Lecture 18:
Electrical Distribution

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Example: Delta-Delta Circuit

A delta-connected three-phase transformer supplies power to a delta-connected resistive load. The transformer secondary has a phase voltage of 208 V and the resistors of the load have a resistance of 100 Ω.

Step 1: Determine transformer phase voltage and line voltage:

Step 2: Determine load phase voltage and line voltage:

Step 3: Calculate load phase and line current:

Step 4: Determine transformer secondary phase and line current:

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Step 2: Determine load phase voltage and line voltage:

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Step 3: Calculate load phase and line current:

Step 4: Determine transformer secondary phase and line current:

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Step 2: Determine load phase voltage and line voltage:

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Step 3: Calculate load phase and line current:

$$I_{L,P} = E_{L,P} / Z_{L,P} = 2.08\text{A} \qquad I_{L,L} = \sqrt{3}\, I_{L,P} = 3.6\text{A}$$

Step 4: Determine transformer secondary phase and line current:

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Step 4: Determine transformer secondary phase and line current:

$$I_{S,L} = I_{L,L} = 3.6\text{A} \qquad I_{S,P} = \frac{1}{\sqrt{3}} I_{S,L} = 2.08\text{A}$$

Example: Delta-Delta Circuit

For previous circuit example, determine real, reactive, and apparent power:

Example: Delta-Delta Circuit

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For previous circuit example, determine real, reactive, and apparent power:

$$PF = 1$$

$$P = 3\,E_{L,P}\,I_{L,P}\,PF = 3 * 208\text{V} * 2.08\text{A} = 1.3\text{kW}$$

$$S = P = 1.3\text{kVA}$$

$$Q = 0\text{kVAR}$$

Example: Delta-Wye Circuit

A delta-connected three-phase transformer supplies power to a wye-connected induction motor. The transformer secondary has a phase voltage of 480 V and motor windings have a total impedance of 20 Ω. The motor operates with a power factor of 0.9.

Step 1: Determine transformer phase voltage and line voltage:

Step 2: Determine load phase voltage and line voltage:

Step 3: Calculate load phase and line current:

Step 4: Determine transformer secondary phase and line current:

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Step 2: Determine load phase voltage and line voltage:

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Step 4: Determine transformer secondary phase and line current:

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Step 1: Determine transformer phase voltage and line voltage:

$$E_{S,P} = 480\text{V} \qquad E_{S,L} = E_{S,P} = 480\text{V}$$

Step 2: Determine load phase voltage and line voltage:

$$E_{L,L} = E_{S,L} = 480\text{V} \qquad E_{L,P} = \frac{1}{\sqrt{3}} E_{L,L} = 277\text{V}$$

Step 3: Calculate load phase and line current:

Step 4: Determine transformer secondary phase and line current:

Example: Delta-Wye Circuit

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A delta-connected three-phase transformer supplies power to a wye-connected induction motor. The transformer secondary has a phase voltage of 480 V and motor windings have a total impedance of 20 Ω. The motor operates with a power factor of 0.9.

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$$E_{S,P} = 480\text{V} \qquad E_{S,L} = E_{S,P} = 480\text{V}$$

Step 2: Determine load phase voltage and line voltage:

$$E_{L,L} = E_{S,L} = 480\text{V} \qquad E_{L,P} = \frac{1}{\sqrt{3}} E_{L,L} = 277\text{V}$$

Step 3: Calculate load phase and line current:

$$I_{L,P} = E_{L,P} / Z_{L,P} = 13.9\text{A} \qquad I_{L,L} = I_{L,P} = 13.9\text{A}$$

Step 4: Determine transformer secondary phase and line current:

Example: Delta-Wye Circuit

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A delta-connected three-phase transformer supplies power to a wye-connected induction motor. The transformer secondary has a phase voltage of 480 V and motor windings have a total impedance of 20 Ω. The motor operates with a power factor of 0.9.

Step 1: Determine transformer phase voltage and line voltage:

$$E_{S,P}=480\text{V} \qquad E_{S,L}=E_{S,P}=480\text{V}$$

Step 2: Determine load phase voltage and line voltage:

$$E_{L,L}=E_{S,L}=480\text{V} \qquad E_{L,P}=\frac{1}{\sqrt{3}}E_{L,L}=277\text{V}$$

Step 3: Calculate load phase and line current:

$$I_{L,P}=E_{L,P}/Z_{L,P}=13.9\text{A} \qquad I_{L,L}=I_{L,P}=13.9\text{A}$$

Step 4: Determine transformer secondary phase and line current:

$$I_{S,L}=I_{L,L}=13.9\text{A} \qquad I_{S,P}=\frac{1}{\sqrt{3}}I_{S,L}=8\text{A}$$

Example: Delta-Wye Circuit

For previous circuit example, determine real, reactive, and apparent power:

Example: Delta-Wye Circuit

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For previous circuit example, determine real, reactive, and apparent power:

