

Scientific Management of Energy and Water Resources

RE Integration and Its challenges

Kerala Vision 2031

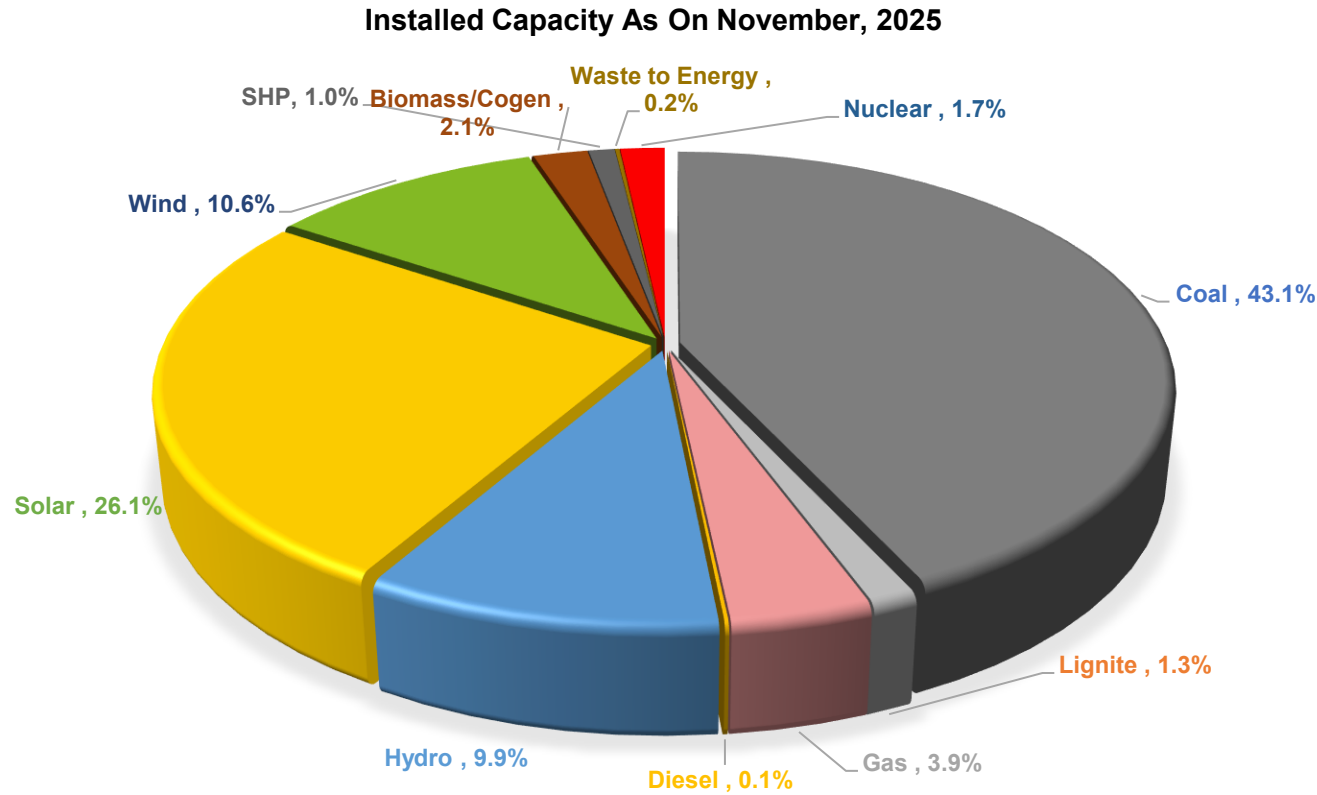
Dt: 15- 02-2026

***Presentation
by
Ravindra Kadam***

Content

- **India's context of Energy Transition**
- **RE integration challenges at inter-state level**
- **Managing the reliability and grid operations**
- **Transmission Planning and Cost**
- **Need for Flexibility**
- **Resource Adequacy**

India's Installed capacity Status (November, 2025)



