Demonstrate knowledge of electricity supply networks

US 18274

Training and Assessment Resource

NCES Level 2

Contents

Training Assessment Resource Introduction

This Training Assessment Resource (TAR) contains the information that you require to complete the written assignment in the assessment pack for this unit standard.

Purpose

People who obtain credit for this unit standard are able to describe the principles of:

> Electricity transmission, distribution and reticulation;

> Switching stations, substations and , associated equipment

1. Introduction

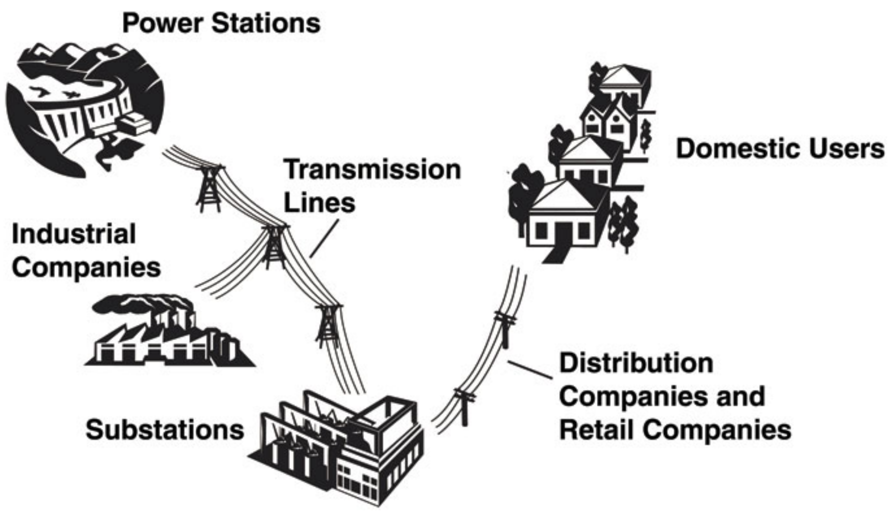
The electricity supply industry in New Zealand has a high degree of regulations in the requirements for entering areas that have restricted access. These are areas that are particularly dangerous to the general public and also to electrical workers required to carry out installation and maintenance work in these areas.

This resource is only a guide towards completion of the unit standard and should be used in conjunction with the Safety Manual – Electricity Industry (SM-EI) Part 1: Minimum Safe requirements, Part 2: General Safety Guide and Part 3: Rules for Work on Equipment.

Important Note: A pass in this unit standard does not allow the trainee to enter restricted areas without complying with the asset owner's policy approval procedures and the issuing of appropriate documentation.

2. Transmission, Distribution and Reticulation

These notes will give you an overview of the key components in the New Zealand electricity network and highlight key characteristics and technical details.



Overview of the New Zealand electricity network.

2.1 Factors Affecting Current Flow in a Conductor

The most significant factors that affect the current flowing in a conductor are:

Cross sectional area (c.s.a.)

Is measured in mm^2 and calculated by using the formula:

$$a = \frac{\Pi D^2}{4}$$

where *a = cross-sectional area in mm^2*
$\Pi = 3.142$
D = diameter of strand in mm

Resistance in a conductor is inversely proportional to the area of the conductor and is expressed by:

$$R \propto \frac{1}{a}$$

So, if you increase the cross-sectional area of the conductor you decrease its resistance.

Length (l)

$$R \propto l$$

The length of a conductor can be measured in metres. The resistance of a conductor is directly proportional to its length and is expressed by:

Temperature

As the temperature of a conductor increases, either through the effect of current flowing through it or through increasing ambient temperature the resistance of the conductor increases. The characteristics of a conductor in respect to temperature change is called the 'temperature coefficient of resistance' and this is measured by:

$$R_t = R_o(1 + a_o t)$$

where R_o = the resistance at 0°C (Ω)
a_o = the temperature coefficient of resistance
t = the temperature rise in 0°C
R_t = the resistance at the increased temperature measured in Ω

Conductor Resistance (Ohms)

The type of material used for a conductor determines its value of resistance. This is called 'resistivity' and is expressed as:

$$R \propto \frac{\rho l}{a}$$

Where R = resistance
ρ = resistivity of material
l = length in metres (m)
a = c.s.a. in m^2

Power (W)

In practical applications the current flowing in a conductor causes heat, power is measured in Watts, symbol W).

$$W = I^2 R$$

This means that the power or 'heat' produced in a cable is proportional to the square of the current, so every one amp increase means the 'heat' is increased four times. This 'heat' is directly proportional to the resistance value of the conductor.

To keep the current flow as low as possible, transmission and distribution uses high voltages as illustrated by the formula:

$$W = VI$$

Activity

What are the four most significant factors that affect the current flow in a conductor?

2.2 Purpose of Transformers

Transformers are used to increase or decrease the voltage level in a grid or network system. Typically voltage is generated at 6,600V (6kV) and for transmission purposes is increased to a high voltage level. The highest alternating voltage used in New Zealand for transmission is 220,000 volts (220kV).

