

# BUILDING A WORLD OF DIFFERENCE

## SUBSTATION DESIGN

SENIOR DESIGN PROJECT



**BLACK & VEATCH**  
Building a world of difference.®

# ABOUT ME

- **Cole Beaulieu**
- **Graduated from ISU in May of 2017**
- **From Plymouth, MN**
- **Started at B&V's Bloomington office in June 2017**

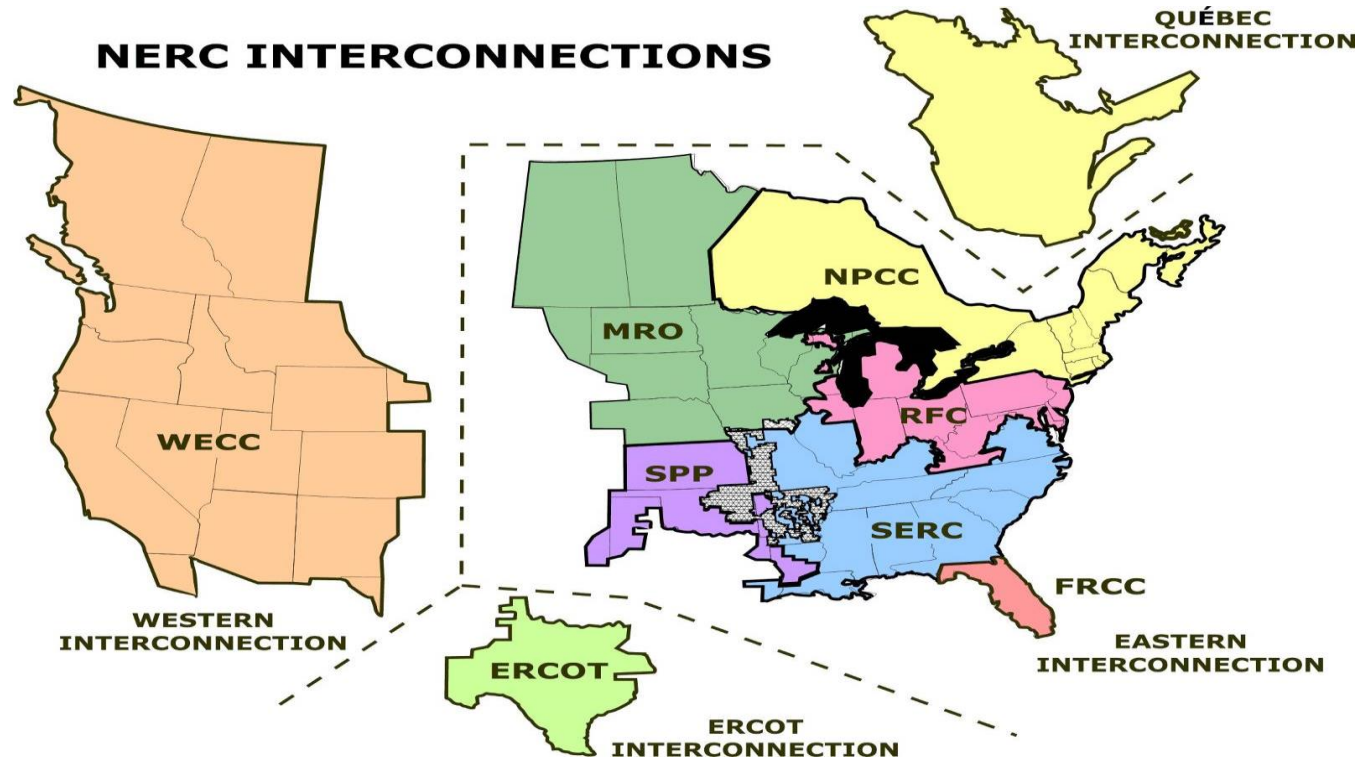


# PROJECT SCOPE

- Protection and Control Design - *one-line diagrams, three-line diagrams, AC & DC Schematics, panel arrangements, and station service power requirements.*
- Engineering Management Services: *budget, schedule, weekly status reports, project review meetings, final reports and presentation.*

