Tutorial 7

1- A three-phase, 10 kVA squirrel-cage induction generator is driven by a fixed speed wind turbine. The generator delivers its rated output at a wind speed of 12 m/sec. The generator is connected to an infinite bus; the line-to-line voltage at the infinite bus is 208 V. The generator is driven at a rated wind speed, delivering its output at a lagging power factor of 0.8.

a) Calculate the active power output, P_o.

b) Calculate the generator output current.

c) Calculate the reactive power the generator needs, Q

d) The wind speed dropped to 8 m/sec; the generator efficiency stayed the same but the aerodynamic coefficient became 80% of what it was. Calculate the power output of the generator.

2- Sketch a diagram showing the main components of a (a) Optislip variable speed wind turbine, (b) doubly-fed induction generator wind turbine, and (c) direct drive permanent magnet synchronous generator wind turbine. Explain briefly the function of key components in each wind turbine generator type.

3- A 2.3MW 4-pole 50Hz wound rotor induction machine is used in a wind turbine as a doubly-fed induction generator. The wind turbine operates according to the curve in Figure Q3. The pitch mechanism is adjusted to activate at 20rpm rotor blade speed. Discard mechanical and electrical losses. Find:

(a) The gearbox gear ratio if the pitch mechanism is activated at 121% the synchronous speed.
(b) The rotor current frequency at the point pitch is activated.
(c) The electric torque of the generator in N.m. What is the electric torque at the rotor hub in N.m.?
(d) Using Figure Q3, find the optimal tip speed ratio of the wind turbine if rotor diameter is 110m.

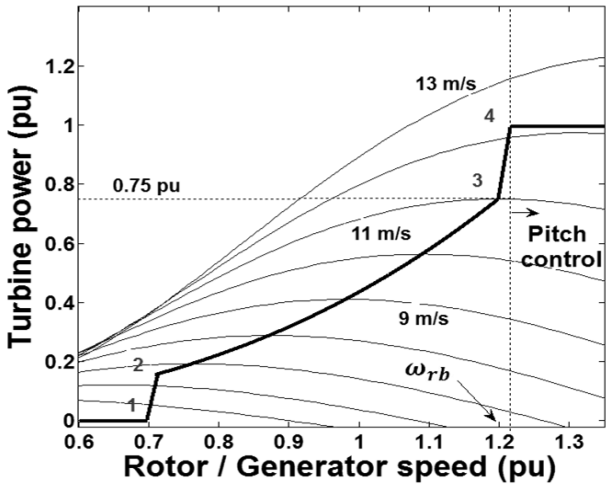

Figure Q3

4- Consider a 5 MW wind farm operating at a leading power factor of 0.98. The single-line diagram of the system is given in Figure Q4. The network voltage (V_0) is 33kV or (1 + j0) per unit and the circuit impedance (Z) is (0.05 + j0.1) per unit on a 10 MVA base.

(i) The voltage at the wind farm terminal (V_1). [Hint: take 3 iterations]

(ii) The current in the feeder in amperes and power loss in the feeder in per unit.

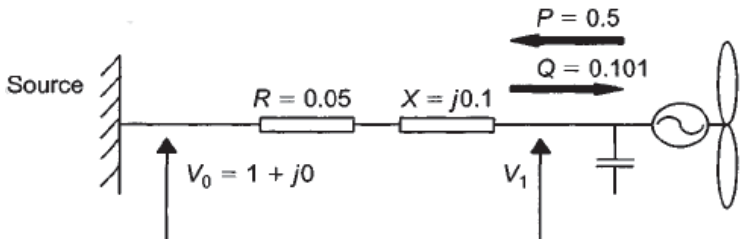

Figure Q4

5- Plot the four quadrant torque-slip (or torque-speed) curve of a single-fed induction machine and indicate on your graph:

a) The motoring and the generating operation regions.
b) The stable operation regions for motoring and generating.
c) The rated slip points for generating and motoring region.
d) The locus of the operating point of a fixed speed wind turbine when the wind speed increases from speed v_1 to v_2.
e) How the torque-slip curve evolves with increased rotor resistance.

6- A 3MW synchronous machine has been specifically manufactured for a wind turbine. Permanent magnets are mounted on the rotor such that the machine has 250 poles.

(a) What would be the generator speed if connected directly to 50Hz grid?
(b) The machine is connected directly to the rotor hub of a wind turbine. Back-to-back full-rated power converters are used to interface the stator to the grid and run the wind turbine along maximum power point tracking curve. If the cut-in wind speed is 5m/s and rated wind speed is 12m/s, find the lowest and rated frequency the synchronous generator produces if optimal tip-speed ratio is 9 and rotor diameter is 130m.