Types of Transformers

There are different types of transformers used in the system. Those that increase the voltage are called 'step-up transformers' and those that decrease the voltage are called 'step-down transformers'.

The term 'Power Transformer' is used to refer to transformers used in the transmission system and are installed in the system with typical voltages ranging from 33,000 volts (33kV) to 220,000 volts (220kV).

The term 'Distribution Transformer' is used to refer to transformers used in the distribution system and are installed in the system with typical voltages ranging from 22,000 volts (22kV) to 400/230 volts. These are the voltage values that are delivered to consumers.

The term ‘Isolating Transformer’ is used to refer to transformers used to provide protection against electric shock when using an electrical appliance, by isolating the supply from earth.

Activity

Explain what a ‘step-down’ transformer is.

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Ratios

Transformers can be ‘double wound’ or single wound’ - this refers to the number of coils or windings used in the transformer. Practically all of the transformers used in the electricity supply network are ‘double wound’. This means that they have two windings which are referred to as a primary winding and a secondary winding. The primary winding is the winding that carries the input and the secondary winding carries the output.

There is a balance between the input voltages, current and number of windings (turns) of a transformer and the output voltages, currents and number of windings (turns). This is expressed by a formula that we call the ‘transformation ratio’. It looks like this:

$$\frac{I_p}{I_s} = \frac{N_s}{N_p} = \frac{V_s}{V_p}$$

where I_s = secondary current
I_p = primary current
N_s = number of secondary turns
N_p = number of primary turns
V_s = voltage secondary
V_p = voltage primary

2.3 Insulating and Protection

Electricity is a commodity that if a person comes in contact with it they can be severely injured or even killed. To prevent the electricity flowing in a conductor or used within plant and equipment from coming in contact with people, insulation is used.

Conductors

Carry electricity and have a low resistance. The resistance of a conductor is measured in Ohms and the earthing circuit of an installation or appliance should have a conductor resistance of not more than one ohm.

Insulators

Have to prevent electricity from flowing and therefore have a very high resistance. The resistance provide by an insulator between a conductor and any exposed metal should be not less than 1,000,000 Ohms (one Megohm). The quality of an insulator is required to be tested with an insulation resistor tester which is a test instruments that provides a potential of 500 Volts DC across the insulation being tested. They are commonly referred to as a 'megger'.

Earthing

To ensure that all exposed to touch metalwork used in an electrical system or an electrical appliance (Class 1 Appliance) is safe to use, it must be effectively earthed. All metalwork associated with an installation is to be bonded to the general mass of earth. This is to ensure that all metalwork is maintained at earth potential.

Common protective devices that protect against electric shock include:

Isolating transformers

Isolate the supply from earth so there is no pathway back through earth for fault currents.

Residual Current Devices (RCD's)

Disconnect the supply when there is a difference between current in the phase and neutral conductors which would normally be caused by abnormally operation (i.e. a leakage current present). They operate very quickly (30mS) and on a very low leakage current (30mA).

Monitored earthed units

Continually monitor the earthing circuit and disconnect the supply if the circuit breaks or has a very high resistance.

Activity

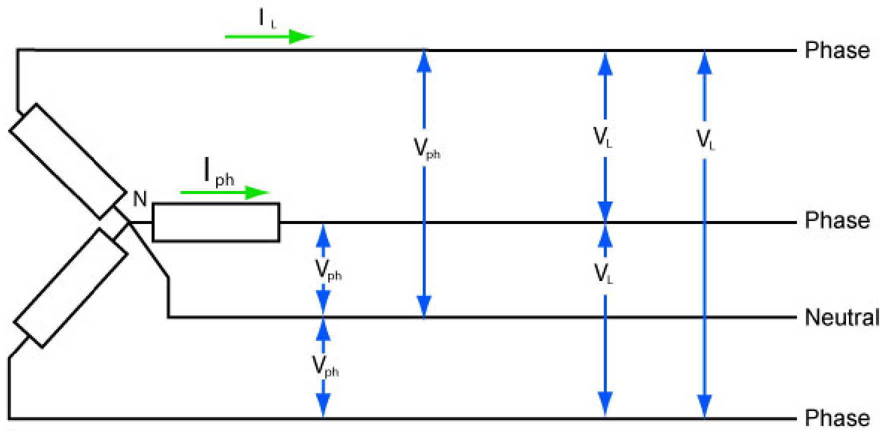
What is the resistance of a conductor measured in?

