SNS COLLEGE OF ENGINEERING

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

19EE711 SOLAR AND WIND ENERGY

UNIT II-WIND GENERATOR TOPOLOGIES

1. Power Flow between Two Synchronous Sources (Active and Reactive power control)

In the power converters that are used in wind electrical systems to convert the Generator output to a suitable voltage and frequency level, a pulse width modulated (PWM) voltage source inverter is used to exchange power between the Generator and a fixed- frequency AC system through a DC link. The inverter produces an output voltage **'V_I'** at the fundamental frequency with the required phase angle and magnitude and synchronized with the ac system voltage **'V_S'**, through an inductor. Under the assumption of balanced sinusoidal voltages, the per-phase steady-state equivalent circuit for the Synchronized Inverter-AC system and its phasor diagram can be drawn as shown in the figure below (5.13).

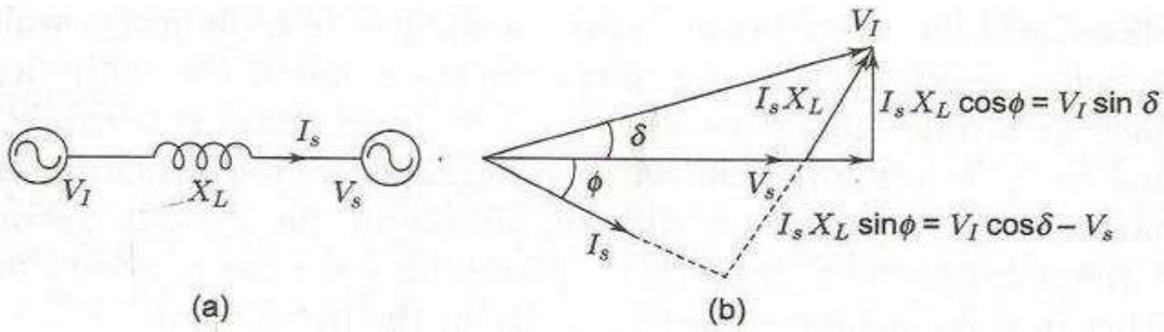

Figure - 13: (a) Schematic diagram of an Inverter /AC system interface (b) Phasordiagram

Thus, the real power and the reactive power flow can be regulated by controlling the inverter output voltage and its phase angle relative to the AC system.

2. Effect of a Wind Generator on the network:

Many wind farms are connected to the local network at low, medium, or high voltage. The injection of wind power into the network has an impact on the voltage magnitude, its flicker, and its waveform at the *point of common coupling (PCC).*

The effect on the voltage magnitude depends on the 'strength' of the utility distribution network at the point of coupling as well as on the active and reactive power of the wind generator(s).The strength of the system at the point of coupling under consideration is decided by the short-circuit power, called the fault level, at that point. The short-circuit power is the product of the short-circuit current, following a three-phase fault at that point, and the voltage of the system. In fact, a power system comprises many interconnected power sources. The loads are fed through extended transmission and distribution networks. At the point of connection, as illustrated in the figure below [Fig. 5.14(a)], an equivalent ideal voltage source in series with impedance **'Z_S'**, may be assumed to replace the power system.