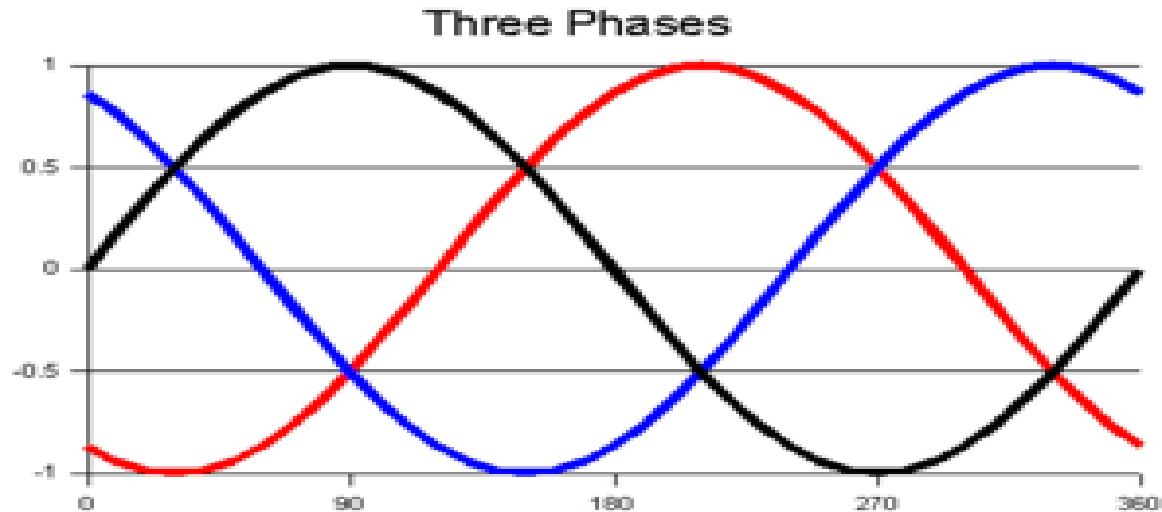


# THE US GRID



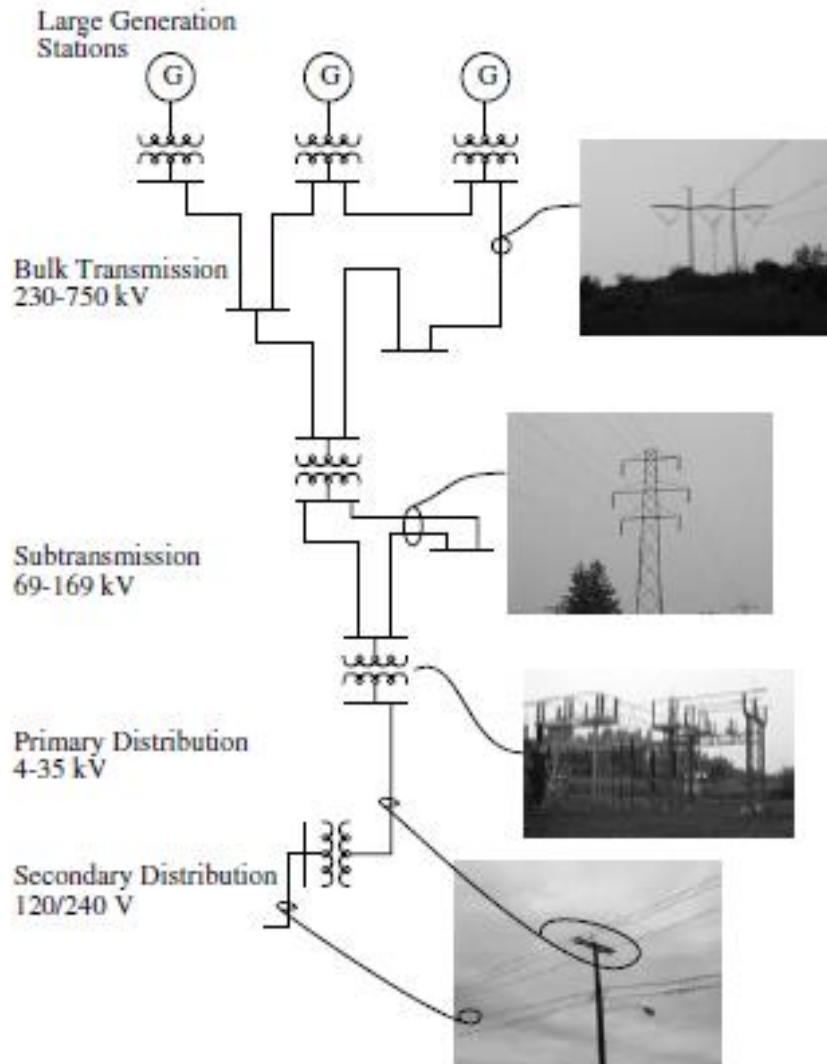
- Florida Reliability Coordinating Council (FRCC)
- Midwest Reliability Organization (MRO)
- Northeast Power Coordinating Council (NPCC)
- Reliability First Corporation (RFC)
- SERC Reliability Corporation (SERC)
- Southwest Power Pool, RE (SPP)
- Texas Reliability Entity (TRE)
- Western Electricity Coordinating Council (WECC)

