ENG15

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) ELECTRICAL & ELECTRONIC ENGINEERING

EXAMINATION SEMESTER 2 - 2022/2023

RENEWABLE ENERGIES

MODULE NO: EEE6016

Date: Wednesday 10th May 2023 **Time: 2:00pm – 4:30pm**

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).**

UNIVERSITY OF BOLTON
SCHOOL OF ENGINEERING
B.ENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATION SEMESTER 2 - 2022/2023
RENEWABLE ENERGIES
MODULE NO. EEE6016

Question 1

(a) Explain how an 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? **[5 marks]**

Total 25 marks

Question 2

The following specification are for a Horizontal-Wind Turbine serving an isolated load:

Load power=40 kW, unity power factor. Turbine rotational speed=36 RPM, gearbox ration=20.83, blade length=6.5 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=0.1 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 δ **[8 marks]**
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 coefficient C_t and the tip speed ratio if wind speed is 12 m/s

[4 marks]

Total 25 marks

PLEASE TURN THE PAGE

UNIVERSITY OF BOLTON
SCHOOL OF ENGINEERING
B.ENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATION SEMESTER 2 - 2022/2023
RENEWABLE ENERGIES
MODULE NO. EEE6016

Question 3

(a) The reservoir of a large conventional hydroelectric plant has a head of 130 m and a volume flow rate of water of 4000 m^3/s. The combined efficiency of the plant is 0.94, and the plant capacity factor is 0.70. Find the electrical energy generated by the plant during a one-year period. **[10 marks]**

(b) A wind farm is connected to a substation with a 50 Hz, 3 single-phase underground cable of 1 km length. The operating line voltage is 66 kV, core diameter is 10 cm, and an insulation of thickness of 7 cm. The relative permittivity of the insulation may be taken as 4. Calculate:

I. The insulation resistance per phase if the insulation resistivity is 13X10^9 Ωm **[5 marks]**

II. The capacitance to neutral **[5 marks]**

III. The charging current per phase **[5 marks]**

Total 25 marks

Question 4

(a) What do you understand by the term Fuel cells? Providing a schematic of the Proton Exchange Membrane (PEM) fuel cell, describe the working of a H2/O2 fuel cell by providing the electrochemical reactions taking place at the anode and the cathode of the fuel cell. **[10 marks]**

(b) Name the two proton conduction mechanisms seen in polymer electrolyte membrane and explain the difference between the two mechanisms. **[5 marks]**

(c) You have learnt that the power output of a fuel cell is a function of the free energy used and the thermodynamics reaction, can you draw the electrical equivalent circuit of a fuel cell indicating all parameter. **[10 marks]**

Total 25 marks

PLEASE TURN THE PAGE

UNIVERSITY OF BOLTON
SCHOOL OF ENGINEERING
B.ENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATION SEMESTER 2 - 2022/2023
RENEWABLE ENERGIES
MODULE NO. EEE6016

Question 5

(a) Determine the efficiency of a typical fuel cell, which is supplying a current of 2A at a voltage of 0.95V over a period of 4minutes? Assuming 30 ml of H_2 is being consumed in this process and the calorific value of H_2 is 11850 kJ/m^3

[8 marks]

(b) Give a brief description of how the solar cell works and explain the principle of p/n junction. **[4 marks]**

(c) Draw a typical I-V curve for a solar cell in dark and under illumination, and explain what are the Voc and Isc, Fill-factor and Efficiency in the I-V figure.

[5 marks]

(d) Explain the concept of parasitic resistance in series and in parallel and describe how a parasitic resistance can affect the efficiency of a solar cell.

[4 marks]

(e) List the methods that can be used to improve the efficiency of a solar cell.

[4 marks]

Total 25 marks

UNIVERSITY OF BOLTON
SCHOOL OF ENGINEERING
B.ENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATION SEMESTER 2 - 2022/2023
RENEWABLE ENERGIES
MODULE NO. EEE6016

Question 6

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

The total power usage for the workshop is 9500 Wh/day. The electricity price is £0.5/kWh. Average sunlight is 5 hours/day.

Solar module on market is rated at a peak power of 120Wp, voltage of 48V and current of 5.0A. The price for a PV module is £145.

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 £34.

The inverter efficiency is 85%.

The installation of PV panels and all other materials for PV panel installation is £1200.

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

2. How many PV modules will be needed to meet the requirement of the workshop use? **[7 marks]**
3. How many batteries are needed to meet the requirement of the workshop use? And how they are connected? **[7 marks]**
4. How many years can the investment get paid back? **[5 marks]**

5. If it is grid-tie solar panel, how many years can the investment get paid back?

[2 marks]

Total 25 marks

END OF QUESTIONS

PLEASE TURN PAGE FOR FORMULA SHEET

UNIVERSITY OF BOLTON
SCHOOL OF ENGINEERING
B.ENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATION SEMESTER 2 - 2022/2023
RENEWABLE ENERGIES
MODULE NO. EEE6016

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

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

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

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

$P_{wind} = \omega . T$

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

$P_{conv} = \tau_{ind}\omega_m = 3E_A I_A \cos\gamma$ $\quad V = \sqrt{{v_d}^2 + {v_q}^2}$

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

Wind Turbine

$S = c \cdot H$

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

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

$C_t = C_L sin\alpha - C_d cos\alpha$, $C_p = C_t . \lambda$

Permanent Magnet Synchronous machine

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

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

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

END OF PAPER