Generating Station Switchyard (Substation)

Substation grounding

1. **It provides means of dissipating electric current into the earth without exceeding the operating limits of the equipment.**

2. **It provides a safe environment to protect personnel in the vicinity of grounded facilities from the dangers of electric shock under fault conditions.**

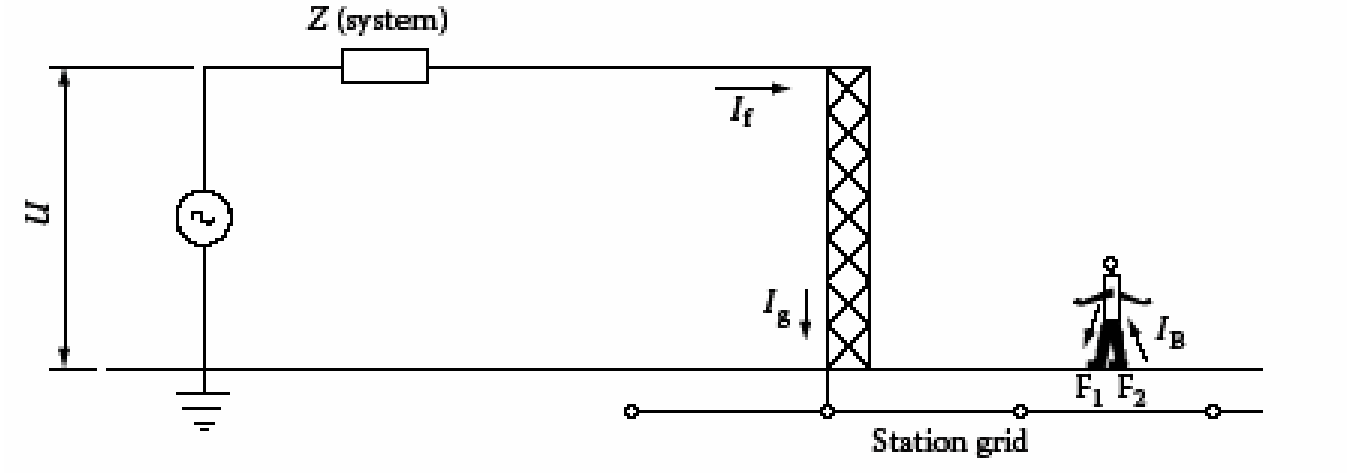
Step and Touch potentials:

A thin layer of high resistivity material s spread over the earth surface to reduce the body current.

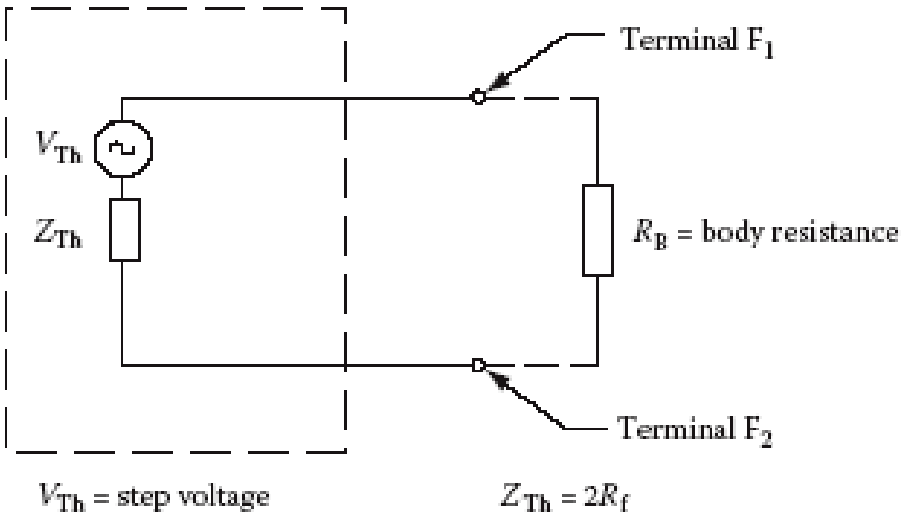
Definition: *Surface layer derating factor (C_S):*

Increases the foot resistance, and depends on soils resistivity, surface material resistivity and surface material thickness.