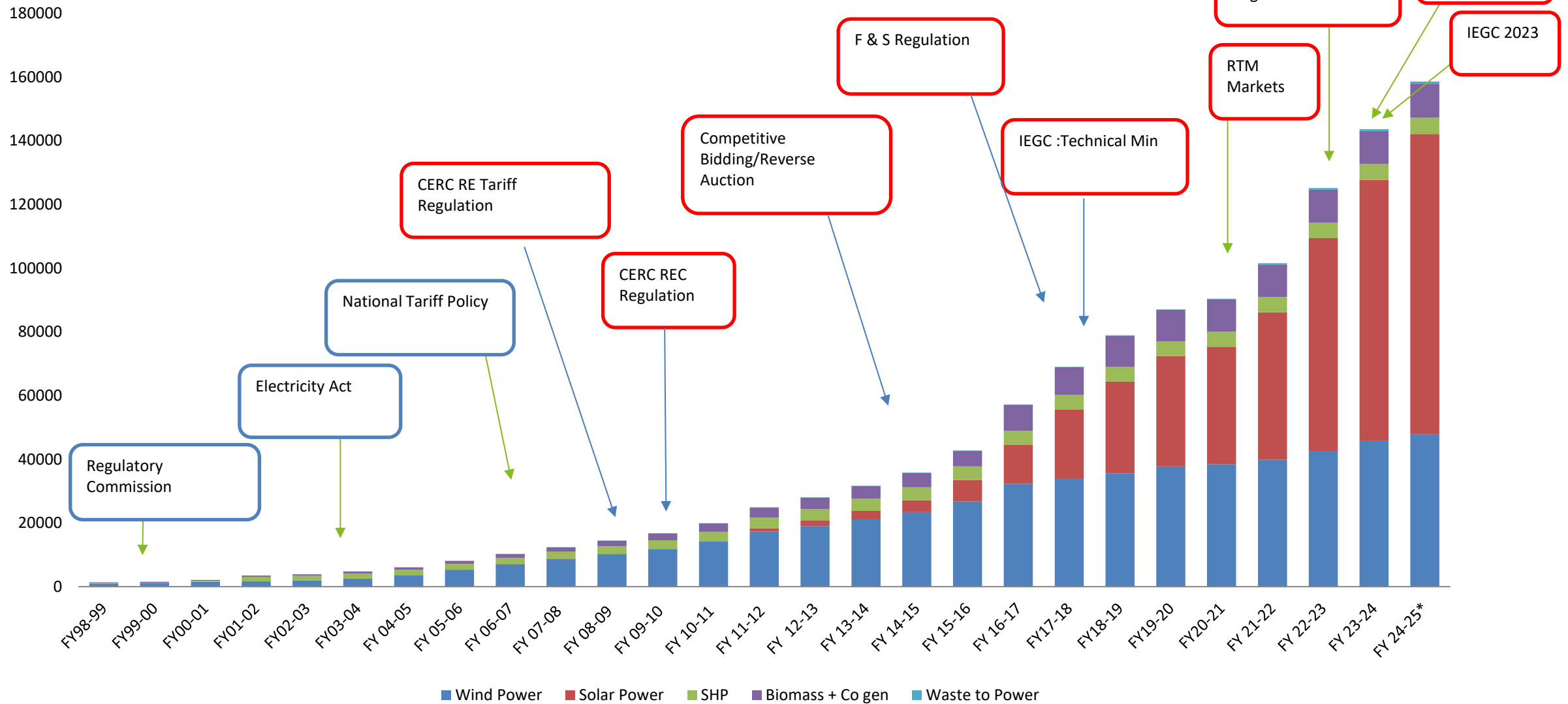
Source: CEA's Executive Summary for Nov,2025

Installed Generation Capacity as on November 2025			
Category	Capacity (GW)	Non-Fossil Fuel	Capacity (GW)
Fossil Fuel		Non-Fossil Fuel	
Coal	219.61	Hydro	50.42
Lignite	6.62	Solar	132.85
		Wind	53.99
Gas	20.12	Biomass/Cogen	10.76
		SHP	5.16
Diesel	0.59	Waste to Energy	0.86
		Nuclear	8.78
Total Fossil Fuel	246.94	Non-Fossil Fuel	262.80
Total Installed Capacity (GW)			509.74

Share The proportion of non-fossil fuel-based capacity is about 51.5%, and the remaining 48.5% is fossil fuel-based.

