UNDERSTANDING ELECTRICAL TRANSMISSION

The *National Grid Transmission Model* is a practical resource designed to support the teaching of electricity generation, transmission and distribution. There is an accompanying booklet '*Understanding Electrical Transmission: A Guide to the National Grid Transmission Model'*, which describes a range of teacher demonstrations that can be undertaken. These demonstrations are intended mainly for students aged 14-16, but the approaches can be adapted for younger or for older students. In addition, there is a set of PowerPoint presentations that can be used by teachers in the classroom.

What's in this document?

This document includes the slides and the accompanying notes for teachers for all of the PowerPoint presentations. A number of demonstrations involve the generation of high voltages, *and these demonstrations must not be undertaken by students under any circumstances*. You should refer to the booklet 'Understanding Electrical Transmission: A Guide to the National Grid Transmission Model' for further information before using the practical resources.

The teacher demonstrations

The teacher demonstrations are grouped into five sections:

A Introducing the system: generation and transmission
- A1 How is electricity generated and transmitted?

B A closer look at the parts of the system
- B1 How does the coil work?
- B2 Generating electricity
- B3 Connecting the generator to a load
- B4 How is the voltage changed?
- B5 Step-up and step-down transformers

C Maximising the efficiency of transmission
- C1 Transformers and power
- C2 Why are high voltages used for transmission?

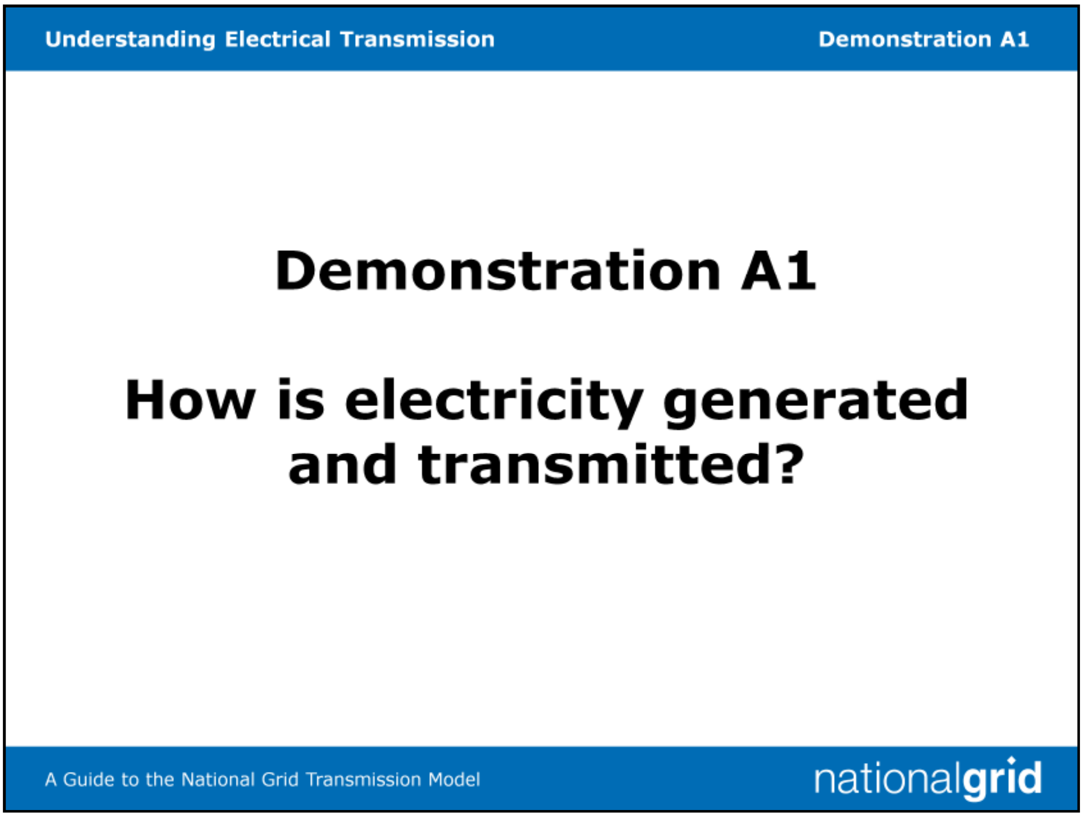
D Making measurements of power
- D1 Power losses in transmission

E Electricity demand
- E1 Monitoring the National Grid frequency

Obtaining the resources

A pdf version of the booklet 'Understanding Electrical Transmission: a Guide to the National Grid Transmission Model' and a set of PowerPoint presentations are available on the National Grid website (http://nationalgrideducation.com/resources/).

The National Grid Transmission Model is available for purchase from Mindsets (product code NAT GRID1) (http://www.mindsetsonline.co.uk).



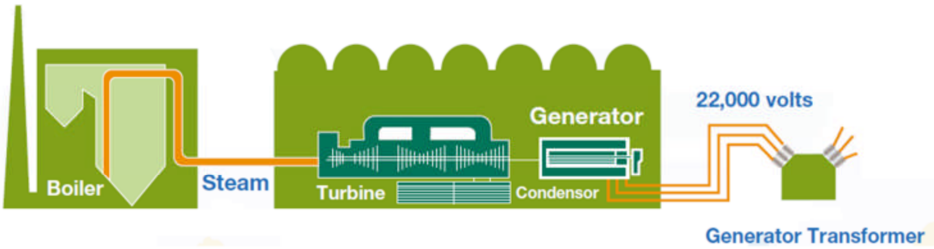
This PowerPoint presentation accompanies the booklet *Understanding Electrical Transmission: A Guide to the National Grid Transmission Model*. A pdf file of the booklet can be downloaded from http://nationalgrideducation.com/resources/. This includes a series of teacher instruction sheets for the demonstrations which can be used alongside the PowerPoint presentations: alternatively, the instructions are also reproduced in the notes for each slide.

The demonstration described here uses the National Grid Transmission Model, and *involves high voltages*. It should only be undertaken by a teacher. Questions for students are shown in the boxes.

The National Grid Transmission Model is a simple model of the way that electricity is generated and transmitted in the UK. This demonstration looks at some of the key components of the kit and how they relate to the real-world electricity system – from the power station to our homes.

Understanding Electrical Transmission — Demonstration A1

Generation of electricity



Power stations are owned and operated by energy companies.

A Guide to the National Grid Transmission Model

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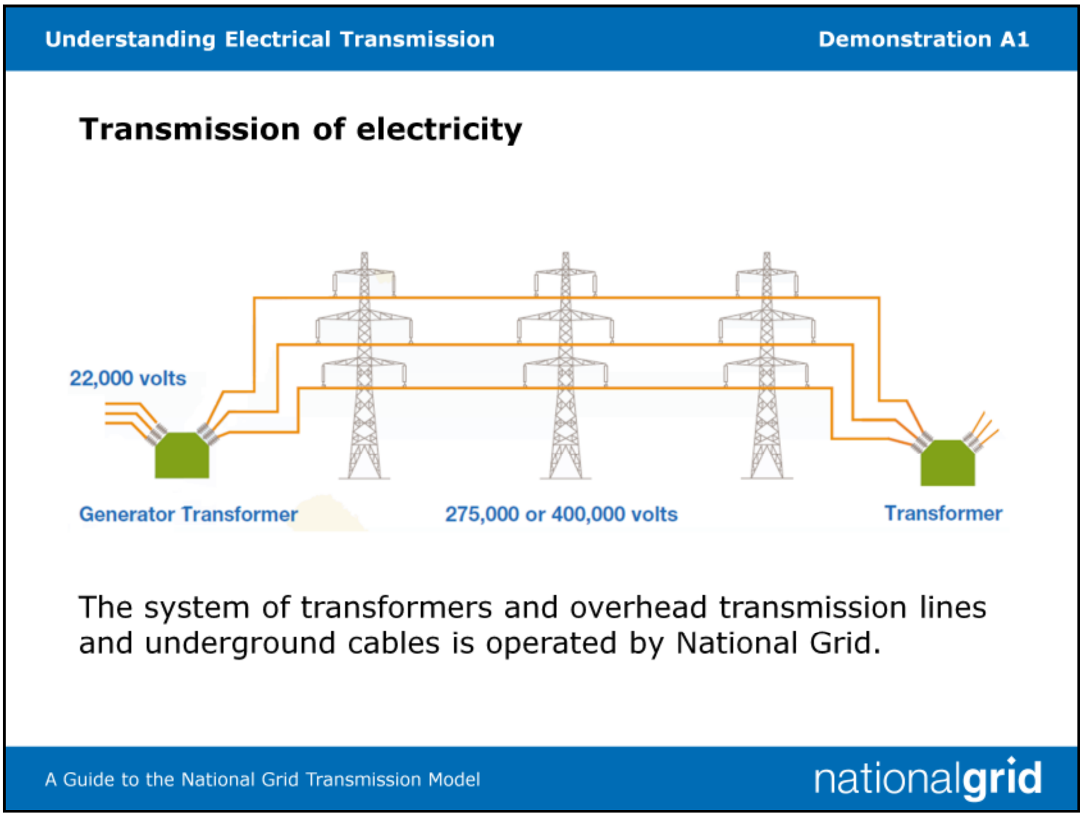
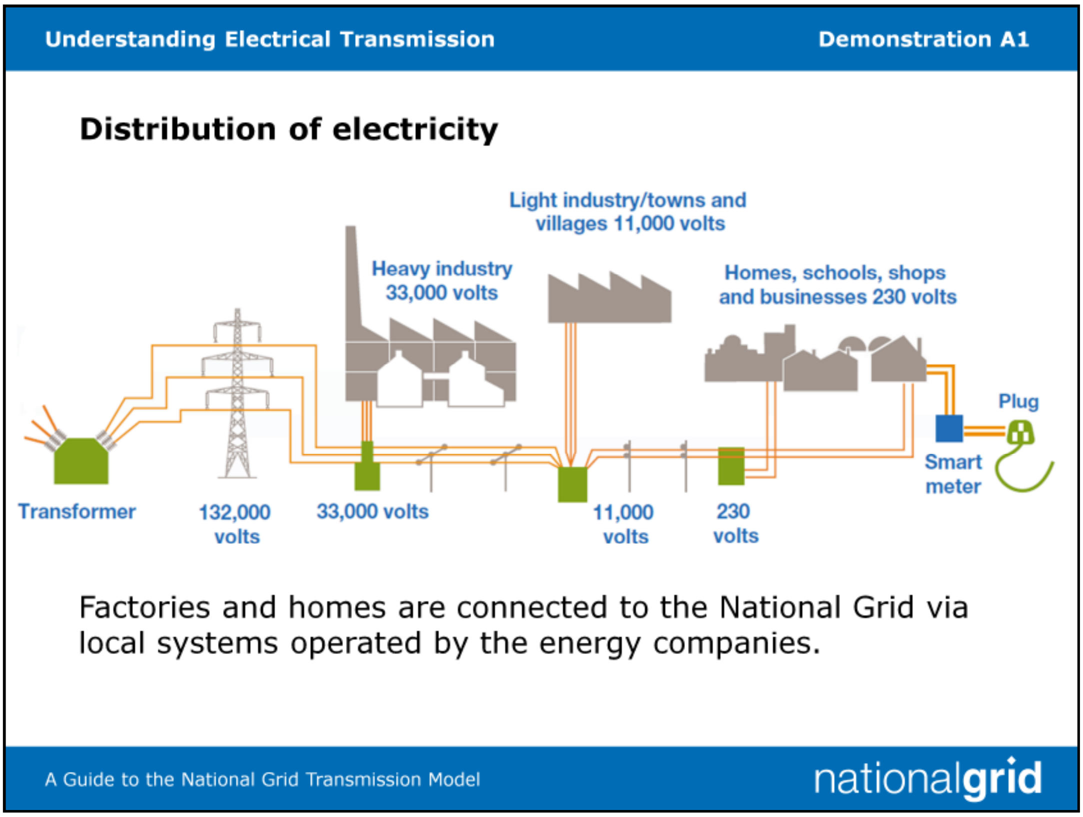
Today, electricity is generated from a variety of energy resources. Most electrical power is produced from fossil fuels (gas and coal) in thermal power stations. Water in a boiler is heated by burning fuels creating steam. This high-pressure steam passes over the turbine blades making the shaft rotate. This turns the generator, producing an electric current.

Nuclear fuels (and biofuels and geothermal energy) are used in a similar way, making water hot to generate steam. A number of renewable resources (wind, hydroelectric, tidal and wave power) are used to turn the generators directly. Photovoltaic cells (solar power) can generate an electric current directly.



