Comparative Study of Load Forecasting Methodologies in Electrical Power System

Swapnendra Singh Chauhan[1], Praveen Bansal[2], Neetu Agarwal[3]
[1,3] VITM, Gwalior, [2]MITS,Gwalior

Abstract - This paper picturesquely depicts the comparison of different methodologies adopted for predicting the load forecastingand highlights the changing trend and values under new circumstances using latest non analytical soft computing techniques employed in the field of electrical load forecasting. A very clear advocacy about the changing trends from conventional and obsolete to the modern techniques is explained in very simple way. Load forecast has been a central and an integral process in the planning and operation of electric utilities. Many techniques and approaches have been investigated to tackle this problem in the last two decades. These are often different in nature and apply different engineering considerations and economic analysis. Further a clear comparison is also presented between the past standard practices with the current methodology of electrical load demand forecasting. Besides all this, different important points are highlighted which need special attention while doing load forecasting when the environment is competitive and deregulated one.

Keywords:. Load forecasting, short term load forecast, midterm load forecast, long term load forecast.

I. INTRODUCTION

Load forecasting came in picture with the introduction of power system. The primary objective of an electric power system is to supply the various types of customers’ i.e. Commercial, industrial, military, agricultural and domestic customers at a 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.

II. CLASSES OF LoAD FORECASTING METHODOLOGIES

Electrical Load Forecasting is the estimation for future load by an industry or utility company. Load forecasting is vitally important for the electric industry in the deregulated economy. A large variety of mathematical methods have been developed for load forecasting. It has many applications including energy purchasing and generation, load switching, contract evaluation, and infrastructure development. Now days, development in every sector is a heading at a very rapid pace and in the same pattern, the demand for power is also growing. While speaking about electrical power, it is important to understand that it has three main sectors i.e. generation, transmission and distribution. Electrical power generated by any source is then transmitted through transmission lines at different voltage level and then distributed to different categories of consumers later on. It is not as simple as described in few words but every stage is a complete independent system in itself. Effective load forecasts can help to improve and properly plan these three fields of power systems [1].load forecasting has three techniques as shown in figure 1.1.

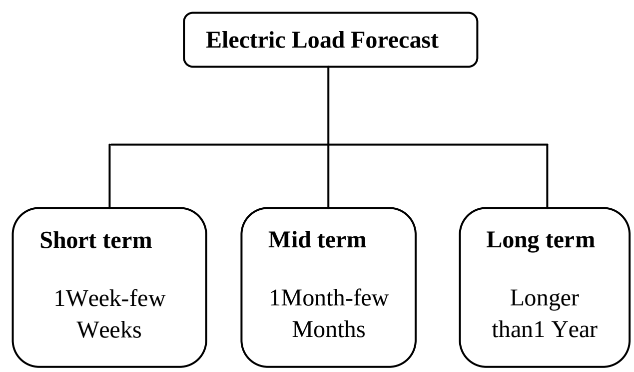

Fig. 1.1 Basic Load Forecasting Techniques.

Samuel Insull, an innovator and investor of electric utilityindustry, 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:

- Short term Load forecasting: this is usually for a few hours to few weeks.
- Medium Term Load Forecasting: this is usually for a few months to few months.
- Long Term Load Forecasting: This is valid for longer than 1 year.

III. SHORT TERM FORCASTING

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].

High forecasting accuracy and speed are the two most important requirements of short-term load forecasting and it is important to analyze the load characteristics and identify the main factors affecting the load. In electricity markets, the traditional load affecting factors such as season, day type and weather, electricity price that have voluntary and may have a complicated relationship with system load.

Various forecasting techniques have been applied to short-term load forecasting to improve accuracy and efficiency. In general, these techniques can be classified as either traditional or modern. Traditional statistical load forecasting techniques, such as regression, time series, pattern recognition, Kalman filters, etc., have been used in practice for a long time, showing the forecasting accuracy that is system dependent. These traditional methods can be combined using weighted multi-model forecasting techniques, showing adequate results in practical systems. However, these methods cannot properly represent the complex nonlinear relationships that exist between the load and a series of factors that influence it, which are typically dependent on system changes (e.g., season or time of day).

