INDIAN ENERGY EXCHANGE DAY AHEAD MARKET: THE ISSUE OF STATIONARITY

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Abstract : ***A robust trading system is vital to promote competition and growth in the Indian energy exchange. With electricity being a peculiar commodity exhibiting characteristics of seasonality and periods of spikes and jumps, price modeling, forecasting, and risk management have become the need of the hour. Although, various studies in the existing body of literature have been conducted modeling spot electricity prices across the globe but very few have worked in the Indian context. But before applying any technique, the fundamental question which arises is that whether the Indian spot price data is stationary. This study investigates the same by using daily spot prices for each of the five regions (North, South, East, West and North East) further divided into 13 bid areas (A1, A2, E1, E2, N1, N2, N3, S1, S2, S3, W1, W2 and W3) from August, 2008 till August, 2017 of the Indian Energy Exchange and applying unit root tests such as Augmented Dickey-Fuller Test, Phillips Peron Test, Kwiatkowski–Phillips–Schmidt–Shin Test and ADF- Elliott- Rothenberg- Stock Point Optimal to check for the stationarity. This study will encourage the stakeholders such as generators and distribution companies to further apply time-series econometric models which would further help in preparation of a risk mitigation model.***

Index Terms - Spot electricity price, Indian electricity market, ADF, KPSS , Unit root, PP

I. INTRODUCTION

The enactment of the Electricity Act, 2003 has brought a revolution in the Indian Electricity market. With various reforms in the electricity sector, a vertically integrated private or public monopoly market structure was transformed into a competitive wholesale and retail mechanism (Sehgal et al, 2017) making the electricity market more efficient, liquid and transparent (Mediratta et al, 2008)

Since, electricity as a commodity (Barouti and Hoang, 2011) has certain peculiar features with non-storability being the unique one; therefore various measures have to be taken in order to either provide storage or to manage it properly. The storage cost of electricity is generally very high, hence an introduction to price modeling and pricing of derivatives in the electricity market is considered to be a better option. Globally the electricity market is very mature (Srivastava et al, 2011).

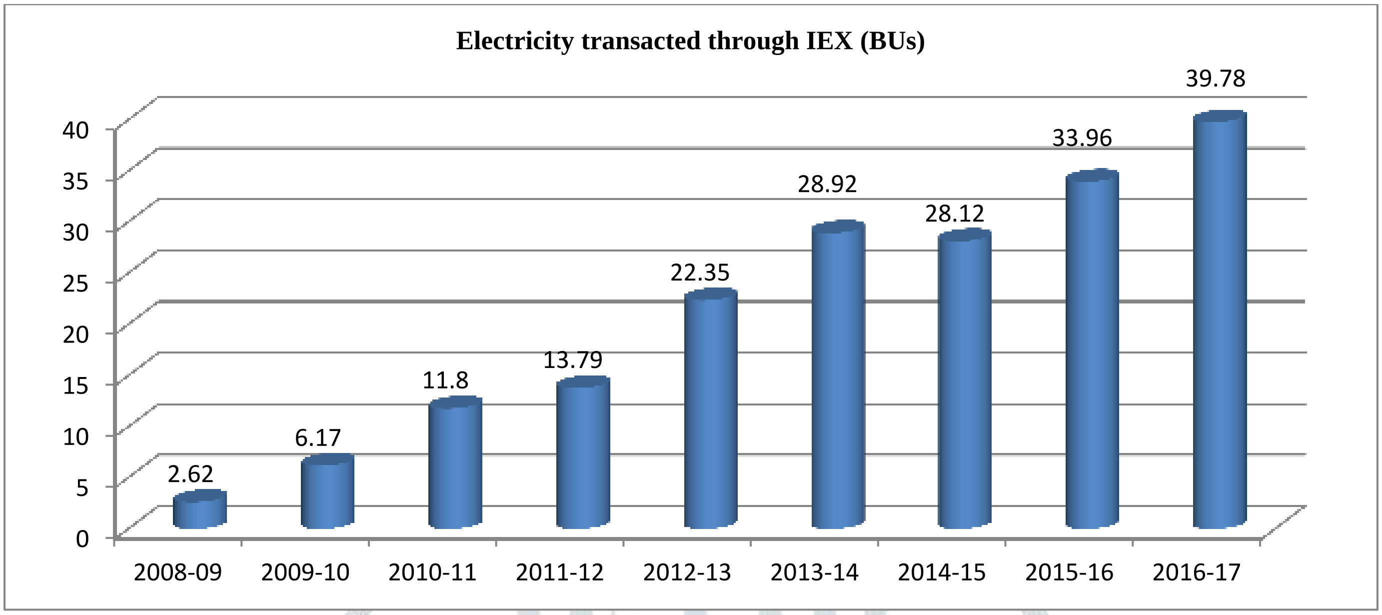
In India, there is a huge demand-supply gap in the electricity market at geographical level i.e. power deficit in certain regions (Northern, Western and Southern) and power surplus in other regions (Eastern and North Western). Hence the need for power trading is inevitable.

