Challenges Faced and Measures Adopted for RE Integration in Indian Power system

P.K. Agarwal

Power System Operation Corporation Ltd.
India
pkagarwal@posoco.in

S.K. Jain

Power System Operation Corporation Ltd.
India
skjain@posoco.in

SUMMARY

In India, generation is predominantly thermal (63%) followed by Hydro (13%) and because of this fact all the regulations, policies and practices were built around traditional thermal& hydro generators. India is among world's leading thermal generators as presently installed capacity is 226 GW. During last 7-8 years, there has been a strategic shift and the RE (Renewable Energy) generation have come up at great pace i.e. 24 GW to 78 GW. The RE generation has more than tripled during the said period in which installed capacity has increased 1.78 times only (from 200 to 356 GW). RE mix has increased it's share from 12 to 22% in total generation. This fast pace of RE ingress has been challenging, but with advance preparedness of policy makers, regulators and stakeholders present RE mix has settled in the grid without any major hiccups. With the current pace, approx. 100 GW of RE power is expected to be commissioned by 2022, which will be a real challenge for the grid. In this paper, the authors have carried out in depth analysis of challenges of RE, it's integration, policy framework, operating principles and future preparedness.

KEYWORDS

Power System, Renewables, Renewable Integration.

INTRODUCTION

India is a federal polity with the Centre and States having different but complementary responsibilities on governance. On the renewable front also, there remains a significant gap in vision between the Centre and States which prevents policy makers to design universally accepted policies and obtain the desired results. So, all policies have gone through a long gestation period and now these have got matured and started yielding desired results.

Commencing in year 2008, National Action Plan for Climate Change (NAPCC) proposed that states should procure/consume minimum 5% RE power with 1% increase per year upto 10 years. In the year 2010, Jawahar Lal Nehru National Solar Mission (JNNSM) proposed RE target of 20 GW solar capacity by 2022. However, in 2015, Govt. of India revised the RE target 2022 to 175 GW (Solar- 100 GW, Wind- 60 GW, Biomass- 10 GW, Small Hydro – 5GW) in line with COP21 Paris Agreement. In addition to this, Government of India, as a part of it's Nationally Determined Contributions (NDC), is committed to have 40% of its installed capacity from non-fossil sources by 2030. Such ambitious targets has been set by the Indian Govt., because most parts of the Indian subcontinent have solar resource potential in the range of 5.0 to 6.0 Kwh/Sqm/Day and lot of solar potential is yet to be tapped. The solar resource potential in India is shown in Fig 1. Due to strenuous efforts undertaken by power sector professionals and reduction in prices of solar panels, pricing of RE power has also come down from Rs.17 to Rs. 2-3 range. However, this low pricing can be a challenge to commercial viability of RE projects. Hence, RE promotional policies, financing for RE installation (through subsidies or schemes), favourable regulations, strengthening of evacuation corridor, priority of dispatching (because of limited availability in a particular time period), etc. are mandatory to meet the targets envisaged by the government.

