[ENG 08]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) ELECTRICAL & ELECTRONIC ENGINEERING

EXAMINATION SEMESTER 2 - 2021/2022

RENEWABLE ENERGIES

MODULE NO: EEE6016

Date: Tuesday 17th May 2022 **Time: 10:00 – 12:30**

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).**

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Question 1 A vertical-axis wind turbine has the following specifications:

Generator output power=40 kW, Turbine rotational speed=34 RPM, Gearbox ration=23, blade length=6.5 m, rotor diameter=18 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]**
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 2

(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) Compare between VAWT and HAWT turbines **[5 marks]**

Total 25 marks

Question 3

(a) Explain with drawings the operation of a wind turbine unit connected to the grid. Stating any necessary requirements and conditions. **[10 marks]**

(b) Enumerate the energies available in moving water **[6 marks]**. What is the amount of power **[6 marks]** and energy **[3 marks]** available in falling water in watts and joules respectively where the water falls 5.5 m, the flow is 0.3 m^3/s, the density of water is 1000 kg/ m^3, and the gravitational constant is 9.8 m/s^2.

Total 25 marks

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Question 4

(a) What are fuel cells? For a PEMFC utilising Pt catalysts, what reactions are expected on the cathode and anode side? **[5 marks]**

(b) A typical polarisation curve of a PEMFC is shown in Figure Q4. On the curve, mark out the typical losses expected during the start-up and operation of a PEMFC. Also provide a brief description of the nature of these losses.

[10 marks]

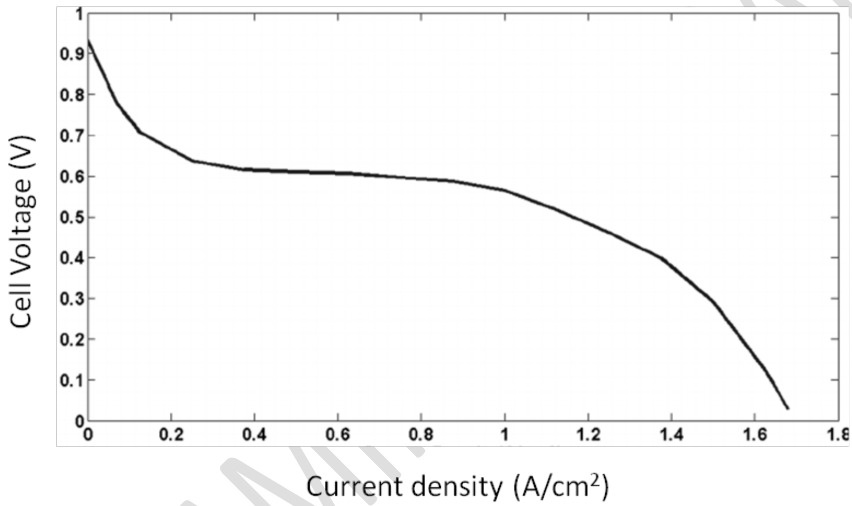

Figure Q4 typical polarisation curve of a PEMFC

(c) Draw and describe the operation of the circuit for conversion of the DC output of a PEMFC to a single-phase AC supply. **[10 marks]**

Total 25 marks

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Question 5

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

The total power usage for the house is 8500 Wh/day. The electricity price is £0.25/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%.

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

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

(b) How many PV modules are needed to meet the requirement of the workshop use?

[7 marks]

(c) How many batteries are needed to meet the requirement of the workshop use?

[7 marks]

(d) 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

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Question 6

a) Assuming the calorific value of H_2 as 11920 kJ/m^3, determine the efficiency of a typical fuel cell which is supplying a current of 3 A at voltage of 1.55V over a period of 70 seconds? During this process, 30 ml of H_2 is being consumed. **[5 marks]**

b) For a PEMFC operating at 100 ^{o}C utilising pure H_2 and O_2 at standard pressure (0.1 MPa), with the underlying process of:

$$H_2 + 1/2O_2 \rightarrow H_2O,$$

the Gibbs free energy of formation per mole, $\Delta\overline{g_f}$ of H_2O is -225.2 kJ/mol. Assuming that the process is entirely reversible, what output voltage can be expected for this PEMFC? **[10 marks]**

c) answer these two questions:

i. What is n-type of semiconductors? How to make a n-type of Si? **[4 marks]**

ii. Explain the principle of a p/n junction? What is the depletion region? **[6 marks]**

Total 25 marks

END OF QUESTIONS

FORMULA SHEET FOLLOWS ON THE NEXT PAGE

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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= $\frac{1}{2}\rho C_t\, ARU^2$

$P_{wind} = \omega.T$

$$I = \sqrt{{i_d}^2 + {i_q}^2}$$

$$P_{in} = \tau_{app}\omega_m \, , \; P_{conv} = \tau_{ind}\omega_m = 3E_A I_A \cos\gamma$$

$$P = \sqrt{3} V_L I_L cos\theta$$

Wind Turbine

$$S = c \cdot H$$

$$S_a = R \cdot L$$

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

$$C_t = C_L sin\alpha - C_d cos\alpha$$

$$C_p = C_t . \frac{\lambda}{R}$$

Permanent Magnet Synchronous machine

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

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

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

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

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

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Energy From water:

$$P = \frac{W}{t} = \frac{mgh_{eq}}{t} = \left(\frac{mg}{t}\right)h_{eq}$$

$$P = \gamma Q_v h_{eq}$$

$$h_{eq} = h + \frac{p}{\gamma} + \frac{v^2}{2g}$$

END OF PAPER