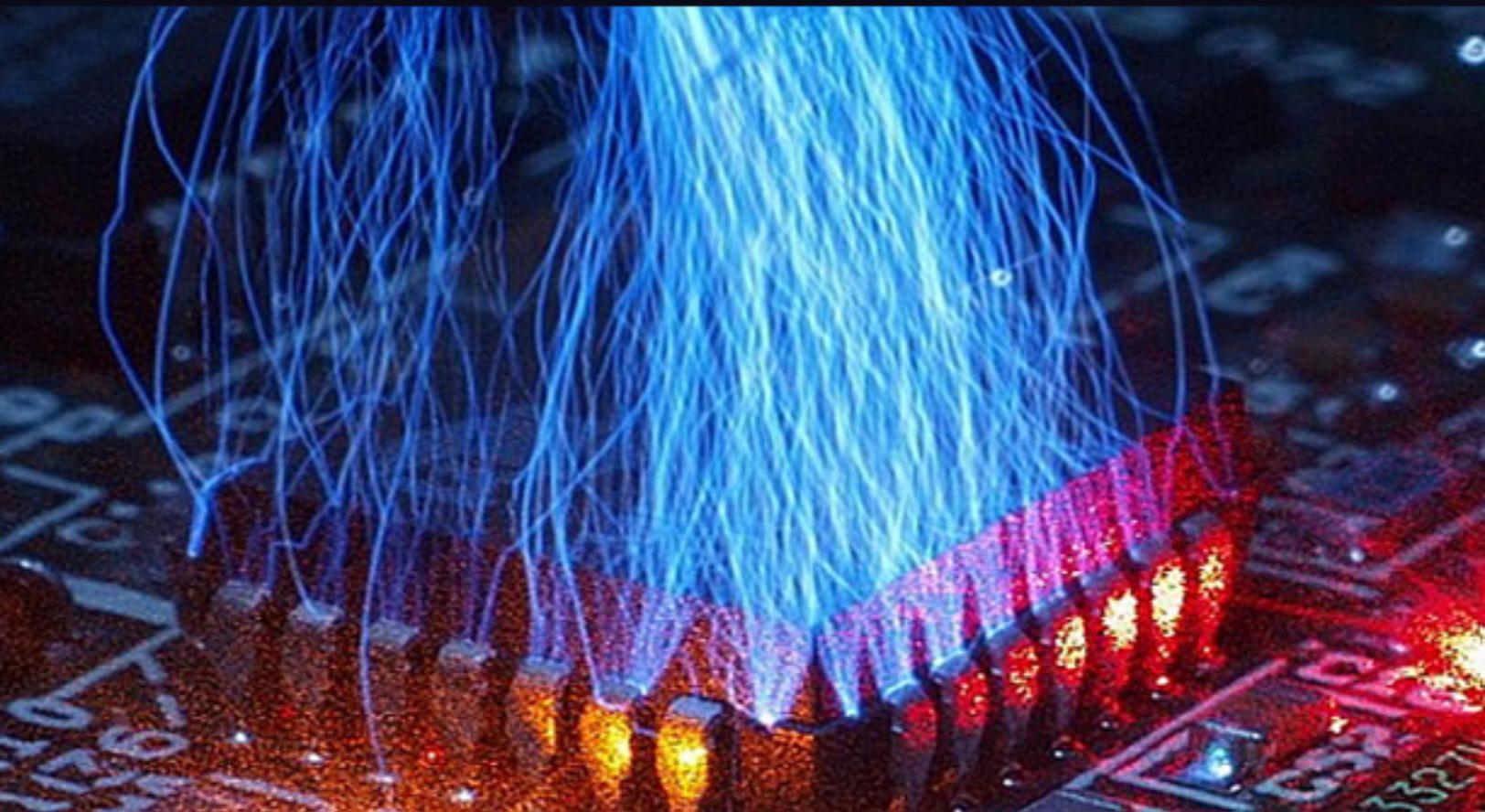


VTU eNotes On CAED

Computer Aided Electrical Drawing



**Electrical And
Electronics Engineering**

Single Line Diagram of Substations

Substations

Electric power is produced at the power generating stations, which are generally located far away from the load centers. High voltage transmission lines are used to transmit the electric power from the generating stations to the load centers. Between the power generating station and consumers a number of transformations and switching stations are required. These are generally known as substations. Substations are important part of power system and form a link between generating stations, transmission systems and distribution systems. It is an assembly of electrical components such as bus-bars, switchgear apparatus, power transformers etc.