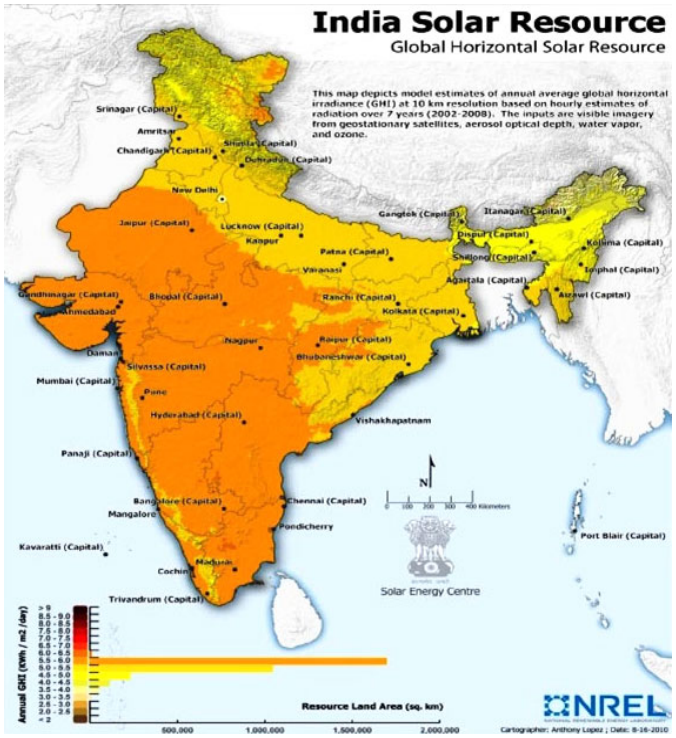

Fig 1 – Solar resource potential in India *(Source- NREL)*

CHALLENGES OF RE GENERATION IN INDIA

India is seventh largest country admeasuring approx. 3.28 crore sq.km in area having plains, mountains, rivers, sea and deserts wherein temperature ranges from -45 deg C (in Kashmir) to 51 degree centigrade (in Rajasthan). Every year, India faces drought in some parts and floods in some parts of India. The sunlight is available for a longer period in India i.e. 12- 14 hrs in summer {sunrise time - 0422 hrs in Nalabari (Assam) and sunset by 1924 hrs. in Jalandhar (Punjab) and 8 – 10 hrs in Winter. These data depicts the geographical diversity which is advantageous in one way and disadvantageous in other way. In context of Indian grid, the demand and generation have a larger timescale and if the generation has appropriate mix of thermal, hydro, nuclear and RE, operator can handle the load generation balance with ease.

Depletion of coal reserves and high coal import bill of over Rs.1 lakh crores (2014-15) has been constant pain of Thermal generation and also greater carbon emission has forced Indian government to drastically change it's strategy and immediate shift to RE has been crucial for it's survival. Due to these facts, RE generation mix has increased in India at a great pace in recent years (from 0% in the year 1999 to approx. 20% in 2019) and further targeted to 40% by 2022. Fig 2 & 3 represents the mix of installed capacity and RE growth till 2022 respectively.

Wind and Solar RE generation are intermittent in nature. Due to diurnal and seasonal variations, shorter timescale, RE power have higher impacts on the grid balance. To understand the variable nature, e.g., one RE rich state of India, Tamil Nadu has huge variation of RE power across two seasons i.e. 30 – 35% from June to September and 5-10% during remaining months in energy terms which is very difficult to handle.

Since forecasting and scheduling responsibilities lies with states and generators, Operators at regional and national level have very low visibility w.r.t Wind and solar. Frequency excursions is a common phenomena, which grid operators apprehend would exacerbate due to higher penetration of REs. Handling such a giant grid with weather varying diurnally and seasonally and also different demand patterns across the year have always been a challenge for operators, planners, regulators and policy makers.

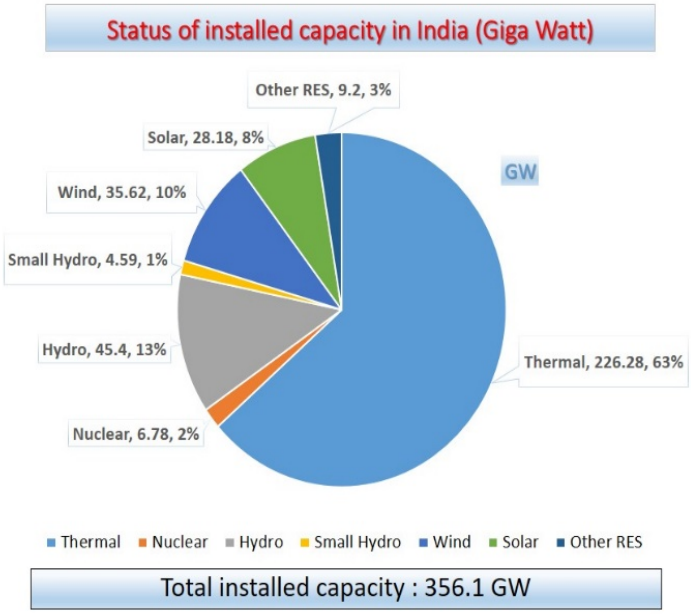

Fig 2 – Status of Energy mix in installed capacity in India(Source: CEA)