# POWER DELIVERY



- Bulk power delivery is three-phase alternating current (AC)
- 60Hz in the U.S.
- Provides for a constant power delivery at all times
- Best for machines (generators and motors)

# ELECTRICITY INFRASTRUCTURE



- **Transmission Voltages (Bulk System, Long Distances)**  
*765-kV, 500-kV, 345-kV, 230-kV*
- **Sub-transmission Voltages**  
*138-kV, 115-kV, 69-kV, 34.5-kV*
- **Distribution Voltages**  
*Too many to list: 24.94-kV, 13.8-kV*
- **Residential**  
*120/240V, 208V*

# SUBSTATIONS



Outdoor Substation

## Service Requirements:

(1) Transformer substations

*Step-up substations, Primary grid substations, Secondary substations & Distribution substations*

(2) Switching substations

(3) Converting substations

## Construction features:

(1) Indoor substations

(2) Outdoor substations

(3) Underground substations

(4) Pole mounted substations

# BUS CONFIGURATIONS

- Radial Bus
- Sectionalized Radial Bus
- Main & Transfer Bus
- Ring Bus
- Breaker & One-Half Bus
- Single Breaker Double Bus
- Double Breaker Double Bus



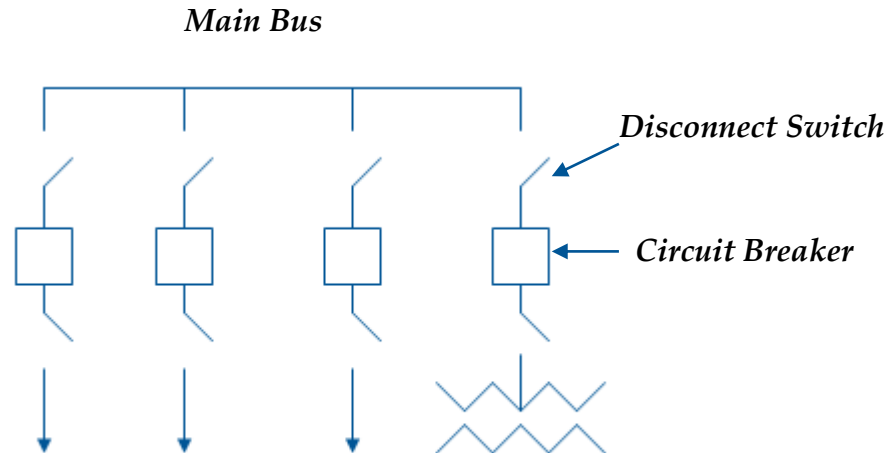
# RADIAL BUS

## Advantages

*Simple operation & protective relaying, low initial cost, low maintenance, easy to expand*

