Various Electricity Load Forecasting Techniques with Pros and Cons

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Abstract: The rapid growth of stored information in the demand forecasting, associated with data analysis provoked an utmost need for generating a powerful tool which must be capable of extracting hidden and vital knowledge of load forecasting from available vast data sets. Being a promising sub domain of computer science, numerous data mining techniques suits the solution to this problem very well. This paper presents a vast, rigorous and comparable survey of tremendous data mining techniques useful in forecasting the electricity load demand of different geographic area. Based upon the rigorous survey, primary challenges involved in the current technologies and future goals are also discussed.

Keywords: Load Forecasting, Regression, Time Series and Artificial Neural Networks.

I. INTRODUCTION

The main challenge to forecast demand is to choose an effective technique. With the growth of 3 to 7 percent in electricity energy demand per year, many factors have become dominant to the generation of electricity energy. Electricity load forecasting has always been very important for planning of customer’s requirements and new operations and maintenance of distribution of electricity. Electric load refers to the consumption of electricity in the form of energy or power. Electric Energy is the curial issue in our daily life and growth. The electricity price, demand and dependence on the fossil fuels are increasing rapidly. The development of novel electricity demand forecasting for meeting the growing needs is great challenge for any country about power or energy. Since the electrical energy is very difficult to store in buffer, therefore to ensure proper delivery of electricity energy to consumers of electricity it is important to forecasts electricity demand. The forecasted values of electricity demand are used for following:-

- Load Scheduling and Distribution Planning.
- Deciding the fuel allocation amount to generation units and their maintenance.
- Meeting the customer requirements in different seasons.

II. CLASSIFICATION OF LOAD FORECASTING

Load forecasting can be classified into two types based on the consumption of electricity; one is spatial forecasting and second is temporal forecasting. Spatial forecasting means forecasts the electricity load for the particular region on the earth, such as whole country, a state or the particular city. Temporal forecasting means forecasts the electricity load for specific supplier or collection of consumers for future related particular time like hours, days.

Table 1. Temporal Load Forecasting

| Forecasting          | Period            | Purpose                                                               |
|----------------------|-------------------|-----------------------------------------------------------------------|
| Long Term load       | 5 to 20 years     | • Planning and growth of the generation capacity.                      |
| forecasting           |                    | • Planning to building new substations and new lines.                  |
| Medium Term load     | Few weeks to few  | • Decision making whether to add new features in existing systems.    |
| forecasting           | months            | • Staff hiring                                                         |
| Short Term load      | From few hours to | • Hourly electric load Prediction calculation.                         |
| forecasting           | few weeks         | • Weekly and Daily Max load of electricity energy generation.          |
| Very Short Term load | From minute to an | • Usage: fuel allocation to generation units; short term maintenance; generator unit commitment. |
| forecasting           | hour              | • Used in Energy Management Systems (EMS).                            |

III. CLASSIFICATION OF LOAD FORECASTING TECHNIQUES

There are different approaches introduced for electricity demand predictions and they can group into two main categories: Models and methods. These models and methods follow a more classical approach i.e. which apply concepts stemming from time series & regression analysis models which belong to fields of artificial and computational Intelligence [5]. Another classification of electric load forecasting is: Univariate modeling and multivariate modeling. Univariate models also called time series models, in which the load is modeled as a function of its past observed values this forecasting ignores the exogenous factors such as weather and day type. Examples of these types of models are multiplicative autoregressive models, dynamic linear or non-linear models, threshold autoregressive models, Kalman filtering [3]. Multivariate models are the models in which load is modeled as a function of some exogenous factors specially weather and social variables. Examples are Box and Jenkins transfer functions, ARMAXS models, non–parametric regression, curve fitting
procedures. Multivariate models are also called causal methods [4].

IV. OVERVIEW OF DIFFERENT METHODS

5.1 Regression based models: These models are used to make correlation between electric load and exogenous variables i.e. Max Temp, Min Temp and Days related data that are mainly used linear regression. In regression, forecast seems to mean to estimate a value whether it is future, current or past w.r.t. the given data. Problems exist in identifying the best model, which is due to the nonlinear correlation between electric loads and influencing factors [5]. It is easy to make relationship between output and input variables of model. These models easily implement and handled. Multiple regression models also exist to state the load as a function, of exogenous factors [4].

