SUMMER TRAINING REPORT
ON

Familiarization of 400 kV, 220 kV, 132 kV Substation Equipment

(Venue- 400/220/132/33 kV Kukurmara Grid Substation, Mirza)

Submitted in partial fulfillment of the requirement for the Degree of

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in

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COMPANY PROFILE

Assam Electricity Grid Corporation Limited is a vibrant growth oriented Public Sector Company registered under ‘Company Act, 1956’. It was formed out of restructured Assam State Electricity Board in 2003 and was notified as the State Transmission Utility (STU). Its core business is to efficiently transport electrical power from electrical power Bulkheads to the distribution company networks in the state of Assam.

Assam Electricity Grid Corporation Limited inherited 3862 circuit kms. of EHV lines above 66 kV voltage class and 38 numbers of EHV sub-stations having a total transformation capacity of 1636.50 MVA at its birth in 2003. Since its inception, it has added 1584 circuit kms of EHV lines and has added 4125 MVA transformation capacity by way of commissioning 17 new EHV sub-stations and augmenting existing sub-stations. It has also added Reactive Power Compensation at 33 kV bus to the tune of 285 MVAR. Assam Electricity Grid Corporation Limited had also added one 400/220 kV Grid Substation and One 220/33 kV GIS Sub Station during the preceding years. As on 01.07.2017, AEGCL has 63 nos. of EHV Grid Substations (400 kV-1 no., 220 kV- 10 nos. and 132 kV - 52 nos.) with total Transformation capacity of 6046MVA.

Assam Electricity Grid Corporation Limited is playing a strategic role as it is the largest ‘STU’ in NE region. It also understands its responsibility towards the entire North East India and is always extending a helping hand by way of transporting a fair share of power to the other sister states of the region.

Assam Electricity Grid Corporation Limited has consistently maintained the transmission system availability over 99% which is at par with other National Transmission Utilities.

Assam Electricity Grid Corporation Limited vows to ever strive till all transmission bottlenecks get eradicated. It pledges to deliver unrelenting brilliance in performance, deliver power efficiently but economically, show high safety standards and is committed to respect environmental and heritage issues.

Figure 1: 400/220/132/33 kV Kukurmara Grid Sub-Station

Chapter 1

INTRODUCTION TO THE SUB-STATION

A Substation in general receives electrical power from a generating station via incoming feeders and delivers electrical power through outgoing feeders and it is used for controlling the power on different routes. Generally substations are unattended, relying on SCADA (Supervisory control and data acquisition) for remote supervision and control. A substation is a part of electrical power generation, transmission and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels. A substation may include transformer to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages. The Grid Sub-Station (GSS) at Kukurmara, Mirza is basically a connector between two grids of 400 kV and 220 kV. Construction of this Sub-Station is done on TURKEY Basis.

This project is made to overcome the electricity crisis and to meet the power demand of Guwahati region of Assam. To meet the requirement, this substation is set up by looping in and looping out (LILO) Bongaigaon-Shilchar 400 kV double circuit line. The 400 kV is then stepped down to 220 kV and it is sent to Agia, Boko and Sarusajai as the outgoing line of the substation. The 132 kV and 33 kV outgoing lines are under construction. The substation has 2×315 MVA, a 50 MVA and a 25 MVA transformer for 220 kV, 132 kV and 33 kV lines respectively.

1.1 SITE SELECTION

Main points considered for selection of site at Kukurmara are:-

1. The site is easily approachable by highways (NH 37) and railways (NFR).
2. The site is geographically situated between two HV grids and it is a fairly plane land
3. This riverside land is slightly inclined .This solves water logging problem during rainy season.
4. The selected site has scope for future expansion.
5. The site is a bit away from residential area. This permits a safe approach

1.2 TYPES OF HIGH-VOLTAGE SUBSTATIONS

The various types of switchgear that are available for high-voltage substations make it possible to provide flexible, individual solutions. The high voltage substations are categorized as follows.

- Sub-Stations with Air Insulated Switchgear (AIS).
- Sub-Stations with gas Insulated switchgear (GIS).
- Mixed technologies substations

- Portable power solutions
- Turnkey solutions

1.2.1 SUB-STATIONS WITH AIR INSULATED SWITCHGEAR (AIS)

AIS substations meet the most demanding challenges and provide:

- an optimum solution when space restrictions and environmental circumstances are not an issue
- easy implementation of a wide range of standard applications
- reliable switching for up to 800 kV, rated currents of up to 8,000 A, and short-circuit currents of up to 80 kA

1.2.2 SUB-STATIONS WITH GAS INSULATED SWITCHGEAR (GIS)

The comprehensive range of GIS for rated voltages from 72.5 kV to 550 kV provides ideal solutions for indoor and outdoor switching applications up to the highest performance rates that require:

- a small footprint
- outstanding reliability
- very low noise and electromagnetic emissions

1.2.3 MIXED TECHNOLOGIES SUBSTATIONS

Mixed technologies substations are:

- ideally suited for new substations when space is limited
- outstandingly compact thanks to the hybridization of GIS and AIS technology
- clearly structured, with good access to all equipment
- modular to suit virtually any network concept

1.2.4 PORTABLE POWER SOLUTIONS

Portable power solutions increase grid development agility and resilience. They ensure maximum flexibility of design and utilization, excellent reliability, and a high return on investment and they have:

- fast installation, small footprint, and easy relocation
- minimum interface management, full pre-commissioning prior to dispatch, and little on-site work
- robustness to transportation and handling constraints, as well as harsh environments

1.2.5 TURNKEY SOLUTIONS:

Turnkey electrical substation solutions that provide:

- a one-stop approach comprising all technical, financial, and ecological aspects of the station's entire life cycle
- customized solutions based on proven Siemens technologies, even for the most challenging demands
- freedom from coordination efforts and minimized financial and technical risk

1.3 SUBSTATION COMPONENTS

Electric power substations consist of two essential parts:

1. Main circuits
2. Auxiliary circuits

1.3.1 MAIN CIRCUITS

The main circuit of a substation is composed of a busbar system and connections of power lines, transformers, etc. to the busbar system through switching devices. Substations are divided into bays.

A bay of a substation is a part of a substation containing extra-high (or high) voltage switching devices and connections of a power line, an interconnecting transformer etc., to the substation busbar system(s) as well as protection, control, and measurement devices for the power line, transformer, etc. If it is a bay used to connect a power line to the busbar system, it is called a line bay, if it is used for connecting a transformer to the busbar system; it is called a transformer bay. Normally, a substation contains a number of line and transformer bays and also other bays. All bays are similar to the line bay.

1.3.2 AUXILIARY CIRCUITS

Auxiliary circuits are electrical circuits containing measurement, signaling, control and protection devices. Consists of three subsystems:

- Protection which is composed of busbar protection, feeder protection and transformer protection.
- Automation which involves load restoration, sequential switching, synchronization and tap-changer control.
- Control/operation: this represents a very important section which is bay interlocking, and whole substation interlocking.

Chapter 2

SUB-STATION BUS

A busbar is an aluminum or copper conductor supported by insulators that interconnects the loads and the sources of electric power in an electric power system There are many different electrical bus system schemes available but selection of a particular scheme depends upon the system voltage position of substation in electrical power system, flexibility needed in system and cost to be expensed. The busbar schemes used in the substation are as follows:

- One & Half Breaker Scheme
- Double Main & Transfer Scheme
- Main-Transfer Scheme
- Bus Sectionalizer

2.1 ONE & HALF BREAKER SCHEME

This is an improvement on the double breaker scheme to effect saving in the number of circuit breaker. For every two circuits, only one spare breaker is provided. The protection is however complicated since it must associate the central breaker with the feeder whose own breaker is taken out for maintenance. For the reasons given under double breaker scheme and because of the prohibitory costs of equipment, even this scheme is not much popular. As shown in the figure that it is a simple design, two feeders are fed from two different buses through their associated breakers, and these two feeders are coupled by a third breaker which is called tiebreaker.

