Modeling and Forecasting Day-Ahead Hourly Electricity Prices: A Review

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ABSTRACT

Electricity markets around the world are being transformed from a highly Government regulated and controlled markets into deregulated markets. Today, electricity trading has transformed from primarily being a technical business, to one in which the product is treated in the same way as any other commodity. The main objective of deregulation is to introduce competition in the power industry and provide more choices to market participants in the way they trade electricity and ancillary services. In the framework of competitive electricity markets, power producers and consumers need accurate price forecasting tools because price forecasts embody crucial information for producers and consumers when planning bidding strategies in order to maximize their benefits and utilities. A Generator/firm/Individual Power Producer (IPP) which is able to forecast prices correctly can adjust its own production schedule accordingly and hence maximize its profits. But one has to bear in mind that electricity is a very unique commodity that cannot be economically stored and the end user demand shows strong seasonality. This current study reviews literature pertaining to short term electricity price modeling and forecasting and gives direction for future researchers.

Keywords: Electricity, Price, Market, Modeling, Forecasting

Introduction

Electricity markets around the world are being transformed from a highly Government regulated and controlled markets into deregulated markets. In recent years, traditional vertically integrated electric utility structure has been deregulated and replaced by a competitive market scheme in many countries world-wide [1]. The main objective of power system restructuring and deregulation is to introduce competition in the power industry and provide more choices to market participants in the way they trade electricity and ancillary services [2].

With deregulation and increased competition, power market participants are facing new challenges everyday. Today, electricity trading has indeed transformed from primarily being a technical business, to one in which the product is treated in the same way as any other commodity [3]. But one has to bear in mind that electricity is a very unique commodity that cannot be economically stored and the end user demand shows strong seasonality. Events like power plant outages, breakdown of electrical transformers, non availability of resources (ex: Non availability of coal for thermal power stations) or imperfect transmission grid reliability may have extreme effects on electricity prices. This makes electricity price forecasting critical for all power market participants. Electricity Price forecasting techniques in literature can be broadly divided into six classes: [4]

- Production-cost (or cost-based) models
- Equilibrium (or game theoretic) approaches [5]
- Fundamental (or structural) methods [6], [7]
- Quantitative (or stochastic, econometric, reduced-form) models
• Statistical (or technical analysis) approaches
• Artificial intelligence-based (or non-parametric) techniques [8], [9], [10]

The deregulation and liberalization of electricity markets around the world has not only led to new challenges for market participants, but, has also created a new field of research. Liberalization and deregulation has propelled research in electricity price modeling and forecasting. The main objective of this study is to review literature pertaining to Short term Electricity Price Forecasting (i.e. for day ahead markets)

Literature Review

According to literature, forecasting of electricity prices can be categorized into: [11]

a. **Long-term price forecasting:** The main objective is for investment profitability analysis and planning (especially for determining the future sites or fuel sources of power plants)

b. **Medium-term forecasting:** These are generally preferred for balance sheet calculations, risk management and derivatives pricing. In many cases, they do not concentrate on the actual point forecasts but on the distributions of future prices over certain time periods

c. **Short-term price forecasting:** This is of particular interest for participants of auction-type spot markets wherein participants are requested to express their bids in terms of prices and quantities. In such markets buy (sell) orders are accepted in order of increasing (decreasing) prices until total demand (supply) is met.

In a power market, the price of electricity is the most important signal to all market participants. Time series forecasting is the prediction of future events based on already known past events using an appropriate model. Accordingly, there are different models that can be used for time series forecasting. [12] Classify Electricity Price forecasting Models broadly into 3 categories:

• Game Theory Models
• Time Series Models
• Simulation Models

According to [12], a lot of researchers and academicians around the world are engaged in developing tools and algorithms for load and price forecasting. They are of the opinion that, load forecasting has reached advanced stage of development and load forecasting algorithms having mean absolute percentage error (MAPE) below 3% are available as highlighted by [13] and [14]. However price-forecasting models and techniques, which are being applied by power market participants around the world, are still in their early stages of maturity.

