UNIVERSITY OF ESWATINI

MAIN EXAMINATION, SECOND SEMESTER

MAY/JUNE 2019

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Power Systems

COURSE CODE: EEE452/EE452

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. There are five questions in this paper. Answer any FOUR questions. Each question carries 25 marks.
2. If you think not enough data has been given in any question you may assume any reasonable values.

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THIS PAPER CONTAINS SIX (6) PAGES INCLUDING THIS PAGE

QUESTION ONE ***(25 marks)***

(a) State the major reasons for the use of three-phase power systems. [2]

(b) Explain the difference between a balanced Three-phase system and an unbalanced three-phase system. What conditions typically cause a poly-phase system to become unbalanced? [2]

(c) Fig. Q.1 shows a Y-connected three-phase generator (with the rotor winding shown):

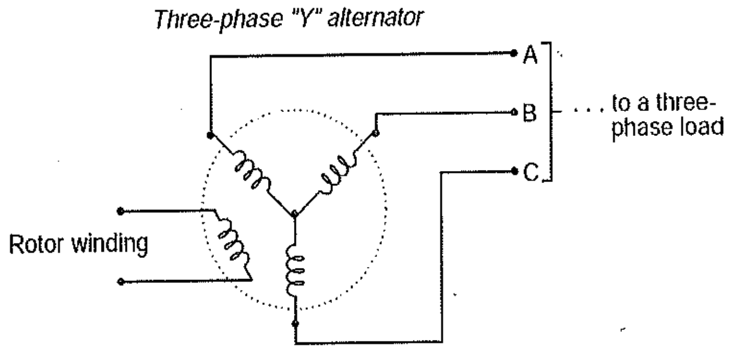


Fig Q. 1

(i) How much AC voltage will appear between any two of the lines (V_{AB}, V_{BC}, or V_{AC}) if each stator coil inside the alternator outputs 277 volts? [2]

(ii) Draw a phasor diagram showing how the phase (winding) and line voltages relate. [4]

(d) A balanced, star-connected load of phase impedance 50 Ω and power factor 0.85 lagging is supplied from the delta-connected secondary of a 3-phase star-delta transformer. The turn's ratio of the transformer is 20:1, and the star-connected primary is supplied at 66 kV.

Draw the circuit described in (d), label and determine the following:

i. Primary phase voltage, secondary line voltage and load phase voltages as V_1 , V_2 and V_3 respectively [6]

ii. Primary line currents, secondary phase current and load phase current as I_1, I_2, and I_3 respectively. [6]

iii. The power drawn from the supply. [3]

QUESTION TWO ***(25 marks)***

A three phase, 50Hz overhead line 200km long has a resistance of 0.16 Ω/km, a conductor diameter of 2cm with spacing of 4m , 5m and 6m transposed and supplying a 50 MVA load at 132kV with 0.8 pf lagging.

Find:

(a) The ABCD constants [12]

(b) V_s, I_s, PF_s *and* P_s [8]

(c) Efficiency of the Transmission line [2]

(d) The receiving end voltage regulation [3]

N.B Assume π model of transmission line

QUESTION THREE ***(25 marks)***

(a) Figure Q.3 shows the schematic of a reversing asynchronous motor, study the schematic, assuming the motor is moving in forward direction can it motor reverse without stopping? Why discuss? [4]

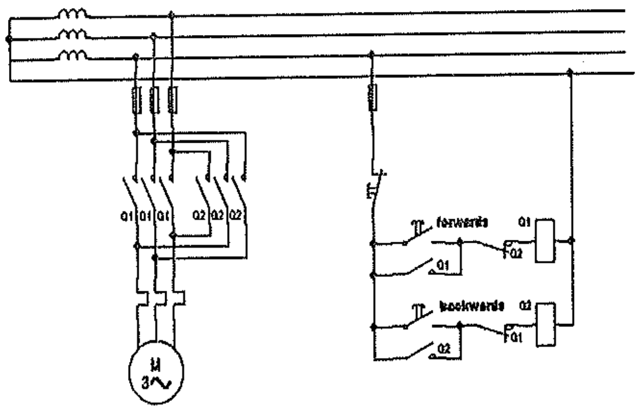


Fig Q.3

(b) Can a wattmeter that has current through its current coil and a potential across its voltage coil, indicate zero? Explain. [3]

