Example 8–1. A 50-hp, 250-V, 1200 r/min dc shunt motor with compensating windings has an armature resistance (including the brushes, compensating windings, and

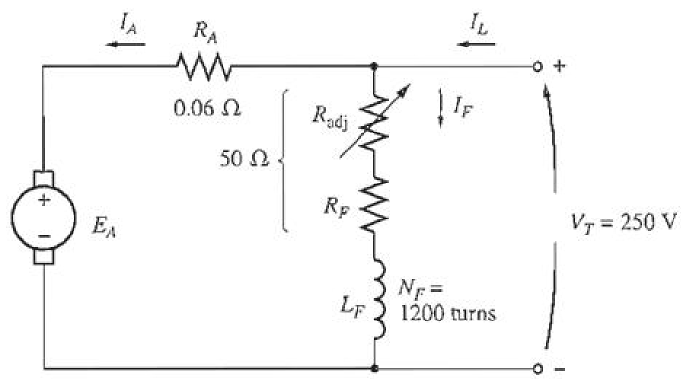

FIGURE 8–7
The shunt motor in Example 8–1.

interpoles) of 0.06 Ω. Its field circuit has a total resistance $R_{adj} + R_F$ of 50 Ω, which produces a *no-load* speed of 1200 r/min. There are 1200 turns per pole on the shunt field winding (see Figure 8–7).

(*a*) Find the speed of this motor when its input current is 100 A.
(*b*) Find the speed of this motor when its input current is 200 A.
(*c*) Find the speed of this motor when its input current is 300 A.
(*d*) Plot the torque–speed characteristic of this motor.

DC MACHINE

THEVENIN

SOLVED PROBLEMS

1. *A DC series motor operates at 800 rpm with a line current of 100A from 230V mains. Its armature circuit resistance is 0.15Ω and its field resistance 0.1Ω. Find the speed at which the motor runs at a line current of 25A, assuming that the flux at this current is 45% of the flux at 100A.*

[BADB-20, BUET]

THEVENIN

4. A 250V shunt motor with armature resistance of 0.5Ω runs at 600 rpm on full load and takes an armature current of 20A. If resistance of 1Ω is placed in the armature circuit, find the speed at full load torque.

[RPCL-19, MIST]

EEE JOB GUIDELINE

Example 1 :

A 208-V, 10-hp, four-pole, 60 Hz, Y-connected induction motor has a full-load slip of 5 percent.

(a) What is the synchronous speed of this motor?
(b) What is the rotor speed of this motor at the rated load?
(c) What is the rotor frequency of this motor at the rated load?
(d) What is the shaft torque of this motor at the rated load?

THEVENIN EEE JOB GUIDELINE

Example 2:

A 480-V, 60-Hz, 50-hp three-phase induction motor is drawing 60 A at 0.85-PF lagging. The stator copper losses are 2 kW, and the rotor copper losses are 700 W. The friction and windage losses are 600 W, the core losses are 1800 W, and the stray losses are negligible. Find the following quantities:

(a) The air-gap power P_{ag}
(b) The power converted P_{conv}
(c) The output power P_{out}
(d) The efficiency of the motor.

Example 4 :

A two-pole, 50-Hz induction motor supplies 15 kW to a load at a speed of 2950 r/min.

(a) What is the motor's slip?
(b) What is the induced torque in the motor in N.m under these condition?
(c) What will the operating speed of the motor be if its torque is double?
(d) How much power will be supplied by the motor when the torque is doubled?

Example 4–1. A 200-kVA, 480-V, 50-Hz, Y-connected synchronous generator with a rated field current of 5 A was tested, and the following data were taken:

1. $V_{T,OC}$ at the rated I_F was measured to be 540 V.
2. $I_{L,SC}$ at the rated I_F was found to be 300 A.
3. When a dc voltage of 10 V was applied to two of the terminals, a current of 25 A was measured.

Find the values of the armature resistance and the approximate synchronous reactance in ohms that would be used in the generator model at the rated conditions.

