Module - 4 Substations

Normally large power generating stations are built far away from the load centres, There are a number of transformations and switching stations which are built inbin generating stations & to the customers, which are known as substations.

A typical substation consisting of transformers, circuit breakers, disconnecting switches, station bays, insulators, reactors, capacitors, CT & PT's, grounding slm, LA & spark gaps, wave traps, protective relay, station batteries etc.

* Types of substations.

depending on the purpose, the substations may be classified into five categories.

① Generating substations or step up substations:-
In generating substation, the generating voltages are limited and need to be stepped up to transmission voltage therefore large amount of power generation is to be transmitted over long period, in large amount.

Each generating unit is connected to the generating transformers to increase the secondary voltage upto transmission voltage levels.

* Grid substations :- These substations are located in the intermediate points bln the generating stations & load centres. the main purpose of these substations are to provide connections of low voltage lines, some compensating devices etc.

* Secondary substations :- Secondary substations are connected with main grid substation with the help of secondary

secondary transmission line. The voltage at these substation is stepped down to the transmission voltage. Some of the large consumers are also connected to these substations.

* distribution substations :- These substation is located where subtransmission voltage is to be stepped down to the supply voltage. These substations feed power to the actual consumers through distributors & service line

* Special purpose substations :- These substations are specified for some special applications such as for bulk power transmission & supply of industrial loads.

for example → Traction substation & mining substation.

However some special considerations are required in these substations such as load distribution in phases in traction substation & safety precautions in the mining substations.

* depending on physical feature the substations are also classified as follows.

① outdoor type ② Indoor type ③ pole mounted ④ underground type

* outdoor type :- Normally outdoor substations are used for 33-kV voltage and above for cost and safety reasons. The air clearance required is more

All the equipments lie open in the air & control and monitoring is performed inside the control room.

* Indoor type :- The equipments of this substation lie in a room. The operating voltages are normally 400V &

11kV. The substations are usually located in big cities.

* pole mounted or open type :- as the name indicate these substations are mounted on pole, they are very simple and cheap, as their is no building for housing the equipments are required these substations are having very low capacity 500-kVA transformer.

* underground type :- these substations are used when space is not available. whole substation is made underground. The size of the substation can be high or low depending upon the capacity.

Usually the design of substation aims to achieve a high degree of continuity, maximum reliability and flexibility, to meet these objectives with the highest possible economy.

* Location of Substation

Location of distribution substation depends on the several factors such as voltage levels, voltage regulation considerations, subtransmission costs, substation costs, & the cost of primary feeders, mains & distribution transformers.

Some non-technical factors such as availability of land, public safeties etc. are also important as far as the industrial and commercial substations are concerned, they are normally located near to or within the premises of the consumer.

* to select ideal location for a distribution substation, following rules are to be considered →

① Locate the substation as much as close to the load centre of its service area.

② Locate the substation such that proper voltage regulation can be obtained without taking extensive measure.

③ Select the substation location such that it provides proper access for incoming subtransmission line and outgoing primary feeder and also capable to handle the future expansion.

④ Selected location should be in accordance with the the electricity rule and land use regulation.

⑤ The selected substation should help to minimize the number of customers affected by any service discontinuity.

* Bus bar arrangement Schemes

The choice of bus scheme depends on the relative importance assigned to such items as safety, reliability voltage level, simplicity of relay, flexibility of operation, cost, maintenance, available ground area, location of connecting lines, provision of expansion

* Single Bus Scheme

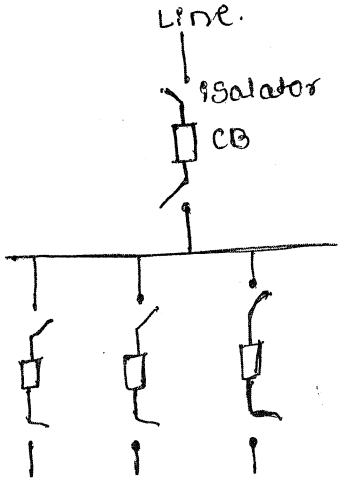

fig - Single bus scheme.