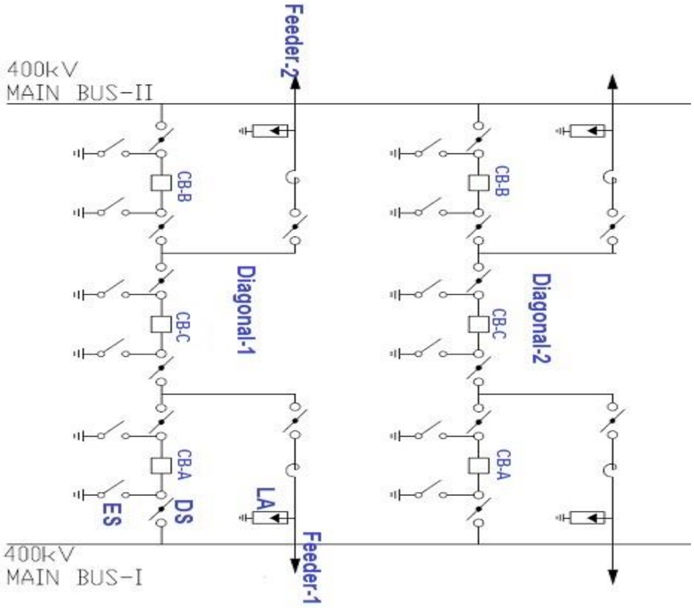


Figure 2: Schematic diagram of One & Half Breaker Scheme

Normally all the three breakers are closed, and power is fed to both the circuits from two buses which are operated in parallel. The tiebreaker acts as a coupler for the two feeder circuits. During the failure of any feeder breaker, the power is fed through the breaker of the second feeder and tiebreaker, therefore each feeder breaker has to be rated to feed both the feeders, coupled by the tiebreaker. The one & half breaker scheme is employed in the 400 kV switchyard of the substation.

2.1.1 ADVANTAGES OF ONE AND A HALF BREAKER BUS SYSTEM

During any fault on any one of the buses, that faulty bus will be cleared instantly without interrupting any feeders in the system since all feeders will continue to feed from other healthy bus.

2.1.2 DISADVANTAGES OF ONE AND A HALF BREAKER BUS SYSTEM:

This scheme is much expensive due to investment for third breaker.

2.2 DOUBLE MAIN & TRANSFER BUS SCHEME

This scheme is the combination of Main-Transfer Bus and Double Bus arrangement. This has got flexibility in transforming any circuit to any of the main buses. For maintenance or any fault occurrence in any bus, a particular bus becomes dead only while the other bus continues to be in service. Any circuit breaker can be taken out for maintenance by transferring that circuit to transfer bus and transferring its protection to transfer bus coupler circuit breaker. This Busbar scheme is employed in the 220 kV switchyard of the substation.

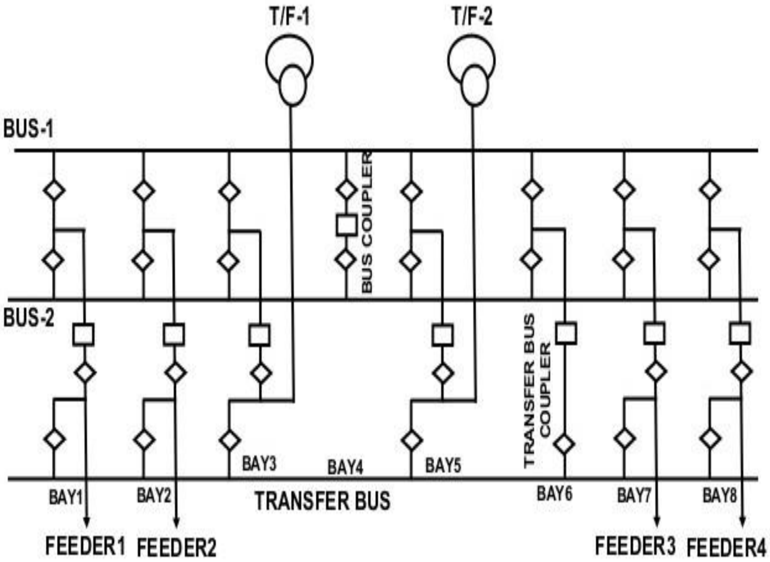


Figure 3: Schematic diagram of Double Main & Transfer Bus Scheme

2.2.1 ADVANTAGES OF DOUBLE MAIN & TRANSFER BUS SCHEME:

This arrangement provides more additional flexibility, continuity of Power Supply permits periodic maintenance without total shut down as the two main buses can be operated independently with the same redundancy.

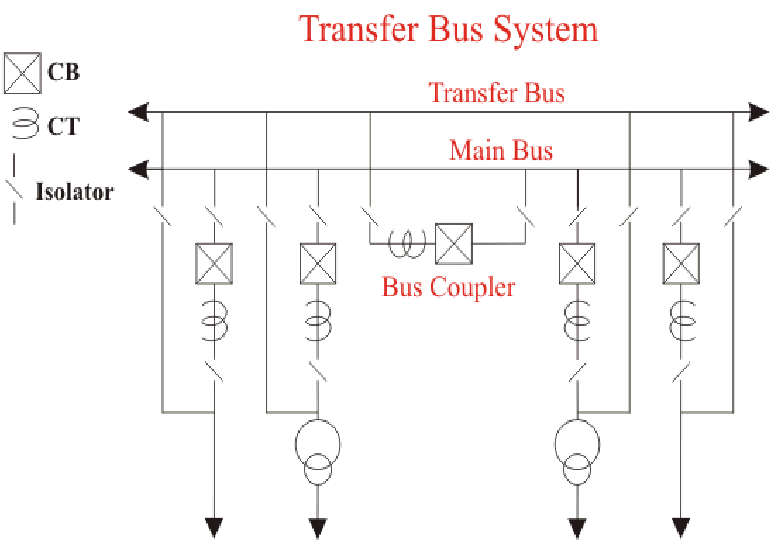


Figure 4: schematic diagram of main & transfer bus scheme

2.3 MAIN & TRANSFER BUS SCHEME

This is an alternative of a double bus system.

The main conception of Main and Transfer Bus System is, here every feeder line is directly connected through an isolator to a second bus called transfer bus. The isolator in between transfer bus and feeder line is generally called bypass isolator.

The main bus is as usual connected to each feeder through a bay consists of the circuit breaker and associated isolators at both sides of the breaker. There is one bus coupler bay which couples transfer bus and main bus through a circuit breaker and associated isolators at both sides of the breaker. If necessary, the transfer bus can be energized by main bus power by closing the transfer bus coupler isolators and then breaker. Then the power in transfer bus can directly be fed to the feeder line by closing the bypass isolator. If the main circuit breaker associated with the feeder is switched off or isolated from the system, the feeder can still be fed in this way by transferring it to transfer bus. This Busbar scheme is employed in the 132 kV switchyard of the substation.

2.3.1 ADVANTAGES OF MAIN & TRANSFER BUS SCHEME:

A satisfactory alternative consists of connecting the line and bus relaying to current transformers located on the lines rather than on the breakers. For this arrangement, line and bus relaying need not be transferred when a circuit breaker is taken out of service for maintenance, with the bus-tie breaker used to keep the circuit energized.

2.3.2 DISADVANTAGES OF MAIN & TRANSFER BUS SCHEME:

Due to its relative complexity, disconnect-switch operation with the main- and transfer-bus scheme can lead to operator error and a possible outage. Although this scheme is low in cost and enjoys some popularity, it may not provide as high a degree of reliability and flexibility as required.

This arrangement is slightly more expensive than the single bus arrangement, but does provide more flexibility during maintenance. Protection of this scheme is similar to that of the single bus arrangement. The area required for a low profile substation with a main and transfer bus scheme is also greater than that of the single bus, due to the additional switches and bus.

