NRC Medium Voltage Circuit Breaker Training

CHAPTER 1

Introduction to Circuit Breakers

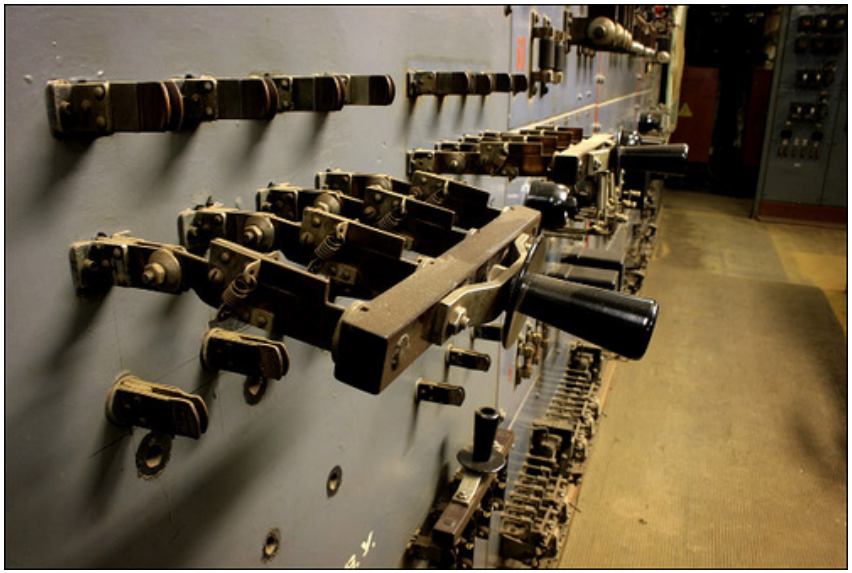
Main Learning Objectives

- Understand Breaker Sizes and types
- Understand breaker arc suppression methods
- Understand where the medium voltage breaker fits into plant operation

Specific Learning Objectives

- State the main function of a circuit breaker.
- Understand the difference between a circuit breaker and a switch.
- Explain the three main breaker voltage groups.
- Name the 4 main methods used for arc extinguishing.
- Describe the attributes of the following breaker types.
  - Oil circuit breaker
  - Air circuit breaker
  - Air Blast breaker
  - Gas Circuit breaker
  - Vacuum breaker
- Understand how the breakers current ratings determine function of the breaker.
- Understand the function of a medium voltage circuit breaker in a power plant distribution system.

Function of A Circuit Breaker



- This is a switch
- Close and electricity flows
- If anything happens to what it feeds. Someone will need to open the switch

Function of A Circuit Breaker

The ability to protect the equipment it supplies is what separates a circuit breaker from a simple switch.

- This is accomplished by a Protective Relay.
- The protective relay detects the problem and trips the breaker

Differential Relay

HOW ARE CIRCUIT BREAKERS CLASSED

Circuit breakers are classed or referred to by their

voltage size

and

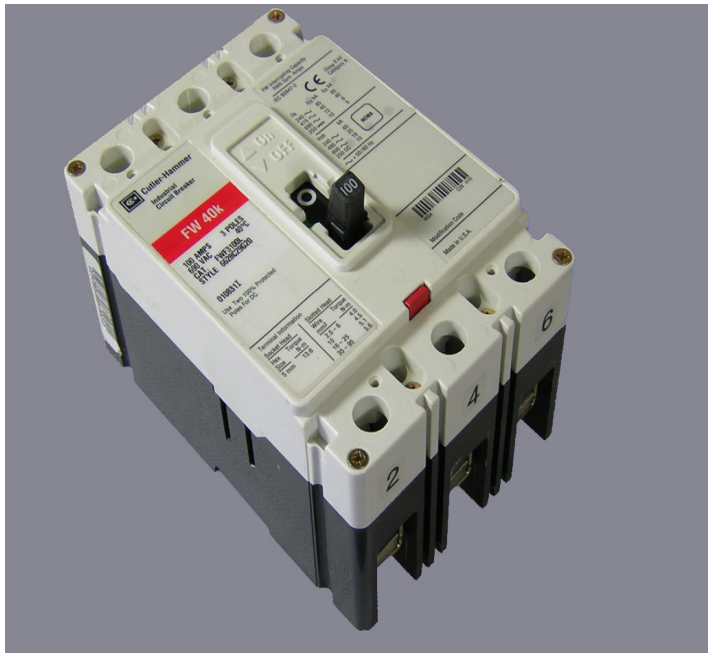
arc extinguishing method.

Classed by Voltage

Circuit breakers are grouped by voltage classes that are normally defined as **LOW, MEDIUM, and HIGH**

- Low Voltage (0-600V)
- Medium Voltage (600V through 15KV)
- High Voltage (Above 15KV)

Molded Case Breaker



- This is a Cutler Hammer 600V breaker.
- This frame would be up to 100A capacity
- As the current increases so will the size

Metal Frame 600Volt Breaker

- This is a 600Volt metal frame breaker.
- Originally manufactured by ITE.
- Used by the Navy as a generator breaker
- 6400 Amp Capacity

Plastic Case 480Volt Breaker

- This is the future for the 600volt distribution
- This is ABB breaker, but is the same design as the Masterpack.
- Plastic enclosed modular components
- Expandable body
- Up to 4000Amp capacity

Medium Voltage

- 5KV is the common designator but could be called by bus voltage 4160
- 7.5 KV also referred too by bus voltage 6.9
- 15KV normally referred to as 13.8