## Disadvantages

*System interrupted in case of repairs & faults, low reliability*



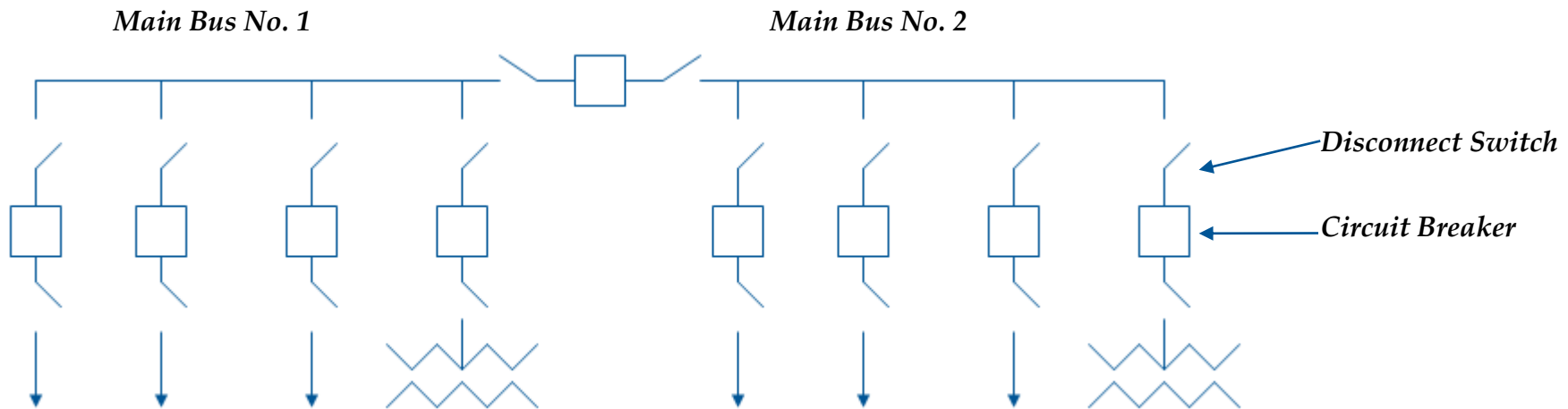
# SECTIONALIZED RADIAL BUS

## Advantages

*Easy to expand, small land area required, increased reliability & flexibility over the radial bus*

## Disadvantages

*Increased cost, complexity of operation & protective relaying over the radial bus*



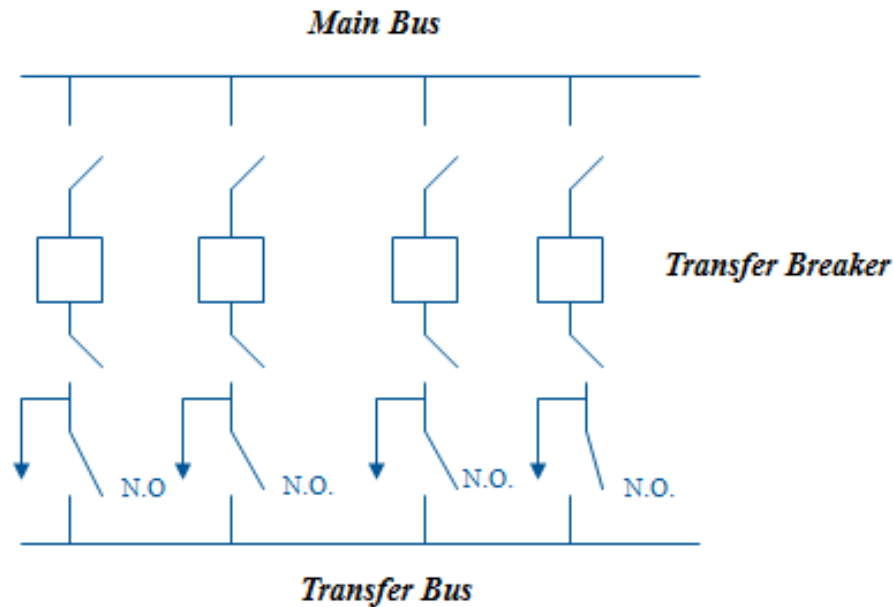
# MAIN AND TRANSFER BUS

## Advantages

*Small land area, easy to expand, increased flexibility over radial bus*

## Disadvantages

*Increased cost, complexity of operation & protective relaying over the radial bus, low reliability*



