higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

19 April 2021

This marking guideline consists of 11 pages.

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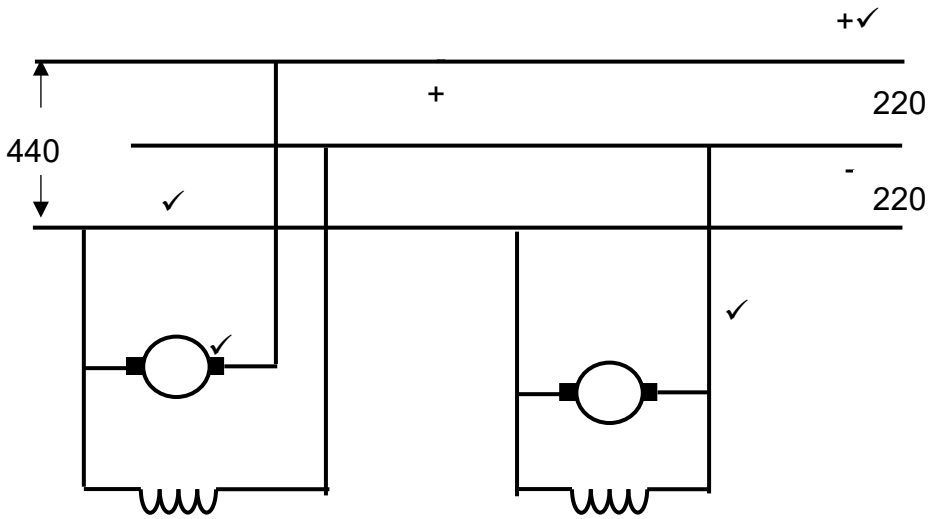
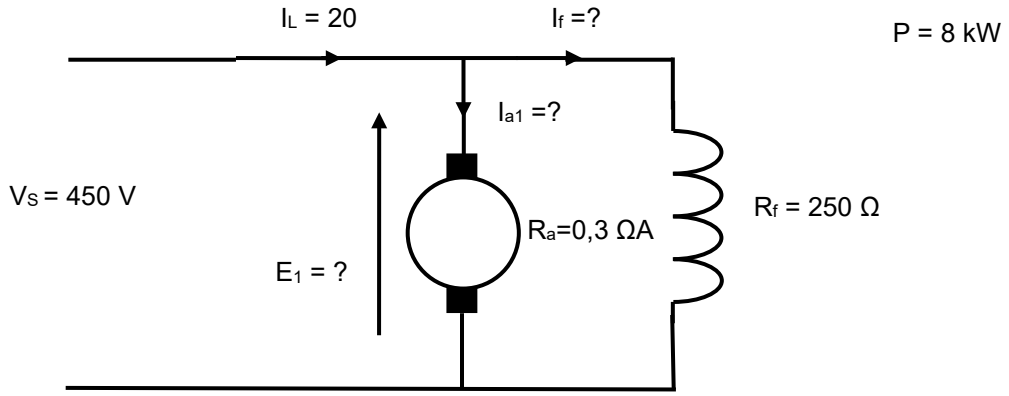
QUESTION 1

1.1



(4)

1.2



1.2.1 $I_{SH} = V/R_{SH} = 450/250 = 1{,}8$ A✓
$I_A = I_L - I_{SH} = 20 - 1{,}8 = 18{,}2$ A✓
$P_{in} = V.I_L = 450 \times 20 = 9$ kW✓
Armature copper loss $= (\mathrm{I_a})^2.\mathrm{R_a} = (18{,}2)^2 \times 0{,}3 = 99{,}372$ W✓

OR

Field copper loss $= (\mathrm{I_{sh}})^2.\mathrm{R_{sh}}$
$= (1{,}8)^2 \times 250$
$= 810$ W✓

Field copper loss $= \mathrm{I_{sh}}.\mathrm{V}$
$= 1{,}8 \times 450$
$= 810$ W✓

Total copper loss $=$ armature copper losse $+$ field copper loss
$= 99{,}372 + 810$
$= 909{,}372$ W ✓

$\text{Total losses} = P_{in} - P_{out} = 9 - 8 = 1\ \text{kW}$✓

$\text{Iron and friction losses} = \text{total losses} - \text{total copper losses}$

$= 1\,000 - 909{,}372$

$= 90{,}628\ \text{W}$ (8)

