



Demonstrate knowledge of the New Zealand electricity supply industry

US 18275

Training and Assessment Resource

NCES Level 2

Contents

Introduction to Training Assessment Resource.....	4
Purpose	4
Introduction.....	5
1. Generation.....	7
1.1 Hydro (Water)	8
Manapouri Power Station.....	9
1.2 Thermal.....	10
Geothermal.....	12
1.3 Fossil Fuel	13
Coal.....	13
Gas	14
Combined Cycle Generation	15
Diesel	15
1.4 Renewable Energy Sources.....	16
Wind.....	16
2. Transmission System	20
2.1 National Grid.....	20
Alternating Current System	21
Direct Current System	22
2.2 Transmission Lines.....	22
2.3 Control Centres	24
North Island	24
South Island.....	25
Substations	25
2.3 High Voltage Direct Current Link.....	27
2.4 New Zealand Electricity Market.....	28
Bids and Offers.....	31
Pricing.....	31
3. Distribution Systems	33

4.	Utilisation of Electricity	35
5.	Relationships Between Key Industry Players	37
5.1	Control Centre Operator	37
5.2	Transpower Coordination Centres.....	38
5.3	Regional Operating Centres	39
5.4	Power Companies, Direct Consumers, Generator Control Centres	40
5.5	Operator Liabilities	41
6.	Trainees in the Electricity Supply Industry	42
6.1	The National Qualifications Framework (NQF)	42
6.2	You and ESITO	43
	Next Steps	45
	Model Answers to Activity Questions	46

Introduction to Training Assessment Resource

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 demonstrate their knowledge of:

- > The major sectors within the New Zealand electricity supply industry
- > The key industry relationships within the electricity supply industry in New Zealand

Introduction

The Electricity Supply Industry (ESI) in New Zealand is divided into four major components. These are:

Generation

Where the electricity is produced.

Transmission

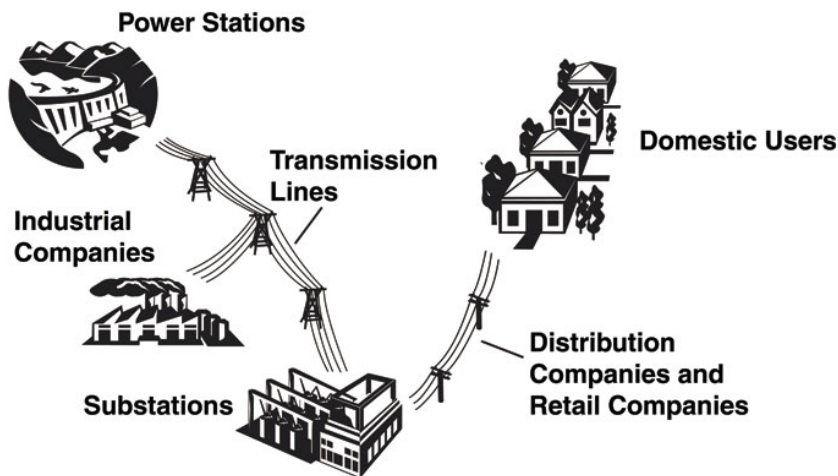
How the electricity is moved from where it is made to major load centres.

Distribution

How the electricity is moved within the load centres.

Utilisation

How the electricity is used by the consumer.



Overview of the New Zealand electricity network.



Activity

List the location of three different types of generation that we use to supply electricity in New Zealand in the table below. The first one has been done for you.

Generation Type	Location within New Zealand
Hydro (water)	Manapouri

1. Generation

Apart from natural uncontrolled phenomena such as lightning, electricity does not exist in a natural form. It must be generated as it is required using the reaction of chemicals (battery), heat (thermo-couple based fuel cell) or the relative movement of an electrical conductor and a magnetic field to provide and sustain an "electro-motive force".

By far the majority of electricity consumed in today's world is generated by the movement of a magnetic field relative to fixed electrical conductors inside an electricity generator.

Magnetic pole pairs are spun inside the generator by "prime mover" turbines powered by a "fuel" source such as:

1. Petrol
2. Diesel
3. Gas
4. Water (Hydro)
5. Geothermal Steam
6. High Pressure Steam
7. Wind

Generators can be found in many places, including cars (for battery charging) and commercial buildings (for standby electricity supply), but larger generators which produce electricity for public supply are invariably installed in power stations.

Steam turbines are the most common prime movers throughout the world.

New Zealand benefits from being able to generate most of its electricity requirements from hydro (water) sources and therefore differs from most other countries.

Voltages of hundreds of thousands of volts can be generated with a demonstration model Van de Graaff generator. Though startling, discharges from the Van de Graaff do not represent a serious shock hazard since the currents attainable are so small. The Van de Graaff was one of the first forms of producing electricity - it was produced by static means

1.1 Hydro (Water)

Generally, a river is dammed at a suitable place and the water is led to the powerhouse through concrete or steel pipes called penstocks. The force of the water against the blades of the "runner" (similar to a large ship's propeller) causes it to spin. The runner, in turn, spins the rotor of the generator which will be, almost always, an alternating current type or alternator. The rotor consists essentially of a frame on which are attached a number of electro-magnetic, north and south pole pairs; as the rotor turns, so do their powerful magnetic fields. The rotor spins inside a series of copper conductors which are able to carry electric current; the fields "induce" in those conductors an electromotive force (EMF). This causes a movement of electrons through the conductors and through an external electrical load.

When such a load is connected and is consuming energy, the generator supplies this energy; the mechanical power input to the generator is matched to the load. Hydro stations produce about 75% of New Zealand's power requirements.

Water-driven generators run at speeds determined by the effective head of water (height from top of dam to the turbine at the power station) available and the power of the generator, generally in the range of 100 - 300 revolutions per minute (rpm) (30 - 10 electro-magnet pairs).

Highest speeds in use are 750 and 1000 rpm (4 - 3 magnetic pairs) at Cobb, which has heads of 554.74 and 533.4 metres.

The slowest in use is 100 rpm at Aviemore which has a head of 37 metres. Each generator is synchronised when it is running in step with and connected to the rest of the system.

One of the more interesting hydro-electric power stations in New Zealand is at Manapouri. The Manapouri power station is the largest hydro power station in New Zealand.

The hydro scheme utilises water and snow from catchments within Fiordland to produce electricity. Water flows from Lake Te Anau down the upper Waiau River to Lake Manapouri. Water is also diverted from the Mararoa River, at the Manapouri lake control structure, into Lake Manapouri, except during times when the water is turbid or highly coloured when it is discharged down the lower Waiau River. Water from Lake Manapouri is used to generate electricity at the underground West Arm power station. The tailwater discharge from the power station is released into Deep Cove in Doubtful Sound.



Hydro machines can be run up from standstill and the generator put on load in a minute or so. The load can be rapidly and widely varied to suit system demand but there is the possibility of runner erosion at prolonged low loads and lower efficiency at certain loadings.

Hydro-electric stations together with control structures, dams and so on, are expensive to build, but the operating costs are low. A very long station life (over 60 years) is usually expected and obtained.

Manapouri Power Station

One of the more interesting hydro-electric power stations in New Zealand is at Manapouri. The Manapouri power station is the largest hydro power station in New Zealand.

The hydro scheme utilises water and snow from catchments within Fiordland to produce electricity. Water flows from Lake Te Anau down the upper Waiiau River to Lake Manapouri. Water is also diverted from the Mararoa River, at the Manapouri lake control structure, into Lake Manapouri, except during times when the water is turbid or highly coloured when it is discharged down the lower Waiiau River. Water from Lake Manapouri is used to generate electricity at the underground West Arm power station. The tailwater discharge from the power station is released into Deep Cove in Doubtful Sound.



- > The power station is located underground within Fiordland National Park.
- > The turbines, generators and other equipment are contained in the powerhouse located in an underground cavern.
- > The cavern was cut from solid rock and is 111 metres long, 18 metres wide and 39 metres high.
- > Vehicles can drive down to the powerhouse through an access tunnel which is more than two kilometres long. It descends at a 1-in-10 gradient, and is wide enough to allow vehicles to pass.
- > The powerhouse can also be reached by an elevator which descends 220 metres (equivalent to a 70-storey building) in two-and-a-half minutes.
- > The power station uses a 178 metre height difference between Lake Manapouri and the sea at Deep Cove.
- > Once water has passed through turbines it leaves the station through two 10 kilometre-long tunnels to Deep Cove. The station was originally built with only one tailrace tunnel, but a second tunnel was commissioned in 2002.

