University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II EXAMINATIONS
ACADEMIC YEAR 2018/2019

School of Electrical and Electronic Engineering

EEEN20090

Electrical Energy Systems

External Examiner: Prof. Andrew Gibson

Head of School: Prof. Peter Kennedy

Head of Subject: Prof. Federico Milano

Module Coordinator: Prof. Federico Milano *

Time Allowed: 2 hours

Instructions for Candidates

Answer all questions from any three of the five sections.
All question papers **must** be handed up with the answer booklets at the end of the exam.
The distribution of marks in the right margin gives an approximate indication of the relative importance of each part of the question.

Instructions for Invigilators

Non-programmable calculators are permitted.

Student No: _____ **Seat No:** _____

Section A

A symmetrical three-phase Y-connected source has $\bar{V}_{an} = 390\angle 30^\circ$ V.
Using a positive phase sequence abc, find:

1. The phase-to-neutral voltage phasor $\bar{V}_{cn}$. 40%
2. The phase-to-phase voltage phasor $\bar{V}_{bc}$. 20%
3. The phase-to-phase voltage phasor $\bar{V}_{ac}$. 40%

Section B

A magnetic circuit consists of two coils with currents i_1 and i_2, respectively. The total magnetic fluxes depend on the currents i_1 and i_2 and on a position x, as follows:

$$\begin{aligned} \lambda_1(i_1, i_2, x) &= x^2 i_1^2 + x i_2 \\ \lambda_2(i_1, i_2, x) &= x^2 i_2^2 + x i_1 \end{aligned}$$

Determine:

4. The coenergy of the system $W'(i_1, i_2, x)$. 30%
5. The magnetic energy of the system $W(i_1, i_2, x)$. 40%
6. The mechanical force $f(i_1, i_2, x)$ developed by the system. 30%

Section C

A three-phase Y-connected induction motor has the following nominal quantitites: 220 V, 7.5 kW, 60 Hz and 6 poles. The parameters of the equivalent circuit of the motor are (all expressed in Ω per-phase):

$$\begin{aligned} R_1 &= 0.294 \qquad R_2' = 0.144 \\ X_1 &= 0.503 \qquad X_2' = 0.209 \qquad X_\mu = 13.25 \end{aligned}$$

Determine:

7. The magnitude of the rotor current I_2', the torque T and the total mechanical power P_2 if the slip factor is $\sigma = 0.03$. 50%
8. The maximum torque $T_{\max}$ that the motor can develop at nominal voltage. 25%

9. The start-up torque T_{su} and the magnitude of the start-up current $I_{1,\text{su}}$ in the stator at nominal voltage. 25%

Section D

A three-phase synchronous machine is connected to a network through a transmission line (see the single-line diagram shown in Figure 1). The Thevenin equivalent voltage and reactance of the network are $\bar{V}_{\text{Th}} = 20$ kV and $0.3\ \Omega$ per-phase, respectively. The synchronous reactance of the machine is $X_s = 2.5\ \Omega$ per-phase, while the series reactance of the line is $X_L = 1\ \Omega$ per-phase.

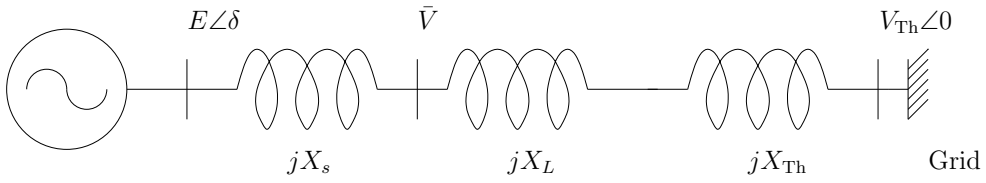

Figure 1 Synchronous machine connected to a network.

Determine:

10. The maximum active power $P_{\max}$ that the machine can supply to the network if the internal emf E of the machine is 25 kV. 30%

11. The active power P generated by the machine at $\delta = 10^\circ$ and the phasor of the phase-to-neutral voltage $\bar{V}$ at the terminal bus of the machine. 40%

12. The voltage regulation $\Delta V_{\%}$ between the terminal bus voltage and the network in the operating conditions of Question 11 and the reactive power Q generated by the machine. 30%

Section E

A balanced three-phase source supplies power to three loads connected in parallel. The three loads are:

- Load 1: 30 kVA at 0.8 pf lagging
- Load 2: 24 kW at 0.6 pf leading

- Load 3: unknown

If the line voltage and total complex power at the point of connection of the loads are 208 V and $120\angle 0$ kVA, respectively, determine:

13. The active and reactive power (P_3 and Q_3) of load 3. 50%

14. The voltage $\bar{V}_F$ of the feeder and the current $\bar{I}_L$ in the line, if the line impedance that connects the feeder to the loads is $0.02 + j0.05\ \Omega$ per-phase. 50%

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