CHAPTER 3

RESEARCH OBJECTIVE AND HYPOTHESIS FORMULATION

3.1. RESEARCH OBJECTIVES

Based on the literature review and the gaps identified in the literature\(^1\), we identify the following objectives for our study:

1) To study the emergence of Indian spot electricity market with emphasis on role of power exchanges [i.e. Power Exchange India Ltd and Indian Energy Exchange] and its impact on short-term electricity prices. \{Gap 1\}

2) To empirically investigate seasonality exhibited by Indian spot electricity price series. \{Gap 2 and 3\}

3) To empirically investigate Spot electricity price forecasting performance of univariate time Series models on Indian spot electricity price series. \{Gap 4\}

4) To investigate whether capturing seasonality exhibited by spot electricity prices yield better forecasting performance for Indian spot electricity price series. \{Gap 5\}

5) To empirically investigate Spot electricity price forecasting performance of volatility models on Indian spot electricity price series. \{Gap 6\}

3.2. HYPOTHESIS FORMULATION

To achieve our research objectives, we formulate the following hypotheses for our study:

\(^1\) Literature as reviewed in Chapter 2. Also refer Girish et al. (2013); Girish et al. (2014) for further review of literature pertaining to spot electricity price forecasting and its relevance for participants of Indian Electricity market.
3.2.1. IMPACT OF ESTABLISHMENT OF POWER EXCHANGES ON ELECTRICITY PRICES

The process of deregulation, liberalization and introduction of competition in Indian Electricity market commenced only after implementation of Indian Electricity Act 2003. Earlier we had electric utilities which were vertically integrated and now we have deregulated competitive markets worldwide (Li, Liu, Mattson and Lawarree, 2007; Amjadi and Daraepour, 2009) with the sole objective of introducing competition in power industry, thereby, providing more options for power market participants to choose from (Amjadi and Daraepour, 2009) and eventually addressing the issue of supply-demand gap and reduction of electricity prices benefiting the end users and customers. Concept of power exchange and organized day-ahead spot electricity market is novel for Indian perspective and its market players. We expect the establishment of power exchanges has helped in reducing average short-term electricity prices in India. We formulate the following hypothesis:

Hypothesis 1: Emergence of competitive power market with establishment of power exchanges reduces short-term electricity prices

3.2.2. SEASONALITY EXHIBITED BY INDIAN SPOT ELECTRICITY PRICE SERIES

Electricity when contemplated from a trade and industry perspective is a non-storable commodity making matching of electricity demand and supply a staggering and critical job at all times. Minor fluctuations in the quantity of electricity generated or variation in demand can propel into great changes in electricity prices within few hours in competitive power/electricity markets. This makes electricity price series of spot electricity markets to display certain stylized

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2 Refer Girish, Panda and Rath (2013)
facts such as Seasonality, Volatility, Mean-Reversion and Jumps/Spikes (Weron, 2006; Bierbrauer et al., 2007; Huisman and Mahieu, 2003; Girish and Vijayalakshmi, 2014; Karakatsani and Bunn, 2008). Seasonal fluctuations in the supply and demand of electric power translates into seasonal behavior of spot electricity prices. Whenever there is increase in demand, Power producing stations with higher marginal costs will be employed in supply side eventually making electricity prices higher. When the demand falls back to normalcy, the generating stations with higher marginal costs will be turned off resulting in decrease of electricity prices. Spot electricity prices also show uncommon but somewhat large spikes or jumps. The reason for these unique characteristics can be traced back to the truth that electricity cannot be stored (economically), inventories do not play a role in smoothening price changes, capacity and transmission problems related to physical infrastructure and need for balancing the demand and supply in these markets in real time. We formulate the following hypotheses to investigate Seasonality exhibited by Indian spot electricity price series for different regions of the Indian Electricity market:

**Hypothesis 2a:** Spot Electricity Prices of Indian Electricity market exhibit Seasonality at a monthly interval

**Hypothesis 2b:** Spot Electricity Prices of Indian Electricity market exhibit Seasonality at a daily interval

**Hypothesis 2c:** Spot Electricity Prices of Indian Electricity market exhibit Seasonality at a hourly interval
3.2.3. FORECASTING PERFORMANCE OF AUTOREGRESSIVE MODELS