2.4 SINGLE BUS SYSTEM WITH BUS SECTIONALIZER

Some advantages are realized if a single bus bar is sectionalized with circuit breaker. If there are more than one incoming and the incoming sources and outgoing feeders are evenly distributed on the sections as shown in the figure, interruption of a system can be reduced to a reasonable extent.

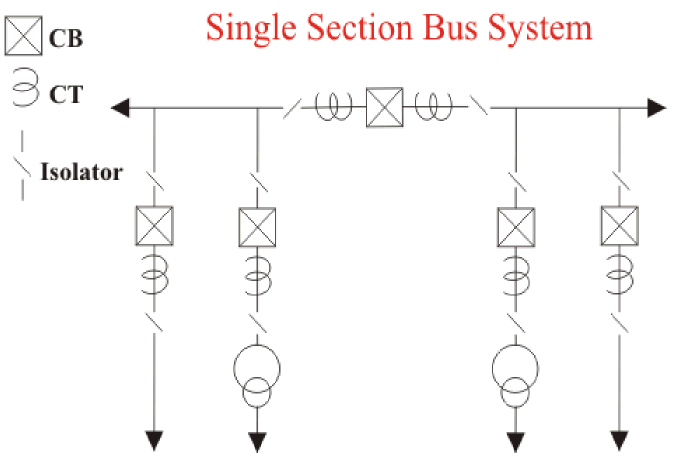


Figure 5: Schematic diagram of Bus Sectionalizer

2.4.1 ADVANTAGES OF SINGLE BUS SYSTEM WITH BUS SECTIONALIZER

If any of the sources is out of the system, still all loads can be fed by switching on the sectional circuit breaker or bus coupler breaker. If one section of the bus bar system is under maintenance, a part load of the substation can be fed by energizing the other section of the bus bar.

2.4.2 DISADVANTAGES OF SINGLE BUS SYSTEM WITH BUS SECTIONALIZER

- As in the case of a single bus system, maintenance of equipment of any bay cannot be possible without interrupting the feeder or transformer connected to that bay.
- The use of isolator for bus sectionalizing does not fulfill the purpose. The isolators have to be operated ‘off circuit’ and which is not possible without total interruption of bus-bar. So investment for bus-coupler breaker is required.

Chapter 3
BAY EQUIPMENT

3.1 LIGHTNING/SURGE ARRESTER

A surge arrester or lighting arrester is a device to protect electrical equipment from over-voltage transients caused by external (lightning) or internal (switching) events. This class of device is used to protect equipment in power transmission and distribution systems. The energy criterion for various insulation materials can be compared by impulse ratio. A surge arrester should have a low impulse ratio, so that a surge incident on the surge arrester may be bypassed to the ground instead of passing through the apparatus.

Figure 6: Surge Arrester

Figure 6 shows a practical surge arrester. To protect a unit of equipment from transients occurring on an attached conductor, a surge arrester is connected to the conductor just before it enters the equipment. The surge arrester is also connected to ground and functions by routing energy from an over-voltage transient to ground if one occurs, while isolating the conductor from ground at normal operating voltages.

3.1.1 Surge Counters

A surge counters (Shown in Figure 7) along with leakage current indicator. This device is connected in series with the surge arrester by means of suitable cable at earth side. The counter counts the number of surges passing through the surge arrester while the leakage current indicator continuously indicates the leakage current through active elements as well as over the surface of the surge arrester.

Figure 7: Surge Counter

3.2 CAPACITOR VOLTAGE TRANSFORMER

A capacitor voltage transformer (CVT or CCVT), is a transformer used in power systems to step down extra high voltage signals and provide a low voltage signal, for metering or operating a protective relay. 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

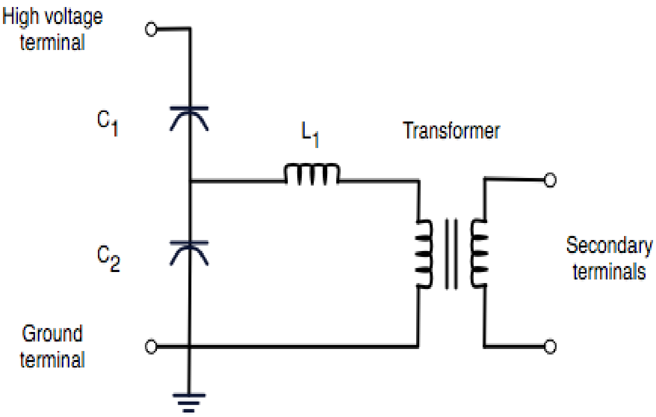


Figure 8: Internal Circuit of CVT

to the instrumentation or protective relay.

3.2.1 PRINCIPLE OF OPERATION

As shown in Figure 8, the 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. As the majority of the voltage drop is on C_1, this reduces the required insulation level of the voltage transformer. This makes CVTs more economical than the wound voltage transformers under high voltage (over 100 kV), as the latter one requires more winding and materials.

Figure 9: Capacitor Voltage Transformer

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, to communicate between substations. The CVT is installed at a point after Lightning Arrester and before Wave trap. A practical CVT is shown in Figure 9.

3.3 WAVE TRAP

A wave trap or line tarp (high-frequency stopper) is a maintenance-free parallel resonant circuit, mounted inline on high-voltage (AC) transmission power lines to prevent the transmission of high frequency (40 kHz to 1000 kHz) carrier signals of power line communication to unwanted destinations. Line traps are cylinder-like structures connected in series with HV transmission lines. The wave trap acts as a barrier or filter to prevent signal losses. The inductive reactance of the line trap presents a high reactance to high-frequency signals but a low reactance to mains frequency. This prevents carrier signals from being dissipated in the substation or in a tap line or branch of the main transmission path and grounds in the case of anything happening outside of the carrier transmission path. The line trap is also used to attenuate the shunting effects of high-voltage lines.

Figure 10: Wave Trap

The wave trap consists of three major components: the main coil, the tuning device, and the protective device (also known as a surge arrester). The protective and tuning devices are mounted inside the main coil. A line trap may be covered with a bird barrier, in which case there are four components. The main coil is the outer part of the line trap which is made from stranded aluminum cable. The reactor coil, depending on the device, can be made up of several aluminum wires, allowing equal distribution amongst the parallel wires. The next major component is the tuning device. This device is securely installed inside the main coil. It adjusts blocking frequency or bandwidth, and consists of coils, capacitors, and resistors. This smaller coil is attached to both ends of the main coil. Its purpose is to create a blocking circuit which provides high impedance. There are three types of tuning devices: wideband tuning, single frequency tuning, and double frequency tuning. The tuned circuit is usually a dual-circuit broadband type. If the traps are self-tuned, they do not require the use of any tuning devices. With the use of a tuning device, a line trap can be tuned to a frequency of 1000 Hz. The last main component is the protective device, which is parallel with the main coil and the tuning device. It protects the main coil and the tuning device by lowering the over-voltage levels. The bandwidth of a line trap is the frequency range over which the line trap can provide a certain specified minimum blocking impedance or resistance.

Line traps are connected in series with power line and thus their coils are rated to carry the full line current. The impedance of a line trap is very low at the power frequency and will not cause any significant voltage drop. In order to communicate, high-frequency line traps are used as they allow substations to communicate with each other through the power lines at the same time as they transmit electrical power. In order to separate power from messages being sent, different frequencies are used. Electrical power has a frequency of 50 Hz or 60 Hz in most places, and the communication waves use frequencies such as 150 kHz and 200 kHz. Line traps consist of filter circuits that allow only power frequency waves to travel to that of electrical equipment. They also stop communication waves from traveling to equipment. Communication is crucial for substations.

3.4 ISOLATORS

The isolator is a mechanical switch which isolates a part of the circuit from the system as when required. Electrical isolators separate a part of the system from rest for safe maintenance works. Isolators are used to open a circuit under no load condition. Its main purpose is to isolate one portion of the circuit from the other and is not intended to be opened while current is flowing in the line. Isolators are generally used on both ends of the breaker so that repair or replacement of circuit breaker can be done without any danger. Isolators employed in this substation are:

3.4.1 HORIZONTAL DOUBLE BREAK (HDB) ISOLATOR

These have three stacks of post insulators as shown in the Figure 11. The central post insulator carries a tubular or flat male contact which can be rotated horizontally with a rotation of central post insulator.

