higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T480(E)(A7)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

(8080085)

31 March 2014 (Y-Paper)
13:00–16:00

Calculators may be used.

This question paper consists of 5 pages and 1 formula sheet of 3 pages.

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. Keep subsections of questions together.
5. Write neatly and legibly.

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QUESTION 1

1.1 Name and explain THREE methods to improve commutation. (6)

1.2 An eight-pole, 1 600 kW, 520 V, DC generator has a wave connected winding with 240 armature conductors.

Calculate the number of turns per pole required for the commutating poles. Assume the compole ampere-turns per pole to be about 1,6 times the armature ampere turns per pole and the brushes to be in geometric neutral axis. (5)

1.3 An eight-pole, lap-wound, 350 V, shunt-excited DC machine draws an armature current of 7,5 A on no-load at 1 200 rpm. When loaded, it draws an armature current of 80 A from the supply and runs at the same speed. The resistance of the armature circuit is 0,6 Ω and there are 900 armature conductors.

Calculate the following:

1.3.1 the generated EMF (2)

1.3.2 the useful flux per pole (4)

1.3.3 the useful torque developed by the machine in Nm (3)

[20]

QUESTION 2

2.1 An impedance of 9+ j 11 Ω is connected in series with two impedances in parallel, one of 11 + j 15 Ω and the other of 15 – j 8 Ω. This combination is then connected across a 150 V alternating current supply.

Calculate the following:

2.1.1 The total impedance (5)

2.1.2 The total current (3)

2.1.3 The power factor (2)

2.2 A coil with a resistance of 30 Ω and an inductance of 0,06 H, is connected in parallel with a circuit consisting of a 190 μf capacitor in series with a 28 Ω resistor. The supply is 280 V, 50 Hz.

Calculate the following:

2.2.1 The total line current and the current in each branch (8)

2.2.2 Power and power factor (2)

[20]

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QUESTION 3

3.1 Name TWO methods that are used to cool transformers. (2)

3.2 A single phase transformer with a supply voltage of 310 V has an equivalent resistance of 0,4 Ω and an equivalent leakage reactance of 0,95 Ω, referred to the primary.

The secondary is connected to a coil with a resistance of 50 Ω and a reactance of 180 Ω. The secondary winding has 5 times as many turns as the primary.

Calculate the secondary terminal voltage. (11)

3.3 Three similar inductors, each of resistance 29 Ω and inductance 0,028 H, are delta-connected to a three-phase, 400 V, 50 Hz sinusoidal supply.

Calculate the following:

3.3.1 Line current (5)

3.3.2 Power factor (2)
[20]

QUESTION 4

4.1 Draw a neat labelled sketch showing how the two-wattmeter method can be used to measure power in a three-phase network. (6)

4.2 Two wattmeters are connected to measure the input to a balanced three-phase circuit. The readings are 3 300 W and 720 W respectively.

Find the power factor of the circuit when:

4.2.1 both the readings are positive. (4)

4.2.2 the latter reading is obtained after reversing the connections to the current coil of one instrument. (4)

4.3 Calculate the total resistance, inductance and capacitance of a single-phase, 36 km, overhead line with solid conductors of 1,8 cm diameter spaced 0, 8 m between centres. Take resistivity of conductor material as 1,7 μ Ω cm. (8)
[22]

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QUESTION 5

5.1 Calculate the efficiency and the output power of a three-phase 450 V induction motor, running on load with a fractional slip of 0,05 and drawing a current of 80 A at a power factor of 0,8. When running light at 450 V, the motor has an input current of 30 A and the power taken is 3 000 W. The resistance per phase of the stator winding is 0,8 Ω, delta-connected.

(10)

5.2 A three-phase, six-pole star-connected alternator delivers 375 V between lines on open circuit, running at a speed of 1 450 r/min. There are two conductors per slot and three slots per pole, per phase.

Assume the winding has a pitch factor of 0,8 and a distribution factor of 0,96 and assuming a sine wave form.

Calculate the following:

5.2.1 The frequency (2)

5.2.2 Turns per phase (3)

5.2.3 Useful flux per pole (3)

[18]

TOTAL: 100

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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

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

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

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

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

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

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

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

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

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

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

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

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

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% Regulation

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

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

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

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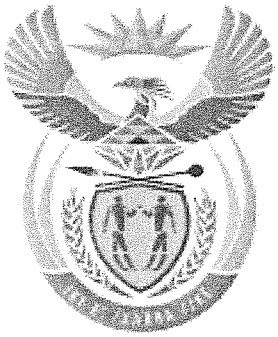

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Department:
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MARKING GUIDELINE

NATIONAL CERTIFICATE

APRIL EXAMINATION

ELECTROTECHNICS N5

31 MARCH 2014

This marking guideline consists of 9 pages.

