Renewable Resources and its Integration to Grid

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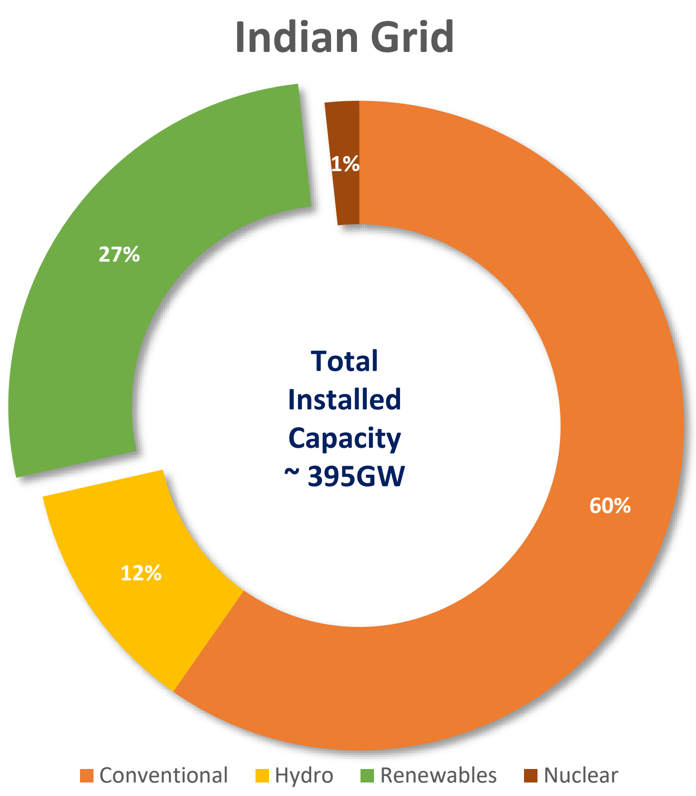
Introduction-Indian Grid Scenario

- India has achieved a cumulative installed renewable energy capacity (excluding large hydro) of **92.54 GW** out of which **5.47 GW** was added in the period April 2020 till January 2021.
- Share of Renewable energy is approximately ~ 27% of total installed generation capacity in India.
- Ambitious vision to achieve 450GW of Renewable Energy Generation by 2030



Grid Integration Challenges for RE Generator

Intermittency
- Solar & Wind resources are intermittent in Nature
- Accurate Scheduling & Forecasting is a challenge

Short Circuit Ratio
- Weak fault feeding source
- No kinetic inertia
- Power Electronics in Inverter & WTG

