University of Glasgow

Degrees of BEng in Engineering

POWER ENGINEERING 3 (UESTC3005)

2016

Attempt all questions. The total number of possible marks is 100.

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

An electronic calculator may be used provided that it does not have a facility for either textual storage or display, or for graphical display.
If a calculator is used, intermediate steps in the calculation should be indicated.

Continued Overleaf

Q1 Consider the single-phase AC circuit shown in Figure Q1.

(i) The current $i(t)$ can be written in the form $i(t) = I_m \cos(\omega t + \varphi)$ A, determine the values of I_m and φ. [4]

(ii) Calculate the average power dissipation P_{avg} (W) in the circuit, and explain where the power is dissipated. [4]

(iii) Construct a phasor diagram showing input voltage $v(t)$ and current $i(t)$ [2].

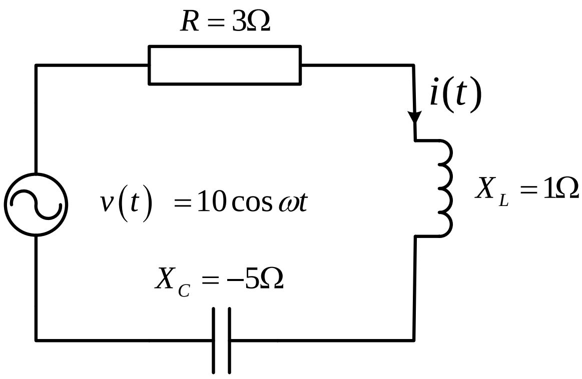

Figure Q1

Continued Overleaf

Q2 (a) A balanced delta connected load of $(3 + j4)\ \Omega$ is connected to a 3-phase 380V/50Hz (line RMS voltages) power supply shown in Figure Q2.

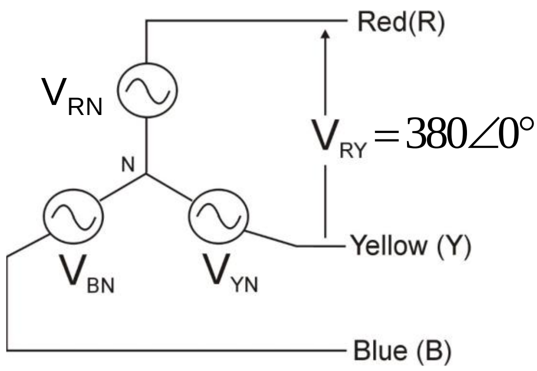

Figure Q2

Draw the circuit diagram and from this:

(i) Calculate the three line currents (I_R, I_Y and I_B). [3]

(ii) Construct a phasor diagram showing all line voltages (V_{RY}, V_{YB} and V_{BR}) and phase voltages (V_{RN}, V_{YN} and V_{BN}). [6]

(b) An unbalanced delta connected load consisting of Z_{RY} (3+j4)Ω, Z_{YB} (4+j3)Ω and Z_{BR} (5+j0)Ω is connected to a 3-phase 380V/50Hz (line RMS voltages) power supply. Draw the circuit diagram including the implementation of a two-wattmeter power measurement and from this:

(i) Calculate the three load phase currents (I_{RY}, I_{YB} and I_{BR}). [3]

(ii) Calculate the three line currents (I_R, I_Y and I_B). [3]

(iii) Calculate the three load phase power consumptions (W) [3]

(iv) Determine the total supply power (W) using the two-wattmeter measurements. [3]

(v) Construct a phasor diagram showing the three line voltages (V_{RY}, V_{YB} and V_{BR}), the three load phase currents (I_{RY}, I_{YB} and I_{BR}) and the three line currents (I_R, I_Y and I_B). [9]

Continued Overleaf

Q3 (a) Given the equivalent circuit parameters shown on Table Q3 for a 220V/15V single phase transformer, draw the equivalent circuit and determine the following for a 2Ω resistive load connected to the secondary terminals:

(i) Output load voltage (V) [2]
(ii) Output load current (A) [2]
(iii) Output load power (W) [2]
(iv) Transformer losses (W) [2]
(v) Efficiency (%) [2]
(vii) Voltage Regulation (%) [2]

Parameter	Value
R_c	5kΩ
X_M	500Ω
R_{1eq}	20 Ω
X_{1eq}	5 Ω

Table Q3

(b) Determine the necessary load resistance for operation at the theoretical maximum efficiency point for the single-phase transformer in question Q3(a).

[4]

(c) A three phase ΔY transformer bank is rated 11kV/2.75kV and delivers 330kVA to a balanced delta connected load at rated voltage. Assuming an ideal transformer, calculate the following:

(i) Bank Ratio and Phase Ratio. [2]
(ii) The magnitudes of the secondary line currents [2]
(iii) The magnitudes of the primary line currents [2]
(iv) The magnitudes of the currents in the primary coils [2]

(d) Construct a phasor diagram showing all primary phase voltages and secondary line voltages for the three-phase transformer in question Q3(c) .

[6]

Continued Overleaf

Q4 (a) No Load and Locked Rotor tests are performed on a 6 pole 3 phase star connected induction motor with the results shown on Tables Q4a and Q4b respectively. Calculate all the equivalent circuit components indicating what each component represents. Note that power (*W*) measurements are per phase powers.

[10]

No Load Test:

Parameter	Value
V_{ph}	220V
I_{ph}	1A
P_{ph}	80W

Table Q4a

Locked Rotor Test:

Parameter	Value
V_{ph}	16V
I_{ph}	16A
P_{ph}	200W
R_s	0.4Ω

Table Q4b

(b) The per phase equivalent circuit parameters for a 3 phase, 4 pole star connected induction machine operating off a 220V (phase RMS voltages), 50 Hz supply is shown on Table Q4c. <u>Assuming that friction and windage losses are negligible,</u> determine the following for operation at 1350rpm:

(i) The slip (%) [2]
(ii) The output power (W) [2]
(iii) The motor torque (Nm) [2]
(iv) All motor losses (W) [2]
(v) The motor efficiency (%) [2]

Parameter	Value
X_M	30Ω
R_c	120Ω
R_s	0.2Ω
R_r	0.2Ω
X_{eq}	1.0Ω

Table Q4c

Q5 A star connected 3 phase wound field synchronous generator with a synchronous reactance (Xs) of 3.5Ω is connected to a 6.6kV (line) grid and supplies 3MW at 0.9 lagging power factor at its terminals. Calculate the phase current and resultant voltage (V_{XS}) across the synchronous reactance, and determine the required excitation voltage (E_{ph}) and load angle (δ).

[10]

End of Question Paper