

STUDY OF 220KV SUBSTATION
PASSIANA(PSTCL)

BY

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PATIALA

JANUARY-APRIL(2016)

DECLARATION

I hereby declare that the project work entitled “Study of 220 KV Sub-Station” is an authentic record of my own work carried out at PSTCL (**220 KV substation**,) as requirements of four months project semester for the award of degree of B.E. Electrical Engineering, PEC University of Technology (Deemed University), Chandigarh, under the guidance of **Er.GIAN CHAND** (Industry Coordinator) and **Prof. SHIV NARAYAN**(Faculty Coordinator), during January to May, 2016.

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Certified that the above statement made by the student is correct to the best of our knowledge and belief.

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SUMMARY

A Power System consists of various electrical components such as Generating units, transformers (Power and Distribution), transmission lines, isolators, circuit breakers, bus bars, cables, relays, instrument transformers, distribution feeders, and various types of loads.

Faults may occur in any part of power system such as short circuit & earth fault. Faults may be of the following types-Single Line to Ground (SLG), Double Line to Ground (DLG), Line to Line (LL), three phase short circuit etc. This results in flow of heavy fault current through the system. Fault level also depends on the fault impedance which depends on the location of fault referred from the source side. To calculate fault level at various points in the power system, fault analysis is necessary.

The protection system operates and isolates the faulty section. The operation of the protection system should be fast and selective i.e. it should isolate only the faulty section in the shortest possible time causing minimum disturbance to the system. Also, if main protection fails to operate, there should be a backup protection for which proper relay co-ordination is necessary.

The scope of the project is

To study and analyze a part of power system in 'PSTCL' with respect to fault analysis at different fault locations and verifying the short time current withstand capacity of the protective devices placed in the system.

To study and ensure the Relay Co-ordination in the part of power system.

To analyze the effect of addition of 54.35 MW captive generation plant on the fault level.

ACNOWLEDGEMENT

Summer training has an important role in exposing the real life situation in an industry. It was a great experience for me to work on training at **PUNJAB STATE TRANSMISSION CORPORATION LIMITED** through which I could learn how to work in a professional environment.

Now, I would like to thank the people who guided me and have been a constant source of inspiration throughout the tenure of my summer training.

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I am sincerely grateful to **ER. GIAN CHAND (SSE) at 220 KV SUBSTATION, Passiana (Patiala)** who rendered me his valuable assistance, constant encouragement and able guidance which made this training actually possible.

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1.INRODUCTION

The present-day electrical power system is A.C. i.e. electric power is generated, transmitted and distributed in the form of alternating current. The electric power is produced at the power stations which are located at favourable places, generally quite away from the consumers. It is delivered to the consumers through a large network of transmission and distribution. At many places in the line of the power system, it may be desirable and necessary to change some characteristic (e.g. voltage, A.C.

to D.C., frequency, Power factor etc.) of electric supply.

This is accomplished by suitable apparatus called sub-station. For example, generation voltage (11KV or 6.6KV) at the power station is stepped up to high voltage (say 220KV or 132KV) for transmission of electric power. The assembly of apparatus (e.g. transformer etc.) used for this purpose is the sub-station. Similarly, near the consumer's localities, the voltage may have to be stepped down to utilization level. This job is again accomplished by a suitable apparatus called '**substation**'.

History

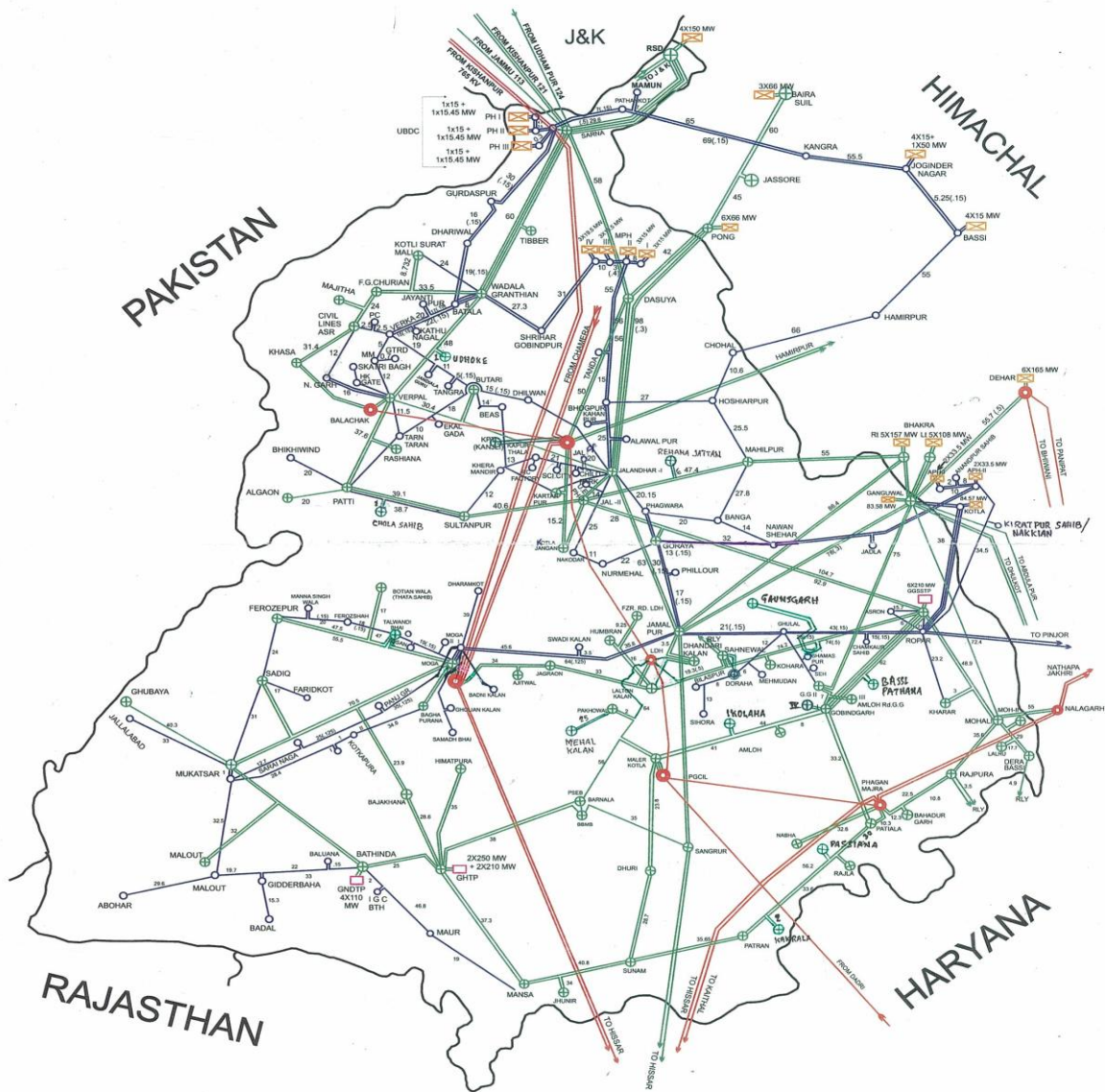
The Government of India has initiated reforms for liberalizing the power sector in the country to contain T&D losses, burgeoning subsidy burden and rampant corruption & for improving overall efficiency by making every individual accountable. The enactment of Indian Electricity Act 2003 was the first step in this direction.

Joining the league of other states in India, regarding implementation of Power sector reforms, Punjab Government has also unbundled Punjab State Electricity Board (PSEB), which was a statutory body formed on 01/02/1959 responsible for Generation, Transmission and Distribution of electricity in the state of Punjab.

Vide Notification No 1/9/08-EB(PR)196, dated-16.04.2010 Govt. of Punjab carved out following two corporations out of erstwhile PSEB:

- Punjab State Power Corporation Limited (PSPCL)
- Punjab State Transmission Corporation Limited (PSTCL), Acting as State Transmission Utility (STU), PSTCL has been entrusted with the transmission business of the erstwhile Punjab State Electricity Board (PSEB). Functions of State Load Dispatch Center shall also be discharged by PSTCL

PUNJAB STATE TRANSMISSION CORPORATION LIMITED **TRANSMISSION MAP OF PUNJAB** **132 KV & ABOVE AS ON 31-3-2013**



NOTE: LINE LENGTH/ARE INDICATED IN KMS ALONG WITH LINES.
CONDUCTOR SIZE OF ALL 220 KV LINES IS 0.4 SQ INCH
ACSR ZEBRA AND OF 132 KV LINES IS 0.2 SQ INCH
ACSR PANTHER UNLESS INDICATED OTHERWISE.

LEGEND				
Sr.No	Description	Trans Lines	Grid Sub Sln	Power Houses
1	132 KV SC DC			Thermal
2	220 KV SC DC			Hydro
3	400 KV SC DC			

ISSUED BY PLANNING PSTCL

Fig.1.1 Guide Map of PSTCL

ABOUT 220 KV SUBSTATION PASSIANA

220 KV Passiana substations is one of the important substations of PSTCL. It is a main source of power supply in the district of Patiala. The grid 220 KV Sub-Station, Passiana is situated 7-8 km from bus stand of Patiala to Samana Road. It contains 60.5 acres of land, 20.2 acres for yard and the rest of land for office building and residential colony. Land occupied for 220KV grid, Passiana is about 31.8 acres. Until 2007 it was transmitting 66KV energy and on 29 July 2008 it was up graded to 220KV substation.

INPUT FEEDERS OF 220 KV SUBSTATION PASSIANA

220 KV LINES

1. Ablowal
2. Fagganmajra

OUTPUT FEEDERS OF 220 KV SUBSTATION PASSIANA

220 KV LINES

1. Patran
2. Garrison

66 KV LINES

1. Mes
2. Shermajra
3. N.I.S.
4. Jhallan

5. Patiala-I
6. Dhakraba

1.1 CONSTRUCTION – Site Selection & Layout

- The site chosen should be as near to the load center as possible to good extent.
- The land should be have sufficient ground area to accommodate substation
 - equipments, buildings, staff quarters, space for storage of material, such as
 - store yards and store sheds etc. with roads and space for future expansion.
- The site should permit easy and safe approach to outlets for EHV line.
- It should be easily approachable by road or rail for transportation of equipments.
- Land should be fairly leveled to minimize development cost.
- Source of water should be as near to the site as possible. This is because water is required for various construction activities; (especially civil works,), earthing and for drinking purposes etc.
- The sub-station site should be as near to the town / city but should be clear of public places, aerodromes, and Military / police installations.
- Set back distances from various roads such as National Highways, State Highways should be observed as per the regulations in force.
- While selecting the land for the substation preference to be given to the Govt. land over private land.

- The land should not have water logging problem.
- The site should permit easy and safe approach to outlets for EHV lines.

TYPES OF SUBSTATIONS

1. Transformer substation
2. Switch substation
3. Power factor correction substation
4. Frequency change substation
5. Converting substation
6. Industrial substation

According to the constructional features:

1. Indoor substation
2. Outdoor substation
3. Underground substation
4. Pole mounted substation

TRANSFORMER SUBSTATION



Fig.1.2 Tranformer Substation

They are known as transformer substations as because transformer is the main component employed to change the voltage level, depending upon the purpose served.

Transformer substations may be classified into:

STEP UP SUBSTATION

The generation voltage is steeped up to high voltage to affect economy in transmission of electric power. These are generally located in the power houses and are of outdoor type.

PRIMARY GRID SUBSTATION

Here, electric power is received by primary substation which reduces the voltage level to 66KV for secondary transmission. The primary grid substation is generally of outdoor type.

SECONDARY SUBSTATION

At a secondary substation, the voltage is further steeped down to 11KV. The 11KV lines runs along the important road of the city. The secondary substations are also of outdoor type.

DISTRIBUTION SUBSTATION



Fig1.3 Distribution Substation

These substations are located near the consumer's localities and step down to 400V, 3-phase, 4-wire for supplying to the consumers. The voltage between any two phases is 400V & between any phase and neutral it is 230V.

SUBSTATION CHARACTERISTICS

- Each circuit is protected by its own circuit breaker and hence plant outage does not necessarily result in loss of supply.
- A fault on the feeder or transformer circuit breaker causes loss of the transformer and feeder circuit, one of which may be restored after isolating the faulty circuit breaker.
- A fault on the bus section circuit breaker causes complete shutdown of the substation. All circuits may be restored after isolating the faulty circuit breaker.
- Maintenance of a feeder or transformer circuit breaker involves loss of the circuit.
- Introduction of bypass isolators between bus bar and circuit isolator allows circuit breaker maintenance facilities without loss of that circuit.

