

First Course on Power Systems

Module 1: (a) Overview and (b) Review

By
Ned Mohan
Professor of ECE
University of Minnesota

Reference Textbook:
First Course on Power Systems by Ned Mohan,
www.mnpere.com

Module 1: (a) Overview

Chapter 1	POWER SYSTEMS: A CHANGING LANDSCAPE	1-1
1-1	NATURE OF POWER SYSTEMS	1-1
1-2	CHANGING LANDSCAPE OF POWER SYSTEMS AND UTILITY DEREGULATION	1-3
1-3	TOPICS IN POWER SYSTEMS	1-4
	REFERENCES	1-6
	PROBLEMS	1-6

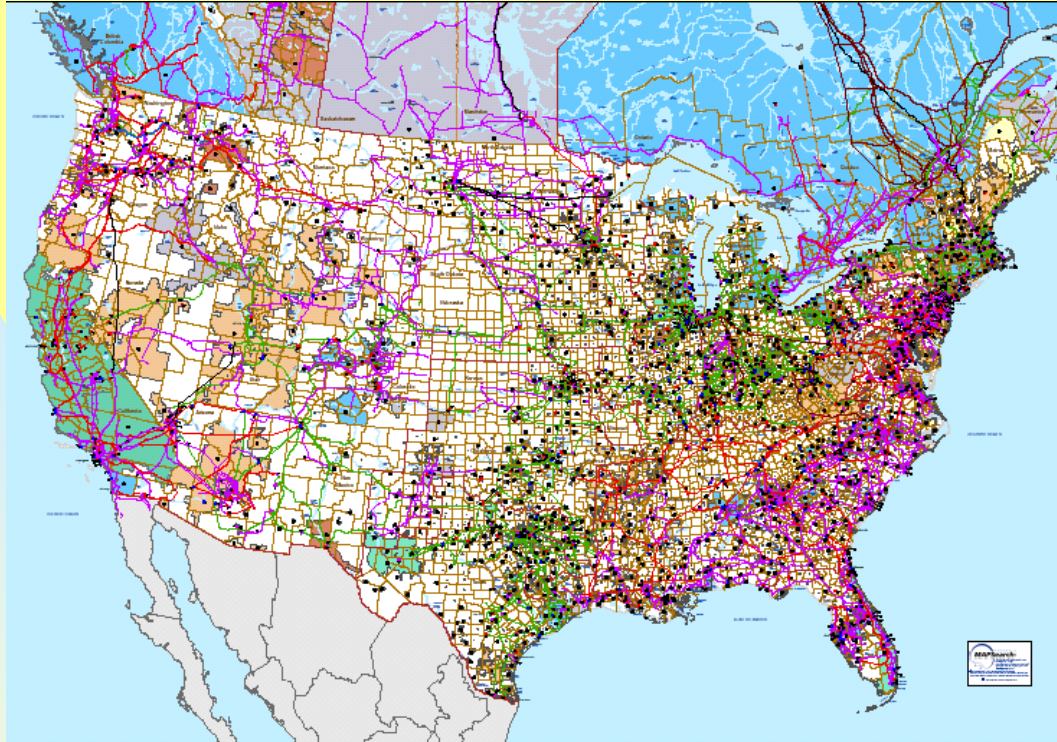
Module 1: (b) Review

Chapter 2	REVIEW OF BASIC ELECTRIC CIRCUITS AND ELECTROMAGNETIC CONCEPTS	2-1
2-1	INTRODUCTION	2-1
2-2	PHASOR REPRESENTATION IN SINUSOIDAL STEADY STATE	2-1
2-3	POWER, REACTIVE POWER, AND POWER FACTOR	2-5
2-4	THREE-PHASE CIRCUITS	2-10
2-5	REAL AND REACTIVE POWER TRANSFER BETWEEN AC SYSTEMS	2-17
2-6	APPARATUS RATINGS, BASE VALUES AND PER-UNIT QUANTITIES	2-18
2-7	ENERGY EFFICIENCIES OF POWER SYSTEM APPARATUS	2-20
2-8	ELECTROMAGNETIC CONCEPTS	2-20
	REFERENCES	2-30
	PROBLEMS	2-30

