Polyphase Systems - Intro

- Introduction
  - Objectives
  - Vocabulary and background
- Analysis
  - Comparison with single-phase
  - Comparison with two-phase
  - Currents and voltage in a three-phase system
  - The Y-Connected generator (vocabulary and circuit intro)

Polyphase Systems- Objectives

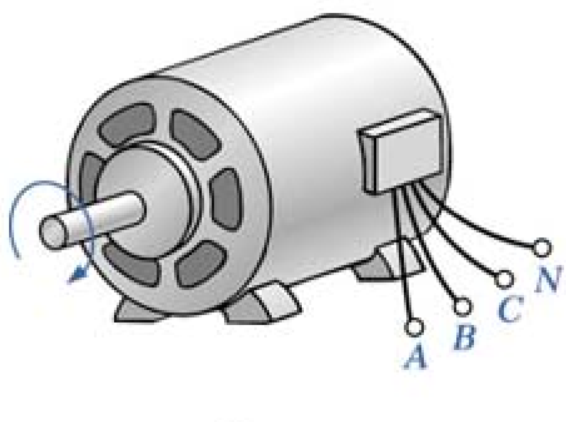
- Become familiar with the operation of a three-phase generator and the magnitude and phase relationship connecting the three phase voltages.
- Be able to calculate the voltages and currents for a three-phase Y-connected generator and Y-connected load.
- Understand the significance of the phase sequence for the generated voltages of a three-phase Y-connected or Δ-connected generator.
- Be able to calculate the voltages and currents for a three-phase-connected generator and Δ-connected load.

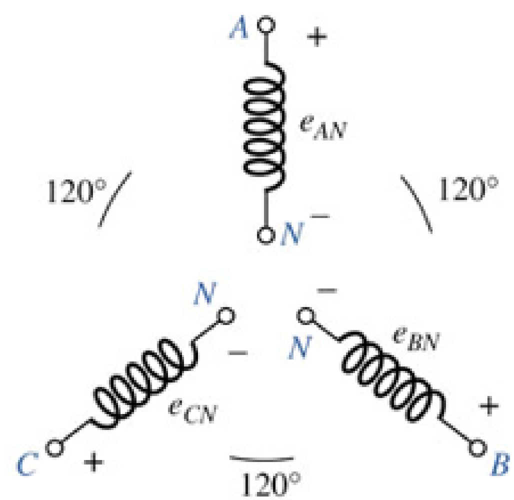
Polyphase Systems - Introduction

- An ac generator designed to develop a single sinusoidal voltage for each rotation of the shaft (rotor) is referred to as a single-phase ac generator.
- If the number of coils on the rotor is increased in a specified manner, the result is a polyphase ac generator, which develops more than one ac phase voltage per rotation of the rotor.
- In general, three-phase systems are preferred over single-phase systems for the transmission of power for many reasons, including the following:
  - 1. Thinner conductors can be used to transmit the same kVA at the same voltage, which reduces the amount of copper required (typically about 25% less) and in turn reduces construction and maintenance costs.
  - 2. The lighter lines are easier to install, and the supporting structures can be less massive and farther apart.
  - 3. Three-phase equipment and motors have preferred running and starting characteristics compared to single-phase systems because of a more even flow of power to the transducer than can be delivered with a single-phase supply.

Polyphase Systems - Introduction

- In general, three-phase systems are preferred over single-phase systems for the transmission of power for many reasons, including the following:
  - 4. In general, most larger motors are three phase because they are essentially self-starting and do not require a special design or additional starting circuitry.

