DEVELOPMENT OF MECHANISMS TO INCENTIVIZE INTER-STATE EXCHANGE OF RENEWABLE ENERGY

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Abstract — **Given the geographical variance of RE resources (surplus and deficit RE states) across the country, inter-state RE exchange shall play a critical role in creating more demand and resulting in higher RE capacity additions. To facilitate higher RE exchange across these RE surplus and deficit states, it requires supportive policy and regulatory framework for bringing inter-state RE exchange into the mainstream, which currently is at very low levels. A detailed quantitative and qualitative analysis of prevailing regulatory framework has been performed to understand the missing inter-linkages among the regulations. Also, issues related to transmission infrastructure, and its existing pricing mechanism for evacuation of renewable energy have been reviewed. Currently, power market, commercial and operational processes are developed for high share of coal generation, so as share of RE increases it will be required to develop commercial and operational procedures to facilitate high RE grid integration. Based on this analysis and consultation with a wide array of stakeholders, measures which facilitate inter-state RE exchange have been recommended.**

Keywords — Regulations, Green Energy Corridor, Transmission Pricing, Imbalance Management, Commercial Mechanism

I. INTRODUCTION

India's Nationally-Determined Contributions (NDCs) target aims to ensure that at least 40 per cent of its electric power installed capacity in 2030 would come from non-fossil based energy resources [1]. In order to achieve NDC targets, Government of India (GoI) plans to add 175 GW Renewable Eenergy (RE) capacity by year 2022 comprising of 100 gigawatt (GW) of solar energy, 60 GW of wind energy, 10 GW of biomass, and remaining 5 GW of small hydro. Given the geographical variance of RE resources across the country, with RE resource availability varying across different states, inter-state RE exchange shall play a critical role in creating more RE demand and resulting in higher RE capacity additions to achieve targets. To facilitate higher RE exchange across these states from current low levels, there is a need for supportive policy and regulatory framework for bringing inter-state RE exchange into the mainstream.

In order to be able to analyse the issues that India must address to successfully promote inter-state exchange of RE power, the aim of this study is to understand the existing issues through data analysis and stakeholder consultations and suggest mechanisms to create an eco-system which will facilitate effective grid integration of RE which is pre-requisite to promote inter-state RE exchange with a long term perspective.

II. PROBLEM STATEMENT

A. Missing Inter-linkages in regualtions

To manage higher RE penetration in grid, Central and State regulators have notified the Forecasting and Scheduling (F&S) regulations for RE plants connected to Central Transmission Utility (CTU) and State Transmission Utility (STU) respectively. Both regulations have a different penalty mechanism for forecast errors.

In order to maintain the grid discipline to manage load-generation imbalance, CERC has also notified Deviation Settlement Mechanism (DSM) and its amendment to limit unscheduled energy consumption. CERC has also notified regulation for Reserve Regulation Ancillary Service (RRAS) to deploy ancillary services on the basis of ex-ante pricing to maintain grid discipline.

Our study analyzes the data to understand the operational and commercial impact of practices evolving from these regulations.

B. Review of Transmission Infrastructure

Transmission infrastructure is a critical component for enabling inter-state RE exchange. Review of planned transmission projects for evacuation of renewable energy and its cost recovery mechanism has been performed.

C. Market & Commercial Framework

As the share of RE increases, grid operators face a complexity in ensuring reliable grid operations due to intermittency in RE generation. Increasing complexity leads to higher cost of grid management. Hence, it is necessary to evolve operating and commercial mechanisms, which can ensure that RE grid integration is cost effective and facilitate inter-state RE exchange.

III. APPROACH

To bring inter-state RE exchange into mainstream, it is necessary to create an eco-system which will address the technical, operational and commercial challenges arising due to increasing grid penetration of RE. A detailed quantitative analysis of large scale data, and qualitative analysis through literature review and consultations with range of stakeholders has been performed to identify the technical, operational and commercial issues which are hindering effective grid integration of renewable energy. Based on the outcome of the analysis, potential intervention measures have been identified.

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IV. ANALYSIS

It is important to create a system for better RE grid integration, to bring down the overall cost of RE consumption.

