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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T480(E)(J28)T
AUGUST EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

(8080085)

28 July 2014 (Y-Paper)
13:00–16:00

Calculators may be used.

This question paper consists of 6 pages and 2 formula sheets.

ENGINEERING

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
ELECTROTECHNICS N5
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. Write neatly and legibly.

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QUESTION 1

1.1 Briefly explain how you would change the direction of rotation of a DC motor. (2)

1.2 A DC motor can be self-regulating due to back EMF.

Briefly discuss this statement. (4)

1.3 An eight-pole generator has a lap-connected armature with 640 conductors. The ratio of the pole arc per pole pitch is 0,8.

Calculate the ampere-turns per pole of a compensating winding to give uniform air gap density when the total armature current is 960 A. (4)

1.4 An 88 kW, 540 V shunt generator has 1 800 turns on each pole of its field winding. On no-load a current of 9A in the field winding produces a terminal voltage of 540 V, but on full-load the shunt current has to be increased to 12 A for the same terminal voltage at the same speed.

Calculate the number of series field turns per pole required for level compounding. (8)

1.5 Name the practical applications of lap and wave windings in DC machines. (2)
[20]

QUESTION 2

2.1 The following ordinates were taken during a half cycle of a symmetrical alternating current wave. The current varies in a linear manner between successive points:

Phase angle in degrees	0	30	60	90	120	150	180
Current in amperes	0	12,6	24,4	31	29	24,4	0

Determine the following without plotting the graph:

2.1.1 The mean value (5)

2.1.2 The RMS value (3)

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2.2 A resonant circuit comprising of a coil of inductance 650 µH and a resistance of 60 ohms in parallel with a variable capacitor, is connected in series with a resistor of 9 900 ohms. The supply across this circuit is 80 V, with a frequency of 1, 5 MHz.

Calculate the:

2.2.1 Value of the capacitor at resonance (4)

2.2.2 Impedance of the parallel circuit (2)

2.2.3 Current in each branch (4)
[18]

QUESTION 3

3.1 Name FOUR methods of reducing leakage flux in transformers. (4)

3.2 Two single-phase transformers are connected in parallel to a load of 900 A, at a power factor of 0,8 lagging.

Test data:

Open-circuit: 12 000/2 800 V for each transformer

Short-circuit with high voltage winding short-circuited:

Transformer A: secondary input 400 V, 450 A, 30 kW

Transformer B: secondary input 250 V, 450 A, 35 kW

Calculate the:

3.2.1 Voltage secondary (10)

3.2.2 Output and power factor of transformer A (3)

3.2.3 Output and power factor of transformer B (3)
[20]

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QUESTION 4

4.1 The input power to a 3 350 V three-phase delta connected induction motor is 180 kW. The power factor of the motor is 0, 85 lagging.

Calculate the:

4.1.1 Line and phase currents (2)

4.1.2 Input power readings on the TWO watt-meters (5)

4.1.3 kVA rating of the motor (2)

4.2 A three-phase transmission line supplies a 2,45 MW star-connected load, having a power factor of 0,8 lagging at a line voltage of 36 kV.

The line has a resistance of 90 ohms per phase and an inductive reactance of 160 ohms per phase.

Calculate the:

4.2.1 Voltage at the sending end (6)

4.2.2 Regulation (5)

4.2.3 Efficiency of the line (2)
[22]

QUESTION 5

5.1 Does an induction motor develop torque when running at synchronous speed?

Discuss the reason for your answer. (4)

5.2 TWO similar three-phase, star-connected alternators are operating in parallel. Each machine has a synchronous reactance of 6,5 Ω per phase and negligible resistance, and is excited to generate an EMF of 2 675 V per phase. The machines have a phase displacement of 30 electrical degrees relative to each other.

Calculate the:

5.2.1 Circulating current (5)

5.2.2 Terminal voltage per phase (2)

5.2.3 Power supplied from ONE machine to another. (3)

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5.3 A star-connected, three-phase alternator, runs at a speed of 1 500 r/min, and has to generate a voltage of 800 V at 50 Hz on open circuit. The stator has two slots per pole per phase and four conductors per slot.

