EN304- ELECTRICAL ENERGY SYSTEMS/POWER SYSTEMS

Department of Energy Science and Engineering

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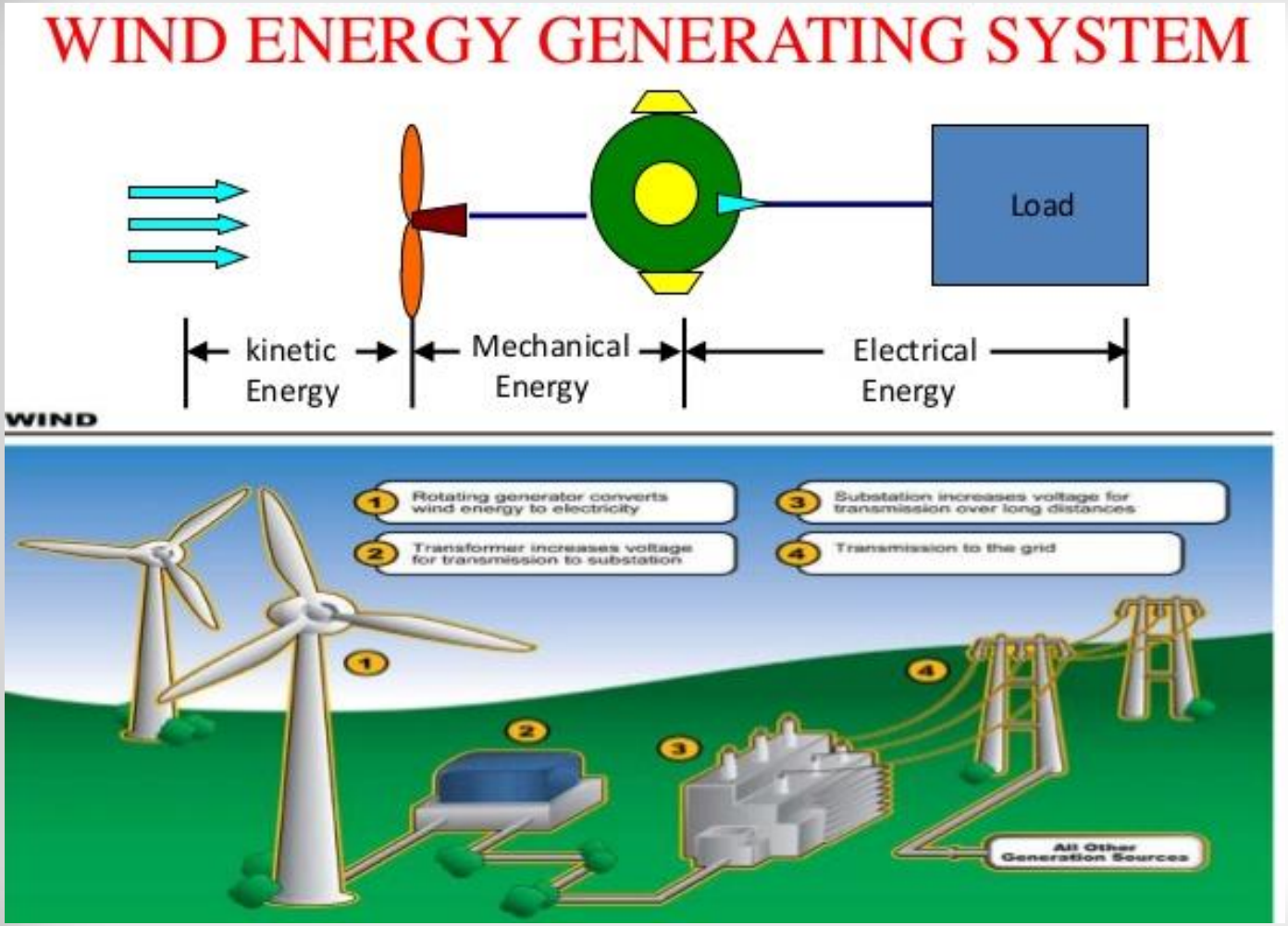
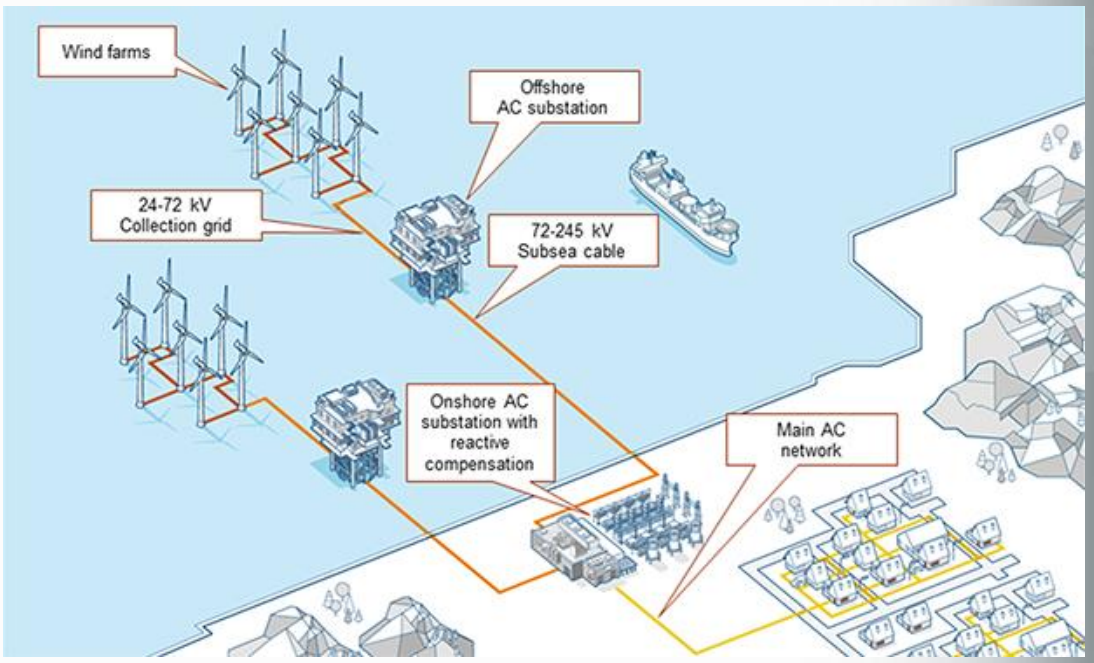
SLIDE DECK 4: Renewable Energy Generators

