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# A Review on Electrical Load Forecasting in Energy Management

**[1]Ja.Sruthi, [2] R.L.Helen Catherine**

[1] PG Scholar, Department of EEE, Anna University/Sri Krishna College of Engineering and Technology, Coimbatore-641038, Tamil Nadu, India

[2] Assistant Professor, Department of EEE Anna University/Sri Krishna College of Engineering & Technology, Coimbatore-641038, Tamil Nadu, India

**Abstract**

The survival of industries, residential and commercial structures primarily depends upon low cost and uninterrupted supply of electrical energy. Energy management is the process and measures executed to achieve the minimum possible energy use and cost while meeting the true needs of the activities occurring within a facility. One of the most important prerequisites in energy management is electrical load forecasting. The electricity demand is not always a constant in any premises. The accuracy of load forecasting has a substantial influence on the quality of electrical transmission and distribution system. Estimation of electrical loads, especially of peak loads, is the basis for the power system state assessment and for technical and economic computations. Proper forecasting and execution of energy management steps leads to efficient use of energy by the consumers in both comfortable and cost-effective way. This paper gives a brief review on various methods of load forecasting in a power system.

***Keywords:*** *Demand side management, Load forecasting methods, Soft computing.*

## 1. Introduction

The electrical energy is the most important forms of energy for making human lives comfortable and productive. There is a huge demand for electricity in various sectors and the world electricity demand is shown in Fig.1.

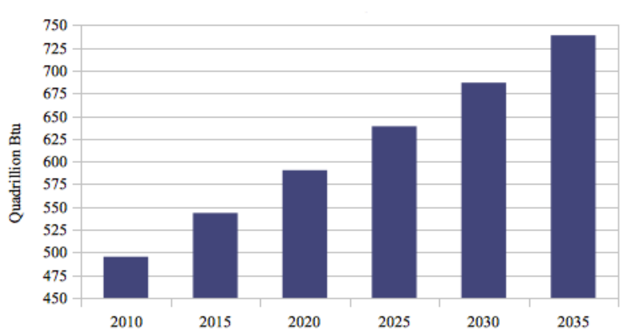


Fig.1. World Electricty Demand

The energy efficiency and conservation becomes a new source of energy. Energy audit in industries plays a key role for an efficient use of energy. Attractive incentives to the customers make them to actively participate in conserving energy [1] [2].

The lack of investment in the conventional grid during the past few decades resulted in an inefficient and increasingly unstable electric system [3]. Climatic changes, increased fuel costs, and new renewable energy projects are the reasons to rethink for an improved power grid infrastructure. Another important point is that the electric power is the reason for 25% of the global green-house gas emissions. It is necessary for the manufacturing managers to understand the interrelated links between advanced processing technologies, primary and alternative energy sources, costs, and energy conservation over a life of a project.

Demand side management (DSM) seems promising to improve energy efficiency and reduce overall electricity consumption. The real-time monitoring of the power grid improves its reliability in terms of both utilization and financial aspects. These changes require a new smarter grid which is the next-generation power system. The smart grid involves technologies, tools and techniques that provide knowledge to power in order to make the conventional grid to work efficiently [4]. The various functions of smart gird are shown below in Fig.2.

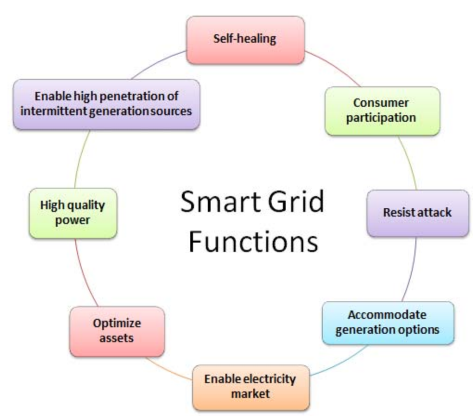


Fig.2. Various functions of next-generation power system

Electric power systems have the following three important characteristics. (i) as the electricity cannot be stored economically, so it is necessary to maintain a narrow gap between the supply and demand. (ii) grid conditions can change remarkably from day-to-day, hour-to-hour, and even within moments as the demand levels vary at different times. (iii) the electric system is highly capital-intensive.

An active participation of the consumers which is referred as Demand Response is the key characteristic of smart grid. It is a tariff or a program that acts as a motivating force for changes in electricity use by the consumers in response to any change in the market electricity price [5] [6]. It also refers to incentive programs for the customers using lower electricity during peak demands and high market prices or during grid failures. The price-based demand response such as real-time pricing (RTP), critical-peak pricing (CPP) and time-of-use (TOU) tariffs reflects the electricity costs at different times.