One of the significant properties of energy spot-prices is that of mean-reversion (Brennan, 1991; Gibson and Schwartz, 1990). As literature suggests (Cuaresma et al., 2004), the benchmark model for capturing this property is simple first order autoregressive model (AR(1)), which can be considered exactly as discretized version of Ohrstein–Uhlenbeck process (Knittel and Roberts, 2005). An extension to this simple model is a complete autoregressive moving average (ARMA (p, q)) model. If differencing or seasonal differencing is required to make the time-series stationary, we make use of autoregressive integrated moving average model (ARIMA (p,d,q)) or Seasonal ARIMA model (Contreras et al., 2003). Based on the results of existing literature, we expect seasonal ARIMA model to forecast better than ARMA process and simple AR model. We formulate the following hypothesis:

**Hypothesis 3a:** Forecasting performance of ARMA-process is better than simple AR-type model for Indian spot electricity prices

**Hypothesis 3b:** Forecasting performance of Seasonal ARIMA model is better than simple ARMA-process for Indian spot electricity prices

3.2.4. FORECASTING PERFORMANCE OF SEASONALITY CAPTURED SPOT ELECTRICITY PRICES

Spot electricity price series are found to exhibit strong seasonality at annual level, weekly level and daily level along with other stylized facts such as mean reversion, volatility and spikes/jumps (Huisman, 2009; Janczura et al., 2013; Weron, 2006). It has been observed in literature that robustness of modeling electricity spot price improves if the spot price series is filtered for outliers and the filtered data is properly estimated for identifying the seasonal pattern.
(Janczura et al., 2013; Weron 2006). With this backdrop we expect that the forecasting performance of filtered and deseasonalized spot electricity prices to be better in case of Indian spot electricity prices. We formulate the following hypothesis:

**Hypothesis 4:** Forecasting performance of time series models capturing seasonality using seasonal dummy variables for spot electricity prices is better than forecasting performance of time series models using spot electricity prices directly.

### 3.2.5. FORECASTING PERFORMANCE OF VOLATILITY MODELS

The major focus of Short term electricity price forecasting literature has been on modeling the cyclical as well as seasonal patterns of electricity prices. However, volatility modeling seems to have been explored to a lesser extent (Hickey et al., 2012). There is consensus about the fact that volatility of spot electricity prices has profound impact on all power market participants and stakeholders. And the fact that electricity prices are more unstable than that of any other commodities makes volatility modeling and forecasting even more critical (Johnson and Barz, 1999; Hickey, Loomis and Mohammadi, 2012; Bowden and Payne, 2008; Hadsell et al., 2004; Weron, 2006; Escribano et al., 2002; Liu and Shi, 2013). Literature suggests that electricity price volatility is usually area specific and performance of volatility models depend on horizon of forecasting as well as the regulation status i.e. Regulated or Unregulated status of the electricity market (Hickey et al., 2012). GARCH volatility model explicitly models the time varying volatility process as given by Engle (2001). In GARCH specification, only magnitude of lagged residuals can influence conditional variance but not the direction. If positive and negative shocks have dissimilar impact on volatility, then, an asymmetric GARCH specification like EGARCH is preferable (Hickey et al., 2012). Another restraining feature of GARCH model is the supposition
of squared power term, which is not at all times suitable and can be overcome using Power ARCH (PARCH) model of Ding et al. (1993) or Asymmetric power ARCH (APARCH) model. We expect the performance of APARCH model to be the best among all volatility models similar to the results of Hickey et al (2012) and formulate the following hypothesis.

**Hypothesis 5a:** Forecasting performance of ARIMA-EGARCH model is better than simple ARIMA-GARCH model for Indian spot electricity prices

**Hypothesis 5b:** Forecasting performance of ARIMA-PARCH model is better than ARIMA-EGARCH model for Indian spot electricity prices