

Artificial Intelligence for Automatic Load Management

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Abstract

Demand-side management (DSM) means the load or consumer side management of electric energy for the optimum efficiency of the power system. DSM helps the electric utility by satisfying the requirements of a larger number of consumers with the existing generation capability and it also decreases the requirement for new generation capacity. Demand side management programs can be of great use to the electrical utilities as they eradicate the need to develop new transmission and distribution structures and power plants and it also motivates the consumer to use less energy during the time when demand is maximum. There are many DSM techniques, but load shifting proves to be the best fit to meet the above-mentioned criteria. The existing demand-side strategies need a human operator to carry out the load management process through certain DSM algorithms. This paper presents a model for automatic load management with the help of artificial intelligence to reduce human efforts and eradicate human error. The proposed model with the help of artificial neural networks (ANN) can predict the hourly power consumption of the load shifted curve of the next week with the help of recorded exponential moving averages. The proposed model can benefit the electric utility by automizing the load management process, reducing human involvement, and mitigating human error.

Keywords: Artificial Neural Networks, Load Shifting, Demand-side Management, Exponential Moving Averages

INTRODUCTION

Modern power systems are witnessed to the transformation of human operators to the normal computerized operation. The revolutionary technology that is Artificial Intelligence has been the biggest player in automation in power systems.

The problem with a standard computerized control system is that it cannot take the decision like a human operator in real-time parameters and learn new things on its own. For example, when there is a situation of a natural disaster like a cyclone it is the human operator who has to take the necessary

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precautions and deal with a great decline in load demand. Artificial intelligence may be of first rate use to clear up such problems. Weather forecasting contributes to a great extent to power system like the data provided by the various weather stations are very essential for load forecasting and even at the time of natural calamity, effective management of power system according to the given data by the weather station can prevent blackouts. The main aim of any power system utility is to provide a continuous 24x7 power supply to their end consumers which can be fulfilled with accurate load forecasting and a strong management is needed from the distributor side to provide continuous power supply even at the emergency time. Artificial intelligence and machine learning together can provide a great package that makes sure to achieve the above-mentioned aim. An

antecedent knowledge of load with the help of load forecasting at customer premise can be advantageous for managing power. The load forecasting can be very helpful to know the future demand of energy and also would be useful in planning and generation of power. The vital role of load forecasting in an urban area cannot be overlooked as it has a major impact on the usage and utilization of energy at the regional level. Moreover, load forecasting can be very encouraging to integrate renewable energy sources which are eco-friendly at the load and distribution side. Furthermore, energy consumption in the urban area is often used to changes in weather conditions. Therefore, consideration of load forecasting is very important for the accurate prediction of load demand.

Demand side management (DSM) enables the electric utility to meet the requirements of a larger number of consumers with the existing generation capacity and also decreases the need for new generation capacity. Demand side management programs can benefit the utilities by eradicating the need to develop new transmission and distribution structures and power plants.

LOAD FORECASTING

Storing electrical energy is not possible. It must be generated in line with the call for for it. It is, therefore, important for electric powered strength utilities that the weight on their structures need to be forecasted in prior. This prediction of load in prior is commonly known as load forecasting and it plays a vital role in power system planning. Expansion of power system begins with the help of future load requirements using load forecasting approach. The operation and making plans of a energy application organization want the right version for forecasting of energy demand. Load forecasting can be of great use in difficult times for electric utilities to derive conclusions related to the decision on generating and purchase electric power, voltage control, network reconfiguration, load switching, and infrastructure development. Forecasting of power demand uses the past load data and forecasted weather information for the prediction of future power demand. Various fashions had been advanced withinside the beyond for electric powered load forecasting with accuracy. With the introduction of irregularity in power systems, several new difficulties have come up against the power system network. Forecasting of wind power, electric loads, and energy prices has become a major issue in power systems. The challenging problems in power system are forecasting of power demand, wind power, and cost of energy. Moreover, to make sure of the safe operation of the power system, the study of its behaviour under various conditions is required. Load forecasting is a very essential part in the making of any model for planning of electricity dispatch, particularly in the present improving power system structure. The numerous forms of load forecasting are:

Short-term Load Forecasting

The term of short-time period load forecasting lasts for few minutes, hours to someday in advance or a week. Approximation of load flow can be done with the help of it and it can also make us capable of making a decision that can prevent overloading. It provides the required information for the system management of everyday operations and unit commitment.