Assume all the conductors per phase to be series connected and coils to be full-pitched. kd = 0,96

Calculate the:

5.3.1 Number of poles (2)

5.3.2 Useful flux per pole (4)
[20]

TOTAL: 100

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ELECTROTECHNICS N5

FORMULA SHEETS

Armature ampere-turns/pole $= \frac{1}{2} \cdot \frac{I_a}{C} \cdot \frac{Z}{2P}$

$$E = V \pm I_a R_a$$

$$E = \frac{2pNZ\Phi}{60c}$$

$$T = 0{,}318 \frac{I_a}{c} ZP\Phi$$

$$k = n\sqrt{\frac{R_1}{r_m}}$$

$$r_1 = R_1\left[\frac{k-1}{k}\right]$$

$$r_1 = R_s \frac{1-y}{1-y^m}$$

$$R_1 = bR_1\,(k-1) \times \frac{1-b^n}{1-b} + r_m$$

$$y = \frac{I_2}{I_1}$$

$$r_1 = bR_1\,(k-1)$$

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

$$\frac{T_1}{T_2} = \frac{K\Phi_1 I_{a1}}{K\Phi_2 I_{a2}}$$

$$I_{ave/gem} = \frac{i_1 + i_2 + i_3 + \ldots i_n}{n}$$

$$I_{rms/wgk} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 + \ldots + i_n^2}{n}}$$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f = \frac{1}{2\pi L}\sqrt{\frac{L}{C} - R^2}$$

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

$$P_1 = V_L I_L \, Cos\,(30 - \phi)$$

$$P_2 = V_L I_L \, Cos\,(30 + \phi)$$

$$\tan\phi = \frac{\sqrt{3}\,(P_2 - P_1)}{(P_2 + P_1)}$$

% Voltage regulation

$$= I_1 \frac{(R_e \, Cos\phi \pm X_e \, Sin\phi)}{v_1} \times \frac{100}{1}$$

$$Z_e = \sqrt{R_e^2 + X_e^2}$$

$$\%Z_e = \frac{I\,Z_e}{V} \times \frac{100}{1}$$

$$S_1 = S \frac{Z_2}{Z_1 + Z_2}$$

$$E = 2{,}222 \; k_d k_p \; Z\Phi f$$

$$I_r = \frac{E_r}{Z_r}$$

$$E_o = V_p \frac{Z_r}{Z_s}$$

$$Cos\phi_r = \frac{R}{Z_r}$$

$$s = \frac{2\pi T(n_s - n_r)}{2\pi T \, n_s}$$

$$L = 0{,}05 + 0{,}2 \, Lin \, \frac{d}{r}$$

$$C = \frac{1}{36 Lin \dfrac{d - r}{r}}$$

$$C = \frac{1}{18 Lin \dfrac{de}{r}}$$

% Regulation

$$= \frac{V_s - V_R}{V_R} \times \frac{100}{1}$$

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MARKING GUIDELINE

NATIONAL CERTIFICATE

AUGUST EXAMINATION

ELECTROTECHNICS N5

28 JULY 2014

This marking guideline consists of 9 pages.

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QUESTION 1

1.1 Can be changed by reversing either the field✓ or armature connections. ✓ (2)

1.2 The voltage which is generated due to the moving of the armature conductors through the magnetic field flux is called the back EMF. ✓ This voltage is in opposition to the applied voltage by which it is generated. The motor will speed up until the necessary back EMF is built up because a low back EMF will cause a high armature current which will supply the extra driving torque to speed up the armature. ✓ Any change in the back EMF will result in speed change. ✓ The back EMF acts like a governor and therefore the motor is self-regulating. ✓ (4)

1.3 Pole = 6 p = 3

c = 2p = 2 x 4 = 8 ✓ Z = 640

$\frac{\text{Pole arc}}{\text{Pole pitch}} = 0,8$

I = 960 A

$\text{At / p} = \frac{IZ}{2c\ 2p} \times \frac{\text{Pole arc}}{\text{Pole pitch}}$ ✓