Example 4–2. A 480-V, 60-Hz, Δ-connected, four-pole synchronous generator has the OCC shown in Figure 4–23a. This generator has a synchronous reactance of 0.1 Ω and

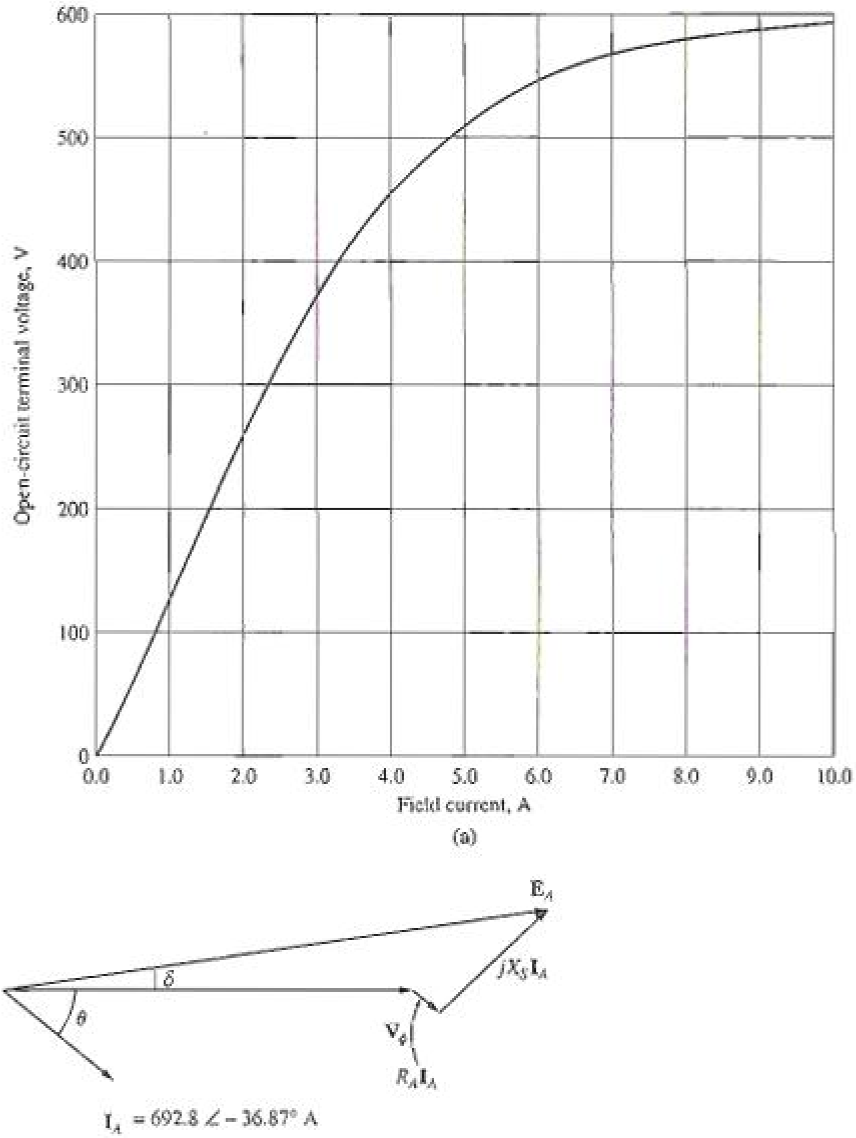

FIGURE 4–23
(a) Open-circuit characteristic of the generator in Example 4–2. (b) Phasor diagram of the generator in Example 4–2.

(a) What is the speed of rotation of this generator?
(b) How much field current must be supplied to the generator to make the terminal voltage 480 V at no load?
(c) If the generator is now connected to a load and the load draws 1200 A at 0.8 PF lagging, how much field current will be required to keep the terminal voltage equal to 480 V?
(d) How much power is the generator now supplying? How much power is supplied to the generator by the prime mover? What is this machine's overall efficiency?
(e) If the generator's load were suddenly disconnected from the line, what would happen to its terminal voltage?
(f) Finally, suppose that the generator is connected to a load drawing 1200 A at 0.8 PF *leading*. How much field current would be required to keep V_T at 480 V?

Solution

Example 4–3. A 480-V, 50-Hz, Y-connected, six-pole synchronous generator has a per-phase synchronous reactance of 1.0 Ω. Its full-load armature current is 60 A at 0.8 PF lagging. This generator has friction and windage losses of 1.5 kW and core losses of 1.0 kW at 60 Hz at full load. Since the armature resistance is being ignored, assume that the I^2R losses are negligible. The field current has been adjusted so that the terminal voltage is 480 V at no load.

(a) What is the speed of rotation of this generator?
(b) What is the terminal voltage of this generator if the following are true?

1. It is loaded with the rated current at 0.8 PF lagging.
2. It is loaded with the rated current at 1.0 PF.
3. It is loaded with the rated current at 0.8 PF leading.

