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DATA DRIVEN INSIGHTS FROM STATISTICAL ANALYSIS OF ELECTRICITY TRADING IN DAY AHEAD AND REAL TIME MARKETS AT THE INDIAN ENERGY EXCHANGE

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Abstract: The Indian Energy Exchange (IEX) is the largest and most liquid electric power trading exchange currently operational in India. The power trading data freely available through its online portal have been analyzed in this study. The real time, day ahead and green day ahead market characteristics from October 2024 to September 2025 have been examined in terms of market clearing prices and energy volumes. For the day ahead market, the monthly average clearing prices vary from Rs 1833/MWh to Rs 6780/MWh. For the green day ahead market, the observed price range is Rs 2445-7032/MWh. For the real time market, it is Rs 1412-7480/ MWh and this market is seen to have the broadest price range and is also the most volatile out of the three considered. Within-day price volatilities are higher than within month volatility. Prices and volumes at market clearing conditions as also log returns on price are approximately normally distributed for all three markets. But they do not show uniform linear correlation throughout the year, with positive and negative values at different times. Price spreads in different markets vary significantly, with average day ahead market clearing prices being lower than that in the green day ahead market and higher than the real time market prices.

Keywords: electricity trading; India; IEX; power market; statistics

JEL classification: C1, L1, L9

1. INTRODUCTION

1.1. Electricity Markets

Electricity markets provide a platform to power producers and consumers to interact and they lead to price discovery through demand supply matching over different time blocks in a day. It leads to economically efficient outcomes for the agents involved in power trading. Electricity markets are a critical component of emerging energy systems and the clean energy transition, where deep, economy-wide electrification will play a key role in energy sector and industrial decarbonization, including that in the net zero emissions targets of India **(Bhattacharyya et al, 2022)**. Cost effective and reliable electricity production and supply are the bedrocks of this energy transition, which is likely to be better facilitated through organized, efficient and liquid market structures that maximize social welfare.

Internationally, very well-developed and regionally integrated power markets exist in the European Union, UK, and USA with sophisticated trading platforms, arrangements and pricing mechanisms in place. These include Nordpool and European Energy Exchange. Market data in these regions have been used extensively in research work, for example in a recent evaluation of the historical volatility characteristics of the intra-day market of the Netherlands **(Birkeland et al, 2024)**.

The Indian electricity sector is quite complex as it is a concurrent subject in the Indian constitution; hence it is under the purview of both Central and State agencies. There are multiple agencies representing generation, transmission and distribution activities (which have now been unbundled) and various kinds of power users and regulatory agencies making up the rest of the landscape. The Indian power market operation is still dominated by long term power purchase agreements (PPAs) between power generators and purchasers or end users. Prices are mainly determined by tariff policies and enforced through these contracts and not by real time dynamics of power demand and supply. However, the markets must evolve to keep up with changes in the supply mix such as the need for clean energy transition and increased end use electrification, decarbonization of the power sector, facilitating the integration of higher shares of VREs in the power generation side, incorporation of demand side measures, energy storage and flexibility mechanisms in the electricity grid

to ensure demand supply matching and overall efficiency of power supply to users **(Bhattacharyya et al, 2024)**. Many mechanisms and policy changes to enable these transformations are being brought into the electricity sector. One of them has been the establishment of power exchanges like the Indian Energy Exchange (IEX) to facilitate greater efficiency in power trading.

Indian Energy Exchange is the largest electric power exchange in India at present (the two others being Power Exchange of India Ltd./PXIL and Hindustan Energy Exchange Ltd./HXL). It was set up in 2007 and its operations began in 2008. Here optimal scheduling of generation and physical trading of power takes place, with settlement of the price and quantity bids in different markets. It facilitates the operation of several types of electricity markets such as the day ahead market (DAM) with trading happening 24 hours before the date and time of settlement, real time market (RTM) with settlement in the next 1 hour and green day ahead market (GDAM) for transactions involving renewable electricity, along with facilities to trade renewable energy certificates and energy savings certificates **(IEX, 2025)**. There is also a term ahead market (TAM) and a high-priced segment of the day ahead market. The IEX platform is currently used by over 850 conventional power generation companies, more than 2100 renewable energy producers and over 4900 industrial and commercial power consumers and end-users. Currently, the total volume of energy traded through IEX is about 8-10% of total electricity generated in India (for example, 11803 million units of electricity were traded on IEX in August 2025 as against the national total consumption of 150.47 billion units), but there have been recent calls to trade all generated power in India through these exchanges. Recently all three power exchanges of India have been market-coupled to enable uniform power price discovery across the country. Electricity derivatives in the form of futures contracts of 1 to 3 months' maturity duration are also being traded on the National Stock Exchange (NSE) and Multi Commodity Exchange (MCX) since July 2025 in trading units of 50 MWh, as a way to hedge against electricity price volatility, adverse price movements and to manage the associated financial risks to industrial power consumers **(MCX, 2025)**.

A limited number of prior academic studies on energy markets of India and energy trading platforms have been performed. Dalvadi and Trivedi **(2011)** have provided a brief overview of the initial few years of operation of the IEX. A compilation of data on renewable energy certificate trading in India through

IEX and PXIL in FY 2012-13 has been provided **(Girish et al, 2015)** but without detailed statistical assessments. The role of India Energy Exchange and power volumes traded through it during initial few years till 2014 have also been reported **(Girish and Vijayalakshmi, 2015)**. A comparison of IEX and PXIL operations has been made using trading data up to 2015 **(Trivedi, 2016).** A detailed review of energy trading in India with focus on IEX and PXIL has been carried out **(Santhosh, 2019).** Congestion characteristics of IEX and performance with respect to meeting renewables purchase obligations in India have been evaluated using trading data **(Ahmad and Alam, 2019).** A detailed evaluation of the real time market in India has also been reported **(Agrawal, 2022)**. IEX and PXIL performance in the context of global electricity exchanges in 20 nations have been evaluated as well, highlighting that electricity prices decrease as the share of power made available through exchanges increases in a country **(Gupta and Guha, 2024)**. The specific contributions of power exchanges to support the green power market in India has been the subject matter of a recent study **(Reddy et al, 2025)**.

1.2. Motivation and Objectives of the Study

The operations of IEX have attracted the attention of researchers but none of these studies have performed a detailed statistical characterization of the recent performance of the power exchange. This study is motivated by the need to address this gap area. The available price and volume data sets from 3 major market segments of IEX are studied to extract key statistical insights into the working of the electricity market in India in recent times. This is important because these data sets have signatures of both demand side and supply side of the market, integrated through the market clearing and price discovery process. The intended objectives of this academic study based on energy market data analytics are to obtain data driven insights to support following aspects:

i) The seasonal and diurnal characteristics of power trading in India and their statistical features for use in forward looking analyses for electrified products and services, including techno-commercial studies, project financial modeling including assessments under uncertainty of input data by methods like Monte Carlo simulations,

ii) Possibilities of evaluation of operations planning and power consumption scheduling in industries according to the dynamic

pricing trends; industries can thus take advantage of lower prices in off-peak hours to reduce average energy procurement costs for their operations,

iii) Potential for energy arbitrage operations and scheduling the deployment of flexible loads (e.g., water electrolysers) and energy storage to take up surplus available energy or low-cost power as per availability, while minimizing or completely preventing generation curtailment to the extent possible,

iv) Provision of inputs towards pricing of financial products like electricity derivatives which are meant to provide a hedge against power price risk to commercial and industrial consumers.

2. DATASETS AND ANALYSIS METHODOLOGY

The analysis is carried out for the time-series data set for the one-year timeframe from 1st October 2024 to 30th September 2025. All data (as stated in Table 1) are obtained from the IEX website (available at www.iex.com). For each type of market analyzed in this study, daily data on average market clearing price (MCP) and market clearing volume (MCV) are collected and used for each month to understand monthly and seasonal trends in these variables. Data for one representative day per month (in this study, the 15th day of each month is chosen) are also examined at hourly resolution to decipher intra-day trends of power trading in different markets during different seasons of the year. Using the raw data, first data visualizations are created. Then the statistical distributions of prices and volumes in different months and within a typical day are examined and the corresponding key statistical features such as means, variances, covariances are extracted from them. Spreads in prices across different markets are also studied.