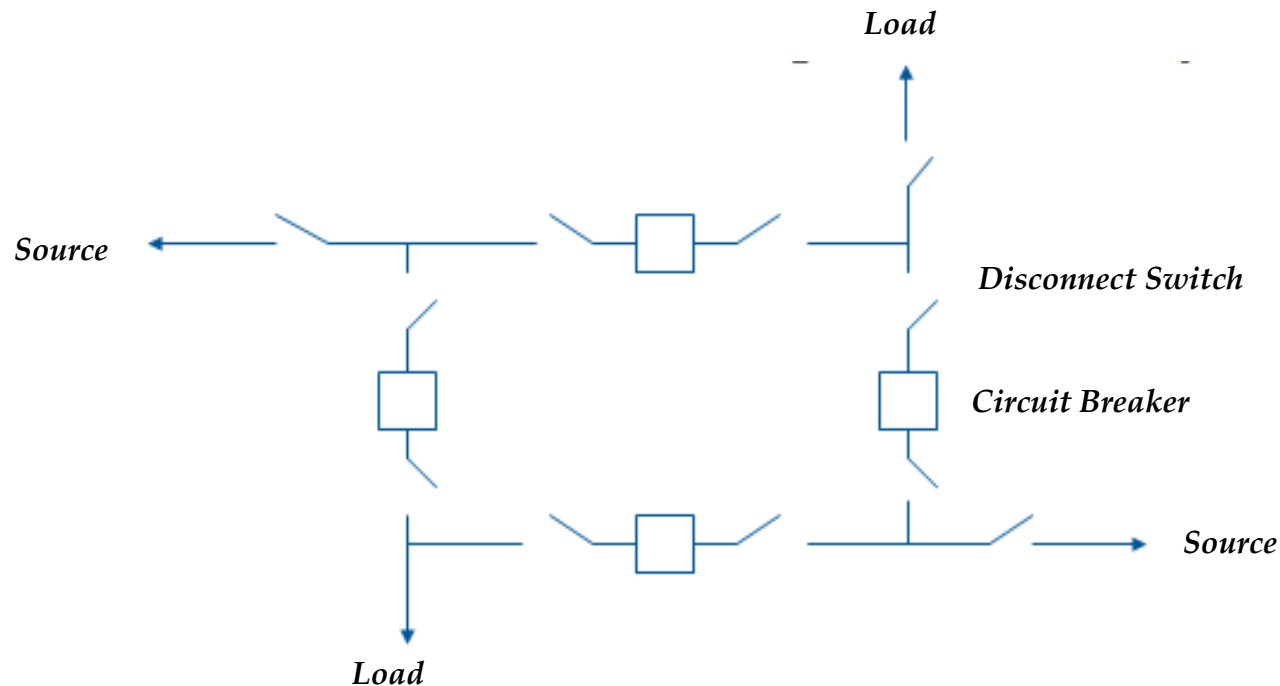
# RING BUS

## Advantages

*Low cost, high reliability, flexible operation, flexible operation, removal of a circuit breaker will not affect outage*

## Disadvantages

*Complex relaying and control*



# BREAKER AND ONE HALF BUS

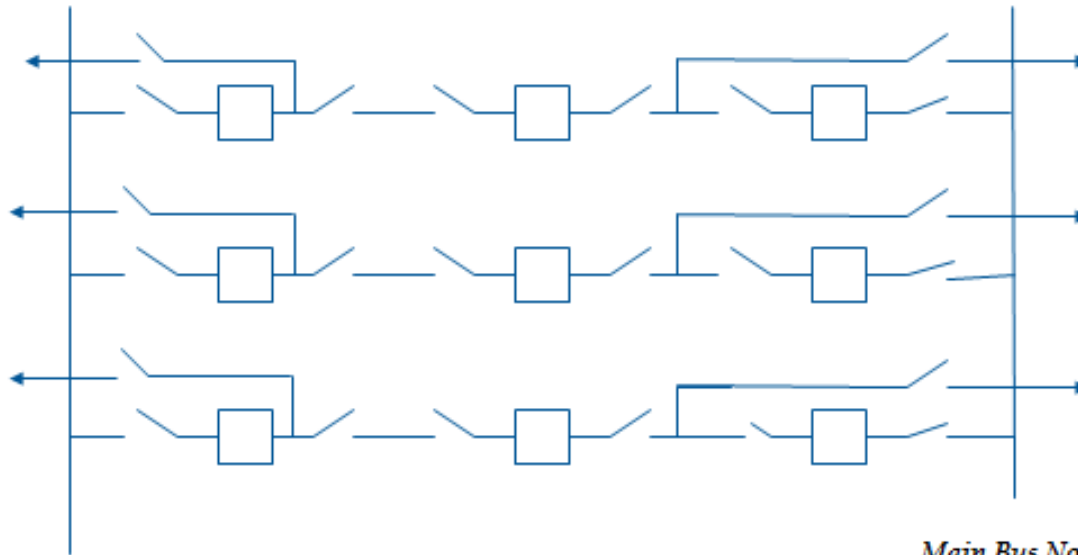
## Advantages

*Easy to expand, very high reliability, very high flexible operation and removal of a circuit breaker without an outage*