Step Potential:



$$E_{step} = I_B(R_B + Z_{th})$$



Transformer


Two winding transformers

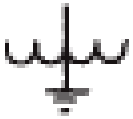

Transformer with teritary winding


Tap changing under load transformer


Constant-current (street light) transformer

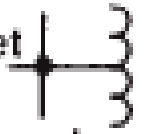

Auto transformer

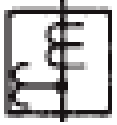

Auto transformer with tertiary winding


Zig zag grounding transformers


Current transformer


Potential transformer


Control power or station light and power transformer


Outdoor metering outfit


OCB Bushing-type current transformer


OCB Two bushing-type current transformer


Step regulator

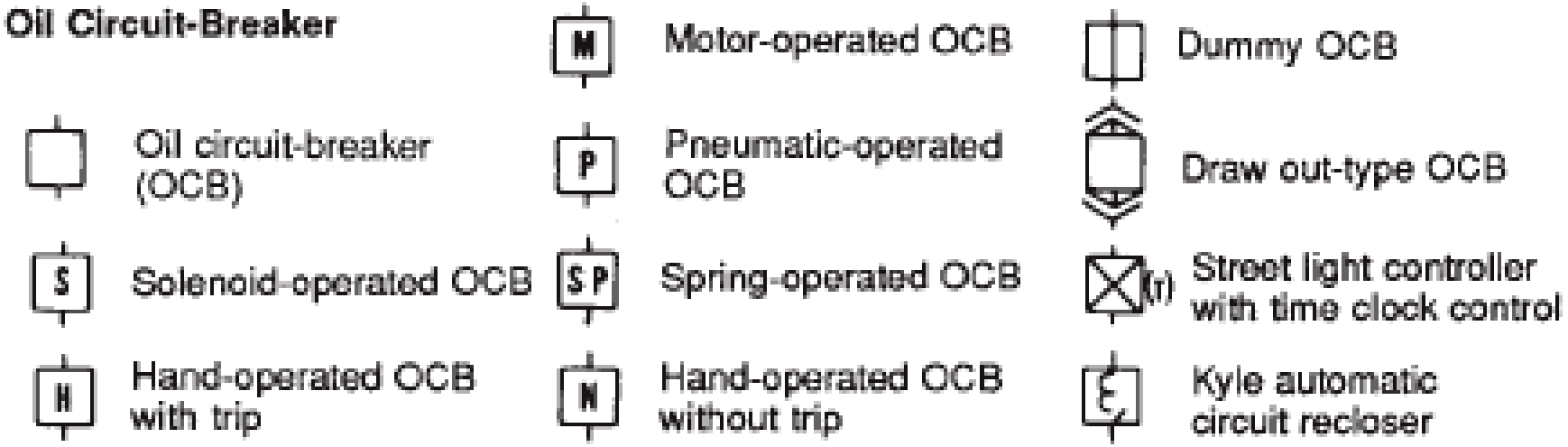

Induction regulator


Air core reactor


Iron core reactor

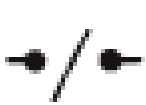
Air Circuit-Breaker

Oil Circuit-Breaker

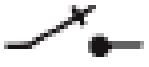


Switches


Stick-operated disconnect switch


Stick-operated disconnect switch blade de-energized when open.


