Net Load Ramping Requirements of Southern Region by 2022

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***Abstract* - Maintaining Load–Generation Balance (LGB) dynamically at every instant is the most critical requirement for ensuring secure and stable grid operation. However, it would be one of the biggest challenge for the grid (system) operator with addition huge quantum of RE generation of highly infirm & intermittent in nature and many limitation on accurate forecast. On the other hand, implementation of Government of India's target of integrating 175 GW of renewable energy by 2022 is on track and it is a critical & important mile stone in reducing carbon footprint.**

In the year 2022, renewable energy capacity in Southern region alone would be about 59 GW, which amounts to more than 35% of SR energy mix. With this type of energy profile it would be a great challenge for system operator to accommodate the sharp ramping, sudden reduction, and deep duck curve effect.

As renewable sources are highly variable in nature, estimating net load is important for the system operator for managing the variability effectively. In this paper the expected net load of Southern Region during 2022 for peak demand scenario & peak wind scenario are presented by analyzing likely renewable generation along with projected demand.

***Index Terms*-Net load, penetration, Renewables, Flexibility**

I. INTRODUCTION

Load-Generation balance is vital for stable grid operation. Renewable energy sources like wind and solar, are highly variable and intermittent in nature. Generation from these sources have both seasonal as well as time of the day variations. Considering such generation as negative load for power system operation purpose, *Net load* may be derived as the difference of actual load and renewable generation. Based on the derived net load, system operator has to flex the generation of conventional power stations in order to achieve load-generation balance, on real time basis.

Indian electricity grid, which is one of the largest synchronously operated grids in the world, is demarcated into five regions for operation purpose. Southern region (SR) is one among the five regional grids with installed capacity of around 90 GW, including 20 GW of wind & solar (combined) as on 30-06-17. The 24 hours of a day are divided into 96 blocks, each with time period of 15min, for the purpose of scheduling and accounting. This paper aims to discuss the ramping requirements in different time blocks of the day during peak demand and peak wind seasons for Southern Region of India.

General characteristics of solar and wind power generation are shown in sections II and III respectively. Intra-day variations in solar generation along with seasonal & intra-day variations of wind generations have also been discussed in these sections. In Section IV, the demand profile of 2022 is plotted against the net load profile during peak demand and peak wind seasons for 80% and 100% of RE targets. Ramping requirements in different scenarios have also been discussed in detail. Section V highlights the various tools available to address the ramping requirements.

II. SOLAR GENERATION CHARACTERISTICS

Solar generation characteristics are derived from analysis of one year generation data of a solar park located in Andhra Pradesh. Solar generation over a sample day without cloud cover plotted as percentage of installed capacity is shown in Fig. 1(a). However, in many cases cloud cover affects solar generation over the day. The general 3-D trend of SR solar generation over a sample month is plotted in Fig. 1(b).