For a time-series data set represented as $y[k]$, with a total of N observed elements such that k goes from 1 to N, the mean value is calculated as **(Navidi, 2011)**

$$\bar{y} = \frac{1}{N} \sum_{k=1}^{N} y[k] \tag{1}$$

In this study, *y[k]* represents the series of market clearing prices of electricity or market clearing volumes of energy in a given market of IEX, with the index k going from 1 to N. Depending on the month, N varies from 28 to 31 for the monthly time series with daily data and has value of 24 in case of a daily time series data set at hourly data resolution.

The standard deviation σ_y of the elements of the time series $y[k]$ is

$$\sigma_y = \frac{1}{N-1}\sqrt{\left(\sum_{k=1}^{N}(y[k]-\bar{y})^2\right)} \tag{2}$$

The coefficient of variation (*COV*) for a given series shows the spread in the elements of the time series relative to the mean and it is given by

$$COV = 100 \times \frac{\sigma_y}{\bar{y}} \tag{3}$$

For two time series data sets given by $y[k]$ and $x[k]$, the linear correlation coefficient ρ_{xy} between them is given by

$$\rho_{xy} = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \tag{4}$$

where the covariance σ_{xy} is calculated as

$$\sigma_{xy} = \frac{1}{N-1}\sqrt{\left(\sum_{k=1}^{N}(y[k]-\bar{y})\left(\sum_{k=1}^{N}(x[k]-\bar{x})\right)\right)} \tag{5}$$

The spread in values of two time series $x[k]$ and $y[k]$ with respect to $x[k]$ is evaluated as

$$spread[k] = \frac{100 \times (x[k]-y[k])}{x[k]} \tag{6}$$

The log returns $R[k]$ from adjacent values in a time series data set $y[k]$ are calculated as follows:

$$R[k] = ln\frac{y[k+1]}{y[k]} \tag{7}$$

Table 1: Power market types and analyzed data sets

Type of power market	Market data analyzed
Day ahead market	1. Market clearing power prices and market clearing volumes at daily intervals for 1 year
Real time market	2. Hourly data on prices and volumes for a specific day of each month
Green day ahead market	

3.   RESULTS AND ANALYSES

3.1. Day ahead market

Figs. 1a and 1b show the trends in average market clearing prices and total traded power volumes of each day of each month. The overall range of average daily power prices has remained between Rs 1.83/kWh (in June 2025) to Rs

6.78/kWh (in April 2025), indicated by the horizontal magenta lines in Fig. 1a. The non-stationary nature of the time series data is also demonstrated, as the means and variances have changed from month to month. On a single day, total energy volume traded has ranged from about 83 GWh (in April 2025) to 256 GWh (in December 2024). Across different months, the ratios of maximum to minimum daily traded volumes are seen to lie between 1.20 to 2.54, while the maximum to minimum price ratios for days in a month range from 1.56 to 3.01.

In Fig. 2a, the almost completely uncorrelated nature of daily average market clearing price and total volume traded at the clearing point is seen from the high levels of scatter in the data (linear correlation coefficient = +0.049).

Fig. 2b shows the distributions of the daily average clearing price and market clearing volumes for the whole year, in the form of histograms. For the price data, skewness is 0.077 and kurtosis is 2.855. For the volume data, the corresponding values are -0.126 and 2.566 respectively. Fig. 2c shows the normal probability plots of these quantities which further helps establish that the data for both variables appear to conform reasonably to Gaussian distributions.
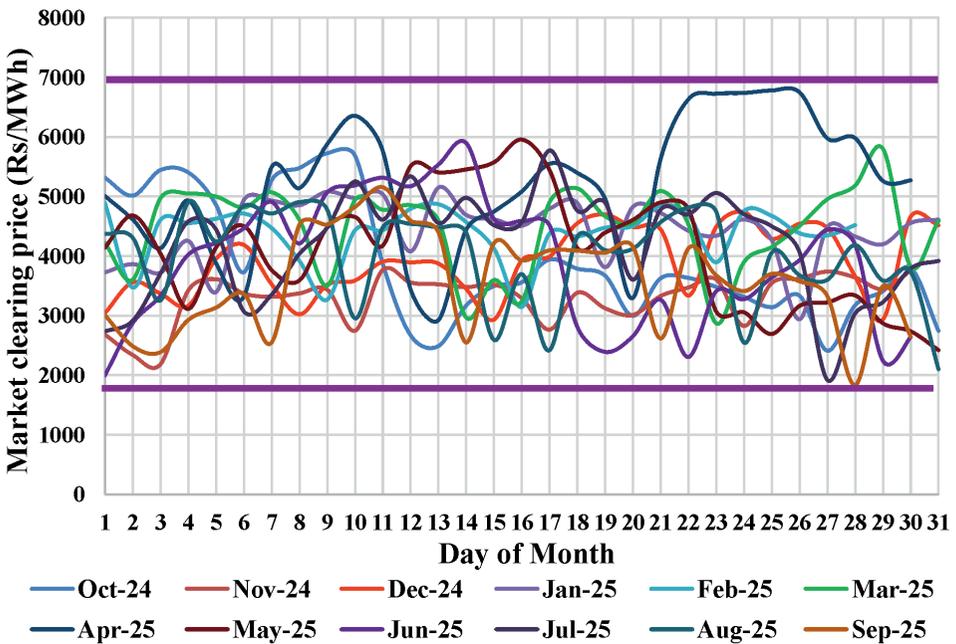

Fig. 1a: Daily average market clearing price data from day ahead market of IEX (October 2024 to September 2025)
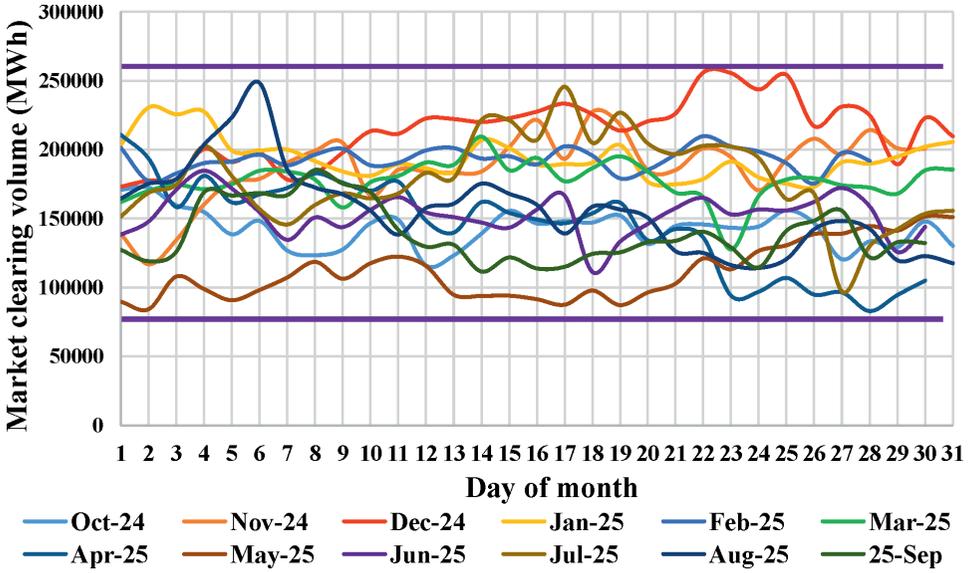
Fig. 1b: Daily market clearing volume data from day ahead market of IEX (October 2024 to September 2025)

