RQF LEVEL V

TRADE: HYDROPOWER ENERGY

MODULE CODE: HPOPS501

TEACHER'S GUIDE

Module name: PERFORM SUBSTATION INSTALLATIONS

Table of content

Contents

Acronyms

PPE: Personal Protective Equipment

CT: Current Transformer

PT: Potential Transformer

AVR: Automatic Voltage Regulator

VAR: Voltage-Ampere Reactive

GIS: Gas-Insulated Switchgear

ACB: Air Circuit Breaker

AC: Alternative Current

DC: Direct Current

HVDC: High Voltage Direct Current

LV: Low Voltage

HV: high Voltage

CB: Circuit Breaker

RQF: Rwanda Qualification Frame work

MV: Medium Voltage

CVT: Capacitive Voltage Transformer

OCB: Oil Circuit Breaker

SLD: Single Line Diagram

SWD: Switching Duty

Introduction

This particular module describes the skills, knowledge and attitude required to install a substation. The electrician will be able to interpret the substation design, implement it and test it. It applies to electricians working as hydropower plant electrical supervisor.

HPOPS501 PERFORM SUBSTATION INSTALLATIONS

Learning Units:

1. **PERFORM PRELIMINARY ACTIVITIES**
2. **INSTALL SUBSTATION ELEMENTS OR EQUIPMENT**
3. **TEST SUBSTATION INSTALLATION**

LU1: PERFORM PRELIMINARY ACTIVITIES

STRUCTURE OF LEARNING UNIT

Learning outcomes:

1. Interpret electrical diagrams.
2. Prepare tools, equipment and materials
3. Apply safety precautions at the workplace

Learning outcome 1.1: Interpret electrical diagrams.

Duration: 2hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify the symbols of substation equipment
2. Describe block diagram
3. Describe single line diagram
4. Describe architectural diagram
5. Describe wiring diagram

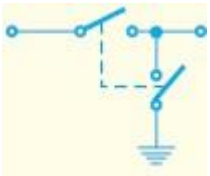
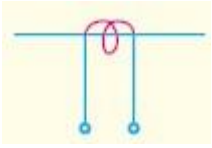
Resources

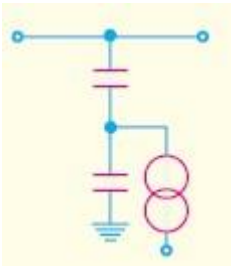
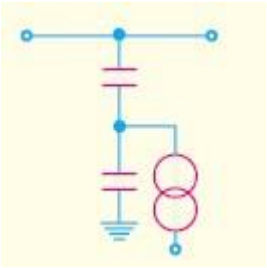
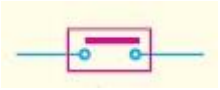
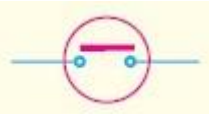
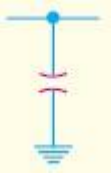
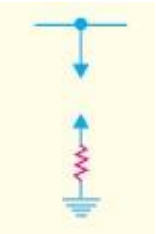
Equipment	Tools	Materials
Helmets **Safety Shoe** **Overall** **Goggles** **Nose protection mask** **Security belt**	**Screw Drivers** **Pliers** **Wrench** **Or Spanner** **Hammer**	**Cables** **Oil** **Cable ties** **Clips** **Bolts** **Nuts** **Screws**

Advance preparation:

.Tools, materials and equipments must be available in the classroom or in the workshop where the course will take a place

INDICATIVE CONTENT 1.1 : Symbols for equipment in substations

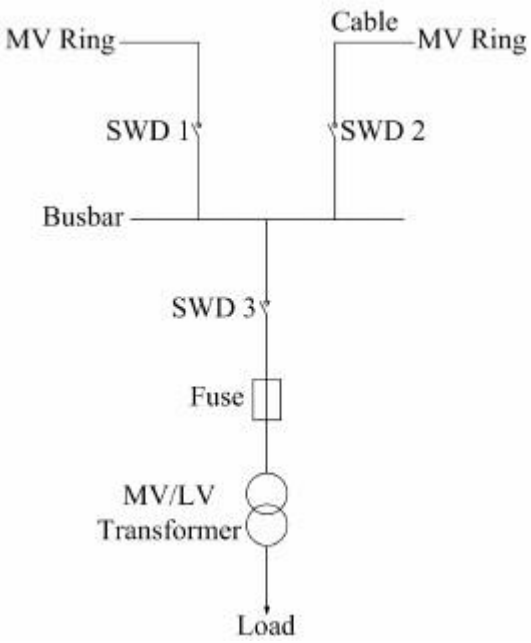
S/N	Circuit element	Symbol
1.	Bus-bar	
2.	Single-break isolating switch	
3.	Double-break isolating switch	
4.	On load isolating switch	
5.	Isolating switch with earth Blade	
6.	Current transformer	

7.	Potential transformer	
8.	Capacitive voltage transformer	
9.	Oil circuit breaker	
10.	Air circuit breaker with overcurrent tripping device	
11.	Air blast circuit breaker	
12.	Lightning arrester (active gap)	
13.	Lightning arrester (valve type)	

Symbols Used for equipments in substation

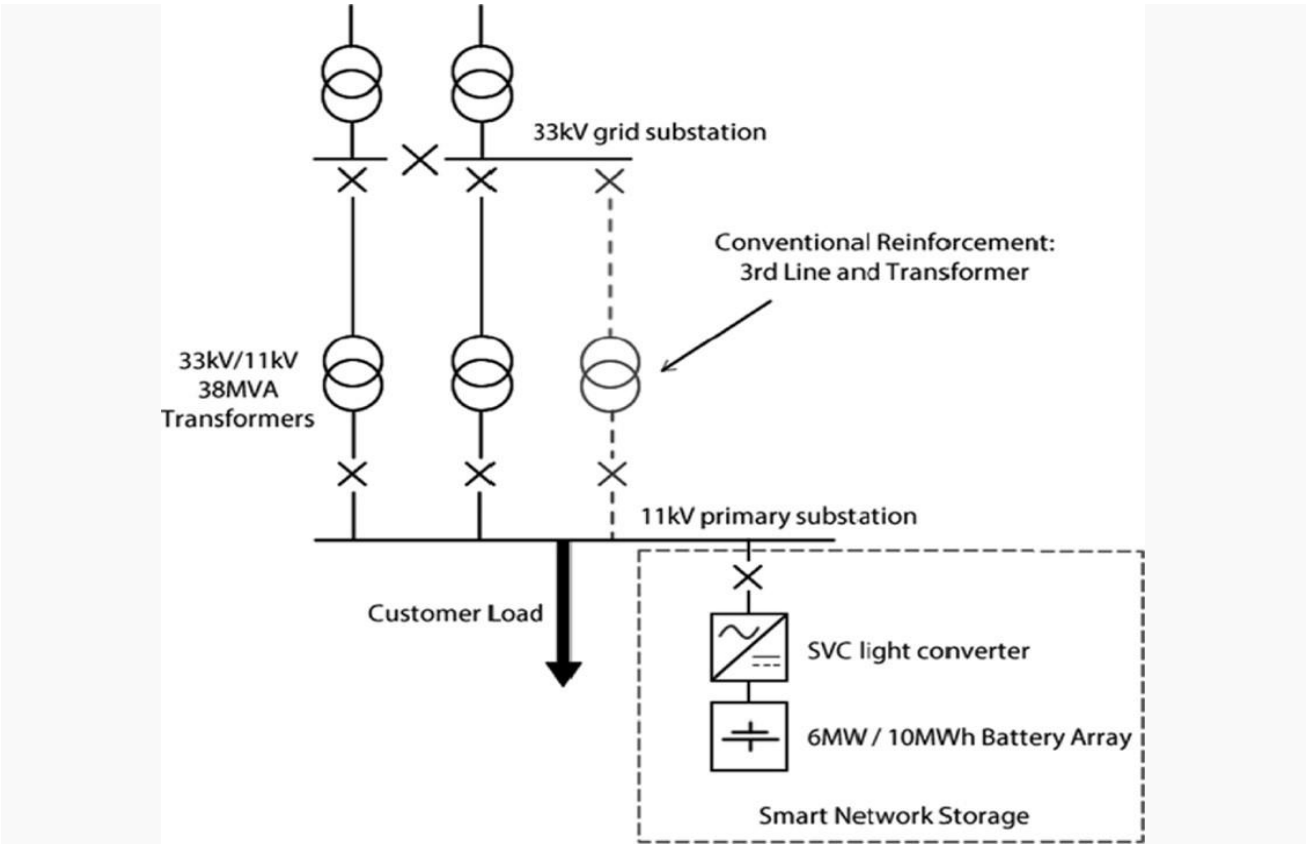
Indicative Content 1.2: Electrical installations' diagrams used in substation

The starting point for new substation work is the block diagram or single line diagram (SLD). The advantage of this type of diagram is that the complete system can be seen as a whole in semi pictorial form. Although not meant to be a detailed guide for the layout of the controls and instruments on the control panels, it is sufficiently concise to enable the designer to check that all the facilities required by the operator are present.



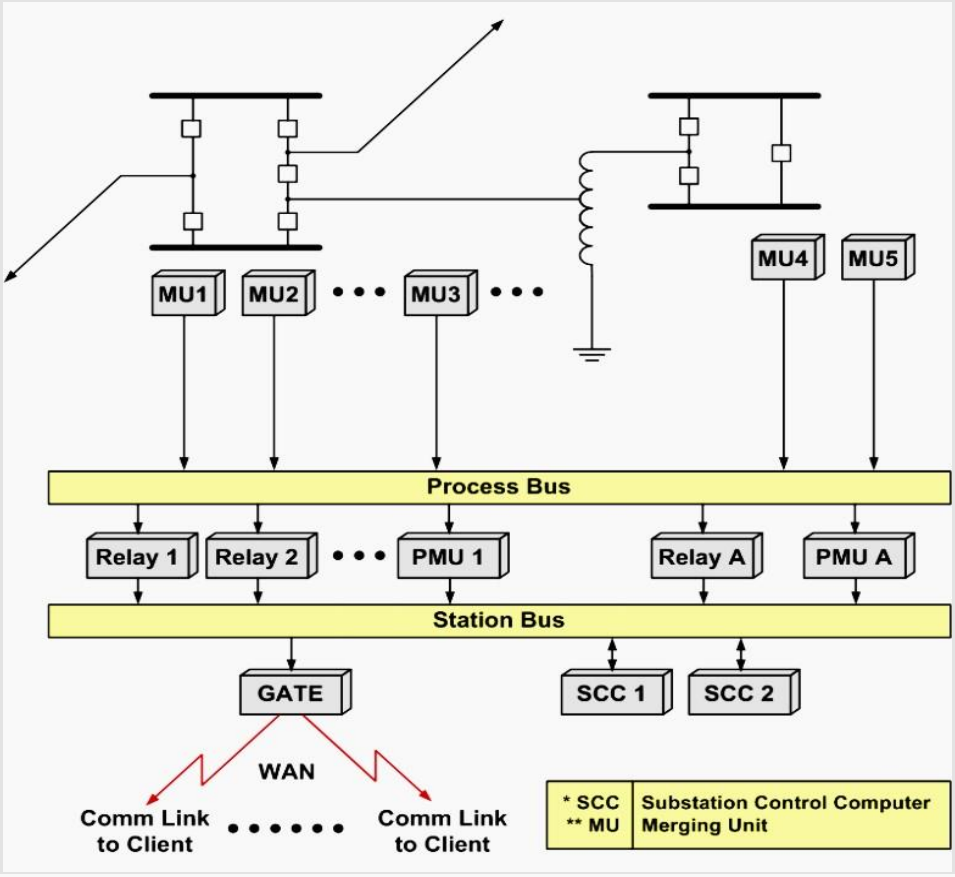
B. Single-line diagrams (SLD)

A single-line diagram shows the **disposition of equipment in a substation**, or network, in a simplified manner, using internationally accepted symbols to represent various items of equipment such as transformers, circuit breakers and disconnectors, generally with a single line being used to represent three-phase connections.



C. Architectural Diagrams

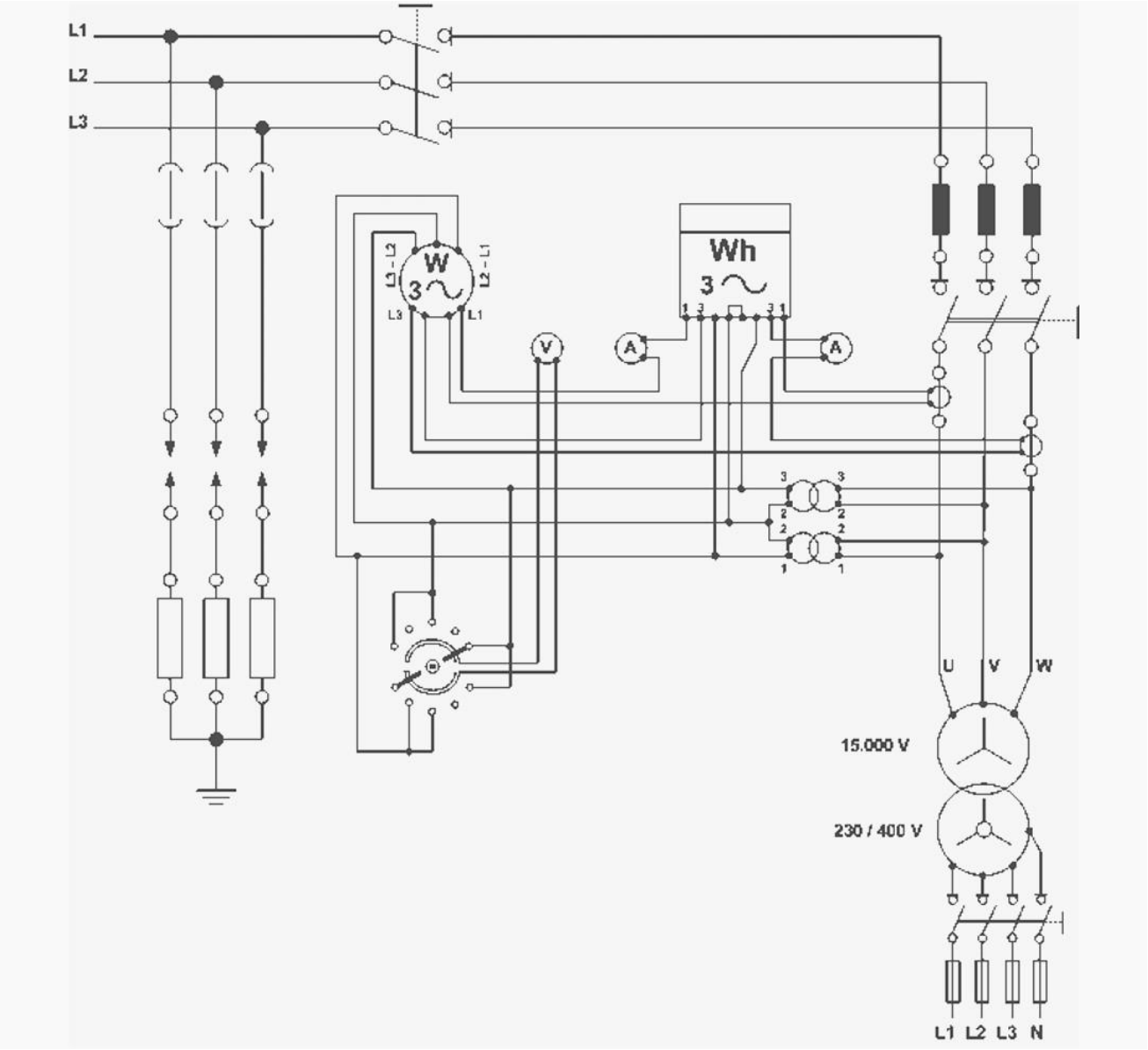
Architectural diagrams describe the main and auxiliary circuits for control, signaling, monitoring and protection systems. They are drawn in sufficient detail to explain to the user the circuitry and its mode of operation. They allow circuits to be 'followed through' when tracing faults.