1.2 Thermal

Thermal stations use the energy trapped in fossil fuels (oil, gas, coal) to turn water into steam. The steam is passed over the blades of a turbine, causing it to spin. The turbine is connected to a generator, in much the same way as in a hydro station. In a geothermal station, steam is obtained directly from under the earth.

Steam turbines are used where energy is available naturally as geothermal steam, or where fuel is to be burned in a boiler. The fuel may be natural gas, oil or coal. In nuclear stations the heat from a reactor is used to produce steam, and the steam is then used to drive conventional steam turbines and generators.

Steam Turbine Principles

The purposes of turbine technology are to extract the maximum quantity of energy from the working fluid, to convert it into work with maximum efficiency, by means of plant having maximum reliability, minimum cost, minimum supervision and minimum starting time.

Steam Flow process

Steam is admitted to one end of the turbine and travels between rotor and cylinder to the exhaust end, in the process extracting the (heat) energy and providing useful work at the turbine shaft end. The steam from the exhaust usually goes to a condenser that condenses the steam back to water for re-use in the supply boiler.

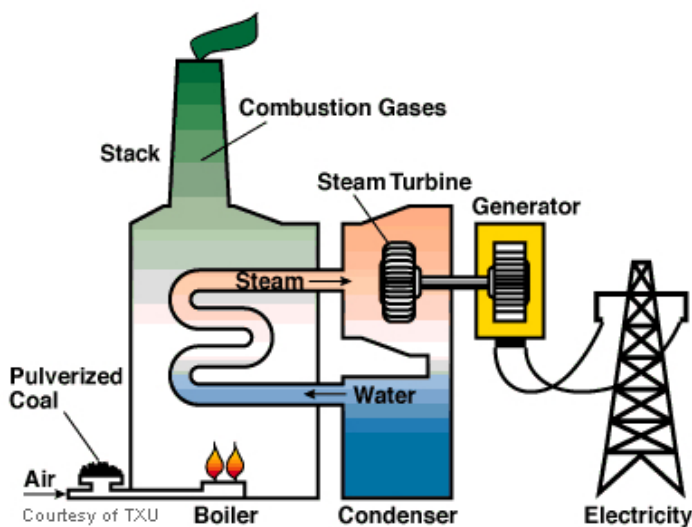


Diagram of a thermal station.

Mechanically the basic steam turbine is superior to any other heat engine as it only has one moving part - the rotor, and only two rubbing surfaces - the main bearings. The steam-driven generator, for which a high speed is technically desirable, may have only one electro-magnet pair and run at 50 revolutions per second or 3000 revolutions per minute (3000 rpm).

The efficiency of a well designed steam turbine plant can be as high as 85-90%



Activity

What are Wairakei and Ohaaki power stations supplied with?

Name the only moving part in a basic steam turbine.

Geothermal

New Zealand has nine geothermal power stations. Seven are in the Waikato region. There are plans to build others and expand existing stations, in the Waikato, Bay of Plenty, and Northland regions. The table below lists the stations in this region.

Geothermal System	Site	Owner(s)	Productive output (MW)	Year built
Wairakei-Tauhara	Wairakei	Contact Energy	140	1958
	Wairakei Binary	Contact Energy	14	2005
	Poihipi Rd	Contact Energy	30	1997
	Tauhara	Contact Energy	(15)	Planned
	Tukairangi Rd	Geotherm	(60)	Planned
Mokai	Mokai A	Tuaropaki Power Company	55	2000
	Mokai B	Tuaropaki Power Company	37	2005
Rotokawa	Rotokawa	Rotokawa Joint Venture	30	1998
	Rotokawa B	Tauhara North No. 2 Trust	(30)	Planned
Ohaaki	Ohaaki	Contact Energy	30	1988

As well as these large power stations, about 40 commercial operations extract small or medium quantities of geothermal water and energy in the region. Most operations take the water from wells or springs, but others take water from hot streams such as the Onekeneke at Taupo. This heated water is used mainly for public baths or motel pools.

At Wairakei and Ohaaki the power stations are supplied with natural (geothermal) steam.



Activity

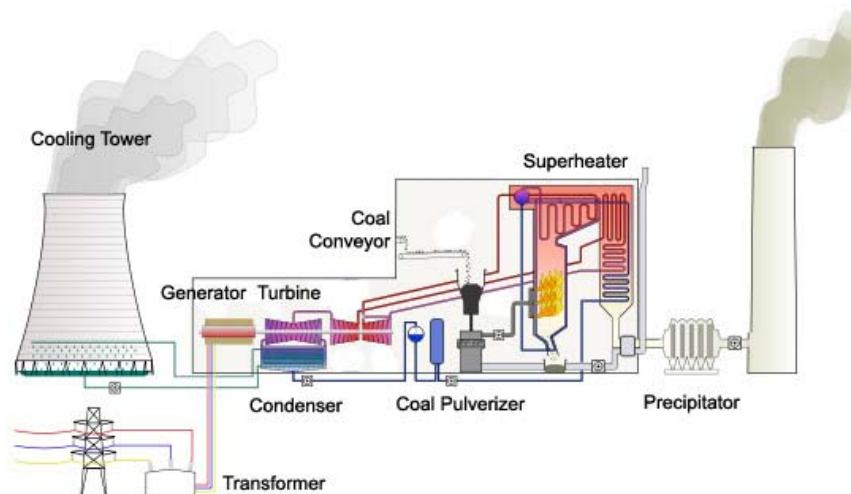
How many geothermal power stations are there in New Zealand?

1.3 Fossil Fuel

Coal

The principle behind the coal-fired power station is very simple.

Coal is burnt to heat water until the water turns to steam. The steam is forced under great pressure through a turbine. The turbine turns a generator, which produces the electricity. The turbine in the power station is turning the generator at 3000 revolutions per minute (rpm). This produces an alternating current with a frequency 50 Hertz. (Hertz is the unit for frequency. 50 Hertz means the electricity changes direction 50 times per second. A "step-up" transformer increases the output of the generator to a much larger voltage. The large voltage is necessary in order to "push" the electricity over the long distances it has to travel.



Coal fired power station.

Advantages

1. New Zealand does have a supply of coal.
2. Coal is a relatively cheap source of energy.
3. Electricity supply is reliable.

Disadvantages

1. Coal is not a renewable resource.
2. During the production of electricity carbon dioxide is released, increasing the amount of greenhouse gases in the atmosphere.
3. Sulphur dioxide, nitrogen oxide and nitrogen dioxide are also produced in these emissions and can produce acid rain.
4. Mining coal damages the environment.
5. Coal-fired power stations create thermal pollution, i.e. increasing the temperature of an environment above natural levels creating a potential hazard to ecosystems.

Gas

There are two types of gas fired powered stations. One will use gas to heat water to make steam which then drives a steam turbine as shown below. The other will use the raw gas to drive a gas engine which is coupled to the generator.

The complete generating unit consists of a gas generator coupled indirectly to a gas-powered turbine which is directly coupled to a conventional high speed generator of the same kind that is used with a steam turbine.



The purpose of the gas generator is to produce large quantities of high velocity gas. It consists of an air intake, a multi-stage rotary axial-flow compressor and a ring of parallel-connected combustion chambers into which the fuel (gas or oil) is introduced and burned.

The much-expanded gases first pass through a turbine which is directly coupled to the compressor at the intake end. This rotating system of compressor and turbine is entirely separate from the other rotating parts, and usually runs at a higher speed.

The gas generator described is virtually a conventional aircraft jet engine and standard aircraft jet engines have been successfully used in electricity industry gas turbine stations. When used for power generation the gas output from the engine is not used to produce thrust but is instead directed to a power turbine which is directly coupled to the generator.

The power turbine and generator run at 3000 rpm. Aircraft jet engines are highly developed, reliable and easy to maintain. They do not need expensive foundation, housing or many auxiliary services and so the installation costs are low. When suitably modified they can burn fuels cheaper than aviation fuel, for example gas, light oil, or kerosene.