Renewable Growth in India

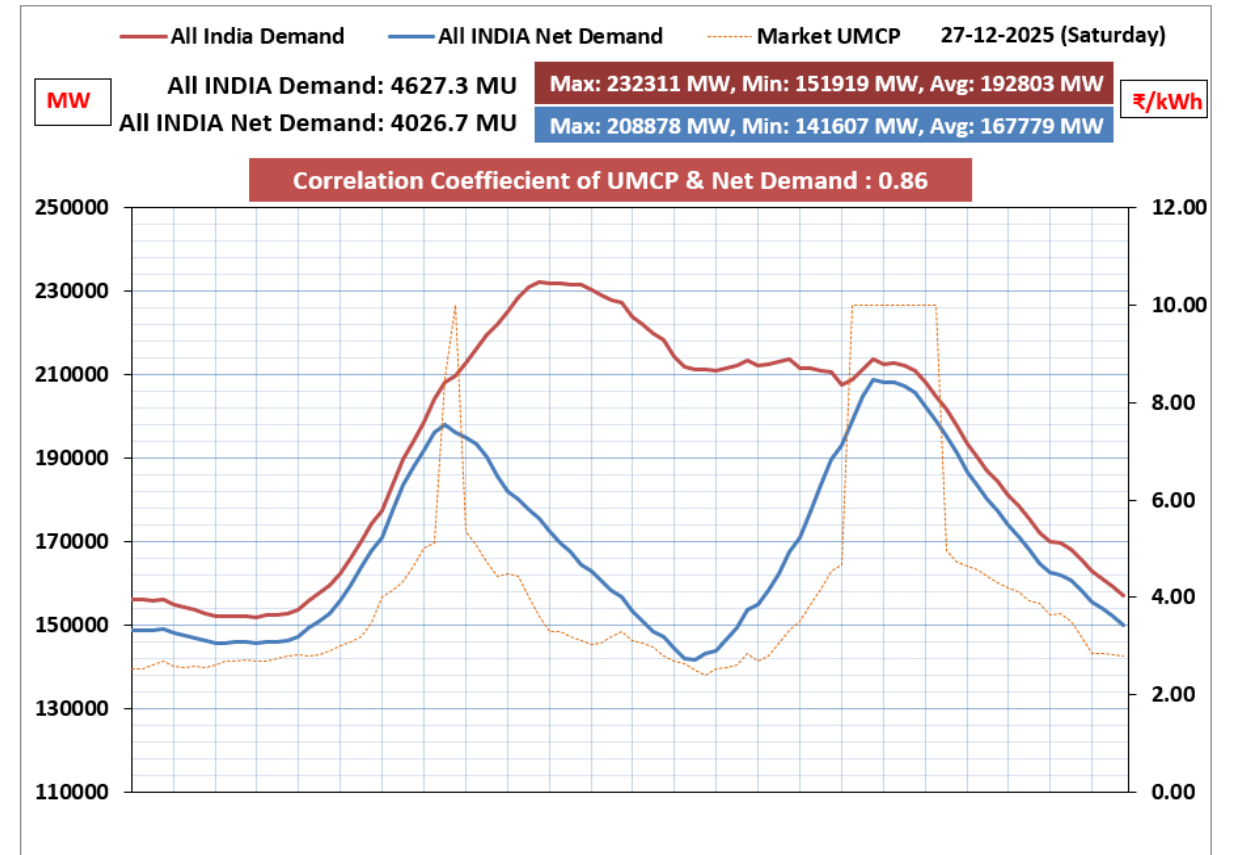