High Voltage Above 15KV

115KV Oil breaker

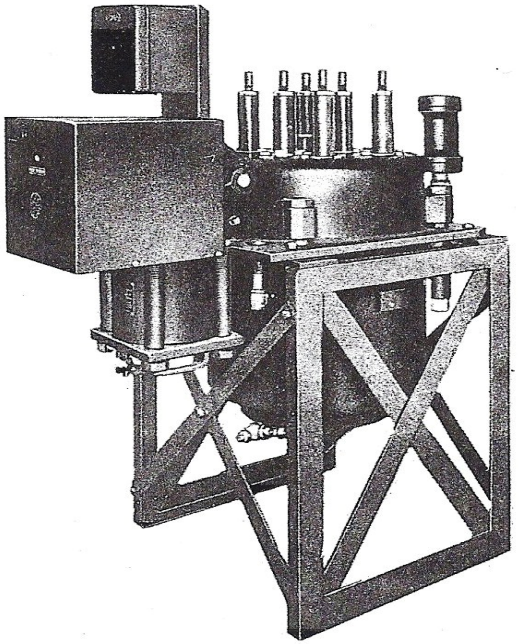
- Most high voltage breakers are out door type
- Can be Air Blast, Oil or SF6 Gas

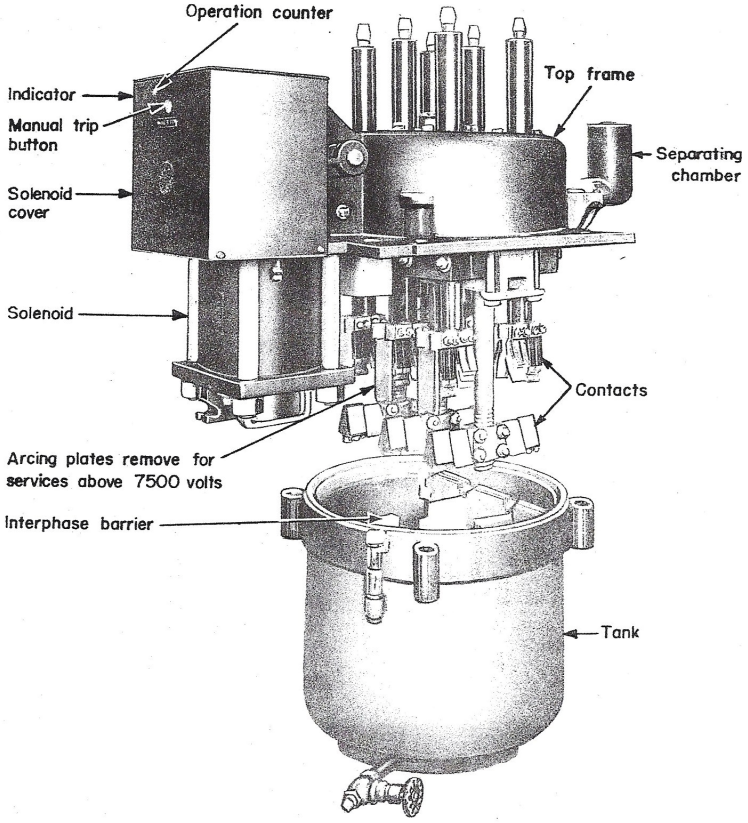
CLASSED by Arc Extinguishing Method

There are 4 common mediums used to extinguish an arc during breaker contact separation

- **Oil**
- **Air**
- **Gas**
- **and opening in a Vacuum.**

Oil Circuit Breakers (OCB)





FK-255-100 solenoid operated oil breaker

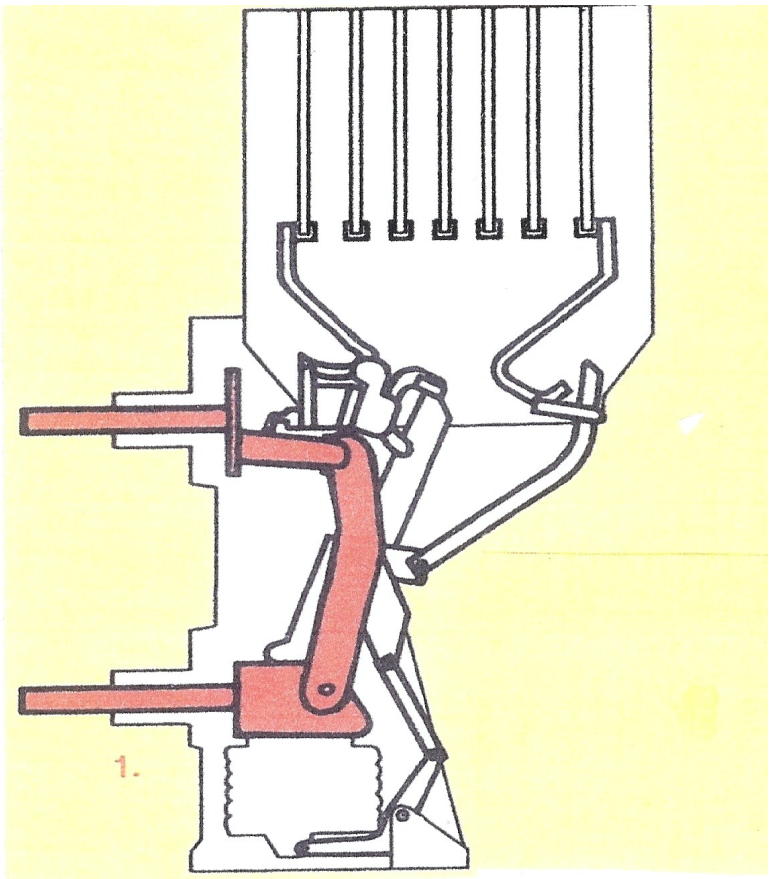
Oil Circuit Breakers (OCB)

- Were used until the 1960's mostly in 15kV – 242kV applications.
- Have been replaced with SF6 because of maintenance costs and environmental concerns.