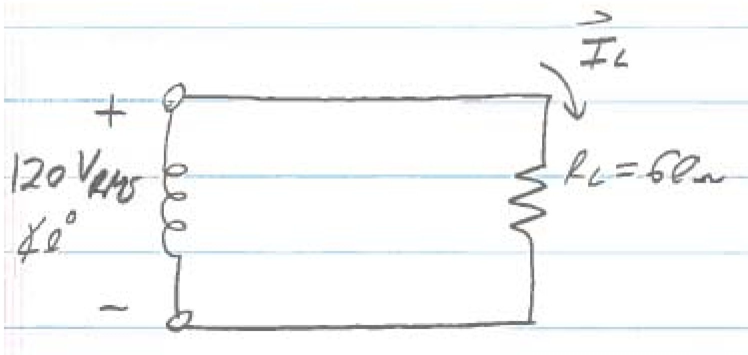




Same voltage magnitude on each coil, 120 degree phase-shift between waveforms

Polyphase Systems – Comparison with Single Phase

Consider the following single-phase system with a 240W load



$$P_{RL} = \frac{(120 V_{RMS})^2}{60\Omega} = \boxed{240W}$$

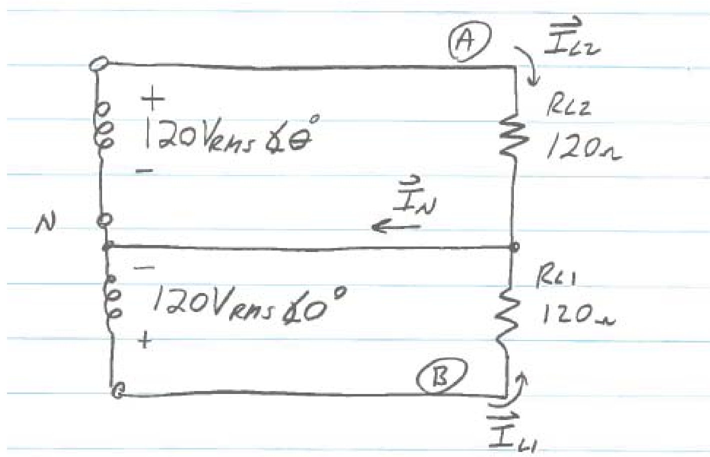
$$\vec{I}_L = \frac{120 V_{RMS}\angle 0°}{60\Omega} = \boxed{2A_{RMS}\angle 0°}$$

Note: conductors are required to carry 2ARMS to AND from the load

Total copper cross section required: 2ARMS + 2ARMS = 4ARMS

Polyphase Systems – Comparison with Two-Phase

Consider the following two-phase system with a <u>240W load</u>



$$\vec{I}_{L2} = \frac{120\,V_{rms}\angle\theta^\circ}{120\Omega} = 1\,A_{rms}\angle\theta^\circ$$

$$\vec{I}_{L1} = \frac{120\,V_{rms}\angle 0^\circ}{120\Omega} = 1\,A_{rms}\angle 0^\circ$$

$$P_T = \left[(1A_{rms})^2\,120\Omega\right]\times 2 = \boxed{240W}$$

$$\vec{I}_N = 1A_{rms}\angle\theta^\circ + 1A_{rms}\angle 0^\circ$$

When will the neutral current, **I_N** be at a minimum? What is that value (of theta)?

$$\theta = 180^\circ : \vec{I}_N = 0A$$

Total copper cross section required: 1ARMS + 1ARMS = 2ARMS

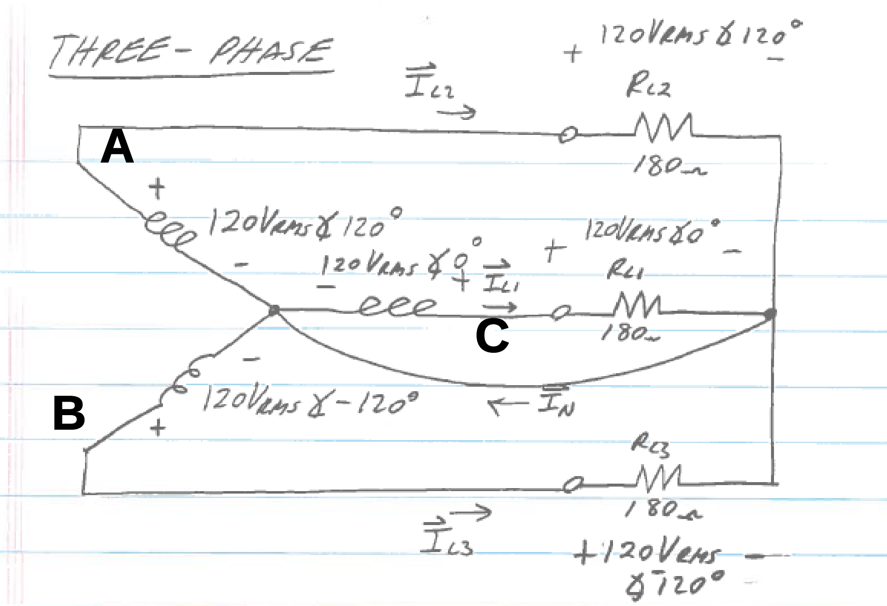
- ½ of the single-phase case
- Assumes a balanced load (**I_N** = 0ARMS)

