US10508

Trainee Workbook

Unit Standard **10508**

Identify electricity systems in preparation for work

Level **2** Credits **6**

Name:..

Learning POWER ESITO

www.esito.org.nz

Contents

Glossary

The words in this glossary are in green throughout the book.

When I see this word…	It means…
Bundling	Combining two or more conductors.
Capacitance	Is the ability of a system to store electric energy, similar to the function of a battery.
Captured	Caught by something or someone. Taken possession of.
Configuration	An arrangement of parts or elements. The way something is made up.
Constant	Always the same.
Corona	A faint purple glow close to the surface of an electrical conductor at high voltage.
Economic	Relating to the production, distribution, and use of money and goods and services.
Efficiency	Efficiency means doing good work without spending too much time or using too many resources (such as energy, material and labour).
Export and import	Send goods and services away and receive goods and services (generally between major ports or countries).
Flashover	An explosion (electrical discharge) around or over the surface of an insulator.
Guidelines	Information that helps you understand something or explains how to do something.
Multiple	More than one.
Parallel	Straight lines going in the same direction but not meeting.
Predetermined	Decided in advance.
Precision process	A series of actions that happen in an exact way and that must be accurate.
Readily transformed	Easily changed.
Referred to	Known as. For example, a Hazard ID form is often referred to as a Tailgate form.
Responsible for	In charge of looking after something.
Telecommunication	The sending of signals using radio waves and electric cables (such as via telephone, radio or television).
Time intensive	If something is time intensive, it takes a lot of time.
Withstand	Hold out against.

1. Introduction

Unit standard objectives

Unit standard 10508 forms part of the National Certificate in Electricity Supply (Level 2). It is an important introduction to the electricity supply sector.

When you have worked your way through this workbook, you will be able to identify:

- transmission, distribution, telecommunication and traction lines
- which system circuit operating voltages apply to transmission, distribution and traction lines
- different types of conductors and related fittings
- cables used below ground and the related fittings
- various types of electricity system structures and the function they perform.

Prerequisite

There are no prerequisites for this unit standard.

Getting started

Icons are used throughout the ESITO trainee workbooks. The most common are listed below.

Pay attention: This information will be important.

Activity: The activities will help you prepare for the assessment task. The activity asks you to:

- think about your past experiences
- think about the information and ideas you have been studying
- think about how you can use new skills in the future.

Website: This icon refers to the world wide web.

Additional information that might be of interest. Sometimes, this space is used to explain ideas in more detail.

2. Knowledge check

This section looks at your prior knowledge and prepares you for what's to come. Answer the questions to find out what you do and don't already know.

Briefly describe how electricity gets from the power stations to your home.

Think about the different types of electric lines you might see as you travel around. Can you name at least four different types of lines? The first one is done for you.

1 Telecommunications

2

3

4

Explain the difference between AC and DC.

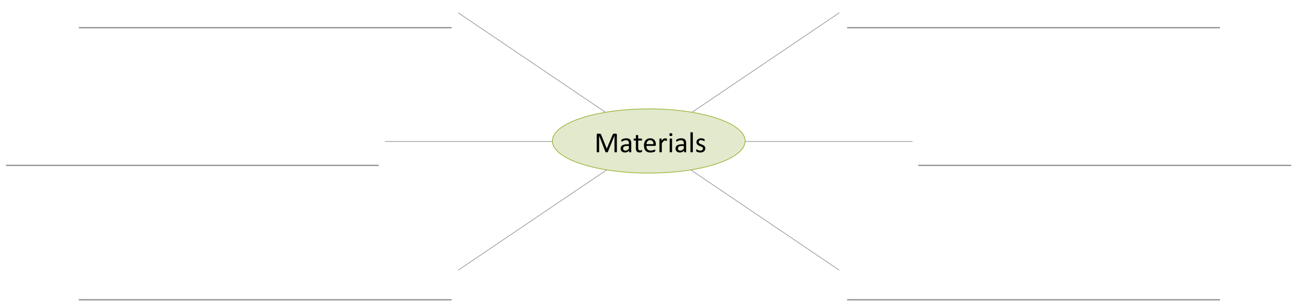
AC:

DC:

Do you know what transmission voltages are commonly used in New Zealand? List them below.

Where would you find insulators on a power pole in your neighbourhood?

What construction materials can be used for pylons or power poles?



3. The big picture

The New Zealand electricity supply industry

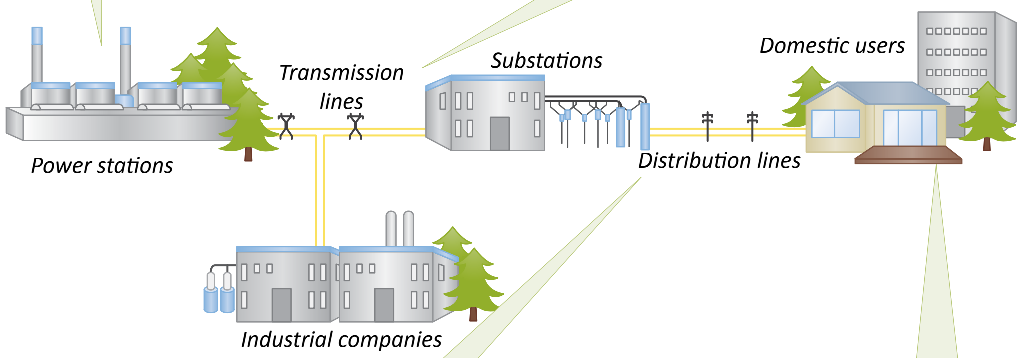
The New Zealand electricity supply industry has a clearly defined electricity system, supported by four main sectors. These are the generation, transmission, distribution and electricity retailing sectors.

1. Generation

This is where the electricity is produced. It is also known as the source.

2. Transmission

This is the sector that moves the electricity from the generation source to the major centres of use. These centres of use are also known as load centres and include substations and large companies.



3. Distribution

This is the sector that moves the electricity from the substations to the end users.

4. Electricity retailing

This sector includes the electricity market and the consumers who use the electricity, in homes or in businesses.

In this workbook, we will be looking at how electricity is delivered around the country and the equipment that supports this.

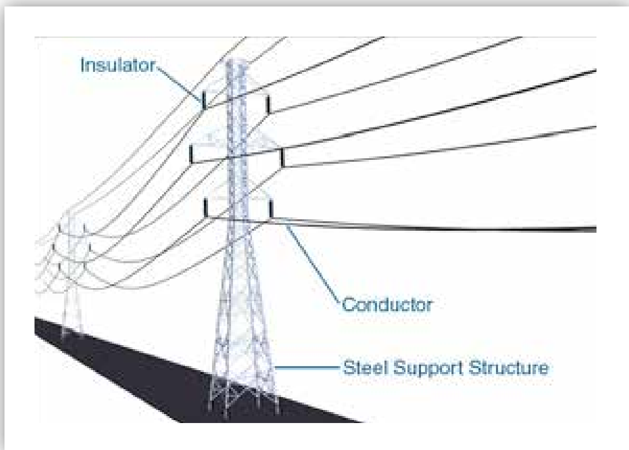
There are four types of electric line.

1. Transmission.
2. Distribution.
3. Traction.
4. Telecommunication.

Before we look at each of the lines above, let's have a look at the major delivery components common to them all.

Major delivery components common to electric lines

The three major components involved in moving electricity between the generator and the user are conductors (wires), support structures and insulators.