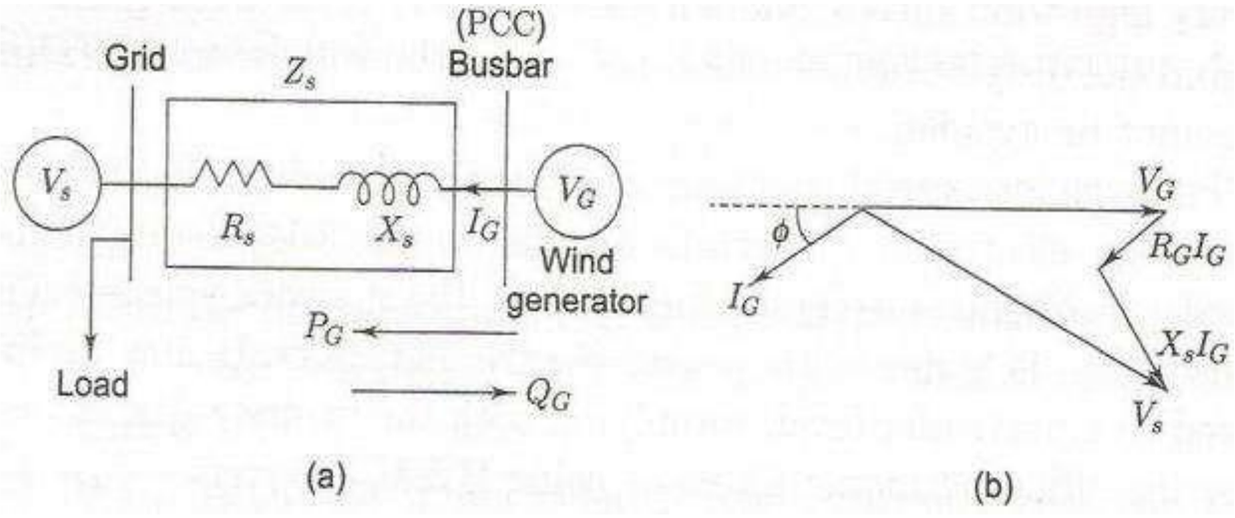

Figure - 14: (a) Schematic diagram of a Generator connection to Distribution Network (b) Phasor diagram

Thus, the higher the fault current, the lower the source impedance. The windfarm with induction generators receives reactive power from the network and delivers real power to it. Without contribution from the wind generator, the fault level at the point of connection near the wind farm is

$$M = I_f V_s$$

Where

$$I_f = V_s / Z_s$$

Thus the fault level and hence the network strength are indicative of the source impedance. Areas of high wind velocity are suitable locations for wind farms. These areas are usually sparsely populated. Long transmission and distribution lines are normally required for connecting wind farms with the power system network. As a result, fault levels at the wind farms are generally low, making them weak electrical systems.

With reference to figure 5.14 (b), if the phase difference between **'V_S'** and **'V_G'** is not large, the voltage at the PCC will be close to:

$$V_G = V_s + R_s I_G \cos \varphi - X_s I_G \sin \varphi$$

$$\mathbf{= V_s + P_G R_s / V_G - Q_G X_s / V_G}$$

Thus, at low power delivery, the voltage at the PCC reduces if the induction generator absorbs reactive power from the grid, while, at increased power flow, the voltage rises. *'Flicker'* is defined as the unsteadiness of the distribution network voltage. It may be caused by the continuous operation of a wind turbine or the switching operations of turbines. While operating, the rotor of a wind turbine experiences a cyclic torque variation at the frequency with which the blades move past the tower. This cyclic power variation may lead to flicker, and depends on the wind speed distribution at the site. While being connected to the network, the induction generator draws excessive current. Soft-start systems are usually employed to minimize the transient inrush current. However, at very high wind speeds, sudden disconnection of the wind generator from the distribution network may cause the voltage to dip, which cannot be avoided.

Interfacing variable-speed wind turbines with the network through electronic converters results in the injection of higher order harmonic currents, which distort the network voltage. This distortion is higher with weaker electric networks. It may be limited to a particular level, complying with the utility requirements, by installing harmonic filters or using PWM inverters

3. Summary - Important Concepts/Relations

- This chapter deals with Grid-connected Induction Generator operational details.
- The detailed schemes with both Squirrel Cage and Wound Rotor Induction Machines, whose stator windings are directly connected to the grid have been presented and explained.
- The near-synchronous-speed squirrel cage induction generator, driven by a wind turbine via a gear box, prevails dominantly (more than 80%) over the other types of generators in the wind power market. Their manufacturing range extends up to 1.5 MW. Both *classical stall* and *active stall* are used with these fixed-speed turbines to limit the power generation at high wind speeds.

  This system is cheap and simple, but it draws the least amount of energy from wind compared to other technologies for the same wind speed statistics at a given site. This is so because with a fixed speed of Wind Turbine **'C_p'** is not optimized for capturing maximum power from wind.
- For variable-speed operation, the wound rotor induction machine is used. The stator is directly connected to the grid. The rotor also feeds power to the grid via a converter. This system, known as a Double Output Induction Generator, is the favored choice for variable-speed, high-capacity turbines in the range 1-
  4.5 MW.
- In order to extract the maximum amount of power from wind, the tip speed ratio must be kept fixed at the optimal value while the wind speed fluctuates continuously. This requires corresponding change of Turbine speed according to wind speed variation. Consequently, the electrical generator should be able to operate at variable speed. Since variable-speed generation is most energy efficient this chapter deals with the variable-speed-based generation schemes with Synchronous Generators both with wound field and Permanent Magnets also.
- Even though constant-speed wind turbines with grid-connected Squirrel Cage Induction Generators have dominated the wind market, there is a clear trend over the past few decades towards use of variable-speed wind turbines with DFIG and Synchronous Generators (both wound field and Permanent Magnet).
- For direct drive applications permanent magnet synchronous machines are attractive.