Different Price Forecasting Techniques and their Application in Deregulated Electricity Market: A Comprehensive Study

Nivedita Pandey[1] and K.G. Upadhyay[2]

***Abstract*—Since early 1980's the electrical industry is going under a continuous change. This change is leading to a complete different atmosphere where the ultimate benefit is provided to the end use customers, with a reliable and cheap electricity supply. This market is a customer driven market and price forecasting is an important tool to the market players. Various models and techniques have been developed by the researchers to determine the correct price in order to obtain the maximum profit. Discussion on various price forecasting techniques and their application in various electricity markets around the world has been discussed in this paper.**

I. INTRODUCTION

The power industry across the globe is experiencing a major change in its business as well as in an operational model where, the vertically integrated utilities are being unbundled and opened up for competition with private players putting an end to the era of monopoly. Today energy price forecasting is an important area of research. Market participants of this market such as generators, power suppliers, investors and trades need to maximize their profit [1]. In comparison to load forecasting, electricity price forecasting is much more complicated process. It is because of the distinctive character of electricity which makes it different from other commodities such as its non-storable nature, inelasticity of demand, maintaining a constant balance between demand and supply of power [2]. This paper reviews some of the methods for price forecasting and their application in various electricity markets. The paper follows as: Section II deals with the major factors that affect price. III section tells about classification of price forecasting methods. In Section IV typical price forecasting approaches are discussed separately. Accuracy criteria for forecasting is given in section IV. Conclusion is given in and Section V.

II. FACTORS AFFECTING PRICE FORECASTING

Due to various technical, physical and economic factors fluctuation is very common for electricity price. Figure 1 represents various factors affecting price. Demand is the most important factor affecting the spot price as demand varies with temperature and weather condition, spot price also varies. It is proven that if demand increases spot price also increases. Other important factor such Fuel costs, generation reserves, power plant construction, maintenance, operating costs and maintenance of transmission system to deliver electricity contributes to the cost of electricity [3,4].

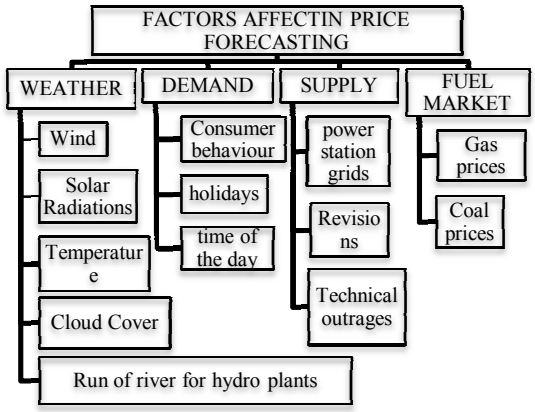

Fig. 1: Factors Affecting Price Forecasting

III. PRICE FORECASTING TECHNIQUE

Based on the time factor electricity price forecasting is divided as short, medium, and long which is discussed in Fig. 2. Study revealed that different methods have been developed for forecasting. A rough classification is shown in the Fig. 3 [1] [4].

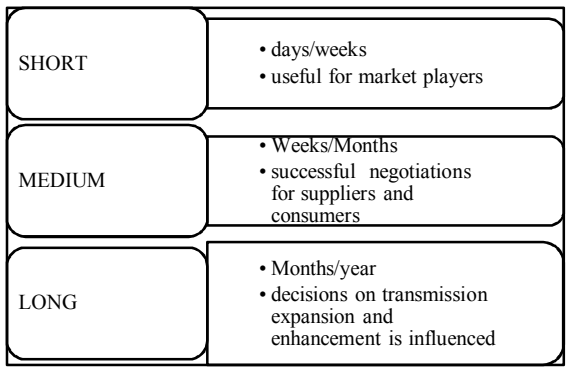

Fig. 2: Types of Price Forecasting

[1,2]*Department of Electrical Engineering, Madan Mohan Malviya University of Technology, Gorakhpur*
E-mail: [1]niveditapandey91@gmail.com

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Generally price forecasting approaches can be classified into two categories 1) time series and 2) simulation approach, time series mainly depends on the historical data of market prices. Where as in simulation approach precise modelling of power system equipments and their cost information is required, because of large amount of data involved simulation method can be computationally intensive. Data mining is the new addition to this tree. As per the survey ANN is the most popular method. Now researchers have come with the hybrid models that overcome the short comings of the individual models [6][7].Simple process for price forecasting is given in Fig. 4.