Conductors

Conductors are the wires that carry the electric current. They can be made of copper or aluminium.

Support structures

Support structures may be pylons, towers or poles and may be made of galvanised steel, concrete or wood. Each support structure will have a mechanism to support the conductors at a safe distance above the ground. There are guidelines for how far apart the conductors must be spaced on the support structure, and how far above the ground they must be placed.

Insulators

An insulator is used to attach each conductor to the support structure and they prevent live conductors from coming into contact with the support structure and each other. The length of the insulator is related to the voltage being transmitted. As a general rule, the longer the insulator, the higher the voltage.

Insulators are usually made of glass (clear or light green) or porcelain (brown or light grey). Some of the more modern insulators are made from fibreglass and special rubber. They come in a range of colours and lengths, depending on voltage and location.

The support structures must be strong enough to safely carry the overall weight of the conductors, and to withstand the additional weight and pressure of ice, snow and high winds.

Support structures, conductors and insulators can differ depending on the voltage they are carrying. Sections 10 and 11 of this workbook give more information on insulators and support structures.

3.1 In your own words, explain what the following sectors in the Electricity Supply Industry do.

Generation:

Transmission:

Distribution:

Electricity retailing:

3.2 Match the delivery components to the materials that can be used to make them.

Delivery components	Materials
Conductors	Special rubber
Support structures	Wood
Insulators	Copper
	Aluminium
	Galvanised steel
	Porcelain
	Concrete
	Glass

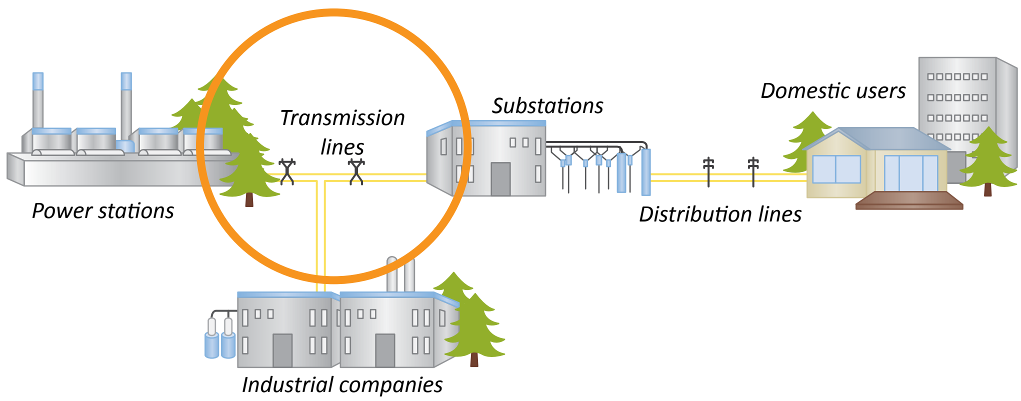
4. Transmission lines

Introduction to transmission lines

Transmission lines carry electricity around the whole country. The transmission network in New Zealand is known as the National Grid and is made up of over 12,000 km of high-voltage (HV) transmission lines and more than 170 substations.

The National Grid is owned by Transpower which is a state-owned enterprise. Transpower is responsible for the operation, maintenance and upgrading of the National Grid.

The transmission 'network' connects generation stations, owned by generating companies, to the substations that feed the local distribution networks. These distribution networks then deliver the electricity to homes and businesses via the distribution lines discussed in the next section.



4.1 What is the name of the transmission network in New Zealand?

4.2 What is the transmission network made up of?

1

2

Types of transmission line

The National Grid uses two types of transmission line:

1. alternating current (AC)
2. direct current (DC).

1. Alternating current

Alternating current (AC) is an electric current that repeatedly changes its direction or strength. Its major advantage is that it can be readily transformed from one voltage to another during the transmission process.

High voltage AC is used for transmission around the country, whereas low voltage AC is used for distribution to most industrial and domestic users. The National Grid mainly uses AC transmission voltages of 220kV and 110kV. Local electricity networks, owned by the distribution lines companies, typically use the lower AC voltages of 33kV, 22kV and 11kV.

You can tell if a transmission line is carrying an alternating current by counting the number of insulators and conductors it holds. Alternating current is transmitted using insulators and conductors in sets of three. Each pairing of an insulator with a conductor is referred to as one phase. Each set of three is referred to as 'three-phase' transmission. Where a large amount of electricity is needed, additional conductors can be added to a single insulator. Wherever two or more conductors are supported on the same insulator, this is referred to as bundling (bundling is explained on page 18).

Transmission line carrying alternating current (AC) in two three-phase circuits

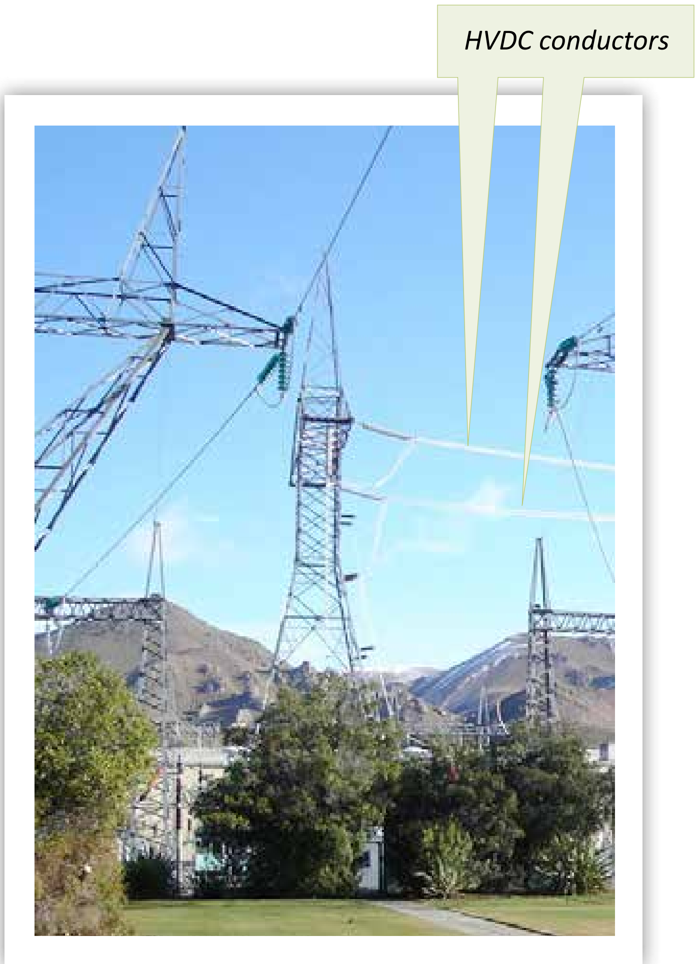
2. Direct current

Direct current (DC) is an electric current that has a constant strength in one direction. DC has less loss of transmission energy than AC and is used for long distance, high voltage transmission because of this. The major disadvantage of DC is that it cannot be readily transformed from one voltage to another during the transmission process.

High Voltage Direct Current (HVDC) is used to export and import electricity between the North Island and South Island, via a submarine (undersea) HVDC power cable. The power cable links the North Island and South Island across Cook Strait.

At each end of the HVDC 'link' a conversion process takes place. Alternating current is converted to direct current at the transmission end and direct current is converted to alternating current at the receiving end. HVDC in New Zealand is transmitted at 350kV and the HVDC system has a maximum carrying capacity of 1040MW.

