PROGRAM	:	BACCALAUREUS TECHNOLOGIAE *ENGINEERING: ELECTRICAL*
SUBJECT	:	**ELECTRICAL MACHINES IV**
CODE	:	**TEF 441**
DATE	:	SUPPL EXAMINATION / JANUARY 2020 JANUARY 2020
DURATION	:	3 HOURS
WEIGHT	:	40: 60
TOTAL MARKS	:	**100**
FULL MARKS	:	**100**

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MODERATOR	:	DR. L. MASISI
NUMBER OF PAGES	:	5 PAGES

REQUIREMENTS

- STANDARD STATIONARY.
- NO-PROGRAMMABLE CALCULATOR MAY BE USED

INSTRUCTIONS

- READ INSTRUCTIONS CAREFULLY.
- ALL CALCULATIONS AND ANSWERS MUST BE DONE WITH A MINIMUM OF 3 DECIMALS.
- WRITING MUST BE IN BLUE OR BLACK INK PEN ONLY- NO PENCIL WRITING WILL BE MARKED
- WORK NEATLY, UNTIDY WORK MAY BE PENALIZED.
- DRAW A SOLID LINE TO INDICATE THE END OF A QUESTION
- ALL UNITS MUST BE SHOWN-MARKS WILL BE DEDUCTED FOR NO OR WRONG UNITS
- ALL CALCULATIONS MUST BE DONE IN COMPLEX NOTATION AND ANSWERS MUST BE WRITTEN IN POLAR FORM, WHERE APPLICABLE.

SECTION A:
GENERAL INTRODUCTION AND OPERATION OF SYNCHRONOUS MACHINES

QUESTION 1 **[17 Marks]**

1.1 During the short-circuit test of a 250 MVA, 11 kV, 50 Hz, 2-pole, star-connected, turbo-alternator, an excitation current of 100 A circulated the full-load current in the armature winding. On open-circuit, the same excitation current produced the terminal no-load voltage of 12.7 kV (Line). Considering that the effective armature resistance is neglected, and by means of the synchronous impedance method, compute the % full-load voltage regulation for a 0.8 lagging power factor. **(7)**

1.2 The rotor of a 20-pole, 50 Hz, three-phase, star-connected, salient-pole alternator is driven at synchronous speed. The armature winding is housed in 180-slots and has 10 conductors per slot configured in two layers. The coils are spanned by 7/9 of a pole pitch. The magnetic flux is assumed to be sinusoidal and it is found to be 0.067 Wb per pole. Compute the r.m.s value of the line induced e.m.f**.** **(10)**

QUESTION 2 **[13 Marks]**

A 250 kVA, 2.2 kV, 4-pole, 50 Hz, three-phase star connected, round-rotor, synchronous generator has a synchronous impedance of $6.083\angle 80.54^{o}$ Ω/phase and operates at a lagging power factor of 0.8. Compute;

2.1. the induced e.m.f **(5)**
2.2. the developed power **(3)**
2.3. the electromagnetic torque, and **(3)**
2.4. the input mechanical power if rotational and field losses are 3 kW. **(2)**

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SECTION B
APPLICATION AND STABILITY OF SYNCHRONOUS MACHINES

QUESTION 3 **[21 Marks]**

3.1.A three-phase, 4-pole, 50-Hz, 0.44 kV, delta-connected, synchronous motor has a stator impedance of (0.554+j2) Ω/phase. The stator absorbs 24387.275 W at a leading power factor of 0.8. Neglecting the field losses and the rotational loss to be 3 kW, compute:

3.1.1. the back e.m.f (line) and load angle **(3)**
3.1.2. the electromagnetic power and torque **(4)**
3.1.3. the shaft power and torque **(4)**

3.1.4. the efficiency **(2)**

3.2. A 250-MVA, 6.6-kV, 50-Hz, 8-pole, 50-Hz, three-phase, star-connected alternator has a synchronous reactance of 0.2 p.u and is connected to infinite bus. Calculate the synchronizing power and torque per mechanical degree of phase displacement, when operating on full-load with a lagging power factor of 0.8. **(8)**

QUESTION 4 **[9 Marks]**

Discuss the periodic swing of the rotor for the turbo-alternator power-load angle characteristic in **Figure 1**, when the steam is suddenly raised from P_1 to P_2