Air-break switch


Gang-operated switch


Motor-operated air-break switch


Load-break switch

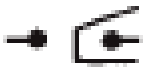

Double-break load-break switch

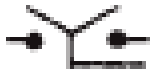

Fuse disconnect switch


Draw out-type fuse disconnect


Bayonet switch


Regulator bypass switch


Single-pole double-throw switch


Double-blade double-throw switch

Miscellaneous


Key interlock equipment

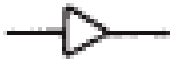

Potheads


Generator


Ground

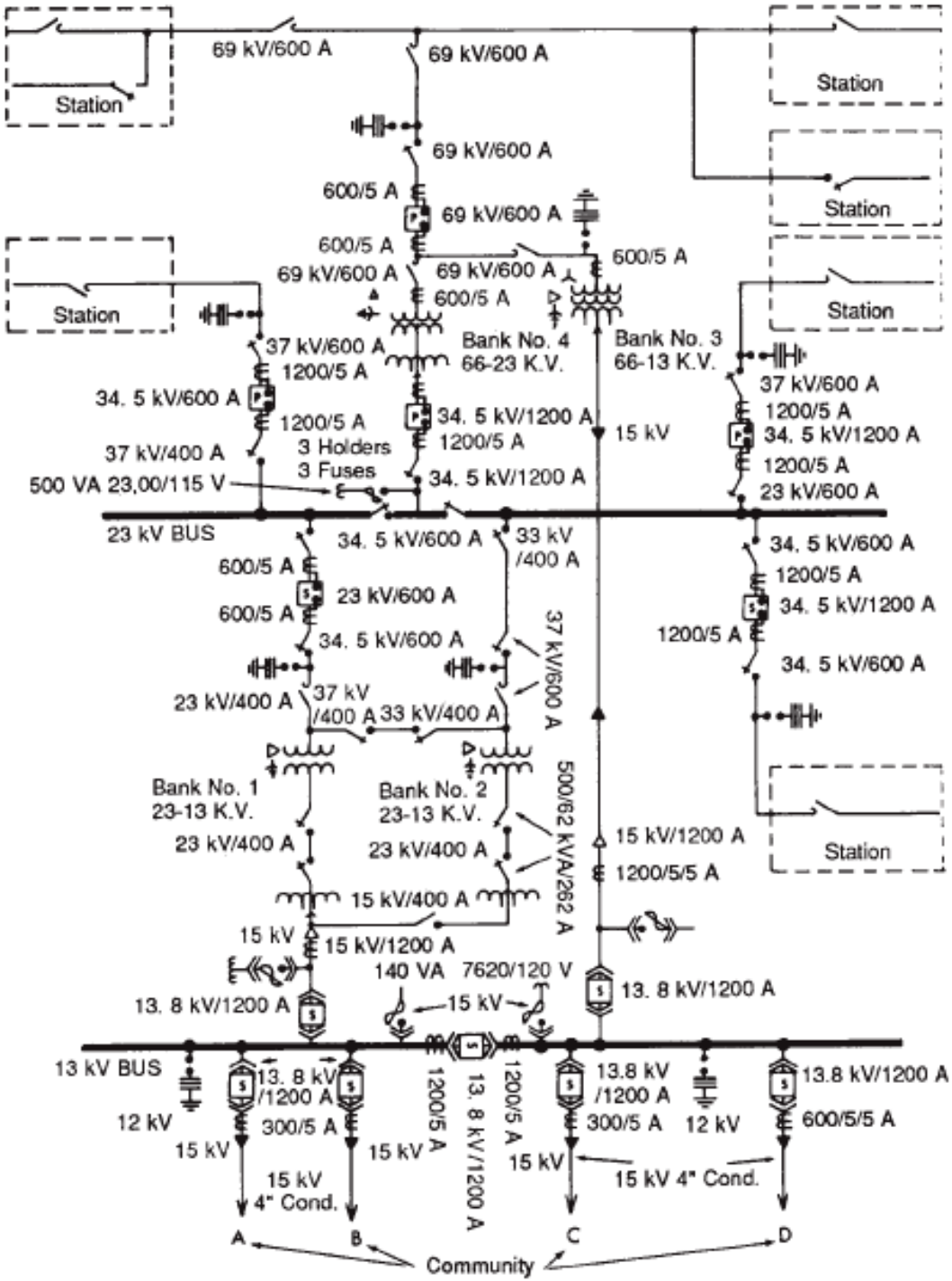

Hot-line tap


Capacitor


Roof bushing


Splice box with roof bushing

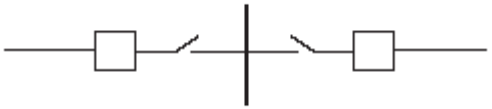

Lightning arrester


69 kV/600 A
69 kV/600 A
Station
69 kV/600 A
600/5 A
69 kV/600 A
Station
600/5 A
69 kV/600 A
69 kV/600 A
600/5 A
600/5 A
Station
Station
37 kV/600 A
1200/5 A
Bank No. 4
66-23 K.V.
Bank No. 3
66-13 K.V.
34. 5 kV/600 A
1200/5 A
34. 5 kV/1200 A
1200/5 A
15 kV
37 kV/600 A
1200/5 A
34. 5 kV/1200 A
37 kV/400 A
3 Holders
3 Fuses
1200/5 A
500 VA 23,00/115 V
34. 5 kV/1200 A
1200/5 A
23 kV/600 A
23 kV BUS
34. 5 kV/600 A
33 kV
/400 A
34. 5 kV/600 A
600/5 A
23 kV/600 A
1200/5 A
34. 5 kV/1200 A
600/5 A
34. 5 kV/600 A
37 kV/600 A
1200/5 A
34. 5 kV/600 A
23 kV/400 A
37 kV
/400 A
33 kV/400 A
Bank No. 1
23-13 K.V.
Bank No. 2