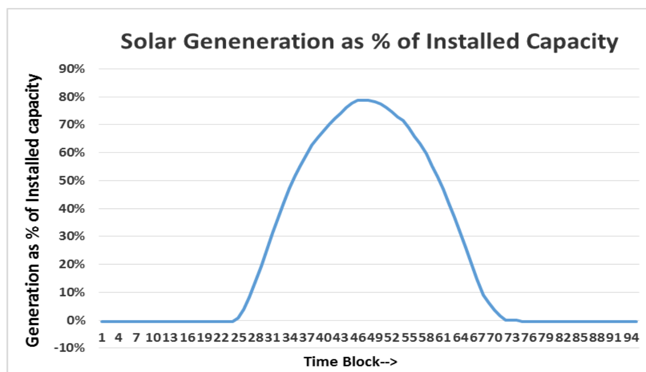

Fig.1 (a) Solar generation as percentage of installed capacity

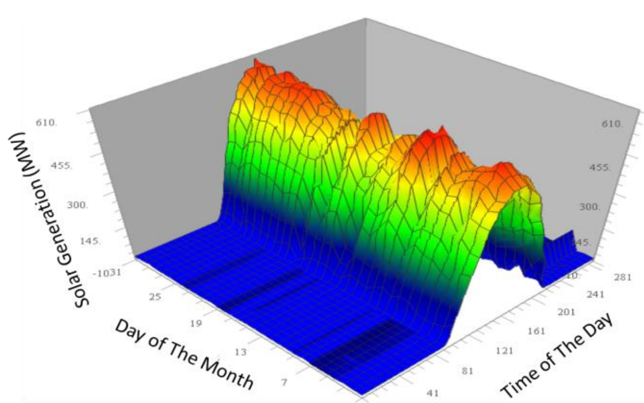

Fig.1 (b) 3-D plot of solar generation

Solar generation generally starts picking up from 26th time block of the day. From 26th block to 48th block, the generation increases over time and after 49th block, generation starts reducing and touches zero in 73rd block.

The variation in generation in each time block of the day is as shown in Fig. 2.

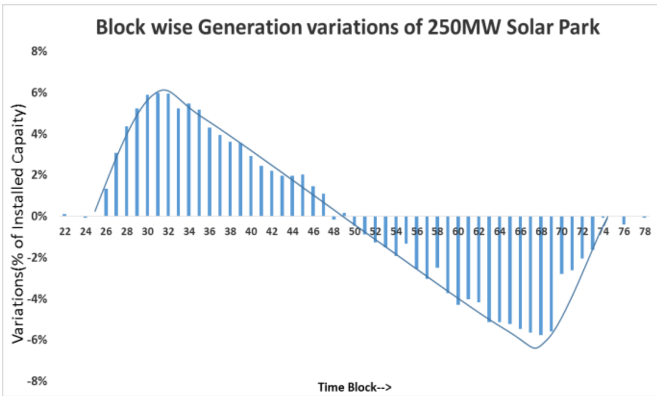

Fig. 2.Block wise solar generation variations

Generation variations can be summarized by dividing the total solar generation curve into two parts. First part is the period of generation increase i.e., 25th to 49th blocks and the next is the generation decrease period from 50th to 73rd blocks. The summary of approximate ramps in different blocks are given in Table1.

Table1: Approximate ramps in different blocks

Time Blocks	Time Period	Average Ramp Rate as % of Installed Capacity	Remarks
26-27	06:15 - 06:45	2.20%	Slow Ramp
28-38	06:46 - 09:30	5.00%	Steep Ramp
39-45	09:31 - 11:15	2.40%	Slow Ramp
46-53	11:16 -13:15	(+/-) 1 to 1.5 %	Minimum Ramps
54-58	13:16 - 14:30	-2.20%	Slow Ramp
59-69	14:31 -17:15	-5.00%	Steep Ramp
70-73	17:16 - 18:15	-2.50%	Slow Ramp

As observed from the table, the average maximum ramp during a block is around 5%. However in few individual blocks like 31-33, variation up to 6% of installed capacity is observed and similarly, -6% variation was observed during 64-68 blocks.

III. WIND POWER VARIATIONS IN SOUTHERN REGION

Wind generation is dependent on seasons. Seasonal variation of wind generation in SR is plotted in Fig. 3(a) during a period of three and half years. Good amount of wind generation starts from end of May and continues till the end of September. Highest wind generation is observed in the months of June, July & August. During high wind season share of wind generation in total energy consumption of SR is around 20 - 23% in present condition. November to mid of May is lean wind season, during this period wind generation forms only 2 - 3% of total energy consumption of SR.

