RTB | RWANDA TVET BOARD

RQF LEVEL 5

TRADE: Industrial Electricity

MODULE CODE: IELPS 501

TEACHER'S GUIDE

Module name: Perform substation

Table of Contents

Acronyms

CVT or CCVT: Capacitive voltage transformer: A capacitor voltage transformer

OCB: Oil circuit breaker

CB: Circuit breaker

CT: Current transformer

PT or VT: Potential (voltage) transformer

PPE : Personal protective equipment

REG: Rwanda Energy Group

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 transmission technician.

Module Code and Title: IELPS 501 Industrial Electricity

Learning Units:

1. Perform preliminary activities
2. Install substation elements or equipment
3. Test substation installation

Learning Unit 1: Perform preliminary activities

STRUCTURE OF LEARNING UNIT

Learning outcomes:

1.1 Interpret electrical diagrams

1.2 Prepare tools, equipment and materials

1.3 Apply safety precautions at the workplace

Learning outcome 1.1: Interpret electrical diagrams

Duration: 10 hrs

Learning outcome 1 objectives:

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

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

1. identify correctly symbols of equipment used in substations,
2. interpret clearly symbols of equipment used in substations,
3. Describe correctly electrical diagrams used in substation.

Resources

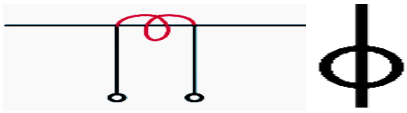
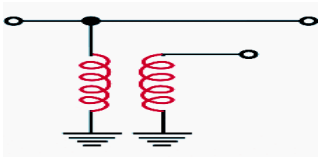
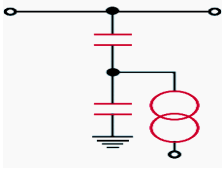
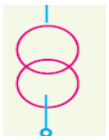
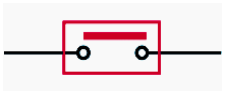
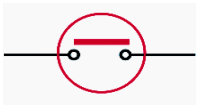
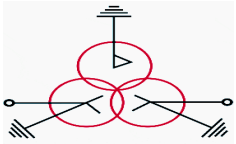
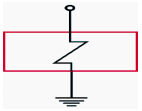
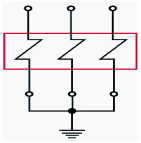
Equipment	Tools	Materials
Safety shoes **Overall**	**Pencil** **Eraser** **Ruler** **Mathematical set** **Protractor**	**Drawing sheets** **Notebook**

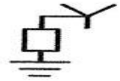
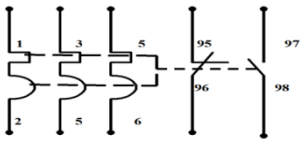
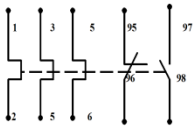
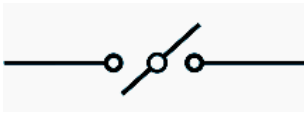
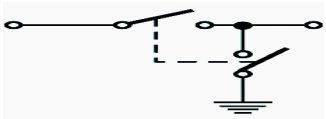
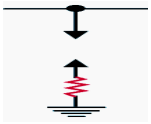
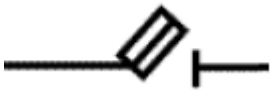
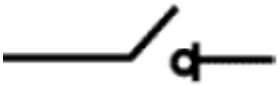
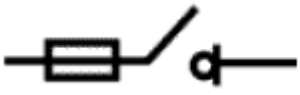
Advance preparation:

- Rulers
- Compass
- Chalks or mark pen of different colour
- Drawing board
- Blackboard of white board

Indicative content 1.1.1: Symbols for equipment in substations

✓ **Symbols for equipment in substations**

Current transformer (CT) 	Potential (voltage) transformer (PT or VT)  
Capacitive voltage transformer (CVT) 	Capacitive voltage transformer (CVT) 
Oil circuit breaker 	Air-blast circuit breaker 
Air circuit breaker with overcurrent tripping device 	Circuit breaker 
phase transformer 	Three phase transformer connection 
Earth fault relay 	Overcurrent relay 

Star Connection - Resistor Grounded Neutral 	Star Connection - Solid Grounded Neutral 
Magneto-thermal relay 	Thermal relay 
Arcing horn 	Busbar
 wave trape	Surge arrester 
Fuse 	switch 
Single-break isolating-switch 	Double-break isolating-switch 
On-load isolating switch 	Isolating switch with earth blade 
disconnector-fuse(fuse combination unit) 	Lightning arrester (valve type) 
fuse disconnector 	Lightning arrester (active cap) 
switch disconnector 	
fuse switch-disconnector 	Earth switch 
switch-disconnector-fuse(fuse combination unit) 	Earth switch 

Theoretical learning Activity

Ask trainees to select substation equipment based on symbols

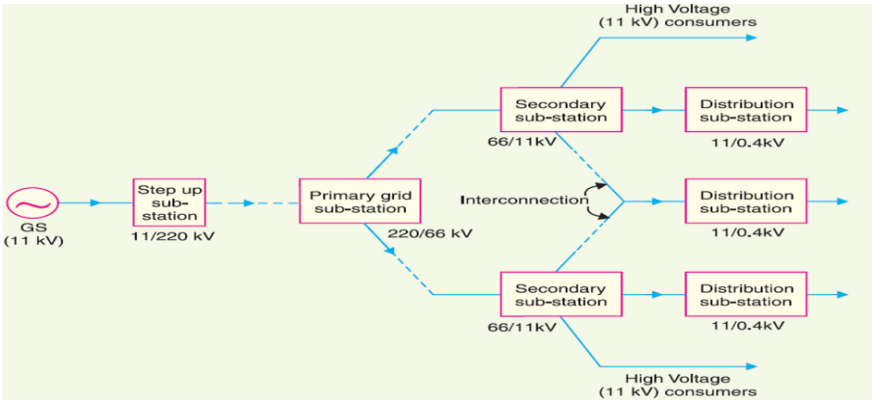
Points to Remember (Take home message)

- Symbols of substation equipment

Indicative content 1.1.2: Electrical installations' diagrams used in substation

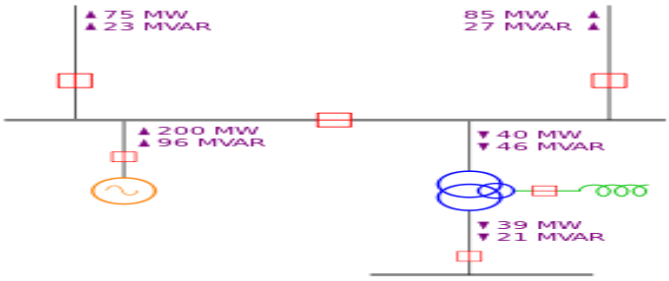
Block diagram

A block diagram is a diagram of a system in which the principal parts or functions are represented by blocks connected by lines that show the relationships of the blocks.



Single line diagram

In power engineering, a single-line diagram (SLD), also sometimes called one-line diagram, is a simplified notation for representing a three-phase power system.



- **Architecture diagram**

  The basic architecture of a utility automation system can be viewed as a multi-layered stack. The overall architecture can be viewed as two layers, each made up of several sub layers. The first or lowest layer, the data acquisition and control layer, is made up of substation-resident equipment. The second or highest layer, the utility enterprise, can be viewed as the information infrastructure layer.

- **Wiring diagram**

It is a simplified conventional pictorial representation of an electrical circuit. It shows the physical appearance of the installation and the components.

Advantages of wiring diagram

- It shows the components of the circuit as simplified shapes,
- And it shows how to make the connections between the devices.
- A wiring diagram usually gives more information about the relative position and arrangement of devices and terminals on the devices.
- It shows easily connection
- It shows estimated physical appearance of the installation

Disadvantages of wiring diagram

- It is complex in analysis
- It is difficult to detect fault

Theoretical learning Activity

Engage trainees in different group work. (Expert and home group)

To discuss difference between electrical installations' diagrams used in substation

Points to Remember (Take home message)

Difference between

- Block diagram
- Single line diagram
- Architecture diagram
- Wiring diagram

LEARNING OUTCOME 1 WRITTEN ASSESSMENT FORMATIVE ASSESSMENT

Q1. Give the symbols of the following items used in installation of substation

i) Single-break isolating-switch :

ii) Double-break isolating-switch:

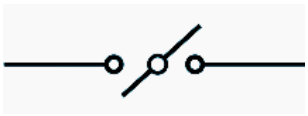
iii) Arcing horn:

iv) Air circuit breaker with overcurrent tripping device:

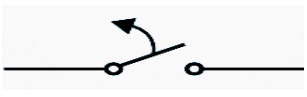
v) Air-blast circuit breaker:

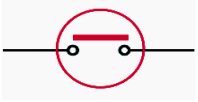
ANSWER

i) Single-break isolating-switch : 

ii) Double-break isolating-switch: 

iii) Arcing horn: 

iv) Air circuit breaker with overcurrent tripping device: 

v) Air-blast circuit breaker: 

Practical assessment

Rwanda Energy Group needs to install new substation transformer. Technicians are wondering where to start. As a young electrical technician you help, them to select diagram are used during installation. You must accomplish this task in only 30 minutes.

Practical assessment checklist

Checklist	**Score**		**comments**
	Yes	**No**	
Identification of symbols of substation equipment is well done			
Block diagram is well interpreted			
Single line diagram is well interpreted			
Architectural diagram is well interpreted			

References:

1. https://electrical-engineering-portal.com/hv-substation-elements
2. Electrical Substation Components List - Diagram, Working & Functions | PDF | Electrical Substation | Electric Current (scribd.com)

Learning outcome 1.2: Prepare tools, equipment and materials

Duration: 6 hrs

Learning outcome 1.2 objectives:

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

4. identify correctly symbols of equipment used in substations,
5. interpret clearly symbols of equipment used in substations,
6. Describe correctly electrical diagrams used in substation.

Resources

Equipment	Tools	Materials
Ladder Lifting crane	Screw drivers Pliers Spanners Drilling machine Pince a certile (crimping tool) Viseuse (Screw driver machine) Hammer Spirit level	Transformer Measuring instrument (voltage, current, power, frequency,) Lightening arrestor surge arrestor Earth protective device Bus bar

Advance preparation:

- Tools equipment prepared
- Table be used for demonstration

Indicative content 1.2.1: Tools used in installation of substation

- **Tools /equipments used in installation of substation**

The equality of electrician in most cases can be judged from his appearance and tools, kits occupied by his firms clients, his closing should be wet and tidy with no loose end hanging around. the tools should be suffient and the correct types to carry out efficiency the job in hand

- **Tools**
  - **Screw drivers:** variety of screw drivers from small terminal one up to a rarge size for open/ close screws
  - **Pliers:** They are used for cutting cables and twisting or bending conductors for entry into terminals
  - **Spanners:** open/close bolts and nuts
  - **cutting plier:** cutting wire
  - **Hand drilling machine:** for drilling different holes
  - **Hammer:** used with chisels and for nailing and fitting
  - **Spirit level**: indicate the verticality and horizontality of the surface
  - **Crimping tool**

Theoretical learning Activity

Ask trainees to form group and discuss on Tools /equipments used in installation of substation

Practical learning Activity

Ask trainees to select Tools /equipments used in installation of substation

 Points to Remember (Take home message)

Definition of :

- Screw drivers
- Plier
- Spanners
- cutting plier
- Hand drilling machine
- Hammer:
- Spirit level

Indicative content 1.2.2: Equipment used in installation substation

- Ladder

  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.

- Lifting crane

  A crane is a type of machine, generally equipped with a hoist rope, wire ropes or chains, and sheaves, that can be used both to lift and lower materials and to move them horizontally. It is mainly used for lifting heavy things and transporting them to other places.

