

Basic Substation Configurations and the Components






Moderator

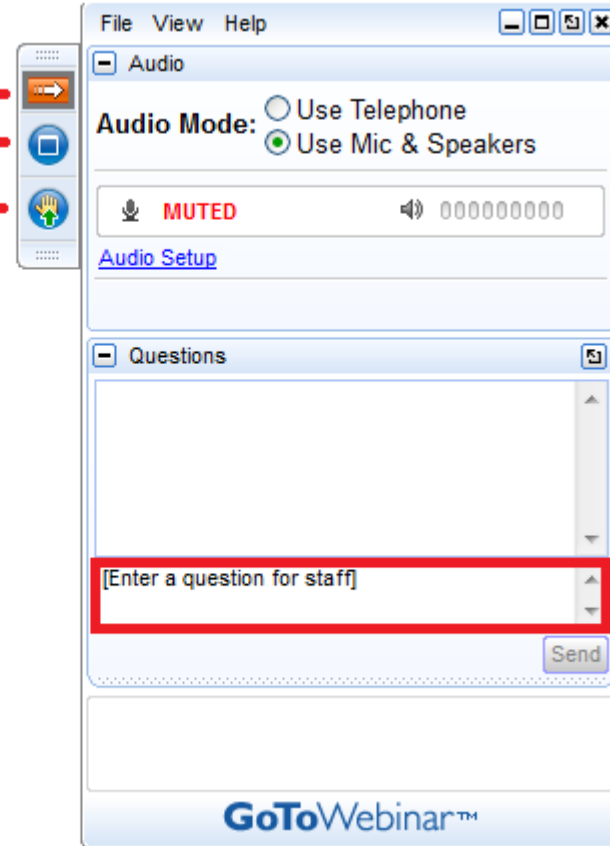
- **Ron Spataro**

AVO Training Institute Marketing Manager

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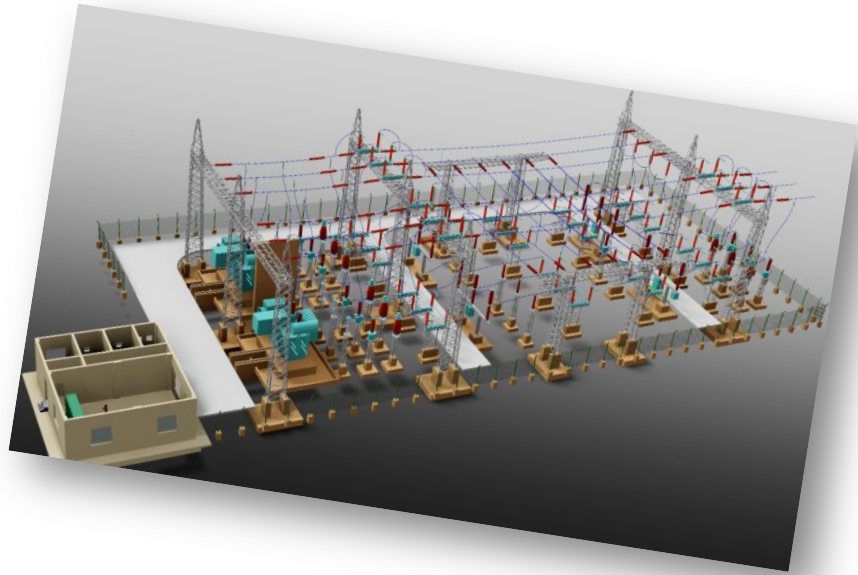
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Today's Presenter

- **Greg Richmond**
AVO Training Specialist

Substation Configurations and its Components

- Power Generating Systems
- Grounding
- Types of Substations
- Substation Equipment