D. Wiring diagrams

Wiring diagrams show **the interconnection of the multicore cables**, for example, between the switchgear and the associated control panels, and the routing of individual wires to the equipment installed in the relay and control panels.

These diagrams are required **to facilitate the wiring of the measurement, protection and control equipment at the substation construction stage**.



The starting point for new substation work is the block diagram or single line diagram (SLD). The advantage of this type of diagram is that the complete system can be seen as a whole in semi pictorial form.

Theoretical learning Activity

- ✓ Within groups trainees brainstorm about different types of electrical diagrams
- ✓ Within groups trainees brainstorm about how to draw different types of electrical diagrams

Practical learning Activity

- ✓ Trainees in pair perform the task of drawing different types of electrical diagrams

Points to Remember (Take home message)

- ✓ Differentiate types of electrical diagrams

End of learning outcome 1.1 assessment

Q1. The name of  is:

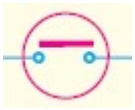
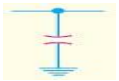
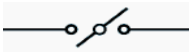
a) Current transformer
b) Arcing horn
c) Potential transformer

Q2. Fill the gap space with appropriate word found in the note.

A single-line diagram shows the……in a substation, or network, in a simplified manner

(Answer: **Disposition of equipment**)

Q3. Q2. Complete the following table **/5marks**

Symbols	**Names**
	**Air blast circuit breaker**
	**Lightning arrester (active gap)**
	**Double-break isolating switch**
	Bus bar

Reference:

V.K MEHTA , ROHIT MEHTA Second Edition (2004), Principles of Power System, , S.CHAND &COMPANY, NEW DELHI

FRANK PONEMUNSKI Second Edition (2002), Textbook for Vocational Training

Learning Outcome 1.2: Prepare tools, equipment and materials

Duration: 5hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify tools ,equipments and materials
2. Proper use of tools
3. Arrange tools ,equipments and materials

Resources

Equipment	Tools	Materials
Helmets **Safety Shoe** **Overall** **Goggles** **Nose protection mask** **Security belt**	**Screw Drivers** **Pliers** **Wrench** **Or Spanner** **Hammer**	**Cables** **Oil** **Cable ties** **Clips** **Bolts** **Nuts** **Screws**
 **Advance preparation:** .Tools, materials and equipments must be available in the classroom or in the workshop where the course will take a place		

Indicative Content 1.2.1: Tools used in installation of substation

✓ **Screw drivers:** are used for opening/ closing screws

a) Flat-blade screwdriver

- Installing and removing slot-head screws

b) Phillips screwdriver

- Installing and removing phillips-head screws

c) Rotating speed screwdrivers

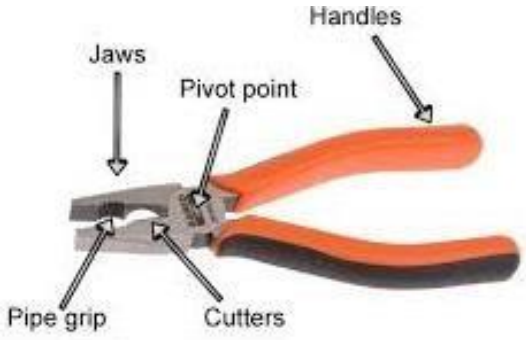
d) Star

Used for trim work, installing switch and receptacles

Installing and removing special screws with special heads

screwdrivers:

✓ **Pliers:** are used for joining wires



a) **Wire strippers**

- Stripping insulation from conductors
- Cutting small conductors
- Crimping wire lugs

b) **Side cutter pliers** (Lineman's pliers)

- Cutting large conductors
- Forming loops on large conductors
- Pulling and holding large conductors

c) **Diagonal pliers** (dykes)

- Cutting small conductors
- Cutting conductors in limited spaces

d) **Needle-nose pliers**

- Forming loops on small conductors
- Cutting and stripping small conductors

e) **Combination pliers:**

- Cutting and gripping wires

✓ **Spanners:** are used for opening/closing bolts and nuts

- ✓ **Hand drilling machine:** are used for drilling different holes

- ✓ **Hammer:** are used for hammering

- ✓ **Spirit level**: are used to indicate the verticality and horizontality of the surface.

The followings are toolds used in Substation installation:

Screw Drivers

Pliers

Spirit Level

Hammers

Spanners

Drilling Machine…..

Indicative Content 1.2.2: Equipment used in installation of substation

- **Ladder:** is a structure for climbing up and down and enables you to reach high places. It used to be widely utilized within the workplace and at home. The person required to perform this job does not need to actually carry the heavy object and climb a **ladder** which can be dangerous for the worker.

- **Lifting crane:** It is used for lifting heavy thing(object)

Ladder: is a structure for climbing up and down and enables you to reach high places.

While

Lifting crane: It is used for lifting heavy thing(object)

Indicative Content 1.2.3: Disposition /arrangement of tools, materials and equipment on the workplace

In order to keep tools in good working condition during storage, there are some basics preparatory steps that should be taken. It is important to follow the cleaning and storage instruction

- ✓ Clean tools after each use
- ✓ Dispose of Any Broken or detective tools
- ✓ Use metal protectant spray on all metal parts

- ✓ Never store tools near the ground
- ✓ Get creative with storage options
- ✓ Make a list of all items that are stored

Storage

Storage of materials shall not create a hazard. Ensure materials stored in tiers are blocked, interlocked, and limited in height so they are stable and secure against falling, sliding, or collapse.

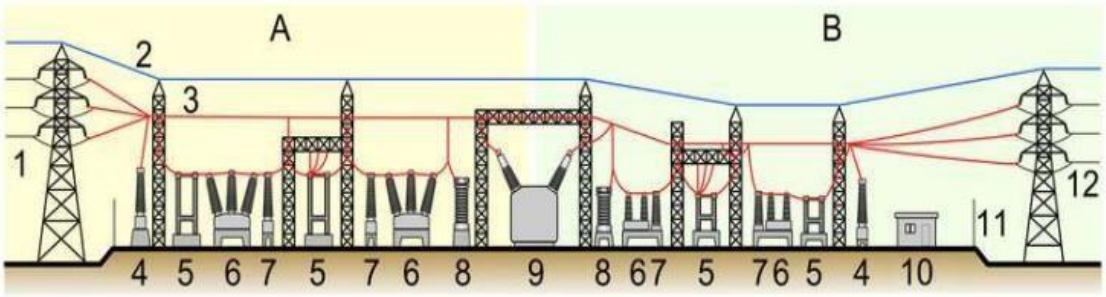
Lifting

Mechanical handling aids must be used when lifting materials heavier than 50 pounds or awkwardly shaped items that are impractical for one person to lift themselves. If mechanical handling aids are not feasible, then get help from additional workers before lifting such heavy or awkward items.

Equipment

Ensure that equipment is working properly to make it easier to use. Workers should not suffer bodily discomfort from performing job tasks or using equipment. Such discomfort may be observed in workers via bodily signs, such as shaking of the arms or hands or rolling of the shoulders, or via personal mitigation efforts, such as bringing wrist braces or back belts into work.

Sub-station Layout



A:Primary power lines' side

1.Primary power lines
2.Ground wire
3.Overhead lines
4.Transformer for measurement of electric voltage
5.Disconnect switch
6.Circuit breaker
7.Current transformer
8.Lightning arrester

B: Secondary power lines' side

7.Current transformer
8.Lightning arrester
9.Main transformer
10.Control building
11.Security fence
12.Secondary power lines

Now this incoming line connect to Bus which is connect to transformer which step up or step down the voltage and transfer the power

. It is important to follow the cleaning and storage instruction

- ✓ Clean tools after each use
- ✓ Dispose of Any Broken or detective tools
- ✓ Use metal protectant spray on all metal parts

Theoretical learning Activity

- ✓ Within groups trainees brainstorm about how to use, Tools and Equipment with their specific tasks
- ✓ Within groups trainees brainstorm about how to Dispose /arrange Materials, Tools and Equipment

Practical learning Activity

- ✓ Trainees in pair perform the task of selecting tools, materials and equipment according to the given work

Points to Remember (Take home message)

Using tools , equipments and materials properly

End of learning outcome 1.2 assessment

Q1. Answer with true or false

a. Wire stripper is used for stripping the insulation from conductors True
b. Plier is equipment used to join the wires False
c. Drilling machine is used to cut the pipes False
d. Screw driver is used to screw and unscrew the vices True

Q2. In order to keep tools in good working condition during storage, there are some basics preparatory steps that should be taken, what are them?

Answer:

- ✓ Clean tools after each use
- ✓ Dispose of Any Broken or detective tools
- ✓ Use metal protectant spray on all metal parts
- ✓ Never store tools near the ground
- ✓ Get creative with storage options
- ✓ Make a list of all items that are stored

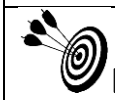
Reference:

V.K MEHTA , ROHIT MEHTA Second Edition (2004), Principles of Power System, , S.CHAND &COMPANY, NEW DELHI

FRANK PONEMUNSKI Second Edition (2002), Textbook for Vocational Training

Learning Outcome 1.3: Apply safety precautions at the workplace

Duration: 3hrs



Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Use PPES Properly
2. Identify electrical hazards
3. Describe safety precautions on high voltage

Resources

Equipment	Tools	Materials
Helmets **Safety Shoes** **Overall** **Goggles** **Nose protection mask** **Security belt**	**Screw Drivers** **Pliers** **Wrench** **Or Spanner** **Hammer**	**Cables** **Oil** **Cable ties** **Clips** **Bolts** **Nuts** **Screws**

Advance preparation:

.Tools, materials , equipments and PPEs must be available in the classroom or in the workshop where the course will take a place

Indicative Content 1.3.1: Apply safety precautions at the workplace

Definition of PPE: PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety for workers from hazard. This includes most types of protective clothing, and equipment such as eye, foot and head protection, safety harnesses, life jackets and high visibility clothing, respirators, goggles, face masks, gloves, footwear and aprons.

- Overall

An overall is a type of garment which is usually used as protective clothing when working in the workshop.

Figure. Workshop overall

- Gloves

This is for Hand and Fingers protection from injuries in the work place (fig1).

Fig. safety gloves.

- **Safety shoes**

Safety shoes or strong/rubber boots: Those are for foot protection from injuries.

Figure. Safety shoes.

- **Helmet**

Safety helmet: Those are for Head protection from any dropped material or tools to the head. It is important to plumbers who need to spend time on rooftops, up ladders and scaffoldings.

Figure.

Safety helmet. ➢ **Earmuff**

Safety earplugs: Those are for ear protection from noise.

Fig. Earmuff

- Goggles

Safety goggles: those are for eye protection from eyes injuries, resulting in pain, discomfort, loss of income and even blindness

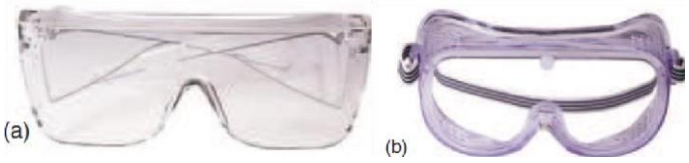


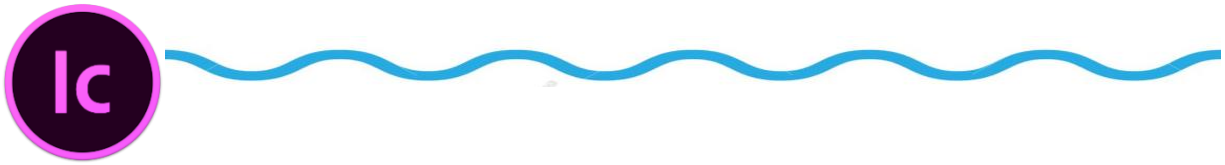
Figure. Safety goggles.

- Nose protection mask

Respirator protection: this one is used to prevent the microbes and germs from different area

Figure.respirator protection

Definition of PPE: PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety for workers from hazard. This includes most types of protective clothing, and equipment such as eye, foot and head protection, safety harnesses, life jackets and high visibility clothing,



Indicative Content 1.3.2: Types of high-voltage electrical hazards

- Contact with Energized Sources

Hazards regarding contact with energized sources are electrical shock and burns. Electrical shock occurs when the body becomes part of the electric circuit (when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor).

- Contact with Power Lines

Overhead and buried power lines are hazardous because they carry extremely high voltage. Fatalities are possible as electrocution is the main risk; however, burns and falls from elevations are also hazards that workers are exposed to while working in the vicinity of high voltage power lines.

- Improper Use of Extension and Flexible Cords

Normal wear and tear on extension and flexible cords can loosen or expose wires, creating a hazardous condition. Hazards are created when cords, cord connectors, receptacles, and cord- and plug connected equipment are improperly used and maintained. If the electrical conductors become exposed, there is a danger of shocks, burns, or fire.

BE SAFE! Electrical hazards expose workers to the following:

Burns*:* Three types; electrical, arc flash, or thermal contact.

Electrocution: Electrocution is fatal; it means to kill with electricity.

Shock*:* A response to electric current passing through the body.

Arc Flash/Blast*:* Emits heat and intense light that causes burns.

Fire*:* Occurs with faulty outlets, old wiring, cords, and switches.

Explosions*:* When electricity ignites explosive material in the air.

How to Protect Yourself:

- Inspect all electrical tools and equipment PRIOR to use.
- GFCIs are required on temporary electricity and wet locations.
- Never use anything that is damaged.
- Treat all electrical wires as if they were energized.
- Maintain a 10 FT clearance from all overheard lines.
- Allow only Qualified Electricians to perform electrical work.
- Keep at least 3 feet from all electrical panels.
- Ensure all tools and wiring are properly grounded.
- Require the proper PPE for the work being performed.
- NEVER work on hot electrical equipment, always de-energize.
- Follow the NEC and other Electrical Safe Work Practices.
- Train others on basic electrical safety and hazard recognition

Hazards regarding contact with energized sources are electrical shock and burns. Electrical shock occurs when the body becomes part of the electric circuit (when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor).

