Initiatives taken for Facilitating Large Scale Integration of Renewable Energy in India

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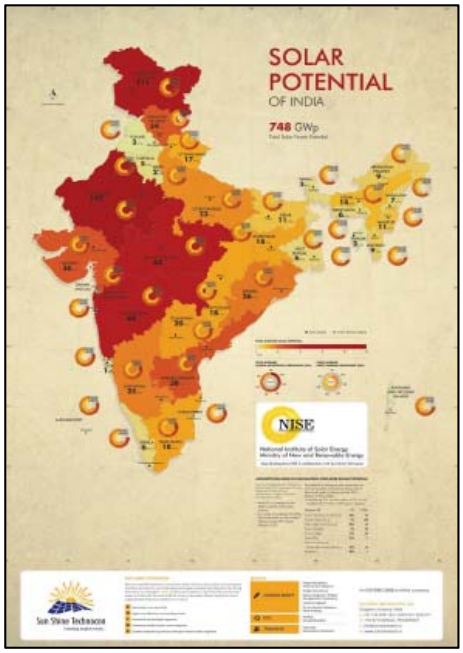
***Abstract*—India is blessed with huge potential of renewable energy. Such a large potential has encouraged India to setup an ambitious target of 175 GW renewables by 2022. In order to integrate such large scale renewables in the power system of India, a number of steps have been taken by policy makers, regulators, transmission planners and system operators which are discussed in this paper. Electricity Act 2003, National Electricity Policy 2006, Tariff Policy 2016, National Solar Mission etc. have provided the conducive environment for renewables to foster. Based on the policy guidelines, regulators have provided the framework for forecasting, scheduling and imbalance handling of renewables. Changes in market design have also been done to provide level playing field to renewables. Green Energy Corridors, a comprehensive scheme covering transmission system strengthening at intra state and interstate level has been evolved to provide access to renewables. Dedicated control centre for renewables are under implementation along with upgradation of existing control centres for better renewable management. Several Studies such as renewable integration studies, load analysis, market analysis and optimization of hydro resources have also been undertaken by system operators to better understand the interaction of renewables with all other factors. All these measures have given a confidence that 175 GW Renewable Energy (RE) by 2022.**

Keywords- Electricity Act, Tariff Policy, Market Design, Green Energy Corridors, Renewable Integration Studies

I. INTRODUCTION

Government of India (GoI) has set up a target of 175 GW of Renewables by 2022 [1]. It includes Solar (utility-scale, distributed, off-grid/mini-grid – 100 GW), Wind (utility-scale – 60 GW), Small hydro (5 GW) and Bioenergy (10 GW). Further, India has also committed for 40% cumulative Electric power capacity from non-fossil fuel based energy resources by 2030 under United Nations Framework Convention on Climate Change (UNFCC) [2]. India is blessed with huge potential of renewables. Under the National Wind Resource Assessment program, National Institute of Wind Energy (NIWE) and State Nodal Agencies (SNA) have assessed the potential for wind power generation for grid interaction at about 302 GW at 100 m agl [3]. National Institute of Solar Energy (NISE) has calculated the State wise solar potential in the country estimated at about 748 GWp [4].

FIGURE 1 : SOLAR POTENTIAL OF INDIA



All these factors have led to a spurt of renewable growth in the country. Renewable capacity has grown with a cumulative annual growth rate of 18% over the last few years. At present, renewables contributes around 58 GW out of 330 GW of total installed capacity of India, second highest contributor after coal based generation [5]. Such large scale addition of renewables in the power system requires not only meticulous planning but also policy and regulatory support to integrate them in cost effective and reliable manner. This challenge has been understood by the key stakeholders such as policy makers, regulators, planners and system operators in India which has led to a number of measures being taken which are discussed in the subsequent sections.