This rod type contact is also called moving contact. The female type contacts are fixed on the top of the other post insulators which fitted at both sides of the central post insulator. The female contacts are generally in the form of spring-loaded figure contacts. The rotational movement of male contact causes to come itself into female contacts and isolators become closed. The rotation of male contact in the opposite direction makes to it out from female contacts and isolators become open. Rotation of the central post insulator is done by a driving lever mechanism at the base of the post insulator, and it connected to operating handle (in case of hand operation) or motor (in case of motorized operation) of the isolator through a mechanical tie rod.

Figure 11: HDB Isolator

3.4.1.1 EARTH SWITCHES

Earthing switches (Shown in Figure 12) are mounted on the base of line side isolator. Earthing switches are usually vertically broken switches. Earthing arms (contact arm of earthing switch) usually are aligned horizontally at off condition during switching on the operation, these earthing arms rotate and move to vertical position and make contact with earth female contacts fitted at the top of the post insulator stack of the isolator at its outgoing side. The earthing arms are so interlocked with the main isolator moving contacts that it can be closed only when the primary contacts of the isolator are in open position. Similarly, the main isolator contacts can be closed only when the earthing arms are in open position.

Figure 12: Earth Switch

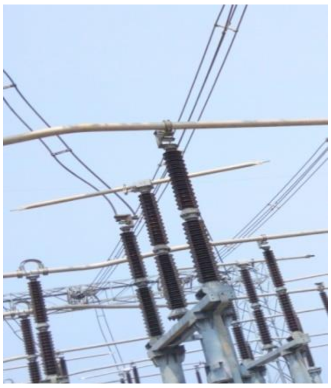


Figure 13: Tandem Isolator

3.4.2 TANDEM ISOLATOR

It is the isolator where the three poles are aligned diagonally i.e. all the three pole phases are connected one behind another so that the jumpering can be done on the bus bar. It’s main application is to provide jumpering between the bus bar. Figure 13 shows a practical tandem isolator.

3.5 CORONA RING

Figure 14: Corona Ring

A corona ring, also called an anti-corona ring, is a toroid of conductive material, usually metal, which is attached to a terminal or other irregular hardware piece of high voltage equipment. The role of the corona ring is to distribute the electric field gradient and lower its maximum values below the corona threshold, either preventing corona discharge entirely or transferring its destructive effects from the valuable hardware to the expendable ring. Corona rings are used on very high voltage power transmission insulators and switchgear, and on scientific research apparatus that generates high voltages. A very similar related device, the grading ring is used around insulators.

Corona rings are used on extremely high voltage apparatus like electric power transmission insulators, bushings and switchgear. Manufacturers suggest a corona ring on the line end of the insulator for transmission lines above 230 kV and on both ends for potentials above 500 kV. Corona rings prolong the lifetime of insulator surfaces by suppressing the effects of corona discharge.

Figure 15: Gang Operated SF_6 CB

3.6 SULFUR HEXAFLUORIDE (SF_6) CIRCUIT BREAKER

A circuit breaker in which the current carrying contacts operate in sulphur hexafluoride or SF_6 gas is known as an SF_6 circuit breaker. SF_6 has excellent insulating property. SF_6 has high electro-negativity. That means it has high affinity of absorbing free electron. Whenever a free electron collides with the SF_6 gas molecule, it is absorbed by that gas molecule and forms a negative ion.

Figure 16: Double Break SF_6 CB without PIR

3.6.1 TYPES OF SF_6 CIRCUIT BREAKER

There are mainly three types of SF_6 CB depending upon the voltage level of application-

- Single Break/Gang Circuit Breaker
- Double Break Circuit Breaker
- Multi Break Circuit Breaker

3.6.1.1 SINGLE BREAK SF_6 CIRCUIT BREAKER

In Single Break Circuit Breaker (fig. 15), only one moving and fixed contacts are present. This means that, there will only be one interrupter unit in such breaker. Single break SF6 circuit breaker is used for 220 kV applications. Generally when utilities wanted to procure circuit breakers (CBs) in past as well as today, their preference is always for three pole operated circuit breakers due to cost effectiveness. Three poles operated or Gang Operated circuit breakers are not only economical, but they also do not cause any electrical pole discrepancy. The term ‘Gang’ has introduced in this case because of the capability of breaking the three phases together.

3.6.1.2 DOUBLE BREAK SF_6 CIRCUIT BREAKER

In such type of breaker (Fig. 16 and fig. 17), there are two set of moving and fixed contacts connected in series. Therefore, to enclose two set of contacts, there must be two interrupt units in series. This type of breaker is used in 400 kV applications. In double break circuit breaker, grading capacitors are used to equalize the voltage distribution across each contact. Thus for 400 kV application, the voltage across each contact will be 200 kV. Two types of Circuit Breakers are used in 400 kV Switchyard. They differ in only one features i.e. Pre Insertion Resistor (PIR). One type has PIR whereas other has no such provision. Both type of breaker are self-compensating spring to Open and Spring to close type. SF6 gas is used as arc quenching medium. The normal pressure of SF6 gas is 6 bar(g).

Purpose of PIR:

PIR is pre-insertion-resistor. This is a resistor of about 200-400 ohms which gets temporarily closed before closing the circuit breaker. The sequence is (close order)->closing of PIR->10-12milliseconds->closing of main break. But while opening, PIR is first disconnected by the Breaker operating mechanism and then i.e. after 10 ms, main contacts of Breaker are opened. The main purpose of PIR is to limit the initial charging current of line

Figure 17(a): Double Break SF_6 CB with PIR

3.6.13 MULTI BREAK SF_6 CIRCUIT BREAKER

In multi break circuit break, more than two set of fixed and moving contacts are used. Such type of breaker is used in EHV applications.

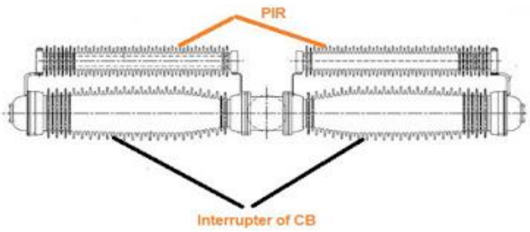


Figure 17(b): Cross section of PIR sF6 CB

3.6.2 ADVANTAGES OF SF_6 CIRCUIT BREAKER

- SF_6 gas has excellent insulating, arc extinguishing and many other properties which are the greatest advantages of SF_6 circuit breakers.
- The gas is non-inflammable and chemically stable. Their decomposition products are non-explosive and hence there is no risk of fire or explosion.
- Electric clearance is very much reduced because of the high dielectric strength of SF_6.
- Its performance is not affected due to variations in atmospheric condition.
- It gives noiseless operation, and there is no over voltage problem because the arc is extinguished at natural current zero.
- There is no reduction in dielectric strength because no carbon particles are formed during arcing.
- It requires less maintenance and no costly compressed air system is required.
- SF_6 performs various duties like clearing short-line faults, switching, opening unloaded transmission lines, and transformer reactor, etc. without any problem.

3.6.3 DISADVANTAGES OF SF_6 CIRCUIT BREAKERS

- SF_6 gas is suffocating to some extent. In the case of leakage in the breaker tank, the SF_6 gas being heavier than air and hence SF_6 are settled in the surroundings and lead to the suffocation of the operating personnel.
- The entrance of moisture in the SF_6 breaker tank is very harmful to the breaker, and it causes several failures.
- The internal parts need cleaning during periodic maintenance under clean and dry environment.
- The special facility requires for transportation and maintenance of quality of gas.