Air Circuit Breakers (ACB)

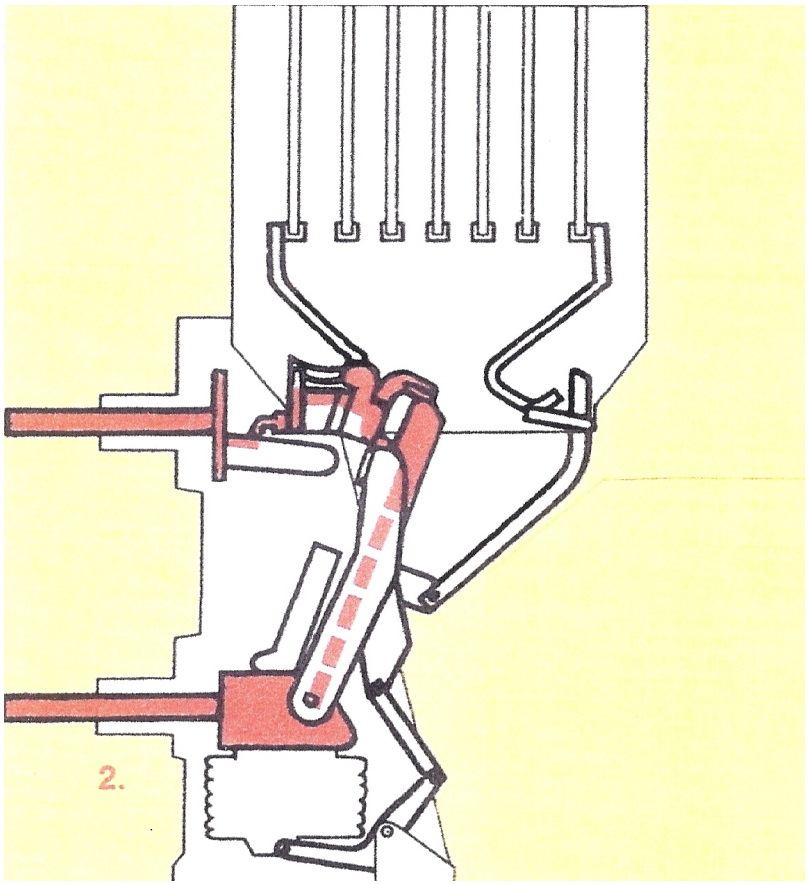
ACB contacts open in air and use a combination of the characteristic of the arc, air and a magnetic field to extinguish the arc.

ARC Extinguishing in ACB



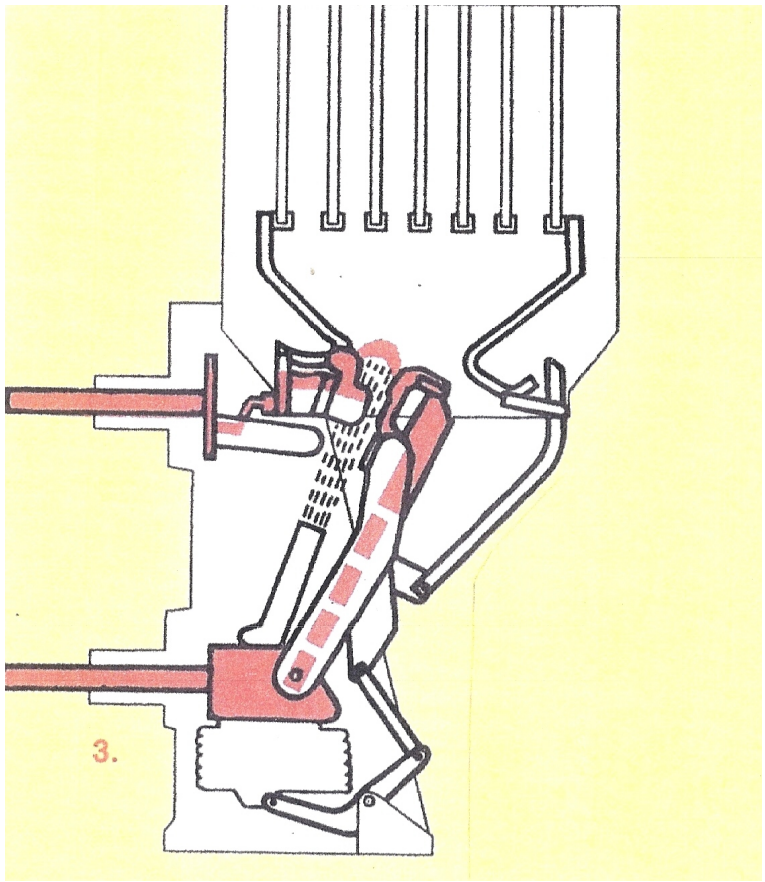
- the breaker closed current flowing through the contacts.

