Ancillary Services Facilitating Large Scale Integration of Renewable Energy in India

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***Abstract*— This paper discusses the implementation and experience of Ancillary Services Operations in Indian Electricity Market. The authors present the features of the implemented framework for Ancillary Services which have facilitated and benefitted the large scale integration of renewables in India. Analysis of the role of Ancillary Services in maintaining secure and reliable grid operation, ramp management and congestion management has also been discussed through relevant case studies.**

Keywords- Ancillary Services; Congestion Management; Indian Electrcity Market; Renewable Integration;

I. INTRODUCTION

The basic services of electricity generation, transmission and distribution need support services to operate the electricity grid in a reliable and secure manner. These support services include frequency control, voltage control, generation reserves, blackstart etc. It is, however, complicated by the fact that the same infrastructure needs to supply basic services and support services. Another dimension is that both the basic services and support services are inter-dependent as well as depend upon dynamic grid conditions.

These support services known as "Ancillary Services" are value-added services, generally, despatched by the system operator. Figure 1 depicts the types of ancillary services, response time and duration [1].

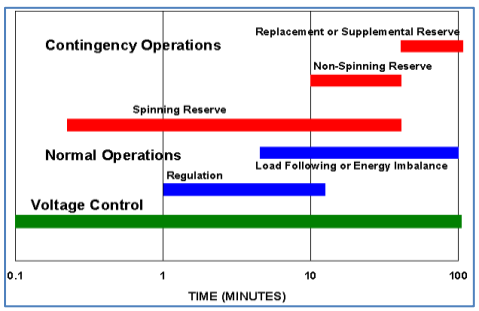

Figure 1: Types of Ancillary Services and Duration [1]

However, since the deregulation of the electricity supply industry, the system operator often has no direct control over individual grid resources and has to procure these services from the different grid entities. The increasing penetration of renewables demands increased requirement for ancillary services to handle the associated variability and intermittency.

Renewables have an inherent technological advantage, wherein, they are capable of acting as 'suppliers' of ancillary services as well. The power electronics equipment associated with renewable installations has the capability to provide many of the ancillary services that are traditionally provided by conventional generators and power system equipment. These services include ramping capability through regulation up/down, controllable reactive power support, fast frequency response, voltage regulation, flicker control, harmonic cancellation and active power filtering.

Therefore, implementation of ancillary services framework in April, 2016 is a key enabler to achieve the target of 175 GW of renewables by 2022 set by Government of India. The benefits to renewables through ancillary services, analyzed from over a year of experience, include improved frequency profile, ramp management, grid resilience, congestion management and reliability support.

II. ANCILLARY SERVICES FRAMEWORK

The first step towards introduction of ancillary services in Indian electricity ecosystem was initiated by the Central Electricity Regulatory Commission (CERC) i.e. the central regulator in 2009. Through CERC (Unscheduled Interchange) Regulations, 2009, it was envisaged that ancillary services shall comprise of load-generation balancing related activities and despatched by system operators.

In line with the above, CERC (Indian Electricity Grid Code) Regulations, 2010 (IEGC) [2] defined Ancillary Services as below:

"…Regulation 2(1) (b)

Ancillary Services" means in relation to power system (or grid) operation, the services necessary to support the power system (or grid) operation in maintaining power quality, reliability and security of the grid, e.g. active power support for load following, reactive power support, black start etc.;…"

In 2010, as per the provisions of the CERC UI Regulations 2009, National Load Despatch Centre (NLDC) submitted an Approach Paper on Ancillary Services in Indian Context to CERC. Three major categories of Ancillary Services were proposed namely Load Generation Balancing Service, Network Control Ancillary Services and System Restart Ancillary Services. The use of undespatched surplus generation for ancillary services was recommended.

In 2012, CERC Central Advisory Committee (CAC) expressed the need for introduction of ancillary services in India for improved security and reliability of grid operation. Stakeholder consultation was organized by way of a national level workshop in June, 2012 by the Forum of Load Despatchers (FOLD) where the various aspects of ancillary services mechanism were discussed.

In 2013, CERC staff paper on "Introduction of Ancillary Services in Indian Electricity Market" [3] proposed ancillary services through bidding in a separate market segment in the Power Exchange. The ancillary services were envisaged to be provided by the surplus generation capacity (i.e. either un-requisitioned surplus capacity by the beneficiaries of that plant or generators whose bids could not be cleared in Over-the-counter (OTC) bilateral/power exchange markets or surplus captive power generation capacity)

In May, 2015, CERC floated draft Ancillary Service Operations Regulations. Tertiary frequency control through utilization of un-despatched surplus capacity available in generating stations at the inter-state level, whose tariff is determined / adopted by CERC, was proposed to be introduced as Reserve Regulation Ancillary Service (RRAS). Incentive mechanism for RRAS Providers was also envisaged.