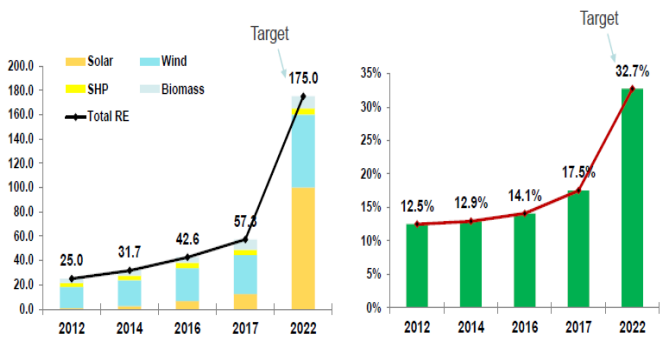

Fig 3 – Growth of RE & targets till 2022(Source: MNRE)

POLICY AND REGULATORY MEASURES FOR RE AND RE INTEGRATION

A wide variety of policies have been designed in India explicitly to promote renewable energy revolution, viz., Direct equipment subsidies, rebates, net metering laws to support roof top solar, Renewable Power obligations (RPO), ESCerts/REC, conducive Grid access & wheeling policies, waiver of transmission charges to RE generators, etc. RE power from wind and solar have must run status as per IEGC code.

Further, CERC has mandated for implementation of REC mechanism in India vide REC (Renewable Energy Certificate) regulations, 2010. As per these regulations, "RE generators are eligible to obtain RECs based on RE power generated and the obligated entities are required to either generate RE power or purchase these RECs to meet the allocated quantum of RPOs."

India's accelerated depreciation policy allows 100% depreciation in the first year of operation to wind generators, which has helped spur the largest wind power industry among developing countries. However, this policy led to large investments without sufficient regard to long term operating performance and maintenance, resulting in capacity factors lower than for wind power installations elsewhere.

Ministry of New and Renewable Energy (MNRE), Govt. of India through it's agencies viz., NISE (National Institute of Solar Energy), NIWE (National Institute of Wind Energy), IREDA (Indian Renewable Energy Development Agency), etc. is consistently working for promoting RE power. SECI (Solar Energy Corporation of India) is also working rigorously under MNRE for installation of Solar plants, parks & rooftop solar. MNRE has notified a scheme named "*Pilot-cum-Demonstration Project for Development of Grid Connected Solar PV Power Plants on Canal Banks and Canal Tops"* in the year 2014. The objective of this scheme is to achieve gainful utilization of the unutilized area on top of canals and also the vacant Government land along the banks of canals, for setting up Solar PV power generation plants for feeding the generated power to Grid and to set up a total capacity of 100 MW solar PV power projects. MNRE is providing fixed capital subsidy of Rs.3cr./MW of installed capacity (AC output) for Canal Top SPV projects and Rs. 1.5cr/MW of installed capacity (AC output) for Canal Bank SPV Projects.

MNRE has also introduced solar roof top & National Wind - Solar Hybrid Policy in 2015 & 2018 respectively. These advanced and promotional measures have accelerated the growth of RE power in India.

CONTRIBUTION OF THERMAL GENERATION IN RE INTEGRATION

With large scale integration of renewables planned in India, thermal generation mix (presently at 63%), will definitely be reduced, but role of thermal generation will remain vital in view of seasonal, intermittent and variable nature of RE. The new role of thermal generators desires that it should have more flexible attributes such as high ramping rate, lower technical minimum, frequent start-stop characteristics, etc. with operational requirements.

To quantify the ramp rates being provided by thermal generating units in India, POSOCO has recently published a report titled "Analysis of Ramping capability of Coal fired generation in India." Although CEA standards specifies +/-3% per minute ramp rate, IEGC has mandated it as +/-1%, but as per the said report actual ramping of some generators are below +/-1%. To incentivise higher ramp rate, CERC has notified "Terms and Conditions of Tariff Regulations' 2019 which

mandates that the generators will get additional 0.25% ROE for every 1% per minute increase in ramp rate over and above ramp rate subject to ceiling of additional ROE of 1% and vice versa w.e.f. 01.04.2020.

Earlier CERC has also reduced technical minimum from 70 % to 50 % of their capacity on bar and also compensate for station heat rate vide its amendment'2016 to IEGC.

NTPC, the thermal generator of India is also taking many initiatives for RE as it has already commissioned approx.. 1000 MW RE power and further adding RE power to it's generation capacity. NTPC has also proposed a mechanism for allowing flexibility in generation such that GENCOs are allowed to utilize RE capacities for supplying power against existing commitments to supply the power from thermal or hydro stations anywhere in India with the consent of procurers. These small but far reaching steps have been contributing in smooth RE integration in India.