Their main functions are to receive power transmitted at high voltage from the generating stations and reduce the voltage to a value suitable for distribution. Some substations provide facilities for switching operations of transmission lines, others are converting stations. Substations are provided with safety devices to disconnect equipment or circuit at the time of faults. Substations are the convenient place for installing synchronous condensers for the purpose of improving power factor and it provide facilities for making measurements to monitor the operation of the various parts of the power system.

The substations may be classified in according to service requirements and constructional features. According to service requirements it is classified in to transformer substations, switching substations and converting substations.

(1) Transformer substations: Majority of the substations in the power system are in the type. They are used to transform power from one voltage level to another voltage level. Transformer is the main component in such substations. Transformer substations are further classified into Step-up substations, Primary grid substations, Secondary substations and Distribution substations.

(a) Step-up substations: These substations are usually located at the generating stations. Generating voltage of the order of 11kV needs to be stepped up to a primary transmission voltage level of the order of 220kV or 400kV.

(b) Primary grid substations: These substations are located at the end of primary transmission lines and the primary voltage is stepped down to suitable secondary voltages of the order of 66kV or 33kV.

(c) Secondary substations: The voltage is further stepped down to 11kV. Large consumers are supplied power at 11kV.

(d) Distribution substations: These substations are located near the consumer localities to supply power at 400V, three phase or 230V, single phase to the consumers.

(2) Switching substations: These substations are meant for switching operations of power lines without transforming the voltage. Different connections are made between the various transmission lines.

(3) Converting substations: Such substations are meant for either converting AC to DC or vice versa. Some are used to change the frequency from higher to lower or vice versa for industry utilisations.

According to constructional features substations are classified into Indoor substations, Outdoor substations, Underground substations and Pole mounted substations.

(1) Indoor substations: All equipments of the substation are installed within the station buildings.

(2) Outdoor substations: All equipments such as transformers, circuit breakers, isolators, etc., are installed outdoors.

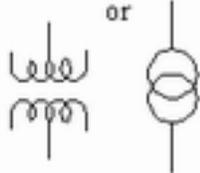
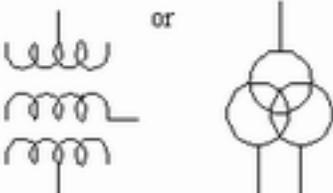
(3) Underground substations: In thickly populated areas where the space is the major constraint, and cost of land is higher, under such situation the substations are laid underground.

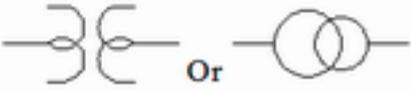
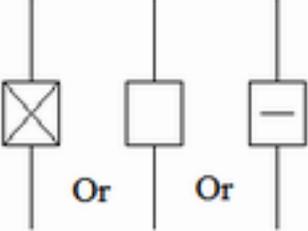
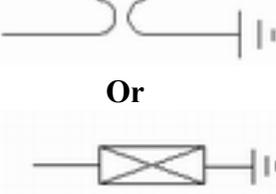
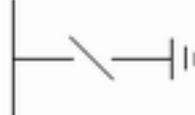
(4) Pole mounted substations: This is an outdoor substation with equipments installed overhead on a H pole or 4 pole structure.

Single Line Diagram

Any complex power system even though they are three phase circuits, can be represented by a single line diagram, showing various electrical components of power system and their interconnection. In single line representation of substation the electrical components such as power transformers, incoming and outgoing lines, bus-bars, switching and protecting equipments, are represented by standard symbols and their interconnections between them are shown by lines. Single line diagrams are useful in planning a substation layout.

Some of the standard symbols used to represent substation components are given in Table below.

Sl No	Electrical components	Symbols
1	AC Generator	
2	Bus Bar	
3	Power transformer -Two winding	
4	Three winding transformer	

5	Current Transformer (CT)	
6	Voltage transformer or Potential transformer (PT)	
7	Circuit Breaker (CB)	
8	Circuit breaker with isolator	
9	Isolator or Group Operating Switch(GOS)	
10	Lighting Arrestor (LA)	
11	Earth Switch (ES)	
13	Wave or Line trap	

14	Coupling Capacitor (CC)	
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Power transformers: Power transformers are used generation and transmission network for stepping-up the voltage at generating station and stepping-down the voltage for distribution. Auxiliary transformers supply power to auxiliary equipments at the substations.