Fig. 2a: Daily market clearing volume versus average market clearing price from day ahead market of IEX (October 2024 to September 2025)
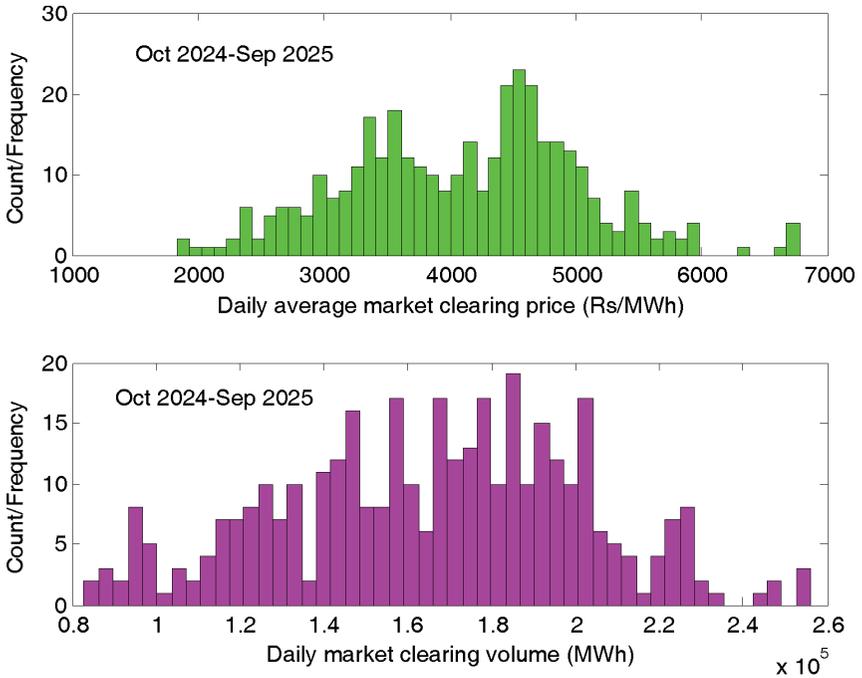
Fig. 2b: Distributions of daily average market clearing price and volume in day ahead market of IEX (October 2024 to September 2025)
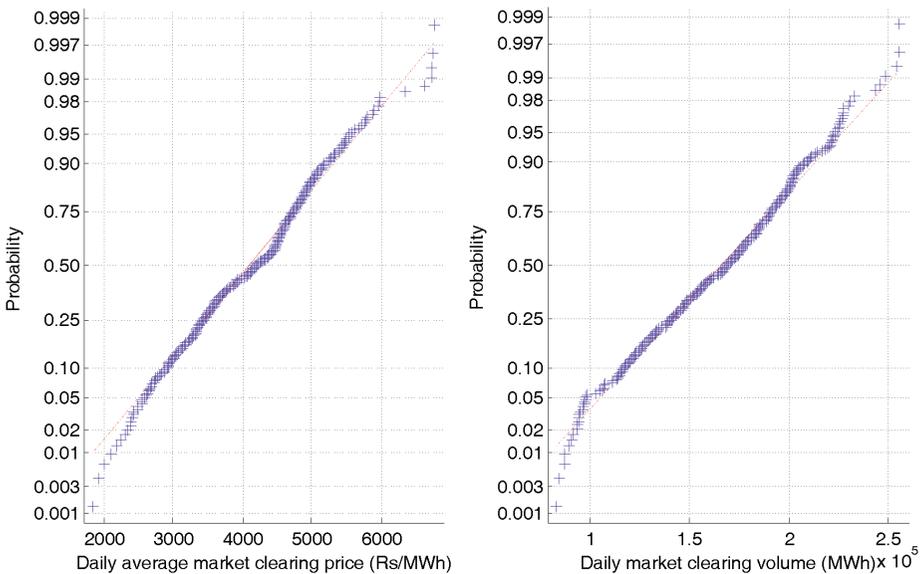

Fig. 2c: Normal probability plots of daily average market clearing price and total traded volume in day ahead market of IEX (October 2024 to September 2025)

Table 2 presents calculated key statistics for the clearing price and volume data for each month. The across-months volatility in market clearing price is higher than the volatility of traded volumes as seen from the corresponding COV values reported here. The correlation coefficient between these two variables within a month shows values ranging from -0.72 to +0.77, which shows that these values are far better correlated within a given month than that across a whole year. This indicates a strong seasonal characteristic of day ahead energy trading at IEX.

Table 2: Key statistics on daily traded volumes of electricity and market clearing prices in day ahead market of IEX

Month	Mean volume (MWh)	Standard deviation (MWh)	COV of volumes (%)	Mean price (Rs/MWh)	Standard deviation (Rs/MWh)	COV of price (%)	Price-volume correlation coefficient
October 24	142576.2	13885.3	9.74	3923.54	1013.33	25.83	0.35
November 24	187231.2	24989.19	13.35	3295.99	410.03	12.44	0.68
December 24	214294.5	23093.99	10.78	3894.09	576.91	14.82	0.51
January 25	194109.3	14813.98	7.63	4438.92	526.54	11.86	-0.25
February 25	193164.2	8159.355	4.22	4381.30	458.32	10.46	0.19
March 25	177373.4	14161.83	7.98	4466.82	710.24	15.90	0.09
April 25	145057.1	34218.2	23.59	5203.07	1099.02	21.12	-0.42
May 25	111652.1	20466.45	18.33	4129.75	987.07	23.90	-0.72
June 25	152699.1	15026.42	9.84	3904.19	1092.53	27.98	0.30
July 25	178805.9	31585.11	17.66	4189.15	874.37	20.87	0.77
August 25	156013.6	31380.49	20.11	4001.16	791.91	19.79	0.37
September 25	139050.7	20954.29	15.07	3579.59	883.86	23.29	0.20

Figs. 3a and 3b show results of pricing and trading dynamics within a typical day of each month, at hourly resolution. Here, the 15th day of every month is chosen as a representative day. Volatility in prices on hourly basis within a day is found to be much higher than volatility on daily average price basis for a given month, as is seen by the calculated values of intra-day COV reported in Table 3. Both price and volume data show a day time and an evening time peak in each month, though the magnitude of this peak varies greatly from month to month. The power price cap of Rs 10000/MWh is also hit at certain times of the day in certain months, notably during evening hours and midnight to early morning hours. These are hours of high power demand relative to the supply available on the exchange. This feature is not revealed

by analyzing only the daily average prices for each month; on a monthly average basis, therefore market price cap is not hit. Power price depression is also seen during morning and afternoon hours, very substantially in some months of the year. This is mainly due to surplus solar power availability on the exchange. These hours may therefore be considered the best times for serving discretionary loads such as electric vehicle charging, and battery energy storage system charging and other non-critical services.
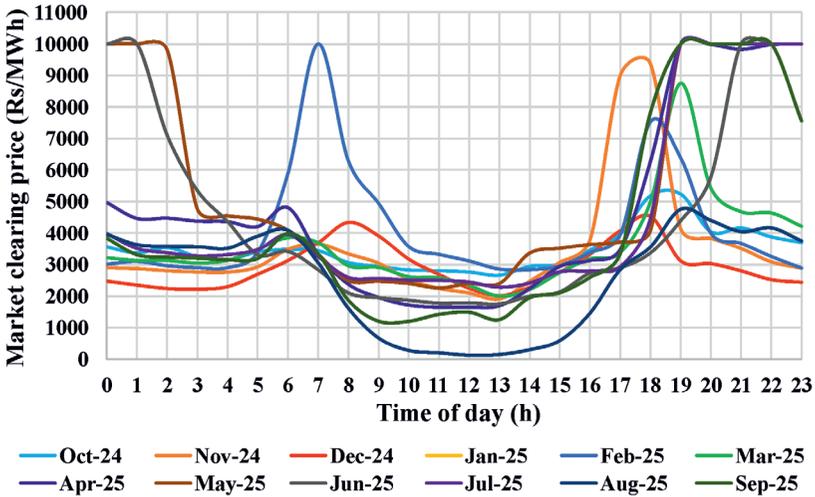

Fig. 3a: Hourly price data from day ahead market of IEX for a representative day of each month (October 2024 to September 2025)
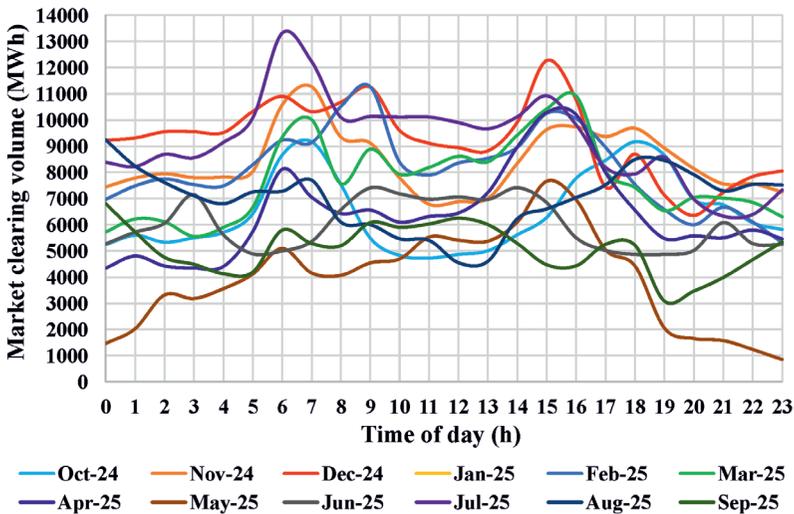