MEASURES ADOPTED FOR EVACUATION INFRA FOR RE INTEGRATION

Gestation period for a Solar and Wind power project is about 6-12 months and development of evacuation infra take longer time i.e. 3-5 years depending on line length and Right of Way (ROW) issues. RE Pooling station with grid network at PCC (Point of Common Coupling) also takes longer time than generation gestation period. So, advanced planning and construction of evacuation infra is pre-requisite for evacuation of RE generation. To resolve this issue, POWERGRID, the TSO of the country has planned Green energy corridor pan India covering the areas where the solar and wind power plants are coming up. Some parts of the corridor has already been constructed and remaining corridor shall be completed by 2022. Fig. 5 depicts the Green energy corridor scheme of India covering all parts of the country.

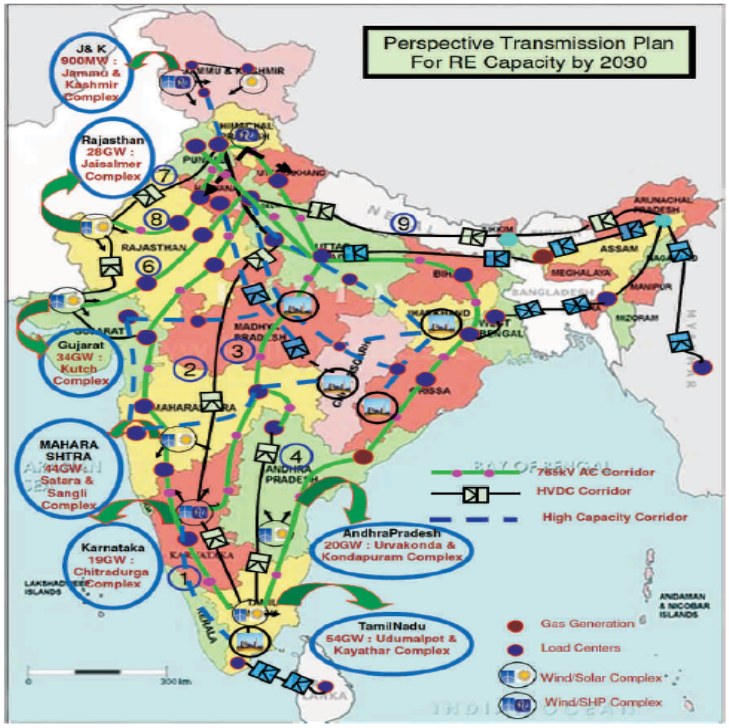

Fig. 5 – Green Energy Corridor Scheme of India(Source-Powergrid)

OPERATIONAL CHALLENGES OF RE INTEGRATION AND ITS SOLUTIONS

From the Grid operator's perspective, fast response, flexible demand/supply resources, accurate forecasting & scheduling, robust SCADA & PMU system, ancillary services, AGC and incorporation of data analytic tools are some of the key requirements for smooth RE integration. During the year 2017 -18, Operators have managed demand variability of order 3000-5000 MW/block of 15 minutes in 2017-18, which is shown in Fig.6.