Above fig shows typical single bus scheme for voltage of 33kV. or lower & has a simple design.

* It is used in small small outdoor substations with few no of outgoing or incoming feeders and lines.

* The main advantage is its cost is low.

at the same time it has several disadvantages they are as follows. ① dependancy on a single bus may cause serious outage during the bus failure.

② difficulty to do any type of maintenance work.

③ Bus can't be extended without completely de-energizing the substation

④ It can be used only where load can be interrupted

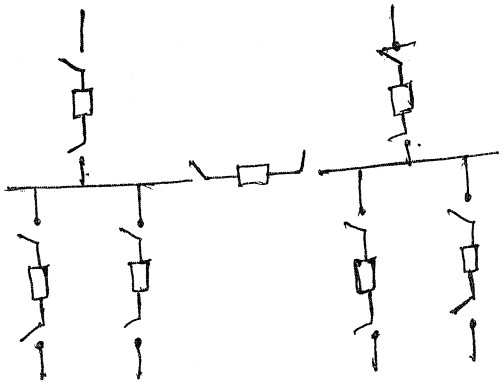

fig b) Single bus scheme with bus sectionalizer.

As shown in the above fig, In single - bus bar scheme with sectionalizer, in which bus bar is normally divided into two sections, with the help of breaker & isolator.

* The incoming & outgoing circuits are evenly distributed each section acted as a separate bus bar

* <u>double Bus with double Breaker</u>

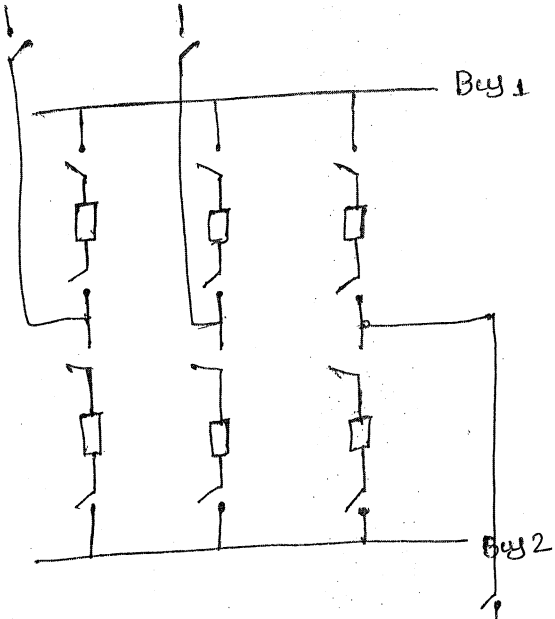

fig - Double bus with double breaker

Such type of scheme are much more useful in most of the purpose. addition of load & well continuity supply increases the cost. The main advantages are :-

a) Each circuit by two dedicated breakers.
b) Any breaker can be taken out for maintenance
c) It is more reliable than Single bus scheme
d) It is much more flexible.

* <u>double bus with Single breaker</u>

As shown below this scheme use two main buses & connected with two disconnecting switches → a bus tie - CB <u>or</u> bus coupler is used as it enable

a load change over from one bus to other.

the advantages are

① It permits some flexibility with two operating buses

② either bus 1 or bus 2 can be isolated for maintenance.

③ circuit can be transferred by the use bus the breaker & isolator.

