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Spot electricity price discovery in Indian electricity market

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ABSTRACT

This paper investigates the spot electricity price discovery that exists among the five regions of Indian electricity market using hourly spot electricity price data from 1st January 2014 to 31st December 2015. Using Augmented Dickey-Fuller (1981) and Narayan and Popp (2010) unit root tests, we find that the spot electricity prices for both peak and off-peak hours across all the regions are stationary at level. Then by applying Granger causality test for a reduced VAR model at level, the results show that there hardly any causality exists between these electricity markets barring few regions. Though we did not find any causality between peak price and off-peak price for all individual region, but we formed two panels by using peak and off-peak price data of all five regions. Our results showed short-run and long-run panel Granger causality between peak price and off-peak price. The results of the study suggests that though India as a nation has all the regions inter-connected with single frequency of Power grid operation since 2008, however, these markets are not highly integrated in comparison to electricity markets of developed nations around the world.

1. Introduction

The Indian electricity market is broadly divided into five regions namely the southern region, north-eastern region, eastern region, western region and northern region [16]. The Ministry of Power (MoP) of the Indian Government oversees policy formulation, planning and has been entrusted with the responsibility of effective implementation and administration of IEA 2003 which introduced competition and has completely reorganized the power sector. In India, Power/Electricity is the responsibility of both Central Government and the respective State Governments who are the stakeholders. Central Electricity Authority (CEA) has been entrusted with statutory functions including overseeing the technical coordination and supervising implementation of various programs and schemes of the Government [5]. The Central Electricity Regulatory Commission (CERC) is the independent regulator for power sector in India along with State Electricity Regulatory Commissions (SERCs) for each of the state. National Load Dispatch Centre (NLDC) which was constituted in the year 2005; is the apex body in India for ensuring integrated operation of the national power system [35]. NLDC is entrusted with supervising the functioning of other Regional Load Dispatch Centers (RLDCs). NLDC and RLDCs together overlook scheduling, dispatch of power/electricity both intra as well as inter-regional links, maintaining grid security and proper monitoring of system operations. Transmission in India is entrusted with Central transmission utilities, State transmission utilities and transmission licensees. Power sector companies should get license and prior approval from the Central Electricity Regulatory Commission for commencing operations. Appellate tribunal is responsible for hearing appeals against any of the orders of adjudicating officer or any Commission under the IEA 2003.

India currently has two energy/power exchanges namely the Indian Energy Exchange (IEX) and the Power Exchange India Limited (PXIL) which are regulated under the provisions made in Power Market Regulations 2010 which was issued by the Central Electricity Regulatory Commission. Similar to electricity industry restructuring by enactment of Energy Policy Act 1992 and following it up by Federal Energy Regulatory Commission (FERC) Order 888 in USA, in India, the Indian Electricity Act (IEA) 2003 paved way for electricity industry restructuring particularly encouraging competition in Generation, Distribution and Power trading which was followed up by Power market regulations in 2010 issued by the Central Electricity Regulatory Commission (CERC) of India. Electricity as a commodity (man-made) is matchless since it is highly unlikely to be stored cost-effectively due to its physical properties as well as meeting the demand which usually tends to illustrate strong seasonality [22,40]. Previously vertically integrated electric utilities have now been deregulated into competitive markets with introduction of competition world-wide (Li et. al, 2007;

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[2,15]) empowering power market participants with more options to choose from [1,2,19]. Post the enactment of IEA 2003 and further deregulation of the sector, 100% Foreign Direct Investment (FDI) has been allowed for Generation, Distribution and power trading in India.

In power exchanges around the world, one of the important product and service in wholesale competitive deregulated electricity market is that of day-ahead spot market. The spot electricity markets operate all 24 h, 365 days of a year. Day-ahead spot electricity market typically consists of 24 hourly auctions that take place simultaneously one day in advance [22,30,32,41]. Spot electricity prices are more volatile than any other commodity and are known for extreme price volatility [18,27,39,41]. In such a market, spot electricity price forecasts having lead times of a few hours/few days is awfully significant. A power market participant with precise short-term price forecasts can fine-tune his own production schedule by buying/selling power from power exchange depending on when it is more profitable, ensuring power requirements are met and thereby maximizing his profits. It further makes sense to investigate the price-discovery process in such a market [10].

The key highlight of the paper is that to the best of our knowledge, this is the first study in literature to explore Spot Electricity Price discovery in a market which is energy deficient albeit having energy exchanges IEX and PXIL functioning i.e. Indian electricity market. Though India is the 3rd largest electricity producer in the world after China and USA and one of the largest consumers of electricity in the world, it still faces a critical issue of energy deficit. The result of the study paves way for policy consideration on introducing futures electricity market in India, inter-connection among various regions, transmission and congestion management. Earlier studies by [16,22,21,17,20] have explored forecasting spot electricity prices in India.