Activity

List three disadvantages of coal fired power stations:

Combined Cycle Generation

This provides a link from the exhaust heat of the Gas Turbine gasses, and transfers that heat onto a Boiler Unit (as explained in the Thermal Generation part of this course material). This thermal boiler unit then in turn produces super heated steam to rotate a steam thermal turbine. The steam turbine is coupled to the same drive shaft that connects the rotating turbines to the electrical generator.



This form of generation is considered very efficient as it harnesses two prime movers from one fuel supply effectively rotating one large generator

Diesel

The internal combustion engine of the reciprocating type is no longer used in New Zealand for main generation. Diesel engines (usually of two stroke design) may be used as standby units for example in major steam stations to supply auxiliary power for start-up when isolated from the main system. ("Black Starting").



These engines can be brought on load quickly and they require only a moderate energy source to get them started. They run at speeds between 600 and 1500 rpm, but maintenance costs are high.

1.4 Renewable Energy Sources

The world's natural energy resources, such as fossil fuels, are not limitless. International energy industries are constantly working to find alternative, cheaper methods to generate power. Solutions range from wind, solar, hydro, and wave to nuclear energy.

Alternative energy generation is always sort after. Goals for new types of energy are:

1. Increased efficiency of energy production and use.
2. Reduction of energy costs.
3. Minimising the impact on the environment.

Wind

Wind is currently not the most cost effective generation for NZ especially given the abundant hydropower capabilities. However, as wind technologies improve we can expect wind generation to be more cost effective. Many NZ areas record in excess of 30km/hour annual wind speed, so technically wind could generate more than 20% of our electricity needs.



Wind Advantages

Wind energy offers two important advantages:

1. It is sustainable in the long term, and
2. Environmental impacts are minimal.

The wind turbines can be as high as 30 metres tall and can weigh in at over 20 tonnes.

The wing generator can operate at speeds ranging from 12km/hour (gentle breeze) to 90km/hour (a strong gale). They are designed to survive 200km/hour wind speeds, however to avoid damage in very high winds (over 80km/hour) the turbine automatically shuts down and the blades are feathered for minimum resistance to the wind.

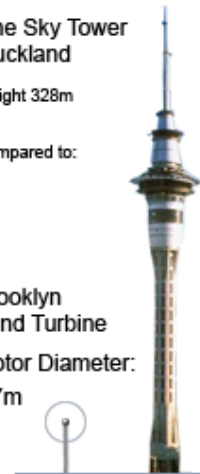
**The Sky Tower
Auckland**

Height 328m

compared to:

**Brooklyn
Wind Turbine**

Rotor Diameter:
27m



Rotor Blades

Each of the three rotor blades (typically made from fibreglass-reinforced polyester) can be approx 12 metres long.

The angle of the blades affects the level of the output. In low winds they have their widest surface against the wind. As the wind speed increases, the blades pivot (feather), offering less reaction to the winds pressure.

As with the example of the wind turbine at Wellington, the blades can rotate at different speeds. In winds up to 23km/hour they rotate at 33 rpm. Winds higher than that automatically switch the rotation speed to 44 rpm and trigger a second generator to process the increased output.

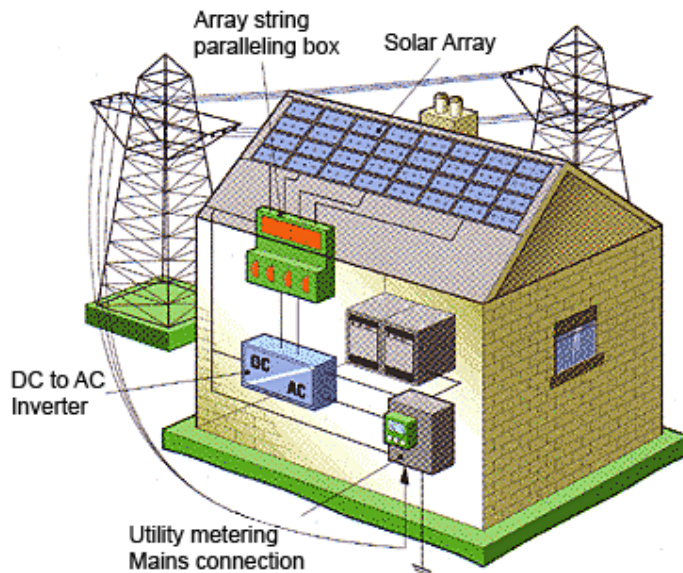
The Control Process

The turbines can be electronically controlled with microprocessors that automatically start, stop, and monitor the turbine.

Communication links connect the data to display screens and printer at either a local or remote control centre.

Solar

This is relatively expensive for large amounts of electricity requirements but is excellent to provide energy for remote plant and equipment and eco-sensitive environments.

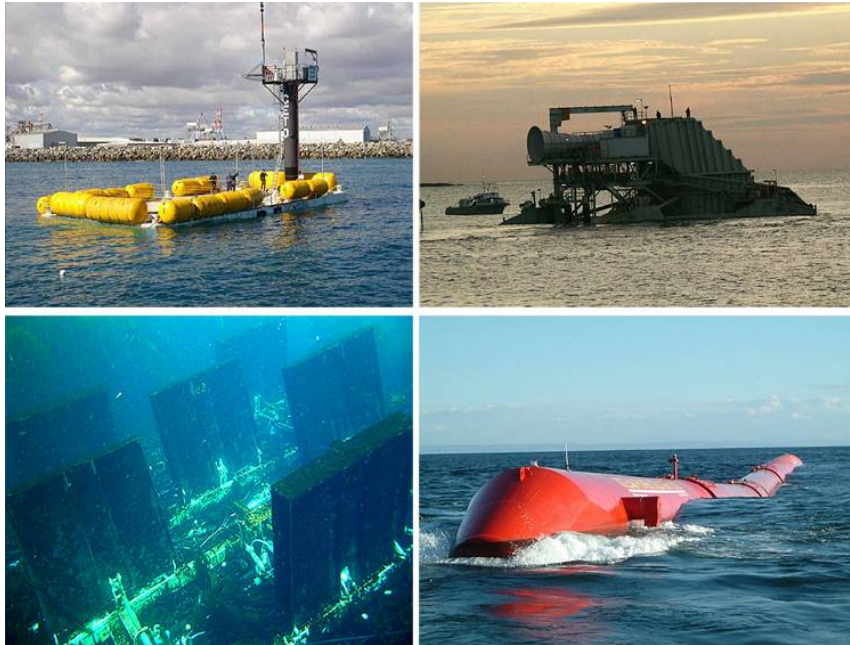


Example of solar electricity generation.

Wave Motion

Wave energy today is where wind energy was around a decade ago. And just as wind energy technology has advanced, wave energy offers many possibilities.

More detailed information is available at www.rise.org.au/info/Tech/wave/index.html.



Examples of wave motion electricity generation.



Activity

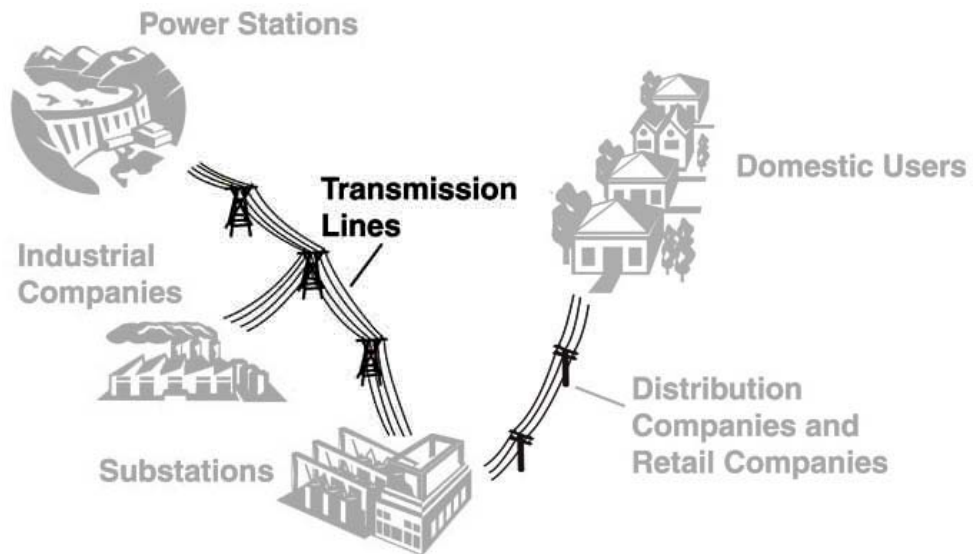
What is the disadvantage of solar electric generation?

