

End Semester Examinations - 2015-16 Even Semester - May 2016

14EE3014 Wind Energy

Set A

Time : 3 hrs
Total Marks: 100

1. Discuss the modern wind turbine design with the principal subsystems of a typical (land-based) horizontal axis wind turbine [10]
- Based on average speed data only, estimate the annual energy production from a horizontal axis wind turbine with a 14m diameter operating in a wind regime with an average wind speed of 9 m/s. Assume that the wind turbine is operating under standard atmospheric conditions ($\rho=1.225 \text{ kg/m}^3$). Assume a turbine efficiency of 0.5 [10]
- [OR]**
- OR**
2. A 40m diameter, three-bladed wind turbine produces 700kW at a wind speed (hub height) of 14 m/s. The air density is 1.225 kg/m^3 . Find:
- (a) The rotational speed (rpm) of the rotor at a tip speed ratio of 5.0. (b) What is the tip speed (m/s)?
- (c) If the generator turns at 1800 rpm, what gear ratio is needed to match the rotor speed to the generator speed?
- (d) What is the efficiency of the wind turbine system (including blades, transmission, shafts, and generator) under these conditions? [20]
3. An inventor proposes to use a rotating cylinder to produce lift in a new wind energy device. The cylinder will be $D=0.75\text{m}$ in diameter and will be $H=7.5\text{m}$ high. It will rotate with a speed of $n=60 \text{ rpm}$. (a) Find an expression for the lift per unit height around a rotating cylinder in terms of the free stream wind velocity, U (m/s), the rotational speed, n (rpm), and the diameter, D (m), of the cylinder. (b) Find the lift force produced by the cylinder in the inventor's device in a 10 m/s wind. [20]
- [OR]**
- OR**
4. Define the Blade Shape, Determine Basic Rotor Parameters, Calculate Rotor Performance and Modify Blade Design by Method 1 – Solving for C_l and α , Method 2 – Iterative Solution for a and a' [20]
5. A small wind turbine generator (single phase) produces a 60 Hz voltage at 120Vrms. The output of the generator is connected to a diode bridge full-wave rectifier, which produces a fluctuating DC voltage. What is the average DC voltage? A silicon-controlled rectifier (SCR) is substituted for the diode rectifier. Under one condition the SCRs are turned on at 60 degrees after the beginning of each half cycle. What is the average DC voltage in that case? [20]
- [OR]**
- OR**
6. A variable-speed wind turbine control system uses blade pitch and speed variations to provide constant power to the grid. What are the trade offs between fluctuations in rotor speed and the time response of the pitch control system? [20]
7. The low-speed shaft of a wind turbine has a length, l , of 10m and a diameter, D , of 0.5 m. It is made of steel with a modulus of elasticity of $E=160 \text{ GPa}$. It is rotating at 12.1 rpm and the turbine is generating 5MW. Find: (a) the applied rotor torque, assuming an overall drive train efficiency of 90% , (b) the angle of deflection (c) the energy stored in the shaft , (d) the maximum stress in the shaft.

[20]

[OR]

OR

8. A wind turbine manufacturer wants to design a yaw drive control system. To minimize wear on the drive gears the yaw is to be locked with a yaw brake until the ten-minute time-averaged yaw error is more than some specified amount (the 'yaw error limit'). At that point the yaw drive moves the turbine to face the previously determined ten-minute time-averaged wind direction.
- (a) What consequences does the choice of yaw error limit and averaging time have on machine operation?
- (b) What approach would you take to determining the quantitative trade offs between yaw error limit and other factors? [20]
9. Discuss the overall economics of wind energy systems, covering the topic of Generating Costs of Grid-connected Wind Turbines [20]

Wishing you All the Best