1.2 STEPS IN DESIGNING SUBSTATION

Earthing and Bonding:

The function of an earthing and bonding system is to provide an earthing system connection to which transformer neutrals or earthing impedances may be connected in order to pass the

maximum fault current. The earthing system also ensures that no thermal or mechanical damage occurs on the equipment within the substation, thereby resulting in safety to operation and maintenance personnel. The earthing system also guarantees equipotential bonding such that there are no dangerous potential gradients developed in the substation.

In designing the substation, three voltages have to be considered these are:

Touch Voltage:

This is the difference in potential between the surface potential and the potential at earthed equipment whilst a man is standing and touching the earthed structure.

Step Voltage:

This is the potential difference developed when a man bridges a distance of 1m with his feet while not touching any other earthed equipment.

Mesh Voltage:

This is the maximum touch voltage that is developed in the mesh of the earthing grid.

1.3 Substation Earthing Calculation Methodology

Calculations for earth impedances, touch and step potentials are based on site measurements of ground resistivity and system fault levels. A grid layout with particular conductors is then analyzed to determine the effective substation earthing resistance, from which the earthing voltage is calculated.

In practice, it is normal to take the highest fault level for substation earth grid calculation purposes. Additionally, it is necessary to ensure a sufficient margin such that expansion of the system is catered for.

To determine the earth resistivity, probe tests are carried out on the site. These tests are best performed in dry weather such that conservative resistivity readings are obtained.

Earthing Materials

Conductors:

Bare copper conductor is usually used for the substation earthing grid. The copper bars themselves usually have a cross-sectional area of 95 square millimeters, and they are laid at a shallow depth of 0.25-0.5m, in 3-7m squares. In addition to the buried potential earth grid, a separate above ground earthing ring is usually provided, to which all metallic substation plant is bonded.

Connections:

Connections to the grid and other earthing joints should not be soldered because the heat generated during fault conditions joint to fail. Joints are usually bolted, and in this case, the face of the joints should be tinned could cause a soldered.

Earthing Rods:

The earthing grid must be supplemented by earthing rods to assist in the dissipation of earth fault currents and further reduce the overall substation earthing resistance. These rods are usually made of solid copper, or copper clad steel.

Switchyard Fence Earthing

The switchyard fence earthing practices are possible and are used by different utilities. These are:

- Extend the substation earth grid 0.5m-1.5m beyond the fence perimeter. The fence is then bonded to the grid at regular intervals.
- Place the fence beyond the perimeter of the switchyard earthing grid and bond the fence to its own earthing rod system. This earthing rod system is not coupled to the main substation earthing grid.

CONDUCTORS USED IN SUBSTATION DESIGN:

1. An ideal conductor should fulfill the following requirements:
2. Should be capable of carrying the specified load currents and short time currents.
3. Should be able to withstand forces on it due to its situation. These forces comprise self weight, and weight of other conductors and equipment, short circuit forces and atmospheric forces such as wind and ice loading.
4. Should be corona free at rated voltage.
5. Should have the minimum number of joints.
6. Should need the minimum number of supporting insulators.
7. Should be economical.

Overhead Line Terminations

Two methods are used to terminate overhead lines at a substation.

1. Tensioning conductors to substation structures or buildings
2. Tensioning conductors to ground winches.

The choice is influenced by the height of towers and the proximity to the substation. The following clearances should be observed:

VOLTAGE LEVEL	MINIMUM GROUND CLEARANCE
less than 66kV	6.1m
66kV - 110kV	6.4m
110kV - 165kV	6.7m
greater than 165kV	7.0m

Table1.Clearance in accordance with voltage value

CLEARANCES

Distinction should be made between electrical clearances; necessary to ensure satisfactory performance in service and safety clearances which are required for safety of personnel in inspection; operation and maintenance work. Electrical clearances - This is minimum distance required between live parts and earth materials (earth clearance) or between live parts of different potentials (phase clearances) in order to prevent flashovers. Safety clearances to the conductor - {Live Part} - Minimum distance required between live conductor and the limits of work section for safety to personnel working.

GROUND CLEARANCES

The minimum distance required between any exposed insulator which supports or contains live conductor, and limits of work section where safety of personnel is ensured. Work Section - The space where the person may work safely provided he remains within that space.

FOR 220KV SYSTEM – (SINGLE BUS)

- ❖ Height and Bus forms ground - 12.5 meter
- ❖ Width to Bay - 18 Meters.
- ❖ Distance between formulations - 4.5 meters.
- ❖ Distance between equipments - 4.5 meters. (Right angle to Bus)
- ❖ Height of Earth wire from ground 15.5 meters 220KV / Bus two / three.
- ❖ Height of 1st Steel Bus above ground - 18.5 meters.
- ❖ Height of 2nd Bus - 25 meters (From ground).
- ❖ Height of Earth wire - above ground - 28.5 meters.

2. MAIN EQUIPMENTS

1. Power transformers.
2. Bus-Bar.
3. Potential transformer.
4. Current transformer.

5. Lightning arresters.
6. Circuit breaker.
7. Isolator.
8. Bus coupler and Sectionalizer
9. Power line communication equipment (PLCC).

3. TRANSFORMERS

Transformer is a static machine, which transforms the potential of alternating current at same frequency. It means the transformer transforms the low voltage into high voltage & high voltage to low voltage at same frequency. It works on the principle of static induction principle.

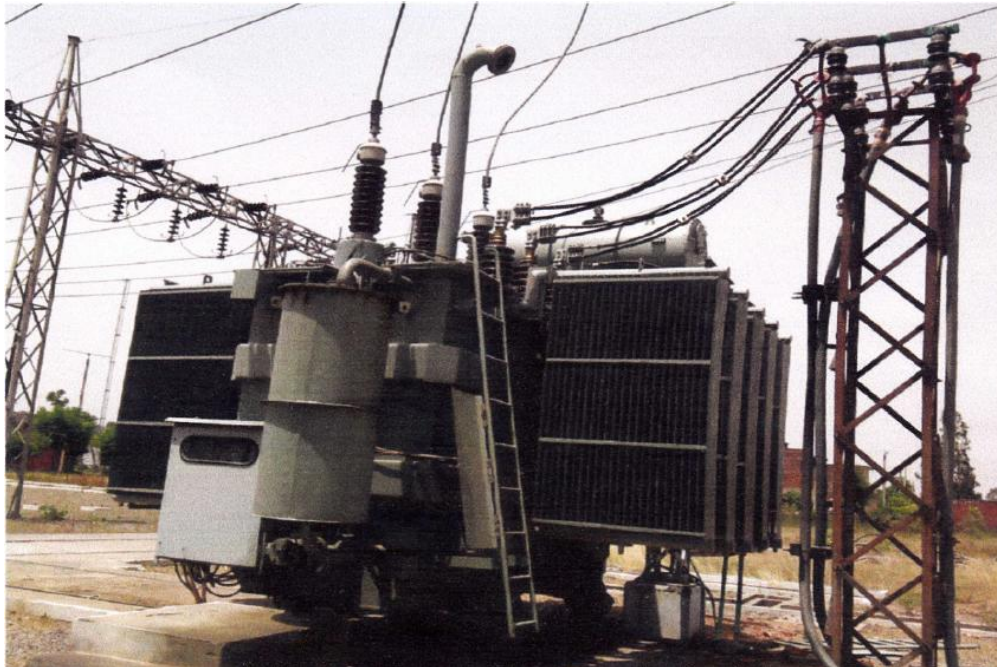


Fig.1.4 Transformer

When the energy is transformed into a higher voltage, the transformer is called step up transformer but in case of other is known as step down transformer.

TYPES OF TRANSFORMER

- (1)Power transformer
- (2)Instrument transformer
- (3)Auto transformer
- (4)On the basis of working

(5)On the basis of structure

POWER TRANSFORMER



Fig.1.5 Power Transformer

Types of power transformer:

- a) Single phase transformer
- b) Three phase transformer

INSTRUMENT TRANSFORMER

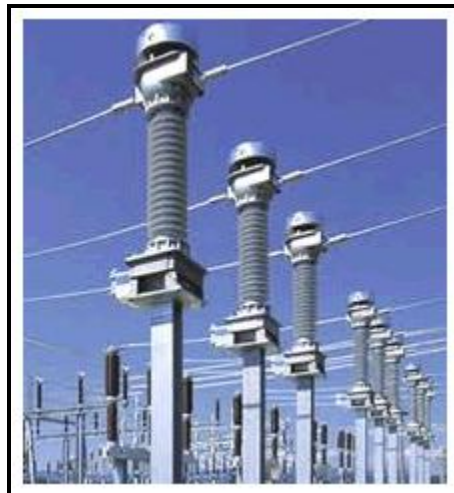


Fig.1.6 Instrument Transformers

- a) Current transformer
- b) Potential transformer

AUTO TRANSFORMER



Fig.1.7 Auto Transformer

- 1)Single phase transformer
- 2)Three phase transformer

POWER TRANSFORMER

The sub station has the two 220/66KV power transformers (100 MVA) installed made by BHEL and ABB and two 66/11KV power transformer (20 MVA) made by ECE and TA. The power transformers are used to step down the 220 KV incoming to 66KV and further step-down 66KV to 11KV.



Fig.1.8 Power Transformer

The power transformer serves as step down transformer it consist of transformer tank in which the windings are placed mounted on the core which is further attached to the sets of bushes there is a oil tank which is filled with transformer oil the tank serves for the cooling purposes. The buchholz relay is provided for the protection. The oil-filled tank often has radiators through which the oil circulates by natural convection; some large transformers employ forced circulation of the oil by electric pumps, aided by external fans or water-cooled heat exchangers. Oil-filled transformers undergo prolonged drying processes to assure that the transformer is completely free of water vapor before the cooling oil is introduced. This helps prevent electrical breakdown under load. Oil-filled transformers may be equipped with Buchholz relays, which detect gas evolved during internal arcing and rapidly de-energize the transformer to avert catastrophic failure. Oil-filled transformers may fail, rupture, and burn, causing power outages and losses. Installations of oil-filled transformers usually include fire protection measures such as walls, oil containment, and fire-suppression sprinkler systems.

CURRENT TRANSFORMER

There are 3 sets of the current transformers installed at the sub-station. Each set have three current transformers. Like any other transformer, a current transformer has a primary winding, a magnetic core, and a secondary winding. The alternating current flowing in the primary produces a magnetic field in the core, which then induces a current in the secondary winding circuit. A primary objective of current transformer design is to ensure that the primary and secondary circuits are efficiently coupled, so that the secondary current bears an accurate relationship to the primary current. The most common design of CT consists of a length of wire wrapped many times around a silicon steel ring passed over the circuit being measured. The CTs primary circuit therefore consists of a single 'turn' of conductor, with a secondary of many hundreds of turns. The primary winding may be a permanent part of the current transformer, with a heavy copper bar to carry current through the magnetic core.



Fig.1.9 Current Transformer

Care must be taken that the secondary of a current transformer is not disconnected from its load while current is flowing in the primary, as the transformer secondary will attempt to continue driving current across the effectively infinite impedance. This will produce a high voltage across the open secondary which may cause arcing. The high voltage produced will

compromise operator and equipment safety and permanently affect the accuracy of the transformer.

Potential Transformer

There 4 sets of the PT of 220kv/110v and 17 sets of 66kv/110v is installed at the substation. Potential transformers are instrument transformers. They have a large number of primary turns and a few number of secondary turns. It is used to control the large value of voltage. These are used for the metering purposes.



Fig.2.0 Potential Transformer

The potential transformer works along the same principle of other transformers. It converts voltages from high to low. It will take the thousands of volts behind power transmission systems and step the voltage down to something that meters can handle. These transformers work for single and three phase systems, and are attached at a point where it is convenient to measure the voltage. Potential Transformer is designed for monitoring single-phase and three-phase power line voltages in power metering applications.

The primary terminals can be connected either in line-to-line or in line-to-neutral configuration. Fused transformer models are designated by a suffix of "F" for one fuse or "FF" for two fuses.

A Potential Transformer is a special type of transformer that allows meters to take readings from electrical service connections with higher voltage (potential) than the meter is normally capable of handling without a potential transformer.