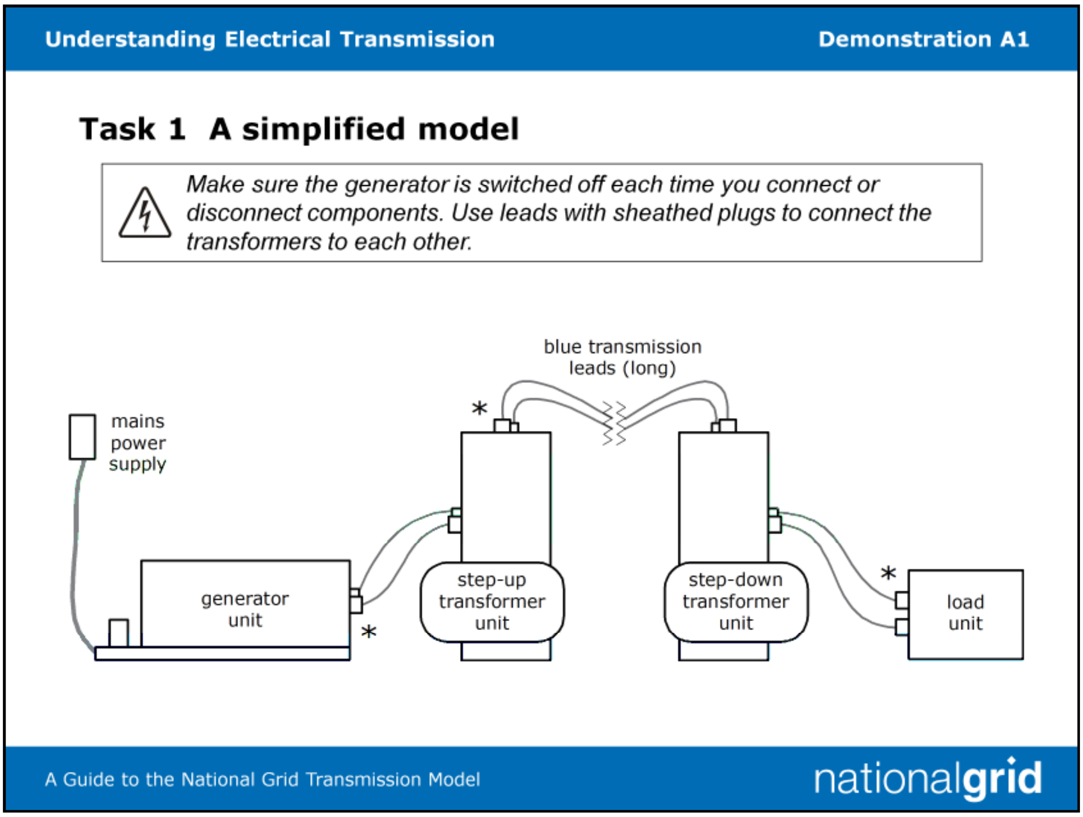
A thermal power station generates electricity at around 22 000 V, though the exact voltage depends on the power station. This is stepped up at the generator transformer, before transmission via the National Grid at either 275 000 V or 400 000 V. The modern national Grid consists of 7000 kilometres of overhead lines, 22 000 transmission towers, over 1300 kilometres of transmission electrical underground cables and around 300 substations.

The substations are the connecting points for the system, and include the transformers (for changing the voltage), and circuit breakers (for controlling the flow of electricity). The grid is now also connected overseas via underwater cables known as ‘interconnectors’ to Northern Ireland, France and the Netherlands.



The National Grid is connected to local distribution systems and the voltage is now stepped down using the grid supply transformers. The distribution system supplies customers with a wide range of needs, and for domestic use the voltage is successively stepped down until it reaches our homes at 230 V.

Note that in these schematic diagrams, the electricity supply is represented by three lines, until this becomes two lines for domestic supply. This is because the generator actually contains three electrical circuits producing currents in sequence as a magnet rotates past them. This is known as ‘three-phase’ and makes better use of the available space inside the generator. Factories use all three phases for greater power, though in the home we only use one of these phases (the ‘live’ wire).



Connect the four parts of the system as shown (using the long blue transmission leads between the two transformer units). With the generator unit switched off, plug in its mains power supply.

Set the drive control on the generator unit to ‘8’ and set the load unit to ‘High’.

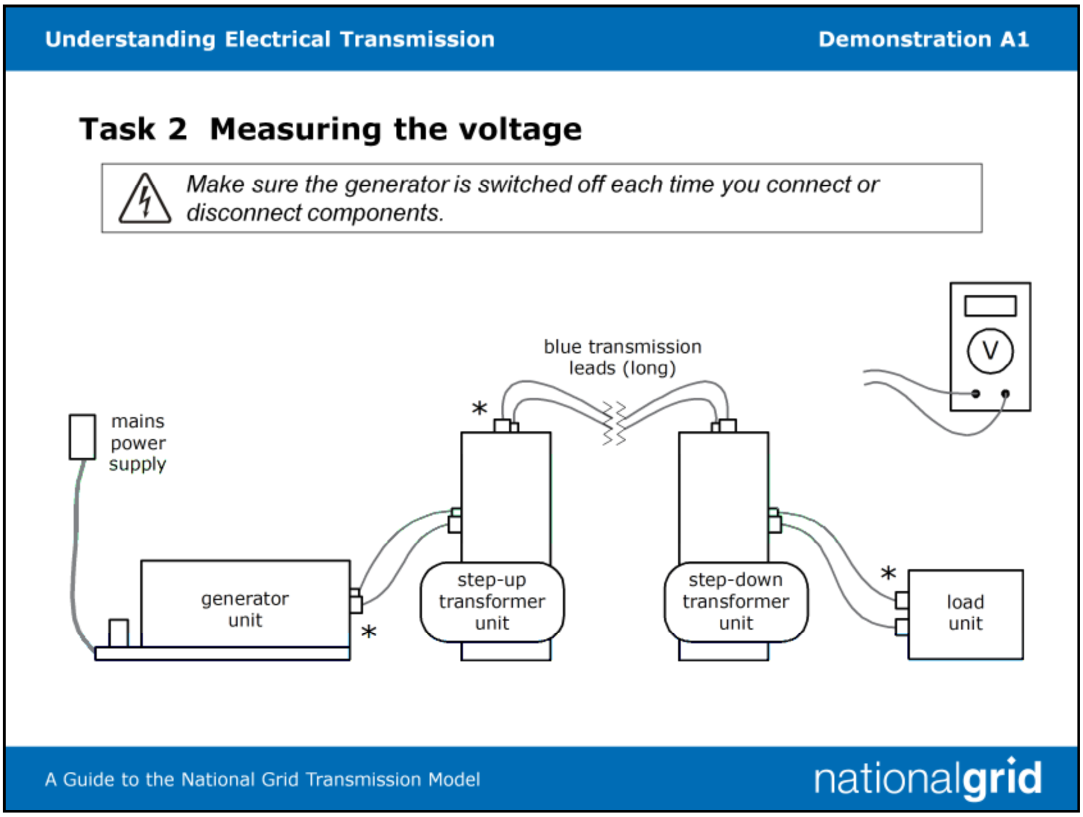
Switch the generator unit on. The LED on the load unit should light.

Note the key parts of the system that can be related to the real-world system – the drive motor, the magnet and coil, the step-up transformer, the transmission leads, the step-down transformer, the load unit.

1. Key parts of the model are the drive motor, the magnet and coil, the step-up transformer, the transmission leads, the step-down transformer, the load unit.

Below is a list of key elements related to electricity transmission. What do they correspond to in the transmission model?

- boiler and turbine
- generator
- generator transformer
- overhead power lines
- transmission towers (pylons)
- underground cables
- substation
- grid supply transformer
- factories and homes.



You will need three multimeters (a.c. voltage setting): one of these needs to accept shrouded plugs.

Switch off the generator. Connect the multimeters in the following three positions (marked *):

- across the output sockets of the generator
- across the output sockets at the top of the step-up transformer (using leads with shrouded plugs)
- across the input sockets of the load unit.

Switch on the generator and note the three voltage readings.

Switch off the generator and disconnect the multimeters.

2. For the transmission model, what are the voltages of the following?

- generator output
- transmission leads
- load input.

3. For the real-world system, what are the voltages of the following?

- generator output
- overhead power lines
- home electricity supply.

Understanding Electrical Transmission **Demonstration A1**

Task 3 Changing the load

4. What can you hear when the load is switched on and off?

5. What is the effect of the load on the speed of the generator?

6. Why do you think this happens?

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Switch on the generator (with the load unit set to ‘High’).

Listen carefully while you switch the load off. Listen again while you switch it back on.

Understanding Electrical Transmission | Demonstration B1

Demonstration B1

How does the coil work?

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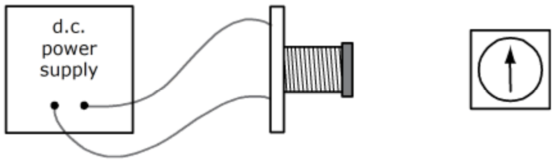
The demonstration described here uses the National Grid Transmission Model. Questions for students are shown in the boxes.

An essential part of the generator unit is a small coil of copper wire. This demonstration looks at the way that this coil behaves, and at the way that magnetic fields and electrical currents are related. These principles are applied in a wide variety of devices including motors, loudspeakers, dynamos and generators.

Understanding Electrical Transmission **Demonstration B1**

Task 1 Passing a current through the coil



1. What happens to the compass needle when the coil is moved closer to it? What does this show about the coil?

2. What happens to the compass needle when the power is switched on and off? Why do you think this happens?

3. This effect is sometimes called the 'motor effect'. Why do you think it is given this name?

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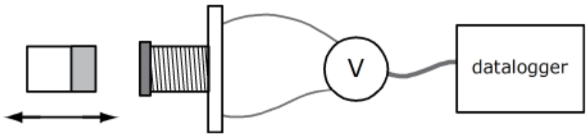
Connect the test coil to a power supply (1 V d.c.), and switch on the power.

Hold the coil in your hand and move it closer to the needle of a compass. Move the coil away.

Switch off the power and hold the coil close to the compass. Switch the power on and off several times.

Understanding Electrical Transmission — Demonstration B1

Task 2 The effect of a magnet on the coil



4. What happens to the voltage across the coil when the magnet moves towards the coil?

5. What happens to the voltage when the magnet moves away from the coil?

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Remove the coil from the power supply and connect it to the voltage sensor (e.g. ±1 V) of a datalogger connected to a computer.

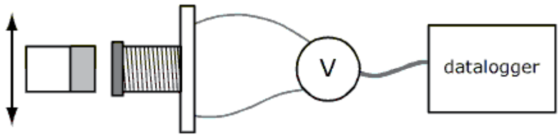
Select suitable settings for the datalogger (e.g. scale: ±500 mV, duration: continuous, sample interval: 30 ms).

Start the datalogger to show a real-time graph.

Hold the test magnet in your hand with its face pointing at the end of the coil. Bring it up slowly to the coil, and hold it there. Then move it away.

Repeat, trying the effects of moving the magnet at different speeds.

Understanding Electrical Transmission | **Demonstration B1**



6. What happens to the voltage across the coil when the magnet oscillates in front of it?

7. Which of the following is true?
- A voltage is produced across the coil when the magnet is held near it.
- A voltage is produced across the coil when the magnet is moved near it.

8. What factors affect the size of the voltage?

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Hold the face of the magnet close to the end of the coil. Then move it from side to side in front of the coil.

Repeat, doing it a little closer to the coil.

Ask a student to move the magnet across the face of the coil. What do they feel?