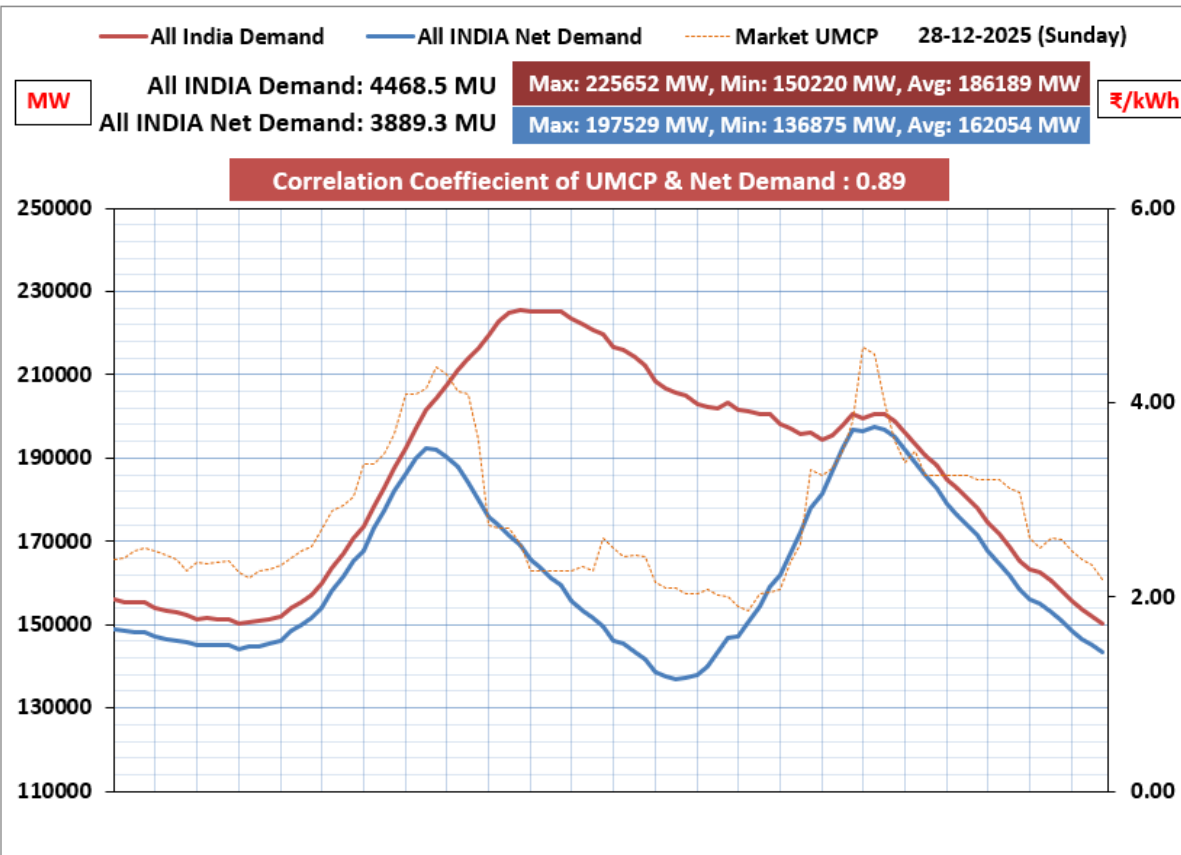
Cumulative RE Installed Capacity (in MW) in India



