UNIVERSITY FRANCISCO JOSÉ DE CALDAS

Faculty of Engineering - Electronic Engineering

Engines and Generators

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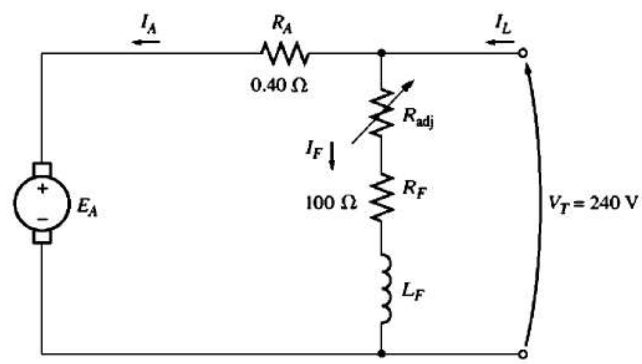
First Cut Exercises

1. Problems next refer to the following dc motor:

$P_{rated} = 15\text{ hp}$	$I_{L,rated} = 55\text{ A}$
$V_T = 240\text{ V}$	$N_F = 2700$ turns per pole
$n_{rated} = 1200\text{ r/min}$	$N_{SE} = 27$ turns per pole
$R_A = 0.40\ \Omega$	$R_F = 100\ \Omega$
$R_S = 0.04\ \Omega$	$R_{adj} = 100$ to $400\ \Omega$

Rotational losses are 1800 W at full load. Magnetization curve is as shown in Figure P9-1. Assume that the motor described above is connected in shunt. The equivalent circuit of the shunt motor is shown in Figure.



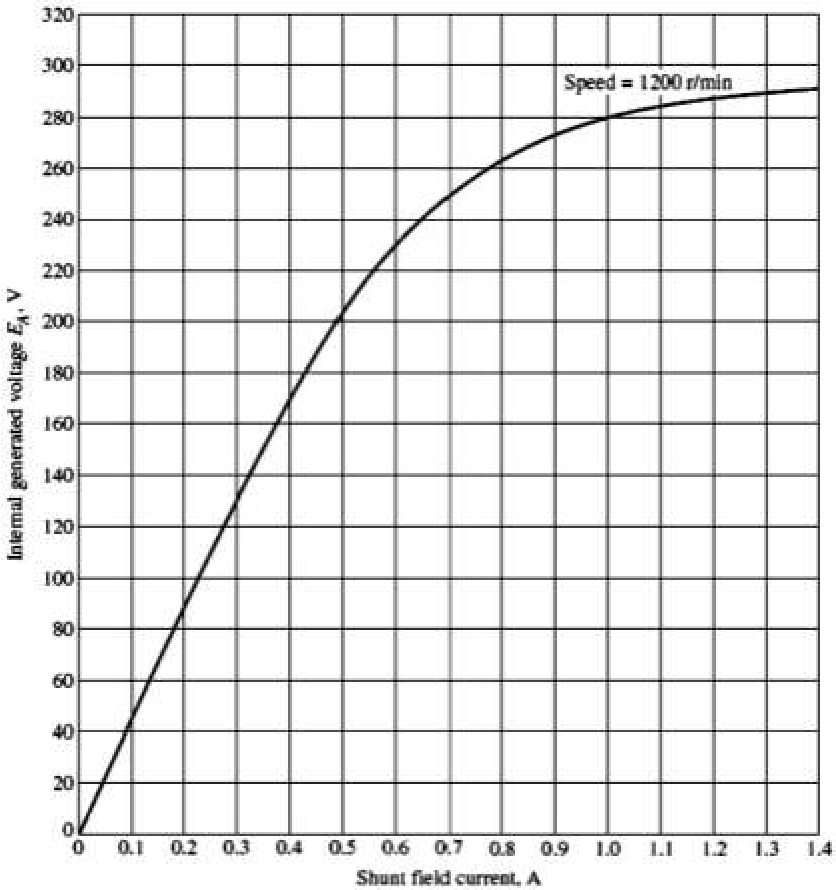


FIGURE P9–1
The magnetization curve for the dc motor in Problems 9–1 to 9–12. This curve was made at a constant speed of 1200 r/min.