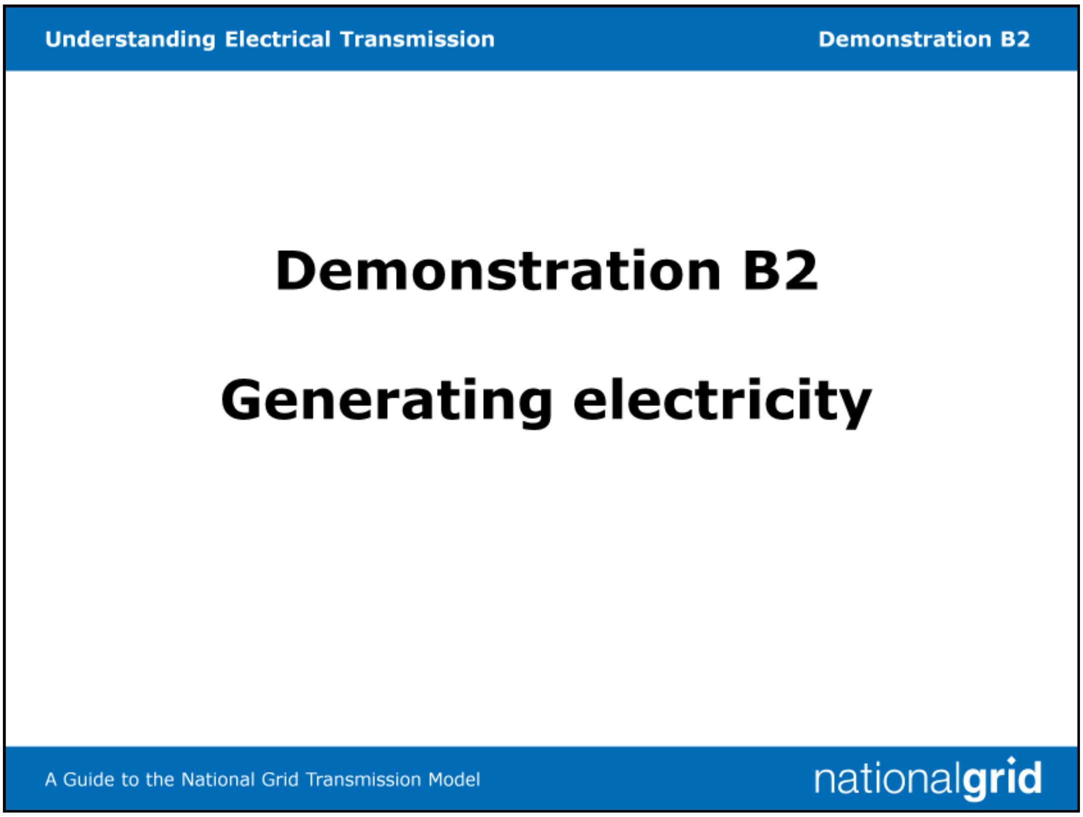
Task 3 Summarising these ideas

The previous two tasks both explore the relationship between the following:

- electric current
- magnetic field
- movement.

9. Use these three terms in a sentence to summarise:

- the key idea in Task 1
- the key idea in Task 2.



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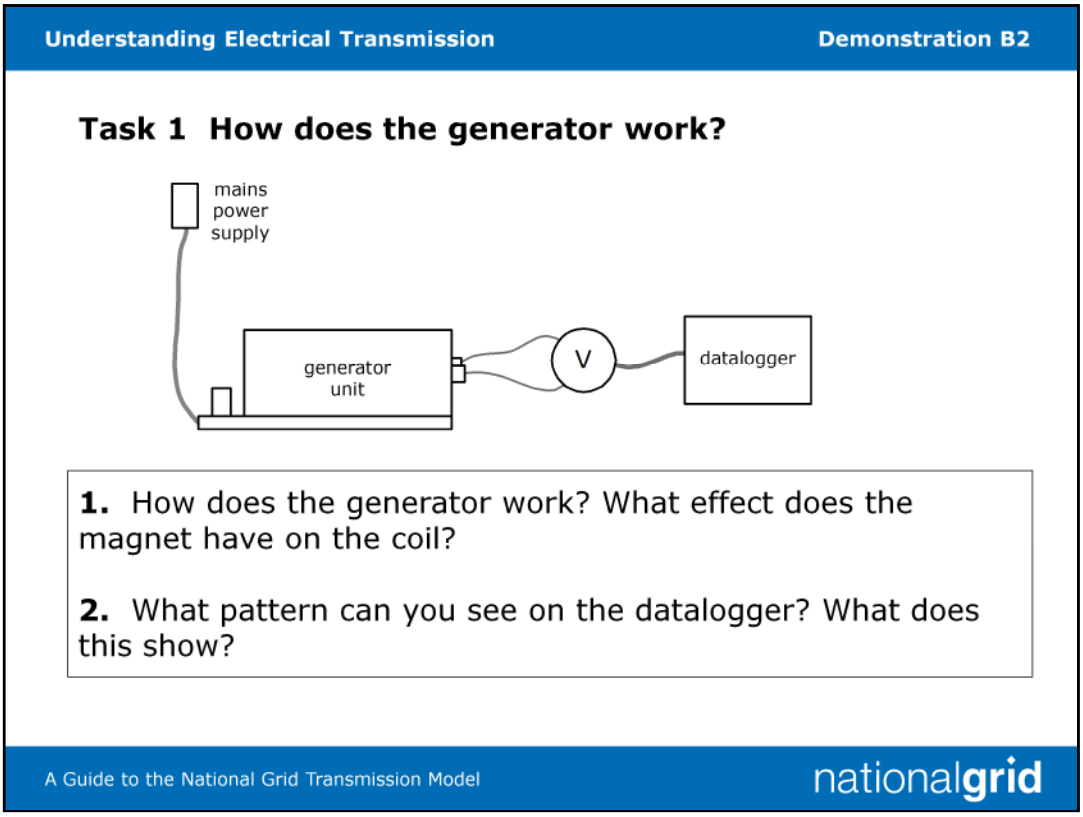
The generator used in the transmission model is simply a device for making a magnet move rapidly across the face of the coil – just doing what could be done by hand but faster. The output is an alternating current (a.c.) in contrast to the direct current (d.c.) output of a battery.



Connect the output of the generator unit to the voltage sensor (e.g. ±20 V) of a datalogger connected to a computer. With the generator unit switched off, plug in its mains power supply.

Select suitable settings for the datalogger (e.g. scale: ±10 V, duration: 1 second, sample interval: 1 ms).

Set the drive control to ‘6’ and then start the datalogger.

Understanding Electrical Transmission **Demonstration B2**

3. What is the highest value of the output voltage?

4. How can you work out the frequency from this display?

The model is now run at a lower speed, then a higher speed.

5. How does slowing down or speeding up the generator affect the pattern on the datalogger display?

6. What effect does the generator speed have on the output voltage?

7. What effect does the generator speed have on the output frequency?

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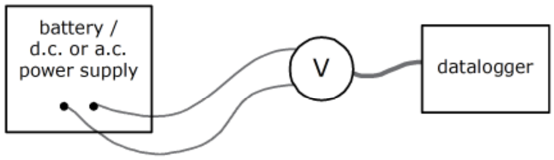
Repeat this procedure, with the drive control set at a lower speed (‘4’). Repeat with a higher speed (’8’).

Understanding Electrical Transmission

Demonstration B2

Task 2 Looking at the output from other sources



8. In what way is the output from a battery different from that of the generator?

9. Does the output from the a.c. power supply look similar to the output from the generator? What is its frequency?

10. How does the output from the d.c. power supply compare to the battery?

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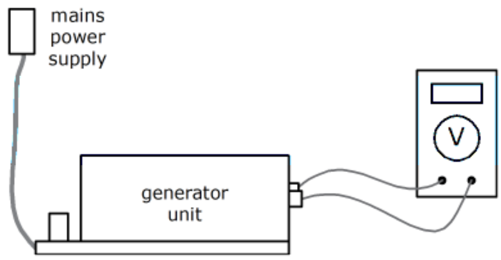
Repeat the procedure looking at the output voltage from the following:

- 1.5 V battery
- power supply set at 2 V a.c.
- power supply set at 2 V d.c.

Understanding Electrical Transmission — Demonstration B2

Task 3 Making voltage measurements

11. What is the maximum output voltage as shown on the datalogger?



12. What is the output voltage as recorded by the multimeter? Is this the same or different from the maximum voltage shown on the datalogger display? Why is this?

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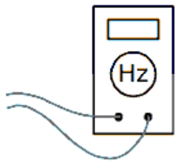
Run the generator unit on setting ‘6’ and display the output on the datalogger.

Now connect the output from the generator unit to a multimeter (a.c. voltage setting) to measure the voltage.

Understanding Electrical Transmission

Demonstration B2

Task 4 Making frequency measurements



13. What is the reading on the multimeter? How does this compare to the value you worked out from the datalogger?

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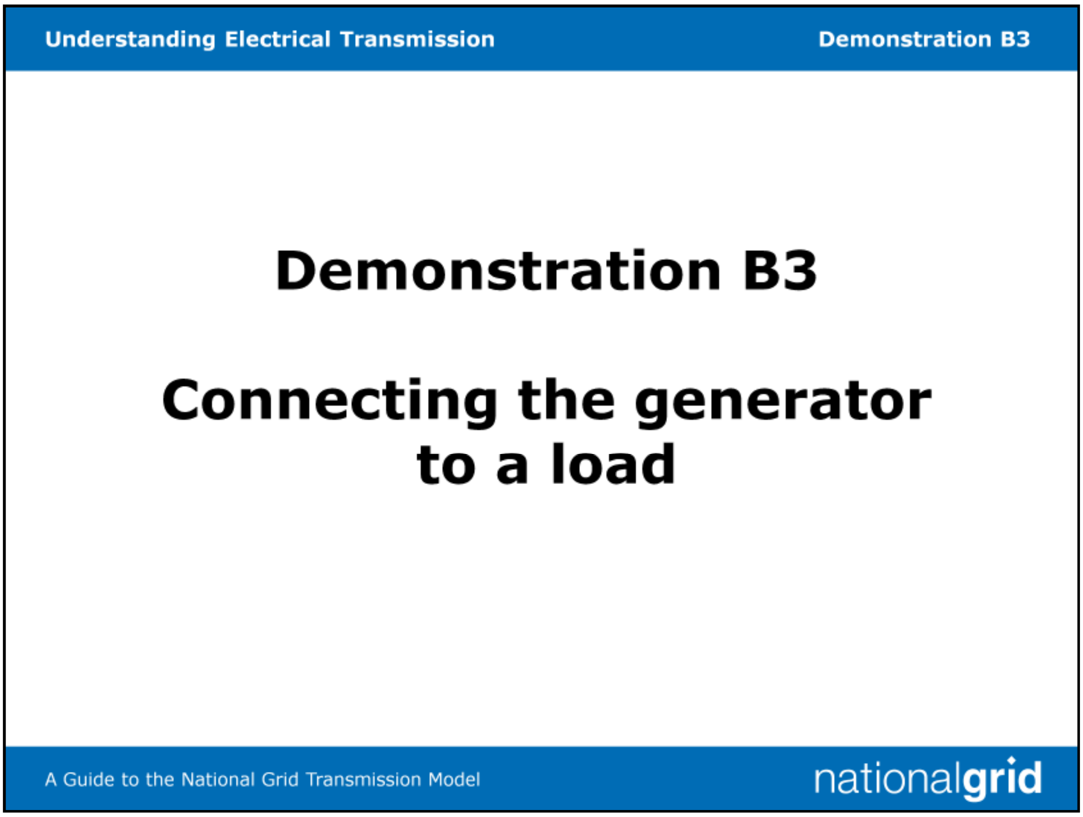
Connect the output from the generator unit to a multimeter (frequency setting).



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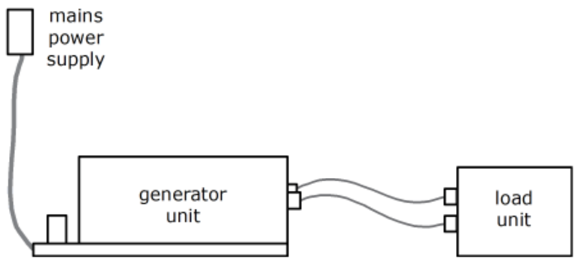
A 'load' refers to whatever is connected to an electrical power supply – in our homes this could be lighting, televisions, washing machines or fridges. This demonstration looks at the importance of having a power supply that is sufficient to meet the demands of the load.

Understanding Electrical Transmission — Demonstration B3

Task 1 Changing the speed of the generator



1. Does the LED produce a steady light or does it flash?

2. Why do you think this is?

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Connect the generator unit to the load unit. With the generator unit switched off, plug in its mains power supply.

Set the drive control on the generator unit to ‘0’ and the load unit to ‘Low’.

Switch the generator unit on, and turn up the drive control until the LED just lights. Then slowly increase the drive control and observe the LED.

Understanding Electrical Transmission — Demonstration B3

Task 2 Changing the size of the load

3. What effect does increasing the load have on the frequency?

4. How can a constant frequency be maintained even if the size of the load varies?

5. If a constant frequency is maintained, does this mean that the power output of the generator stays the same? Explain why.