## Disadvantages

*Complex relaying and control, high cost and a large area of land is required*

*Main Bus No. 1*



*Main Bus No. 2*

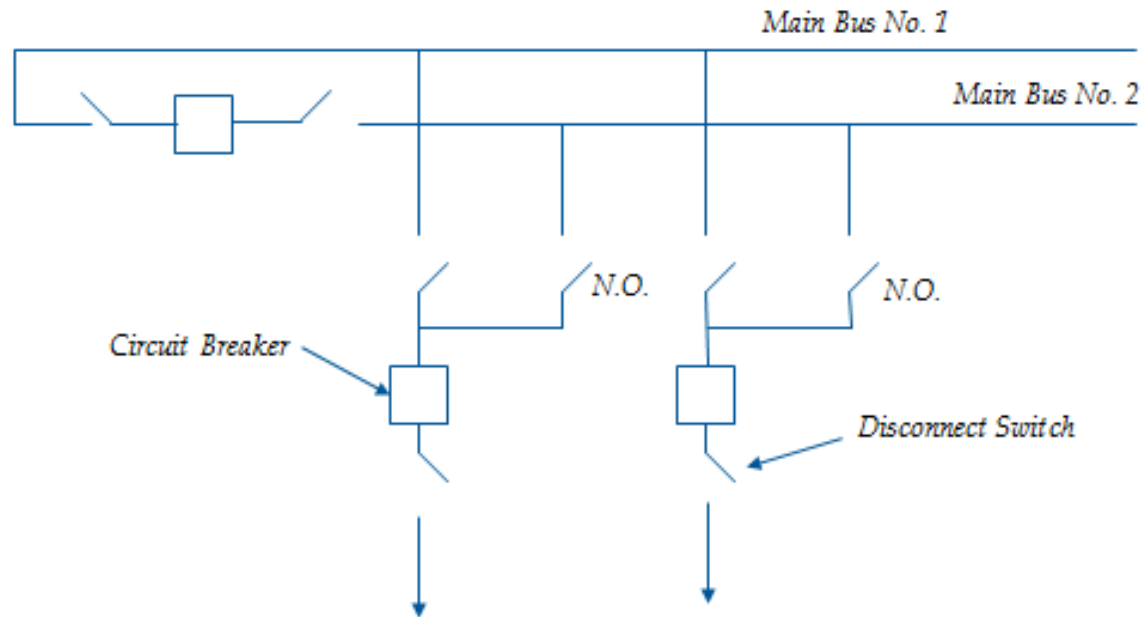
# SINGLE BREAKER DOUBLE BUS

## Advantages

*Easy to expand, increased reliability and flexibility over radial bus*

## Disadvantages

*Increased cost and complexity of protective relaying over radial bus*



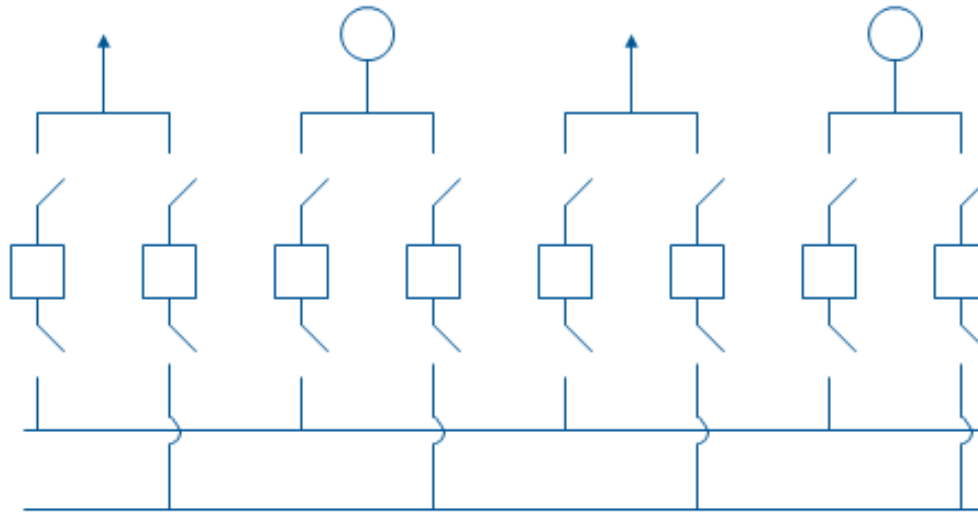
# DOUBLE BREAKER DOUBLE BUS

## Advantages

*Easy to expand, very high reliability, very high flexible operation and removal of a circuit breaker without an outage*

## Disadvantages

*Complex relaying and control, high cost and a large area of land is required*



# SUBSTATION EQUIPMENT

- Power transformers
- Tap changing equipment
- Steel structures
- Lightning arresters
- Circuit switchers
- SF<sub>6</sub> circuit breakers
- Oil circuit breakers
- Air circuit breakers
- Vacuum circuit breakers
- Disconnect switches
- Coupling capacitors
- Potential transformers
- Current transformers
- High-voltage fuses
- Metal-clad switchgear
- Shunt reactors
- Meters
- Relays
- Supervisory control
- Remote terminal units
- Digital fault recorders
- Capacitors
- Voltage regulators
- Control house
- Conduits
- Control wires
- Control panels
- Power-line carrier equipment
- Microwave equipment
- Batteries



