RPSC AEn-2024 Main Test Series

ELECTRICAL ENGINEERING

Test 3

Test Mode : • Offline • Online

Subjects : Electrical Machines

DETAILED EXPLANATIONS

PART-A

1. Solution:

$$V_2 = 4200 \text{ V},$$
$$V_1 = 230 \text{ V},$$
$$T_2 = 2000$$
$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$
$$T_1 = 2000 \times \frac{230}{4200}$$
$$= 109.52 \text{ turns}$$

The number of turns should be a whole number

$$\therefore \quad T_1 = 110$$

2. Solution:

$$\text{Voltage regulation} = R_{ep.u.} \cos\phi_2 + X_{ep.u.} \sin\phi_2$$
$$= 0.02 \times 0.8 + 0.05 \times 0.6$$
$$= 0.046 \text{ p.u.} = 4.6\%$$

3. Solution:

$$Q = \frac{E_f V}{X_S} - \frac{V^2}{X_S}$$

At synchronism, $E_f = V$

$$\therefore \quad Q = \frac{V^2}{X_S}(\cos\delta - 1)$$

Since the machine is supplying real power to the bus, δ cannot be zero. That is, cos δ < 1. Consequently Q is negative. Hence, the synchronous generator is consuming reactive power under the condition.

4. Solution:

The short-circuit ratio of a synchronous machine is defined as the ratio of the field current required to generate rated voltage on open circuit to the field current required to circulate rated armature current on short circuit.

5. Solution:

$$I_{st} = 0.6,$$

$$I_{SC} = 0.6 \times 5I_{fl} = 3I_{fl}$$

$$\tau_{st} = \tau_{fl}\left(\frac{I_{st}}{I_{fl}}\right)^2 \times S_{fl} = \tau_{fl}(3)^2 \times 0.05$$

$$= 0.45\,\tau_{fl}$$

6. Solution:

Causes of hunting:

- Sudden changes of load.
- Faults occurring in the system which the generator supplies.
- Sudden changes in the field current.
- Cyclic variations of the load torque.

7. Solution:

Here, $P = 4, \quad A = 2,$

$Z = 720, \quad N = 1000$ rpm

$$\therefore \quad n = \frac{N}{60} = \frac{1000}{60}\text{r.p.s.}$$

$$\therefore \quad \phi = 20 \text{ mWb} = 20 \times 10^{-3} \text{ Wb}$$

$$E = \frac{nP\phi Z}{A} = \frac{1000 \times 4 \times 20 \times 10^{-3} \times 720}{60 \times 2} = 480 \text{ V}$$

8. Solution:

$$s = 0.04,$$
$$\text{Stator input} = 90 \text{ kW},$$
$$\text{Stator loss} = 2 \text{ kW}$$

Rotor input, P_{ri} = Stator output
$= 90 - 2 = 88$ kW

Rotor cu loss, $P_{cr} = S \times$ rotor input
$= 0.04 \times 88 = 3.52$ kW

Mechanical power developed,

$$P_m = P_{ri} - P_{cr} = 88 - 3.52$$
$$= 84.48 \text{ kW}$$

9. Solution:

Lenz's law states that the direction of the induced emf in a coil is such that, if it is allowed to cause a current, then the current so produced opposes the cause of producing it.

10. Solution:

Conservator is a small sized tank which is placed on top of the main tank. This arrangement ensures that the surface area of oil exposed to air is limited so as to prevent fast oxidation of oil. It also provides space for expanded oil due to heating in the transformer.

PART-B

11. Solution:

1. **Copper Loss (P_{cu}):**

   This loss is variable loss,

   Total copper loss = Primary copper loss + Secondary copper loss

2. **Iron Loss (P_i):**

   This loss is constant loss,

   Iron loss = Hysteresis loss + Eddy current loss

   - The iron-loss can be reduced by reducing the core flux density which means that for same flux, the core cross-sectional area must be increased.

- Size of distribution transformer is larger as compare to similar power transformer as iron to copper ratio of distribution transformer is higher.

3 **Stray load loss:**

It largely results from leakage flux including eddy currents in the tank walls, conductors etc.

4. **Dielectric loss:**

The seat of this loss is in the insulating materials particularly in transformer oil and solid insulations of high voltage transformers.