Name three renewable energy resources:

List two disadvantages of wind energy:

2. Transmission System

In the following text, unless otherwise made clear, the word "transmission" is used for brevity to denote the carrying of electricity from the power station all the way to load centres. The distribution network then distributes the electricity to consumers.



Transmission system.

2.1 National Grid

The National Grid is the 11,7685km network of power pylons, poles, cables and 173 electricity substations throughout NZ. Transpower, on behalf of the NZ Government owns and manages the National Grid.

There are national control centres at Hamilton and Wellington as well as at major centres of generation and distribution.

Electricity is carried in two ways on the National Grid:

1. Via the Alternating Current (AC) System, and
2. Via the Direct Current (DC) System

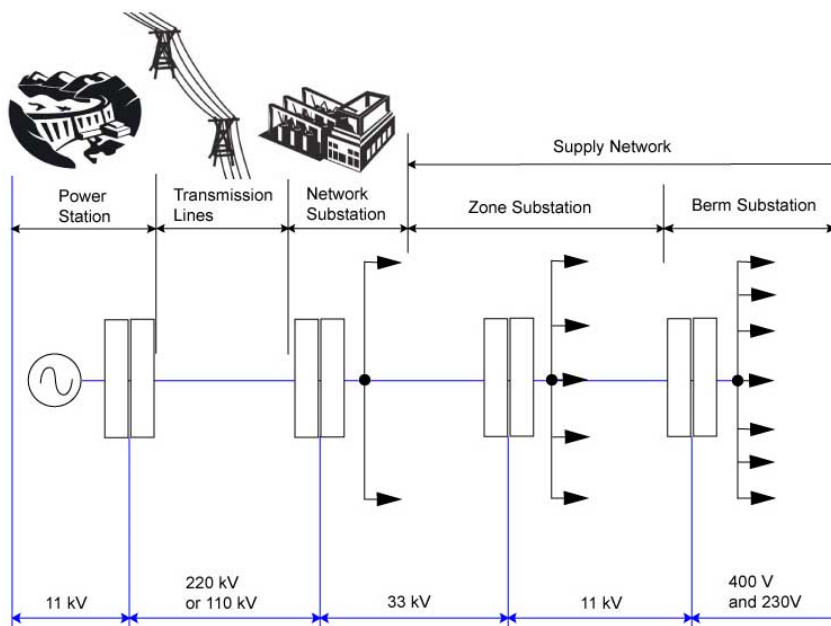
Alternating Current System

Alternating current (AC) is the type of electricity where electrons move back and forth along a wire. This back and forth movement transmits the electrical energy, but individual electrons do not travel far. In NZ this back and forth movement occurs exactly 50 times a second (50 Hertz)

AC is transmitted at a high voltage but a low current, so that heat (energy) loss from the wires is reduced. Transformers are an easy way to raise or lower the Voltage.

Electricity is generated at 6,600 Volts or 11,000 volts and leaves most of the Power Station at 220 000 Volts (220 kV) and then:

1. Joins the National Grid,
2. Is transformed down to 110kV, 66kV, 50kV, 33kV or 11kV near towns and cities,
3. Is transformed down to 230V AC near houses, and then
4. Travels through electrical appliances and equipment.



Generation, transmission and distribution system.



Activity

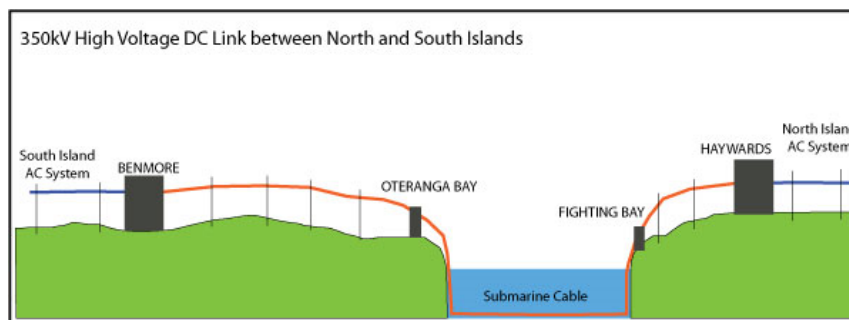
Who owns and manages the national grid?

Direct Current System

Direct Current (DC) is when the electrons move in one direction along a wire. For convenience, this is considered to be from positive to negative.

Direct Current is only used in one situation in the National Grid, which is the 575km DC cable from Benmore, Otago to Haywards, Wellington. This cable joins the power supplies of the North and South Islands. Ninety five percent of the time the current flows North. The cable carries up to 1040MW of power at 500KV, hence its name "High Voltage Direct Current" - or HVDC for short.

When built in 1965, the HVDC link was the world's largest and longest DC cable, incorporating the world's largest submarine cable. The success of this engineering feat has earned it a Millennium Award from the Institute of Professional Engineers of NZ (IPENZ)



HVDC link.



Activity

Describe the two ways that electricity is carried on the National Grid:

2.2 Transmission Lines

Overhead transmission circuits consist of conductors (through which electricity flows easily) supported on steel towers or wooden poles. Conductors are generally made of aluminium strands, often on a core of steel strands, or of copper strands.

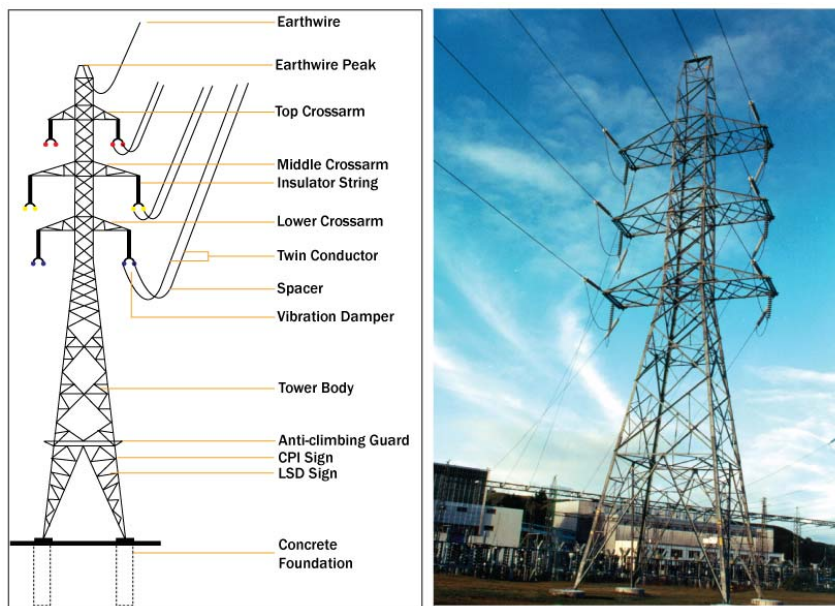
Glass or porcelain insulators (which withstand voltage and resist current flow) are used to suspend conductors on overhead lines.

An AC transmission circuit comprises one 3-phase circuit but double circuits are often carried on the same towers, i.e. 6 wires. These are sometimes protected from lightning by one or two earth wires carried above the phase conductors. Earth wires are commonly installed in the vicinity of the ends of the circuit.

The transmission circuit voltage may be estimated by counting the insulators in one "string" - about 12 for 220kV, 6 for 110kV, three for 33kV and one for 11kV. A reticulation circuit (from a distribution substation to the premises of end-users) often consists of a three-phase 400 volt circuit. This consists of a conductor for each phase and an additional (common return) neutral conductor.

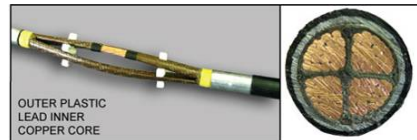
The higher the voltage, the greater is the distance required between live conductors and supporting structures.

Single-phase (230 volt) domestic supply is given from one phase conductor and the neutral conductor. Large end users may require three-phase supply.



Transmission lines.

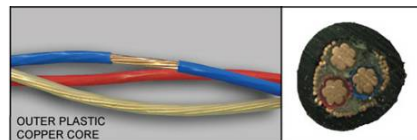
Higher voltage cables used for transmission or sub-transmission are usually enclosed in a lead or aluminium sheath.



