SMART GRID SYSTEMS

PE/PE/HT/324C

Professional Elective Course

Integrating Renewable Energy Sources to Smart Grid

- Renewables. What it is and its different types
- Status on how far renewables are being used- Global and India
- Major components of smart grids vis-à-vis renewable energy
- The integration of RES in SG process
- Challenges in the integration process
- Addressing those challenges
- RE integration status in India

What is Renewable Energy?

- Renewable energy, also called clean energy, is energy derived from renewable sources of energy.

- Renewable energy sources are those which are replenished by nature on a human timescale.

These include:

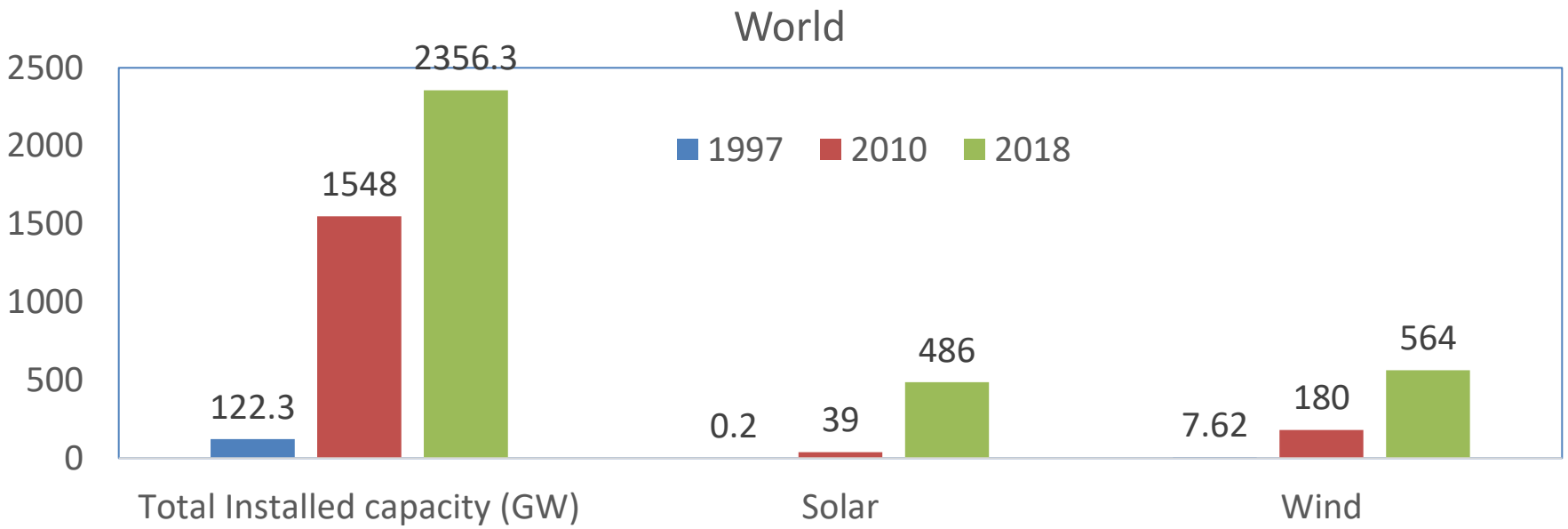
- Wind
- Solar
- Hydel
- Geo-thermal
- Tidal
- Biomass

