Review of AC Circuits & First Look at a Transmission System

Smith College, EGR 325
March 25, 2008

Objectives

- Know EGR 220 concepts
  - Power calculations and terminology
- Expand understanding of electrical power
  - from simple linear circuits to
  - a high voltage power system

Review (on own) Objectives

- EGR 220
  - Sinusoidal waveform representation
  - Root mean square
  - Phase shift
  - Phasors
  - Complex numbers
  - Complex impedance
- Electric Power
  - Complex: real & reactive power
  - Power factor and power factor correction

Objectives

- E-M energy storage
  - Capacitance & inductance
- Power calculations and terminology
- Expand understanding of electrical power
  - from simple linear circuits to
  - a high voltage power system

Dynamic Circuit Elements

- What does 'dynamic' mean (versus static)?
- Why / how are capacitors and inductors dynamic?

Capacitor & Inductor Concepts

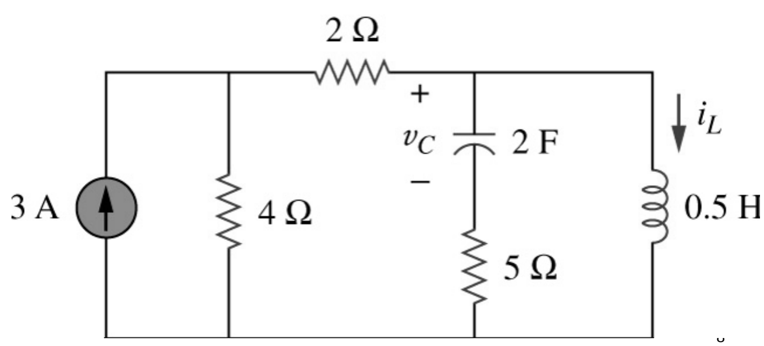
- Capacitors and inductors store energy
  - Matter that is capable of storing electromagnetic energy is said to have *capacitance* and/or *inductance*
- Energy cannot be stored or extracted instantaneously, but instead requires time
  - Capacitors store electric energy ->
  - Inductors store magnetic energy ->
- Ideal elements: assume internal R = 0
- Real elements have (significant) resistance

C & L Properties

- How is energy stored in a capacitor?
- To dc sources, capacitors are seen as ______ circuits (open/short)?
  - ➢ dc ________ (current/voltage) is zero?
- How is energy stored in an inductor?
- To dc sources, inductors are seen as ______ circuits (open/short)?
  - ➢ dc ________ (current/voltage) is zero?

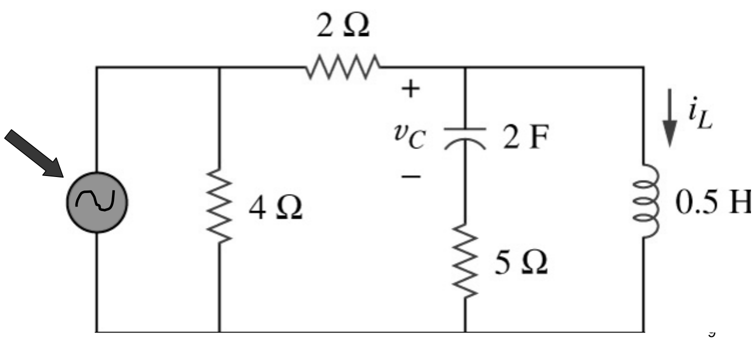
Circuit Analysis with Energy Storage

- How do we find v_C, i_L and the energy stored in the capacitor and inductor.



Circuit Analysis with an ac Source

- How do we find v_C, i_L and the energy stored in the capacitor and inductor.