A DC transmission line requires only two conductors, compared to multiples of three for AC. In some situations the mass of the earth is used as a conductor so only one overhead conductor is required. Support structures for the HVDC grid in New Zealand carry two bundled conductors, as shown in the photo below.



Support structure carrying direct current (DC)

4.3 Answer the following questions.

a What is one major advantage of using DC transmission of electricity instead of AC transmission?

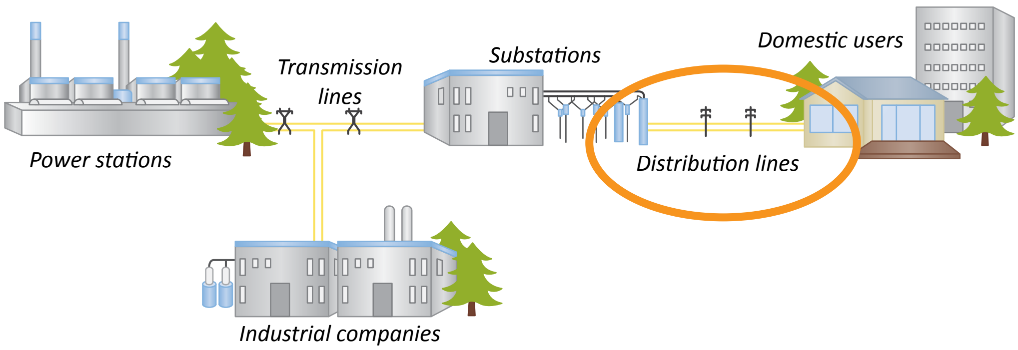
b What are the voltages that are typically used on the AC National Grid.

In industry, three-phase transmission and distribution is most common.

5. Distribution lines

Introduction to distribution lines

The distribution network is the network of lines which move the electricity from substations for supply to domestic or business users.



How do distribution lines work?

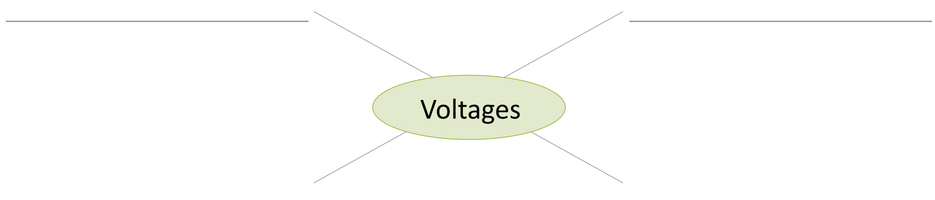
Distribution lines are used to perform the following tasks:

- supply electricity to domestic, business and industrial users
- carry telecommunication cables on poles
- provide street lighting.

When electricity comes into a distribution substation, from the National Grid, the voltage is lowered so that it's ready to enter the distribution lines. Distribution lines can carry different supply voltages on the same support structures and the voltages will depend on the amount of electricity required and the distance between the consumers and the distribution substation.

Typical distribution voltages for New Zealand are 33kV, 22kV, 11kV and 230/400V. The higher voltages are converted at the substations (33kV is converted to 11kV) and transformers in local neighbourhoods convert the 11kV to 230/400V for supply to consumers.

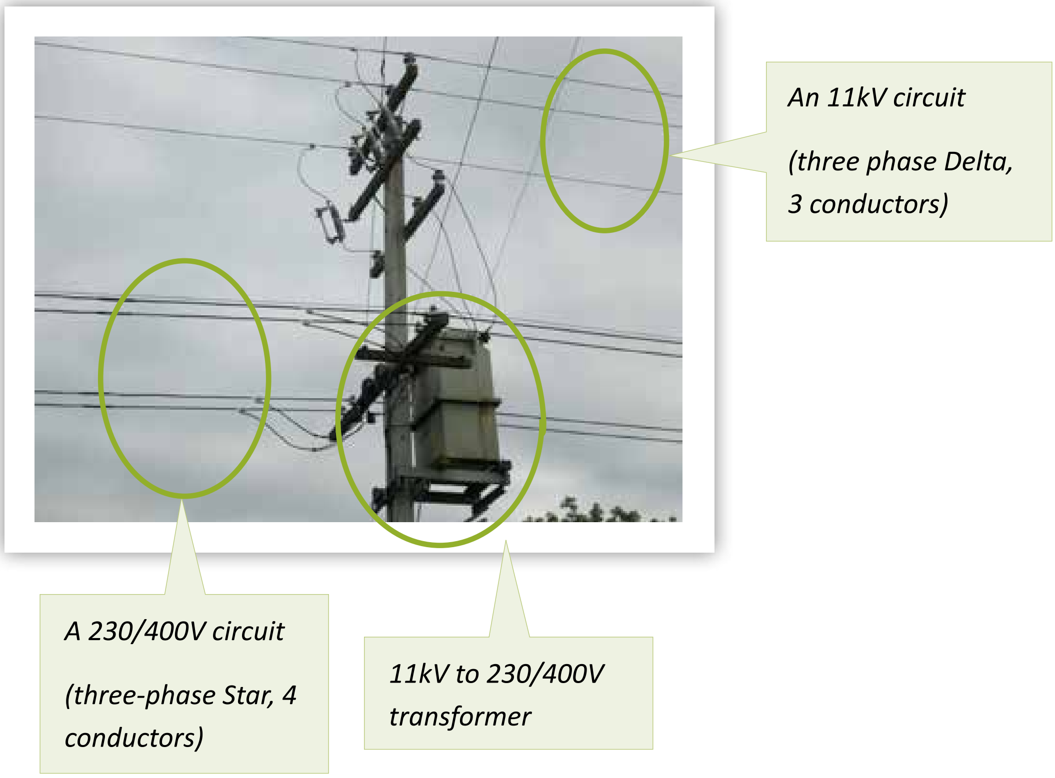
5.1 What are the typical distribution voltages for New Zealand?



The distribution line system can supply different voltages on the same circuit. The 230/400V line system uses multiples of four conductors instead of the multiples of three mentioned for transmission lines. In the 230/400V system, three of the conductors are energised and the fourth is a neutral conductor. This is referred to as three-phase Star distribution.

If the consumer is connected to an energised conductor and the neutral conductor, they will be supplied with 230V. Domestic households are connected to the 230V circuit.

If the consumer is connected to two or more energised conductors, they will be supplied with 400V. These consumers are likely to be from the industrial and business sectors. Some industrial consumers will be supplied with both voltages.



Pole structure showing several supply voltages for local distribution

5.2 How can 230V and 400V supplies be obtained from three energised and one neutral conductor?

Street lighting

Some older pole structures carry a conductor that is only used to remotely control groups of street lighting. Modern street lighting is directly connected into the 230/400V distribution lines and is remotely controlled by electronic relays. Many of these electronic relays have smart features like:

- automatic dimming, that responds to changing light conditions
- energy metering
- fault indication.

In rural locations there is another option for controlling street lighting. Light sensitive relays are used to detect when light levels drop below predetermined levels.

This luminaire is supplied with electricity by its own energised conductor, not by the distribution circuit.

