GRID MODERNIZATION LABORATORY CONSORTIUM
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Power System Equipment

Kevin Schneider
Pacific Northwest National Laboratory (PNNL)

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Power System Equipment

- Part 1: Substation Equipment
- Part 2: Distribution Equipment

Part 1: Substation Equipment

Distribution Substations

- Distribution substations form the source of energy for the majority of distribution circuits.
- Main purpose is to step down the voltage from transmission levels to levels appropriate for local distribution.
- Usually characterized by voltages up to 230 kV on the primary side and 4.2, 12.47, 13.2, 13.8, 24.9, or 34.5 kV on the secondary side.
- 12.47 kV is by far the most common voltage in the U.S.
- The power transformers commonly used in this application are two-winding type and may be single-phase or three-phase units.

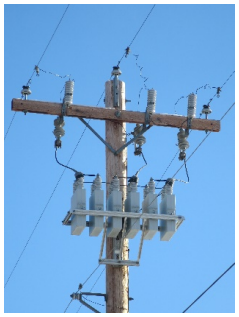
Substation Transformers

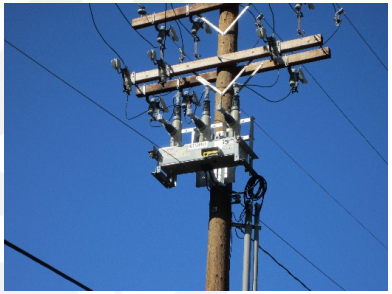
- The substation transformer is one of the most expensive pieces of equipment at the distribution level.
- Substation transformers are capital assets expected to remain in operation for 30+ years, with some in service > 50 years.
- They connect the high voltage transmission system to the lower voltage distribution system.
- Overload of these units is the primary concern since it leads to significant reduction in equipment lifetime.

Part 2: Distribution Equipment

Distribution Equipment

- Much of the distribution level equipment can be located at the substation and/or in the field on the circuit
- Important equipment includes:
  - Conductors
  - Transformers
  - Voltage Control Devices
  - Protective devices
  - Switches

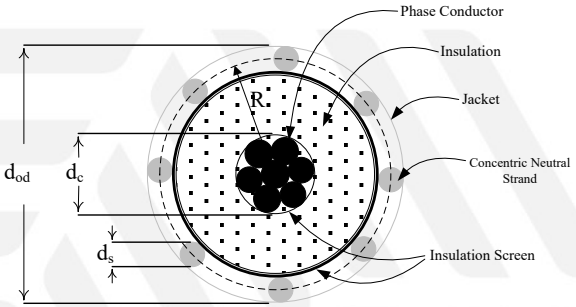




Overhead Lines

- Much more common than underground cables, due to cost.
- Typically aluminum and steel, sometimes copper.
- Typically bare conductors, not insulated.
- Faults will occur when the conductor comes into contact with the ground, vegetation, animals, or people...

Underground Cables



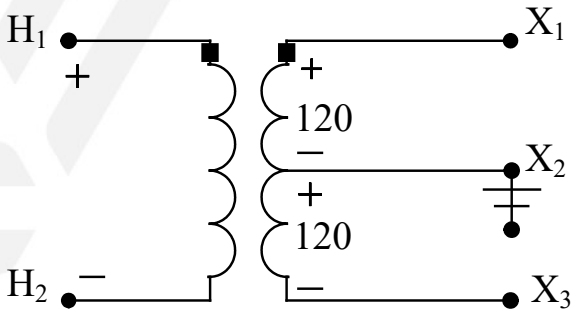
- Underground cables may be used in a number of situations:
  - In areas where there are numerous momentary faults, e.g. wind storms.
  - In urban areas where overhead lines may not be practical or desirable.
  - In communities where there is a desire to not have visible infrastructure.
- Cables can be directly buried or laid into conduits and/or vaults.
- Underground cables have some desirable characteristics but they can be up to ten times the cost of overhead lines.
- When faults do occur, it can be difficult to locate and fix the fault. It may be necessary to dig the cable up to fix the fault.