The amended Tariff Policy by Government of India, in January 2016, mandated the implementation of Ancillary Services [4]. The relevant extracts are as follows:

"…7.4 Ancillary Services

(1) The Central Commission may introduce the norms and framework for ancillary services, including the method of sharing the charges, necessary to support the power system or grid operation for maintaining power quality, reliability and security of the grid…."

A Technical Committee on Large scale integration of Renewable Energy, Need for Balancing, Deviation Settlement Mechanism and other associated issues was constituted by Ministry of Power, Government of India. The Committee in its report [5], in April, 2016, recommended that Ancillary Services need to be put in place for operationalization of spinning reserves, congestion management and optimization at Regional & National Level and thereby facilitates integration of renewables too.

The final CERC (Ancillary Services Operations) Regulations were notified on 13th August, 2015 [6]. CERC, in February 2016 through a separate order, set the mark-up for participation in Regulation 'Up' RRAS at 50 paise/kWh. The Detailed Procedures were also approved by CERC in March 2016.

Thus, policy initiatives by the Ministry of Power and the regulatory interventions by CERC enabled the launch of Ancillary Services by the Nodal Agency i.e. NLDC in coordination with RLDCs on 18th April, 2016.

III. Salient Features of Ancillary Services

- All the regional entity generators whose tariff for the full capacity is determined or adopted by the CERC are mandated to provide ancillary services as RRAS Providers.
- The designated Nodal Agency for Ancillary Services Operations is NLDC, through the RLDCs.
- The Nodal Agency is mandated to prepare the merit order stack based on variable cost of generation.
- Various triggering criteria for despatch of ancillary services have been defined such as extreme weather /special day, generation or transmission line outages, trend of load met and frequency profile, abnormal events such as outage of hydro generating units due to silt, etc., excessive loop flows, trend of computed regional Area Control Error (ACE) and recall by the original beneficiary.
- A pseudo regional entity called "Virtual Ancillary Entity (VAE)" created in the respective Regional Pool acts as counterparty for scheduling and accounting in the regional pool.
- The quantum of RRAS despatch instruction, by the Nodal Agency, is directly incorporated in the schedule of respective RRAS providers. The RRAS instruction is scheduled to the VAE in any one or more regions.
- The deviation in schedule of the RRAS Providers, beyond the revised schedule as per RRAS despatch instructions, is settled as per the CERC Deviation Settlement Mechansim (DSM) Regulations. The energy despatched under RRAS is deemed delivered ex-bus.
- Nodal Agency directs the respective RRAS Provider to withdraw RRAS when the circumstances leading to triggering of RRAS have been normalized.
- RRAS Energy Accounting is done by the respective Regional Power Committee (RPC) on weekly basis along with DSM Account, based on data from interface meters and the implemented schedules.
- A separate RRAS statement is being issued by RPC along with Regional DSM Account. Any post-facto revision in rates/charges by RRAS providers is not permitted.
- In case of RRAS Up, fixed and variable charges are payable to the RRAS providers from the respective regional pool. Markup as per CERC order is also payable to the RRAS providers.
- In case of RRAS Down, 75 percent of the variable charges are payable by RRAS providers to the respective regional pool and fixed charges are reimbursed by RRAS providers to the original beneficiaries in proportion to the power surrendered.
- No commitment charges are payable to the RRAS providers. There are penalties for persistent failure to provide RRAS and violation of directions of Nodal Agency.

IV. RRAS Despatch Mechanism

Nodal Agency i.e. NLDC has deployed a Web-based Reserve Regulation Ancillary Services software application (home page depicted in Figure 2) which has been developed in-house. The Schedule, Declared Capability (DC), Un-despatched power (DC – Schedule), Technical Minimum, Minimum Run Time and Schedule under RRAS instruction have been made available for each RRAS Provider through the web based portal of the Nodal Agency/concerned RLDC in the respective region.

