NATIONAL UNIVERSITY OF SINGAPORE

EE2029 – Introduction to Electrical Energy Systems

(Semester 1 : AY2020/2021)

Time Allowed : 2 Hours

INSTRUCTIONS TO STUDENTS

1. Please write only your Student Number. Do not write your name.
2. This assessment paper contains **FIVE** questions and comprises **SIX** printed pages.
3. Students are required to answer **ALL** questions.
4. Students should write the answers for each question on a new page.
5. This is an **OPEN BOOK** assessment.
6. Non-programmable electronic calculators are allowed.

Section A [50 marks]

Q.1

(a) A balanced three-phase voltage source has negative phase sequence. What will be the V_{ca} (line) voltage if the V_{bn} voltage is 220 ∠60° V?

(5 marks)

(b) A balanced three-phase system with positive phase sequence has line-to-line voltage of 415V. A delta connected load has each phase impedance equal to Z_{Δ}= 300+ j 300 Ω. What is the phasor for line current I_a if V_{ab} is taken as reference?

(5 marks)

(c) A purely resistive lamp draws 100W power when connected to an AC single phase supply of 110V and 50 Hz. The lamp is then connected in series with a purely inductive element of same impedance as the resistance of the lamp. The combined circuit (lamp in series with inductor) is now connected to a 220V single phase source of 50Hz. What will be the real power consumed by the lamp and inductor combination with the 220V supply?

(5 marks)

(d) An inductive load is made of a series combination of R=30 Ω and X_L=30Ω. The load is connected to a single-phase AC supply of 230V/50Hz. What is the value of capacitance required to be connected in parallel to the load, if the combined power factor seen by the source is to be 0.9 lagging?

(5 marks)

(e) Three single-phase loads are connected in parallel to an AC source of 230 V / 50 Hz. The power drawn by the loads are specified as follows:

Load 1 draws an apparent power of 200 VA with a power factor of 0.8 lagging.

Load 2 draws real power of 100 W and reactive power of 100 Var.

Load 3 draws a real power of 100 W with a power factor of 0.9 leading.

What is the total complex power drawn from source?

(5 marks)

(f) A three-phase synchronous generator is connected to three-phase grid with terminal line-to-line voltage of 415 V. The generator's armature resistance is negligible and its per-phase synchronous reactance is 5 Ω. The generator is supplying real power of 3000 W at power factor of 0.8 lagging to the grid. If

the field excitation is maintained and the real power supplied by the grid is doubled to 6000 W, what will be the new power factor seen at the grid?

(5 marks)

Q.2 Answer the following question as TRUE/FALSE. Each question is worth 2 marks.

i. In a series RLC load, the supply frequency is set at a value higher than the resonance frequency. The resulting circuit will draw power at a leading power factor.

ii. The real power output of the grid-connected generator is usually controlled by adjusting the field excitation.

iii. Two balanced three-phase loads are connected in parallel across a balanced three-phase source. One is a delta-connected load whereas the other is a wye-connected load. The complex power drawn by both loads are of same value. The line current drawn by the delta connected load is higher than the line current drawn by the wye-connected load.

iv. In the per phase equivalent circuit for a synchronous generator, the synchronous reactance represents the armature reaction only.

v. In a synchronous generator connected to the grid, the internal excitation voltage magnitude can be lower than the grid voltage for leading power factor.

vi. A balanced three-phase delta-connected load with a lagging power factor is connected in parallel to a balanced three-phase source. If a wye-connected inductor is added in parallel across the load, the overall power factor seen the source will be higher.

vii. According to convention, the reactive power drawn by a capacitor is negative whereas the reactive power drawn by inductor is positive.

viii. An over-excited synchronous generator supplies reactive power to the grid whereas an under-excited synchronous generator will absorb reactive power from the grid.

ix. A parallel RLC circuit at resonance will have maximum effective impedance.

x. A series R-L-C load connected to an AC source has 50V(RMS) drop across each of the R, L and C part, respectively. The source voltage must be 150V(RMS).

