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STATEMENT OF THE PROBLEM

OBJECTIVES

HYPOTHESES

RESEARCH METHODOLOGY

RESULTS & DISCUSSION

FINDINGS

RECOMMENDATIONS/SUGGESTIONS

CONCLUSIONS

SCOPE FOR FURTHER RESEARCH

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APPENDIX/ANNEXURE

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- Sharma T., Kwatra, G. (2008) Effectiveness of Social Advertising: A Study of Selected Campaigns, Corporate Social Responsibility, Edited by David Crowther & Nicholas Capaldi, Ashgate Research Companion to Corporate Social Responsibility, Chapter 15, pp 287-303.

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SPOT ELECTRICITY PRICE MODELLING AND FORECASTING

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ABSTRACT

Structural reforms and deregulation since early 1990's around the world has transformed Electricity markets from highly regulated and controlled markets, into, deregulated and competitive markets. Electricity trading is no more a technical business. Today, electricity is treated and traded like any other commodity. A power market participant, who will be in a position to forecast prices correctly, can make an informed decision of adjusting production schedule, buy/sell electricity at an appropriate price from an energy exchange and maximize profits. In this study, literature pertaining to spot electricity price modelling and forecasting is reviewed.

JEL CODES
D43, G16, H44, L11, L13, P23

KEYWORDS
Electricity, Forecasting, Modelling, Spot Price.

INTRODUCTION

Structural reforms and deregulation since early 1990's around the world has transformed Electricity markets from highly regulated and controlled markets, into, deregulated and competitive markets. Today, vertically integrated electrical utility structure which was the norm traditionally for an electrical utility has been completely replaced by a competitive market scheme not just in developed countries but also in developing countries (Li et al. 2007). Countries around the world have proactively engaged in this transformation of power system structure with an agenda of introducing competition in all the sub sectors of power industry such as Generation, Transmission, Distribution as well as Trading of electric power.The rationale behind this move is to provide more choices to the power market participants especially in the way electricity is traded along with its ancillary services (Amjady and Daraeepour, 2009).
Liberalization, deregulation and increased competition have resulted in power market participants facing newer challenges every time. Electricity trading is no more a technical business. Today, electricity is treated and traded like any other commodity(Pilipovic, 1997). It is interesting and very important to note the fact that electricity is undoubtedly a unique commodity because it cannot be economically stored, it cannot be seen unlike other commodities, it has to be consumed the moment it is produced and user demand shows strong seasonality at every interval of time (hourly, daily, weekly and monthly). Unfortunate and extreme events such as outages power plants, electrical transformers malfunction or breakdown, unavailability of resources due to unavoidable constraints (ex: Transportation problem resulting in Non availability of coal for thermal power stations) or faulty/imperfect transmission grid reliability will result in having severe effect on electricity prices. This aspect of electricity makes modeling and price forecasting critical for all the power market participants.

OBJECTIVE OF THE STUDY

The deregulation and liberalization of electricity markets worldwide has not only led to new challenges for power market participants, but, has also created a new field of research. Liberalization, deregulation and introduction of competitive power markets have propelled research in electricity price modeling and forecasting. The main objective of this study is to review literature pertaining to spot electricity price modelling and forecasting.

SIGNIFICANCE OF THE STUDY

In today's world of competitive electricity markets, the power market participants i.e. power producers and power consumers need accurate price forecasting tools. Price forecasts signify by embodying crucial information which is essential for power producers and consumers when they are planning for bidding strategies with an objective of managing price risk as well as maximizing their benefits i.e. utility.
According to Weron (2006), if classical notion of volatility i.e. Standard deviation of returns is considered, and is calculated on the daily scale (i.e. for average 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%!!!

Karakatsani and Bunn (2004) highlight that Electricity Price curve exhibits considerably richer structure when compared to the load curve with the following unique characteristics of:

- 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 are mainly due to the following reasons which distinguish electricity from other commodities (Bunn, 2000).

- 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

As described by Girish et al. (2013), for power market participants, price forecasts are necessary for developing bidding strategies to maximize 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. Spot electricity price modeling and forecasting is of prime importance in day-to-day market operations for these power market participants. In this study, all relevant Univariate Time Series Econometric models used for spot electricity price modeling are reviewed.

SPOT ELECTRICITY PRICE MODELLING AND FORECASTING LITERATURE

Electricity Price forecasting techniques in literature can be broadly divided into six classes: (Weron 2006)