Fig. 3b: Hourly MCV data from day ahead market of IEX for a representative day of each month (October 2024 to September 2025)

**Table 3: Key statistics of hourly power trading in day ahead market of
IEX within a representative day of each month**

Day of the month	Mean volume (MWh)	Standard deviation (MWh)	COV of volumes (%)	Mean price (Rs/MWh)	Standard deviation (Rs/MWh)	COV of price (%)
15 October 24	6485.17	1462.35	22.55	3493.57	673.56	19.28
15 November 24	8409.54	1197.02	14.23	3520.04	1829.19	51.97
15 December 24	9284.52	1438.94	15.50	2931.39	720.84	24.59
15 January 25	8136.06	1501.95	18.46	4129.35	1824.60	44.19
15 February 25	8136.06	1501.95	18.46	4129.35	1824.60	44.19
15 March 25	7712.31	1540.31	19.97	3596.52	1407.53	39.14
15 April 25	6422.31	1692.48	26.35	4745.60	2990.17	63.01
15 May 25	3919.46	1868.99	47.68	5572.34	3258.21	58.47
15 June 25	5973.06	931.99	15.60	4622.77	3132.78	67.77
15 July 25	9219.62	1682.68	18.25	4517.28	2924.89	64.75
15 August 25	6999.39	1197.73	17.11	2592.67	1656.81	63.90
15 September 25	5075.54	928.65	18.30	4212.70	3124.81	74.18

Fig. 4a and 4b show market clearing conditions within two selected 15-minute time blocks on a specific day (e.g., 25.9.2025 in this work). Fig. 4a shows market clearing at a sufficiently low power price of about Rs 1.35/kWh (i.e., lower than the average values reported in Tables 2 or 3) at about 10 AM, whereas Fig. 4b shows the conditions when market clearing occurred at about 8:45 PM on the same day at the price cap or ceiling of Rs 10/kWh currently set at the exchange.

3.2. Green day ahead market

The green day ahead market of IEX trades renewable electricity drawn from solar, non-solar and hydel power generators. Table 4 reports the major statistics drawn from the daily trading data. Volatility in the scheduled volume of energy is less than that in the price; this is like the trend observed in the day ahead market as well. The volume of green energy traded in a day is about 15 to 26% of the volume traded in the general day ahead market; this is also roughly in conformity with the share of non-fossil electricity generated in India relative to the total electricity generation as per the currently installed generation mix. Within a given month, the ratio of maximum to minimum price is found to be between 1.78 and 2.77; for the traded volumes, the ratio takes on values between 1.58 and 2.00. The linear correlation between price and volume in this

market is negative (-0.47); this is a major difference from the characteristics of the day ahead market where the correlation is very weakly positive.

Table 5 shows the contributions of various renewable generation technologies to the total traded volume of the green day ahead market at the market clearing condition. The seasonal nature of these contributions is quite evident from the results in Table 6; the solar shares in the green day ahead market is high in most months but they drop markedly in the monsoon months while hydel power and non-solar (mainly wind energy) share rises correspondingly.

Fig. 5a shows the spread or difference between average power prices in the day ahead and green day ahead markets on the same trading day, in the form of a percentage difference figure. As seen from this figure and Fig. 5b, on IEX, this spread is mostly negative, clearly seen in the left skew of the distribution of spread values. The difference ranges from – 64.3% to +19.5%, with an annual average of -13.5%. This is a measure of the "green premium" observed in electricity prices in IEX over the study period. Based on the number of positive and negative values of this daily difference, it is concluded that the average green day ahead market prices have been higher than the average regular day ahead market prices in about 87.1% of all days between October 2024 to September 2025.

Fig. 4a: Day ahead market clearing conditions at 10:00-10:15 AM on 25ᵗʰ September 2025 (Image source: IEX website)

Fig. 4b: Day ahead market clearing conditions at 20:45-21:00 PM on 25th September 2025 (Image source: IEX website)

Table 4: Key statistics on daily traded volumes of electricity and market clearing prices in green day ahead market of IEX (October 2024 to September 2025)

Month	Mean volume (MWh)	Standard deviation (MWh)	COV of volumes (%)	Mean price (Rs/MWh)	Standard deviation (Rs/MWh)	COV of price (%)	Price – volume correlation coefficient
October 24	26533.18	2607.68	9.83	4556.75	871.34	19.12	-0.41
November 24	26343.15	1524.59	5.79	3813.44	311.67	8.17	-0.26
December 24	24914.22	3426.28	13.75	4217.75	481.86	11.42	-0.74
January 25	22406.11	2412.82	10.77	5027.77	385.84	7.67	-0.38
February 25	18852.30	3009.12	15.96	4822.59	338.75	7.02	-0.34
March 25	18587.19	1686.25	9.07	4846.80	436.93	9.01	-0.43
April 25	22791.09	2447.65	10.74	5576.05	863.19	15.48	+0.03
May 25	26596.61	4412.88	16.59	4982.12	1125.41	22.59	-0.86
June 25	31269.78	3673.97	11.75	4386.63	1162.80	26.51	-0.57
July 25	32222.72	4974.77	15.44	4380.08	895.36	20.44	-0.18
August 25	29101.96	3654.29	12.56	4373.17	646.57	14.78	-0.28
September 25	33149.03	4484.87	13.53	4041.42	784.34	19.41	-0.64

Table 5: Share of various renewable generators in market clearing volumes of green day ahead market of IEX (October 2024 to September 2025)

| Month	Mean solar share (%)	Standard deviation of solar share (%)	Mean non-solar share (%)	Standard deviation of non-solar share (%)	Mean hydel share (%)	Standard deviation of hydel share (%)
October 24	52.66	7.88	41.59	6.62	5.75	2.08
November 24	49.84	11.48	46.85	12.07	3.31	0.71
December 24	29.64	7.31	67.76	7.50	2.60	0.63
January 25	36.56	6.62	61.08	6.30	2.36	0.56
February 25	33.72	5.24	64.25	5.02	2.04	0.61
March 25	47.54	5.01	49.44	5.26	3.02	1.18
April 25	63.44	10.63	34.36	10.07	2.20	1.06
May 25	61.22	5.74	35.75	5.51	3.04	0.82
June 25	52.17	12.67	43.26	10.43	4.57	2.64
July 25	38.41	9.54	51.44	7.70	10.16	3.32
August 25	39.16	9.00	46.17	7.17	14.66	4.56
September 25	48.16	9.41	39.42	8.52	12.43	2.44
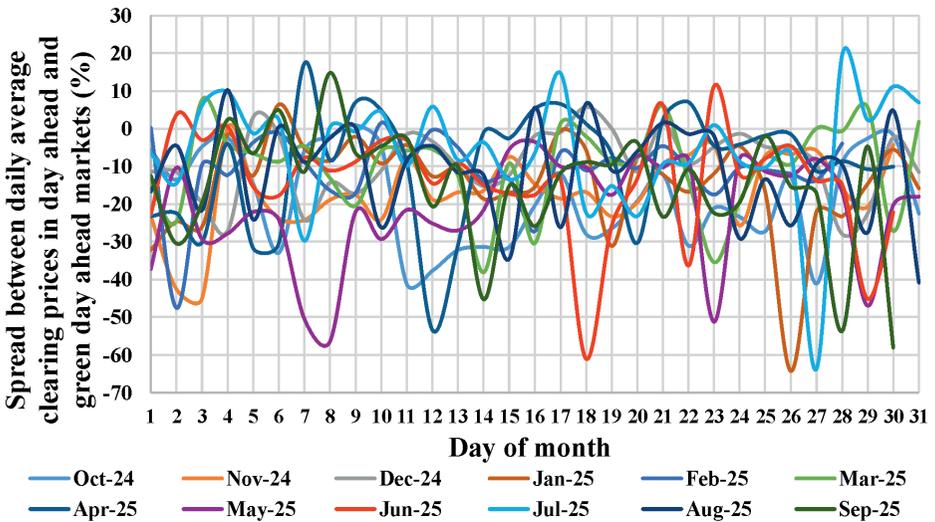
Fig. 5a: Difference between daily average market clearing prices in day ahead and green day ahead markets of IEX (October 2024 to September 2025)
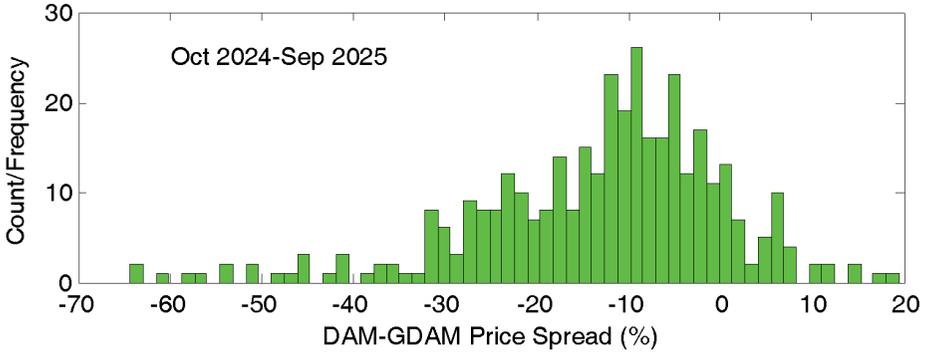
Fig. 5b: Distribution of price spreads in day ahead and green day ahead markets