II. POLICY MEASURES

India has a federal structure of governance and "electricity" is a concurrent subject, with both the central and state governments having jurisdiction. At the central level, the Ministry of Power (MoP) and the Ministry of New and Renewable Energy (MNRE) provide the policy framework for promotion of RES. The initiatives taken at the policy level are as follows:

A. Electricity Act 2003

Electricity Act 2003 [6] consolidates the laws relating to generation, transmission, distribution, trading and use of electricity. It is applicable to both inter-state as well as intra-state entities. The preamble of the Electricity Act of 2003 ('the Act') defines the "promotion of efficient and environmentally benign policies" as an objective; the Act also provides legal mandates toward this goal. The Act stipulates tariff determination by appropriate regulatory commission, state-wise Renewable Purchase Obligation (RPO), grid connectivity and development of electricity market. The Electricity (Amendment) Act, 2014 was introduced in the parliament on 19.12.2014 which has inter-alia provisions related to promotion of renewables.

B. National Electricity Policy, 2006

Section 3 (1) of the Electricity Act 2003 requires the Central Government to formulate, inter alia, the National Electricity Policy [7] in consultation with Central Electricity Authority (CEA) and State Governments. The policy recognizes the need for promotion of generation from non-conventional sources of energy and envisages reducing costs of generation from renewables by promoting competition and development of renewable energy technologies. The policy also mandates the respective State Electricity Regulatory Commissions (SERCs) to fix a percentage of the total consumption of electricity in the state through RES which may be done progressively through competitive bidding process.

C. Tariff Policy, 2016

The revised Tariff Policy [8] was notified by Central Government in January 2016. It has several provisions aimed at accelerating deployment of renewable energy in the country, including, inter alia, provisions for 8% solar RPO by the year 2022, Renewable Generation Obligation (RGO) on new coal/lignite based thermal plants, bundling of renewable power with power from plants in case of fully depreciated power plants whose Power Purchase Agreements (PPAs) have expired and exemption of renewable energy from inter-state transmission charges. The Government has also issued guidelines for long term growth of RPOs for non-solar as well as solar energy.

D. National Solar Mission

Under the revised National Solar Mission [9], Central government has rolled out a scheme for development of Solar Parks and Ultra Mega Solar Power Projects. It envisages setting up at least 50 Solar Parks and Ultra Mega Solar Power Projects targeting over 40 GW of installed capacity within a span of 5 years starting from 2014-15. Competitive bidding guidelines have been issued by MNRE for procurement of wind and solar power by the states. Till July, 2017, 34 solar parks with aggregate capacity of 20 GW have been proposed in 21 States. Under the National Solar Mission, lowest bid for solar power in the country @ Rs. 2.44/unit has been received for solar PV power plants to be set up at Bhadla Solar Park in Rajasthan.

E. MNRE Guidelines for Development of Onshore Wind Power Projects.

MNRE has issued the guidelines for development of onshore wind power projects in Oct 2016 [10] to facilitate the development of wind power projects in an efficient, cost effective and environmentally benign manner taking into account the requirements of project developers, State and national imperatives. The recently concluded first round of wind power auctions for 1000 MW saw the wind power price years falling to Rs 3.46 / kWhr.

F. India's Renewable Electricity Roadmap 2030

NITI Aayog in February, 2015 carried out an analysis of the opportunities and barriers to rapid deployment of RE named "India's Renewable Electricity Roadmap 2030" [11]. It identifies legal, institutional and policy changes that will be needed to successfully adopt renewables on large scale. It recommended for National RE Law and/or Policy to establish targets, identify financial support required for achieving targets, and undertake integrated energy resources planning. Support mechanisms for compliance and timely implementation of renewable energy projects, more efficient grid operation with latest technology and faster operation controls were some of the other recommendations. It also recommended for moving towards 5 minute scheduling & dispatch and expand balancing areas to promote flexible demand and supply resources.

G. National Energy Policy, 2017(Draft)

Draft National Energy policy [12] has been prepared by Niti Aayog and published for public comments in June 2017 with the objective of access at affordable prices, improved security and independence, greater sustainability and economic growth. It aims to chart the way forward to meet the Government's recent announcements in the energy domain. The New Energy Policy proposes actions to meet these objectives in such a way that India's economy is 'energy ready' by the year 2040.

H. Expert Committee at GOI level on Large Scale Integration of RE

A high level Technical Committee was constituted by Central Government in April, 2015 to look into various issues relating to large scale integration of renewable generation. A number of recommendations [13] were made such as bringing flexibility in the conventional generation, tighter frequency control, maintaining generation reserves, introduction of ancillary services, forecasting, scheduling, imbalance handling mechanism and robust data telemetry and communication systems.

