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Electricity Price Forecasting Model - Defining the Need and Approach for India Market

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I. INTRODUCTION

Over the last few years, the Indian Power sector has undergone structural changes that include unbundling of the State Electricity Board (SEB) to create separate Generation, Transmission and Distribution companies and establishment of independent regulator in most of the states. There is a clear intent of reforming the sector with the introduction of favourable policies, regulation and laws thereby bringing in competition which in turn is creating avenues for newer players to address the gaps in the power sector. One such area is Power Trading and today most of the Utilities are trading power either through exchange or traders

In Indian Power Exchanges, Electricity is traded between wholesale buyers and sellers through an auction mechanism. Participants submit their buy and sell bids in terms of prices and quantities for the 24 hours or the pre-defined interval of the next day. The market clearing price is determined by the intersection between the aggregated supply and demand curves.

II. NEED FOR ELECTRICITY PRICE FORECASTING MODEL

The need for price forecasting model is driven out of the typical characteristic of the power sector which involves long term capital investment, highly specific nature of assets and distinct characteristic of electricity compared to other commodities. Governments want predictability as electricity is directly linked to the economic development; customers want protection from price variations and investors want confidence. Thus the objective of Price Forecasting model is to visualize future electricity market dynamics to assist in present decision making process. Load and demand forecasting tools have been widely developed and deployed globally but usage in India is still low. There is immense need for such a tool but complex requirements in India may not be met by a standard product or model. It needs to consider dynamics of Indian power sector, demand patterns, weather patterns and various other local data inputs; which makes it a unique solution.

III. ELECTRICITY PRICE FORECASTING BENEFICIARIES

The benefits of Electricity Price Forecasting can be realized across the power sector value chain as detailed below

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A. Generators and Investors/Financial Institutions: - Profitability and Confidence

Huge investments are happening in increasing power generation capacity with active participation of private developers. Many such projects are financed by private financial institutions or investors and profitability of such investments is directly dependent on future price of electricity. Due to uncertainty in the future price of electricity, such investment decisions carry huge risk; apart from the other risks pertaining to regulatory decisions etc. Long term price forecasting tool can be instrumental in the decision making process and mitigating several investment risks. Such tool can consider several factors such as location, transmission and other constraint, slippages in meeting capacity addition targets.

For generators, profit can be maximized by optimal scheduling of their dispatch and have appropriate bidding strategy in place. Scheduling needs to be done considering power generation cost of each unit so that lowest cost generation can be dispatched. the application of price forecasting is not limited to long term forecasting but medium and short term as well for effective scheduling of the dispatch between various plants and units within a power plant.

B. Transmission Organization and System Operators - Demand on the Transmission Network

Transmission network has expanded on demand based planning models but now the load and demand is influenced by several factors e.g. new participants in the market, tariff structures like Availability based Tariff (ABT) etc. Hence it important to ensure that these factors are considered in the network expansion decisions.

New technologies and initiatives such Smart Grid, which can enable innovative price structure can further influence the load and demand pattern of the grid. At present retails consumers are not active player in the power market thus their consumption pattern is unaffected by the price variations in the power market. But it is not too far when consumers shall be making decisions on their consumption pattern on hourly or daily basis which would be possible by the use of Smart meters. Usually transmission expansion plans are based on network congestion at the supply point and consumer demand is considered as static and not affected by the price signals from the energy market in the medium and short term market. Price forecasting can play a significant role in predicting the prices at various nodes or zones (as applicable) which can help in long term planning and short term congestion management. Hence a good price forecasting model can be instrumental for Central Transmission Utility for effective network planning and expansion.

C. Regional and State Load Dispatch Centers (RLDCs/SLDCs)

Such a tool can also help Regional and State Load Despatch Centers whose primary responsibility is to ensure grid discipline, facilitate load scheduling & dispatch functions and energy accounting & settlement. This price prediction tool can help them in understanding the behavior of market by understanding the price sensitivities so that they can plan the resources in advance and ensure smooth operations. They can provide inputs for national grid planning to the Authority and the Central Transmission Utility.