1.2.2 $\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{8}{9} \times 100\%$✓

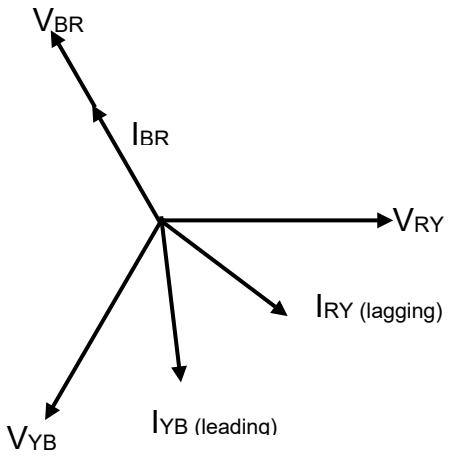
$= 88{,}89\%$✓ (2)

[14]

QUESTION 2

2.1 Active power is dissipated in the circuit resistance✓ while reactive power is developed in the inductive reactance✓ of the circuit. (2)

2.2



$I_{RY} = 30\angle\text{-}36{,}87°$

$I_{YB} = 35\angle 36{,}87°$

$I_{BR} = 25\angle 0°$

$V_L = 400\ \text{V}$

$Z_{RY} = \frac{V_{RY}}{I_{RY}} = \frac{400\angle 0°}{30\angle -36{,}87°} = 13{,}333\angle 36{,}87°\ \Omega$✓ $= 10{,}667 + \text{j}8\ \Omega$✓

$R_1 = 10{,}667\ \Omega$✓

$X_1 = 8\ \Omega$✓

$Z_{YB} = \frac{V_{YB}}{I_{YB}} = \frac{400\angle -120°}{35\angle -83{,}13°} = 11{,}429\angle -36{,}87°\Omega$✓ $= 9{,}143 - \text{j}6{,}857\ \Omega$✓

$R_2 = 9{,}143\ \Omega$✓

$X_2 = 6{,}857\ \Omega$✓

$Z_{BR} = \frac{V_{BR}}{I_{BR}} = \frac{400\angle 120}{25\angle 120°} = 16\angle 0°\ \Omega$✓ $= 16 + \text{j}0\ \Omega$✓

$R_3 = 16\ \Omega$✓

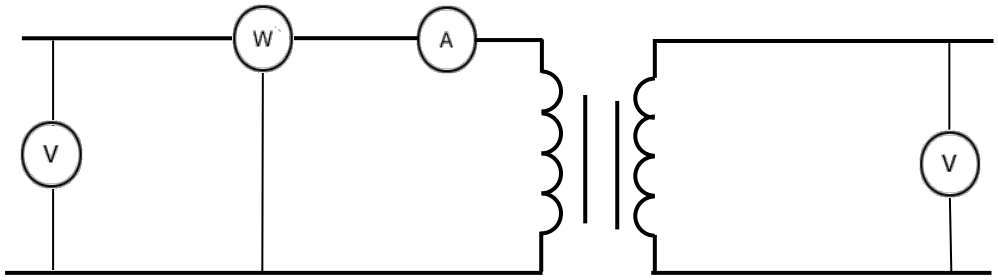
$X_3 = 0\ \Omega$✓ (12)

[14]

QUESTION 3

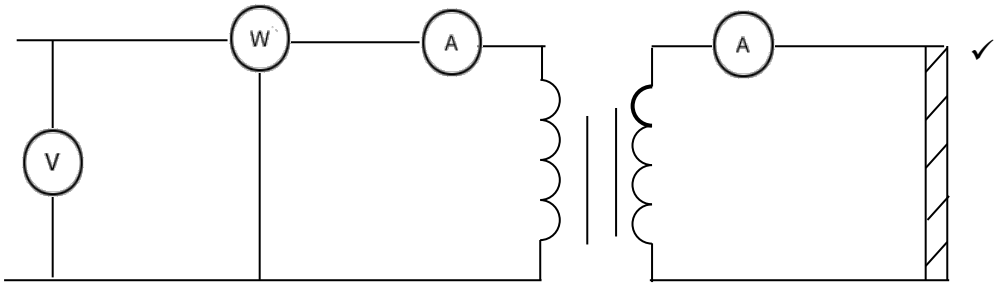
3.1 **Open-circuit test**

✓



The primary winding is connected to the normal voltage and frequency while the secondary winding is open (no load).✓ The wattmeter reads the iron (core) losses (Po).✓