Current transformers (CT): The lines in substations carry currents in the order of thousands of amperes. The measuring instruments are designed for low value of currents. Current transformers are connected in lines to supply measuring instruments and protective relays. For example a 100/1A CT is connected in a line carrying 100A, and then the secondary current of CT is 1A.

Potential transformers (PT): The lines in substations operate at high voltages. The measuring instruments are designed for low value of voltages. Potential transformers are connected in lines to supply measuring instruments and protective relays. These transformers make the low voltage instruments suitable for measurement of high voltages. For example a 11kV/110V PT is connected to a power line and the line voltage is 11kV then the secondary voltage will be 110V.

Circuit breaker (CB): Circuit breakers are used for opening or closing a circuit under normal as well as abnormal (faulty) conditions. Different types of CBs which are generally used are oil circuit breaker, air-blast circuit breaker, vacuum circuit breaker and SF₆ circuit breaker.

Isolators or Isolating switches: Isolators are employed in substations to isolate a part of the system for general maintenance. Isolator switches are operated only under no load condition. They are provided on each side of every circuit breaker.

Lightning arresters (LA): Lightning arresters are the protective devices used for protection of equipment from lightning strokes. They are located at the starting of the substation and also provided near the transformer terminals.

Earth switch: It is a switch normally kept open and connected between earth and conductor. If the switch is closed it discharges the electric charge to ground, available on the uncharged line.

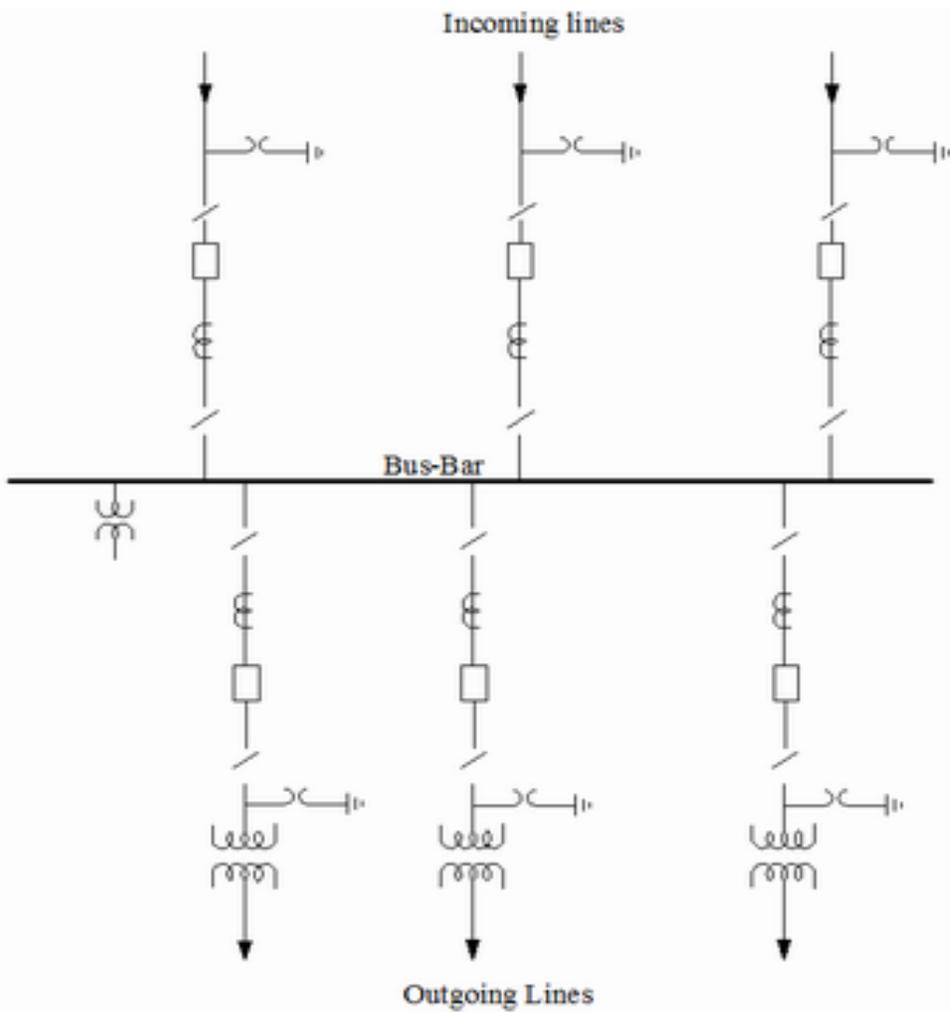
Wave trap: This equipment is installed in the substation for trapping the high frequency communication signals sent on the line from remote substation and diverting them to the telecom panel in the substation control room.