D. Power Traders /Load serving entities– Long term and Short term contracts

For the load serving entities it is beneficial to use price forecasts to develop strategies and negotiation positions for entering into long term and short term contracts with customers. This can also enable them to exercise call and put options and hedge their risks in the power exchanges or by entering into bilateral agreement or financials ones. This could be a tool for decision making in terms of trading the forward contracts in the future markets.

The knowledge of market clearing prices of the previous day and also historic data on the MCP of the past months/year along with good forecast of the next day's price is a crucial input in formulating bidding strategies.

E. Distribution Utility – Planning and Scheduling Power Purchase and Trading

Unbundling of State Electricity Boards into separate entities for transmission, generation, distribution and trading functions has helped in improving efficiency of the power sector. Now the responsibility to procure power at a best price resides on distribution utilities and they need to do better planning and scheduling to ensure that they do not get into position wherein they have to procure power at very high rates during peak demand periods. Hence it is not only important for them to predict load forecast but also predict market price so that they can take calculated risk and even enter into bilateral agreements in advance. There are instances where decision needs to be taken whether to run own generating units to meet captive requirements or to buy power from the grid because surplus cheap power is available in the grid. In such situation, crucial decision needs to be taken whether to sell surplus power in the spot market in the power exchange or shut down high cost generating units.

Hence the price forecasting and generation cost forecasting tools will be useful in strategic decisions thereby improving the profitability. On one hand it can help distribution companies to reduce power purchase cost with efficient power purchase strategy and on the other hand it can help manage monthly peak and energy demand.

F. Large industrial Open Access (OA) customers & CPP - Hedge their risks through long-term, fixed price contracts.

As per the Electricity Act 2003, the mechanism of "Open Access" has been introduced and it has been adopted across few states and others states may eventually follow. This provides option to large consumers to choose its supplier. The price forecasting has found its relevance among these consumers as it is instrumental in the decision making process for spot markets and long-term contracts. Price forecasts are necessary to develop bidding strategies or negotiate contract in order to maximize profit. Price forecast for future (daily, monthly, yearly etc.) can help consumers in planning their production and power consumption. Captive power plants can also make decisions on whether to their generation plants or procure power from the grid.

G. Regulators – Policy and Tariff Fixation

One of the primary responsibilities of regulators is the fixation of tariff according to the provision of the Electricity Act for:

- Generating company for supply of power
- Wheeling charges for transmission of electricity
- Retail tariff to be charged by Distribution Licensees

Price forecast tools can assist regulators in decision for tariff fixation. The different models can be created for this process and they can virtually simulate different conditions and see the overall impact.

The policy makers can evaluate the option of using the price forecasting models for power trading in the global market wherein different countries can have an option to strategize and pool its reserve capacity thereby reducing cost for extra power stations and limiting requirement of spinning reserve.

IV. Electricity Price Forecasting Model – Applications

For all the beneficiaries the price forecasting can be applicable in various time frames based on their specific requirements but then the accuracy of the forecast is low in the short term forecast due to the incomplete information or uncertain bidding strategy of the market participants but the accuracy is more reasonable with the time frame enlarged. The purpose of classifying the forecasting in different time frames is due to the fact that there is a different forecasting methods and approach which is applicable for each of the time frames. It is not advisable to use the methods applicable for short term forecast for long term forecast as short term forecast will be have quantitative analysis while on the other hand the long term forecast which are strategic in nature and used in business decisions. Different methods in Forecasting are categorized as mentioned below:

- Qualitative methods - where there is no formal mathematical model (long-term forecasting)
- Regression methods –Here a variable is thought to be linearly related to a number of other independent variables
- Multiple equation methods – There are no of dependent variables that interact with each other through a series of equations (as in economic models)
- Time series methods – There is a single variable that changes with time and whose future values are related in some way to its past values. These techniques are mostly used for short and medium term forecasts

Table 1 Price Forecasting Applications

Long Term Above 2 years	Medium term (1Year to 2 Year)	Short Term (Within 1 Year)
• Transmission Expansion and augmentation • Setting up New Generating Stations and Generation Augmentation • Distribution Planning • Regional Energy Exchanges • Bidding Strategies **Usually required for Strategic Decisions**	• Negotiations of Bilateral contracts • Congestion Management • Portfolio Allocation **Can be used for Tactical decisions**	• Opportunity cost (Reserves and capacity) • Risk Assessment • Trading Scenarios **Mainly the Operating decisions**

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V. ELECTRICITY PRICE FORECASTING MODEL – INFLUENCING FACTORS

To do accurate Electricity price forecast it is important to detail the influencing factors on the electricity prices and these are mainly categorized into segments as mentioned in the Table 2.