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QUESTION 1

1.1 Shifting of brushes. ✓
Moving brushes forward in a generator and backwards in a motor.
Increasing the brush contact resistance. ✓
If carbon brushes are used instead of copper brushes, the resistance is much higher, therefore the current is much lower and the arc much smaller. ✓
Using commutating poles (interpoles). ✓
The interpole induces an EMF in the short-circuit coil, which lies directly under the interpole.✓
The EMF in the interpole reduces the reactive voltage in the short-circuit coil, resulting in smooth commutation. ✓ (6)

1.2 P = 1 600,000W, V= 520,pole=8 P =4 , Z =240 C=2 WAVE,
Ia = P/V
= 1 600 000/ 520
= 3 076,92 A✓

Armature At/p = Ia Z/4 p c
$= \frac{3\,076{,}92 \times 240}{4 \times 4 \times 2}$ ✓

= 23 076,9 ✓

Compole At/p = 1,6 x 23076,9
= 36 923,04 ✓

t/p = $\frac{\text{compole At/p}}{\text{Ia}}$
= 36 923,04/ 3076,92
= 12 turns / pole ✓ (5)

1.3 1.3.1 p = 4 (8 pole)
c = 2p = 8
V = 350 N = 1 200 r/min Z = 900
E = V – Ia Ra
= 350 – (80 x 0,6) ✓
= 302 V ✓

1.3.2 $E = \frac{2\,\Phi\,Z\,p\,N}{60\,c}$

$302 = \frac{2 \times \Phi \times 900 \times 4 \times 1200}{60 \times 8}$ ✓

$\Phi = \frac{302 \times 60 \times 8}{2 \times 900 \times 4 \times 1200}$ ✓

$= \frac{1\,449\,60}{8\,640\,000}$ ✓

= 0, 01678 Wb.✓ (2)

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1.3.3 Output $= \frac{2\pi NT}{60}$

E Ia $= \frac{2\pi NT}{60}$

$302 \times 80 = \frac{2\pi\ 1200\ T}{60}$ ✓ (4)

$24\ 160 \times 60 = 2\pi \times 1200\ T$

$T = \frac{1449600}{7539,8}$ ✓

$= 192,26$ Nm. ✓

ALTERNATE SOLUTION

$T = 0,318\ Ia/c\ ZP\Phi$
$= 0,318 \times 80/8 \times 900 \times 4 \times 0,01678$
$= 192,1$ Nm (3)
[20]

QUESTION 2

2.1.1 $Z3 = 9 + j\,11 = 14,21 < 50,7$

$Z2 = 15 - j8 = 17 < -28,07$

$Z1 = 11 + j15 = 18,6 < 53,75$

$ZP = \frac{Z1 \times Z2}{Z1 + Z2}$

$= \frac{18,6 < 53,75 \times 17 < -28,07}{11 + J15 + 15 - J8}$ ✓

$= \frac{316,2 < 25,68}{26 + j\,7}$

$= \frac{316,2 < 25,68}{26,93 < 15,07}$ ✓

$= 11,74 < 10,61$

$= 11,54 + j\,2,16$ ✓

$ZT = Z3 + ZP$
$= 9 + j11 + 11,54 + j\,2,16$ ✓
$= 20,54 + j\,13,16$
$= 24,39 < 32,65$ ✓ (5)

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2.1.2 $I_T = V/Z_T$ ✓

$= \frac{150 < 0}{24,39 < 32,65}$ ✓

$= 6,15 < -32,65$ ✓ (3)

2.1.3 pf = cos 32,65 ✓ = 0,84 lagging ✓ (2)

2.2.1 $X_L = 2\pi f L$

$= 2 \times \pi \times 50 \times 0,06$

$= 18,85\ \Omega$ ✓

$X_C = 1 / 2\pi f C$

$= \frac{10^6}{2 \times \pi \times 50 \times 190}$

$= 16,75\ \Omega$ ✓

$Z1 = 30 + j\,18,85 = 35,43 < 32,14$

$Z2 = 28 - j\,16,75 = 32,62 < -30,89$

$Z1 + Z2 = 58 + j\,2,1 = 58 < +2,07$ ✓

$Z_T = \frac{Z1 \times Z2}{Z1 + Z2} = \frac{35,43 < 32,14 \times 32,62 < -30,89}{58 < +2,07}$ ✓