CAPACITIVE VOLTAGE TRANSFORMER

A capacitor voltage transformer (CVT), or capacitance coupled voltage transformer (CCVT) is a transformer used in power systems to step down extra high voltage signals and provide a low voltage signal, for measurement or to operate a protective relay. In its most basic form the device consists of three parts: two capacitors across which the transmission line signal is split, an inductive element to tune the device to the line frequency, and a transformer to isolate and further step down the voltage for the instrumentation or protective relay. The tuning of the divider to the line frequency makes the overall division ratio less sensitive to changes in the burden of the connected metering or protection devices. ^[1] The device has at least four terminals: a terminal for connection to the high voltage signal, a ground terminal, and two secondary terminals which connect to the instrumentation or protective relay. CVTs are typically single-phase devices used for measuring voltages in excess of one hundred kilovolts where the use of wound primary voltage transformers would be uneconomical. In practice, capacitor C_1 is often constructed as a stack of smaller capacitors connected in series. This provides a large voltage drop across C_1 and a relatively small voltage drop across C_2 .

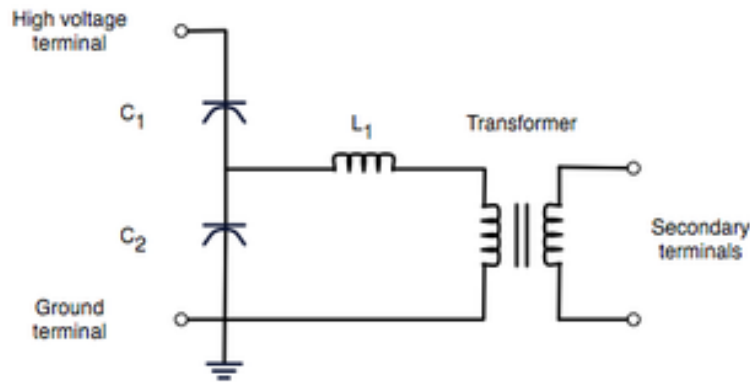


Fig.2.1 CVT

The CVT is also useful in communication systems. CVTs in combination with wave traps are used for filtering high frequency communication signals from power frequency. This forms a carrier communication network throughout the transmission network.

ON THE BASIS OF WORKING

Step down: Converts high voltage into low voltage.

Step up: Converts low voltage into high voltage.

ON THE BASIS OF STRUCTURE

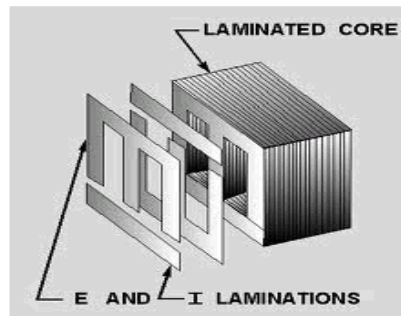


Fig.2.2Core type

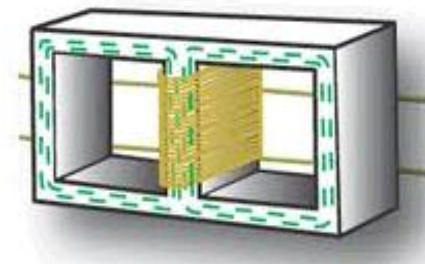


Fig.2.3Shell type

CORE

Cores can be constructed as either a toroidal or laminated. Toroidal units typically have copper wire wrapped around a cylindrical core so the magnetic fluxes, which occur within the coil, doesn't leak out, the coil efficiency is good, and the magnetic flux has little influence another components. Laminated refers to the laminated-steel cores. These steel laminations are insulated

with a non-conducting material, such as varnish, and then formed into a core that reduces electrical losses.

WINDING

In most practical transformers, the primary and secondary conductors are coils of conducting wire because each turn of the coil contributes to the magnetic field, creating a higher magnetic flux density than the single conductor.

Windings are usually arranged concentrically to minimize flux leakage. The winding material depends on the application. Small power and signal transformers are wound with insulated solid copper wire, often enamelled. Larger power transformers may be wound with wire, copper or aluminium rectangular conductors, or strip conductors for very heavy currents. High frequency transformers operating in the tens to hundreds of kilohertz will have windings made of Litz wire, to minimize the skin effect losses in the conductors. Large power transformers use multiply-stranded conductors as well, since even at low power frequencies non-uniform distribution of current would otherwise exist in large windings. Each strand is insulated from the others, and the strands are arranged so that either at certain points in the winding or throughout the winding, each portion occupies different relative positions in the complete conductor. This "transposition" equalises the current flowing in each strand of the conductor, and reduces eddy current losses in the winding itself. The stranded conductor is also more flexible than a solid conductor of similar size. Windings on both primary and secondary of a power transformer may have external connections (called taps) to intermediate points on the winding to allow adjustment of the voltage ratio; taps may be connected to automatic on-load tap changer switchgear for voltage regulation of distribution circuits. Audio-frequency transformers used for distribution of audio to public address loudspeakers have taps to allow adjustment of power supplied to each speaker. A centre-tapped transformer is often used in the output stage of an audio power amplifier in a push-pull circuit. Tapped transformers are also used as components of amplifiers, oscillators, and for feedback linearization of amplifier circuits.

INSULATION

The conductor material must have insulation to ensure the current travels around the core and not through a turn-to-turn short-circuit. In power transformers, the voltage difference between parts of the primary and secondary windings can be quite large. Insulation is inserted between layers of windings to prevent arcing, and the transformer may also be immersed in transformer oil that provides further insulation. To ensure that the insulating capability of the transformer oil does not deteriorate, the transformer casing is completely sealed against moisture ingress. The oil serves as both cooling medium to remove heat from the core and coil and as part of the insulation system.

TRANSFORMER OIL

The insulating oil has three purposes. It provides additional insulation, protects the insulation from dirt and moisture and it carries away the heat generated in the cores Coils. The heat is produced in the metal of the transformer, passes through the insulation and raises the temperature of oil and is then conducted either through the walls of the tank to the surrounding air or to the water through water cooling tubes. The oil which is extensively used is called transformer oil. It is obtained from the fractional distillation of the crude petroleum.

Transformer oil must fulfill the following specifications:

1. High dielectric strength
2. Low viscosity
3. Purity
4. High flash point
5. Good resistance to emulsion

In the main transformer T-2 the total quantity of oil used is 69920litres.

OIL GAUGE

It is used to indicate the oil level so that it can be read by a person standing on the floor. The oil gauge may be provided with the alarm contacts which give an alarm to the switch board when the oil level has dropped beyond permissible level due to oil leak, damage of cooler and due to any other reasons.

CONSERVATOR OR EXPANSION TANK

The main operation of conservator tank is to keep the oil clean and dry utmost temperatures. The oil level of a transformer changes with the change in load. The oil expands with the increase in load and vice versa. Large power transformers are also liable to over -loads which may overheat the oil and consequently there is a sludge formation if air is present. Occasionally large power transformer also suffer short-circuits and temperature rise become excessively high. This causes vaporizations of the oil. The oil vapours form explosive mixture with air that ignites and may cause a considerable damage. For these reasons it is necessary to prevent the oil from having contact with air as well as moisture. For this purpose conservators are employed.

BUCHHOLZ RELAY

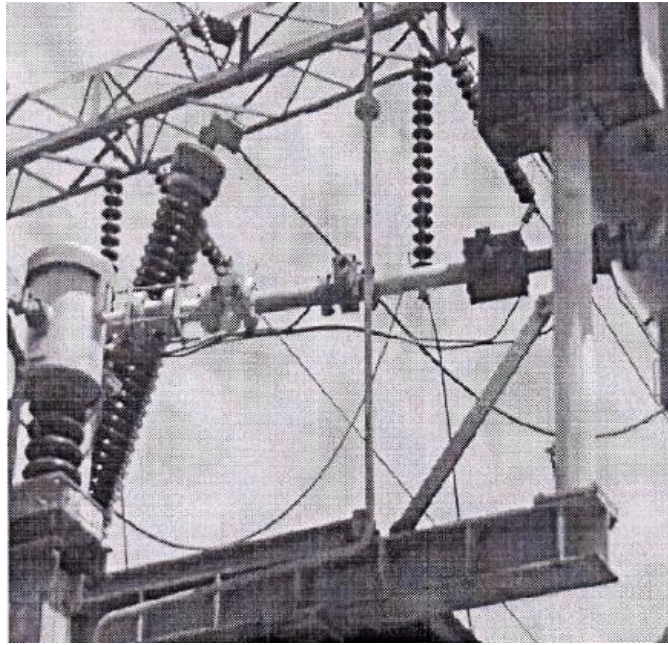


Fig.2.4 Buchholz Relay

It is gas and oil protective device and it is practically universally used on the oil immersed transformers having more than 750kva. It is installed in the pipe joining the main tank of the transformer to the conservator and is used to give alarm in case of minor fault and to disconnect the transformer from supply mains in case of severe internal faults. The use of such relay is possible only with transformer having conservators.

COOLANT

All transformers must have some circulation of coolant to remove the waste heat produced by losses. Small transformers up to a few kilowatts in size usually are adequately cooled by air circulation. Larger "dry" type transformers may have cooling fans. Some dry transformers are enclosed in pressurized tanks and are cooled by nitrogen or sulphur hexafluoride gas. The windings of high-power or high-voltage transformers are immersed in transformer oil - a highly-refined mineral oil that is stable at high temperatures. Large transformers to be used indoors must use a non-flammable liquid. Formerly, polychlorinated biphenyl (PCB) was used as it was not a fire hazard in indoor power transformers and it is highly stable. Due to the stability of PCB and its environmental accumulation, it is no longer permitted in new equipment. Today, nontoxic, stable silicone-based oils or fluorinated hydrocarbons may be used, where the expense of a fire-resistant liquid offsets additional building cost for a transformer vault. Other less-flammable

fluids such as canola oil may be used but all fire resistant fluids have some drawbacks in performance, cost, and compared with mineral oil. The oil cools the transformer, and provides part of the electrical insulation between internal live parts. It has to be stable at high temperatures so that a small short or arc will not cause breakdown or fire. The oil-filled tank may have radiators through which the oil circulates by natural convection. Very large or high-power transformers (with capacities of millions of watts) may have cooling fans, oil pumps and even oil to water heat exchangers.



Fig.2.5 Coolant

View of three Phase oil-cooled transformer. The oil reservoir is visible at the top. Radiative fins aid the dissipation of heat.

3.1 Transformer cooling

When the transformer is in operation heat is generated due to iron losses the removal of heat is called cooling.

There are several **types of cooling methods**, they are as follows:

Air natural cooling:

In a dry type of self cooled transformers, the natural circulation of surrounding air is used for its cooling. This type of cooling is satisfactory for low voltage small transformers.

Air blast cooling:

It is similar to that of dry type self cooled transformers with to addition that continuous blast of filtered cool air is forced through the core and winding for better cooling. A fan produces the blast.

Oil natural cooling:

Medium and large ratings have their winding and core immersed in oil, which act both as a cooling medium and an insulating medium. The heat produce in the cores and winding is passed to the oil becomes lighter and rises to the top and place is taken by cool oil from the bottom of the cooling tank.

Oil blast cooling:

In this type of cooling, forced air is directed over

Forced oil and water (OWF) cooling:

In this type of cooling oil flow with water cooling of the oil in external water heat exchanger takes place. The water is circulated in cooling tubes in the heatexchanger.

BREATHER



Fig.2.6 Breather

The breather is of silica gel type provided with seal to ensure the gel is not in direct contact with the external atmosphere but only with the quantity of air entering the conservator when transformer is breathing. active dry stage of the charge is indicated, the colour will change to whitish pin. Heating the charge in oven at 300f until such time blue colour of charge has been restored may do reactivation.

3.2 TESTS OF TRANSFORMER

While certain preliminary tests, carried out at different stages of manufacture provide an effective tool which assures quality and conformation to design calculations. The final tests on fully assembled equipments guarantee the stability of the equipment for satisfactory performance in service. In India, transformers are tested in accordance with is 2026|EC76 and CBIP guide lines. In this unit it is intended to cover the purpose and methodology of performing main tests on the power transformer.

