



SECONDARY DISTRIBUTION SYSTEMS

Introduction

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☐ Outline

- ☐ Review Primary (Because there is some overlapping material)
- ☐ Secondary Distribution
 - What is it used for?
 - Voltages and Applications
 - Y and Delta
 - Customer Distribution
 - Transformers configurations
 - Types of Secondary Networks
 - Construction of Secondary Distribution
 - Overhead
 - Underground
- ☐ Additional Information
 - Metering
 - Renewable energy integration

Introduction

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☐☐☐ Goals

- ☐ Integrate primary and secondary distribution
- ☐ Cover different types of secondary distribution and applications
- ☐ Basic construction principles and concerns involved with secondary distribution
- ☐ (Very basic) Introduction to renewable energy integration.

Introduction

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- ▣ Secondary distribution covers energy distribution from substations to customers' meter.

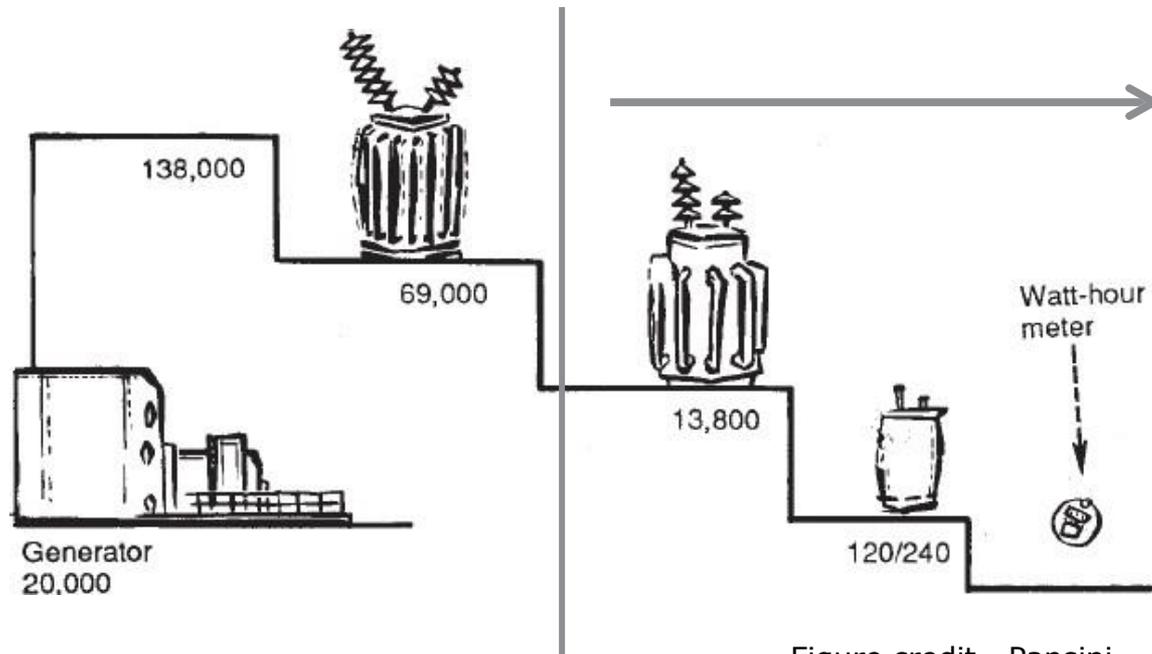
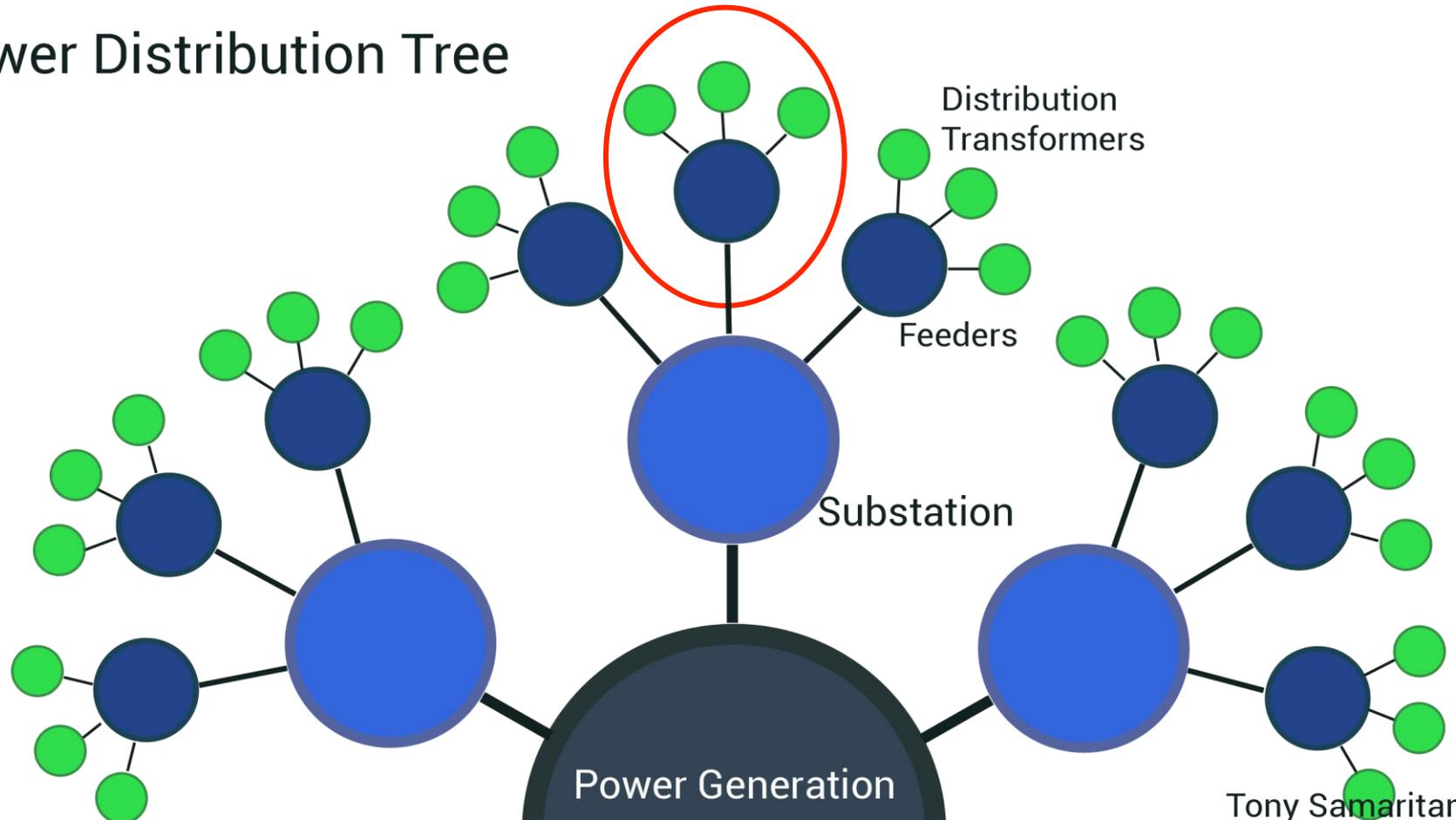


Figure credit - Pansini

Introduction

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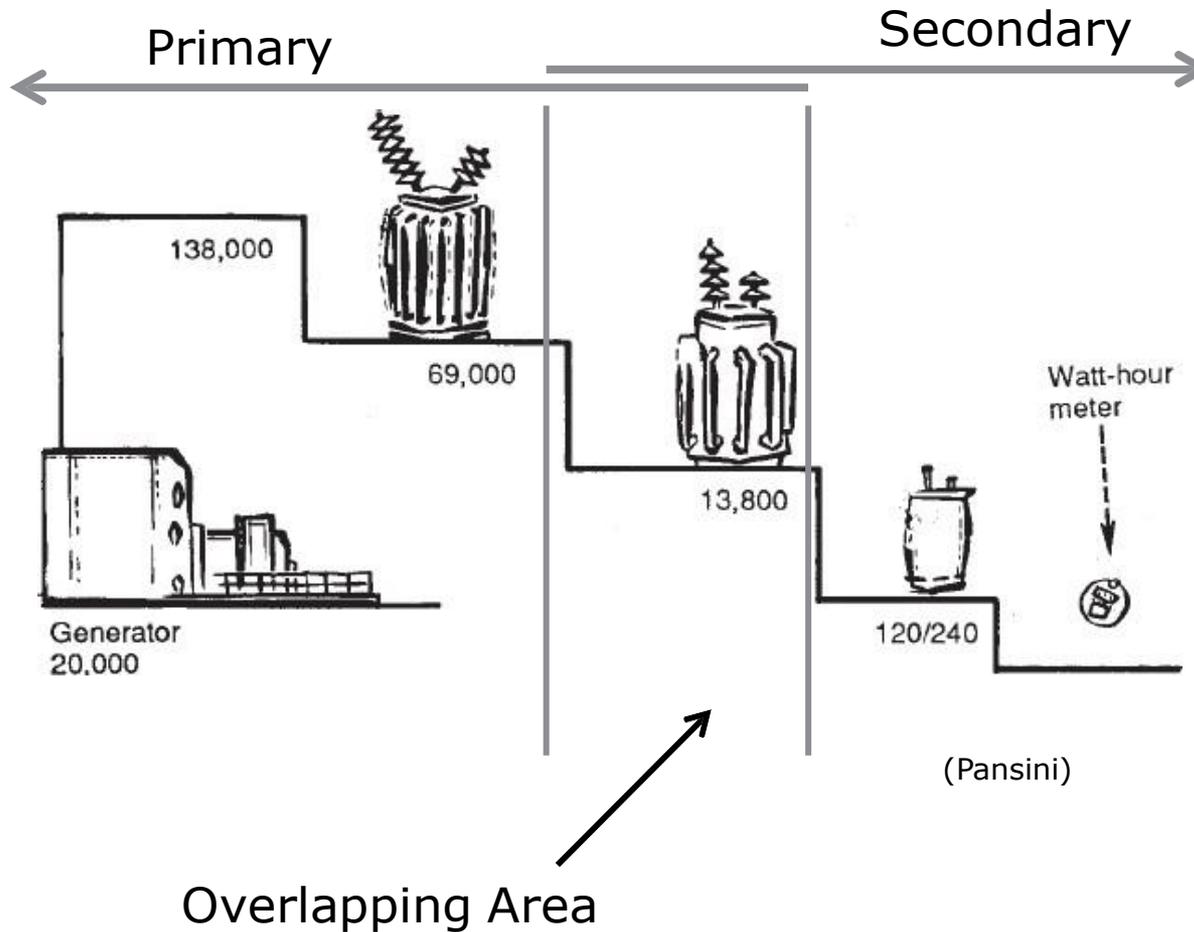
Power Distribution Tree