Indicative Content 1.3.3: Precautions on high voltage electrical installations (High voltage risks assessment

- ❖ De- energize (disconnection) procedures of substation

Firstly: Open circuit breaker

Secondly: Open isolator (Disconnector)

Thirdly: closes earth switch

- ❖ **Isolation procedure of substation equipment**

Procedure for Removal of Supply

No High Voltage equipment within substations is to be taken out of service without the prior approval of the Electrical System Operator, except where a life threatening situation exists.

The Authorized Person issuing the Permit must arrange for the removal of supply with the Electrical System Operator. The Electrical System Operator must request any other Network Operator involved for the removal of supply from their services where required, and for them to issue an Operating Agreement if necessary.

Procedure for Restoration of Supply

Danger Tags and earths must not be removed and supply to high voltage equipment within substations must not be restored, until all associated Permits have been cancelled.
The Authorized Person cancelling the Permit must arrange for the restoration of supply with the Electrical System Operator. The Electrical System Operator must advise the other Network Operator that their Operating Agreement, if issued, has been signed off and supply may be restored. **WARNING**

The equipment must not be returned to service until any necessary tests and phase checks have been carried out.

❖ Earthing down procedures

The process of transferring an unintended electrical energy directly to the earth through a low resistance wire is called electrical earthing. It refers to the connection of a noncurrent-carrying part of the equipment or neutral of supply system to the ground, which represents the zero potential.

> No High Voltage equipment within substations is to be taken out of service without the prior approval of the Electrical System Operator, except where a life threatening situation exists.

Indicative Content 1.3.4: High-voltage safety signs

There are four groups of safety signs:

- ❖ Mandatory signs
- ❖ Prohibition signs
- ❖ Warning signs
- ❖ Information signs.

Mandatory signs

These signs are circular and show white symbols on a blue background and it always shows

What must be done by all site personnel at the site e.g. wear head protection and many others.

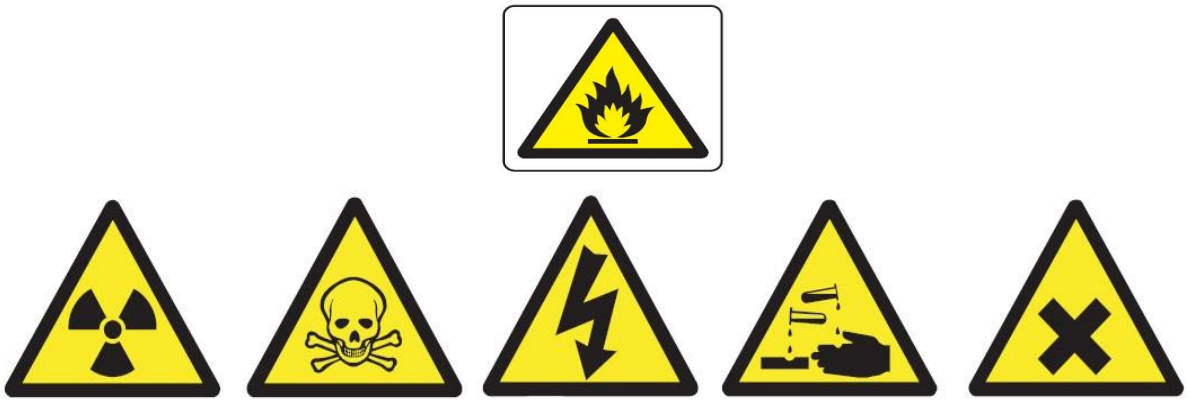
Prohibition signs

These signs are circular and show black symbols on a white background,

The signs also have a red border with a red line passing through the centre of the circle.

Warning signs

These signs are triangular in shape, have a black border and show black symbols on a yellow background and it shows potential dangers, e.g. flammable material.



Information signs

These signs are square or rectangular in shape and show white symbols on a green background. And it shows information usually relating to access or health and safety, e.g. first aid.

There are four groups of safety signs:

- Mandatory signs
- Prohibition signs
- Warning signs
- Information signs.

Theoretical learning Activity

- ✓ Within groups trainees brainstorm about different safety signs categories
- ✓ Within groups trainees brainstorm about high voltage risks assessments

Practical learning Activity

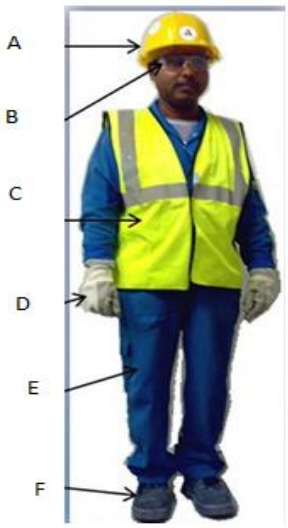
Points to Remember (Take home message)

- ✓ Differentiate categories of safety signs

Q1. Chose the best answer, **PPE** means:

a) People Protective Equipment
b) Personal Protective Equipment
c) Personal Provider Equipment

Q2. Complete the name of letter A, B, C, D, E, F. as the personal protective equipment you need during the installation of special switch **/6 marks**



ANSWER:

A) Helmet, B) Googles, C) Overcoat, D) Grooves E) Overall F) Safety shoes

LU2: Install substation elements or equipment

STRUCTURE OF LEARNING UNIT

Learning outcomes:

2.1 Describe a substation
2.2 Protect substation installation

2.3 Fix and connect equipment of a substation

Learning outcome 2.1: Describe a substation

Duration: 15hrs

✓  Learning out come 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. define substation
2. describe the main function of substation
3. classify substation
4. identify substation equipment and its function

 **Resources**

Equipment	Tools	Materials
❖ Bus-bar ❖ Single-break isolating switch ❖ Double-break isolating switch ❖ On load isolating switch ❖ Isolating switch with earth Blade ❖ Current transformer ❖ Potential transformer ❖ Capacitive voltage transformer ❖ Oil circuit breaker ❖ Air circuit breaker with over ❖ current tripping device ❖ Air blast circuit breaker ❖ Lightning arrester (active gap) ❖ Lightning arrester (valve type) ❖ Arcing horn ❖ Three-phase Power transformer ❖ Over current relay	❖ Pictures ❖ Books ❖ internet	❖ **chalk** ❖ **paper**

❖ Earth fault relay		

Advance preparation:

. Picture of each equipment must be shown by trainer before give an explanation to it.

.Each equipment must be shown by trainer before give an explanation to it.

Indicative content : 2.1.1 Definition of substation

Electrical Substation

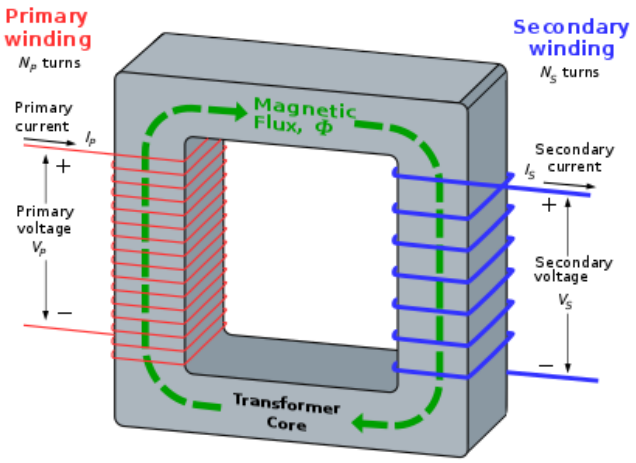
Definition: The electrical substation is the part of a power system in which the voltage is transformed from high to low or low to high for transmission, distribution, transformation and switching. The power transformer, circuit breaker, bus-bar, insulator, lightning arrester are the main components of an electrical substation.

Definition of substation: is the part of a power system in which the voltage is **transformed from high to low** or **low to high for transmission**, **distribution**, **transformation and switching**.

Indicative content :2.1.2 Main functions of substations

- ✓ **Voltage transformation:** voltage Transformers change the voltage of the electrical signal coming out of the power plant, usually increasing (also known as "stepping up")

the voltage. Transformers also reduce ("step down") the voltage in substations, and as distribution transformers.



- ✓ **Circuit switching:** Switch transmission and distribution circuits into and out of the grid system.
- ✓ **Voltage regulation:** Voltage regulation describes the ability of a system to provide near constant voltage over a wide range of load conditions.
  An automatic voltage regulator (AVR) is an electronic device that maintains a constant voltage level to electrical equipment on the same load. The AVR regulates voltage variations to deliver constant, reliable power supply.
- ✓ **VAR control:** VAR is an abbreviation of voltage-ampere reactive, a term that is used extensively in definition and measurement of reactive power within electrical circuits. Reactive power is the average of electrical power that is originated from active components like capacitors and inductors. This type of power is only observed in AC (alternating current) electrical circuits, and the unit of VAR is used to determine its levels. VAR control is used to manage the relationship of varying current and voltage that collectively originates from active electrical components.
  Volt/VAR Optimization & Control is an advanced function that determines the best set of control actions for all voltage regulating devices and Var control devices to achieve a one or more specified operating objectives without violating any of the fundamental operating constraints (high/low voltage limits, load limits, etc.),

System protection: is a feature that creates restore points on a particular drive when it detects changes.

- ✓ **The main function of substation are : Voltage transformation, Circuit switching,Voltage regulation, VAR control**

Indicative content: 2.1.3 Layout considerations of a substation.

- ✓ Today, we'll be looking at factors needed to be considered before going ahead to design a substation. However, before going into that; it will be unwise if we don't define a substation.Substations are the points in the power network where transmission lines and distribution feeders are connected together through circuit breakers or switches via busbars and transformers. This allows for the control of power flow in the network and general switching operations for maintenance purposes. In setting out the layout of a substation, a lot of factors are considered. These are what we are going to be looking at in substation layout design considerations.

- ✓ Land area :The cost of purchasing a plot of land in a densely populated area is considerably high.Therefore, there is a trend towards compact substation design.This is made possible by the use of indoor gas-insulated switchgear (GIS) substation designs or by using such configurations as the transformer feeder substation layout.

- ✓ Cost :Satisfactory cost comparison between different substation lay-out designs Is extremely difficult because of the differences in performances and maintainability.It is preferable to base a decision for a particular layout on technical grounds.Then, determine the most economic means of achieving these technical requirements.

- ✓ Reliability of supply:This means That the arrangement of Equipment (layout) must be such that the electric power supply is guaranteed for as long as possible.This means that a fault at any point in the substation circuit must not result in the complete shut down of the entire substation.In order to achieve this, most of the protective devices is usually duplicated to act as back up protection for any of the devices that fail.

- ✓ Extendibility : The design should allow for future extendibility.Due to the fact that demand for power might increase, it is paramount to provide space for extension during design.

- ✓ Maintainability : The design must take into account the electricity supply company (e.g BEDC) system planning and operations procedures together with a knowledge of reliability and maintenance requirements for the proposed substation equipment.

- ✓ Operational flexibility :The physical layout of individual circuit and group of circuits must permit the required power flow control. It is mostly carried out with a two transformer substation operation.Here, the goal is to avoid loss of service when switching from one transformer to another or feeding with both.

- ✓ Protection arrangement : The design must allow for multiple busbar arrangement. This will provide greater flexibility than a ring bus bar. The protection of each system element by the provision of suitable CT locations to ensure overlapping of protection zones should be considered.

- ✓ Short circuit limitation : In order to keep fault levels down, parallel connections (transformers or power sources feeding the substation) should be avoided.Multi busbar arrangement with sectioning facilities allows the system to be split or connected through a fault limiting reactor.

The following are Layout considerations of a substation :

- ✓ **Land area**
- ✓ **Cost**
- ✓ **Reliability of supply**
- ✓ **Extendibility**
- ✓ **Maintainability**
- ✓ **Operational flexibility**
- ✓ **Protection arrangement**
- ✓ **Short circuit limitation**

Indicative content :2.1.4 Classification of substations according to service

requirements

- ✓ Transformer sub-station :A substation transformer is a large piece of electrical equipment that is used to step down the voltage of electricity

from the high voltage transmission lines to a lower voltage suitable for distribution to homes and businesses.

- ✓ A switching substation : is a substation without transformers and operating only at a single voltage level. Switching stations are sometimes used as collector and distribution stations. Sometimes they are used for switching the current to back-up lines or for parallelizing circuits in case of failure.

- ✓ Power factor correction substation : Those sub-stations which improve the power factor of the system are called power factor correction sub-stations. These sub-stations are generally located at the receiving end of a transmission line.

- ✓ Frequency changer sub-station : Those sub-stations which change the supply frequency are known as frequency changer sub-stations. Such a frequency change may be required for industrial utilization.

- ✓ Converting sub-station : Is a substation which converts between high-voltage AC and DC power. Converter substations are commonly found at the ends of HVDC power cables.

- ✓ Industrial sub-station: Those sub-stations which supply power to individual industrial concerns are known as industrial sub-stations.

The following are classification of substation according to the service Requirement :

- ✓ **Transformer sub-station**
- ✓ **A switching substation**
- ✓ **Power factor correction substation**
- ✓ **Frequency changer sub-station**

- ✓ **Converting sub-station**
- ✓ **Industrial sub-station**

Indicative content : 2.1.5 Classification of substations according to construction features

- ✓ **Indoor sub-stations.** For voltages up to 11 kV, the equipment of the sub-station is installed indoor because of economic considerations. However, when the atmosphere is contaminated with impurities, these sub-stations can be erected for voltages up to 66 kV.
- ✓ **Outdoor sub-stations.** For voltages beyond 66 kV, equipment is invariably installed outdoor. It is because for such voltages, the clearances between conductors and the space required for switches, circuit breakers and other equipment becomes so great that it is not economical to install the equipment indoor.
- ✓ **Underground sub-stations.** In thickly populated areas, the space available for equipment and building is limited and the cost of land is high. Under such situations, the sub-station is created underground.
- ✓ **Pole-mounted sub-stations.** This is an outdoor sub-station with equipment installed overhead on H-pole or 4-pole structure. It is the cheapest form of sub-station for voltages not exceeding 11kV (or 33 kV in some cases). Electric power is almost distributed in localities through such substations. For complete discussion on pole-mounted sub-station.

The following are classification of substation according to construction features:

- ✓ **Indoor sub-stations.**
- ✓ **Outdoor sub-stations.**
- ✓ **Underground sub-stations.**
- ✓ **Pole-mounted sub-stations.**

Indicative content : 2.1.6 Substation equipment and its functions

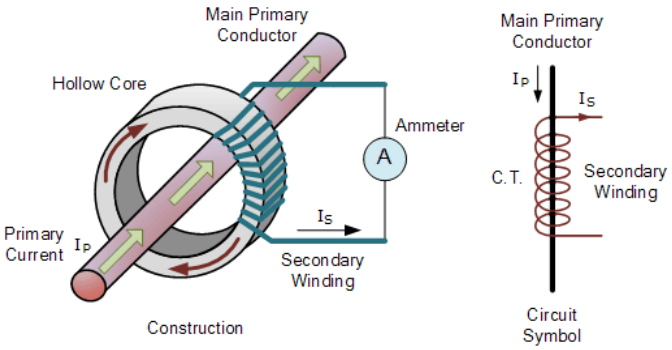
- ✓ **Bus-bar:** In electric power distribution, a **bus bar** (also **bus bar**) is a metallic strip or bar, typically housed inside switchgear, panel boards, and bus way enclosures for local high current power distribution. They are also used to connect high voltage

equipment at electrical switchyards, and low voltage equipment in battery banks. They are generally uninsulated, and have sufficient stiffness to be supported in air by insulated pillars.