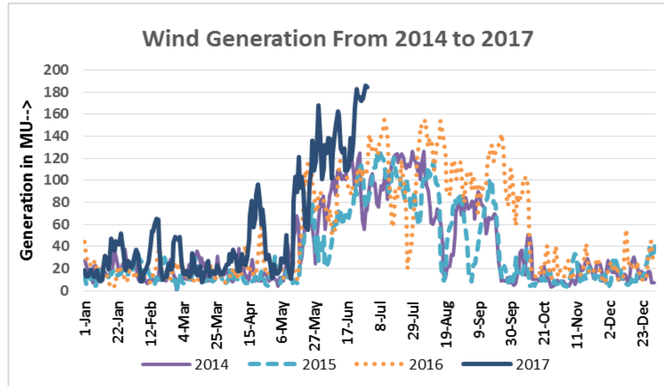

Fig. 3(a).Wind generation of SR from 2014 to 2017

The general seasonal trend of wind diversity in SR along with intraday variations can be observed from Fig. 3(b).

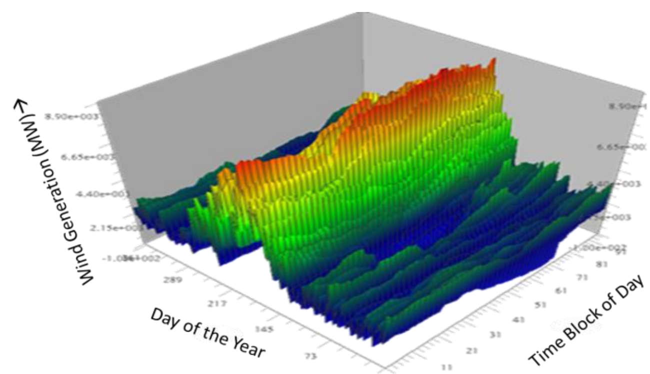

Fig. 3(b). 3-D plot of Wind diversity in SR

Wind generation characteristics during high wind season: In SR, wind generation follows specific characteristics during high and lean wind season. General wind generation characteristics during high wind season, derived from the data of June & July 2017, average wind generation in MW as percentage of total installed capacity (15 GW) is as given in Fig. 4.

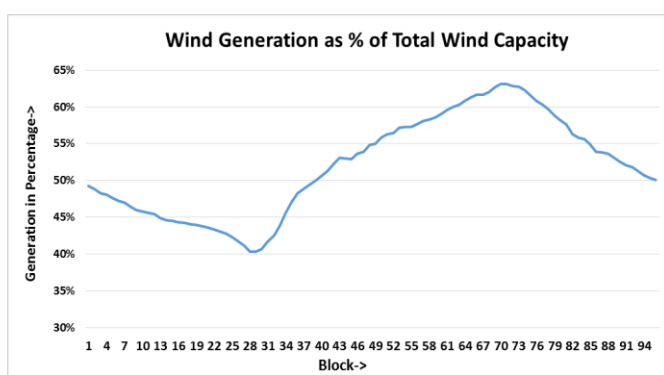

Fig. 4.Wind generation curve during high wind season

From the above wind generation pattern it can be seen that the generation curve over a day can be divided into three sections based on ramping of wind Generation, details are given in Table 2.

Table 2: Approximate ramps in different blocks

Section	Blocks	Average Ramp Rate as % of Installed Capacity per Block
Section 1	01 - 28	-0.34 %
Section 2	29 - 73	+0.50 %
Section 3	74 - 96	-0.50%

Wind generation characteristics during low wind season: General Wind generation characteristics for low wind season are plotted in Fig. 5.

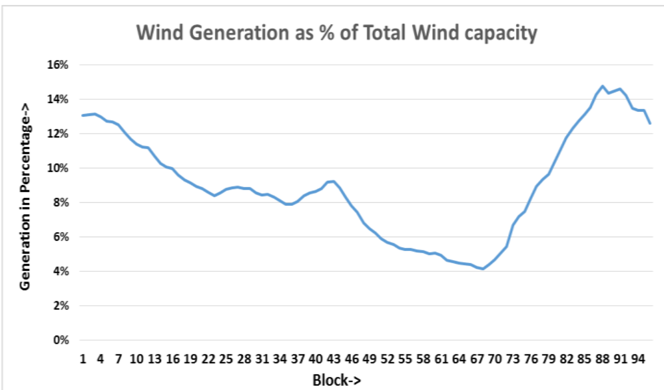

Fig. 5. Wind generation during low wind season

During low wind season wind generation caters only 2 – 3% of the total SR energy consumption. During early morning hours & late night hours wind generation is slightly higher compared to day time, as seen in Fig. 5.

