Technological Forecasting and Decision Making

EMGT 6910

Literature Review on Short Term Load Forecasting

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INTRODUCTION

During the last decade, electric power generation industry has undergone a significant transformation due to deregulation of the energy market. In this aspect, energy planning plays a crucial role for in a competitive electric power generation industries. Since large amounts of energy cannot be stored, electricity must be produced as it is used. To supply electricity to the customers, their load must be known. The process of making predictions of load of future is called 'Load Forecasting'. Forecasting of load should be should be done around 3% of error, if it is underestimated, reliability and security may be affected. On the other side, if the system load is overestimated, which leads to costly operation of the plant without generating electricity.

Though forecasting is not accurate, but by using better techniques and models we can improve accuracy of load forecasting and profit share of a utility. Forecasting is the basic aspect of decision making in energy providing utilities. It has a lot of application in energy purchasing, operations, generation and infrastructure development. Electricity has become popular and essential commodity in the business of electric utilities as other commodities.

Load forecasts can be divided into three major categories based on input information and time horizons: short term load forecasting(STLF), which is period of 1 hour to one week, middle term load forecasting(MTLF), which ranges from a week to 3 years, long term load forecasting(LTLF), is from three to twenty years, these help companies to plan their investment, plan generation, transmission and distribution systems. Short term load forecasts have become increasingly important since the rise of competitive energy markets and deregulation; it helps to provide a great profit and secured transmission of electricity to customers. Many techniques were used; these can be classified: 1. Statistical approaches and 2. Artificial Intelligence approaches.

Load forecasting techniques are majorly classified into 2 groups:

1. Statistical techniques
    - 1.1 Multiple Linear Regression (MLR)
    - 1.2 Semi-Parametric Additive Models
    - 1.3 Autoregressive and moving average
    - 1.4 Exponential smoothing

2. Artificial Intelligence techniques
    - 2.1 Artificial Neural Network
    - 2.2 Fuzzy regression
    - 2.3 Support vector machine
    - 2.4 Gradient boosting machine

The literature review presented below talks about various STLF techniques used in various journals. Review has been done considering techniques followed, data used and its results.

Literature Review

Tao Hong, Pu Wang and H. Lee Willis [1] presented benchmark model for short term load forecasting. Authors used Multiple Linear Regression (MLR) based technique to forecast hourly load. The paper has been organized as follows: brief discussion on MLR, model description and variables used for forecast accuracy. The benchmark model consists of main effects, interaction effects, class variables like Hour, Day and Month and quantitative variables like trend and temperature. The data being used in this case study is of four years (2005-2008) of hourly load and temperature. Results were analyzed using MAPE in % of the benchmark model of 7 days as horizon. The paper does not consider weekend effect, holiday effect in the benchmark model.

Rothe, Wadhwani and Wadhwani [2] used Multi Parameter Regression method and programmed in MATLAB to forecast accuracy and results. In this paper, authors focused on weather parameters to forecast one hour ahead load. Authors stated load depends on parameters such as ambient temperature, wind speed, humidity, precipitation and cloud cover. All unknown coefficients in the MLR were solved using MATLAB. Validation of model was done using absolute function, but paper does not describe any other methods to check accuracy of forecast. Paper concludes that ANN and Adaptive approach towards multiple regression models would give much efficient results.

Taylor and McSharry [3] covered wide range of univariate models such as ARIMA, periodic AR modelling, double seasonality of Holt-Winters exponential smoothing. The paper used dataset from 10 European countries. **First model** was simple naïve benchmark model, prediction based on previous week and the second model was average of previous 4 weeks. **Second model** used seasonal ARMA Modeling was done using Box-Jenkins methodology, the model used polynomials up to order three. **Third model** examined autocorrelation at a specified lag, and studies shown that only AR terms were considered from their analysis. **Fourth model** is of double seasonal holt- winters exponential smoothing which is adapter to consider two seasonal factors in the data. At the evaluation phase, authors tabulated results of different models with error statistic MAPE as the base to know the best model for prediction. Out of 4 models, double seasonal Holt- Winters method was the best model based on error measure. Authors appeals, univariate methods only be used to forecast load up to four to six hours from their analysis. At the end writers said that, weather based load forecasting works, if weather variables are available, otherwise univariate methods perform or give better results in terms of robustness and online load predictions.