It also emphasized on establishment of Renewable Energy Management Centres (REMCs), augmentation and strengthening of Transmission system as well as compliance to Regulations & Standards by renewable generation. A number of actions have also been taken by various entities based on these recommendations.

I. Guidelines on Cross Border Trade of Electricity, 2016

Central Government has issued guidelines on Cross Border Trade of Electricity [14] in Dec 2016 with the objective of facilitating cross border trade of electricity between India and neighboring countries. It aims to promote transparency, consistency and predictability in regulatory approaches across jurisdictions and minimize perceptions of regulatory risks. Larger footprint of the grid would not only facilitate integration of renewable in India but also help neighboring countries to access clean and green power.

J. National Electric Mobility Mission Plan (NEMMP)

Government of India launched the National Electric Mobility Mission Plan (NEMMP) – 2020 [15] to achieve national fuel security by promoting hybrid and electric vehicles in the country. It has the potential to bring about a transformational paradigm shift in the automotive and transportation industry in the country. It is a composite scheme using different policy measures such as:

1) Demand side incentives to facilitate acquisition of hybrid/electric vehicles

2) Promoting R&D in technology including battery technology, power electronics, motors, systems integration, battery management system, testing infrastructure, and ensuring industry participation in the same

3) Promoting charging infrastructure

4) Supply side incentives

5) Encouraging retro-fitment of on-road vehicles with hybrid kit

The scheme is expected to provide a major push for early adoption and market creation of both hybrid and electric technologies vehicles in the country.

III. Regulatory Interventions

India also has a federal structure for regulators. Central Electricity Regulatory Commission (CERC) at central level for interstate transmission and State Electricity Regulatory Commission (SERC) at state level for intra state transmission are mandated to provide regulatory framework for electricity. The regulatory initiatives taken to facilitate integration of renewable energy are as follows:

A. Scheduling, Accounting, Metering and Settlement of Transactions in Electricity (SAMAST)

Intra State Balancing and Deviation Settlement System in some form has been introduced only in 6 States/Union Territories of India. Forum of Regulators (FOR) constituted a Technical Committee in November, 2015 to evolve the Scheduling, Accounting, Metering and Settlement of Transactions in Electricity (SAMAST) for India. The report [16] also suggests the action plan for implementation in all the States. The recommendations covered, inter-alia, Facilitating Economic Despatch, Ensuring Interface Meter Adequacy, Implementation of Scheduling Mechanism, Real-Time Generation Dispatching, Implementation of Energy Accounting System, Implementation of Settlement System, Transparency, Integrity and Probity of Accounts, HR Skill Development, Human Resource and Logistics.

B. Model Regulations by FOR

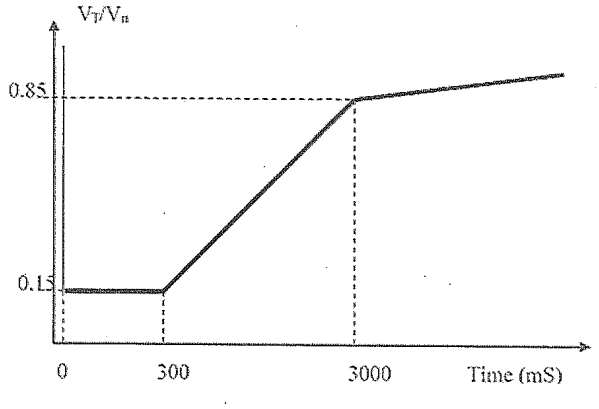
FOR has worked extensively to introduce and harmonize regulatory framework with regard to renewables at the state level. FOR have also brought out Model Regulations on Forecasting, Scheduling and Deviation Settlement of Wind and Solar Generating Stations [17] at the State level in November, 2015. Eight (8) states have floated draft regulations. Karnataka state has notified the final regulations.