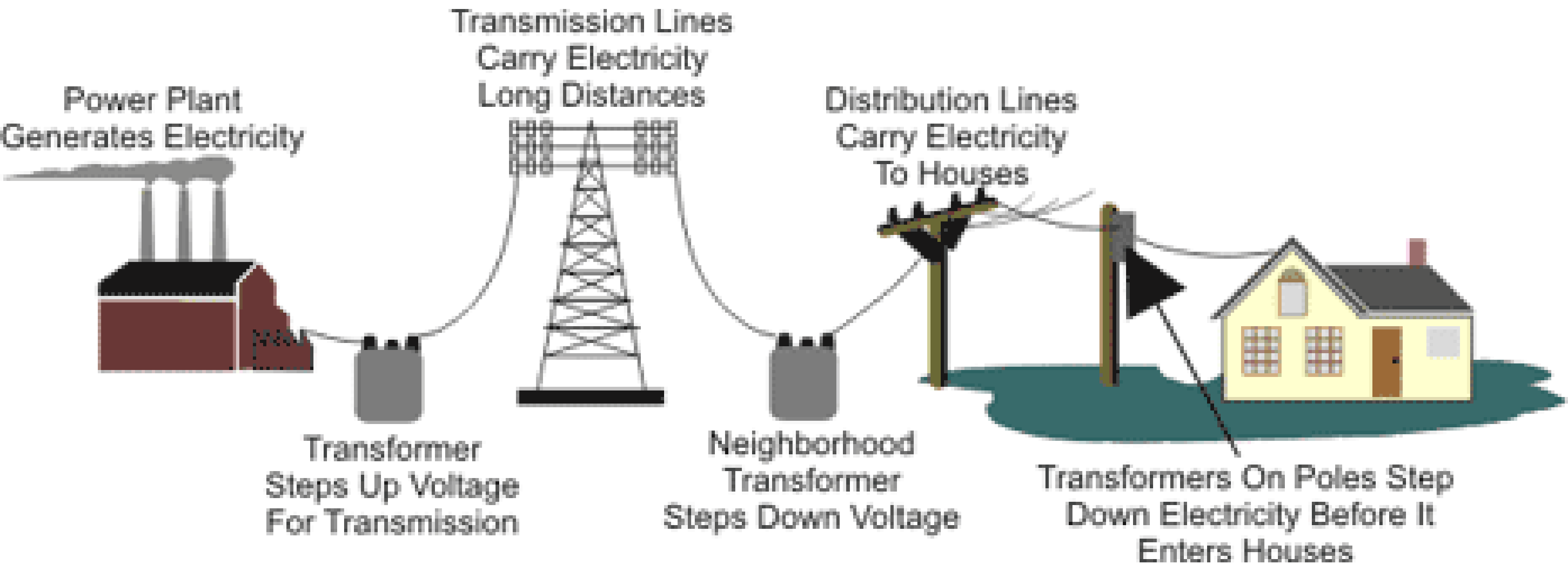
$$PF = 0.9$$

$$P = 3\,E_{L,P}\,I_{L,P}\,PF = 3 * 277\text{V} * 13.9\text{A} * 0.9 = 10.4\text{kW}$$

$$S = \frac{P}{PF} = \frac{10{,}400}{0.9} = 11.6\text{kVA}$$

$$Q = \sqrt{S^2 - P^2} = 5.04\text{kVAR}$$

Electrical Distribution



NOTE: Book defines everything post-generation pre-use as distribution. Typically though, this system is broken-up into transmission and distribution.