Tony Samaritano, 2012

Primary Distribution

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Primary Distribution

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Generation

- Nuclear, Coal, Natural Gas, Wind farms, etc.
- Steps up voltage for primary transmission

Substation

- Receive primary transmission and/or subtransmission bus and steps down voltage to feeders

Feeders

- Immediate output to from substations
- Supplies distribution transformers and customers with power

Primary Distribution

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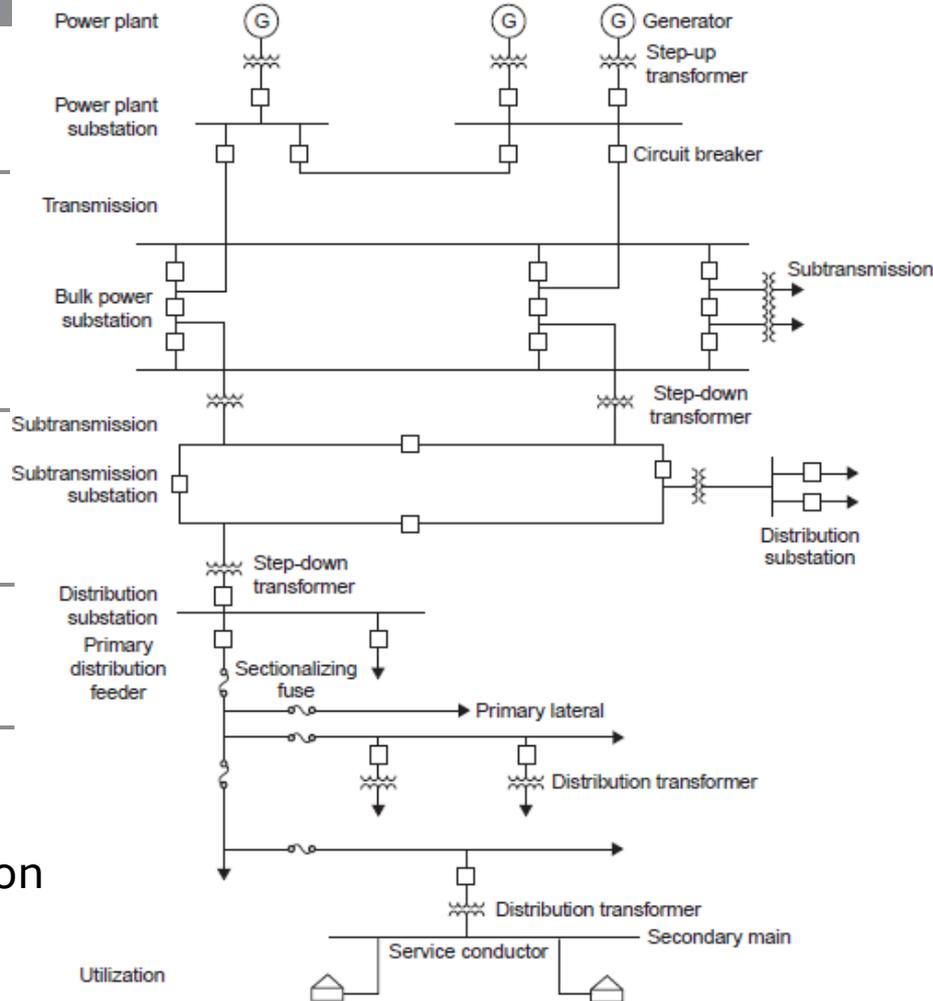
Power Generation

Primary Distribution

Substation

Feeders

Secondary Distribution



(Glover, Sarma, and Overbye)

Power Plant

Transmission Substation

High tension distribution and subtransmission

Substation

Feeders which distribute power to various secondary networks

Primary Distribution

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Secondary Distribution

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Applications

- Residential
- Commercial
- Industrial



Electricity powers almost every system in all three primary applications, therefore secondary distribution is very, very important (duh)

Secondary Distribution

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- ▣ Secondary voltages occur after the distribution transformer.
 - Three main secondary voltages used for most residential/commercial/industrial applications.

System voltage	Voltage class	Nominal voltage (kV)	Voltage category
Secondary	Under 600	0.120/0.240/0.208 0.277/0.480	Low voltage (LV)
Distribution	601–7200	2.4–4.16	Medium voltage (MV)
	15,000	12.5–14.4	High voltage (HV)
Distribution or subtransmission	25,000	24.9	
	34,500	34.5	

(Blume)

Voltage	# Phases	# Wires	Application
120/240 V	Single-phase	Three	Residential
208Y/120 V	Three-phase	Four	Residential/Commercial
480Y/277 V	Three-phase	Four	Commercial/Industrial/High Rise

(Glover, Sarma, and Overbye)

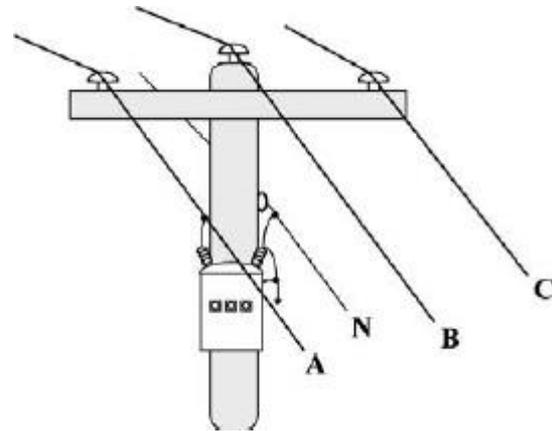
Secondary Distribution

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- ▣ Substation normally use 4 wire, multi-ground Y configurations to distribute power (feeders) to the secondary systems.



(Blume)



(Blume)

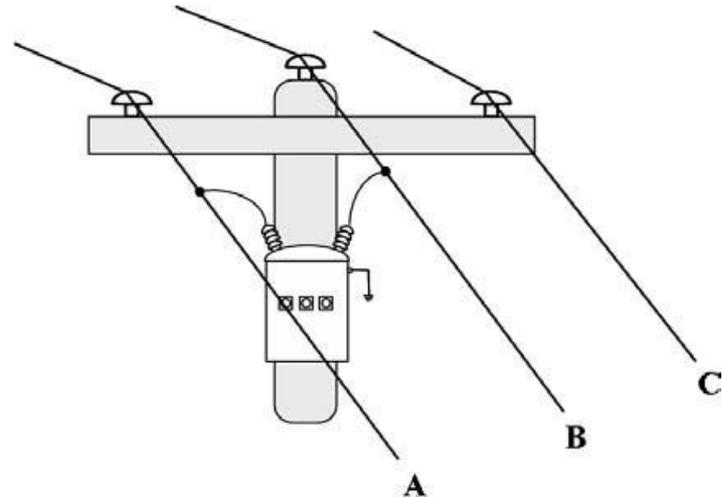
Secondary Distribution

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- Less common but still used is the delta configuration for secondary distribution. Delta configurations were more widely used when the power grid was first being deployed but are in the long process of being converted to Y. (Blume)



(Blume)

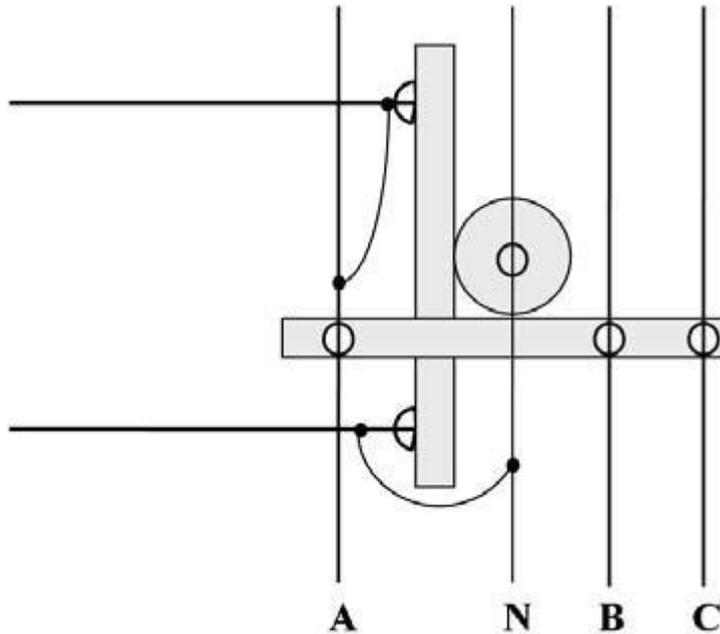


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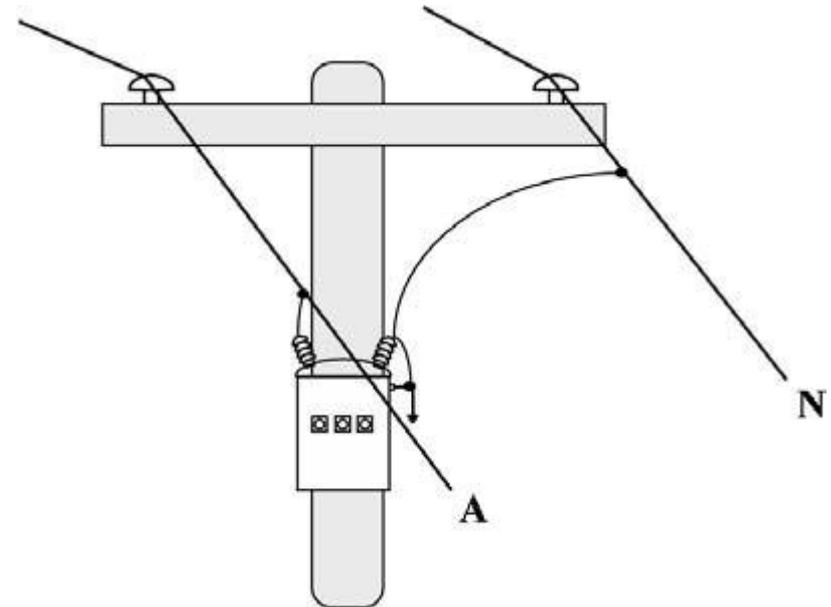
Secondary Distribution

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How phases are tapped from branches (4 wire Y configuration)



(Blume)