IV. EXPECTED NET LOAD BY 2022

In the light of targeted 175 GW of Renewable energy 2022[1], Southern Region needs to integrate 28200 MW of wind & 26531 MW of Solar power [1]. Source wise expected installed capacity by April 2022 is shown in Fig. 6[2]. Wind & Solar forms around 38% of total generating capacity of SR in 2022.

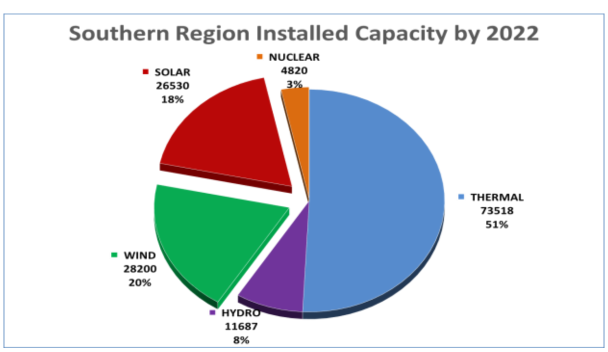

Fig. 6 Expected SR Installed capacity by 2022

Net load is defined as the difference between actual connected load and generation from Wind & Solar. Net Load gives an idea to system operator about the amount of flexibility required from conventional generation to accommodate renewables. In this section, the expected net load for SR is calculated for the following four scenarios in 2022.

1. Peak demand season
   a. Scenario 1: 80% of RE Target achieved
   b. Scenario 2: 100% of RE Target achieved

2. Peak Wind season
   a. Scenario 1: 80% of RE Target achieved
   b. Scenario 2: 100% of RE Target achieved

Assumptions:

i) Total wind & solar generation power would be evacuated without any constraints.
ii) Intraday variations in Solar due to cloud cover & sudden variations in wind power are not considered, which can be better assessed only near to real time.
iii) Demand profile of 2022, is assumed similar to 2017

19th Electrical Power Survey (EPS) [3] predicted SR demand would reach a peak of 62975MW by 2022. Considering the peak demand of 42277MW in 2017, the load profile in 2022 is estimated using demand data of March & April 2017 raised in the ratio of peak demands in 2022 and 2017. Solar and wind generation in 2022 is calculated from the curves presented in Section I & II raised in the ratio of installed capacities of 2022 & 2017.

Peak Demand Scenarios 1(a) & 1(b)

Peak demand in SR is observed during March & April, which coincides with lean wind season. Actual load and Net Load for Scenario 1(a) &1(b) for 2022, plotted in Fig. 7

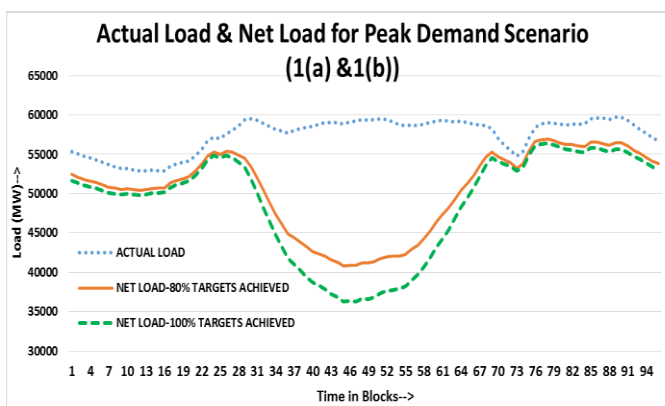

Fig. 7.Actual Load & Net Load for Scenarios 1(a) & 1(b)

In this scenario, the net Load ramping requirements are majorly due to variations in solar generation and demand. Being a lean wind season, effect of variations in wind generation on net load is almost negligible.