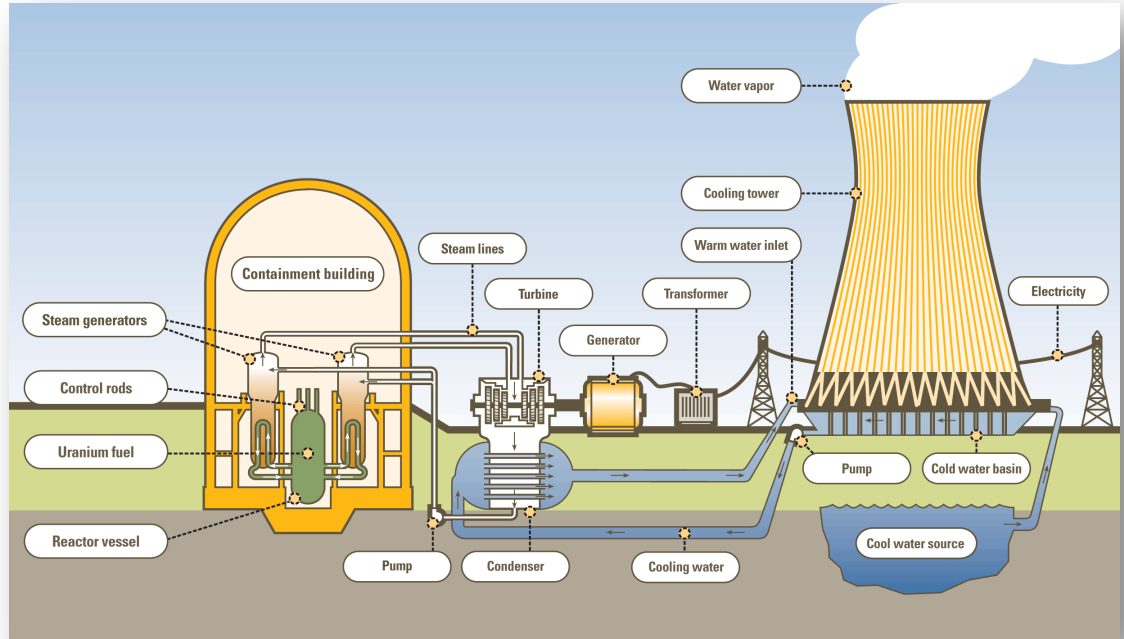
Power Generating Systems

Types of Power Generating Systems

- Nuclear
- Fossil Fuel
- Hydro
- Wind
- Solar

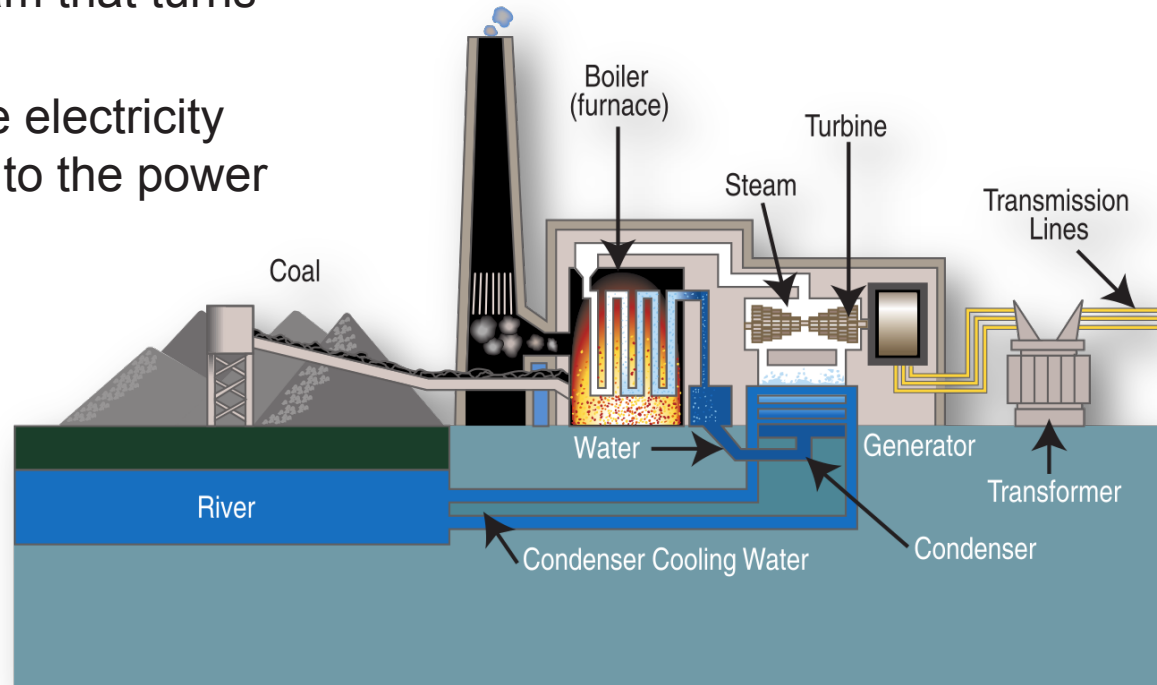
Nuclear Power Generation

- Nuclear reaction turns water into steam
- Steam turns turbines
- Turbine turns the generator producing electricity



