CHAPTER 3

Basic Considerations and Distribution System Layout

Utility Load Classifications

The electrical power distribution system is that portion of the electrical system that connects the individual customer to the source of bulk power.

The types of loads:

1. **Resistive** (lighting and heating)
2. **Inductive** (motors)
3. **Capacitive** (rectifier bridges with capacitor filters)

Most electrical system loads are predominantly **inductive**.

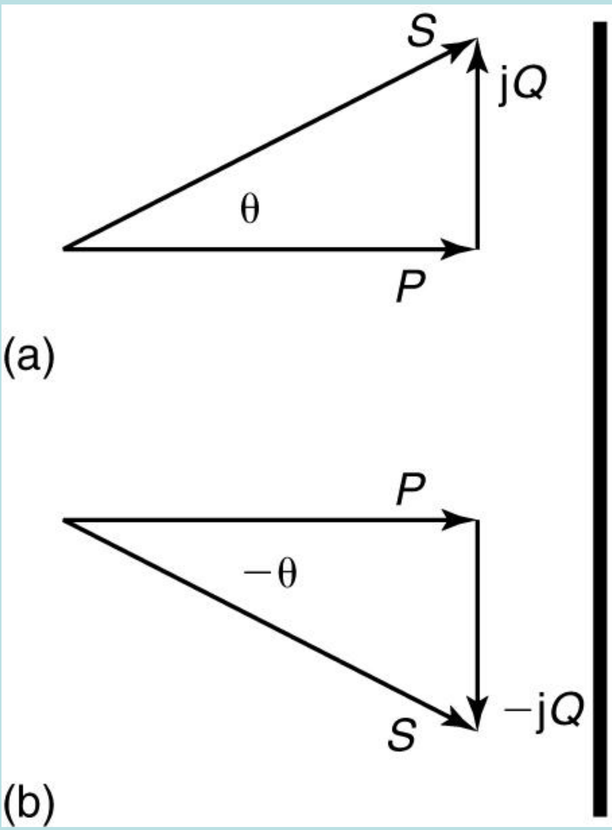
Utility loads are usually classified by the occupancy of the structures that use the power instead of the type of electrical load.

Residential loads:
The combined loads of single family dwellings and apartment complexes.
The types of loads are predominantly *lighting, heating* (water, space, and cooking), and *motors for appliances* such as air conditioners, washing machines, and refrigerators. Residential loads are the largest group of electric utility customers, comprising up to 85%, and require the largest investment in distribution equipment.

Commercial loads
Make up about 15% of an electric utility's customers. They consist of *office buildings and complexes, schools, shopping malls, and stores*. The types of loads are primarily lighting, heating, air conditioning, and office equipment such as computers, copying machines, word processors, and coffee makers.

Industrial loads
Make up about 5% of an electric utility's customers but they may use up to 25 to 30% of the kilowatt hours supplied. The loads consist of the same types of loads as commercial businesses plus *large motors control panels, and production equipment*.

Complex Power: **Power Factor**



Real power

Reactive power

$$\boldsymbol{S} = P + jQ$$

$$S = |\boldsymbol{S}| = \sqrt{P^2 + Q^2}$$ Magnitude of the complex (apparent) power

$$P = S\cos(\theta)$$ Relationship between the real and apparent power.

$$Q = S\sin(\theta)$$ Relationship between the reactive and apparent power.

$$F_p = \cos(\theta) = \frac{P}{S}$$ Power factor

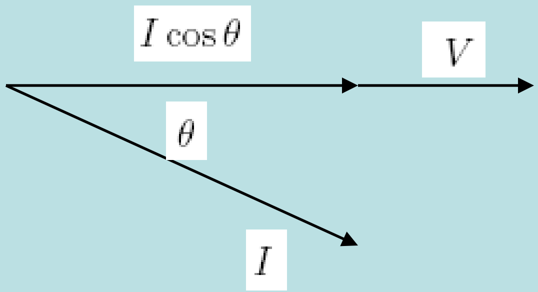
$$\tan(\theta) = \frac{Q}{P}$$

(c)

Angle theta is the angle of the current with respect to the voltage.
If the current lags the voltage (inductive load) then theta is negative.
If the current leads the voltage (capacitive load) then theta is positive.
Power factor is always positive and less than 1.