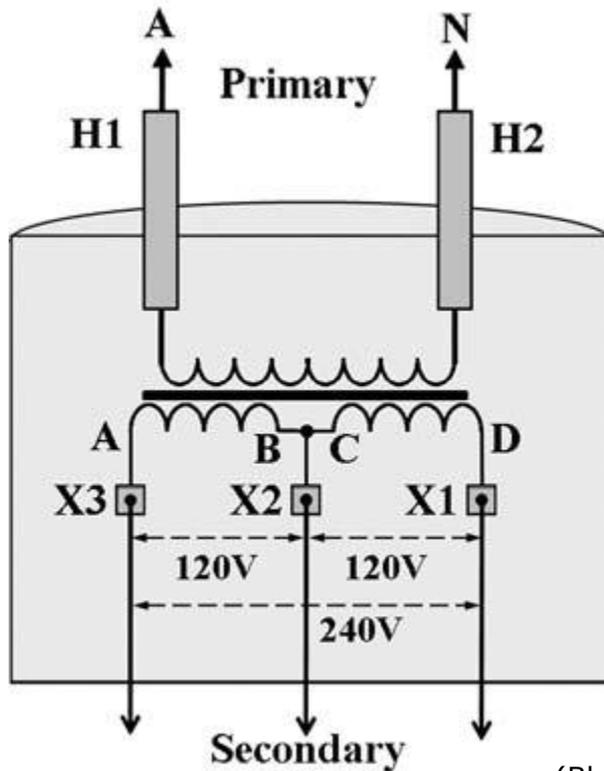


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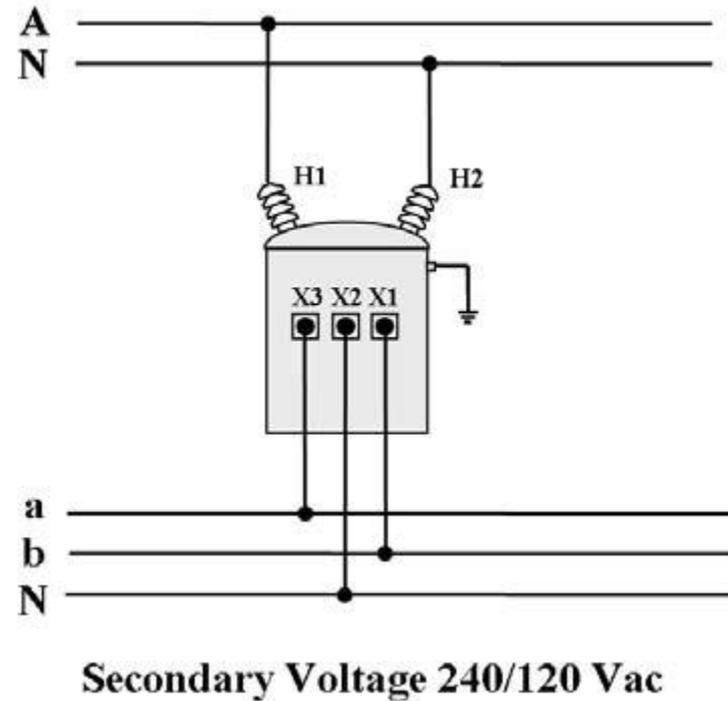
Secondary Distribution

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Single phase distribution transformers (240/120 V)



(Blume)



Secondary Voltage 240/120 Vac

(Blume)

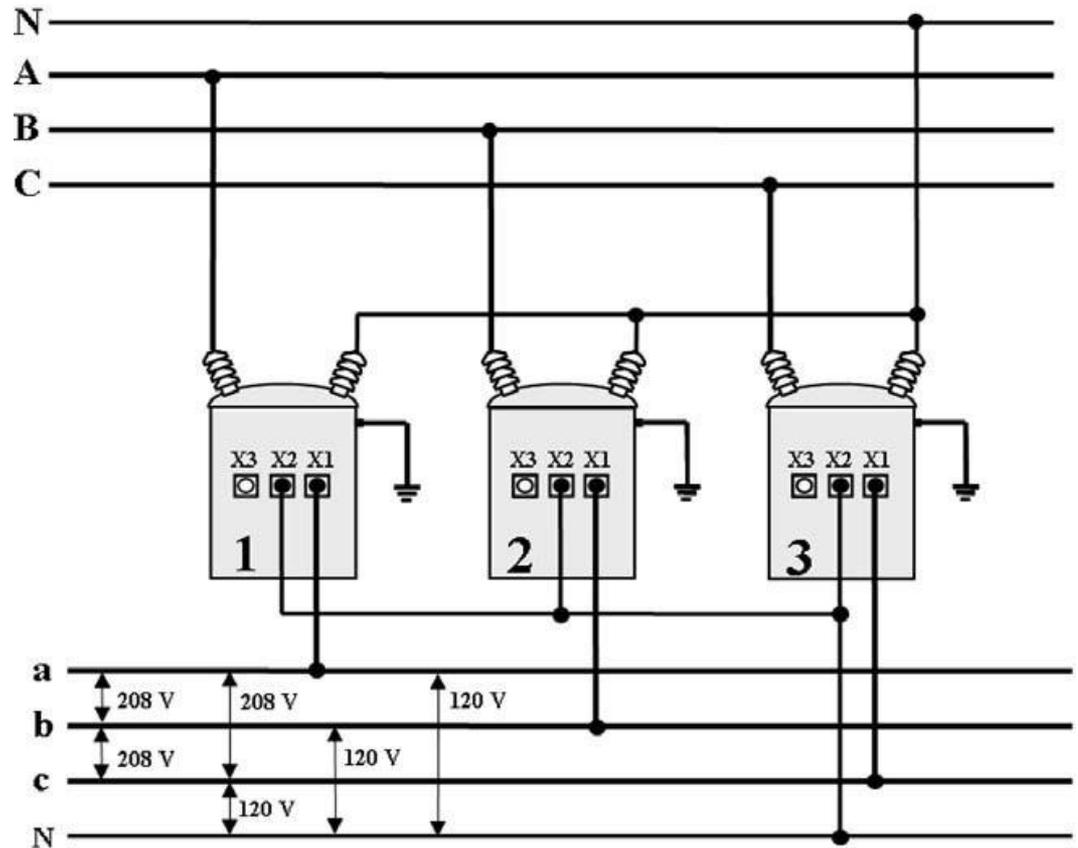
Secondary Distribution

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Three phase distribution transformer bank (208Y/120 V).



(Blume)

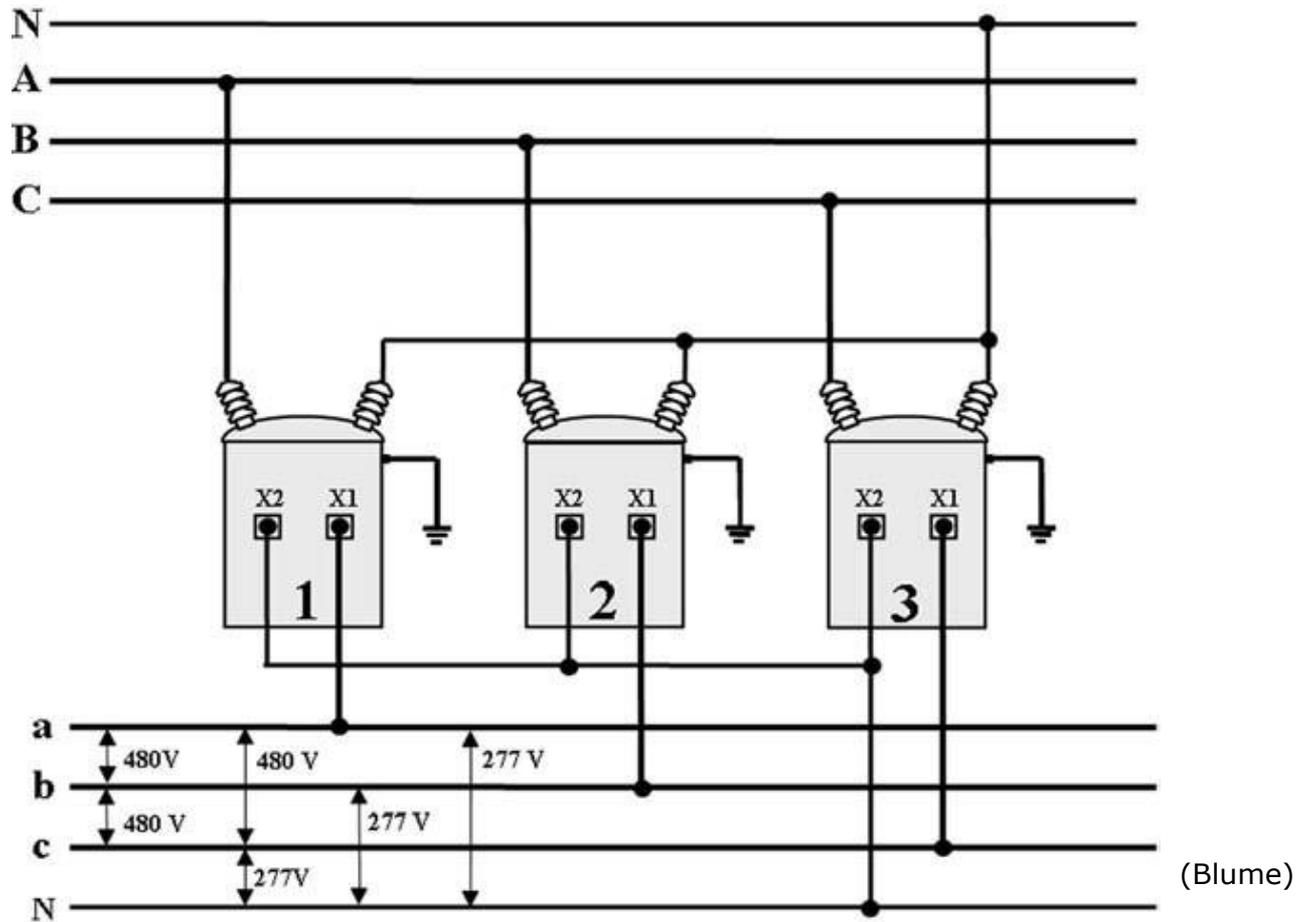


(Blume)

Secondary Distribution

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Three phase distribution transformer bank (480Y/277V).



Secondary Distribution

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▣ Residential

- ▣ 120/240V single-phase, three wire service is most common in residential distribution systems (suburban and rural areas)
 - ▣ 120V is general use – lighting, entertainment and computer systems, etc.
 - ▣ 240V is for large household appliances such as electric ranges, dyers, heaters, etc.