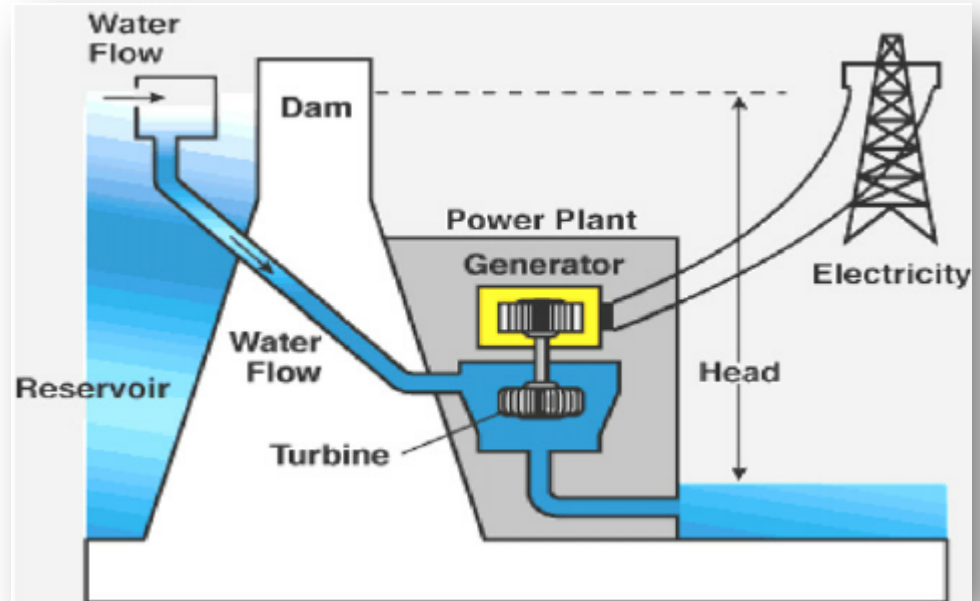
Fossil Fuel Power

- Uses coal, oil and gas to turn water into steam that turns the turbines
- Generating the electricity and sending it to the power grid.



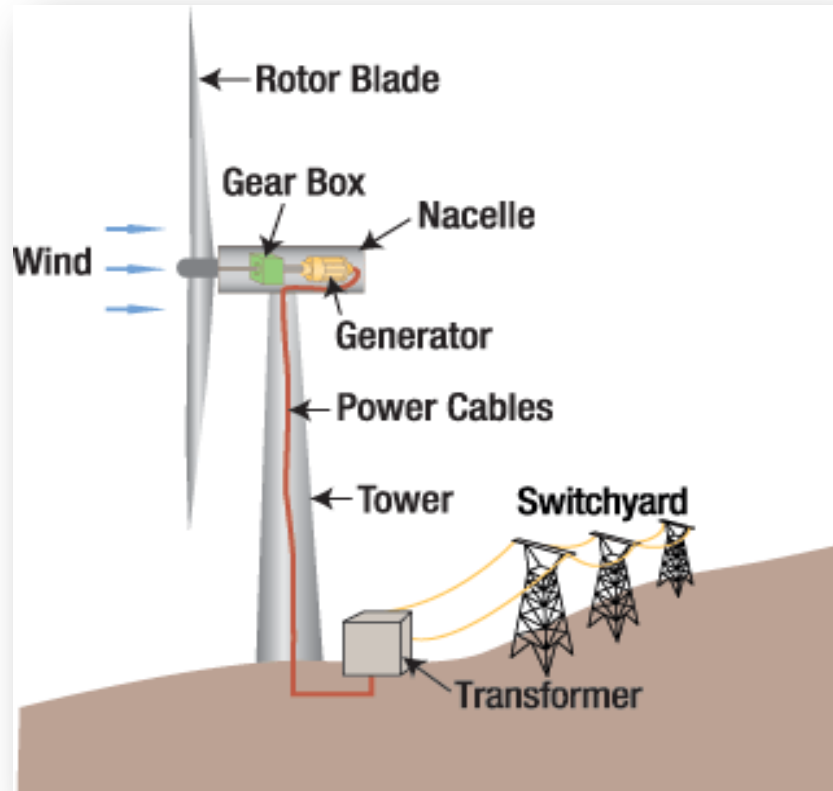
Hydro-Electric Power

- Water is stored
- Then released to spin a turbine which activates a generator to produce electricity.



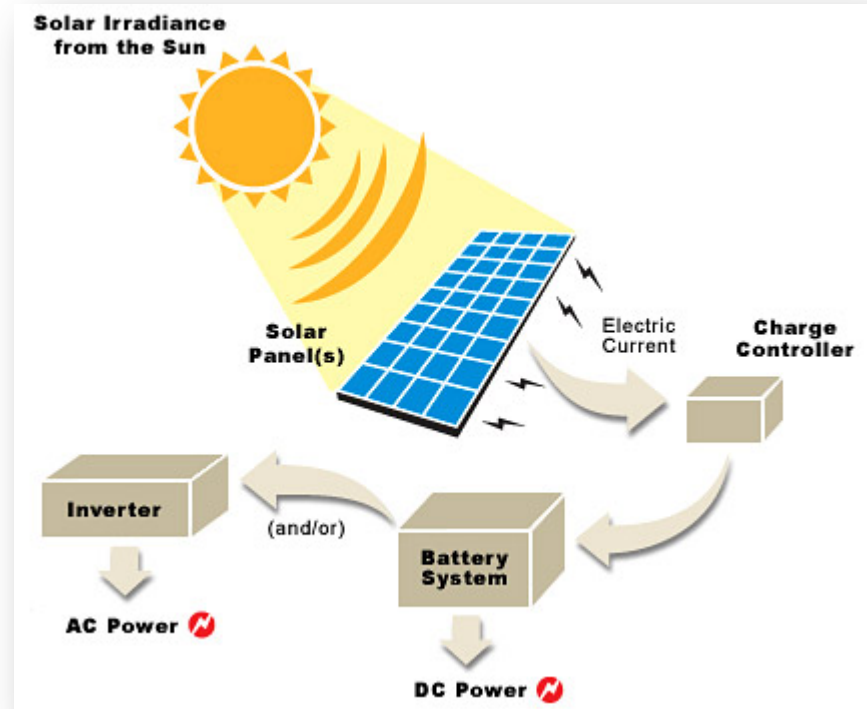
Wind Energy

- Wind turns the rotor
- Generator couples to the generator
- Voltage is increased by the transformer
- Power is fed to the grid