Indicative content 1.2.3: Disposition /arrangement of tools, Materials and equipment on the workplace

- tools, Materials and equipment on the workplace based on their type, nature and use

- to ensure proper performance of tools and equipment they are some tips to respect ;
  - Inspect tools and equipment for safe conditions before and after work.
  - Clean your workplace after every work with proper tools
  - Use a proper storage of materials/equipments
  - Each tool/material have to perform its desired work

Theoretical learning Activity

Involve trainees in explanation of working principle of equipment used in substation

Practical learning Activity

Disposition /arrangement of tools, Materials and equipment on the workplace

Points to Remember (Take home message)

Working principle of

- Ladder
- Lifting crane
- Disposition /arrangement of tools, Materials and equipment on the workplace

LEARNING OUTCOME 1.2 WRITTEN ASSESSMENT FORMATIVE ASSESSMENT

Q1. In the list provide circle a tool that can be used to remove insulation on wire.

a) Cutting plier

b) Screw driver

c) Hammer

d) Stripping plier

e) None

Answer: is D

Q2. Provide the difference between the following equipment used in substation

A. Ladder, B. Lifting crane

Answer:

- **Ladder**

  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.

- **Lifting crane**

A crane is a type of machine, generally equipped with a hoist rope, wire ropes or chains, and sheaves, that can be used both to lift and lower materials and to move them horizontally. It is mainly used for lifting heavy things and transporting them to other places

Practical assessment

Chief of NENGO substation located at Gisenyi have a task to manage substation's components in substation and in those component there are heavy component to be lifted. You as intern in this substation ask to accomplish the task. What will you need and for which reason.

Practical assessment checklist

Checklist	**Score**		**comments**
	Yes	**No**	
Selection of equipment used is well done			
Lifting crane is well selected			
Arrangement of tools according to nature is well done			
Arrangement of materials according to the type is well done			
Arrangement of materials according to nature is well done			
Arrangement of equipment according to the type is well done			
Arrangement of equipment according to nature is well done			

References:

1. https://automationforum.co/15-basic-electrical-tools-which-are-used-by-an-electrician/
2. https://www.scribd.com/document/417252933/Electrical-Substation-Components-List-Diagram-Working-Functions

Learning Outcome 1.3: Apply safety precautions at the workplace

Duration: 14hrs

Learning outcome 1.3 objectives:

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

1. Describe properly PPE used in substation installation
2. indicate clearly correctly high-voltage electrical hazards in substation installation
3. recognize accurately high voltage electrical installations Precautions in substation installation
4. Interpret correctly High-voltage safety signs used in substation installation.

Resources

Equipment	Tools	Materials
Helmet Safety shoes Overall Gloves nose protection earmuff security belt	Screw drivers Pliers Spanners Drilling machine Pince a certile (crimping tool) Viseuse (Screw driver machine) Hammer Spirit level	Transformer Measuring instrument (voltage, current, power, frequency,) Lightening arrestor surge arrestor Earth protective device Bus bar

Advance preparation:

Make sure you have

- complete set of PPEs
- electrician tool box
- safety signs tags

Indicative content 1.3.1: description of Personal protective equipment

✓ **PPE**

Personal protective equipment: is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety for workers from hazard. Workers must wear the following personal protective equipment (PPE) as it is required at the workplace and when by the supervisor instructed:

- **Shoes or strong/rubber boots:** Those are for protection against any sharp object on the floor.
- **gloves**: This is for Hand and Fingers protection from injuries in the work place
- **Helmet:** Those are for Head protection from any dropped materials or tools to the head. This device is needed where heavy machines are suspended. This is a must in all construction companies.
- **Overalls:** Those are work clothes to prevent your everyday clothing from becoming contaminated by oils, grease fluxes or general dust and dirt.
- **Goggle and Eye lids**: This equipment protects the eyes during welding and grinding operations.
- **Earmuff /Nose protection mask**: Those are for ear protection from noise.
- **Security belt**: is used in conjunction with other safety equipment when working on the Utility poles, the reason of this is to avoid fall hazards

Theoretical learning Activity

Ask Brainstorming on personal protective equipment

Practical learning Activity

Ask trainees to perform wearing of personal protective equipment

Points to Remember (Take home message)

Description of PPE

- **Shoes or strong/rubber boots**
- **gloves**
- **Helmet**
- **Overalls:**
- **Goggle and Eye lids**
- **Earmuff /Nose protection mask**
- **Security belt**:

Indicative content 1.3.2: description of Types of high-voltage electrical hazards

Electrical hazard can be defined as a serious workplace hazard that exposes workers to electrical accident or injuries.

Electrical accidents are far more likely to be fatal than other types of incidents. There are four main types of electrical injuries:

- **Electrocution (death due to electrical shock):** Electrocution results when a human is exposed to a lethal amount of electrical energy. It is death caused by electric chock.
- **Electrical shock**: Electrical shock is defined as a reflex response to the passage of electric current through the body.
- **Burns**: An electrical burn is a burn that results from electricity passing through the body causing rapid injury.

Theoretical learning Activity

Engage trainees to form Group and discuss on electrical high voltage installations hazards,

Practical learning Activity

Ask trainees to discuss on ways of preventing electrical high voltage installations hazards.

Points to Remember (Take home message)

Difference between:

- Electrical hazard
- Electrocution (death due to electrical shock
- Electrical shock
- Burn

Indicative content 1.3.3: citation of Precautions on high voltage electrical Installations

SAFETY AND PRECAUTIONS FOR ELECTRICIAN

1. A great care should be taken against electric shock while doing any work on the main line.
2. Switch off the main switch immediately to release the victim of electric shock. If the main switch is not in easy approach then use dry wood or any other insulating material to release the victim.
3. Don't touch the main line with bare hands.
4. Shut off the main switch before the replacement of a fuse.
5. Always use insulated tools while doing any work on the main line.
6. Use safety belt while working on an electric pole.
7. The ladder should always be firmly help by helper while doing any overhead work, so that it may not slip.
8. Before supplying mains to any equipment, check that the equipment is in perfect working order and it is properly earthed.

9. All metallic parts and the metallic cover of an electric machine should be well earthed.
10. Before switching – on main-switch, check that nobody is working on the main-line.
11. Before starting a repair work on the main-line, switch off the main switch and pull out the fuses.
12. Before starting a job, be ensured that you are authorized to do the job.
13. The battery charging room should be well airy and lighted.
14. Don't charge the batteries in a dark or in a closed room.
15. The battery charging room should be away from the fire or the flames.
16. A fire caused due to an electric spark should be extinguished with dry sand and carbon dioxide type fire extinguisher
17. To work on a clear and clean place
18. To see (check) if all equipments are on their proper position

Persons who intend to or are required to work on high-voltage equipment after switching, isolation, short circuiting and earthing must be appropriately instructed and provided with an access permit issued by an appropriately trained authorized person (High Voltage Switching Operator).

- **De-energize (disconnection) procedures**

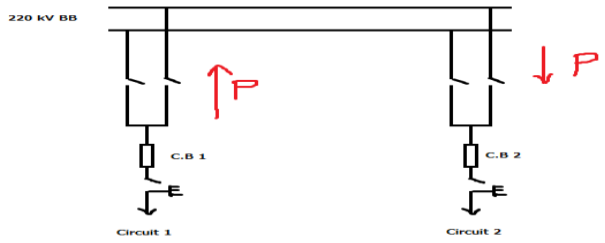
  De-energizing a substation for maintenance is typically not done because the load served by the substation must remain in service. When maintenance is required, only those parts of the substation that require service are taken off-line by the operation of opening circuit breakers and isolation switches. If the total substation needs to be de-energized.

The following (general) procedure would be:

1. If alternate power sources are available, transfer substation load to feeders served by other substations by temporarily synchronizing to the alternate sources
2. Open feeder breakers and open feeder isolation switches
3. Open the high-voltage breakers and isolation switches
4. All substations will also have a station-service voltage source often served by the distribution-voltage bus.
5. All substations also have a DC storage battery system to operate all critical protection and control système. Should the substation remain off-line for a prolonged period of time, a backup AC source needs to be provided to keep the storage battery charged until power is restored.

- **To shut down**
    1) The rules that must be followed:
    2) Disconnect loads first.
    3) After disconnecting loads, you can disconnect source.
    4) Circuit breakers opened first, then isolators.

For example, assume you have the following substation which connected to 2 circuits as following:



- **Isolation procedures**

The process of isolation in a substation is as mentioned below:

1) Open the Main & Tie CB or Main/Transfer CB of the Lines/Feeders to be isolated. The opening of CB may be done from Control Room
2) After opening of CB from one end ensure that the CB from other end is also opened after receipt of direct trip signal. This can be checked by ensuring that the voltages in all three phases are zero.
3) Open the line isolators at both ends after ensuring current/voltage zero in previous step.
4) Close the line Earth Switch of both ends.
5) It is important to mention here that; never open isolator without ensuring voltage/current zero otherwise it will have consequential effect.
6) This process is applicable for Lines/feeders. In case of Transformers, instead of both ends of line, the area of concern shifts to HV & IV side of transformers.
7) In case of isolation of a single bay, first open CB, then open isolators of both side of CB then close earth switch after ensuring that primary is de-energized

- **Earthing down procedures**

  Earthing Down in High Voltage System**:** It is an additional safety procedure for high voltage systems. Earthing down ensures all the stored electrical energy in the circuit insulation is safely discharged to earth. Hence earthing ensures that isolated electrical equipment is safe to work

Theoretical learning Activity

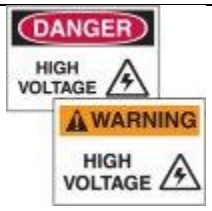
Ask trainees to discussion on safety precautions of high voltage electrical Installation

Points to Remember (Take home message)

SAFETY AND PRECAUTIONS FOR ELECTRICIAN

- De-energize (disconnection) procedures
- Isolation procedures
- Earthing down procedures

Indicative content 1.3. 4: interpretation of High-voltage safety signs

 *Danger or Warning High Voltage Labels (With Graphic)*	*International Symbols Labels - High Voltage* 	*Danger Signs - High Voltage Inside Do Not Open* 	 *International High Voltage Symbols On A Roll*
Lockout Hazard Warning Labels- Danger High Voltage Turn Off Power 	*Danger Signs - High Voltage Underground Cable* 	*Caution Signs - High Voltage Do Not Enter This Enclosure* 	 *Safety Alert Signs - Danger - High Voltage*
Eco-Friendly Signs - Danger High Voltage Unauthorized Persons Keep Out 	Danger Signs - High Voltage Keep Away 	*Warning Signs - High Voltage* 	*Electrical Warning Labels - Danger High Voltage* 

Lockout/Electrical Signs - High Voltage 	*Lockout Hazard Warning Labels- High Voltage, Entry By Authorized Personnel Only* 	*Safety Floor Signs- High Voltage (With Graphic)* 	*Lockout/Electrical Signs - High Voltage Overhead* 

Theoretical learning Activity

Ask trainees to form group and discus on safety and precautions for electrician

Practical learning Activity

Involve trainees in Physical demonstration of high voltage safety signs

Points to Remember (Take home message)

High-voltage safety signs

LEARNING OUTCOME 1.3. WRITTEN ASSESSMENTFORMATIVE ASSESSMENT

Q1. Identify any five (5) personal protective equipment used in installation of substation

Q2. Circle two of the below statement which are not safety and precautions for electrician working in substation

1. A great care should be taken against electric shock while doing any work on the main line.
2. Switch off the main switch immediately to release the victim of electric shock. If the main switch is not in easy approach then use dry wood or any other insulating material to release the victim.
3. Don't touch the main line with bare hands.
4. Always use insulated tools while doing any work on the main line.
5. Use safety belt while working on an electric pole.
6. The ladder should always be firmly help by helper while doing any overhead work, so that it may not slip.