POWER FACTOR CORRECTION

Most commercial and industrial loads are inductive in nature. As a result the kVAs drawn from the utility are larger than the kWs, and the current lags the voltage:



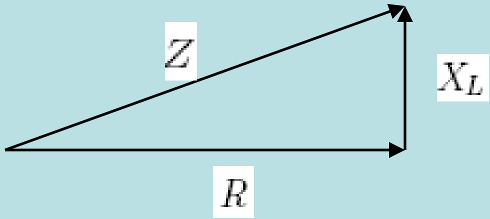
$$P = VI\cos\theta$$

Only the component of the current that is in phase with the voltage provides useful work. The out of phase component increases the total current that the utility must supply so a premium may be charged to a customer with a power factor that is below a value fixed by the electric utility (usually 0.7).

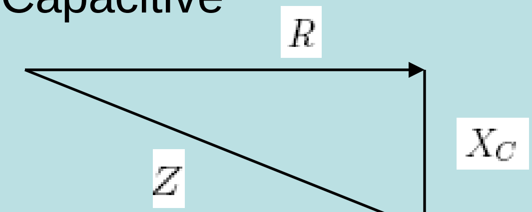
Utilities charge the customers for the kVA hours, not kW hours, that they use. Thus customers have an economical interest in improving the power factor of their facilities. The trend has been to improve power factors to between 0.9 to 0.95 or even better as the cost of electricity has risen in recent years.

Impedance diagrams:

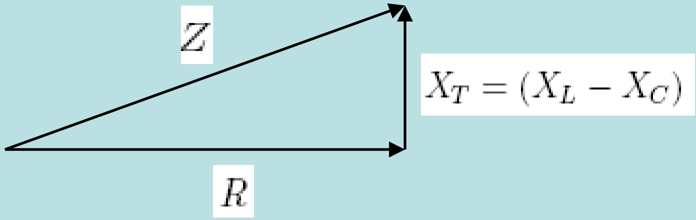
a) Inductive



b) Capacitive

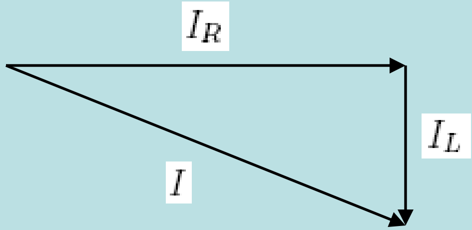


c) General $Z = R + j(X_L - X_C)$

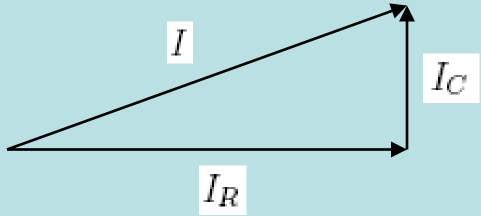


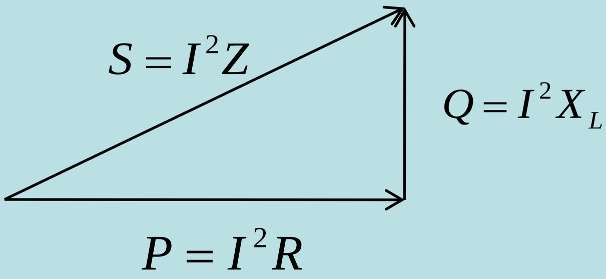
Current

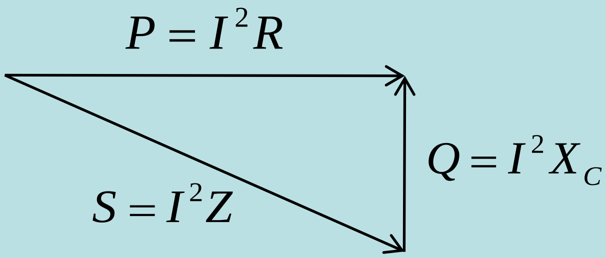
a) Inductive - lagging



b) Capacitive - leading







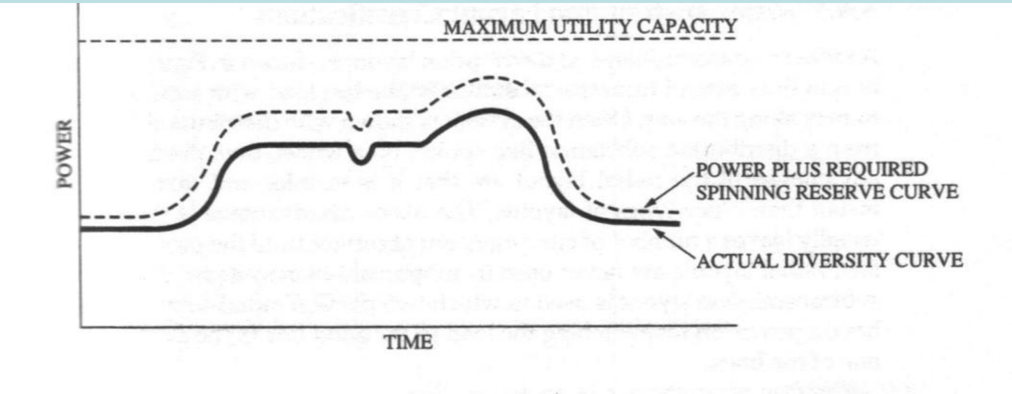
Power triangles

a) With inductive load

b) With capacitive load

Utility Factor

Utility factor is a measure of how much of the total capacity of a utility is in use. If all of the power a utility can generate is being used the utility factor is 100%.
The requirement for reserve power, and the load diversity:



The reserve capacity should be always available in case of failure by some generating equipment.

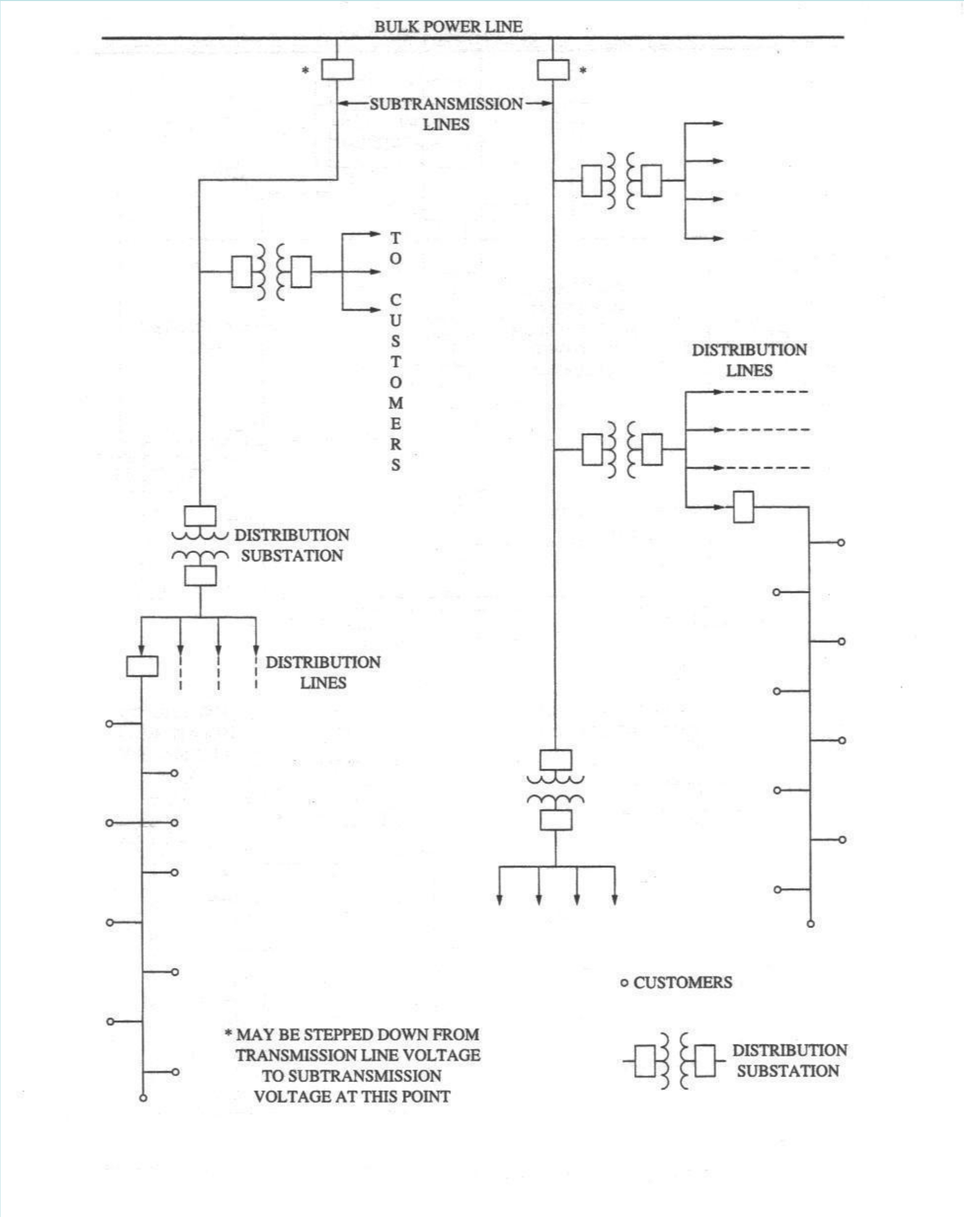
The reserve requirements are for both spinning reserve and stand-by reserve.