(c) What is the efficiency of this generator (ignoring the unknown electrical losses) when it is operating at the rated current and 0.8 PF lagging?
(d) How much shaft torque must be applied by the prime mover at full load? How large is the induced countertorque?
(e) What is the voltage regulation of this generator at 0.8 PF lagging? At 1.0 PF? At 0.8 PF leading?

Example 4–5. Figure 4–31 shows a generator supplying a load. A second load is to be connected in parallel with the first one. The generator has a no-load frequency of 61.0 Hz and a slope s_P of 1 MW/Hz. Load 1 consumes a real power of 1000 kW at 0.8 PF lagging, while load 2 consumes a real power of 800 kW at 0.707 PF lagging.

(a) Before the switch is closed, what is the operating frequency of the system?
(b) After load 2 is connected, what is the operating frequency of the system?
(c) After load 2 is connected, what action could an operator take to restore the system frequency to 60 Hz?

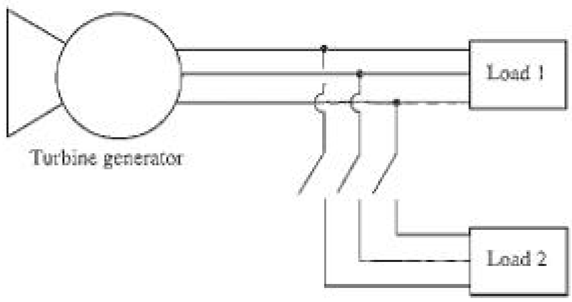

FIGURE 4–31
The power system in Example 4–5.

Example 4–6. Figure 4–38a shows two generators supplying a load. Generator 1 has a no-load frequency of 61.5 Hz and a slope s_{P1} of 1 MW/Hz. Generator 2 has a no-load frequency of 61.0 Hz and a slope s_{P2} of 1 MW/Hz. The two generators are supplying a real load totaling 2.5 MW at 0.8 PF lagging. The resulting system power-frequency or house diagram is shown in Figure 4–39.

(a) At what frequency is this system operating, and how much power is supplied by each of the two generators?
(b) Suppose an additional 1-MW load were attached to this power system. What would the new system frequency be, and how much power would G_1 and G_2 supply now?
(c) With the system in the configuration described in part b, what will the system frequency and generator powers be if the governor set points on G_2 are increased by 0.5 Hz?

Example 12.8

Two balanced loads are connected to a 240-kV rms 60-Hz line, as shown in Fig. 12.22(a). Load 1 draws 30 kW at a power factor of 0.6 lagging, while load 2 draws 45 kVAR at a power factor of 0.8 lagging. Assuming the *abc* sequence, determine: (a) the complex, real, and reactive powers absorbed by the combined load, (b) the line currents, and (c) the kVAR rating of the three capacitors Δ-connected in parallel with the load that will raise the power factor to 0.9 lagging and the capacitance of each capacitor.

Practice Problem 12.8

Assume that the two balanced loads in Fig. 12.22(a) are supplied by an 840-V rms 60-Hz line. Load 1 is Y-connected with $30 + j40\ \Omega$ per phase, while load 2 is a balanced three-phase motor drawing 48 kW at a power factor of 0.8 lagging. Assuming the *abc* sequence, calculate: (a) the complex power absorbed by the combined load, (b) the kVAR rating of each of the three capacitors Δ-connected in parallel with the load to raise the power factor to unity, and (c) the current drawn from the supply at unity power factor condition.

Answer: (a) $56.47 + j47.29$ kVA, (b) 15.7 kVAR, (c) 38.813 A.

Example 12.9

The unbalanced Y-load of Fig. 12.23 has balanced voltages of 100 V and the *acb* sequence. Calculate the line currents and the neutral current. Take $\mathbf{Z}_A = 15\ \Omega$, $\mathbf{Z}_B = 10 + j5\ \Omega$, $\mathbf{Z}_C = 6 - j8\ \Omega$.

Practice Problem 12.9

The unbalanced Δ-load of Fig. 12.24 is supplied by balanced line-to-line voltages of 240 V in the positive sequence. Find the line currents. Take $\mathbf{V}_{ab}$ as reference.

Answer: $21.66\underline{/-41.06^\circ}$ A, $34.98\underline{/-139.8^\circ}$ A, $38.24\underline{/74.27^\circ}$ A.

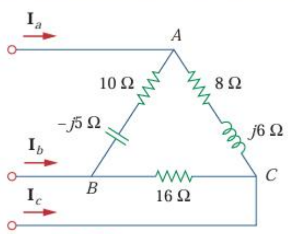

Figure 12.24
Unbalanced Δ-load; for Practice Prob. 12.9.