23-13 K.V.
500/62 KVA/262 A
15 kV/1200 A
1200/5/5 A
23 kV/400 A
23 kV/400 A
Station
15 kV/400 A
15 kV
15 kV/1200 A
140 VA 7620/120 V
13. 8 kV/1200 A
13. 8 kV/1200 A
15 kV
13 kV BUS
13. 8 kV
/1200 A
1200/5 A
13. 8 kV/1200 A
1200/5 A
13.8 kV
/1200 A
13.8 kV/1200 A
12 kV
300/5 A
15 kV
15 kV
300/5 A
12 kV
600/5/5 A
15 kV
15 kV
4" Cond.
15 kV
15 kV 4" Cond.
A
B
C
D
Community

Arrangement of switching devices and bus-bars in switchyard

1. ***Single bus***
2. ***Double bus–double breaker***
3. ***Main and transfer (inspection) bus***
4. ***Double bus–single breaker***
5. ***Ring bus***
6. ***Breaker-and-a-half***

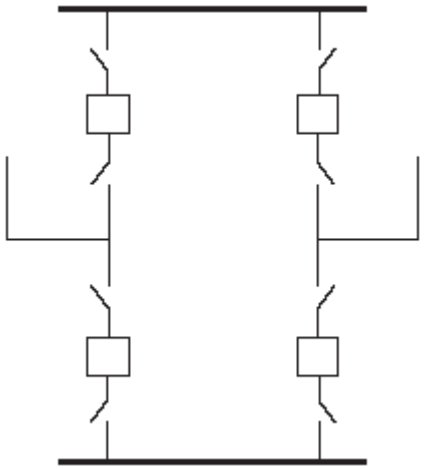
Single bus arrangement



- ***Simple***
- ***Low reliability & Low operational flexibility***

  → Limited to low load levels & lows availability requirements

Double bus – double breaker arrangement



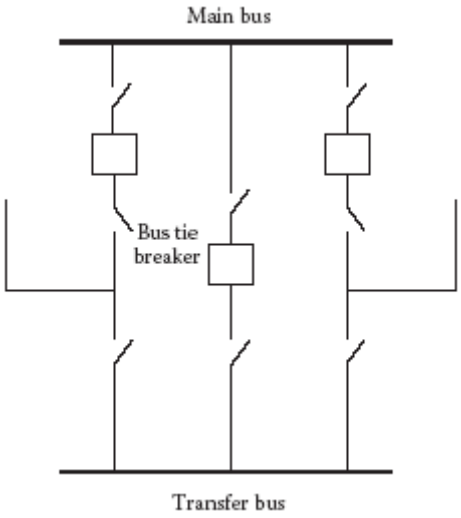
- A single bus failure can be isolated without interrupting any circuits or loads.
- A circuit failure of one circuit will not interrupt other circuits or buses.

→ ***Reliability of this arrangement is extremely high.***

- Switching devices can be taken out-of-service as needed and circuits can continue to operate with partial protection & switching devices in-service.