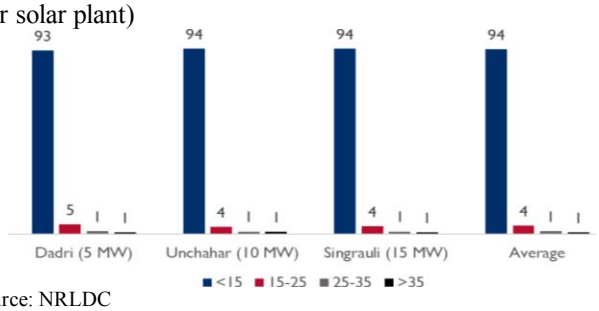
A. *Regulatory Framework*

To bring grid discipline, regulators have brought regulations governing various stakeholders i.e. RE generators, conventional generators, and power distribution companies, to improve grid operations. For example, 1) forecasting and scheduling regulation is applicable to central and state RE plants with different penal mechanisms for center and state level RE power plants, 2) deviation settlement mechanism, which penalizes generators and power distribution companies to limit deviation in schedule generation and drawl, and 3) reserve regulation ancillary services, so system operators can deploy ancillary services to maintain grid frequency at 50 Hz. These three regulations are intended to create a mechanism to handle deviations, however different pricing methodologies towards electricity transacted to manage deviation under these provisions, needs to be addressed.

1) Forecasting & Scheduling (F&S) Regulation

CERC notified the F&S regulation in August 2015[2]. The regulation is applicable to all regional wind and solar energy generators connected to inter-state transmission network. F&S regulations have also been issued by most state regulators and implemented at the state level is applicable to wind and solar generators connected to intra-state transmission network. Renewable energy plants have a must run status so they do not fall under a merit order dispatch, though they do need to provide block wise forecast of generation to the grid operator under F&S regulation, deviation from which attracts forecasting penalty. To understand the differential impact of forecasting error penalty on inter and intra-state RE plant, an analysis has been performed. Forecasting error profile of three solar plants has been averaged and based on which penalty has been calculated,

Figure 1: Distribution of Forecasting Errors for FY 2018-19 (for solar plant)



Source: NRLDC

To assess the impact of forecasting errors on revenue of RE plants due to differential penalty mechanisms for inter-state and intra-state (state of Rajasthan is considered) plant, average error profile is considered (as shown in figure 1):

Table 1: Impact of Forecating Error on Revenue

Particulars	Inter-State Generator	Intra-State Generator
Generator Capacity (MW)	1	1
Annual Generation (MU)[1]	1.66	1.66
PPA Rate (INR/kWh)	2.76[2]	3.93[3]
Forecast Error Penalty (INR)	43,171	2,06,336
Impact on Revenue	0.95%	3.16%

Source: GTG-RISE Analysis

It is evident from above table that, due to differential penalty mechanism, inter-state and intra-state plant will have different impacts over the revenue even with similar forecasting errors. Different penalty mechanism also creates issues, if a plant switches transaction from intra-state to inter-state or vice-versa due to complexity in commercial settlement procedures.

2) Deviation Settlement Mechanism

CERC implemented the DSM regulation in 2014 which governs operational and commercial practices to be adopted to limit the deviation from drawal by power distribution companies, and injection schedule of electricity by regional entities and thereby maintains grid discipline and grid security. CERC specified the deviation limit for a state as function of installed RE capacity in the state and, schedule of drawl and generation. Higher the installed RE capacity, higher is a state's deviation limit. For states having RE installed capacity less than 1000 MW, the deviation limit is 150 MW. For states with 1000 MW to 3000 MW, deviation limit is 2000 MW, and states with capacity above 3000 MW, the limit is 250 MW [3]. This provides additional room for RE rich states to manage deviations in state's regional drawal.

Any deviation beyond these specified limits would result in additional deviation penalties for the state. In November 2018, CERC brought fourth amendment in regulation, by modifying the pricing mechanism (by linking the price of electricity transacted under DSM with daily average Area Clearing Price discovered in Day Ahead Market at 50 Hz), for electricity transacted beyond permitted deviation limit, under DSM mechanism. A detailed quantitative analysis has been performed to develop deviation profile of states in the Western, Southern and Northern regions.

a) Operational Impact

States with high deviations cotribute towards grid instability at the national level. The reason can be attributed to high share of RE in a state or inefficient grid management practices. For FY 2018-19, deviation profile [4] has been developed for the states of Northern, Western and Southern regions.