2.4 Relationships between line and phase values

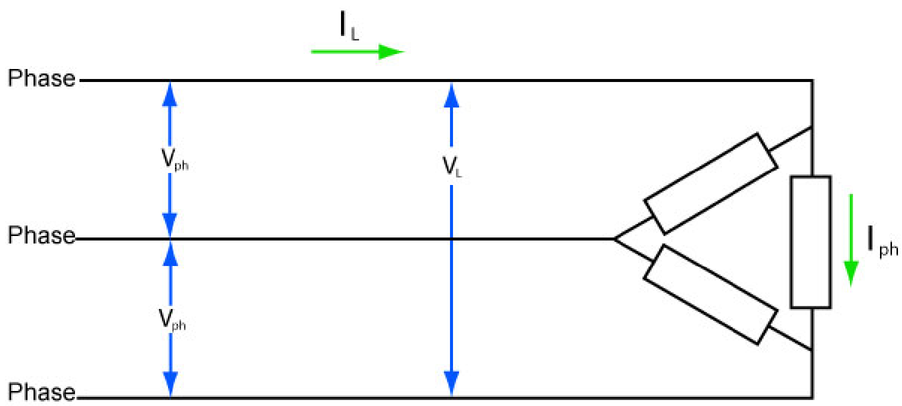
The following table shows the relationships between line and phase values in star and delta connected balanced loads. This is outside the scope of level two work but included here for interest.

In a three phase system there are line voltages and currents and phase voltages and currents. Different configurations like star and delta connections affect these values.

Three Phase Four Wire Star Connection showing Line and Phase Relationships



Three Phase Delta Connection showing Line and Phase Relationships



The following table shows the relationships between line and phase values in star and delta connected balanced loads.

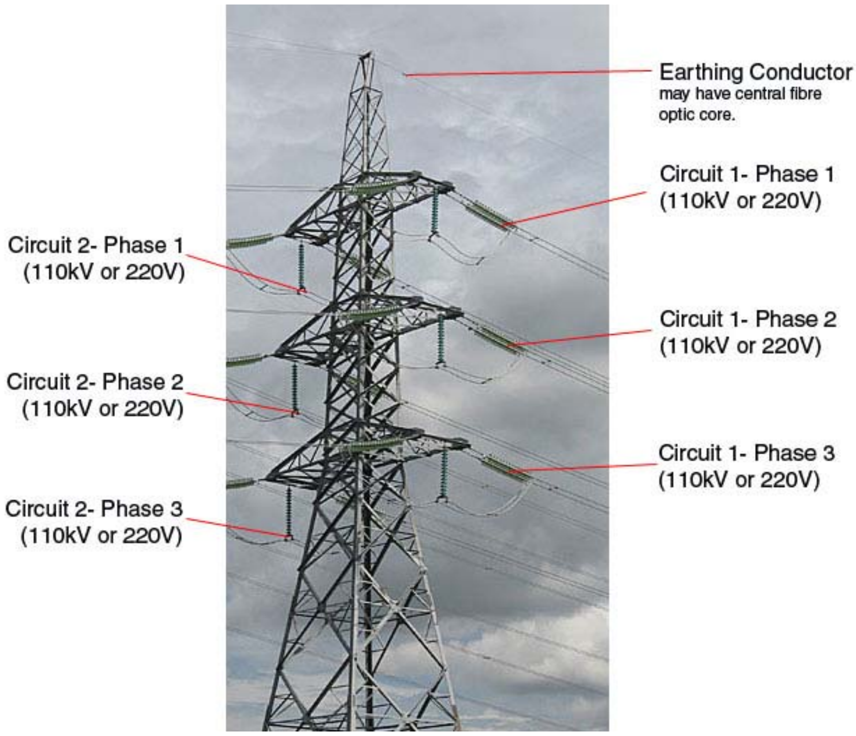
This is outside the scope of level two work but included here for interest.

Star-Connected Balanced Load	Delta-Connected Balanced Load
Phase current: $I_{ph} = I_L$, Line current: $I_L = I_{L1} = I_{L2} = I_{L3}$	$I_p = \frac{I_L}{\sqrt{3}}$ Phase current: Line current: $I_L = I_{1L} = I_{2L} = I_{3L}$ and $I_p = I_{p1} = I_{p2} = I_{p3}$
$V_p = \frac{V}{\sqrt{3}}$ Phase voltage: Line voltage: $V_L = V_1 = V_2 = V_3$	Phase voltage: $V_1 = V_{p1}$, $V_2 = V_{p2}$, $V_3 = V_{p3}$ Line voltage: $V_L = V_{L1} = V_{L2} = V_{L3}$

