Challenges in running the grid, Cases from the field – Addressing system challenges: Integration, synchronisation and cost

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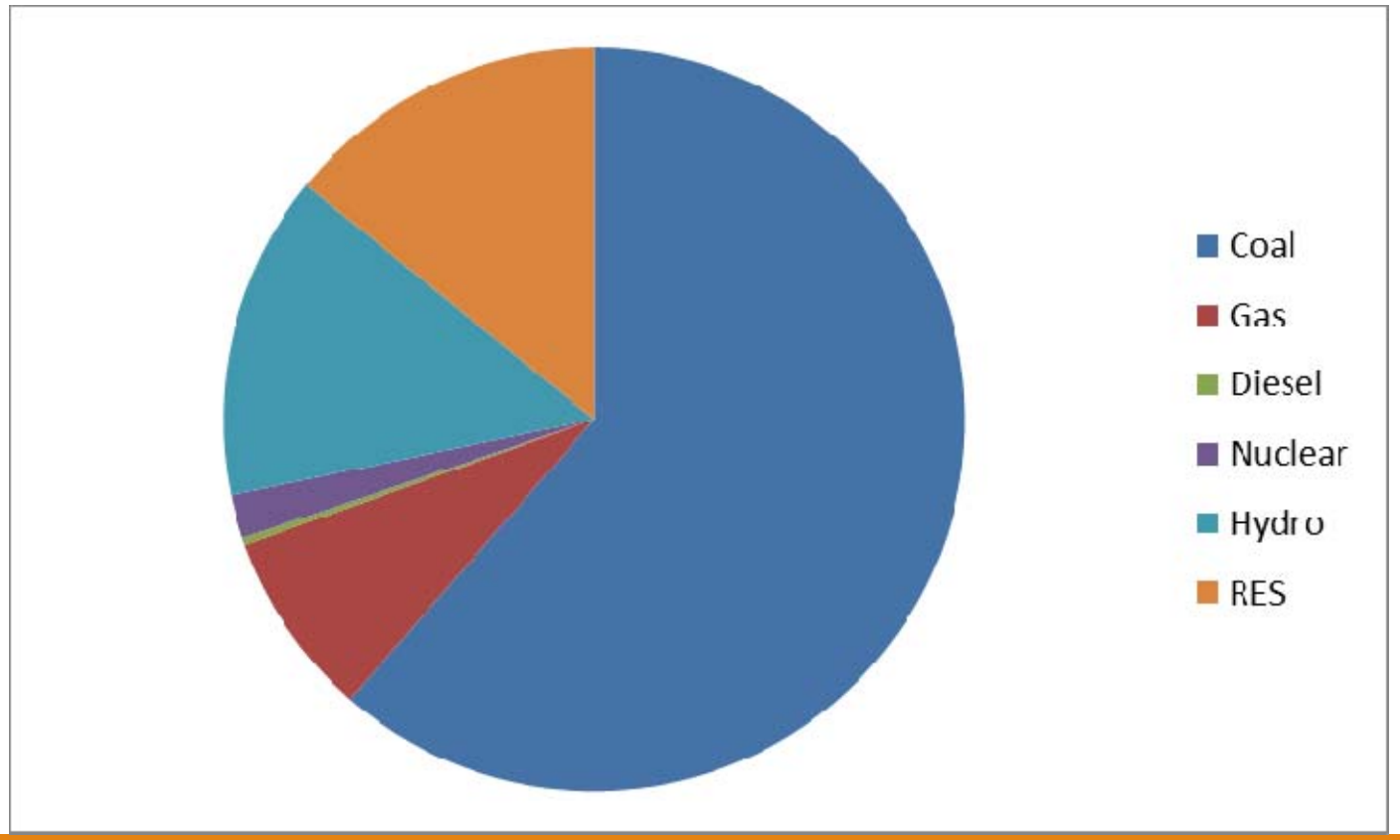
Break-up of generating capacity in India as on 30.6.2016 (in MW)

Coal	186213
Gas	24509
Diesel	919
Nuclear	5780
Hydro	42848
Renewable Energy Sources	42849
	303118

Break-up of generating capacity in India as on 30.6.2016 – Total capacity 303118 MW.



Target

1,75,000 MW from Renewable Sources of Energy by March 2022.

1,00,000 MW from Solar power

60,000 MW from Wind power

10,000 MW from bio-mass

5,000 MW from small hydro

Indian Electricity Grid Code

System operator (SLDC/ RLDC) shall make all efforts to evacuate the available solar and wind power and treat as a **must-run station**.

However, System operator may instruct **the solar /wind generator to back down generation on consideration of grid security or safety** of any equipment or personnel is endangered and Solar/ wind generator shall comply with the same.

For this, **Data Acquisition System facility shall be provided** for transfer of information to concerned SLDC and RLDC

SLDC/RLDC may direct a wind farm to **curtail its VAr drawl/injection in case the security of grid or safety of any equipment** or personnel is endangered.

During the wind generator start-up, the wind generator shall ensure that the reactive power drawl (inrush currents incase of induction generators) shall not affect the grid performance.

Forecasting and scheduling mandated.

Standards for Connectivity of Renewables

Central Electricity Authority (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013.

(for Connectivity below 33 kV)

Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2013.

(for Connectivity at 33 kV and above)

CERC (Deviation Settlement Mechanism and related matters) (Second Amendment) Regulations, 2015

Notified on 7 th August, 2015.

Effect from 1 st November, 2015.