Short-circuit test



✓

A low voltage is applied to the primary and adjusted to circulate full-load current in both windings.✓ The wattmeter reads the full-load copper loss (P_{sc}).

$$\eta = \frac{P_{output}}{P_{input}} \times 100\%$$

$$= \frac{P_{output}}{P_{output} + P_{losses}} \times 100\%$$

$$= \frac{\text{k. S. cos}\theta}{\text{k. S. cos}\theta + (P_o + P_{SC})} \times 100 \text{ ✓✓}$$

Where: k = fraction of full load at which efficiency must be determined
S = transformer rating (VA)
cosθ = power factor (7)

3.2 **Given:** A transformer with an iron loss and a full-load copper loss as below:

S = 12 kVA
P_o = 340 W
P_{sc} = 240 W

3.2.1
$$\eta = \frac{\text{k. S. cos}\theta}{\text{k. S. cos}\theta + (P_o + k^2 P_{SC})} \times 100$$
$$= \frac{0,25 \times 12\,000 \times 1}{(0,25 \times 12\,000 \times 1) + (240 + (0,25^2 \times 340))} \times 100\%$$
$$= 91,989\% \checkmark\checkmark$$ (2)

3.2.2
$$\eta = \frac{\text{k. S. cos}\theta}{\text{k. S. cos}\theta + (P_o + P_{SC})} \times 100$$
$$= \frac{0,75 \times 12\,000 \times 0,8}{(0,75 \times 12\,000 \times 0,8) + (340 + 240)} \times 100\% \checkmark$$
$$= 92,545\% \checkmark$$ (2)

3.2.3
$$\text{P}_\text{O} = \text{k}^2 . \text{P}_\text{SC}$$
$$\text{k} = \sqrt{\frac{\text{P}_\text{o}}{\text{P}_\text{SC}}} = \sqrt{\frac{240}{340}} = 0,84 \checkmark$$
$$\therefore \text{S} = 0,84 \times 12\,000 = 10,08\ \text{kVA} \checkmark$$

Method 1:

$$\eta = \frac{\text{k. S. cos}\theta}{\text{k. S. cos}\theta + (P_o + P_{SC})} \times 100$$
$$= \frac{0,84 \times 12\,000 \times 0,8}{(0,84 \times 12\,000 \times 0,8) + [240 + (0,84 \times 340)]} \times 100\% \checkmark$$
$$= 93,881\% \checkmark$$

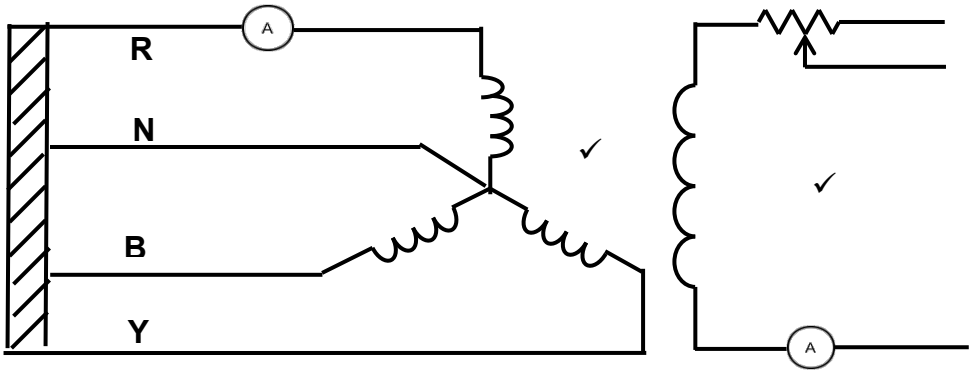
Method 2:

$$\eta = \frac{\text{k. S. cos}\theta}{\text{k. S. cos}\theta + 2P_o} \times 100 \checkmark$$
$$= \frac{0,84 \times 12\,000 \times 0,8}{(0,84 \times 12\,000 \times 0,8) + (2 \times 240)} \times 100\% \checkmark\checkmark$$
$$= 94,382\% \checkmark$$ (4)

[15]

