Price Uncertainty in Indian Electricity Market : A Statistical Analysis

Satyaveer Singh, Sunil Kumar Goyal, Nagendra Kumar Swarnkar

***Abstract*— Indian power system is being restructured for improving system efficiency and consumer benefits. As a result, Independent Power Producers (IPPs) and Distribution Companies (DISCOs) can sell or purchase power in electricity market through bidding. The trading operation of Indian electricity market is managed by two Power Exchanges (PXs) namely Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL). Due to oligopolistic competition, demand and unit outage uncertainties electricity prices in Indian day-ahead electricity market is highly volatile. In the above context, the present paper aims to analyze Indian market price uncertainty using different statistical distribution. Obtained results show that lognormal distribution can efficiently characterized Indian electricity market price uncertainty.**

***Index Terms*— Indian electricity market, Price uncertainty, Statistical distribution.**

I. INTRODUCTION

The fluctuating market price has become a crucial factor for the participants in a competitive power market. Pool price will vary each hour and will be determine by the market clearing, while the level of demand can be reasonably estimated. In the Indian electricity market uncertainty in electricity prices is caused by the several factors such as fluctuation in plant capacity due to water inflow uncertainties (hydro) or demand fluctuation due to water condition, electricity price can be influenced by economic factors, government policies, taxes, inflation, fuel price of generating unit and plant operating cost and when the load demand gets unexpectedly high or some unexpected generation or transmission outages occur [1-4]. These combinations may cause temporary price fluctuations. This fluctuation brings the difficulties in prediction of electricity price which may affect the planning operations and their bidding strategies [8].

Proper modeling of the bidding strategy of electricity price behavior will be useful in dealing with the risks which arise from price volatility [5]. The price model used in various studies appears to be conceptually reasonable although the need to be verified in real Indian market. For any market, proper representations and accurate parameters will be quit important of the participants to make optimal decisions. So identify statistical natures of the electricity price by conducting statistical analysis of Indian energy price from India energy exchange (IEX) has been used in this study [6].

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In the result section to be conclude that one hour data is selected for two year data draw the histogram and apply test of statistical distribution as normal, lognormal and weibull. Therefore, it is crucial to understand the characteristics of electricity price specific to different markets and the historical data in different power markets may be quite useful for this purpose. Proper representation and accurate parameters will be quite important for market to make optimal decisions. For continuous functions, the testing is carried out by checking whether the theoretical Cumulative distribution function agrees well with the sample data.

The Indian electricity market power uncertainty price in of Indian energy exchange and power exchange India Limited give the better statistical distribution in the trading operation. The lognormal distribution can efficiently characterize Indian electricity market price in the market is highly volatile and base price.

The organization of this paper is as follows. Section II describes the Indian electricity price market IEX and PXIL traders and section III analyze the Indian electricity market behavior of the price uncertainty. In the section IV, data of sixteen hour of the year 2010 and 2011 are taken and apply the statistical distribution to find the better distribution.

II. INDIAN ELECTRICITY MARKET

A. An Overview

The Indian electricity grid is among one of the largest power grids in the world. Five regional grids namely Northern, Eastern, West, South, North Eastern, with N-E-W grid. Power System Operation Corporation (POSOCO) to ensure the accuracy of data/information and the data/information in this report is believed to be accurate, reliable and complete [9]. The Power Exchange implementation in India is the operation of multiple Power exchanges in a single market handling physical delivery. Two Power Exchanges are operational in trade market.

Power Exchange India Limited (PXIL) had sought the Intervention NLDC or POSOCO for an early solution. The better price discovery for power traded on the exchange in the short-term market, the lower priority accorded to exchange traded power for transmission corridor capacity continues to be a disincentive to trade on the exchanges, thereby coming in the way of natural growth of the exchange market. PXIL and IEX has, therefore, requested POSOCO to allow transmission capacity reservations to exchange traded power so that more transactions can take place on the exchange platform leading to better price discovery and transparency in power transactions. In order to regulate the power markets more comprehensively, NLDC has notified power Market regulations and stream-lined the processes for availing of inter-state open access. Government Sector company to

provide the electricity for the NLDC. The transparent and efficient electronic platform provided by the exchange is imperative in order to unlock existing capacities and create a better demand supply balance [8].