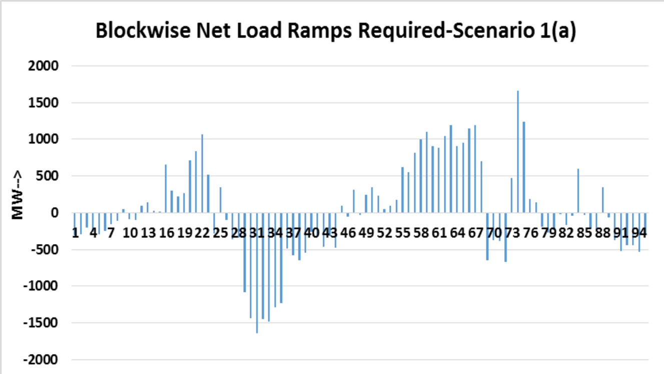

Fig. 8. Net load ramping requirements - Scenario 1(a)

In scenario 1(a), the expected net load in the 28th time block of the day is ~55GW and has come down to ~41GW during 49th time block and again increased to ~55GW in 70th time block as shown in Fig. 7. This calls for a flexibility requirement of around 14GW in 21 time blocks (on an average 670 MW per block) in both the cases of ramping up and down. However between 30th and 34th time blocks, ramping down requirement is as high as 1500 MW per block. From 49th to 69th time blocks, when the solar generation starts reducing, the average ramping requirements remains same as that of forenoon i.e., ~670 MW/Block. During 58th to 67th time blocks the maximum ramping up requirement is crossing 1000 MW per block.

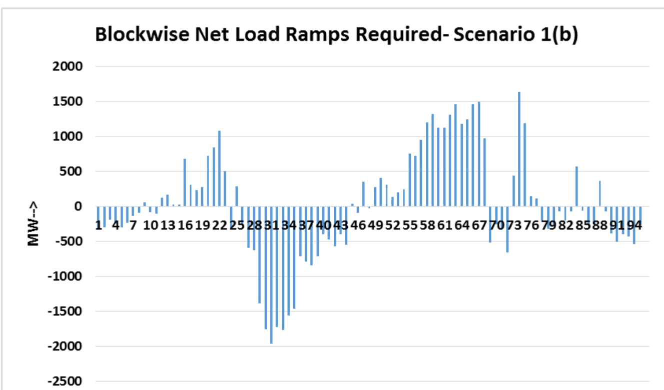

Fig. 9. Net load ramping requirements- Scenario 1(b)

In scenario 1(b), average ramping requirement rises to 900MW per block, as the net load goes down from 55GW in 28th block to 36GW in 49th block. At times, ramping requirements are touching ~2000MW per time block, as shown in Fig. 9. The post-noon ramping requirements are not as steep as the forenoon ones and are hovering around 1200MW per block.

Peak Wind Scenarios 2(a) & 2(b)

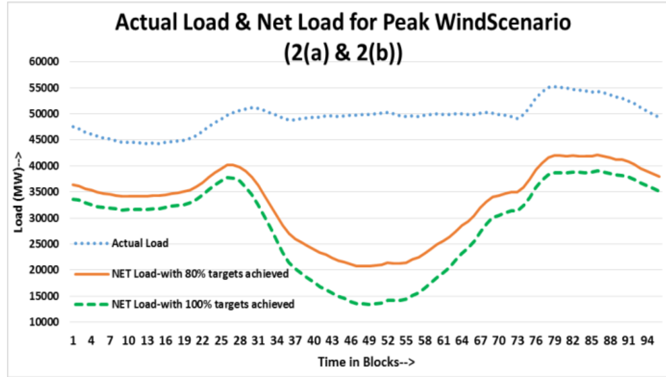

Fig. 10.Actual Load and Net Load for Scenarios 2(a) & 2(b)

The load, Wind and Solar generation and net load profiles for 2022 is computed on the similar lines as explained earlier. The net load thus obtained from the difference of the above two, throws much remarkable facts.

