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A Study of the Dynamic Behaviour of Daily Load Curve for Short Term Predictions

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Abstract: Electricity demand is one of the most controversial topics in Sri Lanka as the price of electricity increases rapidly, due to the scarcity of electricity generation sources to meet the demand. Fulfilling the peak demand, starting around 6.30p.m and ending around 9.30p.m, of the load curve is identified as the most crucial aspect that needs to be addressed. During this period, high cost power plants are used to generate electricity, which cannot be met using other low cost options such as hydro power. The Ceylon Electricity Board has to bear a huge loss in order to accommodate this high demand at peak times. Therefore, it is an essential task for a developing country as Sri Lanka to consider developing strategically approached mechanisms to provide a reliable electricity supply at an affordable price. This research focuses on studying the statistical nature of the daily load curve for different consumer categories and for different days of the week to capture the dynamics of electricity usage. An extensive literature is carried out to identify similar research and methodologies used to arrive at a solution by dynamically predicting the daily load curve and smoothing the peak using Demand Side Management strategies.

Key words: Short Term Load Forecasting; Demand Side Management

I. Introduction

Electricity demand has become one of the most controversial topics in Sri Lanka as the price of electricity increases rapidly, due to the scarcity of electricity generation sources to meet the demand. Electricity demand varies in accordance with consumers' activities with respect to time of the day and the day of the week. As a result of these variations, the total daily load requirement is never a constant throughout a particular day. Thus predicting electricity demand accurately is considered as one of the most important aspects to optimize the electricity production, transmission, distribution and even to plan for fulfilling future electricity demand. These predictions can be mainly classified into three categories as short term, medium term and long term forecasts where each type has special advantages in decision making regarding the electricity industry. This study is mainly focused on short term load

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forecasting which can be used to mange available daily electricity generation sources in an optimal manner.

Daily electricity load curve which can be drawn to represent the electricity load as a function of time, plays an important role in short term load forecasting. When considering the average daily load curve in Sri Lanka, a clear pattern can be observed over the past years with a gradual increase of load from year to year (Figure 1). It is noticeable that there are two sudden increments in the morning and in the night of each plot. The peak demand, starting around 6.30p.m and ending around 9.30p.m is identified as the most crucial aspect that needs to be addressed. During this period, high cost power plants are used. Therefore, the Ceylon Electricity Board has to bear a huge loss in order to accommodate to this high demand at peak times. It is an essential task for a country to consider developing strategically approached mechanisms. As at the early stage of this research, an extensive literature survey carried out to identify similar projects and methodologies used in related issues will be presented in this paper.

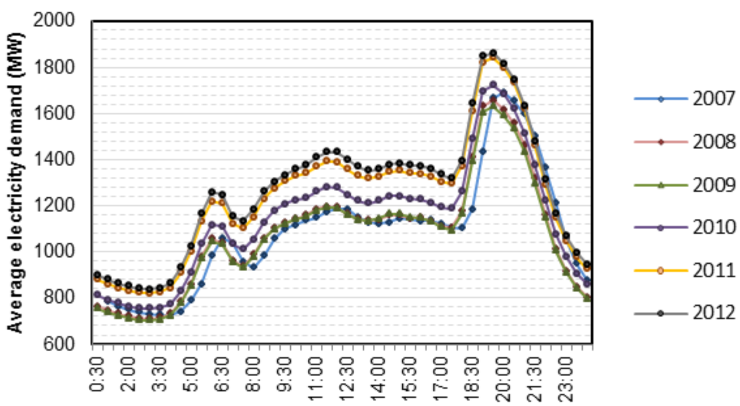


Figure 1: Change in daily load curve over the years.

II. Predicting the Electricity Demand

In order to curtail the sharp peak in the load curve, as the initial step, future electricity demand should be predicted accordingly. This forecast should be a short term one as the demand varies from minute to minute with respect to various reasons and efficient decisions should be taken where necessary. Literature reveals the importance of short term load forecast for the control and scheduling of power systems, as the predicted values will be taken as inputs for the scheduling algorithms[1].