Fig. 6 shows the linear correlation coefficient between daily average prices in each month for the day ahead and green day ahead markets. The prices have moved reasonably in tandem with one another from month to month, as can be seen from the moderate to high positive values of the month-wise correlation coefficients.

Fig. 7a and 7b exhibit the general distributional characteristics of the green day ahead market clearing prices and volumes. The skewness of price and volume data distributions are respectively 0.061 and 0.413, while kurtosis values are 2.915 and 3.083 respectively, showing that the data are reasonably approximated as being normally distributed.
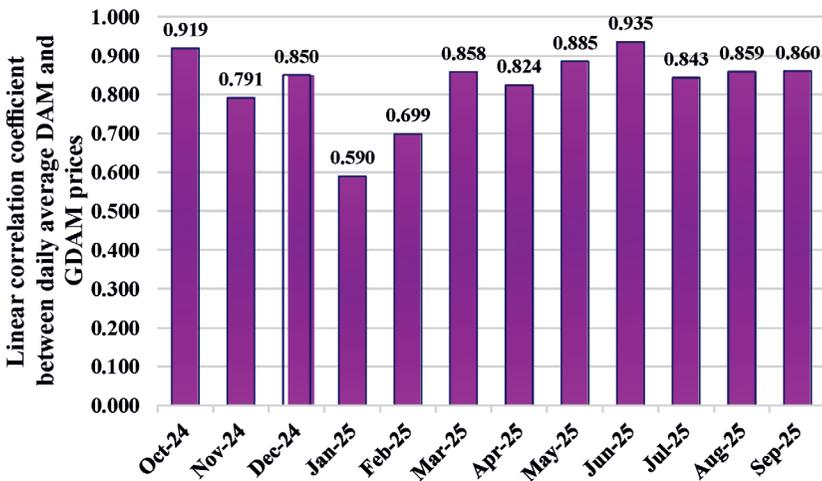
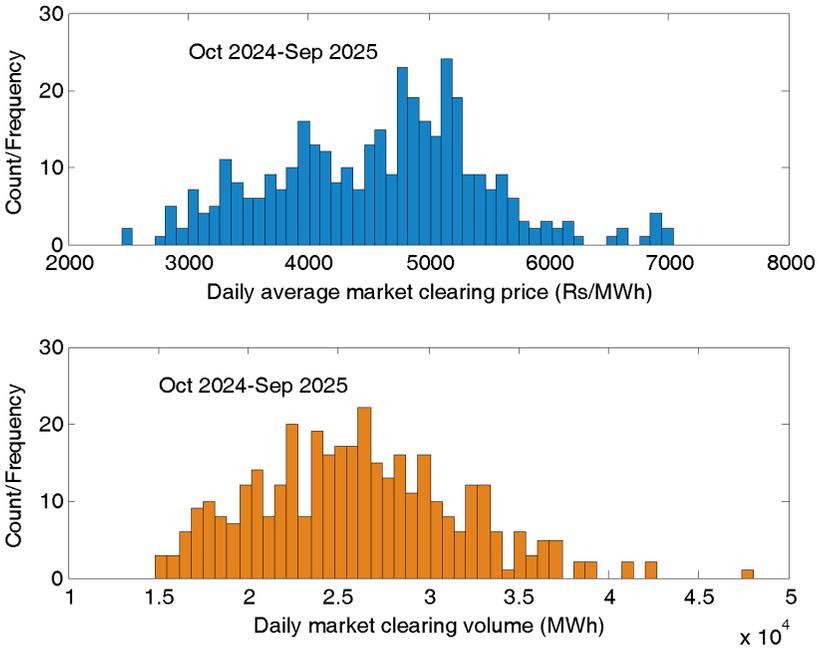**Fig. 6: Linear correlation between daily average market clearing prices at DAM and GDAM of IEX**

Fig. 7a: Distributions of daily average market clearing price and volume in green day ahead market of IEX (October 2024 to September 2025)
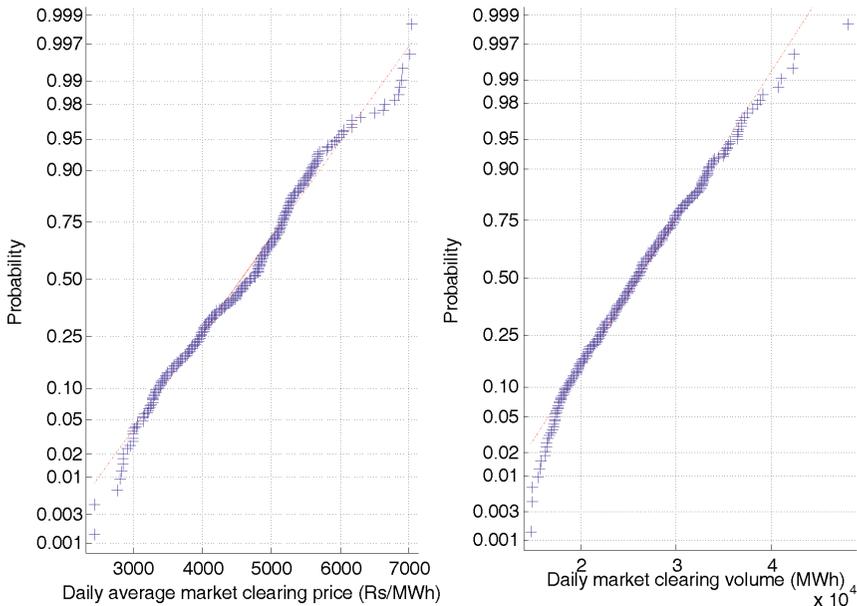

Fig. 7b: Normal probability plots of daily average market clearing price and total traded volume in green day ahead market of IEX (October 2024 to September 2025)

