Waterpower

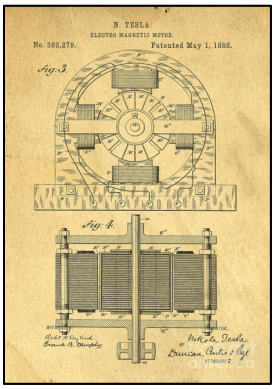
# HYDRO BASICS COURSE



Co-located with: HYDROVISION INTERNATIONAL

Organized By: HYDRO TRAINING INSTITUTE

- Electrical Fundamentals
  - ✓ Four Properties of Electricity
  - ✓ Ohms Law
  - ✓ AC/DC Current
  - ✓ The Power Triangle
- Hydropower Generating Assets - Electrical




# Overview: Power Generation Electrical Assets

- The Switchyard & Take-off Structures
- Switchgear & Transformers
- Generator & Excitation
- Protective Devices
- Bearings
- Braking System
- DC Systems
- Instrumentation & Control

Electricity is the flow of electrons through conductors within an electrical circuit.

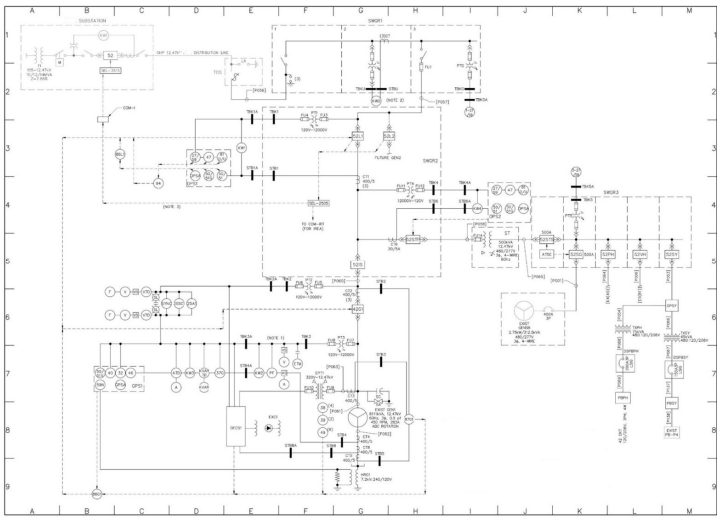
Electrical circuit in hydropower include.

- Generator
- Protective Devices
- Conductors & transmission lines
- Transformers
- Switchgear

Electricity must have a complete path in order to flow from the source to the load.

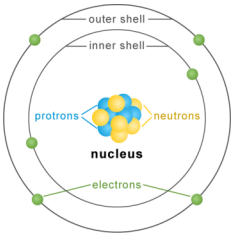
What does an electrical circuit look like on paper?

Typical One-Line Diagram



# The Atom

- Protons (+) & Neutrons (-) are contained in the nucleus.
- Electrons are moving in valence shells.
- Like charges repel.
- Opposite charges attract.




*Source: U.S. Energy Information Administration*

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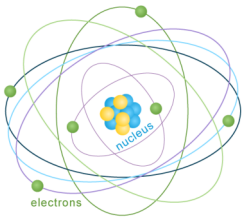
Introduction to the origins of electricity and how electrons can move from one atom to another.




Source: U.S. Energy Information Administration

- Some electrons are held loosely in the outer shell.
- This makes it easier to move from 1 atom to another.
- That movement of electrons is the foundation of how electricity starts.



Introduction to the origins of electricity and how electrons can move from one atom to another.

## Four Properties of Electricity

1. **Current**
   - Symbol: *( I )*
   - Measured in *amperes or amps.*
   - Current is the ***flow*** of electrons between 2 points through a conductor within an electrical circuit.

