Cork Institute of Technology

Higher Certificate in Engineering in Electrical Engineering - Award

(NFQ Level 6)

Summer 2007

Electrical Engineering

(Time: 3 Hours)

Attempt **Five** Questions.

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Q1. (a) An impedance of (1.665+j10.9) Ω is connected in series with two impedances of (12-j9) Ω and (8+j6) Ω, which are in parallel. Calculate the magnitude and power factor of the main current when the combined circuit is supplied at 30 V. Find also the voltage across each impedance. (

(b) The load taken from an a.c. supply consists of: (i) a load of 30kW at 0.85 power-factor lagging; (ii) a motor load of 20kVA at 0.6 power-factor lagging; (c) a load of 15kW at 0.75 power-factor lagging.

Calculate the total load from the supply in kW and kVA and its power-factor. (7 marks)

(c) What would be the kVAr rating of a capacitor to bring the power-factor to 0.95 lagging and how would the capacitor be connected? (3 marks)

Q2. (a) Explain the advantage of connecting the low-voltage winding of distribution transformers in star. (5 marks)

(b) A factory has the following load with power factor of 0.85 lagging in each phase. Red phase 40 A, yellow phase 45 A and blue phase 60 A. If the supply is 400 V, three-phase, four-wire, calculate the current in the neutral and the total power. (15 marks)

Q3. (a) Give an expression for the time constant of a circuit consisting of a capacitor C in series with a resistor R.

A resistor is connected in series with a capacitor across a 200 V d.c. supply.

What is the voltage across the capacitor after one time constant? (5 marks)

(b) A 10 μF capacitor is connected in series with a 100 kΩ resistor across a 1000 V supply. To what voltage is the capacitor charged when the charging current has decreased to 80% of its initial value? (6 marks)

(c) What is the time taken for the current to decrease to 40% of its initial value? (4 marks)

(d) What is the voltage across the resistor after 3 s? (5 marks)

Q4. (a) With the aid of a circuit diagram show that two wattmeters can be connected to read the total power in a three-phase, three-wire system. (5 marks)

(b) Two wattmeters connected to read the total power in a three-phase system supplying a balanced load read 25 kW and 20 kW respectively. Calculate the total power and the power factor of the load. (10 marks)

(c) Explain the significance of: (i) equal wattmeter readings, and (ii) a zero reading on one wattmeter. (5 marks)

Q5. (a) Explain with a circuit diagram how the short-circuit test is performed on a single phase transformer. What information can be got from the short-circuit test? (5 marks)

(b) A single-phase transformer is rated at 1.8 kVA, 240 V/120 V. When the secondary terminals are open-circuited and the primary winding is supplied at normal voltage (240 kV), the power taken is 18 W. When the secondary terminals are short-circuited, the power required to circulate full load current in the short-circuited secondary is 24 W. Calculate: (a) the efficiency of the transformer at full load, unity power factor; (b) the load at which maximum efficiency occurs; (c) the value of the maximum efficiency.

(15 marks)

Q6. (a) Describe the construction of the stator and slip ring rotor of a three-phase induction motor. Why is the motor provided with slip rings? (8 marks)

(b) A three-phase, 50 Hz induction motor with its rotor star-connected gives 300 V at standstill between the slip rings on open circuit. Calculate the current and power factor at standstill when the rotor winding is joined to a star-connected external resistance of 8 Ω per phase. The resistance per phase of the rotor winding is 0.8 Ω and its inductance is 0.03 H. Also calculate the current and power factor when the slip rings are short-circuited and the motor is running with a slip of 3%. Assume the flux to remain constant. (15 marks)

Q7. (a) Explain why a starter is needed with a d.c. shunt-wound motor. Where in the circuit would the starter be connected? (5 marks)

(b) A shunt-wound motor has a field resistance of 400 Ω and an armature resistance of 0.2 Ω and runs on a 240 V supply. The motor takes a current of 1.2 A on no-load and the no-load speed is 3500 r/min. When the motor is loaded the armature current is 32 A.

Assuming that armature reaction weakens the field by 2%, calculate the speed of the motor at full load. (

(c) Give two different ways by which the speed of a shunt motor might be varied and comment on the advantages of each method. (5 marks)

Useful Formulae

Parallel Circuit

Two Impedances in Parallel $Z_T = \frac{Z_1 Z_2}{Z_1 + Z_2}$

Only when Z_1 and Z_2 are expressed in complex form.

Transients in RC-Networks

Time Constant $T = RC$ (s)

Charging
Growth of voltage across a capacitor

$$v_c = V\left\{1 - e^{\frac{-t}{RC}}\right\} \quad \text{(V)}$$

$$i = \frac{V}{R} e^{\frac{-t}{RC}} \quad \text{(A)}$$

Discharging

$$v_c = V\left\{e^{\frac{-t}{RC}}\right\} \quad \text{(V)}$$

$$i = \frac{V}{R} e^{\frac{-t}{RC}} \quad \text{(A)}$$

Three-Phase

Unbalanced Load $P_T = P_1 + P_2 + P_3$ (W)

Power Factor Correction $Cap.kVAr = kW(Tan\theta_2 - Tan\theta_1)$

Power Factor $= \frac{TruePower}{ApparentPower}$

Reactive Power $= VISin\theta$ (VArs)

True Power $= VICos\theta$ (W)

Apparent Power $= VI$ (VA)

Two Wattmeter Method

Total Power $W_1 + W_2$ (W)

$$Tan\theta = \sqrt{3}\frac{W_1 - W_2}{W_1 + W_2}$$

The Transformer

$$\frac{OutputPower}{OutputPower + IronLosses + CopperLosses} x100\%$$

The Three-Phase Induction Motor

Synchronous speed N_s = 60f/p (r/min)

f = frequency
p = pairs of poles

Per Unit Slip $s = \frac{N_s - N_r}{N_s}$

Rotor Speed $N_r = N_s(1-s)$ (r/min)

Rotor Frequency $f_r = sf$

Rotor EMF per phase at standstill E_r (V)

Rotor Reactance per phase at standstill X (Ω)

Rotor Current per phase at standstill $I_r = \frac{E_r}{\sqrt{R^2 + X^2}}$ (A)

Rotor Power Factor at standstill $Cos\theta = \frac{R}{\sqrt{R^2 + X^2}}$

At Slip s

Rotor EMF per phase at slip s sE_r (V)

Rotor Reactance per phase at slip s sX (Ω)

Rotor Current per phase $\frac{sE_r}{\sqrt{R^2 + (sX)^2}}$ (A)

Rotor Power Factor $\frac{R}{\sqrt{R^2 + (sX)^2}}$

DC Machines

D.C. Motor

$$E_b = V - I_a R \quad \text{(V)}$$

$$N = K \frac{V - I_a R}{\phi} \quad \text{(r/min)}$$

$$E_b = KN\phi$$