques. We Also proposed a solution for forecasting the demand electricity.**

Keywords— Demand forecasting, smart city, ANN, ICT, Electricity management system.

I. INTRODUCTION

With increase in number of people moving towards cities, there is a need to find new ways to manage complexity, reduce expenses, increase efficiency and improve quality of life urban people. As urbanisation is increasing there is a need for the cities to need to get smarter. Smart City is one with developed area including advanced technology, better infrastructure, better integration of different technologies and good quality of living to its citizens. Major characteristics of smart city includes smart mobility, smart living, smart people, smart environment, smart economy and smart governance. In order to provide smart governance and smart living, the cities need to have proper waste management, water supply, proper transportation facility, healthcare and educational facilities. Proper electricity management is also crucial component of a smart city.

The motivation of this research work stems as Demand forecasting is an important key for electricity management system. Along with its importance in reducing the cost of production, it is also important for the reliability of energy systems. The load forecasting result are used by system operator to form a basis of off-line network analysis in order to determine vulnerability of the system. Corrective actions like load shedding and electricity purchases can be performed in case of vulnerability. Power production of next day is scheduled everyday hence demand forecasting is necessary. Both under or over estimation of demand can be a cause of trouble as under prediction leads to insufficient reserve capacity preparation and, therefore, resulting in increase of the operating cost with expensive peaking units.

While over prediction leads towards unnecessarily large reserve capacity that also results into high operating cost. Estimation of the future demand with the historical data is a difficulty till now, especially for the demand forecasting of days and months with extreme weather conditions. With the development recent improvement in Data Mining, mathematical and artificial intelligence tools, it has become possible to improve the demand forecasting results. Errors in forecasting leads to more purchasing electricity cost t to keep the electricity supply and demand balance in the real-time dispatch operation. Thus, an adaptable and accurate technique is required for demand forecasting.

The prediction might be just for a fraction of an hour to as much as 20 years ahead for operation and planning purposes. Thus, the electricity demand forecast for different time horizon are important for different operations within a company. These forecasts [1] are different in nature as well. The forecasts are divided into different categories depending upon the duration for which the demand is predicted. The various classes of prediction are shown in Table 1.

TABLE I
DEMAND FORECASTING CLASSIFICATION

Nature of Forecast	**Duration**	**Applications**
Very short-term forecast	Few seconds to few minutes	Generation, contingency analysis for system security and distribution schedule.
Short term forecasting	Half an hour to few hours	Maintenance scheduling, spinning reserve allocation, operational planning and unit commitment.
Midterm forecasting	A few hours to few weeks	seasonal peak-summer, peak-Winter.
Long term forecasting	A few months to few years	Generation growth planning.

The rest of the paper is described as follows, in the section II, we describe the problem statement and the challenges faced in demand forecasting in electricity. In section III, we present the overview of various forecasting techniques, models and comparison between them. Next section provides the possible solution to the electricity demand forecasting problem.

II. PROBLEM STATEMENTS AND CHALLENGES

This paper incorporates the present state of the art in the field of load forecasting by purposing the answer to various present research questions.

- What is demand forecasting of electricity?
- What are the various techniques for demand forecasting?
- Which technique of load forecasting is more appropriate and provide justice for electricity demand forecasting with weather data and previous demand record?

This work starts systematically with definite research questions. Load forecasting techniques are compared and appropriate one is selected based upon type of dataset available and performance of various techniques.

III. FORECASTING TECHNIQUES

Demand forecasting with lead-times, from a few minutes to several days, from days to months, helps the system operator to efficiently schedule management of electricity and its allocation. In addition to these economic reasons, load forecasting is also useful for maintaining system security, it can provide valuable information to detect many vulnerable situations in advance. The optimal utilization of generators and power generating stations is completely dependent upon the accuracy and efficiency of demand forecasting. The various techniques used for forecasting are shown in fig.1.

A. Parametric Models

Parametric methods use mathematical models to relate electricity demand to its affecting factors. Estimation of parameters for the model is done using statistical techniques that are applied upon historic data of demand and its factors affecting.

1) Classification: Parametric model is further classified into three well-known types that are trend analysis, end use analysis and the last is econometric model.