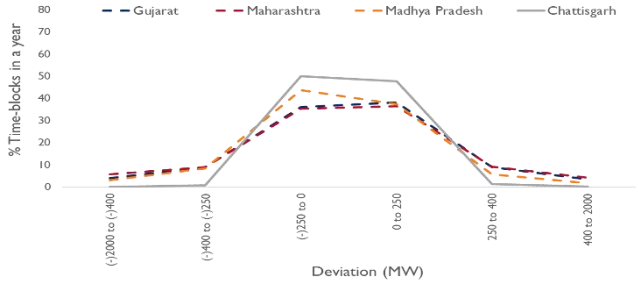
[1] Assumed CUF 19%

[2] SECI Solar Tender September, 2018

[3] RERC Order for Solar PV Tariff Determination during FY 2017-18, http://rerc.rajasthan.gov.in/TariffOrders/Order272.pdf

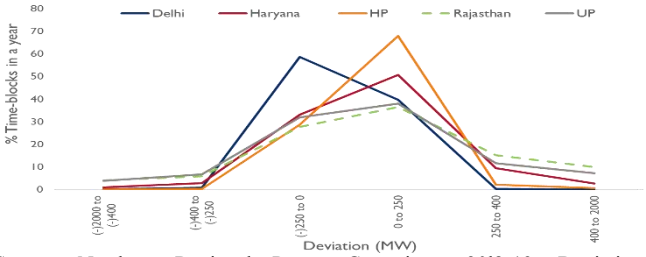
[4] Dashed line represents the RE rich-state (having RE share more than 1000 MW)

Figure 2: State-wise Deviation Profiles in Western Region in MW (FY2018-19)



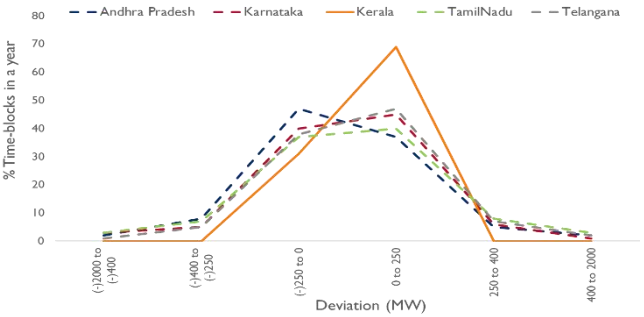
Source: Western Regional Power Committee. 2018-19. Deviation Settlement Account

Figure 3: State-wise Deviation Profiles in Northern Region in MW (FY2018-19)



Source: Northern Regional Power Committee. 2018-19. Deviation Settlement Account

Figure 4: State-wise Deviation Profiles in Southern Region in MW (FY2018-19)



Source: Southern Regional Power Committee. Deviation Settlement Account. 2018-19

In the Northern region, deviation for Rajasthan, Uttar Pradesh (UP), and Haryana is high compared to other states. States of UP and Haryana have low RE penetration as compared to Rajasthan, so higher deviation can be on account of operational practices towards load management. However, state with high RE penetration encounter problems in managing load-generation imbalance, due to inefficient RE forecasting and unavailability of flexible generating sources.

Since, January 2019, CERC has linked the price of electricity transacted under DSM to the daily average Area Clearing Price discovered in Day Ahead Market at 50 Hz, for electricity transacted beyond permitted deviation under DSM mechanism [4].

Table 2: Summary of deviation of various states in India for year 2017-18 (1) & 2018-19 (II)