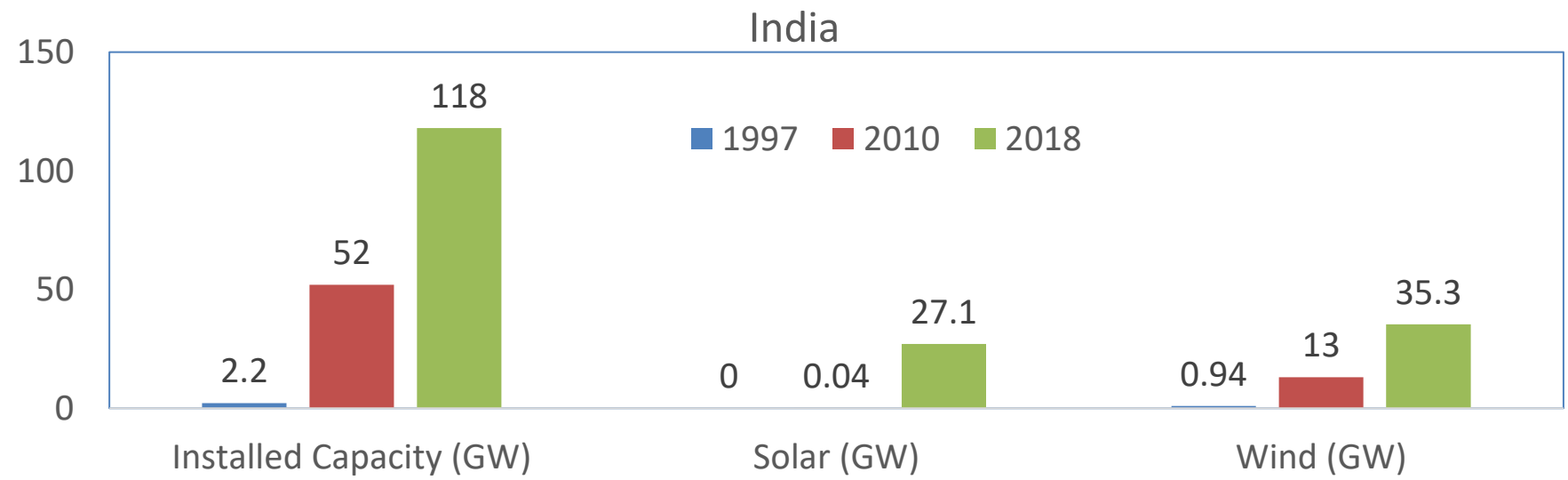
…. and more





Renewable Energy Growth





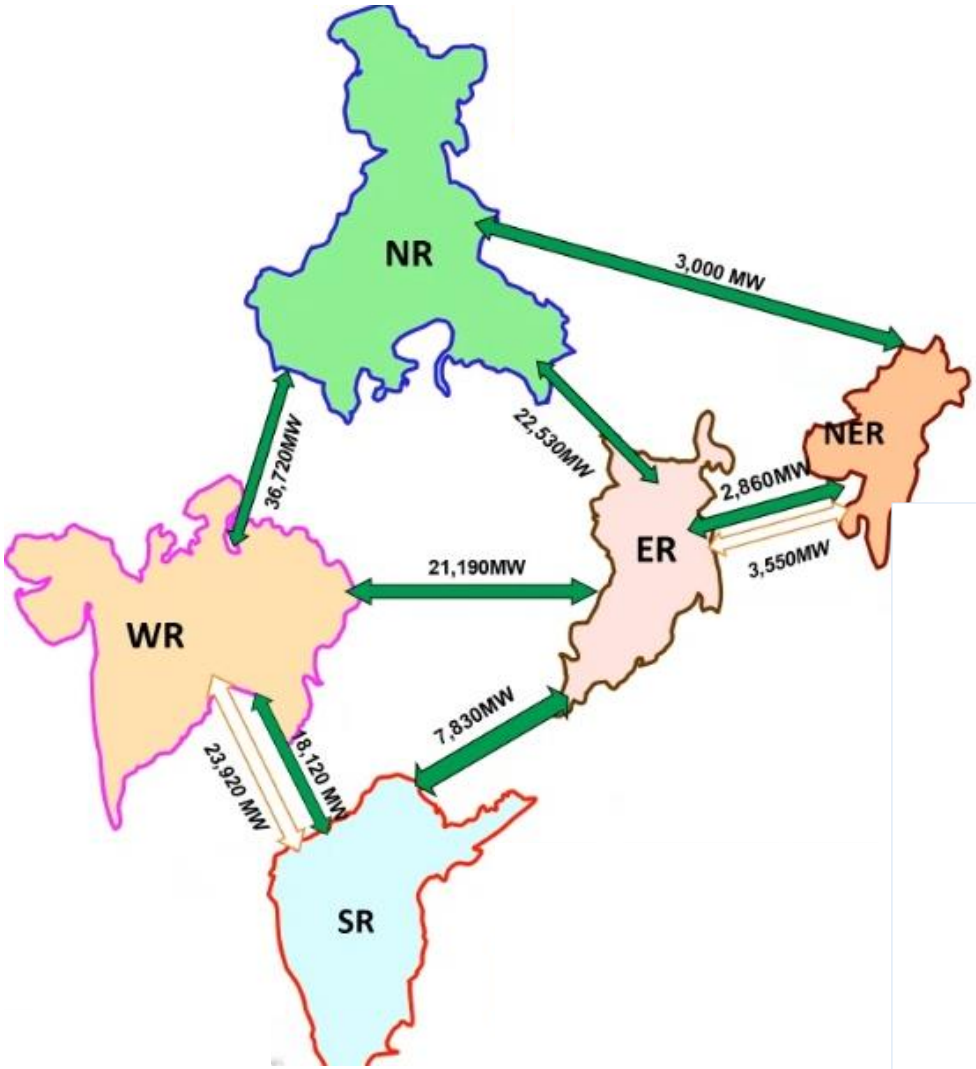
State-wise Renewable generation 2022

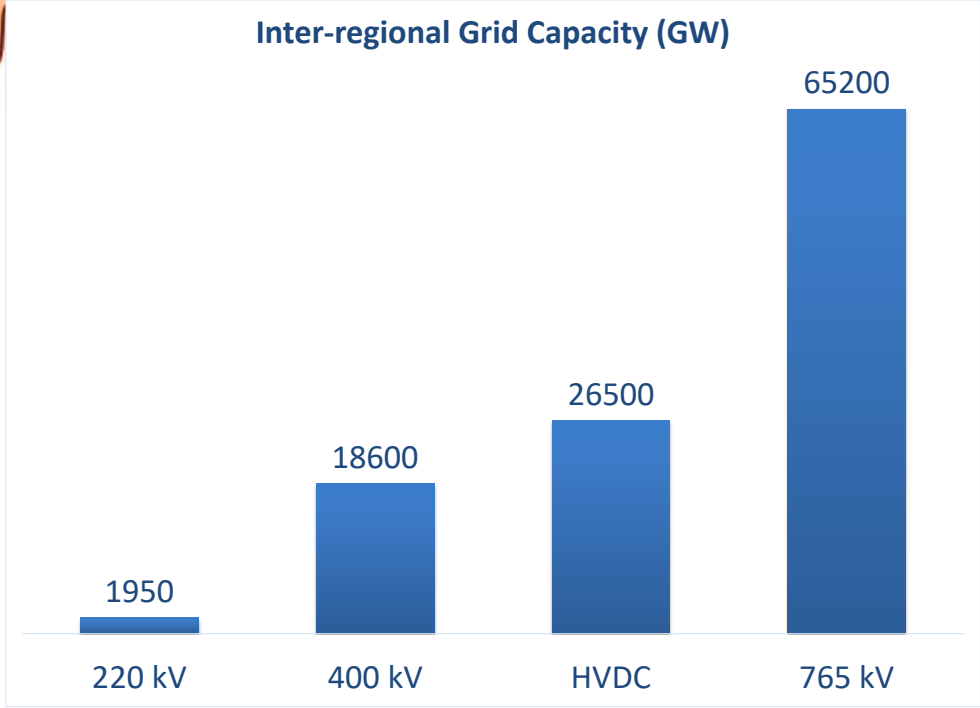
State	Solar (MW)	Wind (MW)	SHP (MW)	Bio-mass (MW)
Delhi	2762			
Haryana	4142		25	209
Himachal Pr	776		1500	
Punjab	4772		50	244
Rajasthan				
UP				
Uttarakhand				
Gujarat				
Maharashtra				

State-wise Renewable generation 2022

State	Solar (MW)	Wind (MW)	SHP (MW)	Bio-mass (MW)
Andhra Pr	9834	8100		543
Karnataka	5697	6200	1500	1420
Tamilnadu				
Bihar				
WB				
North east	1205		615	