Further, FOR has also issued model regulations for Deviation Settlement Mechanism at intra state level [18] in March 2017. These model regulations cover the areas like pre-conditions for participation in DSM, principles for operationalizing DSM, charges for deviations, limits on deviation volume and consequences of crossing limits and provisions regarding accounting & settlement of deviation charges.

C. Connectivity Standards for Renewables

Draft amendments in the provisions related to connectivity requirement for RE in Technical Standards for connectivity to the Grid, Regulations, 2007 [19] has been notified for stakeholder consultations. These amendments include provisions related to frequency response, HVRT, LVRT, ramping requirements, voltage regulations requirements, compliance monitoring etc.

FIGURE 2 : PROPOSED LVRT CAPABILITY OF WIND AND SOLAR GENERATING STATIONS AND UNITS



D. Amendments to Indian Electricity Grid Code (IEGC) to incentivise Flexbility

Flexibility of conventional generation is one of the important factor in accommodating renewables in any system. The 4th amendment to IEGC [20], 2010 notified on 06th April 2016 recognized this aspect and provided

for additional compensation for degradation of Station Heat Rate (SHR) for running the plan below the maximum continuous rating (MCR) and additional start/stop of machines. Furthermore, technical minimum of conventional generation has been defined as 55% of MCR. This has provided a cushion of additional 5 GW for accommodating renewables.

TABLE I. CHANGE IN SHR WITH CHANGE IN UNIT LOADING AS PER IEGC, 2010

S.No.	Unit Loading as a % of installed Capacity of the Unit	Increase in SHR (for supercritical units) (%)	Increase in SHR (for subcritical units) (%)
1	85-100	Nil	Nil
2	75-84.99	1.25	2.25
3	65-74.99	2	4
4	55-64.99	3	6

E. *Forecasting and Scheduling Framework*

3rd amendment to IEGC has also provided for forecasting and scheduling framework for renewable connected at inter-state level. CERC has mandated for decentralized forecasting framework wherein, forecasting may be done both by the wind/solar generator(s) and the concerned Regional Load Despatch Centre (RLDC). The forecast by RLDC forms basis for secure grid operation and forecast by wind / solar energy generator(s) forms the basis of scheduling and commercial settlement. Wind/Solar generator has been provided with the choice to either tale the RLDC forecast or carry out its own forecast.

Wind/solar generators at the inter-state level whose scheduling is done by the RLDCs are scheduled like any other generator and are to be paid as per scheduled generation. A maximum of 16 revisions for each one and half hour time slot in a day starting 0000 hrs is allowed to the Wind/solar generators to revise their schedules.

F. *Imbalance Handling*

Deviation Settlement Mechanism [21] is implemented in India since Feb 2014. In accordance with this mechanism, the deviation of renewables is calculated as the difference between scheduled and actual generation as a percentage of available capacity. Unlike conventional generation, deviation charges of renewable generation have been delinked with the frequency. When the error is less than or equal to 15%, the charges for deviation are computed at a fixed rate for the shortfall energy for absolute error up to 15%. When the error is more than 15%, there are additional charges for deviation along with the fixed rate.

Further, CERC took note of the concerns in handling Inter-State deviations for large and high renewable penetration states. In order to address the stakeholder concerns, “Renewable-rich State” has been defined as a State that has 1000 MW or more of installed wind/solar capacity. Two categories of RE-rich states have been created taking into account the quantum of renewable penetration in the state grid.

