ECE 3600 Single-Phase Induction Motor Examples

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Ex. 1 From Fin F11. A Single-phase, 1/3-hp, 120-V split-phase motor draws 5 A in its main winding, and 3 A in its start winding when it is first switched on. The two currents lag the supply voltage by 40° and 15°. respectively.

a) Find the initial start-up current (magnitude) and power.

$$\mathbf{I_L} := 5 \cdot A \cdot e^{-j \cdot 40 \cdot deg} + 3 \cdot A \cdot e^{-j \cdot 15 \cdot deg} \qquad |\mathbf{I_L}| = 7.822 \cdot A \qquad arg(\mathbf{I_L}) = -30.672 \cdot deg$$

$$P_{start} := 120 \cdot V \cdot |\mathbf{I_L}| \cdot \cos(arg(\mathbf{I_L})) \qquad P_{start} = 807.36 \cdot W$$

b) To improve this motor, you want to add a capacitor in series with the start winding so that currents will be 90° out of phase with each other. Find the value of the required capacitor.

The original: $\mathbf{Z_{start}} := \dfrac{120 \cdot V}{3 \cdot A \cdot e^{-j \cdot 15 \cdot deg}} \qquad \mathbf{Z_{start}} = 38.637 + 10.353j \cdot \Omega$

The start winding current should now lead the voltage by 50°.

$$X_{start} + X_C = -38.637 \cdot \Omega \cdot \tan(50 \cdot deg) = -46.046 \cdot \Omega$$

$$X_C := -46.046 \cdot \Omega - 10.353 \cdot \Omega \qquad X_C = -56.399 \cdot \Omega = -\frac{1}{\omega \cdot C} \qquad C := \frac{1}{-X_C \cdot \omega} \qquad C = 47 \cdot \mu F$$

c) The new start winding current is about 2 A. The motor starting torque is proportional to the sine of the angle between the winding currents. It is also proportional to the magnitudes of the currents. How much bigger is the strarting torque with the additional capacitor?

$$\frac{(2 \cdot A) \cdot (5 \cdot A) \cdot \sin(90 \cdot deg)}{(3 \cdot A) \cdot (5 \cdot A) \cdot \sin(40 \cdot deg - 15 \cdot deg)} = 1.577$$

Ex. 2 From Fin F12. A 1/4-hp, 120-V, 60-Hz, single-phase, capacitor-run, induction motor has two identical windings set 90° apart in the motor housing. Each winding draws 3 A at 30° lag when the rotor is locked and 1.5 A at 40° lag when the motor is running at its rated speed.

a) Find the ideal capacitor to place in series with one of the windings at startup.
Note: the ideal capacitor would create the ideal phase difference between the winding currents.

$$\mathbf{Z_{start}} := \frac{120 \cdot V}{3 \cdot A \cdot e^{-j \cdot 30 \cdot deg}} \qquad \mathbf{Z_{start}} = 34.641 + 20j \cdot \Omega$$

$$X_{start} + X_C = -34.641 \cdot \Omega \cdot \tan(60 \cdot deg) = -60 \cdot \Omega$$

$$X_C := -60 \cdot \Omega - 20 \cdot \Omega \qquad X_C = -80 \cdot \Omega = -\frac{1}{\omega \cdot C} \qquad C := \frac{1}{-X_C \cdot \omega} \qquad C = 33.2 \cdot \mu F$$

b) Find the ideal capacitor to place in series with one of the windings at rated speed.

$$\mathbf{Z_{run}} := \frac{120 \cdot V}{1.5 \cdot A \cdot e^{-j \cdot 40 \cdot deg}} \qquad \mathbf{Z_{run}} = 61.284 + 51.423j \cdot \Omega$$

$$X_{run} + X_C = -61.284 \cdot \Omega \cdot \tan(50 \cdot deg) = -73.035 \cdot \Omega$$

$$X_C := -73.035 \cdot \Omega - 51.423 \cdot \Omega \qquad X_C = -124.458 \cdot \Omega = -\frac{1}{\omega \cdot C} \qquad C := \frac{1}{-X_C \cdot \omega} \qquad C = 21.3 \cdot \mu F$$

c) Find a compromise capacitor to place in series with one of the windings. Choose this capacitor to make the current magnitude in the two windings exactly the same at rated speed. (Don't worry about the phase angles.)

$$X_C := -2 \cdot 51.423 \cdot \Omega \qquad X_C = -102.846 \cdot \Omega = -\frac{1}{\omega \cdot C} \qquad C := \frac{1}{-X_C \cdot \omega} \qquad C = 25.8 \cdot \mu F$$

d) Find the input power at rated speed with the compromise capacitor in place.

$$\mathbf{I_L} := 1.5 \cdot A \cdot e^{-j \cdot 40 \cdot deg} + 1.5 \cdot A \cdot e^{j \cdot 40 \cdot deg} \qquad |\mathbf{I_L}| = 2.298 \cdot A \qquad arg(\mathbf{I_L}) = 0 \cdot deg$$

$$P_{start} := 120 \cdot V \cdot |\mathbf{I_L}| \cdot \cos(arg(\mathbf{I_L})) \qquad P_{start} = 275.8 \cdot W$$