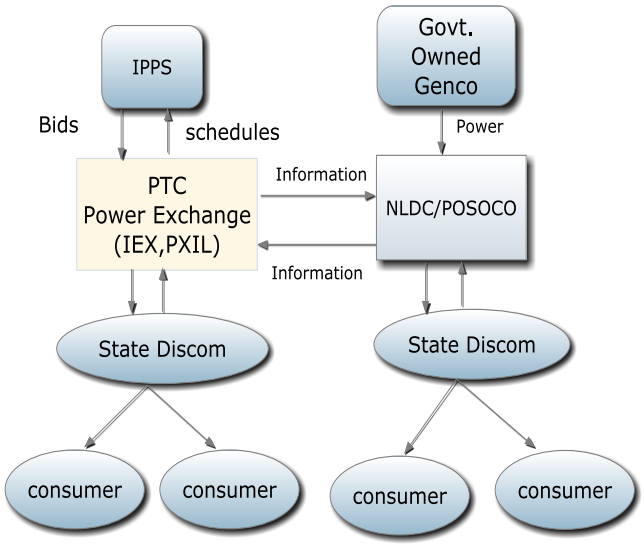

Figure 1. Indian power sector trading platform

Allocation of available transfer margins, congestion management and interplay between the bilateral market, day-ahead market in Power Exchanges and the real time market to gain from the operation of multiple power exchanges in a single physical delivery market in India,. Operation of the Indian power grid is monitored and coordinated through the National Load Dispatch Centre (NLDC) and five regional load dispatch centers (RLDCs). In India many state load dispatch centers (SLDCs) and several sub-load dispatch centers are established. Each control center has been provided with SCADA/EMS system which provides necessary data visualization to the grid operators. State, Regional and National Load Dispatch Centers as mandated by the Electricity Act 2003 carry out the supervision and control of Indian electricity grid. The grid operators at Load Dispatch Centers monitor and supervise system parameters and tie line flows with neighboring control areas and ensure integrated operation of the power grid within their jurisdiction. Power Trading Corporation of India Ltd. (PTC) is having two sub trader companies in electricity price market IEX and PXIL. The leading provider of power trading services in India is trading power on a sustained basis since June 2002 through purchase from surplus utilities and sales to deficit State Electricity Boards (SEBs) at an economical price, providing best value to both the buyers and sellers and ensuring that the resources are utilized optimally. PTC is a 'pure-play' trading entity, and does not own any generating units or transmission facilities. PTC acts as a single-window service provider that manages both financial as well as operational risks for the buyer and seller entities in its trading transactions.

Generating companies may enter into contracts to supply the generated power to the power dealers/distributors or bulk consumers or sell the power in a pool in which the power brokers and customers also participate. In a power-exchange, the buyers can bid for their demands along with their willingness to pay.

III. PRICE UNCERTAINTY

In restructure power system, electricity is traded in day-ahead and real-time electricity markets, which are cleared before actual power delivery. Electricity prices in such markets is highly volatile, due to stochastic nature of demand and other uncertainties. Electricity price data from IEX, which consisted of hourly electricity price of 2010 and 2011[6]. The scope of analysis was narrowed to study price behavior during peak hour and off peak hours.