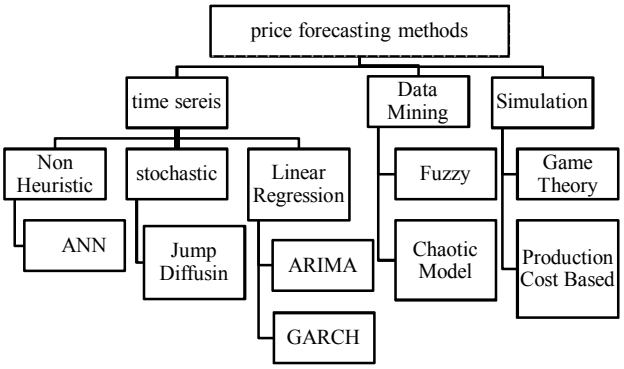

Fig. 3: Price Forecasting Techniques

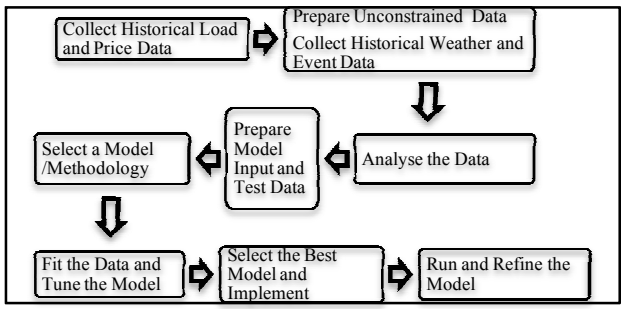

Fig. 4: Process of Price Forecasting

IV. METHODS OF FORECASTING

A. ARIMA

Autoregressive moving average (ARMA) model introduced by Box and Jenkins is a stochastic process that is built-in to time series data to get more understanding of the data and to do future predictions in the series. Non-seasonal ARIMA is denoted by (x,y,z) in which *x*, *y*, and *z* are positive integers, where x is defined as order of the Autoregressive model, y degree of differencing, and z is the order of the Moving-average model. In Seasonal ARIMA models are given by ARIMA (x,y,z) $(X,Y,Z)_n$ where n is number of periods in each season. X,Y,Z refers to the autoregressive, differencing, and moving average terms for the seasonal part of the ARIMA model. These models provide reliable and accurate forecasting.

ARIMA models have already been used for forecasting of oil, gas, and natural as well as load forecasting in power system with good results. Some examples of energy market where this model is being used. Simpler version of ARIMA Auto Regressive (AR) models have already been being used in Norwegian system for forecasting weekly prices [8]. ARIMA model is also used in California and mainland Spain markets and satisfactory results are obtained [9].The use of ARIMA Models along with wavelet transform was used to predict price in mainland Spain for year 2000 was done [10]. For Californian power market also the ARIMA models was used for forecasting daily average prices, based on historical data was done [11].

B. GARCH

Electricity price is so unpredictable, that price spikes are surely to happen this makes forecasting difficult. In order to solve this problem, we put up another model that is generalized autoregressive conditional heteroskedasticity GARCH, can resolve this volatility problem. It considers the conditional variance as time dependent hear price is expressed in terms of its history and a white noise process. Some case studies have been made which uses GARCH method for price forecasting with the aim to model the dynamic character of price [12]. A comprehensive explanation of the GARCH models and its application in mainland Spain and Californian markets are presented in paper [13] and also examined on Spanish and PJM electricity markets along with the comparison with other forecasting methods [14].

C. Jump Diffusion

The deterministic character of price curve are told in the time series model such as ARIMA and GARCH while the stochastic characters are explained by jump diffusion. This model is used to create hourly determined prices for short term planning maximum for a year. A Jump-diffusion model takes care of seasonality, mean-reversion, time-dependent jump intensity and heteroskedastic disturbance of electricity spot prices, while maintaining the logical tractability of futures prices. Jump component has more dominant role compare to the diffusion component in the variation of spot prices another thing is that diffusion risk and the jump risk are priced in different way [16].

D. Neural Networks

Price of electricity is a non linear function of its inputs features all the time series models are linear forecaster, which makes these time series techniques difficult to capture the exact behaviour of price. Thus use of Neural Network for electricity price forecasting has come up as an improvement to above mentioned techniques. Neural networks are resemblance to the

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neurons of brain they are extremely organized well connected simple processing units which performs a particular task as brain does. ANN models are classified on the basis of no. of hidden layers, learning algorithm, type of learning function, and etc. Mostly a three layered neural networks is taken for forecasting of electricity price.