5.3 Name at least two smart features of electronic relays that are used with street lighting.

1 ______________________________

2 ______________________________

Single Wire Earth Return

Single Wire Earth Return (SWER) is an alternative method of electricity distribution. It is a method that uses only one overhead conductor with the mass of the earth used as the other conductor. SWER is becoming much less commonly used but still provides an economic supply method for rural areas where electrical loads are small. SWER is also used for traction lines. In this case, the other conductor is a steel railway track, not the mass of the earth.

SWER – Single conductor and insulator on a pole

For lines companies there are cost advantages associated with using SWER. There is a reduction of hardware on each pole as there is only one insulator and no cross arms. In addition, there are longer spans between poles. This is because there is no risk of conductors touching each other and there is less risk of sag due to the small electrical load being carried. There are also fewer switching and protection devices required.

As rural load has increased, many of the original single conductor SWER installations have been replaced by the three conductor distribution systems. Telephone interference and stray electric voltages are also issues with SWER systems.

In the past, it was not uncommon to use No 8 fencing wire as the overhead SWER conductor.

5.4 State one advantage of using a SWER electricity distribution system.

Ground conductors

Low voltage (LV) distribution lines may have a 'ground conductor' located below the energised conductors. The ground conductor provides protection against shock hazards should any equipment or plant (such as a yacht mast or the boom of a crane) accidently come into contact with the energised conductors. In theory, if ground mounted equipment and plant were to come into contact with the energised conductors, they would touch the ground conductor first. Any fault current that occured would then flow back to ground through the ground conductor, not through the equipment or plant.

A ground conductor is used on HV transmission structures for a different purpose. It is located at the top of the structure and acts like a shield to the energised conductors. It attracts lightning in order to minimise the likelihood of a direct lightning strike to the energised conductors. A direct strike could result in damage to substations.

Ground conductor at the top of an HV transmission pylon

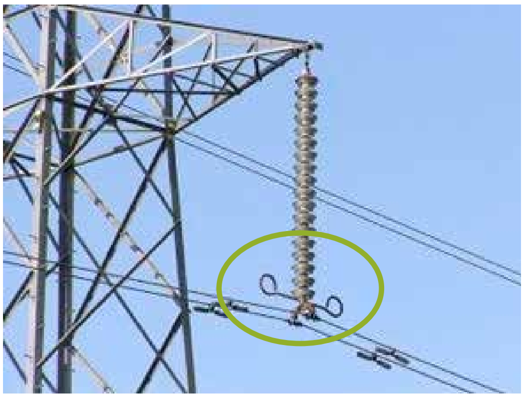
5.5 Briefly explain the purpose of using a ground conductor for distribution and transmission lines.

Distribution lines	Transmission lines

Bundled conductors

Combining two or more conductors on the same insulator is known as bundling. Bundling increases the amount of current that can be handled by the line and reduces transmission energy loss.

It is common for 220kV transmission lines to combine in two-conductor bundles – as the transmission voltage increases, so does the number of conductors in the bundle. Spacers are inserted between the conductors to keep them physically separated so that they do not touch each other in high wind or during fault situations. These spacers are placed at regular intervals between the pylons.



The energised conductors on the pylon are shown as being bundled in pairs.

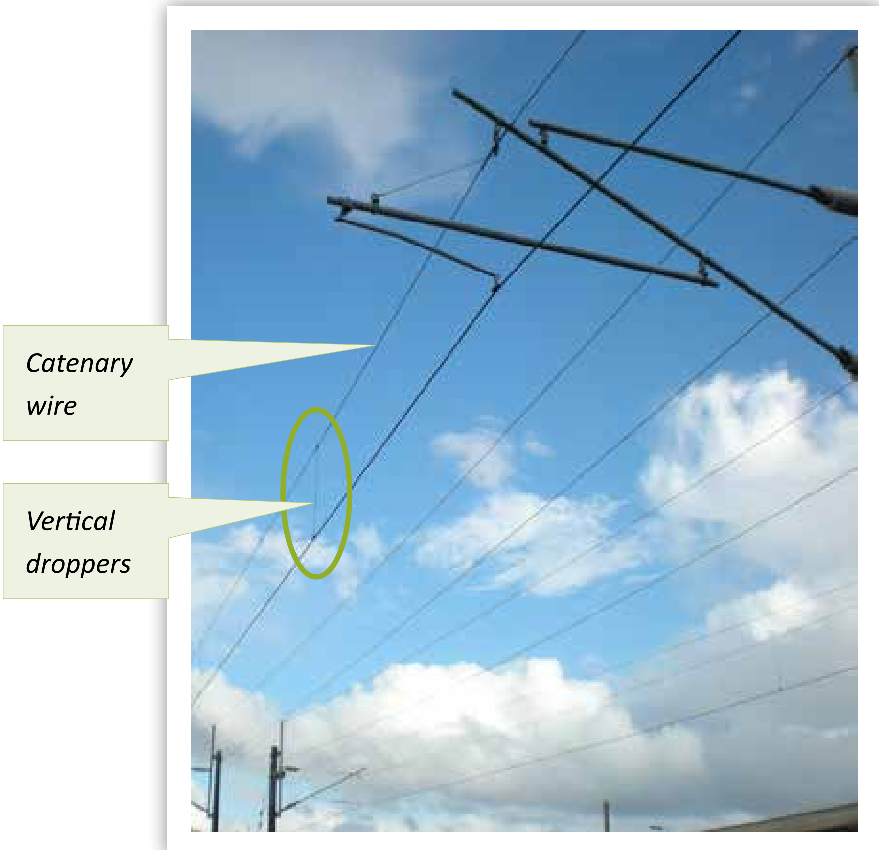
The distribution system often uses a different method of bundling. The conductors are individually insulated and then twisted together with a steel catenary wire. The catenary wire gives mechanical support.

This form of bundling is used in situations where a narrow distribution line structure is required, or when lines are taken through tree-tops.

Catenary wire

A catenary wire is a steel cable, used to provide mechanical support to conductors. It must be bonded to the earth. As mentioned on the previous page, in a power distribution system a catenary wire may be bundled with insulated conductors.

A catenary wire is also used where energised conductors must be parallel to the ground. An example of this is the overhead electric train distribution system. In this system, the catenary wire sits above the energised conductor and uses vertical droppers and insulators to hold the conductor parallel.



A catenary wire and vertical droppers keep the energised conductor parallel to the ground

6. Traction lines

Introduction to traction lines

Traction lines are used to supply electricity to transport that runs on electricity. This includes:

- electric trains
- trolley buses
- trams.

Electricity is supplied to electric trains and trams through single or double overhead conductors or an energised third rail on the railway tracks. The electricity is earthed through the non-energised rails on the track. Trolley buses use two conductors, one being the non-energised return to earth.

Traction lines can be AC or DC. A major advantage of AC traction lines for trains and trams is that voltage can be boosted along the railway track, with little difficulty. When a train or tram brakes, the energy generated can be captured and converted into electricity. The electricity is inserted back into the traction lines, improving overall efficiency of power usage.

Electric trains running the 411 kilometre North Island main trunk operate on 25kV AC. The commuter trains in Wellington use 1.5kV DC, while the new commuter rail system in Auckland runs on the same AC voltage as the main truck line. The Wellington buses use a nominal voltage of 550V DC.