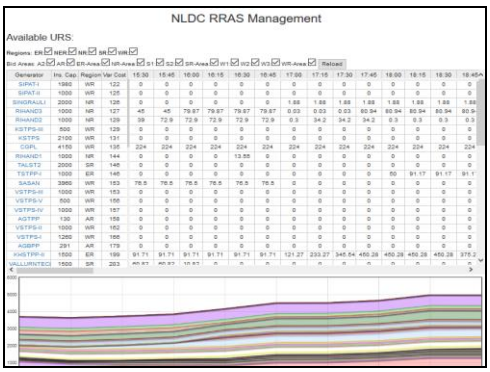

Figure 2: Nodal Agency Web Based Portal

The merit order stack of RRAS providers is prepared on monthly basis based on the data provided by RRAS providers. The availability of generation reserves over the next few hours is also monitored (Figure 3).

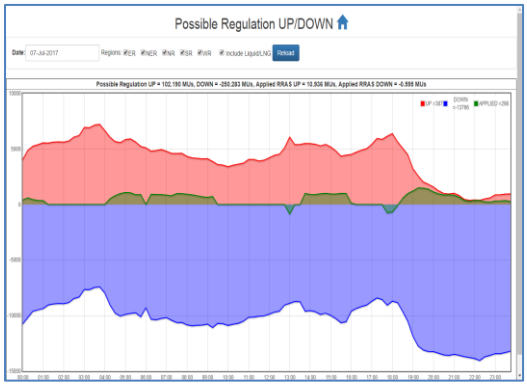

Figure 3: Reserve Monitoring Display

The control room system operators visualize the requirements for RRAS despatch based on the information available in real time in SCADA as shown in Figure 4.

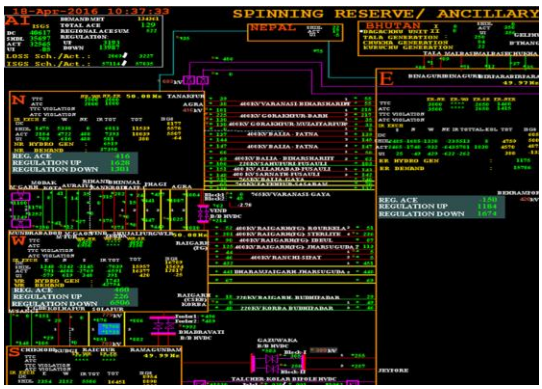

Figure 4: SCADA Display of Ancillary Services

System operator is also taking cues from the climate forecast, historical frequency profile, load forecast, spinning & non-spinning reserves along with real time system conditions while taking RRAS despatch decisions. After matching with the triggering criteria, Regulation Up/Down RRAS despatch instructions are given to the concerned RRAS Providers, through the respective RLDCs, for implementation. The communication is done through electronic medium for the sake of fast implementation of RRAS instructions.

V. Key Statistics

The details of RRAS providers are as below:

- Number of RRAS Providers and Installed Capacity: 49 Nos. totaling to around 52.5 GW
- Variable Charges [Assumption: 1 US $ = ₹ 60]
  - Lowest Variable Charge (Pit Head Coal Fired Plant) @ 123 Paisa (US$ 0.02)/ kWh
  - Highest Variable Charge (Gas Power Project (Liquid Fuel)) @ 793 Paisa (US$ 0.13)/ kWh
- The statistics of the RRAS despatch instructions is tabulated in Table 1:

Table 1: RRAS Despatch Instructions

Period: April 2016 to June 2017	Regulation Up	Regulation Down
Number of Instructions Issued	2390 Nos.	442 Nos.
Energy Despatched	2767 MU	336 MU
Average Energy Despatched per Day	7 MU	1 MU
Maximum Power Despatched in a Time-block	3746 MW	2366 MW

VI. Ancillary Services Facilitating Renewable Integration

A. *Improved Frequency Profile*

The frequency fluctuations have reduced considerably with frequency remaining within the IEGC prescribed band (49.90-50.05 Hz) for more than 75 % of the time.

On 17 July, 2017, conditions of high demand in Northern region and low demand in Western region were prevailing implying a skewed scenario. Ancillary services were despatched to manage congestion and maintain flows on inter-regional corridors within the safe limits (Figure 5).

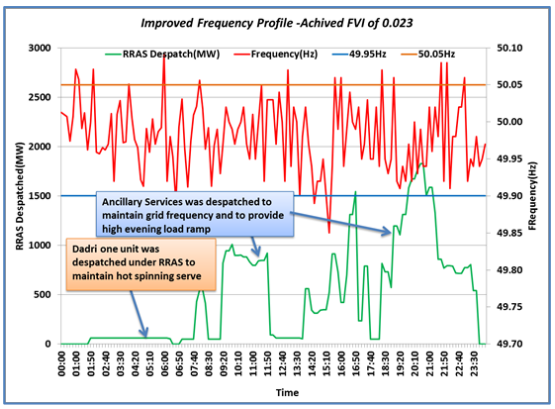

Figure 5: Case Study-Improved Frequency Profile

Additional generation was also brought on bar in the Northern Region to manage congestion, maintain hot spinning reserve and facilitate ramping during the peak hours. Frequency remained 88.18 % of time within IEGC prescribed band on 17 July, 2017.