Wind Energy Conversion System

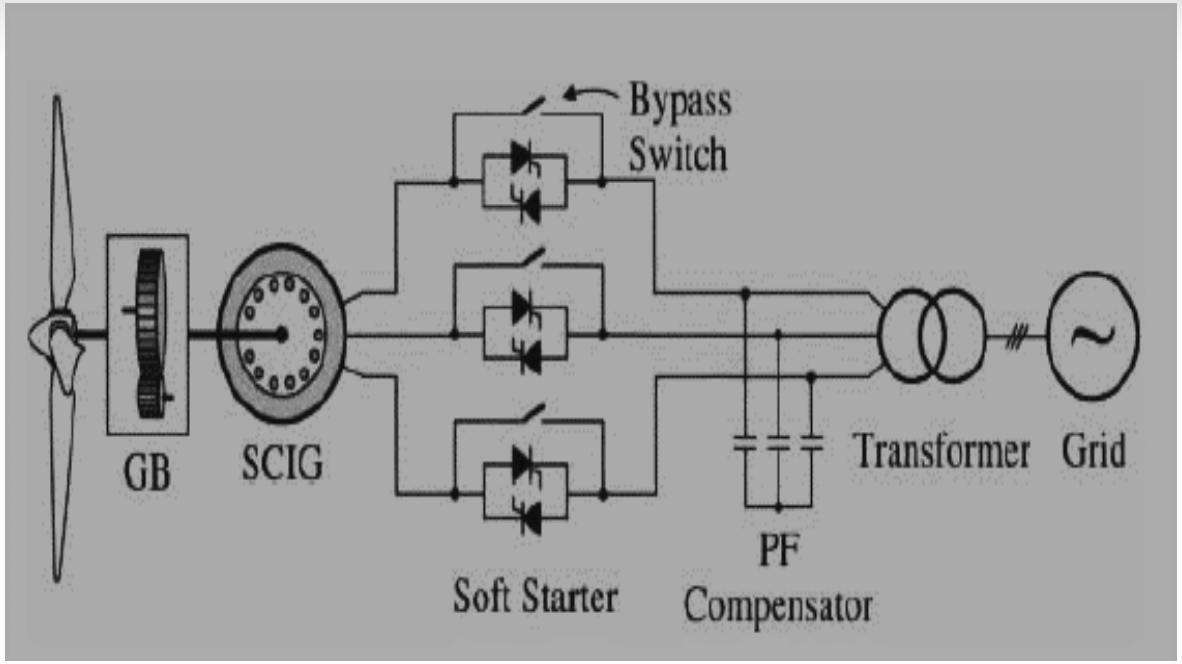


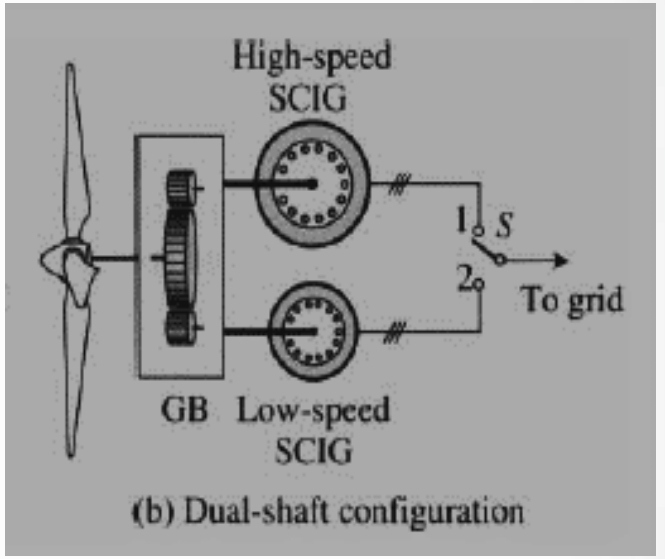


Induction Generators

- Squirrel cage IG: Fixed speed
- Wound rotor IG
- Doubly-Fed IG
- Squirrel cage IG with full converter

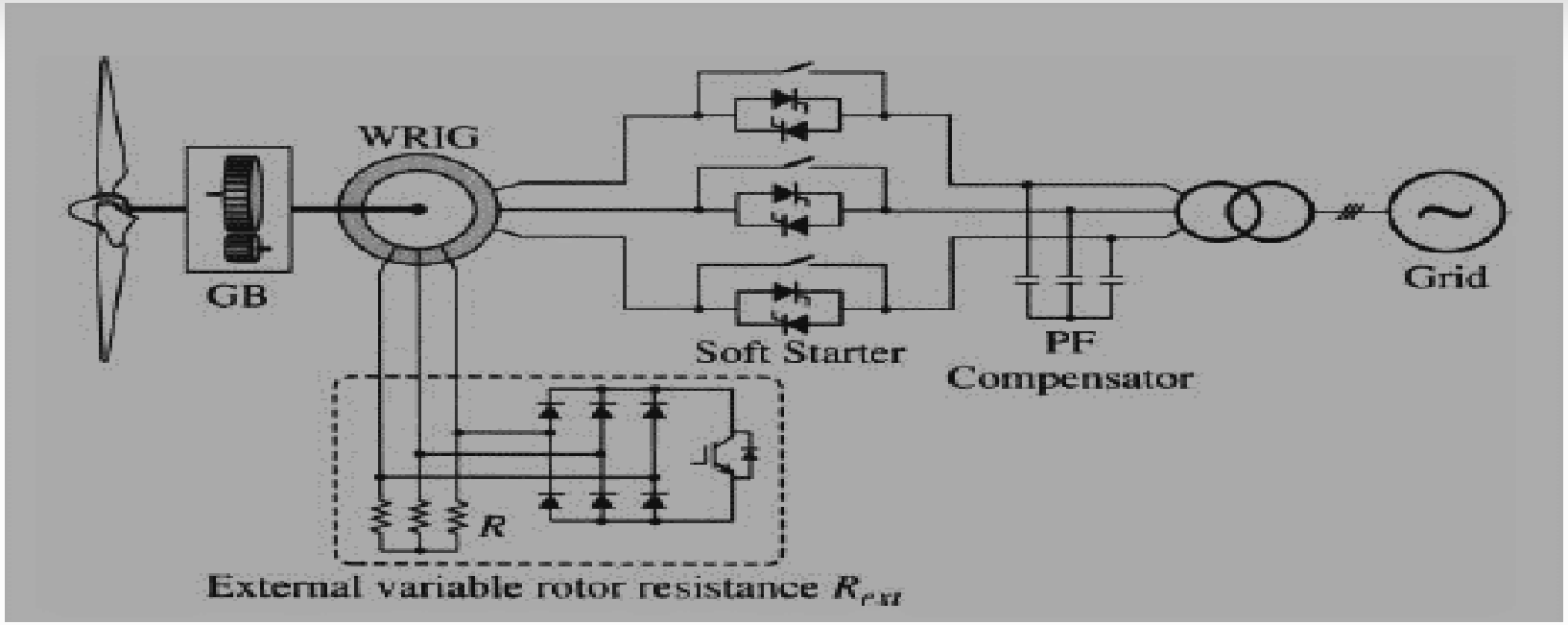
SCIG based Fixed Speed WECS





- Single-speed WECS, in which the generator operates at only one fixed speed; and
- Two-speed WECS, in which the generator can operate at two fixed speeds.
- The turbine is normally of horizontal-axis type with three rotor blades rotating at low speeds, for example, 15 rpm as the rated speed.