QUESTION 4

4.1



The short-circuit curve is obtained by short-circuiting the alternator terminals through ammeters✓ and taking readings of the short-circuit current and the field current.✓ The short-circuit current is plotted against the field current and it is a straight line through the origin.✓ (5)

4.2 **Given:** A three-phase, star-connected alternator:

V = 12 kV
S = 2 MVA
Pf = 0,8 lagging
Z = (1,2 + j8) Ω

4.2.1 $V_p = V_L/\sqrt{3} = 12 \times 10^3/\sqrt{3} = 6\,928{,}203\ V$✓

$I \cdot R = \%R \cdot V_p = 0{,}06 \times 6\,928{,}203$

$= 415{,}692\ V$✓

$I \cdot X = \%X \cdot V_p = 0{,}3 \times 6\,928{,}203$

$= 2\,078{,}461\ V$✓

Method 1:

$\cos\theta = 0{,}85 \quad \therefore \theta = \cos^{-1} 0{,}85 \quad = 31{,}788°$

$E_p = V_p \angle\theta + I \cdot R \angle 0° + I \cdot X \angle 90°$✓

$= 6\,928{,}203 \angle 31{,}788° + 415{,}692 \angle 0° + 2\,078{,}461 \angle 90°$✓

$= 8\,518{,}216 \angle 42{,}257°\ V$✓

$E_L = \sqrt{3} \cdot E_p = \sqrt{3} \times 8\,518{,}216 = 14\,753{,}983\ V$✓

Method 2:

$\cos\theta = 0{,}85 \qquad \text{and} \qquad \sin\theta = 0{,}527$

$E_p = \sqrt{\left(V_p \cdot \cos\theta + I \cdot R\right)^2 + \left(V_p \cdot \sin\theta + I \cdot X\right)^2}$ ✓

$= \sqrt{\left((6\,928{,}2 \times 0{,}85) + 415{,}69\right)^2 + \left((6\,928{,}2 \times 0{,}53) + 2\,078{,}5\right)^2}$ ✓

$= 8\,533{,}251\ \text{V}$ ✓

$\text{E}_\text{L} = \sqrt{3} \cdot \text{E}_\text{p} = \sqrt{3} \times 8\,533{,}251 = 14\,780{,}024\ \text{V}$ ✓ (7)

4.2.2 $\text{Regulation} = \dfrac{\text{E}_\text{p} - \text{V}_\text{p}}{\text{V}_\text{p}} \times 100\%$

$= \dfrac{8\,533{,}251 - 6\,928{,}203}{6\,928{,}203} \times 100\%$ ✓

$= 23{,}167\%$ ✓ (2)

4.2.3 $\tan(\emptyset + \alpha) = \dfrac{AB}{OA} = \dfrac{V\sin\emptyset + IX}{V\cos\emptyset + IR}$

$= \dfrac{(3\,810{,}512 \times 0{,}6) + 787{,}296}{(3\,810{,}512 \times 0{,}8) + 52{,}486}$

$= 0{,}991$

$(\emptyset + \alpha) = \tan^{-1}(0{,}99)$

$= 44{,}747°$

$\therefore\ \alpha = 44{,}747° - 36{,}87°$

$= 7{,}877°$ ✓ (1)

[15]

QUESTION 5

5.1
- Power-factor correction
- Constant-speed, constant-load drives
- Voltage regulation (Any 2 × 1) (2)

5.2 **Given:** A three-phase, star-connected synchronous motor:

S = 750 kVA P = 600 kW
V_L = 3,5 kV% Z = (5 + j60) percent

5.2.1
$$\cos\theta = P/S$$
$$= 600/750$$
$$= 0{,}8 \text{ leading} ✓$$ (1)

5.2.2
$$V_p = V_L/\sqrt{3} = 3\,500/\sqrt{3} ✓$$
$$= 2\,020{,}73 \text{ V} ✓$$
$$V_r = (I_p R)_{drop} = \frac{5 \times V_p}{100} = \frac{5 \times 2\,020{,}73}{100} ✓$$
$$= 101{,}037 \text{ V} ✓$$
$$V_x = (I_p X_s)_{drop} = \frac{60 \times V_p}{100} = \frac{60 \times 2\,020{,}73}{100} ✓$$
$$= 1\,212{,}438 \text{ V} ✓$$ (6)