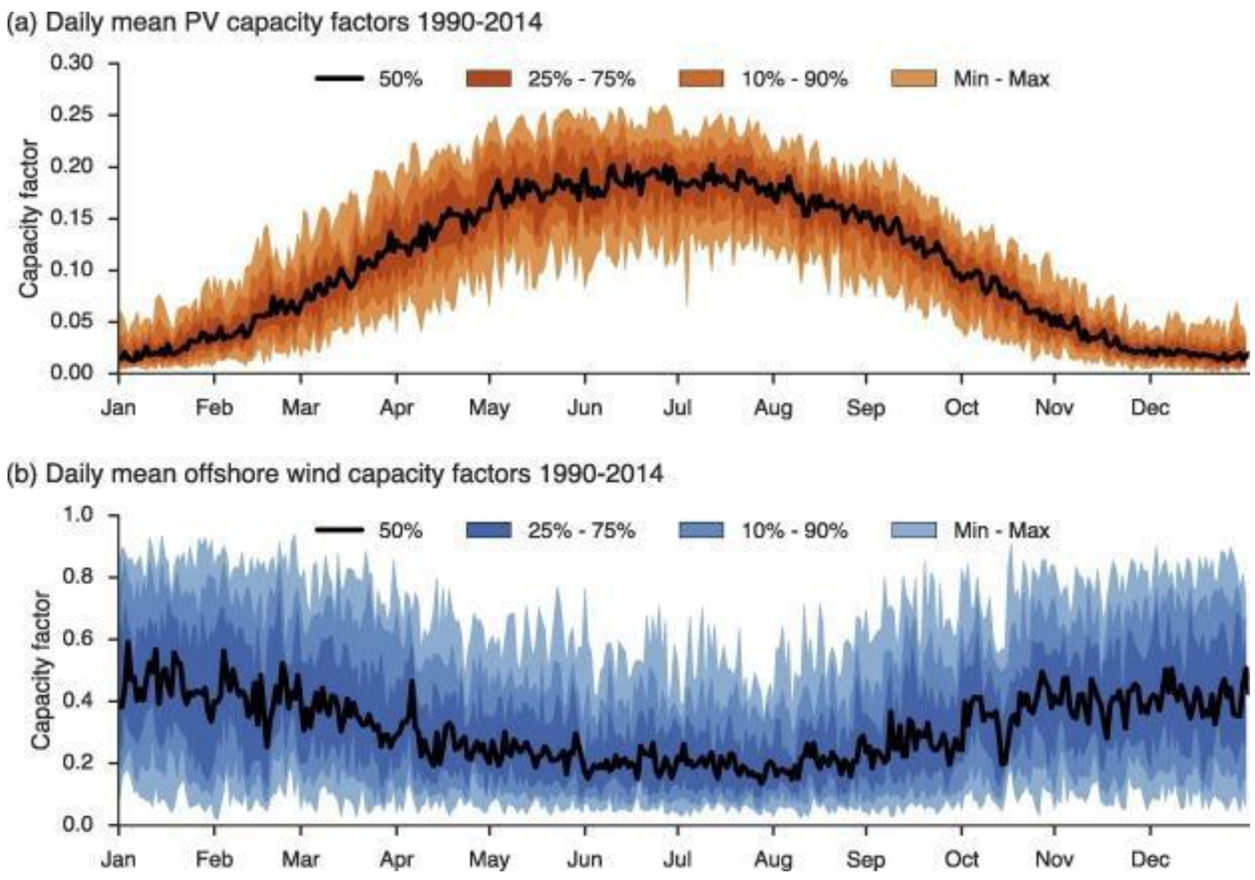
Frequency Response
- Weak Frequency Response
- No positive response unless curtailed

Reactive Power Capability
- Limited Q capability
- Q capability depends on generator terminal voltage
- Voltage crisis at tail feed generator
- Overall limited Q capability due to distributed generators

Large Ramp
- Fluctuations in output
- Cloud cover
- Wind gust

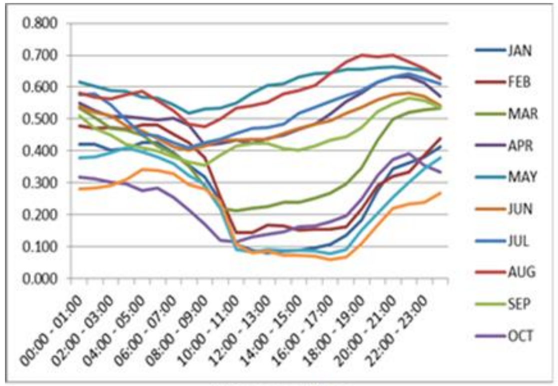
Intermittency in Renewable Energy

- Renewable energy and intermittency go hand in hand due to the inherent nature of these technologies (E.g. Wind & Solar).
- Solar and Wind generation varies across the day and across seasons depending on the available resource and weather patterns.
- Forecasting of RE generation has still not matured and is unpredictable.
- Maximum CUF for Solar is 29% - 30%, whereas for Wind it is 30% - 45%.
- The intermittency of these renewable energy sources becomes more pronounced as the share of renewables increases in the grid. Availability and serviceability of balancing sources such as thermal, gas, hydro and batteries becomes even more important.