“**Absolute Error**” shall mean the absolute value of the error in the actual generation of wind or solar generators which are regional entities with reference to the scheduled generation and the **'Available Capacity**' (AvC), as calculated using the following formula for each 15 minute time block: Error (%) = **100 X [Actual Generation– Scheduled Generation] / (AvC)**

Table – I: Deviation Charges in case of under injection

Sr. No.	Absolute Error in the 15-minute time block	Deviation Charges payable to Regional DSM Pool
1	<= 15%	At the Fixed Rate for the shortfall energy for absolute error upto 15%
2	>15% but <= 25%	At the Fixed Rate for the shortfall energy for absolute error upto 15% + 110% of the Fixed Rate for balance energy beyond 15% and upto 25%
3	>25% but <=35%	At the Fixed Rate for the shortfall energy for absolute error upto 15% + 110% of the Fixed Rate for balance energy beyond 15% and upto 25% + 120% of the Fixed Rate for balance energy beyond 25% and upto 35%
4	> 35%	At the Fixed Rate for the shortfall energy for absolute error upto 15% + 110% of the Fixed Rate for balance energy beyond 15% and upto 25% + 120% of the Fixed Rate for balance energy beyond 25% and upto 35% + 130% of the Fixed Rate for balance energy beyond 35%

Table – II: Deviation Charges in case of over injection

Sr. No.	Absolute Error in the 15-minute time block	Deviation Charges payable
1	<= 15%	At the Fixed Rate for excess energy upto 15%
2	>15% but <= 25%	At the Fixed Rate for excess energy upto 15% + 90% of the Fixed Rate for excess energy beyond 15% and upto 25%
3	>25% but <=35%	At the Fixed Rate for excess energy upto 15% + 90% of the Fixed Rate for excess energy beyond 15% and upto 25% + 80% of the Fixed Rate for excess energy beyond 25% and upto 35%
4	> 35%	At the Fixed Rate for excess energy upto 15% + 90% of the Fixed Rate for excess energy beyond 15% and upto 25% + 80% of the Fixed Rate for excess energy beyond 25% and upto 35% + 70% of the Fixed Rate for excess energy beyond 35%

CERC(Deviation Settlement Mechanism and related matters)(Third Amendment) Regulations, 2016

Renewable Rich State means a State whose minimum combined installed capacity of wind and solar power is 1000 MW or more.

Special Dispensation for Renewable Rich States

Deviation Limits for Renewable Rich States

S.No	States having combined installed capacity of Wind and Solar projects	Deviation Limits (MW)- "L"
1	1000– 3000 MW	200
2	> 3000 MW	250

BASICS OF POWER SYSTEM OPERATION

Electricity is a commodity

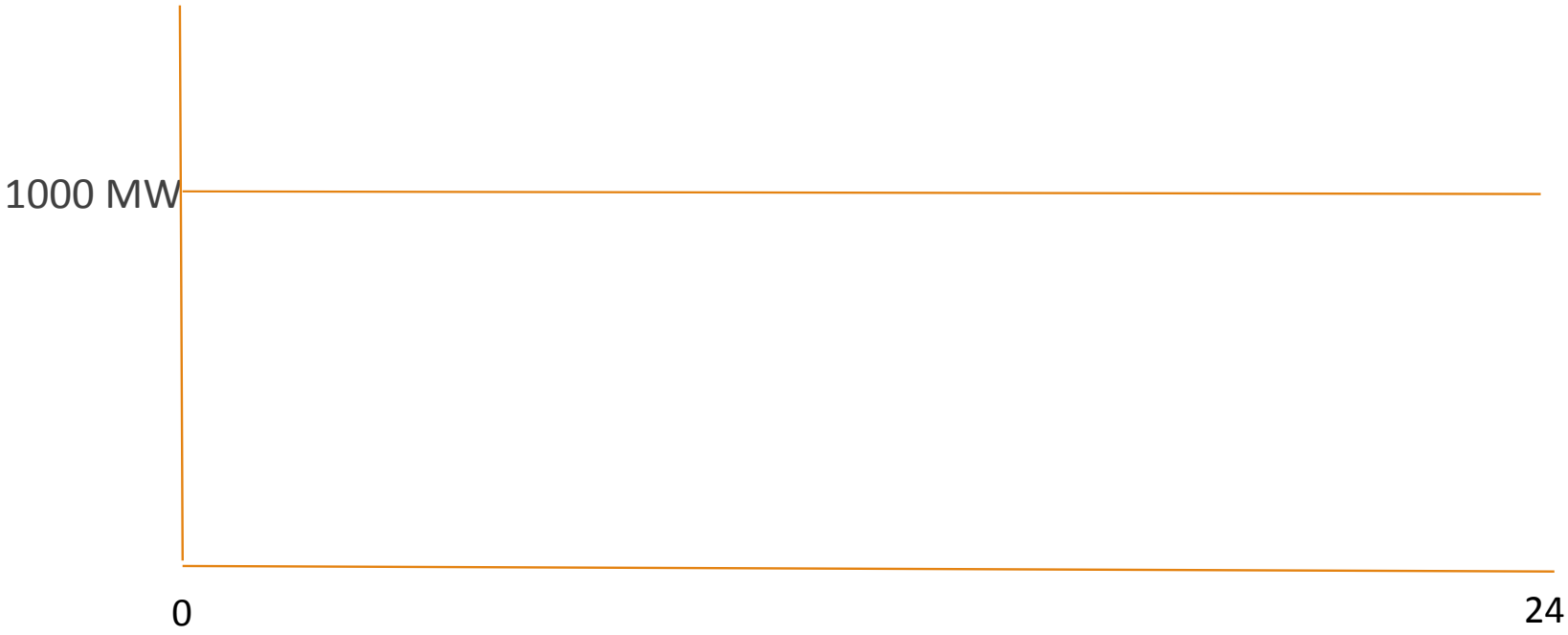
- Consumed at the instant of generation.
- Cannot be stored to a large extent.
- Therefore, power system operation is carried out in a **planned way** on day-ahead basis, through estimation of electric generation availability and electricity demand.

