higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T550**(E)**(A7)T

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

7 August 2019 (X-Paper)
09:00–12:00

This question paper consists of 5 pages and a formula sheet of 4 pages.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
ELECTROTECHNICS N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Sketches must be large, neat and fully labelled.
5. Write neatly and legibly.

QUESTION 1: DC MACHINES

1.1 A series motor is running on a 440 V circuit with a regulating resistance of R ohms connected in series for speed adjustment.

The armature and field coils have a total resistance of 0,3 Ω. On a certain load with R = zero ohms the current is 20 A and the speed is 1 200 r/min.

With another load, and R = 3 Ω, the current is 15 A. Assume the field strength at 15 A to be 80% of that at 20 A.

Calculate the following:

1.1.1 New speed (6)

1.1.2 Ratio of the two values of the power output of the motor (2)

1.2 State TWO main advantages and TWO disadvantages of the Swinburne method used to determine the efficiency of a DC machine. (4)

1.3 State ONE condition under which a DC machine may work at maximum efficiency. (2)

[14]

QUESTION 2: AC CIRCUIT THEORY

2.1 Name TWO devices used for improving or correcting a power factor. (2)

2.2 A voltage, $e = 250 \sin(\omega t) + 50 \sin(3\omega t + \pi/3) + 20 \sin(\omega t + 5\pi/6)$, is applied to a series circuit with a resistance of 20 Ω and an inductance of 0,05 H.

Calculate each of the following:

2.2.1 Expression for the current (4)

2.2.2 r.m.s. value of the current (2)

2.2.3 r.m.s. value of the voltage (2)

2.2.4 Total power supplied (2)

2.2.5 Power factor (2)

[14]

QUESTION 3: TRANSFORMERS

A 50 kVA, 4 400/220 V transformer has R_1 = 3,45 Ω and R_2 = 0,009 Ω. The reactance values are X_1 = 5,2 Ω and X_2 = 0,015 Ω.

Calculate each of the following:

3.1 Equivalent secondary resistance as referred to the primary (4)

3.2 Equivalent secondary reactance as referred to the primary (2)

3.3 Total equivalent primary resistance and reactance (4)

3.4 Total equivalent primary impedance (2)

3.5 Total copper loss, first using individual resistances of the TWO windings and secondly, using equivalent resistances as referred to each side (4)
[16]

QUESTION 4: AC MACHINES – ALTERNATORS

4.1 Explain, with the aid of a neat diagram, how an open-circuit test is carried out on a three-phase star-connected alternator. (5)

4.2 A three-phase 11 kV star-connected alternator has an armature resistance of 0,25 ohms per phase and a synchronous reactance of 3 ohms per phase.

Calculate the percentage regulation for a load of 2 000 kW at a power factor of 0,8 lagging. (9)
[14]

QUESTION 5: AC MACHINE – SYNCHRONOUS MOTORS

5.1 Explain, with the aid of phasor diagrams, how the power factor of a synchronous motor working on a constant mechanical load depends on its excitation. (6)

5.2 A 5 kVA 400 V three-phase 50 Hz star-connected synchronous motor is fully loaded and draws 3,5 kW at a leading power factor. The machine has a percentage impedance of (4 + j40) %.

Calculate the following:

5.2.1 Power factor (1)

5.2.2 Resistive and reactive volt drops (3)

5.2.3 EMF to which the machine is excited (3)

5.2.4 Load angle in electrical degrees (1)
[14]

QUESTION 6: AC MACHINE – INDUCTION MOTORS

6.1 Explain *plugging* as used in motor control. (2)

6.2 Name the TWO main parts of an AC motor. (2)

6.3 The input of a six-pole three-phase 50 Hz induction motor is 45 kW at a speed of 950 r/min. The stator losses of the motor are 1 kW and the friction and windage losses are 1,5 kW.

Calculate each of the following:

6.3.1 Slip (3)

6.3.2 Rotor copper loss (4)

6.3.3 Output of the motor (2)

6.3.4 Full-load efficiency (1)
[14]

QUESTION 7: GENERATION AND DISTRIBUTION OF AC

A 3-phase transmission line delivers 75 MVA at 132 kV and 50 Hz, with a lagging power factor of 0,8.

Each conductor has a resistance of 0,28 ohms per km per phase, an inductive reactance of 0,63 ohms per km per phase and a capacitance to neutral of 0,03 μF.