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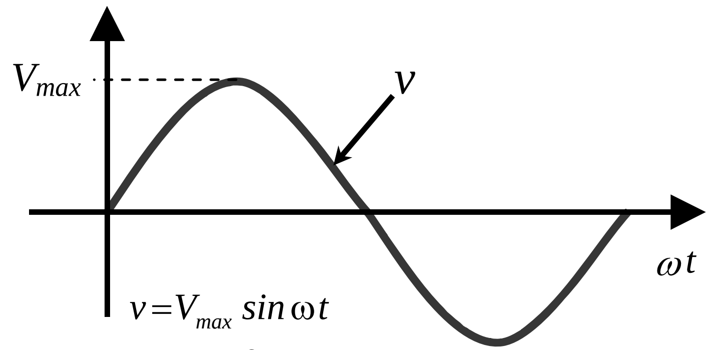
ac Waveform



$v = V_{max} \sin \omega t$

$\omega = 2\pi f$

f is the frequency of the waveform

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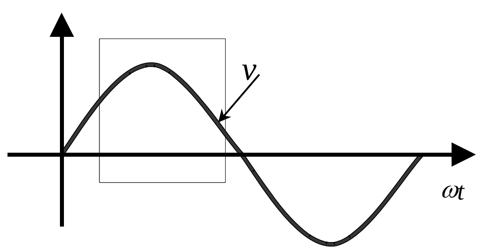
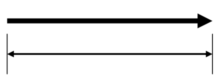
AC Phasor Representation





$$V_{rms} = V = \frac{V_{max}}{\sqrt{2}}$$

$$v = V_{\max} \sin \omega t$$

$$\omega = 2\pi f = 377\ rad/\sec$$

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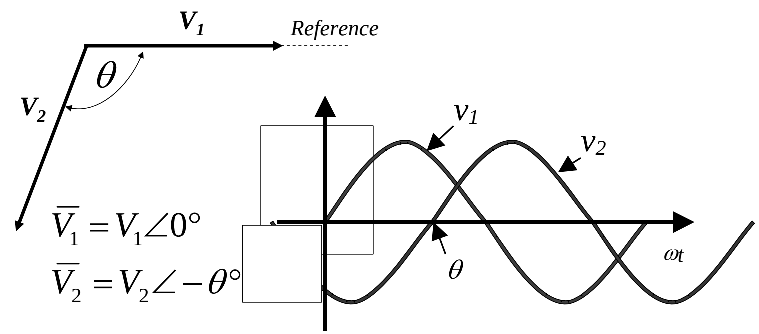

$\bar{V}_1 = V_1 \angle 0°$

$\bar{V}_2 = V_2 \angle -\theta°$

$$v_1 = V_{1\max} \sin \omega t$$

$$v_2 = V_{2\max} \sin(\omega t - \theta)$$

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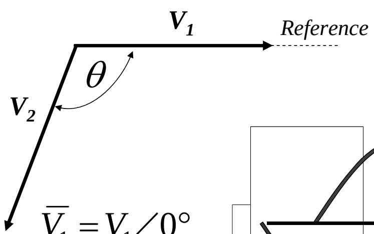
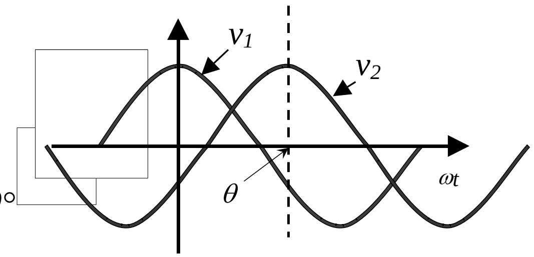




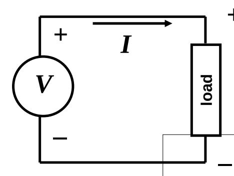
$\bar{V}_1 = V_1\angle 0°$

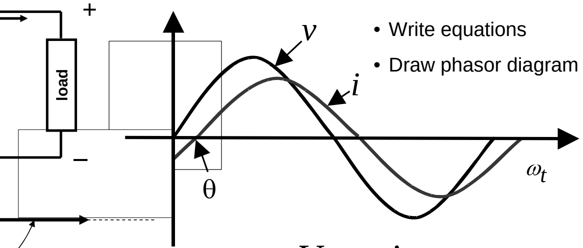
$\bar{V}_2 = V_2\angle -\theta°$

$v_1 = V_{1\max}\cos\omega t$

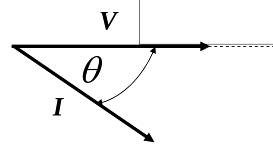
$v_2 = V_{2\max}\cos(\omega t - \theta)$