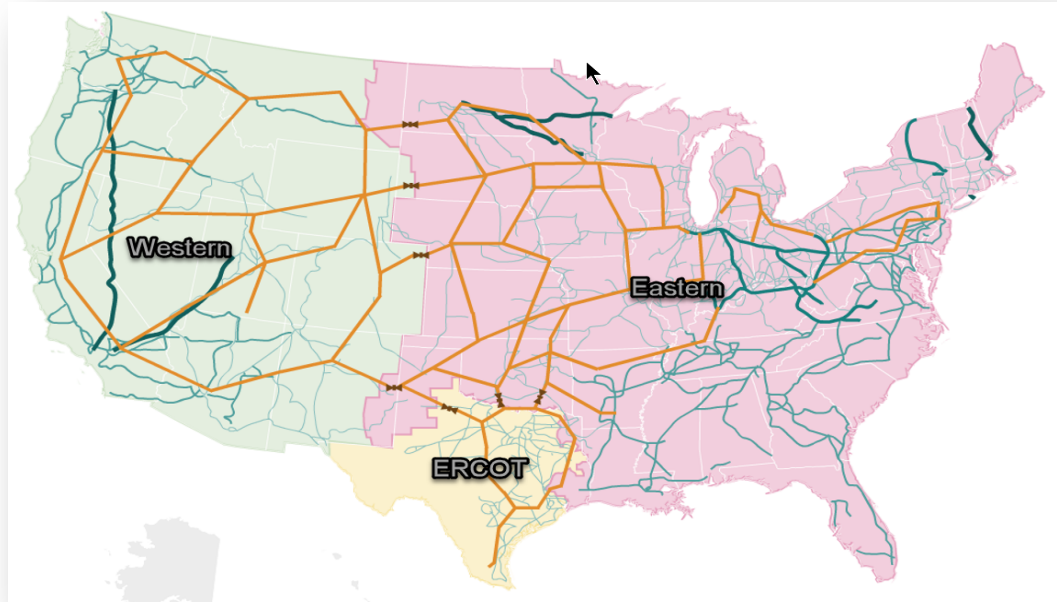
Solar Power

- Solar-powered panels convert the sun's rays into electricity
- exciting electrons
- Charge converter sends to batteries for DC
- Or to an inverter for AC



The Three Major Bulk Power Grids in the US

Most of the power delivery systems are all tied together in one of the three major grids.



What is the purpose of a Substation?

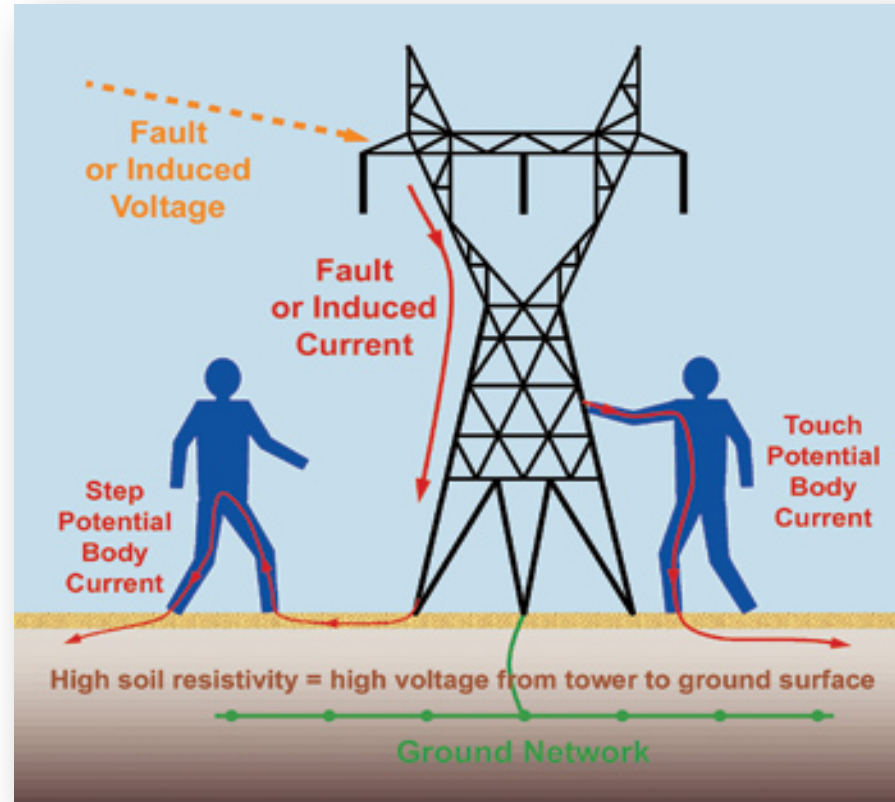
Substation Definition

- Critical for generation, transmission, and distribution system
- Performs several important switching functions
- May have various voltage levels before it reaches the customer
- Owned and operated by an electrical utility or a large industrial/commercial customer
- Usually relying on SCADA for remote supervision and control