Fig. 8a and 8b express the nearly inverse nature of the relation between intra-day price and volume at market clearing conditions in the green day ahead market, using data from specific days of each month. This is more apparent from the performance of the green day ahead market compared to the characteristics of the general day ahead market (shown in Fig. 3a and 3b). Table 6 also shows that market clearing price and volume are almost similarly volatile within a given day in case of the green day ahead market, whereas the prices were more volatile for the ordinary day ahead market.
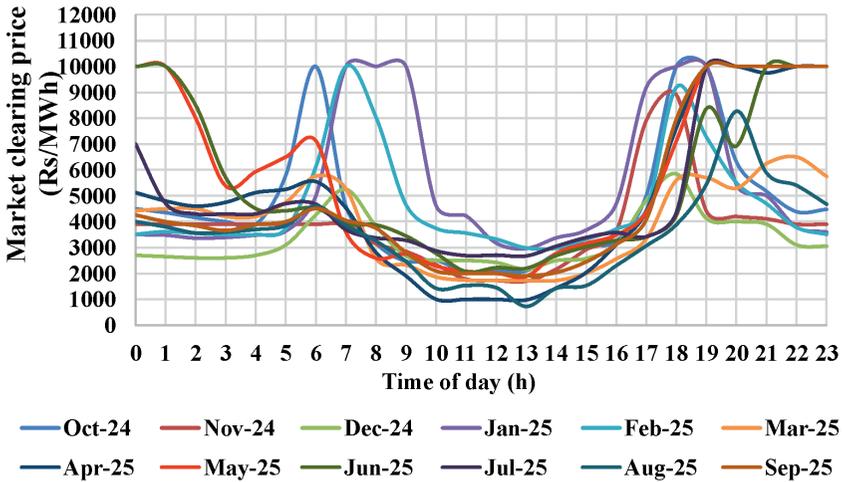
Fig. 8a: Hourly price data from green day ahead market of IEX for a representative day of each month (October 2024 to September 2025)
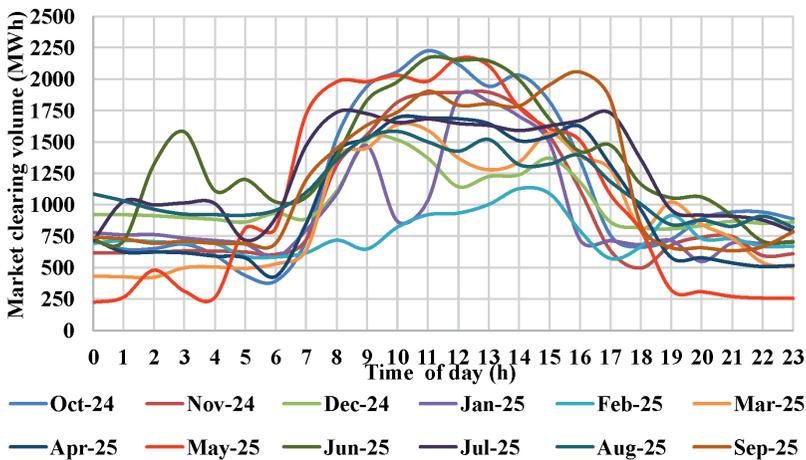
Fig. 8b: Hourly MCV data from green day ahead market of IEX for a representative day of each month (October 2024 to September 2025)

Table 6: Key statistics of hourly power trading in green day ahead market of IEX within a representative day of each month

Day of the month	Mean volume (MWh)	Standard deviation (MWh)	COV of volumes (%)	Mean price (Rs/MWh)	Standard deviation (Rs/MWh)	COV of price (%)
15 October 24	1153.30	620.59	53.81	4589.91	2386.50	51.99
15 November 24	1015.60	527.10	51.90	3781.90	1661.52	43.93
15 December 24	1032.65	229.44	22.22	3292.42	991.54	30.12
15 January 25	942.62	404.99	42.96	5399.65	2711.35	50.21
15 February 25	762.33	156.31	20.50	4677.62	1996.75	42.69
15 March 25	945.00	446.88	47.29	3928.97	1668.10	42.46
15 April 25	1015.10	492.55	48.52	4866.53	3189.22	65.53
15 May 25	1054.28	761.59	72.24	5877.54	3204.44	54.52
15 June 25	1356.45	488.37	36.00	5421.23	2938.97	54.21
15 July 25	1264.44	385.87	30.52	5127.74	2714.93	52.95
15 August 25	1138.28	259.00	22.75	3487.86	1747.66	50.11
15 September 25	1180.48	551.44	46.71	4851.50	2974.18	61.30

3.3. Real time market

The real time or spot market of IEX enables real time trading of power and settlement of the electricity delivery contracts to correct for near term imbalances between demand and supply. Unscheduled green power (e.g., excess solar power) may also be traded through this market.

Table 7 shows that the total power volumes traded in the real time market are somewhat lower than that in the corresponding month in the day ahead market for most of the months, except May and August 2025 (values of day ahead market shown in Table 2). However, the price volatility in this market in terms of the calculated COV values is found to be much higher than that in the corresponding months of the day ahead or green day ahead markets. Price-volume correlations are mostly negative within a month and considering the full annual data, the correlation coefficient is estimated as -0.44, which is similar to that in green day ahead market.

Fig. 9a shows the per cent difference or spread in the day ahead and real time market daily average clearing prices for every month; the spread ranges from -43.82% to +58.97%. Fig. 9b shows the distributional characteristics of the price spread between these markets, with 37.5% of the values being negative, indicating that the probability of having day ahead prices less than

the real time prices in about 0.375. It is also estimated from these data that here the day ahead price is on average, 5.31% higher than that in the real time market.

Table 7: Key statistics on daily traded volumes of electricity and market clearing prices in real time market of IEX (October 2024 to September 2025)

| Month	Mean volume (MWh)	Standard deviation (MWh)	COV of volumes (%)	Mean price (Rs/MWh)	Standard deviation (Rs/MWh)	COV of price (%)	Price-volume correlation coefficient
October 24	100731.22	10805.25	10.73	3773.92	799.99	21.20	0.018
November 24	100638.37	9000.43	8.94	3455.15	539.73	15.62	-0.369
December 24	102582.08	13734.44	13.39	3850.55	720.29	18.71	-0.668
January 25	97932.90	11026.72	11.26	4423.07	694.93	15.71	-0.495
February 25	103124.02	9980.47	9.68	4412.39	650.16	14.73	-0.372
March 25	120412.01	13341.98	11.08	4152.59	697.76	16.80	-0.300
April 25	129839.60	23896.43	18.40	4575.33	1307.86	28.58	-0.814
May 25	154466.74	24290.51	15.73	3433.74	1071.26	31.20	-0.505
June 25	144690.04	18974.86	13.11	3731.25	1308.59	35.07	-0.572
July 25	165261.97	14880.38	9.00	3833.11	923.54	24.09	-0.309
August 25	162474.87	24189.21	14.89	3384.28	850.61	25.13	-0.595
September 25	159629.93	25882.30	16.21	3313.39	900.77	27.19	-0.654
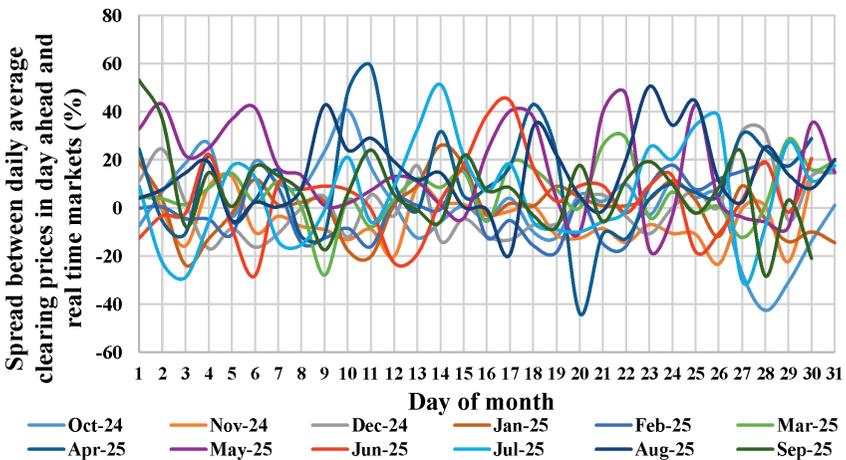
Fig. 9a: Difference between daily average market clearing prices in day ahead and real time markets of IEX (October 2024 to September 2025)
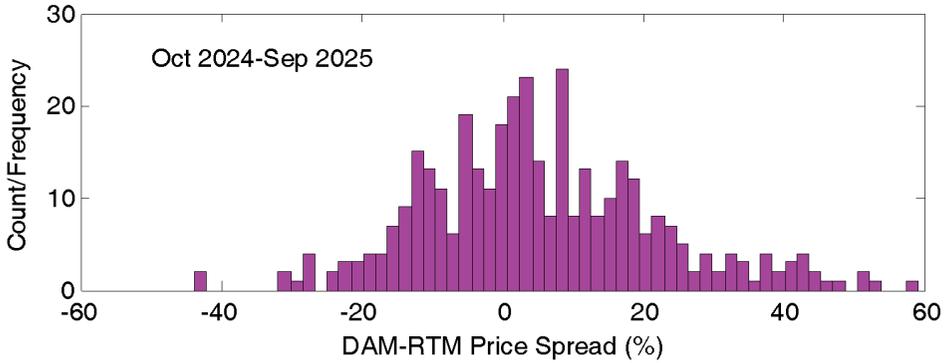
Fig. 9b: Distribution of price spreads in day ahead and real time markets

Fig. 10 shows that the linear association between real time and day ahead market prices are weaker than that in the day ahead and green day ahead markets (as shown in Fig. 6).