B. Ramp Management

Ancillary services have also helped in meeting the fast morning/evening load ramps, which can be up to 500-600 MW/min. On 07 June, 2017, RRAS Regulation Down of around 1000 MW was implemented due to low demand during early morning hours (Figure 6).

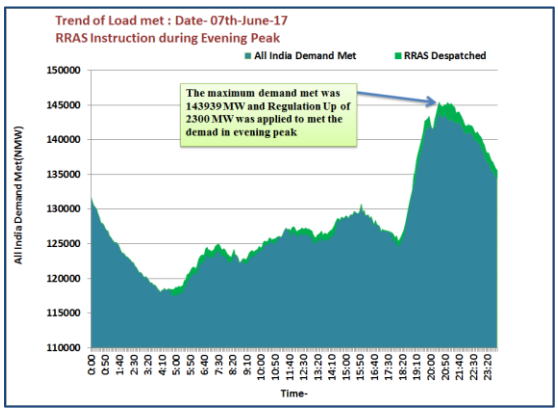

Figure 6: Case Study-Ramp Management

Regulation Up of around 2300 MW was implemented during evening hours to meet the high peak ramp requirement.

C. Grid Resilience – Handling Variability of Renewables

Ancillary services are aiding the system operator as a tool to handle events such as variability of renewables, sudden outage of large generating stations, highly loaded evacuation systems especially for wind and solar parks etc.

On 03 April, 2017, wind generation during evening hours was continuously around 2200 MW, with maximum generation of 2400 MW. From 17:40 hrs. wind generation started reducing and came down to around 1700 MW, thereby, causing generation reduction of around 700 MW (Figure 7).

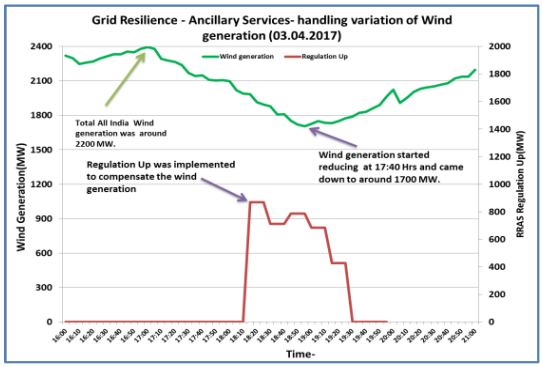

Figure 7: Case Study-Handling Variability of RE

In order to handle this variability, RRAS Regulation Up was applied, from 18:15 hrs. to 19:15 hrs., with quantum of around 900 MW to compensate for the reduction in wind generation.

D. Real Time Congestion Management

Ancillary services have helped in congestion management during outage of critical grid elements such as generating units, transmission lines etc. RRAS instructions are despatched by the system operators to control the loadings of critical inter-regional transmission corridors so as to minimize the impact of congestion on real time basis.

On 01 May, 2017, HVDC Talcher –Kolar Pole-I tripped at 15:21 Hrs. Due to outage of this critical inter-regional HVDC transmission line, the net import Available Transmission Capacity (ATC) of Southern Region (SR) reduced from 7050 MW to 5050 MW (Figure 8).

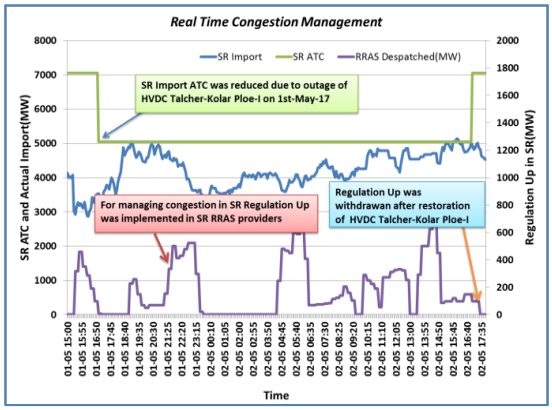

Figure 8: Case Study-Congestion Management

In order to manage the impact of congestion towards SR, all available Un-despatched surplus of SR RRAS providers was despatched through Ancillary Services till restoration of the HVDC transmission line. HVDC Talcher–Kolar Pole-I was restored at 13:17 hrs. on 02 May, 2017.