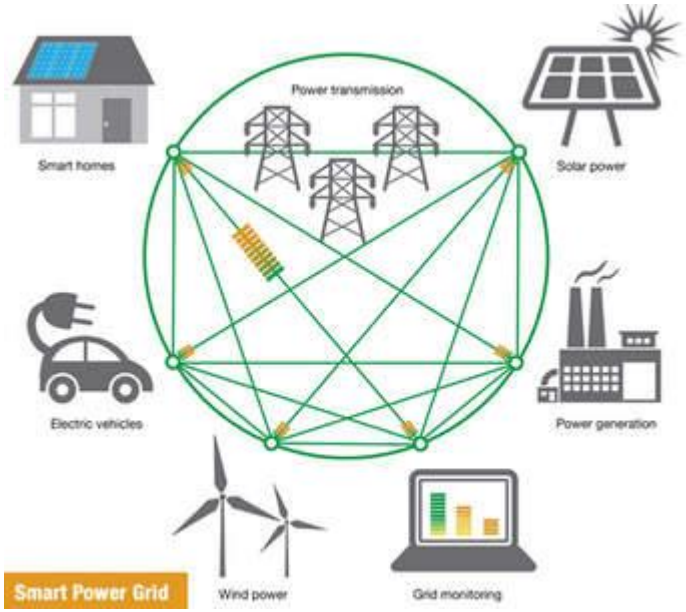
Indian National Power Grid





Integration of RE in SG. How and why

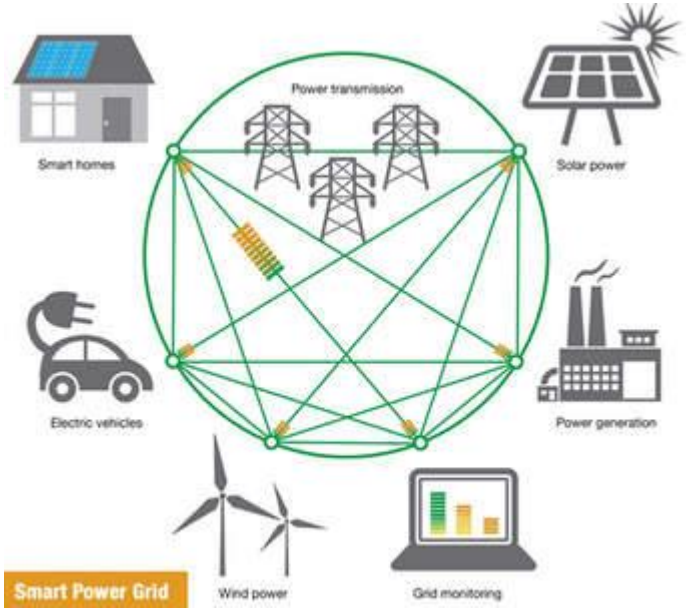
- RE can be introduced at various levels into the grid:
  - Large scale generating stations
  - Industries can be motivated start generating electrical energy through renewable energy sources by installing solar panels, windmills, etc. while remaining connected to the grid.
  - Domestic consumers with RE generation modules can also generate power for their own consumption while staying connected to the grid for balancing if generation is inadequate or surplus.



Integration of RE in SG. How and why

- Fluctuations and intermittency, two major issues of RE sources like solar or wind, can be more effectively dealt with if it is connected to the smart grid

- Stand alone RE generation will be more expensive, but integrating it to the grid will help ease the transition and may reduce the initial installation cost especially at domestic levels as certain features like storages will not be absolutely necessary.

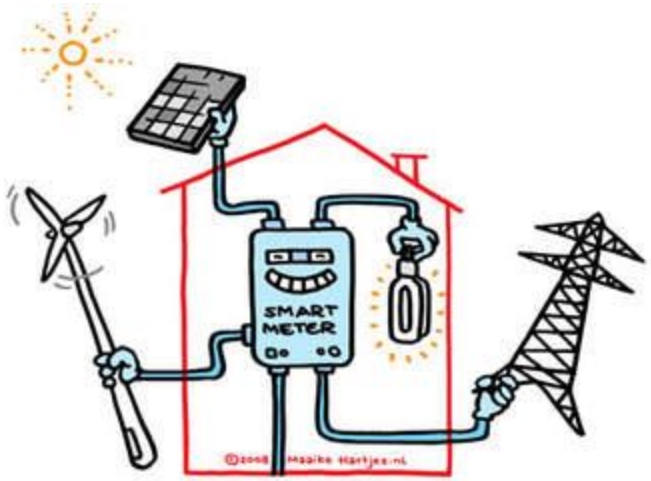


Interdependence of renewable energy and smart grids

- Smart grids are bi-directional not only in terms of information, but also for power
  - This calls for distributed generation, which is only plausible with renewable energy sources like wind or solar which can even be privately owned and operated on small or large scales.
- A major issue with renewable sources like solar or wind is the fluctuations and intermittent nature
  - This necessitates the effective use of control techniques, better distribution automation, demand response and better forecasting, all of which require smart grid.

Interdependence of renewable energy and smart grids

- With distributed generation and more consumers using renewable energy sources like solar panels, comes the need for smart metering systems, which is a feature of smart grids.
- Smart grid opens the door to electric vehicles
  - Use of either plug-in hybrid electric vehicles or fully electric vehicles using concepts like V2G or G2V implies replacing petroleum based fuels with electricity, which if produced from renewable sources is a huge stride for renewable energy.