Primary-side Distribution

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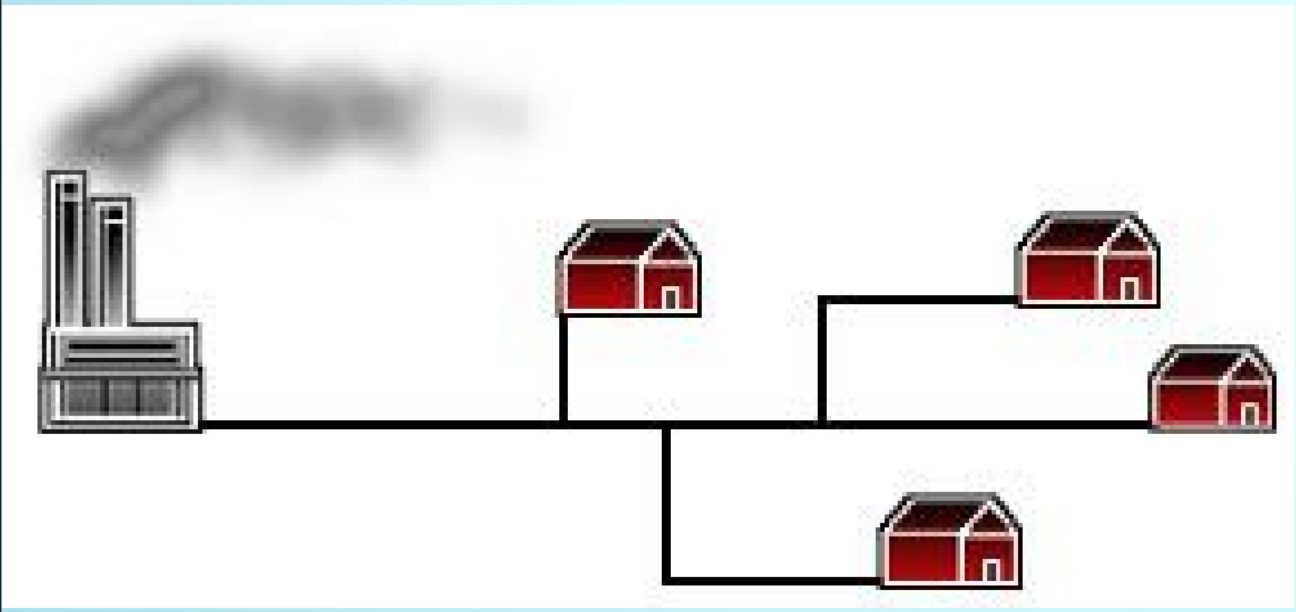
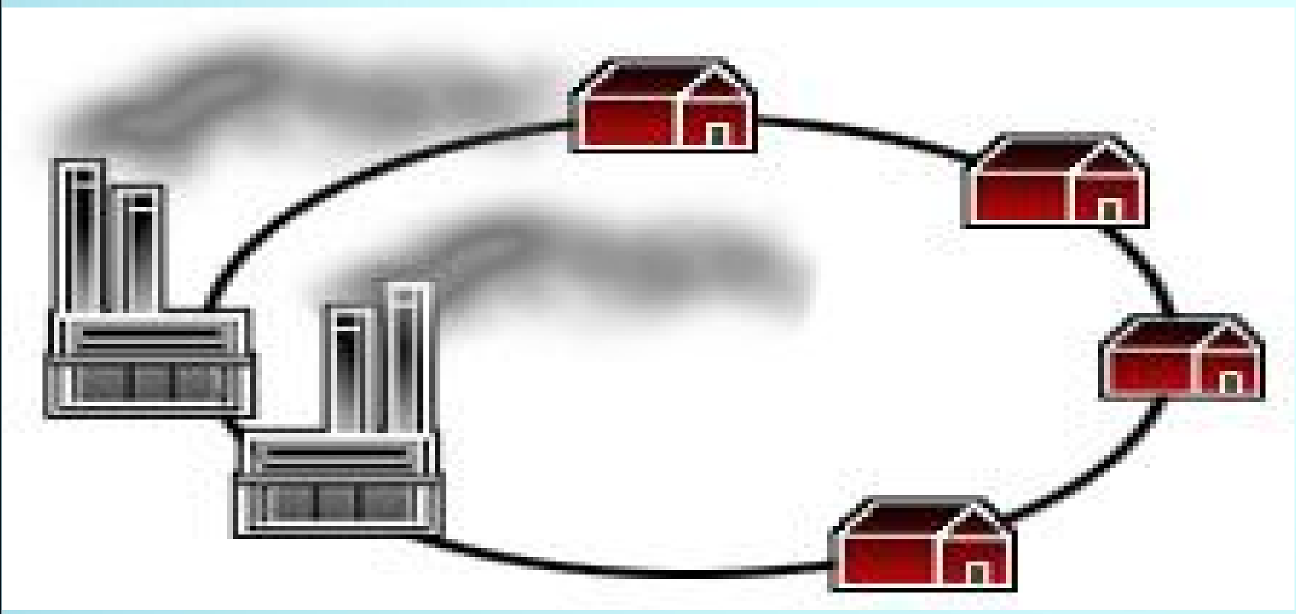
Radial Distribution Network



- Power delivered along a single distribution path
- Cheapest to build
- Used often in rural areas
- Grid disruption → shut down entire line

Primary-side Distribution

Loop Distribution Network



- Power delivered by loop(ed) distribution path(s)
- More expensive than radial
- Allows isolation of grid disruptions with minimal effect on customers