# TRANSFORMER

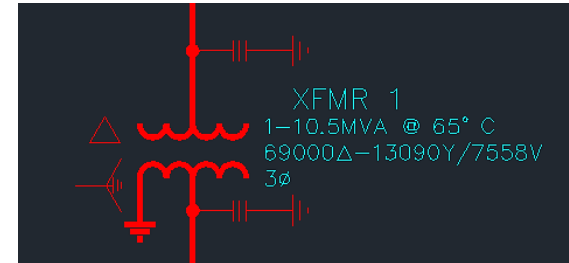
## Purpose

- *Change voltage from one level to another*
- *Regulate voltage level.*

## Types

- *Generator Step-Up (GSU) transformers*
- *Step-down (to load) distribution transformers*

## Symbol



# CIRCUIT BREAKER

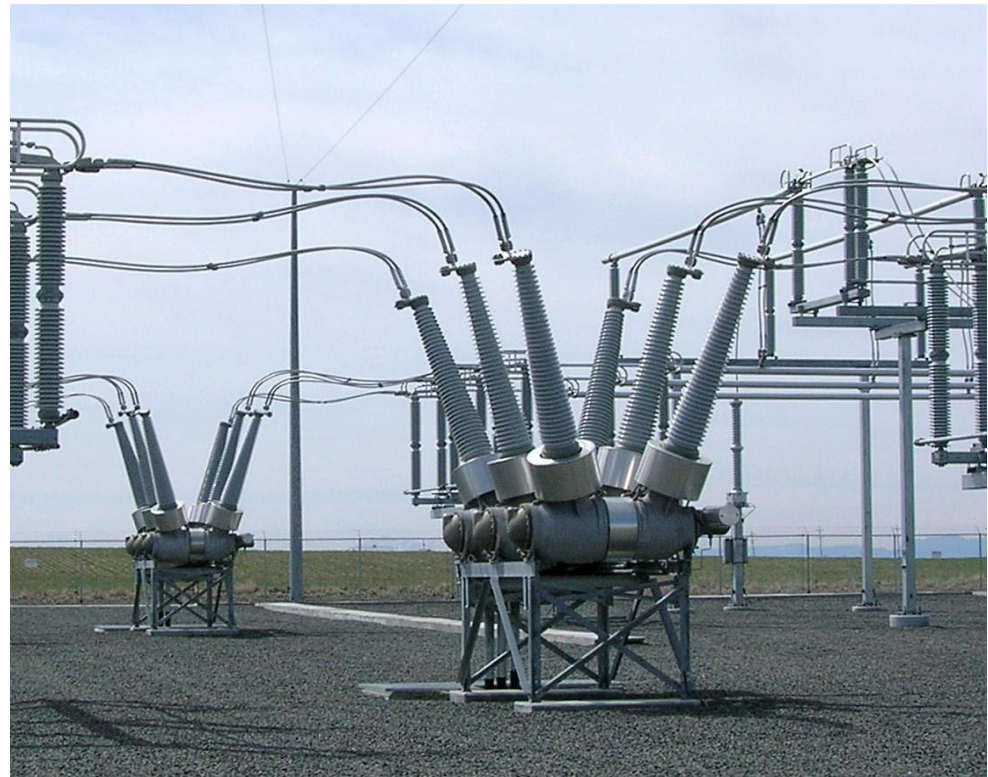
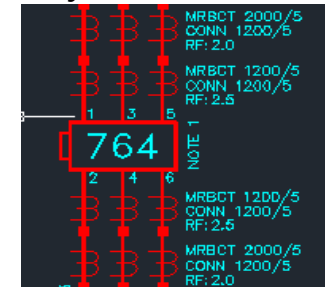
## Purpose

*Detect faults and interrupt current flow*

## Types

*Oil, air, SF<sub>6</sub> gas, vacuum*

### Symbol



# DISCONNECT SWITCHES

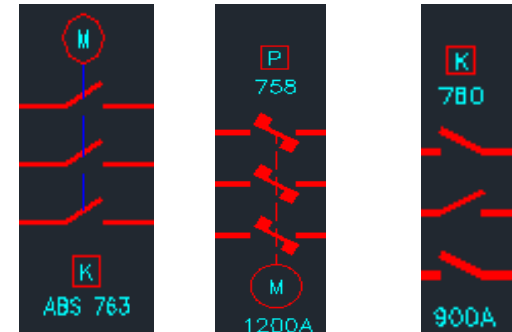
## Purpose

*Equipment usually connected in series with disconnect switches to isolate lines and equipment for maintenance*