Underground (and submarine) cables consist of conductors surrounded by paper or other insulation such as plastic.



Lower voltage cables used for distribution or reticulation may be similar but they may also be insulated with plastic with or without a copper earthed shield to control voltage stresses in the insulation.



2.3 Control Centres

The National Grid is controlled from the main control centre in Hamilton which because of its importance is duplicated in Wellington. A centre in Christchurch, Islington, also provides an important role and deals predominantly with South island needs. The amount of power to be transmitted north from the South Island (or vice versa) is decided by the Generation and Retail Market, and the two system control centres manage the restraints of the fluctuating demands for power for all hours of the day and night.

North Island

One main source for electricity generation in the North Island is the Waikato River which drives the turbines in eight hydro stations and provides the cooling water for two geothermal and one gas fired station. The electricity from the Waikato stations is relayed through the Whakamaru switching station (as distinct from the power station of the same name).

The North Island network includes an extensive 220 kilovolt system reaching all the main centres, and 110 kV and 50 kV circuits to smaller areas. The 220 kV network covers 2120 km. The main grid is supplemented by over 3200 km of 110 kV circuits and 705 km of 50 kV circuits. There are also over 70 substations varying from smaller unmanned installations to large 220kV substations whose buildings and outdoor equipment may cover several hectares.

South Island

The principal feature of the southern system is the 220 kV grid extending almost the whole length of the island from Stoke, near Nelson, to Tiwai, near Bluff. The northern part of the West Coast is supplied by a 110 kV circuit from Kikiwa and the southern part by two 66 kV circuits from Coleridge through Otira.

The South Island network contains about 1600 km of 220 kV circuits and 1400 km of 110 kV circuits. There are also 1186 km of 66 kV circuits, one small circuit of 33 kV capacity and 53 substations of varying capacity

Substations

They play a major role in the transmission and distribution systems. Large industries such as the synthetic fuel plant cement industries and in steel production rely on a continuous uninterrupted supply of electricity. A loss of electricity to the synthetic fuel plant for one minute would cost the company millions of dollars.



Not only do substations link the transmission network together and distribute electricity to local power authorities, they are also the control, protection and metering centres for our industry. Control equipment allows areas and circuits to be shut down for maintenance to be carried out. Protection equipment ensures that people's lives are less threatened and that expensive equipment is not damaged during fault conditions. Metering is what gives us, as an industry, our revenue.

To perform these operations, along with the substations other functions, there needs to be an assortment of high voltage AC and low voltage DC equipment. Benmore and Haywards also have high voltage DC equipment. The picture shown on the right is a totally enclosed substation at Clyde, in the South Island.

The main function of a substation is to connect the country's main transmission systems to the distribution companies who, in turn, deliver the power to the consumer. At any station handling electric power, it is necessary to have one set of conductors to which all incoming and outgoing circuits can be connected. The conductors are called the bus bar or just the bus. Bus bars can be defined in simple terms as devices which are used to: "electrically connect transmission circuits, generators and distribution feeders together, along with other items of plant".

Substations also have many other functions. Substations, with the use of special equipment, control the voltage within the system. As is covered with transformers, the tapings on the secondary winding provide one method of voltage control. There are three more items of substation equipment, however, which are used as voltage control devices. They are:

1. The synchronous condenser,
2. Static capacitor bank, and
3. The reactor.

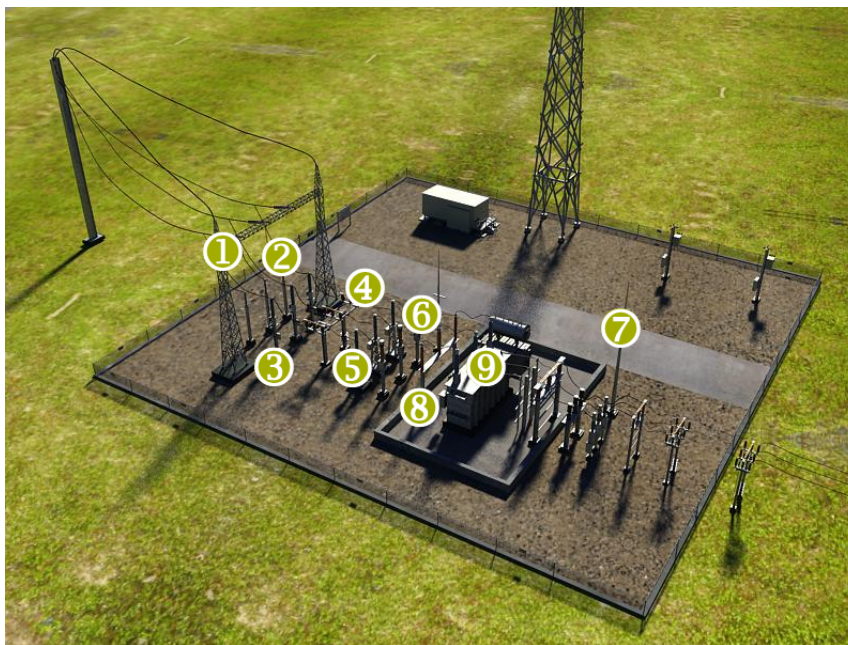
Each of the above regulates the voltage in a specific way. Power station generators are also capable of regulating voltage but they are normally too far from major load centres to be effective. Substations control equipment which can switch off, both manually and automatically, transmission circuits and power distribution feeder circuits when necessary. They can therefore respond more quickly to local conditions. For example, during times of critically low power supply, substations may provide those distribution companies with hospitals or industries, which must have a continuous supply, with power, in preference to those supplying household consumers.

Substations also have protection equipment which automatically operates during dangerous conditions. Should a power circuit somehow become short circuited, the protection equipment will trip the circuit breaker on that circuit to protect people and equipment from possible danger.

Substation protection equipment is quick to react, reliable, discriminative and stable. Each of these qualities is a must when considering the lives and property of consumers and staff. Telemetry is also necessary at most large substations to provide control centre with information which could affect the future loading of the power system.

Equipment

High voltage transmission circuits bring power into substations where it is collected together on bus bars. As the circuits come in, they pass through several disconnector switches and a circuit breaker as well as current transformers and in the case of 110 and 220 kV circuits, circuit traps. The disconnector switches and circuit breakers are part of both the protection and control systems of the substation.



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

The current transformers are an important part of the protection system as they detect changes in current caused by fault conditions. They send this current to the protective relays which instruct the circuit breaker to open when necessary.

Line traps, found on the ends of 110 and 220 kV transmission circuits and looking much like cotton reels suspended or supported high in the air, are used for communication between substations, power stations and the control centre.

Step down transformers are used to change the high voltage into a lower voltage suitable for distribution. The low voltage side of the transformer is normally provided with a tap changing mechanism which allows the load on the distribution bus bars to be controlled. There may be many distribution feeders leaving the substation to provide several distribution network companies with distribution circuits.

The load, so commonly referred to, is the amount of power being drawn from the supply by the customer demand. This load fluctuates during the day and night depending largely upon the type of consumers and the weather conditions at the time. The type of load will determine the type of equipment within the substation.

A consumer area which has a lot of industrial machines, causes a peak loading during the working hours about three times as great as the load in the same area during out of work hours. This peak load causes the voltage on the transmission circuits to drop. During the night when the machines are not working, the voltage on the same transmission circuits tends to be too high. A synchronous condenser is employed in the substation to regulate the voltage.

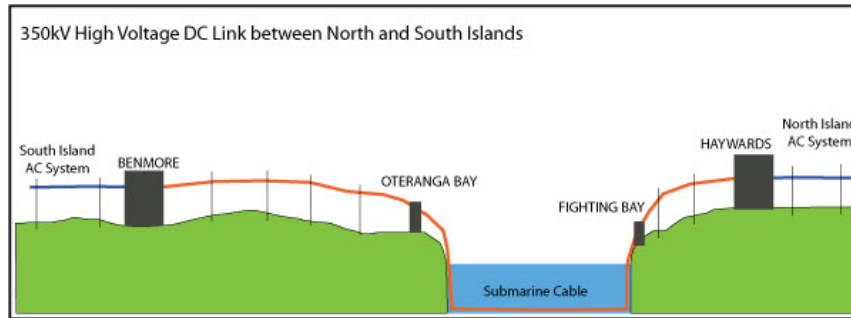


Activity

What can cause the 'load' to fluctuate?