Medium-term Load Forecasting

The term of medium-time period load forecasting is every week to at least one year (probable years). The reason of medium-time period load forecasting is unit control and scheduling gasoline supplies. For several operations within a utility company, the forecasts for various time horizons are very important.

Long-term Load Forecasting

The term of long-time period load forecasting is extra than a year. It can be useful for the management of power demand with accurate forecasting of future requirements for staff hiring, equipment purchase, or expansion. However, to forecast the power demand of the upcoming year with an accuracy same as the short-term load forecasting is not possible and it may make the forecast unavailable. But the probability distribution load based on previous weather remarks for the forecasting of the peak load of the upcoming year is possible. The prediction of typically named

climate normalized load is likewise viable and it might show up for common annual top climate situations or maybe worse than common top climate situations for a selected area. The load forecasting for the regular climate situations that are the common of the climate is known as climate normalized load. Artificial intelligence algorithms or statistical strategies inclusive of regression, neural networks, fuzzy logic, and professional structures are a number of the normally used forecasting methods. Econometric approach and end-use are the two methods that are mostly used for long-term and medium-term forecasting. Several regression models, neural networks, fuzzy logic, time series, and expert systems are adopted and used for short-term forecasting. Various mathematical methods and proposals are used for load forecasting. The accuracy of load forecasting may be stepped forward via way of means of the improvement and reforming of appropriate mathematical tools. The accuracy does not only depend on several load forecasting techniques but also on information provided by various weather stations i.e., weather forecasting. In this paper, we are specifically addressing the use of artificial intelligence which is the most trending technology for creating intelligent systems. Various intelligent systems have been developed for experimental and near-practical use in operations of power system. A Model-primarily based totally on neural networks for load forecasting consisting of load additives like electric powered heater, Lightings, cooking, etc. is given in paper [1]. This study is helpful for an individual home EMS only. In [2] a way changed into proposed to locate aggregated energy call for of thermostatically managed masses and it offers facts concerning a particular load simplest and calculates the strength financial savings for that unique load. The have a look at of load prediction of a industrial constructing with the assist of computational intelligence is provided withinside the paper [3]. It uses clustering and regression methods for load prediction. Regional power consumption and its forecasting is presented in the paper [4]. A review of demand-side management and several energy demand forecasting models is given in the paper [5]. In the earlier period of time, various forecasting models that incorporate calendar and weather variables have been proposed and tested [6–10].

Customized load forecasting is required in most of power system applications. The use of smart grid technologies and electric vehicles has made accurate forecasting at low/medium voltage levels a necessity [11–13]. Weather performs an vital position in energy consumption. Models which have included the weather parameters for load forecasting are being widely used. Though the temperature is a often used climate variable, different variables like wind velocity and relative humidity also are utilized in load forecasting models [14, 15].

DEMAND-SIDE MANAGEMENT (DSM)

Demand Side Management is the load or consumer side management of electric energy for the optimum efficiency of the power system.

Demand Side Management (DSM) has become eminent among the electrical utilities around the globe. The construction and operating cost of transmission, distribution, and generation unit is continuously increasing and the space issues to set up new generation units compels the electrical utilities to opt for other alternatives without compromising the customer's comfort level or quality of power delivered. Demand Side Management withinside the Power Sector is cost-powerful and socially useful to manipulate energy demand.

The classification of power management system i.e., supply-side management and demand-side management (DSM) is given in [16]. Along with energy-efficient appliances many countries for the past few decades, have started to incorporate energy conservation activities mainly through the DSM approach [17]. DSM has a pivotal role in the power system to keep electricity grids safe and reliable and maintain security as shown in a study carried out in North America [18] and others in Gulf countries [19, 20].