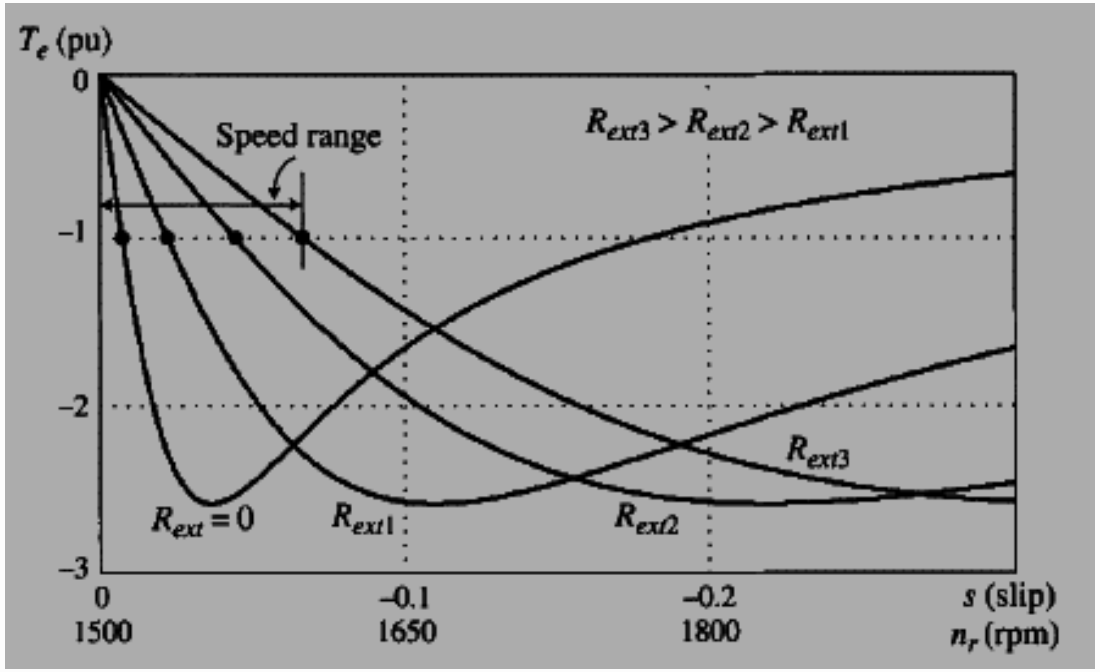
Wound-Rotor Induction Generator (WRIG)



- The system configuration is the same as that of the fixed-speed wind energy system except that the SCIG is replaced with the WRIG.
- The external rotor resistance, is made adjustable by a converter composed of a diode bridge and an IGBT chopper.
- The equivalent value of R_{ex}, seen by the rotor varies with the duty cycle of the chopper.

Wound-Rotor Induction Generator (WRIG)

- The torque-slip characteristics of the generator vary with the external rotor resistance R_{ext}.
- With different values of R_{ext}, the generator can operate at different operating points.
- This introduces a moderate speed range, usually less than 10% of the rated speed.