Distribution Transformers

- The service transformer steps voltage down from the primary distribution level to the customer's voltages.
  - Primary: 4.2 – 35 kV
  - Secondary: 120/240V

- Secondary transformers can last 50+ years if they are not routinely overloaded.

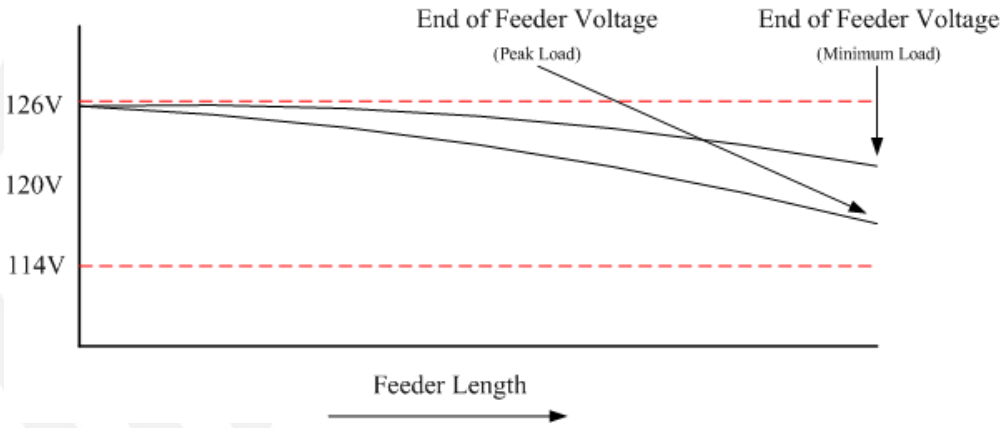
- The standard method of providing three-wire service is from a center-tapped single-phase transformer.



- In this type of connection there are two 120 volt circuits and one 240-volt circuit.

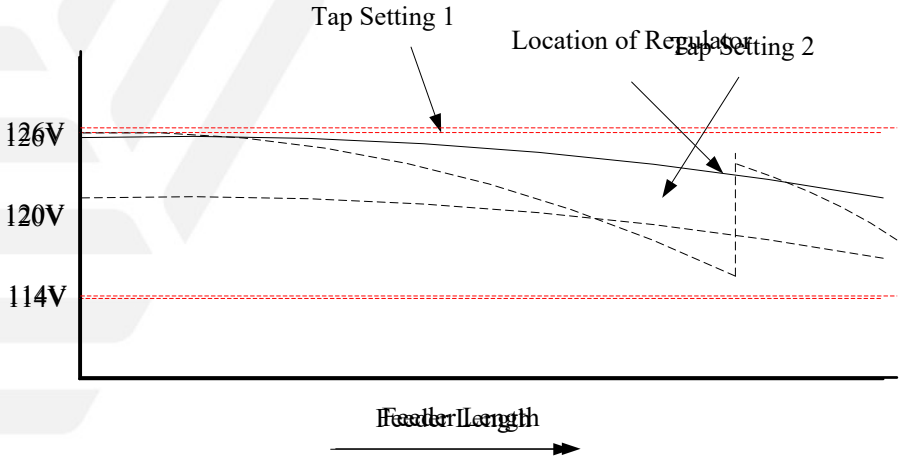
Distribution Voltage Control

- The voltage supplied to the customer is generally maintained within the limits set by ANSI C84.1, Range A.
- This is done by setting the voltage at the “head” of the feeder at the high end of the band, to ensure that the voltage drop at peak load does not exceed limits.
- The voltages shown in the figure below are the voltages seen by the end-use customer. The voltage supplied to the end-use customer will affect their energy consumption.