▣ High Density Residential and Commercial

- ▣ 208Y/120V three phase, four wire service
 - ▣ 120V used for lighting and light motor loads
 - ▣ 208V used for large loads like large motors and commercial/residential high power systems

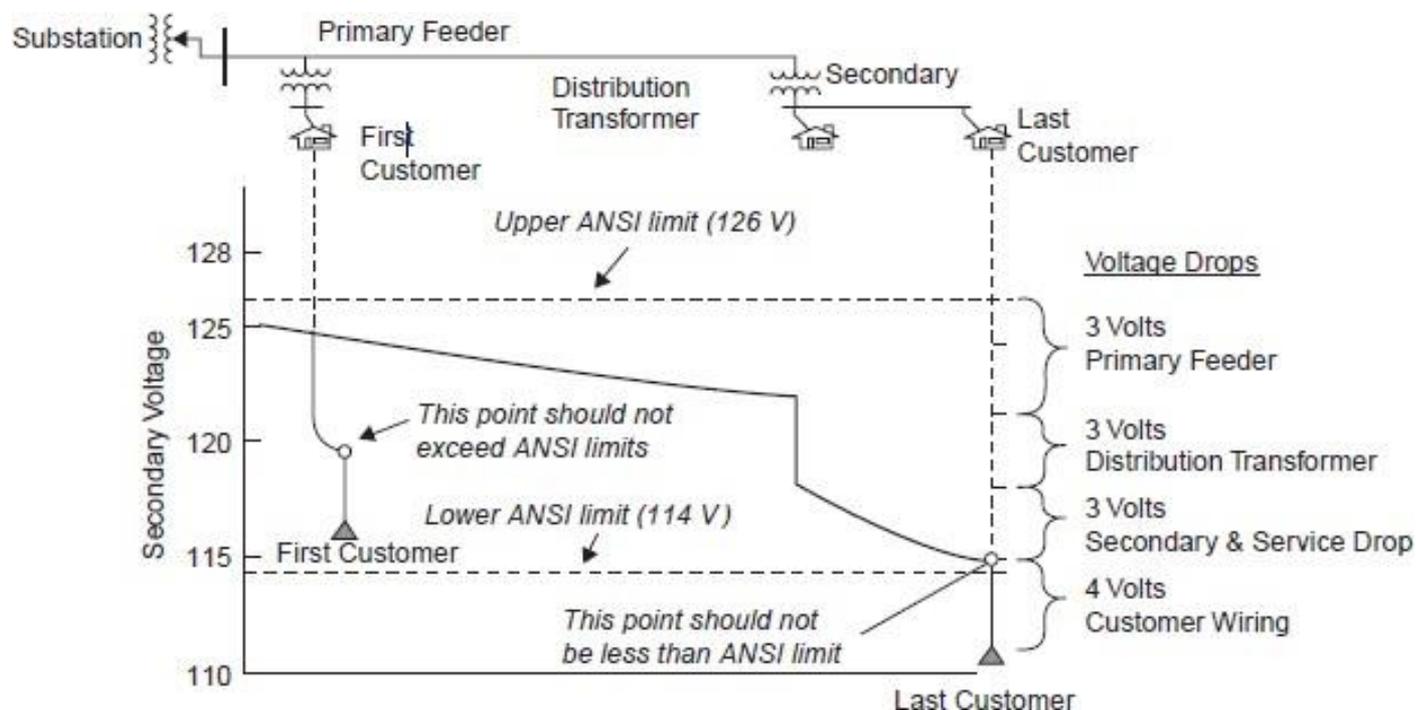
▣ Very High Density and Industrial

- ▣ 480Y/277V three phase, four wire service
 - ▣ 277V used for large fluorescent lighting
 - ▣ 480V used for motor loads and other high power systems

Secondary Distribution

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- Typical residential customer voltage profile.
 - In accordance with ANSI standards, the first customer's voltage must never exceed 126V (+5%) during light loads.
 - Similarly, the last customer's voltage must never drop below 114V (-5%) during heavy loads.

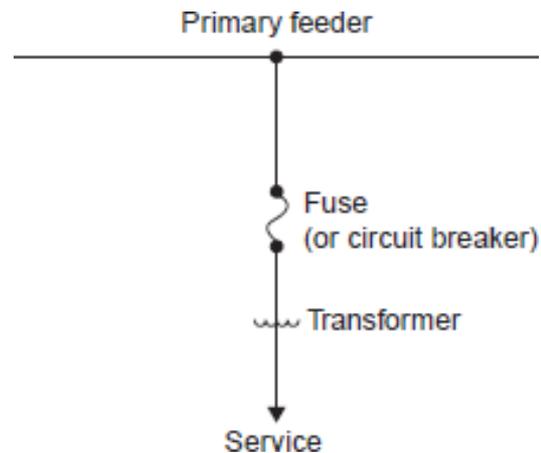


Secondary Distribution

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Individual Distribution

- Used when supplying one customer
- Common in rural areas where distanced between customers are large and long secondary mains are impractical.
- Used for customers with large loads.
- Used for customers who would otherwise have low voltage problems.



(Glover, Sarma, and Overbye)

Secondary Distribution

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▣ Individual Distribution

- Advantages
 - Simple
 - Reliable
 - Heavy loads
- Disadvantages
 - Expensive

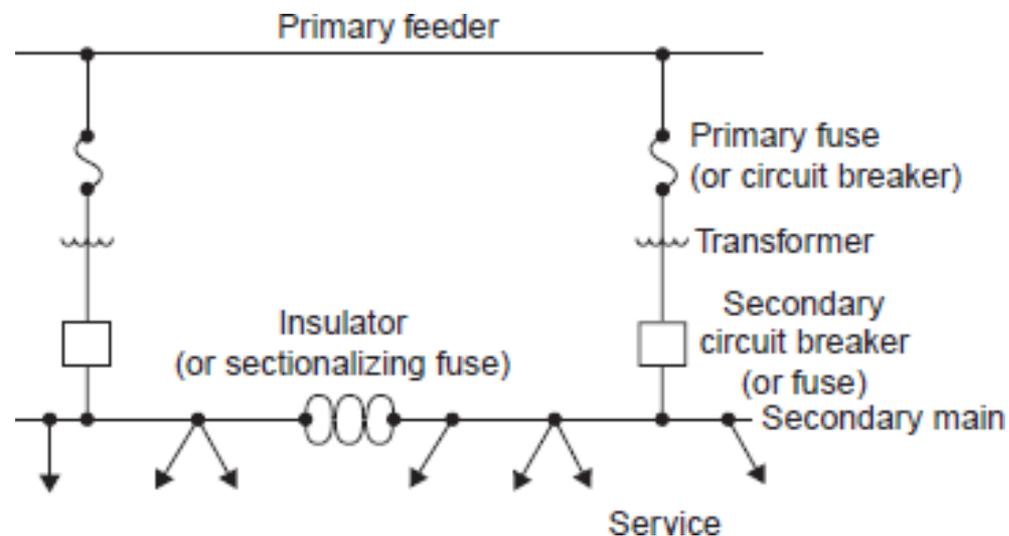
(Glover, Sarma, and Overbye)

Secondary Distribution

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Common Secondary Main

- Takes advantage of diversity between customers
- Good for large transient loads (i.e. motors starting)
- Separated into sections by insulators. Sometimes fuses are installed along secondary main which results in banking of distribution transformers



(Glover, Sarma, and Overbye)

Secondary Distribution

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Common Secondary Main

- Advantages

- Cheap
- Easy to deploy
- Good for transient loads

- Disadvantages

- Not incredibly reliable on individual customer basis

Secondary Distribution

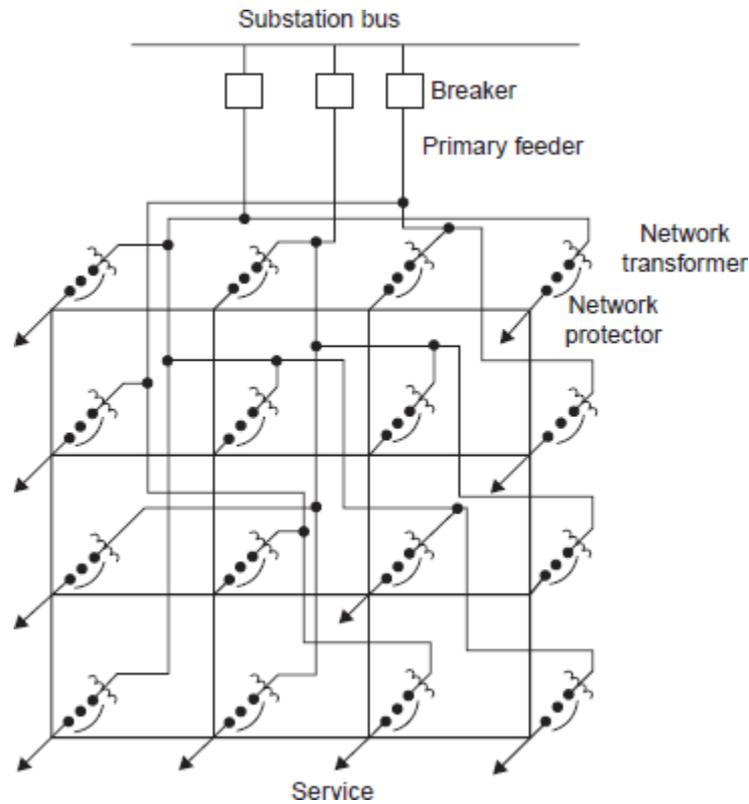
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▣ Secondary Network

- Primarily used for high density, high demand areas such as cities.
- Normally deployed only where high degree of reliability is required and revenues justify grid costs.
- In the U.S. secondary networks operate at either 480Y/277V or 208Y/120V three phase services

Secondary Distribution

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(Glover, Sarma, and Overbye)

Secondary Distribution

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▣▣ Secondary Network

□ Advantages

- Reliable
- Can handle very heavy loads
- Good for high density areas

□ Disadvantages

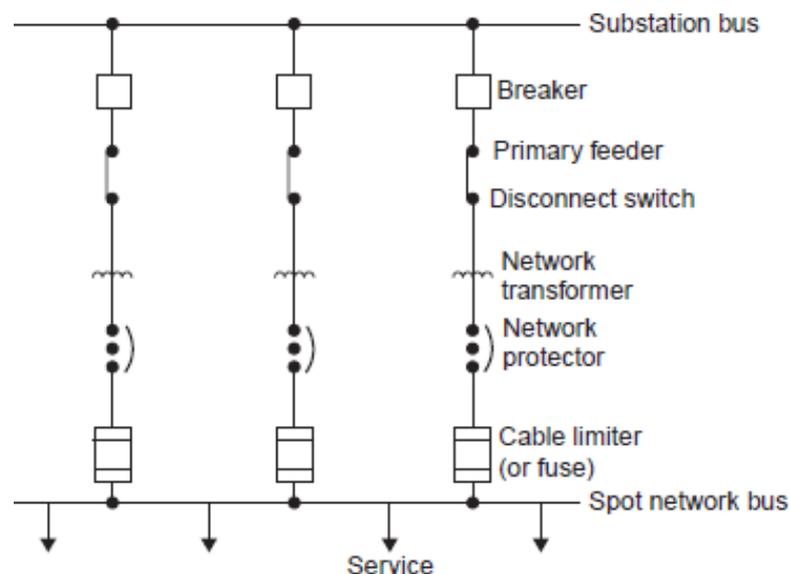
- Very expensive (only used when cost effective)
- Large infrastructure

Secondary Distribution

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Spot Network

- Supplies single, high density loads
- Network bus is simultaneously supplied by two or more primary feeders
- Most run on 480Y/277V in the U.S.
- Offer high reliability



(Glover, Sarma, and Overbye)

Secondary Distribution

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▣ Secondary Network

□ Advantages

- Very high reliability
- Flexible operation
- Secondary is continuously energized by two or more distribution transformers
- Great for large office buildings, shopping centers, Hospitals, etc.