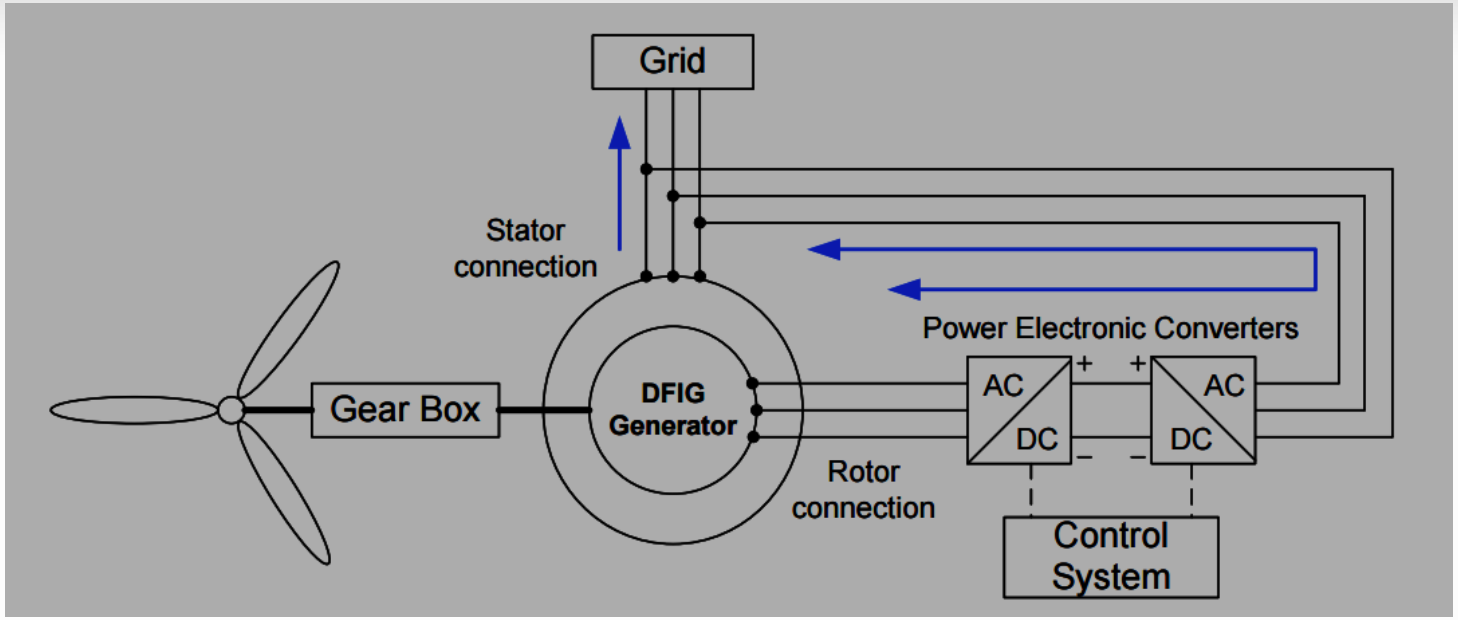
Wound-Rotor Induction Generator (WRIG)

- Slip rings and brushes of the WRIG can be avoided in some practical WECS by mounting the external rotor resistance circuit on the rotor shaft. This reduces maintenance needs, but introduces additional heat dissipation inside the generator.

- The main advantage of this configuration compared to the variable-speed WECS is the low cost and simplicity.

- The major drawbacks include limited speed range, inability to control grid-side reactive power, and reduced efficiency due to the resistive losses.

Doubly-Fed Induction Generator (DFIG)



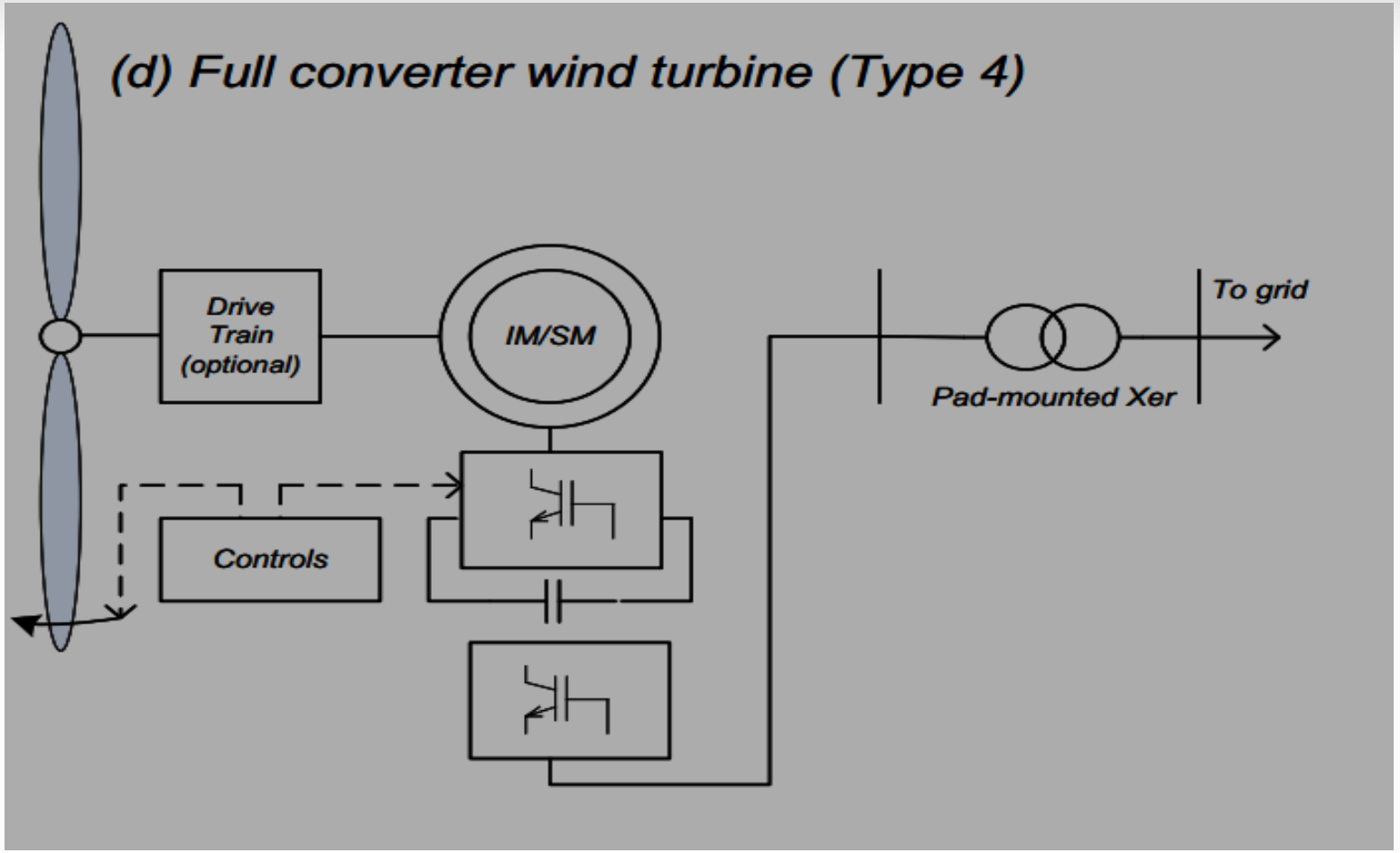
Speed variability of around 30%.