Q3. Answer by True or False the following statement

A. **The First step undertake when shutting down a substation outgoing line is open** Circuit breakers, then isolators**,**

B. **Firstly step in De- energize (disconnection) procedures of substation include** Open circuit breaker

C. **Second step undertake when shutting down a substation outgoing line is** disconnect source

D. **Secondly step in De- energize (disconnection) procedures of substation is** closes earth switch

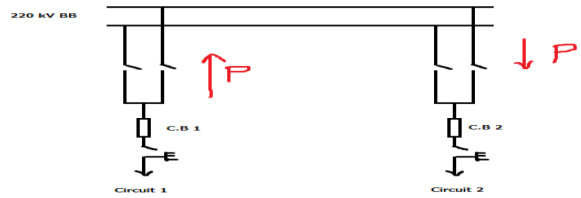
E. Lastly **when** you are **shutting down a substation outgoing line** disconnect source,

F. **Thirdly step in De- energize (disconnection) procedures of substation** Open isolator (disconnector)

Answer

A. **F**, B. **T**, C**. F**, D. **F**, E. **F**, F. **F**

Q4. Consider **CIRCUIT 1** as supply source to substation and **CIRCUIT 2** as load interpret the shutdown procedure of this substation.



ANSWER: As the power flow direction is known there will not be needing to contact the control center .We will first open the C.B 2, then open isolators and connect the earthing switch in the circuit 2. After this we go open C.B 1 then open isolators for circuit 1, and also connecting the earthing switches.

After this you can found your substation isolated from the grid receiving no power, exporting no power so it's completely shut down. Note that we first disconnected load then disconnected source and also opened first C.B then isolators.

Practical assessment

A new substation has to be installed by Rwanda Energy Group (REG). To assist with the installation of substation protection tools and equipment, they need qualified people. You are employed as an electrician to install substations. Select the protective equipment you will need for the substation installation, and use precaution around any high-voltage electrical systems. The assignment has to be finished in one hour

Checklist	**Score**		**comments**
	Yes	**No**	
Personal protective equipment for substation installation is well selected			
high-voltage electrical hazards is well identified			
Precautions on high voltage electrical installations is well identified			
High-voltage safety signs is well selected			

References:

1. https://iaeimagazine.org/issue/may-june-2020/understanding-the-3-main-types-of-electrical-hazards/
2. https://ehs.ncsu.edu/occupational-health/electrical-personal-protective-equipment-ppe
3. https://www.bing.com/images/search?q=high-voltage+safety+signs+in+substation&qpvt=High-voltage+safety+signs+in+substation&form=IGRE&first

Learning Unit 2: Install substation elements or equipment

Picture

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: 10 hrs

Learning outcome 2 .1 objectives :

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

1. Define correctly the term “substation” used in electricity.
2. Identify properly the main function of substation used in electricity
3. Classify effectively substation as used in electricity
4. Describe clearly Substation equipments as used in electricity

Resources

Equipment	Tools	Materials
Helmet Overall Safety shoe Goggles Gloves Ladder Lifting crane	Screw drivers Pliers Spanners Drilling machine Pince a certile (crimping tool) Viseuse (Screw driver machine) Hammer Spirit level	• 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

Advance preparation:

- Image of substation
- Simulation objects for substation equipments
- Transformers

Indicative content 2.1.1: Definition of 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, and transformation and switching. The power transformer, circuit breaker, bus-bar, insulator, lightning arrester are the main components of an electrical substation

Theoretical learning Activity

Ask trainees to brainstorm about definition of substation

 Points to Remember (Take home message)

Definition of substation

Indicative content 2.1.2: Main functions of substations

– **Main tasks of with sub-stations in the transmission and distribution system**

1. Protection of transmission system.
2. Controlling the Exchange of Energy.
3. Ensure steady State & Transient stability.
4. Load shedding and prevention of loss of synchronism. Maintaining the system frequency within targeted limits.
5. Voltage Control; reducing the reactive power flow by compensation of reactive power, tap-changing
6. Securing the supply by proving adequate line capacity.
7. Data transmission via power line carrier for the purpose of network monitoring; control and protection.
8. Fault analysis and pin-pointing the cause and subsequent improvement in that area of field.
9. Determining the energy transfer through transmission lines.

10. Reliable supply by feeding the network at various points.
11. Establishment of economic load distribution and several associated functions.

Essential functions of substation in power transmission

- **Voltage transformation**: In such type of substation, transformers are installed for transforming the power from one voltage level to another level as per need.

- **Circuit switching**: A switching substation, or switchyard, is a substation without transformers that operates only at a single voltage level. Switchyards, used mainly for connections and interconnections, are essential for transmission, distribution, collection, and controlling the flow of electricity

- **Voltage regulation**: Voltage regulators can be found both at the substation and out on distribution lines to help maintain a constant voltage level along the entire feeder. ... They raise or lower the voltage on the distribution line to provide a more or less constant voltage as the amount of load on the line changes
- **VAR control:** is one of the important controls at a distribution substation which convention- ally involves regulation of voltage and reactive power (or power factor) at the substation bus
- **System protection**

Theoretical learning Activity

Engage trainees in formation of group the discuss on main functions of substations

 Points to Remember (Take home message)

Main and Essential functions of substation in power transmission for

Voltage transformation
Circuit switching
Voltage regulation
VAR control
System protection

Indicative content 2.1.3: Layout considerations of a substation

The continuity of supply depends to a considerable extent upon the successful operation of sub-stations. It is, therefore, essential to exercise utmost care while designing and building a sub-station. The following are the important points which must be kept in view while laying out a sub-station:

- It should be located at a proper site. As far as possible, it should be located at the centre of gravity of load.
- It should provide safe and reliable arrangement. For safety, consideration must be given to the maintenance of regulation clearances, facilities for carrying out repairs and maintenance, abnormal occurrences such as possibility of explosion or fire etc. For reliability, consideration must be given for good design and construction, the provision of suitable protective gear *etc.*
- It should be easily operated and maintained.
- It should involve minimum capital cost.

Other factors should be evaluated when selecting a substation site

- Safety and reliability
- Easily operated and maintained
- Capital cost
- Centre of gravity of loads
- Location of existing and future sources of power
- Availability of suitable right-of-way and access to site by overhead or underground
- transmission and distribution circuits
- Alternative land use considerations
- Location of existing distribution lines
- Nearness to all-weather highway and railroad siding, accessibility to heavy equipment under all
- weather conditions, and access roads into the site
- Possible objections regarding appearance, noise, or electrical effects
- Site maintenance requirements including equipment repair, watering, mowing, landscaping, storage, and painting
- Possible objections regarding present and future impact on other private or public facilities

Theoretical learning Activity

Ask trainees to work in group and provide instruction on how to proceed

Points to Remember (Take home message)

Layout consideration of substation

Indicative content 2. 1.4: Classification of substations

✓ **Classification of substations according to service requirements**

- **Transformer sub-station:** In such type of substation transformers are installed for transforming the power from one voltage level to another level as per need.
- **Switching sub-station:** The substations use for switching the power line without disturbing the voltage is known as the switching substations. This type of substations is placed between the transmission lines.
- **Power factor correction sub-station:** The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment. A high power factor is generally desirable in a transmission system to reduce transmission losses and improve voltage regulation at the load
- **Frequency changer sub-station:** A frequency changer is a motor-generator set that changes power of an alternating current system from one frequency to one or more different frequencies, with or without a change in the number of phases, or in voltage. Sometimes a converter is used to accomplish this.
- **Converting sub-station:** In such types of substations, AC power converting into DC power or vice versa or it can convert high frequency to lower frequency or vice versa.
- **Industrial sub-station**: they are also known as bulk substations and are traditionally referred to as distributive substation; however, these are for dedicated consumers only e.g. industries requiring bulk power to be supplied.

✓ **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.

- **Advantages of Outdoor Substation**

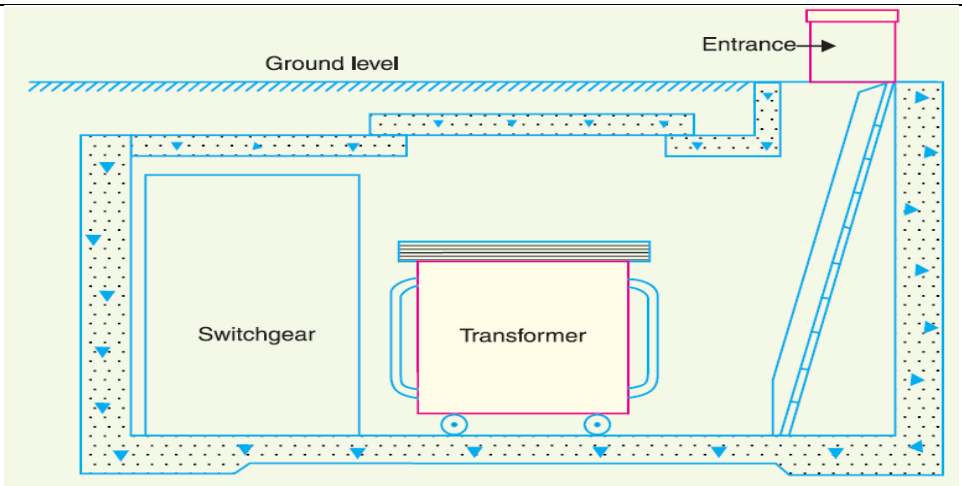
The outdoor substations have the following main advantages. These are

  - All the equipment in the outdoor substations is within view, and therefore fault location is easier.
  - The expansion of the installation is easier in the outdoor substations.
  - The time requires in the construction of such substations is lesser.
  - The smaller amount of building material like steel, concrete is required.
  - The construction work required is comparatively less, and the cost of the switchgear installation is also very low.
  - Repairing work is easy, and proper space is provided between the apparatus so that the fault occurs at one point will not be carried over to another point.

- **Disadvantages of Outdoor Substation**

  - More space is required for the outdoor substations.
  - Protection devices are required to be installed for the protection against lightning surges.
  - The length of the control cables increases which increase the cost of the substation.
  - Equipment designed for outdoor substation are more costly because outdoor door substation equipment required additional protection from the dirt and dust.

- **Underground sub-stations**



In thickly populated cities, there is scarcity of land as well as the prices of land are very high. This has led to the development of underground sub-station. In such sub-stations, the equipment is placed 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.

Theoretical learning Activity

Ask trainees to brainstorm on class of substations used in power transmission

Practical learning Activity

Demonstrate the illustrative image of substation and Ask trainees to differentiate them.

Points to Remember

Class of substations according to:

– service requirements

– construction features

Indicative content 2.1.6: Substation equipment and its functions

✓ **Substation equipment and its functions**

- **Bus-bar:** A bus bar structure is an assembly of bus conductors with associated connection joints and insulating supports. It can have bare or insulated conductors. A bus bar is a grounded metal enclosure, containing factory-mounted, bare or insulated conductors, which are usually copper or aluminium bars, rods, or tubes (generally of rectangular x-section).

- **Single-break isolating switch**: In this type of isolator, the 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:** This type of isolator consists of three loads of post insulators. The middle insulator holds a flat male or tubular contact that can be turned straightly by a spin of middle post insulator

- **On load isolating switch:** Are designed to isolate an electrical circuit from its power source under load condition. It can also be termed as on load disconnectors or load break switch (LBS). Load switches may have short circuit making capacity but it does not possess a short circuit breaking capacity.
- **Isolating switch with earth Blade**: Main function of earth switch is to ground the isolated bus/conductor. It is interlinked with isolator, when isolator opens the circuit, earth switch is closed & when isolator closes the circuit, earth switch is opened. So earth switch provides extra safety to the working personnel
- **Current transformer:** A current transformer is a gadget utilized for the transformation of higher value currents into lower values. It is utilized in an analogous manner to that of AC instruments, control apparatus, and

  meters. These are having lower current ratings and are used for maintenance and installation of current relays for protection purpose in substations.

