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Can Real Time Electricity Market In India Act As An Enabler For Growth Of Renewable Energy Sector?

Insights from Intraday Power Trading At Indian Energy Exchange

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Abstract: The Ministry of New and Renewable Energy (MNRE), Government of India is planning to install 1 lakh MW solar and 65 MW wind power capacity in next 5 years. However, a crucial issue that looms large when it comes to integrating power generated from these sources of renewable energy with the main grid is that both these sources are of intermittent nature. Thus they inherently tend to disrupt the conventional methods for planning the daily operation of the electric grid. Currently, because of very low renewable capacity in the country, grid frequency is manageable and grid discipline could be maintained. But as RE capacity progressively increases in line with the aforementioned targets set by MNRE then grid management will turn out to be an onerous task. To tackle this problem, what India might be requiring is a properly functional and efficient real time power. Currently in India, among different electricity markets that are in operation, the intra-day market (where there is 3 hrs. gap between trading and delivery time) can be considered as the closest prototype of a real time market. In view of this, the paper carried out an analysis of the functioning of intraday electricity market and explore whether an efficiently functioning intra-day market has the potential to acclimatize itself with the challenges of intermittency and grid discipline as the RE capacity progressively increases. Paper finds that In India yet Intraday market has not achieved the pace. After analyzing Intraday/Real Time Electricity market of other countries, paper provides the areas where policy and regulators needs to work to make intraday market more efficient which can address intermittency nature of RE sources in a better way and which can leads to attract the investment in the sector.

Keywords: Electricity Market, Indian Energy Exchange (IEX), Intraday Market, Renewable Energy, Real Time Electricity Market

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INTRODUCTION

In the energy portfolio of India, coal and gas based thermal power is the most preferable energy source. Currently around 66% of the total power generation capacity is based on thermal power. There are many reasons of giving preference to this source of electricity generation by energy planners like mature technology, abundant availability of coal, low gestation period and providing a firm power.

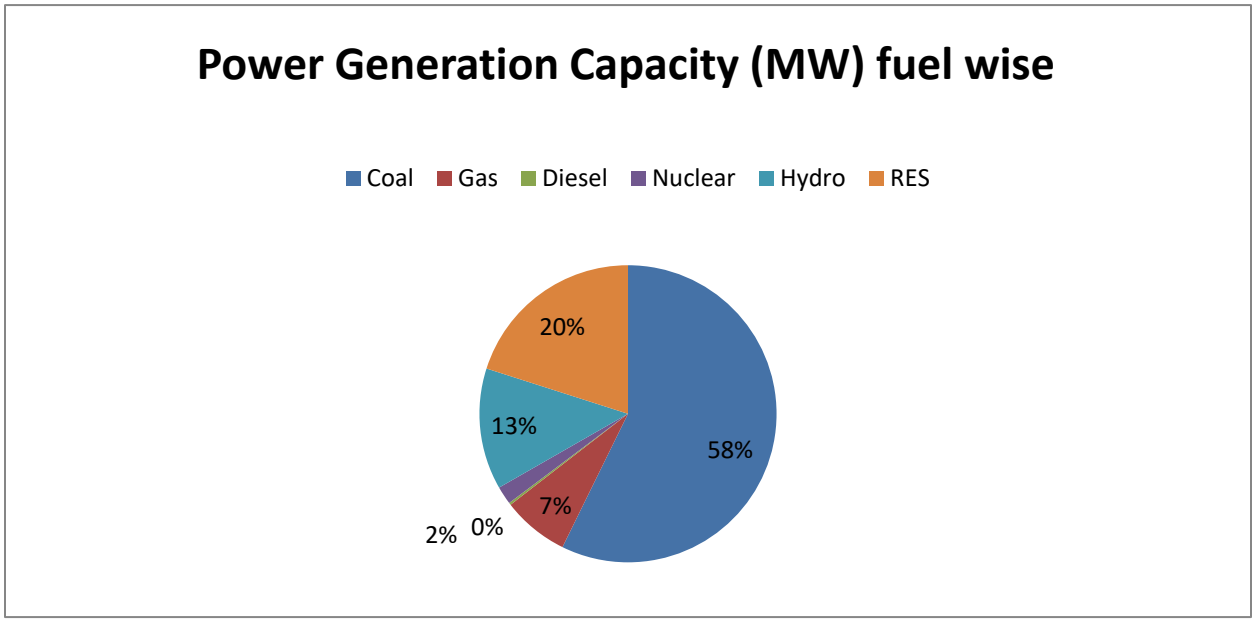

Fig 1: Present Power Scenario inIndia[1] (As on 30 June, 2018)

From the above chart, we can see that in present scenario, thermal based power capacity which includes coal, gas and diesel, constitutes around 66% of the total installed capacity of power generation whereas share of renewable energy sources is around 20% only. For sustained growth of the country, energy is a very important input and presently India is facing huge shortage of energy supply. Keeping in view of energy security and rising environment considerations, optimal utilization of fossil fuels and development of renewable energy are the only options to achieve the target of sustainable growth of the country. As it can be seen from the above chart that presently renewable energy constitutes only 20% of the total installed capacity in the country, keeping in views its importance, it has become necessary to give a push to increase its share. At global level, lots of efforts are being done to promote renewable energy technologies. Countries like Germany, Norway, Canada, and US are the leading countries in this way. Germany has increased its net-generation from renewable energy sources from 6.3% in 2000 to about 30% in 2014[2]. On Sunday, 15 May 2016 at 14:00 hours, all of its domestic electricity demand was fulfilled by renewable energy sources. This shows the commitment of Germany to develop the renewable energy in its country [3].