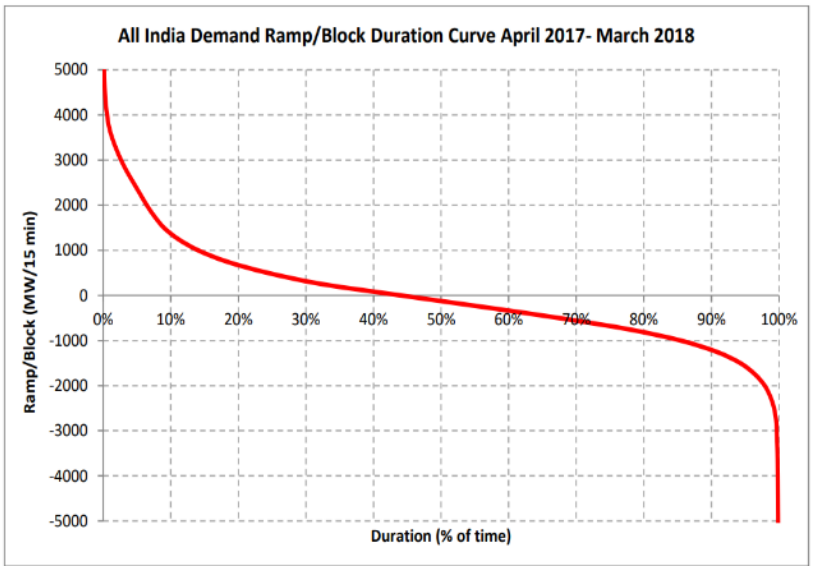

Fig. 6 – Duration curve of All India Demand Ramp during 2017-18 (MW/block of 15 minutes)
(Source: POSOCO's report on analysis of ramping capability of coal fired generation in India)

As the penetration of variable renewable energy (VRE) increases in the Indian grid, balancing operations becomes critical in real time. The measures adopted by operators and stakeholders for RE integration can be summarised as below:

(i) Expanding balancing area & wider visibility

Requirement of suitable balancing mechanism is essential to ensure grid security. Enhancing balancing area increases operational flexibility and significantly lower the overall cost to consumers as ancillary services requirements are reduced substantially. Initially, Indian grid was operating as asynchronous grid divided in five regions operating at different frequencies. Later, some of the regions got interconnected via HVDC back to back links, but by 2013, Indian grid was transformed in single AC grid operating at one frequency. Now, it became easier to control different balancing areas from a single point. This exercise expanded the ambit of control over larger balancing area thus imparting flexibility to the operator.

CERCissued notification regarding pilot SCED implementation w.e.f. 01.04.2019, which optimises the cost on pan India basis and dispatch the cheapest available generators in silos which are invisible to regions thus enhancing visibility at NLDC (National Load Despatch Centre) level. SCED not only optimises the cost but increases balancing area and add to flexibility in operation as well.Spatial distribution of generators and the variable cost for a certain period is as shown in Fig 7.

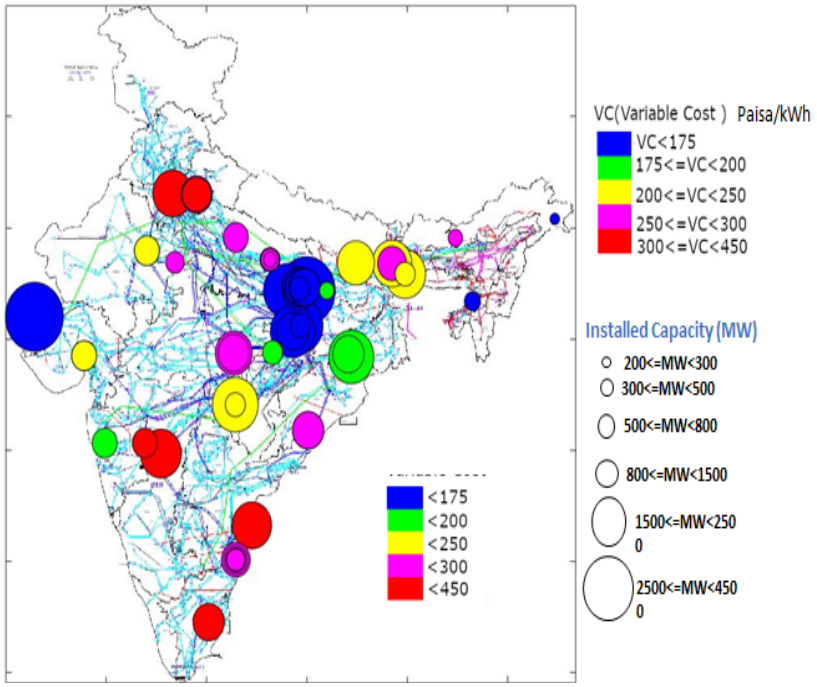

Fig. 7 - Spatial Distribution of Variable Cost of Generators under SCED(Source-POSOCO)

(ii) Establishment of REMCs

RE has peculiar characteristics of intermittency and variability, therefore its geographical dispersion, distribution & transmission level connectivity, requires real time monitoring of generation as well as study of its dynamic impact on the system round the clock. It requires dedicated centres to monitor and control RE. In view of these aspects, 11 nos. Renewable Energy Management Centres (REMC) covering entire India has been planned in first stage and is presently under construction.The hierarchy of REMC and typical data flow architecture for various functionalities envisaged at the Renewable Energy Management Centre is as depicted in Fig 8 & Fig 9 respectively. Real time monitoring of RE generators with geo spatial visualization, scheduling and single source information repository utilizing auto adaptive algorithm for statistical combination of multiple forecasts are the key features of these upcoming REMCs.