2. **Voltage**
   - Symbol: *( E or V )*
   - Measured in *volts.*
   - Voltage is the amount of charge or "***pressure***" in a conductor. Electromotive Force (EMF)



Brief discussion on the four properties of electricity: Main points: Current = measures flow, Voltage = measures pressure,

3. **Resistance**
   - Symbol: *( R )*
   - Measured in *ohms.*
   - Resistance (DC) or impedance (AC) is the opposition to *current flow.*

4. **Power**
   - Symbol: *( P )*
   - Measured in *watts [ instantaneously or a given point in time ]*
   - Measured in *watt-hours* or *kilowatt-hours [overtime] as Energy*



Main Points: Resistance in DC systems (or impedance in AC systems) = opposite to current flow, Power = a way to measure electricity instantaneously or over time. Example = Residential monthly electric bill

## Ohm's Law Triangle

**Formulas**

V = I x R

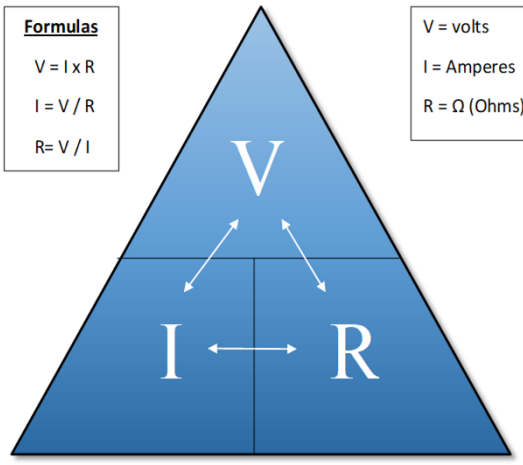
I = V / R

R= V / I

V = volts

I = Amperes

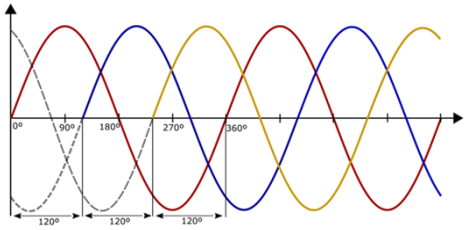
R = Ω (Ohms)



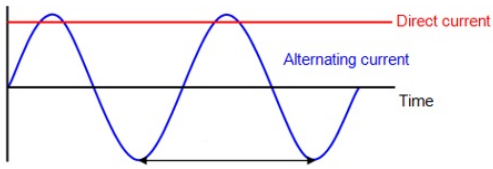



Main Point: Ohm's law illustrates the relationship between Current, Voltage & Resistance, Calculations and formulas using the triangle

# 2 Types of Current in Electrical Systems




Alternating Current [AC]

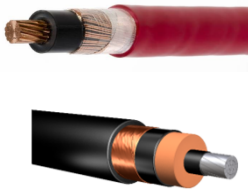



Direct Current [DC]



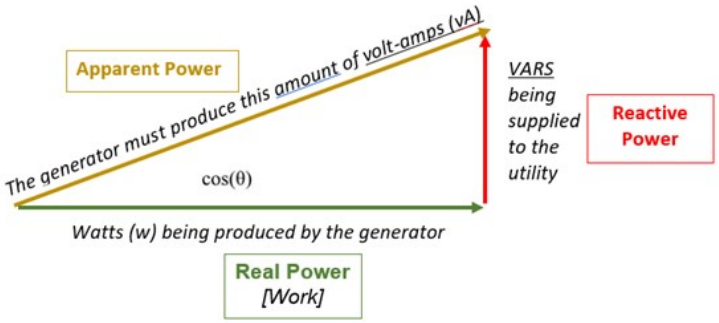
Main Point: AC moves back & forth in a conductor, Current & Voltage vary constantly and moves back and forth (referred to as polarity) from source to load over time. In AC circuits, electricity can be stepped up or stepped down by using a transformer. DC power is constant and unidirectional meaning it flows in one direction.