ARC Extinguishing in ACB



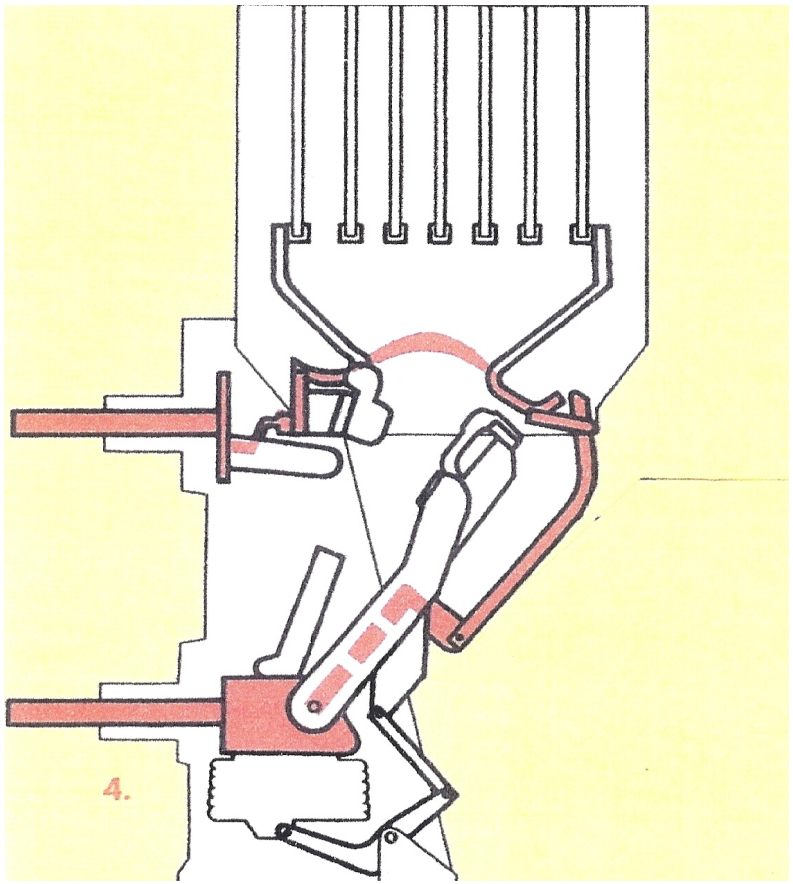
- the main contacts open arc contacts are closed

ARC Extinguishing in ACB



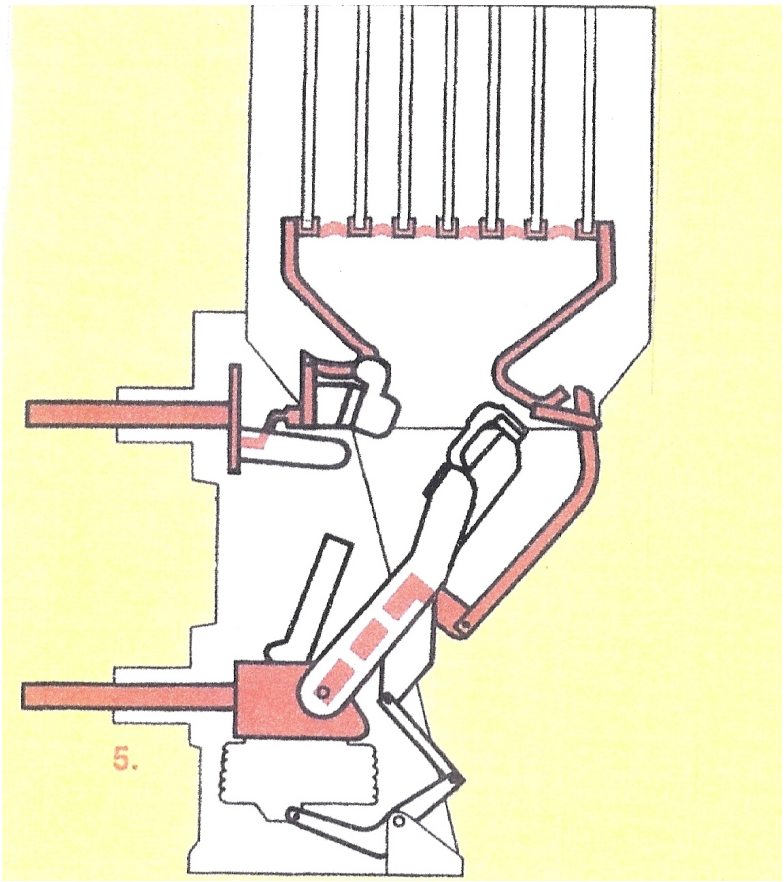
- arcing contacts separate and arc strikes.