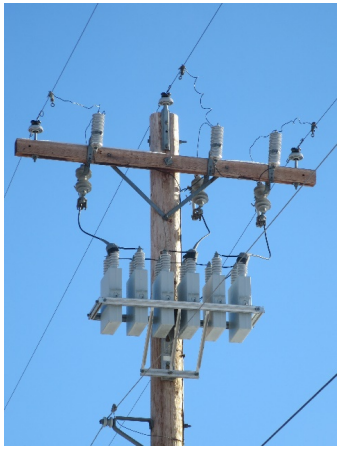
Voltage Regulators

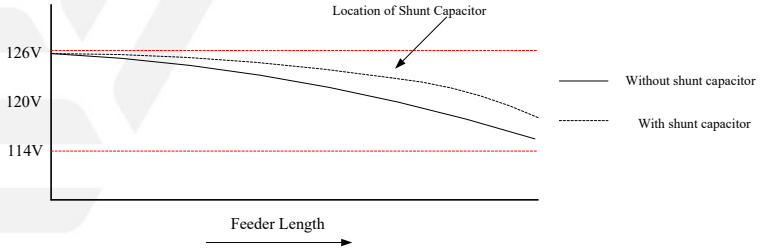
- Regulators are often installed at the substation in order to adjust the voltage at the head of the feeder. This can help to improve the voltage regulation.
- They can also be installed in banks of three, or individually, on the circuit.
- Voltage regulators are sometimes also used at the sub-transmission level, which will affect the voltage at the distribution substation.
- Regulators are electromechanical devices that physically change the “taps” on a special type of transformer.
- Because of their electromechanical nature, over operation can lead to increased maintenance and/or reduce life expectancy.



Shunt Capacitors

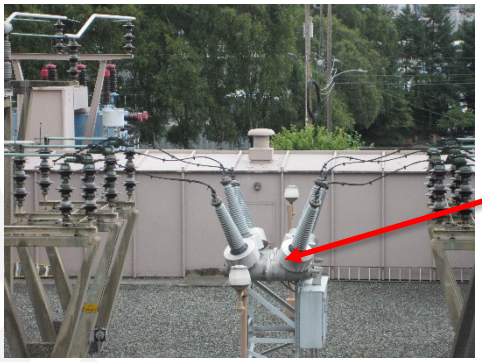
- Another solution to address voltage drop is the installation of shunt capacitors to reduce the reactive power flows.
- By supplying the leading reactive power locally, this reduces the reactive power needs of the feeder and allows for increased loads to be supported.
- When both voltage regulators and shunt capacitors are used, their set points must be coordinated to prevent “fighting” between units.

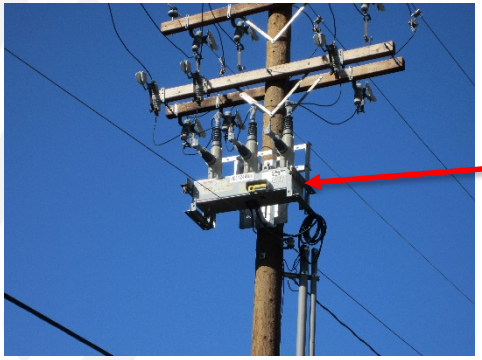


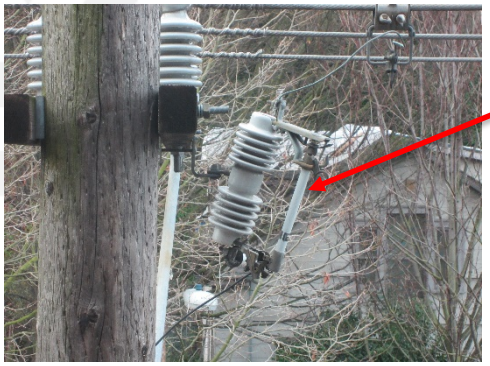


Protective Devices

- Protective devices are designed to interrupt the flow of fault current to protect equipment.
- **Circuit Breaker**: typically located at the substation to protect a transformer or circuit.
- **Recloser**: similar to a breaker but it has the ability to reclose one or more times in case the fault was temperature, which can be important in heavily wooded areas.
- **Fuse**: similar in function to traditional automotive fuses, except that they work slightly differently to handle the large fault currents of power systems.







Switches

- The primary function of a switch it to provide electrical isolation.
- Switches are not protective devices; unlike breakers they cannot interrupt current.
- Switches at a substation can transfer load between substation transformers.
- At the distribution level switches are used to reconfigure a feeder.
- Switches can be used to transfer load from one feeder to another.
- Switches can also be used as part of a system repair strategy in order to isolate portions of the system while repairs are conducted.
- Switches may be remotely controllable (SCADA) or require manual operation.