India also has planned to increase its renewable power capacity by manifolds but seeing past trends, it is very difficult to say that it will achieve the target. This paper analyzes those issues and problems which are behaving as barriers for growth of renewable energy sector in the country.

The next section of the paper explain the importance of real-time/Intraday electricity market to address the variability of renewable power which is one of the biggest factor in hampering the growth of this sector and how it (real-time/intraday market) can boost the confidence of investors to invest in this sector.

After this section, paper focuseson the existing intraday market in India and also does a proper analysis of functionalities of not only existing intraday market in India but also also real-time/Intraday electricity market in other countries to take-out the best practices of those markets.

Renewable Energy: At Global and Indian Level

As per REN21, 2018 report, globally, estimated share of electricity production from renewable energy is 26.5% and the total renewable power capacity is 837 GW (excluding hydro) and 2195 GW (including hydro). China, United States and Germany are the leading countries in development of RE sources which have capacities of 334 GW, 161 GW and 106 GW respectively[4].

In spite of no of benefits of renewable energy, its growth in India has been very slow. Today, the RE sector contributes only 20% of the total installed power capacity of the country (see figure 1). As it is mentioned in above paragraph, global average RE power production is more than 26%, this is the time for India to make RE favorable policies which helps in attractingthe investment in the sector.

There are different RE technologies like Solar, Wind, small hydro, Bio, Waste to Energy and Geothermal. The share of each technology in the total RE capacity installed in the country is shown in the figure below.

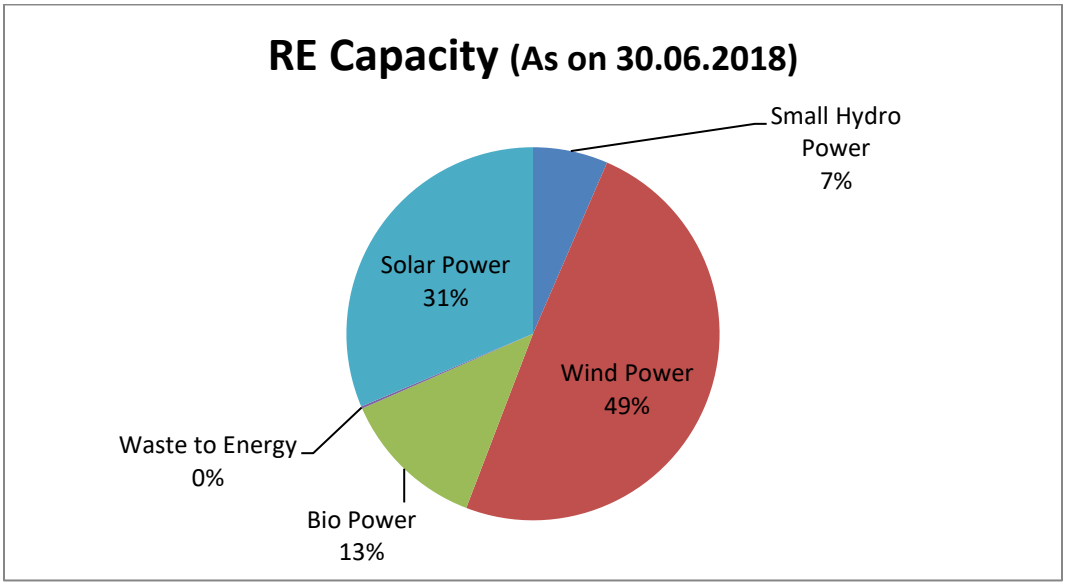

Fig 2: Technology Wise RE Capacity[5]

From the above chart, it is clear that wind technology comprises the highest share in the total RE capacity in the country. Solar power - whether PV or thermal – comes on the second position and it yet has to get momentum. In India, total renewable energy potential is 249188 MW and out of which till today, only 27% potential has been harnessed [6].