## Types

*Vertical break, Center break, Side break, Double end break, Pantograph, Motor-operated*

### Symbols

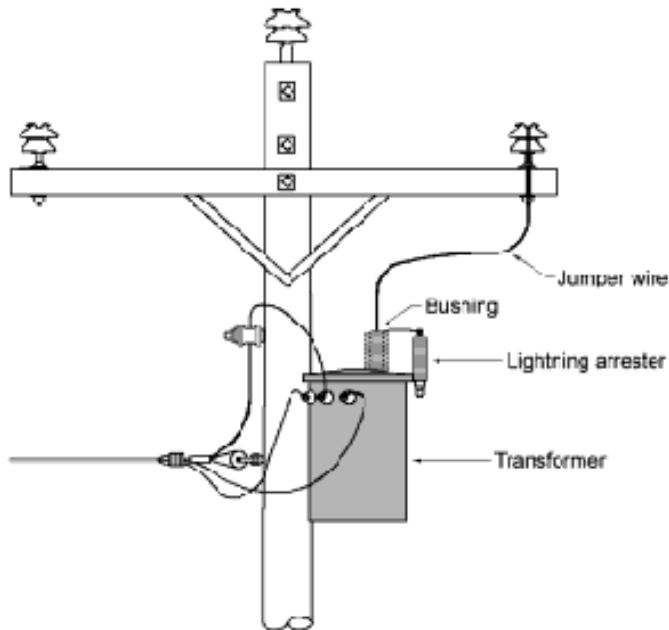
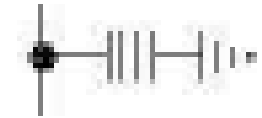


# LIGHTNING ARRESTERS

## Purpose

- *Protect substation equipment and electric system from lightning strokes*
- *Installed near power transformers*

Symbol

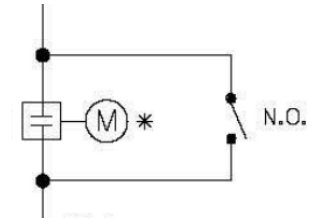


# CIRCUIT SWITCHER

## Purpose

- *For switching and protection of transformers, lines, cables and capacitor banks*
- *Some models have bypass switches*

Symbol



## Types



*Vertical interrupter circuit switcher*



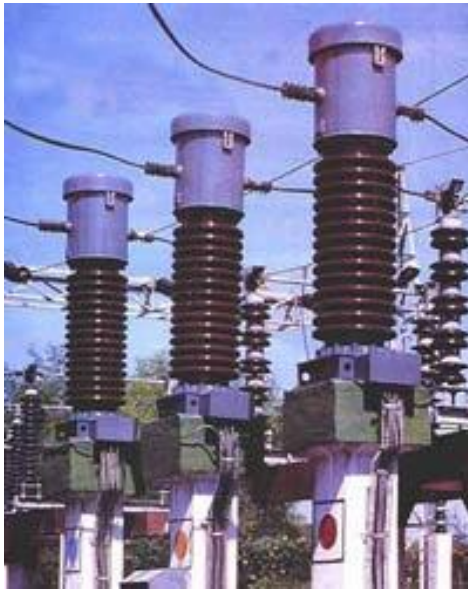
*Horizontal interrupter circuit switcher*

# CURRENT TRANSFORMERS

## Purpose

- *Connected in lines to measure alternating electric current*
- *Electrical inputs for operation of protective relays and measuring instruments*

Symbol

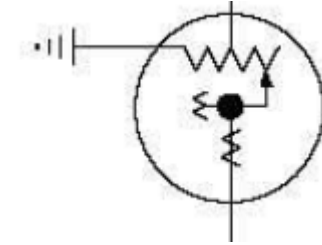


# VOLTAGE REGULATORS

## Purpose

*Provides voltage boost or buck in a system to provide a more or less voltage constant voltage as the amount of the load.*

Symbol



# CONTROL HOUSE/PANEL ARRANGEMENT

## Purpose

*To protect the control equipment including panels, batteries, battery chargers, relays, meters, etc.*





# ELECTRICAL & CONTROL DELIVERABLES

## Drawings

- Control Building Arrangement
- Panel Layouts
- Key Protection Diagram
- Three-line diagrams (AC Schematics)
- DC Schematics
- Wiring Diagrams

## Documentation

- Project Design Document (Needs to be worked on throughout the project)
- Project schedule (Gantt Chart)
- Project budget
- Materials List

# CONTACT INFORMATION

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