The short term load forecasting methods are

- Similar Day Lookup Approach
- Regression Based Approach
- Time Series Analysis
- Artificial Neural Network
- Expert System
- Fuzzy logic
- Support Vector Machines.
- Hybrid Techniques

1) Similar Day Lookup Approach: Similar day approach is based on searching historical data of days of one, two or three years having the similar characteristics to the day of forecast. The characteristics include similar weather conditions, similar day of the week or date. The load of the similar day is considered as the forecast. Now, instead of taking a single similar day, forecasting is done through linear combinations or regression procedures by taking several similar days. The trend coefficients of the previous years are extracted from the similar days and forecast of the concern day is done on their basis.

2) Regression Based Approach: 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. There are several regression models for the next day peak forecasting. Their models contain deterministic influences such as holidays, random variables influences such as average loads, and exogenous influences such as weather.

3) Time Series Analysis: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.

4) Artificial Neural Network: Artificial 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 timefeedback are also utilized to increase the accuracy of model.

5) Expert System: Expert systems are new techniques that have emerged as a result of advances in the field of articial intelligence. An expert system is a computer program that has the ability to reason, explain, and have its knowledge base expanded as new information becomes available to it.To build the model, the knowledge engineer' extracts load forecasting knowledge from an expert in the by what is called the knowledge base component of the expert system. This knowledge is represented as facts and IF-THEN rules, and consists of the set of relationships between the changes in the system load and changes in natural and forced condition factors that effect the use of electricity. This rule base is used daily to generate the forecasts. Some of the rules do not change over time, while others have to be updated continually.

6) 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. 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. Liu et al. (1996) observed that a fuzzy logic system has great capability in drawing similarities from huge data. The similarities in input data (L¡i ¡ L0) can be identified by different first order differences (Vk) and second-order differences (Ak), which are defined as:

$$V_k = (L_k - L_{k-1})/T, \ \& \ A_k = (V_k - V_{k-1})/T$$

The fuzzy logic-based forecaster works in two stages: training and on-line forecasting.

7) Support Vector Machines: Support Vector Machines (SVM) are the most powerful and very recent techniques for the solution of classification and regression problems. This approach was come to known from the work of Vapnik's, his statistical learning theory. Other from the neural network and other intelligent systems, which try to define the complex functions of the inputs, support vector machines use the nonlinear mapping of the data in to high dimensional features by using the kernel functions mostly. In support vector machines, we use simple linear functions to create linear decision boundaries in the new space. In the case of neural network, the problem is in the choosing of architecture and in the case of support vector machine, problems occurs in choosing a suitable kernel.

8) Integrated Techniques or Hybrid Techniques:

9) 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. Different 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

IV. COMPARISON OF APPROACHES

In addition to classifying load-forecasting approaches, it is important to compare different categories and individual techniques. A number of researchers have attempted to empirically compare some of the methods used in load forecasting. One of the earliest and most comprehensive comparisons is made by Willis and Northcote-Green (1984), who performed comparison tests on 14 load forecasting methods. Atlas *et al*. (1989) compared the performance of different structuresof neural networks with regression models. Dash *et al*. (1995a) also compared several fuzzy neural network based methods. Another comparison between neural networks and econometric models of forecasting electricity consumption was performed by Liu *et al*. (1991). Girgis *et al*. (1995) used actual load data to compare estimation errors of one-hour ahead and one-dayahead forecasts associated with three self-learning forecasting techniques. These techniques are: adaptive Kalman Filter, neural networks, and expert systems.On the basis of a simulation study, Liu *et al*. (1996) compared three other techniques of fuzzy logic (FL),neural networks (NN) and autoregressive models (AR),concluding that NN and FL are much superior to AR models of STLF. Other limited comparative data exist, provided by many researchers to establish the superiority of their proposed forecasting methods over a limited number of previously published methods. For example, Mbamalu and El-Hawary (1993) compared their interactive autoregressive model to the Box-Jenkins method. Willis *et al*. (1995) compared their simulation-based method to two other simulation methods. Wu and Lu (1999) compared their fuzzy modelling method to Box- Jenkins transfer functions and ANN. Srinivasan *et al*. (1999) compared their NN-fuzzy expert system methodology to a regression-based model, showing significant improvement in forecasting accuracy. The need for upto-date comprehensive comparisons of the di€ erent load forecasting methods provides a challenging opportunity for future research, given the wide variety of objectives and assumptions, and the unlimited possibility of mixingand matching different components of various methods.