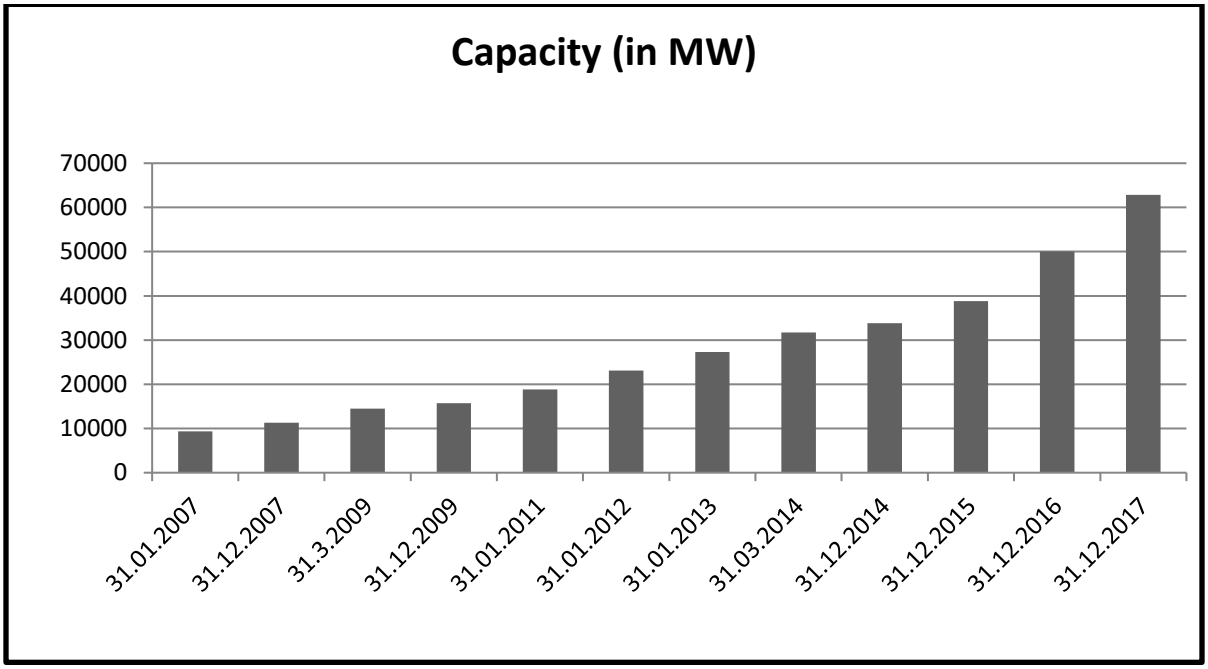

Fig 3: RE Capacity Addition from 2007 - 2017 [7]

In the last 11 years RE capacity increased at the CAGR of 18.9%, from 9372 MW in 2007 to 62846 MW in the end of 2017. So in these years, total RE capacity addition was around 53.5 GW. If we compare this capacity addition with other countries like china, US and Germany which was respectively 200+ GW, 70+ GW and 60+ GW, India is far behind in terms of development of RE based power generation capacity [8].

India aims to increase the capacity to installed renewable energy by 175 GW by 2022. But by looking progress of previous years, it seems that achieving the target would be an onerous task. It's not like that Government did not take initiative to stimulate the growth of the renewable energy. Many steps were taken to attract investment in this sector like on 11th January 2010;JNNSM (Jawaharlal Nehru National Solar Mission) scheme was launched to attract investors to invest in solar power. At that time, this schemehad the ambitious target of deploying 20,000 MW solar power by 2022 which was increased to 1 lakh MW in budget 2015. Out of this, 40000 MW will come from solar rooftop system [9]. Other than this, in electricity act 2003, to encourage RE sector,it is notified that each state will have to purchase some fixed percentage of its total electricity purchase, from renewable energy sources as per its Renewable Purchase Obligation (RPO). If any discom is not able to meet its RPO target by purchasing electricity direct from RE sources, can fulfill its obligation by purchasing REC (Renewable Energy Certificates) from the market. Currently REC certificates are traded at both energy exchanges i.e. Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL).

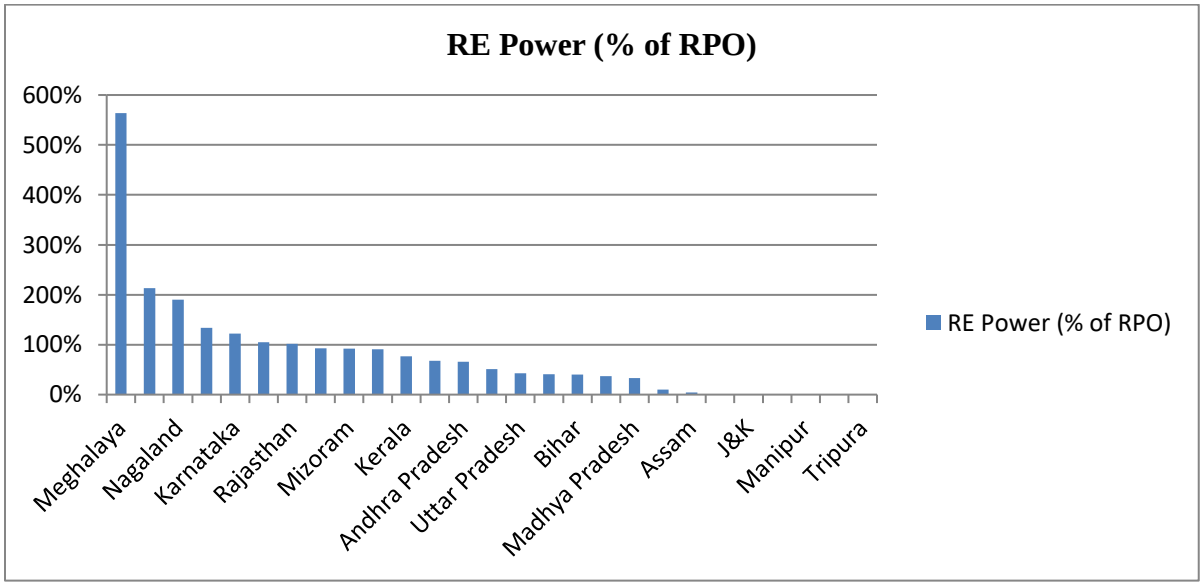

Fig 4: Renewable Energy Report Card for the States[10]

With reference of above figure of RPO, it can be stated that obligation of renewable power purchase is not being fulfilled by the discoms. Any obligated entity can fulfill its RPO obligation through three underlined routes.