□ Disadvantages

- Very expensive

Secondary Distribution System Construction

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■ Goals

- Understand construction requirements and concerns with deploying overhead and underground secondary distribution systems
- Understand engineering challenges associated with deploying secondary distribution systems

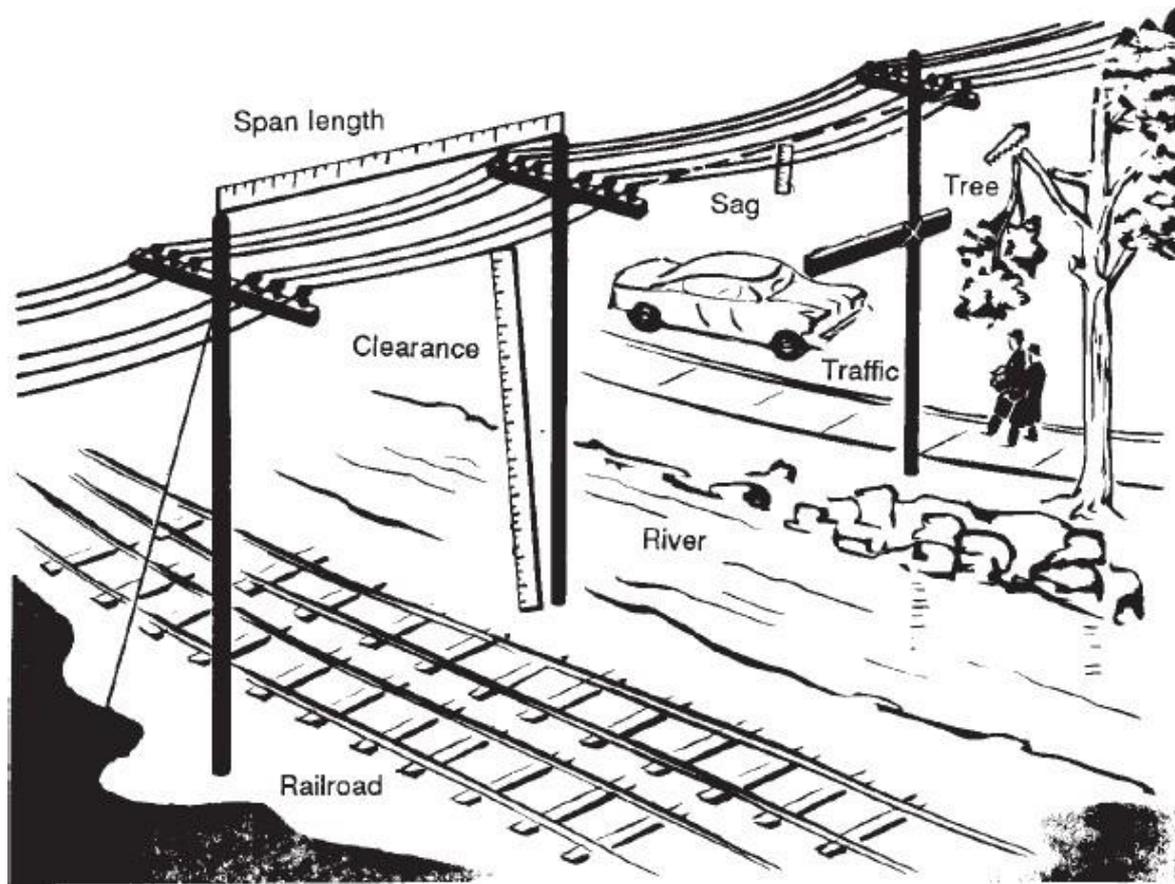
Overhead Construction

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- ▣ There are many factors that need to be taken into account when constructing overhead secondary distribution networks
 - Sag
 - Clearance
 - Traffic
 - Span
 - Obstacles
 - Other power lines
 - Pole installation and anchoring

Overhead Construction

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(Pansini)

Overhead Construction

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- Minimum wire clearance according to National Electric Safety Code (NESC)

<i>Types of Location</i>	<i>Guys, Messengers, etc.</i>	<i>Voltages</i>		
		<i>0 to 750</i>	<i>750 to 15,000</i>	<i>15,000 to 50,000</i>
<i>When crossing above</i>				
<i>railroads</i>	<i>27</i>	<i>27</i>	<i>28</i>	<i>30</i>
<i>streets, roads, alleys</i>	<i>18</i>	<i>18</i>	<i>20</i>	<i>22</i>
<i>private driveways</i>	<i>10</i>	<i>10</i>	<i>20</i>	<i>22</i>
<i>pedestrian walks</i>	<i>15</i>	<i>15</i>	<i>15</i>	<i>17</i>
<i>When wires are along</i>				
<i>streets or alleys</i>	<i>18</i>	<i>18</i>	<i>20</i>	<i>22</i>
<i>roads (rural)</i>	<i>15</i>	<i>15</i>	<i>18</i>	<i>20</i>

(Pansini)

Overhead Construction

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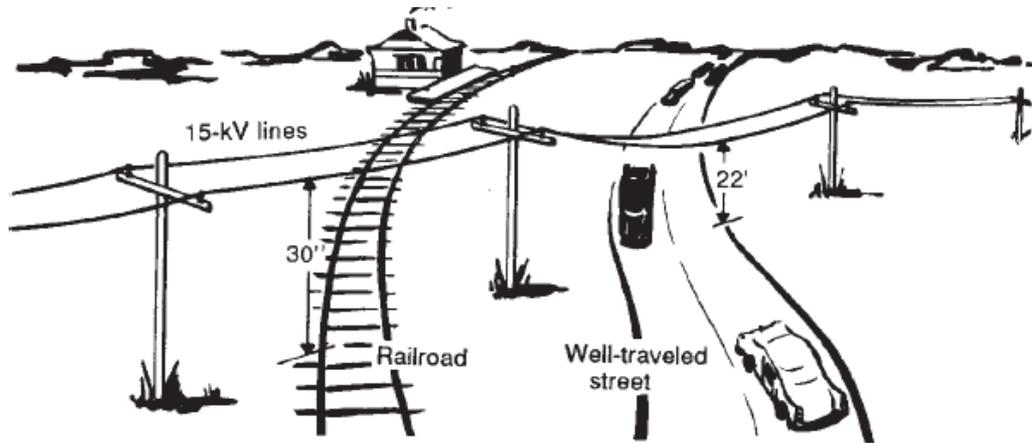
- Most overhead wires are unshielded
- Therefore it is necessary to have minimum clearances between transmission lines.

<i>Nature of Wires Crossed Over</i>	<i>Communi- cation, Guys</i>	<i>Services, Guys, Arrester Grounds</i>	<i>Voltages Between Wires</i>		
			<i>0 to 750</i>	<i>750 to 8700</i>	<i>8700 to 50,000</i>
<i>Communication circuits</i>	2	2	4	4	6
<i>Aerial supply cables</i>	4	2	2	2	4
<i>Open supply wire</i>					
<i>0 to 750 V</i>	4	2	2	2	4
<i>750 to 8700 V</i>	4	4	2	2	4
<i>8700 to 50,000 V</i>	6	4	4	4	4
<i>Services, guys, arrester grounds</i>	2	2	2	4	4

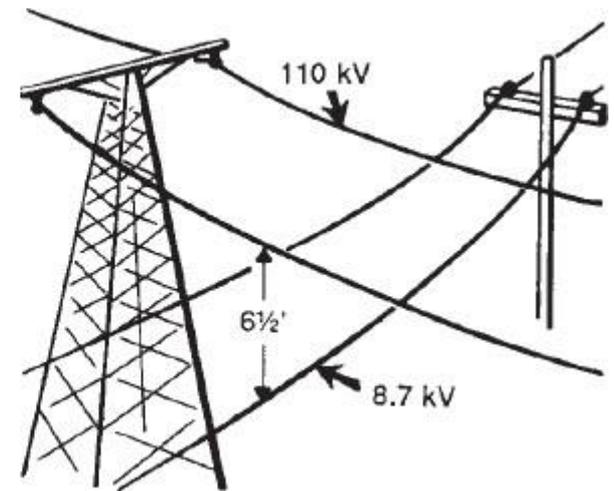
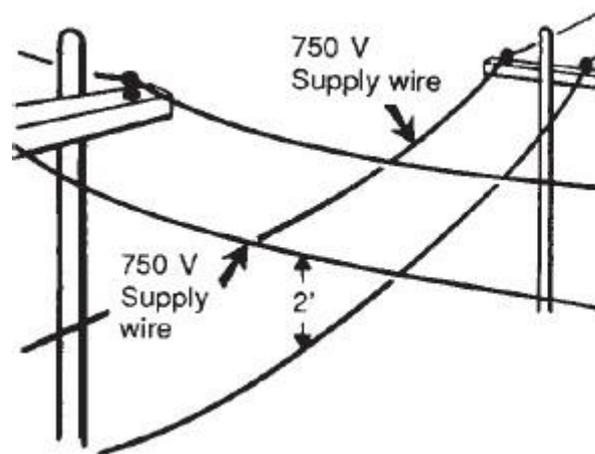
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Overhead Construction

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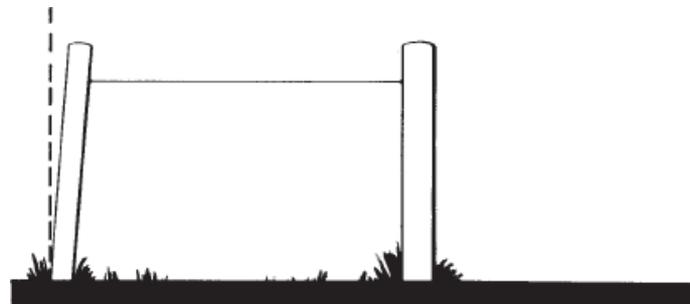
(Pansini)

Overhead Construction

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☐☐ Sag

- ☐ When a conductor is strung between two poles, it sags.
- ☐ Special care needs to be taken to make sure that on the coldest days, the conductor is not stressing poles and on the warmest days the conductor is not violating minimum clearances.