Parameters to be kept a watch on :

- Frequency
- Voltage
- Line loading
- Angular stability

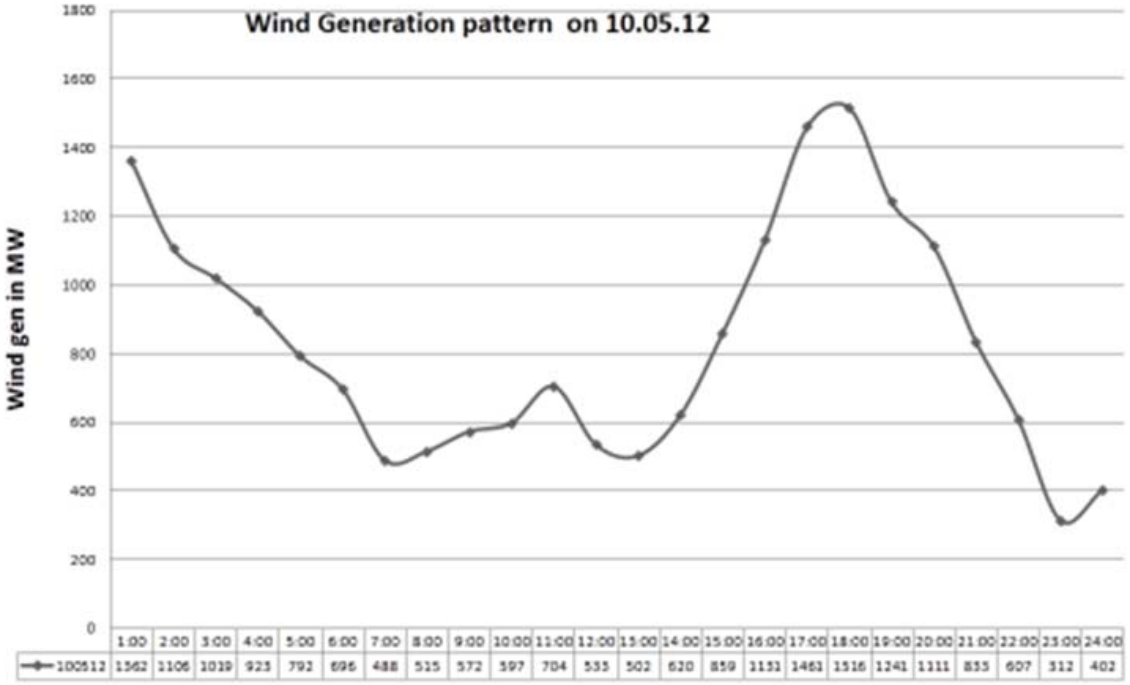
Coal-based thermal power plant

Generation from a coal-based thermal power plant

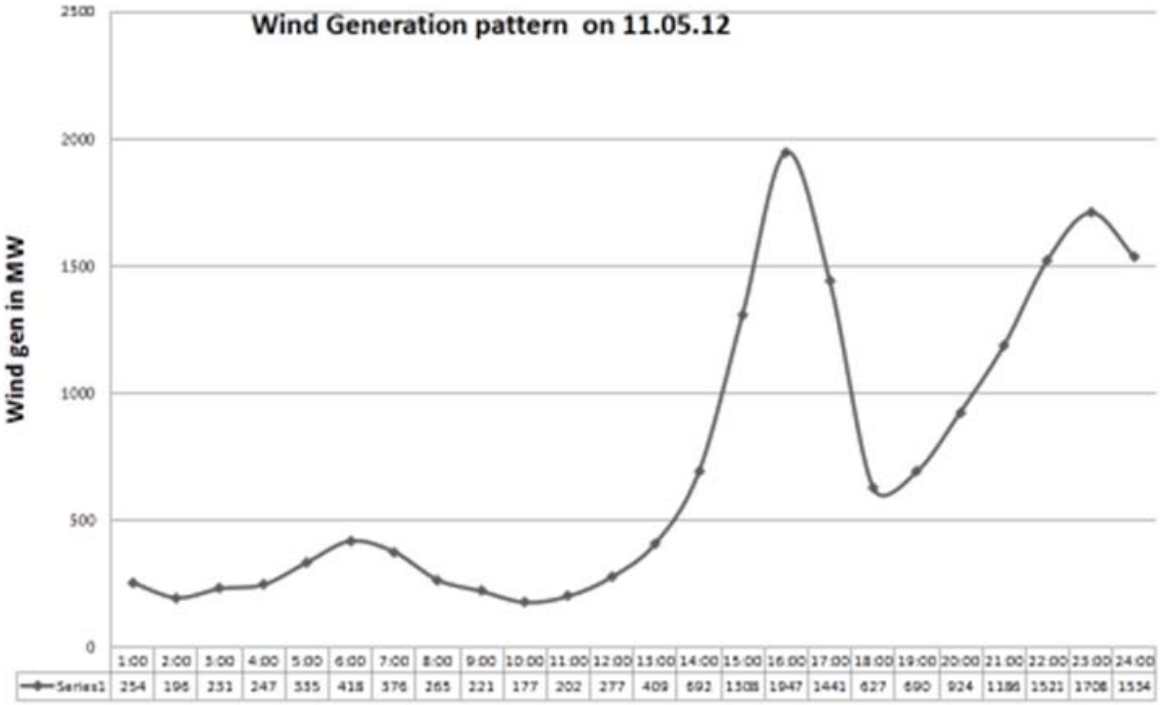