- **Potential transformer:** The potential transformers are similar in characteristics as current transformers but are utilized for converting high voltages to lower voltages for protection of relay system and for lower rating metering of voltage measurements
- **Capacitive voltage transformer:** A capacitor voltage transformer (CVT or CCVT), is a transformer used in power systems to step down extra high voltage signals and provide a low voltage signal, for metering or operating a protective relay

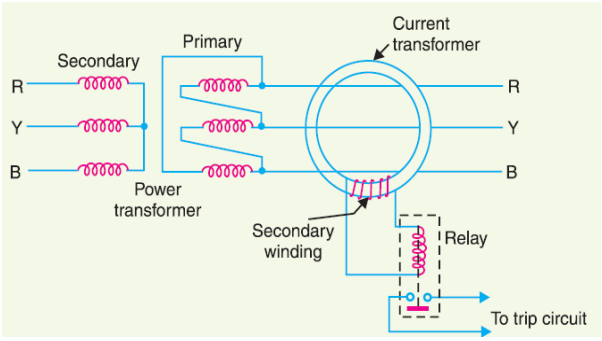
- **Oil circuit breaker:** An Oil circuit breaker (OCB) is a type of circuit breaker that uses insulating oil as a dielectric medium to quench the arc and break the circuit safely. The oil used is insulating oil used usually transformer oil that has better dielectric strength than air. There are two types of Oil circuit breaker:

  - Bulk Oil Circuit Breaker
  - Minimum Oil Circuit Breaker

- **Air circuit breaker with over-current tripping device** : Air circuit breaker (ACB) is an electrical device used to provide over current and short circuit protection for electrical circuits over 800 Amps to 10KA .the air circuit breakers have completely replaced oil circuit breakers
- **Air blast circuit breaker:** Air blast circuit breaker used compressed air or gas as the arc-interrupting medium. In the air blast, circuit breaker compressed air is stored in a tank and released through a nozzle to produce a high-velocity jet; this is used to extinguish the arc
- **Lightning arrester (active gap**): It is one of the simplest forms of the arrester. In such type of arrester, there is an air gap between the ends of two rods. The one end of the arrester is connected to the line and the second end of the rod is connected to the ground
- **Lightning arrester (valve type):** The gap between the electrodes intercepts the flow of current through the arrester except when the voltage across the gap raises beyond the critical gap flashover. The valve type's arrester is known as a gap surge diverter or silicon carbide surge diverter with a series gap. Such type of resistor is called nonlinear diverter
- **Arcing horn**: arc-horns are projecting conductors used to protect insulators or switch hardware on high voltage electric power transmission systems from damage during flashover. Overvoltage on transmission lines, due to atmospheric electricity, lightning strikes, or electrical faults, can cause arcs across insulators (flashovers) that can damage them.
- **Three-phase Power transformer:** Three-phase Transformers are the backbone of electrical power distribution whether Delta or Star connected windings

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

- **Over current relay**: An over current 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 over current (DTOC) relay. In a typical application, the over current relay is connected to a current transformer and calibrated to operate at or above a specific current level. When the relay operates, one or more contacts will operate and energize to trip a circuit breaker.
- **Earth fault relay**: The earth fault relay is basically a protection device used selectively for earth fault protection. These can be used for both primary and backup protection in an electrical system.



Theoretical learning Activity

Ask trainee to describe difference substation equipment and its functions

Points to Remember (Take home message)

Substation equipment and its functions

LEARNING OUTCOME2.1. WRITTEN ASSESSMENT FORMATIVE ASSESSMENT

Q1.Provide the difference between the following Substation equipment and its functions: Single-break isolating switch and Double-break isolating switch

Answer

Single-break isolating switch: In this type of isolator, the 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: This type of isolator consists of three loads of post insulators. The middle insulator holds a flat male or tubular contact that can be turned straightly by a spin of middle post insulator

Q2.Substations are classified in many classes. As a technician give the disadvantages of Outdoor Substation as one of the type of substation.

[5 marks]

- More space is required for the outdoor substations.
- Protection devices are required to be installed for the protection against lightning surges.
- The length of the control cables increases which increase the cost of the substation.
- Equipment designed for outdoor substation are more costly because outdoor door substation equipment required additional protection from the dirt and dust.

PRACTICAL ASSESSMENT

Due to Due to the increasing buildings in our country Rwanda Energy Group (REG) has decided to construct new substation you are one REG's substation technician you are requested to install this transformer substation within 15 hours . Classify according to their classes.

Formative assessment checklist

Checklist	Score		comments
	Yes	No	
Classification of substations according to construction features is well done			
Classification of substations according to service requirements is well done			
Identification of Substation equipment and its functions is well done			
Layout considerations of a substation is well done			
Description of Main parts of a substation is well done			

REFERENCE

1. https://www.sciencedirect.com/topics/engineering/substations
2. Electrical Substations : Different Types & Their Working (watelectrical.com)
3. https://circuitglobe.com/classification-of-substations.html
4. https://electricianworld.net/electrical-substation-equipment/

Learning outcome 2.2 Protect substation installation

Duration: 5 hrs

Learning outcome 2 objectives:

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

1. Describe clearly common faults occur in substation

2.Identify correctly Rules governing selection of protection devices to be used in substation

3. Describe properly protection procedure used on substation equipment

Resources

Equipment	Tools	Materials
Helmet Overall Safety shoe Goggles Gloves Ladder Lifting crane Insulation tester	Screw drivers Pliers Spanners Drilling machine Pince a certile (crimping tool) Viseuse (Screw driver machine) Hammer Spirit level	Buchholz Earth-fault Over-current Differential system

Advance preparation:

- pedagagical document ready
- image or simulation object
- video of damaged component in substation

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

- **Overvoltage faults:** High voltage equipment, particularly that which is installed outside, such as power transformers and overhead power lines, is commonly subject to transient over voltages, which may be caused by phenomena such as lightning strikes, faults on other equipment, insulation failure , arcing ground or switching surges during circuit re-energisation. Overvoltage events such as these are unpredictable, and in general cannot be completely prevented

- **Overload faults:** They are as a result of a transformer or other device doing work more than its rated capacity. When this happens, the device/transformer will be drawing current more than its rated capacity that will result to a higher temperature in the device/transformer windings and over time might cause it to burn and get damaged. Line terminations, at which a transmission line connects to a busbar or transformer bushing, are at greatest risk to overvoltage due to the change in characteristic impedance at this point.

- **Earthing /grounding faults:** When the live conductor comes in contact with earth at any case, it is called earth fault or ground fault. To identify this fault, one terminal of the megger is connected to the conductor and the other terminal connected to earth. If the megger indicates zero reading, it means the conductor is earthed.

Theoretical learning Activity

Group discussion on faults in substation installations, protection of transformers, bus-bar protection and overvoltage protection

Points to Remember (Take home message)

Causes and means of protection of common faults in a substation Overvoltage faults Overload faults Earthing /grounding faults

Indicative content 2.2.2: identification of Rules governing selection of Protection devices in substation

Following are one of rules governing selection of protection devices: - Rated voltage - Rated current - Shot circuit current - selectivity - speed - sensitivity - reliability - simplicity - economy - Cost

Theoretical learning Activity

Ask trainees in pair to brainstorm on Rules governing selection of protection devices

Points to Remember (Take home message)

Rules governing selection of protection devices

✓ **Introduction**

Transformers are static devices, totally enclosed and generally oil immersed. Therefore, chances of faults occurring on them are very rare. However, the consequences of even a rare fault may be very serious unless the transformer is quickly disconnected from the system. This necessitates providing adequate automatic protection for transformers against possible faults.

Small distribution transformers are usually connected to the supply system through series fuses instead of circuit breakers. Consequently, no automatic protective relay equipment is required. However, the probability of faults on power transformers is undoubtedly more and hence automatic protection is absolutely necessary.

There are Common transformer faults Of power transformers such as **open circuits**, **overheating**, **winding short-circuits**

✓ **Protection Systems for Transformers**

- **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 leakage joints etc.

- **Earth-fault** relays providing protection against earth-faults only. If any winding comes in contact with earth point, then this relay trips the transformer circuit at once

- **Over-current** relays providing protection mainly against phase-to-phase faults and overloading.

- **Differential system** providing protection against both earth and phase faults.

✓ **Bus-bar and line protection**

- Differential protection

  The basic method for bus bar protection is the differential scheme in which currents entering and leaving the bus are totalised. 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.

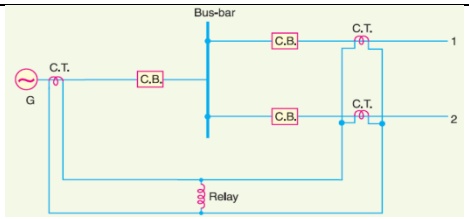


Figure above shows the single line diagram of current differential scheme for a station bus bar

- Distance protection

Distance-type relays operate on the combination of reduced voltage and increased current occasioned by faults. They are widely applied for the protection of higher voltage lines. A major advantage is that the operating zone is determined by the line impedance and is almost completely independent of current magnitudes.

- Fault bus protection It is possible to design a station so that the faults that develop are mostly earth-faults. This can be achieved by providing earthed metal barrier (known as fault bus) surrounding each conductor throughout its entire length in the bus structure

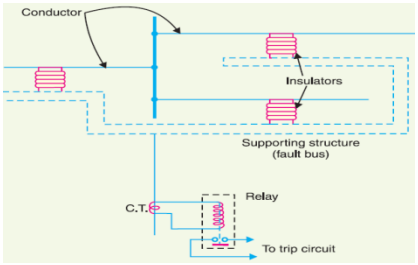


Figure above show the schematic arrangement of fault bus protection

Theoretical learning Activity

Ask trainee to describe Protection Systems for Transformers used in substation

Practical learning Activity

Points to Remember (Take home message)

Protection system for transformers **Bus-bar and line protection**

LEARNING OUTCOME 2.2 WRITTEN ASSESSMENT FORMATIVE ASSESSMENT

Q1. Identify the common faults occurred in a substation

Q2. Match the column A with Column B

A. Protection devices	B. function
1.Buchholz **2. Earth-fault** 3. **Over-current** **4. Differential system**	A. 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 leakage joints B. Relays providing protection mainly against phase-to-phase faults and overloading. C. Relays providing protection against earth-faults only. If any winding comes in contact with earth point, then this relay trips the transformer circuit at once

Answer:

A. Protection devices	B. function
1. Differential system **2. Earth-fault** 3. **Over-current** **4. Buchholz**	A. 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 leakage joints B. Relays providing protection mainly against phase-to-phase faults and overloading. C. Relays providing protection against earth-faults only. If any winding comes in contact with earth point, then this relay trips the transformer circuit at once

PRACTICAL ASSESSMENT

There are Common transformer faults of power transformers such as open circuits, overheating, winding short-circuits as substation technician how will protect you transformer again that transformer faults

Formative assessment checklist

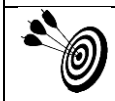
Checklist	**Score**		**comments**
	Yes	**No**	
Overvoltage faults is known			
Overload faults is known			
Earthing /grounding faults is known			
Buchholz devices is is chosen			
Earth-fault relays is chosen			
Over-current relays is chosen			
Differential system is chosen			
Buchholz devices is chosen			

References:

1. https://circuitdigest.com/article/all-about-transformer-protection-and-transformer-protection-circuits
2. https://www.eeeguide.com/electrical-and-electronics-engineering-articles/protection-of-busbars-and-lines/
3. **https://circuitglobe.com/bus-bar-protection.html**

Learning outcome 2.3 : Fix and connect equipment of a substation

 **Duration: 5hrs**



Learning outcome 1 objectives:

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

1. interpret correctly Connection scheme (order) of equipment of a substation
2. describe clearly Fixing methods and rules of substation equipment
3. perform correctly Fixation and connection equipment of a substation

 **Resources**

Equipment	**Tools**	**Materials**
Helmet Overall Safety shoe Goggles Gloves	Screw drivers Pliers Spanners Drilling machine Pince a certile (crimping tool) Viseuse (Screw driver machine) Hammer Spirit level	• 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

 **Advance preparation:**

Simulated object

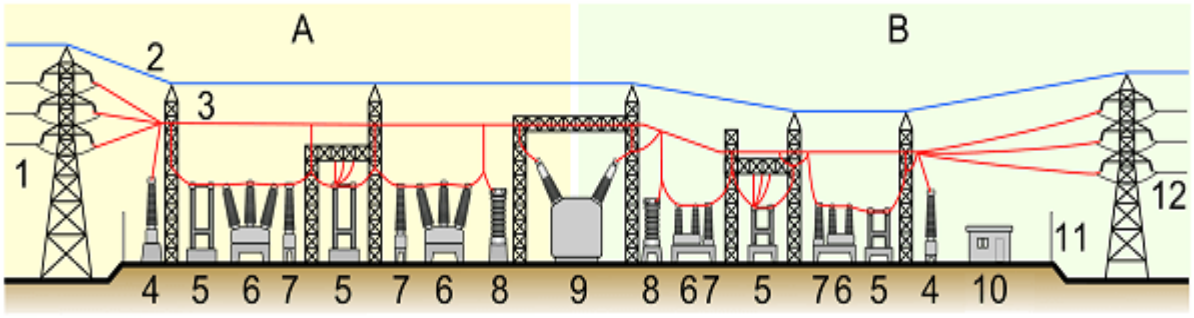
Photos related to devices in content

Video related to devices in content

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

✓ **Connection scheme (order) of equipment of a substation**

- The connection of the substation
  - Incoming or power feeder connection
  - Power transformer connection.
  - Instrument transformers connection for control and metering
  - Outgoing feeder for feeding the other subsequent substations or switchgear.