V. CONCLUSION

Different techniques have been applied to load forecasting.Eight approaches have been reviewed in this paper viz are Similar Day Lookup Approach, Regression Based Approach,Time Series Analysis,Artificial Neural Network,Expert System ,Fuzzy logic, Support Vector Machines & Hybrid Techniques.After surveying all these approaches, we can observe a clear trend toward new, stochastic, and dynamic forecasting techniques. It seems a lot of current research effort is focused on three such methods: fuzzy logic, expert systems and particularly neural networks. There is also a clear move towards hybrid methods, which combine two or more of these techniques.

VI. FUTURE SCOPES

For utilities that are responsible for developing one to three year ahead volumetric sales forecasts by class of

service (e.g. Residential, Commercial, Industrial), the larger the customer base the more accurate the forecasts. The key sources of forecast errors are under/over forecasting customer growth and actual weather conditions differing ignificantly to average or normal weather conditions which are used for the forecast.

For utilities or system operators responsible for transmission /distribution/generation capital investment, the forecast accuracy values depend on the length of the forecast horizon. Longer term forecasts (i.e., 5 to 20 years or longer) depend heavily on accurate customer growth forecasts.For energy retailers and utilities that are responsible for procuring short-term power to meet the energy needs of their portfolio of clients the forecast accuracy range depends heavily on the composition of the customer portfolio. In general, the larger the portfolio (i.e. the greater the number of customers served) the more accurate the forecasts become. This is due to the fact that as bigger the number of the portfolio size is, the bigger the number of the customers' electricity demand that is taking into consideration as an input in the forecasting methods and the predictions of the load and price are more accurate than the case of a small portfolio size.

REFERENCES

[1] P. O. Reyneau, "Load Prediction on residence circuits," *Electrical World, A review of current progress in electricity and its practical application,* Mc Graw Hill Company, New York, Vol. 71, no.19,pp.969-971, 1918.

[2] Godard, W. Wallace, "Electrical Utility Load Forecasting [includesdiscussion]," *Transactions of the American Institute of Electrical Engineers Power Apparatus and Systems, Part III*, vol.74, no.3, Jan.1955.

[3] R. G. Hooke, "Forecasting the demand for electricity," *Electrical Engineering*, vol.75, no.2, pp.132-132, Feb. 1956.

[4] G. T. Heinemann, D. A. Nordmian, and E.C. Plant, "The Relationship Between Summer Weather and Summer Loads - A Regression Analysis," *IEEE Transactions on Power Apparatus and Systems*, Vol.PAS-85, no.11, pp.1144-1154, Nov. 1966.

[5] Z. A. Yamayee, and H. Hakimmashhadi, "A Flexible Generation Planning Approach Recognizing Long Term Load Growth Uncertainty," *IEEE Transactions on Power Apparatus and Systems*, Vol.PAS-103, no.8, pp.1990-1996, Aug. 1984.

[6] M. M. Dalvand, S. Azami, and H. Tarimoradi, "Long-term load forecasting of Iranian power grid using fuzzy and artificial neural networks," *Proceedings of 43rd International Universities Power Engineering Conference, UPEC 2008*, pp.1-4, Sept. 2008.

[7] S. P. Moutter, P. S. Bodger, and P. T. Gough, "Spectral decomposition and extrapolation of variations in electricity loading," *Proceedings on IEE C on Generation, Transmission and Distribution*, vol.133, no.5, pp.247-255, July 1986.

[8] N. X. Jia, R. Yokoyama, Y. C. Zhou, and Z. Y. Gao, "A flexible longterm load forecasting approach based on new dynamic simulation.theory — GSIM," *International Journal of Electrical Power & Energy Systems*, Vol. 23, Issue 7, pp. 549-556, October 2001.

[9] C. W. Gellings. *Demand Forecasting for Electric Utilities*. The Fairmont Press, Lilburn, GA, 1996.

