Electrical Engineering - Optional For IAS (UPSC)

Energy Conversion - 2015-2021

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UPSC – ELECTRICAL Engineering optional – 2015 Questions

1. A 8-pole, 240 V lap-wound, series motor has armature and series field resistances of 0.2 ohm and 0.02 ohm respectively. There are 660 armature conductors. If the flux per pole is 0.03 Wb and the torque developed in the armature is 320 N-m, find the current taken by the motor and its speed. **[20M]**

2. Prove that mechanical power developed by a self excited DC shunt motor is maximum when back e.m.f. is equal to half the applied voltage, if the field loss is neglected. **[10M]**

3. A 440 V dc shunt motor has a no-load speed of 2000 rpm. It is running at 1000 rpm at full load torque, reduced armature voltage and full field current. If load torque is reduced to 50% of rated value with armature voltage and field voltage held constant at previous values, the speed increases to 1050 rpm. Find the armature voltage drop at full load. Neglect the effect of armature reaction. **[20M]**

4. Draw the circuit for the speed control of a separately-excited dc motor from a single-phase source and explain it. **[10M]**

5. The efficiency of a 20 kVA, 2500/250 V, single-phase transformer at unity power factor is 98% both at rated load and half rated load. Determine:

(i) the core loss and ohmic losses and

(ii) thep.u. value of the equivalent resistance of the transformer. **[20M]**

6. A 3- phase, 12 pole alternator is coupled to an engine running at 500 r.p.m. The alternator supplies power to an induction motor which has a full-load speed of 1455 r.p.m. Find the slip and number of poles of the motor. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2016 Questions

1. What do you mean by V-curves of a synchronous motor? Draw them showing the leading power factor and lagging power factor regions. **[10M]**

2. A 20 hp, 230 V, 1150 r.p.m.d.c. shunt motor has four poles, four parallel armature paths and 882 armature conductors. The armature circuit resistance is 0.188 Ω. At rated speed and rated output, the armature current is 73 A and the field current is 1.6 A. Calculate the electromagnetic torque. **[10M]**

3. The resistances and leakage reactances of a $10\,\text{kVA}, 50\,\text{Hz}, 2300/230\,\text{V}$ distribution transformer are

$$r_1 = 3.96\,\Omega \text{and}\, r_2 = 0.0396\,\Omega, x_1 = 15.8\,\Omega\; and\; x_2 = 0.158\,\Omega$$

Subscript 1 refers to HV and 2 refers to LV winding

The transformer delivers rated kVA at 0.8 p.f. lagging to a load on the LV side. Find the HV side voltage necessary to maintain 230 V across load terminals. Also find the percentage voltage regulation. **[20M]**

4. It is known that the stator core loss amounts to $1200\,\text{W}$ and the rotational losses equal 950 W. Moreover, at no-load the motor draws a line current of $18\,\text{A}$ at a power factor of 0.089 lagging. When the motor operates at a slip of 2.5%, find the input line current and power factor. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2017 Questions

1. A 15-hp, 220-V, 3-phase, 50-Hz, 6-pole, Y-connected induction motor has the following parameters per phase:

$r_1 = 0.128\,\Omega, r'_2 = 0.0935\,\Omega, (x_1 + x'_2) = 0.496\Omega, r_c = 183\,\Omega, x_\phi = 8\,\Omega$

The rotational losses are equal to the stator core losses (hysteresis and eddy-current). For a slip of 3%, find the line current and power factor. **[10M]**

2. The following test data were taken on a 30-kVA, $2400/240$ V, 50-Hz, single-phase transformer:

$$\text{Open} - \text{circuit test} : \text{V} = 2400\,\text{V}, \text{I} = 0.3\,\text{A},\;\; \text{P} = 230\,\text{W}$$
$$\text{Short} - \text{circuit test} : \text{V} = 70\,\text{V}, \text{I} = 18.8\,\text{A},\;\; \text{P} = 1050\,\text{W}$$

Determine the primary voltage, real and reactive power input, and efficiency, when a current of $12.5\,\text{A}$ at $240\,\text{V}$ is drawn from the low-voltage side by a load of 0.8 p. f. lagging. **[20M]**

3. An industrial consumer is operating a 1 kW induction motor at a lagging power factor of 0.8 and at a source voltage of $200\,\text{V}$ r. m. s. In order to reduce expenditure on power consumption, he wishes to raise the power factor to 0.95 lagging by connecting a circuit element in parallel with the load. Indicate the type of the circuit element (inductive or capacitive) and find the value if the operating frequency is 50 Hz. **[10M]**

4. A 230-V, 10-hp Dc series motor draws a line current of 36 A, when delivering rated power at its rated speed of 1200 r. p. m. The armature circuit resistance is 0.2 Ω and the series field winding resistance is 0.1 Ω. The magnetization curve may be considered linear.