Load forecasting is a difficult task and hence stochastic methods are required for an increased reliability and accuracy. This paper is organized as follows. The importance of energy management and their benefits are discussed in Section II. The basics of electrical load forecasting and their types are given in brief in Section III. The various techniques that are evolved for load forecasting with their key features are described in Section IV. The conclusions are provided in Section V.

## 2. Energy management and its importance

The international standard ISO 50001 was released in 2011 that established the framework of Energy Management among the industries, government sector, and other commercial buildings to manage energy consumption. It is the approach of regulating and optimizing energy, using energy management systems and procedures so as to reduce energy requirements and costs [7].

Energy management incorporates engineering designs, operations, applications and maintenance of the electrical power system to attain an optimal use of electrical energy. The saving of energy in any industrial plants can be achieved by some housekeeping measures, process modifications, better utilization of equipment, and reduction of losses in building shell [8] [9]. IEEE Std 739-1995 provides the energy management and energy conservation for motors, systems, and electrical equipment which prevails the industries to consume energy efficiently. Apart from the standards and limits, most of the non-residential buildings use some automatic controllers with a central processor, which is collectively called as an Energy Management System (EMS). A successful energy management involves a cyclic process as shown in Fig.3.

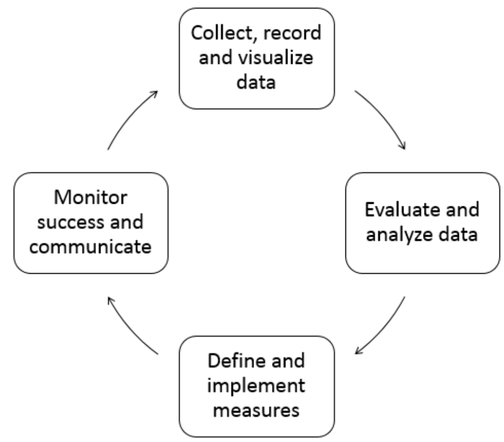


Fig. 3. Steps involved in Energy Management

The increased concern about global warming has impelled many industrialized countries for the reduction of $CO_2$ emissions. The various intelligent techniques involved in energy management systems with limited power consumption results in carbon emissions [10] [11].

## 3. Load Forecasting – Types

Electric load forecasting is of three types based on duration:

- Short - term load forecasting (STLF)
- Medium - term load forecasting (MTLF)
- Long - term load forecasting (LTLF)

The short-term forecasting is mainly meant for sufficient scheduling and operation of power systems. It is of more importance for a proper and profitable management of the electrical utility. The two important necessities of short-term load forecasting are its high accuracy and faster response to study the characteristics of the electrical loads and the various factors affecting them. Those factors may include climatic changes, season and pricing that have a complicated relationship with the loads.

Medium term load forecasting that ranger over a period up to a year explicitly depends on progressive factors that have an impact on electricity demand such as seasonal variations, addition of new loads, advancement in the technologies used and maintenance of larger equipment in industries [12] – [15]. This forecasting is also used to find the peak load within a span of time. With all the above details it can be decided whether the maintenance of equipment is necessary in the given period of time. It is also used for any testing events, commissioning and providing any changes to the equipment.

Table 1: Features of various load forecasting

| ***S.No*** | ***Load forecasting*** | ***Duration*** | ***Objective*** | ***Accuracy*** | ***Responsiveness*** |
|---|---|---|---|---|---|
| 1. | Short – term | Few minutes – 1 week | • Economic load dispatch<br>• Load Scheduling<br>• System security assessment<br>• Reliability studies | High | Faster |
| 2. | Medium – term | 1 week – 10 weeks | • To determine peak load<br>• Commissioning<br>• Development of power system infrastructure | Medium | Intermediate |
| 3. | Long – term | 1 year – 20 years | • Economic planning of power system | Low | Slow |

The major difference between short-term and medium-term forecasting is that the latter has less responsiveness than the former. The long term load electrical load forecasting has a significant role in planning of generation, transmission and distribution of the power system. The main objective of power system planning is to discover an economic expansion of the equipment and facilities to meet up with future electricity demand by the consumers with utmost reliability and power quality [16]. For the planning of the power system, it requires high accuracy of long-term load forecasting which has a significant effect on developing future power grid. Proper planning with respect to financial aspects is very important. Unfortunately, it is a very difficult task to forecast load demand with high accuracy due to the uncertain nature of the forecasting process [17].

## 4. Various methods of load forecasting

The main objective of load forecasting with respect to demand side management is shown in Fig.5. It is the idea of energy utilization by a place where the demand is high from the place, having non-peak hours, i.e. both energy saving and the better utilization the saved energy. The following are various methods of the electrical load forecasting.