Coupling capacitor: A coupling capacitor is used in substations where communication is done by AC power line. It offers very low impedance to high frequency carrier signal and allows them to enter the line matching unit and blocks the low frequency signal.

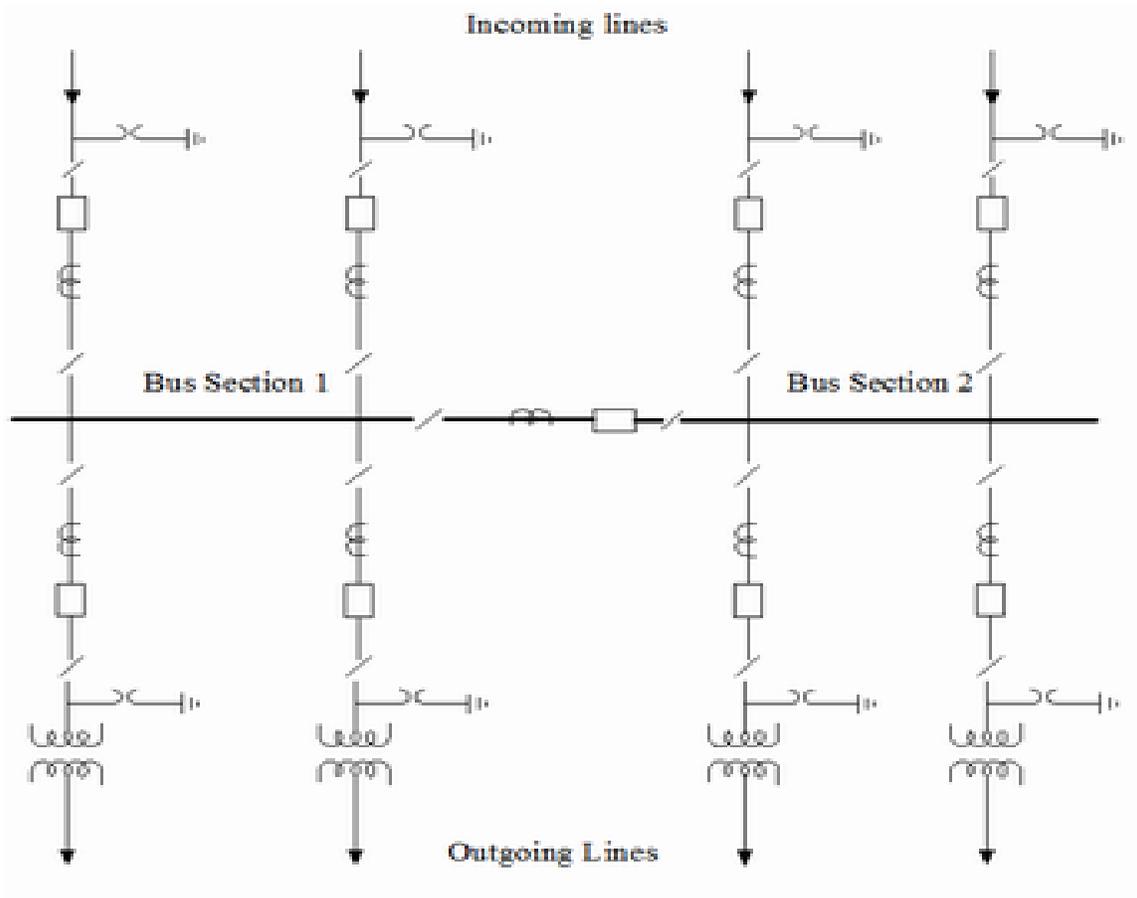
Bus-bar: When number of lines operating at the same voltage levels needs to be connected electrically, bus-bars are used. Bus-bars are conductors made of copper or aluminum, with very low impedance and high current carrying capacity. Different types of bus-bar arrangements are single bus bar arrangements, single bus-bar with sectionalisation, double bus-bar arrangements, sectionalised double bus-bar arrangement, double main and auxiliary bus-bar arrangement, breaker and a half scheme/1.5 Breaker scheme, and ring bus-bar scheme.

Single bus-bar arrangement: It consists of single bus-bar. Both incoming and outgoing lines are connected to the single bus-bar. The advantages of this arrangement are low maintenance, low initial cost and simple operation. The drawback of this arrangement is if any repair work is to be done on bus-bar, complete system get interrupted.