(i) Find the speed of this motor when it drawn a line current of 20 A.

(ii) What is the developed torque at the new condition? **[10M]**

UPSC – ELECTRICAL Engineering optional – 2018 Questions

1. A squirrel cage induction motor has a starting current of six times the full load current, at a slip of 0.04. Calculate the line current and starting torque in p.u. (per unit) of full load values for the following starting methods: **[10M]**

(i) Direct switching

(ii) Star-Delta starting

2. The maximum efficiency of a 50 KVA transformer is 97.4% and occurs at 90% of full load, at unity power factor. Calculate the efficiency at **[20M]**

(i) Full load at 0.8 power factor (p.f.)

(ii) Half the full load at 0.9 power factor (p.f.)

3. A 400 volts D.C. shunt motor draws 30 amperes while supplying the rated load at a speed of 120 rad/sec. The armature resistance is 1.0 ohm and the field winding resistance is 250 ohms. Determine the external resistance that must be inserted in series with armature circuit so that, the armature current should not exceed 150% of its rated value, when the motor is plugged. Find the braking torque, at the instant of plugging. **[20M]**

4. A.D.C. generator has an armature e.m.f. of 100 volts, when the useful flux per pole is20 mWb and the speed is 800 r. p. m. Calculate the generated e.m.f.

(i) with the same flux and a speed of 1000 r. p. m.

(ii)with flux per pole of 24 m Wb and a speed of 900 r. p. m. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2019 Questions

1. A 15 kW, 230 V, 3-phase, Y-connected, 50 Hz, 4-pole squirrel cage induction motor has a starting torque of 115 percent and a maximum torque of 187 percent of its rated load torque. Neglecting the effects of stator resistance and rotational losses and assuming constant rotor resistance, find the slip and speed at maximum torque. Assume proper data, if required, with proper justification. **[10M]**

2. Explain the operation of a two-phase induction motor under unbalanced operation with the help of relevant equivalent circuit models and phasor diagram.

If the applied stator voltages to this motor are $\hat{V}_\alpha$ and $\hat{V}_\beta$. (in time quadrature but unequal in magnitude), prove that the starting torque of this motor is same as that developed when balanced two-phase voltage of magnitude $\sqrt{V_\alpha V_\beta}$ is applied. **[10M]**

3. A DC shunt generator running at rated speed of 1000 rpm can supply a full load current of 120 A at a nominal voltage of 105 V DC. The no load (open loop) characteristics at rated speed nominal voltage is given below:

Field Current, A	1	2	3	4	5	6	7
Generated Voltage, V	36	66	86	100	110	118	123

Graphically determine the field resistance of shunt generator for its operation at nominal voltage at rated speed as a ratio of its critical field resistance.

If the total fixed losses (rotational and iron) are 600 W; find the value of maximum efficiency of the generator; given that the generator operates at 85% efficiency in nominal conditions. **[20M]**

4. Show that the locus of the tip of the armature current phasor is a circle for a synchronous machine (Generator/Motor) operating at a constant terminal voltage V_t and a constant excitation voltage E_{af} with a fixed synchronous reactance X_S. Draw the phasor diagram and show the circular locus of I_a. **[10M]**

5. A magnetic circuit shown below consists of two sections of Al-ni-co-5 of length $l_m = 1.0$ cm embedded in a core of high permeability $(\mu \to \infty)$.The cross sectional areas of core, Al-ni-co-5 and air-gap are equal. The air-gap length $'g' = 0.2$ cm has neglible fringing effect.

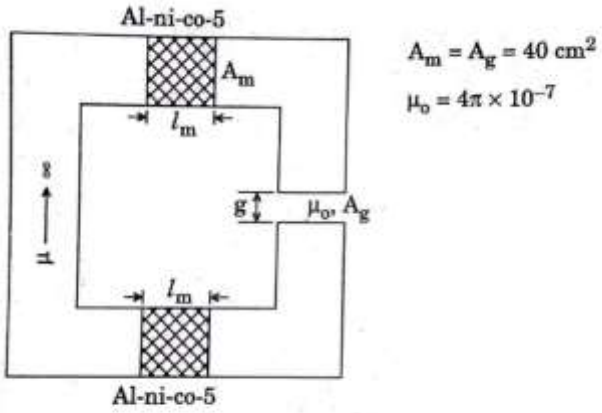

Figure 8(c-1)

If Al-ni-co-5 material B-H curve in second quadrant is linearly approximated, it can be given as below.