Chapter 1

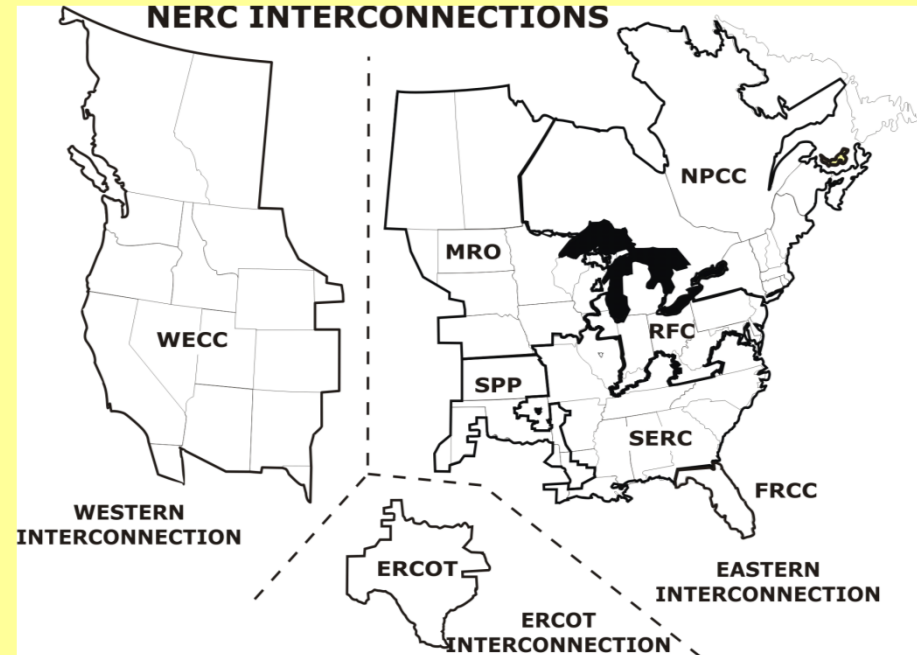
POWER SYSTEMS: A CHANGING LANDSCAPE

NATURE OF POWER SYSTEMS



- **Thousands of Generators operating in synchronism**
- **Over 200,000 miles of Transmission Lines over 230 kV**
- **Advantages of an interconnected system**
 - **Continuity of service**
 - **Lowest cost**

Interconnections and Control Areas



NERC's Mission

- Bulk Electric System is Reliable, Adequate and Secure
- Three interconnections are divided into 152 Control Areas
 - Each control area controls its own generation
 - maintain its interchange schedule
 - contributes to frequency regulation of interconnection

One-line Diagram

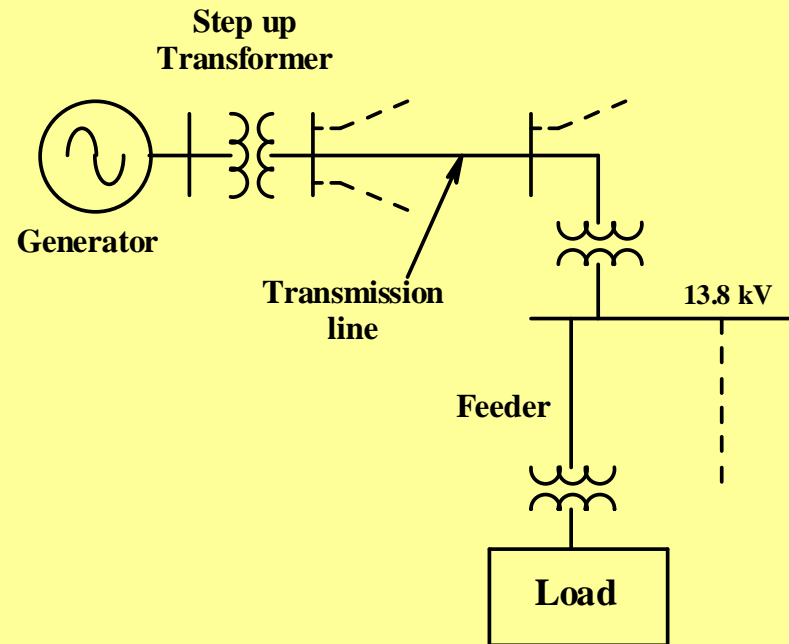


Fig. 1-3 One-line diagram as an example.