$= \frac{960 \times 640}{2 \times 8 \times 2 \times 4} \times 0,8$ ✓

= 3 840 At ✓ (4)

1.4 $I = \frac{88\ 000}{540} = 162,96$ A ✓

At/p for full load = 12A x 1 800 t/p ✓ = 21 600 At/p ✓

t/p for no load = 9A x 1 800 t/p ✓ = 16 200 At/p ✓

At / p for series winding = 21 600 – 16 200 ✓

= 5 400 At/p ✓

No. of series t/p = 5 400 / 162,96
= 33,14 ✓
Say 34 (8)

Lap-wound - for low voltage and high current ✓ (1)

1.5 Wave-wound - for high voltage and low current. ✓ (1)
[20]

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QUESTION 2

2.1 2.1.1

$i_1 = 0 + 12,6 / 2 = 6,3A$
$i_2 = 12,6 + 24,4 / 2 = 18,5$ ✓
$i_3 = 24,4 + 31 / 2 = 27,7$
$i_4 = 31 + 29 / 2 = 30$ ✓
$i_5 = 29 + 24,4 / 2 = 26,7$
$i_6 = 24,4 + 0 / 2 = 12,2$ ✓

$I\ ave = i_1 + i_2 + i_3 + i_4 + i_5 + i_6 / n$ ✓
$= 6,3 + 18,5+27,7+30+26,7+12,2 / 6$
$= 121,4 / 6$
$= 20,23\ A$ ✓ (5)

2.1.2 $I\ rms = \sqrt{i^2_1 + i^2_2 + i^2_3 + i^2_4 + i^2_5 + i^2_6 / n}$ ✓

$\sqrt{6,3^2 + 18,5^2 + 27,7^2 + 30^2 + 26,7i^2 + 12,2^2 / n}$ ✓

$= \sqrt{2910,96 /6}$

$= 22,03\ A$ ✓ (3)

2.2 2.2.1 $XL = 2 \pi f L$
$= 2 \pi \times 1,5 \times 10^6 \times 650 \times 10^{-6} = 6126,11\ \Omega$ ✓

$f(res) = 1 / 2 \pi \sqrt{LC}$

$1,5 \times 10^6 = 1 / 2 \pi \sqrt{650 \times 10^{-6} \times C}$ ✓

$\sqrt{650 \times 10^{-6} \times C} = 1 / \sqrt{2 \pi 10^6 \times 1,5}$
$650 \times 10^{-6} \times C = (1 / 2 \pi 10^6 \times 1,5)^2$ ✓

$C = 1.73 \times 10^{-11}$

$= 17,3 \times 10^{-12}\ F$ ✓ (4)

2.2.2 $Z\ parallel = L/CR$

$= \frac{650 \times 10^{-6}}{17,3 \times 10^{-12} \times 60}$ ✓
$= 626,204\ k\Omega$ ✓ (2)

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2.2.3 I = V/ZT
= 80/ 9900 + 626204
= 80 / 636104
= 0,126 mA ✓

pd across coil = $0,126 \times 10^{-3} \times 626204$ = 78,9 V ✓

I coil = $78,9 / \sqrt{(60)^2 + (6126,11)^2}$

= 12,88 mA ✓

I cap = $2\pi \times 1,5 \times 10^6 \times 1,73 \times 10^{-12} \times 78,9$

= 0,129 mA ✓ (4)
[18]

QUESTION 3

3.1 Making the transformer window long and narrow. ✓
Arranging the primary and secondary windings concentrically. ✓
Sandwiching the primary and secondary windings. ✓
Using shell-type construction. ✓ (4)