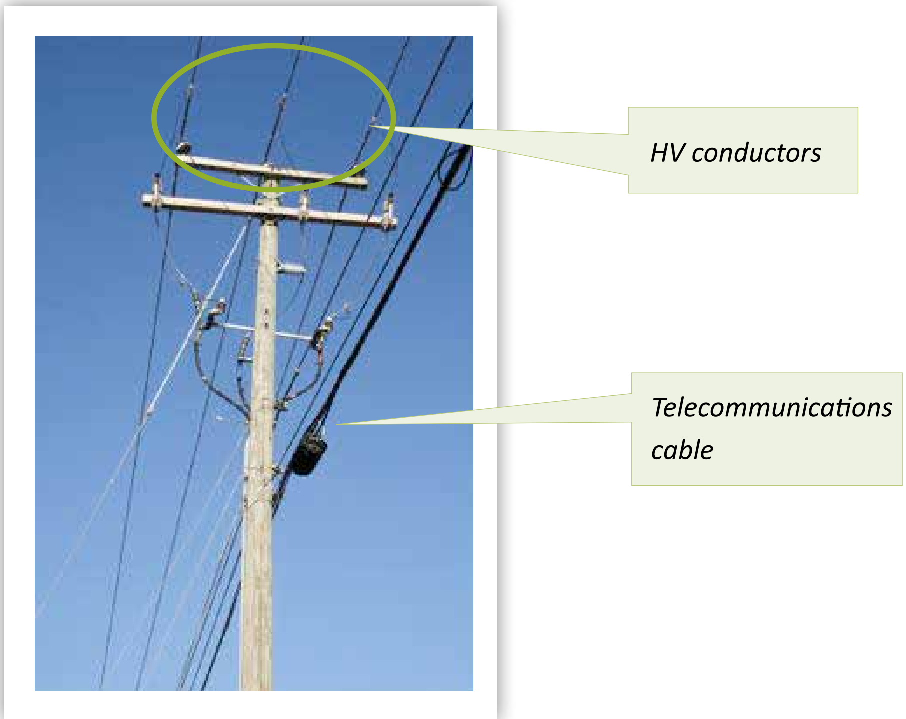
6.1 What is the operating voltage used by the new commuter railway network in Auckland?

7. Telecommunication lines

Introduction to telecommunication lines

Most telecommunication networks use their own poles for overhead lines. However, telecommunication lines, known as ‘cables’, are increasingly supplied as an underground service.

Telecommunications cables for telephones and cable TV are sometimes carried by the electricity distribution network. They are placed below the electricity conductors at the required electrical spacing distance. The placement of the telecommunications cables is demonstrated in the image below.



Traditionally, telecommunication cables have been made of copper but these are now being replaced by fibre optic cables.

Fibre optic cables are made up of strands of very thin optically pure silica glass and data is transmitted along the cable by use of an invisible light beam. The outer protective coating on the fibre optic cable guides the light along its length. In copper telecommunications cables, data is transmitted by electric current.

Advantages of fibre optic cable

The advantages of using fibre optic cables over copper are:

- high speed data communication
- suitable for data transmission over long distances
- data transmission is secure – it is not possible to tap into the cable to "listen in"
- can service tens of thousands of individual users per cable
- total resistance to any form of electrical interference.

Fibre optic cable is an electrical insulator, whereas Copper acts as an electrical conductor. Because of this difference, fibre optic cable overcomes many of the issues relating to fault situations that can occur when LV conductors drop and come into contact with the telecommunications cable.

Disadvantage of fibre optic cable

Connecting optical fibres is a precision process which is more costly and time intensive than the joining of copper cables. Specialist equipment is required in order to fuse together the ends of the strands.

7.1 What are at least two advantages and disadvantages of using optic cables?

Advantages	Disadvantages

8. Circuit operating voltages

Circuit operating voltages on the networks

Earlier in this workbook we looked at the two networks that deliver electricity around the country – the transmission network and the distribution network. The transmission network connects generation stations to the substations that feed the local distribution networks. And the distribution networks deliver the electricity to homes and businesses via the distribution lines.

We outlined that the transmission network uses only high voltage levels while the distribution network uses both high and low voltage levels. Because the transmission and distribution networks are electrical circuits, we refer to the voltages used on them as circuit operating voltages.

Now that we've looked at the difference between the networks, let's look more closely at the differences between circuit operating voltages.

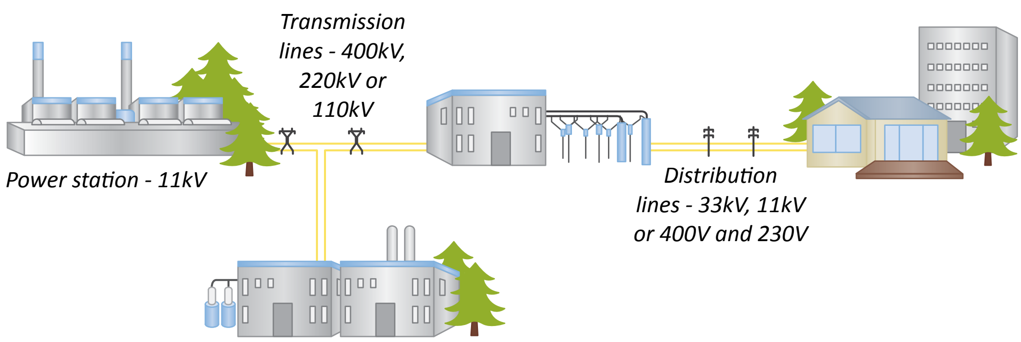
Low voltage (LV)

LV is any voltage between 50 – 1000 volts AC, or 120 – 1500 volts DC. On a pylon, tower or pole carrying high and low voltages, the low voltage conductors will be placed lower down the structure. Low voltage conductors need smaller insulators.

High voltage (HV)

HV is voltage over 1000 volts AC or 1500 volts DC. On a pylon, tower or pole carrying high and low voltages, the high voltage conductors will be at the top of the structure. High voltage conductors need larger insulators.

As at May 2012, the transmission voltages on the National Grid are 110 kV and 220 kV. A new Whakamaru to South Auckland national transmission link is near to becoming operational and is designed to carry 400kV. It will initially be operated at 320kV.



8.1 Look at the different circuit operating voltages below and decide whether they are low voltage (LV) or high voltage (HV).

Circuit operating voltage	LV	HV
1200V AC	◯	◯
150V DC	◯	◯
150V AC	◯	◯
1600V DC	◯	◯
60V AC	◯	◯
15000V AC	◯	◯
1400V DC	◯	◯
110V AC	◯	◯
230V DC	◯	◯
320V DC	◯	◯

9. Conductors

Conductors carry electric current

Conductors are the wires which carry electric current. They come in a range of sizes and are made in various ways from a range of materials.

Let's look at each feature of a conductor in a bit more detail ...

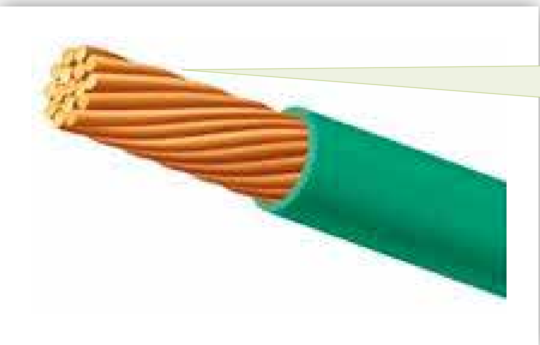
Construction of transmission and distribution conductors

Stranded conductors

It is common practice for the transmission and distribution networks to use stranded conductors. Stranding is a term used to describe a conductor that is made up of a number of finer wires twisted together. A stranded conductor is stronger and more flexible than a solid single wire conductor and will lose less electricity in transmission.