*drawbacks are.

a) an extra breaker is required.

b) four isolators are required per circuit.

c) Bus tie-breaker fault takes entire substation out of service.

d) It will not permit maintance without stopping supply

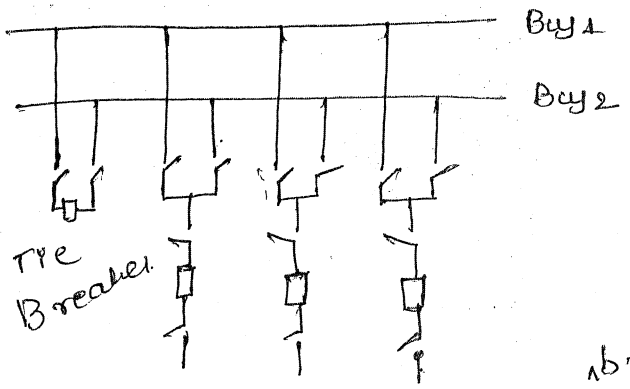

fig- double bus single breaker scheme.

* Main & transfer Bus.

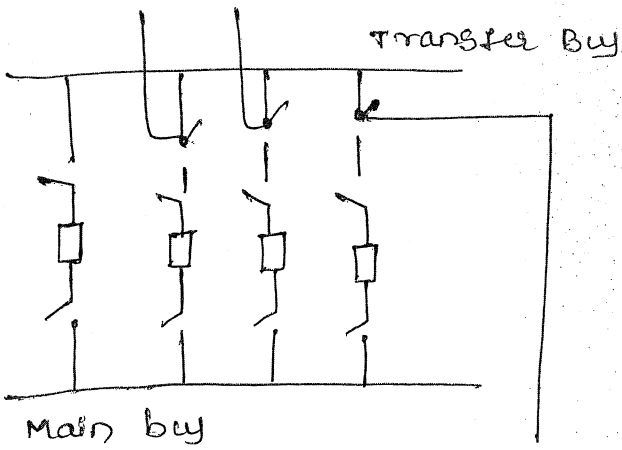

fig - Main bus & transfer Bus.

The above fig shows main & transfer bus, which is more commonly used in distribution substation.

In this scheme several circuit breakers are saved, however one extra breaker is provided to tie the main and transfer bus.

* the main advantage of this scheme is its intial cost is low, & ultimate cost is also low.
* any breaker can be taken out of service for maintenance and potential devices may be used on the main bus for relaying.
* The main drawback of the sim is — Switching is some what complicated when maintaining a breaker, failure of bus or any of CB results in complete shut down of entire substation. & it may addition of circuit breaker.

* Ring Bus

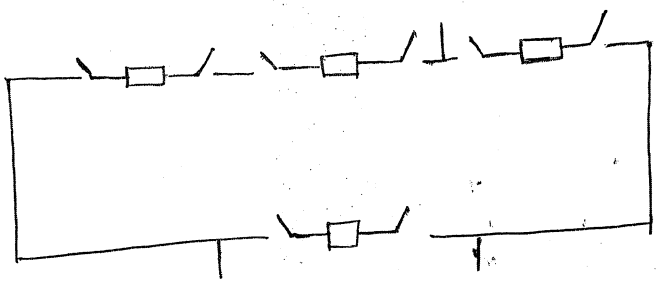

fig - Ring bus or mesh scheme

* disadvantage
① Automic reclosing & protective relaying circuitary is complex
② during fault occurance ring is divided into two sections.

The scheme is also known as mesh scheme, it requires only one CB per circuit. The advantages of the scheme are→
① low initial cost ② flexible operation for breaker maintenance
③ any breaker can be taken out for maintenance purpose without interrupting load. ④ it does not use main bus ⑤ each circuit is fed by two breakers
⑥ all switching is done through breaker.

* Breaker and a Half with two main Buses

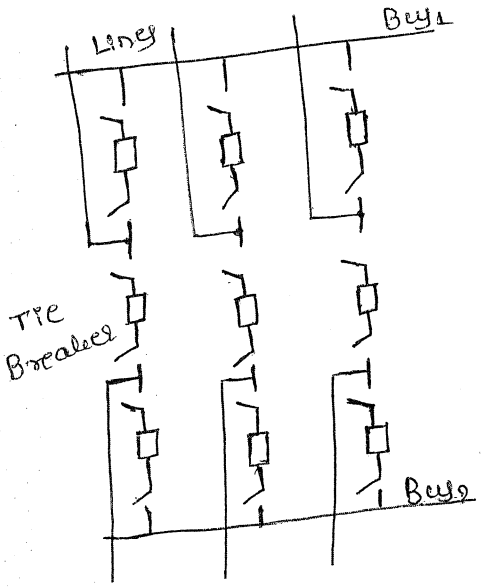

fig- Breaker & a half scheme

It is an improvement double-bus, double-breaker scheme to save the cost of breakers. As shown above three breakers are used in series b/n the main buses.

