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Energy Demand Forecasting: A Review on Methodologies and Technique

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Abstract**--** Nowadays, a country's economy development is estimated from tracking light from space at night. Therefore, electricity has become a major factor in determining national economy. Accurate models have become necessary to help electricity companies to forecast load in advance so that electricity is always present in every corner of a country. In this paper, we have made an attempt to review electricity load forecasting techniques. This review paper overviews the existing electricity demands prediction approaches such as traditional approaches, statistical approaches and machine learning based approaches. It further presents the pros and cons of various techniques. It also presents the challenges of this predictive analysis.

Keywords**—**Prediction, smart grid, artificial neural network, short-term load forecasting.

I. INTRODUCTION

The world's energy consumption is increasing by an annual rate of 2.3%. In order to satisfy the emerging need of energy, the power companies need to examine the electricity requirements so that the supply is continuous. Presently, in many developing countries, there is poor management of electric power which leads to power shortages. This survey is carried out to investigate the existing approaches and the challenges faced by electricity companies. This paper also enlists lacunas of theses, if any.

Load forecasting is an important task for electricity suppliers and other participants who are involved in energy production, transmission and distribution. Load forecasting has gain popularity since few decades. With the cities getting smart, there is also a need to reform the power grids to smart grids. Electricity has various sources. It can be produced from nuclear energy, coal energy, hydro energy, solar energy, wind energy etc. The produced energy is then transmitted to the consumers. Therefore, it is necessary to predict the consumption of electrical energy in order to effectively utilize the resources.

The energy requirements can be predicted using various approaches such as Traditional Methods, Statistical Methods and Machine Learning based Approaches.
Hippert et al. indicated that electric demand prediction can be categorized on following different criteria [1].

1. *Very Short-Term Load Forecasting* (Ranges from few minutes to hours) - The purpose of these models is to control flow of electricity.
2. *Short-Term Load Forecasting* (Ranges from several hours to few weeks) - These models are useful in adjusting the demand and generation of electricity for a day to the extent of a week.
3. *Medium-Term and Long-Term Load Forecasting* (Ranges from few months to several years) - These models are generally utilized in planning asset profitability.

The rest of the paper is organized as follows: Section 1 contains introduction of load forecasting and its classification. Section 2 deals with the classification of the existing approaches. Section 3 concludes the paper along with the future research work. Also, summary of the existing works is presented in tabular form at the end of the paper.

II. CLASSIFICATION OF FORECASTING TECHNIQUES

1. Traditional Methods

Autoregressive Integrated Moving Average (ARIMA) Model

Box and Jenkins introduced the ARIMA model for prediction [2]. The ARIMA model comprises of following parts: the autoregressive (AR) part, the moving average (MA), and the differencing process (also called integrated processes). The model is useful in short-term forecasting with high frequency data. The ARIMA model has a drawback of being unstable with respect to the model specifications and the observations which sometimes yield no results.

Seasonal Autoregressive Moving Average (SARIMA) Model

In SARIMA model, a seasonal variable or component is included in the ARIMA model to model the process [2].

Similar to the ARIMA model, it is a combination of past values and errors. The model is used for forecasting next three to four months of values. The model has an advantage of incorporating both seasonal and non-seasonal changes in forecasting electricity demand prediction but it also suffers from problem of being unstable.

The ARIMA based approach is the most popular approach for prediction task. But it doesn't include seasonal changes. Therefore, SARIMA model was introduced which includes a seasonal variable as well.

2. Machine Learning Based Predictive Strategies

Machine Learning based predictions are an obvious choice for any prediction task. Here we present some of the salient works for energy demand prediction using machine learning based techniques.

Neural Network Model

Hamid R. Khosravani et al. compared energy consumption prediction models for a bioclimatic building [3]. In this paper, statistical and analytical method based neural network model is compared with multi-objective genetic algorithm (MOGA) based neural network models. The research is carried out at the Solar Energy Research center bioclimatic building located at the University of Almeria, Spain. The models based on MOGA show better results than the existing Naive autoregressive baseline (NAB) model.

Kangji Li et al. predicted building's energy consumption using optimized artificial neural networks and principal component analysis [4]. In this paper, an optimized artificial neural network model has been presented, in order to improve the accuracy for short-term prediction. Improvised Particle Swarm Optimization (iPSO) is then applied on the weights and threshold values of ANN. Additionally, a genetic algorithm based ANN is proposed in this paper. The results conclude that the iPSO and GA-ANN perform better than ANN based models.

Jihoon Moon et al. forecasted power consumption for higher educational institutions which was based on machine learning [5]. The paper shows a study on prediction models using artificial neural network and support vector regression. The performance was evaluated by using 5-fold cross-validation. Consequently, the prediction models can have an error rate for about 3.46-10%.

S. Saravanan et al. forecasted India's electricity demand using Artificial Neural Network [6]. The forecasting is made for annual data of 10 years (2011-2020). The 27 years of data is used to train the model and 4 years of data is used to test the results. The ANN model is compared with regression analysis. In order to predict the accuracy, mean absolute percentage error is calculated. The absolute error percentage for ANN based model is 1.0265. Thus, the results show that artificial neural network gives better results as compared to regression analysis.