Secondary-side Distribution

Radial Distribution Network

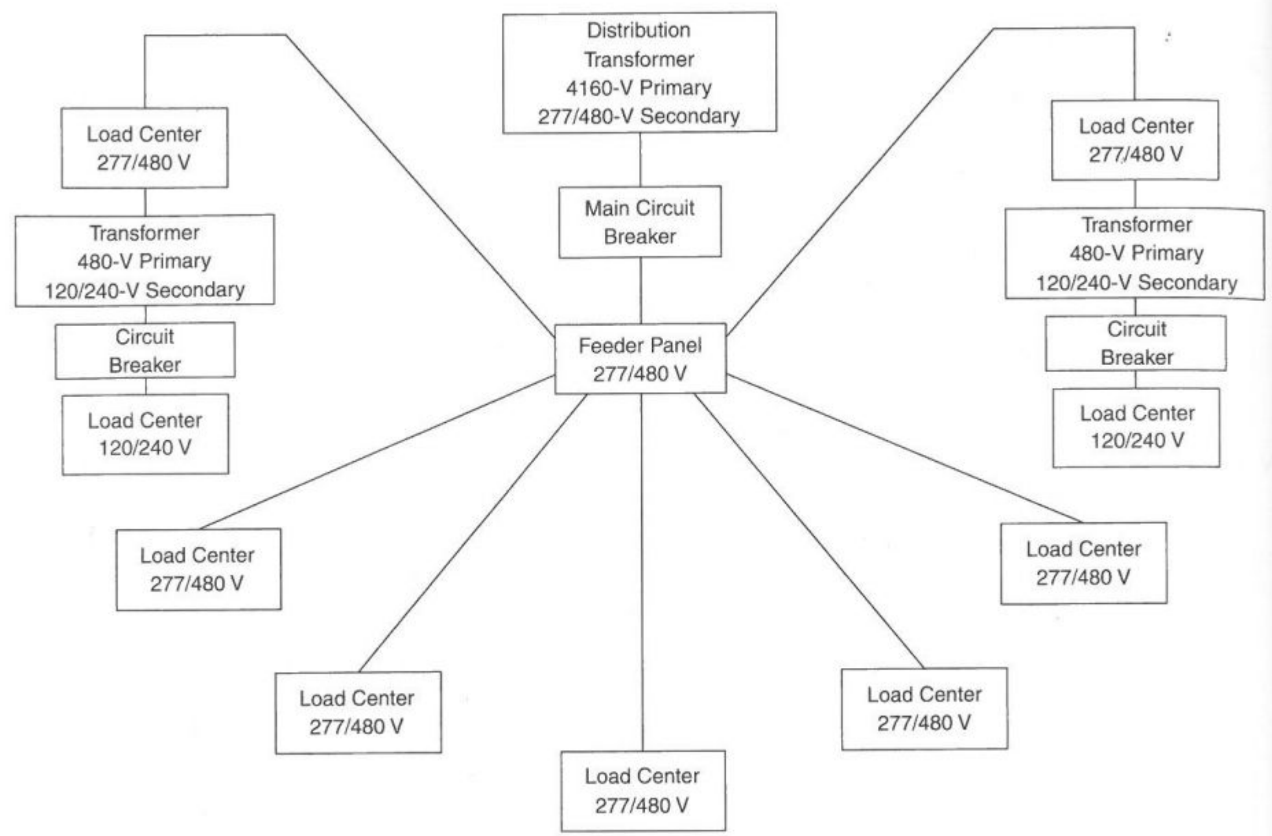


FIGURE 13–3A Consumer radial distribution system.