Wind Farm in Tamil Nadu

Wind generation on consecutive days



Wind generation on consecutive days

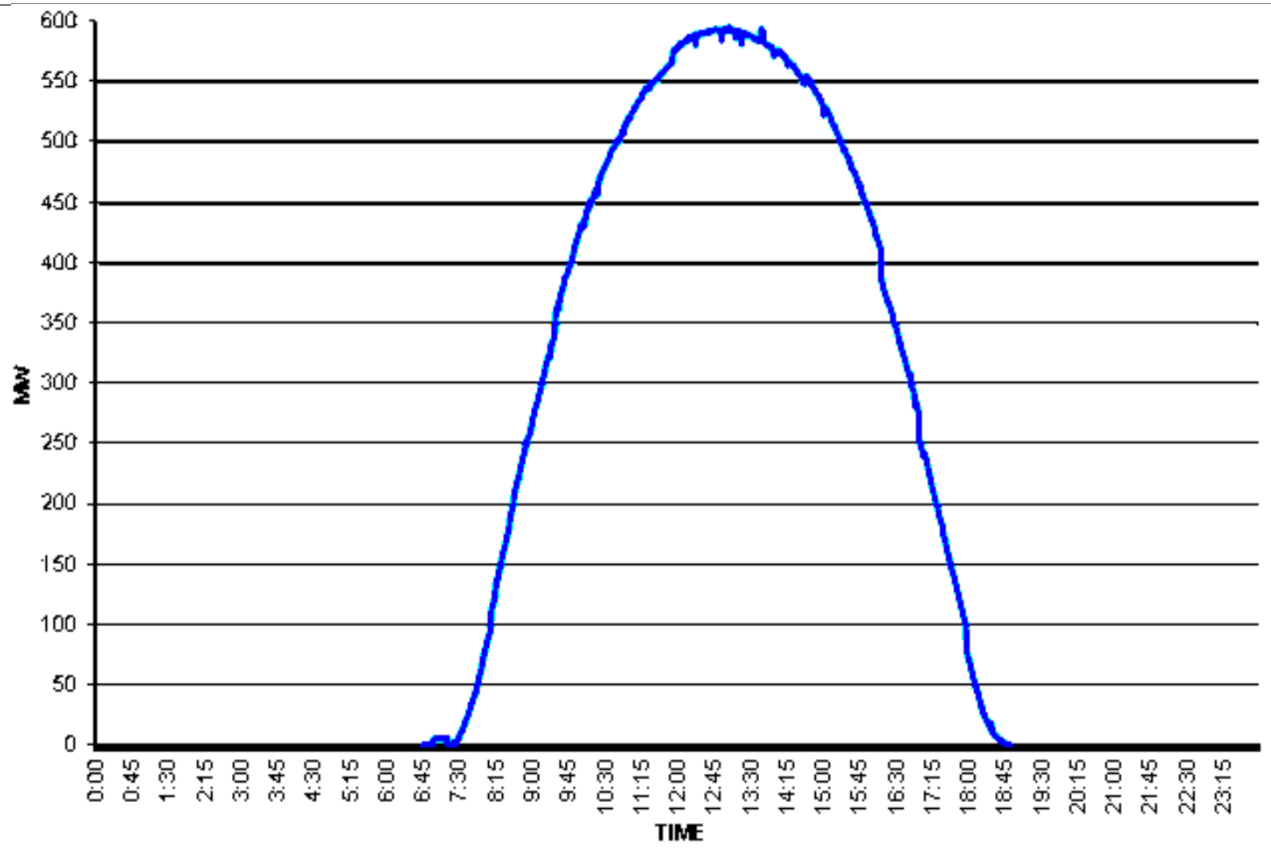


Number of days in the year (2012) for range of variation of wind generation over a day