$= 19,93 < -0,82$ ✓

$I_T = \frac{V}{Z_T} = \frac{280 < 0}{19,93 < 3,32} = 14,041 < +0,82$ ✓

$I_1 = \frac{V}{Z1} = \frac{280 < 0}{35,43 < 32,14} = 7,9 < -32,14$ ✓ (8)

2.2.2 $I_2 = \frac{V}{Z2} = \frac{280 < 0}{32,62 < -30,89} = 8,58 < 30,89$ ✓

$\cos \phi = \cos 0,82 = 0,999$

$P = I^2 Z \cos \phi = (14,041)^2 \times 19,93 \times 0,99 = 3889,9$ W ✓ (3890 W)

ALTERNATE

$P = I V \cos \phi = 280 \times 14,041 \times 0,99 = 3892$ W (2)

[20]

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QUESTION 3

3.1 Oil cooling ✓ (1)

Air cooling ✓ (1)

3.2 $\text{Tan } \phi_2 = X/R = 180/350 = 0,514$

$\phi_2 = 27,2$ ✓

$Rt = Re + RL\ (N1/N2)^2$

$= 0,4 + 350(1/5)^2$

$= 14,4\ \Omega$ ✓

$Xt = Xe + XL\ (N1/N2)^2 = 0,95 + 180(1/5)^2$

$= 8,15\ \Omega$ ✓

$Zt = \sqrt{(Rt)^2 + (Xt)^2}$

$= \sqrt{(14,4)^2 + (8,15)^2}$

$= 16,55\ \Omega$ ✓

or $= Rt + j\,XL$

$= 14,4 + j\,8,15$

$= 16,55 < 29,5$

$I_1 = V_1 / Zt = 310 / 16,55 = 18,73\ A$ ✓

$V/reg = I_1\ (Re \cos \phi + Xe \sin \phi)$

$= \dfrac{18,73\ (0,4 \cos 27,2 + 0,95 \sin 27,2}{310}$ ✓

$= 0,0477\ (4,8\ \%)$ ✓

$V_{2\ (NO\ LOAD)} = V_1 \times N2/N1 = 310 \times 5/1 = 1550\ V$ ✓

Difference $= V_{2\ (NO\ LOAD)} \times reg$

$= 1550 \times 0,048$

$= 74,4\ V$ ✓

V (terminal) $= 1550 - 74,4$ ($\cos \phi$ lagging) ✓

$= 1475,6\ V$ ✓ (11)

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3.3 3.3.1 $IP = \frac{VP}{Z1} = \frac{400 < 0}{30,31 < 16,88}$ ✓

$= 13,12 < -16,88$ ✓

XL $= 2\pi \times 50 \times 0.028 = 8,8$

Z $= 30,31 < 16,88$ ✓

IL $= \sqrt{3}\ I_p$

$= \sqrt{3} \times 13,12$ ✓

$= 22,72$ A ✓

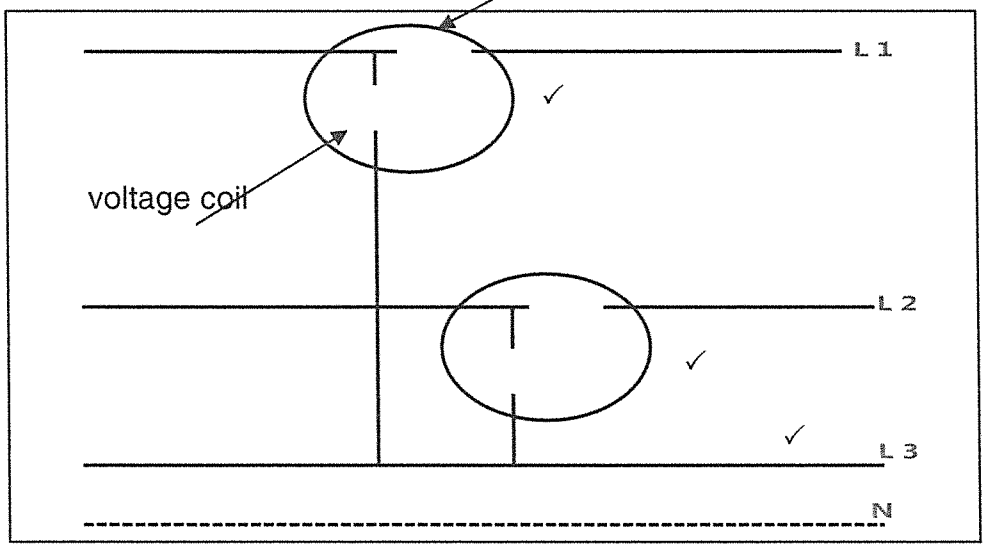
(5)