Fig. 11a and 11b indicate the statistical nature of price and volume data distributions in the real time market. The price skewness is 0.295 and volume skewness is 0.585. The price and volume kurtosis values are respectively 3.212 and 2.609. These distributions are more skewed than those of the other two market data sets analyzed in this study. The normal approximation is not very well applicable to the traded clearing volume data in this market.
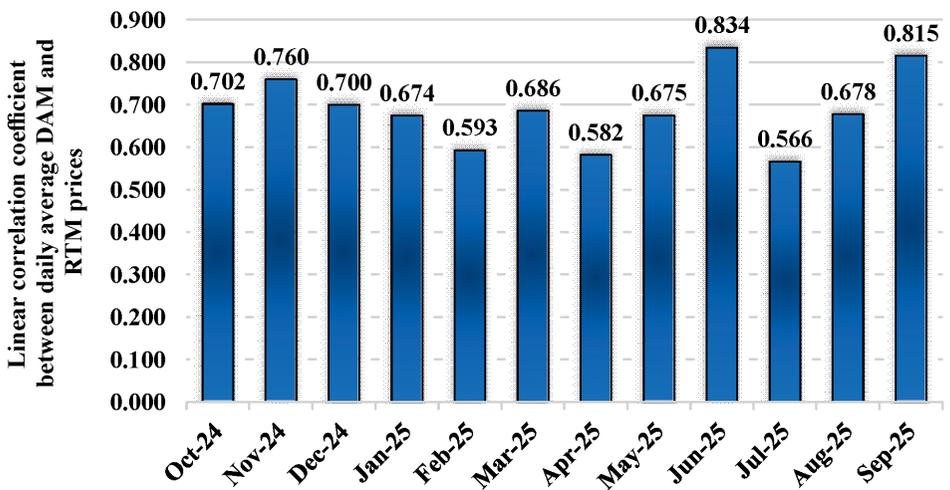

Fig. 10: Linear correlation between daily average market clearing prices at DAM and RTM of IEX
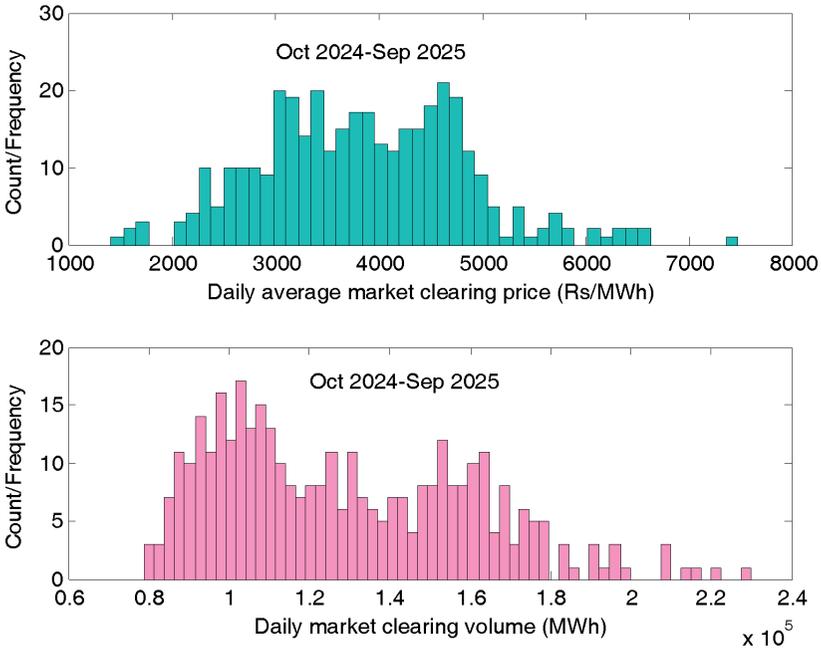
Fig. 11a: Distributions of daily average market clearing price and volume in real time market of IEX (October 2024 to September 2025)
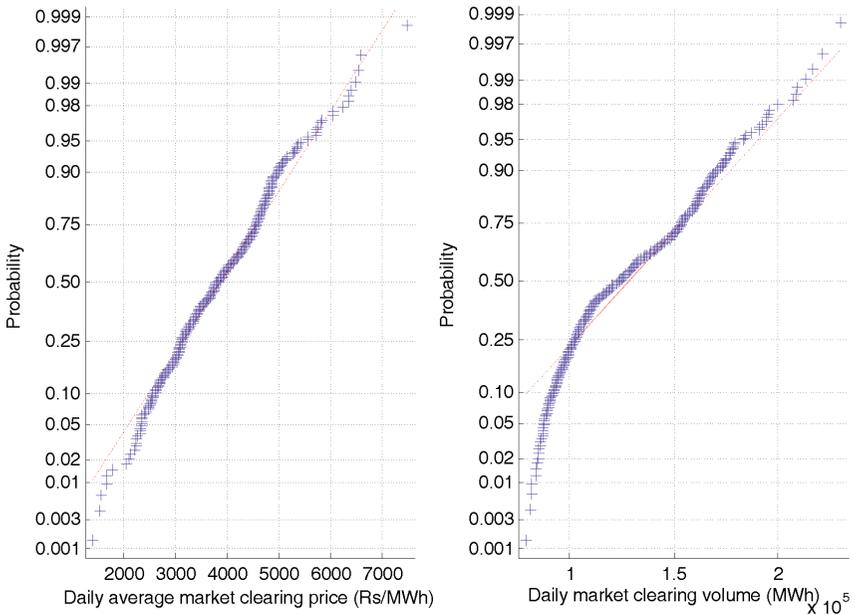

Fig. 11b: Normal probability plots of daily average market clearing price and total traded volume in green day ahead market of IEX (October 2024 to September 2025)

Fig. 12a and 12b present representative hourly characteristics of market clearance using specific data from specific days, clearly showing an inverse relation between price and volume. Much higher volatility is exhibited in the intra-day performance of this market compared to that in the day ahead markets, as is evident from the COV values. The price cap of Rs 10000/MWh is seen to be hit in this market as well. Extremely low prices are also noticed in some hours of August 2025, indicating very low demand (due to cooler
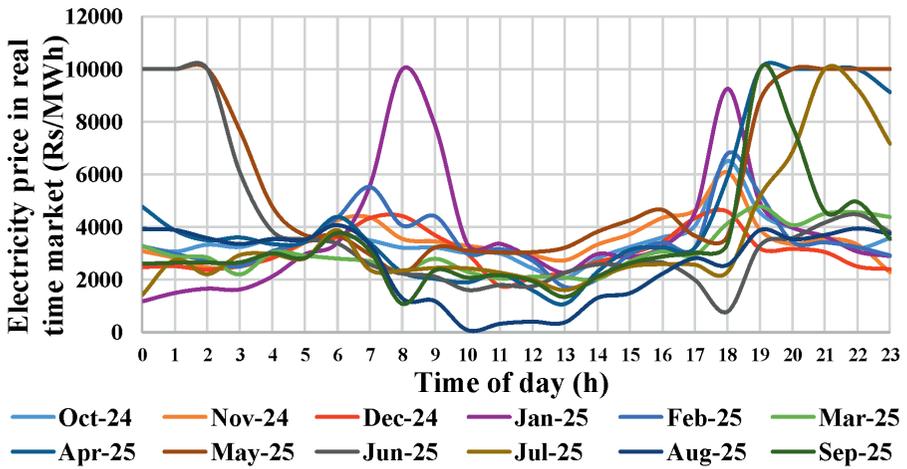

Fig. 12a: Hourly price data from real time market of IEX for a representative day of each month (October 2024 to September 2025)
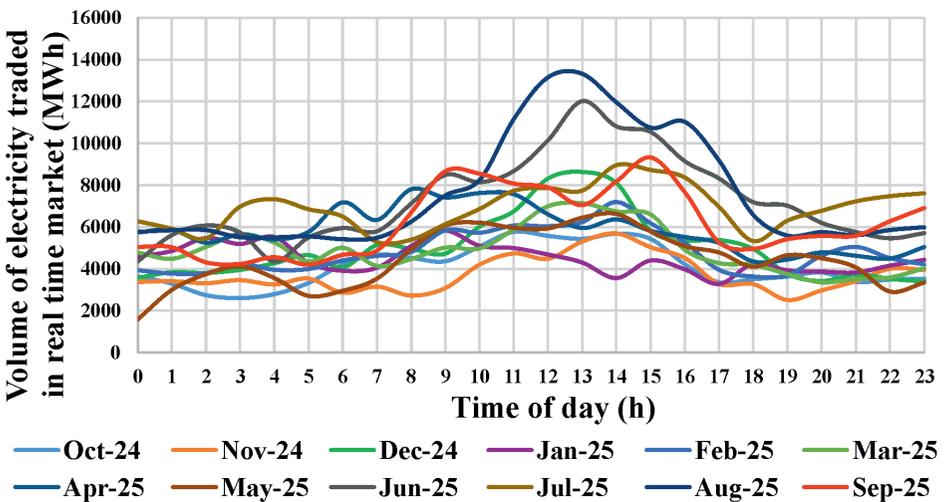

Fig. 12b: Hourly MCV data from real time market of IEX for a representative day of each month (October 2024 to September 2025)

and favourable weather conditions) and high supply situations. These are also opportunities for energy storage and arbitrage provided by the real time market. Table 8 quantifies the key characteristics from the profiles of Figs. 12a and 12b.