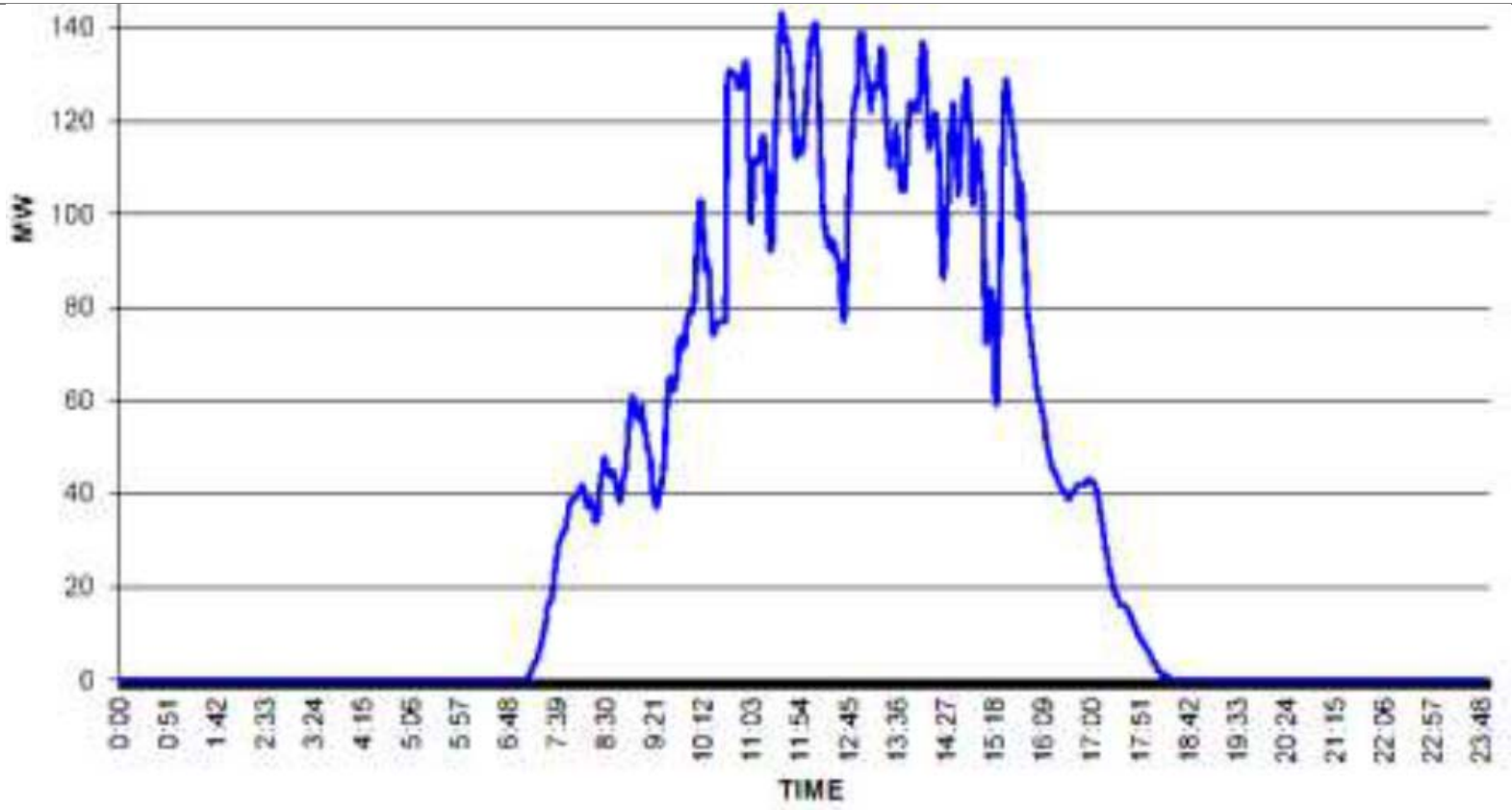
States	Variation Band (MW)	Days
Gujarat	> 500 &<1000	243
	> 1000 &< 1500	55
	1547	1
Tamil Nadu	> 500 &<1500	175
	>1500 & <3000	84
	>3000	2
	3385	1
Rajasthan	>500 & <1000	154
	>1000	11
	1164	1

Solar park

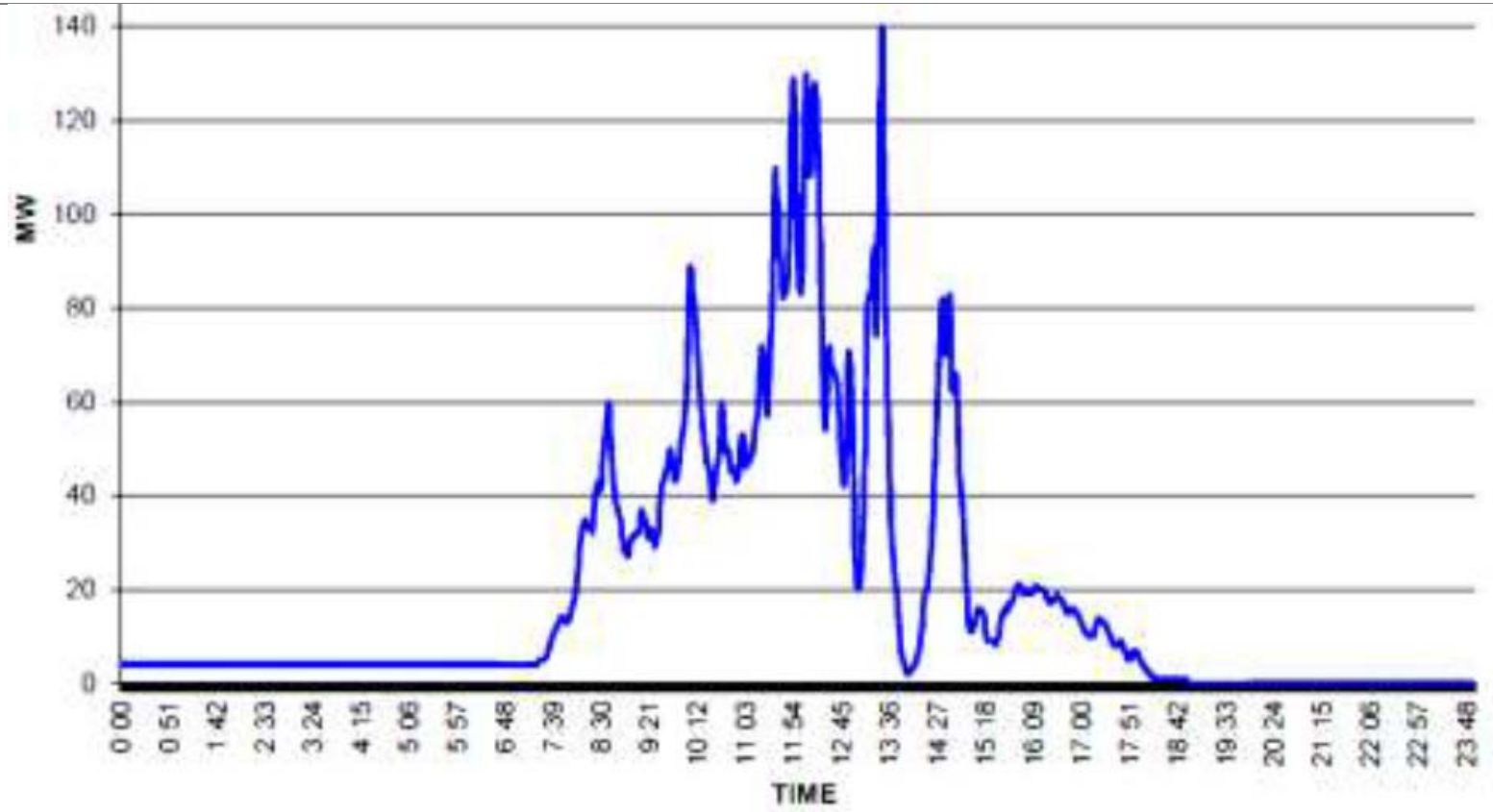
Typical solar generation over a day in Gujarat for a non-cloudy day