[10] E. A. Feinberg, and D. Genethliou, *Applied Mathematics for Power Systems,* State University of New York, Stony Brook, US, 2001.

[11] F. C. W. and T. T. Nguyen, "Models for long term energy forecasting",*IEEE Power Engineering Society General Meeting*, Vol. 1, pp. 235-239, July 2003.

[12] N. L. Y. Dongxiao, "Application of Principal Component Regression Analysis in power load forecasting for medium and long term,"*Proceedings of 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE)*, vol.3, pp. 201-203, Aug. 2010.

[13] M. T. Heque and A. M. Kashtiban "Application of neural networks in power systems; A review," *Transaction of Engineering*, C*omputing and Technology*, Vol. 6, No. 1, pp. 53-57, June 2005.

[14] A. F. Atiya, "Development of an intelligent long term electric load forecasting system," *Proceedings of the International Conference*, *ISAPapos*, pp. 288-292, 1996.

[15] B. S. Kermanshahi and H. Iwamiya "Up to year 2020 load forecasting using neural nets," *Electric Power System Research (Elsevier)*, Vol. 24, No. 9, pp. 789-797, 2002.

[16] Z. A. Jaffery, and Ibraheem, "Fuzzy time series: An Application to Electric Energy Demand Forecasting," *Proc. of the All India Jamia Electrical Engineering on Recent Trends in Power Management,* pp. 28-34, 2003.

[17] V. Shrivastava, and R. B. Misra, "A Novel Approach of Input Variable Selection for ANN Based Load Forecasting," *Proceedings of Joint International Conference on Power System Technology and IEEE Power India Conference, POWERCON*, pp.1,5, Oct. 2008.

[18] N. J. Hobbs, B. H. Kim, and K. Y. Lee, "Long-Term Load Forecasting Using System Type Neural Network Architecture," *Proceedings of International Conference on Intelligent Systems Applications to Power Systems, ISAP*, pp.1-7, Nov. 2007.

[19] T. Q. D. Khoa, L. M. Phuong, P. T. T. Binh and N. T. H. Lien, "Application of wavelet and neural network to long-term load forecasting," *Proceedings of International Conference on Power System Technology Singapore*, pp. 840-844, November 2004.

[20] Z. Ji, P. Zhang, and Z. Zhao, "Application of Wavelet Neutral Network and Rough Set Theory to Forecast Mid-Long-Term Electric Power Load," *First International Workshop on Education Technology and Computer Science, ETCS*, vol.1, pp.1104-1108, March 2009.

[21] K. M. E. Naggar and K. A. A.-Rumaih , "Electric load forecasting using genetic based algorithm, optimal filter estimator and least error square technique: Comparative study," *Transaction of Engineering, Computing and Technology*, Vol. 6, pp. 138-142, June 2005.

[22] K. Karabuluta, A. Alkanb and A. S. Yilmaz, "Long term energy consumption forecasting genetic programming," *Association for Scientific Research, Mathematical And Computational Applications*, Vol. 13. No. 2, pp. 71-80, 2008.

[23] L. A. Zadeh, "The Concept of a Linguistic Variable and its Applicationto Approximate Reasoning Parts 1." *Information Sciences, vol.* 8, 199- 249, 1975.

[24] M. A. Faraht, "Long-term industrial load forecasting and planning using neural networks technique and fuzzy interface method," *Proceedings of 39th International Universities Power EngineeringConference, UPEC*, Vol. 1, pp. 368-372, 2004.

[25] J. Toyoda, Mo-S. Chen, and Y. Inoue, "An Application of State Estimation to Short-Term Load Forecasting, Part I: Forecasting Modeling," *IEEE Transactions on Power Apparatus and Systems,* vol.PAS-89, no.7, pp.1678-1682, Sept. 1970.

[26] A. A. El-Keib, X. Ma, and H. Ma, "Advancement of statistical based modeling techniques for short-term load forecasting," *Electric Power Systems Research*, Volume 35, Issue 1, pp. 51-58, October 1995.