The power electronic interface controls the rotor currents to achieve the variable speed necessary for maximum energy capture in variable winds

Doubly-Fed Induction Generator (DFIG)

- The stator is connected to the grid directly, whereas the rotor is connected to the grid via reduced-capacity power converters.
- The typical stator voltage for the commercial DFIG is 690 V and power rating is from a few hundred kilowatts to several megawatts.
- The power flow in the rotor circuit is bidirectional: it can flow from the grid to the rotor or vice versa. This requires a four-quadrant converter system.
- However, the converter system needs to process only around 30% of the rated power. The use of reduced-capacity converters results in reduction in cost, weight, and physical size as well. Compared with the fixed-speed systems, the energy conversion efficiency of the DFIG wind turbine is greatly enhanced.
- Power converters normally generate switching harmonics. To solve the problems caused by the harmonics, different types of harmonic filters are used in practical wind energy conversion systems

SCIG with full converter (Type-4)



Operational Wind power plants-Examples

An offshore wind farm in the Netherlands

One of the largest wind farm in Europe-in Romania

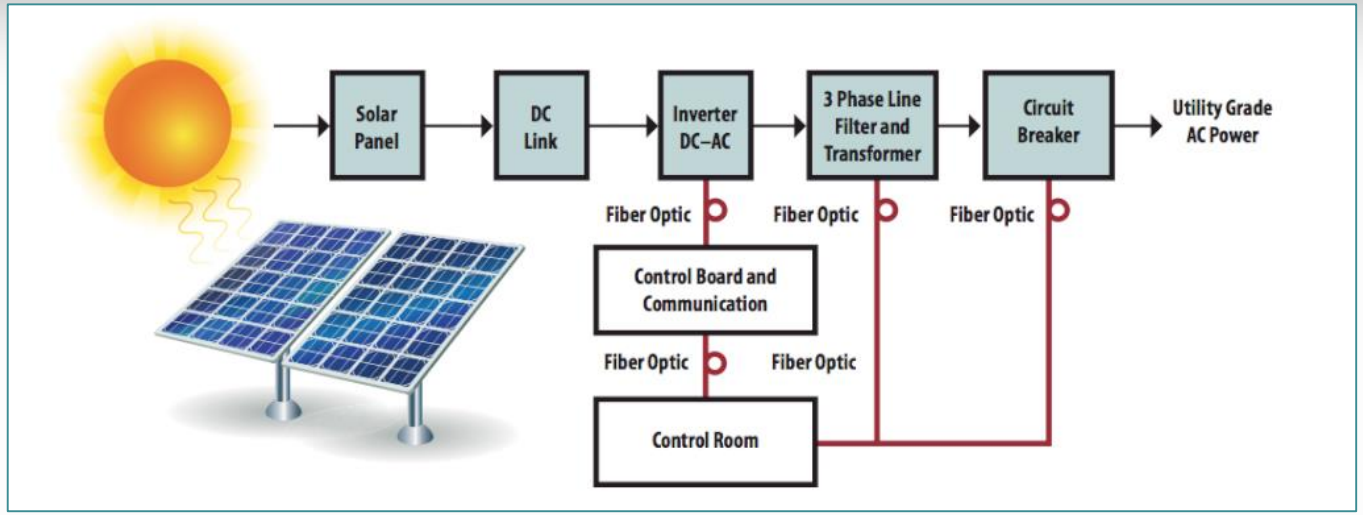
1500 MW wind power plant in Tamil Nadu

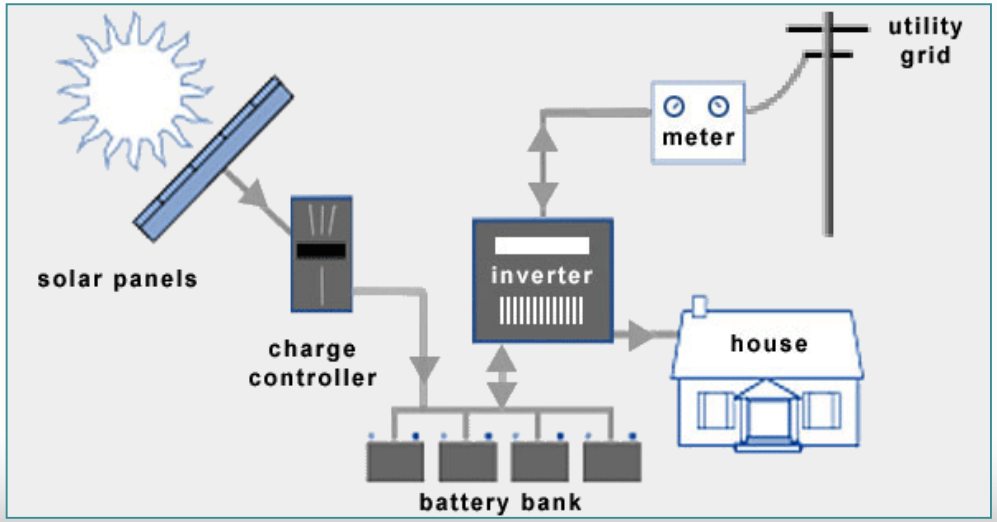