2.3 High Voltage Direct Current Link

Since 1965 the North and South Islands have been linked by the Inter-Island D.C. transmission submarine cables across Cook Strait. In 1976 equipment was installed at Haywards substation and at Benmore to enable electricity to be sent from the North to the South Island if necessary. The electricity generating resources of both islands are able to be co-ordinated to work to the economic advantage of the whole country.



HVDC Link.

Using DC transmission, however, is more economic for long distance point-to-point overhead transfer of power and, in addition, is technically superior for medium to long distance cable transmission.

Transmission of DC requires the conversion of the three-phase AC to DC at the sending end and back again to AC at the receiving end. The AC power is converted to DC power at the Benmore or Haywards terminal of the inter-island link for transmission between the islands (whichever is sending power). It is then converted back to AC power at the receiving terminal.



Activity

Describe the purpose of the HVDC Link.

2.4 New Zealand Electricity Market

The New Zealand Electricity Market (NZEM) is the term for the markets operated by M-Co (the Marketplace Company) where electricity is bought and sold every day. The market participants include generators, purchasers and traders of electricity.

Electricity generators compete to supply electricity to retailers and consumers across the national transmission grid. Generators offer electricity to the spot market, where it goes into a pool. Retailers bid for electricity from the pool to supply their customers. Once the retailer has purchased electricity, it is then transmitted to customers through the national grid. This is called a physical "spot" market.

Approximately three quarters of New Zealand's electricity is traded through the NZEM spot market. The remainder is covered by bilateral contracts directly between generators and consumers.

The key role of the NZEM is to ensure that electricity supply meets demand at all times in the most cost-effective way and to ascertain the spot market price of electricity in a transparent manner.

The key participants in the New Zealand electricity industry include:

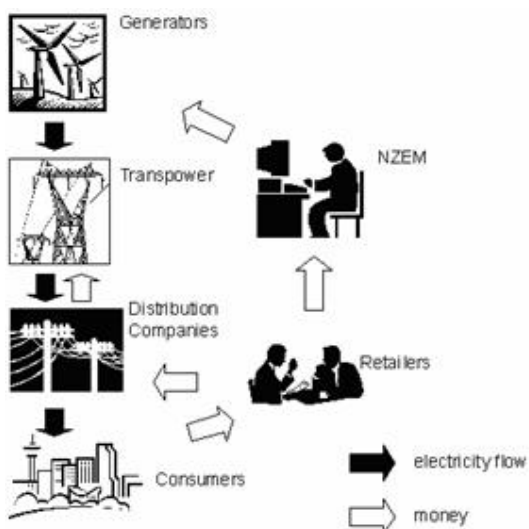
1. Electricity generators (generator market participants), who are capable of generating electricity and injecting it into the national grid for use where required. They submit offers to sell electricity to the NZEM. The main generators are Contact Energy, Genesis Energy, Meridian Energy, Mighty River Power and TrustPower.
2. Transpower, which owns and operates the national grid. The grid consists of a high-voltage transmission system that runs across the country. The grid connects to the power lines or networks owned by the distributor.
3. Electricity retailers (purchaser market participants), who submit bids to buy electricity, i.e. power companies and major industrial users of electricity.
4. Distribution companies, who own low voltage power lines that connect the national grid to households and businesses. They generally sell their services to retailers.
5. Consumers, who can buy electricity from their choice of retailer. Large consumers of electricity may access electricity directly from the national grid.
6. Traders (trading market participants) who buy and sell generation from the NZEM. These include buying groups who act on behalf of power companies and industrial users.
7. Service providers who have contracts to provide services to the NZEM, such as the market administrator, grid operator, scheduler, dispatcher, pricing manager, registry, reconciliation, and clearing manager.
8. Market Surveillance Committee who supervise the business conduct of all market participants.
9. Non-market participants, who do not buy or sell electricity through the spot market, but can affect the grid due to changes in supply and demand.
10. M-Co who provides ongoing services to the New Zealand Electricity Market through contestable contracts. They administer the market and provide secretarial services, host and manage the trading and information systems, along with pricing, clearing and settlement functions.



Activity

What is the role of electricity retailers?

Name two electricity retailers:



The key flows of electricity and money in the market.

Generators may also have contracts to supply electricity directly to companies and other consumers.

The wholesale electricity market was established in 1996. It operates under a self-regulating structure, with mechanisms for selecting a governance board, setting, changing and enforcing its rules, and resolving disputes.

The trading of electricity is governed by the NZEM Rules and a set of industry rules called MARIA (the Metering and Reconciliation Information Agreement).

Bids and Offers

Each trading day, purchasers will submit bids and generators will submit offers to the Scheduler by 1300 hours. The bids detail the prices that the purchaser is prepared to purchase electricity from the Clearing manager for each trading period of the following trading day.

The offers detail the prices that the generator is prepared to generate and sell electricity to the clearing manager for each trading period of the following trading day.

Each offer or bid consists of tranches. A tranche can be defined as a quantity of generation (or reserve) at a particular price level, offered/required for a particular node for a half hourly time period. Any outages, ramp rates and constraints are incorporated into the tranches.

The offers and bids are submitted to the market and then combined to create quantities each generator will produce, and marginal prices (the dispatch schedule), and generation is dispatched.

Pricing

There are two main types of electricity price in New Zealand:

The retail price

The retail price is what domestic consumers pay retailers for supplying them with electricity. The retail price is what consumers see in an electricity bill. The wholesale price is very different - this is the price set by the wholesale electricity pool or NZEM.

The wholesale price

The wholesale price does affect the retail price, but it tends to fluctuate a lot more as it is set by competitive behaviour in the market.

The 'typical' electricity bill is made up of three different charges:

1. Generators charge for the amount of power used and the cost of generation.
2. Transmission and Distribution costs are to pay for the cables and wires that transport electricity.
3. Retailers sell the electricity and provide support services.

The industry has developed a low-cost system so customers can now switch between their electricity retailers.

At the wholesale spot market level, electricity is bought in half-hour slots at whatever price the market ascertains. Before competition there was no direct link between the retailers' cost of buying electricity at each half-hour slot, and the price domestic consumers paid (unless they had a half-hour meter). Retail competition was made possible by introducing a new system linking the two prices - this system is called "profiling".

Essentially, profiling estimates a consumer's half-hourly electricity consumption by looking at their average consumption at different times (their "profile"). Profiling lets the retailer know how much electricity its consumers use on a half-hour basis. More importantly, it enables the retailer to sell electricity to any consumer anywhere in the country.

A national database, called the "Registry", is at the centre of the system that profiles all 1.5 million electricity consumers in New Zealand. It identifies every electricity meter by a unique number or "ICP" (Installation Control Point). ICPs are printed on the consumer's monthly power bill and that number is what they reference if they want to switch electricity retailers.



Activity

Describe the charges that make up a 'typical' electricity bill.

3. Distribution Systems

At substations, electricity is transformed to lower voltages then conducted to end users by overhead wires or underground cables owned by local distribution companies. There are currently 28 of these, mostly regionally based, varying from publicly listed companies to community-owned trusts. The 1998 Electricity Reform Act requires retail, generation and distribution companies to be separate, and preventing lines companies from being generators or retailers.

The Electricity Industry Reform Act was passed and this involved a comprehensive revision of the distribution of electricity within New Zealand. The Electricity Industry Reform Act 1998 limits to a maximum of 10% any cross-ownership between electricity distribution assets and either electricity generation or electricity retailing activities. The term 'Line Business' is used to describe the separated delivery function and there are presently 27 distribution line businesses serving New Zealand's 1.89 million electricity users.