IEEE Std. 80-2000

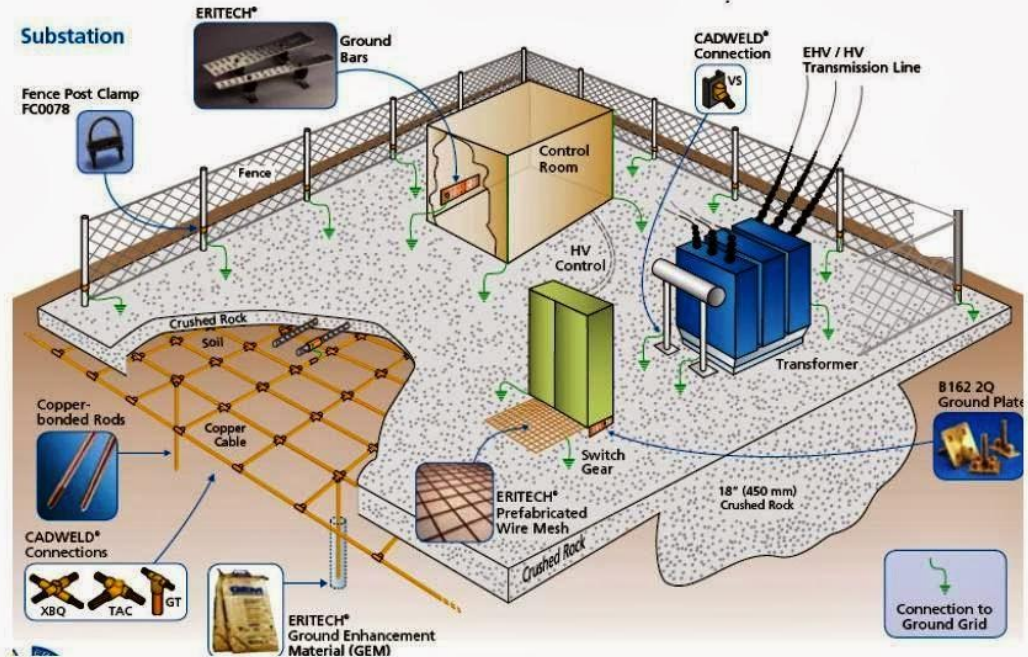
- **Touch Voltage**: The difference between the ground potential rise and the surface potential at the point where the person is standing while at the same time having a hand in contact with a grounded structure.
- **Step Voltage**: The difference in surface potential experienced by a person bridging a distance of 1m with the feet without contacting any other ground object.
- **Mesh Voltage**: This is the maximum touch voltage within a mesh of a ground grid.

Touch and Step Potential



Earthing Materials

- Conductors
- Connections
- Rods
- Fencing



General Arrangement of an Earth Electrode System at an Electrical Sub-Station

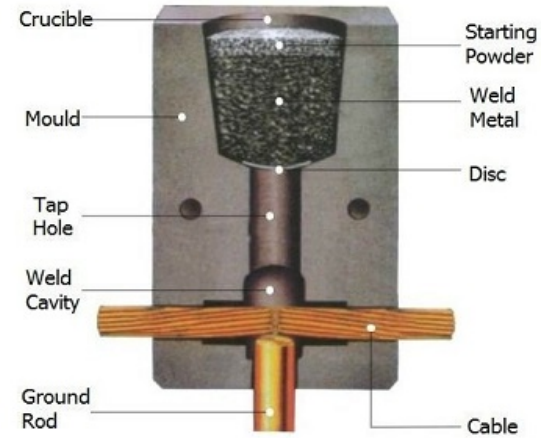
Conductors and Rods

IEEE Std. 80-2000

- Discusses thoroughly conductor sizes, and K factor in relation to faults.
- Current capabilities in cycles in kA.
- Conductor sizing.
- Choosing a conductor with relations to corrosion problems.
- Typically Copper, Copper-Clad Steel, Aluminum, and Steel.