Solar generation on a cloudy day 1-9-2012 in the **Charanka Solar Park** Gujarat (capacity of about 200 MW)



Solar generation on a cloudy day 9-9-2012 in the Charanka Solar Park Gujarat



Issues and Challenges in Grid Operation

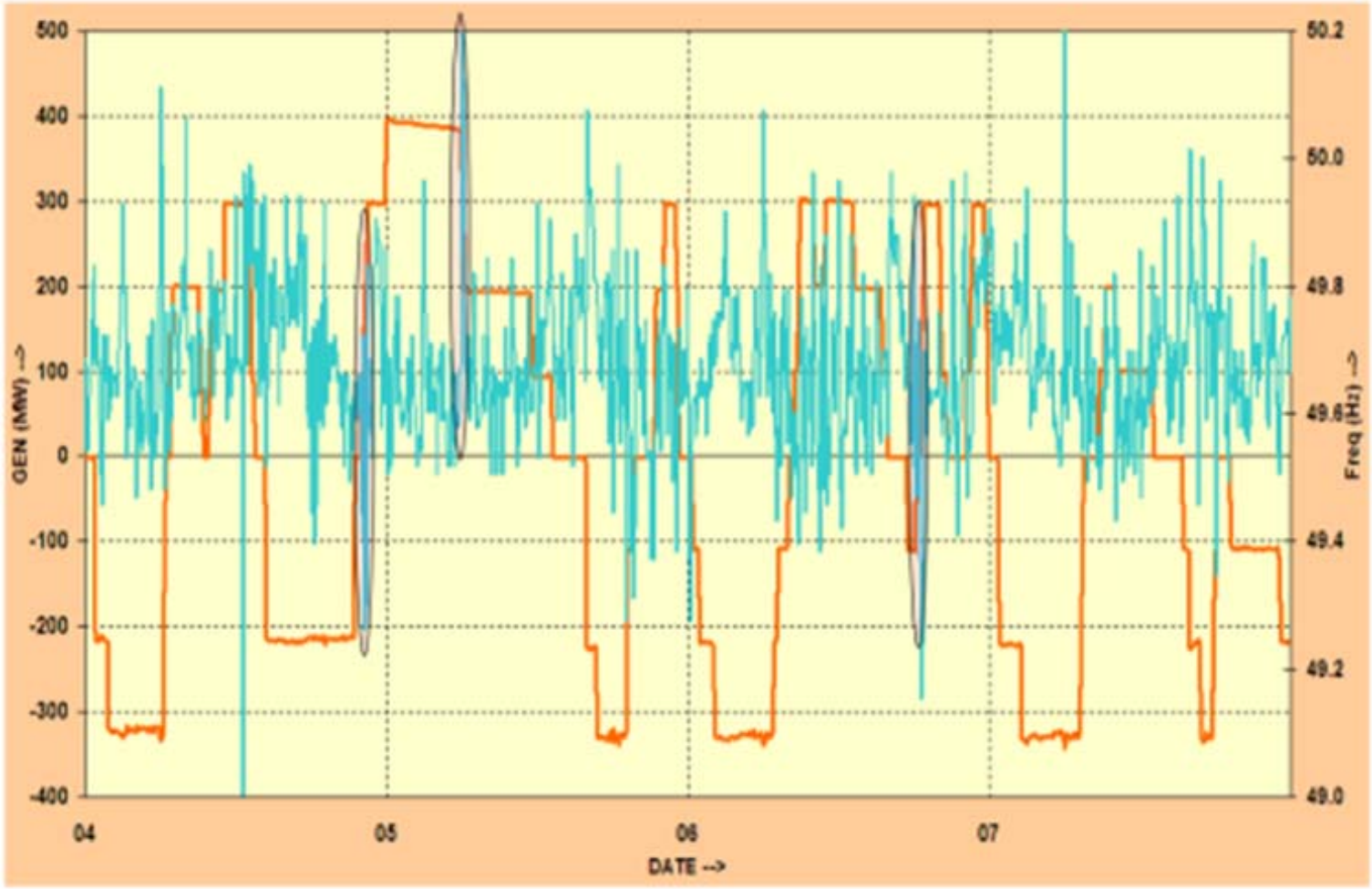
- Frequency Stability
- Voltage Stability
- Transmission congestion
- Angular Stability

