3.5 **Grid integration issues of Wind Power Plants:**

To integrate large amounts of wind power into electricity grid, a number of issues need to be addressed, including design and operation of the power system, grid infrastructure issues, and grid connection of wind power,

A. Transient Stability and Power Quality Problems:

- Consider a grid-connected wind generator system. During a transient fault in the power network, the rotor speed of the wind generator goes very high, active power output goes very low, and terminal voltage goes very low or collapses.
- The wind speed might be considered constant during a transient fault. According to grid code requirements, the voltage level should not be less than 85% of the rated voltage. Usually the wind generator is shut down during these emergency situations.
- Recent tradition is not to shut down the wind generator during a network fault but to keep it connected to the grid through appropriate power electronics control. In other words, the wind generators should have fault ride-through (FRT) capability. This clearly indicates that wind generator stabilization is necessary during network faults.

B. Variability of Wind Power:

- Wind energy does not suddenly trip the system off. Variations are smoother because there are hundreds or thousands of units rather than a few large power stations, making it easier for the system operator to predict and manage changes in supply.
- Especially in large, interconnected grids, there is little overall impact if the wind stops blowing in one particular place. Predictability is key in managing wind power‘s variability, and significant advances have been made to improve forecasting methods.
- Today, wind power prediction is quite accurate for aggregated wind farms. Using increasingly sophisticated weather forecasts, wind power generation models, and statistical analysis, it is possible to predict generation from 5-minute to hourly intervals over time scales up to 72 hours in advance and for seasonal and annual periods.

C. Power, Frequency, and Voltage Fluctuations Due to Random Wind Speed Variation:

- Due to random wind speed variation, wind generator output power, frequency, and terminal voltage fluctuate. In other words, power quality of the wind generator deteriorates. However, consumers need constant voltage and frequency. Thus, frequency, grid voltage, and transmission line power should be maintained constant.

D. Grid Connection Requirements:

The major requirements of typical grid codes for operation and grid connection of wind turbines are summarized as follows:

1. **Voltage operating range**: The wind turbines are required to operate within typical grid voltage variations.

2. **Frequency operating range**: The wind turbines are required to operate within typical grid frequency variations.

3. **Active power control**: Several grid codes require wind farms to provide active power control to ensure a stable frequency in the system and to prevent overloading of lines. Also, wind turbines are required to respond with a ramp rate in the desired range.

4. **Frequency control**: Several grid codes require wind farms to provide frequency regulation capability to help maintain the desired network frequency.

5. **Voltage control**: Grid codes require that individual wind turbines control their own terminal voltage to a constant value by means of an automatic voltage regulator.

6. **Reactive power control**: The wind farms are required to provide dynamic reactive power control capability to maintain the reactive power balance and the power factor in the desired range.

7. **Low-voltage ride-through (LVRT)**: In the event of voltage sag, the wind turbines are required to remain connected for a specific amount of time before being allowed to disconnect. In addition, some utilities require that the wind turbines help support grid voltage during faults.

8. **High-voltage ride-through (HVRT)**: In the event that the voltage goes above its upper limit value, the wind turbines should be capable of staying online for a given length of time.

9. **Power quality**: Wind farms are required to provide the electric power with a desired quality, such as maintaining constant voltage or voltage fluctuations in the desired range or maintaining voltage–current harmonics in the desired range.

10. **Wind farm modelling and verification**: Some grid codes require wind farm owners and developers to provide models and system data to enable the system operator to investigate by simulations the interaction between the wind farm and the power system. They also require installation of monitoring equipment to verify the actual behaviour of the wind farm during faults and to check the model.

11. **Communications and external control**: The wind farm operators are required to provide signals corresponding to a number of parameters important for the system operator to enable proper operation of the power system. Moreover, it must be possible to connect and disconnect the wind turbines remotely.

D.1 Islanding and Auto Reclosure:

- Critical situations can occur if a part of the utility network is islanded, and an integrated distributed generation (DG) unit is connected. This situation is commonly referred to as loss of mains (LOM) or loss of grid (LOG).
- When LOM occurs, neither the voltage nor the frequency is controlled by the utility supply. Normally, islanding is the consequence of a fault in the network. If an embedded generator continues its operation after the utility supply was disconnected, faults may not clear since the arc is still charged.
- Small embedded generators (or grid interfaces, respectively) are often not equipped with voltage control; therefore, the voltage magnitude of an islanded network is not kept between desired limits, and undefined voltage magnitudes may occur during island operation.
- Another result of missing control might be frequency instability. Since real systems are never balanced exactly, the frequency will change due to active power unbalance. Uncontrolled frequency represents a high risk for machines and drives.

- Since arc faults normally clear after a short interruption of the supply, automatic (instantaneous) reclosure is a common relay feature. With a continuously operating generator in the network, two problems may arise when the utility network is automatically reconnected after a short interruption:
- The fault may not have cleared since the arc was fed from the DG unit; therefore, instantaneous reclosure may not succeed.
- In the islanded part of the grid, the frequency may have changed due to active power unbalance. Reclosing the switch would couple two asynchronously operating systems.
- Extended dead time has to be regarded between the separation of the DG unit and the reconnection of the utility supply to make fault clearing possible. Common time settings of auto reclosure relays are between 100 and 1,000 ms.
- With DG in the network, the total time has to be prolonged. A recommendation is to maintain a reclosure interval of 1 sec or more for distribution feeders with embedded generators.
- The only solution to this problem seems to be to disconnect the DG unit as soon as LOM occurred. Thus, it is necessary to detect islands quickly and reliably.

D.2 Other Issues:

- There are some other problems concerning the integration of DG besides those already mentioned.

D.2.1 Ferroresonance

- Ferroresonance can occur and damage customer equipment or transformers. For cable lines, where faults are normally permanent, fast-blowing fuses are used as overcurrent protection.
- Since the fuses in the three phases do not trigger simultaneously, it may happen that a transformer is connected via only two phases for a short time.
- Then, the capacitance of the cable is in series with the transformer inductance that could cause distorted or high voltages and currents due to resonance conditions.

D.2.2 Grounding

- There are possible grounding problems due to multiple ground current paths. If a DG unit is connected via a grounded delta-wye transformer, earth faults on the utility line will cause ground currents in both directions—from the fault to the utility transformer as well as to the DG transformer.

- This is normally not considered in the distribution system ground fault coordination. The problem of loss of earth (LOE) for single-point grounded distribution systems is that whenever the utility earth connection is lost the whole system gets ungrounded.