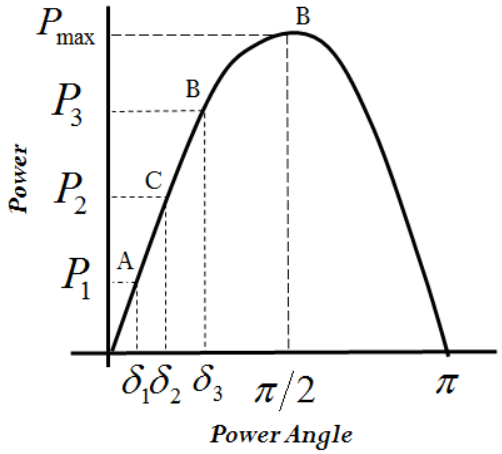

Figure 1: Power-load angle characteristic

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SECTION C:
BASICS OF ELECTRICAL MACHINE DRIVES AND CONTROL

QUESTION 5 **[10 Marks]**

An electronic chopper in **Figure.2** is place between a 750-V and a dc series motor that provides the traction power to passenger trolley-bus. The dc series motor is rated 200-Hp, 1500-rpm, 650-V, 221-A. The dc motor armature resistance and field series resistance are 0.04 Ω and 0.08 Ω respectively. The chopper controls the torque and speed. The chopper frequency varies from 50-Hz to 2-kHz, but the *on* time is fixed at 500-μSec. Compute:

5.1. The chopper frequency and the current drawn from the line when the motor is at standstill and drawing a current of 270-A **(5)**

5.2. The chopper frequency and line current when the motor delivers its rated output. **(5)**

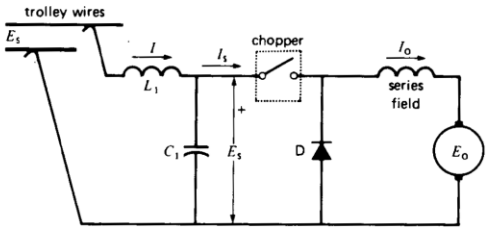

Figure 2: Dc series motor driven by a chopper

QUESTION 6 **[12 Marks]**

A 4-quadrant converter similar to the one shown in **Figure 3** drives a 200 Hp, 250-V, 600-rpm dc motor in voltage variable speed industrial drives. The dc-to-dc converter in **Figure 3** operates at a switching frequency of 2.5-kHz. The converter is fed by a 6-pulse rectifier connected to a 230-V, 3-phase, 50-Hz line. A 400-μF paper capacitor and L_d inductor act like a filter. The dc motor has the following characteristics**:**

- Armature resistance: 12 mΩ
- Armature inductance: 350 μH
- Rated armature current: 620 A

Compute the required on and off times of Q1 and Q4 or Q2 and Q3 respectively, when the dc motor develops its rated torque at rated speed.

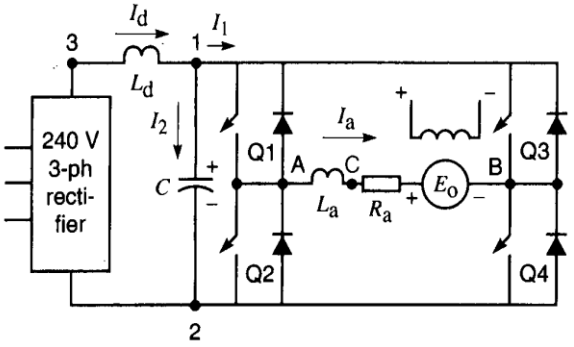

Figure 3: Dc motor controlled by a 4-quadrant dc-to-dc converter.

QUESTION 7 **[8 Marks]**

A 40-Hp, 1165 r. p.m., 460-V, 52-A, 50 Hz, 3-phase squirrel cage induction motor is driven by a current-source frequency converter. The efficiency of motor is 88 % and that of the inverter is 99.4 %. Referring to **Figure 4**, calculate the approximate value of the following:

7.1. The dc power input to converter 2 **(3)**
7.2. The current in the dc link **(2)**

7.3. The dc voltage V_{dc} produced by converter 1 **(3)**

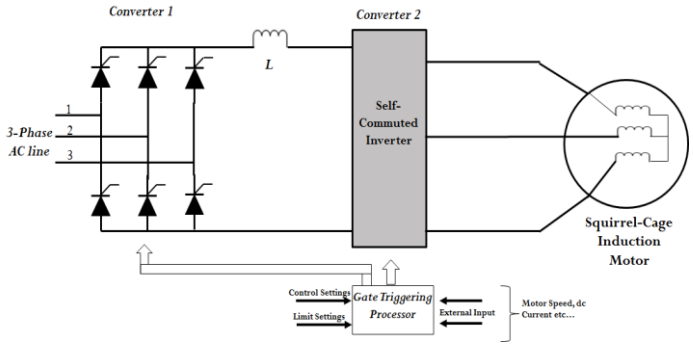

Figure 4: Three-Phase Squirrel Cage Induction Motor Driven by a Current-Fed Frequency Converter

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SECTION D

INTRODUCTION TO GENERALIZED MACHINE AND REFERENCE FRAME THEORIES

QUESTION 8 **[10 Marks]**

A change of variables that formulates a transformation of 3-phase variables of stationary circuit elements to the arbitrary reference frame can be expressed as follows:

$$f_{qd0s} = K_S \; f_{abc}$$

Express $K_S \; and \; (K_S)^{-1}$ in simple matrix equations

[10]

END