3.7 COMPOSITE INSULATOR

3.7.1 FIELD OF APPLICATION:

▪ Bushings for transformers and other devices
▪ Grading capacitors
▪ Voltage and current transformers
▪ Cable connections
▪ Surge arresters
▪ Circuit breakers

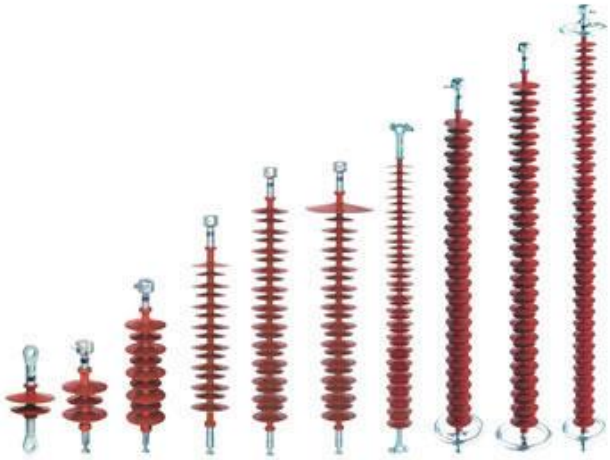


Figure 18: Composite Insulator

3.7.2 CHARACTERISTICS OF COMPOSITE INSULATORS:

▪ Low risk of breakage due to flexible sheds
▪ Easy montage
▪ Low weight
▪ Safety at internal shorts-circuits and earthquakes
▪ No cleaning of silicon housing necessary
▪ Highly resistant to environmental influences and pollution

Figure 19: Inter Connecting Transformer

3.8 INTER CONNECTING TRANSFORMER (ICT)

The Inter Connecting Transformer (fig. 19) is an auto transformer which can step up & step down the voltages for synchronization of grid voltages. As the name suggests the function of the inter-connecting transformer is to inter connect two or more systems at different voltages. They are bidirectional .During the plant start-up, they import power from grid either at 400KV or 220KV and step down to132KV or 110KV to supply the station auxiliaries. Once the plant is started and synchronized to the grid, the same transformer can now be used to export power to the grid. It has a delta connected tertiary winding of about 33KV rating, for providing a circulating path for the Zero sequence currents. The Transformer rating is 400/220/33KV, 315 MVA

3.8.1 TERTIARY WINDING OF TRANSFORMER

In the inter connecting transformer, one winding in addition to its primary and secondary winding is used. This additional winding, apart from primary and secondary windings, is known as Tertiary winding of transformer. Because of this third winding, the transformer is called three winding transformer**.**

3.8.1.1 ADVANTAGES OF USING TERTIARY WINDING IN TRANSFORMER

Tertiary winding is provided in electrical power transformer to meet one or more of the following requirements-

- It reduces the unbalancing in the primary due to unbalancing in three phase load.
- It redistributes the flow of fault current.
- Sometime it is required to supply an auxiliary load in different voltage level in addition to its main secondary load. This secondary load can be taken from tertiary winding of three winding transformer**.**
- As the tertiary winding is connected in delta formation in **3** winding transformer, it assists in limitation of fault current in the event of a short circuit from line to neutral.

3.8.2 TRANSFORMER ACCESSORIES

Conservator- The variation of temperature is the corresponding variation in the oil volume. To account for these an expansion vessel called conservator is added to the transformer with a connecting pipe to the main tank.

Breather- In conservator the moisture from the oil is excluded from the oil through breather it is a Silica Gel Column, which absorbs the moisture in the air before it enters in the conservation air surface.

Radiator- This chamber connected through the transformer to provided cooling of the oil. It has got Fans attached to it to provide proper cooling.

3.8.3 TRANSFORMER PROTECTION

3.8.3.1 OIL TEMPERATURE INDICATOR (OTI):

These devices are used to measure the top oil temperature. An OTI is used for the protection of a transformer.

3.8.3.2 WINDING TEMPERATURE INDICATOR (WTI):

This device measures the LV and HV winding temperature. An WTI is used for the protection of Transformer.

3.8.3.3 PRESSURE RELEASE VALVE (PRV):

The release valve is used to control or limit the pressure in the system which can be built for a process upset. In case of instrument or equipment failure of fire the pressure is relieved by allowing the pressurized fluid to flow from auxiliary passage out of the system.

Figure 20: Transformer Explosion and Fire Prevention System (Nitrogen Protection)

3.8.3.4 NITROGEN INJECTION SYSTEM FOR TRANSFORMER:

Transformers are among the most expensive equipment located in power plants and substations. They generally contain a large quantity of combustible substance, which can spray fire to nearby installations and caused a power failure and huge economic losses. Nitrogen Injection System (fig. 20) is employed to prevent oxidation which reduces corrosion and to maintain an inert gas atmosphere in the space above the oil to keep any combustible from exploding in an oxygen rich environment.

Figure 21: Buchholz Relay

3.8.3.5 Buchholz relay

Buchholz relay(fig.21) in transformer is an oil container housed the connecting pipe from main tank to conservator tank. It has mainly two elements. The upper element consists of a float. The float is attached to a hinge in such a way that it can move up and down depending upon the oil level in the Buchholz relay Container. One mercury switch is fixed on the float. The alignment of mercury switch hence depends upon the position of the float. The lower element consists of a baffle plate and mercury switch. This plate is fitted on a hinge just in front of the inlet (main tank side) of Buchholz relay in transformer in such a way that when oil enters in the relay from that inlet in high pressure the alignment of the baffle plate along with the mercury switch attached to it, will change. In addition to these main elements a Buchholz relay has gas release pockets on top. The electrical leads from both mercury switches are taken out through a molded terminal block.

Figure 20: LT Transformer

3.9 LT TRANSFORMER

An LT transformer or station transformer (fig.20) is the transformer that provides low voltage power for the power station auxiliaries. Power of the lights, computers, fans, air-conditioners, pumps, etc. that are essential for the operation of the substation. The primary of the LT transformer is connected to the tertiary winding of the ICT. The rating of the LT transformer is 33/0.433 kV, 800 kVA.

3.10 CURRENT TRANSFORMER (CT)

A current transformer (CT) is a type of transformer that is used to measure alternating current (AC). It produces a current in its secondary which is proportional to the current in its primary. Current transformers are used extensively for measuring current and monitoring the operation of the grid. High-voltage current transformers are mounted on porcelain or polymer insulators to isolate them from ground. Some CT configurations slip around the bushing of a high-voltage transformer or circuit breaker, which automatically centers the conductor inside the CT window. Often, multiple CTs are installed as a "stack" for various uses. For example, protection devices and revenue metering may use separate CTs to provide isolation between metering and protection circuits and allows current transformers with different characteristics (accuracy, overload performance) to be used for the devices.


Figure 21: Current Transformer


Figure 21: Potential Transformer

3.11 POTENTIAL TRANSFORMER

Potential transformer or voltage transformer gets used in electrical power system for stepping down the system voltage to a safe value which can be fed to low ratings meters and relays. Commercially available relays and meters used for protection and metering, are designed for low voltage. This is a simplest form of potential transformer definition. A voltage transformer theory **or** potential transformer theory is just like a theory of general purpose step down transformer. Primary of this transformer is connected across the phase and ground. Just like the transformer used for stepping down purpose, potential transformer has lower turns winding at its secondary.


Figure 22: Line Reactor

3.12 LINE REACTOR

A line reactor (fig.22) is placed in line at the point of use to maintain stable amperage to the user. When a line is disconnected from the system, the line reactor is also disconnected from the system. Line reactors are often used to compensate line capacitance, mitigate voltage transients due to switching, and to limit fault currents, especially in case of underground transmission lines. A bus reactor and a line reactor are interchangeable as long as they are rated for the same voltage which is dependent upon substation's physical layout, and bus configuration.

3.12.1 NEUTRAL GROUNDING REACTOR

Neutral grounding reactors are used for low-impedance grounding of the neutral point of three-phase networks in order to limit the fault current in the event of a phase-to-ground short-circuit (fault current will be limited to the level of the phase-to-phase short-circuit current). One reactor terminal is connected to the neutral of the network and the other terminal is grounded. During normal operation of the power system the current flow through the reactor is almost zero, since it is only driven by the imbalance of the three-phase network.