In the scenario 2(a), where 80 % of the RE integration targets are achieved, average ramping requirements are in the order of 1000MW per block, as the net load of ~41GW during 28th time block has come down to ~21GW in 49th time block (Fig. 10).

In scenario 2(b), where 100% of RE penetration targets are achieved, the results show much rapid ramping requirements in the order of 1200MW per block.

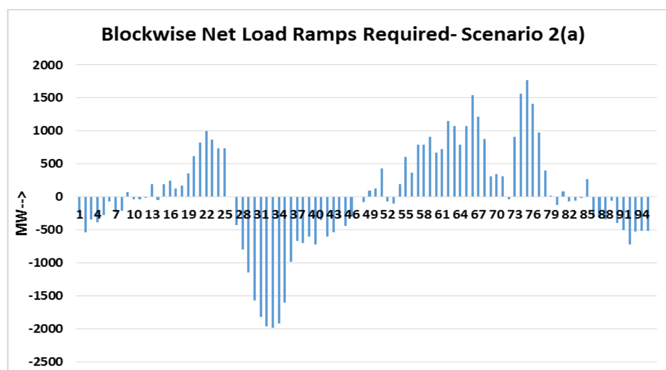

Fig. 11. Net load ramping requirements- Scenario 2(a)

In the scenario 2(a), the net load curve demands a maximum ramping down from conventional generation fleet of around 1800MW per block between 31st and 34th blocks. However the maximum post noon ramping up requirement goes in the order of 1500MW, similar to scenario 1(a) & 1(b).

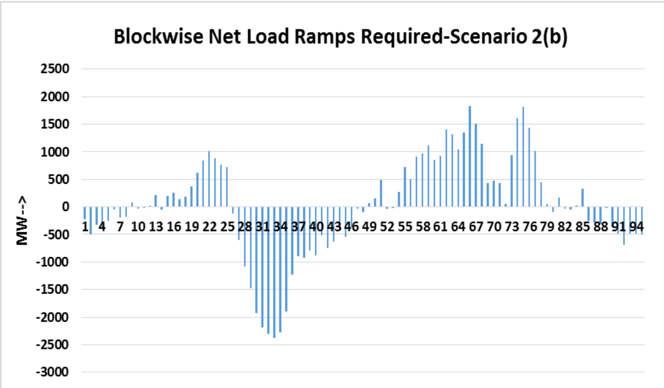

Fig. 12. Net load ramping requirements- Scenario 2(b)

When 100% of RE targets are achieved (Fig. 12), the net load demands a ramping requirement of over 2100MW per block as both solar and wind generation will be in increasing trend during morning hours. The maximum ramping down need goes to a maximum of ~2400MW per block.

V. MANAGING THE LOAD RAMPS – SOLUTIONS

Managing these net load ramps on a daily basis is a very challenging task for the system operator. Following are the various means the system operator may resort to in shielding the system against the variability of the Renewables

Flexing the conventional generation fleet:
Small case study is done with certain assumptions to assess the amount of flexibility can be expected from conventional generating stations. The projected thermal installed capacity by 2022 is around 72GW. Assuming only 65% of the thermal generation i.e. ~ 47 GW is available during peak wind season (As major units go for annual maintenance during monsoon season), and generators running at part load (80% of capacity), a flexibility of 10-11GW may be expected from thermal generation. In the scenario 2(a) & 2(b), a support from Hydel power can also be expected as the peak wind season coincides with monsoon season of the region. Out of 11GW of Hydro stations, around 4-5 GW is expected to be on bar and can cater a flexibility of ~3GW. Hence hydro and thermal, together are expected to provide a flexibility of 13-14GW which is far less than the expected requirement of 19-21GW.