CHANGING LANDSCAPE OF POWER SYSTEMS AND UTILITY DEREGULATION

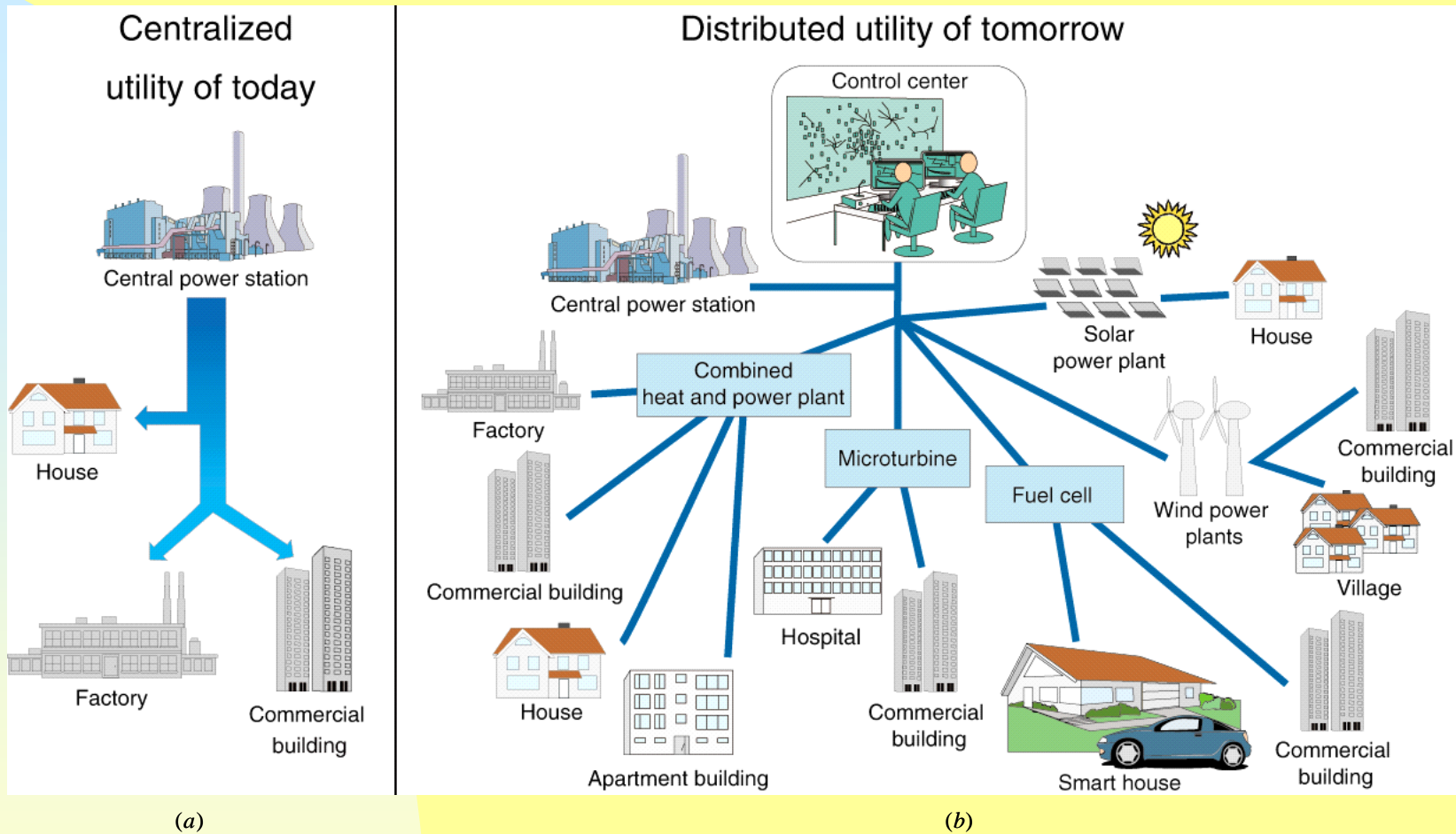


Fig. 1-4 Changing landscape [4]. Source: ABB.