* under normal operating condition all the breakers are closed & the main buses are energized.

* To trip a circuit, two associated CBs must be opened. The disadvantage of the scheme is complicated protection.

* advantages

① Most flexible operation.
② High reliability
③ all switching is done with breakers
④ either main bus can be taken out of service with supply interruption.
⑤ Bus failure does not remove any feeder circuit from service.
⑥ Simple operation & no disconnect switching required for normal operation.

* Double bus-bar with Bypass Isolators

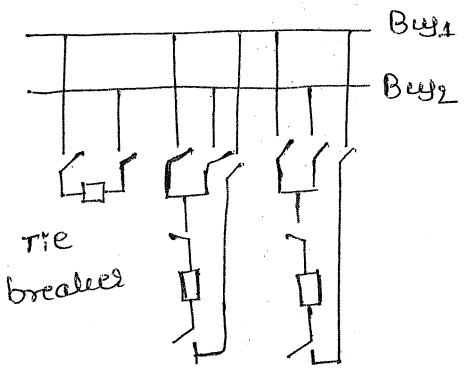

fig - double bus with bypass isolator

This is a scheme similar to main & transfer bus out of both bus any bus can act as main bus & other bus will act as transfer bus.

* The main advantage of the scheme ~~are~~ is any breaker can be taken out of service without interrupting the supply of any feeder, The scheme is very simple & economical.

* Grounding :- A proper grounding is must required for safe and reliable operation of the substation.

* all power systems will operate with grounded neutral.

* The neutral earthing is one of the most important feature is substation design.

* due to defective electrical apparatus & some other reasons, electricity causes electric shock hazards for human being and animals. ∴ it is a common practice to connect electric supply sys to ground at suitable points.

* Grounding is a measure concern to increase the reliability of supply service, as it provides stability of voltage conditions prevents excessive voltage peaks during the disturbances

* Resistance Grounding

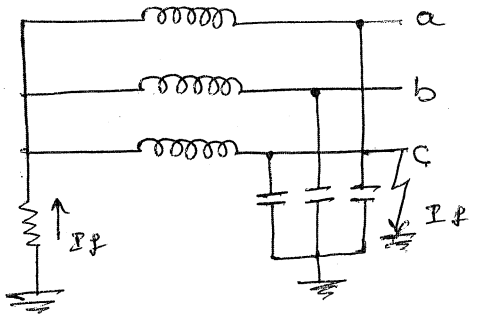

fig - Resistance grounding

For the voltage level b/n 3.3kv & 22kv, the ground clr is not large to use reactance grounding.

* The ground fault clr, for solid grounding become very high. ∴ the neutral point is connected with resistance which is known as resistance grounding.

* To limit the fault clr high resistance is used which save the power loss & improves the stability of the sys during the fault.

* for the ckt below 3.3kv, there is no need of external resistance because the earth fault clr can be limited due to inherent ground resistance ie 1.5 ohm

* In resistance grounding sys, the power loss during the line to ground fault is the main consideration

* Normally resistor value is given by $R = \frac{V_{LL}}{\sqrt{3} I}$

* interconnection of substations.

Where I is the full load c/n of largest m/c in amperes.

* peterson gave the formula for resistor

$$R = (2.0 \text{ to } 1.25) \frac{1}{C_a C_b C_c}$$

Where C_a, C_b, C_c are capacitances of each phase to earth.

* Reactance grounding.