% of Time-blocks in a year		States	% Observations in Deviation Band (MW)											
			(-)400 to (-)2000		(-)400 to (-)2000		0 to (-)250		0 to 250		250 to 400		400 to 2000	
			I	II	I	II	I	II	I	II	I	II	I	II
	WR	Gujarat	6	4	12	9	41	36	33	38	7	9	3	3
		Maharashtra	6	6	9	9	32	35	37	37	11	9	5	4
		Madhya Pradesh	3	3	8	8	43	44	38	37	7	6	2	2
		Chhattisgarh	0	0	1	1	58	50	39	48	2	1	0	0
	NR	Delhi	0	0	1	1	56	59	43	40	0	0	0	0
		Haryana	2	1	4	3	31	33	50	51	10	10	3	3
		Himachal Pradesh	0	0	1	0	30	29	68	68	1	2	0	1
		Rajasthan	2	4	4	6	27	28	43	36	15	15	8	10
		Uttar Pradesh	5	4	6	7	27	32	38	38	14	12	10	7
	SR	Andhra Pradesh	1	2	4	8	41	47	43	37	8	5	3	2
		Karnataka	2	3	4	5	35	40	52	45	5	6	1	1
		Kerala	0	0	0	0	13	31	87	69	0	0	0	0
		Tamil Nadu	7	3	10	7	31	37	36	40	11	8	6	3
		Telangana	3	1	14	5	59	38	22	47	1	7	0	2

Source: State-wise Deviation Profiles in Western, Northern and Southern Regions in MW (FY2018-19)

For the FY 2018-19, following are the observations from above analysis:

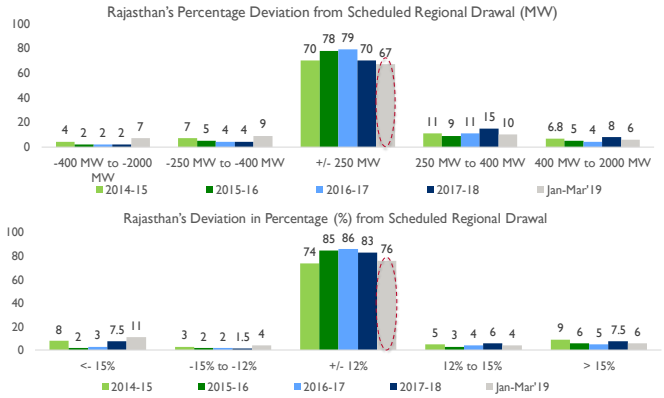
- The over-drawal for the states Gujarat, Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, and Telangana has reduced during FY 2019 as compared to the over-drawal during FY 2018.
- The under-drawal for the states Gujarat, Rajasthan, Andhra Pradesh, Karnataka, Tamil Nadu, Telangana has increased during the same period.
- Non RE-rich states, such as Haryana and UP, have significant deviations which could be on account of grid operation practices.

Post linking of price of electricity transacted under DSM with the market price in January 2019, the states have reduced the over-drawal quantum and frequency from the regional pool. To promote inter-state RE exchange, it is necessary that RE-rich and non-RE-rich states adopt necessary grid management practices that will lead to reliable grid operations which is essential for high RE capacity absorption in the grid.

Rajasthan Case Study

A detail study for state of Rajasthan has been performed to observe the trend of operational and commercial impact of deviations over the years. The total capacity of wind and solar power was 4.2 GW and 3.2 GW, respectively in 2019. The block wise deviation profile for Rajasthan from FY 2014-15 to FY 2017-18 and Jan-March'19, in terms of MW and percentage of scheduled demand, is presented in the following figure --.

Figure 5: Longitudinal Study of Rajasthan Deviation from Regional Schedule



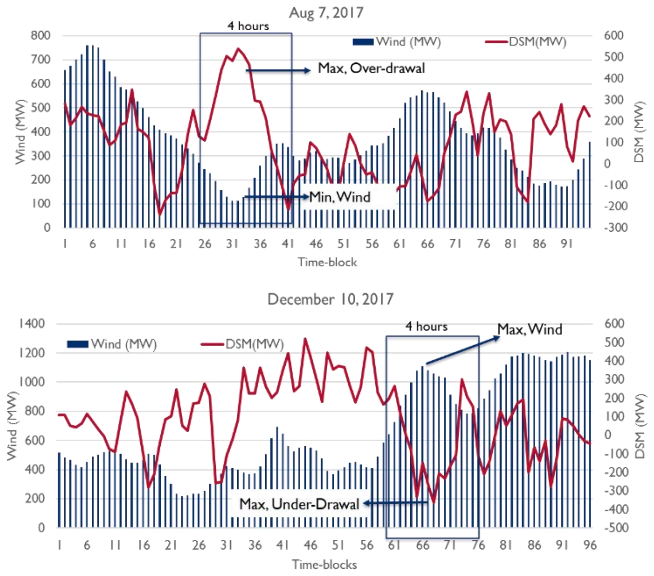
Source: Deviation Settlement Account, Northern Regional Power Committee

The deviation from schedule drawl in case of Rajasthan is within ±12 percent of schedule during 83 percent, while deviation is within ±250 MW for 70 percent of the total time blocks in FY 2017-18. This indicates that even when Rajasthan's schedule deviation stays within ±12 percent of schedule, the deviation in terms of MW, from schedule drawl can be above 250 MW, which leads to additional deviation penalties.