→ ***Maintenance of switching devices in this arrangement is very easy***

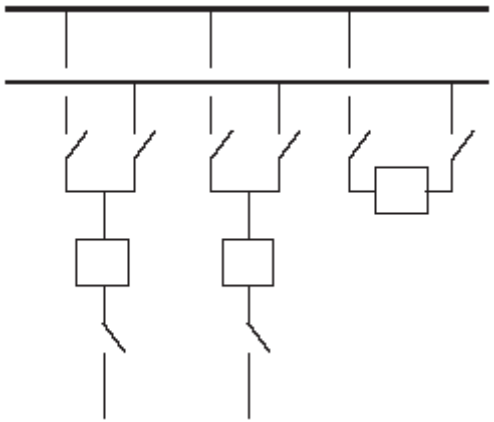
Main and Transfer Bus Arrangement



- The transfer bus is used to improve the maintenance process by moving the line of the circuit breaker to be maintained to the transfer bus.

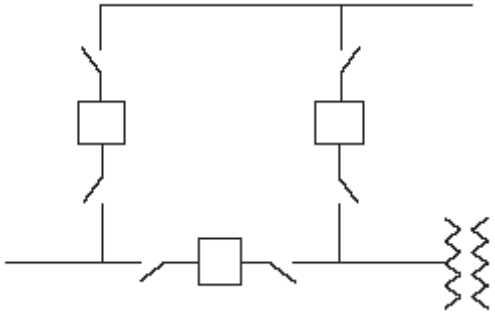
- Limited to low reliability requirements

Double bus – single breaker arrangement



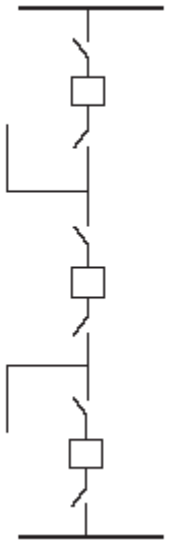
- With the tie breaker operated normally closed, each circuit may be supplied from either bus via its switches.
  → ***Provides increased operating flexibility and improved reliability***.
- ***Bus and circuit crossing in substation are possible***

Ring bus arrangement



- ***Requires more complicated protective relaying***
- ***Very Reliable***
- ***Maintenance flexible***

“Breaker and a Half” arrangement



- A single circuit failure will not interrupt any other circuits.
- A bus section fault, unlike the ring bus, will not interrupt any circuit loads.
  → ***Extremely Reliable***
- ***Maintenance of entire bus and adjacent breakers without transferring loads.***
- ***Relay protection more complex than ring bus due to additional devices***.

Configuration	Reliability/Operation	Cost	Available Area
Single bus	Least reliable—single failure can cause a complete outage. Limited operating flexibility	Least cost (1.0)—fewer components	Least area—fewer components
Double bus–double breaker	Highly reliable—duplicated devices; single circuit or bus fault isolates only that component. Greater operating and maintenance flexibility	High cost (2.17)—duplicated devices and more material	Greater area—more devices and more material
Main and transfer bus	Least reliable—reliability is similar to the single bus arrangement, but operating and maintenance flexibility improved with the transfer bus	Moderate cost (2.06)—more devices and material required than the single bus	Low area—high-profile configuration is preferred to minimize land use
Double bus–single breaker	Moderately reliable—with bus tie breaker, bus sections and line circuits are isolated. Good operating flexibility	High cost (2.15)—more devices and material	Greater area—more devices and more material
Ring bus	High reliability—single circuit or bus section fault isolated. Operation and maintenance flexibility good	Moderate cost (1.62)—additional components and materials	Moderate area—dependent on the extent of the substation development
Breaker-and-a-half	Highly reliable—bus faults will not impact any circuits, and circuit faults isolate only that circuit. Operation and maintenance flexibility best with this arrangement	Moderate cost (1.69)—cost is reasonable based on improved reliability and operational flexibility	Greater area—more components. Area increases substantially with higher voltage levels

Gas Insulated Substation:

-Uses sulfur hexafluoride (SF6), (*which is a superior dielectric, inert, non toxic, non flammable gas*), at a moderate pressure (*400 → 600 kPa*) for phase-to-phase and phase-to-ground insulation.

- High-voltage conductors, circuit breaker interrupters, switches, current and voltage transformers (CTs & VTs) are encapsulated in SF6 gas inside grounded metal enclosures.