Major components of smart grids vis-à-vis renewable energy

- Power electronic devices
  - Smart inverters can provide specific functions that can help to accommodate renewable energy sources:
    - volt-VAR control
    - voltage and frequency event ride-through
  - Improved and efficient converter topologies

- Advanced interfacing and control modules
  - PV voltage levels are fluctuating in nature due to solar radiation variations; so effective interfacing modules are required for connecting to the grid
  - Wind speeds are constantly changing and to maintain the output voltage and of a wind turbine and generator constant, power electronic control mechanisms are essential.

Challenges

- There are various difficulties and challenges in the process of integrating RE into the smart grid. They can be briefly classified under the following headings:
  - Technical
  - Economic
  - Societal
  - Other

❖ Technical Challenges:

- **Interfacing**: Most RE sources like wind and solar energy cannot be directly connected to the grid. Various interfacing topologies and power electronic components are required to maintain constant voltage, frequency and other parameters to ensure a stable connection with the grid.

- **Planning and risk management**: Introducing RE brings a host of new devices, often non linear devices and interfacing and control modules and topologies into the system, which might effect the power quality, system stability and efficiency unless carefully planned and compensated for, wherever needed.

❖ Technical Challenges:

- **Generation prediction**: RE sources are often fluctuating and variable so accurate generation prediction will help make the process more feasible, the operation of these units easier and the grid better balanced.

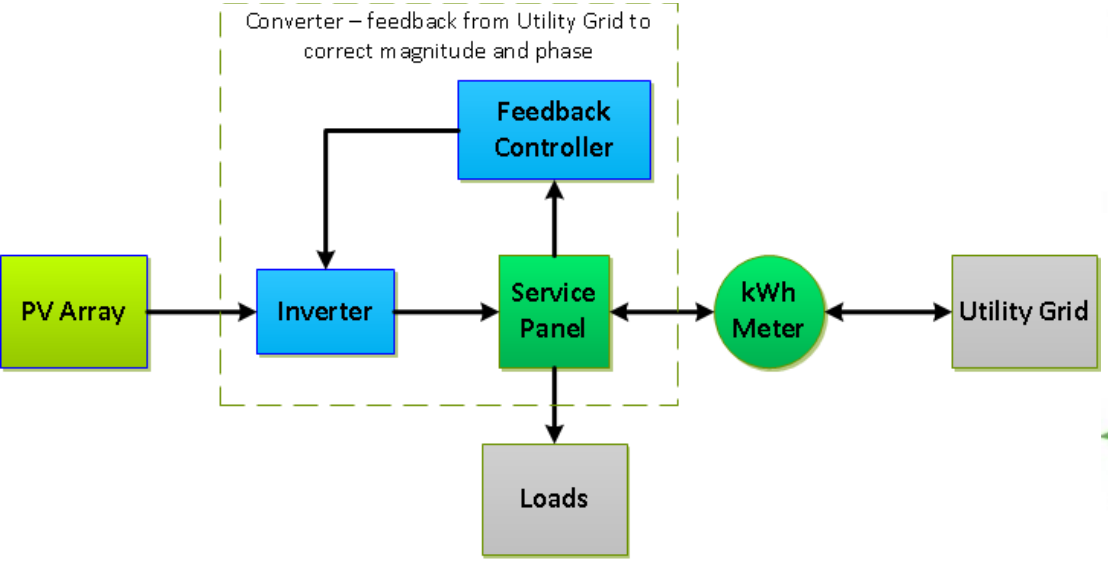
- **Energy Storage**: Storage systems along with power electronics need to be incorporated in energy system due to intermittent behavior
- Currently, available energy storage options are either low on efficiency or too expensive
- Improved storage solutions will facilitate the integration of RE into the grid.

❖ Technical Challenges:

- **Reliability and Security**: RE sources being variable and intermittent, their constant availability and dependency is questionable
- In such a situation, keeping the grid balanced and ensuring continuous and adequate supply of power becomes a challenge.

- **Accurate metering**: With distributed generation coming into the picture, it is necessary that production and consumption are properly monitored and billed fairly
- This mandates the need of smart meters which can ensure accurate billing and constantly monitor the production and consumption to ensure grid balancing and flexibility.