(c) Two watt-meters indicate *100kW* and *30kW* respectively when connected to measure the input power to a 3-phase balanced load, the *reverse switch being operated on* the meter indicating the 30kW reading. Determine

(i) the input power [2]

(ii) the load power factor [4]

(d) Consider balanced loads connected to three phase 415 V supply system , the loads consisting of:

- 100 kW of lighting at unity power factor
- A motor taking 120 kVA at 0.85 p.f lagging
- A number of small motors taking 150 kW at 0.6 p.f lagging.

Determine:

(i) Total Power (kW) [3]

(ii) Total reactive power (kVar) [3]

(iii) Overall kVA [2]

(iv) Overall Power factor [2]

(v) Line current [2]

QUESTION FOUR *(25 marks)*

(a) Discuss the following terms as used in power plant engineering.

- (i) Demand factor. [2]
- (ii) Load factor. [2]
- (iii) Diversity factor [3]

(b) What is meant by the term phase rotation sequence, in a three-phase electrical system and how the phase rotation sequence of a three-phase system is typically denoted? [2]

(c) What is the phase rotation sequence of the following set of voltages? [3]

$$V_a = 240\cos(\omega t + 24^\circ) \quad V$$
$$V_b = 240\cos(\omega t + 144^\circ) \quad V$$
$$V_c = 240\cos(\omega t - 96^\circ) \quad V$$

(d) Discuss the advantages and disadvantages of an Open delta transformer configuration. [5]

(e) A periodic, sinusoidal voltage given by $V(t) = \sqrt{2}\,[200\sin(\omega t) + 40\sin(5\omega t + 55^\circ)]$ is applied to a series, linear, resistance-inductance load of resistance 4Ω and fundamental frequency reactance 10Ω. Calculate :

- (i) THD_V [1]
- (ii) THD_I [3]
- (iii) Power factor [4]

QUESTION FIVE *(25 marks)*

(a) A 25 MVA, 11 kV, three-phase generator has a sub-transient reactance of 20%. The generator supplies two motors over a transmission line with a transformers at both ends as shown in the figure below. The motors have rated inputs of 15 and 7.5 MVA, both 10 kV with 25 % sub-transient reactance. The three-phase transformers are both rated 30 MVA, 10.8/121 kV, connection delta-wye with leakage reactance of 10% each. The series reactance of the line is 100 ohms.

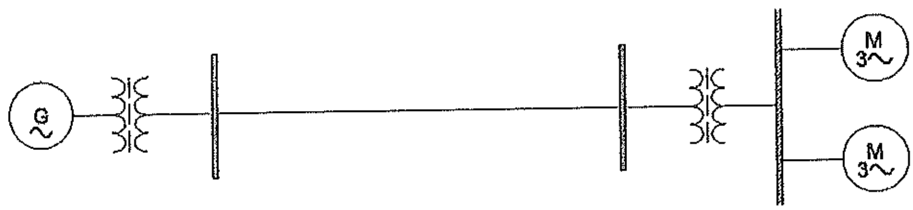
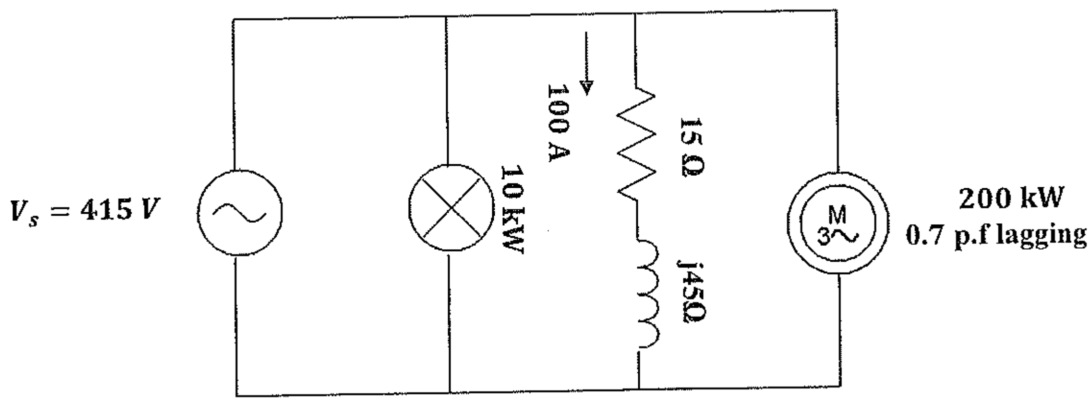