2.5 Common Voltages Used in New Zealand

Transmission Voltages

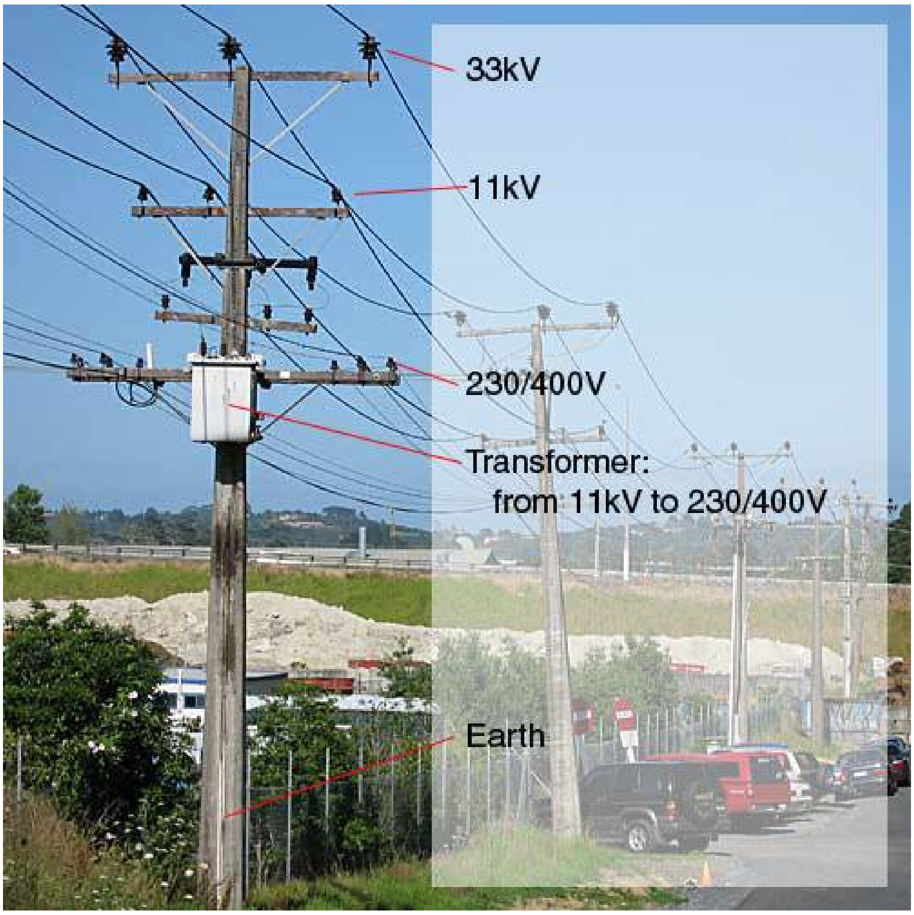
Voltage	Description
220 kV	This is the major lines carrying the electricity to high demand centres. It is considered the 'backbone' of the national grid.
110 kV	Could be referred to as sub-transmission and connects the 220 kV lines to regional grid exit points.
66 kV	Sub-transmission between grid exit points and zone substations.
33 kV	Generally the level of voltage supplied to distribution network owners.



Transmission lines and voltages.

Distribution Voltages

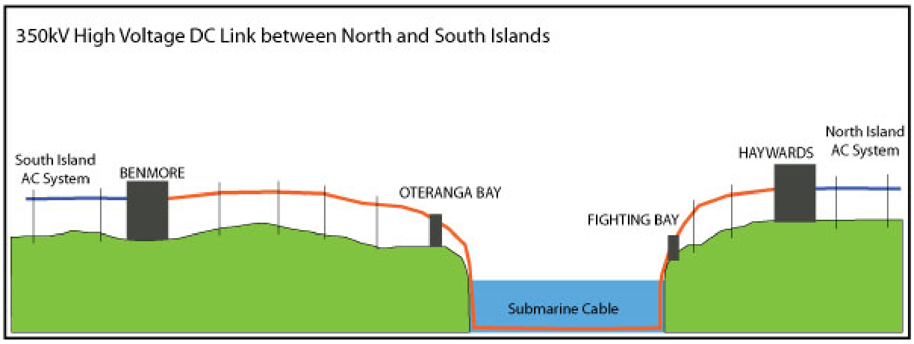
Voltage	Description
33kV	Used in distribution networks to deliver electricity to large load centres and large consumers.
11 kV	For local reticulation around consumer areas and direct to large industry users.
400v/230v	The level of voltage supplied to industrial and domestic consumers.



Distribution lines and voltages.

2.6 Principles for Using High Voltage Direct Current (HVDC) Transmission

The direct current link that joins the South Island and North Island grid systems together is a two wire system which has a positive and negative conductor. The difference in potential between the positive and negative conductors is 625,000 volts (675 kV). The positive conductor is at 350 kV above and below earth potential and the negative conductor is at 275 kV to earth. This system uses the ground or earth, as the 'common' or 'neutral' conductor.



The Alternating Current (AC) generated at the powers stations and transmitted through the National Grid is changed to Direct Current (DC) and back to AC at Benmore in the South island and Haywards in the North Island. The conversion process is achieved using thyristors or mercury arc rectifiers.

Here is an extract from Transpower on the reasons (mainly cost and practicality) for using HVDC transmission in New Zealand.

"Long-distance AC (alternating current) transmission is affected by a transmission line's capacitance to earth and to other lines. This creates a flow of alternating current that charges and discharges the capacitance every cycle. The flow of this 'charging' current does not deliver useful power - it is called reactive power, and is actually 90 degrees out of phase with any flow of real current to a load at the other end. In other words, there is current flowing in the line that doesn't deliver useful power at the end, but causes losses in the line itself.