- ✓ **Single-break isolating switch:** This is the type of isolator, arm contact is separated into two elements. The first arm contact holds male contact, as well as second arm contact, holds female contact. The arm contact shifts because of the post insulator rotation upon which the arm contacts are fixed.

- ✓ **Double-break isolating switch:** The double-break disconnector consists of one arm which is moved by the central insulator supporting it and closes the circuit on two fixed contacts, each of them placed on one of the two side insulators.

- ✓ **On load isolating switch**: An ON load isolator (switch disconnector) meets both the switch requirements and the isolation requirements. It is the 'Isolating Switch' that is intended for installation in water heater circuits.
- ✓ **Isolating switch with earth Blade**: For isolators, the earthing switches make contact with the bus bar when the isolator isolates the circuits, discharging any charges that may have gathered there. An earth switch in switchgear is used to ground the remaining change in a power line after the power line has been removed from its source.
- ✓ **Current transformer:** he **Current Transformer** (C.T.), is a type of "instrument transformer" that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. *Current transformers* reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer.

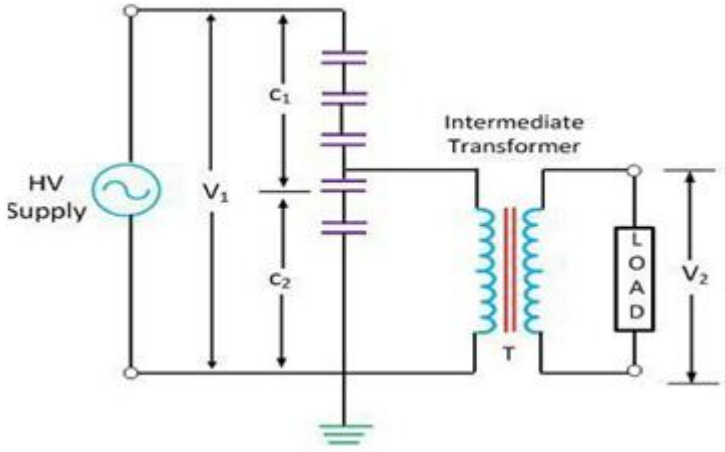


- ✓ **Potential transformer:** The potential transformer may be defined as an instrument transformer used for the transformation of voltage from a higher value to the lower value. This transformer step down the voltage to a safe limit value which can be easily measured by the ordinary low voltage instrument like a voltmeter, wattmeter and watt-hour meters, etc.

Types of Potential Transformer

The potential transformer is mainly classified into two types, i.e., the conventional wound types (electromagnetic types) and the capacitor voltage potential transformers.

Conventional wound type transformer is very expensive because of the requirement of the insulations.**Capacitor potential transformer** is a combination of capacitor potential divider and a magnetic potential transformer of relatively small ratio. The circuit diagram of the capacitor potential transformer is shown in the figure below. The stack of high voltage capacitor from the potential divider, the capacitors of two sections become C_1 and C_2, and



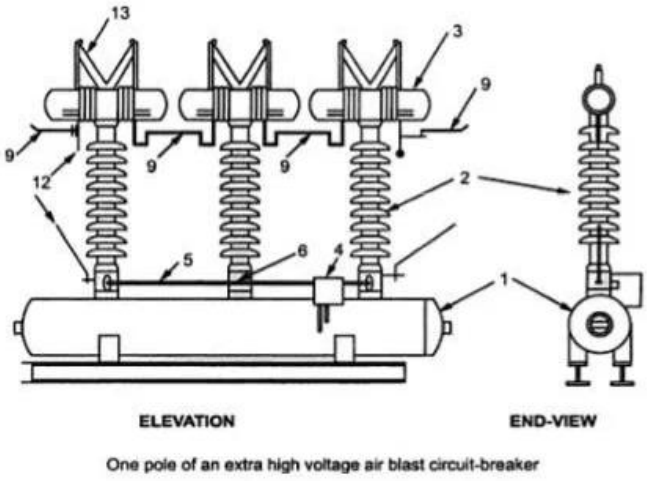
the Z is the burden.

- ✓ **Oil circuit breaker**: is one kind of circuit breaker where the insulating oil can be used as an arc quenching medium. Once the fault occurs within the system, then circuit breaker contacts will be separated and the arc will be struck among the contacts.

- ✓ **Air circuit breaker with overcurrent tripping device**: Air Circuit Breaker (ACB) is an electrical device used to provide Overcurrent and short-circuit protection for electric circuits over 800 Amps to 10K Amps. These are usually used in low voltage

applications below 450V. We can find these systems in Distribution Panels (below 450V).

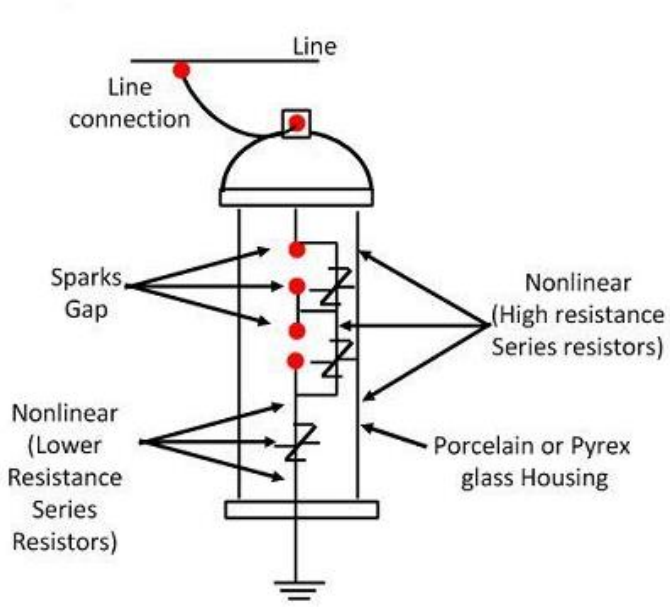
- ✓ **Air blast circuit breaker:** is a type of circuit breaker where at high pressure the air blast is used for arc extinction in the electrical circuit. The main principle behind it is that it has a fixed contact and a moving contact, where high pressure is applied for arc extinction in a circuit breaker.



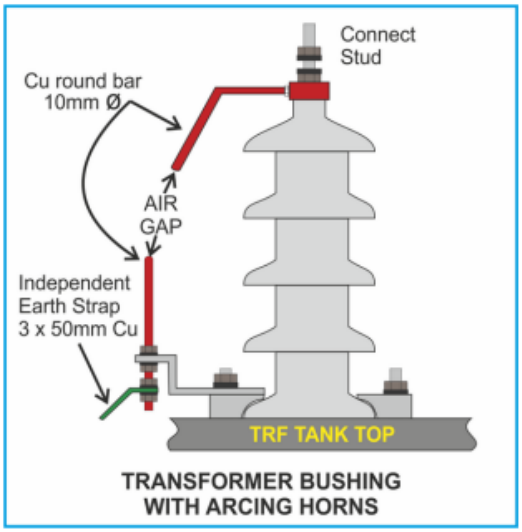
One pole of an extra high voltage air blast circuit-breaker

- ✓ **Lightning arrester (active gap):** It consists of two horn-shaped pieces of metal rods separated by a small distance and connected in a shunt between each conductor and earth. The gap between horns is less at the bottom and large at the top.

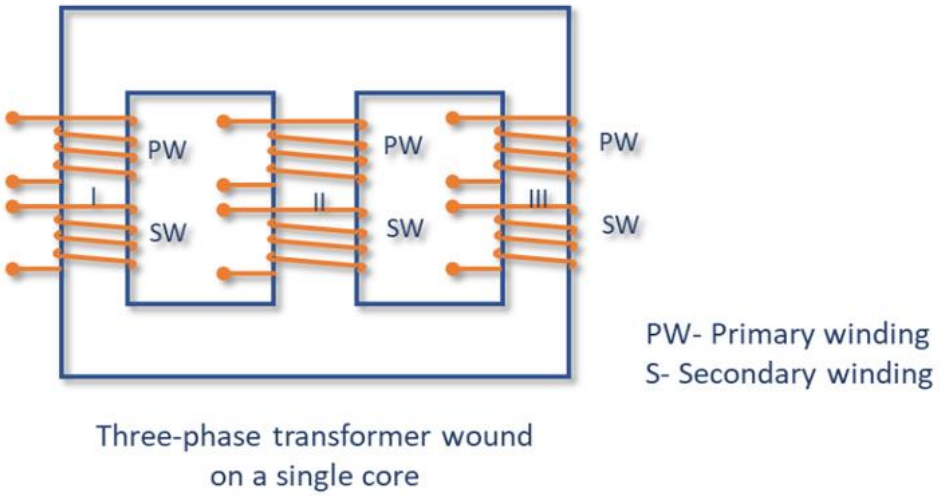
- ✓ **Lightning arrester (valve type):** A valve type lightning arrester is an improved and expensive lightning arrester which is also called a nonlinear surge diverter. A valve type arrester gets its name from the fact that a nonlinear resistor regulates itself from the flow of current and reduces the voltage when high surge currents occur.



- ✓ **Arcing horn :** Arcing horns are used to protect the transmission conductors, insulators, transformers bushings and other transmission equipments from lightning high voltages, transient voltages and surge voltages. Arc horns are working under the principle of arcing.



- ✓ **Three-phase Power transformer:** The Three-Phase Transformer is a transformer made up of three sets of primary and secondary windings. They operate as an electrical system that has three-phase. The three-phase transformers can be constructed in two ways, one is three identical single-phase transformers are connected to form a three-phase transformer bank, or else a single unit of a three-phase transformer with the windings of three phases wound on a single core.



Three-phase transformer wound on a single core

- ✓ **Over current relay**: An overcurrent relay is a type of protective relay which operates when the load current exceeds a pickup value. It is of two types: instantaneous over current (IOC) relay and definite time overcurrent (DTOC) relay.

- ✓ **Earth fault relay** : The Earth Fault Relay is an electrical protection device, designed to detect low earth leakage current and safeguard humans and electrical equipment from earth leakage or faults.

The following are Substation equipment and its functions:

- ✓ **Bus-bar**
- ✓ **Single-break isolating switch**
- ✓ **Double-break isolating switch**
- ✓ **On load isolating switch**
- ✓ **Isolating switch with earth Blade**
- ✓ **Current transformer:** he **Current Transformer**
- ✓ **Potential transformer**
- ✓ **Oil circuit breaker**:
- ✓ **Air circuit breaker with overcurrent tripping device**
- ✓ **Air blast circuit breaker:**
- ✓ **Lightning arrester (active gap):**
- ✓ **Lightning arrester (valve type):**
- ✓ **Arcing horn :**

- ✓ **Three-phase Power transformer:**
- ✓ **Over current relay**:
- ✓ **Earth fault relay** :


Theoretical learning Activity

- ✓ Trainees have to brainstorm about the equipment used in substation and its symbol within groups
- ✓ Trainees have to brainstorm on the equipment of substation and its function, classification of substation, function of substation and substation layout considelation.


Practical learning Activity


Points to Remember (Take home message)

Every trainee must know to explain and describe the following: term substation, main function of substation, classification of substation , equipment of substation and its function

✓ 
Learning out come 2 formative assessment

Q1. Answer by true or false:

d) Current transformer: is an instrument used as measuring instrument in substation. **true**
e) Potential transformer : is used to detect electrical fault in substation. **false**

f) Substation is the part of a power system in which the voltage is transformed from high to low or low to high for transmission, distribution, transformation and switching. **true**

Q2. Give the classification of substation according to service

Answer:

- ✓ Transformer sub-station
- ✓ Switching sub-station
- ✓ Power factor correction substation
- ✓ Frequency changer sub-station
- ✓ Converting sub-station
- ✓ Industrial sub-station

References

1. V.K MEHTA , ROHIT MEHTA Second Edition (2004), Principles of Power System, , S.CHAND &COMPANY, NEW DELHI
2. http://www.ebay.com/bhp/high-voltage-tester

Learning outcome 2.2: Protect substation installation

Duration: 10hrs

✓ Learning out come 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify Causes and means of protection common faults in a substation
2. describe Rules governing selection of protection devices
3. Explain Protection of transformers
4. Interpret Bus-bar and line protection

Resources

Equipment	Tools	Materials
❖ -Transformers ❖ - Erath-fault relays ❖ - Over-current relays ❖ - Bus-bars	❖ Books ❖ Internet ❖ Laptop	❖ **Chalk** ❖ **paper**

Advance preparation:

. Picture of each protective equipment must be shown by trainer before give an explanation to it.

.Each protective equipment must be shown by trainer before give an explanation to it by field visit.

Indicative content : 2.2.1: Causes and means of protection of common faults in a substation

- ✓ Overvoltage faults
  The over-voltages on a power system may be broadly divided into two main categories
  - ❖ Internal causes
  - ❖ Switching surges
  - ❖ Insulation failure
  - ❖ Arcing ground
  - ❖ Resonance
- ✓ External causes i.e. lightning The most commonly used devices for protection against lightning surges are:
  - ❖ Earthing screen
  - ❖ Lightning arresters or surge diverters
  - ❖ Earthing screen provides protection to power stations and sub-stations against direct strokes whereas
  - ❖ Overhead ground wires protect the transmission lines against direct lightning strokes. However,
  - ❖ Lightning arresters or surge diverters protect the station apparatus against both direct strokes and the strokes that come into the apparatus as travelling waves.

Earthing screen: The power stations and sub-stations generally house expensive equipment. These stations can be protected against direct lightning strokes by providing earthing screen. It consists of a network of copper conductors (generally called shield or screen) mounted all over the electrical equipment in the sub-station or power station. The shield is properly connected to earth on at least two points through low impedance. On the occurrence of direct stroke on the station, screen provides a low resistance path by which lightning surges are conducted to ground. In this way, station equipment is protected against damage. The limitation of this method is that it Page 36 of 61 does not provide protection against the travelling waves which may reach the equipment in the station.

- ✓ **Overload faults** an overload occurs when equipment is subjected to current above its rated capacity and excessive heat is produced. Protection against temperature is termed “over current protection.” Over currents are caused by equipment overloads, by short circuits or by ground faults. A short circuit occurs when there is a direct but unintended connection between line-to-line or line-to-neutral conductors. Short circuits can generate temperatures thousands of degrees above designated ratings. A ground fault occurs when

electrical current flows from a conductor to insulated metal that is not designed to conduct electricity. The two most common over current protection devices are fuses and circuit breakers.