Figure below shows that three incoming and three outgoing line are connected to the single bus arrangement.

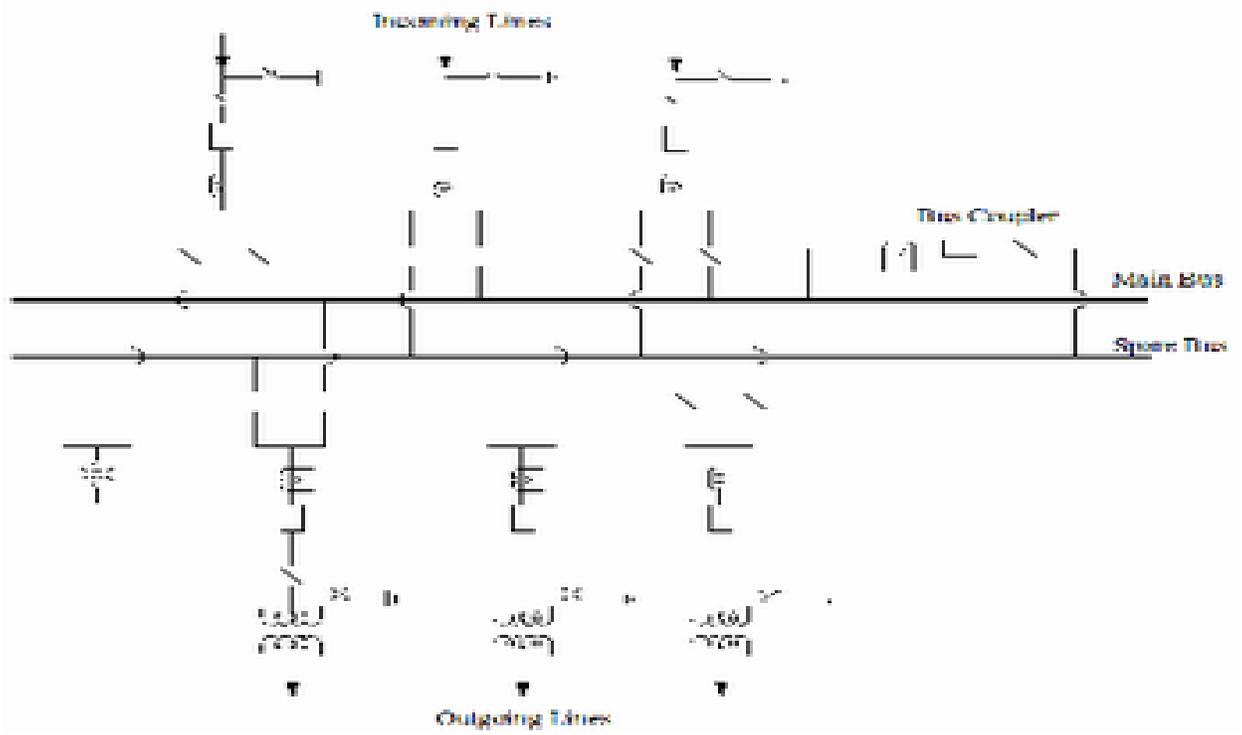


Single bus-bar with sectionalisation: Single bus-bar is divided into sections. Any two sections are connected by circuit breaker and isolators. During fault or maintenance particular section can be de-energised. This eliminates complete shutdown of the system. Figure below shows that two incoming and two outgoing lines are connected bus section 1 and other two incoming and two outgoing lines are connected bus section 2.



Double bus-bar arrangements: This arrangement is also known as duplicate bus-bar system. It consists of two bus-bars 'main' and 'spare' of same capacity. Incoming line and outgoing lines can be connected to either bus by means of bus coupler breaker and isolators. Continuity of supply to the circuit can be maintained during maintenance of main bus-bar or fault occurring on it.

Figure below shows that three incoming lines and three outgoing lines are connected to either bus by a bus coupler.