Table 2: Price Forecasting Influencing factors

Power System	Fuel Factor	Weather	Hydro-Factors	Spot market	Financial market
Consumption Generation (Nuclear, Thermal etc) Unit-Planned Outages Historical load , data on imports /exports Capacity (Excess/shortfall) Transmission congestion index Transmission Corridor Availability	Coal Prices Crude Oil Prices	Precipitation Temperature Wind	Hydro balance Water inflow for reservoirs Ground water level	Prices Turnovers Power exchange (Market clearing price)	Futures contracts Forward contracts

There are a number of parameters that affect the bidding strategy of the generating companies. There are technical constraints on unit operation; load and weather forecast and hydro energy availability are some of the factors.
The variables would vary with regard to the forecasting dimensions, with different input variables for Long and medium term forecast which would not vary considerably in shorter time frame while on the other hand the short term forecast or Day ahead, hour ahead prices forecast the input variables would vary as per the market characteristics. In long term forecasting hydro factor is crucial as the water level in the reservoir is high would help to moderate the electricity prices in the market. The long term Power purchase agreements (PPAs) are also required to be taken into consideration as this would have implication of prices. The volatility in the prices can be largely attributed to the nature of electricity which is different from a normal commodity as it cannot be stored and there is need to maintain balance between demand and supply, also the inelastic nature of demand over short period of time. These factors needs to be categorized into input variable and these variables could be as many 50 no's put across different buckets to understand the impact of the each variable on the final price output by studying the past behavior.

VI. PRACTICAL APPROACH FOR PRICE FORECASTING MODEL DEVELOPMENT

There are various initial activities to be performed before the actual forecast is initiated.
Basic activities to be performed are:

- Data Management – Large Volume of real time and Historic data from various sources which could be the CEA websites, SLDC, RLDCs, Power exchanges, Traders and State utilities need to be collected and stored in a common database.
- Data Preparation– Processing Configuration Validation Analysis and Estimation of data
- Build Data Model
- Forecasting and Optimization Model

A first step to price forecasting is to identify all the crucial factors and variables which set the future price trend in the market. The initial step is the data preparation and doing data analysis thereby clearly identifying the outliers so that the forecasting result is not biased based on them. The historic models and its results need to be studied to select the most efficient model. A basic model is developed initially which can be clearly understood by the power market players and then a comparison between the actual and forecast results is done to do the required optimization of model. There are various method used for electricity price forecasting and it becomes difficult to identify the appropriate method for forecasting, To understand the price forecasting methods better it is important to understand the influencing factors and forecast these influencing factors using the existing and proven methodologies like in the case of weather forecasting or be the load and demand forecasting tools. It is common presumption that these tools can be applied for price forecasting but then it is not very effective and the errors would vary for example Artificial Intelligence (AI) approaches such as neural network, and support vector machine (SVM), which have been successfully applied in load forecast whereas Support Vector Regression (SVR) model which is developed in terms of the particularity of the price forecast in electricity market.

It is also important that the input variables used for the Electricity price forecasting are also predicted using proven methodologies and required modelling is done for them. Figure 3 illustrates one of such approach whereby different input

variables are predicted such as the weather input parameters like temperature humidity etc. is predicted using the weather forecast module and on the other Load forecasting module is utilized for the prediction of load parameters.

For the purpose of Long and medium term forecasting it would be required to setup basic database on the installed capacity and the additional projects in the pipeline for power generation which would be input for Supply forecast. The next step is to input the required data along with historical data's for all the influencing factors also the historic price data. The availability of accurate historic data is a key factor for accurate forecast. The screening of data for accuracy and also in case of some data is missing that needs to be estimated. The data analysis is to be carried which shall be followed by selection of an appropriate model. The next step is to do the application development which shall integerate various models and also do the required reporting. The process is to be repeated with different models to arrive at the optimized state wherein the right model combination is selected for each module and this requires various permutation and combinations to be carried out with due consideration to time factor. This is an iterative process, for an investor who would like to know the Return on Investment (ROI) for his investment and the best method is to calculate the net present value of additions in resources or withdrawals for each year of the forecast period is considered. It is predicted to see of the future prices of electricity can be sufficient to cover the resource, development, operation, maintenance costs this includes his profit margin.