RE integration and challenges for Grid operation

- Challenges due to the RE integration.
 - Steep net demand curves
 - High ramp requirement
 - Frequency excursions
 - Part load operation of thermal fleet
 - Excess generation during peak solar hours: sustained over frequency

Duck Curve



Source: Grid India

- High integration of renewable energy in the Grid
- A steep decline in solar generation during the evening hours

High ramping requirement in the grid

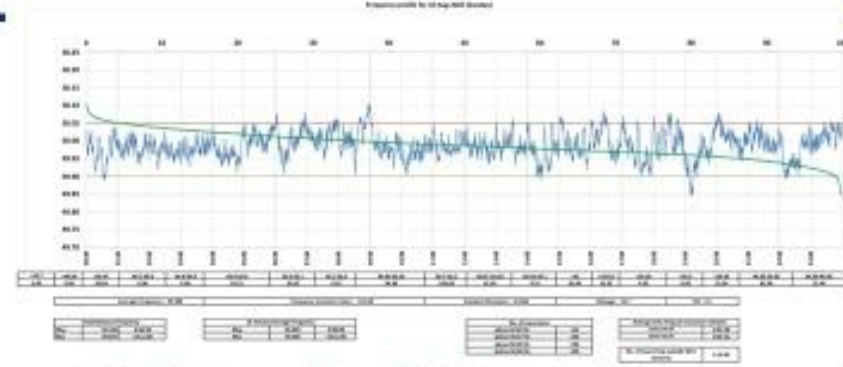
RE Backing Down(TRAS) to handle High Frequency

25th May - Sunday-High Frequency Operation (low demand, inclement weather)



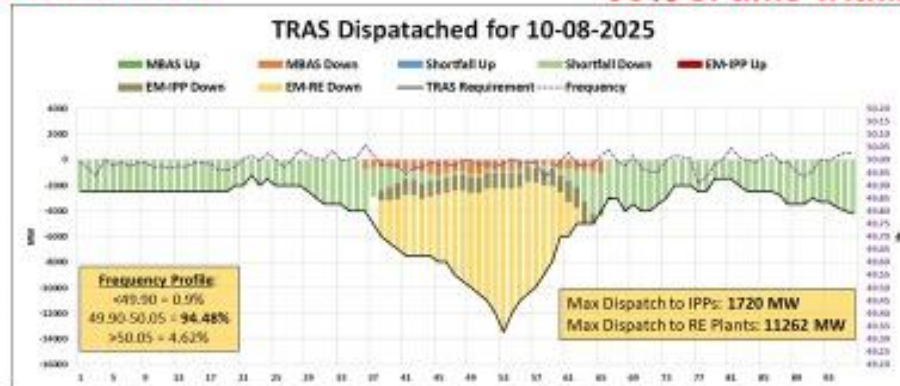
36% of time within IEGC band 49.90 – 50.05

10th Aug 25 – Sunday Best ग्रिड-इंडिया Frequency profile (94.48% in band)^{IA}



95% of time within IEGC band 49.90

Intra-state RE curtailment	Max MW	MU
Maharashtra	30	0.04



Upto 13500 MW TRAS Down

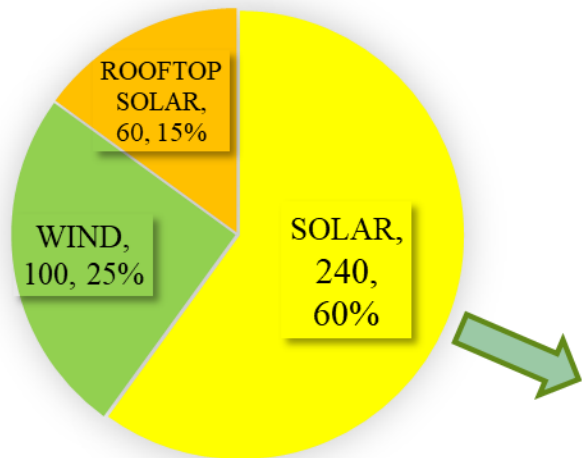
850 MW from TRAS Market
200 MW from Short-fall
1200 MW from IPPs(TR-E)
1260 from RE (TRAS-E)

Note: Dispatch to RE as a last resort after backing down all regional IPPs to 55%

ISTS for Renewable Energy by 2030: as on 09/2025

Non-Fossil Generation

Solar+ Wind: 400 GW



Non fossil Capacity: ~ 500 GW
Solar including Rooftop: 300 GW,
Wind: 100GW, Hydro: 54GW,
Nuclear:15GW, PSP: 19GW,
Others: 16GW

WIND (100) +
SOLAR (240)
: 340 GW

ISTS: 230 GW

INTRA-STATE:
110 GW

Transmission

**ISTS status :
238 GW**

Completed:
53 GW

Under
Construction:
172.5 GW

Under
Bidding:
12.5 GW

** 31 GW Margin in Non-RE ISTS Substations*

Expected impact of Transmission capacity addition on Transmission charges 2030

- Total additional investment (approx.) of Rs. 400000 Crore by 2030 will result in additional transmission charges of Rs 5000 cr per month (@15%)
- With expected GNA quantum of 150000 MW in 2030, average transmission charges of beneficiaries without waiver would be Rs. 5.92 Lacs/ MW/ Month (as compared to current level of Rs 3.25 Lacs/ MW/ Month)

