Coexistence of Day Ahead Market and Real Time Market in Indian power sector

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***Abstract*— In India, Short term open access (STOA) in transmission and distribution provides a range of opportunities to the market players. Sellers and buyers can transact power bilaterally through over the counter contracts or bid collectively through the power exchanges in Day Ahead Market (DAM). Real Time Market (RTM) was introduced in India from 01.06.2020. This has created a new opportunity for the electricity market players for trading in real time with a lead-time of 1.5 hours. RTM provides 48 bidding windows over a day. This provides additional flexibility for last mile portfolio optimization. This paper attempts to analyze the impact of coexistence of DAM and RTM to derive further inferences. It provides an insight to the relationship of the Market Clearing Price (MCP) of DAM and RTM. Trend of MCP of DAM and RTM is analyzed with respect to variation in demand.**

Keywords*— *Day Ahead Market, Market Clearing Price, Market Clearing Volume, Market Coupling, Real Time Market

I. INTRODUCTION

Implementation of Real Time Market (RTM) from 1st June'2020 has given the required boost to the power markets in India. It has introduced a distinct gate closure provision very close to the time of delivery. It provides the distribution companies (DISCOMs) and industrial open access customers an opportunity to optimize their demand and power purchase portfolio. It also allows the generators to sell any surplus power close to real time. Both the Day Ahead Market (DAM) and Real Time Market (RTM) are operating efficiently to extend the opportunity of power portfolio management to market participants. On one hand, DAM gives opportunity to bid for the following day delivery, on the other hand RTM is an opportunity to bid very close to the delivery period. RTM has brought the required flexibility to provide real time balancing opportunity while ensuring optimal utilization of the available surplus generation capacity in the system. It also helps minimizing deviation in real time operations arising out of forecast errors. As observed in past 11 months, i.e., from 01.06.2020 to 30.04.2021 coexistence of these markets has also influenced the operational strategy and load management decision of the utilities.

Presently there are two functional power exchanges (PX) in India viz. Indian Energy Exchange Ltd. (IEX) & the Power Exchange India Ltd. (PXIL). They provide an electronic platform for bidding and extend clearing and settlement services to the market players. Since IEX is the larger exchange with more than 80% market share, input data for our analysis has been taken from the website of IEX.

II. SURVEY OF INTERNATIONAL PRACTICE

Electricity as a commodity is traded in many countries. These countries have developed their own mechanism to establish and promote trade by means of power markets. Some countries e.g., United States of America has developed a system with integrated power markets for distinct control area operated by Independent System Operators (ISO) and Regional System Operators (RTO). These ISOs and RTOs are governed by Federal Electricity Regulatory Commission (FERC) [1]. The ISOs / RTOs in USA provide trading opportunity in both day ahead and real time energy markets. These are also operating to meet different needs of power system. A study of power market structure implemented by PJM Interconnections LLC (PJM) was carried out.

The clearing of day-ahead energy market of PJM is different from real-time market of PJM. The day-ahead energy market of PJM is a forward market in which hourly clearing prices are calculated for each hour of the next operating day based on generation offers, demand bids, increment offers, decrement bids and bilateral transaction schedules submitted into the day-ahead energy market. PJM clears the day-ahead energy market and day-ahead scheduling reserve market using least-cost security constrained resource commitment and dispatch that simultaneously optimizes energy and reserves. The real-time market uses the Real-time Security Constrained Economic Dispatch (RT SCED) program to determine the least cost solution to balance supply and demand.

The day- ahead energy market settlement is calculated for each day-ahead settlement interval (hourly interval). The real-time market balancing settlement is calculated for each real-time settlement interval (five (5) minute interval) based on actual five (5) minute revenue data for settlement MW quantity deviations from day-ahead scheduled quantities. Energy prices after pricing run in both the markets are Locational Marginal Prices (LMP). LMP is a pricing approach that addresses transmission system congestion and loss costs, as well as energy costs. Therefore, each spot market energy customer pays an energy price that includes the full marginal cost of delivering an increment of energy to the purchaser's location.