C. Fan, F. Xiao and S. Wang [12] in this paper present a technique to build up model by ensemble modeling for forecasting energy consumption of next day. The Ensemble modeling is a method of machine training in which more than 2 base models are integrates to create end result. The Ensemble Learning or Ensemble Training is done in two steps: In first step a number of base models are developed these models are either in parallel or in sequence manner and in 2nd step base models are used to make final result by using different grouping schemes. The genetic algorithms are used to determine weights associated to each of the base model used on this technique. This technique is used to forecasting electricity load demand for a building in Hong Kong. In this research work it was observed that Multiple regression takes a more time for computational work.

5.2 Time series approaches: In time series, forecasting seems to mean to estimate a future values given past values of a time series. Among the oldest methods applied in electricity demand prediction, the “Time Series Approach” sometimes used as “Univariate” or “Multivariate”. The advantage of Univariate modeling is that it does not need additional time series of the exogenous factors [3]. The Time Series Approach as univariate models are used for prediction of short term electric energy demand. Univariate models are used to prediction of electricity energy demand, for this work these models used the past experimental values while ignoring the other related variables. Various methods of Univariate modeling are “Multiplicative Autoregressive Models”, “Threshold Autoregressive Models”, “Dynamic Linear Models” and “Methods Based on Kalman Filtering”. The multivariate models are also used to prediction of electricity energy demand but for this work these types of models used the different exogenous factors like Social parameters, Temperature, etc. [4] The limitation of such methods is they are time consuming, require a lot of human intervention and may become numerically unstable [3].

Gonzalez-ROMERA et al. [29] this is research paper they use method of trend extraction to find the electric load of Spain. A two series of approach is used in this research work. The first series gives the trend of the electric load consumption and the second series gives the fluctuation around the trend which is given by the first series. The results from this approach are good compared to direct prediction of electric load forecasting.

The advantages and disadvantages of Time Series methods are [38]:

Advantages
- It examines chronological data sets very fairly.
- A time series operation performed in minimal cost.
- A time series method requires less historical data for operations.
- With the help of time series statistical methods we can evaluate uncertainty of short term load forecasting.

Disadvantages
- Time Series method doesn’t study deeply underlying patterns.
- With time series method it is difficult to find and interpret the sources of errors.
- In time series changes and conversation with operation cannot be possible easily.
- The previous or chronological time series patterns not useful for long term demand forecasting.

5.3 Neural Networks: There are lots of methods and techniques which are very useful for demand forecasting. On the basis of demand and region these techniques and methods are designed and used for demand forecasting. There are lots of factors which are considered for designing and implementation of appropriate technique one the basis of different types of demands. AI based techniques are very important when we study and reviews the literature for demand or load forecasting. AI based techniques are based of neural networks. A Neural Network is a network of two or more neurons. Neurons are used to processing the values of input variables and used for its weight processing in neural network. These neurons are works same as human brain neurons. Neural Network is designed to form the structure in which it performs the task and solve the problems as the way like human brain performs and solve the problems. The network is implemented by simulation in software on a digital computer and by using electronic components. A neural network has the ability to storing previously observed information. Neural Network works in a distributed manner. A Neural Network works like human brain in 2 respects. First Information is stored by neurons interconnected with their weights. Second the information is made by the neural network is from training the network. Neural networks for load forecasting first used by Dillon et al. in 1975 by using single layer preceptor.

S. Badran and O. Abouelatta [1] in this paper presented a technique of ANN with regression method; historical data of electricity demand is used in this work was taken from the Jeddah in KSA. The Electricity load was predicted by using this technique and the comparisons with other techniques were carried out which shows Artificial Neural Network is to be better with results. Weights used for different input variables in Network were initialized by a random number generator. Work is done by technique is divided into two rounds: In first round preprocessing of data is done and in second round prediction of electricity energy is achieved. The Limitation in
this technique was that at beginning adjustments of weights is difficult task.