Spinning reserve refers to reserve power available from generators that are spinning but are not producing full rated output power. Spinning reserve is available almost immediately.

A stand-by reserve equal to the largest single unit in the system is required. The system is defined for standby reserve as all solidly interconnected utilities so interconnected area utility companies can share stand-by reserve.

Major Distribution Layout Classifications

1. A Radial subtransmission and distribution.



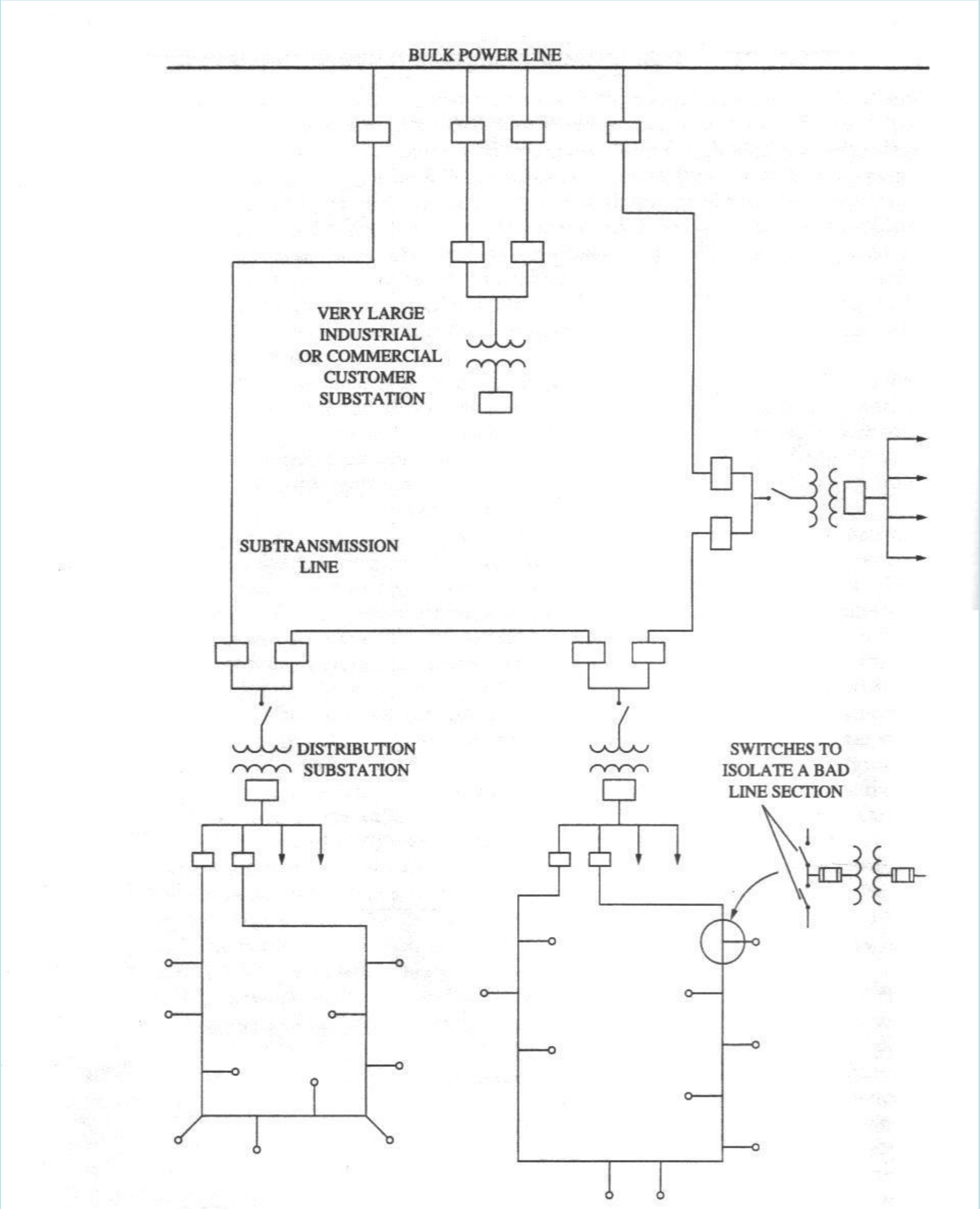
The distribution lines extend from the substation to the last load with service drops to customers along the way.