The day-ahead energy market bid/offer period closes at 11:00 hours on the day before the operating day and the day-ahead market results are posted by 13:30 hours or as soon as practicable thereafter on the day before the operating day. Generators and demand resources may alter their bids for use in the real-time market, during the generation rebidding period

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(from 13:30 hours to 14:15 hours) and period starting at 18:30 hours and up to sixty-five (65) minutes prior to the start of the operating hour [2].

III. Products for Network Access and Short-Term Power Purchase in India

In Indian power sector, transmission access can be availed broadly through Long Term Access (LTA), Medium Term Open Access (MTOA) and Short-term Open Access (STOA) depending on the duration of network access required at inter-state level [3], [4].

TABLE I
TYPE OF ACCESS AS PER THE DURATION

Serial No	ACCESS TYPE	DURATION OF ACCESS REQUIRED
1	Long Term Access	Period exceeding 7 years
2	Medium Term Open Access	Period equal to or exceeding 3 months but not exceeding 5 years
3	Short Term Open Access	Period up to 1 month at one time

STOA transactions are of two types viz. STOA Bilateral and STOA Collective. STOA Bilateral offers four different products with respect to the time lines of application viz. Advance reservation, First come first serve, Day ahead and Contingency transactions. These are applied at and approved by the Regional Load Despatch Centre (RLDC). The STOA Collective segment primarily offers two products viz. Day Ahead Market (DAM) and Real Time Market (RTM). These are facilitated by power exchanges through a double sided, closed, anonymous bidding process.

IV. Power Market Products in Collective Transactions Segment

Power exchanges were introduced in India in the year 2008. These exchanges provide a transparent and competitive platform for trading electricity in short-term. The operation of power exchanges has gradually evolved over the past decade. In India, we follow minimum scheduling and dispatch time window of 15 minutes. The scheduling, dispatch, metering, energy accounting and settlement of all transactions in electricity is done at every 15 minutes, which is considered as one time block. Accordingly, an operating day is divided into 96 time blocks of 15 minutes each. In April 2012, the granularity of transaction was further improved with transition from hourly contracts (comprising of 04 time blocks) to 15 minutes wise contracts for delivery in DAM. This transition in operation of power exchanges over 15 minutes dispatch window, paved the road to bring RTM for electricity in India.

In addition to the DAM, a need was felt for having a market close to real time operation to provide flexibility required for facilitating Renewable Energy Sources (RES) integration. RTM gives 48 auction sessions, one in every 30 minutes in a day and the power is delivered after one hour of closure of the auction. This 30-minute delivery period is a set of two 15 minutes time blocks. In each of 48 auction session's bid / auction period, bidder has to submit bid for each of two relevant time blocks. These bids may be different in quantum and price for each time block.

Every entity can change their schedule before a certain time of commencement of each RTM auction, this is known as right to recall the schedule of the contracts. Revision in schedule made in odd time blocks shall become effective from 7th time block and any revision in schedule made in even time blocks shall become effective from 8th time block, counting the time block in which the request for revision has been received by the RLDCs to be the first one. The auction for each delivery period commences after the end of right to recall. For example, revision request for schedule is received on 1st time block (even time block) of the day is implemented from 7th time block in schedule and from 2nd time block the activity of RTM auction for delivery period of 30 minutes starting from 7th time block is performed. Fig.1 indicates operational timelines of real time market [5], [6].

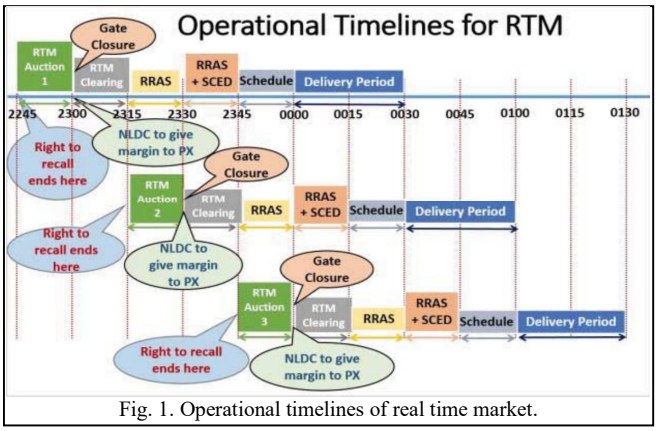

Fig. 1. Operational timelines of real time market.