Slobadan Ilie et al [2] in 2013 in their research work presented a technique for load forecasting for short term based on ANN. This work is divided into two phases: first phase used for preprocessing of data and second phase done the task of energy demand prediction as neural network. It is verified about very strong nonlinear relationship between daily electric load and daily temperature. Three exogenous variables are used as inputs: “Electric Load of Previous Day”, “Temperature” and “Type of Day”. In this technique learning of Artificial Neural Network is done by using “Modified Back Propagation” algorithm. During the Training of neural network sigmoid Activation function is used in all hidden layers. All this work of neural network is performed in MATLAB environment.

Abdel-Aal [3] in their research work presented a method for load forecasting for next year of all months. The data used for this work was Six years back historical data. In this work 2 modelling techniques were used. The first one employing twelve devoted models to forecast the twelve individual months in a straight line and 2nd one is used for prediction of next month electricity energy. In this research work adductive models and different ANN techniques are used for load forecasting for next year of all months.

J. Deng [8] in his research work in the year of 2010 presents a method of modelling and forecasting of electricity consumption of china using ANN. In this method back propagation of learning algorithm is used for prediction and Multi Layer Perceptrons are used for prediction as structure of network. In this approach “Linear Activation Functions” and “Tangent Sigmoid Activation Functions” are used for ANN. The demand of Energy is modeled as the task of the “Gross Domestic Product”, import-export, Population and Data (1990 to 2008) was used for prediction. The limitation of this structure of neural network is that it gives bad results as error method and trial.

W. Mai et al [9] in his research work in the year of 2014 presents methods of electricity load prediction for office in large building based on “Radial Basis Function Neural Network” (RBFN). The Real time data of building was used to learning and testing the model. Radial Basis Function Neural Network has been selected for this reason. The causal models and Statistical Time Series model mostly used for linear type of load forecasting. This is a disadvantage of these types of models. The different types of exogenous variables that are used in prediction of electric loads are normally Non-Linear types. The Different types of exogenous variables are considered in these types of models i.e. Input as Time, inputs as 7 days of week (Mon to Sun days for week), Hours (hour 00:00 to hour 23:59 hours for Day), and Weather Inputs i.e. “Max Temp and Min Temp”, “Humidity”, “Solar Radiation Intensity” and “Electric Load” of Previous days are used as exogenous variables. The other exogenous variables are covered in the load of previous days. This forecasting technique gives advantages over Multi Layer Perceptron. By using an evolutionary method this learning algorithm gives best optimal radius and best center for each unique neuron in all hidden layers.

H. K. Mohamed et al [11] in his research work in the year of 2006 presents a technique for prediction of electricity load for long term Electrical Network in Egyptian. The demand of electricity is credited to 11 different variables i.e. “Temperature”, “Total Electricity Generation”, “Total Electricity Consumption”, “Load Factors”, “Energy Losses”, “Electric Energy Prices”, “Gross Domestic Product”, “Humidity” and “Population”. This forecasting model consists of 4 different steps. The 1st step is used for collection of data and the 2nd step of this model is used to preprocessing of data to find outliers by the methods of Cluster Based Interpolate algorithm and detection of out of scope variables, the regression and histogram algorithm are useful for prediction of energy. In third step forecasting is done with different techniques of regressions in feed forward ANN. This is shows that ANN gives very good results for prediction when Mean Absolute Percentage Error is less than 4% to 5%. In this work different methods are compared and finding better algorithm to analyses result at each phase/step.

Prakash GL et al [13] in this research work presents three different models with Artificial Neural Networks that are used to predict both days ahead and hour’s basis electricity load. The past historical electricity load data as well as the past historical weather forecasted data were collected and then by using clustering techniques the cleansing the data is preformed. The MATLAB environment is used in this research work for building proposed models. The performance of each and every model is then calculated by using MAPE. In this paper they represent a method of data cleansing that is based on data mining techniques. There are three broad classes of neural networks: Different methods that are used in neural network to train the system is called learning or training algorithm, and the activation functions are used to update or modify the weights. The “Back Propagation” is the basic learning algorithm used for training purpose in neural network for load prediction. Several other variations of this algorithm are proposed and are discussed in the section Survey of Neural Network Learning Techniques.

