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NPTEL

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Courses » Electrical Machines - I

Announcements Course Forum Progress Mentor

Unit 11 - Week 10

Week 10: Assignment

1) A starter circuit has to be designed for a 24hp, 250V and 80A dc shunt motor, such that the maximum starting current is limited to 250 percent of its rated armature current and as soon as the current falls to rated value, the sections of starting resistors are to be cut out. The armature resistance of the motor is 0.2Ω and the shunt field resistance is 85Ω. How many stages of starting resistance are needed?

Accepted Answers:
(Type: Numeric) 3

10 points

2) In problem-01, among all the sections of the starting resistors, what is the resistance of the section with maximum resistance? ***10 points***

- 1.2Ω
- 0.77Ω
- 0.93Ω
- 0.54Ω

Accepted Answers:
0.77Ω

3) A 440V dc shunt motor draws 40A while supplying the rated load at 1500rpm. The armature resistance is 0.4Ω and the field-winding resistance is 230Ω. Determine the external resistance that must be inserted in series with the armature circuit so that the armature current does not exceed 150% of its rated value when motor is plugged? ***10 points***

- 15Ω
- 12Ω
- 6Ω
- 8Ω

Accepted Answers:
15Ω

4) For problem-4, find out the breaking torque in Nm?
[Enter the numerical value only]

Accepted Answers:
(Type: Range) 150, 158

10 points

5) A 27hp, 220V, 1800rpm dc shunt motor has an armature resistance of 0.1Ω and field resistance of 176Ω. Assume that $E_a = V_t$ at no load. Data for the magnetization curve at 1800 rpm are ***10 points***

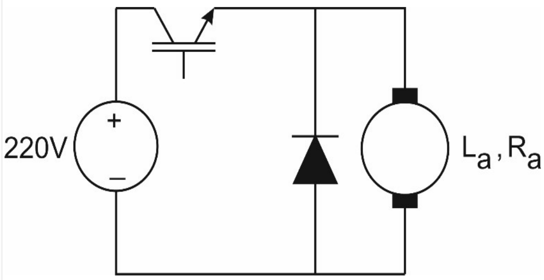
I_f (A)	0.0	0.125	0.25	0.5	0.625	0.75	0.875	1.0	1.25	1.5
E_a(V)	5	33.25	67	134	160	175	190	200	214	223

The motor is used to drive a load which requires a constant power of 16kW. The motor is connected to a 220V dc supply. Determine the speed range possible with a field rheostat of 180Ω.

- 1820 to 2800 rpm
- 1642 to 2400 rpm
- 1788 to 2415 rpm
- 1600 to 2900 rpm

Accepted Answers:
1788 to 2415 rpm

6) The separately excited dc motor in the figure below has a rated armature current of 20A and a rated armature voltage of of 150V. An ideal chopper switching at 5 kHz is used to control the armature voltage. If La=0.1 mH, Ra=1 Ω, neglecting armature reaction, the duty ratio of the chopper to obtain 50% of the rated torque at the rated speed and the rated field current is



Accepted Answers:
(Type: Range) 0.6,0.65

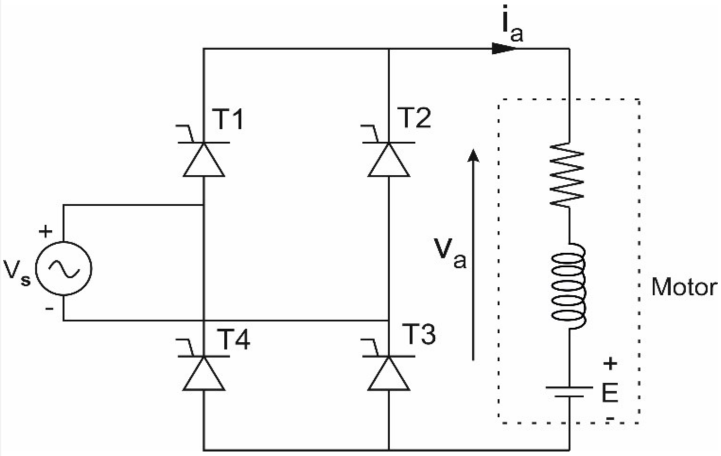
10 points

7) Find the number of sections of the starter required for a 250V shunt motor. The maximum current limit is 67A and minimum current is 50A. Armature resistance is 0.5ohm ***10 points***

- 5
- 6
- 7
- 8

Accepted Answers:
7

8) A 200V, 875 rpm, 150A separately excited dc motor has an armature resistance of 0.06 Ω. It is fed from a single-phase fully-controlled rectifier with an AC source voltage of 220V, 50Hz. Assuming continuous conduction, calculate firing angle (in degree) for rated motor torque and 750 rpm.