Secondary-side Distribution

Loop Distribution Network

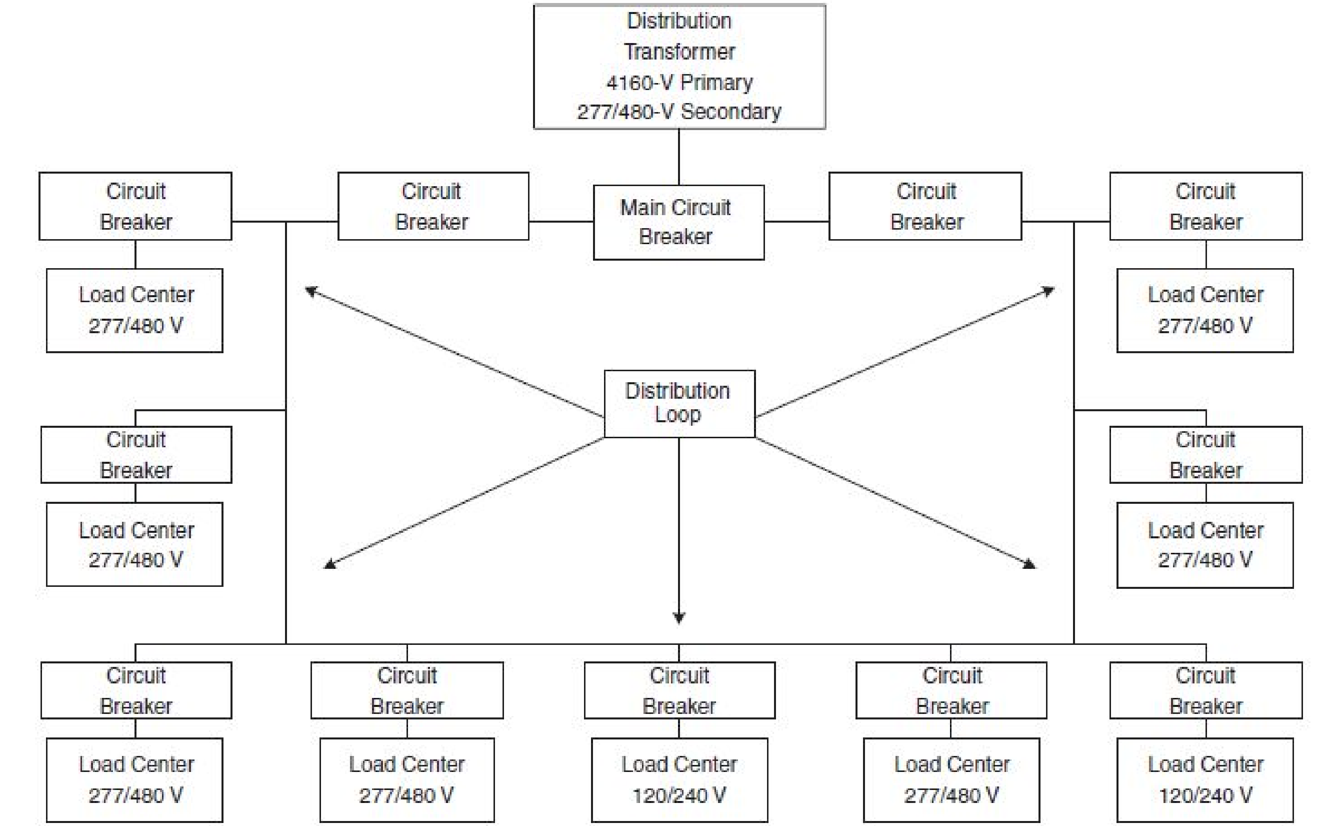
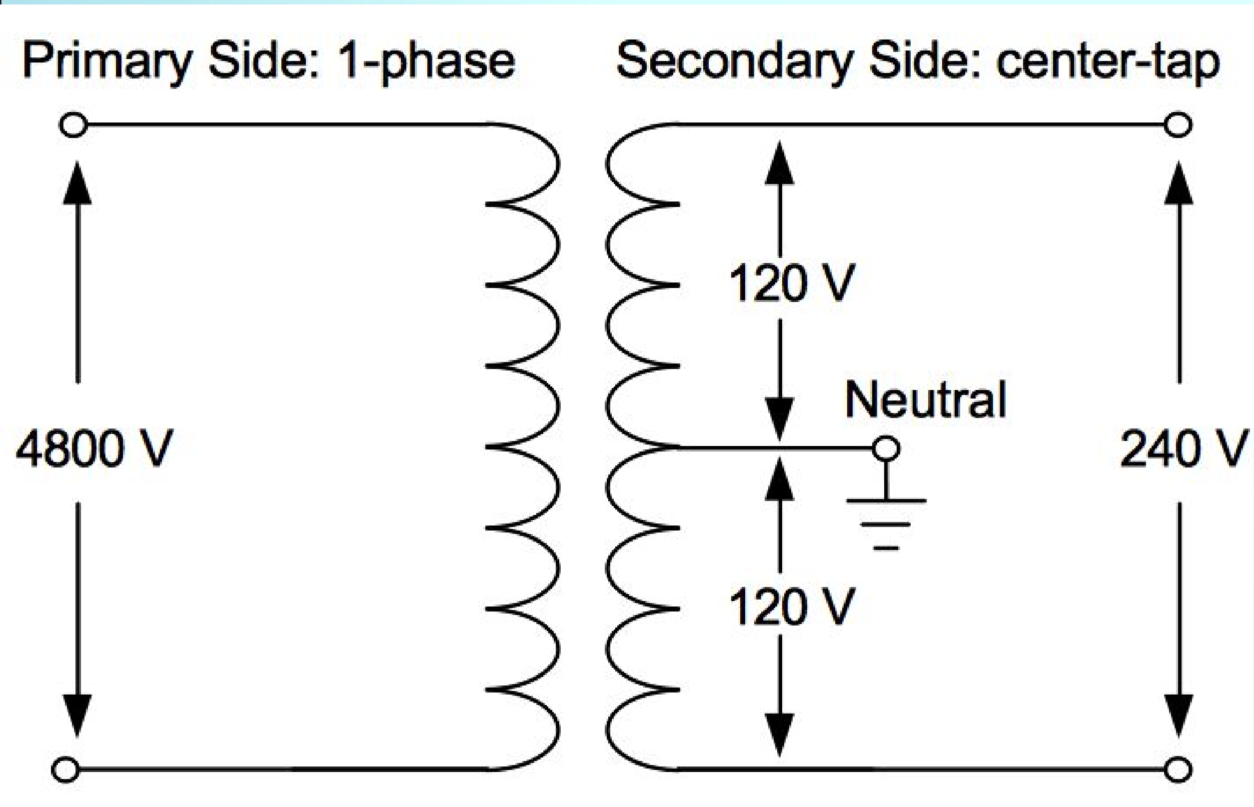


FIGURE 13–3B Consumer loop distribution system. Disconnecting means may be installed anywhere in the distribution loop to provide for isolating sections.