3.3.2 Pf $= \cos \Phi = \cos -16,88$ ✓ $= 0,96$ lagging ✓ (2)

[20]

QUESTION 4

4.1



TWO WATTMETERS IN A THREE-PHASE CIRCUIT

Sketch = 3 marks; labelling = 3marks (6)

4.2 4.2.1 P 1 = 720 W P 2 = 3 300 W

$$\text{Tan } \phi = \frac{\sqrt{3}\,(P2 - P1)}{P2 + P1}$$

$$= \frac{\sqrt{3}\,(3\,300 - 720)}{3\,300 + 720}$$ ✓

Tan ϕ $= 1,11$ ✓

ϕ $= 47,98$ ✓

Cos ϕ $= 0,67$ ✓ (4)

4.2.2 P1 $= -720\ W$

$$\text{Tan } \phi = \frac{\sqrt{3}\,(P2 - P1)}{P2 + P1}$$

$$= \frac{\sqrt{3}\,[3\,300 - (-720)]}{3\,300 + (-720)} \checkmark$$

$$= 2{,}7 \checkmark$$

$\phi = 69{,}68\ (\phi > 60°\ \text{lagging}) \checkmark$

$\text{Cos } \phi = 0{,}347 \checkmark$ (4)

4.3 Loop resistance $= \frac{\rho l}{a}$

$$= \frac{1{,}7 \times 72 \times 10^{5}}{10^{6} \times \pi \times 0{,}9^{2}} \checkmark$$

$$= 4{,}81\ \Omega \checkmark$$

Loop inductance $= 72[0{,}05 + 0{,}2 \log_e d/r]\ mH \checkmark$

$= 72[0{,}05 + 0{,}2 \log_e (80/0{,}9)]\ mH \checkmark$

$= 68{,}22\ mH \checkmark$

Total capacitance $= \frac{36}{36 \log_e \left(\frac{d-r}{r}\right)} \checkmark$

$$= \frac{36}{36 \log_e \left(\frac{80 - 0{,}9}{0{,}9}\right)} \checkmark$$

$= 0{,}23\ \mu F \checkmark$ (8)

[22]

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QUESTION 5

5.1 V = 450 s = 0,05 I = 80 A [stator is Δ Ip = 80/√3]
Pf = 0,8
I no load = 30 A [stator is Δ Ip = 30/√3] P no load = 3 000 W
R = 0,8 Ω

Stator input = √3 IL VL COS ϕ
= √3 x 80 x 450 x 0,8 ✓
= 49 883,06 W ✓

losses

Stator cu losses = 3 I^2 R = 3 (80 / √3) ² X 0,8
= 5 120 W ✓

Rotor cu loss = s (rotor input)
= 0,05 (49883 – 5120)
= 2 238,15 W ✓

Constant losses = P no load - Cu losses (no load)
= 3 000 - [3 x (30 / √3) ² x 0,8] ✓

= 3 000 - 720
= 2 280 W ✓

Total losses = Stator cu losses + Rotor cu loss + Constant losses ✓
= 5 120 + 2 238 + 2 280
= 9 638 W ✓

Output = Input - losses
= 49 883 – 9638
= 40 245 W (40,25 kW) ✓

Efficiency = $\frac{\text{Output}}{\text{Input}}$

= $\frac{40\,245}{49\,883}$

= 0, 81 per unit. 81 % ✓ (10)

5.2 5.2.1 f = n x p = $\frac{1\,450}{60}$ x 3 ✓

= 72,5 Hz ✓ (2)

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5.2.2 No of slots = 3 slots x no of poles = 3 x 6 = 18 (per phase)

z/ph = 2cond x 18 = 36

or

Z = 2 x 9 x 6 = 108 or Z = 36 X 3 (PH) = 108 ✓

Z/ph = 108 / 3 = 36 ✓

Turns/ ph = 36/2 = 18 ✓ (3)

5.2.3 E / ph = 375 / √3 = 216,51 V ✓

E / ph = 4 x ϕ x f x Tp x Kf x Kp x Kd

216,51 = 4 x ϕ x 72,5 x 18 x 1,11 x 0,8 x 0,96 ✓

216,51 = 4 450 ϕ

ϕ = 0,0487 Wb

= 48,7 mWb ✓ (3)

[18]

TOTAL: 100

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