[ENG38]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) ELECTRICAL & ELECTRONICS ENGINEERING

SEMESTER TWO EXAMINATION 2023/2024

RENEWABLE ENERGY

MODULE NO: EEE6016

Date: Wednesday 15th May 2024 **Time: 14:00 – 16:30**

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).**

School of Engineering
B.Eng (Hons) Electrical & Electronics Engineering
Semester 2 Examination - 2023/2024
Renewable Energy
Module No. EEE6016

Question 1

a) Explain how an HAWT-wind turbine rotates when wind blows across its blades. **[2 marks]**
b) Name two advantages of VAWT wind turbines **[2 marks]**
c) What are the main characteristics of HAWT-wind turbine? **[2 marks]**
d) What are the main types of water turbines? and Explain briefly their operation **[8 marks]**
e) Compare between VAWT- and HAWT-turbines **[11 marks]**

Total 25 marks

Question 2

A vertical-axis wind turbine has the following specifications:

Generator output power=40 kW, Turbine rotational speed=34 RPM, Gearbox ratio=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 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 operates in parallel to the grid and generates no reactive power.

Total 25 marks

Question 3

(a) Explain with drawings the operation of a Horizontal Wind turbine unit connected to the grid. Stating any necessary requirements and conditions for constant voltage and frequency. **[10 marks]**

(b) Moving water has kinetic energy that can be converted to useful work directly or by using it to generate electricity. If a water with 0.3 m^3/s flow rate, is falling from 5.5 m height, answer the following:

i. What are the energies available in moving water; **[6 marks]**
ii. What is the amount of power; and **[6 marks]**
iii. Energy available in the falling water where the density of water is 1000 kg/m^3, and the gravitational constant is 9.8 m/s^2. **[3 marks]**

Total 25 marks

Question 4

The Library in the University of Bolton with an average daily energy consumption of 9.5 kWh is planning to install a solar PV system. The location of the library receives an average of 5.5 hours of sunlight per day. The selected solar panels have a capacity of 350Watts each. Answer the following:

a) Draw a schematic diagram of the interconnection of the components that will make up the solar system for this application and name each component and their corresponding function. **[8marks]**

b) Calculate the number of solar panels required for this library. **[4marks]**

c) Determine the AC output and the minimum capacity required for the inverter to be used for this system assuming a D.C power input of 7.5 kW and an inverter efficiency of 85%. **[5marks]**

d) If the library wants to include a battery storage system for backup power during night-time, and they desire 3 days of autonomy with a depth of discharge of 92%, calculate the required battery capacity in kilowatt-hours. **[4marks]**

e) If the overall system efficiency is estimated to be 75% due to losses in wiring, connections, and other factors, recalculate the actual power output of the system. **[4marks]**

Question 5

a. Define a fuel cell and explain the basic principle of its operation. **[7 marks]**

b. Providing a schematic of the Proton Exchange Membrane (PEM) fuel cell, describe the working of a H_2/O_2 fuel cell by providing the electrochemical reactions taking place at the anode and the cathode of the fuel cell. **[7 marks]**

c. A certain fuel cell has a current occupies a volume of 0.05 cubic meters. If 15A of current is being passed into the system over a potential difference of 48V. Calculate the power density of the fuel cell. **[5 marks]**

d. It has been taught that the power output of a fuel cell is a function of the free energy used and the thermodynamics reaction, Draw the electrical equivalent circuit of a fuel cell. **[6 marks]**

Total 25 marks

Question 6

a) Determine the efficiency of a typical fuel cell, which is supplying a current of 2.5A at a voltage of 0.78V over a period of 3minutes? Assuming 35 ml of H_2 is being consumed in this process and the calorific value of H_2 is 11850 kJ/m^3

[5 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 is the **Voc**, **Isc**, Fill-factor and Efficiency in the I-V figure.

[8 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 4 methods that can be used to improve the efficiency of a solar cell.

[4 marks]

Total 25 marks

END OF QUESTIONS

PLEASE TURN PAGE FOR FORMULA SHEETS

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.

Wind Turbine

$$S = c \cdot H$$

$$S_a = r \cdot L$$

$$\omega = \sqrt{\frac{\rho r^2 (SC_t - SC_d - \frac{1}{4} S_a C_{da})}{c + I\ddot{\theta}}}$$

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

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

$$C_t = \frac{C_P}{\lambda}$$

$$W = U\sqrt{1 + 2\lambda cos\theta + \lambda^2}$$

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

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

$$P_{turbine} = \frac{1}{2} \rho C_t\ ARU^2 . \omega_{turbine}$$

PLEASE TURN THE PAGE

Permanent Magnet Synchronous machine

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

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

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

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

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

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

$$P_{in} = \tau_{app}\omega_m \; , \; P_{conv} = \tau_{ind}\omega_m = 3E_A I_A \cos\gamma \; , \; P_{out} = \sqrt{3}\, V_L \, I_L \cos\theta$$

Solar PV CELL

a. $Actual\ system\ output = \frac{Designed\ system\ output}{System\ efficiency}$

b. $Battery\ capacity = \frac{Daily\ Energy\ Consumption \times\ Automomy\ rate}{Depth\ of\ discharge}$

c. $P.D = \frac{Total\ Electrical\ output\ power}{Volume\ of\ fuel\ cell}$

d. $No.of\ Solar\ panels = \frac{Daily\ Energy\ Consumption}{Daily\ Energy\ Production\ per\ Solar\ paneladiance}$

Fuel cell

Efficiency=W_{el}/W_{ch}=(V.I.t)/ V x H_{H2}

END OF FORMULA SHEETS

END OF PAPER