ARC Extinguishing in ACB



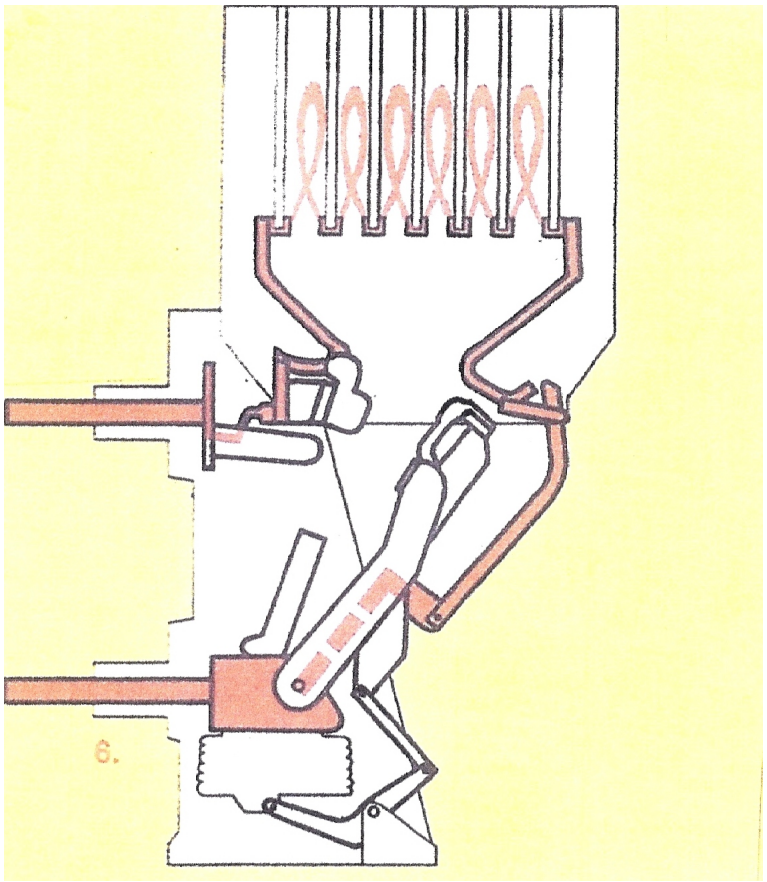
- the arc transfers to the runners

ARC Extinguishing in ACB



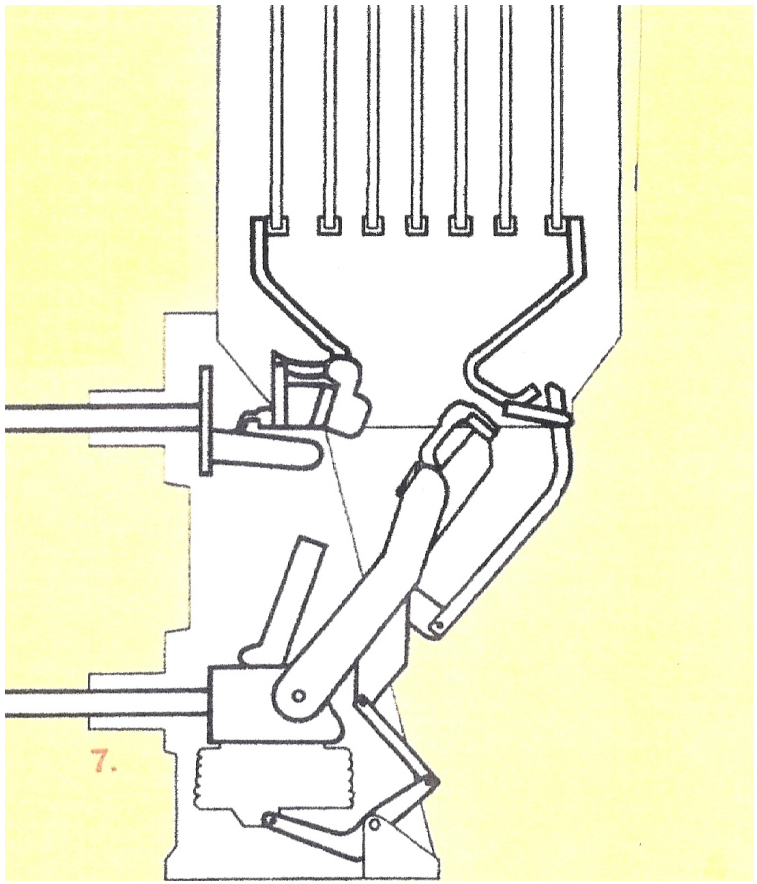
- the arc is transferred to splitter plates to form a number of short series arcs

ARC Extinguishing in ACB



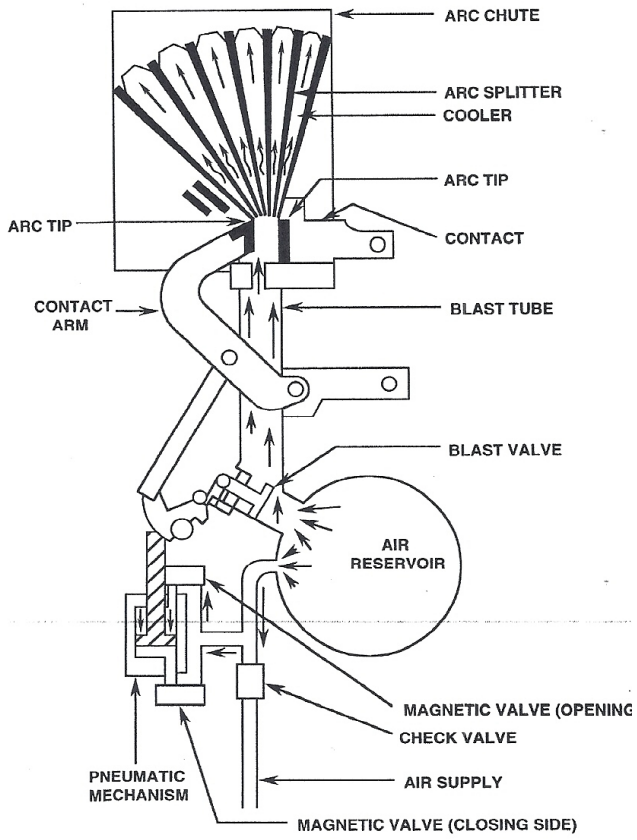
- small arcs are stretched into loops where it is cooled.

ARC Extinguishing in ACB



- arc is extinguished.

Air Blast Breakers



- Not used much today
- Were used was mostly indoor in 15-35 kV where high interrupting or high continuous current were needed
- Also has been replaced by SF6 breakers

Gas Breakers

- Commonly called SF6 breakers for the Sulphur hexafluoride gas used.
- The arc generated during opening is extinguished in a chamber filled with pressurized sulfur hexafluoride gas.
- One advantage SF6 over vacuum breakers is that even if the gas bottle loses pressure the residual SF6 gas is normally enough to allow the breaker to open safely under a normal load.