Figure 23: Neutral grounding Reactor

3.13 BUS REACTORS

A bus reactor (fig.24) is a type of air core inductor, or in some cases, oil filled, connected between two buses or two sections of the same bus in order to limit the voltage transients on either bus. It is installed in a bus to maintain system voltage when the load of the bus changes. It adds inductance to the system to offset the capacitance of the line which varies due to load, humidity, weather, generator excitation and temperature.

Figure 24: Bus Reactor

3.14 CONDUCTOR:

All the conductors found in the site can be divided into two categories:

- Bundled Conductors
- Insulated/Underground Conductors

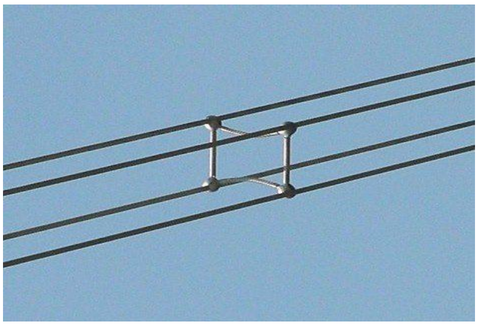


Figure 25: Bundled Conductors with 4 sub conductors

3.14.1 BUNDLED CONDUCTOR

A bundled conductor (fig.25) is a conductor made up of two or more sub-conductors and is used as one phase conductor. For voltages greater than 220 kV it is preferable to use more than one conductor per phase which is known as Bundle conductor. Bundle conductors are used for transmission purpose as it helps in obtaining better voltage regulation and efficiency by reducing the inductance and skin effect present in the power lines. These cause considerable losses in transmission line.

There are many advantages of using bundled conductors in transmission lines

Reduced Reactance: Due to bundling of conductors the self GMD of the conductors is increased, so reactance of conductors decreases. Therefore we get a, reduced voltage drop in the conductors; as a result voltage regulation improves (decreases).

Reduced Corona Loss: There is an optimum spacing between sub conductors of a bundled conductor which give minimum gradient on the surface of sub conductors and hence highest critical disruptive voltage and hence reduced corona loss

Reduced Surge Impedance: Surge Impedance of line is given as square root of (L/C). As inductance is reduced and capacitance is increased (due to self GMD) so surge impedance reduces and hence maximum power that can be transmitted is increased.

3.14.2 INSULATED/UNDERGROUND CONDUCTORS

The 3 cores in the LV belted underground cables are not circular and are insulated by impregnated paper. The cores are generally stranded and may be of non-circular shape to make better use of available space. In a 3 phase cable, the three cores are grouped together and then belted with the paper belt.

Figure 26: A 3 core insulated conductor

The gaps between the conductors and the paper insulation are filled with fibrous material such as the jute. This makes the cable to have a circular cross-sectional shape. A lead sheath is used to cover the belt hence protect it from moisture and provide mechanical strength. The lead sheath is then covered with a single or multiple layers of an armoring material and finally an outer cover. The LV underground cables have uses in transmitting power from the LT transformer to the station auxiliaries etc.

It has some disadvantages, such as,

- Since the electrical field in the three core cables is tangential, the paper insulation and the fibrous materials are subjected to the tangential electrical stresses. This stresses weakens the fibrous material as well as the resistance and dielectric strength for the insulation along the tangential path.
- The weakening of the insulation may lead to the formation of air spaces in the insulation. Under high voltages the air may be ionized and cause deterioration and breakdown of insulation. For this reason, the belted cables are only suitable for voltages up to 11KVa and not higher.
- Due to the large diameter of the paper belt, bending the cable may lead to the formation of wrinkles and gaps.

. SUBSTATION AUTOMATION

4.1 DEFINITION

Substation automation is used for controlling, protecting and monitoring substations. At least from a logical point of view, substation automation systems comprise three levels, the station level with the substation host, the substation HMI (Human Machine Interface) and the Gateway (GW) to the remote control centre, the bay level with all the control and protection units and the process level with more or less intelligent process interfaces to the switchgear. Extended implementations show all three levels equipped with IEDs, where for example a conventional RTU comprises all three levels in one unit. All implemented levels are interconnected by serial communication links. There is not only vertical communication between the levels (e.g. between bay and station level), but also horizontal communication within the level (e.g. in the bay level between bay units for functions like interlocking).

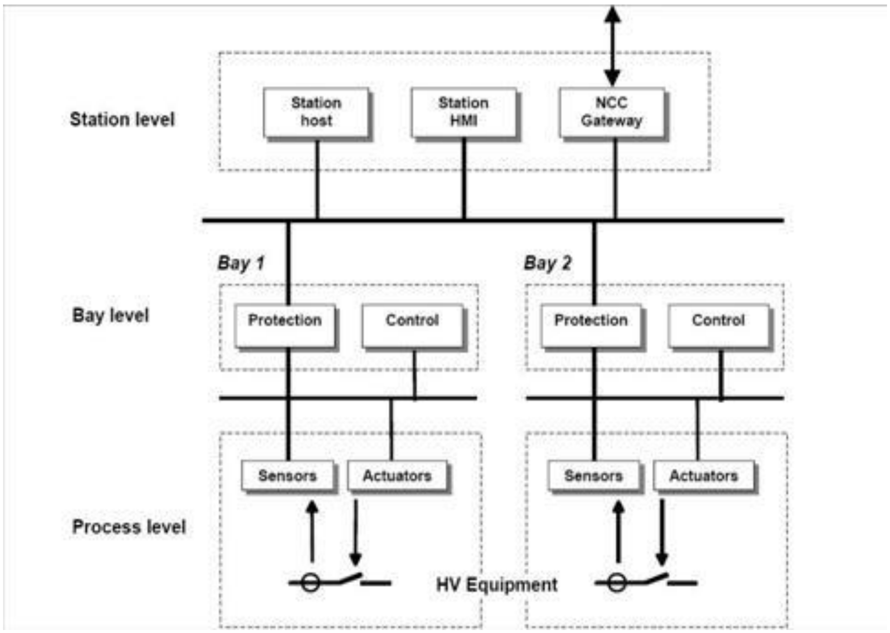


Figure 27: Logical scheme of the three levels of a Substation Automation system

Substation automation can mean different things to different electric utilities. To one, it could mean adding a supervisory control and data acquisition (SCADA) system for remote monitoring and control to a traditional substation with mimic panels and an annunciator. Another utility may replace the mimic panel and annunciator with a station human machine interface (HMI). A third utility might use substation automation to replace all interlocks, cutouts and other controls so that all station control is performed and monitored using a combination of microprocessor-based relays, substation controllers and HMIs. Finally, a utility could take a more literal interpretation of the term and define it as actual station automation, including such items as automatic voltage control, power fail actions, intelligent load transferring between stations, load tap .The BCU is the unit responsible of automation in a bay of substation.

4.2 BAY CONTROL UNIT (BCU)

Bay Control Unit (BCU), is a highly versatile panel-mounted unit providing a wider range of control and automation capabilities at the individual bay or circuit level. Offering a large color operator display (with touch screen option) the BCU has a powerful user interface that can present single line diagrams, status, alarms and measurements at both a single bay or multiple bay level and is a key element within the flexible Substation Automation System.

Figure 28: Bay Control unit

4.2.1 FUNCTION OF A BCU

i. Monitoring

To monitor the whole system remotely away. The status of primary equipment or auxiliary devices can be obtained from auxiliary contacts. Therefore it is possible to detect and indicate both the OPEN and CLOSED position or a fault or intermediate circuit-breaker or auxiliary contact position.

ii. Control

In addition to the monitoring functions, BCU also support all control functions that are required for operating medium-voltage or high voltage substations. The main application is reliable control of switching and other processes. With integrated logic, the user can set, via a graphic interface (CFC), specific functions for the automation of switchgear or substation. Functions are activated via function keys, binary input or via communication interface. Switching authority is determined according to parameters, communication.

iii. Command processing

All the functionality of command processing is offered. This includes the processing of single and double commands with or without feedback, sophisticated monitoring of the control hardware and software, checking of the external process, control actions using functions such as runtime monitoring and automatic command termination after output.