Between the voltage 3.3kV and 22kV, the solid grounding is not used due to excessive fault c/n & resistance & reactance grounding must be used.

∴ resistance & reactance grounding must be used.

To limit the fault c/n resistance is popular in UK. whereas reactance is popular in Europe.

* The reactance connected b/n neutral & ground provides the lagging c/n which neutralize the capacitive c/n.

* there is no rule for use of either resistance or reactance.

* whenever charging c/n is high, such as for cables EHV transmission capacitors of the reactance grounding is used. otherwise resistance grounding is preferred.

* The grounding of solid & reactance is decided by following relations for solid grounded $\sin X_0/X_1 < 3.0$

12.1.5.101.15

9/5/17 — 3, 5, 6, 17, 24, 30, 33, 38, 44, 45, 51, 54, 64, 69

10/5/17 — 7, 12, 14, 15, 17, 19, 20, 24, 25, 27, 34, 50, 51, 53, 56, 64, 68,

* Introduction to Substation equipments

A Substation has several equipments :- transformers, circuit breakers, disconnecting switches, fuses, station buses, insulators, reactors, current & potential transformers, grounding slm, Lightning arrestors, gaps, line traps, protective relay, station batteries etc.

* protective relay :- A protective relay is a type of protective device, which gives an alarm signal or to cause prompt removal of any element from service when the element behaves abnormally.

The functions of protective relay are

① The removal of component which is behaving abnormally by closing the trip circuit of circuit breaker or to sound an alarm.

② In order to disconnect the abnormally operating part to avoid damage or interference effective operation of rest of the system.

③ To prevent the subsequent faults by disconnecting the abnormally operating part.

④ relays are helpful to disconnect the faulty part as early as possible to minimize the damage to the faulty part of the slm itself.

⑤ to improve the slm performance, slm reliability, slm stability & service continuity the relays are helpful.

* Circuit Breaker:- Circuit Breaker normally gets the signal from protective relays to operate, is an automatic switch which can interrupt the fault current. circuit breaker consists of two contacts one is fixed contact & other is moving contact. under normal operating condition both the contacts of CB are fixed, during abnormal running condition the arc is gets introduced bin the contacts of CB & it trip to separate faulty & unhealthy part of power system.

The circuit breakers are classified on the basis of rated voltage such as low-voltage CB & high voltage CB. Based on the medium of arc extinction, the circuit breakers are also classified as follows.

a) Air break circuit Breaker (used upto 12kV) & miniature circuit breaker (up to 600V), & air is considered at the atmospheric pressure.

b) Oil circuit Breaker

c) Minimum oil circuit Breaker (for 3.6-245kV)

d) Air blast circuit breaker (for 245 - 1100kV) where compressed air is used.

e) SF_6 circuit breaker (for 36-420kV) where SF_6 gas is used.

f) Vacuum circuit breaker (up to 36kV) where vacuum is used as arc quenching medium.

⇒ Based on the mode of arc extinction, circuit breakers can be classified as high-resistance interruption circuit Breaker & low resistance (zero point interruption CB.

The circuit breakers are decided based on voltage & fault current of the place where it is to installed.

The voltage rating of circuit Breaker is normally from 1.05 to 1.10 times more than the normal operating voltage. for example if the rating of CB for 400kV would be 420kV.

Most of the EHV circuit breakers are provided with auto reclosure.

* Reactors and capacitors:-

To limit the line charging c/n, long distance EHV lines are connected with line reactors at both the ends, These reactors are permanently connected to the line.

* Beside these, there are bay reactors & tertiary reactors which are connected with switches. These are used during light-loading conditions and at the line charging.
* Bay reactors are connected at the substation bay, where as tertiary reactors are connected in the tertiary winding of the transformers.

By using these reactors Ferranti effect is reduced.