E. Reliability Support

Ancillary services have helped the system operators to provide reliability support, thereby, facilitating better optimization at pan-India level, especially, in RE-rich regions of NR, SR and WR.

On 17 June, 2017, 765 kV Agra-Gwalior-1 transmission line was taken under emergency shutdown from 12:15 hrs. to 15:30 hrs. The shutdown of this critical transmission line impacted the import capability of Northern Region (NR).

In order to facilitate this emergency shutdown, import ATC of NR was reduced from 7400 MW to 6400 MW. Further, RRAS despatch instructions were implemented from 13:00 hrs. to 15:00 hrs (Figure 9).

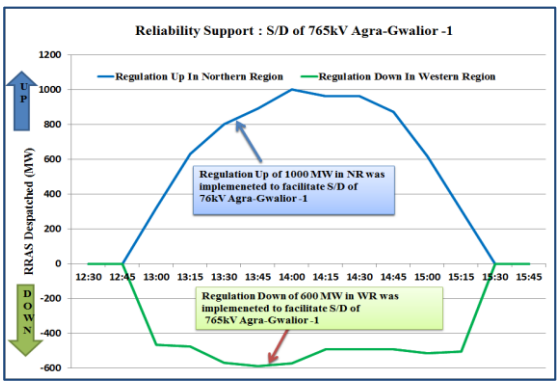

Figure 9: Case Study-Reliability Support

Around 1000 MW of RRAS Regulation Up in NR was instructed to provide reliability support in NR.

Simultaneously, around 600 MW of RRAS Regulation Down was instructed in WR for managing congestion in WR-NR corridor.

F. Extreme Weather Conditions

Ancillary services have helped the system operator in managing contingencies during low probability high impact events such as cyclones, earthquakes, storms, floods etc.

On 07 June, 2017, there was load crash in Northern Region (NR) due to extreme weather conditions. RRAS Regulation Down was instructed to all RRAS providers in all the regions to maintain grid in a secure and reliable manner. The maximum RRAS Regulation Down instruction of 2200 MW was implemented during early morning hours (Figure 10).

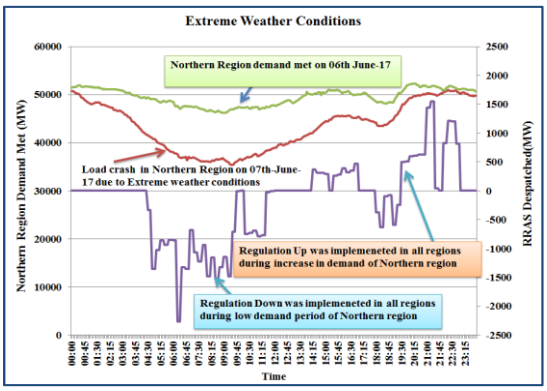

Figure 10: Case Study-Extreme Weather Conditions

The RRAS Regulation down instruction was withdrawn after normalization of Northern Region demand in the evening time and RRAS Regulation Up instruction was implemented to aid in the evening demand ramp.

In the past too, when there was load crash in a particular region, the RRAS instructions in the other regions have rescued the affected region and helped it to maintain the vital grid parameters as close to normal as possible.

VII. Key Learnings and Future Roadmap

This framework is an enforcement of federal structure of our country with freedom and choice of the states retained. The country has been able to harness reserves, without any capital expenditure or fund allocation from the Government, mopping up residuals fragmented across the country. Ancillary Services is being supervised by MOP and CERC with regular review. Larger impact can be achieved if similar Ancillary Services framework can be replicated at state level also. A win-win situation for both generation utility, system operator as well as consumer utility has been achieved through Ancillary Services.

Still, several challenges are being faced such as 'gate closure' in the scheduling process, quantum of reserves to be maintained, better load & renewable generation forecasting, speed of communication of instructions, metrics for performance monitoring, review of charges payable for RRAS. The pilot project on Secondary Control through AGC has been implemented and mock testing has been done. Steps are being taken to expand the ambit of ancillary services to hydro stations, merchant plants and pumped storage plants. More services like Voltage Control and Black Start Ancillary Services are under consideration. In the long run, market based procurement of Ancillary Services is envisaged.

Acknowledgment

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K.V.S. Baba, currently working as CEO, POSOCO, has experience in the Power System Planning, System Operation, Corporate Planning and execution/management of Distribution projects in POWERGRID and POSOCO under various capacities. His areas of interest include System Reliability, Open Access, Regulatory Affairs and Renewable Energy Integration. He currently represents India on the CIGRE Study Committee C2 on Power System Operation.

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