Compared to Air Insulated Substations:

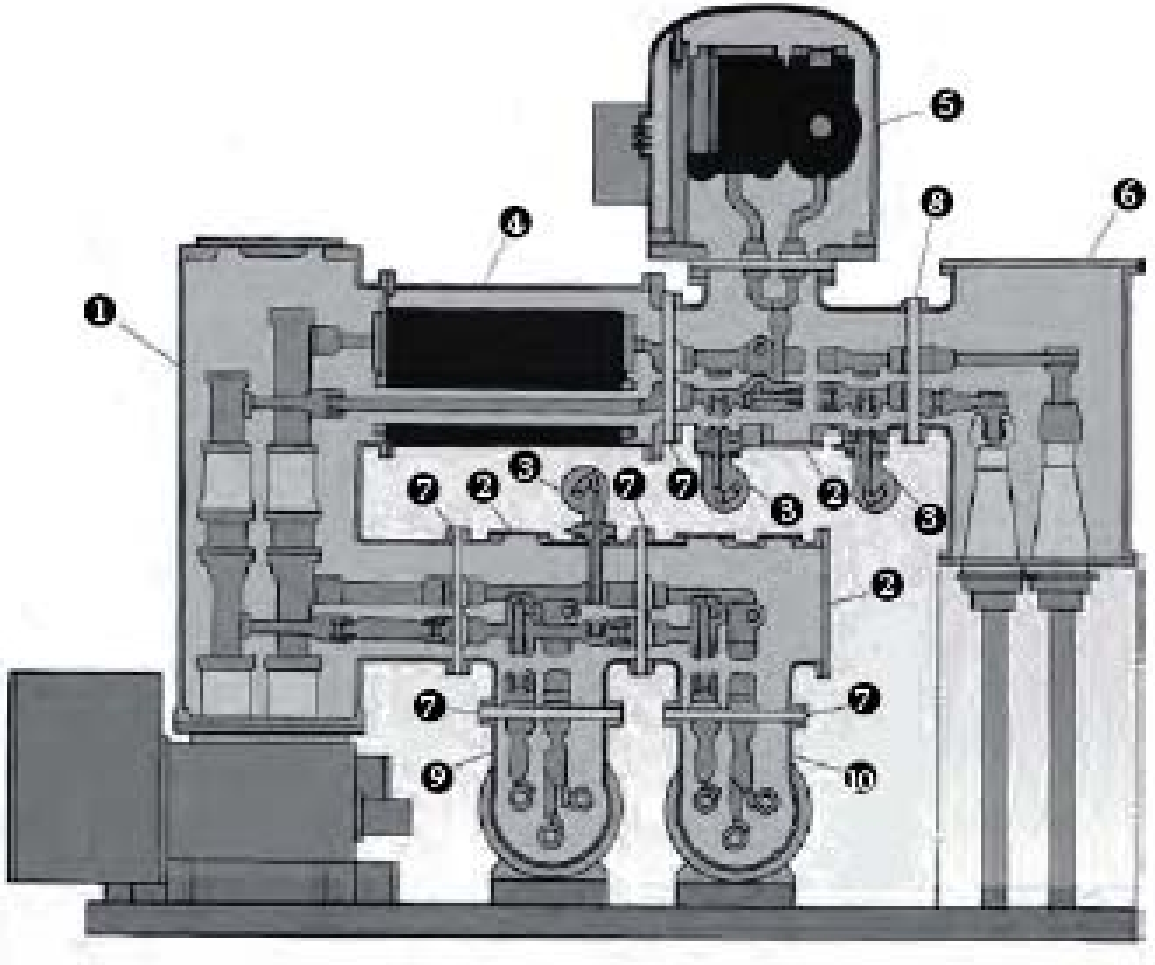
- Requires ***smaller size*** compared to (about 10%) , due to super dielectric quality of SF6 compared to air.

- ***More reliable, requires less maintenance*** and has a ***longer service life*** (more than 50 years) as active parts are protected from deterioration originating from exposure to atmospheric air, moisture and contamination.

- ***More expensive***, mostly used in case of limited space availability.