Already awarded transmission schemes include HVDC system which are capital intensive

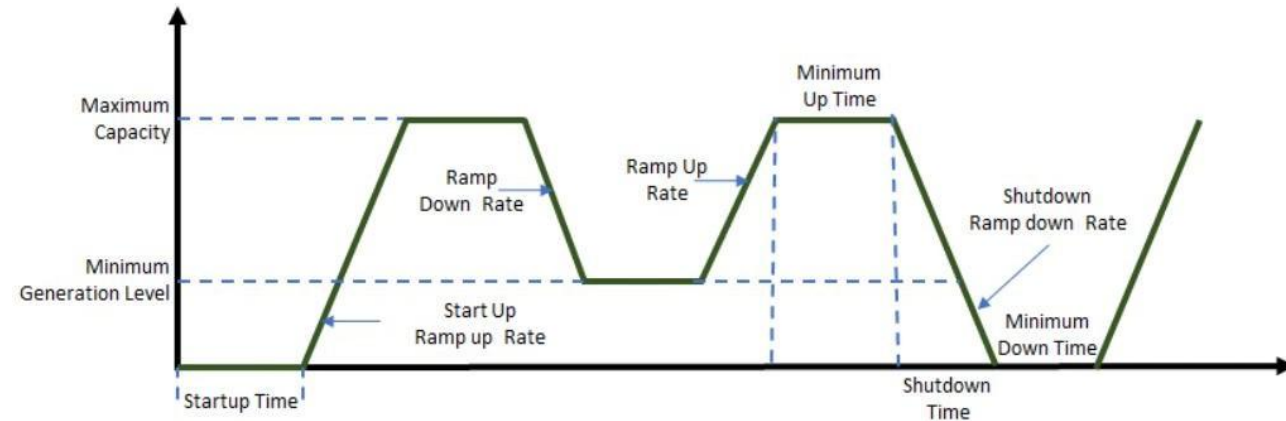
Evacuation of RE through HVDC or setting RE capacity at locations requiring minimal or no transmission ?

If HVDC is needed , then RE CUF needs to be high by utilizing it for solar/non-solar connectivity & ESS

Need of flexibility

Minimum Turndown Level

- Minimum output (as % of capacity) that the generator can sustain continuously
- Lower MTL enables wider operating range of power plant



Ramp rate

- Rate at which generator can change output (as % of capacity/min)
- Faster ramp rate enables meeting net load ramping requirement

Minimum up/down time

- Min. time for which generator has to stay online before going offline and vice versa
- Lower minimum up/down times together with faster startup/shutdown time enables two-shifting operation

Need for Resource Adequacy

Generation and transmission planning

Meeting projected demand at all times

Complying reliability standards

Optimum generation mix

Integration of Variable renewable, flexible resources, ESS, DR, etc.

- ✓ RA analysis provides insight into ascertaining whether there are enough resources and, if not, what type of resources are needed to meet reliability needs.
- ✓ RA focuses on the integration of environmentally benign technologies
- ✓ RA focuses on scaling renewable deployment with less curtailment and less financial and operational stress on conventional assets.
- ✓ RA analysis can help facilitate generation capacity sharing among states, increasing the utilization of existing generation assets.

Challenges in RA implementation



Assessment: quantifying size, frequency, duration, and timing of capacity shortfall is critical to finding the right resource solutions

Static v/s. Dynamic: conventional approach of designing a system solely to meet conditions via a static PRM is no longer appropriate

Resource Diversity: different resources can bring different capabilities and it is important to capture this diversity in an optimal and a least-cost manner

Sharing of Resources: planning in silos may lead to over capacity and thus focus should be on to share available resources to reduce overall system costs.

Thank you