A major portion of electricity generated in India is purchased through long-term power purchase agreements between the power generators and distributors whereas only 10 % of the total volume generated is traded through short-term contracts (CERC Report, 2008-2017). Long-term contracts are basically bilateral contracts ranging from 12 years to 25 years, which are entered to meet the long-term demands of the stakeholders whereas the short-term contract's duration generally ranges between 15 minutes to 3 years which meets the immediate requirements of buyers (CEA Monthly Report, 2008-2017), Hence both are important to improve the reliability of the systems and maintaining grid discipline.

India has two power exchanges: Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL) which started their operations in 27th June 2008 and 22nd October 2008 respectively (IEX and PXIL site). These exchanges cover all the five regions

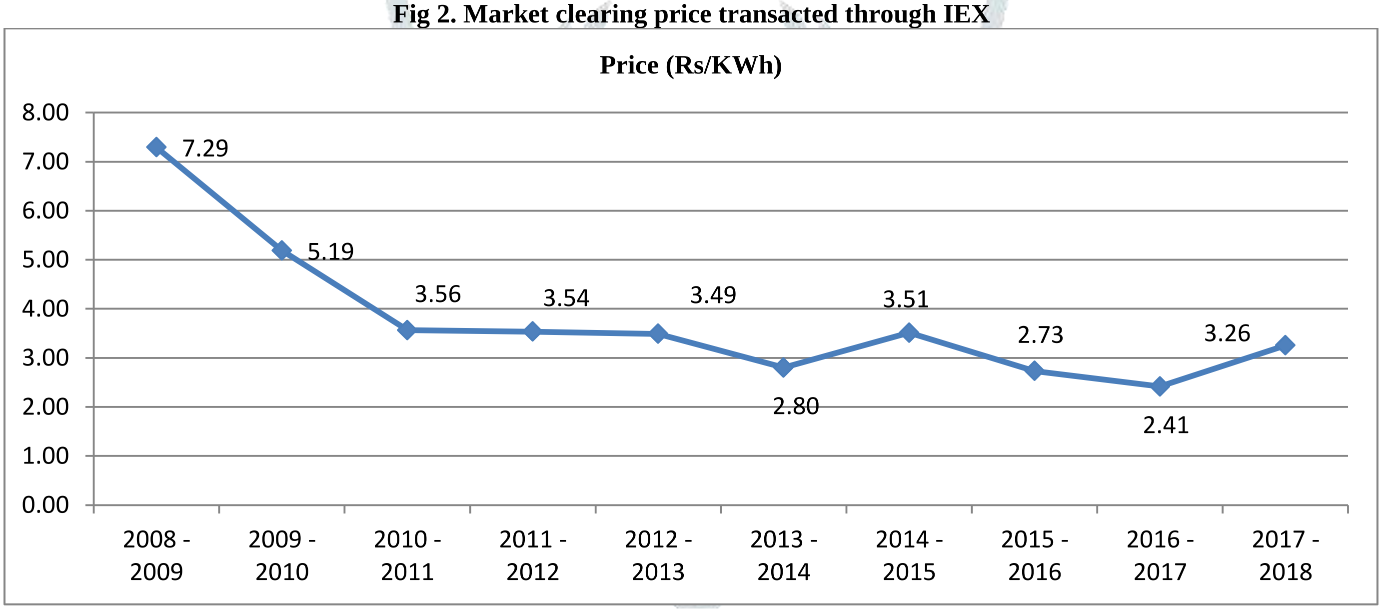
(Northern, Southern, Western, Eastern and North- Eastern) of Indian electricity market offering anonymous and automatic bidding, enabling efficient price-discovery, risk management and attempting to address the supply-demand gap. As on April 2018, out of the total short-term transactions, IEX constituted meager 3.92 % of the total electricity traded (CERC Report, 2008-2017), but the volume of trading has increased over a period of time (shown in Figure 1 below).