The following tests are normally conducted on the transformer

Routine tests

1. Measurements of winding resistance
2. Measurement of voltage ratio and check of voltage vector relationship
3. Measurement of impedance voltage and load losses
4. Measurement of no load insulation resistance
5. Measurement of insulation resistance
6. Separate source voltage withstand test
7. Lightning impulse test

Type tests

1. Temperature rise test
2. Vacuum test on transformer tank during fabricated stage
3. Pressure test on completely assembled transformer

4. Lightning impulse test

Special tests

1. Measurement of zero -sequence impedance of three phase transformer
2. Measurement of harmonic of no load current
3. Short circuit test
4. Power taken by cooling pumps and fans

3.3 SPECIFICATION OF TRANSFORMER USED

At Passiana substation transformers manufactured by B.H.E.L, A.B.B, T.A and E.C.E are installed with their power ratings ranging from 20 MVA for 66/11KV to 100MVA for 220/66KV step down voltages .The main purpose of these transformers is to step down the voltages from 220 KV voltage to 11KV voltages by the use of four different trans formers installed in the substation. These transformers are generally insulated upon lengths of rails fixed on concrete slabs having foundation 1 to 1 and 1/2 meter deep. These transformers are provided with the tap changers with the main aim of regulation of the voltage.

T1 POWER TRANSFORMER



Fig.2.7 T1 Power Transformer

MAKE	B.H.E.L.
POWER RATING	100 MVA
C.T. RATIO	300-150/0.577-1-1-1-1
VOLTS AT NO LOAD (KV)	H.V. : 220 L.V. : 66

T2 POWER TRANSFORMER

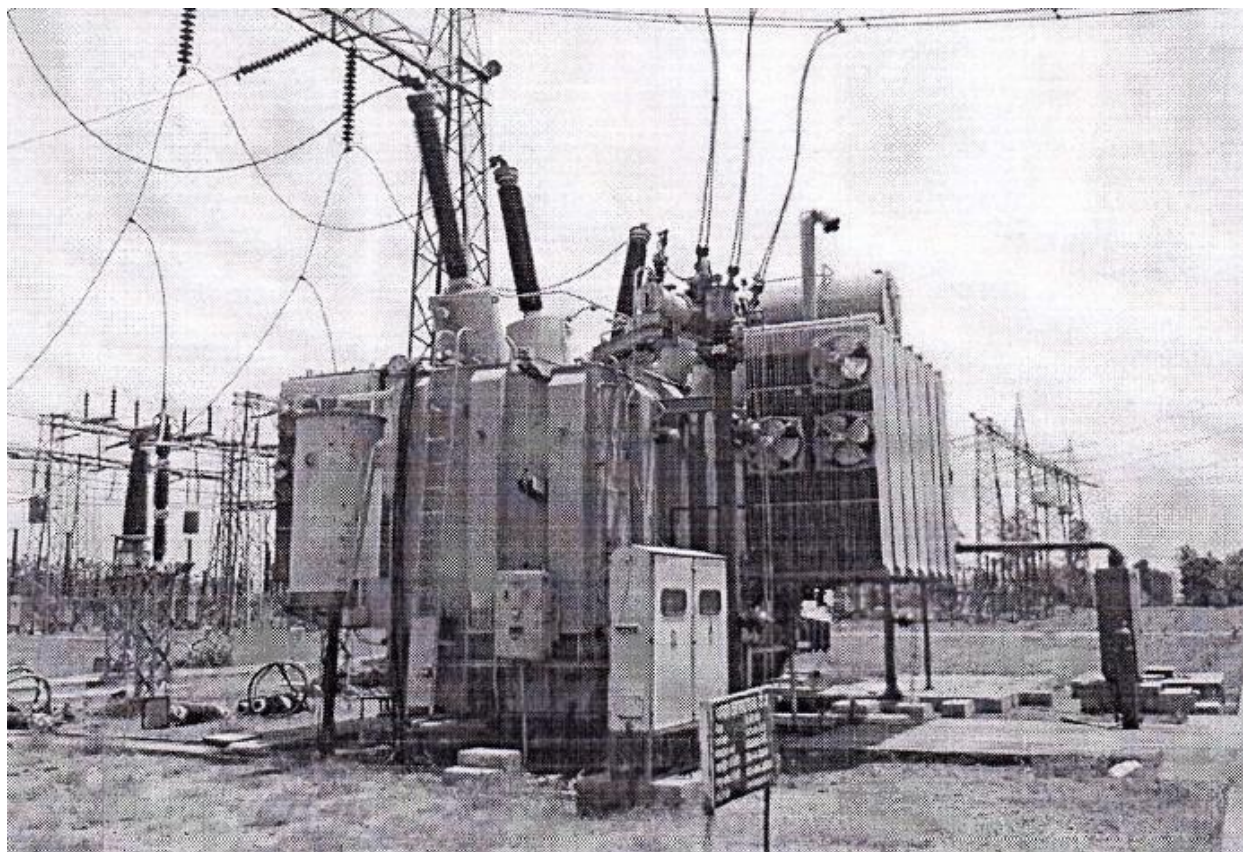


Fig.2.8 T2 Power Transformer

MAKE	ABB
POWER RATING	100 MVA
C.T. RATIO	300-150/0.577-1-1-1-1
VOLTS AT NO LOAD (KV)	H.V. : 220 L.V. : 66

T3 POWER TRANSFORMER



Fig.2.9 T3 Power Transformer

MAKE	T.A.
POWER RATING	20 MVA
C.T. RATIO	200-100/0.577-1-1-1
VOLTS AT NO LOAD (KV)	H.V. : 66 L.V. : 11

4.BUS-BARS

If the bus-bars are of rigid type (Aluminum types) the structure heights are low and minimum clearance is required. While in case of strain type of bus-bars suitable ACSR conductors are strung/tensioned strain by tension insulator discs according to system voltages. In the widely used strain type bus bars stringing tension is about 500-900 kg depending upon the size of conductor used and tensioning is manual by means of rope pulleys or by pull lifts. It may also with the help of tractors.

Here proper clearance would be achieved only if required tension is achieved. Loose bus bars would affect the clearances when it swings while over tensioning may damage insulators. Clamps or even affect the supporting structures in low temperature conditions. The clamping should be proper, as loose clamp would spark under in full load condition damaging the bus bars itself.

The bus bar is provided with lightning protection to safeguard the equipment against direct stroke by providing aerial earth wire giving a protection at 30 degree i.e. height and earth wires such that all the equipment and bus bar should be covered within this 30 degree.



Fig.3.0 Bus Bar

4.1BAR BUS ARRANGEMENT MAY BEOF FOLLOWING TYPES

1. Single bus bar arrangement.
2. Double bus bar arrangement.
 - a. Main bus with transformer bus.
 - b. Main bus-I with Main bus-II.
3. Double bus bar arrangement with auxiliary bus

BUS BAR ARRANGEMENT DEPENDS UPON

1. Interruption tolerable in the supply scheme.
2. Alternative supply arrangements in case of failure of Equipments.

BUS BAR ARRANGEMENT

1. **Single bus bar arrangement**-This arrangement is simplest and cheapest. It suffers,however, from major defects.

- a. Maintenance without interruption is not possible.
- b. Extension of the substation without a shutdown is not possible.

The equipment connections are very simple and hence the system is very convenient to operate. This scheme is not very popular for 33 kV and above, except where the relative importance of the substation is less or the position of the substation does not justify elaborate schemes. The indoor 11 kV switchyards have quite often single bus bar arrangement.

DOUBLE BUS BAR / CONTAINS MAIN BUS- I WITH MAIN BUS-II ARRANGEMENTS

This scheme has two bus bar so that-

- 1. Each load may be fed from either bus.
- 2. The load circuits may be divided in two separate groups if needed from operational consideration. Two supplies from different sources can be put on each bus separately.
- 3. Either bus bar may be taken out from maintenance and cleaning of insulators.

This arrangement has been quite frequently adopted where the loads and continuity of supply is necessary. In such a scheme a bus coupler breaker is mostly provided as it enables on load change over from one bus to other.

The normal bus selection isolators cannot be used for breaking load currents. The arrangement does not permit breaker maintenance without causing stoppage of supply.

DOUBLE BUS BAR ARRANGEMENTS/CONTAIN MAIN BUS WITH AUXILIARY BUS OR (TRANSFER BUS)

The double bus bar arrangement provides facility to change over to either bus to carry out maintenance on the other but provide no facility to carry over breaker maintenance. The main and transfer bus works the other way round. It provides facility for carrying out breaker maintenance but does not permit bus maintenance. Wherever maintenance is required on any breaker the circuit is changed over to the transfer bus and is controlled through bus coupler breaker.

DOUBLE BREAKER

This scheme is the modification of double bus bar scheme. In this arrangement the maintenance of CB or isolator without an outage is possible, which is the main drawback of double bus bar. This arrangement is costly so it varies for various generating stations.

4.2 MESH SCHEME

1. It provides a double feed to each circuit i.e. opening of any breaker for maintenance does not affect the supply to any circuit.
2. It provides breaker maintenance..
3. It is cheaper than the double bus bar or main bus scheme.

THE DISADVANTAGES OF THIS SCHEME ARE

1. If any breaker is to be taken under maintenance, then under this condition tripping of any one circuit breaker may result in loss of supply to a no. of circuits.
2. Expansion of mesh is extremely difficult the scheme is limited to four circuits.

5. MEASURING INSTRUMENT USED

1. ENERGY METER: To measure the energy transmitted energy meters are fitted to the panel to different feeders the energy transmitted is recorded after one hour regularly for it MWH meter is provided.

2. WATTMETERS: Wattmeter's are attached to each feeder to record the power exported from GSS.
3. FREQUENCY METER: To measure the frequency at each feeder there is the provision of analog or digital frequency meter.
4. VOLTMETER: It is provided to measure the phase-to-phase voltage. It is also available in both the forms analog as well as digital.
5. KA METER: It is provided to measure the line current. It is also available in both the forms analog as well as digital.
6. MAXIMUM DEMAND INDICATOR: These are also mounted on the control panel to record the average power over successive predetermined period.
7. MVAR METER: It is to measure the reactive power of the circuit.
8. COS Φ METERS: To indicate the power factor of the power being transferred or imported. These meters are provided on various panels.

6.ISOLATOR

There are 54 sets of isolators installed at the substation. An isolator is used disconnecting switch to allow isolation of circuit breakers and transformers and transmission lines for maintenance. Isolator is an off load device intended to be opened only after current has been interrupted by some other control device. It prevents the voltage from being applied to some given sections of the bus in a switchgear installation or to one or another piece of apparatus in installation. Isolator switches have provision for a padlock so that inadvertent operation is not possible.

There are two types of insulators:

- Single pole isolators
- Three pole isolators



Fig.3.1 Isolator

7.CIRCUIT BREAKER

A **circuit breaker** is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large switchgear designed to protect high-voltage circuits feeding an entire city.

7.1 They can be classified into:

- Oil circuit breaker
- Air-blast circuit breaker
- Sulphur hexafluoride circuit breaker (SF_6)

➤ Vacuum circuit breakers

SF₆ and Vacuum circuit breaker are being used in 220KV distribution substation.

Oil Circuit Breaker



Fig.3.2 Oil circuit breaker

A high-voltage circuit breaker in which the arc is drawn in oil to dissipate the heat and extinguish the arc; the intense heat of the arc decomposes the oil, generating a gas whose high pressure produces a flow of fresh fluid through the arc that furnishes the necessary insulation to prevent a restrike of the arc.

The arc is then extinguished, both because of its elongation upon parting of contacts and because of intensive cooling by the gases and oil vapour.

Air blast circuit breaker

Fast operations, suitability for repeated operation, auto reclosure, unit type multi break constructions, simple assembly, modest maintenance are some of the main features of air blast circuit breakers. A compressors plant necessary to maintain high air pressure in the air receiver.

The air blast circuit breakers are especially suitable for railways and arc furnaces, where the breaker operates repeatedly. Air blast circuit breaker is used for interconnected lines and important lines where rapid operation is desired.



Fig.3.3 Air blast circuit breaker

High pressure air at a pressure between 20 to 30 kg/ cm² stored in the air reservoir. Air is taken from the compressed air system. Three hollow insulator columns are mounted on the reservoir with valves at their basis. The double arc extinguished chambers are mounted on the top of the hollow insulator chambers. The current carrying parts connect the three arc extinction chambers to each other in series and the pole to the neighboring equipment. Since there exists a very high voltage between the conductor and the air reservoir, the entire arc extinction chambers assembly is mounted on insulators.