If the resistor Radj is adjusted to 175Ω. What is the efficiency of the motor?

$Il := 55\ A$ $\quad Vi := 240\ V$ $\quad Rf := 100\ \Omega$ $\quad Radj := 175\ \Omega$

$P_{nominal} := 15 \cdot 746\ W = 11.19\ kW$ $\quad P_{rotor} := 1800\ W$ $\quad Ra := 0.4\ \Omega$

$$Ia := Il - \frac{Vi}{Radj + Rf} = 54.127\ A$$

$$P_{in} := Vi \cdot Il = 13.2\ kW$$

$$P_{out} := P_{in} - \frac{Vi^2}{Radj + Rf} - Ia^2 \cdot Ra - 0.01 \cdot P_{nominal} - P_{rotor} = 9.907\ kW$$

$$n_{eficiency} := \frac{P_{out}}{P_{in}} \cdot 100 = 75.051$$

2. If Radj can be adjusted from 100 to 400 Ω. What are the maximum and minimum no load speeds possible with this motor?

$Vi := 240\ V$ $\qquad I_{linea} := 55\ A$

$Radj := 100\ \Omega$ $\qquad Rf := 100\ \Omega$ $\qquad Ra := 0.4\ \Omega$

$$If := \frac{Vi}{Rf + Radj} = 1.2\ A \qquad n0 := 1200 \qquad Ea0 := 290\ V$$

$Ia := I_{linea} - If$ $\qquad Ea := Vi - Ia \cdot Ra = 218.48\ V$

$$n := \frac{Ea}{Ea0} \cdot n0 = 904.055$$

$Radj := 400\ \Omega$

$$If := \frac{Vi}{Rf + Radj} = 0.48\ A \qquad Ea0 := 200\ V$$

$$n := \frac{Ea}{Ea0} \cdot n0 = 1310.88$$

3. A 15-hp, 230 V, 1800 r/min shunt dc motor has a full-load armature current of 60A when operations at rated condition. The armature resistance of the motor is Ra=0.15Ω, and the field resistance Rf=80Ω. The adjustable resistance in the field circuit Radj may be varied over the range from 0 to 200Ω is currently set to 90Ω. Armature reaction may be ignored in this machine.
What is the efficiency of the motor at full load?

$Ia := 60\ A$ $\qquad Vi := 230\ V$ $\qquad Rf := 80\ \Omega$ $\qquad Radj := 90\ \Omega$

$P_{nominal} := 15 \cdot 746\ W = 11.19\ kW$ $\qquad Ra := 0.15\ \Omega$

$$Il := Ia + \frac{Vi}{Radj + Rf} = 61.353\ A$$

$$P_{in} := Vi \cdot Il = 14.111\ kW$$

$$P_{out} := P_{in} - \frac{Vi^2}{Radj + Rf} - Ia^2 \cdot Ra - 0.01 \cdot P_{nominal} = 13.148\ kW$$

$$n_{eficiency} := \frac{P_{out}}{P_{in}} \cdot 100 = 93.175$$

4. A 250 Vdc shunt motor has an armature resistance of 0.4 Ω a field resistance of 300 Ω. Find the start resistance value for 2 nominals current Iline=30 A, n=1200 rpm. Find the

$I_{nominal} := 30\ A$ $\qquad Vi := 250\ V$ $\qquad Rf := 300\ \Omega$ $\qquad Ra := 0.4\ \Omega$

$$If := \frac{Vi}{Rf} = 0.833\ A \qquad Ia := I_{nominal} - If = 29.167\ A \qquad Imax := 2 \cdot Ia = 58.333\ A$$

$$Rt := \frac{Vi}{Imax} = 4.286\ \Omega \qquad Rs := Rt - Ra = 3.886\ \Omega$$

5. From the last exercise. Find the speed resistance value for n=800 rpm and 30 N m.

$$Ea := Vi - Ia \cdot Ra = 238.333\ V \qquad n_{nominal} := 1200 \qquad T := 30\ N \cdot m \qquad n := 800$$

$$w_{nominal} := n_{nominal} \cdot \frac{2\ \pi}{60 \cdot s} \cdot rad = 125.664\ \frac{rad}{s}$$

$$K\phi := \frac{Ea}{w_{nominal}} = 1.897\ Wb$$

$$w := n \cdot \frac{2\ \pi}{60 \cdot s} \cdot rad = 83.776\ \frac{rad}{s}$$

$$Rs := -Ra - \frac{(K\phi)^2}{T} \cdot \left(w - \frac{Vi}{K\phi} \right) = 5.36\ \Omega$$