The technical minimum schedule considered for an ISGS thermal generator is 55% of the name plate rating [4]. The same shall be implemented at intra state level for achieving further flexibility.
Further, in order to have a minimum RE curtailment renewable energy absorption into the grid, following options may be considered.

1. **Storage:** Storing energy during less demand - high renewables period and discharging the stored energy during peak demand is essential for minimizing curtailment of renewables and load shedding during peak hours. Presently, pumped hydro storage is the only grid scale storage available in SR. Total capacity of pumped storage is ~2000MW. Out of this, only 400MW is being used. Non-operation of other plants, which are due to various factors, needs to be addressed and further development of already planned pumped storage plants[5] needs to be expedited, for achieving more flexibility. CEA Draft technical standards proposes maintaining at least 10% of installed capacity as storage facility [6] for the wind & solar plants of 50 MW and above.
2. **Exporting excess power to other regions**: Southern region is well connected with other regions through HVDC and AC transmission system. Presently SR is importing power from other regions with high penetration of Renewables, SR may face surplus scenario and controlling the ramps will become difficult. SR states may have to explore the option of exporting power to other control areas during the high solar period. The same was pointed out by Greening the Grid study report for India [7].
3. **Altering the load curve**: One of the ways to reduce ramping requirement is to tweak the demand curve. There are market mechanisms like introduction of Time of the Day tariff, which shifts the demand as per price signals. However, this requires lot of infrastructure advancements and the development of market for the same. One other option in the hands of the utilities is the shifting of irrigation loads, which forms around 24% of total demand of SR [3]. As on date, irrigation loads are divided into different groups and each group is given supply at different parts of the day. Govt. of Andhra Pradesh and Govt. of Telangana are planning for uninterrupted power to irrigation sector for 9 hours during the day time [8][9]. Similar initiation of shifting of Irrigation loads by other SR states, like Karnataka and Tamil Nadu, may ease the situation of exploiting renewable energy during day time. These irrigation loads needs to be planned so as to compensate the ramping up / ramping down requirements.

The net load requirement for region as a whole has been computed while in reality it is different for different states based on their RE status. There must be a flexi trading mechanism among different states within the region for smoothening the net load requirement.

VI. ADDRESSING THE INTRA-DAY/SUDDEN VARIATIONS IN RENEWABLES

In addition to the ramping requirements explained earlier, sudden variation in renewables like solar generation variation due to cloud pass etc. also needs to be managed by the operator. Different controls for managing the sudden variations are explained below –

Primary Response or Governor Response: Governor Response from the generators is considered as the first line of defense for safe guarding the grid in case of contingencies.

Currently 25 to 30% of regulatory mandated response is observed from southern region generators. Further improvement in primary response of the generators is required for effective management of grid with high penetration of renewables.

Automatic generation control: Renewable generation variation leads to deviations in the drawls of the utilities, leading to deviations in the tie line flows. AGC is the tool which senses the deviation in the tie lines and automatically gives signals to conventional generation for minimizing the deviation. Presently, pilot projects of AGC are under progress in India and soon will be deployed after gaining experience.

Ancillary services: In India, we have ancillary experience of over a year and the results are very positive. As on date few thermal generating stations at interstate level are under this mechanism. The Un-requisitioned Surplus in such generating stations is being used to schedule under ancillary services. But in order to integrate 175GW of renewables contribution from state generators also required through ancillary services at state level, for which regulatory intervention at state level is required.

VII. CONCLUSIONS

This paper presented the general generation profile of wind & solar and the impact of the same on net load. The variation of net load in different scenarios of peak demand season and peak wind season are presented. This paper explained need for the fast ramping requirements from the conventional generation the necessity of grid-level storage in order to facilitate large scale integration of Renewables.

VIII. REFERENCES

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