1. Feed in Tariff (FiT)
2. Purchase of RE at market price
3. Buying REC (Renewable Energy Certificates)

Feed in Tariff – Under this policy, Regulator set prices for different types of renewable power to compensate producers for the higher cost of generatingrenewable energy. All the discoms have to purchase power from these renewable sources at this regulated and set price.

Purchase of RE at market price -Obligated entity can purchase RE power from any third party at market price.

Renewable Energy Certificates – REC mechanism is a market based mechanism which facilitate the stakeholders an option to fulfill their RPO compliance. Under this mechanism, if any renewable power producer is selling electricity at APPC (Average Power Purchase Cost) will beentitled to get RE certificates. These certificates can be tradedin the market where obligated entities (Didcoms/Open Access buyer/captive power generator) will purchase these certificatesto fulfill their renewable purchase obligation (RPO). In India, trading platformfor these certificates are Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL). To provide clarity and confidence to investors, REC prices at exchange can vary between floor (Minimum Price) and Forbearance price (Maximum Price). These floor and forbearance prices are decided by the CERC based on the generation cost of the renewable power. Here it is imperative to look the REC market at IEX in the last financial year, 2015-16.

Table 1: REC Trading at IEX in year 2017-18 [11]

Year	Category	Buy Bids (REC)	Sell Bids (REC)	Cleared Volume (REC)	Percentage of REC volume cleared
2017-18	Solar	88533	3498912	88533	3%
	Non-Solar	9417343	63509259	9240720	15%

In the financial year 2017-18, around 97% of solar RECs and 85% of non-solar RECs could not be sold (Table No 1). Here it is also important to mention that, in the year 2014, solar REC prices (floor and forbearance prices) were also reduced from Rs 9.3/Kwh to Rs. 3.5/Kwh and Rs. 13.4/Kwh to 5.5/Kwh respectively [12].Even this price slashing could not encourage discoms to purchase RECs to fulfill their obligation. So Before making huge targets for renewable energy capacity addition, it is prerequisite to analyze the reasons that why the utilities are averse in fulfilling their renewable power purchase obligation. So it is required that all the factors which are responsible for this reluctance of discoms in fulfilling their Renewable power purchase obligation, are properly analyzed and necessary actions are taken to address them. Hence in any case,financial incentives provided by Government, to investors for keep investing in this sector are indispensable otherwise, they would not be able sustain in long run and will lose their interest.

BARRIERS FOR DISCOMS TO FULFIL THE RPO

Vol. 5, Issue. 5, 2018, ISSN 2349-0780

Various forms of renewable energy demonstrate different characteristics which attract obligated entities to draw lesser power from these sources. Some of the barriers are discussed here.

1. **Transmission Constraints**
   Most of the wind power plants are located at remote locations which are far away from the load centers. Because of insufficient grid infrastructure, discoms are not able to draw required amount of power from these RE power plants. Even State utilities don't show their interest in developing sufficient capacity of transmissionnetwork as it is not a viable option for the power sources which supply variable power. Hence it isnecessary to create sufficient intra and inter-state infrastructure formaking discomscapable to draw renewable power to comply their obligation. It will also boost confidence of RE developers.

2. **RE Concentration**
   In India, RE potential is concentrated in few states only like wind power is mainly confined to states like Tamilnadu, Karnataka, Gujrat and Maharashtra. In Tamilnadu itself, it is intensified in places like Coimbatore, Thirunelveli, Theni and Ramanathapuram. Solar power is mainly present in states of Gujarat and Rajasthan. Because of insufficient inter – state and Intra – state transmission network, many states are unable to receiverequired amount of renewable power.

3. **Intermittent Power**
   It is the most critical issue with renewable energy sources especially wind and solar technology. There is high variation in power generation from these resources, in a very short spanof time. Because of this, integration of these resources with the grid is very difficult task. As long as variation in RE power is smaller in comparison to the variation in the demand, integrity is not a problem. In case of very high penetration of RE power, grid reliability will affect. For a discom, other than grid stability, power purchase management is also a painful task. In case of highly variable power, demand and supply gap will keep changing and providingreliable power to its consumerswon't be possible. The utility needs to make power procurement strategy accordingly. This paper focusesmainly this issue in elaborated manner.

4. **Cost of Power**
   Initially, high cost of renewable power was a major deterrent for the discoms in purchasing renewable power. But after market development and technically advancement, prices reduced significantly. Solar PV project cost has come down from Rs. 18-20 cr/MW to Rs. 10 Cr/MW. Under JNNSM scheme, through competitive bidding, prices come down to Rs. 7.5 – 8.5 per unit. In case of wind power also, prices has come down to Rs.4-5 per unit. If we compare these prices with thermal power price which is around Rs. 4-5 per unit, solar price is still higher. However with the advancement of technology, the cost of renewable power generation may come down.

All above reasons clearly explain that why obligated entities especially discoms are showing reluctance in fulfilling renewable power obligation. Hence Government and policy makers need to stride to make policy and market to resolve all these above affairs.

Vol. 5, Issue. 5, 2018, ISSN 2349-0780

PROBLEM OF INTERMITTENCY OF RENEWABLE ENERGY

As discussed above that RE sources have intermittency nature specially technologies like Solar and wind which do not provide round the clock electricity or whenever there is demand in the grid. Both technologies produce electricity when the wind is blowing and the sun is shining. This intermittency creates problem in managing the grid.