"For short transmission lines, the effect is not significant, but for very long lines, it becomes quite pronounced. For cables it can be particularly significant, because of the greatly increased capacitance of the cable (the insulation of the cable has quite different dielectric properties). 'Charging' current in very long AC cables can be problematic, and can exceed the useful load current. The flow of the charging current causes energy losses in the resistance of the conductor, which can be so great that little useful power can be delivered.

"DC transmission has no on-going 'charging' current once the voltage has been raised to the normal level, so the losses are considerably less than AC.

“The New Zealand HVDC scheme has around 570 km of overhead transmission lines and the Cook Strait submarine crossing is around 40 km. So using AC transmission would have caused problems, particularly in the late 1950s to early 1960s when the link was first conceived and designed.

“AC transmission requires three conductors (almost all AC transmission systems are three phase), which demands certain physical requirements for the support structures of the transmission line (the pylons or towers). By comparison, a DC transmission system only requires two conductors (positive and negative), requiring a much simpler supporting structure, supporting a lighter load. These differences add up to huge cost savings for a long point-to-point transmission system.

“While it is expensive to convert normal AC power to DC power and back again, the savings in power losses and in construction costs can make HVDC cost-effective if moving more than 500 MW further than about 500 km over a point-to-point link.

“HVDC conversion is highly flexible and can be used to transfer power between two systems in a very flexible way (rather like an automatic transmission in a car is a flexible way of transmitting mechanical power from the engine to the wheels). In some cases this flexibility is extremely valuable, and adds to the economic benefits of selecting a DC transmission scheme. Some countries have ‘back-to-back’ connected HVDC schemes to interconnect different power systems between states or countries. In these cases, there is no transmission line at all, and the justification is simply the highly flexible interconnection.”

The maximum total HVDC power transfer capability is presently 1040 MW (northwards).

The power flow can be southwards, but the capability south is less (around 600 MW).

Actual power levels vary widely during the day, and can range from around 300 MW south, to over 800 MW north, depending on electricity market conditions (which may be influenced by storage levels in hydro lakes etc).

Activity

How many conductors does an AC transmission system require, in comparison to DC?

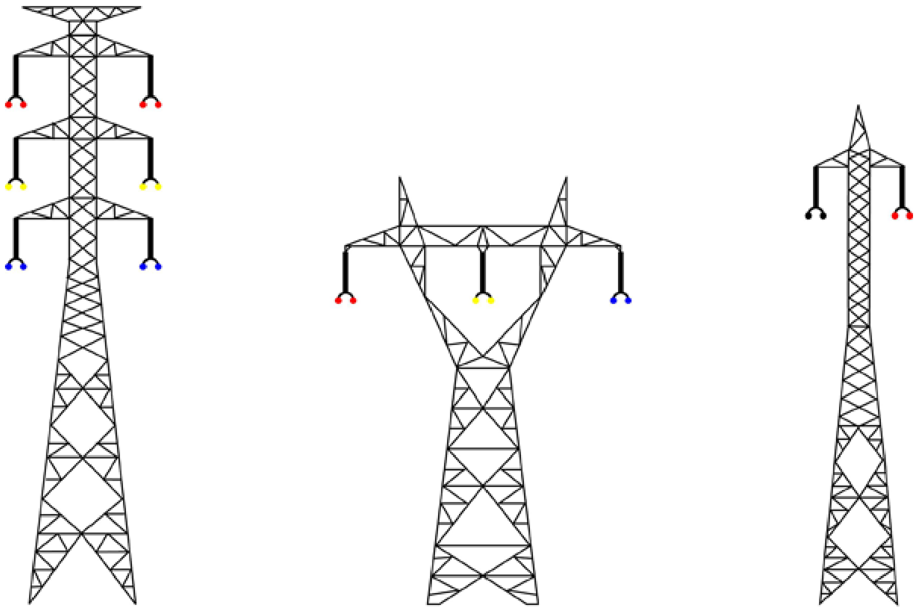
2.7 Overhead power line configurations

Various forms of configuration are used on the structures that support the power lines.

Transmission

Support structures used in the transmission system are usually made of steel. Three types are shown in the diagram below.

1. Able to carry two circuits, one on either side of the structure
2. Able to carry single circuits
3. Able to carry the DC link conductors from Benmore.



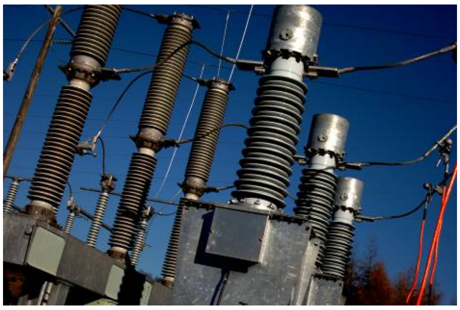
Transmission support structures.