DAM performs bidding, matching and clearing activity on a day ahead (D-1) before the power delivery, for the day (D). Current timing for DAM bidding is 10:00 hours to 12:00 hours of previous day (D-1).

Clearing mechanism of both the markets is same but the processing time duration is different. Received bids of buy and sell for each time block are aggregated and matched using double sided closed auction methodology. Interaction of bids by the two market forces i.e., buyer and seller and market function of demand and supply gives a provisional trade result.

After matching the bids power exchanges submit provisional trade results to the nodal agency i.e., National Load Despatch Centre (NLDC). NLDC verify the combined trade cleared in both power exchanges against the available transmission capability (ATC) for import/export for all transmission corridors. If the combined cleared trade of the two power exchanges is within the ATC, the initial results are confirmed by NLDC to the power exchanges. In the event of the combined cleared trade exceeding the ATC, the allocation of available corridor margin between the power exchanges shall be in the ratio of the initial market clearing volume of RTM in the respective power exchanges, and accordingly, this shall be communicated to the power exchanges. The power exchanges thereafter submit the final trade results in conformity with the available corridor margin as provided by the NLDC. Final trade results are sent for scheduling to NLDC. NLDC further communicates these schedules to RLDC for incorporating collective transactions in the schedules of respective utility / generator.

The processing time of market trades is different in DAM and RTM. In DAM, after ending of bid time at 12:00 hours, schedules are communicated at 17:30 hours of previous day (D-1), where D is the date of delivery. Whereas in RTM, after ending each of bidding or auction, matching and clearing activity is completed in next time block and schedules are communicated in subsequent time block [6].

V. Real Time Market a Trend Follower to Day Ahead Market

Over a period of time power demand of India has shown a typical trend with two specific peaks during a day. At present, day ahead forecasting tools consider historical data along with additional information of weather, holidays, social and special events as primary inputs. Based on the demand forecast, the available generation resources are generally planned to be dispatched by the state load dispatch centers (LDC) on the basis of merit order, resource planning, congestion etc. The load generation balance is ensured by the LDCs by assessing any surplus / deficit during real time operation. A coordinated scheduling & dispatch is facilitated at regional level by the RLDCs in a decentralized manner, while duly factoring the network reliability aspect. The NLDC facilitates a thin layer of centralized scheduling & dispatch by administering reserve regulation ancillary services (RRAS) and security constrained economic dispatch (SCED) over and above the schedules prepared at regional levels so as to ensure grid reliability and overall economy at national level.

To represent the power demand of India, time block wise average of sample of a national holiday and random days of winter, spring and autumn season during observation period are used for plotting the demand curve. Power markets are discovering clearing price and volumes for each time block by allowing to place bid for each time block. Both the DAM & RTM markets are analyzed considering the behavior of Market Clearing Price (MCP) & Market Clearing Volume (MCV) for a particular time block for complete enumeration of all 334 days in the observation period of 11 month (i.e., from June 2020 to April 2021).

Generalization is done for ease of understanding. For example, intensity of sun light varies depending on season, cloud cover and time of the day. But a generalization hints intense sun light in mid-day hours. For ease of understanding, trend of DAM and RTM's MCP and MCV with respect to 96 time blocks of a day are plotted and analyzed for 334 days.

For finding trend of MCP of a market, time block wise MCP for all 334 days is averaged and a single average MCP for each of time block (1 to 96) is derived. For example, MCP of first time block for each 334 day is added and divided by 334 to arrive single average MCP for 1st time block. Similarly, it is calculated and plotted for all the 96 time blocks for RTM and DAM in Fig.2 [7].