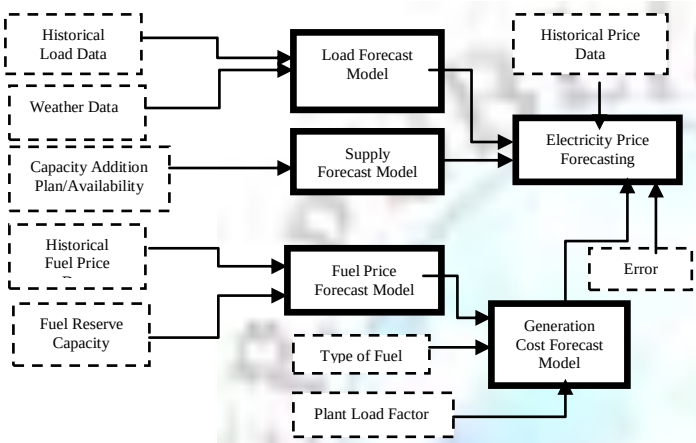

Figure 3 Price Forecasting Modules

There is another approach for short and medium term forecasting which is detailed market simulation approach in which lot of data pertaining to power exchange market is required. This is preferred by the Power utilities and market operators. In this method the actual market condition is simulated by assuming the demand and supply data based on the historic trend and also factor for system operating constraints.

This method can be used as supporting tool over and above the statistical and intelligent models. These approaches forecast future prices using historical operation data. The need for different modules is to accurately predict the Demand Supply ratio as it is observed that the electricity prices follow the demand supply curve and hence the demand supply ratio is major contributor as variable input for the price prediction model.

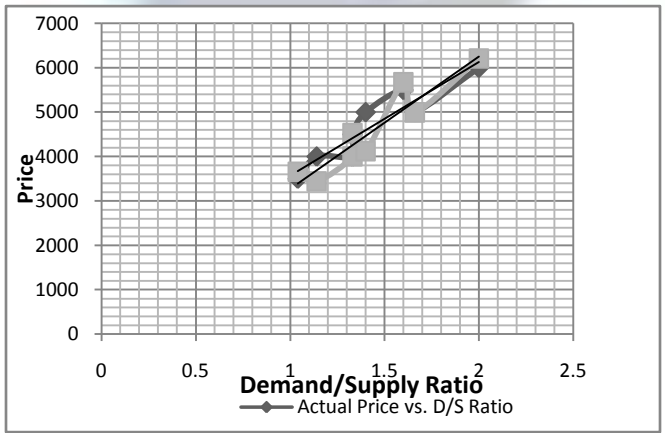

Figure 4 Demand Supply ratio Vs. Prices

Time series models are among the proposed approaches with reasonably good results. ARIMA models, for instance, are reported to predict market prices with a reported MWE forecast error of up to only 5% in Californian market while TF and DF models give a result with an average weekly error of only 3% for the same market. On the other hand, a MAPE of about 9% is reported using ANN for the England-Wales market.

VII. Electricity Price Forecasting Model Application

For application of the price-forecasting methodologies, it is important to understand different type of models, time frame for prediction, input variables required, output variables, data points and analysis. Model needs to be developed using selected methodology and the system needs to be revisited from time to time.

There is still lot of research and case studies being developed on the performance of various methodologies and models developed for electricity price and demand forecasting. The task is to identify right tools and integrate them together as there is no standard product which can be applied to meet the universal requirements. On the contrary the load forecasting tools and methods have matured enough and the errors have within 3 to 4% while the price forecasting is still in the infant stages. It can be really confusing by seeing the available models on the electricity forecasting as published by Electric Power Research Centre (EPRC). It is thus suggested to go for a hybrid approach with ARIMA and ANN models providing more flexibility for price prediction. Auto Regressive Integrated Moving Average (ARIMA) models which is combination of two models mainly Auto Regression and Moving Average while this has been applied to forecast commodity prices like oil or natural gas and also in successfully in load forecasting but due to its accuracy and past experience of results in mainland Spain and Californian markets make them a preferred model.