Samuel, Ojewola, Awelewa, Amaize [4] discussed methods of load forecasting such as : moving average(MA) and exponential smoothing and Artificial Neural Networks (ANN). The data used in this case from Covenant University. First method: MA used with three different orders, they are 3-point, 4-point,5-point moving averages. Second method is exponential smoothing of three smoothing constants of 0.1, 0.2 and 0.3. and an ANN which is a computational model has been applied to short term load forecast. Among three methods, only ANN method is clearly explained with showing the neural network architecture. For measurement of accuracy, MAPE, MAD, and MSE were used. In the results section, next 24 hours' load have been forecasted using above 3 methods, in the comparison of accuracies ANN gave better results, even though longer computational time due the time taken to train network. In the conclusion, authors conclude ANN model was the best method to model nonlinear data. The main disadvantage of this paper, it did not talk about any other popular techniques like MLR, ARIMA etc., so authors sensed to be biased in using different techniques.

Alfares and Nazeeruddin [5] described nine electric load techniques with brief explanation in each section. Techniques used are: MLR, exponential smoothing, weighted least squares, adaptive load forecasting, stochastic time series, ARMAX models, fuzzy logic, neural networks and knowledge-based expert systems. At the end of the paper, authors quote that there is shift from old approaches to new techniques like fuzzy logic, expert's systems and ANN which are producing better results than time series models.

Papalexopoulos and Hesterberg [6] the paper has been published in 1990 with linear regression as technique to forecast hourly ahead load. The dataset used in this case study was from the Pacific Gas and Electric Company's peak and hourly loads. The significance of model includes holiday modelling, temperature modelling using heating and cooling degree functions and estimation of parameters by using weight least square. Authors described system load forecasting(SLF) and improved SLF in detailed way and clearly explained parameters or changes to be done to increase accuracy of forecast. In the new SLF model, which produces an initial daily peak forecast and this is used to forecast hourly demand. All steps are described comprehensibly from variables consideration to parameters estimation. In the comparison of results section, existing and improved model were compared by considering all scenarios like summer, winter, sat-sun, total year for checking accuracy of models. Probably, this paper might in few lists which stated MLR technique clearly in 19th century.

Kadir Sheikh and Unde [7] discussed significance of ANN in short term load forecasting. The paper stated that the most of the reported models are on Multi-Layer perceptron (MLP) network, which are not accurate. So, in this study authors made comparative study of different models using ANN. At the initial stage of the paper, authors stated different factors to be considered to forecast short term load such as: Time factors, Weather data and Customer's classes and it moved to brief discussion and benefits of ANN in the STLF. The data used in this case study of 1 week which are separated by day and holidays. MATLAB 10 has been used to perform computational method of ANN and its implementation has been illustrated clearly step by step. Results were tabulated with forecast accuracies using error statistic MAPE. At the end, authors conclude ANN model with developed structure could give better results in STLF. The main disadvantage of this paper is it did not discuss any other methods to show a comparative study with ANN and paper does not discuss about customer class and seasonal variables in the network.

Tao Hong [8] reviewed three techniques such as ANN, MLR and fuzzy regression in his dissertation. Author used above techniques in his case study to forecast hourly a day ahead load from data of medium sized utility. In addition, the paper discussed about class variables such as month, weekday etc., In evaluation phase, author stated MLR models produced better forecast results than other two techniques.

Shu Fan and Rob J Hyndman [9] developed short-term load forecasting models using semi – parametric additive models. Authors stated electricity demand is nonlinear and volatile, and depends on external factors like temperature, calendar days, demographic and economy of the area, where load to be predicted. The paper focused on a regression methodology, but focuses on the nonlinear relationships between load and driving variables. Developed model has been implemented in the National Electricity Market (NEM) of Australia to forecast the half hourly electricity demand up to seven days ahead. The proposed semi-parametric additive model consists of calendar effects, temperature effects, lagged demand effects to construct STLF model. Authors used forecasting distributions, which conveys more meaningful than point forecast values to generate this, they used bootstrap method. In the result analysis, three models were used such as additive model, ANN and Hybrid model to check accuracies of various methods. And January, has been chosen to check accuracy due to high temperatures, which is tough case for load forecasting. At the end, authors conclude, semi- parametric models performed remarkably both on historical data and in real time implementation.