- Trend analysis analyses of past data constitute towards the forecast. Trend analysis focuses upon past changes in demand of electricity and utilizes it to predict future changes in the demand. Forecasts are modified by utility forecasters depending upon information about future developments which can result in increase of future demand of electricity [2].
- End Use Models directly estimates electricity demand by making use of extensive information available on end users like application used by customer, age of customers, house sizes etc.

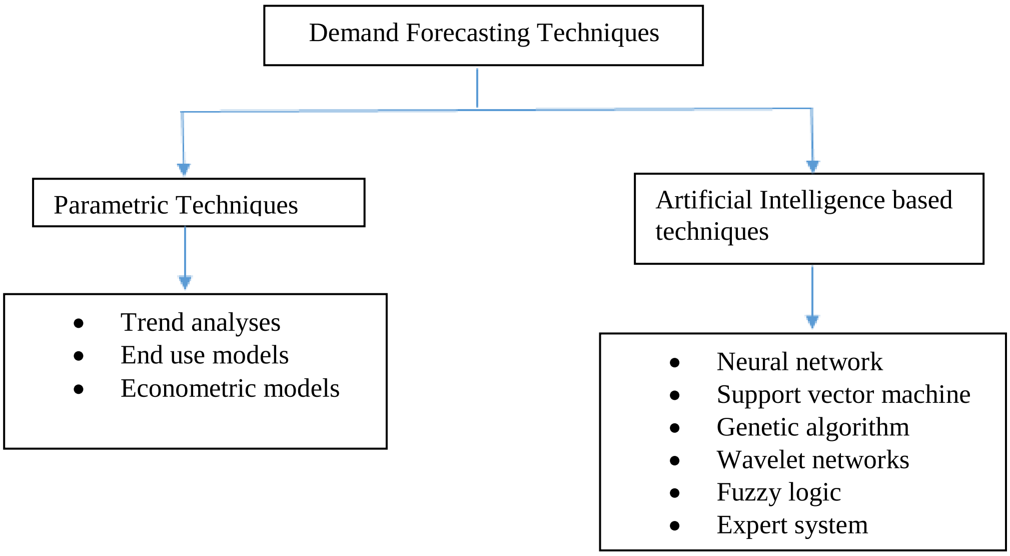

Fig. 1 Various techniques of electricity demand forecasting

This statistical information related to the customer form the basis of this model forecast. It focuses on different uses of electricity in various sectors like residential, industrial and commercial sector [3].

TABLE II
STUDY OF TRENDING TECHNIQUES WHICH IS USED FOR DEMAND FORECASTING

Parametric Model	**Working**	**Pros**	**Cons**
Trend Analysis	Extends past rate of electricity demand into future demand	Simple Quick Inexpensive to perform	Produces only one result i.e. future demand. Does not allow analyzing why demand behaves this way

This model works on the principle that customer demand of electricity for purposes like cooling, light and heating etc. drives the demand of electricity in a region.

TABLE III
STUDY OF END USE MODEL WHICH IS USED FOR DEMAND FORECASTING

Parametric Model	**Working**	**Pros**	**Cons**
End Use Model	Forecasts using extensive information present on user side	Accurate Less historic data required	Sensitive to amount and quality of end use data. Assume a constant relationship between electricity and end-use.

- Econometric model approach of forecasting combines statistical techniques and economic theory for forecasting electricity demand [4]. Time series method or least-square method are used for the estimation of relationship.

Widen, et al, proposed a stochastic Markov chain model using a bottom-up approach for modelling the electricity demand in households in country like Sweden [5].

TABLE IV
STUDY OF ECONOMETRIC MODEL WHICH IS USED FOR DEMAND FORECASTING

Parametric Model	**Working**	**Pros**	**Cons**
Econometric Model	Combines statistical technique and economic theory	Provides detailed information of electricity demand. How factors affect the demand [15].	Assume the changes in electricity remain same in forecast period as in the past.

2) *Comparison among different parametric models:* As mentioned in the trend analysis, analyse the changes in the past years in electricity demand and utilize it to predict future electricity demand, but there is no process to explain why these changes happened. End users and behaviour of end user are not important in this model.

Comparison of these three-parametric model shows that out of econometric, end use model and trend analyses, trend analysis is not as trustworthy in this method as other two models because we require a wise and knowing judge in this case, for recognition of unreal data and to omit them.