Fig. 13 shows the log returns on daily average electricity prices in each of the 3 market segments of IEX, calculated as in Eqn. 7. The returns appear to be distributed quite symmetrically and may be reasonably approximated as normal distributions. It is thus inferred that the time series of clearing price data from IEX are made up of random, uncorrelated numbers and these three market segments of IEX shows high level of efficiency in price formation.
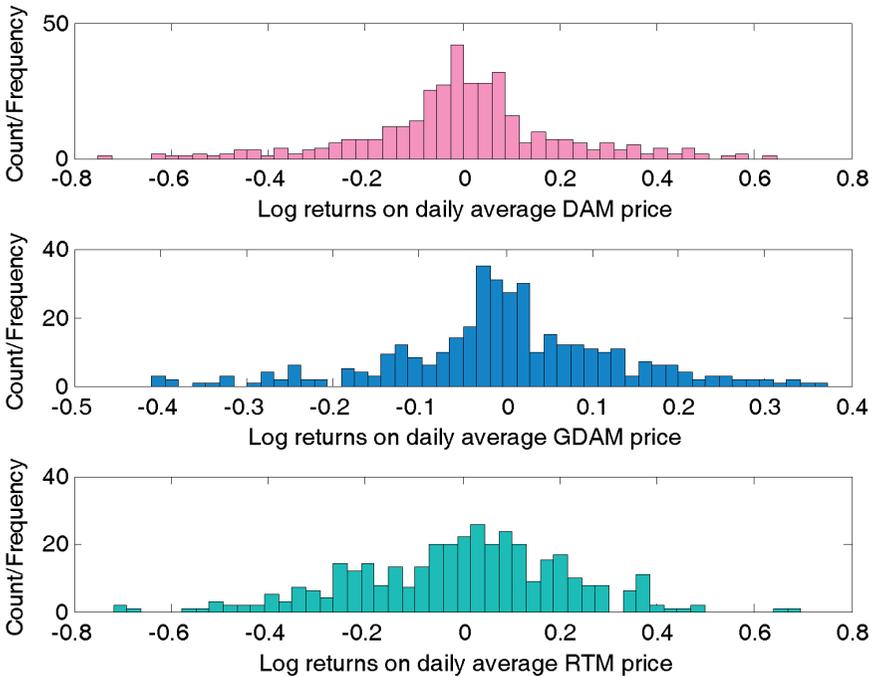

Fig. 13: Distributions of log returns of daily average price in DAM, GDAM and RTM segments of IEX

Table 8: Key statistics of hourly power trading in real time market of IEX within a representative day of each month

Day of the month	Mean volume (MWh)	Standard deviation (MWh)	COV of volumes (%)	Mean price (Rs/MWh)	Standard deviation (Rs/MWh)	COV of price (%)
15 October 24	4088.70	983.65	24.06	3461.60	822.27	23.75
15 November 24	3732.90	845.24	22.64	3470.35	836.08	24.09

Day of the month	Mean volume (MWh)	Standard deviation (MWh)	COV of volumes (%)	Mean price (Rs/MWh)	Standard deviation (Rs/MWh)	COV of price (%)
15 December 24	5007.94	1571.34	31.38	3064.27	783.42	25.57
15 January 25	4482.91	660.17	14.73	3793.16	2303.59	60.73
15 February 25	4823.01	1010.13	20.94	3481.78	1125.17	32.32
15 March 25	4925.35	1096.93	22.27	3058.75	876.27	28.65
15 April 25	5870.62	1055.41	17.98	4509.93	2974.81	65.96
15 May 25	4443.41	1371.50	30.87	5808.63	3090.06	53.20
15 June 25	7255.82	2113.51	29.13	3789.33	2644.06	69.78
15 July 25	6920.26	1044.02	15.09	3535.28	2368.88	67.01
15 August 25	7621.12	2730.00	35.82	2582.22	1388.67	53.78
15 September 25	6209.81	1615.00	26.01	3294.20	1963.18	59.59

4.　CONCLUSIONS AND FUTURE WORK

The study analyses the openly available power trading data (i.e., daily market clearing price and volume data) in 3 major market segments of the IEX, viz. DAM, GDAM and RTM for the 1-year period from 1ˢᵗ October 2024 to 30ᵗʰ September 2025. Daily data for each month and hourly data from one day of each month are evaluated. The useful findings from this analysis are as follows:

(i)　In the day ahead market, the overall range of average daily power prices lies between Rs 1833/kWh to Rs 6780/kWh over the course of the year. For the green day ahead market, the observed daily average price range is Rs 2445-7032/MWh. For the real time market, the daily average observed price range is Rs 1412-7480/MWh.

(ii)　Within a given day, the spread in hour-to-hour values is larger than the day-to-day spread within a month; the upper value of price is also seen to reach the price cap of Rs 10000/MWh set at the exchange (for all three markets) in high demand hours, though the daily average prices remain well below it in all 3 markets.

(iii)　The year-round day ahead price data and market clearing volume data are well characterized as normally distributed variables with very low linear correlation between them. A similar observation is also made for the characteristics of the green day ahead market data and real time market data over the same time frame, though the linear correlations are negative and comparatively stronger for these two markets.

(iv)   The volume of energy traded in IEX's green day ahead market is about 15 to 26% of the volume traded on the regular day ahead market or real time market.

(v)   In the day ahead and the green day ahead markets of IEX, the spread between the daily average market clearing prices is seen to be between -64.3% and +19.5%, showing that green electricity procurement has in general, been more expensive on IEX and may therefore have been procured mostly by emissions intense industries with electrified operations. In the day ahead and real time markets, the spread between the daily average market clearing prices is seen to be between -43.82% and +58.97%.

(vi)   The contribution of solar energy in the scheduled volumes of green energy in the green day ahead market at market clearing point is clearly dominant in most months except the monsoon months of the year. Hydropower is substantial in monsoons.

(vii)   All three markets show substantial price volatility over time within a day, thus exhibiting opportunities for optimal scheduling of industrial activities based on hours of low price as well as potential for energy arbitrage operations through energy storage and conversion systems.

To extend this work further, the following topics may be taken up for study and analyses in future:

(i)   Data from the previous years (viz. what is available from April 2022 onwards) on the IEX platform can be analysed to study the year-on-year evolution of the electricity trading characteristics, including price and volume volatility.

(ii)   The data at higher resolution (i.e., 15-minute time blocks) available on IEX may be used for more granular analyses than the daily and hourly assessments done in this work. The time series characteristics may be studied in depth to understand market efficiency/liquidity characteristics, for example, by evaluating auto-correlation functions of the data sets of price and volume.

(iii)   The previous years' data may be used to forecast future prices or trading volumes on IEX using econometric models such as GARCH

(since the time series characteristics of these data have been shown to be non-stationary and heteroscedastic) or with advanced machine learning models.

(iv) Comparisons of the statistical electricity trading characteristics in IEX with other power exchanges in various countries can be made to identify their structural features and differences.

(v) This work has not attempted to explain the observed patterns in electricity trading at IEX by linking it to changes in demand, weather conditions like temperature or prices of energy commodities. These causation analyses can also be performed as part of forecasting exercises for future electricity prices and volumes.

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