Fig 1. Short-term electricity transactions in India (less than 1 year)



Also the prices of electricity traded in Exchange have decreased making trading a profitable proposition (shown in Figure 2 below).

Fig 2. Market clearing price transacted through IEX



IEX has further divided all the five regions mentioned above into 13 bid areas (shown in Table 1 below) to invite more number of stakeholders (captive power plants, industrial consumers, independent power producers, state private utilities) from each area to trade in the exchange.

Table 1: IEX Bid Areas

S.No.	Bid Area	Region	States
1	E1	Eastern	West Bengal, Sikkim, Bihar, Jharkhand
2	E2	Eastern	Orissa
3	N1	Northern	Jammu and Kashmir, Himachal Pradesh, Chandigarh, Haryana
4	N2	Northern	Uttar Pradesh, Uttaranchal, Rajasthan, Delhi
5	N3	Northern	Punjab
6	A1	North Eastern	Tripura, Manipur, Mizoram, Nagaland

7	A2	North Eastern	Assam, Arunachal Pradesh, Meghalaya
8	W1	Western	Madhya Pradesh
9	W2	Western	Maharashtra, Gujarat, Daman and Diu, Dadar and Nagar Haveli, North Goa
10	W3	Western	Chhattisgarh
11	S1	Southern	Andhra Pradesh, Telangana, Karnataka, Pondicherry (Yanam), South Goa
12	S2	Southern	Tamil Nadu, Pondicherry (Puducherry), Pondicherry (Karaikal), Pondicherry (Mahe)
13	S3	Southern	Kerala

Source: IEX[1]

IEX trades in four major products such as Day-Ahead Market (DAM), Term-Ahead Market (TAM), Renewable Energy Certificates (REC) and Energy Saving Certificates (ESCerts). Since DAM captures the major portion of IEX and trading takes place in 15-minute time blocks in 24 hours of the next day starting at midnight, therefore, conducting volatility analysis is easier in comparison with other products.

In DAM, there are rapid movements in the prices ranging from as low as -43.5 % in September 2009 to as high as 78% in March 2010 (authors own analysis), but whether the data is stationary to conduct further modelling or not, that question still prevails because if the data will be non-stationary, it would lead to infinite persistence of shocks.

The current study is segregated into five sections. The first section (i.e., Introduction) throws light on the general overview of the Indian Electricity market. Section 2 of the paper reviews the literature related to modeling spot electricity prices

Section 3 focuses on the data and research methodology used. Section 4 draws the result of the stationarity tests conducted while Section 5 concludes the paper.

II. LITERATURE REVIEW

Presence of unit root suggests that the data is non stationary (Lisi and Nan, 2014). Many studies have been conducted by various authors to study the electricity markets across the globe (Janczura et al, 2010, 2013). Most widely used methods to check the presence of unit root are Dickey-Fuller and the Phillips-Perron tests which were coined by the statisticians David Dickey and Wayne Fuller in 1979 (Dickey and Fuller, 1979) and Peter C. B. Phillips and Pierre Perron in 1988 (Peter and Perron, 1988) Also there are other tests such as KPSS and ERS-DF- GLS (Efficient Unit root test) introduced by Kwiatkowski, Phillips, Schmidt and Shin (Schmidt and Phillips, 1992) in 1992 and Elliot, Rothenberg, and Stock (Elliott et al, 1996) in 1996 respectively. Various works have been conducted in the electricity markets by applying these methods such as California (Knittel and Roberts,2005), Europe (Haldrup and Nielsen, (2006), Bosco et al, (2007)), Spain (Contreras et al, (2003), Weron and Misiorek,(2005)), United Kingdom (Cavaliere, (2004), Dordonnat et al,(2009) , Karakatsani and Bunn, (2008)) , Italy (Gianfreda et al, 2016), PJM (Bastian et al, (1999), Zhang and Luh. (2005)) and India (Girish et al,(2014) , Sinha and Mathur, (2016), Vijaylakshmi et al, (2017)) regional prices, but no one has conducted study of the Indian Bid areas. This research will delve deeper into the bid areas.