Distribution

Support structures used in the distribution networks are often made from wood poles or more recently from pre-cast concrete.

Example of distribution support structure.

3. Switching Stations, Substations and Associated Plant and Equipment



Within the National Grid and Distribution Networks there is a whole range of plant and equipment that is connected in the system to provide optimum control and protection.

3.1 Protection Against Fault Currents

Protection against the damage caused by faults in an electrical supply system is critical. The purpose of protection equipment is to disconnect the system from the location of the fault so that its effect is minimised.

A fault will occur in a power system when abnormal currents flow as a result of a partial or total failure of the insulation at one or more points. The complete failure of any insulation in a live circuit causes a 'short circuit' and large currents can flow causing severe damage to equipment and endangering the lives of people.

Some common faults are:

Earth faults

Where a conductor or current carrying device comes in contact with earth.

Overcurrent

Where the current flowing in a conductor is in excess of what it is designed to carry causing breakdown in insulation through overheating.

Short circuit between conductors

Where there is a breakdown between the insulation separating two conductors or current carrying devices.

Because the current flowing under fault conditions can be extremely high, all protection devices must be designed to withstand the effects of a high fault current. They must be able to operate without causing damage to themselves or surrounding equipment. This involves dissipating the heat generated and quenching the arc that results from breaking a high current.

Protections systems can include a collection of relays and measurement equipment such as current transformers and voltages transformers that monitor the status and operation of the electrical network. If a pre determined change occurs on the network (such as over current or earth fault) the protection scheme sends a signal to circuit breakers to open therefore disconnecting the equipment from the network.

3.2 Disconnectors and Earth Switches

Disconnectors

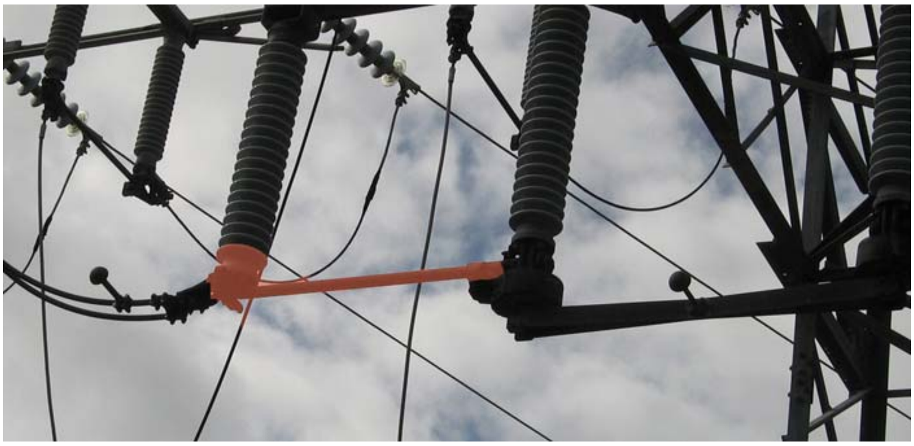
Switching devices that provide isolation of electrical equipment. They are designed to be operated under no-load conditions.

Earth Switches

Devices that are used to connect an electrical line or bus bar to the general mass of earth. There are strict procedures for using these devices. They are used when for maintenance purposes a piece of equipment is taken out of service and to ensure that it is safe to work on.

Example of a disconnect handle.

Example of an open disconnect switch.



Example of a closed disconnect switch.

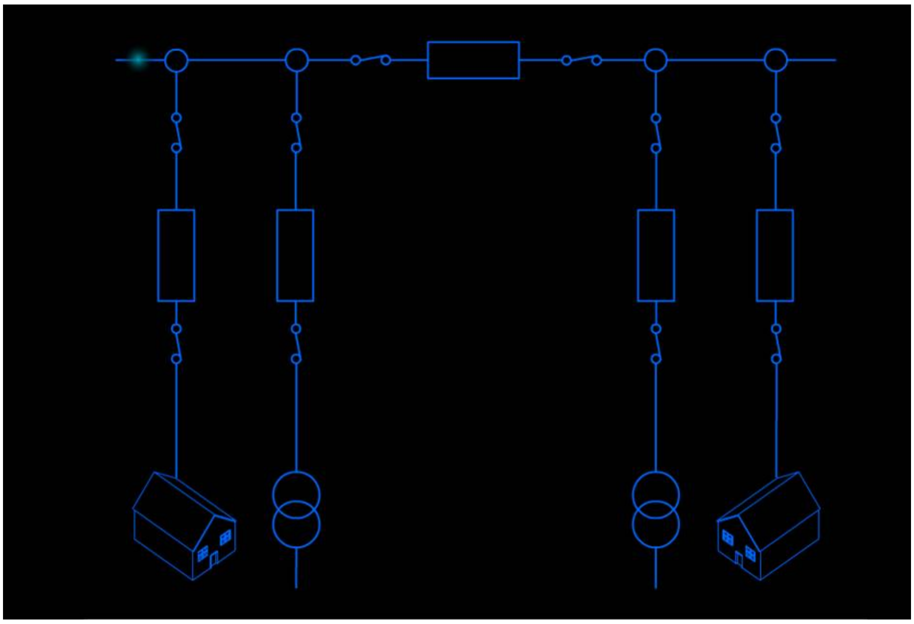
Activity

Provide details of three common faults that may occur when there is an insulation fault.