Solutions – Frequency Stability

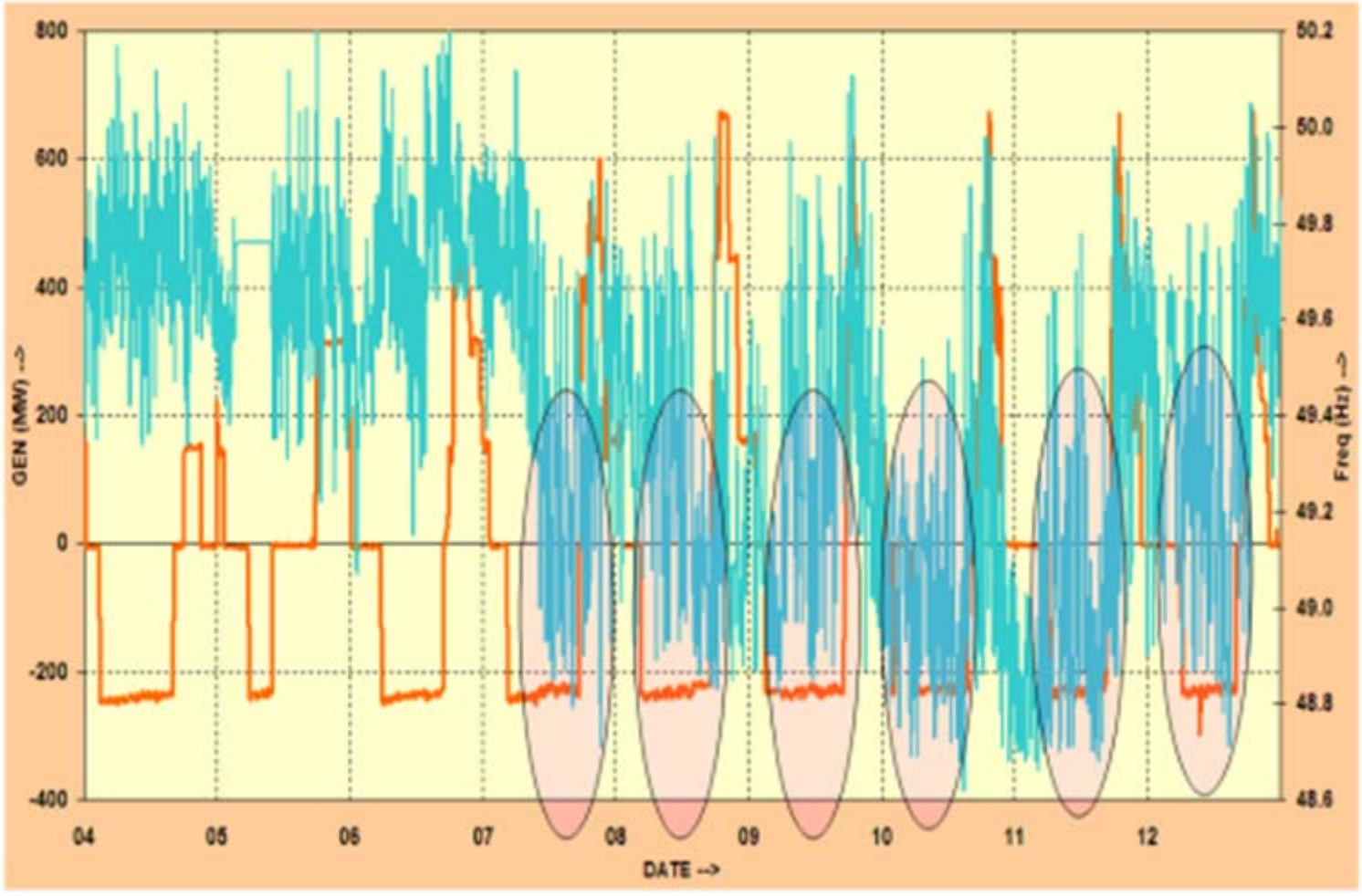
Intermittency of power to be balanced by **quick acting generation** like **hydro** (storage, pondage or pumped-storage storage) and **gas based generating stations.**

Future balancing sources, like MW scale batteries, Compressed Air Energy Storage (CAES), flywheel, thermal storage, etc.