Voltage and Current Phase Difference





- Write equations
- Draw phasor diagram



$v = V_{max}\ \sin\omega t$

$i = I_{max}\ \sin(\omega t - \theta)$

$\bar{V} = V\angle 0°$

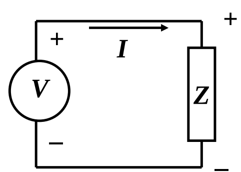
$\bar{I} = I\ \angle -\theta°$

θ is the phase shift of current also known as the <u>power factor angle</u>

It is due to the presence of inductive and capacitive elements.

Example

If V=120 V and Z=4 + j3 Ω, calculate the current and power factor.

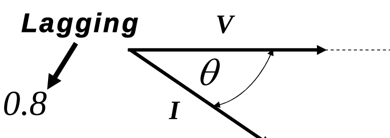


$$\bar{I} = \frac{\bar{V}}{\bar{Z}} = \frac{120\ \angle 0}{4 + j3} = \frac{120\angle 0}{5\angle 37^o}$$

$$\bar{I} = 24\ \angle -37^o\quad A$$

$$pf = \cos\theta = \cos\ 37 = 0.8$$

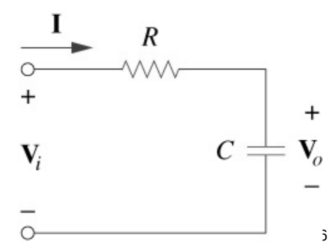
Lagging



Notice that the ***pf angle*** is the ***angle of the impedance***

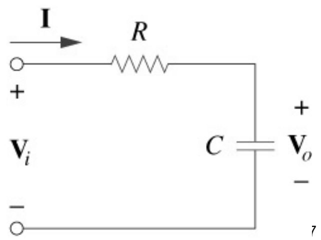
Application: Phase Shifter

- The resistor causes the current to *lead* or *lag* the applied voltage?
- The capacitor causes the current to *lead* or *lag* the applied voltage?



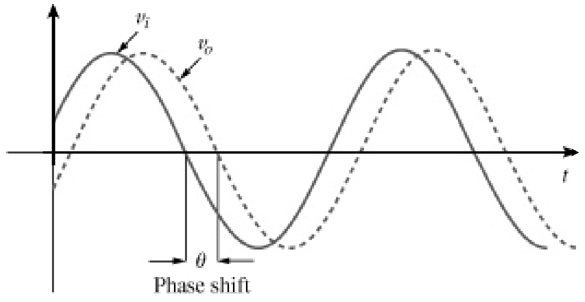
Application: Phase Shifter

- What is the impedance of the circuit?
- How do we find the phase between $\mathbf{V}_i$ and **I**?
- How do we find the phase between $\mathbf{V}_i$ and $\mathbf{V}_o$?



Application: Voltage Signals

- The relative position (phase) of V_i and V_o for the previous circuit.



Example: Power Calculations

- The circuit parameters are
  - V_s = 120V at 60Hz
  - R_L =15Ω and L_L = 0.1H
  - R_{cable} = 0.5Ω and L_{cable} = 0.05H
- Find
  - The load impedance
  - The line current
  - The load voltage
  - The complex current
  - The complex load power consumed
  - The complex power lost in the cable
  - The complex power supplied by the source

Summary

- AC circuits
  - Sinusoidal steady state
- Energy storage elements
  - Capacitors and inductors
  - Source of phase shift
- Phasors & phase angle
- Complex power
  - Real and reactive power
- Significance of the *power factor*