6. An automatic starter circuit is to be designed for a shunt motor rated at 15hp, 240V, and 80A. The armature resistance of the motor is 0.15Ω, and the shunt field resistance is 40Ω. The motor is to start with no more than 250% of its rated armature current. and as soon as the current falls to rated value. a starting resistor stage is to be cut out. How many stages of starting resistance are needed. and how big should each one be?

$$Ra := 0.15\ \Omega \qquad Rf := 40\ \Omega \qquad Vi := 240\ V \qquad I_{min} := 80\ A$$

We get the resistance number

$$I_{max} := 2.5 \cdot I_{min} = 200\ A$$

$$Rt := \frac{Vi}{I_{max}} = 1.2\ \Omega \qquad If := \frac{Vi}{Rf} = 6\ A$$

$$n := \frac{\log\left(\frac{Ra}{Rt}\right)}{\log\left(\frac{I_{min}}{I_{max}}\right)} = 2.269 \qquad n := 3$$

We calculate the resistor values

$$Ea := Vi - I_{min} \cdot Rt = 144\ V$$

$$Rt1 := \frac{Vi - Ea}{I_{max}} = 0.48\ \Omega$$

$$Ea := Vi - I_{min} \cdot Rt1 = 201.6\ V$$

$$Rt2 := \frac{Vi - Ea}{I_{max}} = 0.192\ \Omega$$

$$R3 := Rt2 - Ra = 0.042\ \Omega$$

$$R2 := Rt1 - R3 - Ra = 0.288\ \Omega$$

$$R1 := Rt - R2 - R3 - Ra = 0.72\ \Omega$$

7. This problem refers to a 240V, 100A dc motor which has both shunt and series windings. Its characteristics are

$R_A = 0.14\ \Omega$ $\quad N_F = 1500$ turns
$R_S = 0.04\ \Omega$ $\quad N_{SE} = 12$ turns
$R_F = 200\ \Omega$ $\quad n_m = 1200$ r/min
$R_{adj} = 0$ to $300\ \Omega$, currently set to $120\ \Omega$

This motor has compensating windings and interpoles. The magnetization curve for this motor at 1200 rpm is shown in Figure P9-6.