Module 1: (b) Review

Chapter 2	REVIEW OF BASIC ELECTRIC CIRCUITS AND ELECTROMAGNETIC CONCEPTS	2-1
2-1	INTRODUCTION	2-1
2-2	PHASOR REPRESENTATION IN SINUSOIDAL STEADY STATE	2-1
2-3	POWER, REACTIVE POWER, AND POWER FACTOR	2-5
2-4	THREE-PHASE CIRCUITS	2-10
2-5	REAL AND REACTIVE POWER TRANSFER BETWEEN AC SYSTEMS	2-17
2-6	APPARATUS RATINGS, BASE VALUES AND PER-UNIT QUANTITIES	2-18
2-7	ENERGY EFFICIENCIES OF POWER SYSTEM APPARATUS	2-20
2-8	ELECTROMAGNETIC CONCEPTS	2-20
	REFERENCES	2-30
	PROBLEMS	2-30

Symbols and Conventions

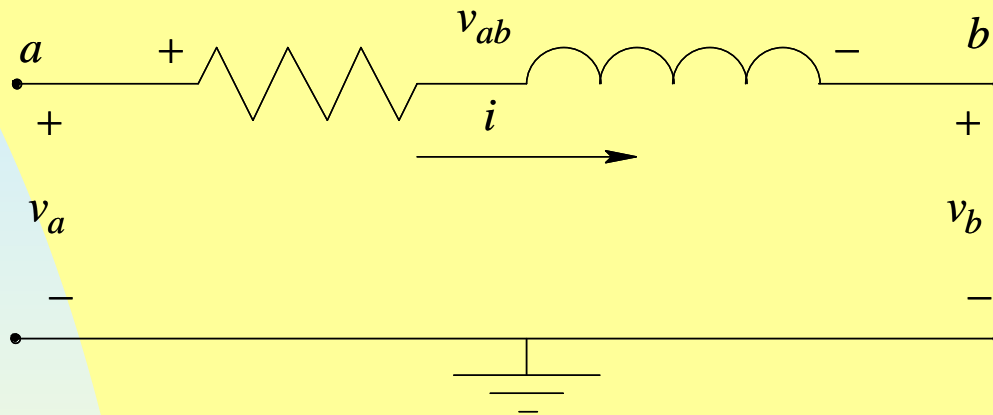


Fig. 2-1 Convention for voltages and currents.

Phasors

$$v(t) = \sqrt{2} V \cos \omega t$$

$$i(t) = \sqrt{2} I \cos(\omega t - \phi)$$

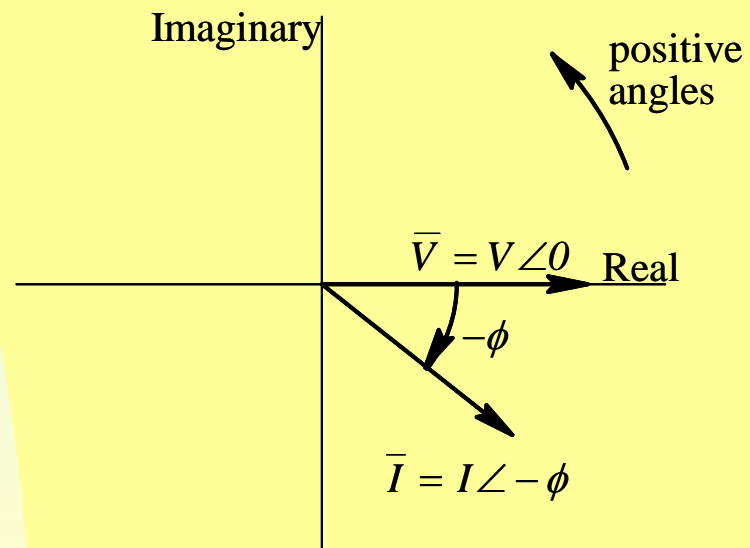


Fig. 2-2 Phasor diagram.