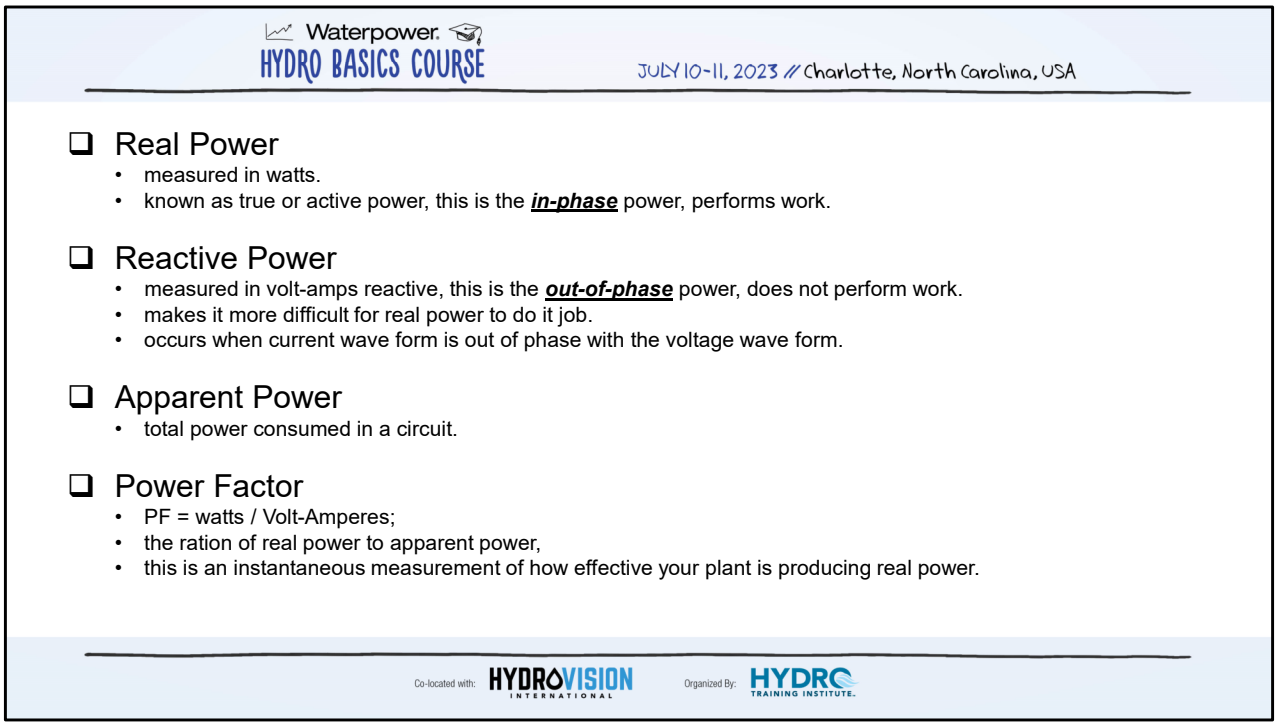
# Conductors





Main Point: Conductors are made of a variety of materials based on the intended application. A good conductor allows electrons to freely move through the material. Hence copper makes a quality conductor because it has 1 electron in the outer valence shell, therefore its waiting for a force like volage to induce them to move. On the opposite side of the spectrum, Rubber acts a quality insulator because it does not allow electrons to freely exchange.

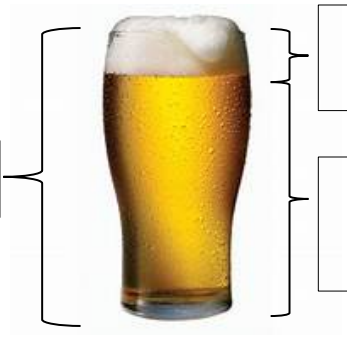

Apparent Power
The generator must produce this amount of volt-amps (vA)
VARS being supplied to the utility
Reactive Power
cos(θ)
Watts (w) being produced by the generator
Real Power
[Work]




Main Point: Real Power = work, Reactive Power = out of phase power not performing work. A perfect power factor = 1.0, called “unity, that means 100% of real power is performing work. A poor power factor means part of the system’s capacity is not performing work efficiently

# Power Factor Explained through the Beer Analogy

The Glass = Apparent Power
Volt-Amps - [vA]

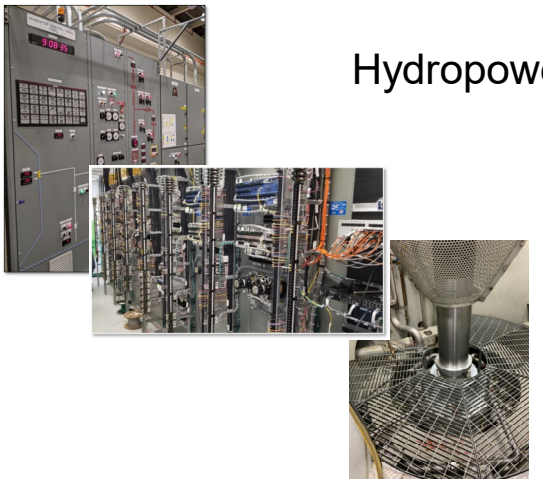


The Foam = Reactive Power
Volt-amps reactive [vars]
***Doesn't provide value, performs no work***