There are various demand-side management techniques to fulfill the above criterion such as (Figure 1):

- Peak Clipping

- Strategic Growth
- Valley Filling
- Flexible Load Shape
- Load Shifting
- Strategic Conservation

X-axis = Time (Hours) Y-axis = Power (kWh)

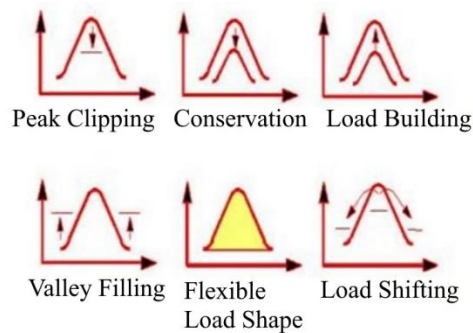


Figure 1. Various Demand-Side Management Techniques to Incorporate Energy Conservation Activities [27].

LOAD SHIFTING

Load Shifting is a way which could lessen height call for at particular intervals which in flip reduces the want for putting in extra energy plant life and the operation fees of energy stations with the aid of using transferring the weight call for to the off-height hours. It is a Technique with Direct manipulate on gadget or via tariff. Load moving is one of the maximum conventional way for load management. The load shifting plays a leading role in agricultural processes. Mostly agricultural loads are shifted to reduce the peak load by using the load shifting approach because they are easy to shift as compared to industrial loads. In DSM, load shifting is a program that elevates the power supply reliability in an electrical system [21]. Based on consumer's precedence the staggered hourly hundreds are shifted toward off-height hours if the hourly electricity call for exceeds the common call for. During this time, the switch of load to off-height durations became carried out with the aid of using ON and OFF switching, the channel became denoted with the aid of using '1' and '0', respectively, withinside the load transferring DSM technique represented in [22, 23]. Chen et al. incorporated an instantaneous load billing scheme to shift end user's peak-hour demand and to charge them adequately for their energy consumption [24]. The appliance scheduling is presented in [25] and it is based on time of operation and further to reduce the peak demand is presented with the help of pricing mechanism. Emphasize related to the scheduling of appliances and learning their characteristics in a residential area is shown by the authors in [25] and [26]. There are plenty of research papers which has proposed some models and methods to forecast the power consumption but after this step there comes the involvement of human operator who has to carry out the process of load management through certain observations and DSM algorithm which is very time-consuming. This creates the lack of presence of automation and this fact has motivated us to develop a model which can automate the load management process.

PROPOSED ANN MODEL

ANN is usually recommended as one in all the best strategies for load forecasting. ANN is ideal at fixing nonlinear problems, this is why it's far greater suitable for load forecasting. The disadvantage of using ANN is that it requires quite a lot of historical data for accurately developing the model. However, ANN is proved to be higher than another load forecasting version because of its self-studying capabilities. On the regular basis, the DSM algorithm for load shifting is applied to the forecasted load curve by the human operator to achieve a load curve which is known as the load shifted curve. In the proposed model we are going to predict the load shifted curve of the next week with the help of artificial intelligence which will eradicate the human involvement factor (Figure 2).