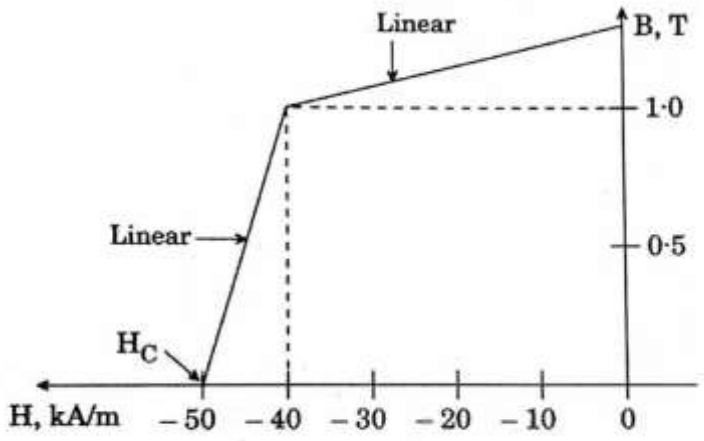

Figure 8(c-2)

Determine the slope of load line for the problem and hence determine the value of flux density (B_g) in the air-gap. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2020 Questions

1. A 220V, 8-pole lap wound dc shunt motor has 1200 conductors and has a field resistance of 220Ω. The motor takes a line current of 50 A at full load and rated speed. Find the additional resistance required in the field circuit if its speed is to be raised by 40 percent while maintaining its torque output at previous full load value. Assume linear magnetic circuit for the machine and resistance of each armature conductor as $50\ m\Omega$. **[10M]**

2. A separately excited dc motor is controlled by varying its armature voltage using a single-phase fully-controlled converter bridge as shown in Figure 5(a). The field current is kept constant at rated value. The motor has an armature resistance of 0.2Ω, and the motor voltage constant is $2.5\ V/(rad/sec)$. The motor is driving a mechanical load having a constant torque of 140 Nm. **[10M]**

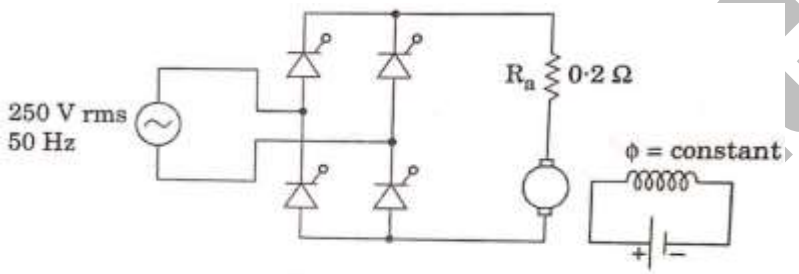

Figure 5(a)

For the firing angle of the converter being $60°$ and assuming the armature current to be continuous and ripple free,

(i) Calculate the motor armature constant.
(ii) Evaluate the motor speed in rad/sec.
(iii) Calculate the runs value of the fundamental component of the input current to the bridge converter.

3. A three-phase 4-pole squirrel cage type induction moto develops maximum torque at 20 percent slip. The maximum to rated torque ratio of the motor is 2.8. If the input voltage fluctuates during its operation, find the minimum voltage as a percentage of full load voltage allowable to develop rated torque. Also find the developed torque as a percentage of full load torque at rated slip under this condition. Assume standstill rotor resistance of 1.5Ω per phase, negligible stator side impedance and linear magnetic circuit. **[10M]**

4. A 220 V, Hz, 3-phase star-connected salient pole alternator has six poles. With a field current of 2.4 A, it produces rated terminal voltage on open circuit condition. On short circuit it requires 0.8 A field current to produce an armature current of 27.0 A. The alternator has X_d to X_q ratio of 1.5. It is connected to bus of 220 V line-to-line and its excitation required under this condition is 250 V. **[20M]**

(i) Find the maximum power that the alternator can deliver and the corresponding load angle with the excitation remaining unchanged.

(ii) Also find the maximum power that the alternator can deliver if a sudden loss of excitation occurs during the synchronized condition. Assume linear magnetic circuit.