The Beer = Real Power
Watts - [w]
***The value add, this is where the work happens***

**The less foam, the better the power factor. No foam equals power factor of 1.0**

# Hydropower Generation Assets



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# The Switchyard *[SWYD]* & Take off Structures

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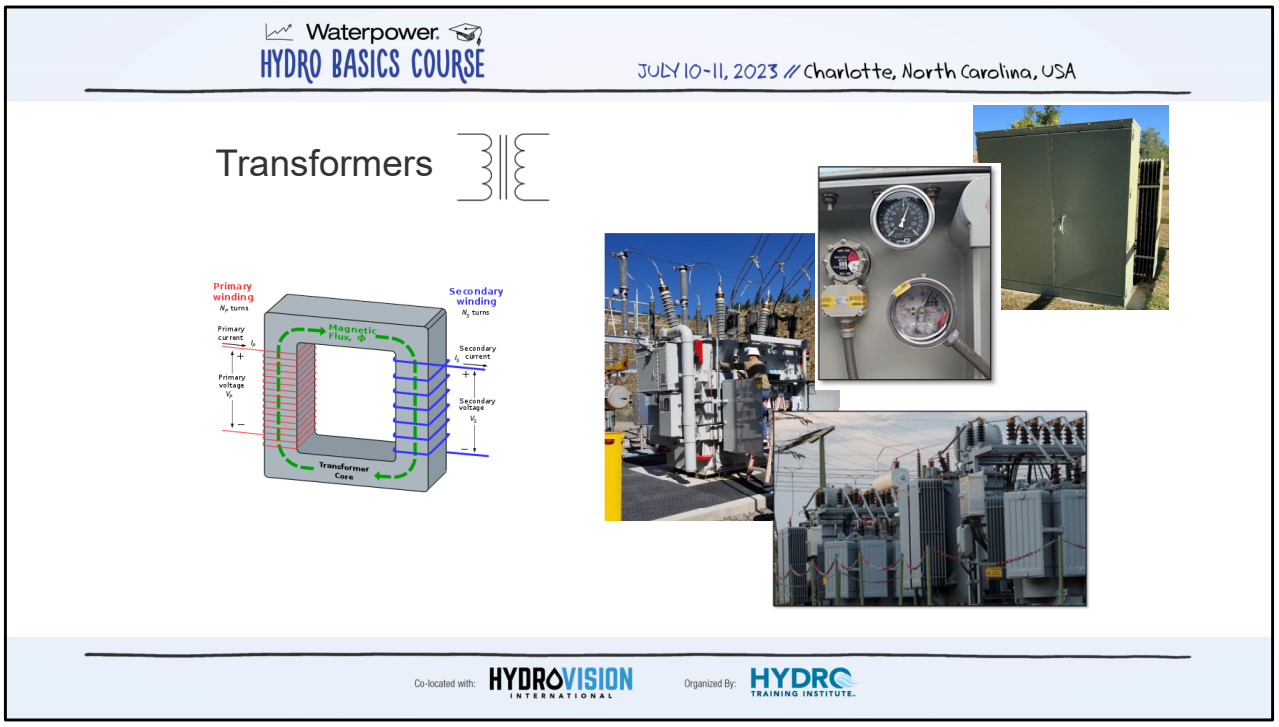
Main Points: The switchyard is an enclosed area located near the power station, contains medium to high voltage electrical equipment; switching gear, transformers, distribution conductors, duct banks, take off structures. This is where electricity is transferred to and from the local utility via the Point of Delivery or Point of Interconnection. Take-off structures can be a tower or pole where electricity leaves the generating facility and becomes parts of the transmission system within the electrical grid.




Main Points: Transformers are used to step-up or step-down voltage depending on the desired application. Stepping up voltage is an efficient way to transmit electricity over long distances. Once it reaches its destination, electricity can be stepped down to a more practical voltage required by the end user, whether it be residential, commercial or industrial application. Conductors are wrapped around either side of a transformers core. The primary side windings (number of turns) are proportionate to the secondary windings (number of turns). Example; if the secondary side contains fewer turns than the primary side, the voltage will be stepped down. Energy losses occur in the form of heat. Over-heating is a leading cause of transformer deterioration. This can be mitigated by using insulating liquid to help dissipate and cool the transformer.