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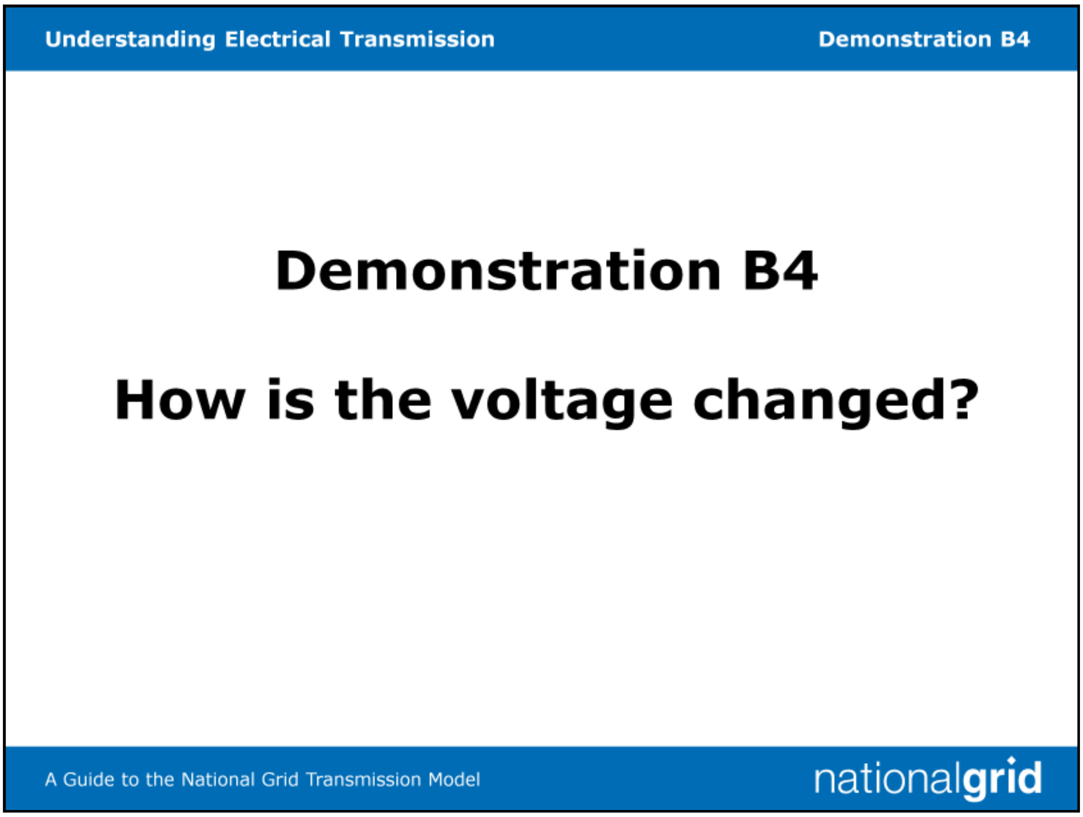
Connect a multimeter (frequency setting) to the load unit.

Set all the switches on the load unit to ‘off’, and adjust the drive control until the multimeter reads about 50 Hz.

Now switch the load to ‘High’. Listen to the change in pitch of the drive motor and note the frequency reading on the multimeter.

Adjust the drive control so that the multimeter reads about 50 Hz again.

Try different loads on the load unit, adjusting the drive control each time to try to maintain a frequency of about 50 Hz.



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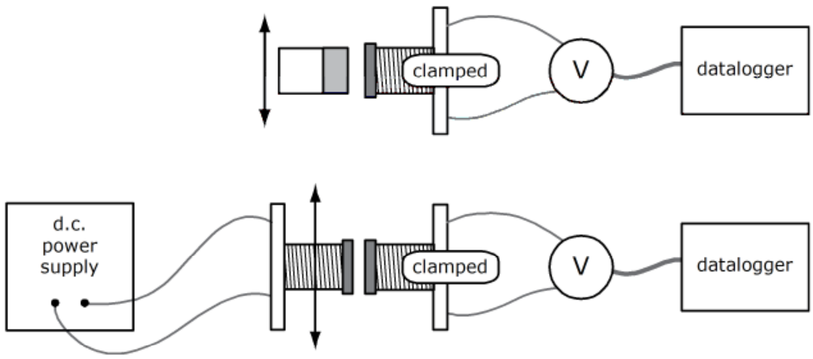
The National Grid transmits electricity at 400 000 V – this is much higher than the voltage at which it is generated. Voltages can be changed by using transformers. This demonstration uses two coils of wire to look at the principle that underpins the way that transformers work.

Understanding Electrical Transmission **Demonstration B4**

Task 1 A moving magnet



1. What can you see on the datalogger? In what way is the coil similar to the magnet? What does this show?

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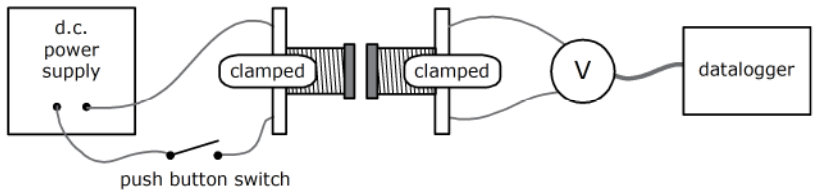
Put a test coil into a clamp stand. Connect the coil to the voltage sensor (e.g. ±1 V) of a datalogger connected to a computer. Select suitable settings for the datalogger (e.g. scale: ±500 mV, duration: continuous, sample interval: 30 ms).

Move the face of the test magnet in front of the clamped coil. The changing magnetic field creates a changing voltage across the coil which can be observed on the datalogger display.

Now connect a second test coil to a low-voltage power supply (set at 3 V d.c.). *Note that the coil will get quite warm.* Hold the coil using the terminals (*avoid touching the coil itself*), and move it in front of the clamped coil.

Understanding Electrical Transmission **Demonstration B4**

Task 2 Switching a d.c. current on and off



2. What happens when the push button switch is turned on and off rapidly? Why?

3. Which of the following is true?
- A voltage is produced across the coil connected to the sensor when a current flows through the other coil.
- A voltage is produced across the coil connected to the sensor when the current through the other coil changes.

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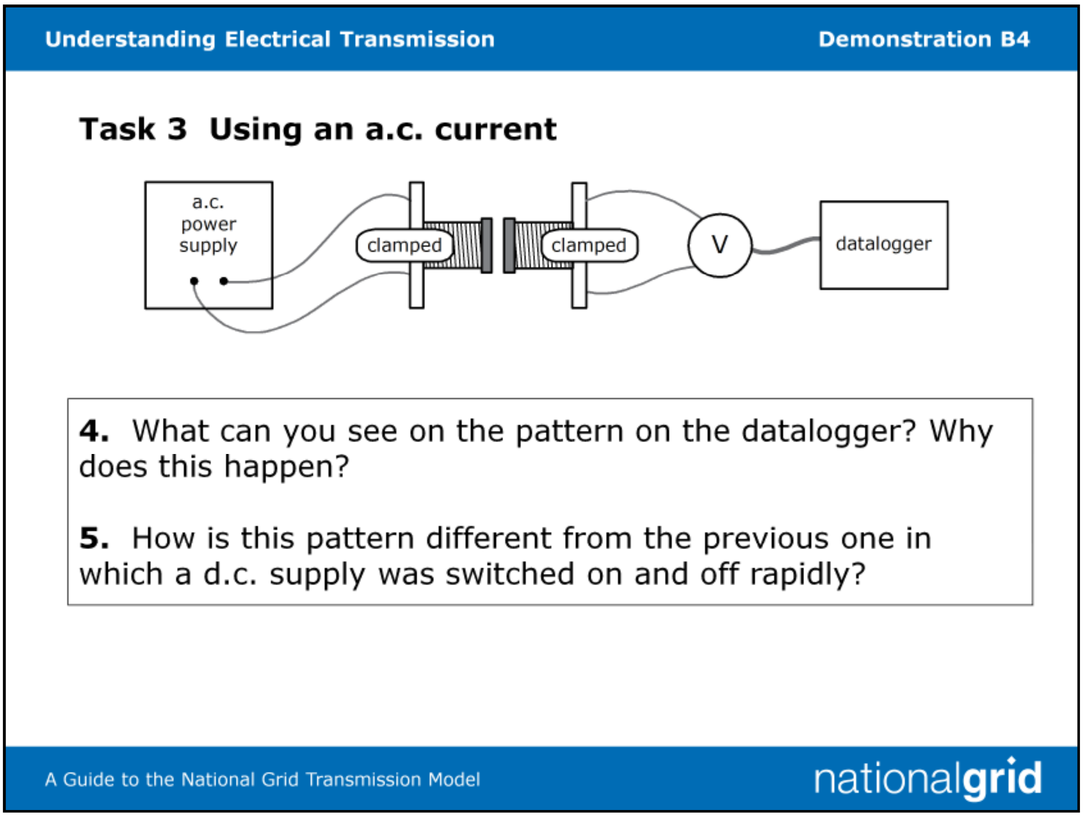
Put the second test coil into a clamp stand. Position it next to the other coil so that they are facing each other.

Add a push button switch into the circuit with the power supply and coil.

Select suitable settings for the datalogger (e.g. scale: ±1 V, duration: 1 second, sample interval: 1 ms).

Press the push button switch rapidly to turn the current through the coil on and off many times a second. While doing this start the datalogger.



Switch off the power supply, and remove the push button switch from the circuit.

Select suitable settings for the datalogger (e.g. scale: ±1 V, duration: 1 second, sample interval: 1 ms).

Set the power supply to 2 V a.c. and switch on the power supply.

Understanding Electrical Transmission **Demonstration B4**

A multimeter can be used to compare the frequencies of the output from the power supply and the output from the second coil.

6. What is the frequency of the output from the power supply?

7. What is the frequency of the output from the second coil?

8. How do the frequencies compare? Why?

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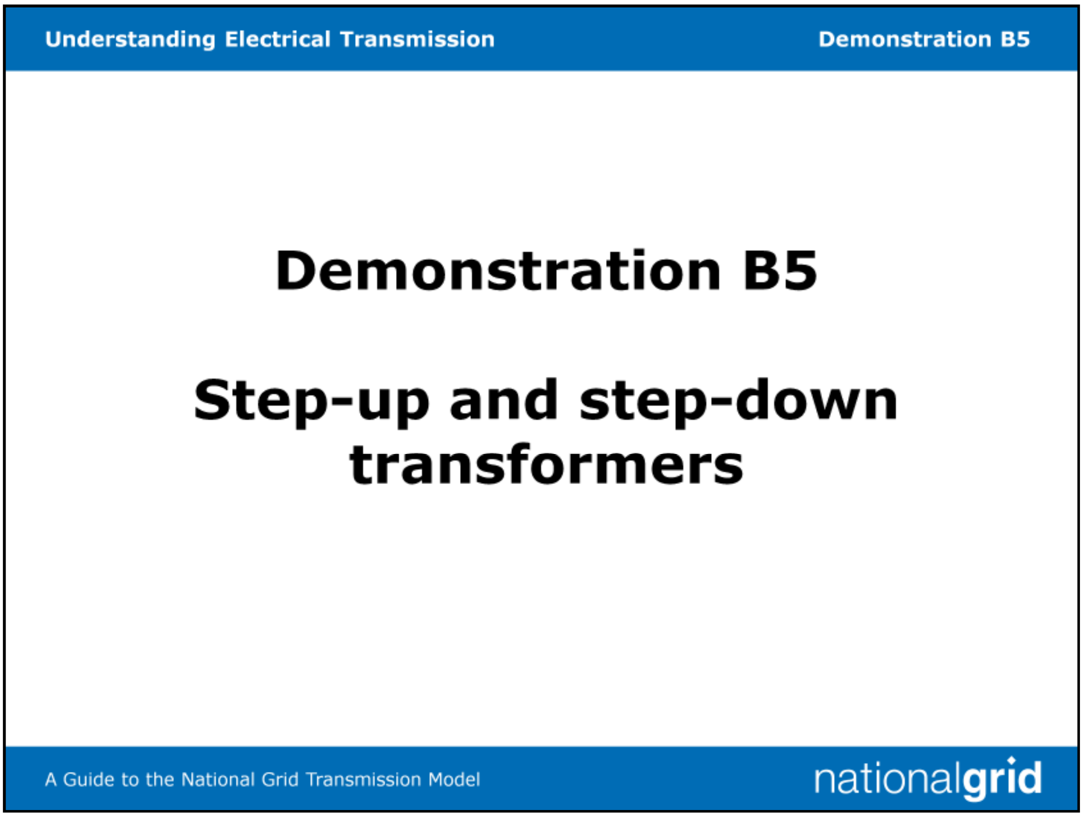
Connect a multimeter (frequency setting) to the a.c. power supply, and measure the frequency.

Connect it to the output of the second coil and measure the frequency.



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Transformers can increase the voltage (step-up) or decrease it (step-down). This depends on the relative numbers of turns in the input and output coils. This demonstration looks at the commercial transformers used in the transmission model, which are much more efficient at transferring energy than simple wire coils.

Task 1 What is inside the transformer units?