Elements of a substation referring to the figure above

A: Primary power lines, side

B: Secondary 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
9. Main transformer
10. Control building
11. Security fence

12. Secondary power lines

While the above are some standard components that are seen in the electrical substations, depending upon the type of substation and their functioning the electrical substation components may slightly change. Also with the advancements in the technology, many components are constantly upgraded to keep with the latest advancements to deliver constant power output.

Theoretical learning Activity

Ask trainees to discuss about the connection scheme of equipment of substation

Practical learning Activity

Ask trainees to interpret the drawing of connection scheme of equipment of substation

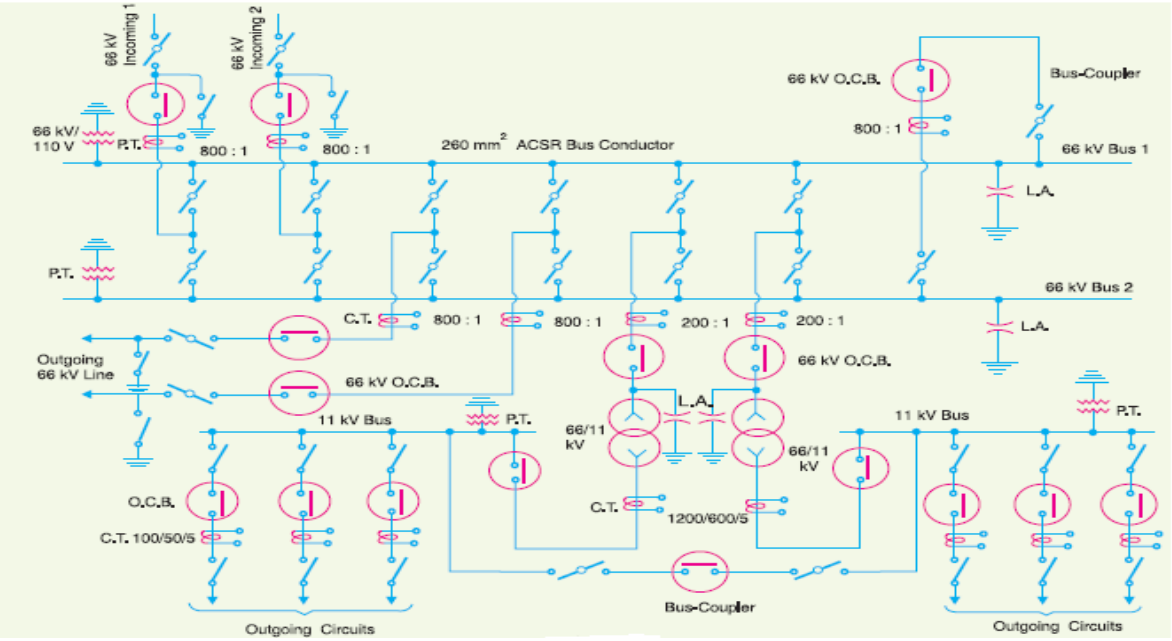
 Points to Remember (Take home message)

Connection scheme (order) of equipment of a substation

Elements of a substation

Indicative content 2.3.2: Fixing methods and rules of substation equipment

The key diagram of a typical 66/11 kV sub-station.



- There are two 66 kV incoming lines marked ‘incoming 1’ and ‘incoming 2’ connected to the bus-bars. Such an arrangement of two incoming lines is called a double circuit. Each incoming line is capable of supplying the rated sub-station load. Either these lines can be loaded simultaneously to share the sub-station load or any one line can be called upon to meet the entire load. The double circuit arrangement increases the reliability of the system. In case there is a breakdown of one incoming line, the continuity of supply can be maintained by the other line.

- The sub-station has duplicate bus-bar system; one ‘main bus-bar’ and the other spare busbar.The incoming lines can be connected to either bus-bar with the help of a bus-coupler which consists of a circuit breaker and isolators. The advantage of double bus-bar system is that if repair is to be carried on one bus-bar, the supply need not be interrupted as the entire load can be transferred to the other bus.

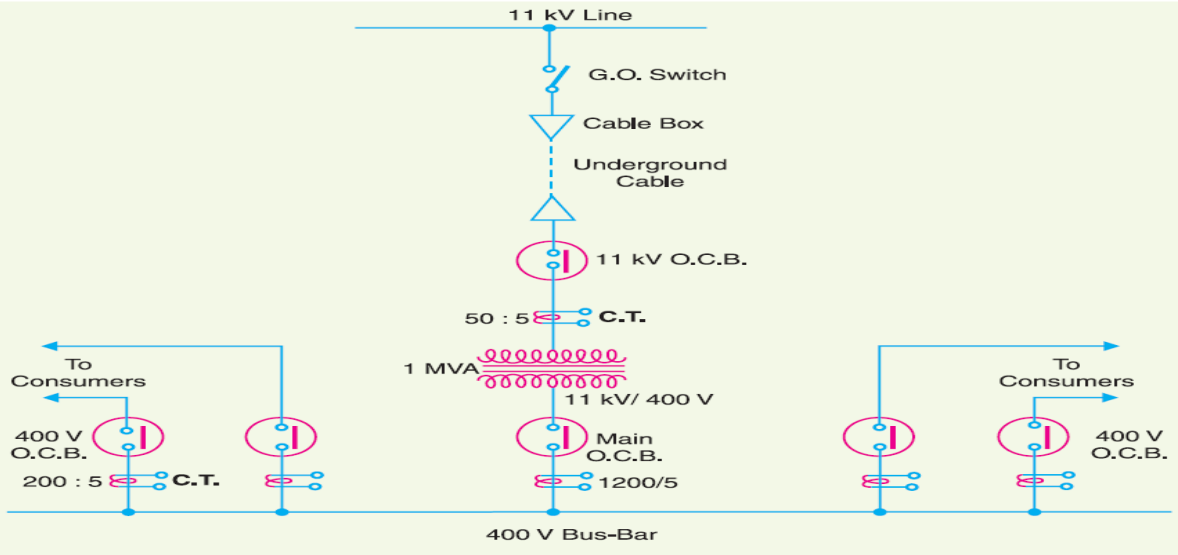
- There is an arrangement in the sub-station by which the same 66 kV double circuit supply is going out *i.e.* 66 kV double circuit supply is passing through the sub-station. The outgoing 66 kV double circuit line can be made to act as incoming line.

- There is also an arrangement to step down the incoming 66 kV supply to 11 kV by two units of 3-phase transformers; each transformer supplying to a separate bus-bar. Generally, one transformer supplies the entire sub-station load while the other transformer acts as a standby unit. If need arises, both the transformers can be called upon to share the sub-station load. The 11 kV outgoing lines feed to the distribution sub-stations located near consumers localities.
- Both incoming and outgoing lines are connected through circuit breakers having isolators on their either end. Whenever repair is to be carried over the line towers, the line is first switched off and then earthed.

- The potential transformers (P.T.) and current transformers (C.T.) and suitably located for supply to metering and indicating instruments and relay circuits (not shown in the figure).The P.T. is connected right on the point where the line is terminated. The CTs are connected at the terminals of each circuit breaker.
- The lightning arresters are connected near the transformer terminals (on H.T. side) to protect them from lightning strokes.

- There are other auxiliary components in the sub-station such as capacitor bank for power factor improvement, earth connections, local supply connections, d.c. supply connections etc. However, these have been omitted in the key diagram for the sake of simplicity.

Key Diagram of 11 kV/400 V Indoor Sub-Station



- The 3-phase, 3-wire 11 kV line is tapped and brought to the gang operating switch installed near the sub-station. The G.O. switch consists of isolators connected in each phase of the 3- phase line.
- From the G.O. switch, the 11 kV line is brought to the indoor sub-station as underground cable. It is fed to the H.T. side of the transformer (11 kV/400 V) *via* the 11 kV O.C.B. The transformer steps down the voltage to 400 V, 3-phase, 4-wire
- The secondary of transformer supplies to the bus-bars *via* the main O.C.B. From the busbars, 400 V, 3-phase, 4-wire supply is given to the various consumers *via* 400 V O.C.B. The voltage between any two phases is 400 V and between any phase and neutral it is 230 V. The single phase residential load is connected between any one phases and neutral whereas 3- phase, 400 V motor loads is connected across 3-phase lines directly.
- The CTs are located at suitable places in the sub-station circuit and supply for the metering and indicating instruments and relay circuits.

The design of underground sub-station requires more careful consideration than other types of sub-stations. While laying out an underground sub-station, the following points must be kept in view:

- The size of the station should be as minimum as possible.
- There should be reasonable access for both equipment and personnel.
- There should be provision for emergency lighting and protection against fire.
- There should be good ventilation.
- There should be provision for remote indication of excessive rise in temperature so that H.V. supply can be disconnected.
- The transformers, switches and fuses should be air cooled to avoid bringing oil into the premises.

Theoretical learning Activity

Group discussion on electrical high voltage elements/equipment fixing considerations and standards

Practical learning Activity

Physical demonstration on how to fix high voltage elements/equipment

 Points to Remember (Take home message)

The key diagram of a typical 66/11 kV sub-station.
Key Diagram of 11 kV/400 V Indoor Sub-Station

Indicative content 2.3.3: Fix and connect equipment of a substation

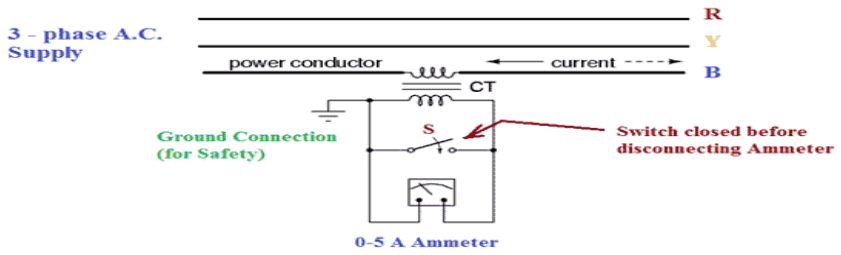
✓ **Fix and connect equipment of a substation**

- Bus bar: In distribution substation, bus bars are used at both high side and low side voltages to connect different circuits and to transfer power from the power supply to multiple out going feeders. Feeder bus bars are available for indoor and outdoor construction. They are fixed on support with bolt and nuts
- Single-break isolating switch: In this type of isolator, the 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: This type of isolator consists of three loads of post insulators. The middle insulator holds a flat male or tubular contact that can be turned straightly by a spin of middle post insulator

- On load isolating switch: Are designed to isolate an electrical circuit from its power source under load condition. It can also be termed as on load disconnectors or load break switch (LBS). Load switches may have short circuit making capacity but it does not possess a short circuit breaking capacity.