For better functioning of the grid, it is necessary that demand and supply should be equal at the grid and to achieve this equality, there are load dispatch centers like SLDC (State Load Dispatch Centers) and RLDC (Regional Load Dispatch Centers) which do scheduling of demand and supply on the day-ahead basis. In this process of scheduling, every generator has to provide hisgeneration (supply) schedule for the next day for every 15 minute block (96 blocks in a day) to the respective load dispatch center. At the same time, all the beneficiaries (Discoms) and open access consumers have to provide their demand schedule for the next day for every 15 minute block. Then Load Dispatch Centers do exercise to match demand and supply for each time block. In this exercise, ifany beneficiary demand more power than availability then he asked to reduce its demand to match supply. In the same context, if any generator wants to supply more than required power then he is asked to reduce its supply to match demand. At the time of delivery, if demand and supply are equal, frequency would be at desired level i.e. 50 Hz. If there is mismatch, then frequency will deviate from 50 HZ and will go up and down based on the gap between demand and supply. If demand (load) is more than the supply; frequency will go below than 50 Hz and if supply is more than the demand; frequency will be higher than 50 Hz. Both the cases, whether frequency go below or up 50 Hz, are not good in perspective of grid management as it can affect the reliability of the power supply and also can damage the grid. In worst cases, there can be complete black out for the large area.

Because of uncertainty and variability in these technologies like Wind and Solar, integration of these technologies with the power system network is major challenge for network operators. As in this paper only, it is discussed above that variability is also a reason for not complying RPO by obligated entities, it is a discouraging situation for investors who want to invest in Renewable energy sector. Variability also impacts on overall utilization of RE plants. It can be explained in more detail with following cases:

Case 1

There is 50 MW solar PV plant in Rajasthan. Let’s assume, for the planning of the any next day (to sell power in the day ahead market and day ahead scheduling), generator seeks the weather forecasting report and according to that, next day there would be a cloudy weather. As there would not be good sunshine on the next day, generator reduces its forecasting of generation from 50 MW to 30 MW. But because of forecasting error, on the next day, there is great sunshine and whole capacity (50 MW) can be utilized for power generation. In absence of real time market, this additional 20 MW power cannot be sold in the market. If he feed that extra power in the grid (without scheduling), he shall liable to pay UI charges as per prevailing grid frequency. Overall it attracts financial loss to power generator.

Case 2

Vol. 5, Issue. 5, 2018, ISSN 2349-0780

With the same assumptions from case 1, according to weather forecasting, next day would be a shiny day. Basis on that, generator schedules its whole capacity (50 MW) to generate. But because of forecasting error, there is cloudy weather on the next day and only 30 MW capacities could be available for generation. This will make generator liable to pay UI charges as per prevailing grid frequency.

Case 3

There is an industry which has installed a 10 MW wind plant to fulfill its own power requirement. Suppose,as per weather forecasting, industry calculate power generation from its captive power plant (Wind Power Plant) which suffices their requirement and do not purchase any power from the Day-Ahead-Market (DAM) for the next day. But forecasting goes wrong and wind mill does not generate that calculated amount of power. This situation will impact on industry's production and that can turn into a heavily financial loss to that industry.

In the above case, if we assume that industry has a backup power system (Diesel Generator) which generate power at a cost (around Rs. 15/Unit) which is very high compare to cost ofpower from renewable sources. It is also possible that some power generator has additional power (because of good sunshine and able to generate more power from its solar PV plant) andif thereis a real time market, can sell that power at the market which surely would be at lower than cost of power from DG set.

NET-METERING

Net metering a concept under which there is a billing agreement between utilities and its consumer and facilitate a special metering for the connection of small renewable energy system to the grid. Under this concept, if at any point of time, a net metering client's renewable energy generator produces more power than his demand, that excess power can be feed into the grid and meter runs backward generating credits. Let's take an example. There is a Net Metering consumer which has 50 KW rooftop solar PV plants which generates 2500 units' electricity in a month. Out of that, consumer consumes 1500 units for his own use and rest 1000 units supply to grid. If he draws 2000 unit of electricity from the grid, giving 1000 units as generation credits, meter will show overall draw 0f 1000 units from the grid.

Complications because of Net-Metering

In the electricity market, demand from the distribution companies is the function of the demand from its consumers. Because of Net-metering, for the utility, it would be very difficult task to make the strategy for power purchase for the next day as forecasting of demand will also include factors like weather and consumer demand which are variable in nature. Suppose there is forecasting of good sunshine for the next day and including that factor, utility scheduled power purchase for that day. But because of some error in weather forecasting, there is cloudy weather and because of that there is no power generation from all Net-metering consumers and in that case all consumers will start drawing power from the grid only. This situation will not only

impact on grid frequency but also impact on financial health of the discom. This situation can be just opposite to this also.

All these above cases demonstrate the importance and need of the real time market in the country to encourage the investors to invest in the renewable energy sector.

REAL TIME MARKET

Real Time Market is a spot market where the product (here product is electricity) is procured for immediate delivery and in which prices (called locational marginal prices) are calculated at five minutes intervals based on actual grid operating conditions. In this form of market, transactions are usually settled on hourly basis. Forecasting of electricity generation from renewable energy sources on the one the same day of delivery (say 1 or 2hr before of delivery) is more accurate in compare to forecasting one day before of delivery.

