higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T490**(E)**(A8)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

8 April 2016 (X-Paper)
9:00–12:00

This question paper consists of 5 pages and 1 formula sheet of 5 pages.

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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. Round off ALL calculations to THREE decimal places.
5. Use the correct symbols and units.
6 Start each question on a NEW page.
7. Keep subsections of questions together.
8. ALL circuit diagrams and vector diagrams must be at least one third of a page and must be fully labelled.
9. Write neatly and legibly.

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QUESTION 1

1.1 Draw and explain the operation of a Ward-Leonard control system, controlling the speed and direction of a large DC shunt motor. (7)

1.2 A 250 V, DC series motor runs at 1 000 r/min while drawing a current of 40 amperes from the supply. The resistances of the armature and series field are 0,25 ohms and 0,1 ohms respectively.

Calculate the speed at which the motor will run if a 0,2 ohm resistor is connected in parallel with the field coils. Assume that there is a 20% increase in the torque and that the field coils are unsaturated. (2)

1.3 Draw TWO fully labelled circuit diagrams used to solve QUESTION 1.2, clearly showing the current flow in both diagrams. (10)
[19]

QUESTION 2

An alternating voltage represented by the expression; $v = 30 \sin (314t + 25^{\circ}) + 10 \sin (942t - 30^{\circ})$ is applied to a resistor of 180 ohms in parallel with a capacitor of 25 micro-farads.

Determine:

2.1 An expression for the instantaneous value of current (8)

2.2 The power factor of the circuit. (State the nature of the power factor.) (5)

2.3 The energy dissipated in the circuit in 10 milli-seconds (1)

2.4 Draw a large vector diagram clearly showing the voltages and currents for the fundamental as well as the harmonic component. (2)
[16]

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QUESTION 3

3.1 State TWO constant losses occurring in a transformer and state precisely where each occurs. (4)

3.2 A 250 kVA, 3 300/240 V, single-phase transformer produces a maximum efficiency of 92% at 80% of full load.

Calculate for a power factor of 0,85 lagging:

3.2.1 The iron losses (2)

3.2.2 The full-load copper losses (2)

3.2.3 The percentage resistance (4)

3.2.4 The per unit full-load voltage regulation of the transformer when it works at unity power factor (2)

[14]

QUESTION 4

4.1 What do you understand by the distribution factor of a synchronous alternator? (3)

4.2 The following information applies to a three-phase, star-connected alternator:

Open-circuit terminal emf = 3,3 kV
Frequency = 50 Hz
Speed = 1 000 r/min
Number of slots/pole/phase = 4
Coil span = 150˚
Useful flux per pole = 55 milli-webers

Calculate the possible number of conductors per slot. (12)

[15]

QUESTION 5

A 380 V, 50 Hz, three-phase, star-connected synchronous motor has an induced emf of 500 volts. The synchronous impedance of the motor is (1,5 + j 4,8) ohms per phase. For a load angle of 25 degrees electrical, calculate:

5.1 The current drawn by the motor (7)

5.2 The power output of the motor if its efficiency is 85% (3)

5.3 Draw a fully labelled vector diagram that you would use to solve this example. (2)

[12]

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QUESTION 6

A 525 V, 6 pole, 50 Hz, three-phase, delta-connected induction motor develops 28 kW when running at a speed of 950 r/min. The rotor iron loss is negligible and the frictional loss in the bearings is 800 watts. For a power factor of 0,8 lagging, calculate:

6.1 The percentage slip at which the motor is operating (2)

6.2 The rotor copper loss (2)

6.3 The power input to the motor if the total losses occurring in the stator amounts to 1 080 watts (2)

6.4 The current drawn from the supply (2)

6.5 The efficiency of the motor (3)
[11]

QUESTION 7

A large industrial consumer takes 1 MVA at a power factor of 0,75 lagging. To reduce maximum demand, a capacitor bank was installed and the overall power factor was improved to 0,9 lagging.

Determine:

7.1 The size of the capacitor bank (5)

7.2 The cost of the capacitor bank if it sells for R295 per kVA (2)

7.3 How many months it will take to pay off the capacitor bank using only the savings in maximum demand charges? Assume that the consumer pays a maximum demand charge of R132 per kVA. (4)

7.4 Draw a neat, fully labelled vector diagram clearly showing the maximum demand before and after the installation of the capacitor bank (2)
[13]

TOTAL: 100

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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

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

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

HOPKINSON EFFICIENCIES THE SAME

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

IRON LOSS

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

$$= C$$

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

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

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AC LOADS
STAR SYSTEMS

$$\bar{I}_R = \frac{V \angle o°}{Z_{RN} \angle \phi_1}$$

R-Y-B VOLGORDE
SEQUENCE

$$\bar{I}_y = \frac{V \angle -120°}{Z_{YN} \angle \phi_2}$$

$$\bar{I}_B = \frac{V \angle 120°}{Z_{BN} \angle \phi_3}$$

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

BALANCED CIRCUIT

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

DELTA-SYSTEMS

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

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

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

THREE-WIRE SYSTEMS

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

$$\bar{V}_{aN} = \bar{V}_{aS} + \bar{V}_{sN}$$

$$\bar{V}_{bN} = \bar{V}_{bS} + \bar{V}_{sN}$$

$$\bar{V}_{cN} = \bar{V}_{cS} + \bar{V}_{sN}$$

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

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

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

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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

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

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

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FORMULAE

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

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

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

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

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

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

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

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

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

AC MACHINES
ALTERNATORS

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

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

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

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

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

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

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

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

SYNCHRONOUS MOTOR

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

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

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IINDUCTION 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

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

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

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

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