Use the π method and calculate the voltage, current and power factor at the sending end of a 100 km long transmission line.

NOTE: Draw the π-method circuit diagram. **[14]**

TOTAL: 100

ELECTROTECHNICS N6

FORMULA SHEET

DC MACHINES

$$E = V - Ia\ Ra$$

$$\frac{E_1}{E_2} = \frac{N_1\ \Phi_1}{N_2\ \Phi_2}$$

$$\frac{T_1}{T_2} = \frac{I_1\ \Phi_1}{I_2\ \Phi_2}$$

SPEED CONTROL

$$E = V - Ia\left(\frac{R\ Rse}{R + Rse} + Ra\right)$$

$$E = V - Ia\ Ra - Ise\ Rse$$

TESTING DIRECT METHOD

$$\eta = \frac{2\pi Nr\ (W - S)}{60\ IV}$$

SWINBURNE METHOD

$$\underset{motor}{\eta} = \frac{IV - (Ia^2 Ra + Ia_o\ V + Is\ V)}{IV}$$

$$\underset{generator}{\eta} = \frac{IV}{IV + Ia^2\ Ra + Ia_o\ V + Is\ V}$$

HOPKINSON EFFICIENCIES THE SAME

$$\eta = \sqrt{\frac{I_1}{I_1 + I_2}}$$

IRON LOSS

$$= I_2\ V - \left\{(I_1 + I_3)^2\ Ra + (I_1 + I_2 - I_4)^2\ Ra + (I_3 + I_4)\ V\right\} = C$$

$$\underset{generator}{\eta} = \frac{I_1\ V}{I_1 V + (I_1 + I_3)^2\ Ra + I_3\ V + \frac{C}{2}}$$

$$\underset{motor}{\eta} = \frac{(I_1 + I_2)\ V - \left\{(I_1 + I_2 - I_4)^2\ Ra + I_4\ V + \frac{C}{2}\right\}}{(I_1 + I_2)\ V}$$

AC LOADS
STAR SYSTEMS

$\overline{V}rn$ = *REFERENCE*

R-Y-B SEQUENCE

$$\overline{I}_R = \frac{V \underline{|o°}}{Z_{RN} \underline{|\phi_1}}$$

$$\overline{I}_y = \frac{V \underline{|-120°}}{Z_{YN} \underline{|\phi_2}}$$

$$\overline{I}_B = \frac{V \underline{|120°}}{Z_{BN} \underline{|\phi_3}}$$

$$\overline{I}_N = \overline{I}_R + \overline{I}_B + \overline{I}_Y$$

BALANCED CIRCUIT

$$\overline{I}n = 0$$

DELTA-SYSTEMS

$$\overline{I}_{RY} = \frac{\overline{V}_{RY}}{\overline{Z}_{RY}} \quad \overline{I}_R = \overline{I}_{RY} - \overline{I}_{BR}$$

$$\overline{I}_{YB} = \frac{\overline{V}_{YB}}{\overline{Z}_{YB}} \quad \overline{I}_Y = \overline{I}_{YB} - \overline{I}_{RY}$$

$$\overline{I}_{BR} = \frac{\overline{V}_{BR}}{\overline{Z}_{BR}} \quad \overline{I}_B = \overline{I}_{BR} - \overline{I}_{YB}$$

THREE-WIRE SYSTEMS

$$V_{sn} = \frac{\frac{\overline{V}_{an}}{\overline{Z}_1} + \frac{\overline{V}_{bn}}{\overline{Z}_2} + \frac{\overline{V}_{cn}}{\overline{Z}_3}}{\frac{1}{\overline{Z}_1} + \frac{1}{\overline{Z}_2} + \frac{1}{\overline{Z}_3}}$$

$$\overline{V}_{aN} = \overline{V}_{aS} + \overline{V}_{sN}$$
$$\overline{V}_{bN} = \overline{V}_{bS} + \overline{V}_{sN}$$
$$\overline{V}_{cN} = \overline{V}_{cS} + \overline{V}_{sN}$$

$$\overline{I}_a = \frac{\overline{V}_{aS}}{\overline{Z}_1}$$

$$\overline{I}_B = \frac{\overline{V}_{bS}}{\overline{Z}_2}$$

$$\overline{I}_C = \frac{\overline{V}_{cS}}{\overline{Z}_3}$$

COMPLEX WAVE FORMS

$$e_1 = E_m \; Sin \; \omega t$$
$$e_2 = K_2 \; E_m \; Sin \; 2 \; \omega t$$
$$e_3 = K_3 \; E_m \; Sin \; 3 \; \omega t$$