The major advantages of the radial layout are that it **is simpler and more economical to install** than other types of layouts.

The major disadvantage is that **any problem usually leaves a number of customers out of service** until the problem is solved.

A modified radial subtransmission layout is more often used in which two parallel radial subtransmission line have a provision for switching the load to the good line in the event of a failure.

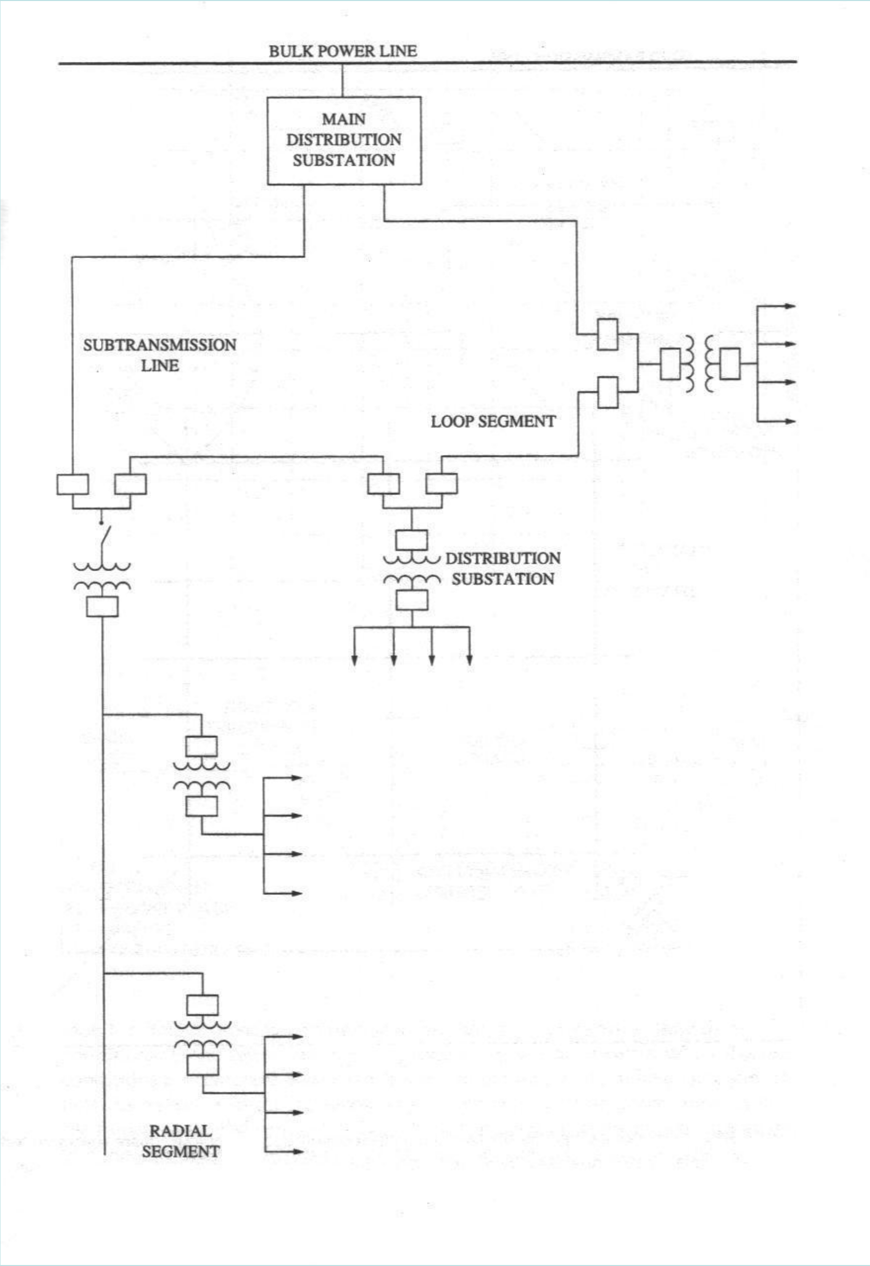
2. The Loop subtransmission and distribution