[12] investigated the state of price-forecasting methodologies by reviewing 47 papers published during 1997 to November 2006 based on the type of model used for forecasting, time horizon for prediction, input variables, output variables, analysis of results, data points used for analysis, preprocessing employed and the model architecture. They have observed that forecasting errors are still high from risk management perspective and the results obtained by different price forecasting methodologies are difficult to compare with each other. The authors are of the belief that most of the electricity markets are still at the stage of infancy, so, the researchers have had to make predictive analysis based on very small data set which is available with them. They also point out that very little work has been done in the direction of prediction of price spikes.

[15] in their study forecasted day ahead hourly electricity price in the electricity markets of mainland Spain and California by making use of price forecasting tools based on time series analysis – i.e. using dynamic regression and transfer function models. The analysis in the paper was based on setting up a hypothetical probability model to represent the data. The models were selected based on a careful
inspection of the main characteristics of the hourly price series {i.e. high frequency, non-constant mean and variance, multiple seasonality (corresponding to a daily and weekly periodicity, respectively), calendar effect (such as weekends and holidays), high volatility, high percentage of unusual prices (mainly in periods of high demand)}. It was found that the Price predictions obtained for the Spanish and Californian electricity markets were accurate enough to be used by producers and consumers to prepare their corresponding bidding strategies. Average errors in the Spanish market were around 5% and around 3% in the Californian market for the weeks under study. However, it had been observed that the Spanish market showed more volatility in general. (Reason being a higher proportion of outliers and a lesser degree of competition) This made the Spanish market less predictable compared to Californian electricity market.

[16] Predicted next-day electricity prices of mainland Spain and Californian markets by making use of ARIMA model. Market clearing prices of the day-ahead pool of mainland Spain and the Californian pool (which are publicly available) was considered for their study. The authors found the following differences between the Spanish electricity market and the Californian electricity market: a) Spanish electricity market showed more volatility in general. Its ARIMA model needed data from the previous 5 hours and did not use differentiation to attain a stable mean. b) Whereas, Price predictions were found to be better for Californian electricity market before the electricity market collapsed. This could be due to the fact that the Californian market showed less volatility in the period considered. ARIMA model for Californian market needed data from the previous 2 hours and required differentiations.

Till 2003, in technical literature, Artificial Neural Networks (ANN) techniques had been widely used for load forecasting and for electricity price prediction. The paper by [16] was one among those very few initial works, in the field of electricity price forecasting using time series analysis and methods, which was supported and funded by the Ministry of Science and Technology (Spain) and the European Union through a grant. If average mean errors are considered for both markets, the results obtained are pretty good, especially considering the complex nature of electricity price time series and in comparison with the results previously reported in the technical literature.

Table 1. Studies Related to Electricity Price Forecasting

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<tbody>
<tr>
<td>1</td>
<td>Autoregressive Models</td>
<td>2</td>
<td>[17] and [18]</td>
</tr>
<tr>
<td>2</td>
<td>ARMA Models</td>
<td>2</td>
<td>[15] and [19]</td>
</tr>
<tr>
<td>3</td>
<td>ARIMA Models</td>
<td>7</td>
<td>[16], [20], [21], [18], [22], [23] and [24]</td>
</tr>
<tr>
<td>4</td>
<td>Multiple Linear Regression Models</td>
<td>1</td>
<td>[25]</td>
</tr>
<tr>
<td>5</td>
<td>Dynamic Regression Models and Transfer Function</td>
<td>3</td>
<td>[26], [15] and [27]</td>
</tr>
<tr>
<td>6</td>
<td>GARCH Models</td>
<td>3</td>
<td>[28], [27] and [21]</td>
</tr>
<tr>
<td>7</td>
<td>Jump Diffusion Models</td>
<td>3</td>
<td>[29], [30] and [31]</td>
</tr>
<tr>
<td>8</td>
<td>Regime Switching Models</td>
<td>5</td>
<td>[32], [33], [34], [35] and [36]</td>
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Why Electricity Price Forecasting?