# The Powerhouse

- Generator
- Turbine
- Turbine inlet valve
- By-pass valves
- Electrical, Instrumentation & Control (EI&C)
- Hydraulic Power Units & Accumulators
- Lube Oil Systems
- Cooling Water & Scraper/Strainer Systems
- Security and Fire & Life safety systems

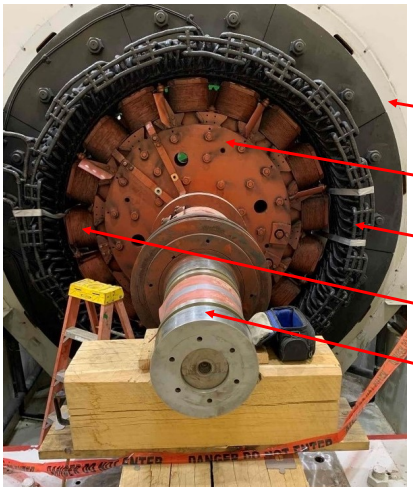
- HVAC equipment
- DWV/Plumbing system/Service Water
- Fire Alarm monitoring systems
- Security and Access Control
- Instrumentation & Control
- Electrical power for station service
- Cargo Handling/overhead cranes
- Lighting Systems
- General building structure

# Switchgear

- ✓ ANSI and IEEE standards define voltage classifications as follows:
- ✓ Switchgear is classified by the maximum voltage it can service.
- ✓ For example, 15 kV switchgear (maximum voltage rating) is commonly applied at various actual voltages including: 12.47 kV, 13.2 kV, 13.8 kV and 14.4 kV.
  - **Low voltage**: up to 600V
  - **Medium voltage:** between 600V and 69 kV
  - **High voltage**: between 69 kV and 230 kV
  - **Extra-high voltage** and ultra-high voltage classes

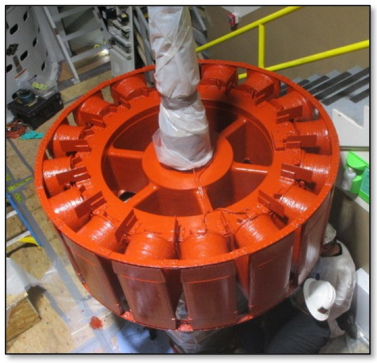


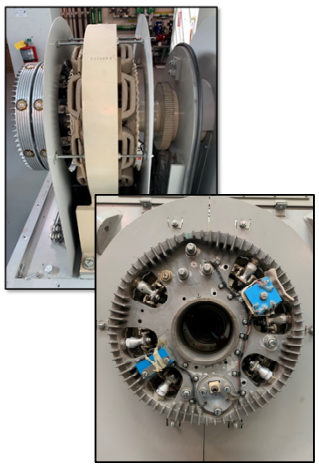
Main Point: Composed of electrical disconnect switches, protective devises, control or isolating devices for electrical equipment. Switchgear can be located in a switchyard or inside the power plant and is used to deenergize electrical equipment for maintenance or to clear electrical faults.



## The Generator

- ❑ Generator Housing
- ❑ Rotor
- ❑ Stator
- ❑ Poles
- ❑ Shaft





## Excitation System

- Continuous DC current to the rotor windings.
- Responsible for maintaining constant terminal voltage in synchronous generators.
- Means of control
- Without excitation current, the generator operates without field current, therefore voltage is not induced in the stator windings.



Main Point: Provides regulated DC current to the field windings in order to produce an output voltage to the electrical field.

## Digital Governor

- Main controller of the prime mover – Turbine.
- Start, maintains and adjusts a unit's speed.
- Adjusts a unit's output when operators or other supervisory control commands are requested.
- Performs normal shutdown operations.
- Responds to emergency shut down during abnormal conditions like overspeed.



Main Point: Provides regulated DC current to the field windings in order to produce an output voltage to the electrical field.