The step-up transformer unit has a transparent box so that you can see what is inside it. The transformer has a block of laminated iron sheets (which can be seen) and an input coil and output coil with different numbers of turns (which cannot be seen).

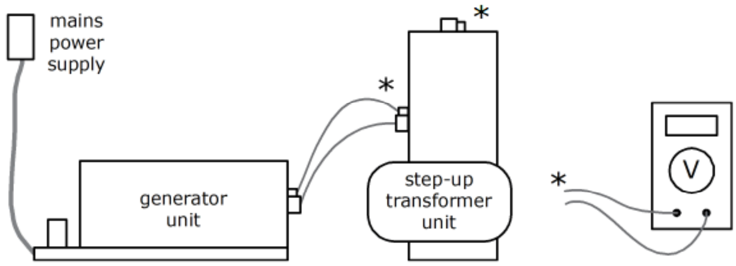
1. What is the purpose of having different numbers of turns on the input and output coils?

2. What is the purpose of the block of iron sheets?

Understanding Electrical Transmission | **Demonstration B5**

Task 2 Step-up transformer

Make sure the generator is switched off each time you connect or disconnect components. Use leads with sheathed plugs to connect to the output of the transformer unit.



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Connect the generator unit to the input of the step-up transformer unit (lower sockets). With the generator unit switched off, plug in its mains power supply.

Set the drive control to ‘8’.

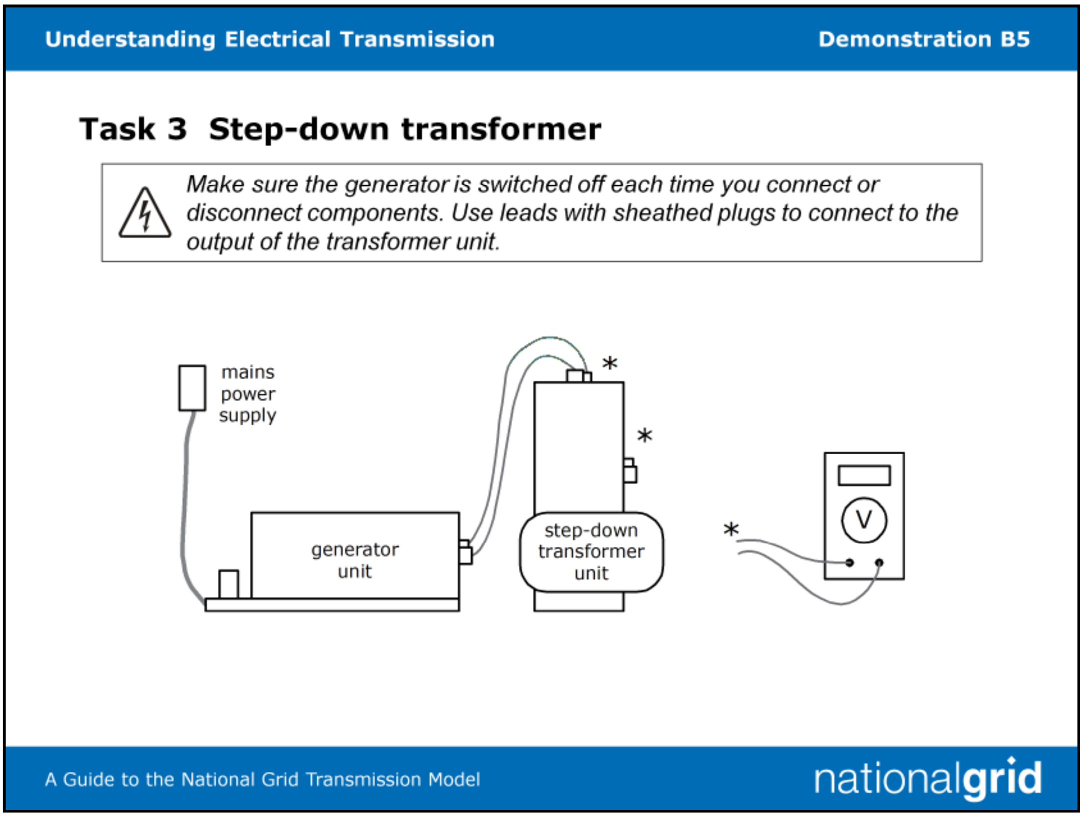
You will need two multimeters (a.c. voltage setting): one of these needs to accept shrouded plugs. Connect the multimeters as follows:

- across the input sockets (i.e. lower sockets) of the step-up transformer.
- across the output (upper) sockets of the step-up transformer (using leads with shrouded plugs).

Switch on the generator unit and note the two voltage readings. Switch the generator unit off.

3. How did the input voltage of the step-up transformer compare with the output voltage?

4. What does this tell you about the number of turns on the input and output coils?



With the generator unit switched off, disconnect the step-up transformer unit. Connect the generator unit to the input of the step-down transformer unit (*upper sockets*).

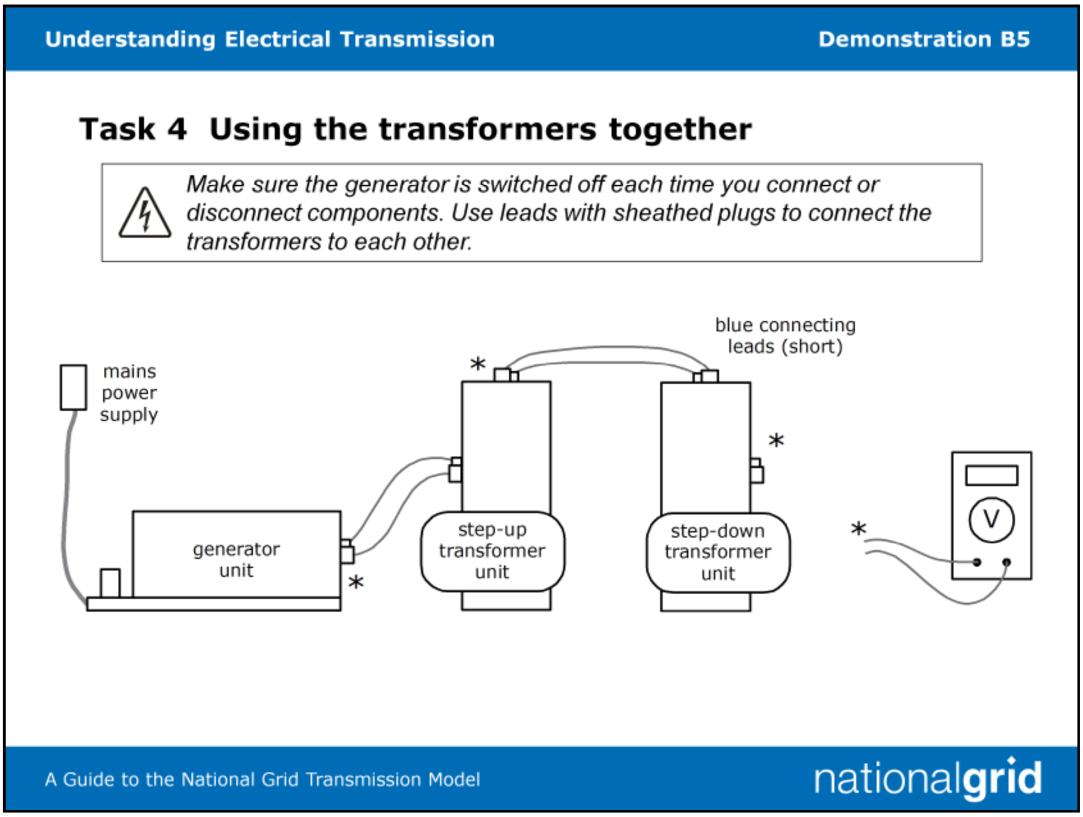
Connect the multimeters as follows:

- across the input sockets (i.e. upper sockets) of the step-down transformer
- across the output (lower) sockets of the step-down transformer (using leads with shrouded plugs).

Switch on the generator unit and note the two voltage readings (the output value is quite low, so you may need to use a smaller range on the multimeter). Switch the generator unit off.

5. How did the input and output voltages compare?

6. What does this tell you about the number of turns on the input and output coils?



With the generator unit switched off, connect the generator unit, step-up transformer unit and step-down transformer unit as shown (using short blue connecting leads between the two transformer units).

You will need three multimeters (a.c. voltage setting): one of these needs to accept shrouded plugs. Connect the multimeters as follows:

- across the output sockets of the generator
- across the output (upper) sockets of the step-up transformer (using leads with shrouded plugs)
- across the output (lower) sockets of the step-down transformer.

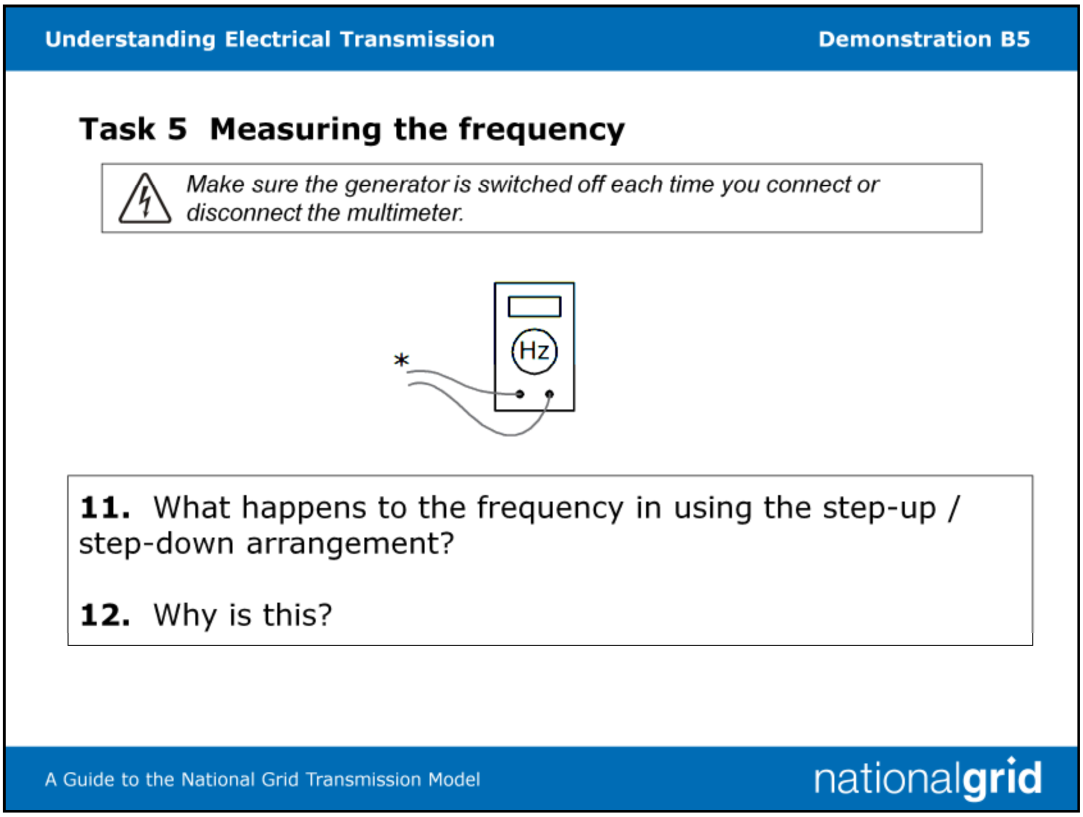
Switch on the generator and note the three voltage readings. Switch off the generator unit.