* Capacitors are normally connected in low-voltage systems during peak-load conditions, the system voltage fall & therefore capacitive reactive power is required.
* In EHV system, it is preferred to use Static VAr System because it takes care of reactive power which can supply both leading and lagging reactive powers.
* In distribution system or in Sub-transmission system, capacitors are connected to improve the power factor of the system.
* Lightning arrester:- It is also known as surge arrestor normally connected b/n the phase and ground at

at the substation, Lightning arrester is used to protect the substation equipments due to lightning and switching surges.

* Surge arrestors offer low resistance to the high voltage surge for diverting to the ground.
* after discharging the surge energy to ground, it blocks the normal current flowing to ground by providing high resistance path.

* Isolators & fuses :- An isolator operates under no-load condition [High voltage disconnect switches] and does not have any c/n breaking & making capacity & it is used for disconnecting the CB from live part. Isolators are used in addition to CBs which can make & break the circuit under normal & short circuit conditions.
* for opening a circuit, the CB is opened 1st & then isolator is operated.
* In addition to isolator & circuit breaker, another device known as load break switch combines the function of isolator and switch.

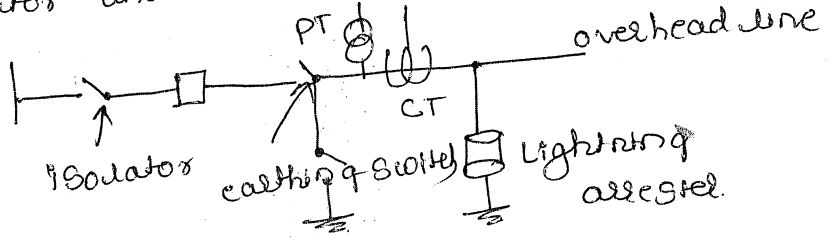

fig - Isolator position

A fuse is a simple protective device, used for protection of excessive currents due to overload or fault. They are normally used up to 600V installations. HRC fuses are more reliable & give better discrimination & accurate characteristics.

* power transformers :- A power transformer is used in a sub-station to step up or step-down the voltage. Except at the power station, all the subsequent sub-stations use step-down transformers to gradually reduce the voltage of electric supply and finally deliver it at utilisation voltage. The modern practice is to use 3-phase transformers in substations, even 3 single phase bank of transformers can be used.

* The use of 3-phase transformer permits two advantages

1) only one 3phase load tap changing mechanism can be used.

2) 3-phase transformer installation is much simpler than three single phase transformers.

The transformer specification includes

1) kVA rating
2) Rated voltage
3) No of phase
4) Rated frequency
5) connections
6) Tapping if any
7) Type of core
8) Type (power or distribution)
9) Ambient Temperature

* ~~High voltage fuse~~

* High voltage disconnect switches [Isolators & fuse] :-

In sub-stations, it is often desired to disconnect a part of the system for general maintenance and repair. This is accomplished by an isolating switch or isolator.

* An isolator is essentialy a knife switch and it is designed to open a circuit under no load. In other words, isolator switches are operated only when the line in which they are connected will not carry current.