Connections

- Exothermic
- Mechanical
- Crimped



Fence Grounding

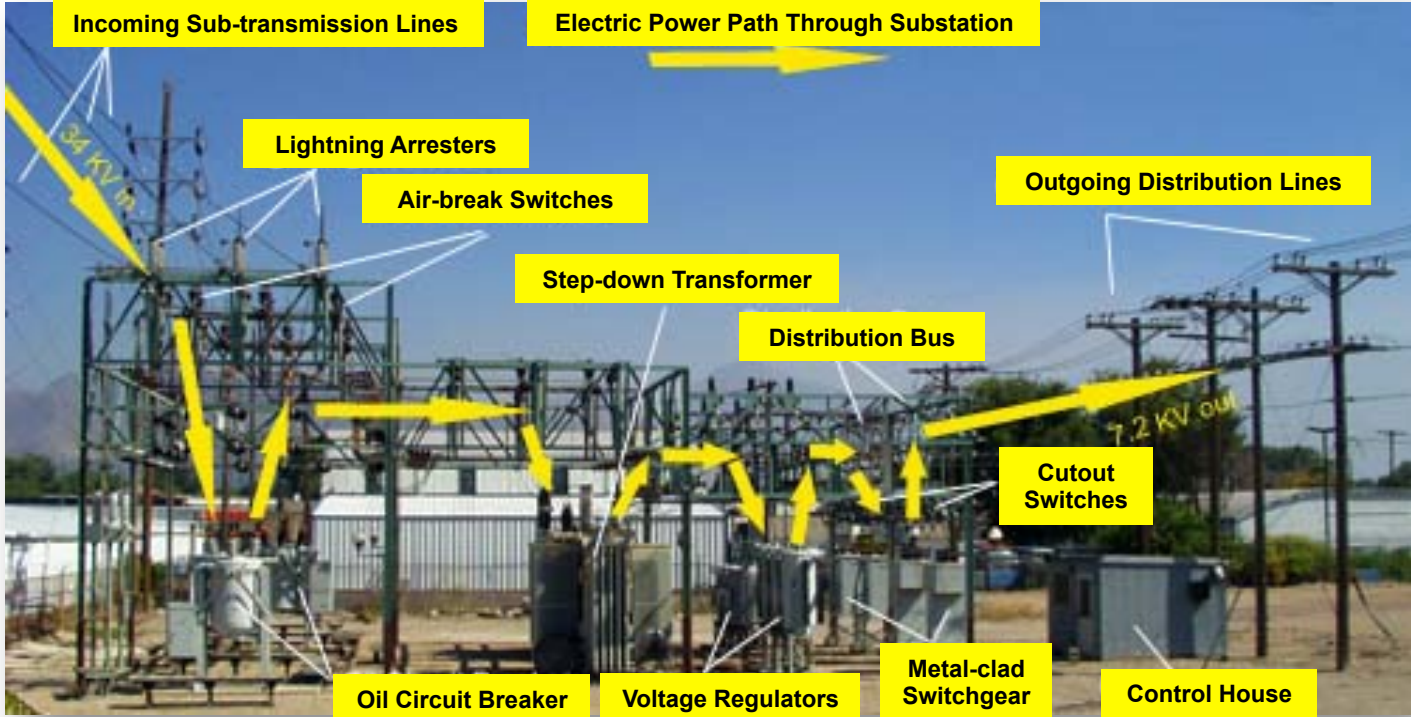
- The National Electrical Safety Code® requires grounding metal fences used to enclose substations with energized electrical conductors or equipment.
- This metal fence grounding requirement may be accomplished by bonding the fence to the substation grounding grid or to a separate underground conductor below or near the fence line using the methods described in the NESC.

Fence Grounding

Various fence grounding practices are:

- Fence is within the ground grid area and is connected to the substation ground grid.
- Fence is outside of ground grid area and is connected to the substation ground grid.
- Fence is outside of ground grid area, but is not connected to the substation ground grid. The fence is connected to a separate grounding conductor.
- Fence is outside of ground grid area, but is not connected to the substation ground grid. The fence is not connected to a separate grounding conductor

Basic Substation Layout



Substation Types

Step-up Transmission Substation

- The three-phase power enters a transmission substation at the power plant
- Transformers "step up" to extremely high voltages for long-distance transmission
- Voltages for long distance transmission range from 155 kV 765 kV



Substation Types

Step-down Substation

- Located at switching points in an electrical grid
- Connect different parts of a grid
- A source for sub-transmission lines or distribution lines



Substation Types

Distribution Substation

- Located near to the end-users
- Changes the transmission or sub-transmission voltage to lower levels for end-users
- Distribution voltages varies from 34,500Y/19,920 v to 4,160Y/2400 v
- Blast and burn generally associated with fault current.



Substation Equipment

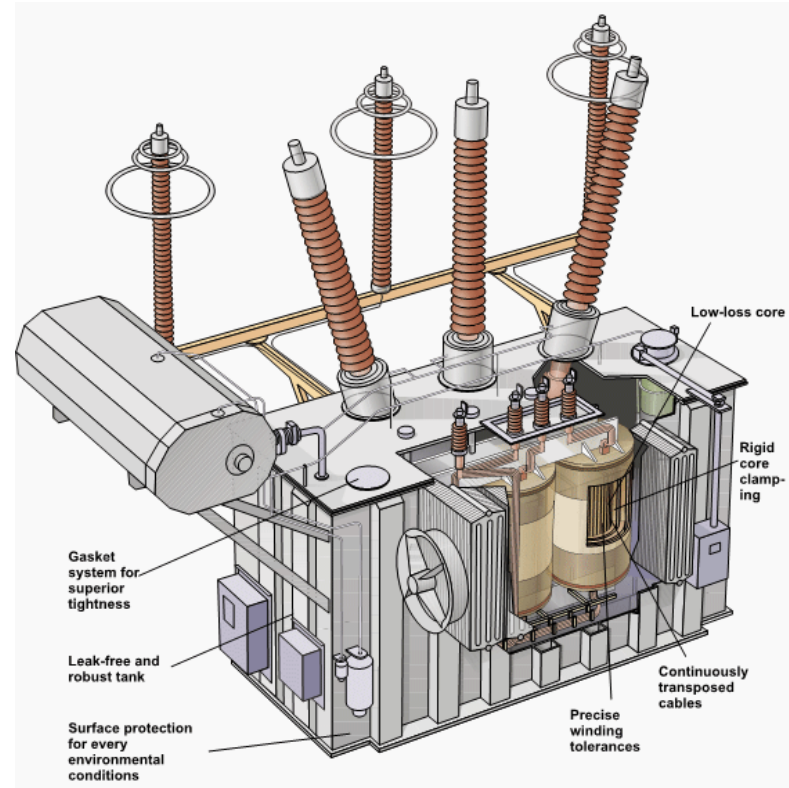
Important components of a substation with functions and responsibilities.