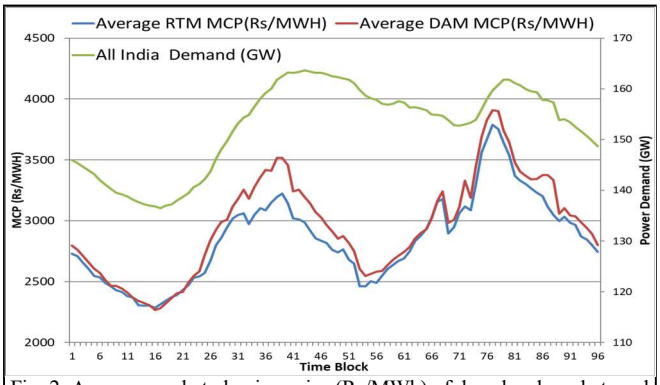

Fig. 2. Average market clearing price (Rs/MWh) of day ahead market, real time market and typical power demand curve of India (GW)

Time block wise Average MCP curves of DAM and RTM are almost similar in shape and the peaks on the curves are appearing in nearby time blocks of demand curve.

Study of time block wise maximum MCP of all 334 days of observation period for DAM and RTM was carried out and the observations are plotted in Fig 3 [7].

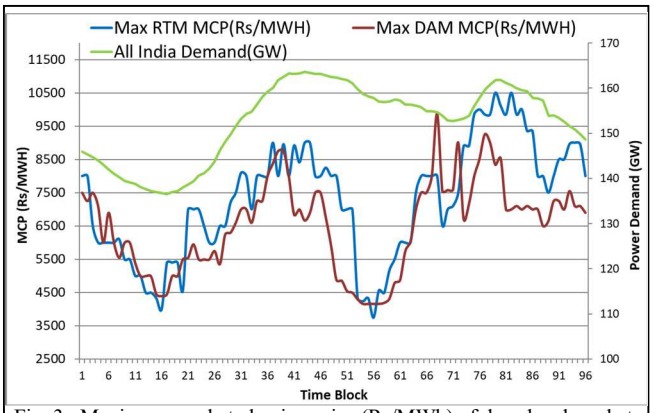

Fig. 3. Maximum market clearing price (Rs/MWh) of day ahead market, real time market and power demand curve of India.

In Fig. 3, the maximum MCP shows that comparatively higher maximum MCP are observed during the time blocks when demand is maximum and a significant dip in maximum MCP is observed between two demand peaks. The curves also indicate trend following pattern between all India power demand and MCP.

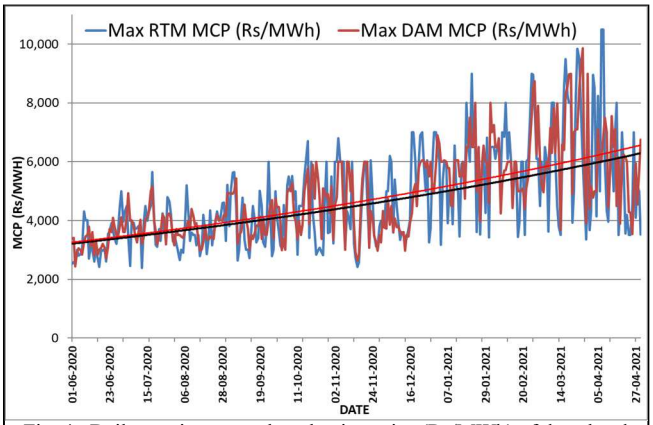

Fig. 4. Daily maximum market clearing price (Rs/MWh) of day ahead market and real time market.

Maximum MCP of a day is analyzed for the complete study period of 11 months. Maximum MCP on a holiday in both the markets are found low as compared to the maximum MCP of adjacent working days. Holidays can be easily identified by the sharp dips as in Fig. 4 [7]. In the observation period till 30 April 2021 Maximum MCP for DAM and RTM is Rs.9.868/kWh and Rs.10.500/ kWh respectively achieved.