For θ=180°, **find** |**V_{AB}**| and |**I_{AN}**| in RMS

For θ=180°,
|**V_{AB}**| = 240 VRMS and
|**I_{AN}**| = 1A RMS

Three-Phase System – Currents and Voltages

Consider the following three-phase system with a <u>240W load</u>



$$\vec{I}_{L1} = \frac{120V_{RMS}\angle 0°}{180\Omega} = \underline{0.667A_{RMS}\angle 0°}$$

$$\vec{I}_{L2} = \frac{120V_{RMS}\angle 120°}{180\Omega} = \underline{0.667A_{RMS}\angle 120°}$$

$$\vec{I}_{L3} = \frac{120V_{RMS}\angle -120°}{180\Omega} = \underline{0.667A_{RMS}\angle -120°}$$

$$P_{L1} = P_{L2} = P_{L3} = (0.667A_{RMS})^2\,180\Omega = \underline{80W}$$

$$\therefore \boxed{P_T = 240W} \leftarrow 240W \text{ LOAD}$$

Find: I_N and the total copper cross-section required to deliver 240W of power:

$$\vec{I}_N = \vec{I}_{L1} + \vec{I}_{L2} + \vec{I}_{L3}$$

For this balanced-load:

I_N = 0ARMS and the total copper cross-section required is:

$$0.667A_{RMS} + 0.667A_{RMS} + 0.667A_{RMS} = \boxed{2A_{RMS}}$$

Much better than the single-phase case and less than two-phase for unbalanced loads

What about $|V_{AB}|$?

This line-voltage is 207.9VRMS, less than the 240VRMS required for the two-phase case