Real Time Electricity Market in India

In 2008, first energy exchange of India, IEX (Indian Energy Exchange) was started with objective of boosting and promoting power trading in the country. After some time one more exchange PXIL (Power Exchange India Limited) was also started in Mumbai. Both exchanges have no. of products or we can say, no of modes to trade the power. These exchanges provide the platform for generators, Buyers (Utilities, Industries), captive generators where they can buy and sell their power. Out of these products of exchange, Day Ahead Market (DAM) is the most preferable product which has 98% share in the total trade of power through exchange.

Day-Ahead-Market (DAM) is a physical electricity trading market for deliveries for any/some/all 15 min time blocks in 24 hours of next day starting from midnight. The prices and quantum of electricity to be traded are determined through a double sided closed auction bidding process. The operations are carried out in accordance with the 'procedure for scheduling of collective transactions' issued by the Central Transmission Utility (PGCIL), CERC (Open Access in Inter-State Transmission) Regulations, 2008, as amended from time to time and the Bye-Laws, Rules and Business Rules of the Exchange [13]. DAM helps in filling the gap between demand and supply.

As stated in the above paragraph, our DAM and overall scheduling by Load Dispatch Centers are done a day before of actual power delivery. Till now, managing the grid is a very challenging task and after coming more renewable energy in the system, things would be more challenging as renewable has intermittent nature and forecasting for the next day for these sources is also very difficult. Now, it is the time that India should move from day ahead scheduling to real time scheduling and Day-Ahead-Market (DAM) to Real-Time-Market (RTM).

Intraday Market

Out of no. of market products at exchange, Intra-day market can be considered as the closest prototype of real time market. Intraday market takes place during the day of operation/delivery, as opposed to day-ahead market where trades are concluded the day before the physical delivery

of the electricity. In India, in intraday market, bids are placed generally 3hr before of delivery. For the first delivery period (04.00 – 05.00), trading time is from 00.30 hrs to 01.00 hrs. For the second delivery period (05.00 – 06.00), trading time is 00.30 hrs to 02.00 hrs and so on. Timelines for intraday contracts are given below:

Table 2: Intraday Trading Timelines at IEX [14]

S.No	Trading Start Time (hrs)	Trading End Time (hrs)	Delivery period (on the same day)
1	00.30	01:00	04.00 - 05.00
2	00.30	02:00	05.00 - 06.00
3	00.30	03:00	06.00 - 07.00
4	00.30	04:00	07.00 - 08.00
5	00.30	05:00	08.00 - 09.00
6	00.30	06:00	09.00 - 10.00
7	00.30	07:00	10.00 - 11.00
8	00.30	08:00	11.00 - 12.00
9	00.30	09:00	12.00 - 13.00
10	00.30	10:00	13.00 - 14.00
11	00.30	11:00	14.00 - 15.00
12	00.30	12:00	15.00 - 16.00
13	00.30	13:00	16.00 - 17.00
14	00.30	14:00	17.00 - 18.00
15	00.30	15:00	18.00 - 19.00
16	00.30	16:00	19.00 - 20.00
17	00.30	17:00	20.00 - 21.00
18	00.30	18:00	21.00 - 22.00
19	00.30	19:00	22.00 - 23.00
20	00.30	20:00	23.00 - 24.00

This above table shows the trading cycle of intraday market at Indian Energy Exchange (IEX). In each cycle, there are 3 hrsgap between trading end time and delivery start time. Once trade executed, would not be revised at any point of time. The delivery point for the electricity would be the regional periphery of seller.

As it is stated above in the paper also that country is planning to increase its renewable power capacity to 1.75 Lakh MW, it is the time when position of current intraday market should be analyzed and studied so that if there is any issue or discrepancy which exist in the current market, can be addressed and resolved now and this market can act like an enabler in growth of the renewable power capacity in the country.

To study the existing intraday market, it is imperative to look on market's traded volume in the last three years (2013-15). Here, last 3 years intraday market data (volume of demand and supply) is given below:

Table 3: Intra-day Market Trading Data at IEX [15]

S. No	Year	Months	Total Traded Volume (MWh)
1	2015	**Jan-2015**	2950
2		**Feb-2015**	6860
3		**Mar-2015**	7485
4		**Apr-2015**	20205
5		**May-2015**	22875
6		**Jun-2015**	16493
7		**Jul-2015**	7019
8		**Aug-2015**	21841
9		**Sep-2015**	31052
10		**Oct-2015**	21184
11		**Nov-2015**	14606
12		**Dec-2015**	20378
13	2016	**Jan-2016**	8037
14		**Feb-2016**	16944
15		**Mar-2016**	14023
16		**Apr-2016**	40115
17		**May-2016**	17653
18		**Jun-2016**	15672
19		**Jul-2016**	14642
20		**Aug-2016**	12040
21		**Sep-2016**	18091
22		**Oct-2016**	21146

S. No	Year	Months	Total Traded Volume (MWh)
23		**Nov-2016**	38926
24		**Dec-2016**	19463
25	2017	**Jan-2017**	7422
26		**Feb-2017**	8945
27		**Mar-2017**	16316
28		**Apr-2017**	28977
29		**May-2017**	20905
30		**Jun-2017**	26254
31		**Jul-2017**	58503
32		**Aug-2017**	33908
33		**Sep-2017**	31878
34		**Oct-2017**	32250
35		**Nov-2017**	20405
36		**Dec-2017**	37391

If we analyze above market data, it is clearly visible that there is no substantial growth of this market. As initially explained, importance of this market for the growth of the renewable energy sector and also its role in grid balancing, here it becomes necessary to find out the reasons of that even after 3 years of introduction of this market, why it could not get that growth which the day ahead market have achieved.