(a)



(b)

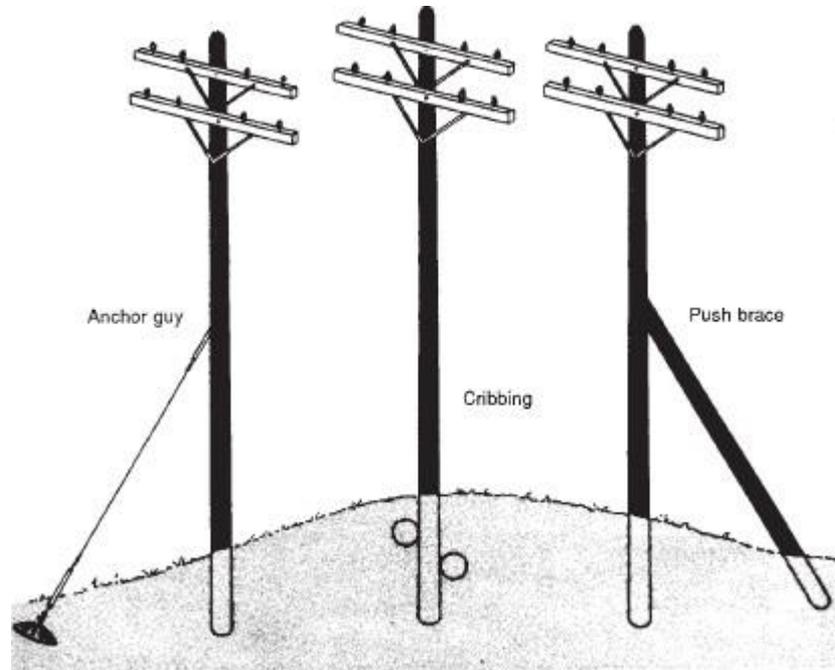
(Pansini)

Overhead Construction

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☐☐ Guying Poles

- ☐ Guys are used to provide extra support to poles when needed.
- ☐ Guys are need because of abnormal loads such as ice, sleet, snow, and wind as well as broke lines, uneven spans, corners, dead-ends, and hills.

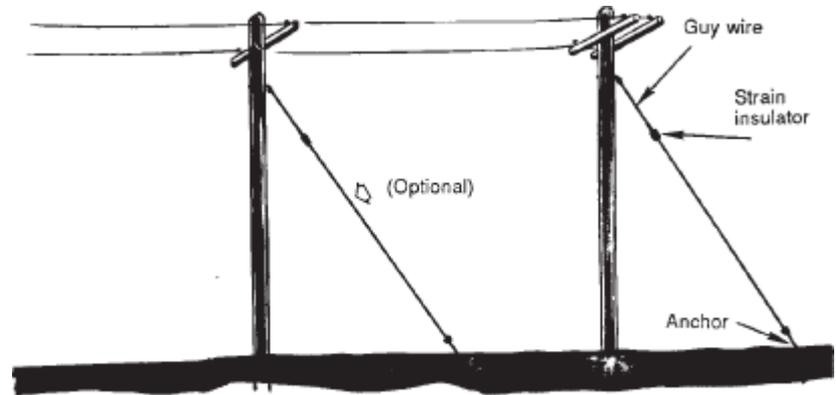
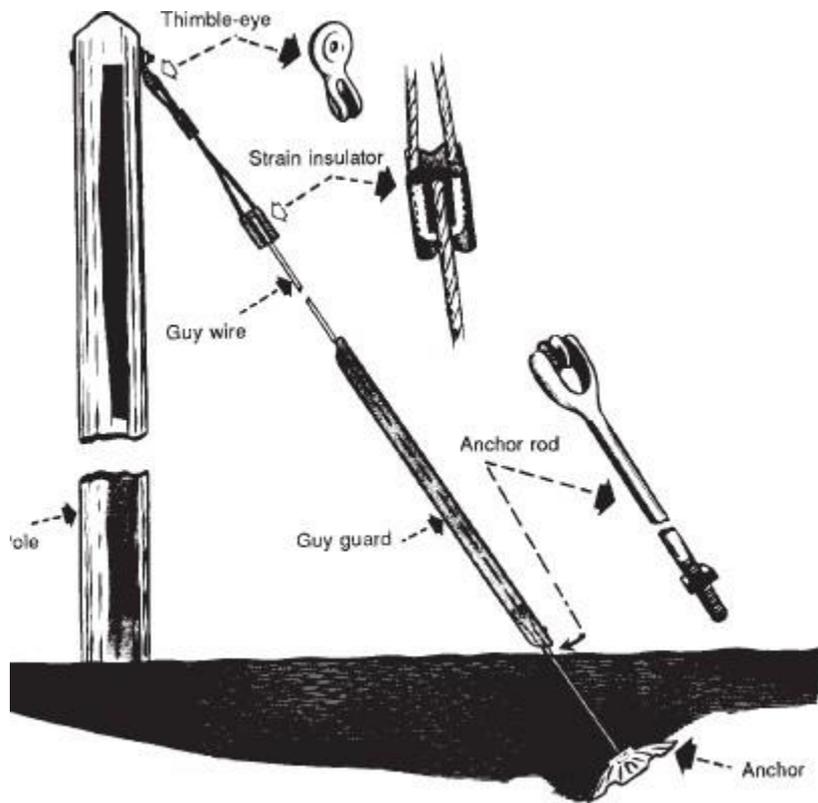


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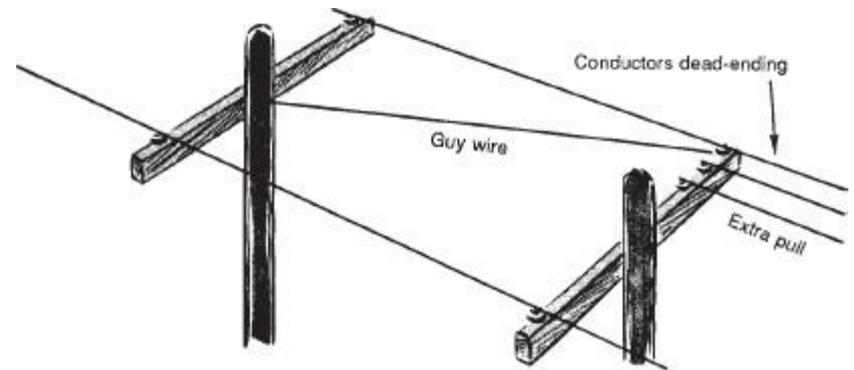
Overhead Construction

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Guy Installation



(a)



(Pansini)

Underground Construction

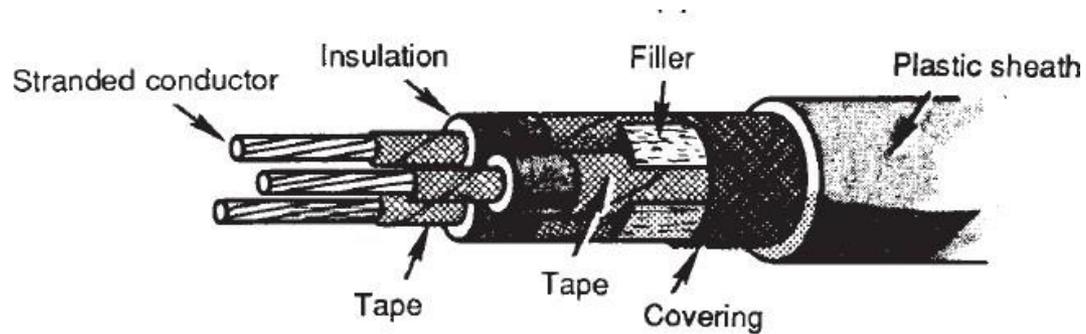
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- Underground construction
 - Used for:
 - General appearance
 - Economic factors
 - Congestion
 - Maintenance conditions
 - High density cities where overhead wires are infeasible
 - Underground cables require more initial infrastructure such as:
 - Underground conduits
 - Ducts
 - Manholes for access to system

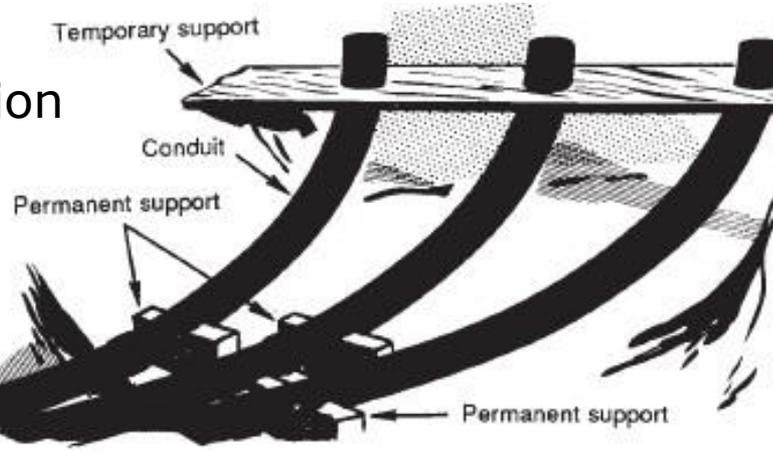
Underground Construction

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Underground Cable



Installation Preparation



(Pansini)