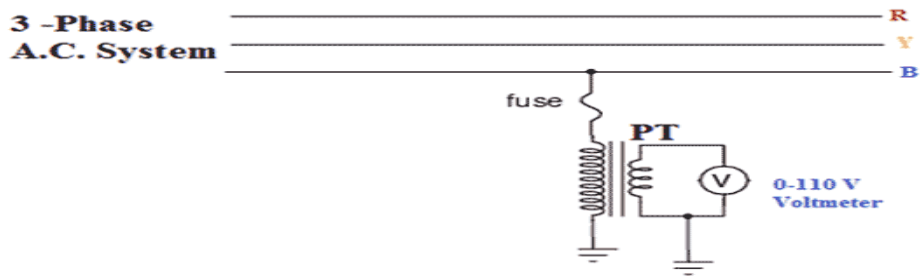
- Isolating switch with earth Blade: Main function of earth switch is to ground the isolated bus/conductor. It is interlinked with isolator, when isolator opens the circuit, earth switch is closed & when isolator closes the circuit, earth switch is opened. So earth switch provides extra safety to the working personnel

- Current transformer: Current transformer is used to step down the current of power system to a lower level to make it feasible to be measured by small rating Ammeter (i.e. 5A ammeter). A typical connection diagram of a current transformer is shown in figure below.



Current Transformer (C.T.)

- Potential transformer:
  Potential transformer is used to step down the voltage of power system to a lower level to make is feasible to be measured by small rating voltmeter i.e. 110 – 120 V voltmeter. A typical connection diagram of a potential transformer is showing figure below.



Potential Transformer (P.T.)

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

- Oil circuit breaker: An Oil circuit breaker (OCB) is a type of circuit breaker that uses insulating oil as a dielectric medium to quench the arc and break the

circuit safely. The oil used is insulating oil used usually transformer oil that has better dielectric strength than air. There are two types of Oil circuit breaker:

- Bulk Oil Circuit Breaker
- Minimum Oil Circuit Breaker

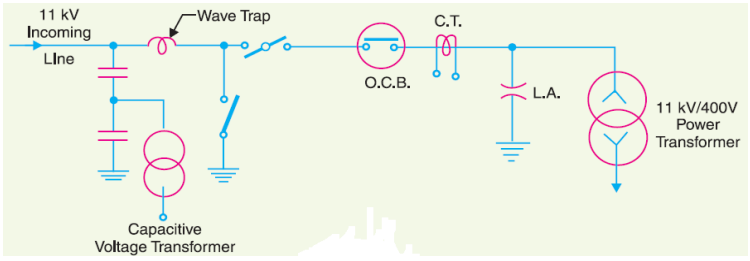
- Air circuit breaker with over-current tripping device : Air circuit breaker (ACB) is an electrical device used to provide over current and short circuit protection for electrical circuits over 800 Amps to 10KA .the air circuit breakers have completely replaced oil circuit breakers

- Air blast circuit breaker: Air blast circuit breaker used compressed air or gas as the arc-interrupting medium. In the air blast, circuit breaker compressed air is stored in a tank and released through a nozzle to produce a high-velocity jet; this is used to extinguish the arc
- Lightning arrester (active gap): It is one of the simplest forms of the arrester. In such type of arrester, there is an air gap between the ends of two rods. The one end of the arrester is connected to the line and the second end of the rod is connected to the ground

- Lightning arrester (valve type): The gap between the electrodes intercepts the flow of current through the arrester except when the voltage across the gap raises beyond the critical gap flashover. The valve type's arrester is known as a gap surge diverter or silicon carbide surge diverter with a series gap. Such type of resistor is called nonlinear diverter

- Arcing horn: Arcing horns are sometimes installed on air-insulated switchgear and transformers to protect the switch arm from arc damage. When a high voltage switch breaks a circuit, an arc can establish itself between the switch contacts before the current can be interrupted. The horns are designed to endure the arc rather than the contact surfaces of the switch itself

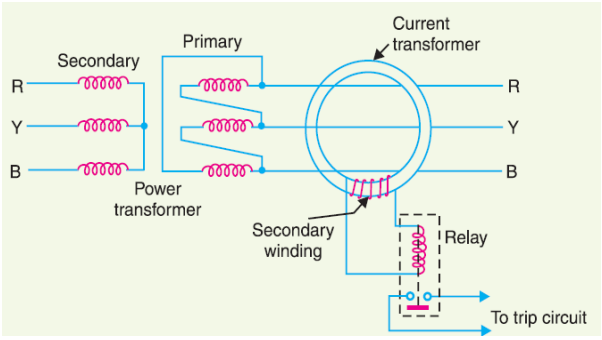
- Three-phase Power transformer



The potential transformer is connected to the bus bar and on the incoming line side. Lightning or surge arrester are connected phase to ground at the incoming line as the first apparatus and also at the terminal of transformer and capacitor bank, the terminal of shunt reactor and a terminal of the generator, the terminal of the large motor to divert switching.

- Over current relay: An over current relay is a type of protective relay, which operates when the load current exceeds a pickup value. In a typical application, the over current relay is connected to a current transformer and calibrated to operate at or above a specific current level

- Earth fault relay: The earth fault relay is basically a protection device used selectively for earth fault protection. These can be used for both primary and backup protection in an electrical system.



Theoretical learning Activity

Ask trainees to discuss on instrument transformer and Fix and connect equipment of a substation

Practical learning Activity

Practical exercises on the fixation of SUBSTATION installation elements

Points to Remember (Take home message)

Fixation and connection of equipment of a substation

LEARNING OUTCOME 2.3 WRITTEN ASSESSMENT FORMATIVE ASSESSMENT

Q1. Differentiate Air circuit breaker from Air blast circuit breaker

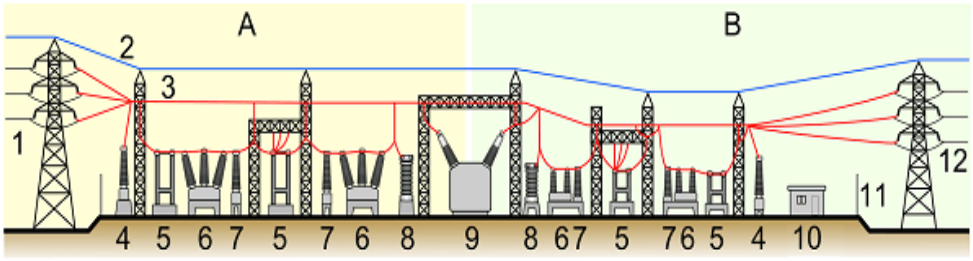
Answer

a) Air circuit breaker with over-current tripping device: Air circuit breaker (ACB) is an electrical device used to provide over current and short circuit protection for electrical circuits over 800 Amps to 10KA .the air circuit breakers have completely replaced oil circuit breakers

b) Air blast circuit breaker: Air blast circuit breaker used compressed air or gas as the arc-interrupting medium. In the air blast, circuit breaker compressed air is stored in a tank and released through a nozzle to produce a high-velocity jet; this is used to extinguish the arc

Practical assessment

Interpret the following diagram by providing name of elements of substation shown on the figure below



Answer: A: Primary power lines, side

B: Secondary 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

9. Main transformer
10. Control building
11. Security fence
12. Secondary power lines

Formative assessment checklist

Checklist	**Score**		**comments**
	Yes	**No**	
Can trainee indicate Primary power lines			
Can trainee indicate			
Can trainee indicate Overhead lines			
Can trainee indicate Transformer for measurement of electric voltage			
Can trainee indicate Disconnect switch			
Can trainee indicate Circuit breaker			
Can trainee indicate Current transformer			
Can trainee indicate Lightning arrester			
Can trainee indicate Main transformer			
Can trainee indicate Control building			
Can trainee indicate Security fence			
Can trainee indicate Secondary power lines			
Can trainee indicate Primary power lines			
Can trainee indicate Ground wire			

References:

1. ***Electrical Substation Components List - Diagram, Working & Functions (watelectrical.com)***
2. https://www.elprocus.com/electrical-substation-components/
3. ***https://electricianworld.net/electrical-substation-equipmen***

Learning Unit 3: Test substation installation

STRUCTURE OF LEARNING UNIT

Learning outcomes:

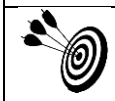
3.1. Select substation testing instruments

3.2. Test substation installation element

3.3. Clean the workplace

Learning outcome 3.1 Select substation testing instruments

Duration: 5hrs



Learning outcome 3.1 objectives:

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

1. Identify correctly testing instrument used in substation
2. Explain correctly the functionality of testing instrument used in substation
3. Use correctly testing instrument used in substation

Resources

Equipment	Tools	Materials
Helmet Overall Safety shoe Gloves Ladder Lifting crane Insulation tester Field strength tester Circuit breaker tester Megohmmeter High voltage detector High voltage multimeter	Screw drivers Pliers Spanners Drilling machine Pince a certile (crimping tool) Viseuse (Screw driver machine) Hammer Spirit level	• 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

Advance preparation:

- Internet
- Testing instrument

- Pedagogical documents ready

Indicative content 3.1.1: Instrument used in substation installation testing

✓ **Identification of testing instruments :**

Mainly testing equipment that will highly needed in a substation is identified as

- High voltage Insulation tester
- High voltage insulation resistance
- tester
- Field strength tester
- Circuit breaker tester
- Protection relay tester
- Megohmmeter
- High voltage detector
- High voltage multimeter

✓ **Instrument used in substation installation testing**

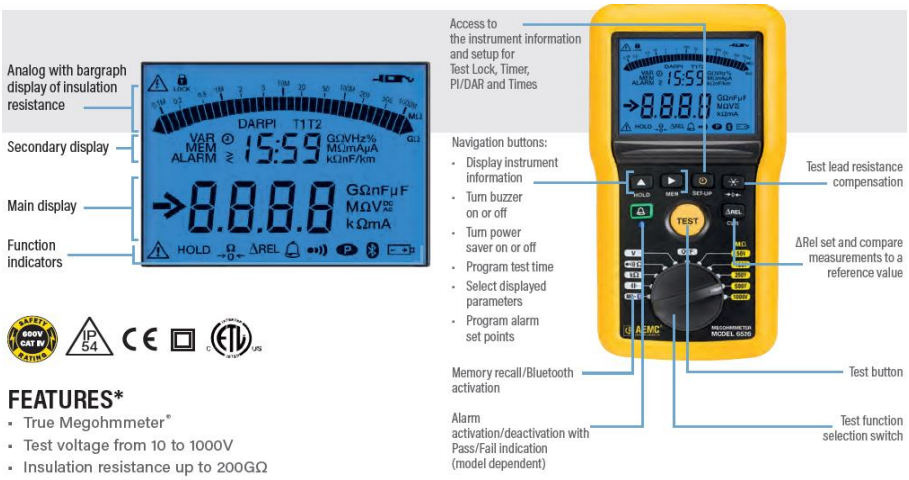
- High voltage Insulation tester
  - 
- High voltage insulation resistance Tester
  - 
- Insulation resistance test: The measured resistance has to be higher than the indicated limit from the international standards. A megohmmeter (also calledinsulation resistance tester, tera-ohmmeter) is then used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

- Field strength tester: A field strength meter is an instrument that measures the electric field strength emanating from a transmitter

- 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

- Protection relay tester :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

- Megohmmeter (High voltage Insulation tester / High voltage 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.