3.3 Circuit Configurations

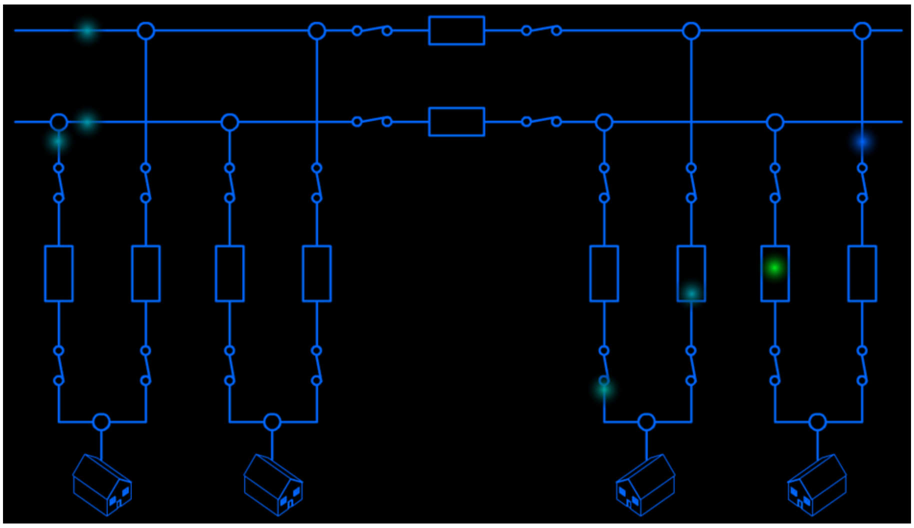
Single Bus Bars

Single bus bars have one common feeder to all outgoing circuits.



Double Bus Bars

Double bus bars have two feeders which can be connected to all outgoing circuits or split into two to be able to provider alternative feeds.

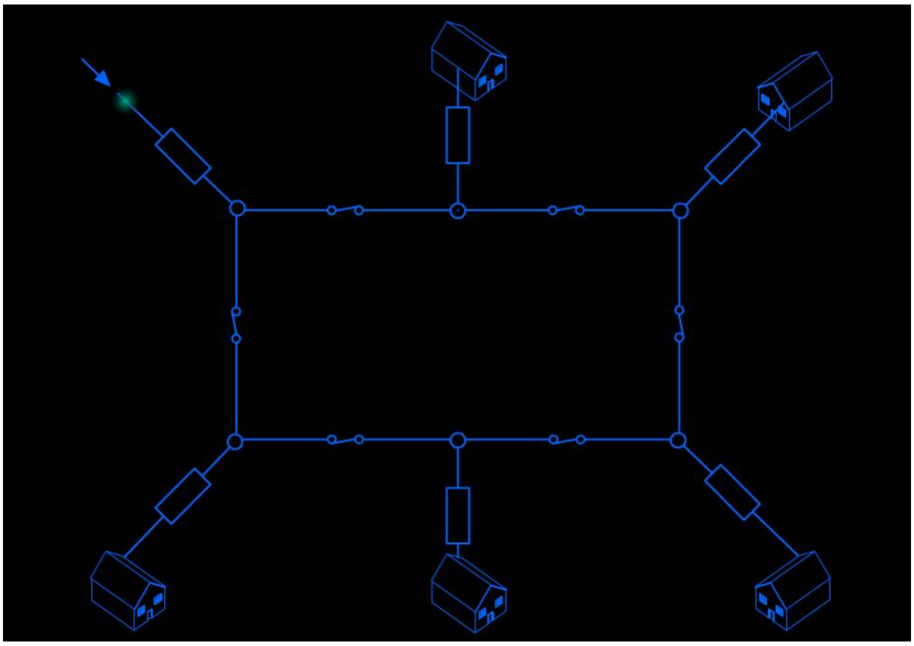


Duplicate feeders

When a bus bar is connected to the supply system by two feeders, we can say that it is fed from duplicate positions.

Ring Feeders

This type of bus bar configuration enables the supply to be maintained from any point in the ring.



3.4 Substation Configurations

Landing Gantry

This structure provides support for the incoming or outgoing conductors and it enables the transition to the equipment in the substation yard.

Surge Arrestor

Provides protection to the people and equipment in the yard from any excessive voltages that might be impressed on the line by lightning.

Capacitive Voltage Transformer (CVT)

This equipment measures the operating voltage of the line.

Disconnector or Isolator

This device isolates the equipment from the line so any work may be done on either the equipment or the line. This equipment is only opened after the circuit breaker has been operated.