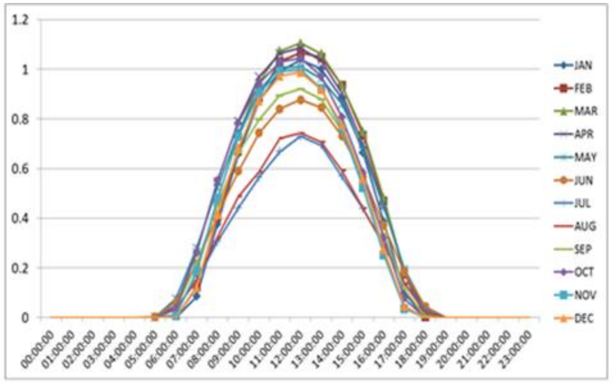


Intermittency ➔ Hybridisation

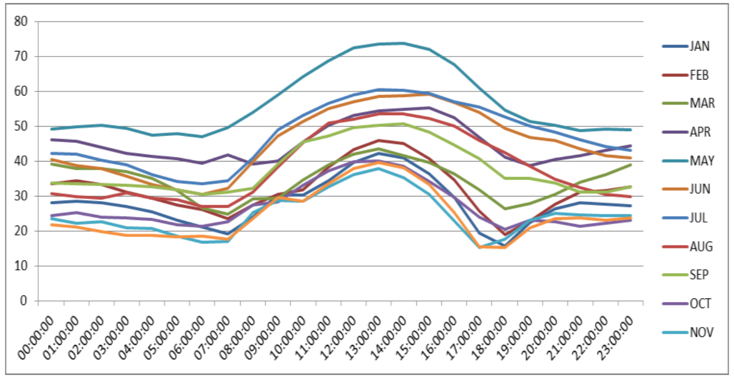
- Solar and Wind Power Plants characteristically generate power at different intervals and during complementary seasons
  - Energy being fed into the grid is steadier than Wind or Solar PV power plants alone
  - The probability of Peak Solar and Wind resource occurring simultaneously at a particular location is very small, thus reducing the possibility of undesirable power peaks
- Key Advantages include
  - Better utilization of grid and infrastructure
  - Lower generation variability due to hybridization
- Certain sites like Kutch (Gujarat) & Jaisalmer (Rajasthan) are endowed with both solar and wind resources making them suitable for hybrid projects