Underground Construction

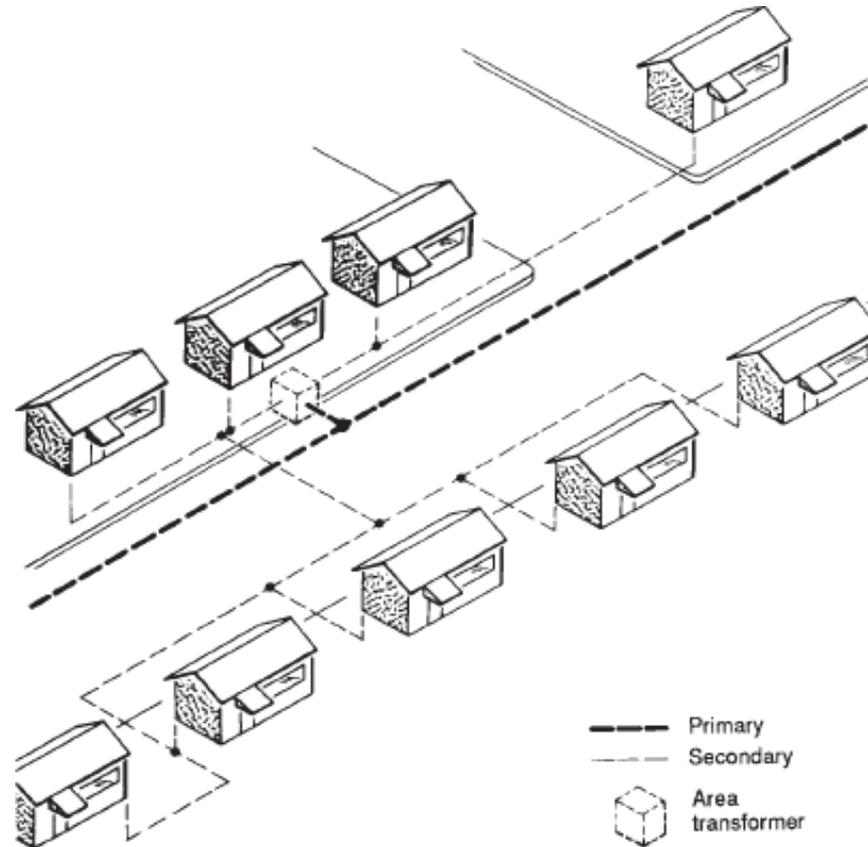
40

- Two general patterns have developed, economics being the deciding factor.
 - Primary supplies a distribution transformer which may feed two or more customers
 - Used in residential developments which house are located close together
 - Primary supplies individual transformers for individual customers
 - Used in residential developments were houses are generally farther apart

Underground Construction

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Area Transformer

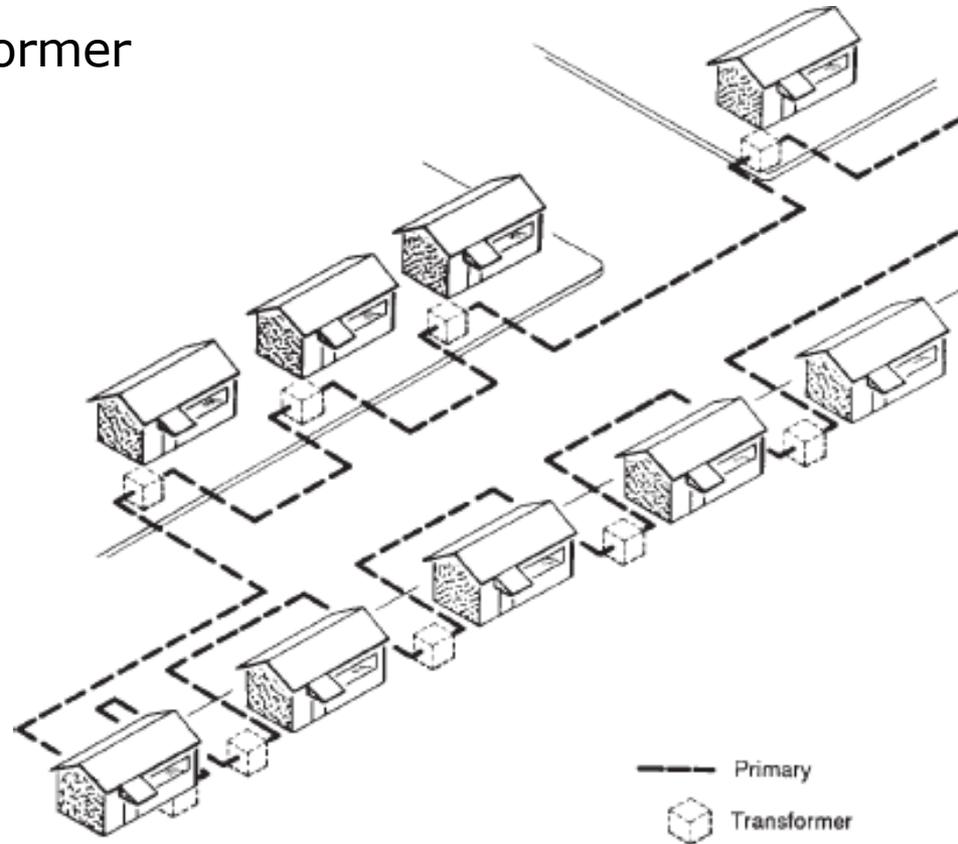


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Underground Construction

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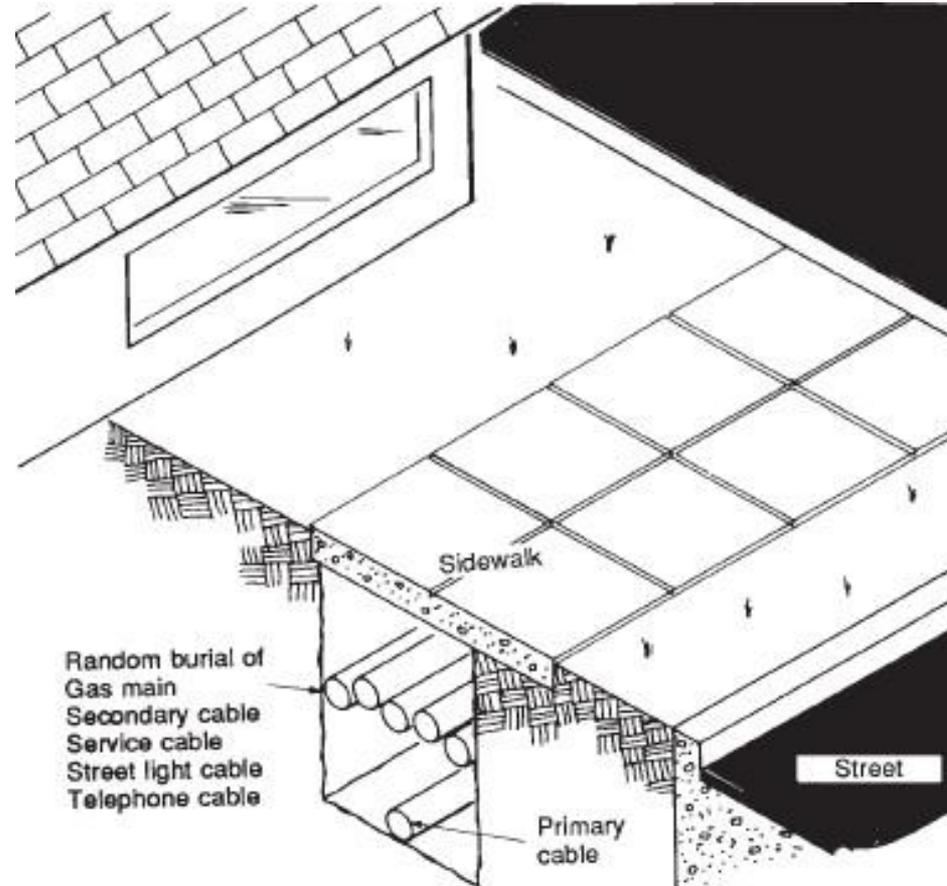
Individual Transformer



(Pansini)

Underground Construction

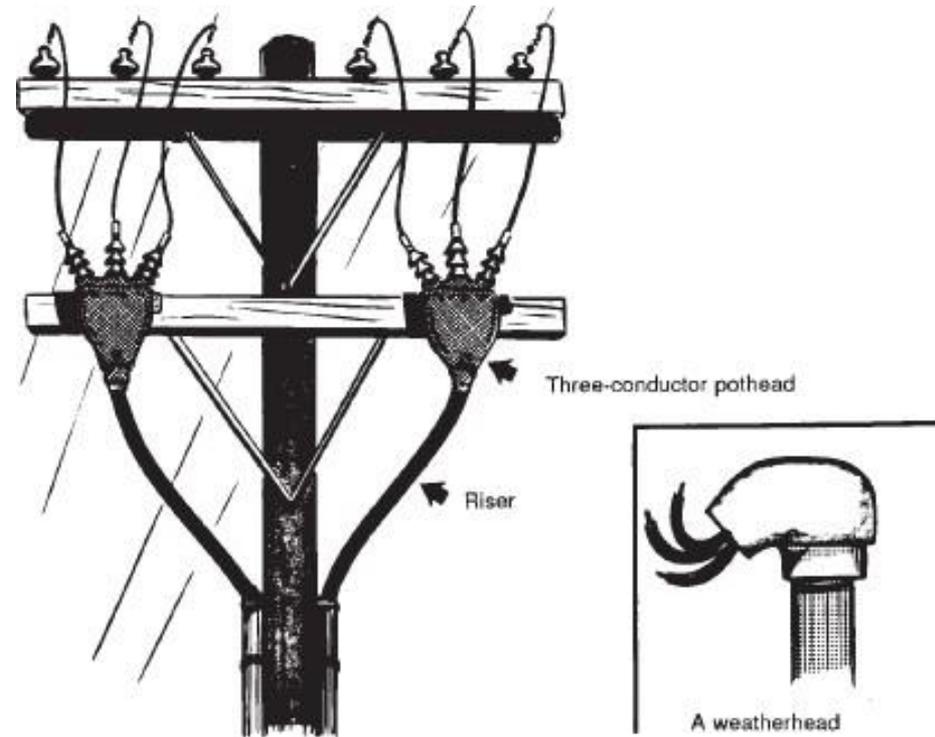
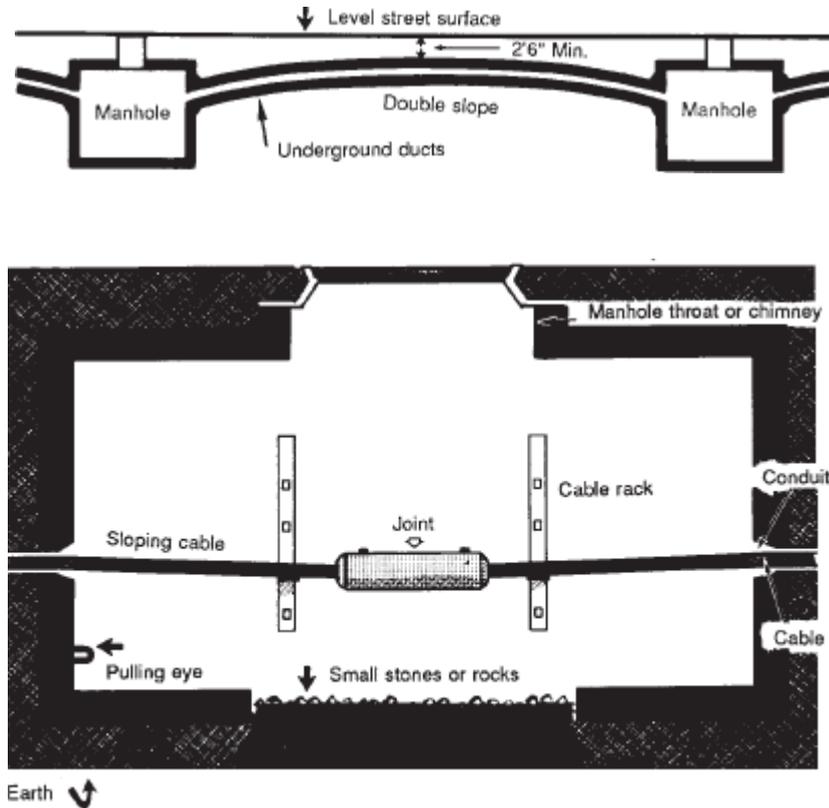
43