The advantages and disadvantages of neural networks methods are [39]:

**Advantages:**
- It works like human thinking.
- Neural Network can handle missing and noisy data.
- Neural Network can handle large number of parameters or variables.
- Neural Network has ability provide solutions for forecasting problems with very good predictive result.
- It has feature of continuous learning.
- Neural Network can works with the non-linearity models.

**Disadvantages:**
- Neural networks are a “black box” and have limited ability to explicitly identify possible causal relationships.
- It is difficult to implement neural network model.
- They use more resources for computational work.
- They have the problem of over-fitting.
- They have issues which are remaining to be resolved like related to development and methodology.

5.4 Support Vector Machine (SVM): The SVM is the machines learning
algorithms and manly used for set of supervised problem. For example SVM is used as classifier in machine learning. In SVM algorithms one very useful algorithm is Support Vector Regression (SVR) algorithm. The Vapnik has developed the SVR in 1995 to solve issues related to regression. The principle of the developed SVR is based on the SVM system [16].

5.5 Hybrid approach: This approach is a combination of more than two approaches or techniques in regulates to defeat the drawback of the original technique [5]. Such approach can be called as a hybrid approach.

V. ISSUES RELATED LOAD FORECASTING

There are so many issues in load forecasting model development and the very basic and main issue is pre processing of data used in training. The main issue of data preprocessing is cleaning of data. Cleaning of data involves the outliers/noise data and missing values in data set. The Outlier/noise data problem is solved by some smoothing techniques. The missing values problem is solved by Mean, Median, Regression, and by interpolation methods.

VI. RESEARCH RESULT

From the various research works we have found the different results like Technique used, Data set, various Inputs, Outputs, Training Methods, and the applications of the proposed research work are as follows.