WIND RESOURCE



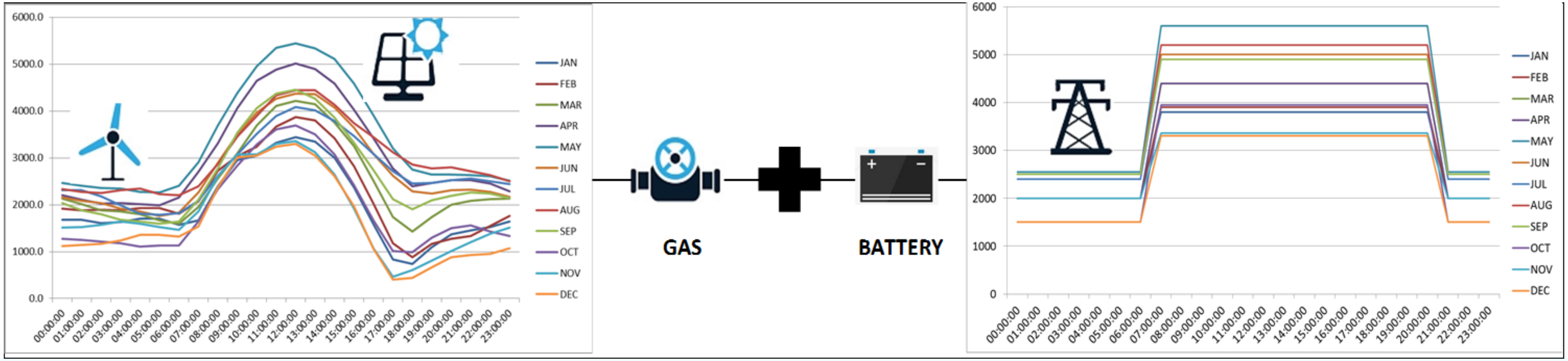
SOLAR RESOURCE



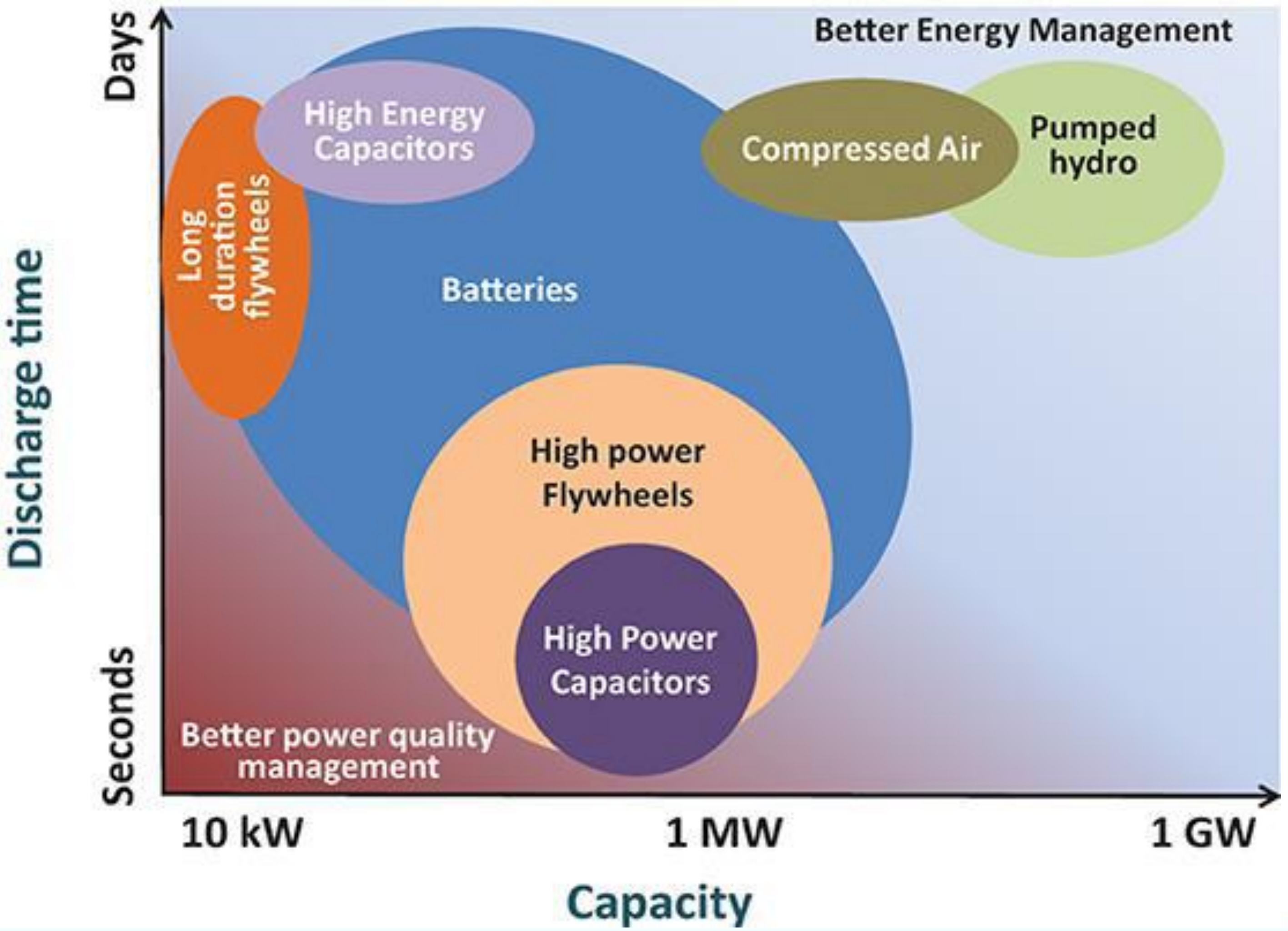
Wind solar hybrid generation at typical hybrid plant *