4. A 3-phase, delta-connected, 6-pole, 50 Hz, 400 V, 925 rpm, squirrel cage induction motor has the following parameters: **[10M]**

$R_s = 0.2\ \Omega,\ R'_r = 0.3\ \Omega, X_s = 05\ \Omega, X'_r = 1\ \Omega$

The motor is fed from a voltage source inverter with constant V/f ratio below 50 Hz and constant voltage of 400 V above 50 Hz frequency. Calculate:

- Speed for the frequency of 35 Hz and half of full-load torque,
- Frequency for a speed of 600 rpm and 80% of full-load torque and
- Torque for a frequency of 35 Hz and speed of 650 rpm.

Assume motor speed – torque curves to be parallel straight lines in the region of interest.

4. A 150 KVA, 11 KV$/415$ V, 50 Hz single-phase transformer has maximum possible efficiency of 98.5% at 50 Hz, 125 KVA, 0.8 lag p. f. load. Its hysteresis and eddy current loss components are also same under this condition. Find the transformer efficiency at rated KVA and unity power factor load with its supply frequency changed to 40 Hz at unchanged input voltage. Assume Steinmetz constant $x = 1.6$ for the transformer core. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2021 Questions

1. A 220 V dc shunt motor has armature resistance $R_a = 0.13\ \Omega$, field resistance $R_a = 250\ \Omega$ and rotational loss 230 W. On full-load, the line current is 9.5 A with the motor running at 1440 rpm. Determine the following: **[10M]**

(i) The mechanical power developed

(ii) The power out

(iii) The load torque

(iv) The full-load efficiency

2. A Scott connected transformer shown in Figure 5(c) is supplied from 11 kV, 3-phase, 50 Hz mains. Secondaries are series connected and supply 1100 A at a voltage of $100\sqrt{2}$ V to a resistive load. The phase sequence of the 3-phase supply is ABC. **[10M]**

(i) Calculate the turns ratio of the teaser transformer.

(ii) Calculate the line current I_B and its phase angle with respect to the voltage of phase A to neutral on the 3-phase A to neutral on the 3-phase side.

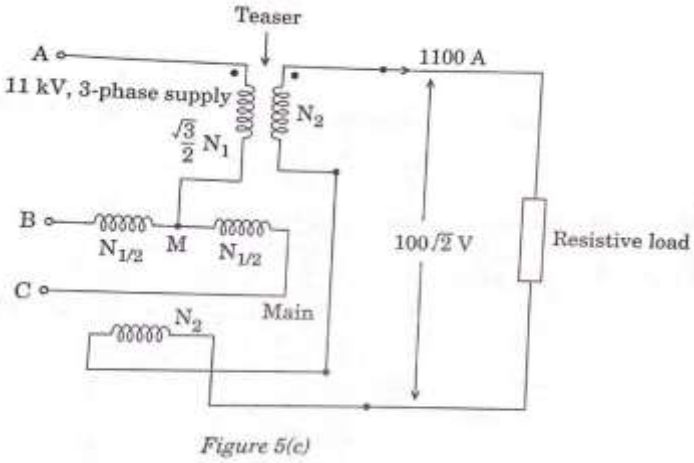

Figure 5(c)

3. The following test data are obtained for a three-phase, 195 MVA, 15 kV, 50 Hz star connected synchronous machine. **[20M]**

Open circuit test:

I_f(A)	150	300	450	600	750	900	1200
V_{LL}(kV)	3.75	7.5	11.2	13.6	15	15.8	16.5

Short circuit test:

$I_f = 750$ A, $I_a = 700$ A

The armature resistance is small.

(i) Draw the open circuit characteristic, the short circuit characteristic, the airgap line and the modified airgap line.

(ii) Determine the unsaturated and saturated values of the synchronous reactance in pu.

(iii) Find the field current required, if the synchronous machine is to deliver 100 MVA rated voltage, at 0.8 leading power factor.

4. A three-phase, 4-pole, 50 Hz induction motor has a rotor resistance of $4.5\ \Omega/\text{phase}$ and a standstill reactance of $8.5\,\Omega/\text{phase}$ with no external resistance in the rotor circuit. The starting torque of the motor is 85 Nm. Neglecting stator voltage drop, determine the following: **[20M]**

(i) The rotor voltage at standstill

(ii) The starting torque, if a $3\ \Omega$ resistance were added in each rotor phase

(iii) The rotor induced voltage and the torque at a slip of 0.03