Circuit Breaker

The circuit breaker has a dual purpose. It provides protection against faults in the system and provides a means of controlling the flow of power in the network.

Current Transformer

This equipment measures the operating current for that part of the system.

Lightning Mast

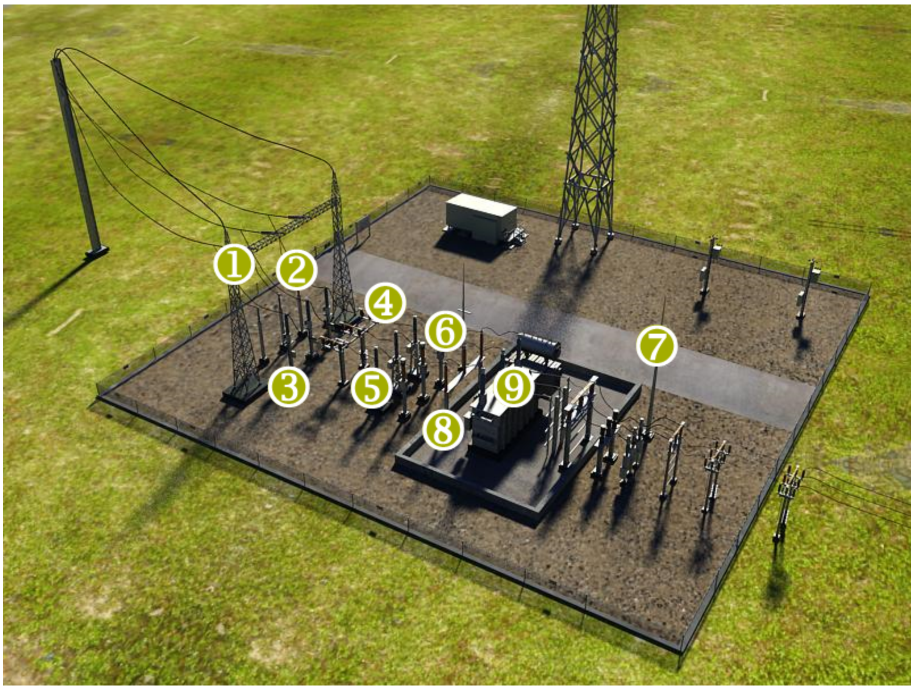
This provides a prominent point in the yard to conduct lightning strikes to the earth and away from the equipment and people.

Post Insulator

Supports the conductor and provides a transition between the equipment and the transformer.

Transformer

Changes the voltage and current. In this case it changes the voltage from 33kV to 132 kV.



Example of a substation configuration. 1. Landing Gantry, 2. Surge Arrestor, 3. Capacitive Voltage Transformer (CVT), 4. Disconnector or Isolator, 5. Circuit Breaker, 6. Current Transformer, 7. Lightning Mast, 8. Post Insulator, 9.Transformer

4. Definitions of Terms

Switchgear

The general term used to describe equipment that can perform a switching operation includes circuit breakers, ring main units, disconnector (or air break switches). Circuit Breakers are used in conjunction with protection relays to interrupt current.

Instrument transformers

Transformers measure voltage (VT), current (CT) capacitive voltage (CVT). These form part of the protection scheme. CT's are normally found adjacent to circuit breakers, VT's on buses and CVT's on line terminations (normally at 220 kV or higher).

Scada

Supervisory control and data acquisition is the collection of electronic data that measures the status and performance of equipment on the electrical network. It also provides remote control over equipment.

Transformers

A device changes the voltage of electricity from transmission (110/220 kV) voltage to sub transmission (66,50,33 kV) or distribution voltages (11/22 kV) or vice versa or to change the voltage of electricity from distribution voltages (11/22 kV) to domestic voltage 400V

Activity

What is switchgear? (Provide examples of switchgear in your answer).

Next Steps

Well done! You have completed the training assessment resource for Unit Standard 18274 – Demonstrate knowledge of electricity supply networks.

When you are ready to complete your assessment tasks, please contact your assessor for instructions.

Model Answers to Activity Questions

Activity (page 7)
What are the four most significant factors that affect the current flow in a conductor?

Length, cross sectional area, resistance and temperature.

Activity (page 8)
Explain what a 'step-down' transformer is.

A transformer that is reducing or 'stepping-down' voltage, e.g., 110kV to 33kV.

Activity (page 10)
What is the resistance of a conductor measured in?

Ohms.

Activity (page 15)
How many conductors does an AC transmission system require, in comparison to DC?

AC transmission has three where DC has two.

Activity (page 20)
Provide details of three common faults that may occur when there is an insulation fault.

Earth fault, short circuit between conductors or overcurrent for the conductor.

Activity (page 24)
What is switchgear? (Provide examples of switchgear in your answer).

The general term used to describe equipment that can perform a switching operation includes circuit breakers, ring main units, disconnector (or air break switches). Circuit breakers are used in conjunction with protection relays to interrupt current.

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