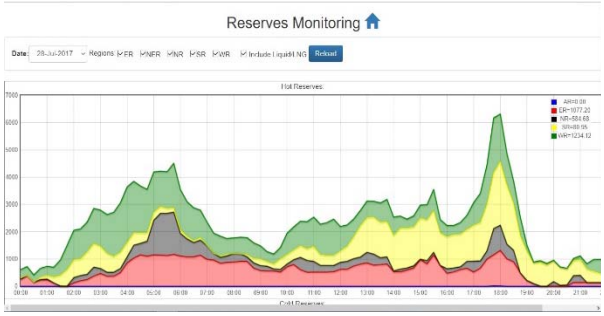
G. *Ancillary Services*

Ancillary Services in India have been implemented with effect from April 2016 [22]. Reserve Regulation Ancillary Services (RRAS) has been implemented to support grid frequency. The RRAS is essentially in the nature of tertiary reserves. At present, the generators whose tariff is either approved or adopted by CERC have been mandated to provide these services depending upon the quantum of unscheduled power. Markup price of Rs 0.5 is being paid for each unit of power scheduled under RRAS up regulation. On the other hand, generators are allowed to take 25% of the fuel cost savings in case of RRAS down regulation. National Load Despatch Centre (NLDC), designated as the Nodal agency, in coordination with Regional Load Despatch Centres (RLDCs), trigger these services in events as unprecedented weather events, tripping of generating unit or transmission line outage and load generation imbalance. It is a layer of centralized despatch over decentralized layer of generating station scheduling process. Refinements such as inclusion of central hydro generators under the ambit of ancillary services and participation of more generators under market based framework is expected to be done sometime in near future.

H. *Reserves and Automatic Generation Control (AGC)*

A committee was constituted by CERC to examine the technical and commercial issues in connection with Spinning Reserves and evolve suggested regulatory interventions in this context. Based on the recommendation of the committee, a roadmap for operationalizing reserves [23] in the country was provided by CERC. It mandated secondary reserves corresponding to the largest unit size in the region. It also mandated tertiary reserves in decentralized fashion by each state control area for at least 50% of the largest generating unit available in the state control area.

FIGURE 3 : RESERVE MONITORING AT POSOCO



All the generating stations that are regional entities have been directed to operationalize AGC along with reliable telemetry and communication. In order to gain experience of implanting AGC, a pilot project has also been executed by POSOCO in association with NTPC at one unit of NTPC Dadri Stage 2 (2 x 490 MW) coal fired generating station. Based on this experience, more machines will be added under AGC to gain confidence.

I. *Changes in Market Design*

Sub hourly bidding (15 minute level) in Power Exchanges has been introduced since April 2012 [24]. This has facilitated consistency with scheduling, metering and accounting timeframes leading to better portfolio management by utilities which has helped in managing variability of renewables. This will help in attracting wind generators and solar generators to power exchanges. Sub-hourly bidding has impacted the scheduling pattern, ramping behaviour, portfolio management of state utilities, price discovery and helped in integration of renewable energy in the Indian Electricity Market.

Regulatory framework for more opportunities to trade in electricity market has been provided through the Power Exchanges with 24x7 extended market sessions from July 2015 [25]. This is expected to help utilities manage the uncertainty of renewables by providing more opportunities to buy/sell from the market.

J. *Renewable Energy Certificate (REC) Mechanism*

REC Regulations [26] were notified by CERC in Jan 2010 to fulfil its mandate to promote renewable sources of energy. The energy generated by the renewable energy sources is split into two components namely the 'Electricity Component' and the 'Green Attribute'. This green attribute can be exchanged in the form of certificates. RE generators have the option to sell the energy generated at a tariff determined by the appropriate commission or under the REC mechanism. One REC represents one MWh of energy generated from renewable sources. REC mechanism, a pan-India market has been created for trading in RECs through the Power Exchanges.

K. *Other Interventions*

Apart from the interventions mentioned above, CERC has also notified draft regulations for Transmission Planning [27] and staff paper for Electricity Storage [28]. CERC has also notified the regulations for communication system for inter-State transmission of electricity [29]. This regulation is expected to improve the visualization at the control centres which will improve the situational awareness of the system operators and assist in integrating large scale renewables in the system.

IV. TRANSMISSION PLANNING

Transmission is considered as the key for large scale renewable integration. Robust and flexible transmission provides utilities to better manage its portfolio along with renewables. Central Electricity Authority (CEA) along with Central Transmission Utility (CTU) have been entrusted with the responsibility of transmission planning. A number of steps have also been taken by the transmission planners to provide robust grid for integrating renewables which are listed below:

A. *Larger Footprint*

Till, 2013, two synchronous grids namely North-East-North East-West (NEW) and Southern Region (SR) grid were in operation. On 31st Dec 2013, NEW and SR grid were synchronized to form one national grid which is meeting around 160 GW at present. Further, cross border interconnections with Nepal, Bhutan, Bangladesh and Myanmar has also expanded the strength and capability of the grid to handle renewables.