Phasor Analysis

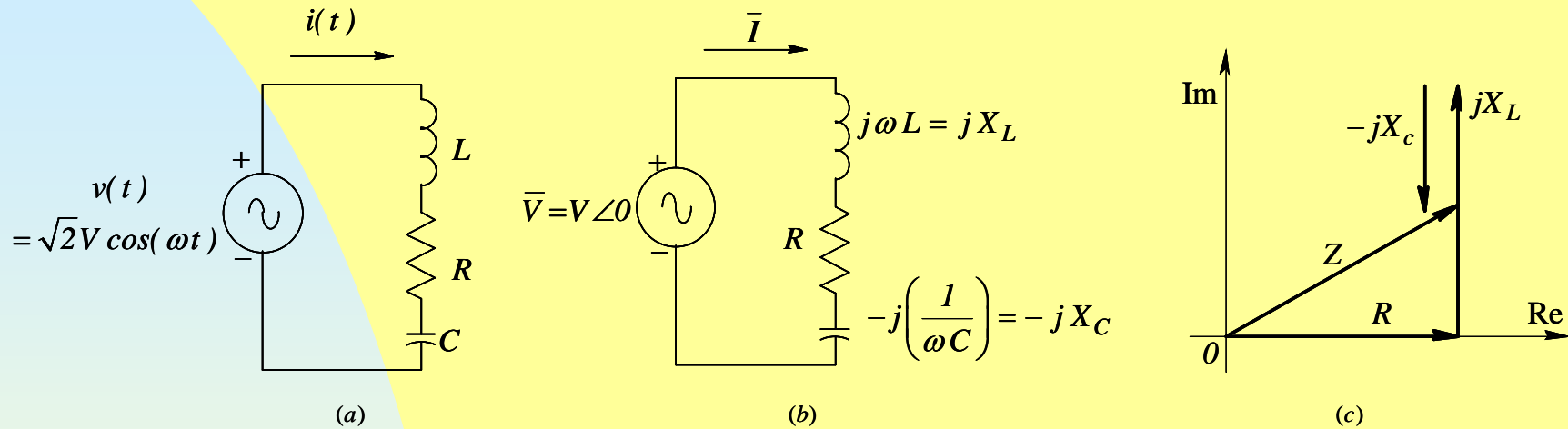


Fig. 2-3 A circuit (a) in time-domain and (b) in phasor-domain; (c) impedance triangle.