For state of Rajasthan, during the quarter Jan-March'19, share of under-drawl and over-drawl blocks were almost equal, while in the earlier years, share of over-drawl was more as compared to under-drawl. So, it can be observed that share of under-drawl has increased while share of over-drawl has been reduced. The market linked pricing of DSM units, will increase the financial burden of the state utilities upon over-drawl. Increasing RE generation will create a need for the states to be better equipped with balancing measures, load and RE forecasting tools, for effective RE grid integration to adhere with the schedules.

The impact of wind generation on the regional deviation for state of Rajasthan has been analyzed for the period FY 2017-18 and FY 2018-19. The data set of 4 hours has been considered to calculate the correlation on annual basis and Pearson correlation statistics has been used to understand the impact of wind variability and Rajasthan's regional deviation. The analysis of 2,190 blocks of 4 hours each shows that around 23 percent of observations have high negative correlation (i.e. between -0.5 to -1.0). This implies that state's wind generation and state's deviation are inversely related i.e. as wind generation drops rapidly, state's over-drawal increases and when wind generation increases rapidly, state's under-drawal deviation increases accommodating for extra wind generation. For illustration purpose, two incidences during which, wind over-generation and under-generation, coinciding with the Rajasthan's under-drawl and over-drawl for the scheduled regional pool, is presented as follows:

Figure 6: Rajasthan wind generation and regional deviation for Aug 7, 2017 & December 10, 2017



Source: Deviation Settlement Account, Northern Regional Power Committee; Wind Energy Generation Data, Rajasthan SLDC

The effect of fluctuation in wind generation on state's deviation is visible and results in over-drawal and under-drawal from the grid resulting in financial penalties and operational challenges to the state. The increase in penetration of variable RE like wind in the states is likely to increase the regional deviation for the state in absence of adequate systems for grid balancing. Though various factors can impact the state's deviation, the effect of variable RE on state's deviation is quite significant.

b) Commercial Impact of DSM

As power distribution companies deviate from the specified limit for the deviation, it is subjected to pay deviation charges. To understand the commercial impact of DSM regulation, analysis has been performed for state of Rajasthan:

Table 3: Deviation Settlement Quantum & Charges for Rajasthan

Parameters	FY 2016-17	FY 2017-18	Jan - Mar 2019
Quantum of units in Over-drawl (MUs)	942.1	1241.0	200
Paid DSM Charges for Over-drawl (INR in Cr)	195.1	329.7	76
Per Unit DSM Charges for Over-drawl (INR per unit)	**2.07**	**2.66**	**3.82**
Quantum of units in Under-drawl (MUs)	-494.3	-441.8	-219
Received DSM Charges for Under-drawl (INR in Cr)	-74.2	-79.4	-39
Per Unit DSM Charges for Under-drawl (INR per unit)	**1.50**	**1.80**	**1.79**

Source: NRLDC

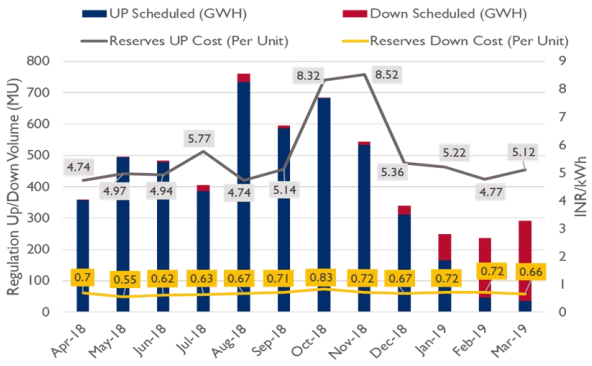
From the above table it can be observed that, post implementation of market linked DSM price, average DSM price (for Jan-March'19) for over-drawl has increased to INR 3.82 per unit from INR 2.66 per unit from FY 18, while average under-drawl price during the Jan-March'19 quarter has not changed significantly. Post linking DSM price with market, average monthly over-drawl and under-drawl quantum decreased and increased, respectively. However, to assess the impact of revised DSM pricing mechanism, on state's deviation from regional schedule, it is prudent to wait

for at-least another for the recent DSM regulatory amendment to take effect.