In the framework of competitive electricity markets, power producers and consumers need accurate price forecasting tools. Price forecasts embody crucial information for producers and consumers when planning bidding strategies in order to maximize their benefits and utilities. According to [4], if classical notion of volatility i.e. Standard deviation of returns is considered, and is calculated on the daily scale (i.e. for daily prices), then:
• Treasury bills and Notes have Volatility of less than 0.5%
• Stock indices have moderate volatility of about 1-1.5%
• Commodities like crude oil or natural gas have volatilities of 1.5-4%
• Very volatile stocks have volatilities not exceeding 4%
• Electricity exhibits extreme volatility – up to 50%!!!

[37] Highlight that Price curve of electricity market exhibits considerably richer structure when than load curve having the following characteristics:

• High frequency
• Non-constant mean and variance
• Multiple seasonality (i.e. daily, weekly, monthly, hourly)
• Calendar effect
• High level of volatility and
• High percentage of unusual price movements

These characteristics of Electricity Price curve can be attributed to the following reasons which distinguish electricity from other commodities [38]

• Non-storable nature of electrical energy
• The requirement of maintaining constant balance between demand and supply
• Inelastic nature of demand over short time period
• Oligopolistic generation side
• Load and generation side uncertainties

For both spot markets and long-term contracts in an electricity market, price forecasts are necessary so that a firm/company can develop bidding strategies or negotiation skills in order to maximize its own benefit/profit. A Generator/firm/Individual Power Producer (IPP) which is able to forecast spot prices correctly can adjust its own production schedule accordingly and hence maximize its profits. Since the

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<td>1</td>
<td>PJM Electricity Market</td>
<td>[39] and [40]</td>
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<tr>
<td>2</td>
<td>California Electricity Market</td>
<td>[16] and [17]</td>
</tr>
<tr>
<td>3</td>
<td>New England Electricity Market</td>
<td>[41] and [42]</td>
</tr>
<tr>
<td>4</td>
<td>Ontario Electricity Market</td>
<td>[43]</td>
</tr>
<tr>
<td>5</td>
<td>Spanish Electricity Market</td>
<td>[15] and [16]</td>
</tr>
<tr>
<td>6</td>
<td>Victoria Electricity Market, NEM</td>
<td>[44]</td>
</tr>
<tr>
<td>7</td>
<td>Queensland Electricity Market</td>
<td>[45]</td>
</tr>
<tr>
<td>8</td>
<td>UK Power Pool</td>
<td>[46] and [47]</td>
</tr>
<tr>
<td>9</td>
<td>European Energy Exchange (Leipzig)</td>
<td>[18]</td>
</tr>
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<td>10</td>
<td>Electricity Markets of China</td>
<td>[48]</td>
</tr>
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<td>11</td>
<td>Korean Power Exchange</td>
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<td>Amsterdam Power Exchange</td>
<td>[50]</td>
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<td>13</td>
<td>Alberta’s Power Market</td>
<td>[51]</td>
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<td>14</td>
<td>New Zealand Electricity Market</td>
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<td>Ukrainian Electricity Market</td>
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<td>Turkey Electricity Market</td>
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day-ahead spot market typically consists of 24 hourly auctions that take place simultaneously one day in
advance, forecasting with lead times from a few hours to a few days is of prime importance in day-to-day
market operations.

The Road Ahead

Short-term Electricity price forecasting (i.e. day ahead hourly electricity price forecasting) in case of
organized power exchanges in developing nations (like India where power sector is getting de-regulated
due to reforms such as Electricity Act 2003) is one of the direction for future research. There are very
few studies related to short term electricity price forecasting for developing countries particularly India
where electricity markets are getting deregulated. With Practical relevance and stakes for implications
of price forecasting for a Generator/IPP/firm being high (i.e. next-day price forecasting is a crucial need
for producers, consumers and energy service companies), accurate forecasting tools and techniques
is valued by power market participants, especially in an emerging economy like India. One of the
directions for future research is developing a Time Series Econometric forecasting model that would
most accurately forecast day-ahead hourly electricity prices in Indian Electricity markets and also
investigate and compare the developed model with all other forecasting models given in literature.

Acknowledgements

I would like to thank Dr. Ajaya Panda, Dr. Subrata Sarkar, Dr. Badri Narayan Rath and Dr. Ban Sharma
for all their valuable comments and feedback

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