Rodrigo F. Berriel et al. forecasted monthly energy consumption using deep learning approach [7]. The work is carried out using Deep Fully Connected Neural Network, Convolutional Neural Networks and Long Short-Term Memory Neural Networks. The chosen dataset was from a Brazilian power company. The system was validated from a real time dataset of about a million customers. The error was calculated using Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE) and Median Absolute Percentage Error (MdAPE). The absolute error calculated was 31.83kWh and relative error was 17.29%.

Support Vector Machine Model

Wei Yu et al. forecasted energy usage in Smart grid using statistical modelling and machine learning approach [8]. The paper developed a statistical approach to derive a statistical distribution of energy usage. The dataset used was a real world meter reading dataset. To achieve a high accuracy, two SVM-based (standard SVM, LS-SVM) machine learning approaches were used. Shapiro-Wilk test and Q-Q plot normality test are the two approaches taken for testing. Consequently, two types of SVM are better approaches than neural network based approaches in terms of accuracy and energy usage forecasting.

Machine learning based approaches are used for building models and extracting data from large dataset. Machine learning approaches are used in combination with other approaches to improve the accuracy of the prediction.

3. Based on Statistical Approach

Statistical techniques have also been used for prediction of electric loads. Some of the approaches have been discussed here.

Linear Additive Models

Shu Fan and Rob J Hyndman forecasted short-term load based on a semi-parametric additive model [9]. The paper estimates the relationship between demand and the driver variables. The method is used to predict the half-hourly electric demand ahead of seven days. The research is carried out for Australian National Electricity Market. This research paper focuses on the non-linear relationship between the load and various variables such as calendar variable, temperature, lagged load etc. The methods proposed here are additive model within the linear regression framework, bootstrap method to generate forecasting distribution. According to the paper, the model works well on historical data as well as on on-site data. The work carried out does not include time series data. The research work did not include time series data into account.

Non-Linear Additive Models

Vincent Thouvenot et al. proposed electricity forecasting using multi-stage estimators of non-linear additive models [10]. This paper showed the correction of middle term forecasting errors. The data was taken from EDF portfolio consumption (French data) and GEFCom 2012 (US data). The paper showed how to recover the relevant features that drive the electricity consumption. The methods used were non-linear regression and variable selection procedures. The work focused on data driven analysis but did not focus on functional data analysis.

Statistical methods provide prediction outcomes which are more precise, when appropriate conditions are met. Statistical methods require lots of historic data to generate accurate prediction results. If any of the variables are left out, then these methods may produce unexpected results.

III. CONCLUSION

In today's scenario, energy consumption has been a topic of interest for both suppliers as well as the consumers who want accurate understanding of future electricity requirements and evolution of the current electric system. Three approaches, viz; traditional approach, statistical approach and machine learning based approach have been discussed in this survey paper. This paper presents a summary of approaches used for energy demand forecasting using distinct techniques/approaches/models. Additionally, it presents the lacunas in these approaches to improve the aforesaid research.

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Table 1: Summary of Related Work Done

Name	Author/s	Technique/s	Published By	Limitations	Year
Time series analysis, forecasting and control [2]	Box GEP, Jenkins GM	ARIMA Model	Holden-Day, San Francisco	The Model seems to be unstable	1970
A comparison of Energy Consumption Prediction Model based on Neural Networks of a Bioclimatic Building [3]	Hamid R. Khosravani, Maria Del Mar Castilla, Manuel Berenguel, An-tanio E. Ruano and Pedro M. Ferreira	Multi Objective Genetic Algorithm, Neural Network	Energies	Dataset was divided manually for training and testing.	2016

Forecasting power consumption for higher educational institutions based on machine learning [5]	Jihoon Moon, Jinwoong Park, Eenjun Hwang, Sanghoon Jun	Artificial Neural Network and Support Vector Regression	Springer	High error rate (10%)	2017
Forecasting India's Electricity Demand Using Artificial Neural Network [6]	S. Saravanan, S.Kannan and C.Thangaraj	Artificial Neural Network	IEEE-International Conference on Advances in Science, Engineering and Management	Very large dataset (31 years).	2012
Monthly Energy Consumption Forecast: A Deep Learning Approach [7]	Rodrigo F. Berriel, Andre Teixeira Lopes, Alexandre Rodrigues, Flavio Miguel Varejao, Thiago Oliveira-Santos	Deep Fully Connected, Convolutional And Long Short-Term Memory Neural Networks	IEEE-International Joint Conference on Neural Networks	High error rate (17.29%).	2017
Towards Statistical Modelling and Machine Learning based Energy Usage Forecasting in Smart Grid [8]	Wei Yu	Support Vector Machine, Back propagation neural network	ACM	The model is complex.	2015
Short-term load fore-casting based on a semi-parametric addi-tive model[9]	Shu Fan and Rob J Hyn-dman	Bootstrap and Regression	IEEE Transaction on Power System	Time series data was not taken into account.	2010
Electricity Forecasting using Multistage Esti-mators of Non-Linear Additive Models [10]	Vincent Thouvenot, Audrey Pichavant, Yannig Goude, Anestis Antoniadis	Non-Linear Regression, Variable Selection	IEEE Transactions on Power Systems	Did not focus on functional Data analysis.	2016

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