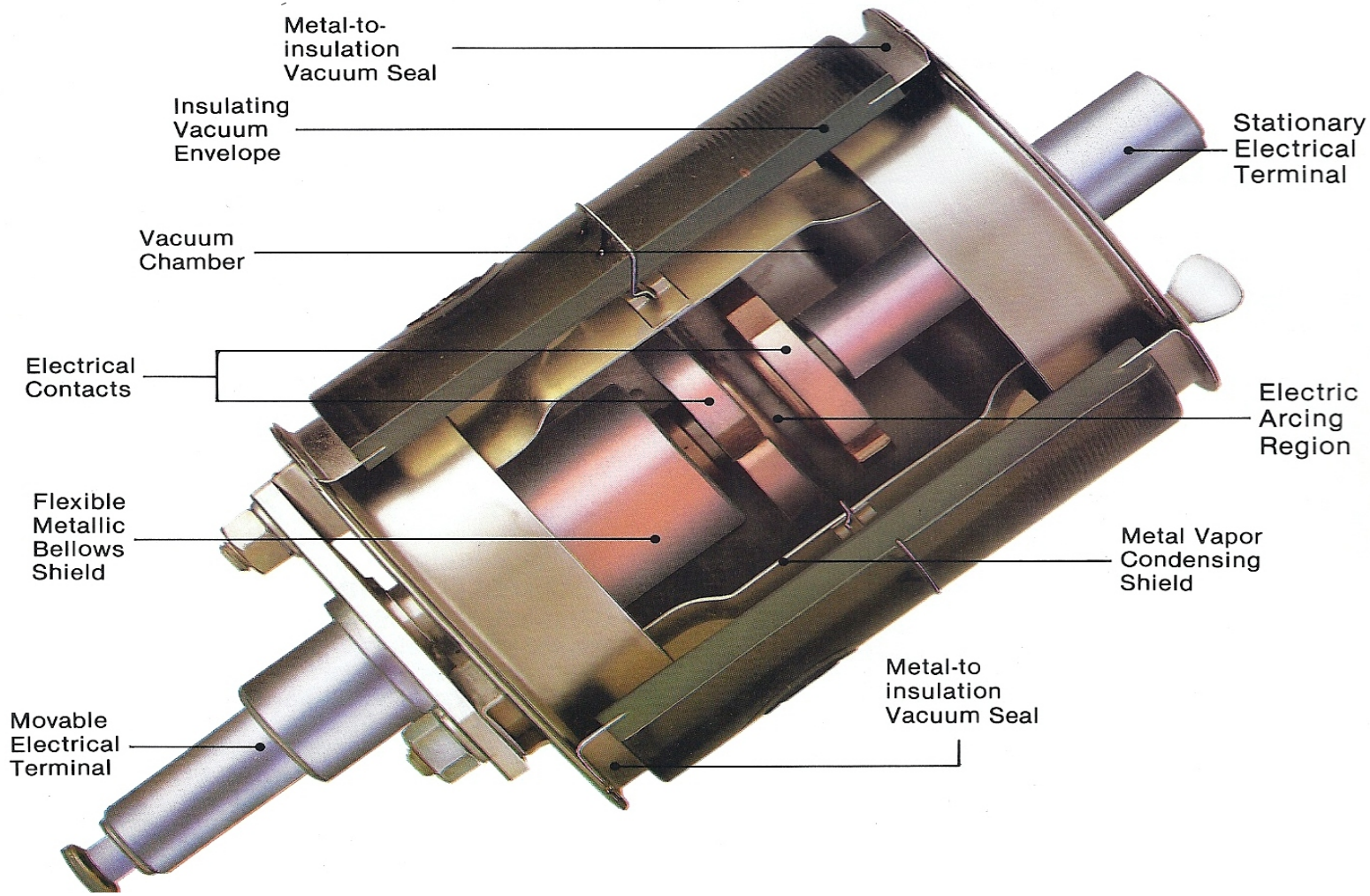
Vacuum Breakers

- The vacuum circuit breaker interrupts the current in a vacuum.
- The contacts of a vacuum breaker are enclosed in a ceramic envelope or "bottle" that is evacuated to an extremely low atmospheric pressure, approximately .0023 in. Hg absolute.

Vacuum Breakers

- The vacuum bottle has a stationary contact firmly mounted on one end
- a moving contact, which travels a very short distance from open to close (1 inch or less)
- is sealed to the other end of the envelope with a flexible bellow

Vacuum Breakers



Circuit Breaker Current Ratings

The three current ratings for circuit breakers are

- Circuit Amperes

  maximum value of the steady state current
- Interrupting Capacity

  MVA Rating-the maximum amperes the breaker is designed to interrupt
- Maximum Momentary Amperes

  maximum instantaneous current the breaker has been designed to close and latch

Power Plant Distribution System

- Power Distribution Grid and Switchyard
- Station startup transformer
- Main electrical generator
- Isolated phase bus duct
- Step-up transformer
- Station auxiliary transformer
- Protective bus duct
- Medium voltage switchgear
- Secondary unit substations
- Motor control centers

Station Startup Transformer

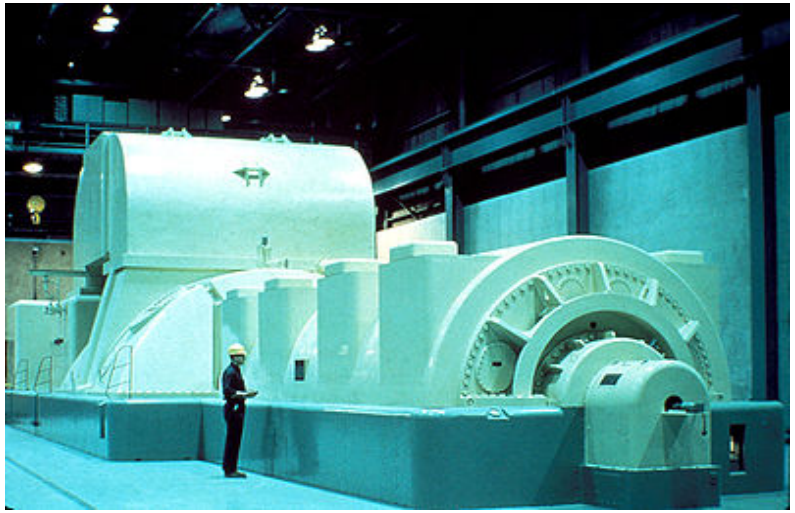
- **Startup Transformer** is the common name for the transformer used to power the plant equipment while starting the unit up from cold conditions (i.e. no fire in the boiler, or the reactor is shutdown). The Startup Transformer is energized from an incoming transmission grid voltage, normally operating at 235kV, 345kV, or 500kV.

