Single-phase induction motor

- Power supply available at residences & small businesses is single phase → Need 1-φ induction motor or universal motor (series connected DC motor) can also be used. 1-φ induction motor has longer life (no commutator brush assembly present) but higher weight to power ratio.

- 1-φ induction motor is similar to 3-φ induction motor in its principle of operation. But single-phase by itself does not do the job, and modification is necessary. The reason is the magnetic field created by 1-φ source does not rotate (simply pulsates):
  \[ B(t) = K i(t) \cos \Theta = K I_m \cos(\omega t) \cos \Theta. \]
  At any Θ, field pulsates between \( \pm K I_m \cos \Theta \).

![Field winding](image)

- Field winding is excited by 1-φ source
  - Rotor is same as 3-φ induction motor (squirrel-cage or wound)

- Since field doesn't rotate, no starting torque exists. Additional insight can be gained by writing
  \[ B(t) = \frac{K I_m}{2} \left[ \cos(\omega t - \Theta) + \cos(\omega t + \Theta) \right] \]
  which is superposition of two oppositely rotating fields. Each field creates its own torque-speed characteristics, which are similar to 3-φ induction motor characteristics.
**Single-phase induction motor**

- Net starting torque is zero, but once speed-up in either direction, a certain torque is delivered.

- To create a non-zero starting torque, an auxiliary winding (besides the main winding) is used. Together the two windings act as a 2-pole induction motor and create a rotating field (need not be uniform).

**Possible configurations:**
- Capacitor-start and capacitor-run
- Capacitor-start only (has a centrifugal switch)
- No-capacitor (also called split-phase)

(All configurations can have a centrifugal switch to disconnect the start capacitor or the aux. winding)

- Speed at which centrifugal switch is open
1-Φ induction motor (Example)

\[ V = 120\text{V}, \quad f = 60\text{Hz} \]

\[ \text{Im} = \frac{120}{6 + j8} = \frac{12}{6} / \begin{bmatrix} 1 & -j \end{bmatrix} = 12 / 53.13^\circ \]

\[ \Rightarrow I_a = -53.13^\circ + 90^\circ = 36.87^\circ \]

\[ I_a = \frac{120}{12+j(9-\frac{1}{\omega c})} \]

\[ \Rightarrow I_a = -\tan^{-1} \left( \frac{9 - \frac{1}{\omega c}}{12} \right) \]

\[ \Rightarrow 9 - \frac{1}{\omega c} = -9 \Rightarrow \frac{1}{\omega c} = 18 \]

\[ \Rightarrow C = \frac{1}{(18)(2\pi)(60)} = 147.4 \text{ mF} \]

Pout = 2hp = 2(746) W

Pin = \frac{2(746)}{0.8} W

\[ \text{VI} = \frac{\text{Pin}}{\text{pf}} \]

\[ \Rightarrow I_{\text{full-load}} = \frac{2(746)}{(0.8)(0.75)240} = 10.36 \text{A rms} \]

It is given that no-load current = \( G \) (full-load current)

\[ \Rightarrow I_{\text{no-load}} = (62.2) (10.36) = 62.2 \text{ A rms} \]

\[ \Rightarrow \text{drop across } 2+2j = 62.2 \sqrt{(2+2j)^2} \text{ V rms} \]

\[ \Rightarrow V_{\text{motor}} = 240 - \sqrt{(12.44)^2} \text{ V rms} \]

\[ \Rightarrow (V_{\text{motor}})_{\text{min}} = 240 - (12.44)(2) = 222.4 \text{ V} \]

\[ \Rightarrow \frac{(240 - 222.4)}{240} = 7.33\% \text{ drop in voltage when motor starts.} \]