TABLE V
COMPARISON OF THREE PARAMETRIC MODEL FOR DEMAND FORECASTING

Models	Pros	Cons	Authors
Trend Analysis	Fast processing and easy data availability. Many commercial tools available.	Suitable only for short-term forecasting.	[6-7]
End Use Model	It is suitable for long-term forecasting. Can simulate demand changes if consumption patterns change or new technologies are introduced.	Model's accuracy is highly based on the information from consumers. If the consumer's sample is limited, it cannot simulate large-scale demand forecasting	[8,9]
Econometric Model	Also, suitable for long-term forecasting and simulation of different scenarios of demand, implementation technologies, policy adoption and consumers' behavioural changes.	Requires historical electricity data, economic and behavioural components for the same consumers' population sample for building the model. Otherwise model's accuracy lowers.	[10-12]

B. Artificial Intelligence based Techniques

In the previous section of this chapter we discussed parametric techniques of Data Mining and compared different parametric techniques.

1) Classification: In this section, we will discuss artificial intelligence based models of Data Mining. The artificial intelligence methods of forecasting demand are further classified in to neural networks, support vector machines, genetic algorithms, wavelet networks, fuzzy logics and expert system methods.

The ability of mapping complex and non-linear relationships has resulted into increase in number of applications in demand forecasting [13]. Load forecasting, fault diagnosis and security analysis are most important ones. Short term load forecasting is often carried out by using these ANN. For long term load forecasting using ANN only a few studies are carried out [14], [15].

Taradar H. et al. [8] proposed some degrees of freedom that must be iterated upon to increase the potential of an accurate demand forecast: (1) fraction of the database to be used for training purpose and testing purpose, (2) transformations performed on the historic database, (3) specifications of ANNs architecture, (4) during training optimal stopping point and (5) relative weights to use in forecast combination.

Kermanshahi et al. [16] proposed a recurrent neural network model for long term load forecasting.

Many advantages offered by ANN are:

- They are extremely powerful computational devices.
- Very efficient due to massive parallelism.
- Learn and generalize from training
- Fault tolerant
- Noise tolerant
- Can do anything a symbolic/logic system can do

TABLE VI
STUDY OF ANN MODEL OF LOAD FORECASTING

Model	working	Pros	Cons
ANN	It performs non-linear modelling and adaptation.	Approximate very accurately, Does not require assumption of any functional relationship between load and weather variables in advance, Model a multivariate problem without making complex dependency assumptions among input variables.	Inaccuracy of weather forecasts, difficulties in weather-load relationship modelling and implementation problems limit the accuracy. [17]

Wavelet theory is introduced to load forecasting recently and it has received wide attention. Then analyse each components characteristic thus resulting into improved accuracy. Wavelet analysis is further extended to wavelet packet analysis for better resolution [18]. Application of wavelet analysis for load prediction is investigated in several papers.

Amjady N. et al. [19] proposed a new hybrid forecast for short term load forecasting.

Bashir Z.A et al [20] proposed a model that wavelet transformed the data during pre-processing stage and then redundant information is extracted by inserted data into neural network.

Managing electricity supply is a complex task. Most important part of this management is forecasting future demand of a region. Genetic algorithm approach is proposed to forecast long term electricity demand. The results of its applications show success in load forecasting with minimal error. This class is based on natural selection, natural genetics and the notion of survival of the fittest mechanism. Fault detection, load flow problems, economic dispatch and load demand forecasting are some of the areas where GA is applied.

One of the most recent and powerful technique for regression and classification problem is Support Vector Machines (SVMs). This was originated from statistical learning theory by Vapnik's [21]. SVM perform a nonlinear mapping using so-called kernel functions. Then simple linear functions are used to create linear decision boundaries in the new space.

Expert systems, includes rules and procedures that are used by human experts in the field of their interest into a software that can then automatically make forecasts without any human assistance. The use of expert system began in the 1960's for applications like computer designing and geological prospecting. It can codify up to thousands of production rules.

2) Comparing Artificial Intelligence based techniques: In previous section, various artificial intelligence based techniques and their application were discussed. In this section, we will compare these techniques. Table VII will show the contrast among these techniques.