❖ Possible solutions

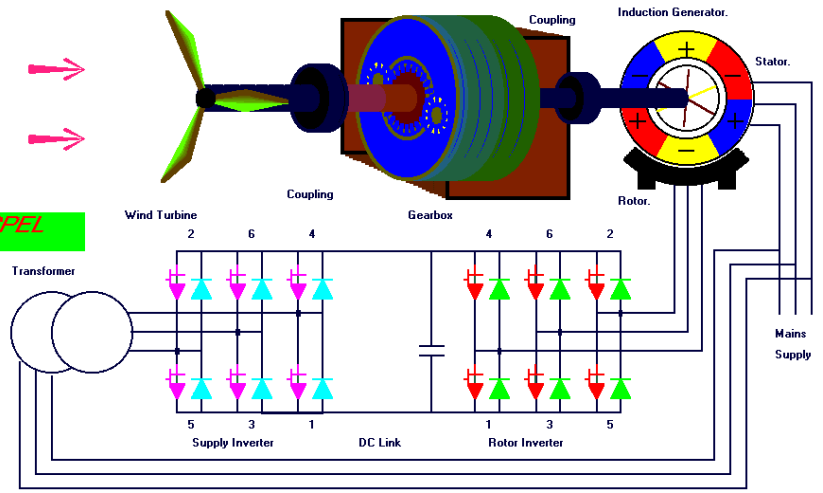


➢ Typical interfacing devices can be:

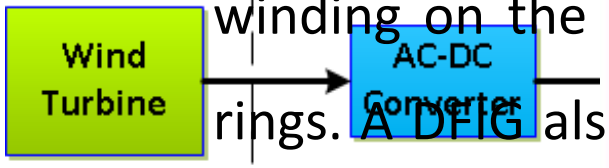
- **single stage** – one dc/ac power inverter which handles the MPPT control and the voltage and current control loops.
- **two stage** – the PV array is connected to a dc/dc chopper first which handles the MPPT control and then to a dc/ac inverter which handles the voltage and current control loops.
- **multi stage** – Each string of PV modules of the array is connected to individual dc/dc choppers whose outputs are fed to the dc bus of the inverter.

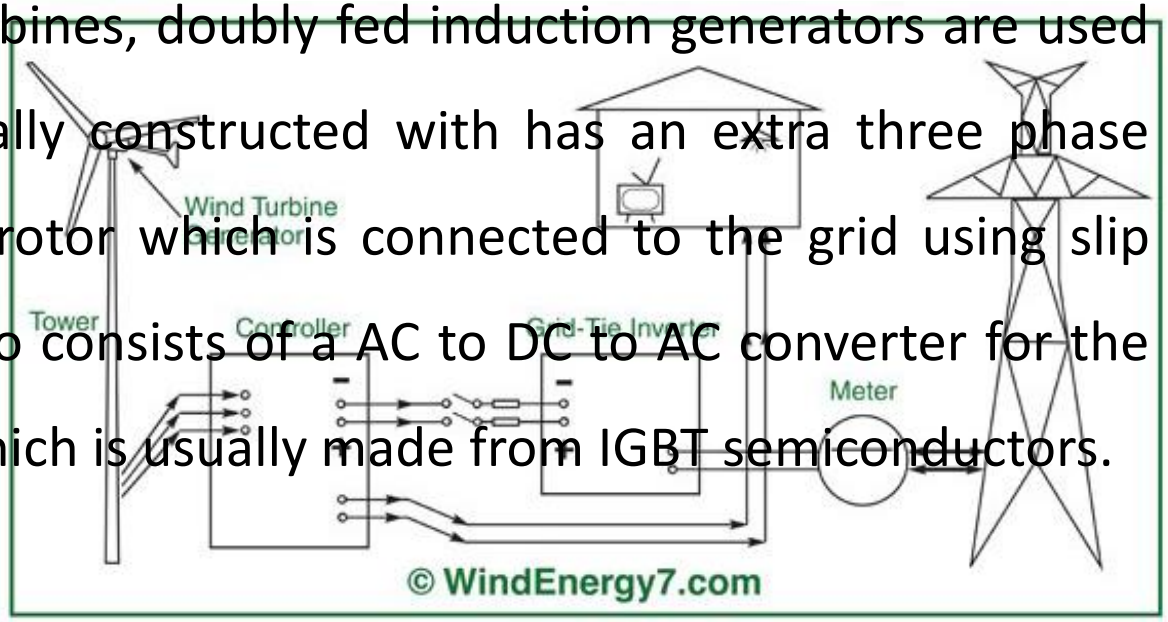
❖ Interfacing Wind turbine with smart grid