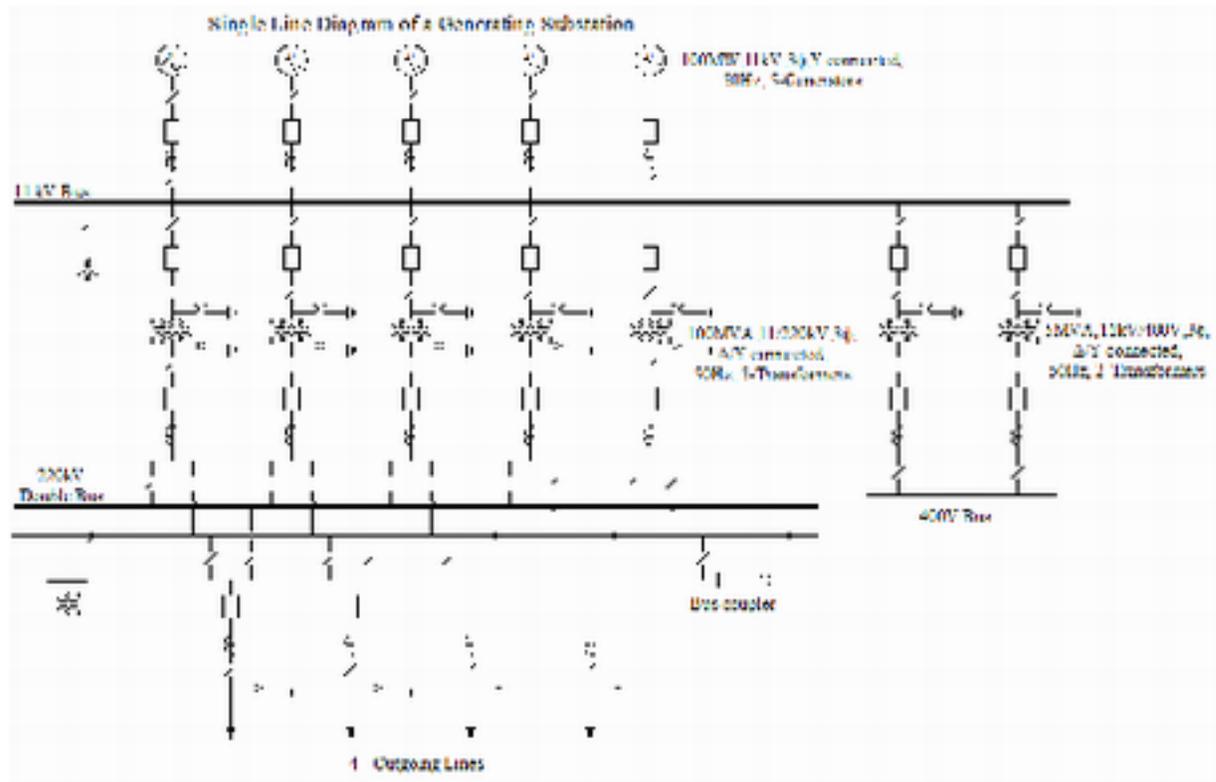


Problem 1

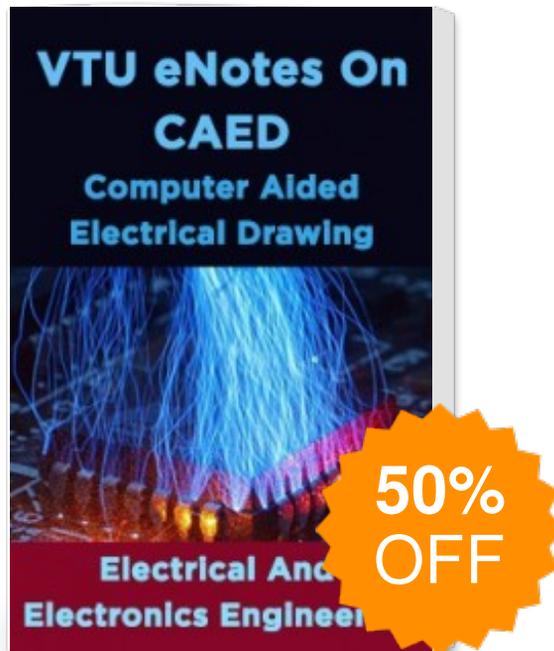
Draw the Single Line Diagram of a generating substation having the following main equipments:

- i) Alternators: Five, 100MW, 11kV, 3F, Y connected, 50Hz
- ii) Step-up transformers: Five, 100MVA, 11/220kV, D/Y, 3F, 50Hz
- iii) Bus: 220kV-Double bus with a bus coupler
- iv) Outgoing lines: Five, 220kV
- v) Station auxiliary transformers: Two, 5MVA, 11kV/400V, D/Y, 3F, 50 Hz

Show the positions of CTs, PTs, isolating switches, lightning arresters, circuit breakers.



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