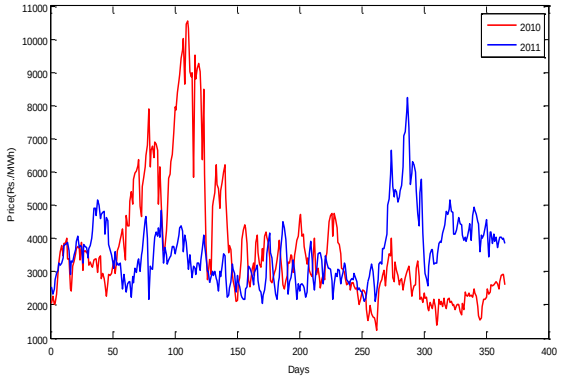

Figure 2. Plot electricity price vs time for year 2010 and 2011

Electricity price graph plot of the year 2010 and 2011 from the IEX power trade is shown in Fig. 2. Price will very high in 2010 year in month of April 2010 and in 2011 year in the month of October 2011. Power production price will be indicated and demand also indicated. As the electricity price is determined by the equilibrium point between the demand and supply, it is accepted that the available generation capacity has a large electricity price factor.

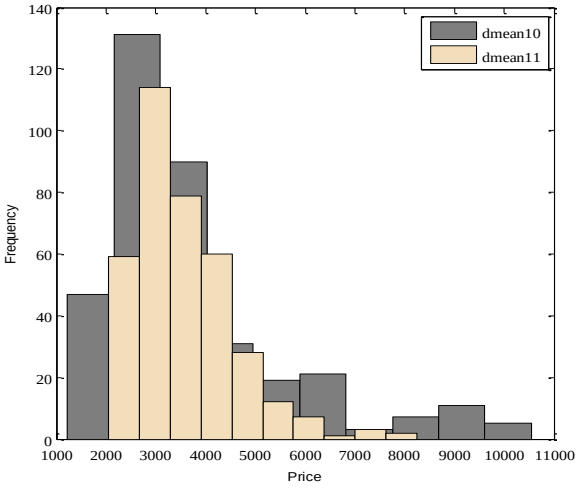

Figure 3. Price frequency histogram mean 2010 and 2011

The mean value of the electricity price exhibits less volatility and less difficulty in its forecast compared to individual price values. The electricity price depends on a particular period which plays an important part for the market participants in optimizing their system operation and hence in there planning studies [7]. To identify the likely statistical distribution, the histograms were prepared in Fig. 3 for price probability in the year 2010 and 2011.

A. Statistical approach

Normal distribution:-

The normal distribution approximates many natural phenomena so well, it has developed into a standard of reference for many probability problems. Continuous for all values of X between -∞ and ∞ so that each interval of real numbers has a probability other than zero. As the normal distribution is actually a family of distributions, two parameters μ and σ are to be taken. Since μ and σ determine the shape of the distribution, the notation (μ, σ^2) means normally distributed with mean and variance.

$$f(x;\mu,\sigma^2) = \frac{1}{\sqrt{2\Pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \qquad (1)$$

Lognormal distribution:-

A random variable is said to have a lognormal distribution with parameters μ and σ if its logarithm has a normal distribution with mean μ and standard deviation σ.

$$f_x(x;\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\Pi}} e^{-\frac{(\ln x-\mu)^2}{2\sigma^2}}, x>0 \qquad (2)$$

Weibull distribution:-

Both α and β are greater than zero and represent the shape and scale parameters, respectively.
The pdf = 0 if x < 0

$$f(x) = \frac{\alpha x^{\alpha-1}}{\beta^{\alpha}} \times e^{-\left(\frac{x}{\beta}\right)^{\alpha}}, x<0 \qquad (3)$$

IV. RESULTS AND DISCUSSION

Three theoretical cumulative distribution functions formed the parameters computed from the sample data shown in figure 4 & 5 which shows the cumulative distribution of one hour 16th hour (from 15:00-16:00) data of 2010 and 2011 for statistical distribution.

The statistical parameters of the price data at one hour could be easily computed from the available data.