Day Ahead Market (DAM) which started in May 2008 at IEX, doing very well and its share in overall short term market is increasing year by year. Trading data of day-ahead market is shown below.

Table 4: Day-Ahead Market Trading Volume at IEX [16]

Year	Purchase Bid (MWh)	Sell Bid (MWh)	MCV (MWh)
2009	9481976.1	10022730	5589241
2010	14944701	18321570	10608122
2011	23403724	22336785	15199722
2012	35467974	29667476	22260566
2013	41254879	49246745	33878850

Year	Purchase Bid (MWh)	Sell Bid (MWh)	MCV (MWh)
2014	45213541	41369841	32179030
2015	41429870	52088295	34366018
2016	46716961	73960742	40894496
2017	54750968	73646200	44216251

The above table showsthe data of yearly total purchase, sell bidand market clearing volume (MCV) of the Day-Ahead Market from year 2009 to 2017. The CAGR of the Market Clearing Volume (MCV), between 2009 and 2017, was 30%. According to a report on short term market by CERC, in 2016-17, 53% of the total electricity transacted in short term market, was from Day-Ahead Market only. Whereas share of term-ahead market (Other than DAM, all markets (Day-Ahead Contingency, Intraday Market, Daily, Weekly market) comes under TAM only) only is around 1% which is far-far lesser in compare to share of DAM [17]. In overall we can say,where day-ahead market is reaching to the new heights year-by-year, intraday market is still fighting for its existence.

Now this is the time when country has a target of 1.75 lakh MWof renewable energy by 2022, issues which are hampering the growth of this (Intraday) market should be identified and also rectified as soon as possible so that more investors can be attracted towards investment in renewable energy as they would be able to utilized full capacity of their power plant.

To identifying the problems and issues in intraday market, first it is required to analyze those electricity markets where this market (Intraday or Real Time) is working successfully. For this, some international electricity markets are analyzed and their rules for functioning of thisparticular market are framed in a tabulated form.

Electricity Market	Country	Trading Rules of Intraday Market	Remark

Electricity Market	Country	Trading Rules of Intraday Market	Remark
Nord Pool	Norway, Finland, Sweden, Denmark, UK , and Germany	A continuous market and trading takes place every day around the clock until one hour before delivery.Prices are set based on first come, first served principle Single Interface to all Nord Pool Intraday markets – Nordic/Baltic/Germany & UK. Latest web-based technology – a HTML5 solution which enables Nord Pool to easily manage new system releases with minimal customer impact or market disturbance.Nord pool support members using the java based intraday platform ELBAS 4. - Unlike the web based trading client, Elbas 4 requires members to download and install Java Runtime Environment 8 (or any later version). Transmission capacities are provided by the TSO once the result of day-ahead auction is out. Capacities can be changed at any time; either from the intraday system manually or by automated system Nord pool maintains electronic trading system (ETS) as well as telephonic trading system (MTS) also. All telephone calls with trading desk and MTS may be recorded in accordance with Applicable Law.	Nord Pool market uses the best technologies like Web Based Technology (HTML Solution) which manages nordpool easily and also more user friendly. It also uses telephonic trading system (MTS) along with electronic trading system (ETS) which provide more options to customers to contact and do trading.
PJM	USA (Pennsylvania, New Jersey, Michigan)	At 5 min intervals. Locational marginal prices (LMP) are calculated for all PJM load buses and generation buses. LMP calculation is based on actual operating conditions in the PJM control area. LMP values are calculated based on a dynamic model of the PJM power grid. LMP calculation takes into account current transmission and generation outages and as well as transmission capacity limitation. All the offer data from generating stations and demand centers are stored in market data base on day before operating day and then LMP is calculated for the day ahead. - If a generator offer is accepted in the day-ahead market then this offer carries over to real time market, otherwise generator can change its bid data for real time market in the re-bid period.	Marginal prices are calculated at every 5 minutes interval which provides customers (both buyers and sellers) an option for doing trading for more clear demand and generation (specially for renewable power)

Electricity Market	Country	Trading Rules of Intraday Market	Remark
EPEXSPOT	Germany	The minimum volume increment is 0.1 MW. The minimum price increment is EUR 0.1 per MWh. Electricity traded for a delivery on the same or on the following day on single hours, 15 min periods or on block of hours. Each hour, 15 min periods or block of hours can be traded until 30 min before delivery begins. Each 15 min index is a volume-weighted average of the price of all transactions for a certain delivery 15-min period on one specific market area (German/Austria).15 min continuous intraday index base corresponds to the simple average price of the 24 indices between the hours 1 to 24 of a specific day on one specific market area. Under the category of single contract orders, there are two types of contracts - i) Unlimited Single Contract Orders, ii) Limited Single Contract Orders. Under the unlimited single contract order, there is no price limit and price is determined by the trading system only. Under the limited contract order, only buy or sell order are executed which falls under the minimum and maximum price limit	EPEXSPOT market provides more options of trading mode i) Unlimited single contract order and, ii) Limited single contract orders.