Line Business	GWh Delivered per year	No. of Consumer Connections
1. Vector	10,300	660,000
2. Powerco	4,200	305,000
3. Orion	3,100	181,000
4. Unison	1,600	105,000
5. Aurora Energy	1,300	76,000
6. WEL Networks	1,000	79,000
7. Northpower	930	51,000
8. Network Tasman	736	34,400
9. Alpine Energy	626	29,200
10. The Power Company	621	32,200
11. Horizon Energy	590	23,900
12. Counties Power	475	34,800

13.	Electricity Ashburton	470	15,800
14.	MainPower	461	30,700
15.	Electra	385	40,500
16.	Marlborough Lines	331	22,900
17.	Top Energy	325	28,500
18.	Waipa Networks	315	21,500
19.	The Lines Company	295	26,200
20.	Eastland Network	283	24,900
21.	Electricity Invercargill	260	16,900
22.	Westpower	211	12,000
23.	Network Waitaki	190	12,000
24.	Nelson Electricity	145	8,900
25.	Centralines	106	7,700
26.	Scanpower	90	6,700
27.	Buller Network	41	4,200

4. Utilisation of Electricity

There are two main players in the use of electricity. They are the retailers and the consumers. The retailers sell the electricity and the consumers buy and use it.

Retail companies sell delivered electricity to end-users. There are currently six energy retailers in New Zealand.



Energy retailers.

Consumers purchase electricity from the retailers and are charged on the basis of how many kilowatts they use over a period of time. The basic unit for charging electricity costs is the kilo-Watt hour (kWh). One kWh is referred to as one unit of electricity.

- > Ten 100W lamps used for one hour will use one unit of electricity.
- > One 1000W heater used for one hour will use one unit of electricity.



Activity

How much do you pay for a unit of electricity (24 hour power).

One 1000W heater used for one hour will use one unit of electricity. Based on the cost of a unit of electricity, how much will it cost to run a 1000W heater for three hours?



Electricity meter measuring electricity usage.

5. Relationships Between Key Industry Players

There are four main key industry players in the electricity sector. They are:

Control Centre Operators

Monitor and operate equipment on transmission lines and/or power generating stations. They control the electricity that is generated and distributed to a particular region.

Transpower Coordination Centres

There is the Hamilton and Christchurch centres. They have overall control of the national grid and are responsible for the restoration of supply following system incidents.

Regional Operating Centres

Are responsible for operating the grid assets to the specific requirements of the Transpower Security Coordinator.

Power Companies/Direct Consumer/Generator Control Centres

Manage Power Company's/Direct Consumer's/Generator's network.

5.1 Control Centre Operator

A Control Centre Operator monitors and operates equipment on transmission lines and/or power generating stations. They control the electricity that is generated and distributed to a particular region. As an Operator your prime responsibility is to monitor the system and ensure that it is operating safely and within the guidelines set by your company and/or industry. Monitoring and operation is typically undertaken using computerised systems that communicate with the equipment.

The distribution demands on a generation station or substation change daily due to system outages, repair work, weather and other factors. It is the Operator's job to coordinate, schedule and direct power loads and line voltages to meet these demands. At various times, there is repair work or construction that requires part of the system to be isolated and shut down. This will require the analysis of power system drawings and preparation of switching orders to isolate the work areas without causing a power outage. Also to be taken into consideration are voltages, load transfers and line capacities in order not to overload part of the system.

Maintenance crews cannot work on a power system without a permit. It is part of the job as an Operator to issue these permits for maintenance work that must be performed on the system. Before maintenance crews receive their permit, the section of the system to be worked on must be de-livened and isolated. This ensures that the crew can work safely without risk of electrical shocks. Most of the switching and shutting down of power is done using the computerised control system.

There may also be a need to inspect transformers, breakers and other equipment at the local station if appropriate. If there is a problem, a maintenance crew should be called.

Control Centre Operators are responsible for the electrical power in their area - either generated, transmitted or distributed power. Much of the role of an Operator consists of monitoring of the system and performing routine duties, but if there is a disturbance or malfunction in the system, it is their responsibility to restore power as quickly and safely as possible.

There are different types of control centres that exist within the electricity supply industry where controllers may work.



Activity

What is a control centre operator's prime responsibility?

5.2 Transpower Coordination Centres

There are two National Coordination Centres managed by Transpower - The North Island Centre in Hamilton, and the South Island Centre in Christchurch. The Transpower centres have overall control of the national grid and are responsible for the restoration of supply following system incidents. There are two roles in each of the centres, that of the Energy Coordinator (who controls the dispatch processes at the generator/transmission interface) and the Security Coordinator (manages the secure operation of the power system). Their combined responsibilities include:

1. Real time management and operational control of the power system, ensuring the optimisation of transmission capability within capacity limits; optimisation of active and reactive power flows; security of the national grid; quality and continuity of supply; management of constraints; compliance with the Coordination Policy, NZEM Rules and any contracted obligations.

-
2. Creation and issue of MW, reserve, voltage, VAr and frequency dispatch instructions. Pre-dispatch planning is undertaken to formulate dispatch instructions. In the real-time, MW dispatch instructions are issued in order to balance supply and demand; reserve is dispatched to ensure that quality of supply is maintained in the event that a contingency occurs; dispatch and optimisation of voltage control equipment ensures that supply quality contracts are met and grid capacity is maximized; frequency keeping is allocated to ensure that the service is provided at least cost while meeting defined quality standards.
 3. Monitoring of connected parties performance to identify and report when dispatch instructions/profiles are not being met.
 4. Fault/contingency management - identification of priorities, appropriate actions, coordination and monitoring of actions.
 5. Voltage management - operation of static capacitors, tapchangers, SVCs and condensers in conjunction with issue of volt/Var dispatch instructions.
 6. Carry out remote circuit breaker operations using SCADA to disconnect and reconnect equipment to the system for planned work and fault restoration.
 7. Liaise with Regional Operating Centres in planning switching sequences to remove and return equipment to service, or during fault restoration switching.
 8. Reporting and logging of internal and external customer information on dispatch instructions; use of ancillary services; schedule deviations; discretionary actions; unplanned events; frequency keeping constraints; bona fide claims; incidences of excursions.
 9. Observance of security requirements as laid down in Standing Instructions, Coordination Policy and any other contractual requirements. Contingency analysis and power flow studies are performed during planning and in real-time to ensure the security of the system.
 10. Development and publication of the pre-dispatch, security, dispatch and frequency keeping schedules in accordance with NZEM requirements.



Activity

Where are the two national coordination centres that are managed by Transpower located?

5.3 Regional Operating Centres

Regional operating centres are located in Auckland, Wellington and Christchurch. The Regional Operator is responsible for operating the grid assets (including HVDC) to the specific requirements of the Transpower Security Coordinator, and within the equipment performance parameters provided by the asset owner(s). Responsibilities include:

1. Normal operational control of grid interface equipment, i.e. switching on 33kV, 22kV and 11kV regional supply buses, associated CBs and disconnectors. The boundary point for this equipment is generally defined as the bus side of the supply transformer LV CB.
2. Operational control of some grid system equipment under an ongoing delegation (transfer of control) from the Security Coordinator.
3. Monitoring of the in-service equipment and reporting of abnormalities.
4. Planning switching sequences for removal/restoration of equipment from/to service.
5. Calling out maintenance contractors for faults and for planned switching when stations require attending.
6. Issuing switching instructions to maintenance switchers to carry out field operation of disconnectors, circuit breakers, VT switching, etc.
7. Issuing and receipt of Transfers of Control (TOC) to/from maintenance switchers on removed from service equipment for maintenance.
8. Monitoring station bus bar voltages.



Activity

List four responsibilities of regional operating centres:

5.4 Power Companies, Direct Consumers, Generator Control Centres

1. Manage the Power Company's/Direct Consumer's/Generator's network.
2. Liaise with the Regional Operating Centre/Transpower Coordination Centre for switching across the Transpower/Power Company/Generator boundary.

The generating set interface circuit breaker is usually owned by the generator and controlled by the generator's controller as required. This may include the interface CB for a number of generating sets connected to the grid at a common point. Transpower normally owns the bus selecting disconnector(s) for the generating set(s). The control of these disconnectors at some sites is delegated to the generator, under a written agreement.

5.5 Operator Liabilities

Control Centre Operators are required to comply with NZ Government Legislation and Regulations in carrying out their duties. This means there are legal implications and consequences in the actions they perform each day.

The regulations are controlled by the NZ Electricity Commission and they are required to work under the NZ Electricity market rules which are written to ensure 'fair play' and safe operations. If an operator is found in-breach of this legislation and rules, there may be financial liabilities imposed on the company they work for.

Actions taken by operators responsible for generating stations may have an impact on resource availability and environmental effects, e.g. storage in hydro lakes, downstream effects, and gas emissions.