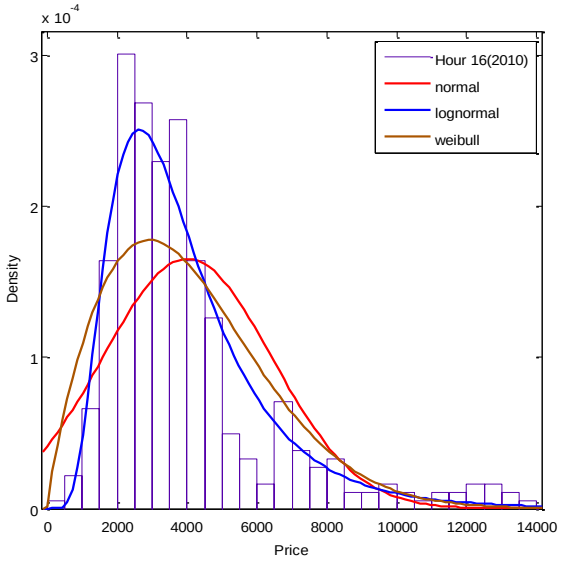

Figure 4. Statistical distribution of 16th hour of 2010

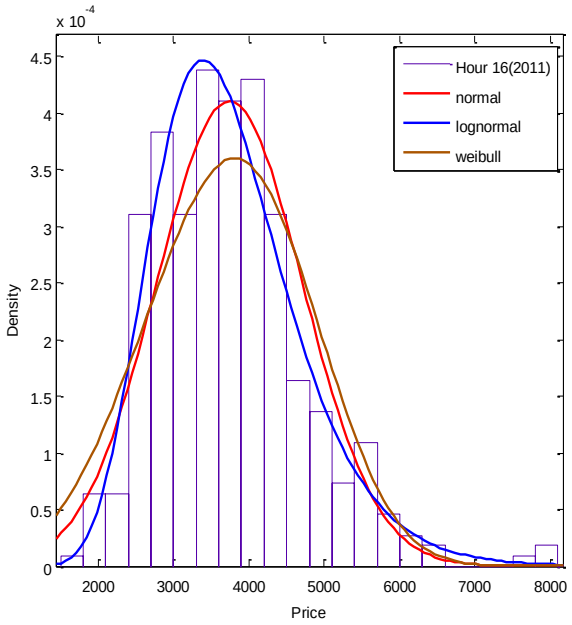

Figure 5. Statistical distribution of 16th hour of 2011

In this data used normal, lognormal and weibull distribution. On the basis of the shape of the histogram, three common theoretical statistical distributions are identified for investigation, which can fit the data are- Normal distribution, lognormal distribution and Weibull distribution [10-11]. The price can be specified only probabilistically. Therefore, the bid for electricity price should be developed such that the probability of its bid being successful and it should be the range of the capacity factor which makes it the most economical distribution.

It can be observed from the normal, lognormal and weibull curve, the lognormal curve seems to fit better during peak and off periods.

If these observations could be generalized, it would make them useful in modeling the price behavior in planning studies and operations planning. Normal and weibull distributions do not fit well during peak and off peak periods.

The comparison of the histogram and the density functions using the parameter (i.e. the mean and standard deviation) calculate from the actual data will also give the better match. The density functions adopting normal, lognormal and weibull distribution along with the actual histogram. It is seen that lognormal distribution is best fit other than distributions.

Indian electricity market price analysis of sixteenth hour data for 2010 and 2011 and find the distribution parameter for the normal, lognormal and weibull distribution. In the lognormal parameter scale and shape give the best approximate result compare to other distribution. So finally lognormal distribution is perform better for data analysis and mathematical distribution parameter.