- ◆ **Transformers**
- ◆ **Switchgear**
- ◆ **Circuit Breakers**
- ◆ **Over-current Protective Devices**
- ◆ **Relaying and Metering Devices**

Substation Equipment

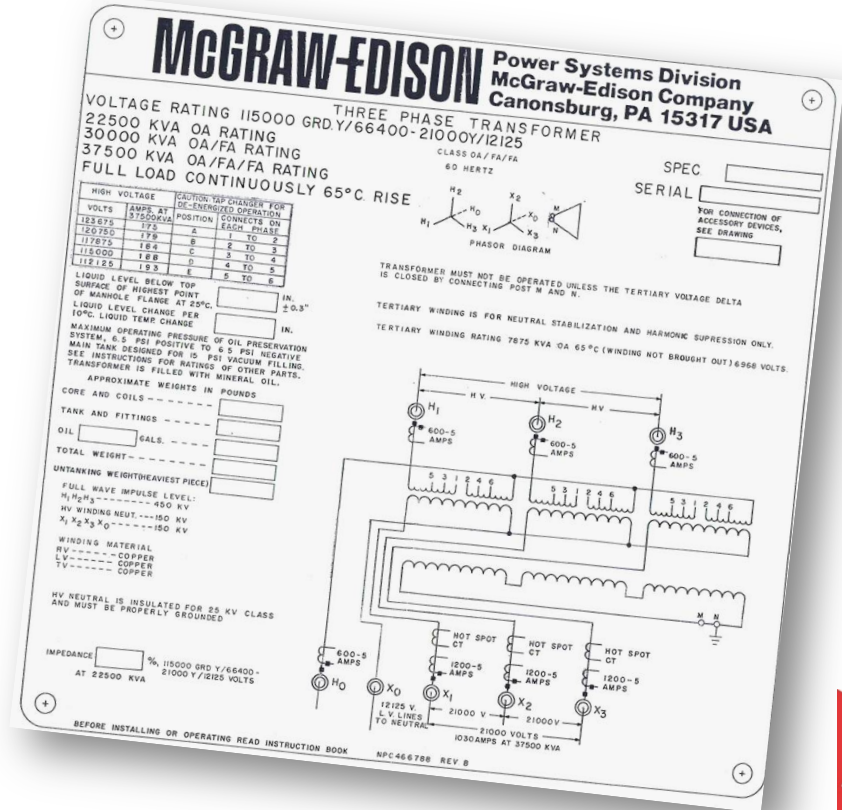
Transformers

- Transformers raise or lower the voltage to serve transmission or distribution circuits
- Rated in:
 - Power (usually MVA/KVA)
 - Insulation (cooling type)
 - Voltage rating
 - Winding connections
 - Voltage regulation (tap changers)
 - Class (cooling design)



Substation Equipment

- Always review and follow the transformers data plate for critical information
- IMPORTANT:** Data plates may not always be accurate
- Test should to verify that data plate information matches the transformer.



Substation Equipment

Switchgear

- Provides equipment protection for transformers, lines, cables, and capacitor banks
- Used to energize and de-energize capacitor banks and other circuits
- Switchgear includes:
 - Breakers
 - Disconnect switches
 - Main bus conductors
 - Interconnecting wiring
 - Support structures with insulators, enclosures, and secondary devices for monitoring and control



Substation Equipment

Circuit Breakers

- Open and close a circuit either automatically or manually.
- Automatic breakers operate on a predetermined overload without damage
- Circuit breakers are designed to terminate all current very quickly
- Arcs are extinguished between 30 and 150 ms after tripped

Substation Equipment

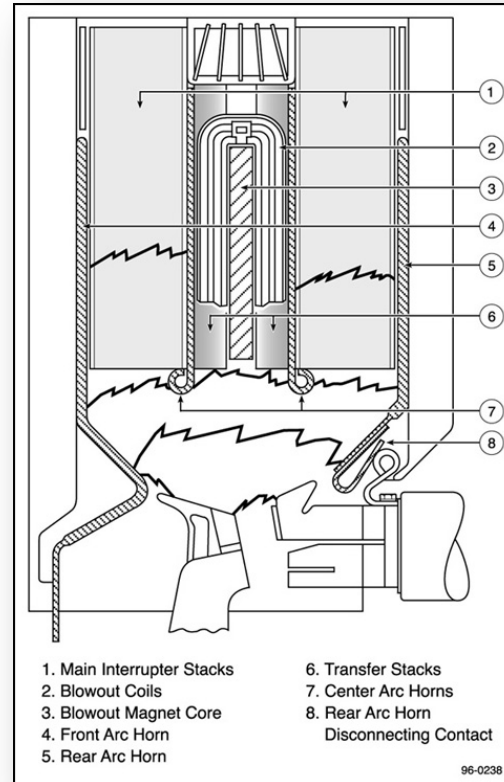
Medium-voltage circuit breakers

- Bolted connections to bus bars or wires, especially in outdoor switchyards
- Often built with draw-out construction
- Allows the breaker to be removed using a motor-operated or hand-cranked mechanism
- Types of mediums used are:
 - ✓ **Air**
 - ✓ **Vacuum**
 - ✓ **SF6**
 - ✓ **Oil**