3.2 3.2.1 S = 2 800 < 0 x 900 < - 36,87

= 2 520< - 36,87 kVA ✓

TRF A

$P = I V \cos \phi$

30 000 = 450 x 400 x COS ϕ
COS ϕ = 0,167

ϕ = 80,39 ✓

IA = 450 < - 80,39

ZA = V/I = $\frac{400 < 0}{450 < -80,39}$ = 0,889 < 80,39 ✓

= 0,148 + j 0,88

TRF.B

$P = I V \cos \phi$

35 000 = 450 x 250 x COS ϕ

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$\cos \phi = 0,3,1$

$\phi = 71,94$

$I_B = 450 < -71,94$ ✓

$Z_B = V/I = \frac{250 < 0}{450 < -71,94} = 0,556 < 71,94$ ✓

$= 0,17 + j\,0,53$

$Z_A + Z_B = 0,148 + j\,0,88 + 0,17 + j\,0,53$
$= 0,318 + j\,1,4$
$= 1,44 < 77,2$ ✓

$Z_T = \frac{Z_A \times Z_B}{Z_A + Z_B} = \frac{0,889 < 80,39 \times 0,556 < 71,94}{1,44 < 77,2}$

$= 0,343 < 75,13$ ✓

$V_D = I_L \times Z_T$
$= 900 < -36,87 \times 0,343 < 75,13$
$= 308,7 < 38,26$ ✓
$= 242,39 + j\,191,16$

$V_S = V$ (NO LOAD) $- V_D$
$= 2\,800 < 0 - 308,7 < 38,26$ ✓
$= (2\,800 + j\,0) - (242,39 + j\,191,16) = 2\,800 + j\,0 - 242,39 - j\,191,16$
$= 2\,557,61 - j\,191,16$
$= 2\,564,74 < -4,27$ ✓ (10)

3.2.2 $S = V_S \times I$ (LOAD)
$= 2\,564,74 < -4,27 \times 900 < -36,87$
$= 2\,308,27 < -41,14$ kVA ✓

$S_A = \frac{S \times Z_B}{Z_A + Z_B} = \frac{2308,27 < -41,14 \times 0,556 < 71,94}{1,44 < 77,2}$
$= 891,25 < -46,4$kVA ✓

$\cos \phi = 0,69$ lagging ✓ (3)

3.2.3 $S_B = \frac{S \times Z_A}{Z_A + Z_B} = \frac{2308,27 < -41,14 \times 0,889 < 80,39}{1,44 < 77,2}$ ✓

$= 1425 < -37,95$ kVA ✓

$\cos \phi = 0,789$ lagging ✓ (3)
[20]

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QUESTION 4

4.1 4.1.1 $P_T = \sqrt{3}\ V_L\ I_L \cos\phi$

$$I_L = \frac{18\,0000}{\sqrt{3} \times 3350 \times 0{,}85}$$

$$= 36{,}5\ A \checkmark$$

$$I_P = \frac{I_L}{\sqrt{3}} = 36{,}5 / \sqrt{3} = 63{,}2\ A \checkmark$$ (2)

4.1.2 $W_1 = V_L\ I_L\ \text{Cos}\ (30 + \phi)$ $\phi = 31{,}79$ ✓
$= 3\,350 \times 36{,}5 \cos\ (30 + 31{,}79)$ ✓
$= 3\,350 \times 36{,}5 \cos\ (61{,}79)$
$= 57{,}8\ kW$ ✓

$W_2 = V_L\ I_L\ \cos\ (30 - \phi)$

$= 3\,350 \times 36{,}5\ \cos\ (30 - 31{,}79)$ ✓

$= 122{,}22\ kW$ ✓ (5)

4.1.3 $kVA = \frac{\sqrt{3}\ V_L\ I_L}{1\,000}$

$= \frac{\sqrt{3} \times 3350 \times 36{,}5}{1\,000}$ ✓

$= 211{,}79\ kW$ ✓ (2)

4.2 Load P = 2,45 MW = $\frac{2{,}45\ MW}{3}$ per phase

$\cos\phi$ = 0,8 lagging ($\sin\phi = 0{,}6$)