7. What happens to the voltage in using the step-up / step-down arrangement?

8. Why is this?

9. Why is it important that the generator gives an a.c. output?

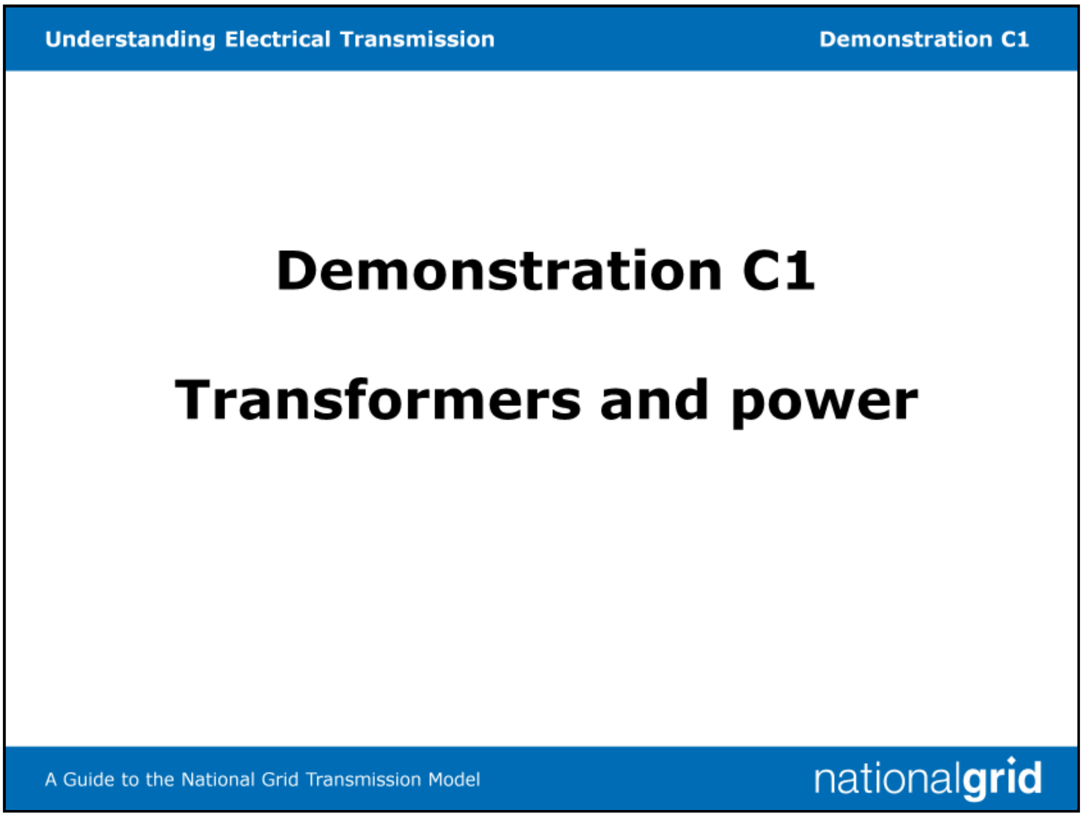
10. What would happen if a d.c. output was used?



Use a multimeter set to measure frequency.

With the generator switched off, connect the multimeter to the output of the generator. Switch the generator on, and note the frequency reading.

Switch the generator off, and connect the multimeter to the output of the step-down transformer. Switch the generator on, and note the frequency reading.



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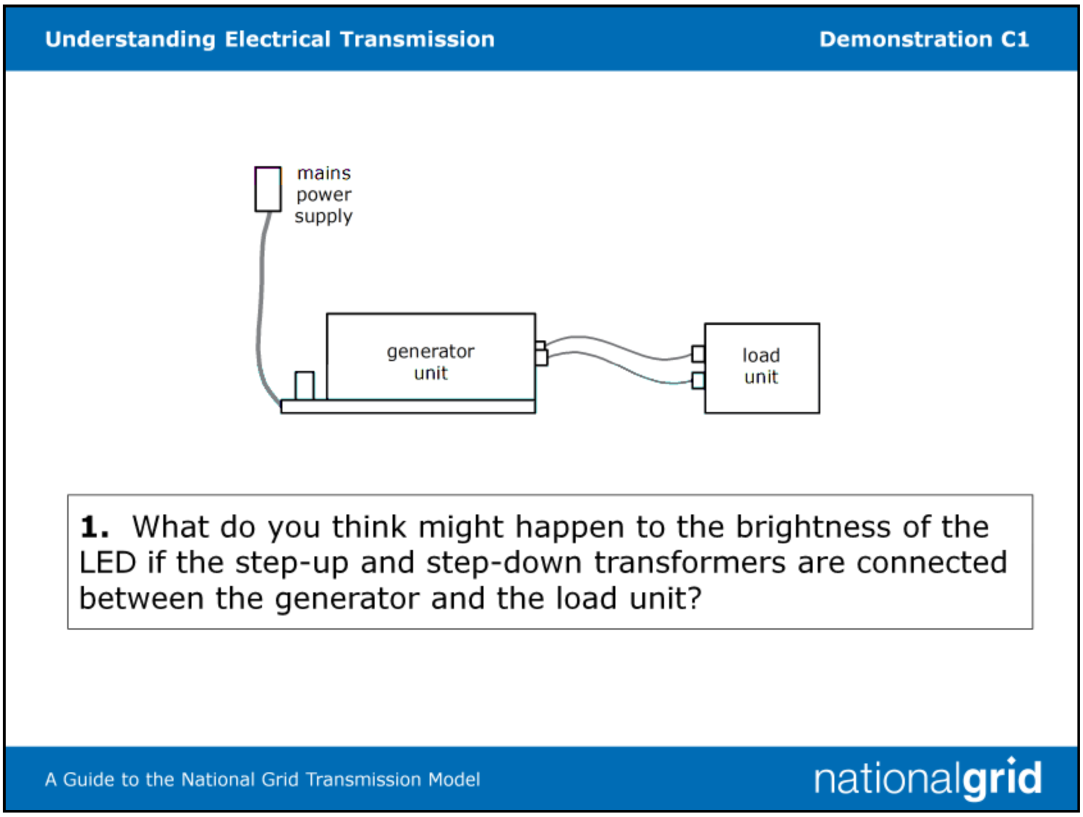
The demonstration described here uses the National Grid Transmission Model, and *involves high voltages*. It should only be undertaken by a teacher. Questions for students are shown in the boxes.

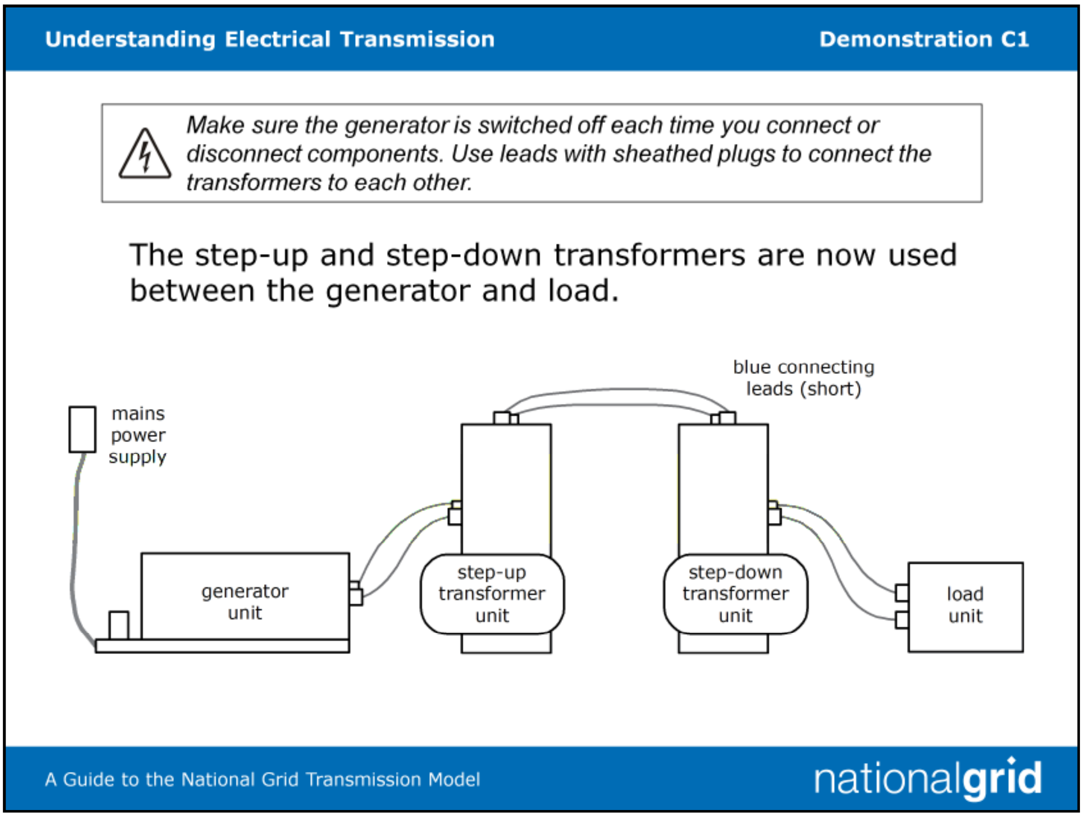
It is costly to construct the huge transformers and to build the tall pylons across the country necessary to safely transmit electricity at 400 000 V. Why not just transmit at the voltage generated in the power station? This demonstration takes a first look at the behaviour of the transformers in the system.



Connect the generator unit to the load unit. With the generator unit switched off, plug in its mains power supply.

Set the drive control to ‘0’ and the load unit to ‘High’.

Switch on the generator unit, and turn up the drive control until the LED on the load unit starts to light up.



Switch off the generator (keeping the drive control setting the same).

Add the step-up transformer unit and step-down transformer unit as shown (using short blue connecting leads between the two transformer units).

Switch on the generator and observe the LED on the load unit.

2. What has happened to the brightness of the LED? Why do you think this has happened?

3. Does this explain why transformers are used in the electricity transmission system?

Understanding Electrical Transmission | Demonstration C2

Demonstration C2

Why are high voltages used for transmission?

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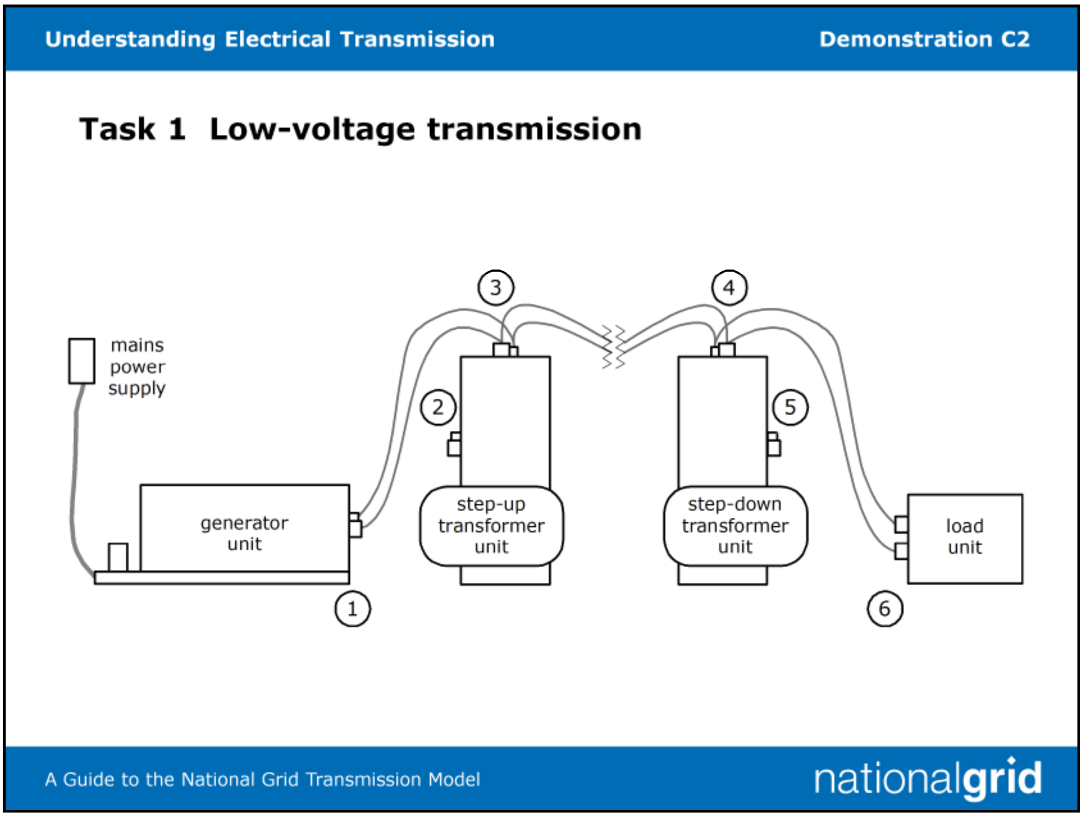
There are power losses in transformers, but there are power losses too in the transmission lines – since they are many miles long they have a significant resistance. This demonstration compares the different power losses involved in using low-voltage and high-voltage transmission.



You will need the two long blue transmission leads, which have a higher resistance than the short blue connecting leads.

Connect the transmission leads from the upper sockets of the step-up transformer unit to the upper sockets of step-down transformer unit. Move the units apart (about 1 metre) until the transmission leads hang between them.

Initially, you will be connecting the generator unit to the load unit directly via the transmission leads (i.e. without using the transformers).

Use the yellow plug-plug leads to connect:

- the generator unit (1) to the *upper sockets* of the step-up transformer (3)
- the *upper sockets* of the step-down transformer (4) to the load unit (6).

With the generator unit switched off, plug in its mains power supply.

Set the drive control to ‘8’ and switch on the generator. Observe the LED indicators as you increase the load as follows:

- ‘Low’ only
- ‘High’ only
- ‘Low’ and ‘High’.