| Year | Ref No | Technique | Data Set | Inputs | Outputs | Training Method | Use |
|------|--------|-----------|----------|--------|---------|-----------------|-----|
| 2006 | 11     | Regression Neural Networks | collected from Egyptian electricity sector | 11 parameter s | Model for Long Term load forecasting is designed | i)Gradient descent for NN with 1 layer ii)Back Propagation algorithm for trainable forward cascade NN | To solve power system expansion planning problem |
| 2007 | 3      | Neural Networks and abductive networks | 6 years historical data obtained from Puget Power utility, Seattle, USA | Load and Temperature | Predicted load | Two approaches were used:- i) Time series ii) Dedicated models | Predicted monthly demand for seventh year |
| 2009 | 4      | SVM | 2 years historical data | Electric load data | Predicted load | SVM Clustering | Prediction of next day load |
| 2010 | 8      | ANN, Linear Regression | Data from National Bureau of Statistics of China (1990 to 2008) | 1.GDP, 2.Population 3.Import-Export 4.Energy demand | Predicted energy demand | Back Propagation | Long Term Prediction of Electric Energy for China till 2050 |
| 2012 | 1      | ANN, Regression | Previous Days Load Data from city of Jeddahin KSA (01/01/98 to 31/12/06) | Electric load data | Predicted load for specific time, day, month & year | Two models were considered One large 24 dimensional NN Second 24 small NN for each hour | Used for prediction up to 2020 Energy Management Systems |
| 2013 | 2      | Neural | Obtained for Electric | Predicted load of | Modified back propagation | Distribution |
| Year | Item | Method | Data Source | Variables | Forecast Period | Algorithm | Model Description |
|------|------|--------|-------------|------------|-----------------|-----------|-----------------|
| 2013 | 41   | Neural Network Ensemble (NNE) | SCADA city of “Abu Dhabi Emirate’s” electricity utility, and “Masdar City’s” Station of Weather. | Energy data, Meteorological data | 24 hourly outputs | Levenberg Marquardt algorithm | Predicts Peak Load |
| 2014 | 13   | Neural Networks | State Load Dispatch Centre, Dehradun, year (2011-13) | Energy data, Meteorological data | Short Term Load Forecasting for Uttarakhand | Levenberg Marquardt algorithm | Prediction of Electricity Load Consumption |
| 2015 | 14   | Neural Networks | SCADA city of “Abu Dhabi Emirate’s” electricity utility, and “Masdar City’s” Station of Weather. | Energy data, Meteorological data | Short Term Load Forecasting for Abu Dhabi | Levenberg Marquardt algorithm | Prediction of Electricity Load Consumption |
| 2011 | 42   | Multiple Classifier System (MCS) | Sep 2008 - Aug 2010; And Validation Training data from Aug 2K9 to Aug 2K10 | Energy consumption and weather based parameters | 24 hourly outputs | A strong NNE based on Regularized Negative Correlation Learning (RNCL) is projected for improving the model of learning and with this improved recognition capability and with less discrepancy. | STLF |
| 2012 | 43   | SVR | Training phase: Feb. 2009 - June 2009; Validation phase: July | Power consumption and climate variables | 24 hourly outputs | The classifier or algorithm can be trained with different parameters. | STLF |
| 2011 | 44   | SVM and MLP | 1 year | Energy consumption | 24 hourly outputs | Multi Layer Perceptor with 01 hidden layer (within 10 neurons). Using the SVR based techniques. | STLF |
| 2011 | 45   | MLR+MA+A NN+Fuzzy | Slovenian power system (1 year) | Temperatures, cloud cover, precipitation, wind, electric load | 24 hourly outputs | In this research work they used the weather sensitive ANN, non weather sensitive moving average and multiple linear regression approach for forecasting electric load. They have used a fuzzy based grouping to minimize the forecasting errors and to increase the robustness. | STLF |
| Year | Num | Method/Model | Description |
|------|-----|--------------|-------------|
| 2011 | 46  | Modified general regression NN | In this research work they use 2 different methodologies for STLF. In the first methodology they produced local loads and in the second methodology they forecast the global loads and the contribution factors to compute the local loads. They use the modified regression neural network for forecasting. In this research paper we also found the procedure to automatically reduce the number of inputs for ANN. |
| 2011 | 47  | ANLR + SVM + QP | In this research paper they use the hybrid forecasting method. This hybrid forecasting method consists of two stages. The first stage gives the daily load consumption predicted by use time series technique. While the second stage gives the deviation which is used by time series method and the other relative factors which are considering for forecasting the load by first stage, for this analysis, an Adaptive Local Nonparametric Regression (ANLR), Quadratic Programming (QP) and Support Vector Machine (SVM) is used. |
| 2002 | 48  | ANN | In this research work they use ensemble neural network technique for prediction of 1 to 10 days ahead electric load consumption. In this weather ensemble NN multiple scenarios are used for weather variable. |
| 2009 | 49  | ANN | In this research work they proposed methodology for forecasting the load for short-term for different multi regions. By focusing the Heat Index parameter they improved the accuracy of load forecasting in Taiwan Power Company’s System |

STLF: Short-Term Load Forecasting
| Year | Number | Method | Details | Forecasting Method | Notes |
|------|--------|--------|---------|---------------------|-------|
| 2010 | 50     | ANN    | Solar power, speed of wind, direction of wind, solar irradiation and circumstantial temperature, day type | 24 Outputs (hourly) | Neural Network is integrated for forecasting. |
| 2009 | 51     | ARMA+ MLP | City (Jiang-Men) 2005; Validation phase: December 2005 | 24 hourly consumption values | In this research paper they used the ARMA model to forecasting the linear elements of the time series. And the errors in this time series can be seen as non linear elements and the MLP has used for finding this non linear errors. |
| 1991 | 52     | MLP    | Nov. 1988 - Jan. 1989 Region (Tacoma -US) | Hourly Power consumption and weather based parameters | Two MLP are used in this research work one is for peak load forecasting and second is for total load forecasting. For first MLP one input layer has 3 neurons, one hidden layer has 5 neurons and output layer has 2 neurons. For second MLP one input layer has 3 neurons, one hidden layer has 5 neurons and one output neuron on output layer. |
| 1998 | 53     | MLP    | ----- | Power consumption, climate variables and social variables | In this work MLP is used which has 15 input variables and one output neuron which is used for repeatedly for forecasting electric load. |
| 1999 | 54     | MLP    | 2 years | Power consumption, climate variables and social variables | In this research work the two same neural networks are used, the training data is randomly divided into two sets for input purpose to two identical ANNs. For output simple averaging of each of the ANN is used for output. |
Various Electricity Load Forecasting Techniques with Pros and Cons

