Province of the
EASTERN CAPE
EDUCATION

DIRECTORATE SENIOR CURRICULUM MANAGEMENT (SEN-FET)

HOME SCHOOLING SELF-STUDY WORKSHEET ANSWER SHEET

SUBJECT	POWER SYSTEMS	**GRADE**	12	**DATE**	JUNE 2020
TOPIC	**THREE – PHASE TRANSFORMERS AND MOTORS & STARTERS**	**TERM 1 REVISION**	(Please tick)	**TERM 2 CONTENT**	(√)

QUESTION 1 THREE – PHASE TRANSFORMERS.

1.1 Losses that occur in transformers

1.1.1 Copper losses
Iron losses
Dielectric losses
Stray losses (ANY 2)

1.1.2 Insufficient circulating air for cooling the transformer.
Insufficient oil in which the transformer is immersed. ✓
Constant overloading.
Internal faults (ANY 2)

1.2 How electromotive force (EMF) is induced in the secondary windings of transformers:

- When AC voltage is supplied to the primary windings, alternating current will flow in the windings. □

- This current will produce alternating magnetic fluxes.
- The produced magnetic fluxes will link with the secondary winding through the magnetic core.
- When these fluxes link with the secondary winding, an electro-motive-force (EMF) is induced in the secondary.

1.3.1 It ensures that the:

- Device does not overheat.
- Life expectancy

1.3.2 To ensure that the transformer is

- Isolated from the supply should internal fault arise.
- Not damaged as a result of a short circuit.

1.4.1 Secondary line current

$$S = \sqrt{3} \times I_L \times V_L$$

$$I_L = \frac{S}{\sqrt{3} \times V_L}$$

$$= \frac{10000}{\sqrt{3} \times 500}$$

$$= 11{,}55 \text{ A}$$

1.4.2 Transformer ratio

$$V_{ph} = \frac{V_L}{\sqrt{3}}$$
$$= \frac{6000}{\sqrt{3}}$$
$$= 3{,}46\ kV$$

$$V_L = V_{ph}$$
$$\frac{V_{ph(p)}}{V_{ph(s)}} = \frac{N_P}{N_S}$$
$$= \frac{3460}{500}$$
$$= 7:1$$

OR

$$= 6{,}92 : 1$$

1.4.3 Input power

$$P_{in} = \sqrt{3} \times V_L \times I_L \times Cos$$
$$= \sqrt{3} \times 500 \times 11{,}55 \quad 7$$
$$= 9{,}70\ kW$$

✓ ✓ ✓

$$P_{in} = S \times Cos\,\theta$$
$$= 10000 \times 0{,}97$$
$$= 9{,}70\ kW$$

1.4.4 Efficiency of the transformer

$$\eta = \frac{P_{in} - P_{loss}}{P_{in}} \times 100$$
$$= \frac{9700 - 80}{9700} \times 100$$
$$= 99,17\%$$

1.5 The kVA rating in the primary windings and the secondary windings of a transformer is identical. The secondary line current in question 1.4.1 will be higher than the primary line current✓, because the voltage in the secondary windings is less✓ than voltage in the primary winding✓.

QUESTION 2 THREE – PHASE TRANSFORMERS

2.1 THREE external conditions that may cause transformer failure:

- Overload
- Lightning
- Surges caused by external switching
- **Poor ventilation.** **(ANY 3)**

2.2 What would happen if an earth fault occurs in one of the three phases of a protected transformer?

The earth fault will cause the phases to be unbalanced;✓ This will lead to a difference in voltage between the phases.✓ As a result the difference will activate the protective relay, ✓isolating the transformer from the supply.

2.3 How an increase in the load would affect the magneto motive force in the primary windings?

- When the load increases the current drawn from the secondary winding of the transformer will also increase, ✓
- The magneto motive force in the secondary windings will also increase. ✓
- The result is that the primary magneto motive force increases✓ because it is directly proportional counteracting the secondary load requirements,
- Keeping the input and output magneto motive force proportionally balanced. ✓ (ANY 3)

2.4 TWO types of cooling methods for a dry transformer:

Air natural (AN).
Air Forced (AF).

2.5 During the transformation process, losses occur ✓and therefore the output power is less than the input power.

2.6 Construction of a three-phase core-type transformer:

- The coils are wound around all three core legs.
- The axis of the core type windings is normally vertical.
- The coils can be removed for maintenance**.**

NOTE: Drawing the transformer will show points 1 and 2 thus receiving 2 marks.

2.7.1 Turns ratio

$$TR = \frac{N_P}{N_S}$$
$$= \frac{600}{80}$$
$$= 7{,}5:1$$
$$= 8:1$$

2.7.2 Primary phase voltage

$$V_{Ph(P)} = \frac{V_{L(p)}}{\sqrt{3}}$$
$$= \frac{6000}{\sqrt{3}}$$
$$= 3{,}46\ \text{kV}$$
$$= 3464\ \text{V}$$
$$= 3{,}46 \times 10^3\ \text{V}$$

2.7.3 Secondary phase voltage

$$V_{Ph(S)} = \frac{V_{Ph(P)} \times N_S}{N_P} \quad \checkmark$$
$$= \frac{3,46 \times 10^3 \times 80}{600} \quad \checkmark$$
$$= 461,33\ V \quad \checkmark$$

OR

$$V_{Ph(S)} = \frac{V_{Ph(P)} \times N_S}{N_P}$$
$$= \frac{3464,10 \times 80}{600}$$
$$= 461,88\ V$$

2.7.4 Secondary line voltage

$V_L = V_{Ph}$ (Delta transformers) ✓ ✓

$V_L = 461,88\ V$

2.8 How mutual induction occurs in a transformer with reference Faraday's law.

Mutual induction occurs when the magnetic field created in the primary windings link ✓ with the secondary windings ✓when current flows✓ thus inducing voltage in the secondary windings in line with Faradays law. ✓

QUESTION 3 THREE-PHASE MOTORS AND STARTERS

3.1 The speed of the rotating magnetic field✓ in the stator windings✓.

3.2.1 Reasons for continuity test:

- Earth continuity
- That there is continuity between the ends of each coil.