Price discovery mechanism in any market is dependent on: (a) Number of Sellers and Buyers in the market, their size and location. (b) Market microstructure in terms of bidding and settlement processes and/or liquidity. (c) Information available about other correlated markets (example: futures market) and (d) Risk management choices available for participants. In case of Indian electricity market, we only have wholesale spot market i.e. IEX and PXIL and do not have futures market thereby making examining the degree of integration five regions of Indian electricity market critical eventually leading us to Spot Electricity Price discovery. The current paper focuses on empirically investigating the degree of market integration that exists in Indian electricity market for all the five regions namely North, East, West, South and North-East region using hourly spot electricity price data. The results of the study suggests that though India as a nation has all the regions interconnected and has single frequency of Power grid operation IEX and PXIL functional since 2008, these markets are not highly integrated in comparison to electricity markets of developed nations around the world. We find that moderate degree of integration among these regional markets in India. The rest of the paper is structured as follows: Section 2 discusses the review literature related to price discovery and integration in electricity markets. Section 3 presents the data and methodology and empirical results are described in Section 4. The final section concludes.

2. Literature review

Emphasis in literature has predominantly been on electricity price modeling and forecasting. Weron [41], Agarwal et. al [1], Girish et. al [22] and Weron [42] classify modeling and forecasting techniques under (a) Production-cost models: These models have the potential to simulate overall operation of electric power generating stations/units. The prime objective is to suffice demand of electricity at lowest cost. One of the major drawbacks of this approach is that strategic bidding practices adopted by other power market players is not considered. (b) Equilibrium models: These models are very much similar to Production-cost based models except the fact that strategic bidding practices adopted by other power market players is also considered. It has been observed that forecasting performance of Equilibrium models has not been satisfactory in deregulated markets. One of the drawbacks of this approach is that it becomes very difficult for drawing quantitative conclusions coupled with the fact that these approaches are computationally challenging. (c) Fundamental models: These models manifest electricity price dynamics by incorporating and modeling impact of all physical factors and economic factors. These models are believed to be better suited for medium-term electricity price forecasting compared to Short term electricity price modeling and forecasting. (d) Quantitative models: These models describe the statistical properties of electricity prices viz-a-viz time and have their practical application in valuation of derivatives and for risk-management motive and purpose. (e) Statistical/Technical analysis approach: These techniques are direct applications of methods inspired from electrical engineering/load forecasting or finance/time series econometric models. The effectiveness, efficiency and appropriate usefulness of adopting technical analysis approach is often questioned in financial/currency markets, however, the same techniques stand better chance in power markets irrespective of the time period considered. The main reason is the fact that electricity prices behave in the way we expect than randomly fluctuating financial asset prices aided mainly by the stylized facts[2] of spot electricity markets and its prices namely Seasonality, Mean Reversion, Volatility and Jumps/Spikes. Spot electricity prices can be modeled with electric power load, price of fuel (fundamental factors) as exogenous variables for modeling and forecasting. (f) Artificial Intelligence techniques: In these techniques, spot electricity prices are modeled by adopting neural networks,[3] expert systems, support vector machines, fuzzy logic etc. which are non-parametric tools having the advantage of being flexible and capable of handling complexity and most importantly non-linearity. Being non-intuitive and often performing below par has been their biggest drawback.

Statistical models and artificial intelligence based approaches are useful for short-term spot electricity price forecasting purpose [1,22,41]. Aggarwal et al. [1] classify short term electricity price forecasting[4] models into three categories namely: game theory models, simulation models and the time-series models. Misiorek et al. [32] have classified forecasting models for electricity prices based on the time-frame for which prediction of electricity price needs to be done as follows: (a) Forecasting of electricity prices for long-term (more than 1 year): The prime objective is for analyzing and planning long term investment profitability particularly for deducing future sites/fuel sources of power plants. (b) Forecasting of electricity prices for medium-term (3 months to 1 year): These classes of models are normally favored for balance-sheet calculations, derivatives pricing and also risk management. The focus is on distributions of future electricity prices for medium term rather than exact point forecasts. c) Forecasting of electricity prices for Short-term price (up to 3 months): Power market participants belonging to auction-type spot markets[5] are particularly interested with forecasting of electricity prices for Short-term where they should participants communicate their bids quoting the price for buying/selling along with quantities. Girish [20] investigated forecasting performance of Indian spot electricity price series employing Autoregressive-GARCH models. Girish and Tiwari [17] compared forecasting performance of models such as ARFIMA, Auto-ARIMA,

[2] Electricity price series exhibits Stylized facts across different electricity markets i.e. Electricity prices exhibit Seasonality, Mean Reversion, Volatility and Jumps/Spikes [1,3,7,8,22,24,41].

[3] Refer Weron [42], Vijayalakshmi and Girish [37] for complete review of forecasting spot electricity prices using Artificial Neural Networks.

[4] Weron [41], Aggarwal et al. [1] and Girish et al. [22] have reviewed techniques inspired from energy economics literature and electrical engineering/load forecasting literature for short-term spot electricity price forecasting for different electricity markets. Most and Keles [33] have reviewed stochastic modeling of electricity prices having traits and inspired from operation research literature.

[5] In spot electricity markets (buy/sell) (bid/ask) orders are accepted in order of (increasing/decreasing) prices till (total demand/total supply) has been met.