5.2.3 **Method 1:**

$$E_p = V_p \angle -\theta + I_p . R \angle 180° + I_p . X_s \angle -90°$$
$$= 2\,020{,}73 \angle -36{,}87° + 101{,}037 \angle 180° + 1\,212{,}438 \angle -90° ✓$$
$$= 1\,515{,}545 - j2\,424{,}879 ✓$$
$$= 2\,859{,}53 \angle -57{,}995° \text{ V} ✓$$
$$E_L = \sqrt{3}.E_p = \sqrt{3} \times 2\,859{,}53 = 4\,952{,}851 \text{ V} ✓$$

Method 2:

$$I_L = S/\sqrt{3}\,V_p = 750\,000/(\sqrt{3} \times 2\,020{,}73) = 214{,}285 \text{ A} ✓$$
$$\%R = I_L . R/V_p$$
$$R = \%R . V_p/I_L = 0{,}05 \times 2\,020{,}75\ /214{,}285 = 0{,}472\ \Omega ✓$$
$$\%X = I_L . X_s/V_p$$
$$X_s = \%X . V_p/I_L = 0{,}6 \times 2\,020{,}73/214{,}285 = 5{,}658\ \Omega ✓$$
$$Z_s = R + jX_s = 0{,}472 + j5{,}658 = 5{,}678 \angle 85{,}231°\ \Omega$$
$$E_r = I_L . Z_s = 214{,}285 \angle 36{,}87° \times 5{,}678 \angle 85{,}231°$$
$$= 1\,216{,}71 \angle 122{,}101° \text{ V} ✓$$

$$E_p = E_r - V_p = 1\,216{,}71\angle 122{,}101° - 2\,020{,}73\angle 0°$$
$$= 2\,859{,}518\angle 158{,}873\ \text{V}\checkmark$$
$$E_L = \sqrt{3}.E_p = \sqrt{3} \times 2\,859{,}518\angle 158{,}873$$
$$= 4\,952{,}831\ \text{V}\checkmark \quad (4)$$

5.2.4 **Method 1**

$\alpha = 57{,}995° - 36{,}87°$
$= 21{,}125°\ \checkmark$

Method 2

$\alpha = 180° - 158{,}873°$
$= 21{,}127°\ \checkmark$ (1)

[14]

QUESTION 6

6.1 *Slip* is the difference in speed of the rotating field✓ and the actual speed of the rotor.✓ (2)

6.2
- Stator
- Rotor (2)

6.3 **Given:** No. of poles = 6 N_2 = 900 r/min
f = 50 Hz P_{stator} = 2 kW
P_{in} = 42 kW $P_{fric\&wind}$ = 2,5 kW

6.3.1
$$N_1 = \frac{60 \cdot f}{p} = \frac{60 \times 50}{3} = 1\,000\ \text{r/min}\checkmark$$
$$S = \frac{N_1 - N_2}{N_1} \times 100\%$$
$$= \frac{1\,000 - 900}{1\,000} \times 100\%\checkmark$$
$$= 10\%\checkmark \quad (3)$$

6.3.2
$$P_{in} = \text{stator output} + \text{stator loss}$$
$$\text{Stator output} = P_{in} - \text{stator loss} = 42 - 2 = 40\ \text{kW}\checkmark$$
$$\text{Stator output} = \text{Rotor input} = 40\ \text{kW}$$

$$\text{Rotor input} = \frac{2 \cdot \pi \cdot N_1.T}{60}$$
$$T = \frac{60 \cdot \text{rotor input}}{2 \cdot \pi \cdot N_1} = \frac{60 \times 40 \times 1\,000}{2 \times \pi \times 1\,000}$$
$$= 381{,}972\ \text{Nm}\checkmark$$

$$\text{Rotor cu. loss} = \frac{2 \cdot \pi \cdot (N_1 - N_2)T}{60}$$
$$= \frac{2 \times \pi \times (1\,000 - 900) \times 381{,}972}{60}\checkmark$$
$$= 4\ \text{kW}\checkmark \quad (4)$$

6.3.3 $P_{in} = P_{out} + P_{stator} + P_{rotor} + P_{friction}$

$P_{out} = P_{in} - \text{total losses}$

$= 42 - (2 + 2{,}5 + 4)$✓

$= 33{,}5\ \text{kW}$✓ (2)

6.3.4 $\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{33{,}5}{42} \times 100\% = 79{,}762\%$✓ (1)

