ENG18

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSc in ELECTRICAL & ELECTRONIC ENGINEERING

EXAMINATION SEMESTER 2 - 2022/2023

ADVANCED RENEWABLE ENERGY TECHNOLOGIES

MODULE NO: EEE7008

Date: Thursday 11th May 2023 **Time: 10:00am – 1:00pm**

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) 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) With the aid of diagrams show 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

(a) A certain installation of solar cells requires 36 V and at least 2 kW of rated power. Describe the configuration using 36-cell modules where each module produces 12 Volts and 4 Amperes. **[8 marks]**

(b) A battery backup system is used with a solar PV system. The load uses 6 kWh/day with voltage of 24 V. The battery backup system has 12 batteries; each battery is rated for 6 V at 370 Ah.

I. How are the batteries configured in this system?
II. How many days can the backup system provide backup if the depth of discharge is 50% and the overall efficiency is 95%? **[8 marks]**

(c) Draw a grid-tie inverter block diagram and explain the function of each block and give the reason of using this inverter with solar PV systems. **[9 marks]**

Total 25 marks

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Question 3

A vertical-axis H-type wind turbine has the following specifications: It has a 3-phase Y-connected load 37 kW, 415 V, unity power factor. The turbine rotational speed is 34 RPM, blade length=6 m, rotor diameter=15 m, its tip speed ratio=2. Blade chord line length=0.6 m, Position of the first blade is 30^o. The generator is a 3-phase, 50 Hz, Y-connected Permanent Magnet Synchronous Generator, its phase winding inductance=1.85 mH, phase winding resistance=0.05 Ω , number of magnetic poles=8, generator efficiency=98%, gearbox efficiency=97%. Gearbox ratio is 22.0588. Wind density=1.2 kg/m^3.

Determine:

(a) The input power of the turbine **[3 marks]**
(b) The generator load angle **[4 marks]**

(c) The low-speed shaft torque **[2 marks]**

(d) The quadrature-axis generator current per phase **[2 marks]**

(e) The azimuth angle, attack angle, effective wind speed, torque coefficients C_{t1} and C_{t2} , and the total torque of the two blades. **[14 marks]**

Total 25 marks

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Question 4

(a) Describe with drawings the operation of a Permanent Magnet Synchronous Generator wind turbine unit connected to the grid. Grid code imposes the frequency and voltage of the unit should be constant and consistent with the grid frequency and voltage. Stating any necessary requirements and conditions. **[10 marks]**

(b) A hydroelectric plant has a gate at the spillway of the reservoir to regulate the flow of water downstream. The required range of electric output power of the plant is 120 to 200 MW. If the head of the reservoir is held constant at 36 m, what is the range of flow rates that the gate must maintain if the combined efficiency is 0.9? assume water density of 1000 kg/m^3, and gravity constant of 9.81 m/s^2. **[8 marks]**

(c) Show in steps how to calculate the capacitance to neutral of a 3-core underground cable. **[7 marks]**

Total 25 marks

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:

a) The slip. **[5 marks]**
b) The rotor current referred to stator. **[5 marks]**
c) The no-load current. **[5 marks]**
d) The stator current. **[5 marks]**
e) The output kVA. **[5 marks]**

Total 25 marks

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Question 6

(a) How can renewable sources and water be used to form molecular hydrogen?

[2 marks]

(b) What is the main difference between a phosphoric acid fuel cell PAFC and a proton exchange membrane fuel cell PEMFC? **[3 marks]**

(c) What are the advantages to using distributed power generators? **[3 marks]**

(d) A fuel cell is connected to a load through a single-phase inverter as shown in Figure Q6d. The fuel cell produce a DC voltage of 100 V and the pulse width angle=180° . The fundamental impedances are given on the figure. The load resistor is R_L= 2 Ohms. Calculate:

i. The fundamental load voltage. **[1 mark]**
ii. The worst harmonic distortion factor of the load voltage **[4 marks]**
iii. The percentage load voltage regulation **[4 marks]**
iv. The volt-ampere rating of the inverter switches and the filter **[5 marks]**
v. The efficiency **[3 marks]**

It is assumed that the harmonics above 7^{th} are negligible. The switch resistance is 20 mOhm.

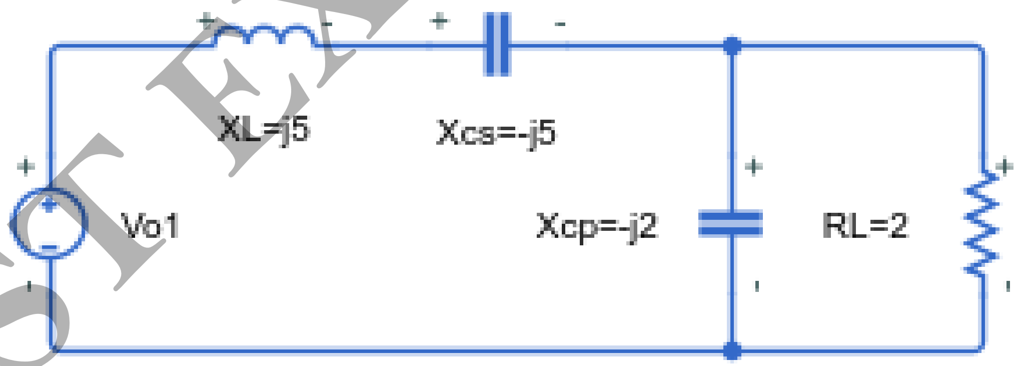

Figure Q6d

Total 25 marks

END OF QUESTIONS

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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.

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

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

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

Faraday's constant = 96485 C

Wind Turbine

Area of Blade=H.C

P_W=0.5Xswept areaXair densityXv_w^3

$P_{wind} = \omega . T$

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

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

$$U_{eff} = U\sqrt{cos^2(\theta \ \ ) + (\lambda + \sin(\theta \ \ ))^2}$$

Permanent Magnet Synchronous machine

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

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

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

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

$$V = \sqrt{{v_d}^2 + {v_q}^2} \ , \ I = \sqrt{{i_d}^2 + {i_q}^2}$$

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

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

$$t_{store} = \frac{(Ah)X(V)X(B_{dod})X(\eta_{inv})}{W_{day}}$$

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