3) *Ancillary Services Operations Regulation*

CERC notified Ancillary Services Operations Regulation in August 2015 with the objective to restore the grid frequency after disturbances and to relieve the congestion in transmission network. This regulation is applicable to all central generating stations which are regional entities whose tariffs are regulated by CERC. The Regulation Reserve Ancillary Services (RRAS) are classified into i.e. regulation up (generation from plants) and regulation down (generation back-down from plants), categories. Ancillary services are deployed by way of utilizing Un-Requisitioned Surplus (URS) of inter-state generating stations to support grid operations as reserves, for regulation up services. The prices of ancillary services are determined on ex-ante basis as per RRAS regulation, while the dispatch is based on merit order basis. Following analysis presents the quantum and average price of ancillary services deployed for regulation up and regulation down services.

Figure 7: Ancillary Services Quantum and Per Unit Cost (FY 2018-19)



Source: POSOCO. 2018-19. "Ancillary Services Monthly Report"

Following are the observations from the above analysis:

- Since January 2019, ancillary service deployment for regulation-up, decreased substantially. One of the reason is the recent DSM regulation amendment to link deviation penalty prices to market prices.
- Till Dec 2018, Regulation up services have large share as compared to regulation down deployment. The deployment of regulation up services is mainly due to the over-drawl by the states from the regional pool.
- From April 2018 to Dec 2018, average monthly volume of regulation up and regulations down services is 507 MUs and 11.3 MUs respectively. While from Jan 2019 to March 2019, average monthly volume of regulation up and regulation down services is 82 MUs and 177 MUs respectively.

The AS in India are currently functioning through an administered price mechanism managed under the regulatory framework. In several advanced power markets, the AS are already procured through a market mechanism. Similar framework can be shortly expected in India.

B. *Transmission Infrastructure Development*

Availability of transmission infrastructure is critical for renewable energy capacity addition. Under the Green Energy Corridor (GEC) project, it is envisaged to develop inter-state and intra-state transmission infrastructure and renewable energy management centre in RE rich states. Planning of the Intra-state GEC network has been done on the basis of discussion between POWERGRID Corporation of India Limited (PGCIL) and State Nodal Agency (SNA)/State Transmission Utility (STUs).

As per MNRE, around 80 GW (as on May 2019) is the grid interactive RE capacity installed at country level [5]. To achieve the target RE capacity addition of 175 GW, around 100 GW of RE capacity need to be added. To support this target, transmission capacity for RE evacuation at intra-state and inter-state level of 19,000 MVA and 18,000 MVA, respectively is under development under GEC and expected to be functional by the March 2020. Currently, Ministry of New & Renewable Energy (MNRE) is planning to add transmission capacity to evacuate solar and wind capacity of 50 GW and 16.5 GW, respectively from the states of Northern, Western and Southern regions. Implementation of planned transmission capacity will require investment of INR 43,235 Cr.

Figure 8: Transmission planning to evacuate 66.5 GW RE generation capacity

Sr No	Region	Phase – I Capacity (GW)	Phase - II Capacity (GW)	Total Capacity (GW)
1	**Western Region**			
A	Gujarat	7	9	16
B	Maharashtra	1	6	7
C	Madhya Pradesh	2.5	2.5	5
	Sub-Total (WR)	**10.5**	**17.7**	**28**
2	**Northern Region**			
A	Rajasthan	10	10	20
3	**Southern Region**			
A	Tamil Nadu	1.5	1.5	3
B	Andhra Pradesh	4.5	3.5	8
C	Karnataka	2.5	5	7.5
	Sub-Total (SR)	**8.5**	**10**	**18.5**
	Total	**29**	**37.5**	**66.5**

Source: Minutes of Meeting, Northern Region Standing Committee on Transmission (September 11, 2018)

PGCIL is targeting for project completion under phase – I and phase – II by December 2020 and December 2021, respectively. Time bound implementation of planned transmission capacity addition, will enable in achieving target of renewable energy capacity addition. In order to fund the investment for transmission capacity addition, MNRE in March 2019 has amended solar park development scheme. MNRE has planned to utilize available solar park fund for the development of external power evacuation infrastructure. However, this fund will meet the partial funding requirements for transmission infrastructure development, hence balance funding will be made through renewable energy project developer's upfront contribution. This is an encouraging step to develop transmission infrastructure for RE evacuation in India.