(20 marks)

SECTION B [20 Marks]

Q.3

There are ten multiple-choice questions, and each are worth two marks. Read each question carefully and select ONE of the options. Incorrect answers are NOT negatively marked.

i. The primary transmission line parameter that is associated with the magnetic flux linkage is:
(a) Resistance
(b) Capacitance
(c) Inductance
(d) Conductance

ii. Underground cables can be best modelled by
(a) Resistance only
(b) Resistance and inductance
(c) Inductance only
(d) Resistance and capacitance

iii. The percentage of voltage regulation is a measure of how well the transformer can
(a) maintain the secondary voltage given a constant primary voltage
(b) regulate the output frequency given a constant supply
(c) regulate the output power factor given a constant supply
(d) All of the above

iv. A transformer cannot transform
(a) Current
(b) Voltage
(c) Voltage and current
(d) Frequency

v. A constant DC voltage is fed to a step-up transformer. Which statement best describes the result?
(a) Transformer generates stepped up DC voltage
(b) Transformer generates stepped up AC voltage with same RMS value
(c) Transformer undergoes magnetostriction loss
(d) Transformer overheats

vi. The power factor of the transformer during the short-circuit test will be
(a) Close to zero lagging
(b) Close to zero leading
(c) Close to unity lagging
(d) Close to unity leading

vii. The effective reactance of a conductor depends on
(a) Geometric placement of conductors only
(b) Geometric placement of conductors and transposition only
(c) Geometric placement of conductors, transposition, and grid frequency only
(d) None of the above

viii. The slip of an induction motor normally does NOT depend on:
(a) Rotor speed
(b) Synchronous speed
(c) Shaft torque
(d) Core loss component

ix. Current is supplied to an induction motor through
(a) Windings on the rotor side
(b) Windings on the stator side
(c) Air-gap
(d) None of the above

x. When the rotor of three-phase induction motor runs at synchronous speed, the value of slip is
(a) zero
(b) above 1
(c) between 0 and 1
(d) below 0

SECTION C [30 Marks]

Q.4

Consider a 100 km three-phase overhead transmission line rated at 220 kV, 50 Hz. Lines are symmetrically transposed. Answer the following:

(a) The three-phase transmission line has three-equilaterally spaced conductors of ACSR *Dove* with a conductor radius of 0.957 cm. If the conductors are 3m apart from each other, determine the per-phase line reactance of the line in Ω/km.

(4 Marks)

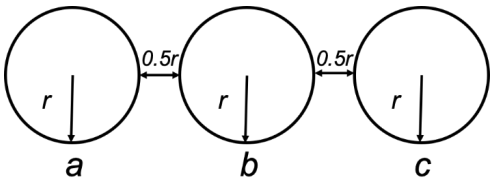
(b) Calculate the *ABCD* constants of the nominal medium-line circuit having a per-phase line impedance of 0.01 + j0.38 Ω/km. The per-phase shunt admittance is j0.1 x 10^{-6} S/km.

(4 Marks)

(c) A three-phase load of 50 MW at 0.95 lagging power factor is connected at the receiving-end at $210\angle 0°$ kV. Using the constants found in part (b), compute the percentage of voltage regulation and the transmission efficiency.

(8 Marks)

(d) The three-phase line is now buried underground in the configuration shown in figure below. Derive the GMR and GMD of the three-phase line in terms of radius *r*.



(4 Marks)

Q.5

A three-phase induction motor runs at 988 rpm at no load, and 902 rpm at full load when supplied from a three-phase, 50 Hz source. The equivalent-circuit parameters per-phase referred to the stator are $R_1 = 0.22\ \Omega$; $R_2 = 0.207\ \Omega$; $X_1 = 1.95\ \Omega$; $X_2 = 2.42\ \Omega$; $X_m = 45.7\ \Omega$.

(a) What is the slip in percent at full load?

(3 Marks)

(b) What is the corresponding frequency of the rotor currents at full load?

(2 Marks)

(c) What is the speed of the rotor field with respect to the rotor at full load?

(2 Marks)

Identify and determine the change(s) in the equivalent-circuit parameter(s) which will result from the following proposed design modifications. Consider each modification separately.

(d) Replace the stator winding with an otherwise identical winding with a wire size whose cross-sectional area is increased by 10%.

(1 Mark)

(e) Replace the aluminum rotor bars (3.5×10^7 mΩ/m) with copper bars (5.8×10^7 mΩ/m).

(1 Mark)

(f) Reconnect the stator winding, originally connected in wye-connection, in a delta-connection.

(1 Mark)

END OF PAPER