To control the spread of Covid-19 Virus systematic lockdown was imposed for 2 months starting from 23rd March 2020. During the lockdown period the industrial loads were stalled. Systematic unlocking began from 1st June 2020 and industries gained pace. In April 2021, during second wave of Covid-19 again partial lockdown was implemented. The impact of the unlocking and partial lockdown is visible as maximum MCP is gradually rising from June 2020 till March 2021 and comparative fall in April 2021.

VI. Generators and Power Utilities Exploring Real Time Market

Earlier bulk load utilities/DISCOMs were managing their load-generation balance by arranging power by using various

products including DAM, STOA Contingency (STOA CON) type applications and any un-predicted variation in load was managed by varying internal / captive generation or drawing from grid under Deviation Settlement Mechanism (DSM). Change in strategy of the handling the real time imbalances due to change in internal generation or captive generation using RTM is also observed during the study period.

Bulk load utilities/DISCOMs have explored RTM with gate closure near to real time dispatch to meet the last mile demand variations. Effective use of RTM can be seen by single day power purchase schedule of a bulk load utility given in Fig. 5. [8]

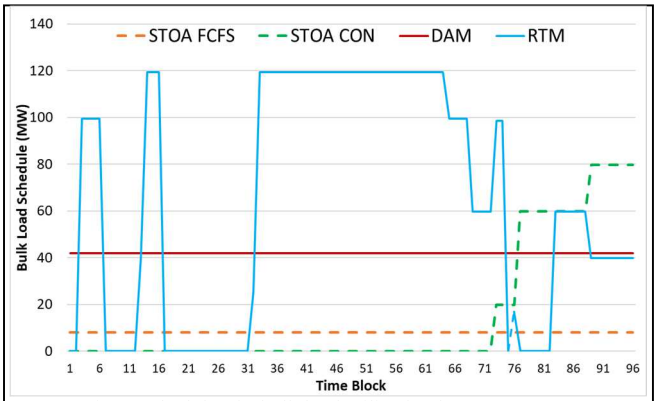

Fig.5. Schedule of a bulk load utility for date 19.09.2020.

Fig 5. Illustrates energy schedule of a bulk power utility located in the Western region of India, which meets part of its load through its internal captive generation. On 19th September 2020, depending on the availability of internal captive generation, the bulk load utility had purchased 47MW from short-term market through STOA Bilateral First come first serve (STOA FCFS) for 7MW and through DAM for 40MW. To meet the real time contingencies (such as, load / generation variation etc.) the utility purchased power through STOA CON and through RTM.

As per Indian Electricity Grid Code (IEGC) "In case of forced outage of a unit of a generating station (having generating capacity of 100 MW or more) and selling power under Short Term bilateral transaction (excluding collective transactions in day ahead market and real time market through power exchange), the generator or electricity trader or any other agency selling power from the unit of the generating station shall immediately intimate the outage of the unit along with the requisition for revision of schedule and estimated time of restoration of the unit, to SLDC/RLDC, as the case may be" [9].

Before implementation of RTM, in case of forced outage of unit, there was no option for revision of schedules of collective transactions. Similarly, there was no provision of availing substitute power for honoring power scheduling under collective transactions. Often this leads to huge deviation charges liability on such generators. Implementation of RTM has given an option of power purchase by generator in case of forced outage of unit, thereby avoiding penal imbalance charges [6]. In the observation period (Jun'20 – Apr'21) 13 generators of Western region of India connected to Inter State Transmission System (ISTS) have exercised this option multiple times and purchased power in RTM during unit tripping [8]. (Refer Fig.6)

Fig.6 illustrates contracts and schedule of a generating station for 20.11.20. This generating plant has multiple units in a single plant and it was selling power though MTOA, STOA and DAM. One unit of plant tripped at 16:44 hours of 19.11.20, the generator purchased power in RTM to fulfil the DAM contract obligation. Thus, the RTM gave an avenue to such generators for managing deviations in real time due to unforeseen events like forced outage of units.