3.2.2 To ensure that there is no electrical connection between:

- Each of the three coils.
- Any of the three coils and earth.

3.3 Operation of the squirrel-cage induction motor.

- When a three-phase supply is connected to the stator winding, a rotating magnetic flux is produced✓.
- This flux will cut the metal rod of the rotor, inducing an e.m.f in it ✓ which is responsible for the flow of current in the rotor. ✓
- This current will create a magnetic flux. ✓
- The stator and rotor magnetic flux will react to each other ✓ and a force will be produced. ✓
- The force will cause the rotor to rotate in the direction of the rotating magnetic flux. ✓

3.4.1 MC_3 (N/C)✓ and MC_2 (N/C) ✓
3.4.2 MC_1 (N/O_1) is connected in parallel with the start button so that when start button is pressed and released, ✓ current could flow in the circuit through it thus keeping the starter on. ✓

To latch/retain the circuit.

3.4.3 Operation of the star-delta control circuit

- When the start button is pressed, MC_1 will be energised ✓closing MC_1 (N/O_1) and MC_1 (N/O_2). ✓
- MC_2 will be energised opening the MC_2 (N/C) and the motor will run in star and prevent MC_3 from being energised and timer T is energised. ✓
- After a pre-set time, the energised timer will open T(N/C) and close T(N/O), de-energising MC_2 ✓and MC_2 (N/C) will close again, thus enabling MC_3 to be energised. ✓
- MC_3 will be energised and MC_3 (N/C) will open and the motor will run in delta and prevent MC_2 from being energised. ✓
- The motor continues to run in delta until the stop button is pressed or the overload is activated.

3.5.1 Synchronous speed

The total of 18 poles = 6 poles per phase = 3 pole pairs per phase

(p = 3) ✓

$$\begin{aligned} N_s &= \frac{60 \times f}{p} \\ &= \frac{60 \times 50}{3} \\ &= 1000 \text{ rpm} \end{aligned}$$

3.5.2 Percentage slip

$$= \frac{N_s - N_r}{N_s} \times 100$$
$$= \frac{1000 - 955}{1000} \times 100$$
$$= 4.5\,\%$$

QUESTION 4 THREE-PHASE MOTORS AND STARTERS

4.1

- Continuity test
- Insulation resistance between windings and earth.
- Insulation resistance between the coils of the motor.
- Check for loose connections in the terminal box. (ANY 3)

4.2 To protect electrical equipment from damage during fault conditions ✓ and to protect the operator of the equipment.✓

4.3.1 Automatic✓ sequence starter✓

Sequence starter with timer✓

4.3.2 What would happen to contactor MC1 if contact MC1 N/O1 was faulty and permanently closed?

- The coil of MC_1 will remain energised✓
- As result MC_1NO_2 will remain closed✓
- In the main circuit✓ L_1, L_2, L_3, T_1, T_2, T_3 will all remain closed✓

4.3.3 Describe the starting sequence of the control circuit:

- When the Start button is pressed, the coil of contactor MC_1 will energise.
- The contact MC_1 N/O_1 will close keeping MC_1 energised after the Start button is released.
- At the same time, MC_1 N/O_2 closes, thus energising the coil of the timer contactor (T).
- The timer will time through after a pre-determined time, T N/O will close energising MC_2

4.3.4 The main function of MC is to electrically control✓ heavy current devices safely.✓

4.4 Explain why the starting current is reduced in a star-delta motor starter.

- To prevent unnecessary tripping of the overload relay at start-up.
- The starting current is reduced when starting the motor, to prevent overcurrent in the motor and prevent cables from overheating or burning out.

4.5.1 Apparent power.

$$S\,(P_{app}) = \sqrt{3} \times V_L \times I_L \quad ✓$$
$$= \sqrt{3} \times 380 \times 29 \quad ✓$$
$$= 19.09\ \text{kVA} \quad ✓$$

OR

$$S\,(P_{app}) = \sqrt{3} \times V_L \times I_L$$
$$= \sqrt{3} \times 380 \times 29$$
$$= 19087{,}19\ \text{VA}$$
$$= 19{,}08 \times 10^3\ \text{VA}$$

OR

$$S = \frac{P}{\text{Cos}\theta}$$
$$= \frac{16000}{0{,}85}$$
$$18\,823{,}53\ \text{VA}$$

4.5.2 Synchronous speed.

Number of poles = 12

$$\text{poles per phase} = \frac{12}{3} = 4 \quad ✓$$

$$\text{pole pairs} = 2 \quad ✓$$

NOTE: If 2 is replaced correctly in the place of p, full marks are awarded

$$n_s = \frac{60 \times f}{p} \quad ✓$$

$$= \frac{60 \times 50}{2} \quad ✓ \quad ✓$$

$$= 1500 \text{ rpm}$$

4.5.3 Percentage slip if the rotor speed is 1 400 r/min.

$$S = \frac{n_s - n_r}{n_s} \times 100 \quad ✓$$

$$= \frac{1500 - 1400}{1500} \times 100 \quad ✓$$

$$= 6,7\% \quad ✓$$