Residential Secondary Distribution



- Residential customers typically get 120V/240V single-phase, 3-wire service
- Taken from 1-phase of 3-phase primary distribution

Residential Secondary Distribution

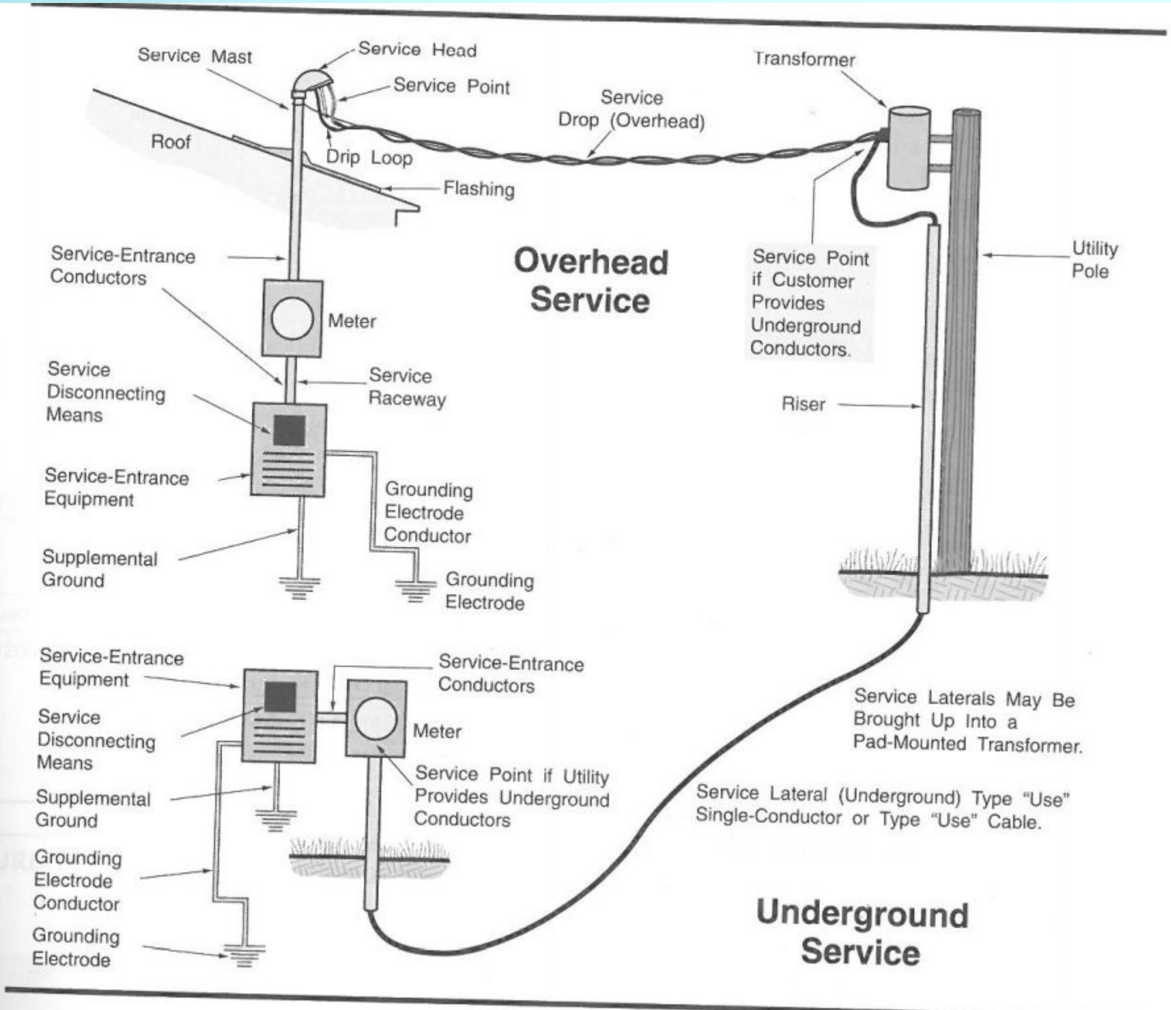


FIGURE 13–2A Examples of overhead and underground residential services.

Commercial and Industrial Distribution

- Commercial and industrial installations
  - Distribution can be:
    - Single-phase, three-wire service or
    - three-phase, four-wire service
  - Includes large residential apartment buildings
  - Service-entrance conductors terminate into a main disconnect
  - Then to individual unit meters / distribution units

Large Commercial and Industrial Distribution

- Electrical Service:
  - Typically 3-phase: 120/208 V or 277/480 V
  - If 277/480 V:
    - Need transformers distributed on-site for 120 V service
  - If large building/plant:
    - Service installed near center point
    - Minimize line loss on branch-circuits.