SF₆ CIRCUIT BREAKER



Fig.3.4 SF₆ Circuit breaker

In such circuit breaker, sulphur hexafluoride (SF₆) gas is used as the arc quenching medium. The SF₆ is an electronegative gas and has a strong tendency to absorb free electrons. The SF₆ circuit breaker have been found to a very effective for high power and high voltage service. SF₆ circuit breakers have been developed for voltage 115 KV to 230 KV, power rating 10 MVA.

It consists of fixed and moving contacts. It has chamber, contains SF₆ gas. When the contacts are opened, the mechanism permits a high pressure SF₆ gas from reservoir to flow towards the arc interruption chamber. The moving contact permits the SF₆ gas to let through these holes.

Vacuum Circuit Breaker

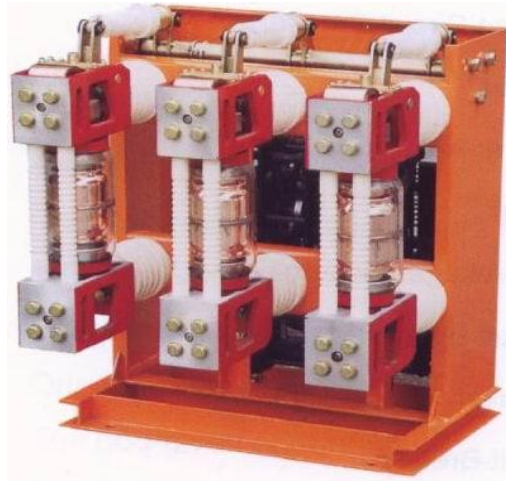


Fig.3.5 Vacuum circuit breaker

Vacuum circuit breakers are circuit breakers which are used to protect medium and high voltage circuits from dangerous electrical situations. Like other types of circuit breakers, vacuum circuit breakers literally break the circuit so that energy cannot continue flowing through it, thereby preventing fires, power surges, and other problems which may emerge. These devices have been utilized since the 1920s, and several companies have introduced refinements to make them even safer and more effective.

8.Lightning arrester

A lightning arrester is a device used on electrical power systems to protect the insulation on the system from the damaging effect of lightning. Metal oxide varistors (MOVs) have been used for power system protection since the mid 1970s. The typical lightning arrester also known as surge arrester has a high voltage terminal and a ground terminal. When a lightning surge or switching surge travels down the power system to the arrester, the current from the surge is diverted around the protected insulation in most cases to earth.

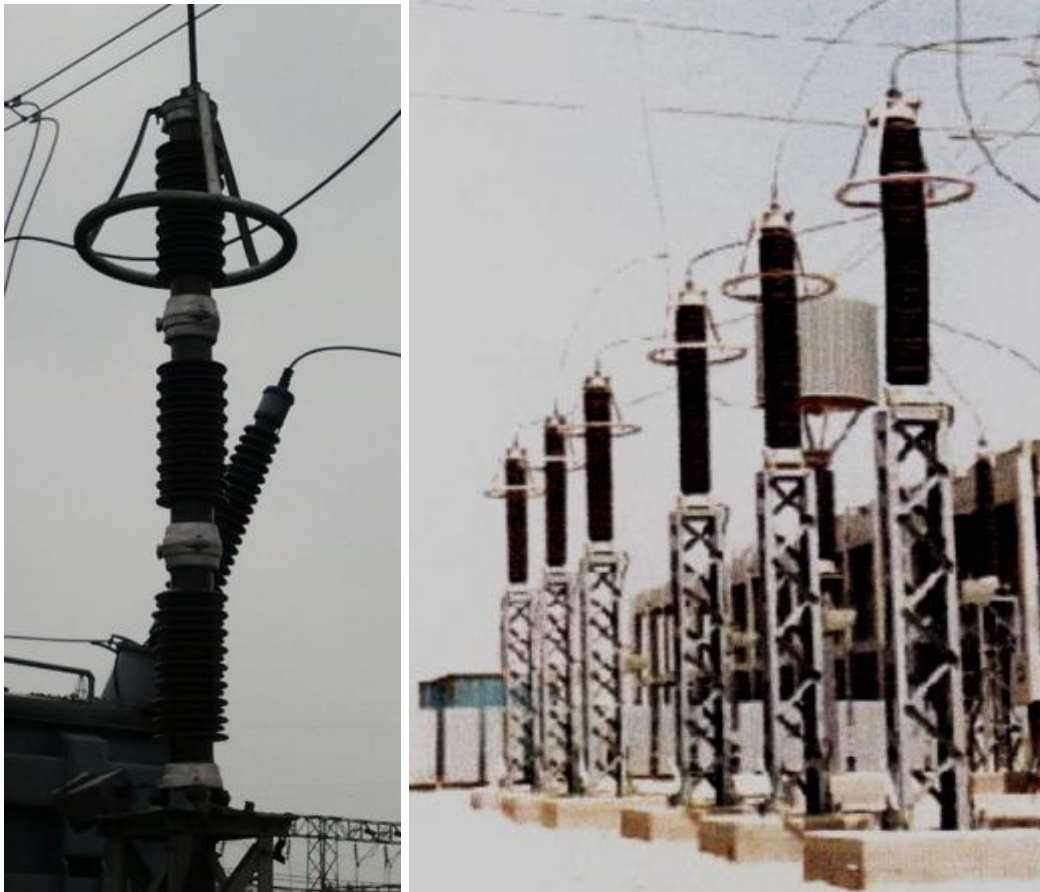


Fig.3.6 Lightning Arrestor

Properties of good lightning arrestors:-

1. It should not take any current at working voltage.
2. It must provide a conducting path as abnormal voltage occurs on the system
3. It must be capable of carrying discharge current without damaging itself under abnormal voltages.

There are four sets of lightning arresters installed for the 220/66KV transformers two sets of lightning arresters installed for the 220/66KV transformers, two sets are installed for the 220KV bus bar and two sets are installed for the 66KV bus bar.

9.INSULATORS

BUS SUPPORT INSULATORS



Fig.3.7 Bus Support Insulator

These are porcelain or fiberglass insulators that serve to isolate the bus bar switches and other support structures and to prevent leakage current from flowing through the structure or to ground. These insulators are similar in function to other insulators used in substations and transmission poles and towers. These insulators are generally made of glazed porcelain or toughened glass. Poly come type insulator [solid core] are also being supplied in place of hast insulators if available indigenously. The design of the insulator is such that the stress due to contraction and expansion in any part of the insulator does not lead to any defect. It is desirable not to allow porcelain to come in direct contact with a hard metal screw thread.

9.1 TYPES OF INSULATORS

There are several types of insulators but the most commonly used are pin type, suspension type, strain insulator and shackle insulator.

PIN TYPE INSULATOR

As the name suggests, the pin type insulator is secured to the cross-arm on the pole. There is a groove on the upper end of the insulator for housing the conductor. The conductor passes through this groove and is bound by the annealed wire of the same material as the conductor. Pin type insulators are used for transmission and distribution of electric power at voltages up to 33 kV. Beyond operating voltage of 33 kV, the pin type insulators become too bulky and hence uneconomical.



Fig.3.8 Pin Type Insulator

SUSPENSION TYPE INSULATOR

For high voltages (>33 kV), it is a usual practice to use suspension type insulators shown in Figure . Consists of a number of porcelain discs connected in series by metal links in the form of a string. The conductor is suspended at the bottom end of this string while the other end of the string is secured to the cross-arm of the tower. Each unit or disc is designed for low voltage, say 11 kV. The number of discs in series would obviously depend upon the working voltage. For instance, if the working voltage is 66 kV, then six discs in series will be provided

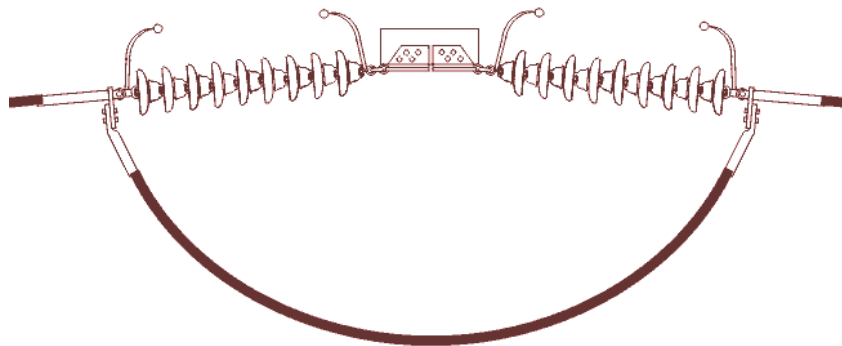
on the string.



Fig.3.9 Suspension Type Insulator

STRAIN TYPE INSULTOR

When there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension. In order to relieve the line of excessive tension, strain insulators are used. For low voltage lines (< 11 kV), shackle insulators are used as strain insulators. However, for high voltage transmission lines, strain insulator consists of an assembly of suspension insulators as shown in Figure 9.4. The discs of strain insulators are used in the vertical plane. When the tension in lines is exceedingly high, at long river spans, two or more strings are used in parallel.



STRAIN INSULATOR

Fig.4.0 Strain Insulator

SHACKLE TYPE INSULATOR

In early days, the shackle insulators were used as strain insulators. But now days, they are frequently used for low voltage distribution lines. Such insulators can be used either in a (ACERC/DOEE/2014-15/PTS/36)horizontal position or in a vertical position. They can be directly fixed to the pole with a bolt or to the cross arm

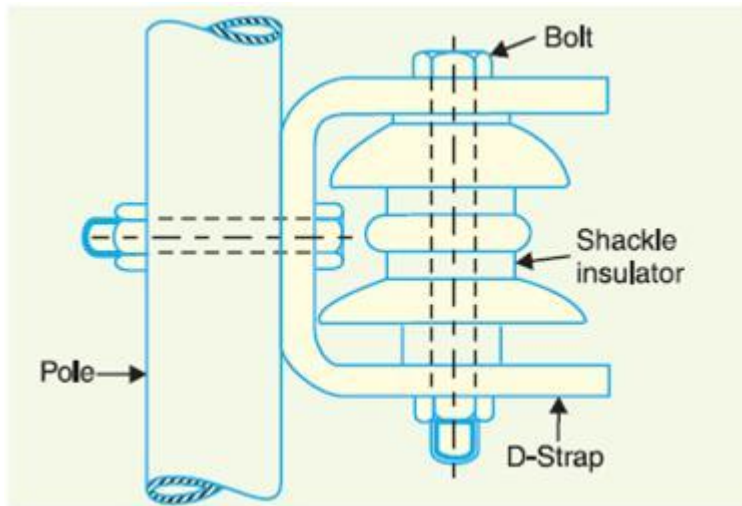


Fig.4.1 Shackle Type Insulator

10.METERING AND **INDICATION EQUIPMENT**

10.1 RELAY



Fig.4.2 Relay

In a power system it is inevitable that immediately or later some failure does occur somewhere in the system. When a failure occurs on any part of the system, it must be quickly detected and disconnected from the system. Rapid disconnection of faulted apparatus limits the amount of damage to it and prevents the effects of fault from spreading into the system. For high voltage circuits relays are employed to serve the desired function of automatic protective gear. The relays detect the fault and supply the information to the circuit breaker.

The electrical quantities which may change under fault condition are voltage, frequency, current, phase angle. When a short circuit occurs at any point on the transmission line the current flowing in the line increases to the enormous value. This result in a heavy current flow through the relay coil, causing the relay to operate by closing its contacts. This in turn closes the trip circuit of the breaker making the circuit breaker open and isolating the faulty section from the rest of the system. In this way, the relay ensures the safety of the circuit equipment from the damage and normal working of the healthy portion of the system.

Basically relay work on the following two main operating principles:

- Electromagnetic attraction relay
- Electromagnetic induction relay

Relays used in control panel of the substation

DIFFERENTIAL RELAY:



Fig.4.3 Differential Relay

A differential relay is one that operates when vector difference of the two or more electrical quantities exceeds a predetermined value. If this differential quantity is equal or greater than the pickup value, the relay will operate and open the circuit breaker to isolate the faulty section.

OVER CURRENT RELAY:



Fig.4.4 Over Current Relay

This type of relay works when current in the circuit exceeds the predetermined value. The actuating source is the current in the circuit supplied to the relay from a current transformer. These relay are used on A.C. circuit only and can operate for fault flow in the either direction. This relay operates when phase to phase fault occurs.