### 4.1 Regression method

It is also referred as trend analysis or time-series analysis [18] - [21]. This is solely based on the historical data of the loads used for future prediction without considering the factors affecting the energy usage. It is the simplest method apart from the proper collection of data. From the collected data graphs are plotted and a mathematical equation is formulated for further process. There are two types:

- Linear regression (usually a straight line)
- Non-linear regression (exponential or polynomial)

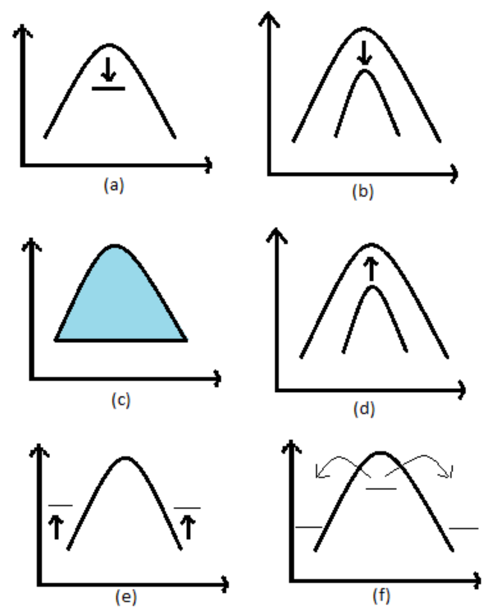


Fig.5. Demand side management – load shape objectives: (a) Peak clipping, (b) Conservation, (c) Flexible load shaping, (d) Load building, (e) Valley falling, (f) Load shifting

The linear regression method is usually carried out by *least square estimation.* One such example of an iterative regression for load estimation is as follows:

$$Y_t = v_t a_t + \varepsilon_t \quad (1)$$

where,

$t$ - sampling time,
$Y_t$ -measured system total load,
$v_t$-vector of variables Ex: day type, wind,

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temperature, hour of the day, time, etc.,

$a_t$-transposed vector of regression coefficients, and

$\varepsilon_t$- model error at time t.

This method is simple and easy to use as the load is assumed to depend only on certain fixed factors like time and temperature, thus its accuracy is quite lesser.
Further improvements in the regression methods are:

- Autoregressive (AR) model
- Autoregressive moving average (ARMA) model
- Autoregressive integrated moving average (ARIMA) model

### 4.2 Load forecasting using Neural Networks

Artificial intelligence technique that mimics the operation of the human brain is called neural networks. It is comprised of many interconnected computers used to perform some stochastic tasks. An important attribute of artificial neural network (ANN) is that they are programmed to adapt for changes by "learning" and has the capability to autocorrect the existing model. And hence it appears to be an effective method for load forecasting than the regression methods [22] - [25]. The two important aspects of neural networks are:

1. Ability to acquire knowledge from the environment by learning.
2. Interneuron connection called as weights used to store the acquired knowledge. A separate learning algorithm is implemented for the learning process.

Back propagation algorithm is the most commonly used algorithm for complex analysis. It consists of multilayer perceptron with hidden layers. The neuron is modelled with a non-linear function involving multilayer usually a sigmoid function:

$$y = \frac{1}{1+\exp(-x)} \quad (2)$$

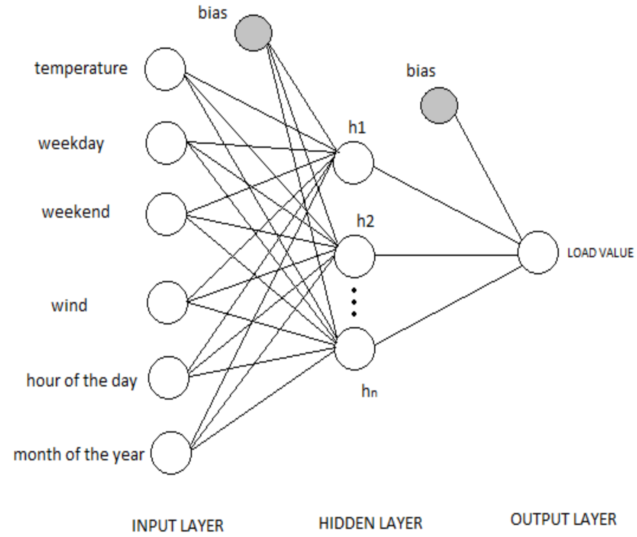


Fig. 6. Neural Network model for load forecasting

Generally the Back Propagation Neural Network (BPN) consists of three layers with input, hidden and output layers is used for load forecasting as shown in Fig.6. With a feedback from output the weights are changed accordingly to get the required output.