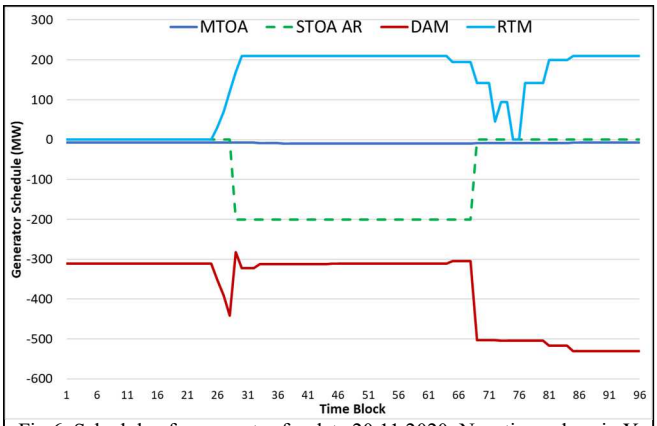

Fig.6. Schedule of a generator for date 20.11.2020. Negative values in Y axis represent sold quantum and positive represent purchased quantum.

VII. Correlation of Real Time Market and Day Ahead Market

The study period of 11 months has 32,064 time blocks. Bid submission and clearing timelines of DAM and RTM are different. MCP for each time block is derived in both the markets. Assessment of closeness of MCP of RTM to the MCP of DAM is done by keeping MCP of DAM as a reference. Study of MCP of RTM of a particular time block with in the tolerance band of +/- 2% of MCP of DAM is done for all 32,064 time blocks.

For example, the MCP of DAM for 41st time block of 16-09-20 is Rs.2500/MWh. So, the +/- 2% tolerance band is from Rs.2450/MWh to Rs.2550/MWh. For the said time block RTM cleared for Rs.2528.16/MWh i.e., between +/-2% tolerance envelope. The same study was also done for tolerance band of 5% and 10% [7].

It is seen that in 47.19% time blocks, MCP of RTM is within 10% tolerance band of MCP of DAM. The percentage has varied from month to month. Out of total time blocks for the month November 2020, MCP of RTM of 64% time blocks were within 10% tolerance band of MCP of DAM for the respective time blocks. During the observation period both DAM and RTM has provided trade facility for 32,064 nos. time blocks in each market. MCP of both the markets for each time block on simple time scale is plotted for in Fig. 7 [7].

Concentration of MCP of the initial period is around Rs. 2082/MWh and by the end of April 2021 it increased to around Rs. 3250/MWh. Fig.7 also indicates that MCP of RTM is fluctuating more as compared to MCP of DAM.

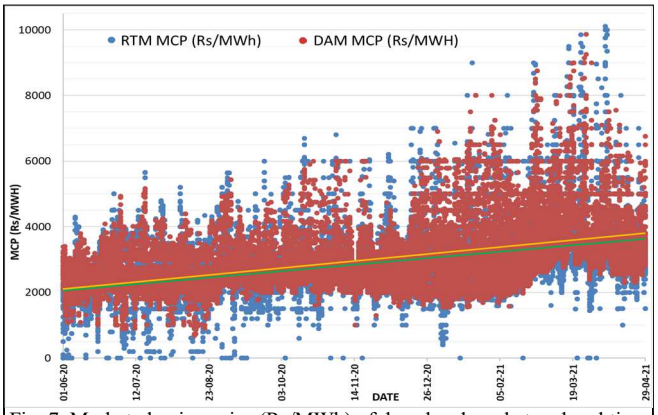

Fig. 7. Market clearing price (Rs/MWh) of day ahead market and real time market.

During the observation period opportunity trades are also seen, as minimum MCP for RTM and DAM is Rs.15/MWh and Rs.680/MWh respectively. Whereas in a single day highest difference between maximum to minimum MCP is Rs.7431/MWh and Rs.6808.37/MWh for RTM and DAM respectively.