- High voltage detector: The High Voltage Detector is a quick 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 500KV Non Contacts High Voltage Detector is a proximity voltage detector for safe detection of electrical presence

- High voltage multimeter: High voltage multimeter it is the same as potential or voltage transformer used in high voltage circuit on substation .it can be used on power generation, power transmission, in substation or in power distribution. It

detects the presence of live AC voltage (some equipment also detects DC voltage), with a sensitivity typically between 5 and 1000 Volts

Theoretical learning Activity

ask trainees to discuss about Instrument used in substation installation testing

Practical learning Activity

Physical demonstration of on substation testing instruments

Points to Remember (Take home message)

Instrument used in substation installation testing

LEARNING OUTCOME 3.1 WRITTEN ASSESSMENT FORMATIVE ASSESSMENT

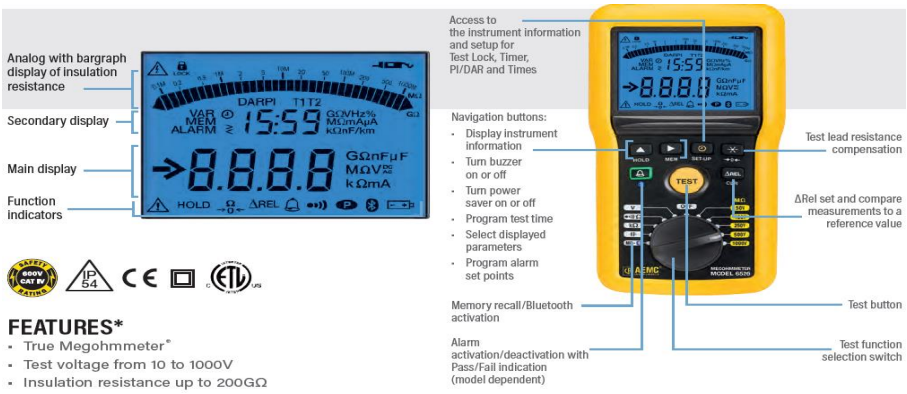
Q1 .What is Instrument used in substation installation testing

ANSWER:

- High voltage Insulation tester
- High voltage insulation resistance tester

- Field strength tester
- Circuit breaker tester
- Protection relay tester
- Megohmmeter
- High voltage detector
- High voltage multimeter

Q2. The testing instrument shown in the picture below is



A. Protection relay tester

B. Megohmmeter

C. High voltage detector

D. High voltage multimeter

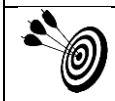
ANSWER: B

References:

1. https://electrical-engineering-portal.com/download-center/books-and-guides/power-substations/substation-maintenance
2. Tools Used In Substations For Testing The Devices Or Equipment (cselectricalandelectronics.com)
3. https://www.amazon.com/Digital-Insulation-Resistance-Megohmmeter-Range

Learning outcome 3.2: Test substation installation element

 **Duration: 10hrs**



Learning outcome 3.2 objectives :

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

1. Identify correctly types of testing performed in substation
2. Describe properly types of testing performed in substation
3. Elaborate clearly test report for substation installation element

 **Resources**

Equipment	Tools	Materials
Helmet Overall Safety shoe Goggles Gloves Ladder Lifting crane	Screw drivers Pliers Spanners Drilling machine Pince a certile (crimping tool) Viseuse (Screw driver machine) Hammer Spirit level	• 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

 **Advance preparation:**

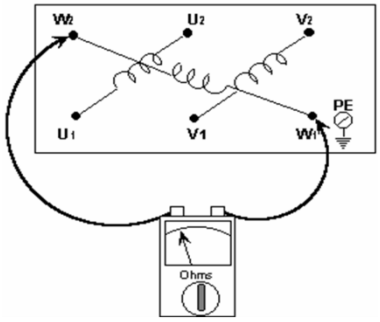
. • Image of substation

- Document
- Internet

Indicative content 3.2.1: Types of tests in substation

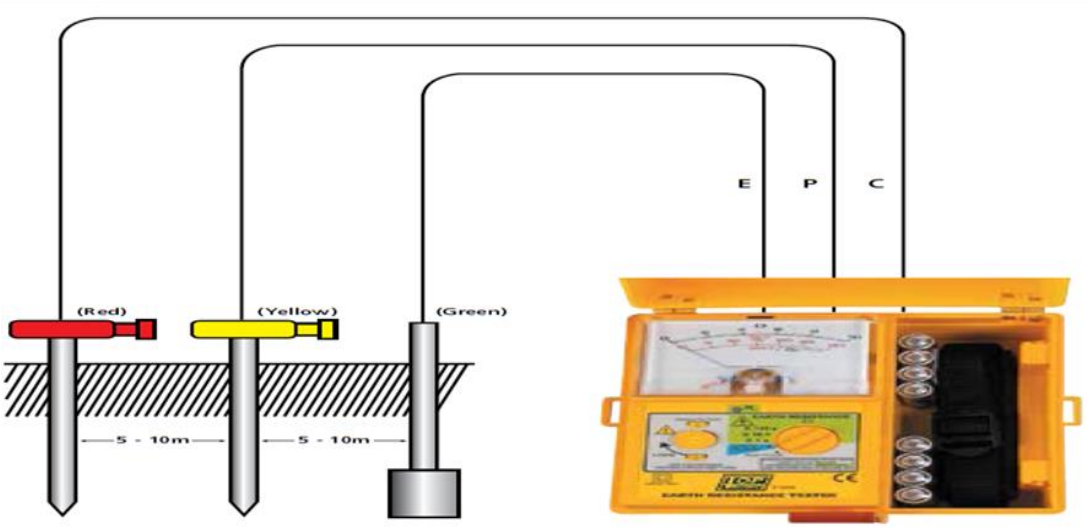
✓ **Types of tests in substation**

Continuity test



Continuity tester: is used simply to confirm that there is electrical continuity on a circuit. The purpose of continuity measurement is to check the continuity of the protective conductors and the main and supplementary equipotential bonds

Earthing test



Earthing test: Before providing the earthing to the equipment, it is essential to determine the resistance of that particular area from where the earthen pit can be dug.

The earth should have low resistance so that the fault current easily passes to the earth. The resistance of the earth is determined by the help of earth tester instrument

- **Insulation test**

  Good insulation is essential to prevent electric shocks. This measurement usually carried out between active conductors and the earth or a power circuit. Involves injecting a DC voltage, measuring the current and thus determining the insulation resistance value. The power must be switched off and the installation must be disconnected before performing this test to ensure that the test voltage will not be applied to other equipment electrically connected to the circuit to be tested, particularly devices sensitive to voltage surges. The device used to check integrity of insulation is known as an Insulation Resistance Tester.

Theoretical learning Activity

Ask trainees to discuss on types of high voltage installation tests.


Points to Remember (Take home message)

Types of tests in substation are

- Continuity test
- Earthing test
- Insulation test

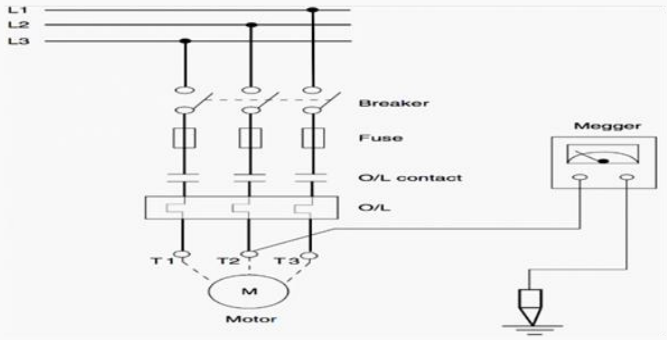
Indicative content 3.2.2: Insulation testing

OPERATION

Good insulation is essential to prevent electric shocks. This measurement usually carried out between active conductors and the earth or a power circuit**.** Involves injecting a DC voltage, measuring the current and thus determining the insulation resistance value. The power must be switched off and the installation must be disconnected before performing this test to

ensure that the test voltage will not be applied to other equipment electrically connected to the circuit to be tested, particularly devices sensitive to voltage surges. The device used to check integrity of insulation is known as an *Insulation Resistance Tester*. Generally, this is used during the installation of high voltage power cables and terminations.

In Figure below, a general motor circuit is shown with breaker, fuses, and overload relay. To check insulation of the circuit (excluding motor), disconnect the power supply by opening the breaker**.**



Then, isolate the motor from the circuit through terminals T1, T2, and T3. First checking insulation resistance between earth and T1, then earth and T2, and finally earth and T3 checks insulation resistances of conductors, as well as other devices. If the insulation resistance of any branch shows zero or a very low reading, then it can be concluded that there is an insulation failure**!**

This test is also used in *fault finding*, to check for earthed motors or cables and for checking insulation failure of conductors. Individual phases of three-phase motor winding can be insulation-tested only if all six leads of the winding are brought out. The winding being tested should be connected to the tester's output with the other two windings connected together and to the earthed frame of the motor. Where only three leads are available, the insulation of the machine winding as a whole can only be tested with reference to the earthed frame of the motor.

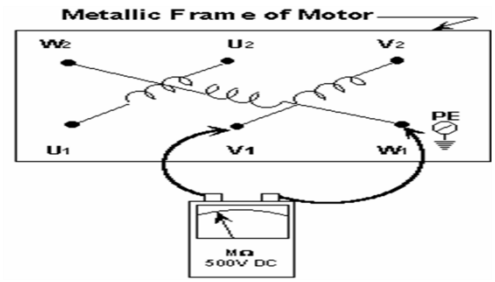
These insulation testers are also often incorrectly called 'Meggers' (by manfacturer MEGGER) and have a built-in energy source (either DC generator or battery) to produce test voltages of rating 500 V DC or more.This is required since the electrical circuit to be tested applies voltage of different ratings.For example, when the insulation resistance of HV cables is checked, 1000 V minimal voltage is applied, whereas for a domestic circuit 500 V is sufficient for testing.

NOTE! Testing on a live circuit requires extreme caution and should be restricted to LV circuits. Precautions should be taken to prevent inadvertent contact of the technician with live parts. The probes and tools must be insulated with minimum exposure of conducting parts. This will minimize inadvertent bridging of two terminals which are at different potentials which can cause a short circuit and arcing leading to burn injuries to the technician.

sulation resistance between conductor and earth

For this test, put OFF the main switch and remove the main fuse carrier. All distribution fuses should be IN. Connect the phase and neutral cables at the outgoing terminals of the main switch together, and connect the one megger terminal to the shorted cables. Connect other lead of megger to the earth connection and rotate the megger and measure the insulation resistance in megohms. The measured insulation resistance of an installation should not be less than one megohm.

insulation resistance between conductors



For this test, switch off the mains and remove the fuse carries. Connect one test prob of megger to the phase cable and other to other conductor.