4.3 INTELLIGENT ELECTRONIC DEVICES (IED)

Intelligent electronic devices (IEDs) being implemented in substations today contain valuable information, both operational and non-operational, needed by many user groups within the utility. An IED is any device that incorporates one or more processors with the capability to receive or send data/control from or to an external source (e.g., electronic multifunction meters, digital relays, controllers). IED technology can help utilities improve reliability, gain operational efficiencies, and enable asset management programs including predictive maintenance, life extensions and improved planning.

IEDs are a key component of substation integration and automation technology. Substation integration involves integrating protection, control, and data acquisition functions into a minimal number of platforms to reduce capital and operating costs, reduce panel and control room space, and eliminate redundant equipment and databases. Automation involves the deployment of substation and feeder operating functions and applications ranging from supervisory control and data acquisition (SCADA) and alarm processing to integrated volt/var control in order to optimize the management of capital assets and enhance operation and maintenance (O&M) efficiencies with minimal human intervention.

Figure 29: REF630 is an example of IEDs

The new substation will typically have many IEDs for different functions, and the majority of operational data for the SCADA system will come from these IEDs. The IEDs will be integrated with digital two-way communications. The RTU functionality is addressed using IEDs, PLCs, and an integration network using digital communications.

Chapter 5

POWER LINE CAREER COMMUNICATION (PLCC)

For large Power System Power Line Carrier Communication is used for data transmission as well as protection of Transmission Lines. Carrier current used for Power Line carrier Communication has a frequency range of 80 to 500 kHz. PLCC in modern electrical Power System is mainly for telemetry and telecontrol. Power Line Carrier Communication is used for the Carrier Tripping and Direct Tripping in case of Distance Protection. Distance protection relay in relay panel at one end of the transmission line gets the input from CT and CVT in line. The output of relay goes to modem of PLCC which in turn is received by the PLCC system at remote end substation.

For communication between the two substations, each end of transmission line is provided with identical PLCC equipment consisting of equipment:

- Transmitters and Receivers
- Hybrids and Filters
- Line Matching Unit
- Wave Traps
- Power Amplifier
- Coupling Capacitors or Capacitor Voltage Transformer

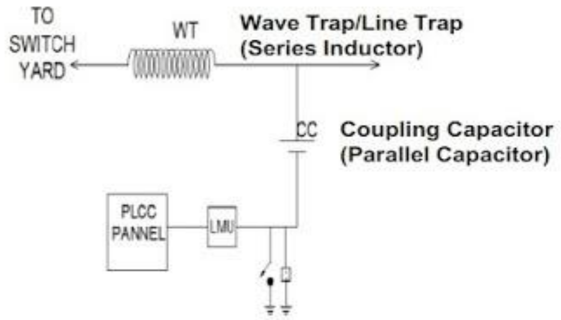


Figure 30: PLCC Circuit Diagram

5.1 PLCC SCHEME

The output of PLCC goes to Coupling Capacitor famously known as Capacitive Voltage Transformer and then to transmission line and travels to another end where it is received through Capacitive Voltage Transformer and inputted to relay and control panel at that end. As the frequency of carrier signal is high, the impedance offered by the CVT = 1/wC will be low and the carrier signal travelling on Transmission Line will be bypassed by the CVT, therefore the carrier signal is received or sent through the CVT (HF point is given on the CVT where PLCC is connected through the Fiber Optic Cable). Wave Trap is provided in the line after the CVT. Wave Trap is nothing but a Choke Coil which chokes out high frequency carrier signal, as the impedance offered by inductor = wL will be high which will not allow the high frequency carrier signal to enter into the substation. The carrier Transmitters and Receivers are usually mounted in a rack or cabinet in the control room, and the line tuner is out in the switchyard. Thus there is a large distance between the equipment and the tuner, and the connection between the two is made using a coaxial cable Fiber Optical (FO) Cable.

Hybrid circuits are provided to enable the connection of two or more transmitters together on one coaxial cable without causing intermodulation distortion due to the signal from one transmitter affecting the output stages of the other transmitter. Hybrids may also be required between transmitters and receivers, depending on the application.

LMU is provided which is a composite unit consisting of Drain Coil, Isolation transformer with Lightning Arrester on its both the sides, a Tuning Device and an earth switch. Tuning Device is the combination of R-L-C circuits which act as filter circuit. LMU is also known as Coupling Device. Together with coupling capacitor, LMU serves the purpose of connecting Audio/Radio frequency signals to PLCC terminal and protection of the PLCC unit from the over voltages caused due to transients on power system.

5.2 APPLICATION OF PLCC:

PLCC in modern electrical power system substation is mainly used for following purpose:

1. Carrier protection relaying of transmission line so that Inter trip command can be issued by relay due to tripping of circuit breaker at any one end. To trip the line circuit breaker nearest to the fault, this is done by:
   a) Distance protection relay (V/I characteristics)
   b) Differential comparison method
   c) Phase comparison method

2. Station to station communication between operating personnel
3. Carrier telemetering, electrical quantities that are telemetered are kW, kVA, kVAR, Voltage and Power factor etc.

STATION AUXILIARY POWER SUPPLY SYSTEM

6.1 AUXILIARY POWER SUPPLY SYSTEMS

The purpose of auxiliary power supply systems is to cater for the necessary energy for the operation of primary and secondary devices at the substation. The auxiliary power systems are normally divided in two categories, namely the AC system and the DC system(s).

Figure 31: ACDB Panel

6.1.1 AC SYSTEM

The AC system normally operates with the country's standardized utility low voltage level 433 V, 50 Hz. The secondary of the 800 kVA LT transformer feeds power to the ACDB as an input.

The Auxiliary loads would typically include the following

- Substation building(s) climate control and lighting
- Outdoor equipment and indoor panels desiccation heaters
- Transformer cooling fans
- Station battery (DC system) charger(s)
- Normal wall socket outlets etc.

Figure 32: Inside of a 220 V Battery Charger

6.1.2 DC SYSTEM

A substation can have more than one or several DC systems. The 400 kV Kukurmara GSS has two DC systems at 220 V and 48 V ratings. The main components of the DC system are battery, charger and distribution switchboard including the DC system monitoring relay. In a typical installation, the batteries are installed in a separate battery room. The ventilation of the battery room should be adequate, considering type and size of the batter.

Figure 33: Units of 220 V Batteries

Temperature level of the battery room should not exceed 25°C, since temperature above this significantly affects the battery lives. The charger and the DC distribution board are normally located in the same room, separate to the battery. Initially the power for battery charging is taken from the ACDB panel and inside the charger panel there is a step down transformer that steps down the 433 V to 220 V and it is fed to the rectifier circuit.

Since the DC system supplying (especially to the relay protection, control and interlocking circuits) is of paramount importance to the substation's reliable and safe operation, the energy supply has to be always available. The need of this reliable supply becomes even more important during disturbances and faults in the high- or medium-voltage primary circuits.