(Pansini)

Underground Construction

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*one, two, three, or four conductors may be enclosed in a single sheath

(Pansini)

Underground Construction

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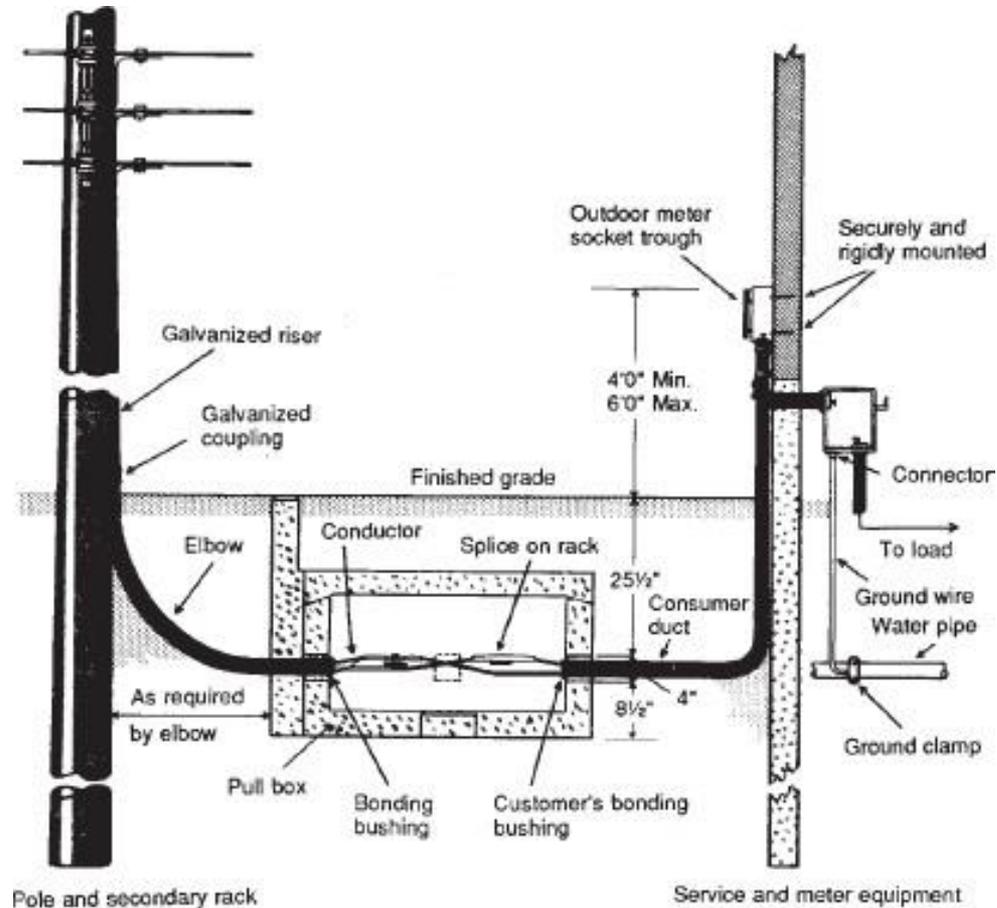


Figure 7-10. Layout for a typical underground service.

(Pansini)

Metering

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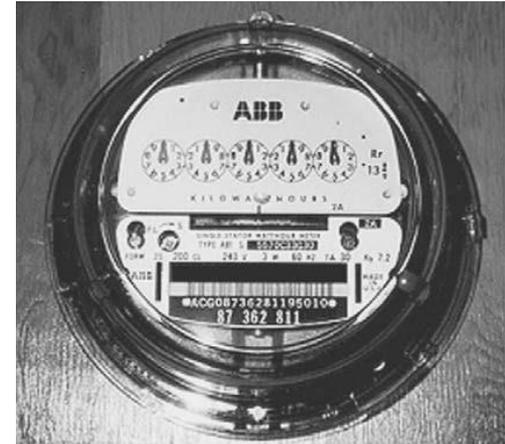
- ▣ Metering is the process of direct measurement of energy consumption.
 - Measured in kilowatt-hours(kWh)
 - Residential customers are metered for energy consumption (kWh).
 - Commercial and small industrial may have a demand meter peak(kW) as part of metering package as well as consumption.
 - Large industry may have consumption, demand and power factor metering (%PF).

Metering

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Residential

- Consumption meter measures energy consumption in kWh.
- Older type dials (still used today) measure actual energy flow in the service wires and spin dials. Each dial represents a magnitude (base 10)



(Blume)



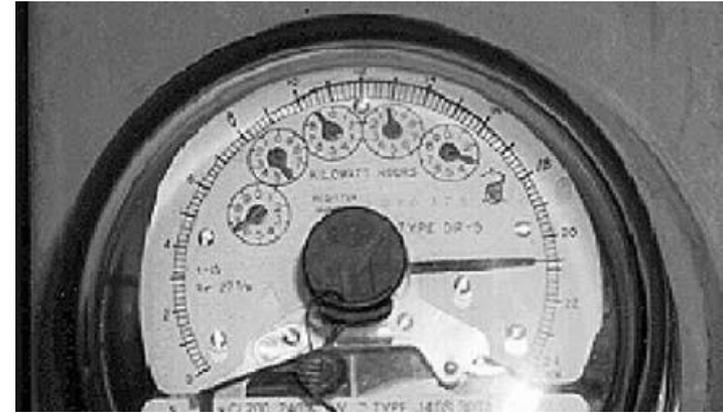
(Blume)

Metering

48

Commercial/Light Industry

- Demand meter is incorporated into metering equipment.
- Customers are charged for the highest sustained 15 minute sliding peak usage within a billing period



(Blume)

Metering

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Heavy industry

- Reactive meters are added to heavy industry because the watt-hour meter cannot measure reactive loads.
- Reactive meters measure kVARh
- Electric utility can use the kWh and kVARh meter to calculate and charge for power factor.

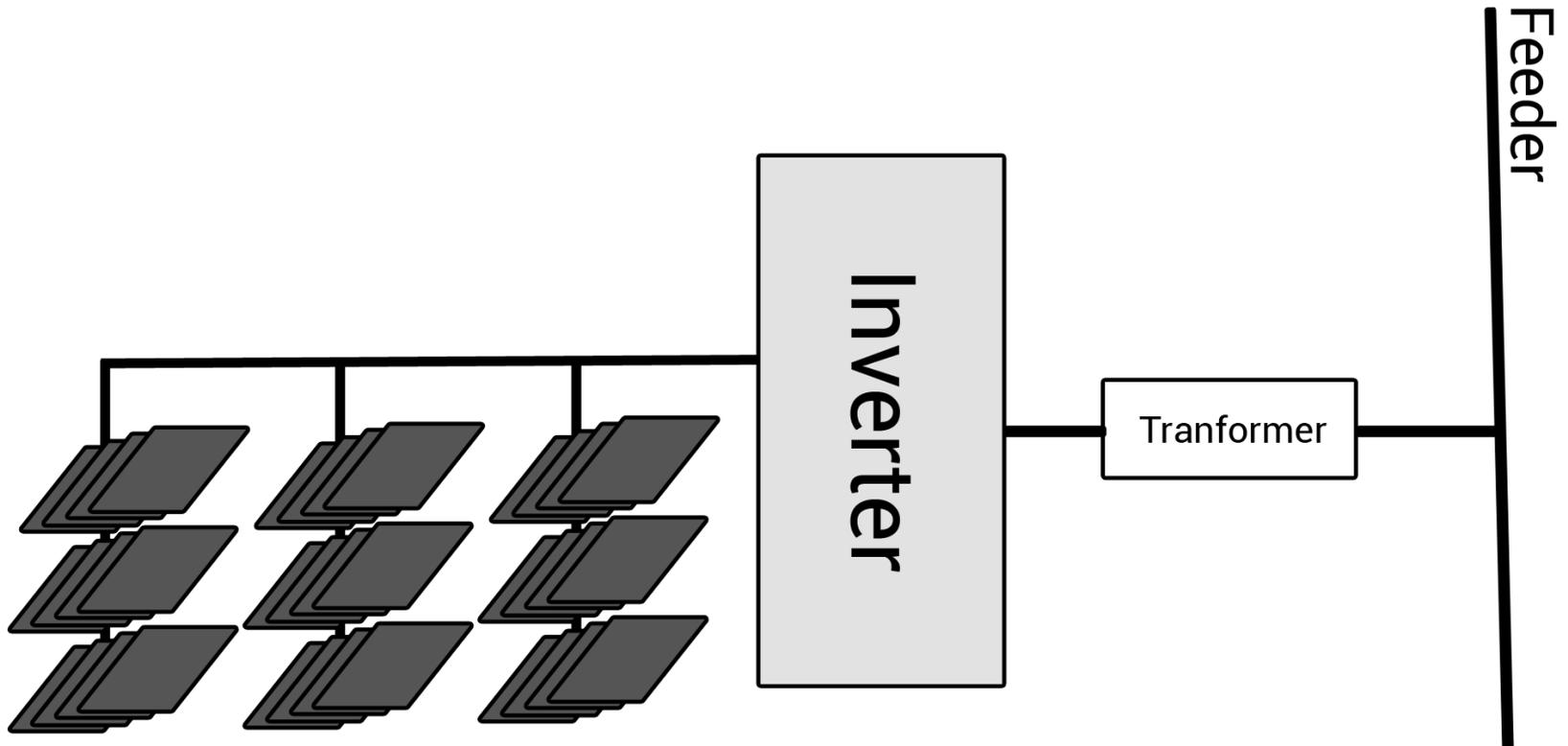
Renewable Integration

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- Local power generation has become more and more common as energy prices have continued to rise and solar and wind technologies have become more inexpensive
- Its important to have a basic understanding of how these energy generation technologies are integrated back into the grid, more specifically secondary distribution grids

Renewable Integration

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Renewable Integregration

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