University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SPRING, 21/22 TRIMESTER EXAMINATIONS

EEEN20090

Electrical Energy Systems

Module Coordinator: Professor Federico Milano

Student Number

Seat Number

Time Allowed: 120 minutes

Material Permitted in the Exam Venue:
Non-programmable calculators are permitted.

Material to be Supplied to Students:
None

Instructions to Students:
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.

Section A

The circuit shown in Figure 1 has $\bar{V}_{ab} = 400\angle 30°$ V.

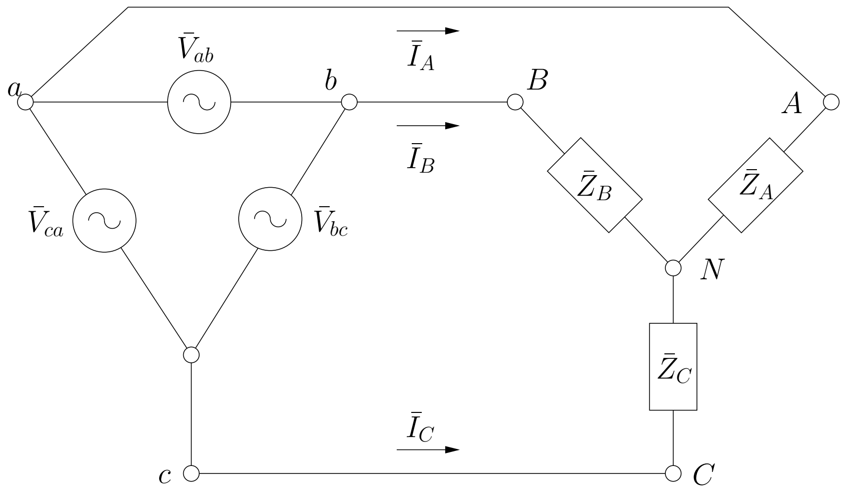

Figure 1

Calculate the line currents ($\bar{I}_A$, $\bar{I}_B$, $\bar{I}_C$) and the complex power ($\bar{S}$) delivered by the voltage source in the following scenarios:

1. Symmetrical voltages and balanced impedances, with $\bar{Z}_A = 9 + j12\ \Omega$. 50%
2. Symmetrical voltages and unbalanced impedances, with $\bar{Z}_A = 9 + j12\ \Omega$, $\bar{Z}_B = 9\ \Omega$ and $\bar{Z}_C = 9 - j12\ \Omega$. 50%

Section B

A rotating electrical machine with a coil on the stator and a coil on the rotor has the following inductances: $L_{11} = 0.1$ H (stator), $L_{22} = 0.04$ H (rotor) and $L_{12} = 0.05\cos(\theta)$ H, where θ is the relative angle between the axis of the stator and the rotor windings.

3. Assume that the rotor rotates at constant speed $\omega = 200$ rad/s and that the current circulating in the stator is $i_1 = 10\sin(200t)$ A. Determine the emf induced in the rotor if the rotor winding is left in open circuit. 50%

4. Assume that the rotor is connected in series with the stator and the current is $i_1 = i_2 = 10\sin(200t)$ A. Determine the angular speed ω of the rotor for which the average torque is not equal to zero. 50%

Section C

A 50-Hz, six-pole, Y-connected wound-rotor induction motor is rated 5 kW, 230 V (line to line). The ratio between stator and rotor voltages is 4. The equivalent circuit parameters are:

$$R_1 = 0.5\ \Omega \qquad R_2 = 0.025\ \Omega$$
$$X_1 = 0.7\ \Omega \qquad X_2 = 0.05\ \Omega \qquad X_\mu = 50\ \Omega$$

Note that R_2 and X_2 are the values measured on the rotor.
The motor is operating with slip of 0.035. Determine:

5. Stator complex power ($\bar{S}_1$) and power factor ($\cos\phi_1$). 50%

6. The maximum electromagnetic torque ($T_{\max}$), the current corresponding to the maximum electromagnetic torque ($I_{\max}$) and the start-up current (I_{start}). 50%

Section D

The synchronous impedance of a three-phase synchronous generator is $0 + j10\ \Omega$. The machine is connected to grid. Its terminal line voltage is $11,000$ V and its stator current is 220 A with unity power factor. From these operating conditions, the internal emf is increased by 25% while keeping the mechanical power and the stator voltage constant. Determine:

7. The stator current magnitude (I_s) and phase angle (ϕ_s) after the emf increase. 50%

8. The maximum active power ($P_{\max}$) that the machine can generate with the increased emf as well as the stator current magnitude ($I_{s\,\max}$) and phase angle ($\phi_{s\,\max}$) at the maximum power. 50%

Section E

A balanced 13.8 kV three-phase source supplies power to three loads connected in parallel through a line with negligible impedance. The three loads are:

- Load 1: 420 kVAr at 0.8 pf lagging
- Load 2: $1,000$ kVA at 0.5 pf lagging
- Load 3: 800 kVA at 0.9 pf lagging

Determine:

9. The current magintude I_S and the power factor $(\cos\phi_S)$ at the source. 50%

10. The value of the Δ-connected capacitors (C) that are required to change the overall power factor at the source to 0.92 lagging. 50%

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