This all means that an operator's job is very critical to the successful operation of the national electricity supply system and personally quite demanding.



Activity

What could happen if a control centre operator did not comply with legislation?

6. Trainees in the Electricity Supply Industry

6.1 The National Qualifications Framework (NQF)

The National Qualifications Framework (NQF) is the structure that contains every approved educational qualification available in New Zealand. It lets students and workers gain nationally and internationally recognised qualifications as they complete particular courses. Anyone who gains a qualification on the NQF has it recorded on his or her Record of Learning. You may already have a qualification.

There are three types of national qualifications:

1. National Certificates (Levels 1-4)
2. Diplomas (Levels 5-6)
3. Degrees (Levels 7-8)

Most qualifications gained in the workplace are national certificates, although some people may progress to complete diplomas and even degrees. A national certificate qualification is made up of a number of unit standards.

A unit standard describes what you should know or be able to do as a result of your learning - it's a learning outcome. Every unit standard is worth a certain number of credits. You are assessed against a Unit Standard, and if you meet the standard, you earn the credits. Once you've earned enough credits, you've earned your national certificate - it's as simple as that. The number of credits allocated to a Unit Standard depends on how much time it is likely to take to complete it. Each credit is approximately 10 -12 hours of learning.

There are more than 17,000 registered unit standards and over 800 national certificates and national diplomas covering almost every area of work and learning.



Where there is an industry training organisation (ITO), the ITO becomes the approved standard setting body (SSB), developing unit standards and national qualifications. ESITO is the national standards setting body for the electricity supply industry (ESI).



Activity

What does NQF stand for?

What is the function of the NQF?

6.2 You and ESITO

The role of ESITO is to help both companies and individuals meet their training needs. We work with your employer to help them develop training programmes for staff. ESITO is also here to help you develop your Career Pathway.

ESITO is the approved standard setting organisation for the Electricity Supply Industry. However, ESITO can also arrange training in a wide variety of courses that are not specific to the Electricity Supply Industry.

As a learner who is registered with ESITO, we will ensure that:

1. You are registered with the NZQA,
2. All credits which you achieve will be recorded on your Record of Learning,
3. You are fully informed of the training you need to complete,
4. You are mentored and coached to help you gain competence in each task,
5. Suitable off-the-job training courses are provided, and
6. Any national qualifications you gain are sent to you.

Every learner being assessed for qualifications receives a Record of Learning. This lists all Unit Standards, National Certificates and National Diplomas achieved in the previous years. You can accumulate Unit Standards over a number of years and from many different Training Providers until you have completed a qualification. Your Record of Learning provides your employer with a profile of your achievements. Your ESITO Record of Learning is available on the ESITO website and you will be issued a pin number to access it.

Being a Trainee means:

1. You will be trained to do your job,
2. You will learn to work safely and to look after the safety of others,
3. You will learn more and more skills,
4. Your skills will be recognised as educational qualifications,
5. You can plan your career, and
6. As you work your way through the training modules you will probably find that getting new knowledge and skills is something that gives you confidence to do your job better and to try to develop your career further by doing more training.

ESITO Training Agreements (TAG's) are required for all Trainees/Learners undertaking ESITO funded Training and assessment programs for Unit Standards and Qualifications.



Activity

What is ESITO's role?

What does it mean to be a trainee?

Next Steps

Well done! You have completed the training assessment resource for Unit Standard 18275 – Demonstrate knowledge of the New Zealand electricity supply industry.

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

Model Answers to Activity Questions



Activity (page 6)

List the location of three different types of generation that we use to supply electricity in New Zealand in the table below. The first one has been done for you.

Generation Type	Location within New Zealand
Hydro (water)	Manapouri

Any of the following or other valid generation types and locations:

Thermal - Southdown, Otahuhu, Huntly

Geothermal – Wairakei, Pohipi, Mokai, Rotokawa

CoGen – Te Rapa

Wind – Palmerston North

Hydro – Waikato River (Arapuni, Karapiro, Waipapa, Maraeti, Whakamaru, Atiamuri, Ohakuri, Aratiatia) Tongaririo, Benmore, Clutha



Activity (page 11)

What are Wairakei and Ohaaki power stations supplied with?

Geothermal steam

Name the only moving part in a basic steam turbine.

Rotor



Activity (page 13)

How many geothermal power stations are there in New Zealand?

Nine



Activity (page 15)

List three disadvantages of coal fired power stations:

Any three of:

1. Coal is not a renewable resource.
2. During the production of electricity carbon dioxide is released, increasing the amount of greenhouse gases in the atmosphere.
3. Sulphur dioxide, nitrogen oxide and nitrogen dioxide are also produced in these emissions and can produce acid rain.
4. Mining coal damages the environment.
5. Coal-fired power stations create thermal pollution, i.e. increasing the temperature of an environment above natural levels creating a potential hazard to ecosystems.



Activity (page 18)

What is the disadvantage of solar electric generation?

Solar electric is very expensive to establish because of the equipment costs.

Name three renewable energy resources:

Wind, solar and wave.

List two disadvantages of wind energy:

1. It is sustainable in the long term
2. Environmental impacts are minimal



Activity (page 21)

Who owns and manages the national grid?

Transpower



Activity (page 22)

Describe the two ways that electricity is carried on the National Grid:

1. High voltage alternating current
2. High voltage direct current



Activity (page 27)

What can cause the 'load' to fluctuate?

Weather, day or night, customer demand, type of consumers.



Activity (page 28)

Describe the purpose of the HVDC Link.

To transport large amounts of electricity over a long distance efficiently. It goes from Benmore to Haywards.



Activity (page 30)

What is the role of electricity retailers?

To provide a place for consumers to purchase electricity. They also provide metering that measures the electricity used at each connection point.

Name two electricity retailers:

Any two of:

Genesis Power

Meridian

Contact Energy

Mercury Energy

Trustpower

Energy Online



Activity (page 32)

Describe the charges that make up a 'typical' electricity bill.

Energy usage in 'units'

Line charges for the national grid and networks



Activity (page 35)

How much do you pay for a unit of electricity (24 hour power).

Depends on the area.

One 1000W heater used for one hour will use one unit of electricity. Based on the cost of a unit of electricity, how much will it cost to run a 1000W heater for three hours?

Calculation will depend on rate but should follow as below:

$$(1000 \text{ W} \times 3 \text{ hours}) \times \$0.18 = \$0.54$$



Activity (page 38)

What is a control centre operator's prime responsibility?

Control centre operators are responsible for the electrical power in their area – either generated, transmitted or distributed power. Much of the role of an operator consists of monitoring the system and performing routine duties, but if there is a disturbance or malfunction in the system, it is their responsibility to restore power as quickly and safely as possible.



Activity (page 39)

Where are the two national coordination centres that are managed by Transpower located?

Christchurch (Islington) and Hamilton (Hall Road).



Activity (page 40)

List four responsibilities of regional operating centres:

Any four of:

1. Normal operational control of grid interface equipment, i.e. switching on 33kV, 22kV and 11kV regional supply buses, associated CBs and disconnectors. The boundary point for this equipment is generally defined as the bus side of the supply transformer LV CB.
2. Operational control of some grid system equipment under an ongoing delegation (transfer of control) from the Security Coordinator.
3. Monitoring of the in-service equipment and reporting of abnormalities.
4. Planning switching sequences for removal/restoration of equipment from/to service.
5. Calling out maintenance contractors for faults and for planned switching when stations require attending.
6. Issuing switching instructions to maintenance switchers to carry out field operation of disconnectors, circuit breakers, VT switching, etc.

7. Issuing and receipt of Transfers of Control (TOC) to/from maintenance switchers on removed from service equipment for maintenance.
8. Monitoring station bus bar voltages.



Activity (page 41)

What could happen if a control centre operator did not comply with legislation?

There could be financial penalties.



Activity (page 43)

What does NQF stand for?

National Qualifications Framework.

What is the function of the NQF?

The structure contains every approved educational qualification available in New Zealand.



Activity (page 44)

What is ESITO's role?

The role of ESITO is to help both companies and individuals meet their training needs. We work with your employer to help them develop training programmes for staff. ESITO is also here to help you develop your career pathway.

What does it mean to be a trainee?

To follow the training pathway and up skill to achieve my qualification.