Tampere University of Technology
Electrical Engineering

Wind Power Systems DEE-54107 15.12. 2016

Enrique Acha Programmable calculator allowed 5 questions/ á 6 p

Question 1:

A) Explain briefly what a wind rose is and sketch a typical twelve-segment wind rose. (1p)

B) Discuss briefly the impact that doubling the size of the turbine's rotor diameter has in power extraction from the wind by the turbine. (1p)

C) Draw the output power-wind speed characteristic of a wind turbine and label all its relevant parts. (1p)

D) State what the tip speed ratio is. (1p)

E) Describe briefly how the power take-up may be controlled in a fixed-speed, large wind turbine. (1p)

F) Describe briefly the role of the gear-box in fixed-speed, wind turbines which are connected to the electric power grid. (1p)

Question 2:

A) When investigating suitable locations for a wind farm, tests show that Location 1 has 10% more wind resource than Location 2. Estimate the potential increase in power that could be obtained by choosing Location 1 over Location 2. (1p)

B) Explain the term *array loss* in connection with a wind farm. (2p)

C) With the power coefficient, C_p, expressed in terms of the interference factor, a, i.e.,

$$C_P = 4a(1-a)^2$$

show analytically or otherwise that C_p carries a maximum value of 59%. (3p)

Question 3:

A) State the main differences, in terms of connection to the supply, between a squirrel-cage induction generator with and with no power electronics and a doubly-fed induction generator when used in a wind turbine application. State what are the advantages of the doubly-fed induction generator over the squirrel-cage induction generator with power electronics and the squirrel-cage induction generator with no power electronics? (4p)

B) The power input of a three-phase induction machine is 60 kW. The stator losses total 1.5 kW. Find the total mechanical power developed by the machine when it is made to operate as a generator with a slip of -1%. Assume rotational losses of 1.5%. (2p)

$4a(1$ $1-2a+a^2$ $12a^2-16a+4$ $a=\frac{4\pm\sqrt{(-4)^2-4\cdot3\cdot1}}{3\cdot2}$

$4(1-a)^2$

$4a-8a^2+4a^3$ $3a^2-4a+1$ $a=\frac{4\pm2}{3\cdot2}=\frac{6}{6}=1$

$\frac{2}{6}=\frac{1}{3}$

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Question 4:

A) Sketch the per-phase equivalent circuit of a three-phase, squirrel-cage induction generator, labelling carefully all its resistance and inductive reactance components. (2p)

B) For the per-phase equivalent circuit of a three-phase, squirrel-cage induction generator, derive an expression for the equivalent impedance, as seen from its stator terminal. Make sure that you include the stator and rotor circuits as well as the magnetizing branch. (2p)

C) Derive expressions for the active power and the reactive power at the generator's terminal, as a function of its equivalent impedance as seen from its terminal and the terminal voltage. (2p)

Question 5: Describe in detail the role that HVDC transmission plays in evacuating the power output of off-shore wind farms. In particular, state which are the transmission distances where HVDC transmission may be the only practical option for the connection of off-shore wind farms. Use as many equations and diagrams that you may find appropriate to aid your description. (6p)

$2 \times 2 = 2 \times 1$

$h' \; 2 \times 1$

$$\begin{bmatrix} Y_{SS} & Y_{SR} \\ Y_{RS} & Y_{RR} \end{bmatrix} \begin{bmatrix} V_S \\ V_R \end{bmatrix} = \begin{matrix} Y_{SS} V_S + Y_{RS} V_S \\ Y_{SR} V_S + Y_{RR} V_R \end{matrix}$$