Conductors are measured by their cross section area (CSA), which is the surface area of the cut end of a conductor. Cross section area is measured in square millimetres and the CSA of conductors ranges from 1.5mm^2 to around 600 mm^2. The higher the current, the greater the cross sectional area required. A greater cross sectional area can be achieved by increasing the number of strands.

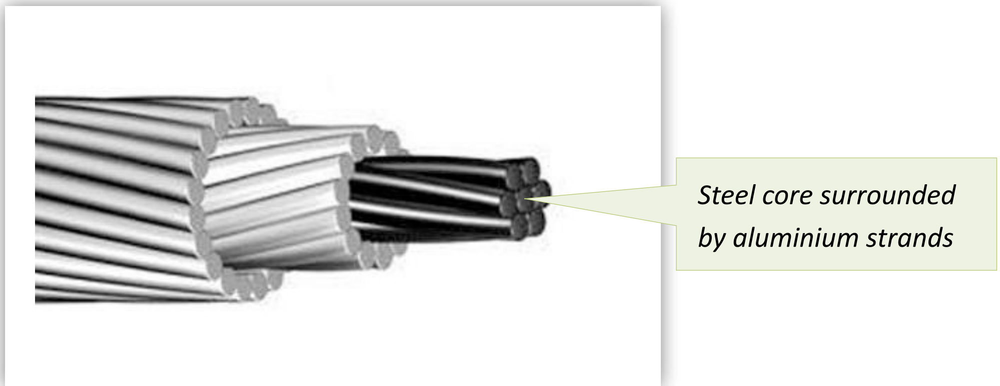
Books on cabling will give you the overall cross sectional area and the current carrying capacity of conductors and cables. You can source these books from cable manufacturers and suppliers.



Stranded conductor (copper) showing a number of finer wires twisted together

Conductors for HV transmission

Conductors for HV transmission are usually made from steel-reinforced aluminium and are commonly known as ACSR (Aluminium Conductor Steel Reinforced) conductors. ACSR is a popular choice for transmission lines as it is more cost effective and lighter than other options. The steel forms the core of the conductor and takes the strain and weight of supporting the aluminium strands. The aluminium carries the electric current.



Aluminium Conductor Steel Reinforced (ACSR)

Conductors for LV transmission

Copper and aluminium are available for LV transmission conductors.

Copper is a very effective conductor of electricity and is considered a better option than aluminium for distribution lines and household wiring. It is heavier and more expensive than aluminium but requires only half the diameter of aluminium to have the same electrical characteristics.

9.1 Briefly explain how the strain and weight of aluminium conductors is overcome when they are used for overhead transmission conductors.

Insulation of conductors

Overhead conductors

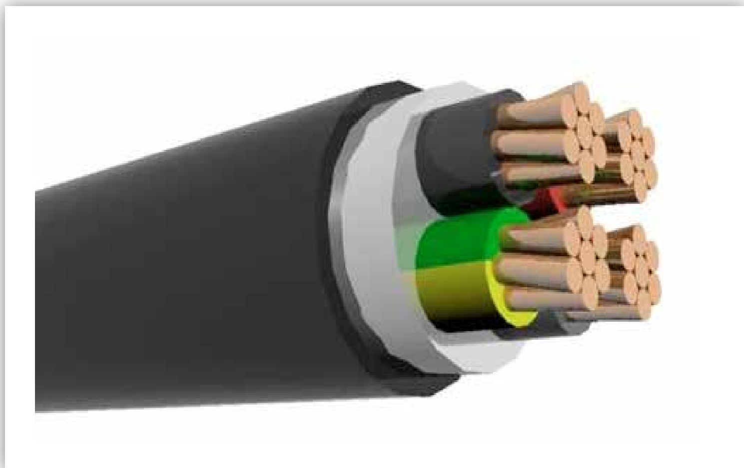
Most HV and LV conductors used on transmission and distribution lines have no insulation around them. In these cases, workers must observe minimum approach distances (MAD) when working on or near the lines. Insulated conductors are used in situations where minimum approach distances cannot be met, or where the lines are running near or through trees.

Insulation for underground cables

When conductors are placed underground, it is usual to combine them within a single insulated cable. The cable itself will have external and internal insulation and the individual conductors will be insulated from each other.

The choice of insulation for underground cables is very important. Insulation must enable the cable to operate at high voltages and withstand the high temperatures which can occur in fault situations.

Older underground cables use oil and paper insulation while modern cables use cross linked polyethylene materials, more commonly known as XLPE.



Underground cable carrying four stranded conductors, individually insulated.

Overhead conductors versus underground cables

There are choices when designing a system for electricity supply. These choices include whether to install a system with overhead conductors or underground cables. Some of the more obvious factors that influence those decisions are wind velocity, changes in temperatures and snow loadings. Other factors, which we will look at in more detail, include:

- environmental issues
- cost
- system voltage and current levels
- the current carrying capacity needed and possible increased demand
- installation and maintenance.

Environmental issues

Overhead line system	Underground cable system
• High voltage overhead lines require a lot of space and many people consider they are environmentally unfriendly. • Electrical discharges (corona effect) can produce noise and interference. • Pollution reduces the effectiveness of overhead conductors and insulators. • The effect of electromagnetic fields is considered a health issue by some.	• Underground cables are usually chosen when environmental factors are most important. • They are used where appearance is critical and land is limited. • Electromagnetic fields can be contained within certain types of underground cable (called neutral screen cables).

Cost

Overhead line system	Underground cable system
• Aerial cables cost less to install and maintain.	• 220kV underground cables are approximately 10 to 20 times more expensive than overhead conductors.

System voltages

Overhead line system	Underground cable system
• Greater distance can be kept between conductors allowing a higher voltage operation.	• The design of underground cables makes it difficult to insulate conductors at high voltages.

Current carrying capacity

Overhead line system	Underground cable system
• Bare aerial conductors have a higher current carrying capacity due to the air movement around them providing better cooling.	• Ground conditions can limit the current carrying capacity. • There is a high chance of cable insulation fault where operating temperatures rise above those expected.

Installation

Overhead line system	Underground cable system
• Conductors are hung from overhead structures at specified heights depending on the operating voltage. • Attention is given to signage to prevent people, equipment and animals coming into the minimum approach distances of the conductors.	• Cables are buried beneath the ground at specified depths, depending on operating voltage and ground conditions. • Signs indicates the location of the cable, warning against excavation.

Maintenance

Overhead line system	Underground cable system
• Maintenance and fault finding is easier because the conductors and supports are visible. • Aerial conductors are exposed to harsher conditions and require regular maintenance.	• Underground cables do not require maintenance unless there is a failure. Some cables, such as oil filled and gas filled cables, require monitoring. • Specialist equipment is required to locate faults, to avoid digging up the whole cable.

9.2 Name three differences between overhead conductors (line system) and underground cable systems.

	Overhead line system	Underground cable system
1		
2		
3		

Insulators support and anchor conductors

Insulators support and anchor the conductors, isolating them from contact with earth. Insulators must make sure that electric current does not leak from the conductor, through the insulator and support structures, to the earth.

Where leakage does occur, it is referred to as 'leakage current'. Insulators are moulded with a wave like shape to increase the surface distance that any leakage current would have to flow. This reduces the likelihood of the leakage current finding a direct path to earth from the conductor.

