higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T430**(E)**(N28)T

NOVEMBER EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

28 November 2016 (X-Paper)
09:00–12:00

REQUIREMENTS: Graph paper

Calculators may be used.

This question paper consists of 6 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. Keep subsections of questions together.
5. Round ALL calculations off to THREE decimal places.
6. Use the correct symbols and units.
7. Start each question on a NEW page.
8. ALL circuit 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 A shunt motor is a constant-speed motor, but its speed can be changed.

Explain how the speed of this motor can be:

1.1.1 Increased above its normal speed

1.1.2 Decreased below its normal speed

(2 × 2) (4)

1.2 A DC series motor operating at full load rotates at 800 r/min.

The speed of the motor has to be increased to 1 000 r/min by inserting a diverter resistance across the series field. The series field has a resistance of 0,25 ohms. The change in speed is to be achieved without changing the current drawn from the supply. Assume that the resistive volt drops are negligible and also that the field system is unsaturated. (7)

Your answer must include two large circuit diagrams clearly showing all the currents for the two different conditions. (2)
[13]

QUESTION 2

2.1 A 380 V, three-phase, unbalanced star-connected load takes the following:

R – N : 20 A at a power factor of 0,6 lagging
Y – N : 4,95 kW at a power factor of 0,9 leading
B – N : 3,8 kVA at a power factor of 0,8 leading

Taking V_{RN} as reference and assuming a phase sequence of R-Y-B, calculate the current in the neutral conductor. (7)

Your answer must include the vector diagram that you used to solve this problem. Show ALL relevant angles. (3)

2.2 A series circuit consists of a resistor of 25 ohms, an inductor of 20 millihenrys with negligible resistance and a variable capacitor. This circuit is supplied by an emf described by the equation: $e = 220 \sin(314t + 20°) + 60 \sin(942t - 30°)$. The circuit is made to resonate at the frequency of the harmonic component by varying the capacitance of the capacitor.

Determine for this resonant condition the value to which the capacitor is set. (4)
[14]

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QUESTION 3

3.1 Explain why transformers are rated in kVA and not in kW? (3)

3.2 A 200 kVA single-phase transformer operating at a power factor of 0,9 lagging produces an efficiency of 95% at both full load as well as half-full load.

Determine the following:

3.2.1 The iron and full-load copper losses of the transformer (7)

3.2.2 The maximum efficiency of the transformer at a power factor of 0,9 lagging (4)

[14]

QUESTION 4

4.1 The pitch factor of an alternator is also known as coil span factor or as chording factor.

Explain what is meant by pitch factor. (3)

4.2 Two similar three-phase, star-connected alternators operate in parallel to supply a common load. Each machine has a synchronous impedance of 0,15 + j 4 ohms per phase. The machines are excited so as to generate an emf of 3 300 V each. The machines have a phase displacement of 30° electrical relative to each other.

Calculate the following:

4.2.1 The current that circulates between the two machines (5)

4.2.2 The terminal voltage of the machines (3)

4.2.3 The power supplied by the one machine to the other (2)

Your solution must be accompanied by a vector diagram clearly showing $E_{(A)}$, $E_{(B)}$, $E_{(R)}$ and the load angle. (2)

[15]

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QUESTION 5

5.1 A three-phase induction motor can rotate in both directions.

State how the direction of rotation of this motor can be reversed. (2)

5.2 A 380 V, three-phase, four-pole 50 Hz induction motor has a delta-connected stator. The rotor impedance at standstill is 0,15 + j 0,9 ohms per phase. Take the stator-to-rotor turns ratio to be 3: 1.

Calculate for a full-load speed of 1 400 r/min the following:

5.2.1 The full-load torque produced by the motor (8)

5.2.2 The maximum torque that the motor can produce (4)

5.2.3 The speed at which maximum torque occurs (2)

Hint: $T_1 = T_m \left[\frac{2.S_1.(R_2)^2}{[\,(R_2)^2 + (S_1R_2)^2\,]\,S_m} \right]$ **[16]**

QUESTION 6

6.1 A poor power factor is not economical.

State TWO popular methods that can be used to improve the power factor of a plant (factory). (2)

6.2 A small power consumer has a single-phase, 220 V, 50 Hz supply. The plant has a resistive load of 8 kW and a 12 kW induction motor which operates at an efficiency of 80% and a power factor of 0,7 lagging.

Calculate the following:

6.2.1 The consumer's maximum demand charge if charged at R140 per kVA (6)

6.2.2 The overall power factor of the plant

State the nature of the power factor. (2)

Your solution must include a fully labelled vector diagram that you used to solve this example. (2)
[12]

QUESTION 7

An overhead transmission line delivers a three-phase load of 30 MW at 132 kV, 50 Hz and a power factor of 0,8 lagging. Each conductor has a resistance of 20 ohms, an inductive reactance of 65 ohms and a total capacitance to neutral of 1,6 microfarad.

Calculate using the nominal π method:

7.1 The sending end voltage (10)

7.2 The sending end current (2)

7.3 The sending end power factor (2)

Your solution must include a neat, fully labelled circuit diagram. (2)
[16]

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

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

R-Y-B SEQUENCE

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

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

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

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

BALANCED CIRCUIT

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

DELTA-SYSTEMS

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

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

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

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

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

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

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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

$$R_2 = SXo$$

Rotorkoperverlies = S rotorinset
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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