Fig. Q.5

Draw the positive and negative sequence networks of the system with reactance's marked in per unit. [15]

(b) An industrial client is charged a penalty of E 2500 per 0.1 p.f deviation per annum, if the plant power factor drops below 0.85 and will be compensated E 1000 per 0.1 p.f deviation per annum if the plant power factor is above 0.85. The equivalent plant loads are as shown below:



(i) What type of tariff is described in (a)? [1]

(ii) Calculate the annual penalty charges for this plant? [9]

Useful Formulae

Transmission line Constants

Parameter	A = D	B	C
Units	p.u.	Ω	S
Short Line G = C = 1	1	Z	0
Medium G = 0 (π *Model*)	$1+\frac{YZ}{2}$	Z	$Y\left(1+\frac{YZ}{2}\right)$
Long Line (*Length l Equivalent* π *Model*)	$\cosh(\gamma l) = 1+\frac{Y'Z'}{2}$	$Z_C\sinh(\gamma l) = Z'$	$\frac{1}{Z_C}\sinh(\gamma l) = Y\left(1+\frac{Y'Z'}{4}\right)$
	$\cos(\beta l)$	$jZ_C\sin(\beta l) = X'$	$\frac{j\sin(\beta l)}{Z_C}$

Equivalent π model of long line:

$$Z' = Z_C\sinh(\gamma l) = Z\frac{sinh(\gamma l)}{\gamma l}$$

$$\frac{Y'}{2} = \frac{1}{Z_C}\tanh\left(\frac{\gamma l}{2}\right) = \frac{Y}{2}\frac{tanh\left(\frac{\gamma l}{2}\right)}{\frac{\gamma l}{2}}$$

Equivalent π model of lossless line:

$$Z' = jX' = jZ_C sin(\beta l)$$

$$\frac{Y'}{2} = j\frac{sin(\beta l)}{Z_C}$$

Hyperbolic Identities

$$cosh(j\beta) = cos(\beta)\quad, sinh(j\beta) = jsin(\beta)\quad, tanh(j\beta) = jtan(\beta)$$

For lossless function

$$Z_C = \sqrt{\frac{L}{C}}\ \ \Omega,\quad \beta = \omega\sqrt{LC}\ \frac{rad}{m}\qquad v = \frac{1}{\sqrt{LC}}$$

NB. L is inductance per unit length.

For a lossy line

$$Z_C = \sqrt{\frac{z}{y}}\quad ,\qquad \gamma^2 = yz$$

$L = \frac{\mu_0}{2\pi} ln\left(\frac{GMD}{GMR_L}\right)$ H/m per conductor $\mu_0 = 4\pi x10^{-7}\ H/m$ or $1.2566x10^{-6}\ H/m$

$C_{an} = \frac{2\pi\varepsilon_0}{ln\left(\frac{GMD}{GMR_C}\right)}$ F/m to neutral $\varepsilon_0 = 8.854x10^{-12}$ F/m