TABLE VII
COMPARISON OF ARTIFICIAL INTELLIGENCE BASED TECHNIQUES OF DEMAND FORECASTING

Model	Working
Artificial Neural Network	Recurrent neural network learns pattern from previous year's data and project patterns and trends for future. Feed forward and back propagation neural network produces an associated output pattern when an input pattern is given. More simple and accurate then RNN.
Wavelet Analysis	Inputs are not spanned. More accurate than multi-layer neural network because of multi resolution analysis property.
Genetic Algorithms	It is a numerical optimization technique based on natural genetics. Quite promising and Produce better results in long term load forecasting. Suitable for parallel implementation.
SVM	It has non-linear mapping capabilities. Parameters if improperly determined can cause under fitting or over fitting of SVM model.
Fuzzy System	Fuzzy rules are combined with neural network to train ANN and to get better load demand forecasting.
Expert System	It is flexible in updating the forecasting methods and heuristic rules.

C. *Factors Affecting Accurate Demand Forecast*

The operation of electricity system is strongly influenced by the accuracy of demand forecast as economy and control of electric power system is quite sensitive to forecasting errors [22-23]. The four important factors affecting load forecast are:

1) *Weather conditions:* Electricity demand has a strong correlation to weather. To develop an efficient and accurate demand forecasting model for electricity much effort has been put to find a relationship between the weather and the demand of electricity. The change in comforts of customer due to change in weather conditions resulting in usage of appliances likes air conditioner, space heater and water heater. It also includes use of agricultural appliances for irrigation. The pattern of demand differs greatly in the areas with large meteorological difference during summer and winter. Dry and wet temperature, humidity, dew point, wind speed, wind direction, sunshine and amount of precipitation are common weather parameters that influence electricity demand. Among the weather variables listed above, two composite weather variable functions, the cooling degree days and heating degree days are broadly used by utility companies.

TABLE VIII
COMPONENTS OF WEATHER OF LOAD FORECASTING

Weather Component	**Impact on demand**
Temperature (degree C)	Demand increases whenever temperature rises or lower than base line
Humidity (%)	Demand increases with increase in humidity.
Wind speed(Km/h)	Depend upon location.
Sunshine	More sunlight leads to more heat. Thus, more demand.
Rainfall (mm)	Less demand due to low irrigation requirements.

2) *Time factors:* The time factors include the day of the week and the hour of the day. Weekdays and weekends experiences different demands. Different weekdays can also behave differently particularly during summers. Forecasting demand on holidays are more difficult than non- holidays due to infrequent occurrence. The arrangement of people's daily life is reflected by the demand variation: working, leisure and sleeping time. Demand variation with time have some rules defined. The demand curve is lower on weekend than the week day curve because of less working load. Another property of the demand curve is the periodicity. Demand data contains strong periodicity daily, weekly, seasonal and yearly. Forecasting results can get benefit from better use of these properties.

3) *Economy*: Electricity is also a form of commodity. Thus, utilization of electricity is also influenced by the economic situation. Demand of electricity strongly depends upon economic factors like the degree of industrialization, cost of electricity and load management policy. The relationship between electricity price and demand has become even stronger with the development of modern electricity markets.

4) *Customer class:* Residential, commercial, and industrial are different types of customers served by most of the electric utilities. Customer belonging to different classes have different electric usage pattern but it is somewhat alike for customers within one class [24]. Therefore, load behaviour most are distinguished on bases of class.

Though demand of electricity is governed by number of factors as mentioned above, but studies have shown that weather is the key factor that drives the demand of electricity. The other factors like economy and time factors are important for daily demand prediction. But for long term forecasting weather variables are the major contributors.

IV. CONCLUSION

Conventional or parametric techniques assume, without proper justification, a linear relationship between load and weather variables. However, the functional relationship among load and weather variable is not stationary. Conventional regression approach does not offer the versatility to address this kind of temporal variation. Rather, it will produce an averaged result. Therefore, the required technique need to be adaptable so that efficient and accurate prediction of electricity demand can be made. Hence neural network is selected for load forecasting because it has capability of forming non-linear relationships.

Neural networks offer remarkable ability to extract meaning from complex or imprecise data. It can also be used to extract trends and patterns that are complex and difficult be noticed by humans or other computerized techniques. A trained neural network is like an "expert" in the analysing information provided to it. This provide projections when new situations are given and answer "what if" questions. It has many other advantages like:

- Adaptive learning: It is capable to learn how to perform tasks based on the given data for training.
- Self-Organization: It can create its own representation and organization of the information it receives during learning period.
- Real Time Operation: It offers parallel computations.

Because of above mention advantages offered by ANN and also due to database type ANN is preferred in this report for carrying out demand forecasting based on weather variables.

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