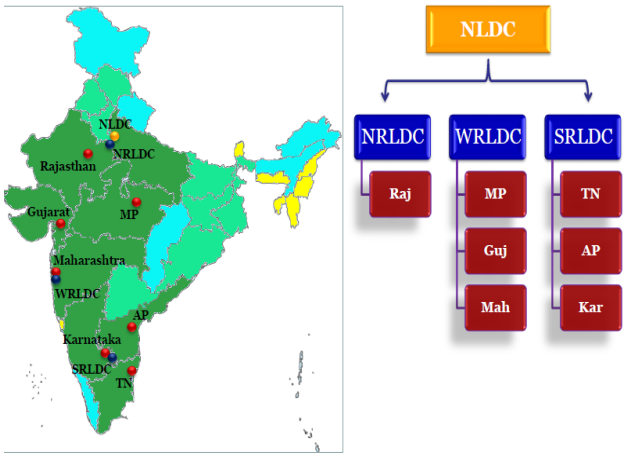

Fig. 8 – REMC Control Centres in India

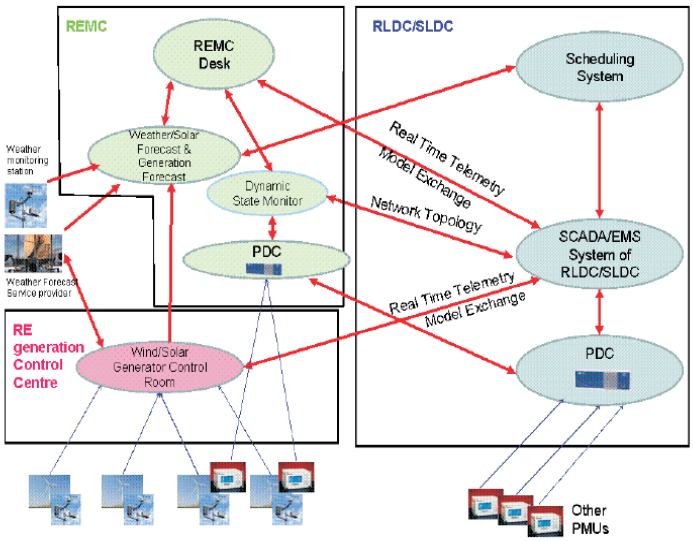

Fig. 9 – REMC Data Flow Structure

(iii) Ancillary services (AS) management for RE integration

Ancillary services are an indispensable part of power system operation, which are required for improving and enhancing reliability of power system. In India, these services were mandated through CERC RRAS (Reserves Regulation Ancillary Services) regulations, 2015. As of now, 67 power plants, which fulfill certain norms are mandated to provide ancillary services. The nodal agency NLDC is dispatching these services to maintain frequency at desired level and to relieve congestion in the transmission network.

These ancillary services have immensely contributed towards RE integration in case of sudden up or down of Wind/Solar power. Ancillary despatch has been very helpful during storms and unprecedentedweather conditions. To expand the ambit of AS, Commission is in process of designing ancillary market to cover more generators for providing AS and also compensate them on the basis of market determined price for dispatched services. This will further provide control for RE integration.

(iv) Commercial measures for integrating RE

Commercial steps like ABT (Availability Based Tariff), DSM (Deviation Settlement Mechanism) and it's latest amendment linking DSM to frequency have incredibly helped to maintain hygiene in Indian power sector and thus contributed towards RE integration. With these mechanisms, stakeholders are motivated towards maintaining load generation balance and hence their injection and drawals do not cross critical limits. RE power is easier to handle in a disciplined grid.

(v) Measures adopted based on power system studies

NLDC in coordination with all RLDCs (Regional Load Despatch Centres) carries out different load flow studies, fault analysis, simulation studies, etc. regularly. Based on these studies, NLDC suggests for strengthening of transmission corridor & Substations, installation of reactors, Voltage & Reactive Compensation through reactors, SVCs, STATCOMs, etc. for maintaining grid parameters. Based on these studies, shift from one hour to 15 minutes scheduling (2011), establishment of power exchange (2009), tightening of grid frequency band from 49.5-50.2 (2010) to 49.9 to 50.05 Hz, etc. are some of the measures CERC has undertaken. These measures have further refined the system and contributed a lot to integrate RE with existing energy mix.