400 MW Anholt offshore wind farm in Denmark

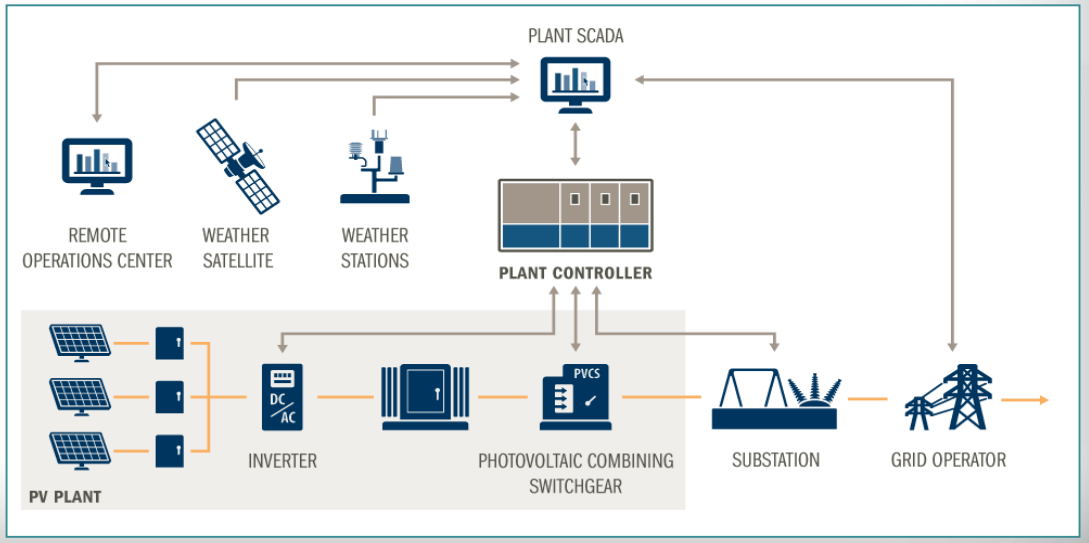
Introduction to Solar PV power

- A solar cell converts energy in photons to electricity (Photo-Voltaic effect)
- When a solar cell is connected to an external circuit, the photo generated current travels from the p-type semiconductor metal contact, through the wire, powers the load, and continues through the wire until it reaches the n-type semiconductor metal contact
- Under a certain sunlight illumination, the current passed to the load from a solar cell depends on the external voltage applied to the solar cell normally through a power electronic converter for a PV system
- A number of such cells connected in series (for higher voltage rating) is called a PV module. A number of such modules in parallel(for higher current rating) is called a PV array
- The parameters that define a PV panel are the rated/ maximum power (P_{mp}), maximum power point voltage (V_{mp}), maximum power point current (I_{mp}), open circuit voltage (V_{oc}) and short circuit current (I_{sc})
- Due to the flexibility in the adjustment of the PV terminal voltage, various maximum power point tracking (MPPT) techniques are available to extract maximum power at varying environmental conditions
- $P_{mp} = V_{mp} \times I_{mp}$ and $Fill\ factor = \frac{V_{mp} \times I_{mp}}{V_{oc} \times I_{sc}}$