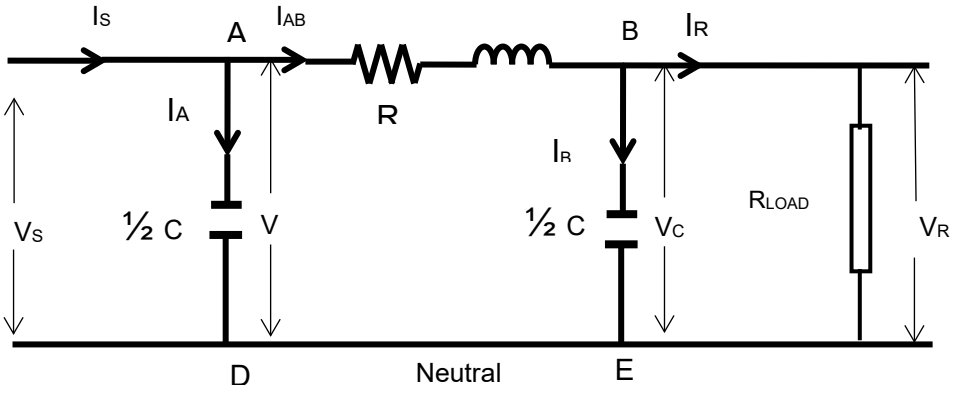
[14]

QUESTION 7

Given: A three-phase transmission line:

S = 40 MVA
V_L = 132 kV
f = 50 Hz

C = 1,2 µF
R = 18 Ω
pf = 0,8 lagging
L = 0,15 H



$X_L = 2 \cdot \pi \cdot f \cdot L = 2 \times \pi \times 50 \times 0{,}15 = 47{,}124\ \Omega$✓

$Z_{AB} = R + jX_L = 18 + j47{,}124 = 50{,}445 \angle 69{,}095°\ \Omega$✓

$$I_R = \frac{P_O}{\sqrt{3} \cdot V_L \cdot cos\ \theta} = \frac{40 \times 10^6}{\sqrt{3} \times 132 \times 10^3 \times 0{,}8} = 218{,}693\ \text{A}$$✓

$\frac{C}{2} = \frac{1,2}{2} = 0,6\ \mu F$

$X_C = \frac{1}{2 \cdot \pi \cdot f \cdot \frac{C}{2}} = \frac{1}{2 \times \pi \times 50 \times 0,6 \times 10^{-6}} = 5\ 305,165\ \Omega$✓

$Z_{BE} = 0 - jX_C = 0 - j5\ 305,165 = 5\ 305,165 \angle -90°\ \Omega$✓

$V_R = \frac{V_L}{\sqrt{3}} = \frac{132 \times 10^3}{\sqrt{3}} = 76\ 210,236 \angle 0°\ V$✓

$I_{BE} = \frac{V_R}{Z_{BN}} = \frac{76\ 210,236 \angle 0°}{5\ 305,165 \angle -90°} = 14,365 \angle 90°\ A$✓

$I_{AB} = I_R + I_{BE} = 218,693 \angle -36,87° + 14,365 \angle 90°$
$= 210,388 \angle -33,739°\ A$✓

$V_{AB} = I_{AB} \cdot Z_{AB} = 210,388 \angle -33,739° \times 50,445 \angle 69,095°$
$= 10\ 613,023 \angle 35,356°\ V$✓

$V_S = V_R + V_{AB} = 76\ 210,236 \angle 0° + 10\ 613,023 \angle 35,356°$
$= 85\ 087,84 \angle 4,139°\ V$✓

$V_L = \sqrt{3} \cdot V_S = \sqrt{3} \times 85\ 087,84 = 147\ 376,462\ V$✓

$I_{AN} = \frac{V_S}{Z_{AN}} = \frac{85\ 087,84 \angle 4,139°}{5\ 305,165 \angle -90°}$ $Z_{AN} = Z_{BN} = 5\ 305,165 \angle -90°\ \Omega$

$= 16,039 \angle 94,139°\ A$✓

$I_S = I_{AB} + I_{AN} = 210,388 \angle -33,739° + 16,039 \angle 94,139°$
$= 200,94 \angle -30,127°\ A$✓

Power factor $= \cos\theta$
$= \cos(30,127° + 4,139°)$
$= \cos 34,266$
$= 0,826$ leading✓ **[14]**

TOTAL: 100

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