## Bearings

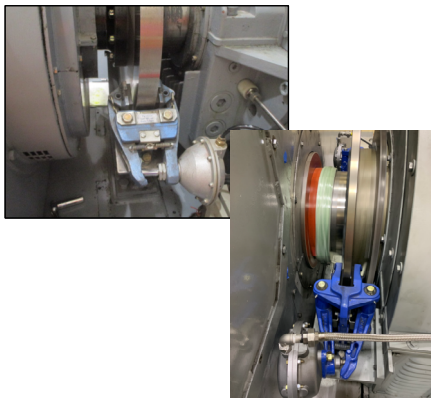
- Carry loads
- Proper Shaft Alignment
- Reduces Friction between moving parts

- Lube Oil Systems provide a continuous, circulation of clean, cool lubricating oil that helps facilitate these functions.



Main Point: Bearings assist rotating equipment and are designed to carry loads, provides proper shaft alignment and reduces friction between moving parts. Proper bearing lubrication is extremely Important.

## Braking System



## DC Systems




Main Point: braking system stops the unit's rotation once the minimum rpm is reached. Braking systems can be automatic or manually actuated. DC systems provide back up power to various facility systems like bypass valves, notification systems, fire & life safety systems, Lube Oil Systems, etc.

# Instrumentation & Controls

- Integrated system of assets working together
- Monitors for safe system operations
- Controls system functionality
- I&C systems transmit data that informs
  - ✓ Automated system adjustments or notifications
  - ✓ Operator driven decision making
- Has the ability to react in real time to changes throughout the system.



Main Points: System of interconnected assets designed to observe, monitor, control, transmit data to a wide variety of automated and non-automated functions across the entire hydropower facility. I&C systems provide feedback on how the system is performing and can react to system changes particularly when hazardous situations occur. I&C offers operators information for decision making across the entire system and provides the ability to make adjustments as needed. Can be located on the front of the GCP (generator control panel) or accessed through SCADA (supervisory control & data acquisition) and Human Machine Interface systems are common.

## Instrumentation & Controls

- Programable Logic Controllers [PLC]
- Generator telemetry
- Temperature sensing devices
  - Resistance Temperature Detectors [RTD]
- Fluid level monitoring
- Flow meters, level sensors, pressure switches
- Vibration sensors



Main Points: System of interconnected assets designed to observe, monitor, control, transmit data to a wide variety of automated and non-automated functions across the entire hydropower facility. I&C systems provide feedback on how the system is performing and can react to system changes particularly when hazardous situations occur. I&C offers operators information for decision making across the entire system and provides the ability to make adjustments as needed. Can be located on the front of the GCP (generator control panel) or accessed through SCADA (supervisory control & data acquisition) and Human Machine Interface systems are common.

# Protective Devises

- Relays
- Circuit Breakers
- Fuses
- Isolation devices
- Reclosure switches

Extremely important for safe operations and to protect equipment.



Main Point:, Breakers are protective devices within an electrical circuit designed to open during an electrical fault. Draw out breakers, pictured above, are designed to be racked out for testing and calibration purposes during maintenance, a way to isolate equipment from the utility. Protective relays monitor and control electrical systems, can initiate sequencing & switching of electrical gear, monitor current conditions in an electrical system. Protective relays have a set of predetermined values or limits that provide alarm notifications and are designed to trip a circuit breaker during an abnormal or dangerous condition.

# Relays


Categories of Relays

- Protection
- Monitoring
- Programing
- Regulating
- Auxiliary



Main Point:, Relays monitor and control electrical systems, can initiate sequencing & switching of electrical gear, monitor current conditions in an electrical system. Protective relays have a set of predetermined values or limits that provide alarm notifications and are designed to trip a circuit breaker during an abnormal or dangerous condition for a variety of causes.

## Circuit Breakers

*Draw out breakers*

- Provides a point of isolation.
- Designed to open during an electrical fault from ***overcurrent***.
- Interrupts ***current flow.***
- All different types and sizes.
- Unlike fuses, circuit breakers are designed for repeated operations



Main Point:, Breakers are protective devices within an electrical circuit designed to open during an electrical fault. Draw out breakers, pictured above, are designed to be racked out for testing and calibration purposes during maintenance, a way to isolate equipment from the utility.

Commonly used Protective Devises in Hydropower

- 42G Main Generator Breaker Control
- 52T Utility Feed Transformer, Breaker Control
- 52L Main Line Breaker Control
- 52STP Station Transformer Primary
- 52STS Station Transformer Secondary
- 86T Main Power Transformer
- 86G – Generator Lockout