As a general rule, the longer the insulator the higher the working voltage of the transmission or distribution system. They must be strong enough to withstand the mechanical stresses caused by the weight of conductors and other forces.

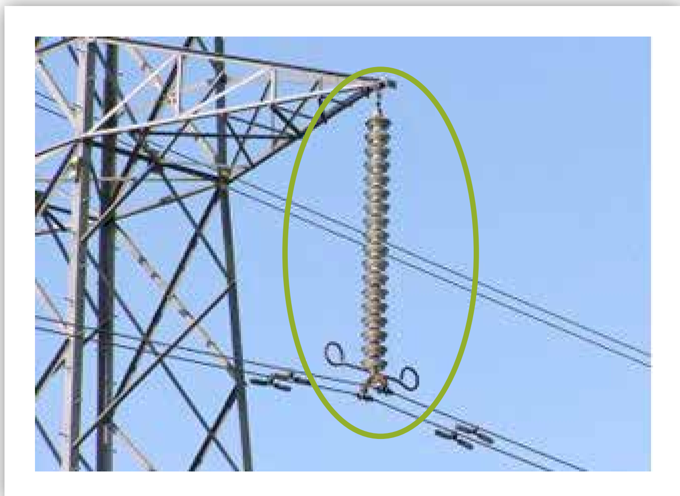
Insulators are usually made of porcelain but glass and other synthetic materials may be used so long as they can provide a very high electrical resistance to electric current.

Types of insulator

There are two main types of insulator – suspension insulators and pin insulators.

Suspension insulators

Suspension type insulators are made of porcelain or glass and are used for transmission voltages above 70kV. They are joined, at either end, to the conductor and the structure by a cap and pin made of galvanised steel.



A suspension insulator on a transmission line.

Pin Insulators

Pin insulators are generally made of porcelain and have several skirts (folds). A steel pin screws into the insulator so that it can be bolted to a support.

Pin insulators

10.1 What is the function of an insulator, in relation to overhead transmission lines?

10.2 What are two advantages of using underground transmission cables instead of overhead transmission conductors?

1

2

11. Support structures

Pylons, towers and poles

Pylons, towers and poles support overhead conductors at a safe distance above the ground and can be made of:

- galvanised steel
- pre stressed concrete
- reinforced concrete
- hardwood
- tanalised wood.

The main functions of support structures are to:

- support the overhead conductor
- make sure a safe distance is kept between the conductors and ground
- in all conditions, keep the distance between conductors to prevent flashover
- minimise the chance of a short circuit
- minimise the effect of capacitance between the conductors.

The structures carrying conductors for the distribution line tend to use concrete or wooden poles. For rural distribution lines, which carry up to 33kV and span around 150 metres, wooden poles are cheaper than concrete and steel supports. However, the life of a wooden pole is uncertain, so the more expensive reinforced concrete poles are gradually replacing them.

For lines over 33kV, galvanised steel towers are generally used. Their construction allows them to resist the higher mechanical stresses associated with larger and heavier conductors. Towers also provide for the larger clearance space needed between the conductors and earth.

Some common support structures

The following are commonly used supporting structures and configurations.

Temporary tower structures

Structures which are replaced by a more permanent structure when possible.

Intermediate towers and poles

These are used between support structures. They lift the overhead conductors, to obtain the correct ground clearance. Intermediate towers and poles are often used in difficult terrain.

Vertical tower structure

A vertical tower structure is used to carry high voltages. It uses only insulators to create the correct spacing between conductors.

Single pole structure

One pole carries a circuit.

Double pole structure

Two poles side by side carry a circuit.

Double pole structure

Flat top tower structure

The flat top structure is used for a single three-phase circuit.

Multiple circuit tower

A multiple circuit tower is used where two or more three-phase circuits are required.

Terminal tower or pole

Terminal towers or poles are used where the overhead line system changes to underground cables.

Strain pole

Strain poles are used where the direction of the line changes. They have additional support, to take the strain and weight of the conductors. This additional support is important where wind, snow or very cold weather is an issue.

Suspension pole

On a suspension pole, the conductors are suspended equally from both sides of the structure rather than being carried from cross arms.

11.1 Draw a line to match the supporting structure to the description.

Single pole structure	Uses insulators to create the conductor spacing.
Double pole structure	Structures intended to be replaced by a more permanent structure.
Multiple circuit tower	Conductors are suspended from both sides of the tower.
Flat top tower structure	One pole carries a single circuit.
Vertical tower structure	Used to convert from overhead to underground conductors.
Temporary tower structure	Two or more circuits on towers.
Terminal pole	Two poles side by side carry a circuit.
Suspension pole	Allows for safe distances between the conductors and the ground and is a horizontal circuit tower.

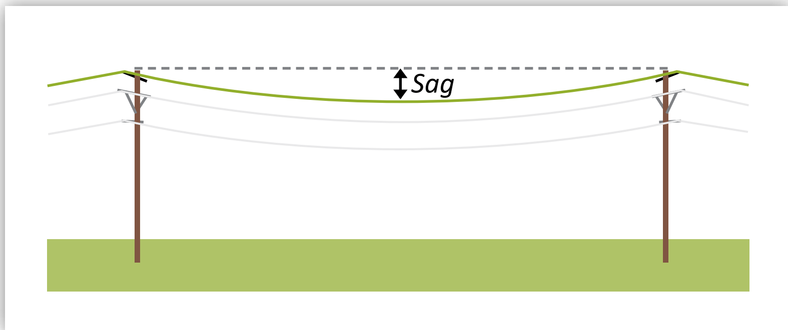
11.2 In your own words, explain what strain poles do.

The sag and span of the line

Several factors must be taken into account when designing the construction of a line. Among the first factors to consider is the conductor size, conductor material and the required 'sag'. Once these factors are known, the height of the support structure and the 'span' can be determined. This section looks at the sag and span of the line in more detail.

Sag

A conductor supported between two points does not stay horizontal, but hangs down in the middle. The vertical distance between the straight (imaginary) line joining the two points on the support and the lowest point of the conductor is called sag.



The sag of a conductor is determined by its physical and mechanical properties. To achieve a smaller amount of sag, the conductor must be tightened, which places greater mechanical stress on the conductor. The span between the support structures will be designed to reduce this stress.

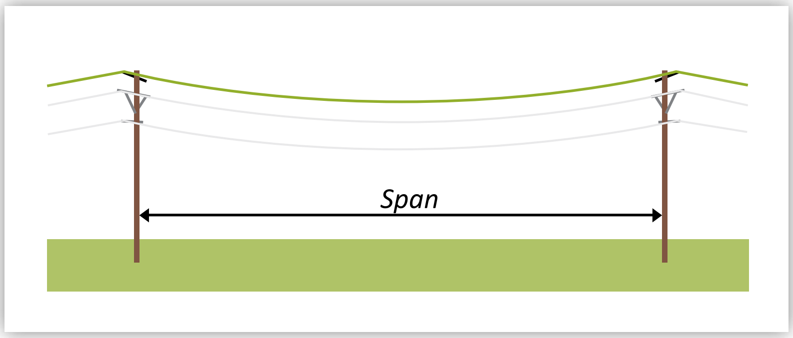
Sag is affected by the temperature of the conductor, which is in turn affected by electrical current and weather conditions. When the temperature of the conductor increases, so does the length of the conductor and this leads to an increase in sag. For instance, if the line is strung in the winter the sag must not be too great, or the conductor will sag even more during the summer temperatures.