A. Incorporating Additional Factors

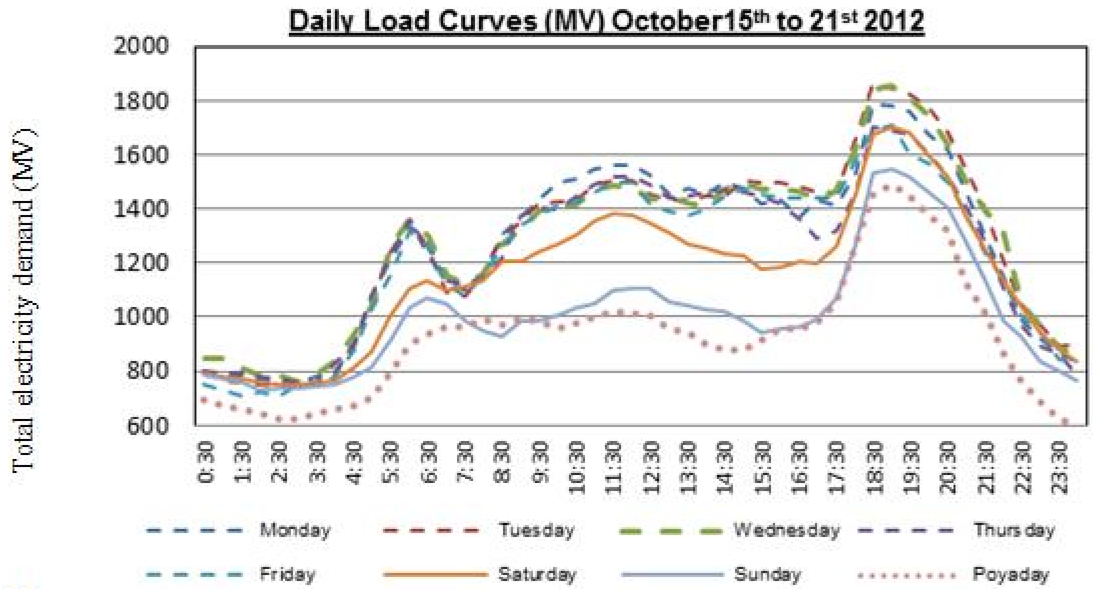
Predominantly forecasts are based on a mathematical combination of previous values. In short term load forecasting, special attention should be paid to increase the accuracy as even a small deviation may result in a huge loss. Since electricity demand is influenced by factors like meteorological conditions, seasonal effects, special events, customer class, population and economic factors, some researchers had incorporated appropriate factors to improve the accuracy of the short term load predictions. Moreover, researchers are now trying to incorporate operators' experience and heuristic rules when they develop expert systems.

When considering meteorological conditions, temperature has been used by many of the researches in different ways; average daily temperature[2], weekly average temperature and weekly[3]. Rather than slecting a single value for the temperature reading, some authors had considered temperature inputs of several cities in tropical, moderate, cold and hot areas to represent the varied weather conditions[4]. Some have also used cloud coverage[5] and wind speed[6]. Rahman and Hazim had tried to incorporate the weather-load relationship to design a weather sensitive model for the load forecast[6]. They had considered 12 weather related parameters which had not been considered for other studies. To smooth out temperature fluctuations and to account for the temperature load lag a new variable had been incorporated.

Soared and Medeiros had incorporated the effects of different types of days to the model as holiday, working day after and before holiday, Saturday after a holiday, working only during the mornings, working only during the afternoons, Special holiday and the seven days of the week[7]. Borges, Penya and Fernandez also had used similar type days and weekends[5] while Cho et al.[3] also had used day types and bank holidays. They also had performed a principal component analysis according to the day type and a segmentation scheme based on the first principal direction.

For the short term load forecast of the Taiwan power system, a research has embedded the facility to update the fitted model by allowing operators to use their heuristic rules to modify the forecast[8].

For this research, apart from the collected half hourly daily electricity load data, from 2007 to 2012 the dataset was augmented by adding new variables. Considering the literature, different day types, daily rainfall and temperature readings of 21 stations have been identified as crucial variables. When considering the descriptive analysis, a clear difference in the load curve can be observed with respect to the type of day (Figure 2). A clear shift can be seen for weekdays and weekends as the displayed in the randomly selected week in Figure 2. In addition, as an economic factor, Gross Domestic Product will also be used after checking its significance to the model.



III.

Figure 2: Different patterns of load curves in weekends and weekdays.

B. Techniques Used in the Literature

The literature regarding short term load forecasting reveals that, a huge variety of researches exists in different fields (especially in the field of engineering). Forecasting methods range from conventional time series models to more sophisticated artificial intelligent approaches. Alfares and Nazeeruddin have classified the techniques used for electricity load forecasting to nine categories as models based on multiple regression, exponential smoothing, iterative reweighted least-squares, adaptive load forecasting, stochastic time series, ARMAX models based on genetic algorithms, fuzzy logic, neural networks and expert systems[9].

The final objective of this research is to implement a real-time computer system which updates the model with the inclusion of new data. For this purpose, a technique combining statistical methods with artificial intelligence approaches is to be utilized. Therefore literature regarding contemporary short term load forecasting methods and expert systems will be discussed.

Two-Level Seasonal Autoregressive model proposed by Soares and Medeiros consist a separate model for each hour of the day[7]. Each model has been constructed with a purely deterministic component related to trend and seasonality and special day's effect and a stochastic component following a linear autoregressive model.

Many researchers point out the importance of using intelligent techniques in the instances where quick weather changes leading to fail accurate predictions or nonlinear relationships[4,10,11]. Thus it seems appropriate in using neural networks and fuzzy logic systems in short term lord forecasts. Senjyu et al. has proposed a one-hour-ahead load forecasting method using neural network with the correction of similar day data in order to reduce the neural network structure and learning time[11]. Euclidian norm with weighted factor has been used to evaluate the similar

days and the neural network is composed of three feed forward layers, consisting 9 input units, 20 hidden units and a single output unit.