B. *Green Energy Corridors*

The short gestation period of renewable energy plants requires transmission to lead generation and upfront investment. This aspect has been recognized by the planners and accordingly a comprehensive scheme covering transmission system strengthening at intra state and interstate level has been evolved under "Green Energy Corridors (GEC)" [30] for about 43 GW of renewables in 8 renewable energy states. The second part of GEC [31] has also been planned covering 20,000MW solar capacity from envisaged 34 Solar Parks in various states. A number of HVDCs have also been planned to provide much needed flexibility in transmission. A study report has also been prepared by POWERGRID for development of desert power utilizing waste land in India's desert regions of the states of Rajasthan (The Thar), Gujarat (Rann of Kutch), Himachal Pradesh (Lahul & Spiti valley) and Jammu & Kashmir (Ladakh), for up to 2050 time horizon [32]. Further, an attempt was also made by POWERGRID to assess the balancing and stability issues with increased RE penetration in Indian context [33].

C. *National Electricity Plan*

Section 3(4) of Electricity Act, 2003 requires CEA to prepare a National Electricity Plan in accordance with the National Electricity Policy and notify such plan once in five years. Accordingly, CEA has notified Draft National Electricity Plan (Volume - I, Generation and Volume - II, Transmission)' in December, 2016 , which covers the generation [34] and transmission [35] plan for 13th Plan period (i.e. 2017-18 to 2021-22) and perspective plan for period beyond 2021-22 for stakeholder consultations. These plans include renewable energy generation as well which may contribute about 20.3 % and 24.2 % of the total energy requirement in 2021-22 and 2026-27 respectively.

V. POWER SYSTEM OPERATION

Power System Operation Corporation Ltd. (POSOCO) which manages NLDC and five RLDCs in each of the five electrically demarcated regions in India is the independent power system operator at inter-state level. Respective State Load Despatch Centres (SLDCs) are responsible for power system operation at intra-state level. The initiatives taken by system operator for renewable integration are listed below:

A. Upgradation of Control Centres and Dedicated Control Centre for Renewables

All the regional control centres have been upgraded with the latest state of the art facilities in 2016. NLDC upgradation is under process and is expected to be done by 2019. Renewable Energy Management Centres (REMCs) have been planned at NLDC, Northern & Western RLDCs and SLDCs of RE rich states with the objective of:

1) Real time tracking of generation from RE sources

2) Forecasting of RE generation in jurisdiction area on day-ahead, hour-ahead, week-ahead,month-ahead basis.

3) Geo-spatial visualization of RE generation

4) Close coordination with respective LDC for RE generation and control for smooth grid operation.

5) Single source information repository and coordination point for RE penetration.

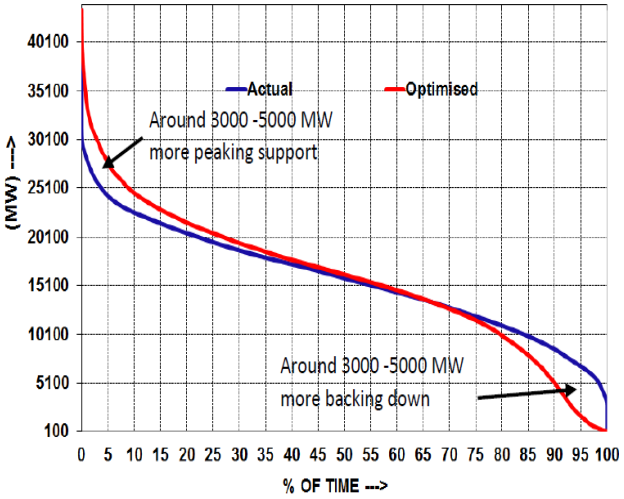
B. Large Scale deployment of Phasor Measurement Units (PMU)

PMUs provide fast, real time, time synchronized data to the system operators for better situational awareness. Large scale deployment of PMUs is being done by POWERGRID in association with POSOCO for improved visualization in real time. More than 1600 PMUs would be installed across the country under the project "Unified Real Time Dynamic State Measurement" (URTDSM). PMUs are also envisaged close to the wind farms/solar parks. A pilot project was also done by POSOCO by installing PMU at a wind turbine to gain useful insights into its operation.