- Wind speeds are constantly fluctuating, so rotor speed and thus the mechanical frequency of t



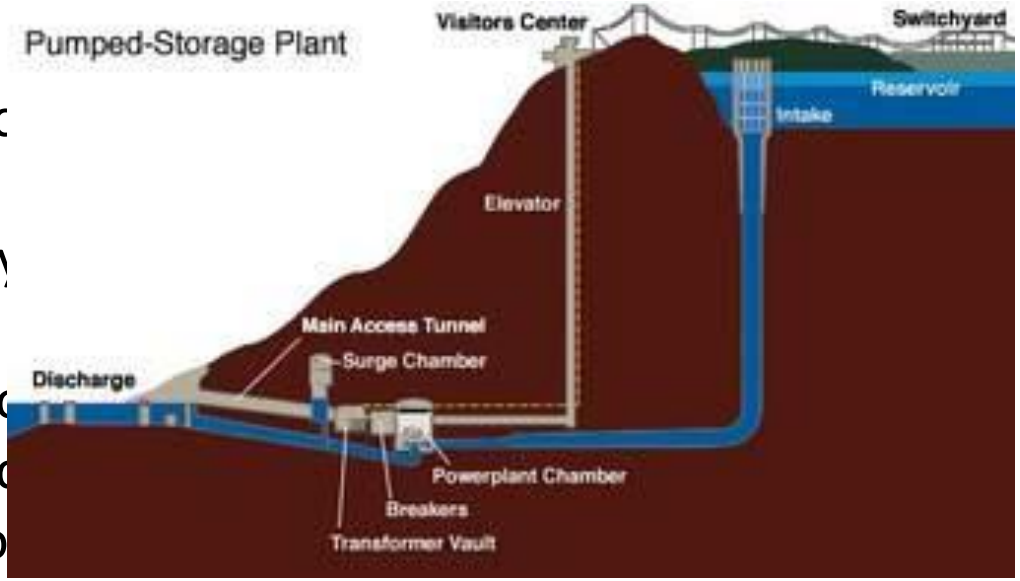
  - To overcome this, for sm generation, an induction ge converted to dc using an ac desirable voltage and freque
  - In large wind turbines, doubly fed induction generators are used which are specially constructed with has an extra three phase winding on the rotor which is connected to the grid using slip rings. A DFIG also consists of a AC to DC to AC converter for the inner winding which is usually made from IGBT semiconductors.





Converter – Isolation
electrical fre

❖ Energy storage systems



- Most renewable energy sourc
  intermittent in nature, but the
- To maintain continuous supply
  are crucial
- These also mitigate the need fo
  number of power failures to a c
- Storage can either be bulk o
  preferred.
- Types of energy storages possible
  - Electro-chemical
    - Battery storage systems (Sodium-Sulphur, Lead-acid, Ni-Cd, Lithium-ion)
    - Hydrogen fuel cells
  - Electromagnetic
    - Superconducting magnetic energy
    - Super capacitors (SC)
  - Mechanical
    - Compressed air energy storage (C
    - Pumped hydroelectric storage (PH
    - Flywheel

❖More technical challenges

❖ Renewable Resource Forecasting

- One- to two-day-ahead predictions using numerical weather prediction (NWP) models. Geographical and topological data can be incorporated in NWP modeling to reduce error.
- One- to six-hour-ahead predictions, also called nowcasting, are made using statistical models that forecast future weather based on real-time local condition

❖ Smart metering systems

- Smart meters are crucial for making the grid bi-directional. A conventional meter only displays, but a smart meter communicates with the grid.
- Smart meters can measure renewable resource output, for compensation, control, and planning.
- Smart meters may collect data on power quality, power outages, power factor, reactive power usage, and grid voltage and frequency.
- This data can be used for improving renewable resource forecasting, better distribution of generation, better demand response

❖ Prevention of cyber threats

Installed grid-connected renewable capacity (2020) India

Source	Installed capacity (MW)
Wind	37,693
Solar – Ground mounted	32,112
Solar – roof top	2,515
Small hydro power	4,683
Biomass and waste-to-energy	10,022
Total	**87,027**

Renewable Energy management Centre (REMC)