The *loop connection is more expensive than the radial because it requires more equipment,* but any point the line has service from two directions.
If one is out, the customer can be fed from the other direction. Switches are placed periodically around the loop so the malfunctioning section can be repaired without removing much of the line from service.

The loop layout is very reliable but expensive.

3. A combination of radial and loop



Is often used to provide *the most reliable service to critical customers, such as business and industrial*, by a loop, and reasonably economical service to residential neighborhoods.

Radial part of the system is arranged so that only a few residential customers will be out of service at one time for any fault condition.

4. Networks

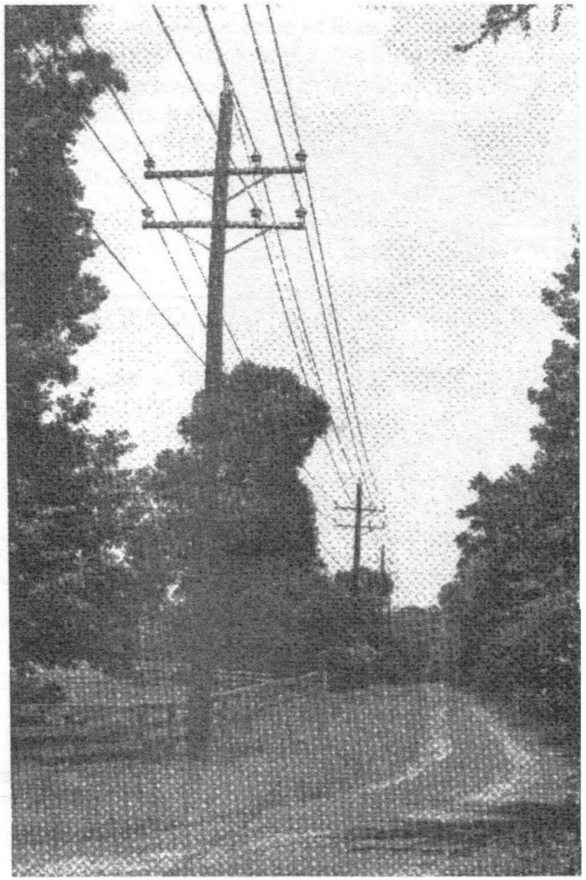
Networks are designed to **provide very reliable service to areas with dense loads such as downtown and suburban business districts containing many multi buildings.**

The network consists of underground secondary lines connected at corners with transformers feeding the network every one to two blocks.

The network equipment is contained in underground vaults with access through main holes in streets and alleys. Although networks can be very large, network sections are seldom larger than four square blocks.

Networks are reliable but expensive.

Overhead and Underground



Overhead distribution is used because the low initial cost and good reliability.
The equipment for overhead distribution costs less than the equipment required for underground distribution, and it is *less costly to maintain*. *Overhead distribution lines are more subject to storm, lightning, and wind damage* than underground lines, but they are more easily and cheaply repaired when damage occurs.

Underground lines are *not as vulnerable to weather conditions*, and they are out of sight so the neighborhood sky lines is less cluttered.
Underground distribution lines require waterproof Insulation of high quality and cost.

Underground lines are higher in electrical loss than overhead lines. The price of equipment for underground distribution decreasing as more underground service is installed.