Accepted Answers:
(Type: Range) 28-32

10 points

9) A 250V shunt motor with constant main field drives a load , the torque of which varies as cube of speed. It takes 40A while running at 500rpm. What will be the speed if a 25ohm resistor is connected in series with armature?

10 points

- 450rpm
- 400rpm
- 300rpm
- 250rpm

Accepted Answers:
250rpm

10) A 4-section starter for a shunt motor limits the current to 45A. What will be the lower current limit? Take armature resistance as 1ohm. Take the total resistance at starting as 17ohms.

Accepted Answers:
(Type: Range) 20-24

10 points

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Assignment - 10 : Solution

Q1 & Q2. Solution

The rated line current of this motor is 80A

The rated armature current is $I_a = I_L - I_F = 80 - \dfrac{250}{85} = 77A$

The maximum allowed starting current $I_{a\_max} = 2.5 \times 77 = 192.5A$

The total initial starting resistance, $R_a + R_{start1} = \dfrac{250}{192.5} = 1.29\Omega$

$$R_{start1} = 1.29 - 0.2 = 1.09\Omega$$

The current will fall to the rated value when E_a rises to

$$E_a = 250 - (1.29 \times 77) = 150.67V$$

Resistance at which the current get back to 192.5A

$$R_a + R_{start2} = \frac{250 - 150.67}{192.5} = 0.516\Omega$$

$$R_{start2} = 0.516 - 0.2 = 0.316\Omega$$

With this resistance, the current will fall to the rated value, when E_a equals to

$$E_a = 250 - (77 \times 0.516) = 210.268V$$

The resistance at which the current get back to 192.5A

$$R_a + R_{start3} = \frac{250 - 210.268}{192.5} = 0.206\Omega$$

$$R_{start3} = 0.206 - 0.2 = 0.006\Omega$$

With this resistance in the circuit, the current will fall to rated value when E_a rises to

$$E_a = 250 - (0.206 \times 77) = 234.138V$$

If the resistance is cut out, when E_a reaches 234.369V,the resulting current

$$I_a = \frac{250 - 234.138}{0.2} = 79.31A$$

79.31 < 192.5

The number of stages of starting resistance : 3

$$R_{start1} = R_1 + R_2 + R_3$$

$$R_{start2} = R_2 + R_3$$

$$R_{start3} = R_3$$

$$R_3 = 0.006\Omega$$

$$R_2 = 0.316 - 0.006 = 0.31\Omega$$

$$R_1 = 1.09 - 0.31 - 0.006 = 0.774\Omega$$

Q3.Solution

$$\text{The field current:} \quad I_f = \frac{440}{230} = 1.91A$$

$$\text{The armature current:} \quad I_a = 40 - 1.91 = 38.09A$$

$$\text{The back emf of the motor:} \quad E_b = 440 - (38.09 \times 0.4) = 424.77V$$

$$\text{The voltage in the armature circuit, at the time of plugging} = 440 + 424.77 = 864.77V$$

$$\text{The maximum allowable armature current} \quad = 1.5 \times 38.07 = 57.1A$$

Thus, the external resistance in the armature circuit at the instant of plugging must be

$$R = \frac{864.77}{57.1} - 0.4 = 14.74\Omega$$

Q4.Solution

$$\text{Breaking torque,} \quad T_b = \frac{E \times I_a}{\omega} = \frac{424.772 \times 57.1}{2\pi \times \frac{1500}{60}} = 154.4Nm$$

Q5.Solution

$$P_{Load} = E_a I_a = (220 - (I_a \times 0.1))I_a = 16,000W$$

$$I_a = 2124A \quad or \quad 75.3A$$

$$\rightarrow I_a = 75.3A$$

$$E_a = 220 - (75.3 \times 0.1) = 212.47V$$

$$\text{For field rheostat at zero position,} \quad I_f = \frac{220}{176} = 1.25A$$

From the magnetization data, for I_f = 1.25A at 1800 rpm, $E_a = 214V$

$$K_a\phi = \frac{214}{1800 \times \frac{2\pi}{60}} = 1.135 \rightarrow n = \frac{212.47}{1.135 \times 2\pi} \times 60 = 1787.6rpm$$

$$\text{Field rheostat at maximum position,} \quad I_f = \frac{220}{180 + 176} = 0.618A$$