Understanding Electrical Transmission **Demonstration C2**

1. Can the generator provide enough power for the maximum load on the load unit?

The voltage across the transmission leads is now measured at the start and at the end.

2. What is the voltage across the transmission leads at the start? What is the voltage across the transmission leads at the end?

3. What causes this difference?

A Guide to the National Grid Transmission Model

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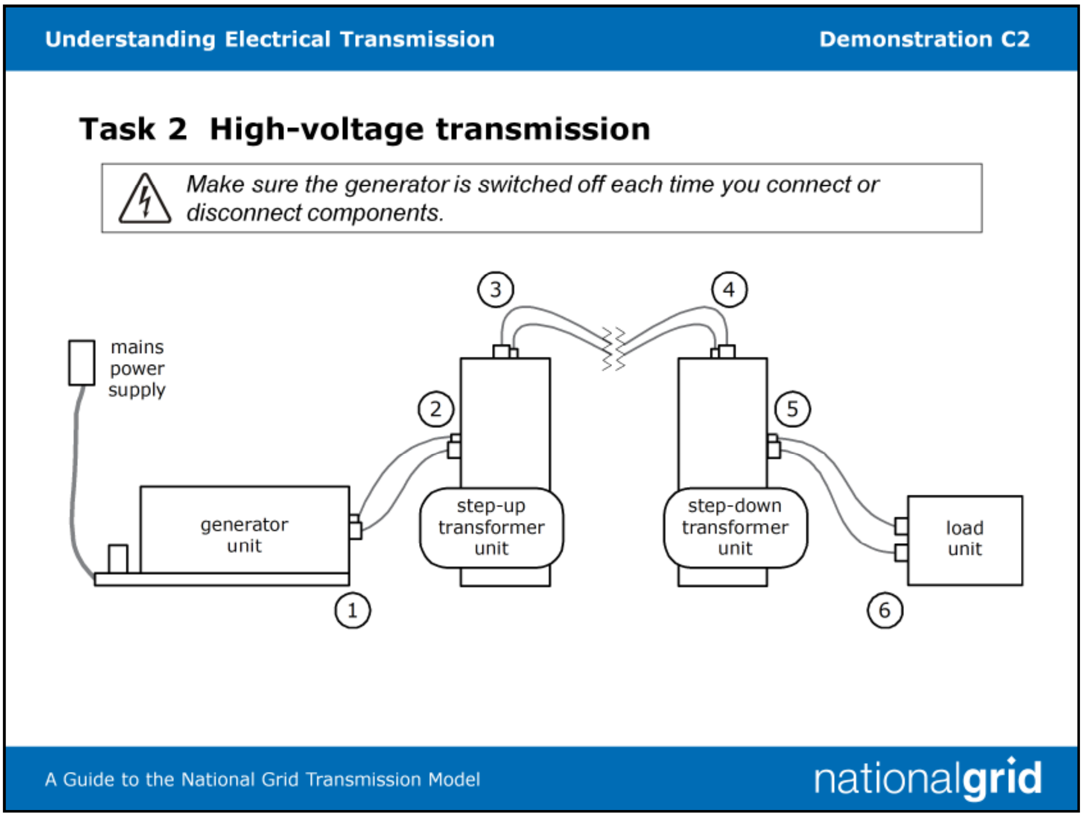
You will now measure the voltage across the start and across the end of the transmission leads.

Set the load unit to ‘Low’.

Switch off the generator and connect a multimeter (a.c. voltage setting) across the sockets at position (3). Switch on the generator and note the voltage.

Switch off the generator and connect the multimeter across the sockets at position (4). Switch on the generator and note the voltage.



Now, you will connect the generator unit to the load unit using transmission leads at a higher voltage (i.e. by using the transformers).

Switch off the generator. Use the yellow plug-plug leads to connect:

- the generator unit (1) to the *lower sockets* of the step-up transformer (2)
- the *lower sockets* of the step-down transformer (5) to the load unit (6).

Keeping the drive control on ‘8’, switch on the generator unit. Observe the LED indicators as you increase the load as before:

- ‘Low’ only
- ‘High’ only
- ‘Low’ and ‘High’.

Understanding Electrical Transmission **Demonstration C2**

4. Can the generator provide enough power for the maximum load on the load unit?

5. What effect does using a higher voltage for the transmission leads have? Why is this?

The voltage across the transmission leads is now measured at the start and at the end.

6. What is the voltage across the transmission leads at the start? What is the voltage across the transmission leads at the end?

7. How does the voltage drop for high-voltage transmission compared to that for low-voltage transmission? Why is this?

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You will now measure the voltage across the start and across the end of the transmission leads.

Make sure the generator is switched off each time you connect or disconnect the multimeter. Use leads with shrouded plugs to connect the multimeter to the high-voltage transmission leads.

Set the load unit to ‘Low’. Switch off the generator and connect a multimeter across the sockets at position (3). Switch on the generator and note the voltage.

Switch off the generator and connect the multimeter across the sockets at position (4). Switch on the generator and note the voltage. Switch off the generator.

Understanding Electrical Transmission **Demonstration C2**

Task 3 Measuring frequency

8. How does the frequency at the generator compare to the frequency at the load?

9. What effect does increasing the load have on the frequency?

10. How can a constant frequency be maintained even if the size of the load varies?

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Connect a multimeter (frequency setting) to the generator output, and switch on the generator. Note the frequency.

Connect the multimeter to the input of the load unit. Measure the frequency.

Set all the switches on the load unit to ‘off’, and adjust the drive control until the multimeter reads about 50 Hz.

Now switch the load to ‘High’. Listen to the change in pitch of the drive motor and note the frequency reading on the multimeter.

Adjust the drive control so that the multimeter reads about 50 Hz again.

Understanding Electrical Transmission Demonstration D1

Demonstration D1

Power losses in transmission

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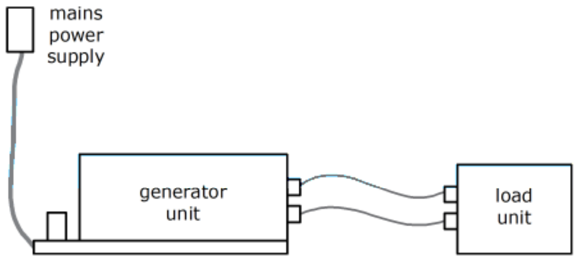
The power input to a load can be found by using a voltmeter and an ammeter to measure voltage and current. The calculated values for power can be used to look at the power losses involved in using transformers and transmission lines, and of low-voltage and high-voltage transmission.

Understanding Electrical Transmission

Demonstration D1

Task 1 Power output from the generator



1. What quantities do you need to measure to calculate the power output of the generator?

2. What instruments would you need to use?

3. How would you connect them in the circuit?

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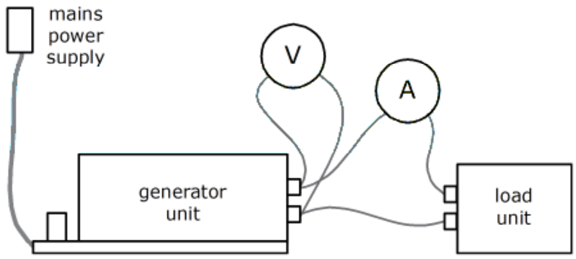
Connect the generator unit to the load unit. With the generator unit switched off, plug in its mains power supply.

Set the drive control on the generator unit to ‘8’ and the load unit to ‘Low’.

Switch the generator unit on. The LED on the load unit lights, indicating that energy is being transferred from the generator unit to the load.

Understanding Electrical Transmission — **Demonstration D1**



4. What is the value of the voltage across the output sockets of the generator unit?

5. What is the value of the current in the circuit?

6. What is the power output of the generator unit?

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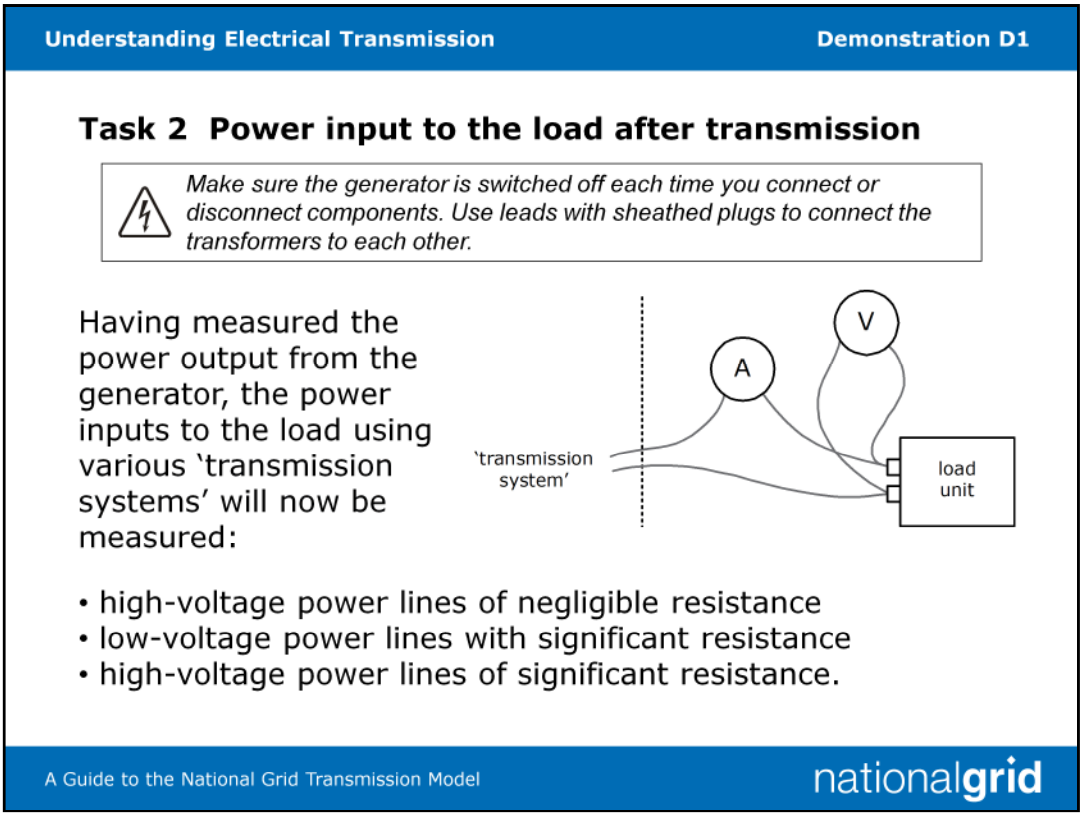
When connecting the voltmeter and ammeter it is better to start with the ammeter.

Switch off the generator and insert an ammeter (multimeter on a.c. current setting) into the circuit as shown. Switch on the generator to show that the circuit is still working.

Switch off the generator, and add a voltmeter (multimeter on a.c. voltage setting) across the input sockets of the load unit as shown.

Switch on the generator, and note the readings on the voltmeter and ammeter.

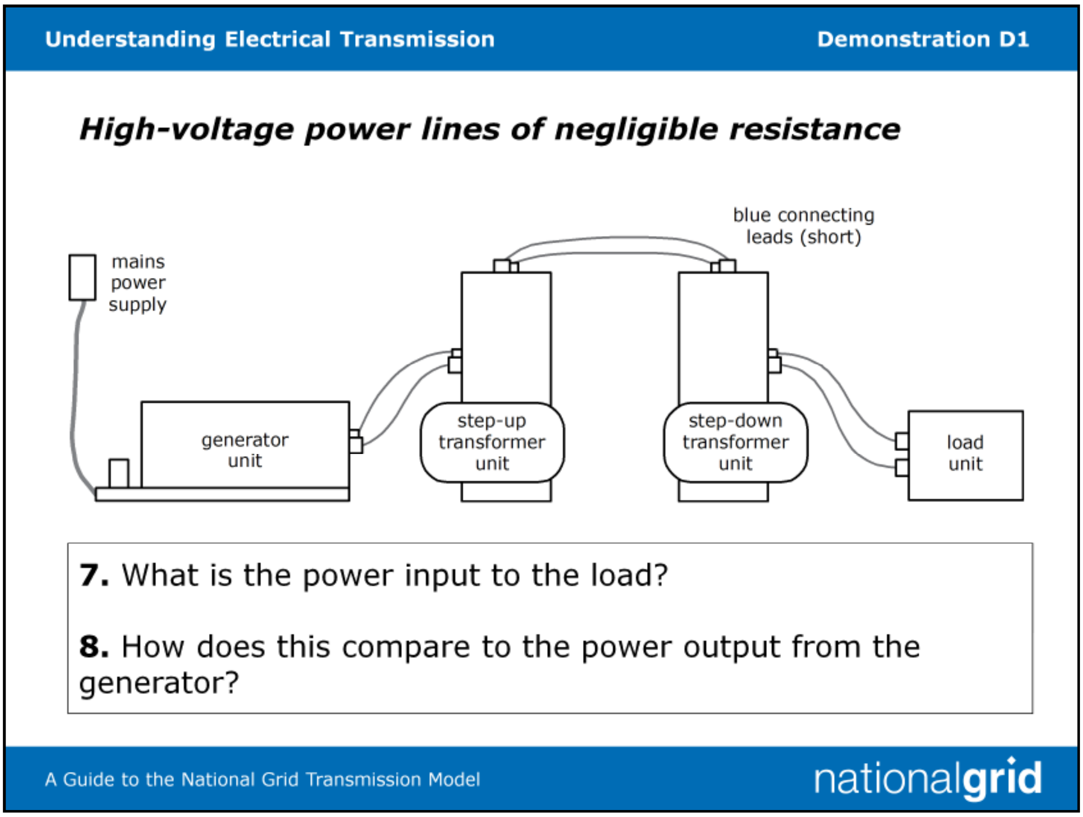


Having measured the power output to the load when connected directly, the next step is to compare with the power inputs using various 'transmission systems':

- high-voltage power lines of negligible resistance
- low-voltage power lines with significant resistance
- high-voltage power lines of significant resistance.