All of which states that the prerequisite to apply any econometric model is that the electricity price series should be stationary. Hence it is important to conduct unit root tests in the data

III. DATA AND METHODOLOGY

The current research focusses on the study of stationarity test of all the 13 bid areas (A1, A2, E1, E2, N1, N2, N3, S1, S2, S3, W1, W2 and W3) of the India Energy Exchange Day ahead market's (DAM) daily spot prices from August, 2008 to August, 2017. Spot price is defined as the "intersection of the total demand curve and the total supply curve, for a given particular hour, for each region of the electricity market" [14]. In this study, we have taken 3312 daily spot electricity price data for A1, E1, N1, S1, W1 and W3. Also, 3294 and 3143 daily spot prices of N3 and S2 are taken respectively. It has been observed that the data of E1 and E2, A1 and A2, N2 and N1, S2 and S3 & W1 and W2 are the same; hence the data of E1, A1, N1, N3, S1, S2, W1 and W3 are taken into consideration.

The descriptive statistics of the data is elucidated in Table 2 below.

Table 2: Descriptive Statistics for Spot Electricity Prices

	N1	A1	E1	N3	S1	S2	W1	W3
Mean	3548.34	3401.14	3357.65	3630.87	4820.49	5131.74	3368.66	3294.25
Median	2925.23	2809.52	2764.21	2974.95	4271.69	4599.24	2779.75	2687.57

[1] Before delivery date 24/08/2011 N3 was part of N1 and W3 was part of W1.
Before delivery date 15/01/2017, Kerala was a part of S2 and Meghalaya was a part of A1.

Maximum	15447.50	13842.93	13842.93	15447.50	17532.89	17532.89	13842.93	13842.93
Minimum	1016.20	467.19	467.19	1016.20	467.19	467.19	467.19	467.19
Std. Dev.	1868.66	1788.95	1800.28	1907.01	2315.31	2510.11	1789.38	1821.53
Skewness	2.36	2.29	2.32	2.28	1.28	1.04	2.35	2.31
Kurtosis	9.28	8.89	8.97	8.65	5.10	4.09	9.11	8.89

From the table, it has been observed that the volatility in the Southern region is highest from the year 2008 to 2017 as the standard deviation is highest in the Southern region and lowest in North Eastern region. The range of prices is highest in the Southern region and lowest in the Northern region. Skewness measures the asymmetry of a distribution. Since the data is positively skewed, it shows that the chance of prices going up in all the regions is comparatively higher than the mean than it going down. The reason behind the prices going up is due to congestion in the transmission corridor. Kurtosis measures the extent to which observations cluster around a central point. Since the kurtosis for each bid area is more than 3, hence the data is leptokurtic i.e. it is dispersed away from the mean.

The following tests were used to test for unit root in the data.

3.1 Augmented Dickey-Fuller (ADF) test.

The primary work on testing for a unit root in time series was done by D.A. Dickey and W.A. Fuller in 1979. The basic objective of the test is to examine the null hypothesis that $\varphi = 1$ in

$y_t = \varphi y_{t-1} + u_t$ against the one-sided alternative $\varphi < 1$.

Where hypothesis of the series was H0: series contains a unit root versus H1: series is stationary.

Said and Dickey in 1984 (Said and Dickey, 1984) augmented the basic autoregressive unit root test to accommodate general ARMA(p, q) models with unknown orders and the new test is referred to as the augmented Dickey-Fuller (ADF) test.