Very Large Commercial and Industrial Distribution

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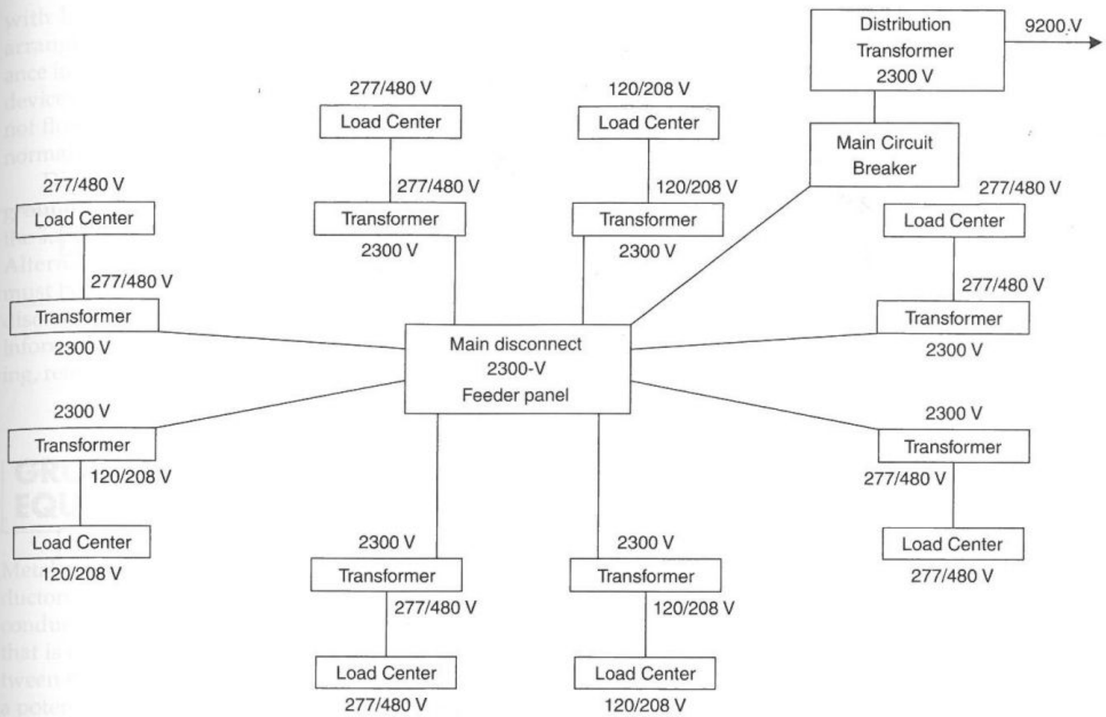

FIGURE 13–4A Secondary high-voltage radial distribution system.

- Purchase electricity at primary voltage / current levels

- Minimize power losses due to vast consumer load network

- Install local transformers at points of load.

Very Large Commercial and Industrial Distribution

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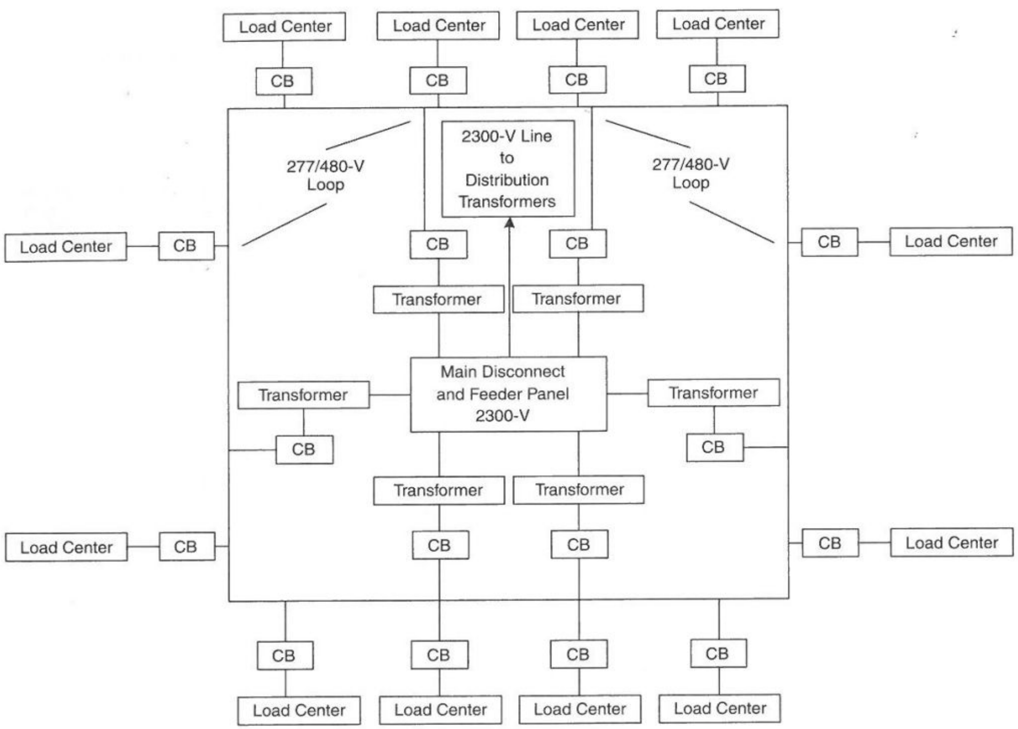


FIGURE 13–5A Secondary high-voltage distribution system: high-voltage radial, low-voltage loop.