- ✓ **Grounding faults** A ground fault is an inadvertent contact between an energized conductor and ground or equipment frame. The return path of the fault current is through the grounding system and any personnel or equipment that becomes part of that system. Ground faults are frequently the result of insulation breakdown. The primary purpose of grounding electrical systems is to provide protection against electrical faults; there are other advantages for a grounded system, such as reduction of shock hazards and protection against lightning. The most common causes of ground faults A ground fault occurs when electricity travels through ground, instead of the intended path back to its source. More than 80% of electrical failures in equipment are ground faults caused by worn insulation, conductive dust or moisture. Deteriorated insulation on wires and cables cause 90% of these events.

- **The Causes and means of protection of common faults in a substation:**
  - ✓ Overvoltage faults)
  - ✓ Overload faults
  - ✓ Earthing /grounding faults

Indicative content : 2.2.2: Rules governing selection of protection devices

- ✓ Rating protection devices Short circuits can produce enough thermal and electromagnetic forces to destroy any protective device.
- ✓ When selecting a protective device, it is very important to consider the available short circuit amperage, which is the potential amperage at any site in the system. Page 37 of 61
- ✓ The SCA will be measured at the equipment terminals, the utility transformer and the distribution panel. The highest value will be at the power transformer.
- ✓ The correct size over current protection device can be chosen when the system's is known. Fuses and circuit breakers are assigned amperage interrupting capacity,
- ✓ Protection devices are rated to manage both the normal maximum load and the potential short circuit amperage at any given part of the system.

Equipment controls should have a short circuit rating that enables them to absorb current while the protective device clears the circuit. If the rating of the controller is lower, a fastclearing fuse with a lower rating than the controller should be used.

- **Rules governing selection of protection:**

✓ Rating protection devices Short circuits can produce enough thermal will be measured at the equipment terminals,
✓ the utility transformer and the distribution panel,
✓ the utility transformer and the distribution panel. The highest value will be at the power transformer, The correct size over current protection device can be chosen when the system's is known.
✓ Protection devices are rated to manage both the normal maximum load and the potential short circuit amperage at any given part of the system.

Indicative content : 2.2.3: Protection of transformers

For protection of generators, Merz-Price circulating-current system is unquestionably the most satisfactory. Though this is largely true of transformer protection, there are cases where circulating current system offers no particular advantage over other systems or impracticable on account of troublesome conditions imposed by the wide variety of voltages, currents and earthing conditions invariably associated with power transformers. Under such circumstances, alternative protective systems are used which in many cases are as effective as the circulating-current system. The principal relays and systems used for transformer protection are:

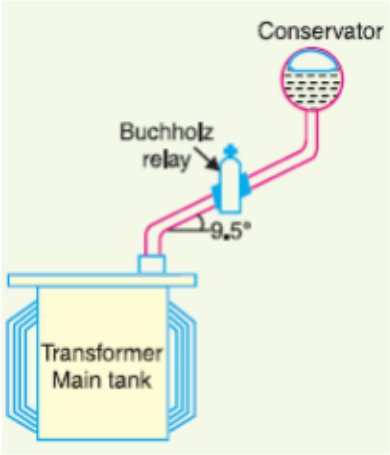
(i) **Buchholz devices** providing protection against all kinds of incipient faults i.e. slow-developing faults such as insulation failure of windings, core heating, fall of oil level due to leaky joints etc.

(ii) **Earth-fault relays** providing protection against earth-faults only.

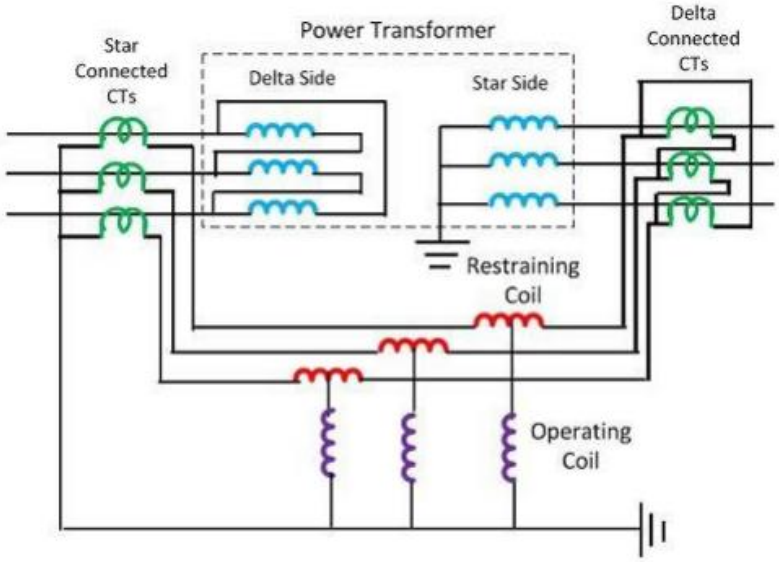
(iii) **Overcurrent relays** providing protection mainly against phase-to-phase faults and overloading.

(iv) **Differential system** (or circulating-current system) providing protection against both earth and phase faults. The complete protection of transformer usually requires the combination of these systems. Choice of a particular combination of systems may depend upon several factors such as (a) Size of the transformer (b) Type of cooling (c) Location of transformer in the network (d) Nature of load supplied and (e) Importance of service for which transformer is required. In the following sections, above systems of protection will be discussed in detail.

✓ **Buchholz Relay Buchholz**: relay is a gas-actuated relay installed in oil immersed transformers for protection against all kinds of faults.



- ✓ **Earth-Fault** or Leakage Protection An earth-fault usually involves a partial breakdown of winding insulation to earth. The resulting leakage current is considerably less than the short-circuit current. The earth-fault may continue for a long time and cause considerable damage before it ultimately develops into a short-circuit and removed from the system.
- ✓ **Differential Protection** of a Transformer The transformer is one of the major equipment in power system. It is a static device, totally enclosed and usually oil immersed, and therefore the fault occurs on them are usually rare. But the effect of even a rare fault may be very serious for a power transformer. Hence the protection of power transformer against possible fault is very important.



Differential Protection for Power Transformers

Working of Differential Protection System Normally, the operating coil carries no current as the current are balanced on both the side of the power transformers. When the internal fault occurs in the power transformer windings the balanced is disturbed and the operating coils of the differential relay carry current corresponding to the difference of the current among the two sides of the transformers. Thus, the relay trip the main circuit breakers on both sides of the power transformers.

Overcurrent relay: is a type of protective relay which operates when the load current exceeds a pickup value.

- **The following are the equipment used to Protect transformers:**

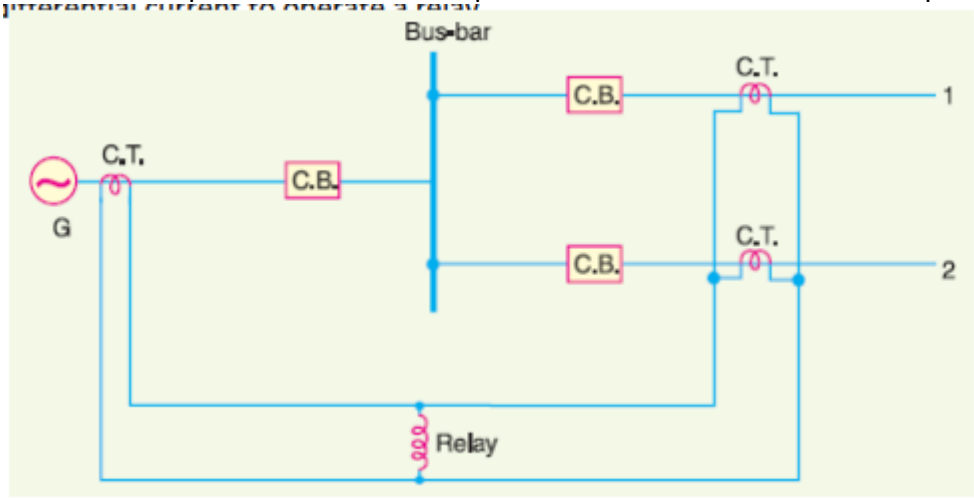
✓ Buchholz devices
✓ Earth-fault relays
✓ Over-current relays
✓ Differential system

Ic

Indicative content : 2.2.4: Bus-bar and line protection

Bus bar Protection Bus bars in the generating stations and sub-stations form important link between the incoming and outgoing circuits. If a fault occurs on a bus bar, considerable damage and disruption of supply will occur unless some form of quick-acting automatic protection is provided to isolate the faulty bus bar. The bus bar zone, for the purpose of protection, includes not only the bus bars themselves but also the isolating switches, circuit breakers and the associated connections. In the event of fault on any section of the bus bar, all the circuit equipment connected to that section must be tripped out to give complete isolation. The standard of construction for bus bars has been very high, with the result that bus faults are extremely rare. However, the possibility of damage and service interruption from even a rare bus fault is so great that more attention is now given to this form of protection. Improved relaying methods have been developed, reducing the possibility of incorrect operation. The two most commonly used schemes for busbar protection are:

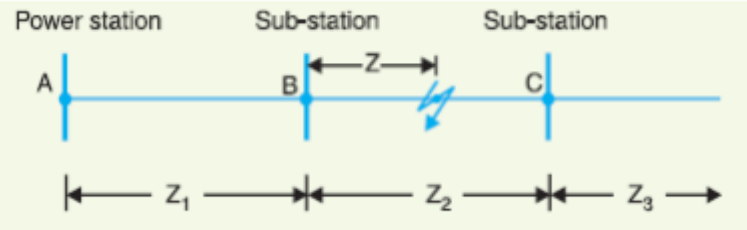
✓ **Differential protection.** The basic method for busbar protection is the differential scheme in which currents entering and leaving the bus are totalized. During normal load condition, the sum of these currents is equal to zero. When a fault occurs, the fault current upsets the balance and produces a differential current to operate a relay.



✓ **Fault Bus protection**: is a method of protection that insulates the bus structure and the switchgear from the ground connecting all the circuit breaker. It provides a single connection to the ground tank through a feeder known as CT that feeds an overcurrent relay. This can be achieved by providing earthed metal barrier (known as fault bus) surrounding each conductor throughout its entire length in the bus structure. With this arrangement, every fault that might occur must involve a

connection between a conductor and an earthed metal part. By directing the flow of earth-fault current, it is possible to detect the faults and determine their location. This type of protection is known as fault bus protection.

- ✓ **Distance Protection**: Both time-graded and pilot-wire system are not suitable for the protection of very long high voltage transmission lines. The former gives an unduly long time delay in fault clearance at the generating station end when there are more than four or five sections and the pilot-wire system becomes too expensive owing to the greater length of pilot wires required. This has led to the development of distance protection in which action of relay depends upon the distance (or impedance) between the point where the relay is installed and the point of fault. This system provides discrimination protection without employing pilot wires.



- The following are Bus-bar and line protection:
  - ✓ Differential protection
  - ✓ Distance protection
  - ✓ Fault bus protection


Theoretical learning Activity

- ✓ Trainees have to brainstorm about the transformer protection, common fault in a substation and bus-bar protection


Practical learning Activity

Points to Remember (Take home message)

Every trainee must know to describe the common faults in substation and how to protect transformer

✓  Learning out come 2.2 formative assessment

Q1.chose the correct answer, the following are protection of transformer

a) Buchholz devices and junction box

b) Earth-fault relays and switch

c) Over-current relays and bus- bar

d) Differential system

Q2. An AZT company has transformer in their institution and that transformer always meet with the different problem concerned with electrical fault and this fault cause the electrical current to be interrupted frequently, as electrician advise this company in order to solve that problems.

Answer: In order to solve this problem we use different protection to that transformer such as: Buchholz devices , Earth-fault relays , Over-current relays , Differential system

References

1. FRANK PONEMUNSKI Second Edition (2002), Textbook for Vocational Training, Institut für berufliche Entwicklung e.V. Berlin
2. http/www.seton.com/best/high-voltage safety signs
3. http://circuitgloble.com/electrical-substation.html

Learning outcome 2.3: Fix and connect equipment of a substation

Duration: 15hrs

✓ Learning out come 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. interpret the connection scheme (order) of equipment of a substation
2. describe the Fixing methods and rules of substation equipment
3. Fix and connect equipment of a substation

Resources

Equipment	Tools	Materials
❖ - Transformers ❖ - Insulators ❖ - Switchgears ❖ - Circuit breakers ❖ - Bus-bars ❖ - Lightning rods	❖ Books ❖ Internet ❖ Laptop	❖ **Chalk** ❖ Conductors

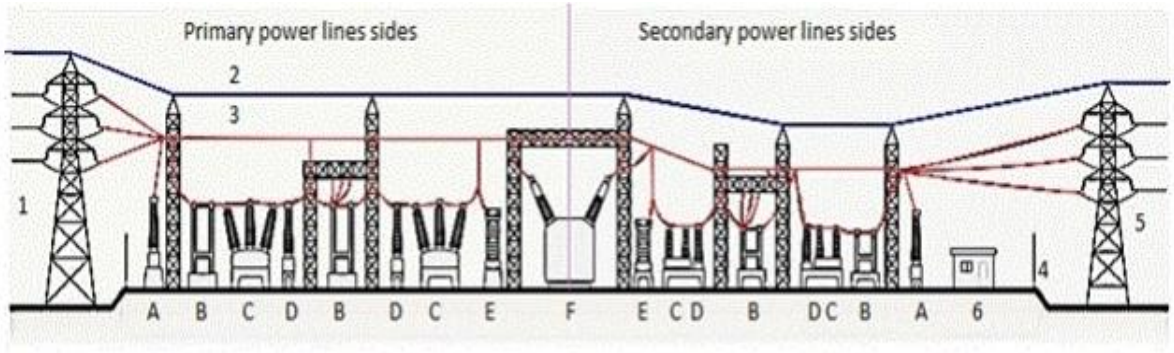
Advance preparation:

. Picture of each equipment must be shown by trainer before give an explanation to it.

.Each equipment must be shown by trainer before give an explanation to it by field visit.

Indicative content : 2.3.1: Connection scheme (order) of equipment of a substation

- ✓ The main electrical connection of a substation, generally known as the primary connection of the substation, serves to indicate the connection mode of such electrical equipment as transformers, circuit breakers, disconnectors, instrument transformers, busbars, and surge arresters, as well as the electrical connection



Side view of Electrical Substation

Description:

1 - Primary power lines	A - Transformer for measurement of electric voltage
2 - Ground wire	B - Disconnect switch
3 - Overhead lines	C - Circuit breaker
4 - Security fence	D - Current transformer
5 - Secondary power lines	E - Lightning arrester
6 - Control building	F - Main transformer

Note: Purple line indicates an imaginary seperation between primary power line sides and secondary power line sides.