In this SLFT there are 2 different types of ANN based methods/techniques are represented. First technique is based on a static approach, and second one is based on dynamic approach. First technique forecasts electric load simultaneously for whole day 24 hours. Second technique gives result 24 hours electric load in sequentially. First technique uses 48 input values, 2 hidden layers and output layer has 24 neurons for 24 output values. Second technique uses 8 input values and 01 hidden layer and output layer with one output neuron.

Country (Korea) 24 hourly consumptio n values 24 hourly consumption values

1992 55 MLP

A three layered network was used for all models

Country (United Arab Emirates) 24 hourly consumptio n values 24 hourly consumption values

1996 56 MLP

Input layer: 29 neurons (Periodic variables are supplied to the neural network in the form of Continues input values; with the development of this network model it is found that this transformation appreciably improves the output result of the neural network.)

Micro grid (small city) 3 years 24 hourly consumptio n values 24 hourly consumption values

2013 57 MLP

STLF

Table 3. Advantages and Disadvantages of different Methods

| Methods | Advantages | Disadvantages |
|---------|------------|---------------|
| MLP     | 1). Accomplishment of MLP in a power utility in USA confirmed that it has very good results and its performance also good with reliability [58] | 1). Lack of information of used dataset. It takes too long time for the process of forecasting [58] |
|         | 2). The proposed forecasting technique can minimize the size of the training data set, and the technique improves accuracy of the forecasting electricity load for hourly and for the peak-load hour of the day and minimize the errors for forecasting for STLF [54] | 2). The time taken for the process of load forecasting is very long [54] |
|         | 3). The method 2 with dynamic approach gives better results comparable with the method 1 with static approach. The method 2 with dynamic approach uses less neurons and fast training. It gives better results for peak hours.[55] | 3). It has no knowledge about the data set and amount of used data for training and validation.[55] |
|         | 4). Suitable for short time series.[56] | 4). High error figures. [56] |
|         | 5). The conclusion of the study explains that how the neural network gives the accurate results for hourly forecasting of loads of energy. [59] | 5). The conclusion of the study explains that how neural network has compound arrangement of neurons with two hidden layers are complex with weights. It is not necessary that gives good with very small dataset for validation. [59] |
The combined ARMA and MLP model has good results over the single ARMA or MLP[51]. Complicated definition of the model equations [51]

ANN

1. The results shows improved load forecasting with minimal errors. It gives good forecasting values for Taipower’s system with ANN parameters.[49]
2. Use of the ANN shows that techniques used for electric load forecasting with weather related parameters[50]
3. It was found in the research that some other factors like industrial related parameters and commercial related parameters can be considered for more perfect results. And Research can be done on Industrial and commercial region.[50]

SVR

The designed method is useful for utilities in load forecasting for end users entity at any granularity level[43]. Some drawbacks of SVR are Small dataset. The developed model validity from January to May has not done[43]

Expert System

Expert systems are very useful for establishing the different load calculations for different shapes. Knowledge and experience from these expert systems can be used for prediction of energy demand[60]. It is difficult to add new rules of knowledge in these expert systems. This characteristic feature of expert system is the disadvantage of these type of knowledge based expert systems[60]

VII. CONCLUSIONS

This study introduced different methods available for demand forecasting. We defined some forecasting terms and also discussed some important issues for analyzing and electricity load forecasting. One more application of short term load forecasting is wireless sensor network. By the use of STLF the redundant data transmission is minimized by short term day a head prediction model of each sensor. In this paper we have given an overview of load forecasting and methods employed for load forecasting. Artificial Neural Networks technique is relatively newer. ANN has so many opportunities to predict and reduce the error between actual demand and forecasting demand.

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Various Electricity Load Forecasting Techniques with Pros and Cons

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