Rating of transformer is given in kVA because constant loss is proportional to voltage and variable loss is proportional to current so total loss in transformer is proportional to volt ampere.

12. **Solution:**

Lap Winding:

In a lap winding, the Finish end of one coil is connected via commutator segment to the starting end of the adjacent coil situated under the same pole.

This Winding is known as lap winding because the sides of successive coils overlap each other. Number of parallel paths for a simplex lap winding are equal to the number of poles P i.e. $A = P$.

This winding is used where low voltage and high current is required.

Wave Winding:

In a wave winding, a coil-side under one pole is connected to a second coil side which occupies approximately the same position under the next pole through back connection.

Wave winding is used where high voltage and low current is required.

The number of parallel paths in wave winding are always 2.

Wave winding is not possible for same number of coil sides as average pitch is to be a whole number some terms are used in winding.

13. **Solution:**

1. **Synchronous Impedance Method (EMF Method):**

Here we assume drop due to armature reaction is considered drop due to leakage reactance. It gives regulation more then the actual value and hence it is called as pessimistic method.

2. **M.M.F. Method (Amp-turn method):**

Here, we assume drop due to leakage reactance is considered as drop due to armature reaction. This method gives regulation less than actual value therefore it is called as optimistic method.

3. **Z.P.F. Method:**

   Plot of V_a versus I_f corresponding to different field current. For maintaining rated armature current at zero p.f. lag called ZPF characteristic or Potier triangle characteristic.

4. **A.S.A. Method:**

   Here effect of saturation is also considered. This method is combination of Z.P.F. and M.M.F. method.

14. Solution:

Speed can be controlled by

Armature voltage control:

- Constant torque drive.
- Speed control is possible only below base speed i.e. $N < N_B$.

Armature resistance control:

- Constant torque drive.
- Speed control is possible only below base speed i.e. $N < N_B$.
- Wide range of speed control is not possible.

Field flux control:

- It is constant power drive.
- Speed control is possible above base speed i.e. $N > N_B$.

15. Solution:

- In synchronous motor excitation is DC whereas in induction motor it is AC.
- Synchronous runs at a single speed i.e. synchronous speed, whereas induction motor always runs below synchronous speed.
- Synchronous motor requires an additional DC power source for energizing rotor winding, while induction motor does not require any such source.
- Synchronous motors can be adjusted to run at any power factor whereas induction motors runs only at lagging power factor.
- Synchronous motor is costlier and more efficient.

16. Solution:

- Salient pole rotors are used in application with speeds from 100 to 1500 rpm.
- They are alternative known as "projected pole" type of rotors. The poles mounted on the rotor are made of laminations made of steel. The poles are connected to the rotor shaft by means of dovetail joints. Each pole has a pole shoe around which the winding is wound.

- The salient pole rotor is generally used in applications where the prime mover is a hydel turbine or a combustion engine which have low or medium speeds.
- Salient pole rotors usually contain damper windings to prevent rotor oscillations during operation.
- Non-salient pole rotors or cylindrical rotors are generally used in application which operate at higher speeds, 1500 rpm and above.
- The prime movers in these applications are generally gas or steam turbines. These are sometimes known as "drum rotors". The rotor is a cylinder made of solid forged steel.
- The slots on which the windings are fixed are milled on the rotor.
- The number of poles is usually 2 or 4 in number.
- Since these rotors are cylindrical, the windage loss is reduced.
- The noise produced is also less. These rotors have higher axial length.
- These rotors do not need damper windings.

17. Solution:

For leading power factor, $E_f^2 = (V\cos\phi - I_aR_a)^2 + (V\sin\phi - I_aX_s)^2$

$$= \left(\frac{400}{\sqrt{3}} \times 0.8 - 52.2 \times 0.25\right)^2 + \left(\frac{400}{\sqrt{3}} \times 0.6 - 52.2 \times 3.2\right)^2$$

$$= (171.6)^2 + (306.57)^2$$

$$E_f = 351.3 \text{ V}$$

$$\text{Line e.m.f.} = \sqrt{3} \times 351.3 = 608.5 \text{ V}$$

Power supplied, $P_i = \sqrt{3}V_L I_a \cos\phi$

$$= \sqrt{3} \times 400 \times 52.5 \times 0.8$$

$$= 29098 \text{ W}$$

18. Solution:

$$E_1 = V - I_{a1}R_{a1}$$

$$= 220 - 20 \times 0.1 = 218 \text{ V}$$

$$E_2 = \frac{N_2\phi_2}{N_1\phi_1}E_1$$

Since, $I_{sh} = \dfrac{V}{R_{sh}}$

The shunt field current I_{sh} remains constant and therefore $\phi_2 = \phi_1$

$$E_2 = \frac{N_2}{N_1} \times E_1 = \frac{520}{800} \times 218 = 141.7 \text{ V}$$