When constructing a line, it is therefore important to calculate the sag so that the conductor stays suspended above the minimum approach distance (MAD) through all temperature changes. Over time, sag will naturally increase due to the natural deforming of the conductor material.

12.1 What conditions might affect the sag? List as many as you can think of.

Span

The span is the the distance between support structures. Line span is mainly determined by the required sag and the amount of mechanical stress that the conductor can withstand. However, support structures may be placed closer together due to limitations caused by the terrain. Once the span has been determined and the support structures have been installed, the conductors can be 'strung' between them.



12.2 List two factors that affect the span of a conductor.

1

2

13. Make connections

Think about how the information you have read applies to what you do at work. Read the questions and answer in the spaces provided.

What distribution voltages can be found at your workplace?

Are these distribution voltages AC or DC?

- ○ AC
- ○ DC

Is the incoming electricity supply to your work premises overhead or underground?

What would be the expected input voltage to the local distribution transformer nearest your home?

What type of insulators are used on the overhead distribution lines nearest your home?

Think about the overhead distribution circuits you see near your home. They often have three conductors (wires) on the top cross-arm and four conductors on the cross-arm below that.

- ○ What distribution voltage would you expect in the top conductors?
- ○ What distribution voltage would you expect in the bottom conductors?

Take a look at a pole mounted luminaire near where you live. Is it supplied from the conductors in the distribution circuit, or is it supplied separately through its own energised conductor? (Hint: does the cross-arm have four or five conductors?)

14. Answers to activities

3.1

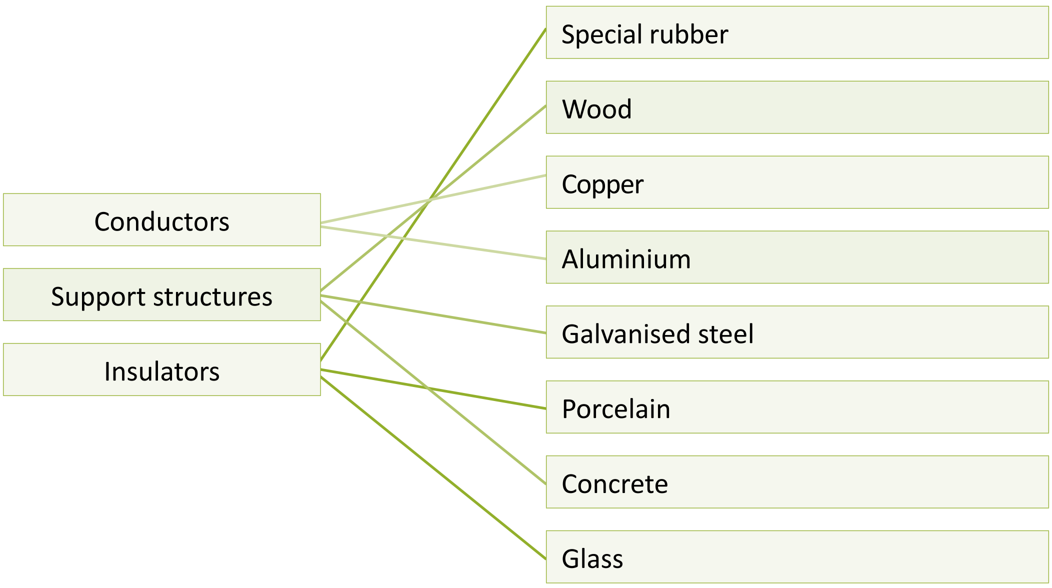
Generation — This is where the electricity is produced. It is also known as the source.

Transmission — This is the sector that carries the electricity from the source to the major centres of use. These centres are also known as load centres and include substations and large companies.

Distribution — This is the sector that carries the electricity from the substations to the end users.

Electricity retailing — This sector includes the electricity market and the consumers who use the electricity, in homes or in businesses.

3.2



4.1 The National Grid

4.2

1 over 12,000km of HV transmission lines

2 more than 170 HV substations

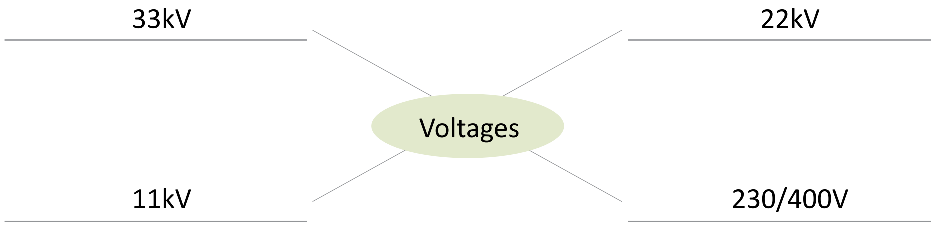
4.3

a one of the following:

- less transmission loss
- less complicated tower
- less conductors

b 220kV and 110kV, could also be 400kV for the new North Island link to Auckland.

5.1



5.2 The lines system combines three energised conductors with a neutral conductor.

5.3 Any two of:

- automatic dimming to match changing conditions
- energy metering
- fault indication.

5.4 One of the following:

- less hardware on poles
- longer spans
- cheaper to install
- less protection systems required
- fewer switching points required

5.5

Distribution lines	Transmission lines
To provide protection against shock hazards when equipment and plant accidentally comes into contact with the lines.	To prevent a direct strike to the energised conductors, which could result in damage to substations.

6.1 25 kV AC

7.1

Advantages	Disadvantages
• High speed data communication. • Suitable for data transmission over long distances. • Data transmission is secure – it is not possible to tap into the cable to "listen in". • Can service tens of thousands of individual users per cable • Total resistance to any form of electrical interference.	Connecting optical fibres is a precision process which is more costly and time intensive than the joining of copper cables. Specialist equipment is required in order to fuse together the ends of the strands.

8.1

Circuit operating voltage	LV	HV
1200V AC	○	✔
150V DC	✔	○
150V AC	✔	○
1600V DC	○	✔
60V AC	✔	○
15000V AC	○	✔
1400V DC	✔	○
110V AC	✔	○
230V DC	✔	○
320V DC	✔	○

9.1 By using a steel inner core

9.2 Answers can be any of the bullet points listed on page 28-29.

10.1 Provide mechanical support for conductors and electrical isolation to earth

10.2 Any of the following:

- environmental factors
- lower maintenance
- less likely to touch bare conductors
- reduced electric fields.

14. Answers to activities

11.1

Single pole structure	Uses insulators to create the conductor spacing.
Double pole structure	Structures intended to be replaced by a more permanent structure.
Multiple circuit tower	Conductors are suspended from both sides of the tower.
Flat top tower structure	One pole carries a single circuit.
Vertical tower structure	Used to convert from overhead to underground conductors.
Temporary tower structure	Two or more circuits on towers.
Terminal pole	Two poles side by side carry a circuit.
Suspension pole	Allows for safe distances between the conductors and the ground and is a horizontal circuit tower.

11.2 Answer could be similar to:

Strain poles are used where the lines change direction. They often have additonal support, to take the strain and weight of the conductors They are very important where wind, snow or very cold weather is an issue.

12.1

- electric current
- weather conditions
- changes in the temperature of the conductor
- natural deforming of the conductor material.

12.2 Any of the following:

- required sag
- mechanical stress on the conductor
- limitations caused by the terrain.

Learning POWER
ESITO