[ENG26]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSc in ELECTRICAL & ELECTRONIC ENGINEERING

SEMESTER 2 EXAMINATIONS 2021/2022

ADVANCED RENEWABLE ENERGY TECHNOLOGIES

MODULE NO: EEE7008

Date: Thursday 19th May 2022 **Time: 10:00 – 13:00**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

CANDIDATES REQUIRE: **Formula Sheet (attached).**

Question 1

(a) Explain how a HAWT wind turbine rotates when wind blows across its blades.

[5 marks]

(b) Name two advantages of VAWT wind turbines. **[5 marks]**

(c) What are the main characteristics of HAWT wind turbine? **[5 marks]**

(d) Explain with the aid of diagrams why do we need to convert the DC voltage of a solar panel to another DC voltage in real life applications? **[5 marks]**

(e) What are the benefits of using pitch angle control in wind turbines? **[5 marks]**

Total 25 marks

Question 2

Design a solar panel system for a workshop. The workshop has a 48V nominal operating voltage supplied by solar panel powered batteries.

The total power usage for the workshop is 8500 Wh/day. The electricity price is £0.3/kWh. Average sunlight is 5.5 hours/day.

Solar module on market is rated at a peak power of 144Wp, voltage of 36V and current of 4.0A. The price for a PV module is £160.

Battery on market is rated at 24V, 12Ah, and only 78% of the power can be used. Battery reserve time is 2.2 days. The price for each battery is £26.

The inverter efficiency is 96%.

Q2 continues over the page….

PLEASE TURN THE PAGE….

Q2 continued….

The installation of PV panels and all other materials for PV panel installation is £980.

I. Draw the configuration of the solar system for application and name each component and their function. **[4 marks]**

II. How many PV modules are needed to meet the requirement of the workshop use? **[7 marks]**

III. How many batteries are needed to meet the requirement of the workshop use? **[7 marks]**

IV. How many years can the investment get paid back? **[5 marks]**

V. If it is grid-tie solar panel, how many years can the investment get paid back? **[2 marks]**

Total 25 marks

Question 3

A vertical-axis wind turbine has the following specifications: Generator output power=40 kW, Turbine rotational speed=34 RPM, Gearbox ration=23, blade length=6 m, rotor diameter=15 m Permanent Magnet Synchronous Generator: star-connected, voltage=415 V line to line, frequency=50 Hz, phase winding inductance=1.85 mH, phase winding resistance=0.05 Ω , number of magnetic poles=8, generator efficiency=98%, gearbox efficiency=97%. Wind: wind density 1.2 kg/m^3, Determine:

i) The input power of the turbine **[4 marks]**

ii) The generator load angle **[8 marks]**

Q3 continues over the page….

PLEASE TURN THE PAGE….

Q3 continued….

iii) The low-speed shaft torque **[3 marks]**
iv) The generator rotational speed **[3 marks]**
v) The quadrature-axis generator current per phase **[3 marks]**
vi) The performance coefficient C_p and the tip speed ratio if wind speed is 12 m/s

[4 marks]

Assume that the generator is connected to the grid and generates no reactive power.

Total 25 marks

Question 4

(a) Explain with drawings the operation of a wind turbine unit connected to the grid. Stating any necessary requirements and conditions. **[10 marks]**
(b) A Horizontal axis wind turbine whose blades are 16 metres in diameter, tip speed ration is 5.0, air density at sea level is 1.2 kg/m^3 and the maximum power coefficient for this turbine is 0.4. Determine:
i) its swept area and the wind speed **[10 marks]**
ii) the mechanical torque of this turbine if its rotational speed is 34 RPM **[5 marks]**

Total 25 marks

PLEASE TURN THE PAGE….

Question 5

A 500 V, 3-phase, 50 Hz , 8-pole, start-connected induction generator has the following equivalent circuit parameters referred to stator side in ohms: R_1=0.13, R_2=0.32, X_1=0.6, X_2=1.48. magnetizing branch admittance Y_m=0.004-j0.05 Ω^{-1} referred to stator side. If the rotor is driven by a wind turbine with speed of 39 RPM with a gearbox ratio of 20 and using the approximate equivalent circuit; calculate:

I. The slip. **[5 marks]**
II. The rotor current referred to stator. **[5 marks]**
III. The no-load current. **[5 marks]**
IV. The stator current. **[5 marks]**
V. The output kVA. **[5 marks]**

Total 25 marks

Question 6

a) A 3-phase,50 Hz, 66 kV system uses three single core cables to connect an offshore wind farm to an onshore substation. The cable is 1 km long having a core diameter of 10 cm and an impregnated paper insulation of thickness 7 cm. The relative permittivity of the insulation may be assumed as 4. Calculate:
   I. The capacitance per phase **[4 marks]**
   II. The charging current per phase and the total charging kVA **[4 marks]**

b) Draw a block diagram of a solar microinverter and define each block indicating its main function. **[9 marks]**
c) Explain briefly the methods used to control the aerodynamic torque of a horizontal wind turbine. **[8 marks]**

END OF QUESTIONS

Formula sheet over the page….

PLEASE TURN THE PAGE….

School of Engineering
B.Eng (Hons) Electrical and Electronic Engineering
Semester Two Examinations 2021/2022
Advanced Renewable Energy Technologies
Module No. 7008

Formula sheet

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

Fuel Cell

$$\eta = \frac{W_{el}}{W_{ch}} = \frac{U \cdot I \cdot t}{H_{H2} \cdot V}$$

Efficiency = (V.I.t)/H_{H2}

Avogadro's number = 6.022 x 10^{23}

Faraday's constant = 96485 C

$$F_T = \frac{1}{2}\rho S C_t W^2$$

$$F_{T\,avg} = \frac{1}{2\pi}\int_0^{2\pi} F_\tau(\theta)\, d\theta$$

$$T = F_T .\ 2R = \frac{1}{2}\rho C_t\, ARU^2$$

$$P_{wind} = \omega . T$$

$$I = \sqrt{{i_d}^2 + {i_q}^2}\ , \quad P_{in} = \tau_{app}\omega_m$$

$$P_{conv} = \tau_{ind}\omega_m = 3E_A I_A \cos\gamma$$

Wind Turbine

$$S = c \cdot H$$

$$S_a = R \cdot L\ , P = \sqrt{3} V_L I_L cos\theta$$

$$\lambda = \frac{\omega R}{U}\ , \quad \alpha = tan^{-1}\left(\frac{sin\theta}{cos\theta + \lambda}\right)$$

$$C_t = C_L sin\alpha - C_d cos\alpha\ , C_p = C_t . \frac{\lambda}{R}$$

Permanent Magnet Synchronous machine

$$v_q = -\left(r + \frac{d}{dt}L_q\right)i_q - \omega_r L_d i_d + \omega_r \lambda_{PM}$$

$$v_d = -\left(r + \frac{d}{dt}L_d\right)i_d + \omega_r L_q i_q$$

$$J_g \frac{d\omega_r}{dt} = T_g - T_d - T_e$$

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left[\left(L_d - L_q\right)i_q i_d - \lambda_{PM} i_q\right]$$

$$V = \sqrt{{v_d}^2 + {v_q}^2}$$

END OF PAPER