DIRECTIONAL RELAY:

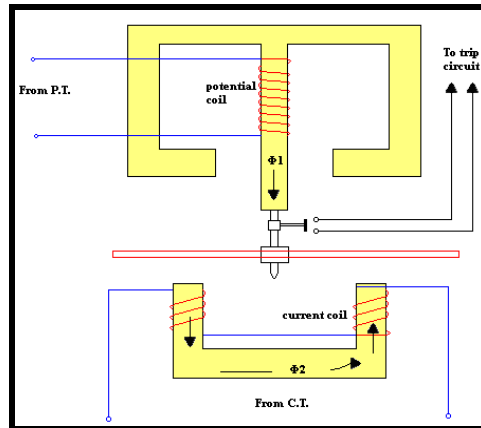


Fig.4.5 Directional Relay

This relay operates during earth faults. If one phase touch the earth due to any fault. A **directional power relay** is so designed that it obtains its operating torque by the interaction of magnetic field derived from both voltage and current source of the circuit it protects. The direction of torque depends upon the current relative to voltage.

TRIPPING RELAY:



Fig.4.6 Tripping Relay

This type of relay is in the conjunction with main relay. When main relay sense any fault in the system, it immediately operates the trip relay to disconnect the faulty section from the section.

AUXILIARY RELAY:



Fig.4.7 Auxiliary Relay

An auxiliary relay is used to indicate the fault by glowing bulb alert the employee

11.MISCELLANEOUS EQUIPMENT

CAPACITOR BANK

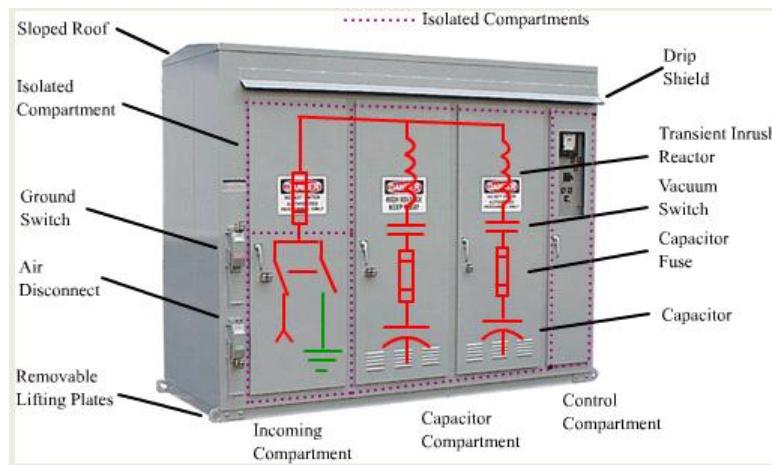


Fig.4.8 Capacitor bank

The load on the power system is varying being high during morning and evening which increases the magnetization current. This result in the decreased power factor. The low power factor is mainly due to the fact most of the power loads are inductive and therefore take lagging currents. The low power factor is highly undesirable as it causes increases in current, resulting in additional losses. So in order to ensure most favorable conditions for a supply system from engineering and economical stand point it is important to have power factor as close to unity as

possible. In order to improve the power factor some device taking leading power should be connected in parallel with the load. One of such device can be **capacitor bank**. The capacitor draws a leading current and partly or completely neutralize the lagging reactive component of load current.

Capacitor bank accomplishes following operations:

- 1) Supply reactive power
- 2) Increases terminal voltage
- 3) Improve power factor

FUSE



Fig.4.9 Substation Fuse

A fuse is a short piece of wire or thin strip which melts when excessive current through it for sufficient time. It is inserted in series with the circuit under normal operating conditions; the fuse element is at a nature below its melting point. Therefore it carries the normal load current overheating.

It is worthwhile to note that a fuse performs both detection and interruption functions.

BUS COUPLER



Fig 5.0Bus Coupler

The bus coupler consists of circuit breaker and isolator. Each generator and feeder may be connected to either main bus bar or spar bus bar with the help of bus coupler. Repairing, maintenance and testing of feeder circuit or other section can be done by putting them on spar bus bar, thus keeping the main bus bar undisturbed.

Bus coupler is a device which is used switch from one bus to the other without any interruption in power supply and without creating hazardous arcs. It is achieved with the help of circuit breaker and isolators.

Marshalling box



Fig.5.1 Marshalling Box

It has two meter which indicate the temperature of the oil and winding of main tank. If temperature of oil or winding exceeds than specified value, relay operates to sound an alarm. If there is further increase in temperature then relay completes the trip circuit to open the circuit breaker controlling the transformer.

CONTROL BATTERIES

There are 110 batteries of 2v each are connected in series. They provide the 220V DC to the control panels.



Fig.5.2 Control Room Batteries

When connecting your batteries in Series you are doubling the voltage while maintaining the same capacity rating (amp hours). This might be used in a scooter, Power Wheels kids vehicle, or other applications. Just use a jumper wire between the negative of the first battery and the positive of the second battery. Run your negative wire off of the open connector from the first battery and your positive off of the open connector on your second battery.

COUPLING CAPACITOR

They are used in range from 2200pf to 10000pf. It offers low impedance to high frequency and allows them to enter line matching unit also it offers high impedance to low frequency signals and block it.



Fig.5.3 Coupling Capacitor

Specification of the Coupling Capacitor

COUPLING CAPACITANCE

FREQUENCY BAND

4400 pf

80-450 KHz

2200 pf

180-450 KHz

10000 pf

70-500 KHz

Line Impedance

450-350-300 Ohm

WAVE TRAP

Line trap also is known as Wave trap. What it does is trapping the high frequency communication signals sent on the line from the remote substation and diverting them to the telecom/teleportation panel in the substation control room (through coupling capacitor and LMU). This is relevant in Power Line Carrier Communication (PLCC) systems for communication among various substations without dependence on the telecom company network. The signals are primarily teleportation signals and in addition, voice and data communication signals. Line trap also is known as Wave trap. What it does is trapping the high frequency communication signals sent on the line from the remote substation and diverting them to the telecom/teleportation panel in the substation control room (through coupling capacitor and LMU). This is relevant in Power Line Carrier Communication (PLCC) systems for communication among various substations without dependence on the telecom company network. The signals are primarily teleportation signals and in addition, voice and data communication signals. The Line trap offers high impedance to the high frequency communication signals thus obstructs the flow of these signals in to the substation bus bars. If there were not to be there, then signal loss is more and communication will be ineffective/probably impossible.



12.Types of Overhead Conductor

In early days copper 'Cu' was used for transmitting energy in stranded hard drawn form to increase tensile strength. But now it has been replaced by aluminum 'Al' due to following reasons:

1. It has lesser cost than copper.
2. It offers larger diameter for same amount of current which reduces corona.

Corona: is ionization of air due to higher voltage (usually voltage above critical voltage) which causes violating light around the conductor and hissing sound. It also produce ozone gas therefor it is undesirable condition

Aluminium also has some disadvantages over copper i.e.

- 1.It has lesser conductivity
 - 2.It has larger diameter which increase surface area to air pressure thus it swings more in air than copper so larger cross arms required which increases the cost.
 - 3.It has lesser tensile strength ultimately larger sag
 - 4.It has lesser specific gravity (2.71 gm/cc) than copper (8.9 gm/cc) cc = cubic centimete
- Due to lower tensile strength aluminium is used with some other materials or its alloys.

AAC (All Aluminium Conductor)

- 1.It has lesser strength and more sag per span length than any other category
- 2.Therefore, it is used for lesser span i.e. it is applicable at distribution level
3. It has slightly better conductivity at lower voltages than ACSR i.e. at distribution level
4. Cost of ACSR is equal to AAC.

ACAR (Aluminium Conductor, Aluminium Reinforce)

- 1.It is cheaper than AAAC but pro to corrosion.

2.It is most expensive.

AAAC (All Aluminium Alloy Conductor)

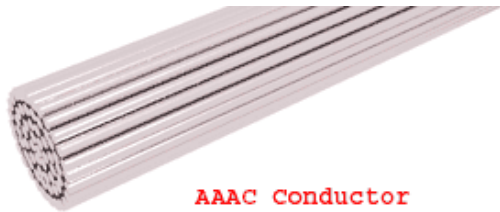


Fig5.6 AAAC

- 1.It has same construction as AAC except the alloy.
- 2.Its strength is equal to ACSR but due to absence of steel it is light in weight.
- 3.The presence of formation of alloy makes it expensive.
- 4.Due to stronger tensile strength than AAC, it is used for longer spans.
- 5.It can be used in distribution level i.e. river crossing.
- 6.It has lesser sag than AAC.
- 7.The difference between ACSR and AAAC is the weight. Being lighter in weight, it is used in transmission and sub-transmission where lighter support structure is required such as mountains, swamps etc.

ACSR (Aluminium Conductor Steel Reinforced)



Fig5.7 ACSR

- 1.It is used for longer spans keeping sag minimum.

- 2.It may consists of 7 or 19 strands of steel surrounding by aluminium strands concentrically.
- 3.The number of strands are shown by x/y/z, where 'x' is number of aluminium strands, 'y' is number of steel strands and 'z' is diameter of each strand.
- 4.Strands provide flexibility, prevent breakage and minimize skin effect
- 5.The number of strands depends on the application, they may be 7, 19, 37, 61, 91 or more.
- 6.If the Al and St strands are separated by a filler such as paper then this kind of ACSR is used in EHV lines and called expanded ACSR.
- .7Expanded ACSR has larger diameter and hence lower corona losses.

13.Battery Testing

Testing is designed to tell us things we want to know about individual cells and batteries.

Some typical questions are:

- Is it fully charged ?
- How much charge is left in the battery ?
- Does it meet the manufacturer's specification ?
- Has there been any deterioration in performance since it was new ?
- How long will it last ?
- Do the safety devices all work ?
- Does it generate interference or electrical noise ?
- Is it affected by interference or electrical noise ?

Indirect Measurements

Although all of the cell parameters the design engineer may wish to measure can be quantified by direct measurement, this is not always convenient or possible . For example the amount of charge left in the battery, the State of Charge (SOC) can be determined by fully discharging the battery and measuring the energy output. This takes time, it wastes energy, each test cycle shortens the battery life and it may not be practical if the battery is in use. It would also be pointless for a primary cell. For more detailed information of how this is done see the State of Charge page.

Similarly, the remaining life of a secondary cell can be determined by continuously cycling it until it fails, but there's no point in knowing the cell life expectation if you have to destroy it to find out. This is known as the State of Health (SOH) of the battery.

What is needed are simple tests or measurements which can be used as an approximation to, or indirect measure of, the desired parameter. For more information see the [State of Health](#) page

The Cell Design Process Testing

A much more detailed testing regime is necessary in the design of new cells. More information can be found on the [New Battery Designs and Chemistries](#) page.

Test Conditions

In all of the following tests, and testing in general, the test conditions must be specified so that repeatable results can be obtained, and meaningful comparisons can be made. This includes factors such as method, temperature, DOD, load and duty cycle. For instance the cell capacity and cycle life, two key performance indicators could vary by 50% or more depending on the temperature and the discharge rate at which the tests were carried out. See also cell [Performance Characteristics](#).

Battery specifications should always include the test conditions to avoid ambiguity.

Qualification Testing

Qualification testing is designed to determine whether a cell or battery is fit for the purpose for which it was intended before it is approved for use in the product. This is particularly important if the cell is to be used in a "mission critical" application. These are comprehensive tests carried out initially on a small number of cells including testing some of them to destruction if necessary. As a second stage, qualification also includes testing finished battery packs before the product is approved for release to the customer. The tests are usually carried out to verify that the cells meet the manufacturer's specification but they could also be used to test the cells to arbitrary limits set by the applications engineer to determine how long the cells survive under adverse conditions or unusual loads, to determine failure modes or safety factors.

The battery packs should also be tested with the charger recommended for the application to ensure compatibility. In particular the potential user patterns must be evaluated to ensure that the batteries do not become inadvertently overcharged. See also the section on Chargers.

13.1 Shake and Bake

- **Mechanical Testing**

Typical tests are included in the safety standards below. They include simple tests for dimensional accuracy to dynamic testing to verify that the product can survive any static and dynamic mechanical stresses to which it may be subject.

- **Environmental Testing**

Typical tests are included in the safety standards below. They are designed to exercise the product through all the environmental conditions likely to be encountered by the product during its lifetime.

13.2 Abuse Testing

The purpose of abuse testing is to verify that the battery is not a danger to the user or to itself either by accidental or deliberate abuse under any conceivable conditions of use. Designing foolproof batteries is ever more difficult because as we know, fools are so ingenious.