Basic model

$$y_t = \beta' D_t + \varphi y_{t-1} + u_t$$

$$\varphi(L)u_t = \theta(L)\varepsilon_t,\ \varepsilon_t \sim WN(0, \sigma^2)$$

The ADF test tests that whether the null hypothesis of the time series y_t is I(1) against the alternative that it is I(0), assuming that the dynamics in the data have an ARMA structure. The ADF test is based on estimating the test regression

$$y_t = \beta' D_t + \varphi y_{t-1} + \sum_{j=1}^{p} \psi_j \Delta y_{t-j} + \varepsilon_t$$

Where D_t = deterministic terms,

Δy_{t-j} captures serial correlation

3.2 Phillips–Perron (PP) test

A more comprehensive test for non- stationarity was developed by Phillips and Perron (Phillips and Perron, 1984). The tests are similar to ADF tests, but they incorporate an automatic correction to the DF procedure to allow for autocorrelated residuals.

The test regression for the PP tests is

$$\Delta y_t = \beta' D_t + \pi y_{t-1} + u_t$$

$$u_t \sim I(0)$$

The PP tests correct for any serial correlation and heteroskedasticity in the errors u_t of the test regression by directly modifying the test statistics $t_{\pi=0}$ and $T\pi$

3.3 Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Test

The ADF and PP unit root tests are for the null hypothesis that a time series y_t is I(1). Stationarity tests, on the other hand, are for the null that y_t is I(0). The most commonly used stationarity test, the KPSS test, was derived by Kwiatkowski, Phillips, Schmidt and Shin in 1992 as:

$$y_t = \beta' D_t + \mu_t + u_t$$

$$\mu_t = \mu_{t-1} + \varepsilon_t,$$

$$\varepsilon_t \sim WN(0, \sigma^2_\varepsilon)$$

where D_t contains deterministic components (constant or constant plus time trend), u_t is I(0) and may be heteroskedastic. Notice that μ_t is a pure random walk with innovation variance σ^2_ε. The null hypothesis that y_t is I(0) is formulated as $H_0 : \sigma^2_\varepsilon = 0$, which implies that μ_t is a constant. Although not directly apparent, this null hypothesis also implies a unit moving average root in the ARMA representation of Δy_t. The KPSS test statistic is the Lagrange multiplier (LM) or score statistic for testing $\sigma^2_\varepsilon = 0$ against the alternative that $\sigma^2_\varepsilon > 0$

3.4 ERS - DF-GLS Tests

ERS (Elliot, Rothenberg, and Stock (1996)) proposed a modified ADF t-statistic based on GLS (Generalised Least Square) detrending as:

$$y^d_t = y_t - \hat{\beta}'_{\bar{\varphi}} D_t$$

where $\hat{\beta}_{\bar{\varphi}} = (D'_{\bar{\varphi}} D_{\bar{\varphi}})^{-1} D'_{\bar{\varphi}} y_{\bar{\varphi}}$.

Using the GLS detrended data, estimate by least squares the ADF test regression without deterministic terms

$$\Delta y^d_t = \pi y^d_{t-1} + \sum_{j=1}^{p} \psi_j \Delta y^d_{t-j} + \varepsilon_t$$

The DF-GLS statistic is the t-statistic for testing $\pi = 0$.

IV. RESULTS AND DISCUSSION

A time-series with mean, variance, autocorrelation and covariance constant over a period of time is said to be stationary. A non-stationary data, according to the rule, cannot be modelled, estimated or forecasted. Hence, it is necessary to test whether data is stationary before applying any volatility or forecasting models.

In our research, we have applied 4 models such as ADF, PP, KPSS and ERS-DF GLS tests on the Indian Energy Exchange's DAM prices as depicted in Table 3 (displaying results of ADF and PP) & Table 4 (displaying results of KPSS and ERS-DF GLS) shown below:

Table 3. Stationarity Test Results for Spot Electricity Prices

	ADF				KPSS				
	Test statistic	**1%**	**5%**	**p-value**	**Test statistic**	**1%**	**5%**	**10%**	**p-value**
A1	-5.18	-3.43	-2.86	0.00	3.27	0.73	0.46	0.34	0.00
E1	-5.17	-3.43	-2.86	0.00	3.23	0.73	0.46	0.34	0.00
N1	-5.82	-3.43	-2.86	0.00	3.36	0.73	0.46	0.34	0.00
N3	-6.52	-3.43	-2.86	0.00	3.24	0.73	0.46	0.34	0.00
S1	-6.09	-3.43	-2.86	0.00	1.61	0.73	0.46	0.34	0.00
S2	-7.67	-3.43	-2.86	0.00	1.29	0.73	0.46	0.34	0.00
W1	-4.58	-3.43	-2.86	0.00	3.29	0.73	0.46	0.34	0.00
W3	-5.13	-3.43	-2.86	0.00	3.28	0.73	0.46	0.34	0.00