1. **Production-cost (or cost-based) models** - These models simulate the overall operation of the generating units. The main aim is to satisfy the demand of electricity at the minimum cost. But the major drawback in this approach is that strategic bidding practices often employed by power market participant is completely ignored.
2. **Equilibrium (or game theoretic) approaches** - These models are similar to cost-based models with consideration for strategic bidding however the performance of these models are questionable, problematic and difficult if any kind of quantitative conclusions have to be drawn and it is computationally demanding.
3. **Fundamental (or structural) methods–**In these methods, price dynamics are described by modeling the impact of certain important physical and economic factors on the price of electricity. However, these models are better suited for medium-term rather than Short Term electricity Price Forecasting.
4. **Quantitative (or stochastic, econometric, reduced-form)models–** These models characterize statistical properties of electricity prices with respect to time. The ultimate objective of quantitative models is its application in evaluation of derivatives and for risk management.
5. **Statistical (or technical analysis) approaches** - Time series Autoregressive models such as ARMA, ARMAX, (Seasonal) ARIMA, GARCH, TAR and Markov regime-switching models fall under this category. Along with spot electricity price series, fundamental factors such as loads, prices of fuels are considered while modeling.
6. **Artificial intelligence-based (or non-parametric) techniques** – Electricity prices are modeled using non-parametric tools such as neural networks, fuzzy logic, etc. The advantage of these techniques is that they are flexible and can handle complexity along with non-linearity. However, they are Not intuitive often performing below par.

Based on the time horizon for which forecasting has to be made, forecasting of electricity prices can be categorized into: (Misiorek et al., 2006)

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.

The following table gives a summary of spot electricity price modeling and forecasting techniques used in the literature (Girish et al. 2013).

TABLE 1: MODELS USED IN THE LITERATURE FOR ELECTRICITY PRICE MODELING AND FORECASTING

S.I No.	Model	Authors
1	Autoregressive models	Cuaresma et al. (2004); Weron and Misiorek (2005)
2	ARMA models	Carnero et al. (2003); Nogales et al. (2002)
3	ARIMA models	Bowden and Payne (2008); Conejo et al. (2005); Contreras et al. (2003); Cuaresma et al. (2004); Garcia et al. (2005); Gianfreda and Grossi (2012); Zhou, Yan, Ni and Li (2004)
4	Multiple linear regression models	Schmutz and Elkuch (2004)
5	Dynamic regression models and transfer function	Karakatsani and Bunn (2008); Lora et al. (2002); Nogales et al. (2002)
6	GARCH models	Mugele, Rachev and Trueck (2005); Karakatsani and Bunn (2004); Garcia et al. (2005)
7	Jump diffusion models	Johnson and Barz (1999); Knittel and Roberts (2005); Skantze and Illic (2000)
8	Regime switching models	Ethier and Mount (1998); Haldrup and Nielsen (2006); De Jong and Huisman (2002); Huisman and Mahieu (2003); Weron et al. (2004)

CONCLUSION AND SCOPE FOR FURTHER RESEARCH

Electricity spot price modeling and forecasting is very crucial for power market participants. A Generator/firm/Individual Power Producer (IPP) which is able to forecast spot prices correctly can adjust its own production schedule, buy/sell power from the market and end up maximizing its profits. Spot electricity price modeling and forecasting is of prime importance in day-to-day market operations for these power market participants. Electricity Spot prices have been modelled for many electricity markets around the world. (See Girish, 2012; Girish et al. 2013)

TABLE 2: PRICE FORECASTING RESEARCH IN VARIOUS ELECTRICITY MARKETS

S.I No.	Market	Authors
1	PJM Electricity Market	Bastian et al. (1999); Xu and Niimura (2004)
2	California Electricity Market	Contreras et al. (2003); Weron and Misiorek (2005)
3	New England Electricity Market	Guo and Luh (2004); Zhang and Luh (2005)
4	Ontario Electricity Market	Rodriguez and Anders (2004)
5	Spanish Electricity Market	Contreras et al. (2003); Nogales et al. (2002)
6	Victoria Electricity Market, NEM	Szkuta et al. (1999)
7	Queensland Electricity Market	Zhao et al. (2005)
8	UK Power Pool	Wang and Ramsay (1998); Yao et al. (2000)
9	European Energy Exchange (Leipzig)	Cuaresma et al. (2004)
10	Electricity Markets of China	Hu et. al. (2004)
11	Korean Power Exchange	Zhou et. al. (2006)
12	Amsterdam Power Exchange	Culot et al. (2006)
13	Alberta's Power Market	Serletis and Shahmoradi (2006)
14	New Zealand Electricity Market	Guthrie and Videbeck (2007)
15	Polish Power Exchange	Mugele et al. (2005)
16	Ukrainian Electricity Market	Frunze (2007)
17	Turkey Electricity Market	Ozmen et al. (2011)

One of the directions of future research is modelling and forecasting spot electricity prices of a developing nation like that of India. India has two power exchanges namely Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL) . Ever since its inception, IEX has emerged as a preferred trading platform nationwide and covers 80 Members & more than 1600 clients registered as on March 31, 2012 (with over 350 private power generators/Independent power producers and more than 1000 direct consumers). IEX has Day-Ahead Market (Hourly contracts for next day by employing double-sided closed Auction, Contingency hourly market for Next day having Continuous Trading and Intraday continuous Trading for the same day which are categorized under Spot

markets), Term-Ahead Market and Renewable Energy Certificates (Solar and Non-Solar). Electricity price spike forecasting is another direction for further research.

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