Instantaneous Power Flow

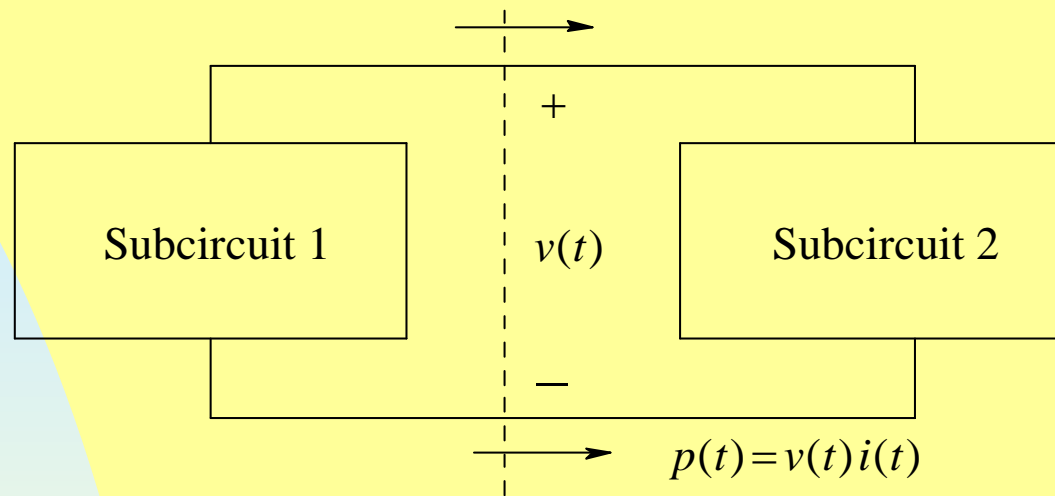
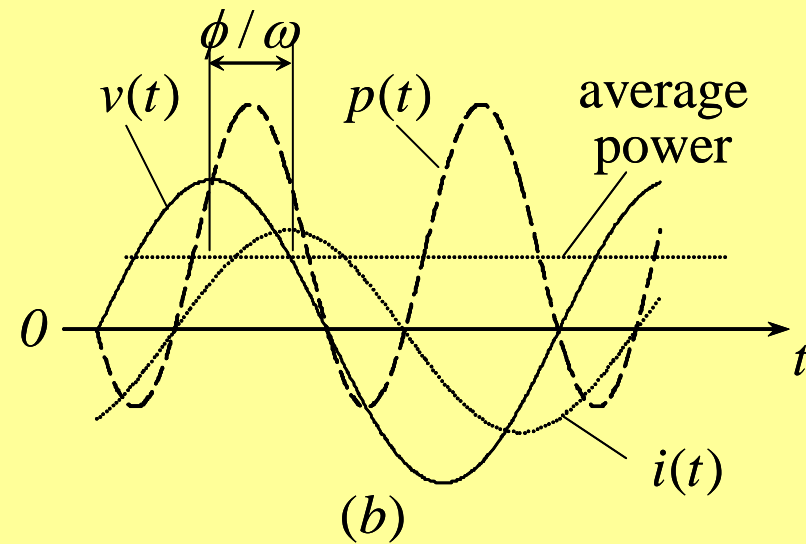
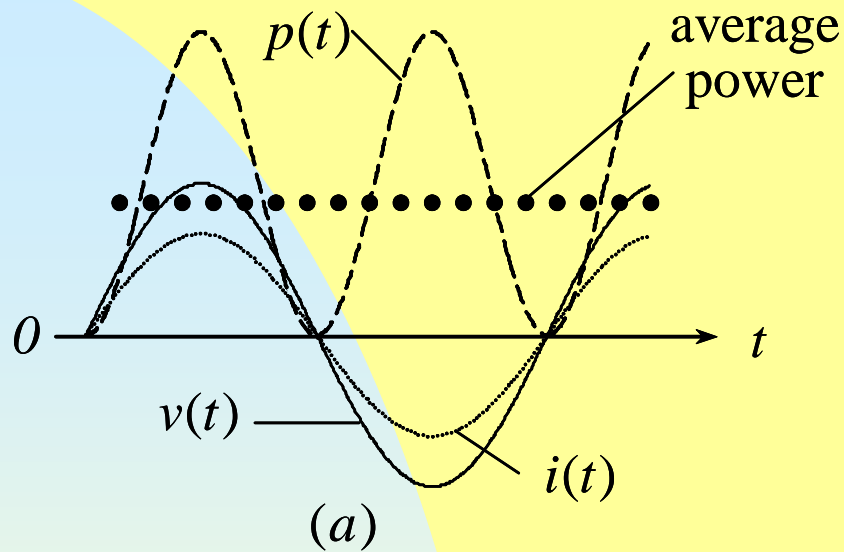


Figure 2-6 A generic circuit divided into two sub-circuits.