To analyze the best practices of Intraday Market in other countries, we selected three markets i.e. i) Nordpool, ii) PJM, and iii) EPEXSPOT. Main reasons for selection of these specific markets are

- Similar functioning of energy market like most of the functioning of energy exchanges in India is similar to Nordpool market.
- High Renewable energy mix in Germany, share of renewable power in gross power production is around 30% [18].
- Mature energy market like PJM

Keeping in view all these above factors, these three markets were selected for study and analysis. All the best practices of functioning of intraday/real time trading of these markets are stated in above table. After studying all three markets, here are some outcomes which may be important and useful to Indian policymakers to incorporate and redesign the functioning of existing intraday market to make it more attractive to both buyers and sellers. These outcomes are:

- Exchanges should use more user-friendly technologies like app based which can be operated by mobile only. Also technologies which can operated in a very fast manner as

for intraday market it is necessary that sharing of information has to happen within 5 minutes only.

- There should be more numbers of modes of tradingas being provided in Nordpool market where other than Electronic Trading System, Telephone mode is also provided for auctioning. It is a necessary requirement in case of renewable power as mostly these power plants are at remote area where internet facility is available. Telephone trading facility, a person at the power plant site, can do bidding.As in an intraday market/real time market time for placing bids is very-very less, it is not possible to pass on weather or any other site information to the head office of the organization, it is necessary that person on the site of plant should place the bid and in that case there should be an option of telephonic trading also.
- Currently, In India in Intraday market, there is gap of 3hrs between auctioning and delivery. Still it is not that much efficient as a real time market is. In other international markets like in PJM, marginal prices are calculated at every 5 minutes interval. Bidder who has placed his bid 3 hrs before of delivery can change his bid even 5minute beforeof delivery. It is necessary in case of renewable, as weather can change 5 or 10 minutes before as well and which can impact on generation output from renewable power plant (wind and solar) as well as demand also.
- Providing more no of options of trading also attract players (buyers and sellers) to participate in any kind of market. Like in EPEXSPOT Intraday market, there are more than one option for trading of electricity i.e. i) unlimited single contract order, ii) limited single contract order.

It is also necessary to study and analyze existing intraday market and also other associated factors which may impact volume of trading at intraday market in direct or indirect way. Toreview this market, we not only studied functioning of this market but had discussion with various traders also.Some of the excerpts of discussion held with traders are mentioned below.

- Auctioning takes place 3 hrs before of delivery of electricity which should be reduced to 1 hr or lesser for getting more clarity of actual demand and supply to players (generators and discoms/consumers)
- Both intraday market and day-ahead market are separate. Any participant who's bid got cleared in day-ahead market is not carried over to intraday market as it happens in some international market like PJM where bid which is cleared in day-ahead market is carried over to real time market where bidder can change its bid at the time of re-bid. This mechanism encourages bidders to make their bid more near to actual demand and supply. Here, in India, when both markets are separate, generally bidders don't want to take hassle of doing bid exercise again.
- It is necessary to increase transmission capacity in India, as even exiting generation capacity is not being fully utilized because of insufficient transmission capacity. Currently, many players (buyers and sellers) are not participating in intraday market as they don't have surety of getting transmission corridor at that time as that's why they bid in day-ahead market to be assured for getting power. Also because of scarcity of transmission capacity, time lag between auctioning and delivery (which is now 3 hrs) is not possible to reduce up to 5 or 15 min. as in other international markets as lot of formalities like taking approval from load dispatch centers (SLDC/RLDS/NLDC) have

to be done which consumes lot of time. To reduce this lag time, first it is necessary to increase transmission capacity.

- In India, around 61% of the total generation capacity is coal based thermal power plant where as gas based is only 8% (as mentioned in fig 1 in paper only). Regarding intraday market, there is big issue with coal based power plant as it takes so much time (minimum 1.5 hr) [19] and that's why coal based power plants cannot participate in intraday/real time market as they would not be able to change their output within minutes according to market demand. A gas based unit can ramp up/down within minutes [20]. In India, as already gas based capacity is very less, in addition country is facing huge gas scarcity. To improve liquidity in real time market and to support deviation in generation output from renewable power plants, it is required to improve the gas based capacity and also gas availability in the country.

These all are above points on which policy makers and regulators can look and after an exhaustive study, can implement to make existing intraday market more attractive and user friendly to electricity market players.

CONCLUSION

In this research paper it is explained that how an intraday market or real time market and its dynamics can attract investors towards renewable energy sector. We also analyzed the existing intraday market and find that in this market liquidity is very less compare to existing day-ahead market.

Study of international intraday market and real time market, reveals that Indian exchanges needs to be made more user-friendly by using latest IT, other media of trading such as telephonic and reduce the time between auctioning and delivery to increase competition, reduce trading price and smooth down the impact of weather variability in forecasting. Even interaction with the traders also revealed that it is required to reduce the time between auctioning and delivery. The traders also mentioned that carry over of day-ahead market bid to intraday real time market with the option of rebidding will boost up the trading competition.

To expedite all above it is prerequisite that transmission corridor is fully strengthened, as even existing generation capacity is not being fully utilized because of insufficient transmission capacity and fast racking the load dispatch centers work of approvals to reduce lag time. This should be accompanied with liquidity in real time market with improved gas based capacity and gas availability in the country.

These suggestions can be implemented after an extensive study of these international markets and existing intraday market as well. In the relevance of intraday market/real time market. It is necessary that Government policy makers and regulators should work to restructure this market in such a way that it can provide better returns in investment in renewable energy sector for investors.

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