Three-Phase System – Currents and Voltages

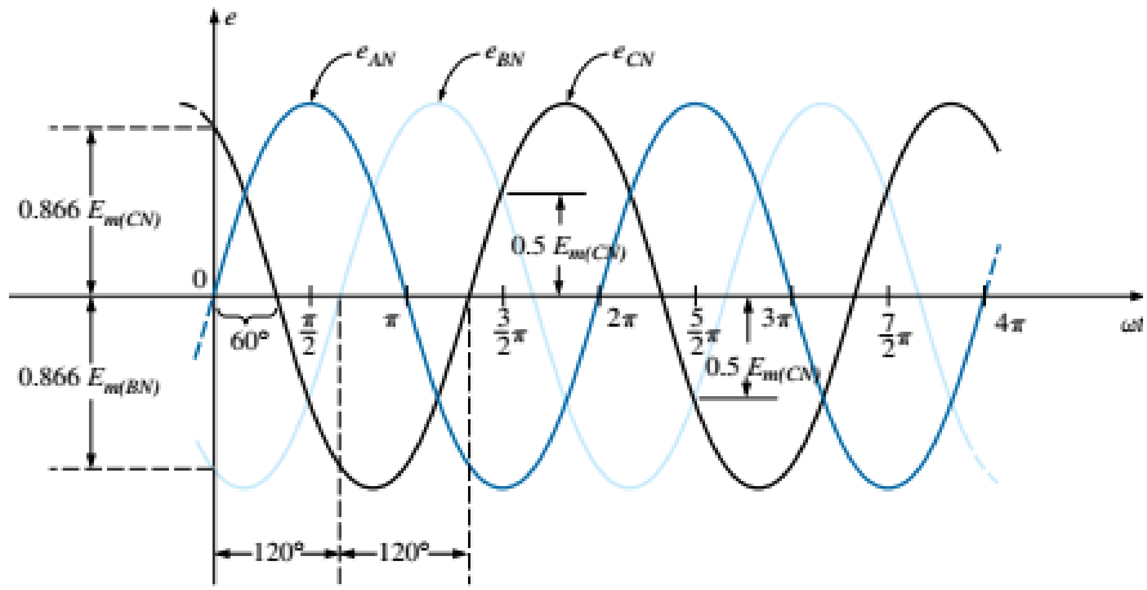


FIG. 24.2

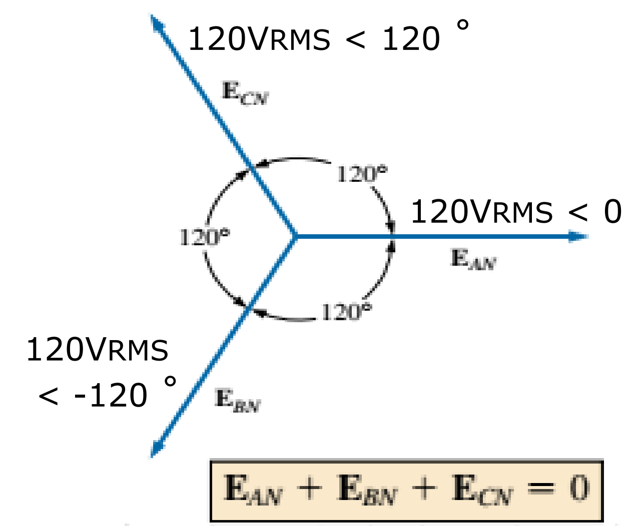
Phase voltages of a three-phase generator.

Phase voltages as functions of time:

- At any "t," the algebraic sum of the three phase voltages = 0V
- When one phase voltage =0V, the other two are at 86.6% of their positive or negative maximums
- When any two phase voltages are equal in magnitude and sign (at 0.5Em), the remaining phase voltage has the opposite polarity and is at it's peak value

Phase voltages as vectors (phasor diagram):

- The phasor sum of the phase voltages = 0



Phasor diagram for the phase voltages of a three-phase generator.

Polyphase Systems – The Y Connected Generator

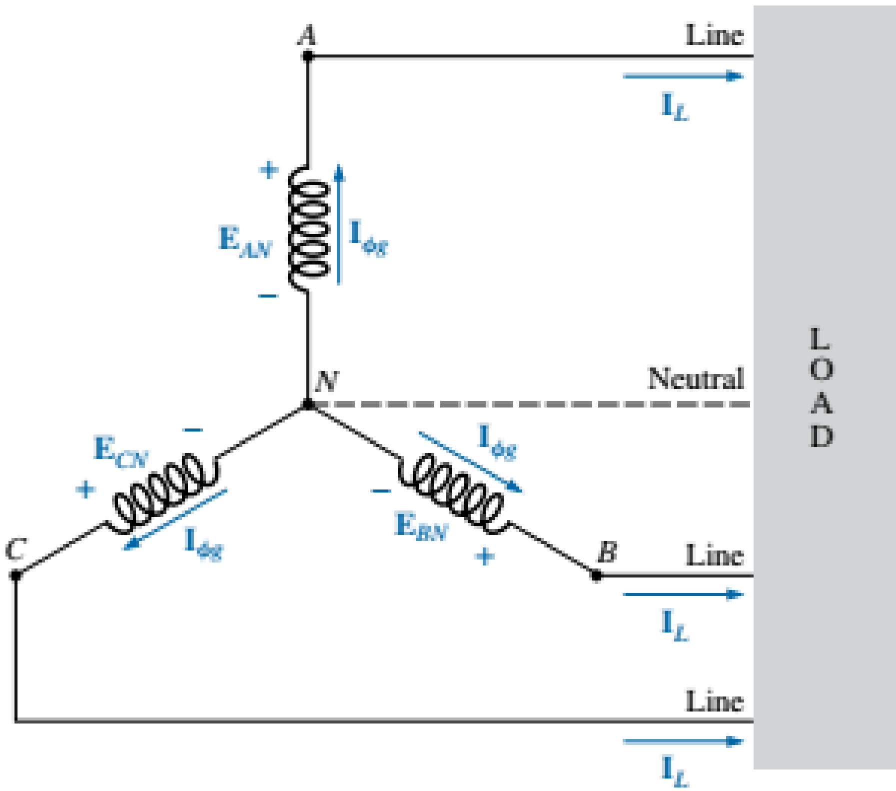


FIG. 24.5

Y-connected generator.

PHASE VOLTAGES

$\vec{E}_{AN}, \vec{E}_{BN}, \vec{E}_{CN}$

PHASE CURRENTS

$I_{\phi g}$: EQUAL FOR A BALANCED LOAD

LINE CURRENTS

$I_L = I_{\phi g}$

LINE VOLTAGES

$\vec{E}_{AB} = \vec{E}_{AN} - \vec{E}_{BN}$

$\vec{E}_{BC} = \vec{E}_{BN} - \vec{E}_{CN}$

$\vec{E}_{CA} = \vec{E}_{CN} - \vec{E}_{AN}$

We will begin with an in-class problem on Wednesday using this system with a balanced load