(vi) Forecasting Initiatives

At RLDC & NLDC, several initiatives of load forecasting based on weather and historical data is being carried out which helps in managing RE.At one of our RLDC, load forecasting is done by aggregating data from SLDCs, comparing it with historical data, considering weather inputs as well. IMD (Indian Meteorological Department) has provided direct link for obtaining weather data, which POSOCO is utilising for managing demand and also handling RE. The RMSE (Root Mean Square Error) is being calculated which is generally in between 1.5% to 5%. The schematic for load forecasting is as shown in Fig. 10.

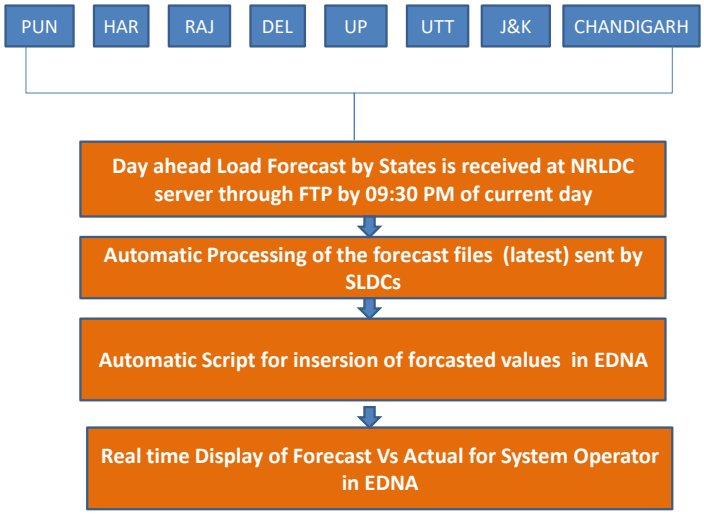

Fig. 10 Schematic of Load Forecast by RLDC

Other RLDCs use the embedded STLF (Short Term Load Forecast) software in SCADA, Time series analysis, etc. to forecast demand with inputs from historical demand data & weather forecast data.

At NLDC, day ahead Load forecast ramp rate is calculated based on ramp rate of N-1st, N-2nd, N-3rd and N-7th day (N= current day). This ramp rate is added to previous day's actual demand to arrive to next day load profile with weather inputs. Several other initiatives, pilot projects are underway at POSOCO in quest of obtainingaccurate load forecast and handle the intermittent nature of RE.

VII. WAY FORWARD

As the percentage of current 20-25% RE mix increases, major steps required for smooth RE integration are summarised as below:

a) Shift from 15 minute scheduling to 5 minute scheduling for finer despatch control.
b) Reserve sharing among different balancing areas.
c) Coordinated scheduling and operation.
d) Forecasting is key to managing RE power, so accurate forecasting by having collaboration with agencies like IMD for power specific requirements needs to be explored and incentive for scheduling based on accurate forecasting may be introduced by regulators.
e) Up-gradation of PMUs and installation of PMUs at all RE generators or group of RE generators for real time information.
f) Introduction of EIM(Energy Imbalance Market) for addressing intermittency and variability of RE.

VIII. CONCLUSION

The steps taken by planners, grid operators and constituents by which approx. 20% RE mix has already been handled smoothly till date and now this share of RE is expected to reach within 30-40% zone and as per global experiences, handling RE beyond 20-25% poses many serious challenges and that needs to be taken care in advance. This paper strongly adheres to the fact that in Indian power sector no overnight miracles happened, but small steps, consistent efforts, long time horizon planning and structural reforms have played a gigantic role in RE integration. Policy makers are still in process of introducing many initiatives based on load flow studies, global experience and India specific requirements. Latest technologies like artificial intelligence, data analytics, blockchain are being explored by the power professionals of Indian power sector to arrive at feasible solutions. Also, to minimise carbon footprints as per COP24 agreement, there is ardent need to retire the old fossil fuel generators and make way for RE generators so as to achieve the target of 175 GW by 2022.

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