Hippert, Pedreira and Souza [10] reviewed ANN in short term load forecasting, authors described ANN and its different methodologies used in different journals from 1991 to 2001. The paper has explained basic terminology in ANN and its input classification based on methods and variables selection. Authors stated, the most of models have been over parameterized and results in most of papers were not carried out systematically, mean did not use any graphical and statistical tool to analyze errors of accuracies

Moghram and Rahman [11] evaluated five techniques in STLF such as: MLR, Stochastic Time Series, Exponential smoothing, state space method and knowledge based approach. Authors applied above five techniques to forecast hourly ahead load and analyzed results in tabulated form. The authors did not explain any models in detailed way, they just mentioned different techniques.

Baliyan, Gaurav, Mishra [12] reviewed different techniques in ANN and hybridization of different techniques are discussed briefly such as: ANN with Back Propagation Algorithm, ANN with Fuzzy Logic, ANN with Genetic Algorithm, ANN with Particle Swarm Optimization. Authors reviewed recent work that has been applied to STLF. Additionally, the paper stated non- parametric based techniques can be used to solve complex relationships, in which parametric techniques could not perform. At the end, paper concludes ANN techniques ultimately reduced the operational cost of power system and increases the efficiency of operation.

Mittal and Saxena [13] this paper presented statistical method of forecasting for predicting the demand on hourly basis. The techniques used are: trend analysis, decomposition and moving average methods. Initially, preliminary analysis was done on time series methods like trend component, weather sensitive, and random terms to under historical data pattern and later each method was applied to forecast hourly load. In the result analysis, authors stated moving average method outperformed among three methods. The main drawbacks of this paper are it did not talk about data used for this case study and no clear information on methodology followed.

Lee and Cha [14] applied ANN to short term load forecasting for one day ahead hourly load. Authors used two methods of application of ANN: 1. static approach which forecast a day head load,2. Dynamic approach 24 –hour load is forecasted using previous load. A nonlinear model using backpropagation algorithm was used to forecast load values. At the end, forecasting error was about 2%, and thus authors confirmed ANN gives the best results for STLF. The drawbacks of this paper, it did not consider other techniques for comparison of forecast accuracies.

Nie, Liu, Li and Wang [15] authors used ARIMA to forecast linear pf load and support vector machines (SVMs) to forecast the non-linear part of load, they used a method based on ARIMA and SVMs to forecast load. Authors added that ANN cannot forecast accurately linear part of load because it concentrates on nonlinear fitting and does not have forecasting precision. The paper first, used ARIMA to forecast the hourly load and used SVMs to correct errors in forecasting. The data used in this case study is from power company in Heilongjiang of China. At the end, results are tabulated by using error statistics MAPE and RMSE to three models; ARIMA, SVMs, ARIMA-SVMs, out of these ARIMA-SVMs turned out be the best model.

Gross, Galiana [16] discussed role of STLF in the on-line scheduling and security functions of an energy management system(EMS). And it also talked about different factors affecting load. Authors took consideration of all factors such as economic, time, weather, and random effects. Among models studied, dynamic model ARMA did well in their case, which can describe time-correlated randomness, periodicities, trends and weather effects. Author stated, ARMA models are easy to build and update model. Paper did not quote data used in this case study and other benchmark models.

Conclusion:

In the end, among two categories of load forecasting method namely traditional and modern intelligent methods. Many authors and papers suggested that traditional methods such as linear regression, ARIMA or any other statistical techniques have the advantage of simple algorithm and easy implementation, but these methods are on linear analysis, which results unable to forecast accurately in nonlinear load series. If we look at intelligent techniques such as ANN, SVMs have potential to give optimal solution and at higher speed and dealing with non-linearity efficiently. It is ambiguous to decide what kind of technique to be used to forecast, but with proper exploratory analysis on data can me decision right. As we know all forecasts are wrong, but they are useful if they are modelled and analyzed as per historical data and requirements of a utility.

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