Even though short term electricity forecast using neural networks is gaining more attention, there is a possibility of excessive data training, which usually increases the out-of-sample forecasting errors[2]. Hence they have proposed a new approach based on machine learning technique using support vector machines. To avoid the said weaknesses, an ensemble model of a promising novel learning technology called extreme learning machine for high-quality short term load forecasting of Australian National Electricity Market was developed[12].

Recently hybrid approaches have become dominant in this regard. Cho et al. had proposed the first level of forecasting by modeling the overall trend and seasonality by fitting a generalized additive model to the weekly averages of the load and the second level by modeling the dependence structure across consecutive daily loads via curve linear regression[3]. At the first level, trends from weekly average loads had been extracted using a generalized additive model, where temperature and other meteorological factors are included as additional explanatory variables.

When there are unusual changes in the electricity load or other used external variables like weather conditions or any other uncertainty, fuzzy logic will often lead to an efficient approach. Fuzzy logic based systems also had performed well in dynamic environments[10]. Seetha and Saravanan have adopted a novel approach using a fuzzy back propagation algorithm to predict 24 hours load ahead[10]. Barzamini at el. has done a modification to the multi layer feedforward neural network by developing a fuzzy system known as Modifier in order to successfully handle abrupt changes in weather condititons and special holidays[4]. A fuzzy system that has been developed to incorporate experienced operator's heuristic rules has been proposed[8].

Considering the gathered literature, a fuzzy inference system based on a back propagated neural network is to be developed for this research. As Seetha and Saravanan suggested, classification or clustering techniques will be used to find simialr patterns to that of the testing pattern will be used in order to reduce the error[10].

After predicting the 24 hours ahead load curve, it would be easier to schedule and manage available electricity generation options in order to take effective decisions easily by utilizing the available resources.

III. CURTAILING THE PEAK DEMAND

Since electricity can be stored for future use by baring huge extra costs, the power stations must produce electricity as and when required. In Sri Lanka, the required electricity is produced according to a merit order scheme that mainly considers the cost of production. Even though there are many types of generating options, only a few options can be used to cater to the peak time as certain generating options has to be continuously used throughout the day to get its optimum benefit of reducing the cost.

During the peak time, high cost diesel-fired thermal power plants should be used, as the demand during this particular time period cannot be met using other low cost options. In this case the CEB has to bare a huge loss, as production cost for one unit is much higher than the selling price of one unit to the customers. Considering the number of such units for which this extra cost has to be borne by the Government, it is an essential task for a country to consider developing a strategically approached mechanism to deal with this problem.

C. **Demand Side Management or Demand Response?**

Activities and incentive programmes implemented and administrated by utilities to modify energy consumption and load shape of customers can be considered as demand side management techniques. These include load control, load shifting, energy efficiency and conservation. Demand response can be seen as demand side management on the customer's terms, where the customer decides on what loads to control and for how long, often in response to an economic/price signals or special requests by utility[13]. Rahman and Rinaldy bring out that demand side management techniques provide workable solution for electicity industry as uncertainity in future demand, fuel prices, construction cost, availability and cost of power from other utilities and the regulatory environment[14].

D. Techniques Used in the Literature

Most of the demand response techniques can be fruitfully utilized when customers' have smart meters which monitor electricity loads with respect to time. Smart meters or Advanced Metering Infrastructure allow bi-directional, real-time communication between the utility and the consumer[15]. According to Rahman and Rinaldy demand side management activity can be characterized as a two level process; load shape objective and end use by technology alternatives or market implementation methods. These methods can be used in oredr to handle situations with steep peaks[14].

Strbac, Farmer and Cory had tried out to redistribute the load rather than load reduction[16]. This method has to be applied baring additional costs as load reduction periods are followed by load recovery periods and those increments are to be supplied by system generators.They had used combined linear programming in order to optimize the schedule of allocating the generators along with the optimal times and levels of load reductions.

The method proposed by Eissa tries to change the electricity usage of end-use customers from their normal consumption patterns in respond to changes of electricity price over time or by giving incentive payments to lower the electricity usage at times of high wholesale market prices or when system reliability is jeopardized[17]. She has considered medium voltage industrial and commercial data and had tried to encourage reduction in peak demand by implementing time of use rates or intensive based programs. Based on different consumption patterns of customers' one of the above methods have been applied. A block scheduling model of load management for price-based demand response is suggested by Li, Jayaweera, Lavrova and Jordan under two different real-time pricing schemes: linear pricing scheme and threshold pricing scheme[18]. For linear pricing, the problem is formulated as a convex optimization problem and the optimal demand response profile is given as a two-dimensional water-filling solution. The suggested methodology consisting a dynamic pricing scheme that encourages the customers to adaption optimal demand-response profile that will naturally lead to peak-load shaving and load profile flattening.

IV. Conclusion

Based on the literature, in order to make an accurate real-time short term electricity load prediction, a model based on artificial intelligence and appropriate statistical techniques can be used. Incorporating fuzzy logic will enhance the capabilities of the model to tolerate unusual, sudden changes to the considered aspects. Additional factors like weather conditions and different day's effect can be used to enhance the accuracy of the model. The predicted load curve can be taken as the input of the demand response technique. Most common methods among literature in order to shave the peak demand are based on a time of use pricing scheme or an incentive based load shifting method.

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