Abuse testing (always interesting to witness) is usually specified as part of the Safety Testing (below). Recent accidents with Lithium cells have highlighted the potential dangers and stricter battery design rules and a wider range of tests are being applied as well as stricter Transport Regulations for shipping the products.

Safety Standards

Consumer products normally have to comply with national or international Safety Standards required by the safety organisations of the countries in which the products are sold. Examples are UL, ANSI, CSA and IEC standards.

Typical contents

Safety Tests	
<p>Casing</p> <ul style="list-style-type: none"> • Strength, rigidity and flammability • Mould stress (Temperature) • Venting • Insulation • Electrolyte not under pressure • No leakage • No explosion or fire risk <p>Protection from or tolerance to</p> <ul style="list-style-type: none"> • Short circuit • Overcharge (time) • Overcharge (voltage) • Over-discharge • Voltage reversal • High temperature • Low temperature • Misuse • Abuse <p>Power output - Load test</p>	<p>Failsafe electronics</p> <p>Marking</p> <p>Instructions for use</p> <p>Safety instructions</p> <p>Mechanical tests</p> <ul style="list-style-type: none"> • Crush tests • Nail penetration tests • Shock test • Vibration test • Impact test • Drop test <p>Environmental tests</p> <ul style="list-style-type: none"> • Heating • Temperature cycling • Altitude • Humidity • Exposure to fire

Table 2

The published safety standards specify the method of testing and the limits with which the product must comply.

DEF Standards

Cells used in military applications usually have to meet more stringent requirements than those used in consumer products.

13.3 Cycle Testing

This is perhaps the most important of the qualification tests. Cells are subjected to repeated charge - discharge cycles to verify that the cells meet or exceed the manufacturer's claimed cycle life. Cycle life is usually defined as the number of charge - discharge cycles a battery can perform before its nominal capacity falls below 80% of its initial rated capacity. These tests are needed to verify that the battery performance is in line with the end product reliability and lifetime expectations and will not result in excessive guarantee or warranty claims.

Temperature, charge/discharge rates and the Depth of Discharge each have a major influence on the cycle life of the cells. Depending on the purpose of the tests, the temperature and the DOD should be controlled at an agreed reference level in order to have repeatable results which can be compared with a standard. Alternatively the tests can be used to simulate operating conditions in which the temperature is allowed to rise, or the DOD restricted, to determine how the cycle life will be affected.

Similarly cycle life is affected by over charging and over discharging and it is vital to set the correct voltage and current limits if the manufacturer's specification is to be verified.

Cycle testing is usually carried out banks of cells using multi channel testers which can create different charge and discharge profiles including pulsed inputs and loads. At the same time various cell performance parameters such as temperature, capacity, impedance, power output and discharge time can be monitored and recorded. Typically it takes about 5 hours for a controlled full charge discharge cycle. This means testing to 1000 cycles will take 208 days assuming working 7 days per week 24 hours per day. Thus it takes a long time to verify the effect of any ongoing improvements made to the cells. Because the ageing process is continuous and fairly linear, it is possible to predict the lifetime of a cell from a smaller number of cycles. However to prove it conclusively in order to guarantee a product lifetime would require a large number of cells and a long time. For high power batteries this could be very expensive.

13.4 Load Testing

Load testing is used to verify that the battery can deliver its specified power when needed.

The load is usually designed to be representative of the expected conditions in which the battery may be used. It may be a constant load at the C rate or pulsed loads at higher current rates or in the case of automotive batteries, the load may be designed to simulate a typical driving pattern.

Low power testing is usually carried out with resistive loads. For very high power testing with variable loads other techniques may be required. A Ward-Leonard controller may be used to provide the variable load profile with the battery power being returned to the mains supply rather than being dissipated in a load.

Note that the battery may appear to have a greater capacity when it is discharged intermittently than it may have when it is discharged continuously. This is because the battery is able to recover during the idle periods between heavy intermittent current drains. Thus testing a battery capacity with a continuous high current drain will not necessarily give results which represent the capacity achievable with the actual usage profile.

Load testing is often required to be carried out with variable load levels. This may simply be pulsed loads or it could be more complex high power load profiles such as those required for electric vehicle batteries. Standard load profiles such as the Federal Urban Driving Schedule (FUDS) and the Dynamic Stress Test (DST) specified by the United States Advanced Battery Consortium (USABC), in the USA, and the United Nations Economic Commission for Europe specification (ECE-15) and the Extra Urban Driving Cycle (EUDC) in Europe have been developed to simulate driving conditions and several manufacturers have incorporated these profiles into their test equipment.

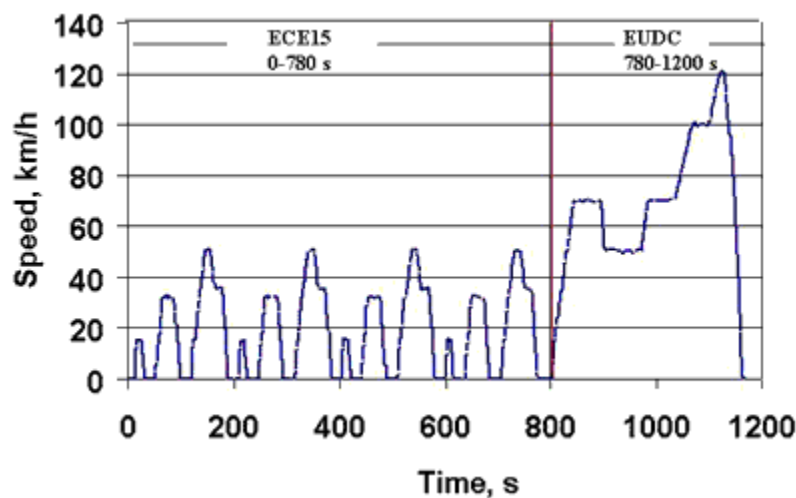


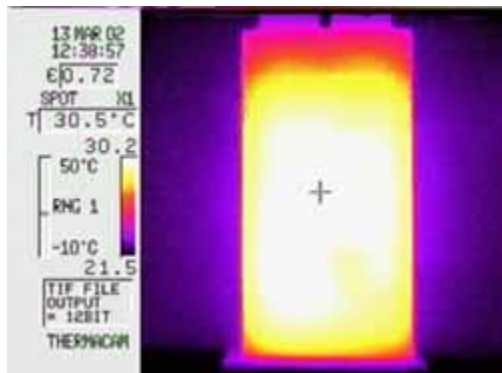
Fig.5.8 Simulated Driving Cycle

While these standard usage cycles have been developed to provide a basis for comparison, it should be noted that the typical user doesn't necessarily drive according to these cycles and is likely to accelerate at least twice as fast as the allowed for in the standards.

CaloriMetry

Battery thermal management is critical for high-power battery packs. Obtaining accurate heat generation data from battery modules is essential for designing battery thermal management systems. A calorimeter is used to quantify the total amount of heat generated by the battery while it is cycled through its charge/discharge cycles. This is essentially an insulated box into which the battery is placed which captures and measures the heat generated the battery during cycling. The system is calibrated by comparing the heat generated by the battery with the heat generated by a known heat source.

13.5 Thermal imaging



Thermal imaging is used to check for "hot spots" which would indicate points of high thermal stress in the cell or the battery pack. It is a photographic technique which records the intensity of the infra red radiation emitted by a subject using a special camera. The image on the left is of a lithium ion pouch cell after a prolonged discharge at 4C. In this case the temperature

Figure 5.9 Thermal Imaging and the cell terminals are running cool. These tests can help to identify problems such as overheating, inadequate heat sinking or air flow, undersized current conductors and interference from neighbouring cells or devices. The images can also be used to determine the best location for the temperature sensors used in protection circuits.

13.6 Electromagnetic Compatibility (EMC) testing

Electromagnetic compatibility (EMC) is the ability of electronic and electrical equipment and systems to operate without adversely affecting other electrical or electronic equipment OR being affected by other sources of interference such as power line transients, radio frequency (RF) signals, digital pulses, electrical machinery, lightning, or other influences.

Note that EMC concerns both the emission of electromagnetic interference (EMI or radio frequency interference RFI) by a product or device and the product's susceptibility to EMI emitted from other sources. The interference may be conducted through power or signal cables or the chassis of the equipment, it may be propagated through inductive or capacitive coupling or it may be radiated through the atmosphere.

Just because batteries are DC devices we can not assume that they are immune from EMC problems. At MPower we have seen the battery protection circuitry in a two way radio disabled by RF interference from the handset's transmitter. Similar problems are possible in automotive applications where the power cabling is notoriously noisy due to interference from the ignition systems and transients from electric motors and switches. While the battery itself may not emit RF interference, the same can not be said of the charger. Many chargers use switch mode regulators which are also notorious for emitting electrical noise. Radiated EMI can be critical to such applications as heart pacemakers, medical instrumentation, communications equipment and military applications.

As with many problems prevention is better than cure and it is wise to start considering EMC at the earliest possible stage of the design to avoid costly design changes when the project is submitted for final approval. This may involve system design choices such as operating frequencies, circuit layouts and enclosure design and the avoidance of designs with high transient currents.

Various techniques are used to minimise the effects EMI. Sensitive parts of the circuit may be physically separated from sources of interference, the equipment may be enclosed in a sealed metal box, individual parts of the circuits may be shielded with metal foil, filters can be added to cables to filter out the noise,

EMC testing involves specialised test equipment and facilities. Testing must be carried out in an environment free from other sources of EMI. This usually means an anechoic chamber or a Faraday cage. Special wide range signal sources and sensitive receivers are needed to generate and measure the interference.

Some examples of EMC requirements are give in the section on Standards

Process audits

Conducting a process audit of the cell manufacturer's production facilities is further way of gaining confidence in the cells under consideration however this option is usually available only to major purchasers of high volume or high cost cells. Unless you are one of these you will have to rely on your friendly pack maker who possibly qualifies for special treatment.

The process audit involves verifying that the cell maker has appropriate quality systems in place and that these are being fully implemented at every stage of the manufacturing process. To be effective this task needs to be conducted by a team with specialist industry knowledge. Again this is a job best left to your pack maker who should have the necessary experience and credibility with the cell makers.

Inspection and Production Testing

The purpose of inspection production testing is to verify that the cells which have been purchased and the products built with them conform to agreed specifications. These tend to be short tests carried out on 100% of the throughput or on representative samples. The composition of the materials from which the components are made should not be overlooked. We have seen examples of unscrupulous suppliers plating connectors with a gold coloured alloy rather than the gold specified and using cheap plastics which buckle in the heat rather than the high quality plastics required.

Typical tests include both mechanical and electrical tests. The components are checked for dimensional accuracy and sample subassemblies are subject to weld strength testing of the interconnections. Electrical parameters measured include the internal impedance and the output voltage of the cell or battery pack with or without a load. The battery is also submitted to short

duration charging and discharging pulses of about 2 milliseconds to check that the unit accepts and can deliver charge.

Battery packs are normally subjected to more comprehensive testing to ensure that the electronics are functioning correctly. The protection circuit is checked by applying a short circuit across the battery terminals for 1 or 2 seconds and checking that the current path is cut within the prescribed period and that the battery recovers afterwards. The output of the fuel gauge is checked and if the battery has built in memory, the data such as cell chemistry code, date and serial number are read out and recorded to permit traceability.

Charge conditioning or Formation

This is normally carried out by the cell manufacturer but in some circumstances it could be the responsibility of the battery pack assembler. In any case the cells must be tested to ensure that they are ready to deliver current.

Performance Monitoring

Performance monitoring is used to verify whether the cell is continuing to perform as required once it is in use in the application for which it was specified. These are individual tests specified by the user.

There are no simple direct measurements, such as placing a voltmeter across the terminals, to determine the condition of the battery. The voltmeter reading may tell us something about the state of charge (with an enormous margin of error), but it cannot tell us how well the battery will deliver current when demanded.

Internal Resistance

It is necessary to know the internal resistance of the cell in order to calculate the Joule heat generation or I^2R power loss in the cell, however a simple measurement with an ohmmeter is not possible because the current generated by the cell itself interferes with the measurement.

To determine the internal resistance, first it is necessary to measure the open circuit voltage of the cell. Then a load should be connected across the cell causing a current to flow. This will reduce the cell voltage due to the IR voltage drop across the cell which corresponds to the cell's internal resistance. The cell voltage should then be measured again when the current is flowing.