Intermittency → Hybridisation → Round The Clock

- Grid demand curve when overlapped with Solar, shows the ramp rates required for base load generation / balancing sources to meet the load demand during evening peak hours.
- Base load plants like thermal plants have limitations w.r.t fast ramping. Also, they have to operate at very low load factor during renewable generation hours, leading to inefficient operation and higher cost of power.
- The concept of deriving flat and firm power from a mix of renewables such as solar & wind and conventional energy sources such as gas turbines.
- Wind and solar being intermittent, gas turbines can be used to back up the chunk of generation when solar / wind is scarce.
- Battery energy storage systems being expensive, can be optimally utilized for regulation of frequency and fine tuning of grid injection during sudden intermittencies.
- Smart scheduling of grid injection based on accurate forecasting and assessment of wind and solar.
- Optimal utilization of grid evacuation capacity.



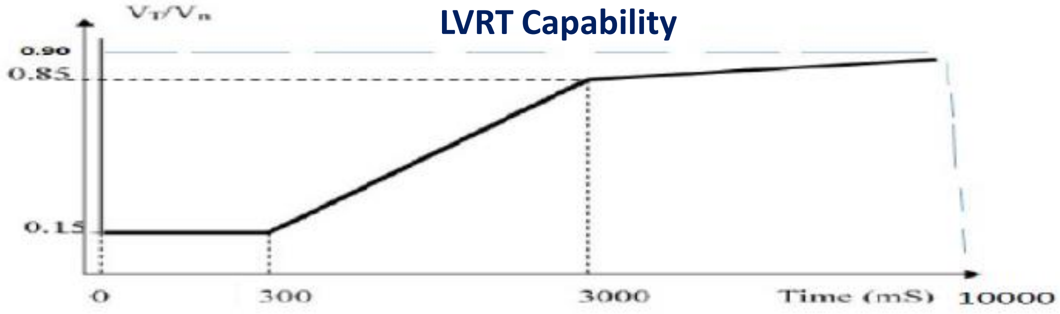
Application Range of Energy Storage System



Grid Code & Regulatory Requirements

- **Fault Ride Through (FRT) Capabilities**
  - Low Voltage Ride Through (LVRT)
  - High Voltage Ride Through (HVRT)
- **Reactive Power Compensation**
  - Reactive Power Support during LVRT & HVRT
  - Reactive Power Compensation at POC
- **Frequency Response**
  - Droop Response in line with the conventional governor system
  - Immediate active power response during df/dt
- **Ramp Rate**
  - Active Power output at rate < $\pm$ 10%