$$e = E_m\ (Sin\ \omega t + k_2\ Sin\ 2\ \omega t + k_3\ Sin\ 3\ \omega t)$$

$$P = \frac{E_m^2 1 + E_m^2 2 + E_m^2 3 + ... + E_m^2 N}{2R}$$

$$P = \left(I_m^2 1 + I_m^2 2 + I_m^2 3 + ... + I_m^2 N\right) R$$

$$I = \sqrt{\frac{I_m^2 1 + I_m^2 2 + ... + I_m^2 N}{2}}$$

$$E = \sqrt{\frac{E_m^2 1 + E_m^2 2 + ... + E_m^2 N}{2}}$$

$$Cos\ \phi = \frac{I^2\ R}{E\ I} = \frac{\frac{E^2}{R}}{E\ I}$$

TRANSFORMERS

$$\eta = \frac{S\ Cos\ \phi}{S\ Cos\ \phi + Po + Psc}$$

Any value of load
at k of full-load

$$\eta = \frac{k\ S\ Cos\ \phi}{k\ S\ Cos\ \phi + Po + k^2\ Psc}$$

MAXIMUM EFFICIENCY

$$K = \sqrt{\frac{Po}{Psc}}$$

$$\eta = \frac{k\ S\ Cos\ \phi}{k\ S\ Cos\ \phi + Po + k^2\ Psc}$$

FORMULAE

$$\%\ R = \frac{I\ \mathrm{Re}}{V}$$

$$\%\ X = \frac{I\ Xe}{V}$$

$$\%\ Z_e = \%\ R_e + j\ \%\ X_e$$

$$V_{SC} = I\ Z_e$$

$$P_{SC} = I^2\ R_e$$

$$Cos\ \phi_e = \frac{P_{SC}}{I_1\ V_{SC}}$$

$$Reg = \frac{V_{SC}\ Cos\ (\phi_e \pm \phi_2)}{V}$$

$$Reg = \frac{I\ Z\ Cos\ (\phi_e \pm \phi_2)}{V}$$

$$Reg = \frac{I\ (\mathrm{Re}\ Cos\ \phi_2 \pm Xe\ Sin\ \phi_2)}{V}$$

AC MACHINES
ALTERNATORS

$$n = \frac{f}{p}$$

$$Kd = \frac{Sin\,\frac{n\alpha}{2}}{n\ Sin\,\frac{\alpha}{2}}$$

$$Kp = Cos\,\frac{\psi}{2}$$

$$E = 2\ Kf\ \ Kd\ \ Kp\ \ f\ \ \Phi\ Z$$

$$E = \sqrt{(V\ Cos\ \phi + IR)^2 + (V\ Sin\ \phi \pm IX}$$

$$E = V + IR\ Cos\ \phi \pm IX\ \ Sin\phi$$

$$\overline{E} = E\,\underline{|\,\phi} + IR\,\underline{|\,o} + Ix\,\underline{|\,90}$$

$$Reg = \frac{E - V}{V}$$

SYNCHRONOUS MOTOR

$$\overline{V} + \overline{E} = \overline{E}_R \qquad \overline{E}_R = \overline{IZ}$$

$$\overline{E} = V\,\underline{|-\phi} + IR\,\underline{|\,180^\circ} + IX\ \underline{|-90^\circ}$$

INDUCTION MOTOR

$$\frac{Eo}{V_1} = \frac{Zr}{Z_s} \qquad E_2 = SEo$$

$$X_2 = SXo \qquad I_2 = \frac{E_2}{Z_2}$$

$$Z_2 = \sqrt{R_2^2 + (SXo)^2} \qquad Io = \frac{Eo}{Zo}$$

$$Zo = \sqrt{R_2^2 + Xo^2}$$

$$I_2 = \frac{SEo}{\sqrt{R_2^2 + (SXo)^2}} \qquad Io = \frac{Eo}{\sqrt{R_2^2 + Xo^2}}$$

MAXIMUM EFFICIENCY

$$R_2 = SXo$$

Rotor copper loss = S rotor input

$$S = \frac{N_1 - N_2}{N_1}$$

$$P = \sqrt{3}\,V_L\ I_L\ Cos\ \phi$$

$$KVA = \sqrt{3}\,V_L\ I_L$$