C. Optimisation of Hydro Resources

Hydro generation is an important source of flexibility for the system operators to cope up with the challenges of large scale renewable integration. In order to assess the performance of hydro generation and scope for further optimization, a working group was constituted by Forum of Load Despatchers (FOLD). The analysis done by the working group suggests that the there is scope of around 3-5 GW additional generation during peak hours and around 3-5 GW additional backing down during off peak hours. Important recommendations have also been made to harness this flexibility.

FIGURE 4 : SCOPE OF HYDRO GENERATION OPTIMISATION



India is endowed with 96 GW pumped storage hydro potential out of which around 4.7 GW of pumped storage hydro generation installed capacity. These resources are being utilized by the system operator along with storage based hydro for real time balancing. Further, efforts are being made to rejuvenate non-operational pumped hydro stations.

D. Renewable Integration Studies

In order to assess the impact of high RE penetration on the power system in 2022, Renewable Integration studies were undertaken by POSOCO in association with NREL under the guidance of Ministry of Power and USAID. The final report [36], released in June 2017, has provided useful insights into the operation of power system under high renewable scenario. Some of the key recommendations are listed below:

1) Coordinate RE generation and transmission at the state level to ensure sufficient in-state transmission

2) Comprehensive regulations are required to incentivise flexibility of conventional generators and hydro generators

3) Performance criteria, such as ramping, specified start-up or shutdown times, minimum generation levels needs to be recognised in tariff

4) Economic scheduling and dispatch considering production cost, transmission congestion and losses, and various other factors to be ensured.

5) Move away from must-run status of RE and employ alternative approaches to limit financial risks, such as annual caps on curtailed hours.

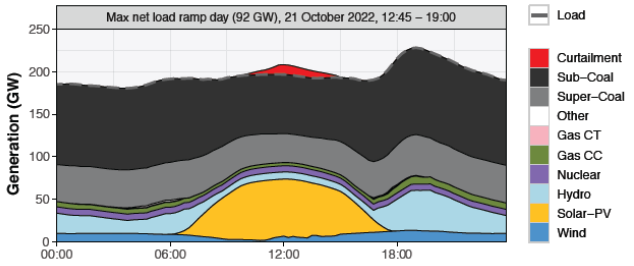
6) Evaluate options for enhanced coordination

7) Equip all states with the latest, state-of-the-art load & RE forecasting facilities.

8) Regulatory guidelines to make it mandatory for stakeholders to provide data required to perform studies

9) Evaluate strategies, targets and scenarios based on production cost modelling simulations

FIGURE 5 : MAX NET LOAD RAMP DAY DISPATCH



E. *Big Data Analytics*

Apart from the work mentioned above, POSOCO has also come out with a number of reports extracting wisdom out of the data archived in last eight years. Two studies have been done to understand the behavior of load [37] [38]. One report discusses the flexibility requirements under high renewable scenario [39]. One report titled "Indian Electricity Market Data Analysis" [40] has been published to understand the behavior and pattern of electricity market. These reports form the basis of analyzing the expected requirements from load and conventional generation under high renewable scenario.

F. *Capacity Building*

Capacity building of all stakeholders is a basic prerequisite to reap benefits out of the initiatives mentioned above. It has also been identified as a key step in fulfilling the challenges posed by large RE integration. Accordingly, collaboration with National (NPTI/NIWE/IIT) agencies and International (GIZ/USAID/USEA) agencies has been done to make latest technical knowledge available to all stakeholders.

VI. Way Forward

Each stakeholder is working relentlessly towards achieving the common goal of the country to provide 24X7 reliable, sustainable and quality power to all. Although a number of measures have been taken by policy makers, planners, regulators and system operators to facilitate large scale renewable integration, a lot is yet to be done. The recommendations made in various reports need to be made a reality. Continuous interaction and capacity building of the stakeholders is essential to understand the grass root problems and provide home grown tailored solutions. Learning from the international best practices would also help better integrate renewables. Strategies and solutions needs to be simulated and studied first before implementation.

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