OPERATION OF PUMP STORAGE PLANT wrt FREQUENCY AT KADAMPARAI



OPERATION OF PUMP STORAGE PLANT wrto FREQUENCY AT PURULIA PS

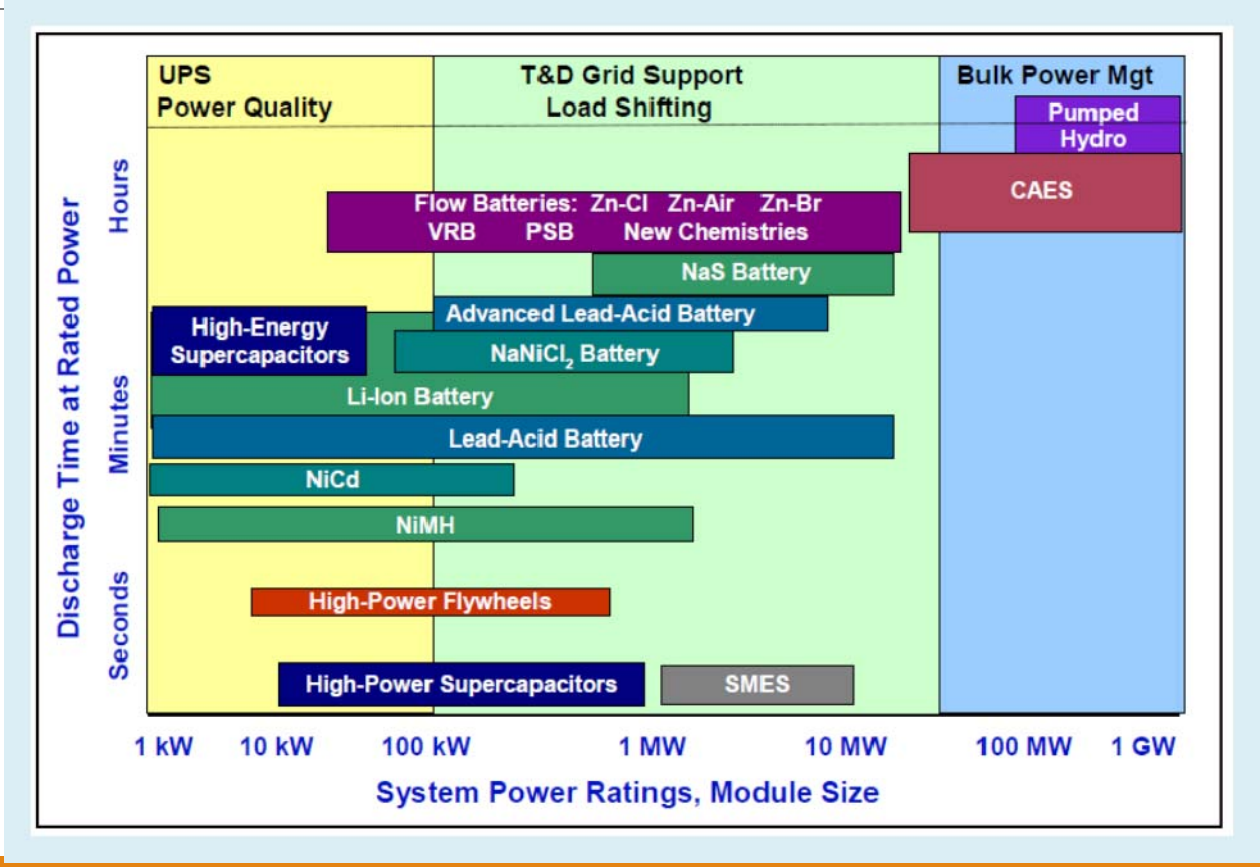


Frequency Stability measures

Pumped storage plants, batteries, CAES, flywheel are all plants that have a double benefit of absorbing excess power and releasing the same when needed.

Preferable to have the balancing sources close to the wind and solar generation for optimum utilisation of the intermittent generation and the transmission system.

Available energy storage technologies (Power vs Discharge Duration) (Source: EPRI / DOE Energy Storage Handbook)



Economics of Energy Storage

While deciding economics of energy storage for renewable integration, a number of key factors need to be considered. These include

- Size of storage (Power vs energy)
- Cycle life
- Depth of Discharge during each cycle (has impact on number of cycles for most electro chemical batteries)
- Charge / Discharge rate (C rate)
- Space and geographical requirements (specially required for pumped hydro and CAES projects)

Demand Response

- One of the biggest sources of balancing the intermittency, which is being increasingly used in developed countries, is ***demand response***.
- Immediately available
- Rules and Smart Meters need to be put into place
- Essential and non-essential loads accompanied with 24x7 and Interruptible tariff

Voltage Stability

Fluctuating wind and solar generation causes variation in reactive power exchange of the wind and solar generators with the grid, and, therefore, the fluctuations of voltage in the grid.

Mitigation measures of the effects of the multiple start-ups include provision of **dynamic reactive power compensation i.e. SVC (Static VAR compensators)/ STATCOM (Static Synchronous Compensator).**

Most of the advanced energy storage systems can also provide reactive power support without need for consuming active energy.

Locational requirement for reactive power could help in determining appropriate location for deploying energy storage systems that can provide multiple value propositions to the grid.

Transmission congestion

Flexible AC Transmission System (FACTS) devices like phase shifting transformers should be installed to shift power from heavily loaded lines to lightly loaded lines in parallel paths.

Strategically placed energy storage devices can also help in relieving transmission congestion by time shifting the flow of energy across constrained paths

Alternately, In order to harness the huge potential of RES in specific States, **high capacity Inter-State and Inter-Regional corridors transmission corridors could be constructed linking high concentration renewable generation areas to balancing generation already located elsewhere in the grid. Market Integration** would have to be provisioned.

Angular Stability

Various type of FACTS devices, which would need to change dynamically, to change the power system parameters in accordance with changing topology of intermittent generation from renewable energy sources, may need to be installed.

System Operator should be aided in this by Phasor Measurement Units (PMUs) installed at critical points in the grid, for visibility in the grid w.r.t. real-time angular difference.

Other Issues

Wind forecasting and Renewable Energy Management Centres

Immediate planning of associated Transmission System

Creation of real-time power markets

Encouragement of Distributed Generation

Regulations for Operation

Forecasting.

Balancing.

Rules of Operation – Virtual inertia, Protection, voltage control, LVRT, etc.

Thank You