An important feature of Artificial Neural Network (ANN) is the ability to learn complex data. For load forecasting, first the basic relationship between the load and the various variable factors affecting them. Then the neural network system is trained with the input data (functions of past load, weather, hour, recent loads, trends in upcoming weather). Based on the available observations, a properly trained neural network can predict the required data. Thus, based on good training the convergence becomes very small for an accurate load forecasting. The main advantage is that it has a quick response to the deviations between the actual load and the predicted one.

### 4.3 Fuzzy Logic based Load forecasting

The fuzzy logic is found to be more advantages over Artificial Neural Network. General block for load forecasting using the fuzzy system is shown below in Fig.7. The fuzzy system has fuzzy set, membership functions, and if-then rules to transform a linguistic rules to computer program.

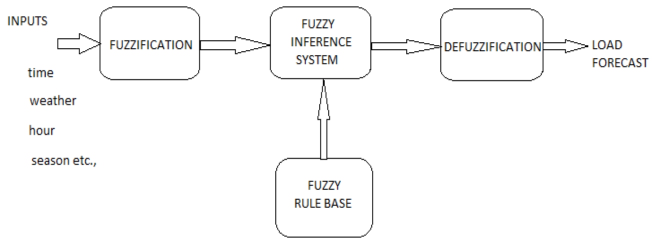


Fig.7. Fuzzy System for Load forecasting

The input data are fuzzified to membership functions and are given to the inference system. If-then rules should be framed carefully by the forecaster so as to forecast the loads correctly. The error is minimized by comparing the obtained and the required output. For any changes in the output of defuzzification, the if-then rules are changed to minimize the error thus increasing its accuracy.

In fuzzy – logic based load forecasting, first the applicable membership functions are developed. Then relevant "if-then" rules are extracted from the historical data. Several rules become activated with the fuzzy membership functions during the forecasting phase. Lastly, the inference system converts the computer data to crisp data (predicted load) at the output.

### 4.4 Genetic Algorithm (GA) based load forecasting

The genetic algorithm is an optimization algorithm based on natural evolution that is used to find the optimal solution quickly and efficiently with the available little data. It has four operators:

- Reproduction
- Crossover
- Mutation
- Survival of the fittest

For load forecasting, firstly sets of forecasts (M) are created randomly from the given historical data and are sorted based on accuracy. Then the most accurate solutions (K) are retained and the least accurate solutions are discarded and this is the survival of the fittest. The retained solutions serve as the parents and the next generation are created by repeating the process of crossover and mutation. By several generations the one optimal solution is the final load forecasted model [32]. The major advantage of using genetic algorithms for load forecasting is that it requires very less training and forecasting time is very low.

### 4.5 Integrated Intelligent Energy Management

The above methods are used mainly for prediction of load alone. The next level of these methods is the integrated intelligent energy management system [33] [34]. Continuous prediction of loads connected to the grid by some network and intelligent techniques enables sharing of energy between the loads at various points if there are some changes as shown in Fig.8.

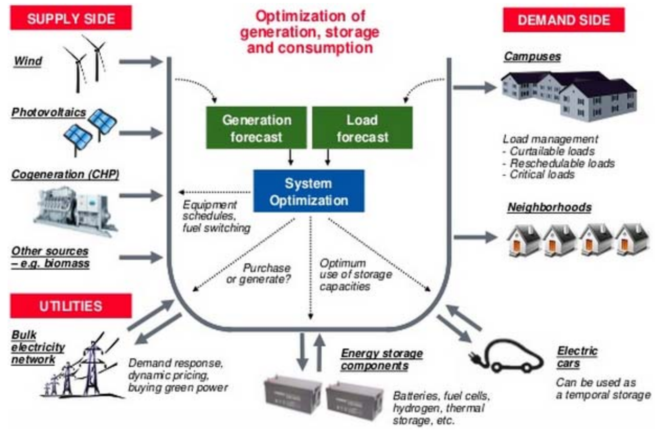


Fig.8. Integrated Intelligent Energy Management system

The participation and communication of both the grid system and the consumers is important for such an energy management. An aggregator is required to make this communication possible between the grid and the users. Zigbee is found to be the most efficient aggregator for communication.

## 5. Conclusion

Electrical load forecasting plays a dominant role in energy management of a power system. Among the types of forecasting, short-term electrical load forecasting is found to be more important as it reflects day to day changes in the energy market. In this paper a brief on some of the load forecasting methods is discussed. Various optimization techniques can be used for intelligent energy management system. The changes in the energy used by the loads can reflect upon the pricing of energy in the electricity market. Active participation of the customers is necessary for an effective and efficient utilization of electricity.

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