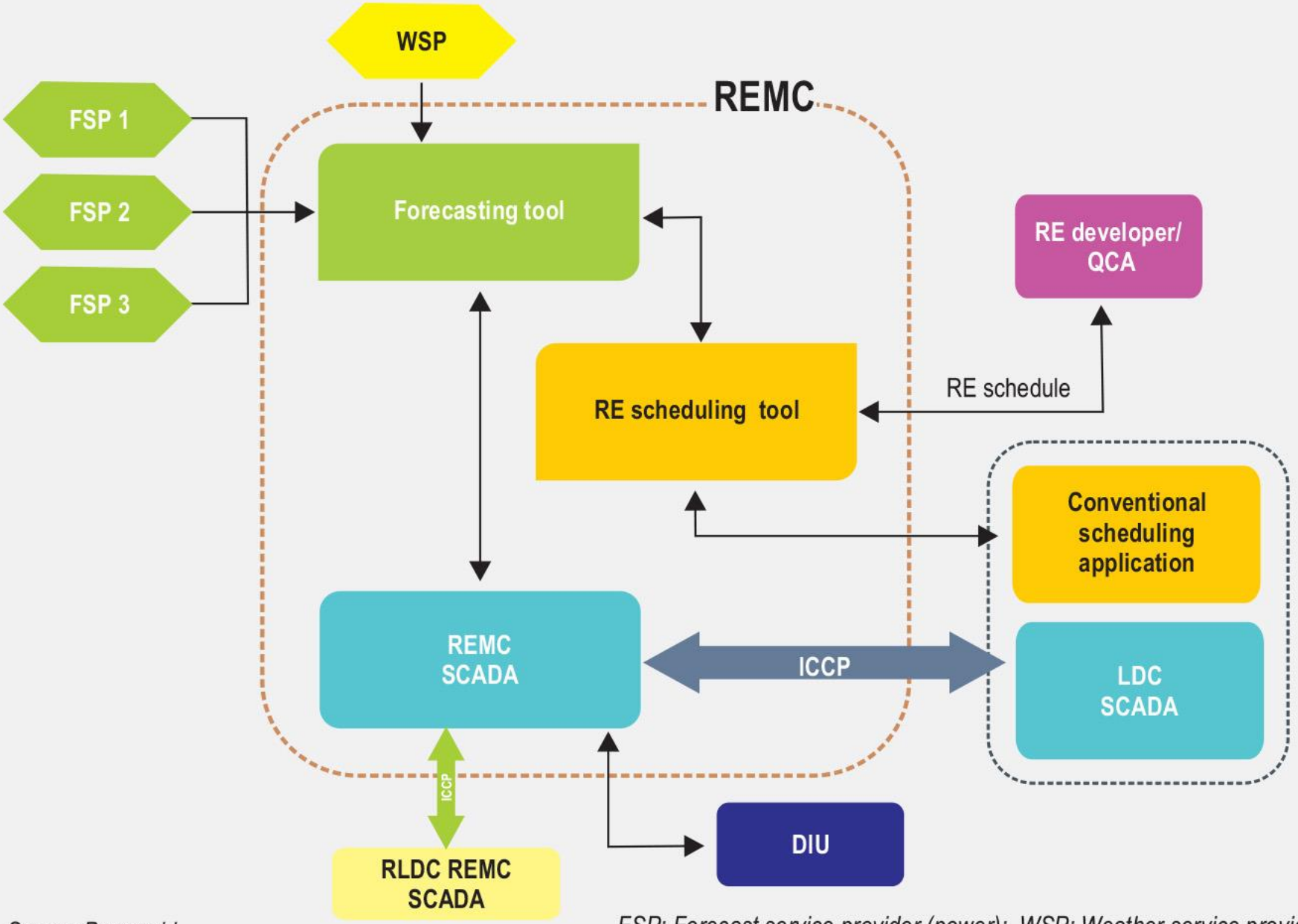
- REMC aims:
  - Addressing variability, intermittency & ramping aspect of the renewable integration
  - Help grid operator to effectively manage power system operations while maintaining grid stability & security

Established in 2020 by the Mistry of Power, GoI, under Power Grid

Renewable Energy management Centre (REMC)

- REMC Objectives:
  - Forecasting of RE generation on different levels such as State/region aggregated, pooling station wise etc. based on information from Forecast Service provider (FSP) as well as Weather Service provider (WSP)
  - Renewable Generation Scheduling
  - Real time tracking of generation of RE sources, integration with REMC SCADA & its visualization
  - Close coordination with respective LDC for RE generation & integration with existing SCADA Technology

REMC architecture



Source: Powergrid

FSP: Forecast service provider (power); WSP: Weather service provider