Theoretical learning Activity

Ask trainee to involve discussion on insulation testing

Practical learning Activity

Practical exercises on how to test substation installation resistance

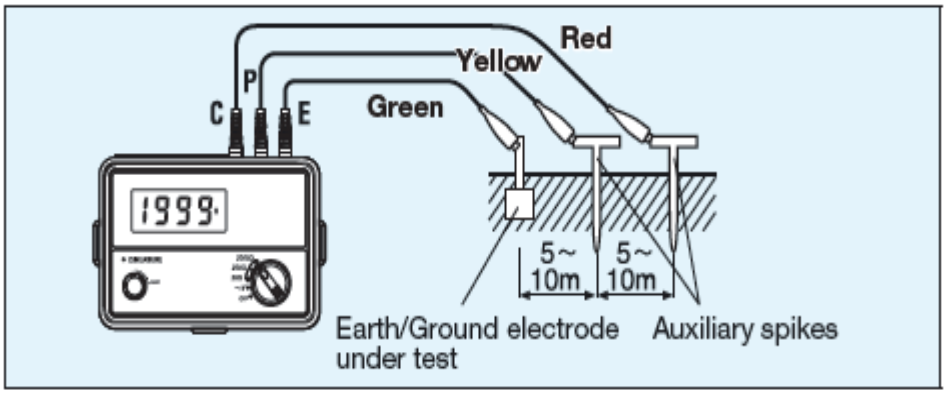
Points to Remember (Take home message)

Insulation testing instrument

✓ **Erath ground insulation resistance testing**

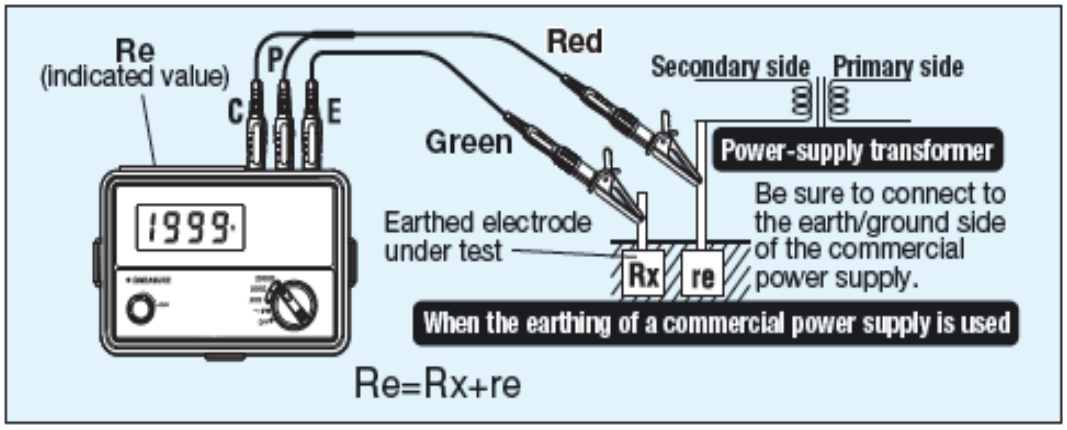
1. Three-Pole Earth Resistance Measurement (Precise Measurement)

Connect the earth/ground electrode (E) and auxiliary spikes (P, C) to the main body using the accessory test lead. Put apart 5 to 10 m between E and P, and P and C, respectively. E, P, and C should be approximately in a line.



2. Two-Pole Earth Resistance Measurement (simplified measurement)

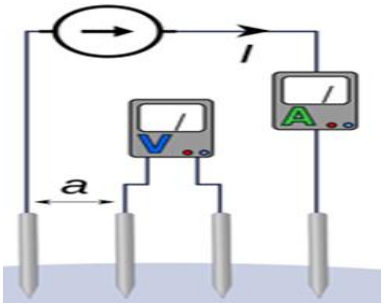
A simplified 2-pole measuring method can be used if there is an almost perfectly earth/ground object such as a lead or iron water-pipe (plastic pipes cannot be used) or if there is an object with a known value of earth resistance, near the measurement site.



3. Four-point method

This method is the most commonly used for measuring soil resistivity, which is important for designing electrical grounding systems. In this method, four small-sized electrodes are driven into the earth at the same depth and equal distance apart - in a straight line - and a measurement is taken.

The amount of moisture and salt content of soil radically affects its resistivity. Soil resistivity measurements will also be affected by existing nearby grounded electrodes. Buried conductive objects in contact with the soil can invalidate readings if they are close enough to alter the test current flow pattern. This is particularly true for large or long objects.



The Wenner four-pin method, as shown in figure above, is the most commonly used technique for soil resistivity measurements.

Theoretical learning Activity

Ask trainee to discuss about Earth ground insulation resistance testing

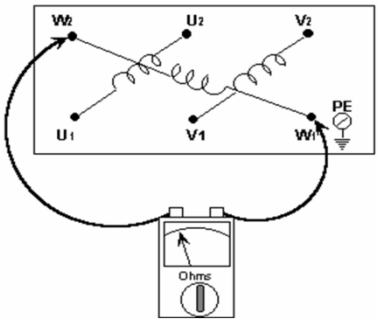
Practical learning activity

Practical exercise on how testing by using Earth ground insulation resistance

Points to Remember (Take home message)

Two-Pole Earth Resistance Measurement (simplified measurement

✓ **Continuity test**



Continuity tester: is used simply to confirm that there is electrical continuity on a circuit.The purpose of continuity measurement is to check the continuity of the protective conductors and the main and supplementary equipotential bonds. The test is carried out using a measurement instrument capable of generating a no-load voltage of 4 to 24 V (DC or AC) with a minimal current of 200 mA. This test is carried out to check the continuity of cables, protective devices and switches in the individual sub-circuits. Before conducting this test switch off all sources of power and fuses should be removed. By Connect the megger terminals to the individual circuit phase and other phase or at the input to output of a device to be mesured, the megger should show zero reading and infinity alternatively.

Theoretical learning Activity

Ask trainee to discuss continuity testing

Practical learning Activity

Practical exercise on testing continuity in substation

Points to Remember (Take home message)

Continuity testing

Indicative content 3.2.5: Circuit breaker testing

- ✓ 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 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.

- ✓ **During inspection of the breaker, the following points should be kept in view:**

  - Check the current carrying parts and arcing contacts. If the burning is severe, the contacts should be replaced.
  - Check the dielectric strength of the oil. If the oil is badly discoloured, it should be changed or reconditioned. The oil in good condition should withstand 30 kV for one minute in a standard oil testing cup with 4 mm gap between electrodes.
  - Check the insulation for possible damage. Clean the surface and remove carbon deposits with a strong and dry fabric.
  - Check the oil level.
  - Check closing and tripping mechanism

Type Tests of circuit breaker

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.

3. **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.
4. **Short -Circuit Test**: Circuit breakers are subjected to sudden short-circuits faults, in short-circuit test laboratories, and oscillograms are taken to know the behavior 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.
5. **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.
6. **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.

- ✓ **Performance of Testing of Circuit Breaker**
  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

Theoretical learning Activity

Ask trainee to discuss the types of Circuit breaker testing.

Practical learning Activity

Practical exercise on Circuit breaker testing

 Points to Remember (Take home message)

Type Tests of circuit breaker

Indicative content 3.2.6: Protection relay testing

✓ 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:

✓ **Type tests:** They 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: they** 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.

Theoretical learning Activity

Ask trainee to discuss about Protection relay testing

Practical learning Activity

Practical exercise on Protection relay testing in substation

Points to Remember (Take home message)

Type tests of Protection relay testing

Indicative content 3.2.7: Transformer testing

- ✓ **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:** 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:** 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 of Transformer Testing

Types of tests of transformer include:

- Winding resistance test of transformer
- Measurement of no-load loss and current (Open circuit test)
- Measurement of insulation resistance
- Dielectric tests of transformer
- Temperature rise test of transformer
- Tests on on-load tap-changer
- Vacuum tests on tank and radiators
- Short-circuit test
- Measurement of the power taken by the fans and oil pumps.
- 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 I^2R 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.

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.

- ✓ **Temperature Rise 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.

Theoretical learning Activity

Ask trainee to describe Transformer testing of substation

Practical learning Activity

Practical exercises on how to test substation by transformer testing

Points to Remember (Take home message)

Transformer testing and Type of Transformer Testing

Indicative content 3.2.8: Elaboration of report

Each trouble report contains the following data:

- Equipment type
- Manufacturer naze
- Model number
- Equipment ratings
- Severity of system disturbance (if any courrez)
- Date of manufacture

- Date of reported trouble
- Problem type

Theoretical learning Activity

Ask trainee to perform on elaboration of report in substation

Points to Remember (Take home message)

Contents of report

Learning unit 3 formative assessment

Written assessment

Q1.Elaborate any five (5) content of report, which is carried out after testing of a substation.

Answer:

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

Q2.During the inspection of the circuit breaker, there are some points in which should be kept in view. Answer the statement by **True** or **False**

1. Check the insulation for possible damage. Clean the surface and remove carbon deposits with a strong and dry fabric.
2. Disconnect all the line and neutral terminals of the transformer
3. Check the oil level.
4. Check closing and tripping mechanism
5. 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

ANSWER:

1. True 2. False 3. True 4. True 5. False

Practical assessment

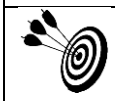
The chief of the ruganda substation in Karongi is tasked with testing the substation's installation component. You request to do the assignment at this substation as a technician. How have you performing?

Formative assessment checklist

Checklist	**Score**		**comments**
	Yes	**No**	
Insulation testing is well done			
Erath resistance testing is well done			
Continuity testing is well done			
Circuit breaker testing is well done			
Protection relay testing is well done			
Transformer testing is well done			
Trainee elaborate the report			
PPE are well used			

Learning outcome 3.3: Clean the workplace

Duration: 5hrs



Learning outcome 1 objectives:

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

1. Identify correctly cleaning tools and equipment used in substation
2. Describe properly cleaning method applied in substation
3. Manage correctly waste in substation

Resources

Equipment	Tools	Materials
Helmet **Overall** **Safety shoe** **Goggles** **Gloves** **Ladder**	**Screw drivers** **Pliers** **Spanners** **Drilling machine** **Pince a certile (crimping tool)** **Viseuse (Screw driver machine)** **Hammer** **Spirit level**	Air blower **Brush** **Water**

Advance preparation:

- Image of substation
- Document and Internet

Indicative content 3.3.1: Cleaning tools and equipment

✓ **Cleaning tools and equipment**

Keeping the electrical components of substation clean and contamination free is quit important for its safe and reliable operation. Cleaning is considered an integral part of every routine maintenance schedule of a substation and separate teams are often assigned to the purpose

- **Proper Tool Maintenance**

  Proper tool care also saves you money because the better they are cared for, the longer they will 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 yourhand 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.

Theoretical learning Activity

Ask trainee to involve in discussion on cleaning tools and equipment used in substation

Practical learning Activity

Practical exercise to select cleaning tools and equipment used in substation

Points to Remember (Take home message)

Cleaning tools and equipment used in substation installation

Indicative content 3.3.2.: Cleaning methods

- ✓ **Cleaning methods**
  - **Cleaning by brushes**
    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 switchgear interior should be used.
  - **Cleaning By air blower** are not recommended for the interior because they spread the contamination further and may push it to delicate electric parts of substation

switchgear. Even if the traditional moping is being performed, a chemical agent should be used to limit the spread of contaminants via air.

- **Cleaning by clothes**

  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.

Theoretical learning Activity

Group discussion on tools and working area cleaning method

Practical learning Activity

Ask trainee to apply Cleaning methods used in substation

Points to Remember (Take home message)

Different cleaning methods

Indicative content 3.3.3.: Manage waste materials

✓ **Manage waste materials**

- **Storage Area and Containment Requirements**
  - 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
- Waste-Specific Management and Disposal Requirements
- 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 will be transported to an appropriate local recycling center.
  - Hazardous waste generated at work areas will be transported at the end of each workday 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 accordance

Theoretical learning Activity

Ask trainee to discuss about management of waste materials

Practical learning Activity

Ask trainee to perform in management of waste materials used in substation

Points to Remember (Take home message)

Storage Area and Containment Requirements

LEARNING OUOME 3.3 WRITTEN ASSESSMENT FORMATIVE ASSESSMENT

Q1. Write down the requirement of storage area and containment of waste materials.

ANSWER:

- 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.

Practical assessment

Task

Rwanda Energy Group (REG) need to perform preventive maintenance. They want 20 qualified workers to help in cleaning substation equipment and tools. As a young electrician, you are hired to perform substation cleaning. Choose method ant tools equipment to be used during cleaning substation and after the task, write the regulation of Manage waste materials used. The task must be accomplished in 1hour.

Formative assessment checklist

Checklist	**Score**		**comments**
	Yes	**No**	
Selection of Cleaning tools and equipment is well chosen			
Application of Cleaning methods is well done			
Management of waste materials is well respected			
Contents of regulation is well done			
PPE are well used			

References:

2. https://engineering.electrical-equipment.org/safety/cleaning-electrical-equipment-switchgear.html

3. https://electricianworld.net/electrical-substation-equipment/