If R_A is the additional resistance inserted in the armature circuit,

$$E_2 = V - I_{a2}(R_{a1} + R_A)$$
$$141.7 = 220 - 20(0.1 + R_A)$$
$$R_A = 3.815 \ \Omega$$

PART-C

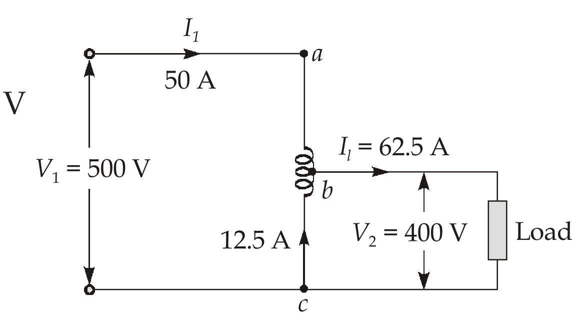
19. Solution:

For a two-winding transformer,

$$S_{in} = S_{out} = V_H I_{H\text{rated}} = V_L I_{L\text{rated}}$$
$$5 \times 1000 = 400 \, I_{H\text{rated}}$$
$$I_{H\text{rated}} = \frac{5000}{400} = 12.5 \text{ A}$$

and $5 \times 1000 = 100 \times I_{L\text{rated}}$

$$I_{L\text{rated}} = \frac{5000}{100} = 50 \text{ A}$$



Here, $V_1 = 500 \text{ V}, V_2 = 400 \text{ V}$

Auto-transformation ratio,

$$a_A = \frac{V_1}{V_2} = \frac{500}{400} = 1.25$$

$$I_H = \frac{I_l}{a_A} = \frac{I_l}{1.25}$$

Current through 400 V winding,

$$I_{cb} = I_l - I_1$$
$$= I_l - \frac{I_l}{1.25} = 0.2 \, I_l$$

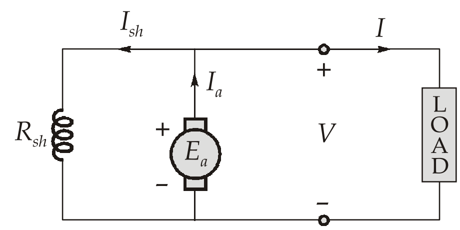
Since the current rating of 400 V winding is 12.5 A

$$0.2 \, I_l = 12.5$$
$$I_l = \frac{12.5}{0.2} = 62.5 \text{ A}$$

The kVA output of the autotransformer

$$S_{auto} = \frac{V_2 \cdot I_l}{1000} = \frac{400 \times 62.5}{1000} = 25 \text{ kVA}$$

20. Solution:



Given, $V = 200$ V

Load output, $P = 30 \times 10^3$ W

$R_a = 0.05\ \Omega$

$R_{sh} = 50\ \Omega$

$P_{iron + friction} = 1000$ W

$$I = \frac{P}{V} = \frac{30 \times 10^3}{200} = 150 \text{ A}$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{50} = 4 \text{ A}$$

$$I_a = I + I_{sh} = 150 + 4 = 154 \text{ A}$$

$$E_a = V + I_a R_a$$

$$= 200 + 154 \times 0.05 = 207.7 \text{ V}$$

Copper losses $= I_a^2 R_a + I_{sh}^2 R_{sh}$

$= (154)^2 \times 0.05 + 4^2 \times 50 = 1985.8$ W

Efficiency, $$\eta = \frac{\text{Output}}{\text{Output + Copperlosses + Ironloss + Frictionloss}}$$

$$= \frac{30 \times 10^3}{30 \times 10^3 + 1985.8 + 1000} = 0.9095 \text{ pu or } 90.95\%$$

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