Figure 34: Units of 48V Batteries

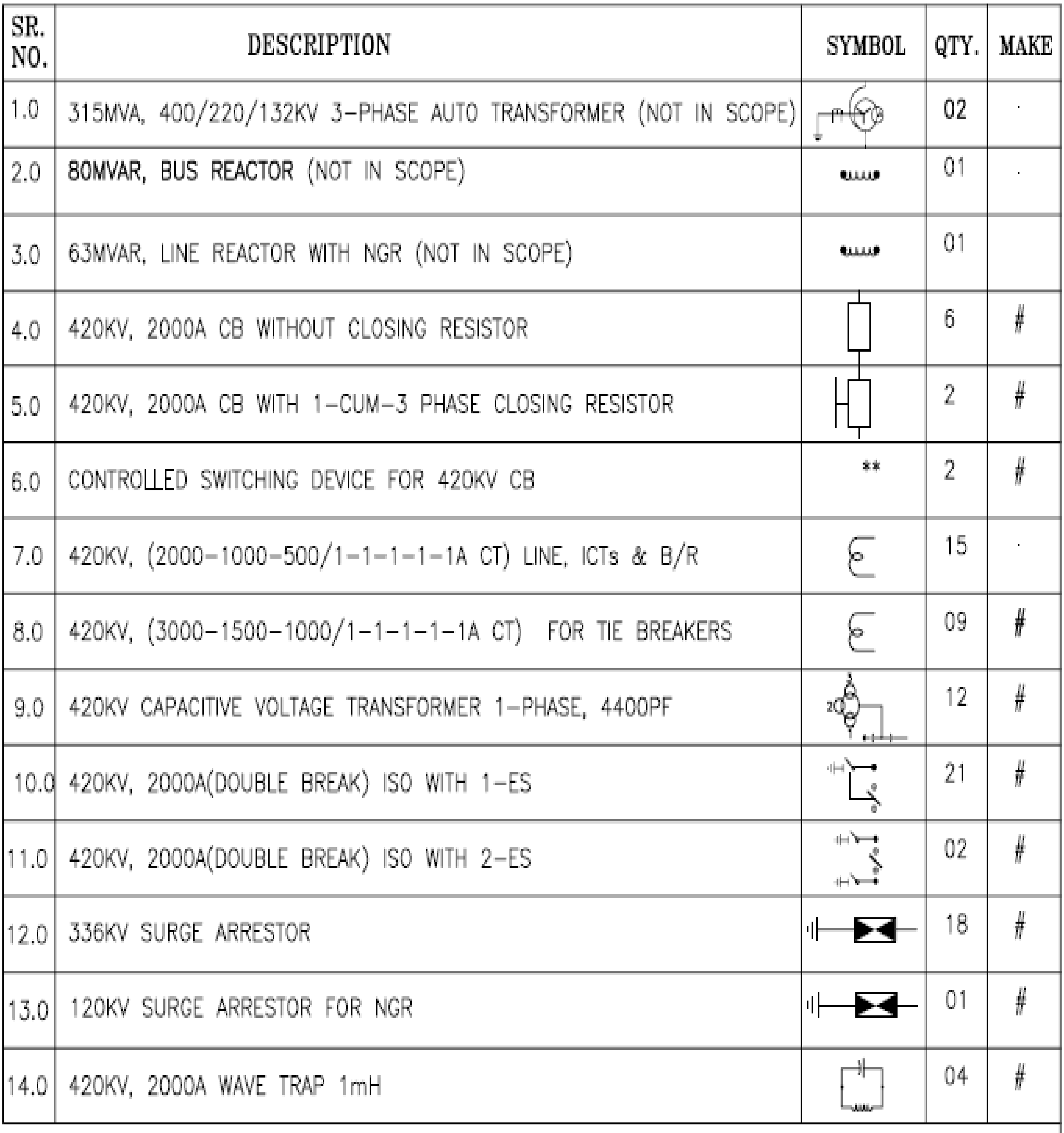
The importance of this reliable DC-auxiliary power is crucial for the substation as such. The higher (more important) role the substation plays from the complete distribution or transmission network point of view, the higher are the demands for the substation's DC auxiliary power systems.

Figure 35: DCDB Panels

APPENDICES

APPENDIX A: SPECIFICATION OF BAY EQUIPMENT

400 kV Switchyard Bay Equipment:



SR. NO.	DESCRIPTION	SYMBOL	QTY.	MAKE
1.0	315MVA, 400/220/132KV 3-PHASE AUTO TRANSFORMER (NOT IN SCOPE)		02	.
2.0	80MVAR, BUS REACTOR (NOT IN SCOPE)		01	.
3.0	63MVAR, LINE REACTOR WITH NGR (NOT IN SCOPE)		01	
4.0	420KV, 2000A CB WITHOUT CLOSING RESISTOR		6	#
5.0	420KV, 2000A CB WITH 1-CUM-3 PHASE CLOSING RESISTOR		2	#
6.0	CONTROLLED SWITCHING DEVICE FOR 420KV CB	**	2	#
7.0	420KV, (2000-1000-500/1-1-1-1-1A CT) LINE, ICTs & B/R		15	.
8.0	420KV, (3000-1500-1000/1-1-1-1-1A CT) FOR TIE BREAKERS		09	#
9.0	420KV CAPACITIVE VOLTAGE TRANSFORMER 1-PHASE, 4400PF		12	#
10.0	420KV, 2000A(DOUBLE BREAK) ISO WITH 1-ES		21	#
11.0	420KV, 2000A(DOUBLE BREAK) ISO WITH 2-ES		02	#
12.0	336KV SURGE ARRESTOR		18	#
13.0	120KV SURGE ARRESTOR FOR NGR		01	#
14.0	420KV, 2000A WAVE TRAP 1mH		04	#

Figure 36: 400 kV Bay Equipment

220 kV Switchyard Bay Equipment:

SR. NO.	DESCRIPTION	SYMBOL	QTY.	MAKE
1.0	100MVA, 220/132KV 3-PHASE TRANSFORMER(NOT IN SCOPE)		02	·
2.0	245KV, 2000A GANG OPERATED CB FOR T/R, TBC & BC		6	#
2.0	245KV, 2000A CB WITH 1-CUM-3 PHASE AR FOR LINES		4	#
3.0	245KV, 1600-800-400/1-1-1-1-1A, CT FOR ICTs, TBC, B/C, LINES		30	#
4.0	245KV, 1600A HDB TANDEM TYPE ISO W/O E/S		17	#
5.0	245KV, 1600A HDB ISO WITH 1-E/S		11	#
6.0	245KV, 1600A HDB ISO WITH 2-E/S		09	#
7.0	245KV, 2000A HDB ISO WITH 2-E/S		02	#
8.0	216KV SURGE ARRESTOR		24	#
9.0	245KV CAPACITIVE VOLTAGE TRANSFORMER 1-PHASE, 4400PF		18	#
10.0	245KV, 1600A WAVE TRAP 1mH		08	#

Figure 46: 220 kV Bay Equipment

132 kV Switchyard Bay Equipment:

SR. NO.	DESCRIPTION	SYMBOL	QTY.	MAKE
1.0	20/25MVA, 132/33KV 3-PHASE TRANSFORMER (NOT IN SCOPE)		02	·
2.0	145KV, CIRCUIT BREAKER 1250A		07	#
3.0	145KV, CT 1200-600/1-1-1A FOR ICTS & TBC		09	#
4.0	145KV, CT 600-300/1-1-1A FOR LINES & POWER T/R		12	#
5.0	145KV, HDB STAGGERED ISO W/O E/S		06	#
6.0	145KV, HDB ISO WITH 1-E/S		07	#
7.0	145KV, HDB ISO WITH 2-E/S		08	#
8.0	120KV SURGE ARRESTOR(METAL OXIDE TYPE)		18	#
9.0	145KV CAPACITIVE VOLTAGE TRANSFORMER		09	#
10.0	145KV,1250A WAVE TRAP 0.5mH		04	#

Figure 56: 132 kV Bay Equipment

CONCLUSION

Industrial Training being an integral part of engineering curriculum provides not only easier understanding but also helps to acquaint with technologies. It exposes an individual to the practical aspect of all things which differ considerably from theoretical models. During my training, I gained a lot of practical knowledge exposure required here that will pay rich dividends to me when I will set my foot as an Engineer.

It is difficult to get a deep knowledge about a substation within a period of 1 month but the training at 400/220/132/33 kV Kukurmara GSS was altogether an exotic experience, since work, culture and mutual cooperation shows it’s excellency within the period. Moreover fruit full result of adherence to quality control awareness of safety and employees fare which is much evident here.

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