From the magnetization data, for I_f = 0.618A at 1800 rpm $= 158V$

$$K_a\phi = \frac{158}{1800 \times \frac{2\pi}{60}} = 0.84 \rightarrow n = \frac{212.47}{0.84 \times 2\pi} \times 60 = 2415.4rpm$$

Speed range: 1788 to 2415 rpm

Q6.Solution

$$\text{Torque (T)} \propto \phi I_a$$

$$\text{But flux } (\phi) \text{ is constant}$$

$$\therefore T \propto I_a$$

$$\text{Speed (N)} \propto E_b/\phi$$

$$\text{Again } N \propto E_b$$

Hence to maintain constant speed, Back emf should remain constant

$$\text{, Under rated conditions } E_{b1} = V_1 - I_{a1} \times R_a$$

$$= 150 - 20 \times 1 = 130V$$

For half rated torque, current should be half rated current

$$\implies I_{a2} = 20/2 = 10A$$

$$\text{Required armature voltage } V_2 \text{ is}$$

$$\therefore V_2 = 130 + 10 \times 0.5 = 140V$$

$$\text{For the buck converter output voltage } V_0 = dV_{in}$$

$$\therefore \text{Duty ratio (d)} = 140/220 = \mathbf{0.636}$$

Q7.Solution

$$R_1 = \text{Total resistance inserted at the begining } = 250/I_1 = 250/67 = 3.73ohm$$

$$\text{Lower limit of current } (I_2) = (3/4)67 = 50.25A$$

$$\frac{I_2}{I_1} = 0.75$$

If 'N' is the total number of section, then

$$\left(\frac{I_2}{I_1}\right)^N = \frac{R_a}{R_1}$$

$$0.75^N = \frac{0.5}{3.14}$$

Taking log on both sides and rearranging

$$N = \frac{log(0.134)}{log(0.75)}$$

$$N = 6.98 = \mathbf{7}$$

Q8.Solution

At rated conditions, Back EMF (E_{b1})

$$E_{b1} = 200 - I_{a1} \times R_a$$

$$= 200 - 150 \times 0.06 = 191V$$

Speed (N) $\propto E_b$(Since flux is constant) $\therefore$ Back EMF corresponding to 750 rpm speed $= \frac{750}{875} \times 191 = 163.714V$

Since torque is still rated, armature current remains same

Terminal voltage at this condition $(V_t) = 163.714 + 150 \times 0.06 = 172.714V$

Output voltage of fully controlled rectifier is given by $V_0 = \frac{2V_m}{\pi} cos(\alpha)$

, where V_m = Peak of supply voltage, α = Firing angle of converter

$$\therefore cos(\alpha) = \frac{V_0 \pi}{2V_m} = \frac{172.71 \times 3.14}{2 \times 220\sqrt{2}} = 0.872$$

$$\implies \alpha = cos^{-1}(0.872) = \mathbf{29.31}$$

Q9.Solution

Torque (T) $\propto I_a$ (since main field constant)

$$T \propto N^3$$

$$\implies I_a \propto N^3$$

$$\frac{I_{a2}}{I_{a1}} = \frac{N_2^3}{N_1^3}$$

$$\frac{N_2^3}{I_{a2}} = \frac{500^3}{40}$$

$E_b \propto N$ (Flux is constant)

$$\therefore \frac{E_{b2}}{E_{b1}} = \frac{N_2}{N_1}$$

$$E_{b2} = \frac{N_2}{500} \times 250 = N_2/2$$

$E_{b1} = 250V$ (since armature resistance is unknown this drop can be neglected)

$$E_{b2} = 250 - 25 \times I_{a2}$$

$$\frac{N_2}{2} = 250 - 25 \times \frac{40N_2^3}{500^3}$$

Rearranging, we get

$$4N_2^3 + 500^2 N_2 - 500^3 = 0$$

Solving for N_3 we get

$$N_3 = \mathbf{250rpm}$$

Q10.Solution

$$\text{Number of sections in starter } (N) = 4$$
$$\text{Maximum current } (I_2) = 45A$$
$$\text{Initial resistance } (R_1) = 17ohm$$
$$\text{Armature resistance } (R_a) = 1ohm$$
$$\text{Lower limit of current } (I_2) = ?$$
$$\left(\frac{I_2}{I_1}\right)^N = \frac{R_a}{R_1}$$
$$\text{Substituting and solving for } I_2, \text{ we get}$$
$$I_2 = \textbf{22.16A}$$