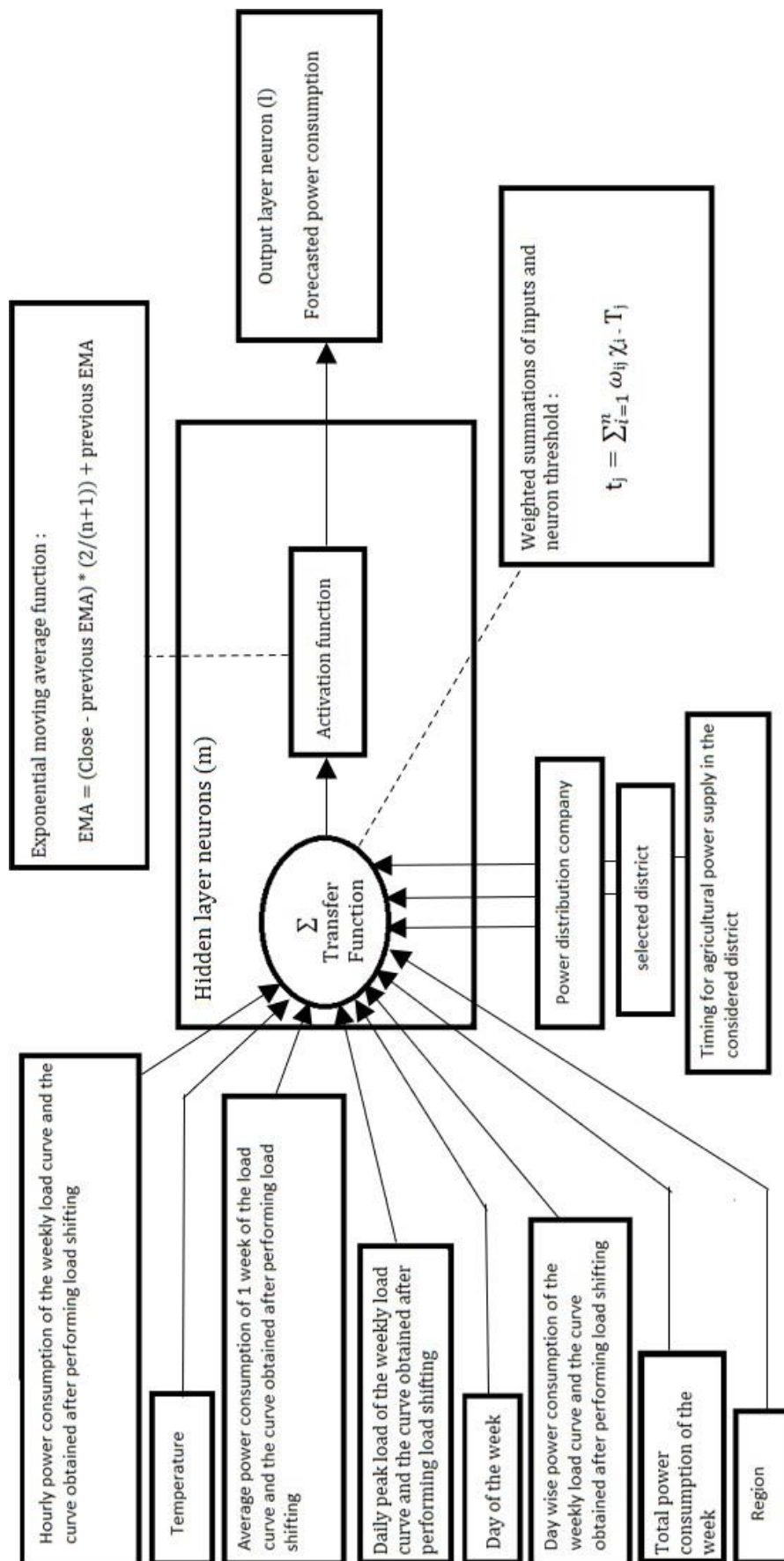


Figure 2. The proposed model to predict the load shifted curve of the week

The above version is a two-layer feed-ahead neural community version. The first layer is called hidden layer and the second one layer is called output layer. Neurons in the hidden layer receive the data from input and then the processed output of each neuron is sent to the outer layer neuron based on activation function. The model uses several input parameters for training the model efficiently and accurately. Hourly power consumption of the previously forecasted load curve and its corresponding load shifted curve of many weeks can be observed to train the model. Daily peak load, day-wise power consumption, average power consumption, temperature, total power consumption of the week, and day of the week are the certain input parameters which are also taken into consideration for accurate prediction. According to the selected state, the input parameters like region, selected district and power distribution company, and timing for agricultural power supply can be considered. Temperature is used as an input parameter to know the seasonality factor present in the load curve and its corresponding load-shifted curve. The power supply is provided to the agricultural load in the time frame of 8 hours out of the 24 hours of a day and these selected 8 hours for the power supply are different for different regions so that the load curve of a single day of the agricultural load out of the 7 days of a week will have the power consumption data of 8 hours instead of 24 hours (Figure 3).