- Connection scheme (order) of equipment of a substation

✓ The main electrical connection of a substation, generally known as the primary connection of the substation, serves to indicate the connection mode of such electrical equipment as transformers, circuit breakers, disconnectors, instrument transformers, busbars, and surge arresters, as well as the electrical connection

Indicative content: 2.3.2: Fixing methods and rules of substation Equipment

Following are the operating and design limits that should be considered in order to provide safe working conditions:

1. **Interrupting devices** must be able to function safely and properly under the most severe duty to which they may be exposed.
2. **Accidental contact with energized conductors** should be eliminated by means of enclosing the conductors, installing protective barriers, and interlocking.
3. **The substation** should be designed so that maintenance work on circuits and equipment can be accomplished with these circuits and equipment de-energized and grounded.
4. **Warning signs** should be installed on electric equipment accessible to both qualified and unqualified personnel, on fences surrounding electric equipment, on access doors to electrical rooms, and on conduits or cables above 600 V in areas that include other equipment.
5. An adequate grounding system must be installed.
6. **Emergency lights** should be provided where necessary to protect against sudden lighting failure.
7. **Operating and maintenance** personnel should be provided with complete operating and maintenance instructions, including wiring diagrams, equipment ratings, and protective device settings.

- Fixing methods and rules of substation equipment:

✓ **Interrupting devices**

✓ **Accidental contact with energized conductors**

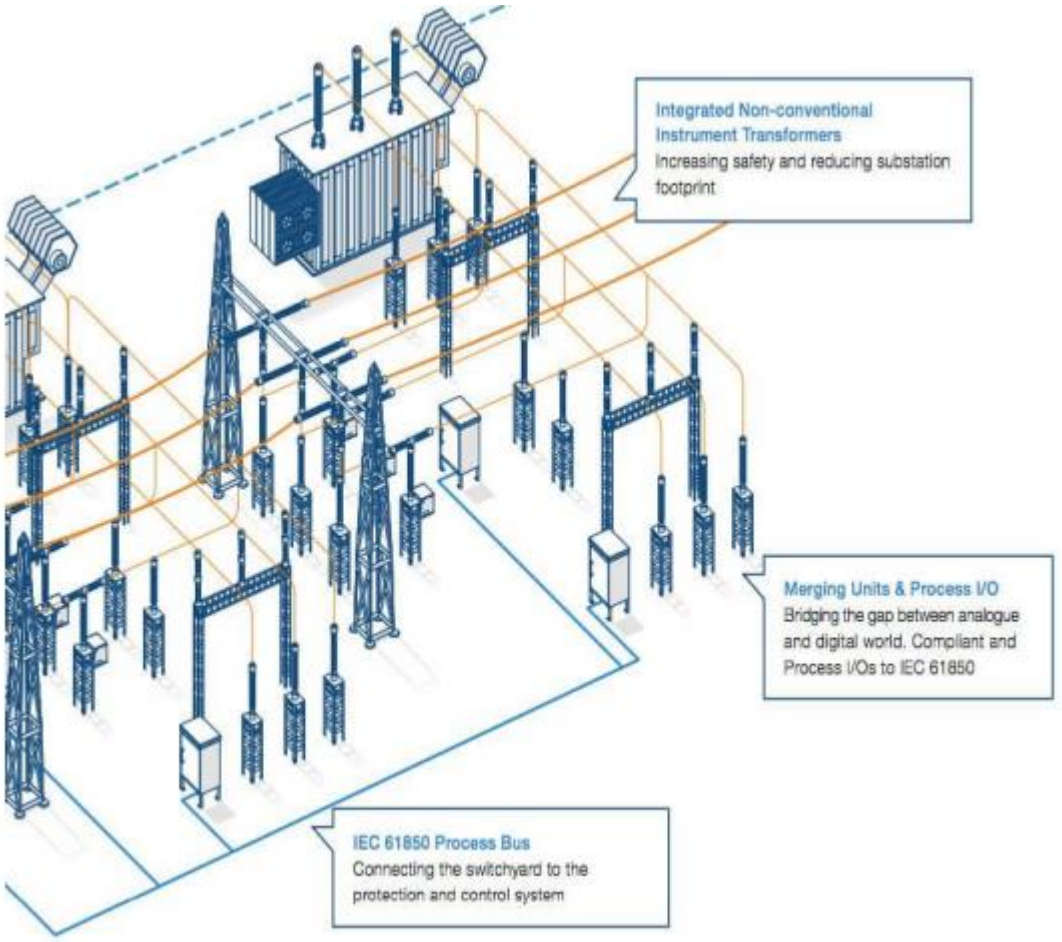
✓ **The substation**

✓ **Warning signs**

✓ **Emergency lights**

✓ **Operating and maintenance**

Indicative content : 2.3.3: Fix and connect equipment of a substation



General Typically, primary plant consists of the high voltage equipment, associated structures and the cable and bus bar interconnections, that make up the high voltage installation of the switchyard, as indicated in the following section Support Structures, Equipment, Cable Trench Covers All support structures, equipment earth points, marshalling boxes and cable trench covers, etc. must be connected to the main earth grid, in accordance with Ergon Energy Substation Standard Earthing Drawings

- ✓ **Power Transformer:** Supply, delivery to site, installation and testing of any power transformers required for the substation is generally the subject of a separate contract between Ergon Energy and the Transformer Supplier (excluding station service transformers).
- ✓ **HV Circuit Breakers** (Outdoor) HV circuit breakers must be erected on their support stands and assembled, in accordance with the Manufacturer's Installation Manual and testing may be required to be completed by the Circuit Breaker Supplier, or other person Trained and Authorized by the Supplier.
- ✓ **Current Transformers:** Including CT Marshalling Box Current transformers are generally fully assembled and filled with insulating oil ready to be erected on their support

structures. CT's must be stored on-site and handled strictly in accordance with the Manufacturer's Instruction Manual.

- ✓ **Voltage Transformers:** Including VT Marshalling Box Voltage transformers are generally fully assembled and filled with insulating oil ready to be erected on their support structures. VT's must be stored on-site and handled strictly in accordance with the Manufacturer's Instruction Manual.
- ✓ **Disconnectors and Earthing Switches:** Disconnectors and earthing switches must be erected strictly in accordance with the erection instructions in the Manufacturer's Instruction Manual. Care must be taken to ensure that all disconnectors and earthing switches are erected with the correct orientation, as indicated on the Switchyard General Arrangement and Section Drawings issued for the Project
- ✓ **Surge Diverters and Station Post Insulators** : Surge diverters and station post insulators must be erected strictly in accordance with the Manufacturer's Instruction Manual. In the event that surge diverters or station post insulators are supplied in more than one section, these sections must be joined together to form one unit before being erected onto the support structure.
- ✓ **Load Control Plant**: The load control plant must be assembled and installed as indicated in the Load Control Drawings, plus the Manufacturer's Assembly Instruction Manual.
- ✓ **Capacitor Banks:** Capacitor banks (either cubicle enclosed or outdoor type) must be installed and erected in accordance with the Project Design Drawings and the Manufacturer's Instruction Manual, as required. Erection of support structures and an enclosure fence may be required for outdoor type capacitor banks. HV connections, auxiliary supply and control cable connections must be made in accordance with the relevant Project Design Drawings.
- ✓ **HV Switchboards**: Before installation of a switchboard in a building on-site, the following requirements must be met:
  - The switch room floor must be prepared to the Switchboard Manufacturer's Specification. The preferred method and finish are supplied with the switchboard drawings and data.
  - The substation building and vehicle access must be sufficiently completed and clear to enable the installation to proceed unhindered.
  - The switch room must be sealed, air-conditioners or other ventilation systems operational (as installed), and a power supply suitable to run the individual switchboard panel heaters must be available.
- ✓ **HV Cables**: Installation and termination of HV and LV cables must be carried out in accordance with SS-1-4.4 Cables and Cabling. Cable-laying must also meet the following requirements:
  - Conduits must be spaced to ensure required current ratings are met (in accordance with the Cable Rating Design Report).
  - Cables to be installed so as to exclude cable wastage and cable damage.
  - The finished cable routes must not undermine foundations of substation equipment or encroach on any other substation works.
  - The HV power cable drum must be placed at an appropriate location to ensure that the cable can be pulled / installed efficiently. Generally the cable drum can be placed at the transformer and the cable can then be pulled from somewhere in the vicinity of the Control Building.

- ✓ Cable Marking and Identification All cables from the power transformers must be permanently marked according to phase with appropriately coloured heat shrink PVC sleeving at four locations:
  (i) Inside the transformer cable boxes.
  (ii) Immediately outside the transformer cable boxes (single core cables).
  (iii) Inside the indoor switchgear or the outdoor Ring Main Units.
  (iv) Immediately outside the indoor switchgear or outdoor Ring Main Units (single core cables).
- ✓ **Bus bars and Conductors**
  - **Overhead Conductors Landing spans, strung bus bars and overhead earth wires** must be installed in accordance with the Substation General Arrangement and Section Drawings, plus the relevant Standard Assembly Drawing(s). The conductors must be strung to the correct sags and/or tensions as specified on the appropriate drawing.
  - **Rigid Bus bars Rigid aluminium tubular bus bars** must be fabricated in accordance with the relevant Fabrication Drawings and erected as indicated on the Substation General Arrangement and Section Drawings.
  - **Droppers and Flexible Connections** Droppers and flexible conductor connections between HV plant must be installed as indicated on the Substation General Arrangement and Section Drawings and the relevant Assembly Drawings
  - **Lightning Lightning protection**, consisting of an integrated combination of lightning masts and overhead earth wires above the incoming feeder landing spans must be installed in accordance with the Substation General Arrangement and Section Drawings, plus the relevant Standard Assembly Drawing(s) and Substation Standard SS-1-8.2 Substation Lightning Protection.
  - **EARTHING The substation,** earthing system must be constructed and commissioned strictly in accordance with Ergon Energy Standards

Extending Fences and Earth Grids in Energised Substations When erecting a fence inside or near the outside of an energized substation, the construction procedures must ensure that no connection is made between the substation earth grid and any remote earth. There must also be no possibility of any Personnel (Staff or Public) being able to contact both the substation earth potential and remote earth potential at the same time, as the substation earth grid potential may be considerably different from that of remote earth

- **Fix and connect equipment of a substation**

- ✓ **Bus-bar**
- ✓ **Single-break isolating switch**
- ✓ **Double-break isolating switch**
- ✓ **On load isolating switch**
- ✓ **Isolating switch with earth Blade**
- ✓ **Current transformer**
- ✓ **Potential transformer**
- ✓ **Capacitive voltage transformer**
- ✓ **Oil circuit breaker**
- ✓ **Air circuit breaker with over-current tripping device**
- ✓ **Air blast circuit breaker**
- ✓ **Lightning arrester (active gap)**

- ✓ **Lightning arrester (valve type)**
- ✓ **Arcing horn**
- ✓ **Three-phase Power transformer**
- ✓ **Over current relay**
- ✓ **Earth fault relay**

Theoretical learning Activity

- ✓ Trainees have to brainstorm about the connection scheme of substation equipment, Fixing methods and rules of substation equipment, and Fix ,connect equipment of a substation

Practical learning Activity

Points to Remember (Take home message)

Every trainee must know to describe the connection scheme of substation equipment, Fixing methods and rules of substation equipment, and Fix ,connect equipment of a substation

✓ 

Learning out come 2.3 formative assessment

Q1. Answer true or false, the following are the equipment of substation

a) Oil circuit breaker, True

b) Hammer, False

c) Air circuit breaker with over, True

d) -current tripping device, True

e) Spoon, False

f) Lightning arrester (active gap), True

g) Electrician knife, False

Q2. By using definition explain current and potential transformer

Answer:

- **current transformer:** is a type of "instrument transformer" that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary.
- **Potential transformer:** The potential transformer may be defined as an instrument transformer used for the transformation of voltage from a higher value to the lower value. This transformer step down the voltage to a safe limit value which can be easily measured by the ordinary low voltage instrument like a voltmeter, wattmeter and watt-hour meters, etc.

References:

1. Principles of power system, V.K MEHTA , ROHIT MEHTA, S.CHAND &COMPANY, NEW DELHI 2004
2. http://www.ebay.com/bhp/high-voltage-tester
3. http://metrosil.com/applications/current-transformer-protection

Learning Unit 3- Test substation installation

STRUCTURE OF LEARNING UNIT

Learning outcomes:

3.1: Select Substation Testing Instruments

3.2: Test Substation Installation Element

3.3: Clean the Workplace

3.1: Select Substation Testing Instruments

Duration: 5hrs

✓ Learning out come 3.1 objectives:

By the end of the learning outcome, the trainees will be able to:

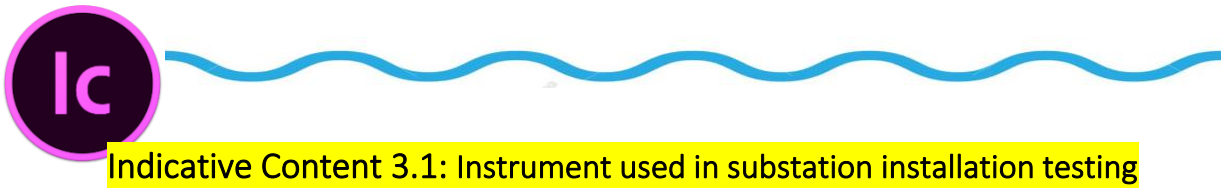
1. Identify substation testing instruments
2. Differentiate substation testing instruments
3. Proper use of substation testing instruments

Resources

Equipment	Tools	Materials
❖ Multimeter ❖ High voltage insulation resistance tester ❖ Protection relay tester ❖ Megohmmeter ❖ High Voltage Detector	❖ Books ❖ Internet ❖ Laptop ❖ Spanners ❖ Screw Drivers ❖ Pliers	❖ **Chalk** ❖ **paper**

Advance preparation:

. Picture of each Measuring instruments must be shown by trainer before giving an explanation to it.



Indicative Content 3.1: Instrument used in substation installation testing

There are many instruments used in substation installation testing:

1. *Megohmmeter*

Portable insulation resistance testers and megohmmeters are designed to help prevent hazards such as electric shock and short-circuits caused when the insulation in electrical devices, parts, and equipment used in industrial plants, buildings, and other settings **degrades** over long periods of use.

Insulation resistance test: The measured **resistance** has to be higher than the **indicated** limit from the international standards. A megohmmeter (also called **insulation resistance** tester, teraohmmeter) is then used to **measure** the ohmic value of an insulator under a direct voltage of great stability.

A hipot **test** (also called Dielectric Withstanding **Voltage** (DWV) **test**) verifies that the insulation of a product or component is sufficient to protect the operator from electrical shock. In a typical hipot **test**, **high voltage** is applied between a product's current-carrying conductors and its metallic shielding.

2. *Circuit breaker tester*

Circuit Breaker Testing is **utilized** to test the operation of each switching systems and the programming of the entire tripping structure. Circuit Breaker Testing is essential to ensure the safe and reliable performance of this key link in the power asset chain.

The circuit breaker tester must provide accurate and repeatable results, to be able to compare from previous tests and predict a malfunction of the breaker before it happens.

A circuit breaker tester can be specialized for medium/high voltage breakers, or for low voltage breakers, but also a multi-purpose circuit breaker tester can be used for both types as is the case of the high current injection systems and the micro-ohmmeters.

Therefore, the need for preventive maintenance will vary depending on operating conditions. As an accumulation of dust on the latch surfaces may affect the operation of the breaker, molded case circuit breakers should be exercised at least once per year. Routine trip testing should be performed every **3 to 5 years**.