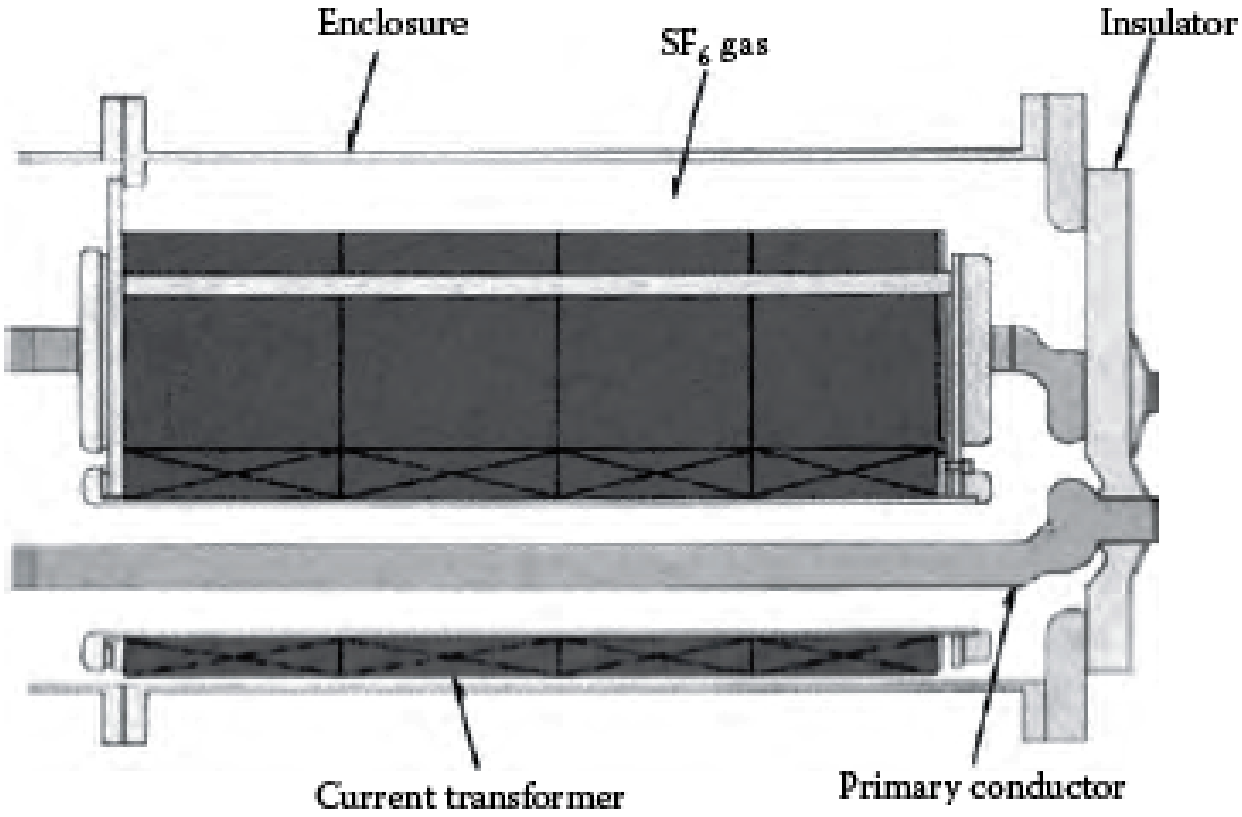
- SF6 emission ***contributes to global warming***, accordingly, it needs special handling, equipment design consideration and recycling.

❶ Circuit breaker
❷ Disconnector (isolator)
❸ Earthing (grounding) switch
❹ Current transformer
❺ Voltage (potential) transformer
❻ Cable sealing end chamber
❼ Gas barrier
❽ Supporting insulator
❾ Main busbar
❿ Reserve busbar