TABLE I
Estimated Parameters of Different Distributions of Year 2010 and 2011

	2010						2011					
Hours	Normal		Lognormal		Weibull		Normal		Lognormal		Weibull	
	Mean	SD	Scale	Shape	Scale	Shape	Mean	SD	Scale	Shape	Scale	Shape
00 – 01	3001.73	1887.81	7.828	0.609	3391.79	1.722	2918.70	1003.20	7.93	0.311	3260.99	2.91
01 – 02	2893.54	1843.19	7.790	0.607	3268.64	1.706	2779.09	987.85	7.88	0.317	3111.13	2.83
02 – 03	2828.02	1798.08	7.770	0.600	3195.62	1.712	2701.25	1007.26	7.85	0.324	3030.37	2.70
03 – 04	2751.65	1707.26	7.754	0.581	3112.88	1.753	2693.22	1024.06	7.84	0.334	3024.59	2.67
04 – 05	2796.50	1611.02	7.789	0.548	3169.76	1.873	2755.51	989.45	7.87	0.318	3087.04	2.81
05 – 06	3165.66	1691.99	7.939	0.485	3593.15	2.011	3022.87	1093.31	7.95	0.341	3389.84	2.87
06 – 07	3299.69	1780.32	7.980	0.482	3747.75	1.999	3102.22	1090.04	7.98	0.350	3477.42	3.07
07 – 08	3434.97	1759.77	8.026	0.475	3899.10	2.093	3260.53	1257.97	8.02	0.378	3670.55	2.76
08 – 09	3647.31	1785.66	8.092	0.468	4137.78	2.186	3430.34	1245.42	8.08	0.358	3849.86	2.93
09 – 10	3830.20	1868.73	8.142	0.464	4345.82	2.195	3625.74	1282.67	8.14	0.343	4062.87	2.98
10 – 11	4023.40	1892.70	8.201	0.441	4561.28	2.267	3825.74	1300.49	8.19	0.333	4277.64	3.10
11 – 12	4095.65	1966.75	8.217	0.442	4643.07	2.214	3994.71	1245.40	8.25	0.307	4443.15	3.35
12 – 13	4032.42	2013.59	8.197	0.450	4574.70	2.136	3982.65	1190.71	8.25	0.291	4418.92	3.46
13 – 14	3920.85	2056.15	8.161	0.465	4449.34	2.043	3852.85	1096.88	8.22	0.281	4262.72	3.67
14 – 15	4026.19	2287.41	8.173	0.489	4570.20	1.909	3848.90	1004.43	8.22	0.259	4232.95	3.92
15 – 16	4010.24	2410.89	8.153	0.526	4545.56	1.815	3740.39	972.14	8.19	0.255	4112.68	3.88
16 – 17	3865.28	2399.22	8.114	0.525	4378.88	1.772	3583.26	1098.46	8.14	0.289	3979.97	3.29
17 – 18	3741.08	2152.05	8.102	0.482	4245.02	1.890	3650.11	1302.99	8.15	0.324	4087.17	2.84
18 – 19	4098.42	1985.36	8.231	0.395	4643.41	2.174	3992.31	1450.42	8.24	0.330	4473.47	2.79
19 – 20	5001.13	2117.38	8.443	0.377	5644.45	2.451	4711.42	1338.94	8.42	0.262	5207.03	3.42
20 – 21	4602.43	2043.75	8.344	0.425	5205.94	2.382	4694.78	1251.70	8.42	0.253	5169.50	3.66
21 – 22	4305.97	2103.25	8.261	0.459	4879.50	2.174	4481.74	1261.44	8.37	0.255	4947.95	3.37
22 – 23	3906.30	2244.33	8.129	0.521	4434.32	1.887	3830.02	1072.51	8.22	0.262	4226.81	3.44
23 – 24	3432.15	2153.28	7.970	0.577	3884.68	1.737	3326.45	1008.48	8.07	0.282	3691.23	3.28

V. CONCLUSIONS

The price behavior in Indian power market has been studied to find a suitable statistical distribution to describe the behavior of electricity price in Indian power market. Three possible theoretical distributions namely the normal, the lognormal and weibull were identified as possible distributions. It was found that after filtering extreme values the results improved to some extent. The results on annual data were not sufficient to statistically characterize the data, hence regrouping of data in monthly samples is done and the results improved significantly. Graphical and statistical analysis has been to find the best fitting theoretical distribution for electricity price. Proposed statistical analysis of Indian electricity market price can give an approach to generation companies to develop optimal bidding strategies.

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