3) FIELD STRENGTH TESTER

A **field strength meter** is an instrument that measures the **electric field strength** emanating from a **transmitter**

4) PROTECTIVE RELAY TESTER

It provides you with an indication of the general health and functioning of the **relay** switch contacts and coil. **Relay** Buddy operates the **relay** several times during each **test** session as it watches for consistency in every cycle.

5) High voltage detector

The High Voltage Detector is a safety device used to verify that transmission lines are not live prior to earthing. Reliably detecting and measuring high voltage on distribution and transmission voltage power lines is critical jobs performed by electric utility linemen. These jobs get done more quickly and safely when the voltage detection equipment is easy to use

High voltage detection equipment (HV detectors) is specially designed for the safe and practical detection of voltages on electrical medium and high voltage systems in the power generation and distribution, rail network, petrochemical and electrical service and maintenance industries.

These instruments let you confirm the presence of voltage on earthed neutral electrical systems.

500KV Non Contacts High Voltage Detector is a proximity voltage detector for safe detection of electrical presence. It is a product designed to warn of the presence of voltage anywhere AC power is present. An eight position rotary switch selects the voltage detection range.

✔*High voltage insulation tester*

High Voltage testing is usually performed to qualify the device to operate safely during rated electrical conditions, a way to check the effectiveness of its insulation. The objective sought during the high voltage testing will determine the type and amount of voltage applied and the acceptable current flow.

It is typical the use of high voltage testing on transformers to confirm performance. The main high voltage tests are included in type and routine tests made by the manufacturer in the factory to meet the required standards, quality and reliability.

Some of them are insulation resistance tests, dielectric type tests, lightning and switching impulse tests, partial discharge measurement, etc. This high voltage testing checks the insulation between primary to earth, secondary to earth and between primary & secondary, using generators of up to 100 KV range and higher, while the onfield testers for maintenance purposes are much lower range.

Other high voltage testing is carried out at site, during commissioning tests and/or periodic maintenance. One of the most typical is the withstand voltage test, to check if the transformer dielectric strength is in suitable condition for the service, or during maintenance programs to demonstrate the equipment keeps capable of withstanding overvoltages during operation.

High voltage insulation tester

For most circuits with a nominal operating voltage of **500 V** or less, the insulation test voltage should be **500 V**. Before testing is carried out, the loads must be disconnected along with surge protection devices and any electronic equipment that might be damaged by the test.

Fig. insulation resistance tester

Portable insulation resistance testers and megohmmeters are designed to help prevent hazards such as electric shock and short-circuits caused when the insulation in electrical devices, parts, and equipment used in industrial plants, buildings, and other settings **degrades** over long periods of use.

Theoretical learning Activity

- ✓ Trainees have to brainstorm about different measuring instruments used in substation

Practical learning Activity

- ✓ Trainees have to measure different electrical parameters available

Points to Remember (Take home message)

Using different measuring instruments properly

End of learning outcome 3.1 assessment

Match the tester instruments with its function

Tester instrument	Function
A. Field strength tester	1. Is **utilized** to test the operation of each switching systems and the programming of the entire tripping structure
B. Protective relay tester	2. Verifies that the insulation of a product or component is sufficient to protect the operator from electrical shock
C. Dielectric Withstanding **Voltage** (DWV) **test**	3. Measures the **electric field strength** emanating from a **transmitter**

D. Circuit breaker tester	4. Used to **measure** the ohmic value of an insulator under a direct voltage of great stability
E. megohmmeter	5. It provides you with an indication of the general health and functioning of the **relay** switch contacts and coil

Answer : A with 3, B with 5, C with 2, D with 1, E with 4

REFERENCES:
http/www.seton.com/best/high-voltage safety signs
http://www.ebay.com/bhp/high-voltage-tester

LO.3.2. Test Substation Installation Element

Duration: 5hrs

✓  Learning out come 3.1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify substation testing installation elements
2. Differentiate types of test in substation
3. Proper use of test in substation

Resources

Equipment	Tools	Materials
❖ Multimeter ❖ High voltage insulation resistance tester ❖ Protection relay tester ❖ Megohmmeter ❖ High Voltage Detector	❖ Books ❖ Internet ❖ Laptop ❖ Spanners ❖ Screw Drivers ❖ Pliers	❖ **Chalk** ❖ **paper**

Advance preparation:

. Picture of each Measuring instruments must be shown by trainer before giving an explanation to it.

Indicative Content 3.2.1: Types of tests in substation

Continuity Test

Continuity test is the checking of an electric circuit to see if current flows (that it is in fact a complete circuit). A **continuity test** is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path.

Earthing Test

Ground resistance testing covers the testing of earth electrodes and the measurement of soil resistivity. Megger offers top end systems for design and soil surveys as well as tough easy to use testers for field engineers. **Insulation Test**

Insulation is subject to many elements that can cause it to perform at a less-than-acceptable level. Excessive heat or cold, moisture, vibration, dirt, oil, and corrosive vapors can all contribute to deterioration. For this reason, routine insulation testing is necessary.

Total current in insulation testing.

Testing the integrity of insulation requires measuring its resistance to current flow across it. A high level of resistance means that very little current is escaping through the insulation. Conversely, a low level of resistance indicates a significant amount of current may be leaking through and along the insulation.

Continuity test is the checking of an electric circuit to see if current flows (that it is in fact a complete circuit). A **continuity test** is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path.

Indicative Content 3.2.2: Circuit Breaker testing

Circuit breaker testing is used to **test** both the performance of individual switching mechanisms and the timing of the overall tripping system.

Circuit Breaker Testing is used to **test** both the performance of individual switching mechanisms and the timing of the overall tripping system.

Circuit Breaker Testing is utilized to test the operation of each switching systems and the programming of the entire tripping structure. Circuit Breaker Testing is essential to ensure the safe and reliable performance of this key link in the power asset chain. Circuit breakers perform **three main tasks**:

Circuit breakers perform a vital role in **protecting expensive equipment from damage through faults** i.e. connecting and disconnecting the electrical power in a reliable way; this requires proving their reliability with on field tests during installation and with regular maintenance tests during its lifetime to prevent costly failures and problems that could even compromising the safety of the substation.

Type Tests of circuit breaker

Type tests are organized with the aim of proving the abilities and making sure the rated characteristic of the circuit breaker are exact. Such tests are conducted in the specially built testing laboratory.

1. **Mechanical Test**– It is mechanical ability type test involving the repeated opening and closing of the breaker. A circuit breaker must close and open at proper speed and do its allocated job and function without any failure.

2. **Thermal Test**– Thermal tests are carried out to check the thermal behavior of the circuit breakers. Due to the streaming of rated current through its pole in a rated condition, the breaker under test undergoes steady-state temperature rises. The temperature rise for rated current should not exceed 40° for current less than 800A normal current and 50° for normal value of current 800A and above.

   Dielectric Test– These tests are performed to check power frequency and impulse voltage withstand capacity. Power frequency tests are kept on a new circuit breaker; the test voltage changes with a circuit breaker rated voltage. In impulse tests, impulse voltage of particular value is employed to the breaker. For outdoor circuit dry and wet tests are conducted.

3. **Short -Circuit Test**– Circuit breakers are subjected to sudden short-circuits in short-circuit test laboratories, and oscillograms are taken to know the behaviour of the circuit breakers at the time of switching in, during contact breaking and after the arc extinction. The oscillograms are studied with particular reference to the making and

breaking currents, both symmetrical and asymmetrical restriking voltages, and switchgear is sometimes tested at rated conditions.

Routine Tests of a Circuit Breaker

Circuit Breaker Trip Test

By analysing the current consumed by the trip coil during the circuit breaker's operation, it is possible to determine whether there are mechanical or electrical issues present. In many cases, such issues can be localised to aid in finding the root cause. Optionally, monitoring the tripping supply's voltage during the operation can detect issues arising with tripping batteries. **Insulation Resistance Test**

Resistance testing is crucial for verifying that the insulating material which makes up the molded cases breakers are performing correctly. In order to test for insulation resistance, an instrument known as a megger is used. **Connection Tests**

Connection testing is important to make sure that an appropriate electrical connection is available and to recognize traces of overheating denoted by colour difference. It is important that electrical connections are properly installed to the CB to prevent and reduce overheating. **Contact Resistance Test**

Normal wear and tear of contacts within the CB emerges after extended usage. An easy method to identify traces of weakening within the circuit breaker is to quantify the resistance across every pole of the breaker.

Indications of abnormal conditions within the CB such as erosion and contamination of contacts are evident if there are excessive millivolt drops across the breaker. The contact resistance test is important in finding out if or not a circuit breaker is still apt for functioning.

Overload Tripping Test

Overload tripping components of CBs can be tested by inputting 300% of the breaker rating into each pole of the circuit breaker to determine that it will open automatically. The motive of this is to make sure that the circuit breaker will operate or not.

Instantaneous Magnetic Tripping

In routine tests, it is relevant to find out that the magnetic feature is functional and will trip the circuit breaker instead of finding the precise value at which the instantaneous magnetic feature functions.

How Testing of Circuit Breaker is performed?

This will define how to test a circuit breaker through different testing tools to be applied to check the equipment under a range of conditions or operation types. Discover how to test a circuit breaker with the different test sets that you can need.

Testing with Circuit Breaker Analyzer

The timing tests of the different open and close operations of the breaker are an efficient way of how to test a circuit breaker, analyzing not only the trip times but also the essential synchronism of the poles in the different operations.

Testing with a Micro-ohmmeter

Circuit breakers generally bear a huge value of current. Greater contact resistance cause greater losses, low current carrying capability and threatening hot spots in the breaker, so that the resistance testing with micro-ohmmeters are other way of how to test a circuit breaker for identifying and avoiding upcoming issues

Testing with a High Current Primary Injection Tester

The analysis of the tripping time characteristics of LV circuit breakers and molded-case circuit breakers is performed using high current injection, as the way to check the entire functionality. primary injection system which easily and quickly adapts its power capacity to the several high currents ratings of the different circuit breakers.

Benefits of Circuit Breaker Testing

- Quick and easy to perform on site
- Circuits can be tested on or off load
- Tests performance of whole tripping cycle
- Tests overall timing of tripping system
- Identifies need for maintenance
- Part of a comprehensive diagnostic maintenance program
- Find early indications of possible problems
- Avoid issues other than pick up pieces
- Build up a test record database for trending
- Pick out the bad actors

Earth ground insulation resistance tester

Ground resistance testing covers the testing of earth electrodes and the measurement of soil resistivity. Megger offers top end systems for design and soil surveys as well as tough easy to use testers for field engineers. We have tried to make the testers self-checking as much as we can, to allow you to concentrate on collating and understanding the results. The instrument requirements depend on the range of applications.

Circuit Breaker Testing is used to **test** both the performance of individual switching mechanisms and the timing of the overall tripping system.

Circuit Breaker Testing is utilized to test the operation of each switching systems and the programming of the entire tripping

Indicative Content 3.2.3: Protection relay testing

Protective relays are used in conjunction with medium voltage circuit breaker (above 600 volts) to sense an abnormality and cause the trouble to be isolated with minimum disturbance to the electrical system and with the least damage to the equipment at fault.

The testing and verification of relay protection devices can be divided into four groups: ○ **Routine factory production tests** ○ **Type tests** ○ **Commissioning tests** ○ **Occasional maintenance tests**

Type of Tests

Type tests are needed to prove that a protection relay meets the claimed specification and follows all relevant standards.

Routine Factory Production Tests

These tests are done to show that protection relays are free from defects during manufacturing process. Testing will be done at several stages during manufacture, to make sure problems are discovered at the earliest possible time and therefore minimize remedial work.

Commissioning Tests

Commissioning tests are done to show that a particular protection configuration has been correctly used prior to setting to work.
All aspects of the configuration are thoroughly verified, from installation of the correct equipment through wiring verifications and operation checks of the equipment individual items, finishing with testing of the complete configuration.

Periodic Maintenance Verifications

These are needed to discover equipment failures and service degradation, so that Corrective action can be taken.

ELECTRICAL TYPE TESTS

Different electrical type tests must be completed, as follows:

a) FUNCTIONAL TESTS

The functional tests consist of using the adequate inputs to the protection relay under test and measuring the performance to discover if it meets the specification. They are typically completed under controlled environmental conditions.

b) RATING TESTS

Rating type tests are completed to make sure that components are used within their defined ratings and that there is no fire or electric shock hazards under a normal loador fault conditions.

.

c) THERMAL WITHSTAND TESTS

The thermal withstand of VTs, CTs and output contact circuits are done to ensure compliance with the defined continuous and short-term overload conditions.

d) RELAY BURDEN TEST

The auxiliary supply burdens, optically isolated inputs, VTs and CTs are measured to determine that the product complies with its specification.

e) RELAY INPUTS

Relay inputs are verified over the specified ranges. Inputs include those for auxiliary voltage, VT, CT, frequency, optically isolated digital inputs and communication elements.

f) RELAY OUTPUT CONTACTS

Protection relay output contacts are type tested to make sure that they follow product specification. Special withstand and endurance type tests have to be completed using DC, since the normal supply is via a station battery.

g) INSULATION RESISTANCE TEST

This is completed between all circuits and case ground, between all independent circuits and across normally open contacts. The pass criterion for a product in new condition is a minimum of 100MΩ. After a damp heat test the pass criterion is a minimum of 10MΩ.

Protective relay Verify that each of the relay contacts performs its intended function in the control scheme, including:

- Breaker trip
- Close inhibit
- lockout Alarm functions

a) Transformer Testing

Type Tests and Routine Tests of Transformer

For confirming the specifications and performances of an electrical power transformer it has to go through a number of testing procedures. Some tests are done at a transformer manufacturer premises before delivering the transformer. Transformer manufacturers perform two main types of **transformer testing** – **type test of transformer** and **routine test of transformer**.

Some **transformer tests** are also carried out at the consumer site before commissioning and also periodically in regular and emergency basis throughout its service life.

Type of Transformer Testing

Tests done at factory

1. Type tests
2. Routine tests
3. Special tests Tests done at site

1. Pre-commissioning tests
2. Periodic/condition monitoring tests
3. Emergency tests

Protective relays are used in conjunction with medium voltage circuit breaker (above 600 volts) to sense an abnormality and cause the trouble to be isolated with minimum disturbance to the electrical system and with the least damage to the equipment at fault.

Indicative Content 3.2. 4: Transformer testing

To prove that the transformer meets customer's specifications and design expectations, the transformer has to go through different testing procedures in manufacturer premises.
Some transformer tests are carried out for confirming the basic design expectation of that transformer.

These tests are done mainly in a prototype unit not in all manufactured units in a lot. **Type test of transformer** confirms main and basic design criteria of a production lot. **Routine Tests of Transformer**

Routine tests of transformer are mainly for confirming the operational performance of the individual unit in a production lot. Routine tests are carried out on every unit manufactured. **Special Tests of Transformer**

Special tests of transformer are done as per customer requirement to obtain information useful to the user during operation or maintenance of the transformer.