Substation Equipment

Air Breakers

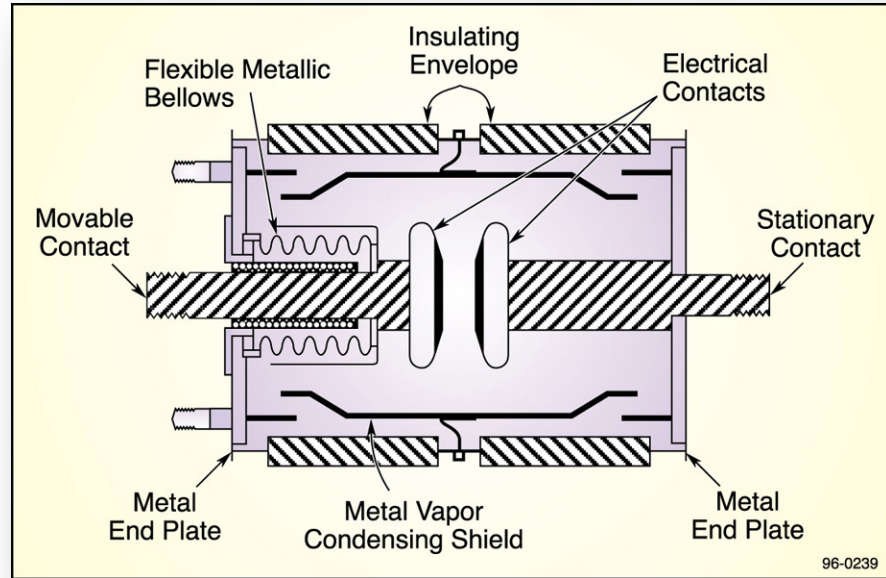
- Air blows out the arc into the interrupting chamber
- Blow out coils assists with control of the magnetic field achieving “current zero”



Involved Substation Equipment

Vacuum Breakers

- Have minimal arcing
- Arc is extinguished when it is stretched
- Used in medium-voltage switchgear up to 35 kV



Substation Equipment

SF₆ Breakers

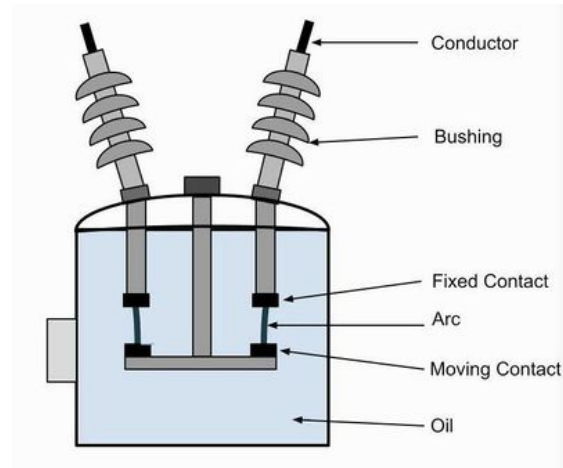
- Switch circuits and equipment in and out of the system.
- Use sulfur-hexafluoride (SF₆) compressed gas to extinguish the arc



Substation Equipment

Oil Circuit Breaker

- Filled with oil to provide cooling
- Prevents arcing when the switch is activated.



Substation Equipment

Instrument Transformers

- Accurate devices used to help isolate or transform voltages or current levels.
- Operate instruments or metering from high voltage or high current circuits
- Safely isolates secondary control circuitry from the high voltages or currents
- Transformer is connected to the high current circuit, and the meter or relay is connected to the secondary circuit

Two common types of Instrument transformers are:

- ✓ **Current**
- ✓ **Potential**

Substation Equipment

Current Transformers

- Provides a secondary current accurately proportional to the current flowing in its primary.

Potential transformers

- Used in system for stepping down voltage to a safe value for low rating meters and relays.

Substation Safety Basics

- Ensure only qualified personnel enter the substation
- Exercise caution near overhead conductors
- Be aware of Step and Touch potential
- Utilize proper PPE
- Close all gates
- Observe all warning signs
- Leave it clean and neat



Summary

- Types of Power Generating Systems
- Essential pieces of substation grounding
- Types of substations and functions
- Substation equipment roles and responsibilities

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“Changes and Updated to the New NFPA 70E Standard”

**Presented by Dennis Neitzel, AVO Director Emeritus and
NFPA 70E Principle Member of the NFPA 70E Technical Committee.**



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