LVRT Capability



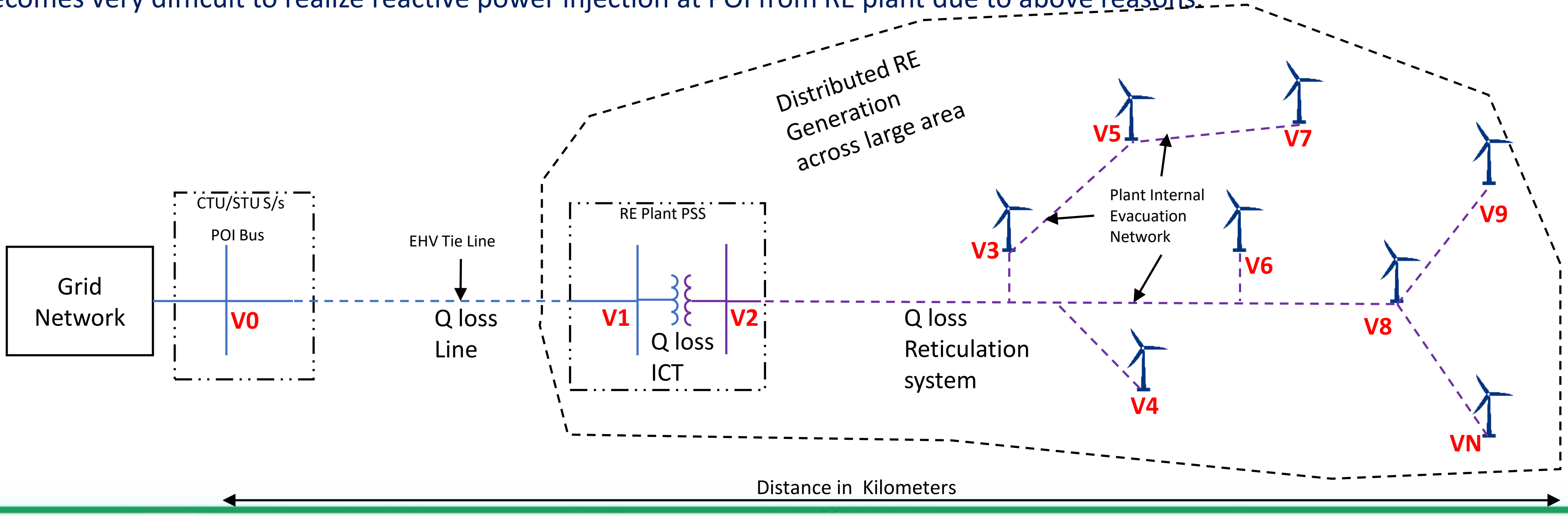
HVRT Capability

Over voltage (pu)	Minimum time to remain connected (Seconds)
1.30 < V	0 Sec (Instantaneous trip)
1.30 $\geq$ V > 1.20	0.2 Sec
1.20 $\geq$ V >1.10	2 Sec
V $\leq$ 1.10	Continuous

- LVRT & HVRT capability at POC is desired
- It is not possible to test these capabilities at POC
- Individual Inverter/WTG is tested at respective terminal

Reactive Power Capability of Renewable Plant

- Utility scale RE Generators such as Solar & Wind are current source generators and hence follow grid voltage. These Generators are having anti-islanding protection and hence can not generate power in absence of grid voltage.
- Q capability of these generator depends on grid voltage available at its terminal which would vary for each generator due to its distributed nature and internal reticulation system.
- Generators residing at tail end or far off from its substation bus and hence POI is very likely to face over voltage while trying to inject reactive power into the grid due to its reticulation system.
- Hence, this shall lead to compromise or limit Q injection capability from these generators.
- These generators are supposed to compensate for the Reactive Power loss in the plant reticulation system and ICTs. Over and above, it is expected to inject reactive power at POI as and when required.
- It becomes very difficult to realize reactive power injection at POI from RE plant due to above reasons.



Resolutions & Way Forward

- **Developing Digital Twin of RE plant**
  - Grid impact studies with actual grid conditions on account of integration of RE plant
  - Design and Planning of T&D infrastructure based on simulation results

- **Centralized Forecasting**
  - Greater consistency in results
  - Lower uncertainty

- **Demand Management**
  - Load management as per RE generation availability
  - Flexible Tariff by discoms for balancing of Generation Vs Load and encourage consumers to consumer energy during access RE generation and discourage them when scarcity of RE generation
  - Load side simulations

- **Ancillary Services**
  - Fast Frequency Response – Gas based power plants
  - Primary Frequency Response – Thermal & Hydro power plants
  - Load Shedding on Under Frequency
  - Contingency Reserves for generation Ramp up services

Thank You