Pre Commissioning Test of Transformer

In addition to these, the transformer also goes through some other tests, performed on it, before actual commissioning of the transformer at the site.

The transformer testing performed before commissioning the transformer at the site is called the pre-commissioning test of transformer.

These tests are done to assess the condition of transformer after installation and compare the test results of all the low voltage tests with the factory test reports.

Type tests of transformer include:

1. Winding resistance test of transformer
2. Transformer ratio test
3. Transformer vector group test
4. Measurement of impedance voltage/short circuit impedance (principal tap) and load loss (Short circuit test)
5. Measurement of no-load loss and current (Open circuit test)
6. Measurement of insulation resistance
7. Dielectric tests of transformer
8. Temperature rise test of transformer
9. Tests on on-load tap-changer
10. Vacuum tests on tank and radiators

Routine tests of transformer include

1. Winding resistance test of transformer
2. Transformer ratio test
3. Transformer vector group test
4. Measurement of impedance voltage/short circuit impedance (principal tap) and load loss (Short circuit test)
5. Measurement of no load loss and current (Open circuit test) 6. Measurement of insulation resistance
7. Dielectric tests of transformer.
8. Tests on on-load tap-changer.
9. Oil pressure test on transformer to check against leakages past joints and gaskets

That means Routine tests of transformer include all the type tests except temperature rise and vacuum tests. The oil pressure test on transformer to check against leakages past joints and gaskets is included.

Special Tests of transformer include

1. Dielectric tests.
2. Measurement of zero-sequence impedance of three-phase transformers
3. Short-circuit test
4. Measurement of acoustic noise level
5. Measurement of the harmonics of the no-load current.
6. Measurement of the power taken by the fans and oil pumps.
7. Tests on bought out components / accessories such as buchhloz relay, temperature indicators, pressure relief devices, oil preservation system etc.

Transformer Winding Resistance Measurement

Transformer winding resistance measurement is carried **out to calculate the I2R losses and to calculate winding temperature at the end of a temperature rise test.** It is carried out as a type test as well as routine test.

It is also done at site to ensure healthiness of a transformer that is to check loose connections, broken strands of conductor, high contact resistance in tap changers, high voltage leads and bushings etc.
Note: Transformer winding resistance measurement shall be carried out at each tap.

Insulation Resistance Test or Megger Test of Transformer

Insulation resistance test of transformer is essential type test. This test is carried out to ensure the healthiness of the overall insulation system of an electrical power transformer.

Procedure of Insulation Resistance Test of Transformer

1. Disconnect all the line and neutral terminals of the transformer
2. Megger leads to be connected to LV and HV bushing studs to measure insulation resistance IR value in between the LV and HV windings
3. Megger leads to be connected to HV bushing studs and transformer tank earth point to measure insulation resistance IR value in between the HV windings and earth
4. Megger leads to be connected to LV bushing studs and transformer tank earth point to measure insulation resistance IR value in between the LV windings and earth

Dielectric Tests of Transformer

Dielectric test of a transformer is one kind of insulation test. This test is performed to ensure the expected overall insulation strength of the transformer. There are several tests performed to ensure the required quality of transformer insulation; the dielectric test is one of them.

Induced Voltage Test of Transformer

The induced voltage test of the transformer is intended to check the inter-turn and line end insulation as well as main insulation to earth and between windings-

Temperature Rise Test of Transformer

Temperature rise test of transformer is included in **type test of transformer**. In this test, we check whether the temperature-rising limit of the transformer winding and oil as per specification or not.

In this type test of the transformer, we have to check oil temperature rise as well as winding temperature rise limits of an electrical transformer.

Elaboration of report

Each trouble report contains the following data:

- Equipment type
- Manufacturer name
- Model number
- Equipment ratings
- Severity of system disturbance (if any occurred)
- Date of manufacture
- Date of reported trouble
- Problem type

Type tests of transformer include:

1. Winding resistance test of transformer
2. Transformer ratio test
3. Transformer vector group test
4. Measurement of impedance voltage/short circuit impedance (principal tap) and load loss (Short circuit test)
5. Measurement of no-load loss and current (Open circuit test)
6. Measurement of insulation resistance
7. Dielectric tests of transformer
8. Temperature rise test of transformer
9. Tests on on-load tap-changer
10. Vacuum tests on tank and radiators

Theoretical learning Activity

- ✓ Trainees have to brainstorm about types of tests in substation
- ✓ Trainees have to experience different testing in substation

Practical learning Activity

- ✓ Perform the test on transformer windings

Points to Remember (Take home message)

Conduct different tests in substations

End of learning outcome 3.2 assessment

Q1. Why do we need to make ground resistance testing?

Answer: testing of earth electrodes and the measurement of soil resistivity

Q2. Discuss the tests of transformer

Answer:

- ✓ Transformer Winding Resistance test
- ✓ Insulation Resistance Test or Megger Test of Transformer
- ✓ Dielectric Tests of Transformer
- ✓ Induced Voltage Test of Transformer
- ✓ Temperature Rise Test of Transformer

Q3. What are the data containing trouble report?

Answer

- Equipment type
- Manufacturer name
- Model number
- Equipment ratings
- Severity of system disturbance (if any occurred)
- Date of manufacture
- Date of reported trouble
- Problem type

REFERENCES:
http/www.seton.com/best/high-voltage safety signs
http://www.ebay.com/bhp/high-voltage-tester

LO.3.3 Clean the workplace

Duration: 5hrs

✓ Learning out come 3.1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify substation cleaning methods
2. Differentiate types of cleaning methods
3. Use Cleaning tools
4 manage waste materials

Resources

Equipment	Tools	Materials
❖ Air Blower ❖ Brush ❖ Cleaning cloth ❖ Sponge	❖ Books ❖ Internet ❖ Laptop ❖ Spanners ❖ Screw Drivers ❖ Pliers	❖ **Chalk** ❖ **paper**

Advance preparation:

. Picture of each Cleaning tool must be shown by trainer before giving an explanation to it.

Indicative Content 3.3.1: Cleaning tools and equipment

Proper Tool Maintenance

Proper tool care also saves you money because the better they're cared for, the longer they'll last.

Hand Tools

Hand tools such as screwdrivers, wrenches, hammers, pliers, levels, and wire cutters are examples of common household tools that are often left out in places such as basements, garages and tool sheds. Tools are tough, but they are not indestructible and exposure to the elements can take its toll.

Below are some tips on how to take care of your tools and store them properly so that you get optimum use out of them.

Power Tools

Power tools such as electric drills, saws, sanders and nailers need routine maintenance just like your hand tools. Because of their mechanical and electrical parts, power tools are more susceptible to problems caused by poor maintenance, dust and debris accumulation and general malfunction.
The following are some helpful tips on how to clean and properly store your tools.
Keep Power Tools Clean with the use of an air compressor or a can of compressed air to blow air into vents and crevices is the best way to remove dirt and dust from inside tools.
Store Power Tools Correctly. Keep your power tools protected from dust, moisture and other adverse conditions by storing them properly after use. Keep them in their original cases if possible.

 Inspect for Wear or Damage. Periodically inspect power tools for any signs of wear or damage, Always unplug electric tools when cleaning them or making any repairs to avoid the danger of electric shock. It's also a good practice to unplug them when not in use.

 Lubricate Moving Parts. Keep moving parts lubricated for premium performance, not only does it keep the mechanics of a tool running smoothly, it also decreases the chance of rust developing.

 Keep Batteries in Shape .

Cordless, battery-powered tools are convenient and portable and have become very popular for contractors and homeowners alike. To keep them running efficiently and effectively, it is essential for their batteries to be maintained.

Power tools such as electric drills, saws, sanders and nailers need routine maintenance just like your hand tools. Because of their mechanical and electrical parts, power tools are more susceptible to problems caused by poor maintenance, dust and debris accumulation and general malfunction.
The following are some helpful tips on how to clean and properly store your tools.

 Keep Power Tools Clean with the use of an air compressor or a can of compressed air to blow air into vents and crevices is the best way to remove dirt

Indicative Content 3.3.2: Cleaning methods

Cleaning electrical equipment and switchgear: methodologies

Different methods exists based on cleaning apparatus, solvents and types of equipment to be cleaned. Let us discuss some of these.

Cleaning by brushes and clothes

Cleaning rags can be used for cleaning the interior of switchgears but special care should be taken. Loose fiber may cause further contamination and result in more harm than good. Cloth rags specially designed for the cleaning of insulators and switch gear interior should be used.

Cleaning cloth should be free of contamination and adhesive agents. Another problem with rags is their tendency to catch up on small parts and they may damage the delicate components of a switchgear trolley.

Cleaning agents

Contamination found in MV and LV switchgear trolleys are usually adhesive and solvents are often required in order to properly remove them. Special care is required when selecting a solvent for the cleaning of electrical apparatus and the solvent should be:

- ✓ Easily removable
- ✓ Nonflammable
- ✓ Inert to the material being cleaned
- ✓ Not interfering with electrical/mechanical functions of the switchgear
- ✓ Easily dryable
- ✓ Environmental friendly and non-toxic

Cleaning by industrial vacuum cleaners

Industrial vacuum cleaners are good choice when it comes to the cleaning of a switchgear.

However certain factors make it more suitable for the purpose which are

i. Gentle suction

ii. Nonmetallic parts and hosing joints iii. Its receiving hose should be designed so as not to damage the insulation if accidently hit or rubbed

Compressed air cleaning methods are not recommended for the interior because they spread the contamination further and may push it to delicate electric parts of a substation switchgear. Even if the traditional moping is being performed, a chemical agent should be used to limit the spread of contaminants via air.

High pressure air

This method is a bit risky and requires special training and strict safety compliance. Gas masks and personal protective equipment are necessary and staff should be trained for the purpose.

Pressure of the air should be within the limits set by safety regulations and the air should be clean and debris free. Presence of water vapors may complicate the situation and air should be as dry as possible. Even the slightest contamination in the air may badly damage the interior and electrical insulation of a switchgear.

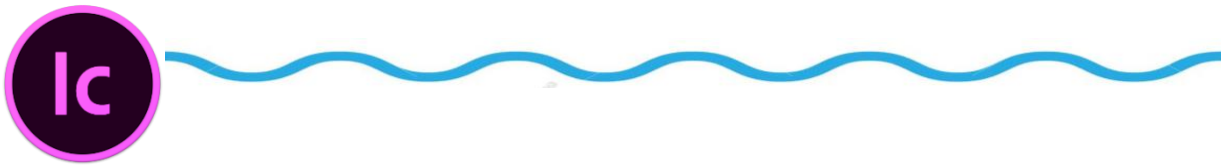
Sand blasting

Tough parts electrical equipment such as external hard racks and doors may be cleaned with sand blasting prior to painting or re-painting. Sand blasting is a special technique and demands proper supervision and adequate training.

Improper sand blasting techniques always result in personnel and property damage and should be avoided completely. Special care should be taken as the coatings of contaminants or adhesions may contain toxic and non-biodegradable substances such as plastics, asbestos or lead oxide paints.

Cleaning rags can be used for cleaning the interior of switchgears but special care should be taken. Loose fiber may cause further contamination and result in more harm than good. Cloth rags specially designed for the cleaning of insulators and switch gear interior should be used.

Cleaning cloth should be free of contamination and adhesive agents. Another problem with rags is their tendency to catch up on small parts and they may damage the delicate components of a switchgear trolley.



Indicative Content 3.3.3: Manage Waste Materials

Storage Area and Containment Requirements ○ Materials will be stored only in designated areas, preferably near construction gates, and away from drainage areas, if possible.

- Materials will be stored on impervious surfaces, if possible, on plastic groundcovers, or with secondary containment to prevent spills or leaks from infiltrating the ground.
- Only necessary quantities of materials will be stored, and materials will not be overstocked.
- Incompatible materials will be stored in segregated areas. Materials that are incompatible will not be placed in the same container or in an unwashed container that previously held such material
- Hazardous waste containers will remain closed during transfer and storage, except when it is necessary to add or remove waste.
- Only personnel trained to accept, unload, package, label, load, prepare shipping papers, and transport hazardous materials will be allowed to perform these tasks.

Hazardous Materials Security Requirements

The hazardous materials stored on site will be secured through compliance with the following requirements:

- Hazardous materials will be stored in a secured (gated, locked, and/or guarded) location to prevent the risk of damage, vandalism, or theft.
- Hazardous materials may be temporarily stored within the ROW during construction hours, but will be returned to a secured location for overnight storage and/or during non construction periods.

Waste-Specific Management and Disposal Requirements

In addition to the BMPs that will be implemented as part of the Project's SWPPPs, the following measures will be utilized to ensure that construction waste is managed and disposed of properly during construction of the Project:

- Only licensed sanitary/septic waste haulers will be used for disposal of sanitary waste that is collected at the Project site. Portable sanitary facilities (e.g. port-o-john) will be emptied of sanitary waste prior to transport.
- Drilling residue and drilling fluids will be disposed of in accordance with applicable regulations.
- Waste generated as part of operation procedures, such as water-laden dredged materials and drilling mud, will be contained and not allowed to flow into drainage channels or receiving waters
- Deposited solids will be removed from containment areas and from containment systems as needed and at the completion of the Project.
- All broken asphalt and concrete will be collected, recycled when feasible, and disposed of in accordance with local, state, and federal requirements.
- Absorbent materials and rags that have been used to clean any spilled fuel will be secured in appropriate storage containers and disposed of at a proper waste-handling facility.
- If concrete or paint residue remains after drying, the area will be swept and the residue will be removed to avoid contact with storm water.
- All temporary construction materials—such as markings, barriers, or fencing—will be removed following completion of construction activities in that area.
- The recyclable materials identified in Section 4.3.0 Waste Procedures will be transported to an appropriate local recycling center.
- Hazardous waste generated at work areas along the ROW will be transported at the end of each work day to a consolidation site. Consolidation sites may include the ECO Substation, Boulevard Substation, and contractor staging areas.
- Non-hazardous waste will be disposed of at Otay Landfill in accordance with facility waste-acceptance criteria, while hazardous waste will be separately disposed of at an

SDG&E-approved, appropriately permitted, and licensed disposal facility in

- Materials will be stored only in designated areas, preferably near construction gates, and away from drainage areas, if possible.
- Materials will be stored on impervious surfaces, if possible, on plastic groundcovers, or with secondary containment to prevent spills or leaks from infiltrating the ground.


Theoretical learning Activity

✓ Trainees have to brainstorm about the cleaning methods


Practical learning Activity

✓ Clean the work place


Points to Remember (Take home message)

Use cleaning methods properly

End of learning outcome 3.3 assessment

Read the following statements and Respond by using TRUE or FALSE

1. Proper tool care can not save you money because the better they're cared for, the longer they'll last.
2. Hand tools such as screwdrivers, wrenches, hammers, pliers, levels, and wire cutters are examples of common household tools that are often left out in places such as basements, garages and tool sheds.

3. Loose fiber may cause further contamination and result in more harm than good one.

ANSWERS 1 FALSE 2 TRUE 3TRUE

REFERENCE:
clean the work place techniques - Google Search