Power Distribution Grid & Switchyard

- The **grid** is a term used to describe the high voltage transmission network that distributes electrical power from power plants to consumers.
- The **Switchyard** is the point of entry and exit for electric power entering and leaving the plant. Common switchyard bus voltages are 22 kV, 161 kV, 235 kV, 345 kV, and 500 kV.

Main Electrical Generator

Generator



- The main generator is normally driven by steam for most large power plants, produced from gas, oil, coal or nuclear. Nuclear power plant main generators normally generate power at 22.5kV.
- The output of the generator is connected to an isolated phase bus duct commonly referred to as Isophase Bus Duct.

Isolated phase bus duct

- The Isophase Bus Duct connects the generator output to the Step-Up Transformer and the Station Auxiliary (Service) Transformer.
- There is one duct for each of the three generator phases coming from the generator; the duct provides physical separation of the phases to prevent phase-to-phase faults. For larger bus ducts a forced air-cooling system is used to reduce the heat generated due to power losses.

Step-up Transformer

- Increases the generator voltage from lower generator output voltage to the higher transmission voltage

Station auxiliary transformer

- Is the power transformer that provides power to the station's auxiliaries during normal operation.
- This transformer is connected directly to the Main Generator through the Isophase bus.

Protective bus duct

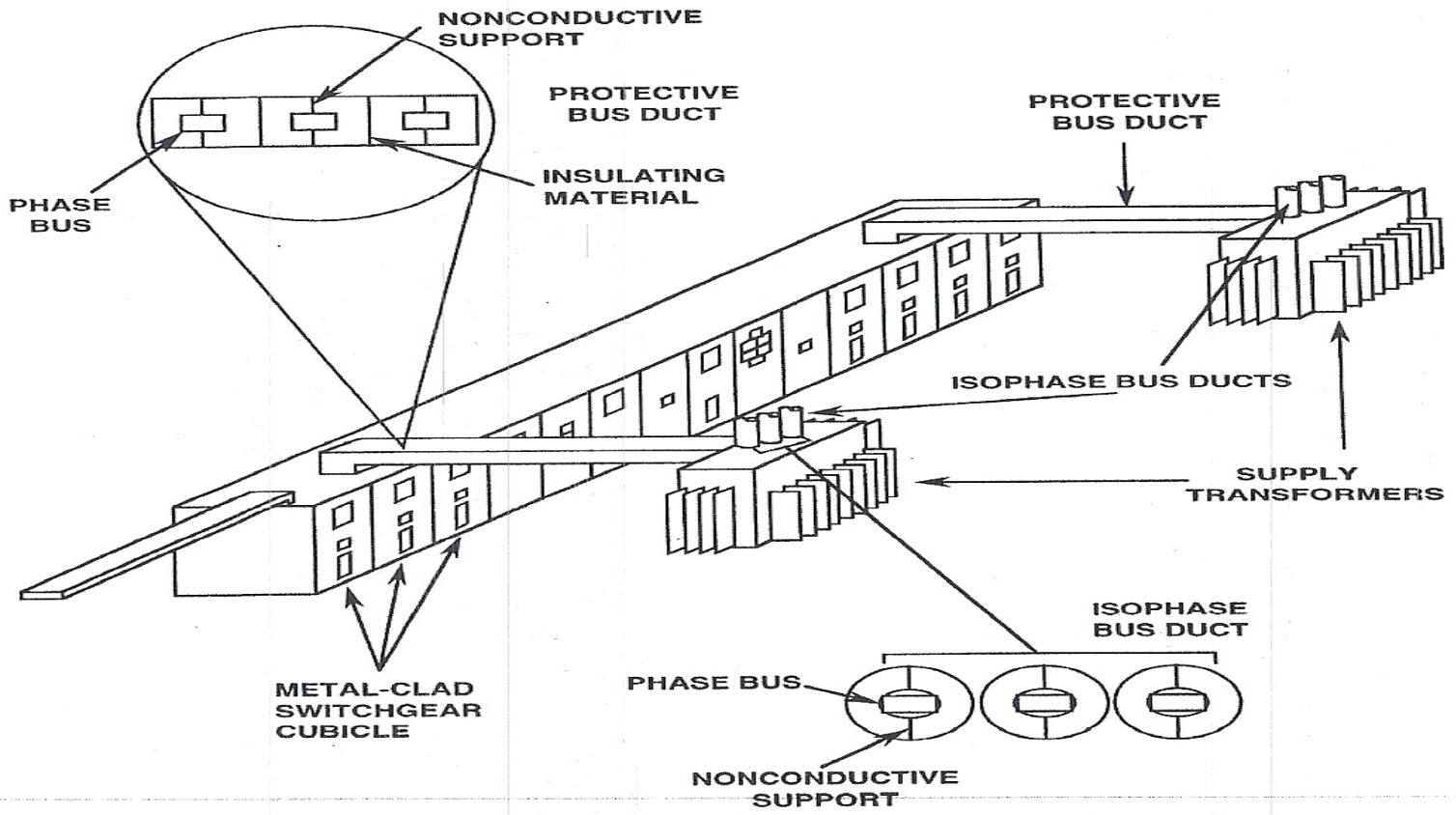
Medium voltage switchgear

- The breakers are housed in a switchgear lineup of a series of cubicles, which are bolted together in a row.