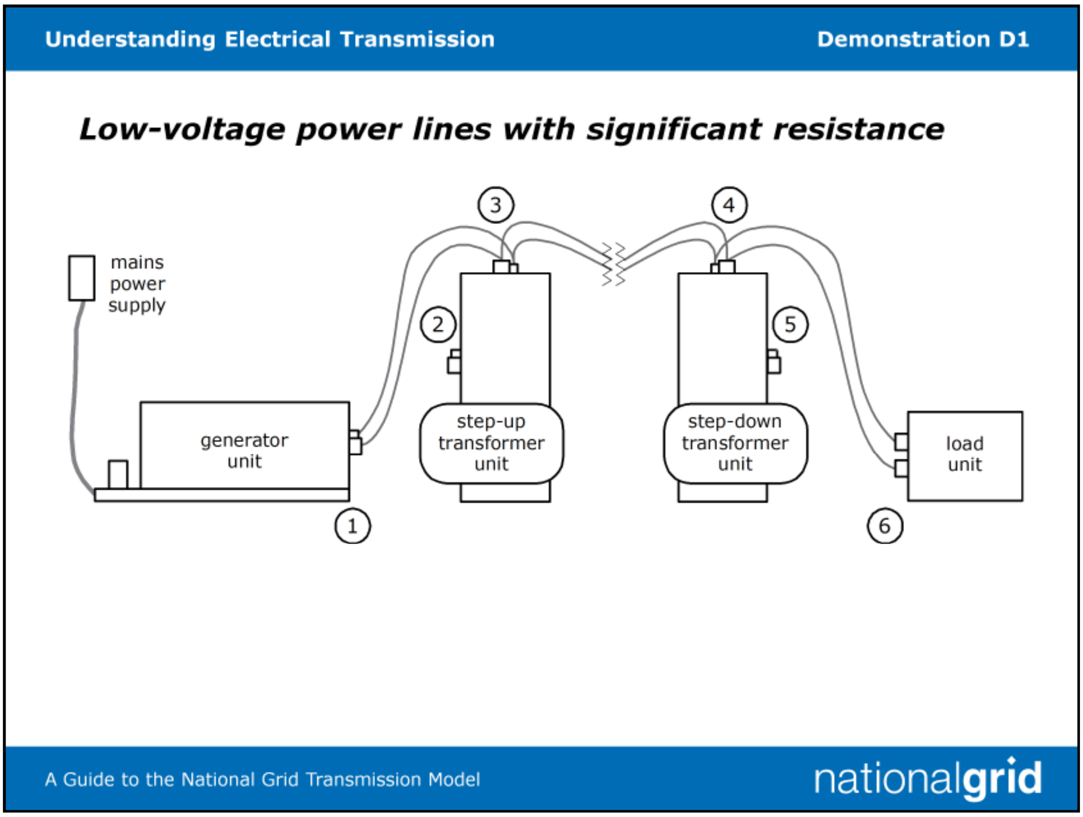
Disconnect the voltmeter from the generator and connect across the load.

Disconnect the generator unit, leaving the ammeter in the same position. This arrangement will now be connected to the three different 'transmission systems'.



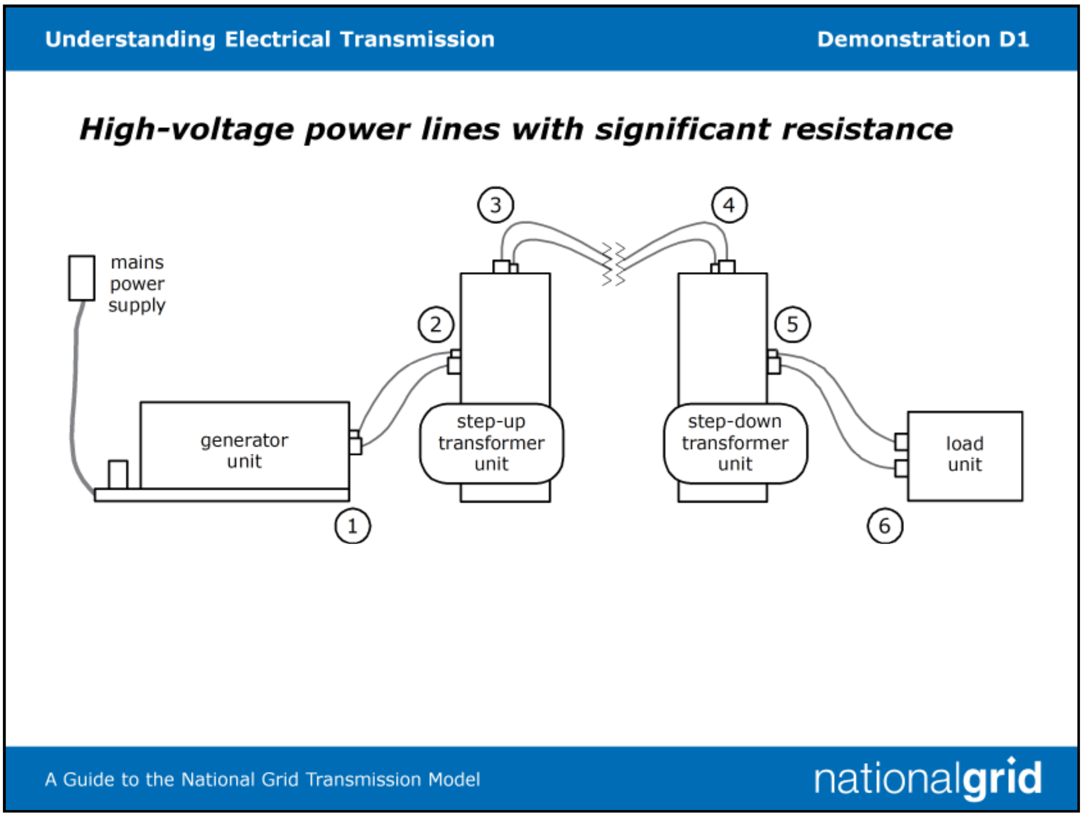
Connect the generator unit to the step-up and step-down transformer units, and connect the transformers together using the short blue connecting leads (as in the second part of Demonstration C1).

Use the same settings as in the previous task (drive control on ‘8’ and load set to ‘Low’). Note the readings on the voltmeter and ammeter.



Connect the generator unit to the load unit using the two long blue transmission leads (as in Demonstration C2 Task 2).

Switch on the generator and note the readings on the voltmeter and ammeter.

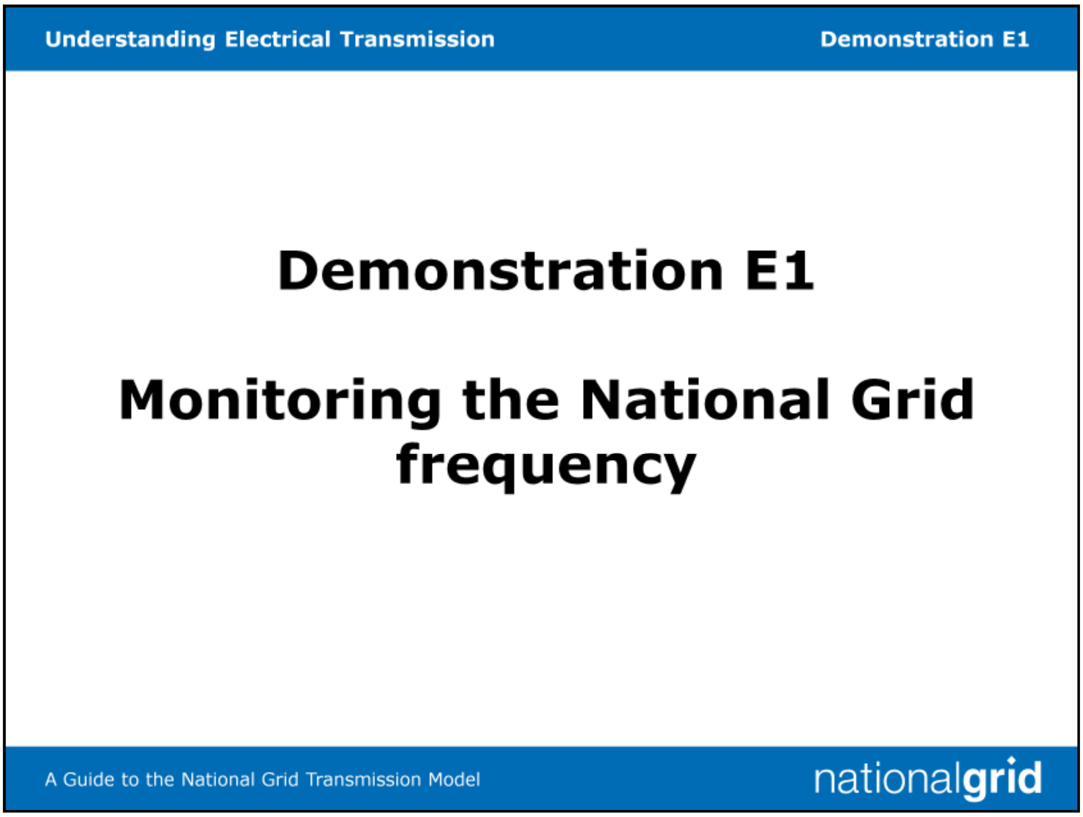


Connect the generator unit to the step-up and step-down transformer units, and connect the transfomers together using the two long blue transmission leads (as in Demonstration C2 Task 3).

Switch on the generator and note the readings on the voltmeter and ammeter.

9. What is the power input to the load in each of these two systems?

10. How do these two systems compare to the first one?



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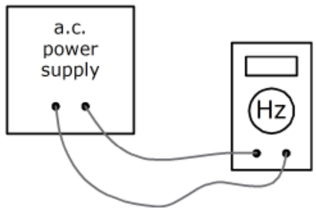
The demonstration described here uses the National Grid Transmission Model. Questions for students are shown in the boxes.

In order to match electricity generation to demand, the National Grid monitors the frequency and adjusts generation to keep as close to 50 Hz as possible. It has a legal requirement to keep the frequency within ±0.5 Hz of this value, though its normal operating limits are set at ±0.2 Hz.

Understanding Electrical Transmission — Demonstration E1

Task 1 Measuring the mains frequency

1. What is the value of the highest frequency over the measurement period? What is the value of the lowest frequency?



2. What are the upper and lower limits of the frequency that the National Grid must maintain by law?

3. What are the values of the upper and lower operating limits?

4. Look at the graph of the data collected. Does the frequency lie between these limits?

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Connect a multimeter with a frequency function to a low-voltage power supply (set at about 2 V a.c.).

Take measurements of the frequency every 15 seconds over the course of a lesson.

Use a spreadsheet to draw a graph showing how the frequency changes over the measurement period.

Understanding Electrical Transmission **Demonstration E1**

Task 2 Comparison with data from the National Grid

5. Compare the current value of frequency on the multimeter with that shown on the website. Are they the same?

6. Compare the real-time website graph with the graph of the data collected in the previous task. Do the patterns match?

7. What are the possible reasons that the frequency might increase?

8. What are the possible reasons that the frequency might decrease?

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Go to the page on the National Grid website that shows real-time frequency data for the last 60 minutes. (The page should should automatically refresh every 15 seconds, but note that there may be a delay in the data shown.)