ANN have advantage that they are able to resolve indeterminate relation between input and output variables, approximate complex nonlinear functions and can implement multiple training algorithms. On the other hand they also have disadvantage that the network is not elastic for the less data and it is over-fitting for too much data. To achieve profit in the this market it is important to predict next-day price both for consumers as well as producers for planning of electric energy resources and for developing intercession skills.

Accuracy of the neural networks can be judged by studying some of the case studies of real world electricity market [17]. For capturing the chaotic character of price an optimum neural network is formed which is used for forecasting in California market [18]. Combination of feature selection technique and neural networks is used for removing the, nonstationarity, nonlinearity and time variance in price behaviour and it is examined on PJM electricity market for forecasting day-ahead LMP [19]. Another paper uses artificial neural network model based on similar days (SD) method is used for predicting day ahead electricity price in PJM electricity market [20]. Ontario electricity market forecasting is done with a Four-layered perceptron model of ANN that has one input layer, two hidden layers, and one output layer and uses Levenberg-Marquardt BP (LMBP) method illustrating its high capability and performances [21]. For New York market Recurrent neural network is applied to eliminate complex and rough fluctuations in price, to get high accuracy and less computation time [22].

E. Fuzzy Model

Fuzzy inference used forecasting purpose is basically a working of fuzzy logic in which rules which are linguistic are used to map the input onto output space without any firm requirement of inputs.

Fuzzy Logic: if X is a universe of discourse with elements denoted by *x*, then the fuzzy set A in X is defined as a set of ordered pairs,

$A = \{x, \mu A(x) \mid x \varepsilon X\}$

$\mu A(x)$ is called the membership function of in A [24].

Fuzzy inference systems (FIS) uses fuzzy rules (IF-Then) and fuzzy reasoning which performs input-output mapping based on fuzzy logic and it is able to handle the concept of incomplete truth instead of absolute truth. ANFIS (Adaptive network based fuzzy inference system) is fuzzy inference system which is used for forecasting is basically a FIS which is implemented in the framework of adaptive network [25].

For utilizing the piece wise continuous nature of electricity price in the time domain clustering of the input data is done by maintaining the variations, Thus FIS is used for handling the data that lies beyond the coverage of NN. The Australian New-South Wales electricity market data was used to test FIS [26].Using efficient neuro-fuzzy combination LMPs of the PJM market were calculated in which fuzzy reasoning and RNN was used. The fuzzy rules were used to perform the linguistic reasoning about the contingencies and the reasoning results served as a part of inputs to the RNNs in above neuro fuzzy method [27]. For forecasting day-ahead electricity prices in the Ontario market and PJM market a novel hybrid intelligent algorithm utilizing a data filtering technique based on wavelet transform (WT), an optimization technique based on firefly (FF) algorithm, and a soft computing model based on fuzzy ARTMAP (FA) network was used [28].

F. Simulation Method

MAPS (market assessment and portfolio strategies) are the simulation model which incorporates complete electrical transmission model representation and the detailed power flow data of the system. MAPS captures hour by hour market dynamics by providing the LMP for any bus, identifying the problems of transmission networks, producing the generation schedules and power flows on the transmission grid. Drawback of this method is that it requires very much detailed information of system operation data and its computational cost is very high. One of the MAPS algorithm is developed by GE Power Systems Energy Consulting and the other is UPLAN software developed by LCG Consulting.

V. Forecasting Model Accuracy

Accuracy parameters are important parameter for all the models as it tells how close we are to the forecasted values. Error is the difference between the actual value and the forecasted value for the particular period. To measure the forecast accuracy, we choose from several indexes, such as Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE)

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{y_1 - y_2}{y_1}\right| \times 100\%$$

Where Y_1 is real data at time stage t; Y_2 is forecasted output data at t.

VI. Conclusion

This paper is about electricity market price forecasting techniques and their application in various markets. For profit maximization forecasting is but forecasting of price forecasting is a complicated because

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of the distinguishing features of price as discussed above. Every electricity market is different type therefore, there is no general method for price forecasting it can vary as per market requirements. Different forecasting methods, such as ANN, GARCH, ARIMA, FUZZY models, are reviewed separately along with different markets they are used in. The future trend is using of Hybrid methods which combine different models to compensate the weakness of individually established models increasing the performance characteristics of these models by reducing forecasting errors.

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