C. Market & Commercial

Prevailing market and commercial framework in Indian power sector is mainly based on high share of conventional power plants. As the share of RE increases in the grid, grid operators needs flexible energy resources to minimize load-generation imbalance. Market based mechanism which incentivize the flexible energy resource need to be evolved. Future power markets need to become more suitable for specific requirements of a grid with higher share of RE. AS of now, generating station are not under control of load dispatch centre which limits their ability to deploy secondary reserves when required. Lack of market based frameworks to promote flexible operations of conventional power plant which provides for compensation for flexible operation and retrofits to enable automatic generation control needs to be addressed. Further, lack of dedicated green power products in power exchange is also an issue which needs to be addressed to facilitate inter-state RE exchange.

V. Way Forward

Inter-state RE exchange is still in the nascent stages in India and moving towards a high level of inter-state RE exchange through market driven efforts will require undertaking measures at multiple fronts. The paper highlights key measures including the below.

A. Immediate measures

- Alignment in intra-state and inter-state penalty methodologies for RE forecasting – Different penalty mechanism at state and central regulations increases complexity in metering, settlement, and accounting that inhibits RE trade. Uniform penalty structure will lead to harmonization in process which shall make it easier for RE generator to engage in either inter or intra state trade.
- Load forecasting regulations – Development of model load forecasting regulations for the adoption of state utilities would help in better understanding of state's load requirements. For the effective implementation of regulation, central agencies can develop a portal, to forecast the state's demand on the basis of their input data, which can be shared to grid operators for better visibility of grid operations.
- Development of automatic generation control (AGC) framework – With the increasing share of renewable energy, operationalization of AGC framework at a wider scale, would be necessary. It is required to develop regulation for market based procurement of AGC services by system operator.
- Commercial framework – A well-defined framework for compensation for flexible operations of conventional power plants shall facilitate balancing.
- Encouraging inter-state RE transactions on the basis of energy banking between states, with complementarity load profile, to trade RE on a short-term or medium-term basis shall prove to be beneficial.
- Improve real-time connectivity from RE plants – Development of communication infrastructure in remote location is critical for accurate RE forecasting and its effective grid integration. Avenues which reduces the cost of telecom infrastructure through business models which share the cost of infrastructure between RE developers and network service providers can be explored.

B. Medium-term measures

- Development of imbalance market – Development of imbalance market will lead to the efficient price discovery of ancillary services. Suitable amendments in ancillary service regulations and corresponding guidelines shall be required.
- IT system implementation strategy – Implementation of IT projects at large scale, offers to optimize the cost of implementation. Different ways of project implementation like shared IT infrastructure among states, aggregation of demands of different states for centralized procurement, or cloud services provide by the Government of India to central or state government's departments/administration can be explored.

C. Long-term measures

- Development of cost recovery methodology to develop transmission infrastructure for RE evacuation – GOI has waived off inter-state transmission charges applicable to wind and solar power plants commissioned till March 2022 to meet RPO requirement of different entities. However, waived transmission charges need to be shared among other users of the transmission corridor. Hence, it is important to device a mechanism for inter-state transmission pricing which shall socialize inter-state RE transmission charges at national level considering the interest of all stakeholders. This shall prove to be beneficial for RE integration and inter-state RE exchange from a long term perspective.

Acknowledgment

The GTG – RISE team benefited from the timely and strategic guidance offered key stakeholders, particularly from state load dispatch centres, renewable energy management centre, power procurement departments, transmission utilities, forecasting service providers, industry association, academic institute, public sector organizations, for sharing their views on critical issues and possible remedial actions that need to be undertaken with regard to effective renewable energy grid integration to promote inter-state renewable energy trading.

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