$V_r = \frac{36\,000}{\sqrt{3}}(\cos\phi + j \sin\phi)$ ✓

$= \frac{36\,000}{\sqrt{3}}\ (0{,}8 + j\ 0{,}6)$

$= 16\,627{,}69 + j12470{,}77$ ✓

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$$I_p = \frac{2{,}45\ MW/3}{36\ 000/\sqrt{3}} = 39{,}29\ A \checkmark$$

$$V_d = I\,Z = 39{,}29\,(90 + j\,160)$$

$$= 3536{,}1 + j\,6286{,}4 \checkmark$$

$$V_s = V_r + V_d$$
$$= 16\,627{,}69 + j12470{,}77 + 3536{,}1 + j\,6286{,}4$$
$$= 20\,163{,}79 + j\,18757{,}17$$

$$= 27\,539{,}24 < 42{,}9 \checkmark$$

Vs line voltage = $\sqrt{3} \times 27539{,}24 = 47{,}7$ kV ✓ (6)

4.2.2 Reg $= \frac{Vs - Vr}{Vr}$

$= \frac{27\,539{,}24 - 36\,000/\sqrt{3}}{36\,000/\sqrt{3}}$ ✓ OR $\frac{47\,700 - 36\,000}{36\,000}$

$= 0{,}325$ p.u. ✓ 0,325 p.u.

Output = 2,45 MW / 3 per phase = 816,67 kW ✓

Power loss = I^2R

$= (39{,}29)^2 \times 90$

$= 138{,}93$ kW ✓

Input = output + losses

$= 816{,}67 + 138{,}93$

$= 955{,}6$ kW ✓ (5)

4.2.3 Efficiency $= \frac{\text{output}}{\text{Input}}$

$= \frac{816{,}67}{955{,}6}$ ✓

$= 0{,}85$ (85 %) ✓ (2)

[22]

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QUESTION 5

5.1 No ✓ If the rotor were to run at synchronous speed, then there would be no relative speed difference between rotating magnetic field and the rotor✓, hence no emf will be induced in the rotor ✓ and therefore there will be no rotor current and so no torque. ✓ (4)

5.2 5.2.1 Xs = 6,5 Ω per phase θ = 30
VP = 2675 V

$$EZ = j\,EA - (EB \sin\theta + j\,EB\cos\theta) \checkmark$$
$$= j\,2\,675 - (2\,675 \sin 30 + j\,2675 \cos 30)$$
$$= j\,2\,675 - 1\,337,5 - j\,2316,62 \checkmark$$
$$= -1\,337,5 + j\,358,38$$
$$= 1\,84,68 \checkmark$$

$$\text{Circulating I} = \frac{Ez}{2Xs} = \frac{1\,384,68}{2 \times 6,5} \checkmark$$
$$= 106,5\ A \checkmark$$ (5)

5.2.2 $$\text{Terminal V/P} = Ea \cos \frac{\theta}{2} \checkmark$$
$$= 2\,675 \cos 15$$
$$= 2\,583,85\ V \checkmark$$ (2)

5.2.3 $P = \sqrt{3}\,IL\,VL$
$VL = \sqrt{3}\,Vp = \sqrt{3} \times 2583,85 = 4475,36\ V \checkmark$

$$= \sqrt{3} \times 106,5 \times 4475,36\ W \checkmark$$
$$= 825,540\ kW \checkmark$$ (3)

5.3 5.3.1 VL = 800 N = 1 500 r/min f = 50

$f = N\,p/60$

$$50 = \frac{1\,500 \times p}{60} \checkmark$$
$$p = 2$$

No of poles = 2 x 2 = 4 ✓ (2)

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5.3.2 No. of slots per phase = 2 x 4 = 8 (or 24 slots for 3 phases)
No of conductors per phase = 8 x 4
= 32 ✓
(or 96 conductors for 3 phase)

$$\text{EMF per phase} = \frac{800}{\sqrt{3}}$$
= 461,88 V ✓

Ep = 2,22 kd kp ϕ f Z / ph

461,88 = 2,22 x 0,96 x 1 x ϕ x 50 x 32 ✓

$$\phi = \frac{461,88}{2,22 \times 0,96 \times 1 \times 50 \times \mathbf{32}}$$ (Z= 32 per phase or 96/3)

ϕ = 0,135 Wb ✓

= 135 mWb (4)
[20]

TOTAL: 100

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