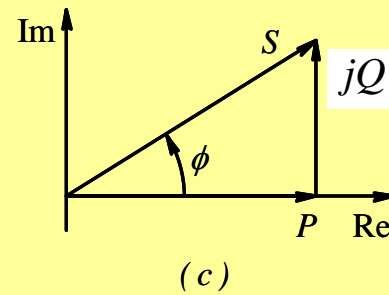
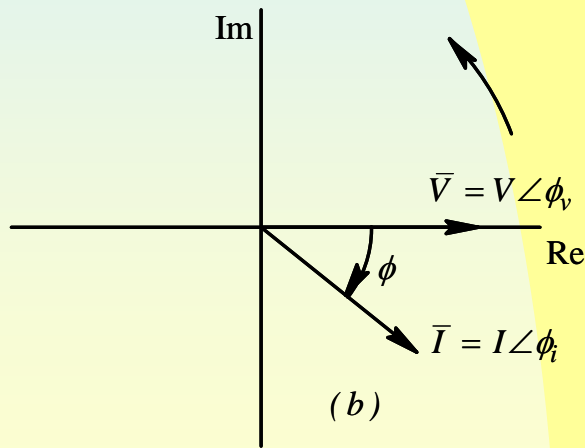
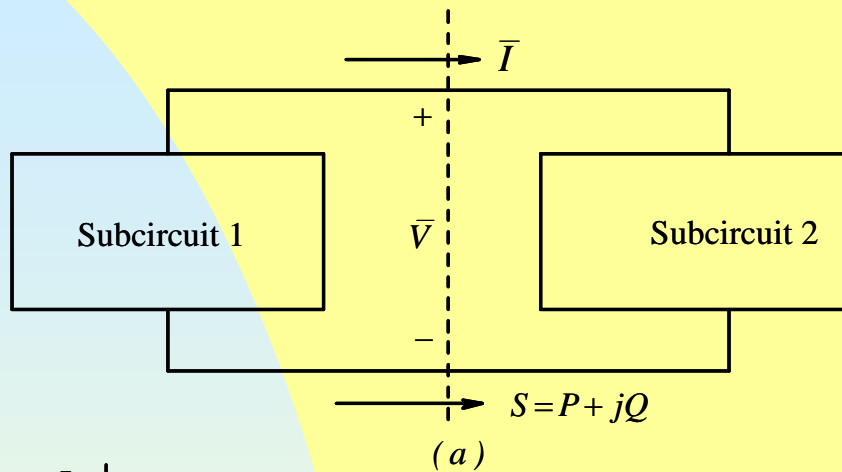
Real and Reactive Power



$$(a) \quad p(t) = \sqrt{2}V \cos \omega t \cdot \sqrt{2}I \cos \omega t = 2VI \cos^2 \omega t = VI + VI \cos 2\omega t$$

$$(b) \quad p(t) = \sqrt{2}V \cos \omega t \cdot \sqrt{2}I \cos(\omega t - \phi) = VI \cos \phi + VI \cos(2\omega t - \phi)$$

P, Q, VA and Power Factor



$$S = \bar{V} \bar{I}^*$$

$$S = V I \angle \phi = P + jQ$$

$$P = V I \cos \phi$$

$$Q = V I \sin \phi$$

$$|S| = \sqrt{P^2 + Q^2}$$

$$\phi = \tan^{-1} \left(\frac{Q}{P} \right)$$

$$\text{Power Factor} = \frac{P}{VI} = \cos \phi$$

Example of Power Factor Correction

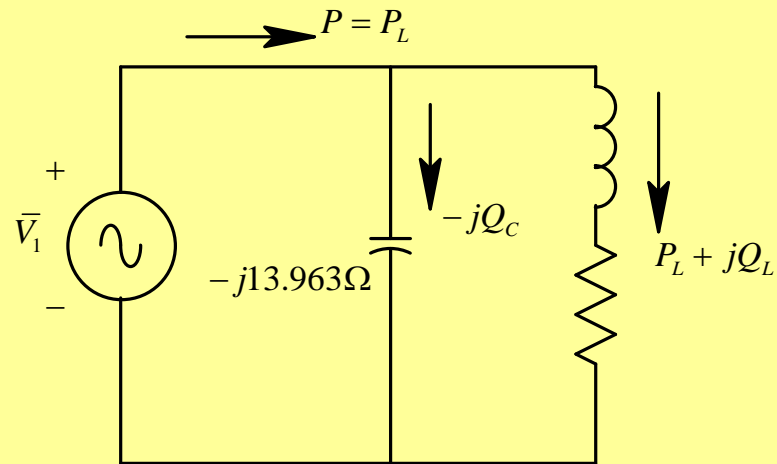


Fig. 2-9 Power factor correction in Example 2-5.

One-line Diagram