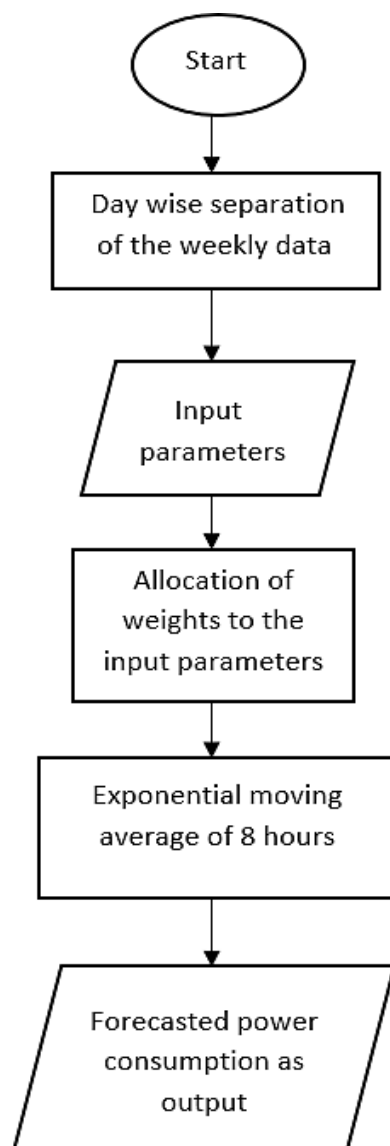


Figure 3. Flowchart of the proposed algorithm uses several input parameters for training the model efficiently and accurately.

DISCUSSION

An exponential moving average is a smoothing technique that can reduce irregularities (random fluctuations) in time series data. From these we can obtain the actual behaviour of the series. Moving averages are taken into consideration because the maximum famous strategies for the pre-processing of time collection. It can clear out out random "white noise" from the statistics to be able to make the time collection smoother or maybe to focus on positive critical informational additives gift withinside the time collection. Here, we have suggested using the exponential moving average function (EMA) because it reduces the lag by providing more weight to recent values. The variety of durations withinside the transferring common comes to a decision the weighting carried out to the maximum latest values. An exponential transferring common is much like a easy transferring common, however while a easy transferring common discards the ancient values because the cutting-edge values end up available, an exponential transferring common calculates the common of all ancient ranges, beginning at the required point.

The EMA can be expressed as,

$$\text{EMA} = (\text{Close} - \text{previous EMA}) * (2/(n+1)) + \text{previous EMA}$$

The $2/(n+1)$ term represents the weighting factor for the EMA, where n is the selected time period and Close denotes the current value. To initiate, we have to obtain the simple moving average (SMA). An exponential transferring common has to begin someplace so SMA is used because the preceding period's EMA for the primary calculation. In other cases, the previous EMA refers to the EMA from the previous period of time. Firstly, we will separate the number of Mondays, Tuesdays, Wednesdays, Thursdays, Fridays, Saturdays, and Sundays present in the provided data. Then we will start taking the exponential moving averages of both the previously forecasted weekly load curves and its corresponding load shifted curve which is obtained after performing the load shifting technique and the time period will be of 8 hours. As a result, we will get day-wise exponential moving averages because the power supplied to the agricultural load is for 8 hours from the 24 hours of a day. Now, these exponential moving averages of both the curves will be provided as input to the model to train the model accurately and efficiently. Also, we will now have a better understanding of the trend and seasonal components present in both curves. Finally, the model can be trained, tested, and simulated in python with the mentioned input parameters so that in output we get the predicted hourly power consumption of the load shifted curve for the next week from the forecasted load curve of that week. These will benefit the electric utility by making the process of getting load shifted curve automatic which will reduce human involvement and hence eradicates human error.

CONCLUSION

Automatic load management with the help of artificial intelligence has the potential to provide many benefits to the electric utility at the generation, transmission, and distribution network level. This paper presents a model for automatic load management that employs artificial intelligence to reduce human efforts and eradicate human error. The proposed model is based on artificial neural networks (ANN) which can predict the hourly power consumption of the load shifted curve of the next week with the help of recorded exponential moving averages which helps to obtain a smoother time series data. The proposed model can benefit the electric utility by automizing the load management process, reducing human involvement, and mitigating human error.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Deep Sheth and Chetan Sheth proposed the main conceptual idea and conducted the research. Bhargesh Patel provided the direction for this research. Deep Sheth and Bhargesh Patel designed the

proposed model. Deep Sheth and Chetan Sheth wrote the paper. All authors declared that this is the final version of paper.

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