Table 4. Stationarity Test Results for Spot Electricity Prices

	ADF- Elliott- Rothenberg- Stock Point Optimal					Phillip Perron			
	Test statistic	**1%**	**5%**	**10%**	**p-value**	**Test statistic**	**1%**	**5%**	**p-value**
A1	-1.53	-2.56	-1.94	1.61	0.00	-7.89	-3.43	-2.86	0.00
E1	-1.26	-2.56	-1.94	-1.61	0.00	-7.62	-3.43	-2.86	0.00
N1	2.52	1.99	3.26	4.48	0.00	-7.93	-3.43	-2.86	0.00
N3	-2.31	-2.57	-1.94	-1.62	0.00	-8.49	-3.43	-2.86	0.00
S1	-3.50	-2.57	-1.94	-1.62	0.00	-8.06	-3.43	-2.86	0.00
S2	-4.03	-2.57	-1.94	-1.62	0.00	-9.63	-3.43	-2.86	0.00
W1	-1.24	-2.57	-1.94	-1.62	0.00	-7.48	-3.43	-2.86	0.00
W3	-1.26	-2.57	-1.94	-1.62	0.00	-7.58	-3.43	-2.86	0.00

The results are as follows:

4.1 Augmented Dickey-Fuller (ADF) test.

ADF test drives with a null hypothesis that $\varphi = 1$ and the time series is not stationary. If the value of the statistic < 95% critical value, then the series is stationary and vice versa. In this case for each of the eight time series data, the ADF test statistic value is < Critical value at 95% indicating that all the eight time series are stationary. The same is confirmed through p-value (<.05).

4.2 Phillips–Perron (PP) test

Similarly in the case of PP test, The t- statistic value is lesser than the critical value at 95% in each of the eight time series data, Also the p- value for each is less than .05. Hence it indicates that the data is stationary.

4.3 KPSS Unit Root Test

KPSS test has a contrasting result wherein the value of the test statistic is greater than the Critical value in all the eight bid areas, hence it can be concluded that the series are not stationary, which can also be confirmed through p-value (<.05).

4.4 ERS - DF-GLS Tests

In this case, the lag length is taken to be 21, based on Schwarz criterion with null hypothesis to be stationary. It has been observed that for A1, E1, W1 and W3 the null hypothesis of a unit root is failed to be rejected since t statistic is lesser than all the critical values. Hence the data is stationary.

For N1 the null hypothesis of a unit root test is rejected at 1% level. For N3 the null hypothesis of a unit root test is rejected at 5% and 10% level. For S1 and S2, null hypothesis for a unit root is rejected at all the levels. Hence, measures have to be taken accordingly.

V. CONCLUSION

Indian Energy Exchange's Day ahead market prices functions all 24 hours, 365 days a year. In this research we have tried to conduct unit root tests on the data to check whether the same is stationary or not. This test is a prerequisite to apply any volatility and forecasting econometric model. We have taken 3312 daily spot electricity price data for A1, E1, N1, S1, W1 and W3. Also, 3294 and 3143 daily spot prices of N3 and S2 were taken respectively. All this data was taken from August, 2008 to August, 2017.

We empirically investigated whether the spot electricity prices were stationary or not using 4 methods such as Augmented Dickey-Fuller Test, Phillips Peron Test, Kwiatkowski–Phillips–Schmidt–Shin Test and ADF- Elliott- Rothenberg- Stock Point Optimal to check for the structural breaks.

The results of the study have suggested that according to ADF and PP test, the prices are stationary whereas KPSS contrasts the result mentioned by ADF and PP test.

ERS-DF GLS test suggests that prices of A1, E1, W1 and W3 are stationary, while rest are not stationary. Hence, measures are to be taken accordingly. These results will encourage the stakeholders such as generators and distribution companies to effectively apply time- series econometric models which would further help in preparation of a risk mitigation model

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