[27] D. Park, M. El-Sharkawi, R. Marks, A. Atlas, and M. Damborg,"Electric Load Forecasting Using an Artificial Neural Network," *IEEETrans. on Power Systems*, Vol. 6, No. 2, pp. 442-449, 1991.

[28] M. S. Abou-Hussien, M. S. Kandlil, M. A. Tantawy, and S. A. Farghal,"An Accurate Model for Short-Term Load Forecasting," *IEEE Transactions on Power Apparatus and Systems*, vol.PAS-100, no.9,pp.4158-4165, Sept. 1981.

[29] S. N. Basu, "Short term localized load prediction," IEEE Transactions on Power Systems, vol.7, no.1, pp.389-397, Feb 1992

[30] H. A. E. Salama, A. F. A. El-Gawad, S. M. Sakr, E. A. Mohamed, and H. M. Mahmoud, "Applications on medium-term forecasting for loads and energy scales by using Artificial Neural Network," *Proceedings of 20th International Conference and Exhibition on Electricity Distribution - Part 1, CIRED 2009*, pp.1-4, June 2009.

[31] Abu-El-Magd, A. Mohamed and N. K. Sinha, "Short-Term Load Demand Modeling and Forecasting: A Review," *IEEE Transactions on Systems, Man and Cybernetics*, vol.12, no.3, pp.370-382, May 1982.

[32] I. S. Moghram, S. Rahman, "Analysis and evaluation of five short-term load forecasting techniques," *IEEE Transactions on Power Systems,* vol.4, no.4, pp.1484-1491, Nov 1989.

[33] S. Rahman, and O. Hazim, "Load forecasting for multiple sites: development of an expert system-based technique," *Electric Power Systems Research*, Volume 39, Issue 3, pp. 161-169, December 1996.

[34] A. D. Papalexopoulos, and T. C. Hesterberg, "A regression-based approach to short-term system load forecasting," *Proceedings of Power Industry Computer Application Conference, 1989. PICA '89,* pp.414-423, May 1989.

[35] T. Haida, S. Muto, Y. Takahashi, and Y. Ishi, "Peak load forecasting using multiple-year data with trend data processing techniques," *Elect.Eng. Jpn.*, 124, pp. 7–16, 1998.

[36] W. R. Christiaanse, "Short-Term Load Forecasting Using General Exponential Smoothing," *IEEE Transactions on Power Apparatus andSystems,* vol.PAS-90, no.2, pp.900-911, March 1971.

[37] J. H. Park, Y. M. Park, and K. Y. Lee, "Composite modeling for adaptive short-term load forecasting," *IEEE Transactions on Power Systems*, vol.6, no.2, pp.450-457, May 1991.

[38] Z. El-Razaz, and N. Al-Mohawes, "Weekly peak load forecasting for fast-developing cities," *Electrical Engineering Journal*, *Canadian*,vol.11, no.4, pp.184-187, Oct. 1986.

[39] V. Miranda, and C. Monteiro, "Fuzzy inference in spatial load forecasting," *IEEE Power Engineering Society Winter Meeting,* vol.2,pp.1063,-1068, 2000.

[40] S.J. Kiartzis and A.G. Bakirtzis, "A Fuzzy Expert System for Peak Load Forecasting: Application to the Greek Power System," *Proceedings of the 10th Mediterranean Electrotechnical Conference*, 3,pp. 1097–1100, 2000.

[41] S. E. Skarman and M. Georgiopoulous. "Short-Term Electrical Load Forecasting using a Fuzzy ARTMAP Neural Network," *Proceedings of SPIE*, pp. 181–191, 1998.

[42] K. Y. Lee, Y. T. Cha, J. H. Park, "Short-term load forecasting using anartificial neural network," *IEEE Transactions on Power Systems*, vol.7,no.1, pp.124-132, Feb 1992.

[43] S. Rahman, and R. Bhatnagar, "An expert system based algorithm for short term load forecast," *IEEE Transactions on Power Systems*, vol.3,no.2, pp.392-399, May 1988.

[44] X. Liu, R. S. Powell, J. Hartley, "Using data and knowledge: an architecture for implementing load forecasting systems," *IEEE Colloquium on Artificial Intelligence in Civil Engineering,* pp.4/1,4/3,Jan 1992.