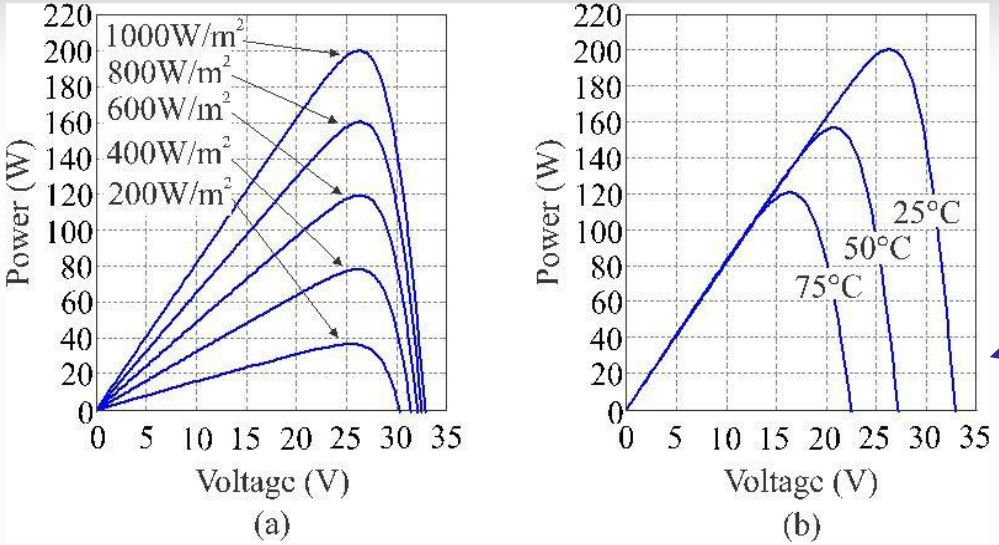
Solar PV power conversion





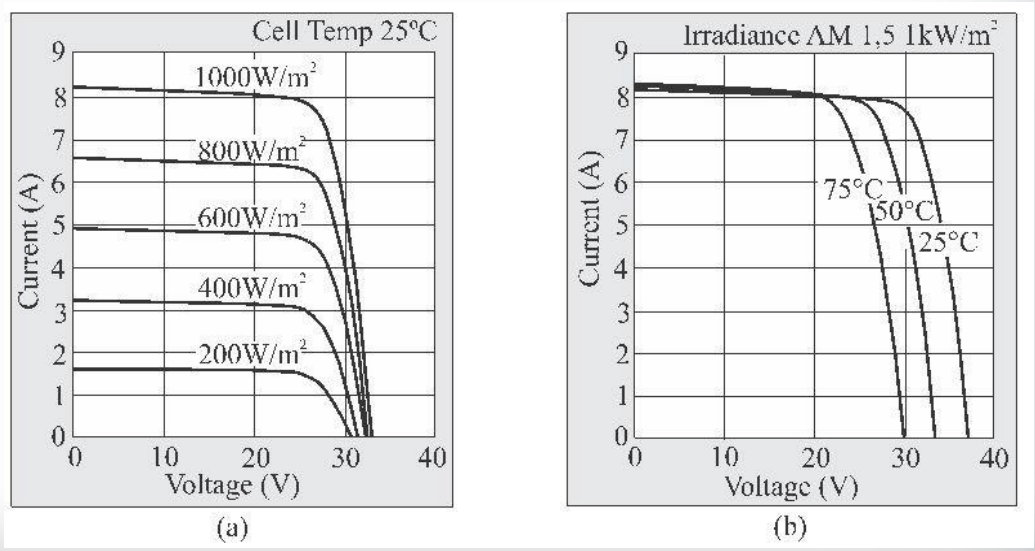


PV Array Characteristics



P-V Characteristics of PV array at
(a) different irradiance
(b) different ambient temperature

I-V Characteristics of PV array at
(a) different irradiance
(b) different ambient temperature



Operational Solar power plants-Examples