Each cubicle contains

- a rear section where the bus bars are located and where the cables are connected from the loads,
- a lower front compartment where the circuit breaker is housed
- an upper compartment where the protective relays and breaker control wiring are located. The type of relay varies depending upon the breaker application.
- Typically, each breaker will have as a minimum some type of over-current relay and ground fault relay.

Medium Voltage Switchgear



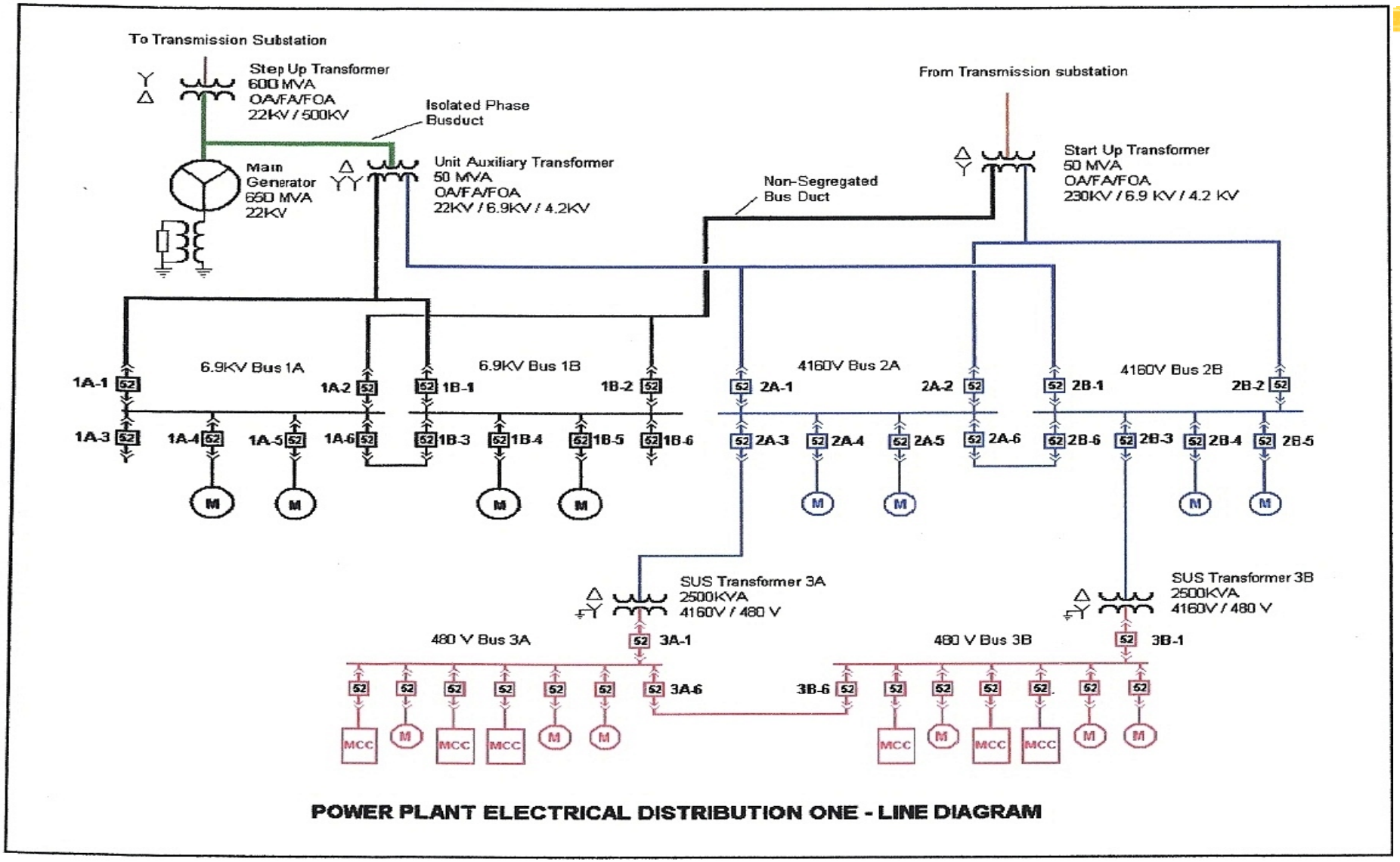
Secondary unit substations

- The Secondary Unit Substations is essentially a repeat of the configuration of the station auxiliary (service) transformer and the Medium Voltage Switchgear but at a lower voltage normally 480V.
- These breakers in turn feed smaller switchboards called the Motor Control Centers.

Motor control centers

- Motor Control Centers are located throughout the power plant and are placed near groups of loads for convenience.
- They are normally comprised of removable sections containing molded case breakers, contactors and protection devices for the equipment they feed.

Plant One Line of a Typical Distribution System



POWER PLANT ELECTRICAL DISTRIBUTION ONE - LINE DIAGRAM

Electrical System Design Requirements.

- The nuclear plant has redundant circuits and back up systems to provide the assurance of safely shutting down the plant. The basic requirement for the design of nuclear power plant electrical distribution systems is provided in General Design Criterion 17 from 10 CFR 50 Appendix A.

Four essential requirements are derived from Criterion 17.

- The onsite electrical distribution system must have at least two separate parts, either of which is capable of providing power to all components required for safe shutdown of the reactor.
- The two parts of the onsite distribution system must be sufficiently separated to preclude the loss of both parts if one part should suffer a loss of power or severe fault, such as a bad ground or short circuit.
- The onsite distribution system shall be provided with two independent power supplies from the offsite transmission network that are promptly available after a loss of all onsite AC power supplies (one offsite supply shall be available within a few seconds). Many nuclear plants operate with the offsite power supply continuously in use for safety-related loads, while other plants have a fast-transfer capability to satisfy this requirement.
- Both of the two separate onsite parts shall have a backup power source available within a few seconds following a loss of coolant accident or loss of offsite and onsite power supplies.