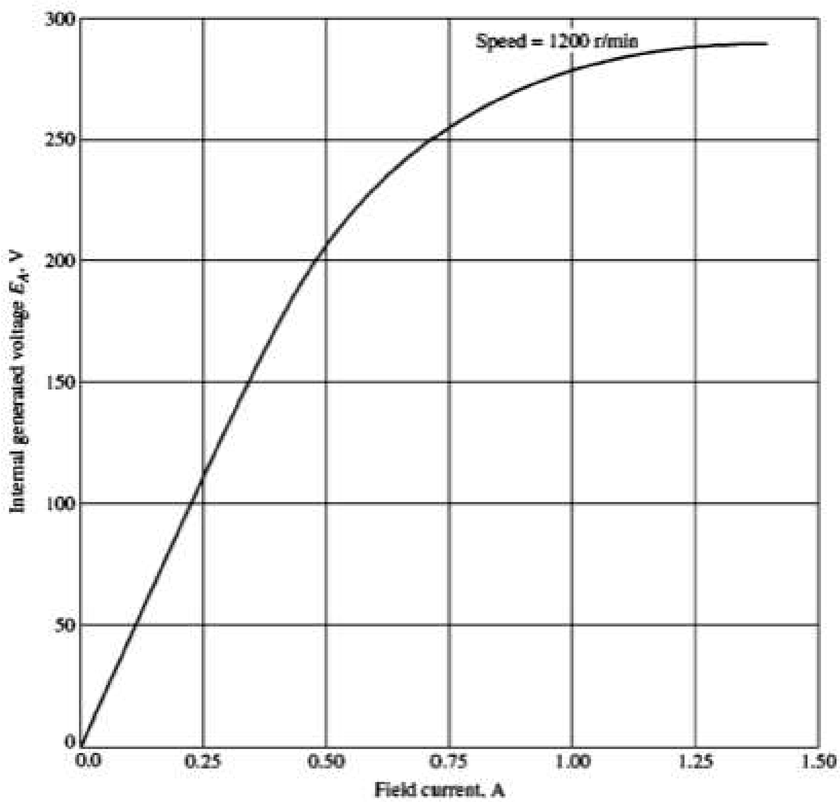


FIGURE P9–6
The magnetization curve for the dc motor in Problems 9–16 to 9–19.

The motor described above is connected in shunt. Under no-load conditions. what range of possible speeds can be achieved by adjusting Radj?

When Radj=0Ω

$Vi := 240\ V$ $\quad Ia := 100\ A$

$Radj := 0\ \Omega$ $\quad Rf := 200\ \Omega$ $\quad Ra := 0.14\ \Omega$

Speed

$$Ea := Vi - Ia \cdot Ra = 226\ V$$

$$n := \frac{Ea}{Ea0} \cdot n0 = 986.182$$

When Radj=300Ω

$$Radj := 300\ \Omega$$

$$If := \frac{Vi}{Rf + Radj} = 0.48\ A \qquad Ea0 := 200\ V$$

$$n := \frac{Ea}{Ea0} \cdot n0 = 1356$$

8. A 15 hp, 240V shunt motor takes a full-load line current of 50A. The armature and field resistance are 0.2Ω and 100Ω respectively. The total brush-contact drop is 2V and core and friction losses are 280W. Calculate the efficiency of the motor.

$$I_{linea} := 50\ A \qquad Vi := 240\ V \qquad Vesc := 2\ V \qquad P_{rotor} := 280\ W$$

$$Ia := I_{linea} - \frac{Vi}{Rf} = 47.6\ A$$

$$P_{nominal} := 15 \cdot 746\ W = 11.19\ kW$$

$$P_{in} := Vi \cdot I_{linea} = 12\ kW$$

$$P_{out} := P_{in} - \frac{Vi^2}{Rf} - Ia^2 \cdot Ra - 0.01 \cdot P_{nominal} - P_{rotor} - Vesc \cdot Ia = 10.031\ kW$$

$$n_{eficiency} := \frac{P_{out}}{P_{in}} \cdot 100 = 83.588$$

9. A 100hp, 250V, 350 A shunt dc motor with an armature resistance of 0.05Ω. It is desired to design a starter circuit for this motor which will limit the maximum starting current to twice its rated value and which will switch out sections of resistance as the armature current falls to its rated value.

$$Ra := 0.05\ \Omega \qquad Vi := 250\ V \qquad I_{min} := 350\ A$$

$$I_{max} := 2 \cdot I_{min} = 700\ A$$

$$Rt := \frac{Vi}{I_{max}} = 0.357\ \Omega$$

$$n := \frac{\log\left(\frac{Ra}{Rt}\right)}{\log\left(\frac{I_{min}}{I_{max}}\right)} = 2.837 \qquad n := 3$$

$$Ea := Vi - I_{min} \cdot Rt = 125\ V$$

$$Rt1 := \frac{Vi - Ea}{I_{max}} = 0.179\ \Omega$$

$$Ea := Vi - I_{min} \cdot Rt1 = 187.5\ V$$

$$Rt2 := \frac{Vi - Ea}{I_{max}} = 0.089\ \Omega$$

$$R3 := Rt2 - Ra = 0.039\ \Omega$$

$$R2 := Rt1 - R3 - Ra = 0.089\ \Omega$$

$$R1 := Rt - R2 - R3 - Ra = 0.179\ \Omega$$