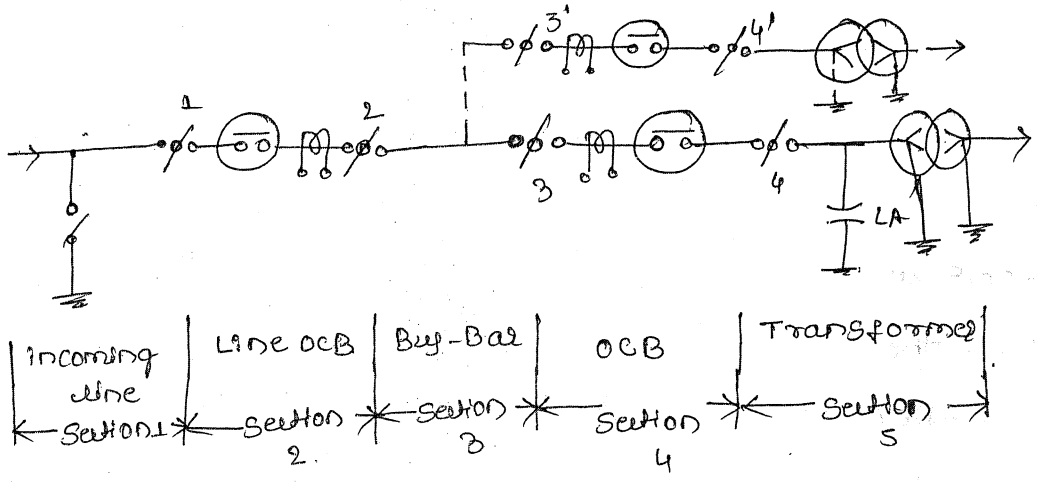

fig - typical Sub-station

The above fig shows use of isolators in a typical sub-station, The entire substation is divided into 5 sections

* Each section is disconnected with the help of isolators for repair and maintenance purpose.
* for example if section 2 is taken for repair purpose initially, open the CB in this section & then open isolators 1 & 2 first & then the CB.

* High voltage insulators :- The insulators serve for two purposes. They support conductors (or bus bars) and confine the current to the conductors.
* most commonly used material for insulator is procelain
* There are several types of insulators (pin type, suspension type, post insulator etc)
* The use of insulator in sub-station depends upon the service requirement, for example post insulator is used for bus-bars,
* A post insulator consists of a procelain body cast

iron cap and flanged cast iron base. The hole in the cap is threaded so that bay-bay can be directly bolted to the cap.

* Voltage Regulators :- voltage regulators are the devices which are used to supply the regulated voltage to power systems.

Voltage regulator is designed to maintain a constant voltage level automatically. depending upon the design, it may be used to regulate one or more Ac or dc voltages. In an electronic power plant, the voltage regulators may be installed at a substation or along distribution lines so that all customers receive steady voltage independent of how much power is drawn from the line

* Storage Batteries :- In electric power stations and large capacity substations, the operating and automatic control ~~body~~ circuits, the protective relay systems, as well as emergency lighting circuits are supplied by station batteries.

* The latter constitute independent source of operative and guarantee operation of the above mentioned circuits irrespective of any fault which has occurred in the station or substation, even in the event of complete disappearance of the ac supply in the installation

* station batteries are assembled of a certain number of accumulator cells depending on the operating voltage of the respective dc circuits.

Lead-acid batteries are most commonly used in power stations and substations because of their higher cell voltage & low cost.

* Measuring instruments :- Ammeters, voltmeters, wattmeters, kWh meters, kVARh meters, power factor meters, reactive volt-ampere meters are installed in substations to control & maintain a watch over the c/n flowing through the circuit and over the power loads.

* power line carrier communication equipment :-

Such equipment is installed in the substations for communication, relaying, telemetering or for supervisory control. The equipment is suitably mounted in a room known as carrier room and connected to the high voltage power circuit.

* Interconnection of power stations

The connection of several generating stations in parallel is known as interconnected grid system.

The various problems facing the power ~~station~~ engineers are reduced by interconnecting different power stations in parallel.

* even though the interconnection of station includes extra cost, yet considering the benefits, nowadays such s/m is gaining more importance.

* Sum advantages of interconnected power station are as follows ⟹

1) Exchange of peak load :- The peak load of the power station can be exchanged with the help of interconnected s/m.

If the load curve of a power station shows a peak demand which is greater than the rated capacity of the plant, then excess load can be shared by the other stations interconnected with it.

2) use of older plants :- The interconnected power s/m makes it is possible to use the older plants & less efficient plants to carry peak load for short duration.

3) Ensures economical operation :- interconnected power s/m makes the operation of concerned power station quite economical, because the sharing of load among the station is arranged such that, more efficient stations operate continuously throughout the year at a higher load factor & less efficient plants work only for peak load condition

4) increases diversity factor

5) ~~Reserve~~ Reduces plant reserve capacity

6) Increases the reliability of supply.

*. ~~[illegible]~~