[ESS018]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) ELECTRICAL & ELECTRONIC ENGINEERING

SEMESTER TWO EXAMINATION 2018/2019

RENEWABLE ENERGIES

MODULE NO: EEE6016

Date: Monday 20th May 2019 **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).

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Examination Semester 2 - 2018/2019
Renewable Energies
Module No. EEE6016

Q1

(a) Explain how lift is created when wind blows across the blade of a wind turbine **[5 marks]**

(b) Name two advantages of locating wind turbines over water **[5 marks]**

(c) What are the main differences between Vertical-Axis and Horizontal-Axis wind turbines ? **[5 marks]**

(d) Explain with the aid of diagrams why do we need to convert the AC power of a wind turbine generator to a DC power. **[5 marks]**

(e) Compare between permanent magnet synchronous generators and doubly fed induction generators in wind energy applications **[5 marks]**

Total 25 marks

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Examination Semester 2 - 2018/2019
Renewable Energies
Module No. EEE6016

Q2. A vertical-axis wind turbine has the following specifications:

Nominal turbine power=30 kW, Turbine rotational speed=34 RPM, Gearbox ration=20, blade length=4 m, rotor diameter=16 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 output power of the generator **[4 marks]**
ii) The generator torque and 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 coefficient $C_{turbine}$ 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

PLEASE TURN THE PAGE…..

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Examination Semester 2 - 2018/2019
Renewable Energies
Module No. EEE6016

Q3

a) For a vertical wind turbine whose wind flow velocities vector diagram shown in Fig. Q_3 below,

i) Define the angles θ and α **[4 marks]**

ii) Derive a mathematical relationship between U_{eff} and angle θ **[4 marks]**

iii) Find the maximum angle of attack if the turbine rotor rotates at 35 RPM and the local wind speed is 14 m/s and has 17 metres diameter

[10 marks]

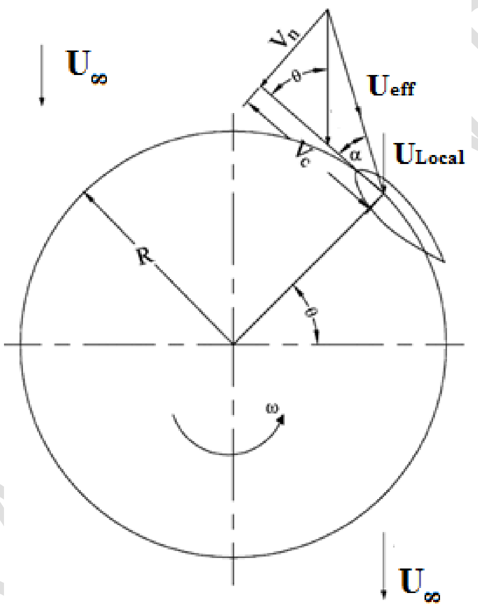

Fig.Q_3 Wind flow velocities vector diagram

Where $v = \omega.R$ the blade tip (tangential) speed vector;
ω= the rotational speed of the rotor;
R= the rotor radius;
θ= the azimuth angle;
U_{local}= local wind velocity vector;
U_{eff} = the effective wind velocity vector;
U_{∞}= the undisturbed wind velocity vector;
α= Angle of attack.

Q3 continues over the page…

PLEASE TURN THE PAGE……

Q3 continued…

(b) A wind turbine whose blades are 14 metres in diameter, its swept area is 175 m^2, air density at sea level is 1.2 kg/m^3, tip speed ratio is 3, and the maximum power coefficient for this turbine is 0.4. Determine:

i) its radius and the wind speed **[4 marks]**

ii) the mechanical torque of this turbine if its rotational speed is 33 RPM **[3 marks]**

Total 25 marks

PLEASE TURN THE PAGE…..

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Examination Semester 2 - 2018/2019
Renewable Energies
Module No. EEE6016

Q4

(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 Fig. Q_4 . 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]

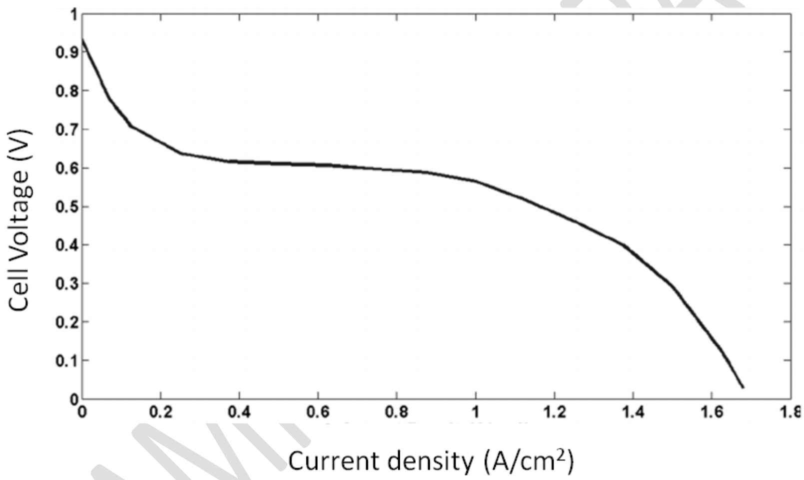

Fig. Q_4 A typical polarisation curve of a PEMFC

Draw then 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

PLEASE TURN THE PAGE…..

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Examination Semester 2 - 2018/2019
Renewable Energies
Module No. EEE6016

Q5

a) Assuming the calorific value of H_2 as 11.92 kJ/m^3, determine the efficiency of a typical fuel cell which is supplying a current of 2A at voltage of 1.65V over a period of 90s? During this process, 32 ml of H_2 is being consumed.

[5 marks]

b) For a PEMFC operating at 100 ^oC 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 meant by life-cycle cost and why is it important in evaluating a solar system?

[4 marks]

ii) Compare a utility solar system with a residential or small commercial system. What are important differences in the types of systems for each?

[6 marks]

Total 25 marks

PLEASE TURN THE PAGE…..

Q6.

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

The total power usage for the house is 8000 Wh/day. The electricity price is £0.25/kWh. Average sunlight is 5hours/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 £180.

Battery on market is rated at 24V, 12Ah, and only 80% of the power can be used. Battery reserve time is 2 days. The price for each battery is £28.

The inverter efficiency is 95%.

The installation of PV panels and all other materials for PV panel installation is £1000.

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 house use? **[7 marks]**

iii) How many batteries are needed to meet the requirement of the house 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

END OF QUESTIONS

PLEASE TURN THE PAGE FOR FORMULA SHEET…

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Examination Semester 2 - 2018/2019
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

Wind Turbine

$$S = c \cdot H$$

$$S_a = R \cdot L$$

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

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

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

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

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

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

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

PLEASE TURN THE PAGE…..

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Examination Semester 2 - 2018/2019
Renewable Energies
Module No. EEE6016

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

$P_{wind} = \omega . T$

Permanent Magnet Synchronous machine

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

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

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

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

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

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

$$i_d = I.sin\delta, \quad v_d = Vsin\delta$$

$$i_q = I.cos\delta\,, \quad v_q = Vcos\delta$$

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

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

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

Faraday's constant = 96485 C

END OF FORMULA SHEET

END OF PAPER