TABLE II
MONTH WISE DETAILS OF CORRELATION COEFFICIENT BETWEEN MCP OF REAL TIME MARKET AND DAY AHEAD MARKET

Serial No	MONTH	Correlation Coefficient
1	Jun-20	0.62
2	Jul-20	0.64
3	Aug-20	0.67
4	Sep-20	0.62
5	Oct-20	0.70
6	Nov-20	0.81
7	Dec-20	0.78
8	Jan-21	0.79
9	Feb-21	0.79
10	Mar-21	0.61
11	Apr-21	0.51
12	Jun'20 to Apr'21	0.75

Maximum correlation coefficient between the MCP of DAM and MCP of RTM is 0.81, which is observed for month November 2020 and overall correlation coefficient is 0.75 during the 11 month period of coexistence of DAM and RTM. Correlation of the data pertaining to clearing volume reveal correlation coefficient of 0.41 during the 11 month period of coexistence of DAM and RTM.

VIII. MARKETS FOR MEETING DEMAND DURING DIFFERENT HOURS

Fig. 8 indicates MCV of RTM and DAM during the observation period. Analysis of clearing volume at markets have given an overview of different aspects that is not limited to market trends and correlation based on MCP. To understand the relationship between time block and MCV during the observation period of 334 days, summation of MCV for respective time block for all 334 days are plotted for all 96 time blocks for DAM and RTM [7]. (Refer Fig.8)

As evident from Fig.8, the DAM has higher volume transactions as compared to the RTM. In the observation period transaction volume of DAM and RTM is 56.84 BUs and 10.93 BUs respectively. As per MCV, it appears that the utilities are using DAM for meeting their power demand and traded volumes are following the demand curve. But RTM clearing volume has a different curve because the traded volume is higher between the two demand peaks of a day when the prices are comparatively lower than the prices during the peaks. In the observation period, in a single day maximum MCV in RTM and DAM is 68.36 MUs and 251 MUs respectively.

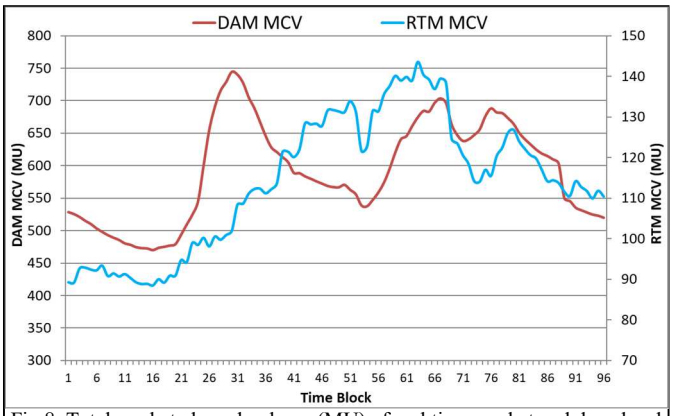

Fig.8. Total market cleared volume (MU) of real time market and day ahead market.

IX. CONCLUSION AND WAY FORWARD

Generators and load entities as well as state control areas in India are utilizing these short term markets which provide an opportunity to trade with bidding time very close to the delivery time. Use of DAM for forecasted load management and RTM for meeting last mile imbalances and contingencies at a discovered price can be seen from the analysis. From the analysis of time block wise average market clearing prices of both markets, it appears that the bids in RTM are placed after close observation of MCP of DAM. The markets are also showing characteristics of competition and opportunity trades as evident from minimum and maximum MCP. The volume and price trends in the market will be closely tracked by the industry. This will offer better avenues for meeting the short term demand and handling imbalances in real time. This would also influence the power procurement strategies of DISCOMs. Market volumes are likely to grow in the near future as greater volume of renewable energy is added to the system and existing long-term PPAs of DISCOMS expire.

With evolving regulatory provisions viz. power market coupling, benefits of coexistence of DAM and RTM may be seen in other aspects in future. Co-existence of the exchange based physical delivery markets viz. the DAM and RTM is essential and their success may help in moving ahead further towards introducing more advanced products like the forward & future contracts in electricity.

X. ACKNOWLEDGEMENT

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