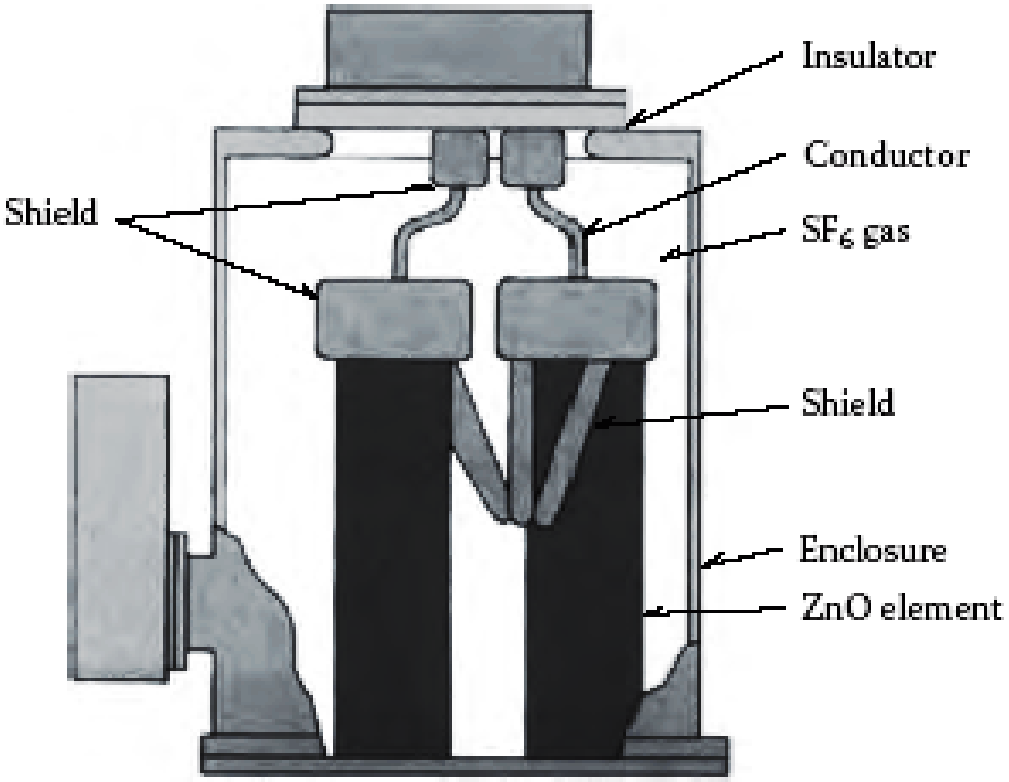


Gas Insulated Substation

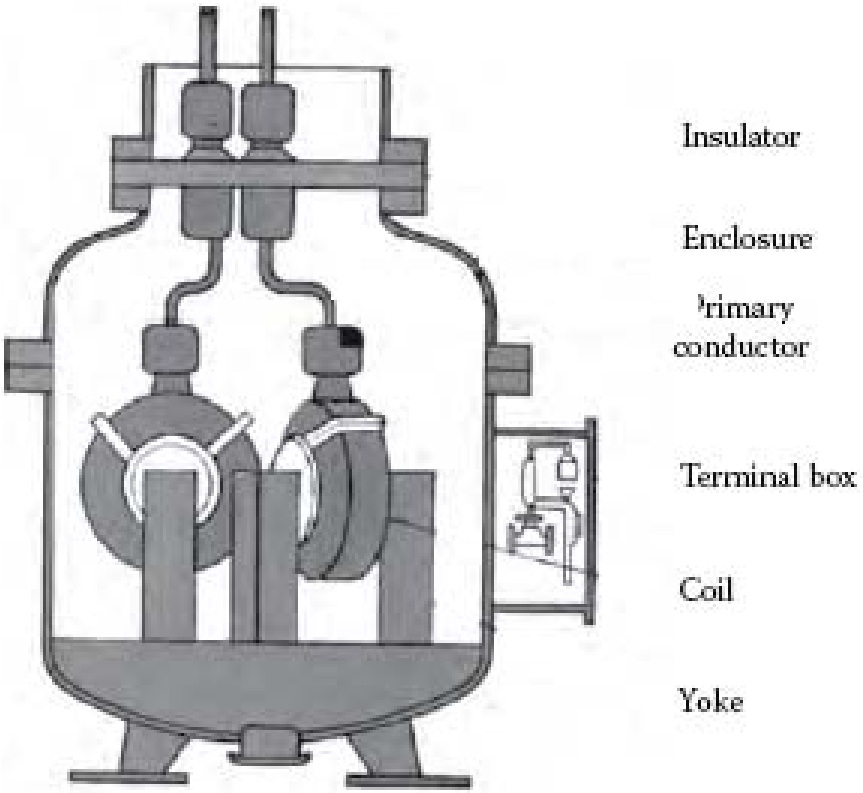
GIS Components



CTs



Surge arrestors



Voltage Transformers