The approach for application development is to calculate the error between the forecast data and the actual outcome and this error which is basically Mean Absolute Error (Average of absolute error of last two forecasted values is fed back into the system as input variable. As discussed in earlier section that important aspect in the price forecasting is the Demand supply ratio and it is observed that the Demand supply ratio follows the price pattern. Hence it is necessary to forecast the demand and supply data through the respective modules and this is applied to the price forecast model.

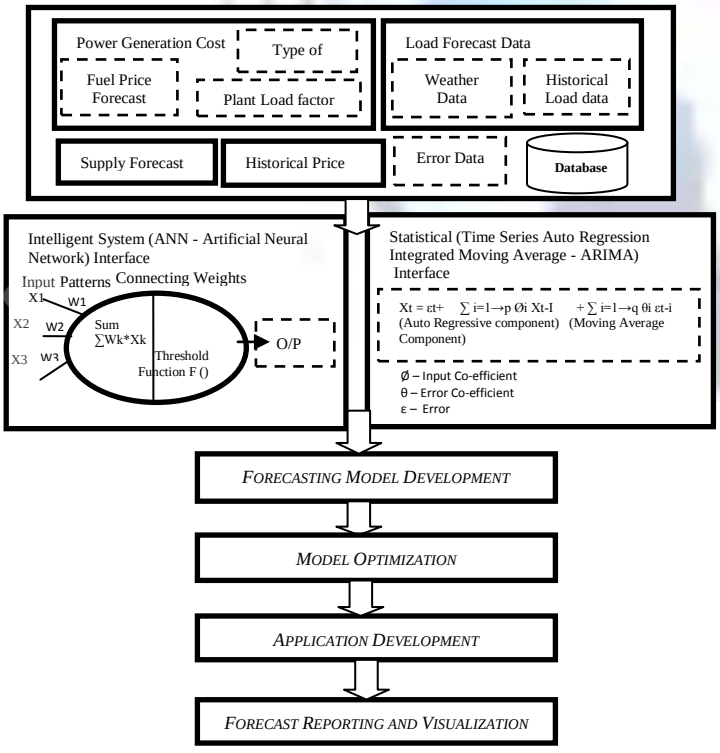

Figure 5: Price Forecasting Approach

The above figure 5 shows one such approach for Electricity price forecasting with the use of combination of statistical Time series model Auto –Regression Integrated Moving Average (ARIMA) and intelligent system Artificial Neural Networks (ANN). The additional use of the thorough Market Simulation techniques could be a best approach for short term or spot prices prediction. The disadvantage of the ARIMA is that it cannot capture nonlinear patterns of complex time series if non-linearity exists. Hence it is important to use a combination model approach with ANN which eliminates the drawback of ARIMA.

It is observed that there is continues need to revisit the coefficients and also the structure of models depending upon the forecast periods or time frame. The objective here is to develop simple price forecast model which allows the use by various entities to predict electricity prices based on their needs. There is no need to re- invent new methods for forecasting rather advisable to use the existing developed models and use the errors to customize the model so that the favourable results can be achieved.

VIII. CONCLUSION

The Electricity price forecasting is complex but based on the various research and case studies it is essential tool which needs to be applied with thorough analysis as there is no standard model or scheme which can adopted off the shelf but approach is to have a different models combined together come out with an expert model and can used alternatively for different forecast period.

The various past research and understanding the requirement of various players and influencing factors, it is observed that forecast methodology varies depending on the forecast requirements in terms of Short term Medium term and Long term forecast and similar is the case of errors which would vary depending on the methods used for the forecasting. In the global market Electricity price forecasting have been developed and deployed. The exchange markets which have very recently come into existence in India and also with lot of development happening in the power sector, this could be the right time when the price forecasting model can be developed and put into use so that the learning curve can be established and as the power exchange market grows the tool shall also get matured enough and can be utilized by the power market players effectively for their benefits.

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