The resistance is calculated by ohms law from the voltage difference between the two measurements and the current which is flowing through the cell.

Open Circuit Voltage OCV

Measuring a battery's open circuit voltage is not a reliable measure of its ability to deliver current. As a battery ages, its internal resistance builds up. This will reduce the battery's ability to accept and to hold charge, but the open circuit voltage will still appear normal despite the reduced capacity of the battery. Comparing the actual internal resistance with the resistance of a new battery will provide an indication of any deterioration in battery performance.

State Of Charge (SOC)

For many applications the user needs to know how much energy is left in a battery. The SOC is also a fundamental parameter which must be monitored and controlled in Battery Management Systems. The methods of estimating the SOC are explained in the section on State Of Charge.

State Of Health (SOH)

The State of Health is a measure of a battery's ability to deliver the specified current when called upon to do so. It is an important factor for monitoring battery performance once it has entered into use. This is treated briefly in the section below and more fully in the section on State Of Health.

13.7 Impedance and Conductance Testing

The discussion about the battery equivalent circuit in the section on Performance Characteristics shows that we can expect the battery impedance to increase with age.

Battery manufacturers have their own definitions and conventions for Impedance and Conductance based on the test method used. Though not strictly correct they serve their purpose. The test method involves applying a small AC voltage "E" of known frequency and amplitude across the cell and measuring the in phase AC current "I" that flows in response to it.

The Impedance "Z " is calculated by Ohm's Law to be $Z=E/I$

The Conductance "C" is similarly calculated as $C=I/E$ (the reciprocal of the impedance)

Note that the impedance increases as the battery deteriorates while the conductance decreases. Thus C correlates directly with the battery's ability to produce current whereas Z gives an inverse correlation. The conductance of the cell therefore provides an indirect approximation to the State of Health of the cell. This measurement can be refined by taking other factors into account.

These are outlined in the page about [State of Health](#).

In addition to impedance and conductance these tests will obviously detect cell defects such as shorts, and open circuits.

These test methods can be used with different cell chemistries however different calibration factors must be built into the test equipment to take into account differences in the aging profiles of the different chemistries.

Impedance and conductance testing are reliable, safe, accurate, fast and they don't affect the battery performance. They can be carried out while the battery is in use or they can be used to continuously monitor the battery performance, avoiding the need for load testing or discharge testing.

13.8 DC measurements

Note that DC measurements do not recognise capacitance changes and therefore measurements of the internal resistance of the cell do not correlate so well with the SOH of the cell.

Using a conventional ohmmeter for measuring the resistance of the cables, contacts and inter-cell links is not satisfactory because the resistance is very low and the resistance of the instrument leads and the contacts causes significant errors. More accuracy can be achieved by using a Kelvin Bridge which separates the voltage measuring leads from the current source leads and thus avoids the error caused by the volt drop along the current source leads. See also [charger voltage sensing](#).

13.9 Battery Analysers

Battery analysers are designed to provide an quick indication of the State of Health (SOH) of the battery. Some analysers also have the dual function of reconditioning the battery.

There are no industry standards for this equipment, mainly because there is no standard definition of State of Health. Each equipment manufacturer has their own favourite way defining and measuring it, from a simple conductance measurement to a weighted average of several measured parameters and the test equipment is designed to provide the corresponding answer. This should not be a problem if the same equipment is used consistently, however it does cause problems if equipment from different manufacturers is used to carry out the tests.

13.10 Failure Analysis

Cell failure analysis is best carried out by the cell manufacturers. Only they will have the detailed specifications of the cell mechanical and chemical components and it normally requires access to expensive analytical equipment such as electron microscopes and mass spectrometers which they should be expected to have. More information see Why Batteries Fail and Lithium Battery Failures

14.LOAD SCHEDULE

The electrical load schedule is an estimate of the instantaneous electrical loads operating in a facility, in terms of active, reactive and apparent power (measured in kW, kVAR and kVA respectively). The load schedule is usually categorised by switchboard or occasionally by sub-facility / area.

Why do the calculation?

Preparing the load schedule is one of the earliest tasks that needs to be done as it is essentially a pre-requisite for some of the key electrical design activities (such as equipment sizing and power system studies).

When to do the calculation?

The electrical load schedule can typically be started with a preliminary key single line diagram (or at least an idea of the main voltage levels in the system) and any preliminary details of process / building / facility loads. It is recommended that the load schedule is started as soon as practically possible.

Calculation Methodology

There are no standards governing load schedules and therefore this calculation is based on generally accepted industry practice. The following methodology assumes that the load schedule is being created for the first time and is also biased towards industrial plants. The basic steps for creating a load schedule are:

- Step 1: Collect a list of the expected electrical loads in the facility
- Step 2: For each load, collect the electrical parameters, e.g. nominal / absorbed ratings, power factor, efficiency, etc
- Step 3: Classify each of the loads in terms of switchboard location, load duty and load criticality
- Step 4: For each load, calculate the expected consumed load
- Step 5: For each switchboard and the overall system, calculate operating, peak and design load

Step 1: Collect list of loads

The first step is to gather a list of all the electrical loads that will be supplied by the power system affected by the load schedule. There are generally two types of loads that need to be collected:

- Process loads - are the loads that are directly relevant to the facility. In factories and industrial plants, process loads are the motors, heaters, compressors, conveyors, etc that form the main business of the plant. Process loads can normally be found on either Mechanical Equipment Lists or Process and Instrumentation Diagrams (P&ID's).
- Non-process loads - are the auxiliary loads that are necessary to run the facility, e.g. lighting, HVAC, utility systems (power and water), DCS/PLC control systems, fire safety systems, etc. These loads are usually taken from a number of sources, for

example HVAC engineers, instruments, telecoms and control systems engineers, safety engineers, etc. Some loads such as lighting, UPS, power generation auxiliaries, etc need to be estimated by the electrical engineer.

Step 2: Collect electrical load parameters

A number of electrical load parameters are necessary to construct the load schedule:

- **Rated power** is the full load or nameplate rating of the load and represents the maximum continuous power output of the load. For motor loads, the rated power corresponds to the [standard motor size](#) (e.g. 11kW, 37kW, 75kW, etc). For load items that contain sub-loads (e.g. distribution boards, package equipment, etc), the rated power is typically the maximum power output of the item (i.e. with all its sub-loads in service).
- **Absorbed power** is the expected power that will be drawn by the load. Most loads will not operate at its rated capacity, but at a lower point. For example, absorbed motor loads are based on the mechanical power input to the shaft of the driven equipment at its duty point. The motor is typically sized so that the rated capacity of the motor exceeds the expected absorbed load by some conservative design margin. Where information regarding the absorbed loads is not available, then a [load factor](#) of between 0.8 and 0.9 is normally applied.
- **Power factor** of the load is necessary to determine the reactive components of the load schedule. Normally the load power factor at full load is used, but the power factor at the duty point can also be used for increased accuracy. Where power factors are not readily available, then estimates can be used (typically 0.85 for motor loads >7.5kW, 1.0 for heater loads and 0.8 for all other loads).
- **Efficiency** accounts for the losses incurred when converting electrical energy to mechanical energy (or whatever type of energy the load outputs). Some of the electrical power drawn by the load is lost, usually in the form of heat to the ambient environment. Where information regarding efficiencies is not available, then

estimates of between 0.8 and 1 can be used (typically 0.85 or 0.9 is used when efficiencies are unknown).

Step 3: Classify the loads

Once the loads have been identified, they need to be classified accordingly:

Voltage Level

What voltage level and which switchboard should the load be located? Large loads may need to be on MV or HV switchboards depending on the size of the load and how many voltage levels are available. Typically, loads <150kW tend to be on the LV system (400V - 690V), loads between 150kW and 10MW tend to be on an intermediate MV system (3.3kV - 6.6kV) where available and loads >10MW are usually on the HV distribution system (11kV - 33kV). Some consideration should also be made for grouping the loads on a switchboard in terms of sub-facilities, areas or sub-systems (e.g. a switchboard for the compression train sub-system or the drying area).

Load duty

Loads are classified according to their duty as either continuous, intermittent and standby loads:

- 1) **Continuous** loads are those that normally operate continuously over a 24 hour period, e.g. process loads, control systems, lighting and small power distribution boards, UPS systems, etc
- 2) **Intermittent** loads that only operate a fraction of a 24 hour period, e.g. intermittent pumps and process loads, automatic doors and gates, etc
- 3) **Standby** loads are those that are on standby or rarely operate under normal conditions, e.g. standby loads, emergency systems, etc

Note that for redundant loads (e.g. 2 x 100% duty / standby motors), one is usually classified as continuous and the other classified as standby. This is purely for the purposes of the load schedule and does not reflect the actual operating conditions of the loads, i.e. both redundant loads will be equally used even though one is classified as a standby load.

Load criticality

Loads are typically classified as either normal, essential and critical:

- 1) **Normal** loads are those that run under normal operating conditions, e.g. main process loads, normal lighting and small power, ordinary office and workshop loads, etc
- 2) **Essential** loads are those necessary under emergency conditions, when the main power supply is disconnected and the system is being supported by an emergency generator, e.g. emergency lighting, key process loads that operate during emergency conditions, fire and safety systems, etc
- 3) **Critical** are those critical for the operation of safety systems and for facilitating or assisting evacuation from the plant, and would normally be supplied from a UPS or battery system, e.g. safety-critical shutdown systems, escape lighting, etc

Step 4: Calculate consumed load

The consumed load is the quantity of electrical power that the load is expected to consume. For each load, calculate the consumed active and reactive loading, derived as follows:

$$P_l = \frac{P_{abs}}{\eta}$$

$$Q_l = P_l \sqrt{\frac{1}{\cos^2 \phi} - 1}$$

Where P_l is the
consumed active load
(kW)

Q_l is the consumed reactive load (kVAr)

P_{abs} is the absorbed load (kW)

η is the load efficiency (pu)

$\cos \phi$ is the load power factor (pu)

Notice that the loads have been categorised into three columns depending on their load duty (continuous, intermittent or standby). This is done in order to make it visually easier to see the

load duty and more importantly, to make it easier to sum the loads according to their duty (e.g. sum of all continuous loads), which is necessary to calculate the operating, peak and design loads.

Step 5: Calculate operating, peak and design loads

Many organisations / clients have their own distinct method for calculating operating, peak and design loads, but a generic method is presented as follows:

Operating load

The operating load is the expected load during normal operation. The operating load is calculated as follows:

$$OL = \sum L_c + 0.5 \times \sum L_i$$

Where OL is the operating load (kW or kVAr)

$\sum L_c$ is the sum of all continuous loads (kW or kVAr)

$\sum L_i$ is the sum of all intermittent loads (kW or kVAr)

Peak load

The peak load is the expected maximum load during normal operation. Peak loading is typically infrequent and of short duration, occurring when standby loads are operated (e.g. for changeover of redundant machines, testing of safety equipment, etc). The peak load is calculated as the larger of either:

$$PL = \sum L_c + 0.5 \times \sum L_i + 0.1 \times \sum L_s$$

or

$$PL = \sum L_c + 0.5 \times \sum L_i + L_{s,max}$$

Where PL is the peak load (kW or kVAr)

$\sum L_c$ is the sum of all continuous loads (kW or kVAr)

$\sum L_i$ is the sum of all intermittent loads (kW or kVAr)

$\sum L_s$ is the sum of all standby loads (kW or kVAr)

$L_{s,max}$ is the largest standby load (kW or kVAr)

Design load

The design load is the load to be used for the design for equipment sizing, electrical studies, etc.

The design load is generically calculated as the larger of either:

$$DL = 1.1 \times OL + 0.1 \times \sum L_s$$

or

$$DL = 1.1 \times OL + L_{s,max}$$

Where DL is the design load (kW or kVAr)

OL is the operating load (kW or kVAr)

$\sum L_s$ is the sum of all standby loads (kW or kVAr)

$L_{s,max}$ is the largest standby load (kW or kVAr)

CONCLUSION

Now from this report we can conclude that electricity plays an important role in our life. We are made aware of how the transmission and distribution of electricity is done. We too came to know about the various parts of the Substation system.

We think that our training was successful and we think that the 220KV sub-station at Passiana is an excellent training centre for inquisitive emerging electrical engineers to learn about the transmission and distribution of high voltage electricity and all other protective devices. In the training session we came to know about the fundamentals of power system which may be quite useful for our fore coming studies.

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