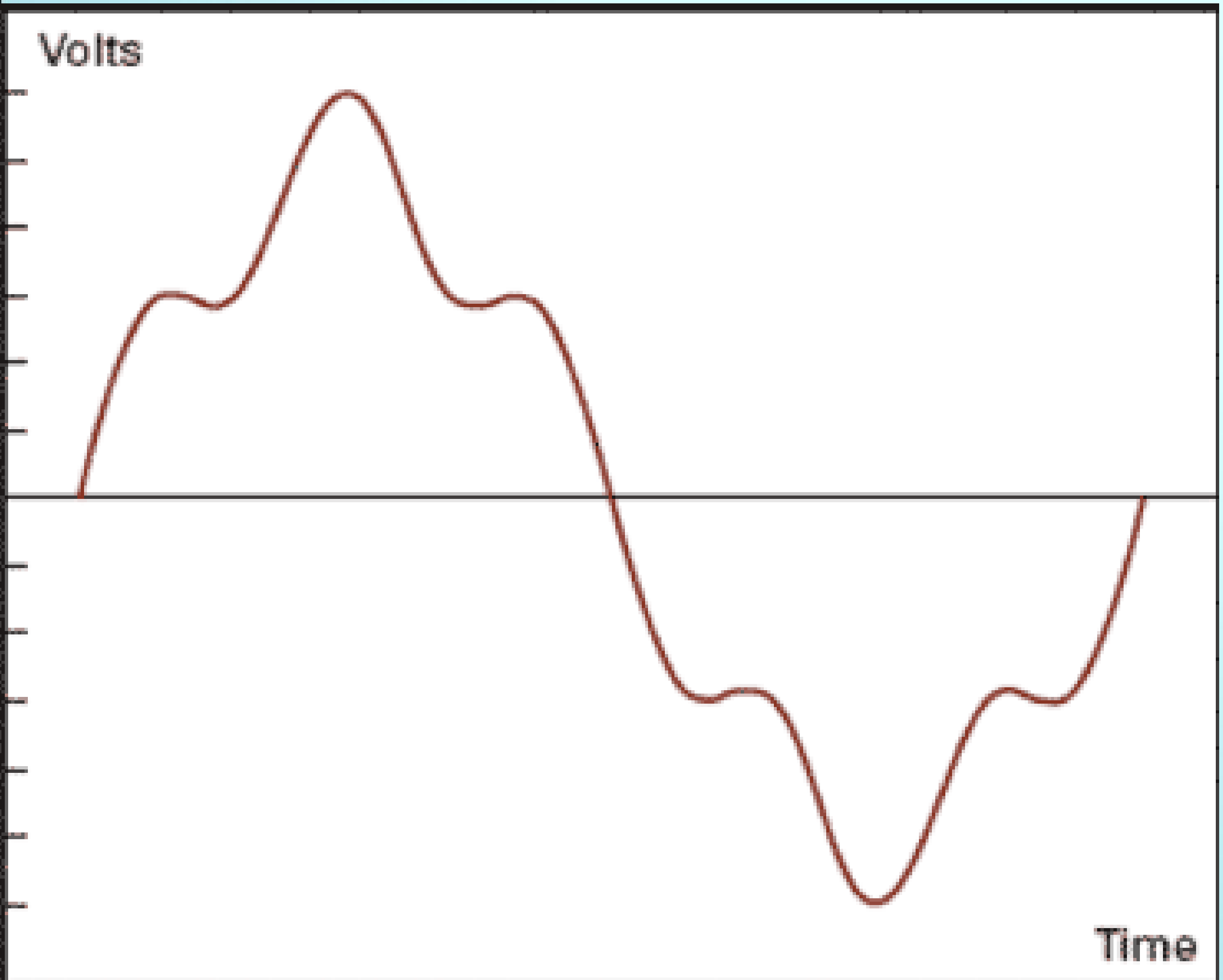
- Purchase electricity at primary voltage / current levels
- Minimize power losses due to vast consumer load network
- Install local transformers at points of load.

Grounding of Electrical Systems

- Most electrical systems must be grounded
  - Limit magnitude of voltage surges from lightning
  - Limit chance of electrocution
  - Protect equipment from shorts

  - Must be low impedance → Ensures over-current protection works
  - No current on ground conductor under normal operation

Harmonic Distortion



- Distortion in sine-wave
- Caused by non-linear loads
  - Fluorescent lights
  - Power electronics
  - Etc.
- Can cause increased power losses/conductor heating

Harmonic Distortion

- North American power systems operate at 60 Hz

- Harmonics multiples of supply frequency
  - e.g. 120 Hz, 180 Hz, etc.

- Cause additional current to flow
  - Additional power loss
  - Additional heating (3-5 percent typical) in line conductors
  - Additional heating (big! As much as 90%) in neutral
  - Might need to increase neutral conductor size if large non-linear loading on distribution circuits