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## The Nature of Electric and Magnetic Fields

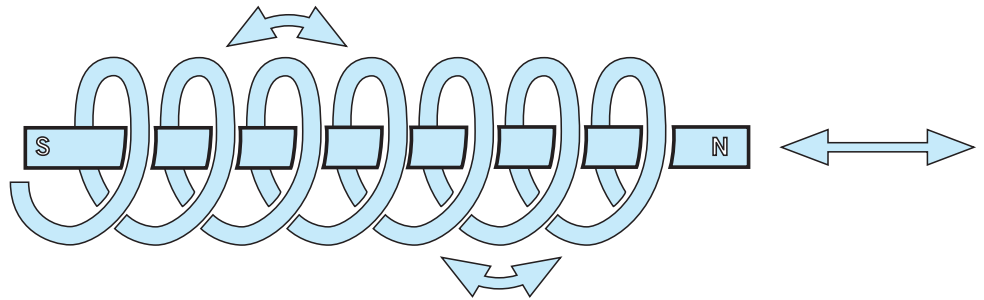
2009

FACT SHEET 1 3 4 5

### What are Electric and Magnetic Fields (EMF)?

**How are electricity and EMF related?** Many people will have seen the attraction or repulsion between poles of a magnet. Attraction is when a magnet sticks to a metallic object (for example, a fridge magnet). Repulsion is when two magnets “push away” from each other when trying to put two magnets together. These properties result from what is known as a magnetic field. The strength of the field weakens as the magnets are moved apart.

If a magnet is moved backwards and forwards through a coil of wire, an electrical current is produced in the wire. The magnetic fields are said to induce a current in the wire. The current along the wire will change direction as the magnet is moved backwards and forwards, demonstrated in the figure below.



Movement of the magnet induces an electric current in the wire

Similarly, if a current is passed through a wire, a magnetic field is produced around the wire. The voltage (or pressure) applied to drive the current through the wire produces an electric field around the wire. As with a magnetic field around a magnet, the electric and magnetic fields associated with a current-carrying wire will reduce rapidly as the distance from the wire increases.

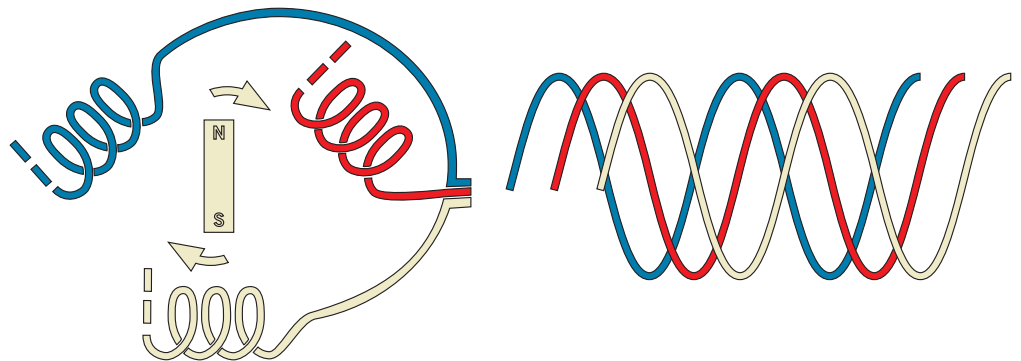
Electricity generation utilises these properties.

A flow of electric charge through a conductor, such as a wire, is called an electric current and is measured in amps.

Voltage is a type of “pressure” that drives electric charges through a conductor and is measured in volts.

## How generation affects the nature of electric and magnetic fields

In one type of electrical generator, a magnet turns within wire coils to induce an electrical current in those coils. The figure below shows this.



Schematic of an electric generator producing three phases of current

As one pole of the magnet passes a coil, the current induced in the coil increases and then decreases. The increase and decrease reflects the approach and then moving away of one pole of the magnet from a coil. When the opposite pole of the magnet then passes the coil, the current induced in the wire moves in the opposite direction. This form of electrical current is known as an alternating current, to reflect this change in current strength and direction.

In New Zealand, the current alternates 50 times per second and is said to be an alternating current with a frequency of 50 Hertz.

Typically, there are more coils than rotating magnets in a generator. Because one pole of a magnet will move past one coil and then subsequent coils there is a consequent difference in timing of the alternating current induced in each coil. This is identified as different “phases” of current.

## Electric and magnetic fields in transmission

The three phases of electricity are transmitted on three separate conductor sets (or wires) to make what is referred to as a single circuit. In the case of transmission lines the conductors are carried on poles or towers (pylons). Transmission lines are usually either single circuit, (carrying three-phase conductor sets), or double circuit (carrying 2 three-phase conductor sets, totalling six conductor sets). These configurations are shown in the figure below. Transmission may also be by underground cables.

This information on phases of electricity is relevant to the options for reducing electric and magnetic fields from transmission facilities discussed later in this fact sheet.

Electricity is transmitted from a source of generation to a point of use across the transmission network. As described above, where a wire carries electricity,

In New Zealand, electricity is transmitted from generators as an alternating current (AC) at 50 Hertz.

an electric and magnetic field will result. This is the case with the transmission of electricity on a national network, such as the New Zealand National Grid, operated by Transpower. It is also the case with local distribution networks and the flow of electricity in the wiring of our homes and businesses and the many electrical appliances within them.

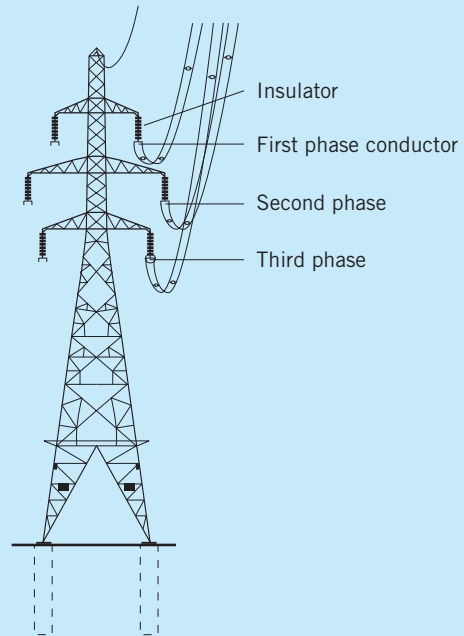
The strength of the magnetic field relates to the size of the current being carried. The strength of the electric field relates to the voltage of the line.

The towers or poles that carry energised conductors are electrically isolated from them by insulators. As such there is no substantive electric or magnetic field associated with the towers or poles themselves.

### Electricity transmission line components

#### Double circuit tower

A second circuit of three conductor phases can be carried on this side of the tower



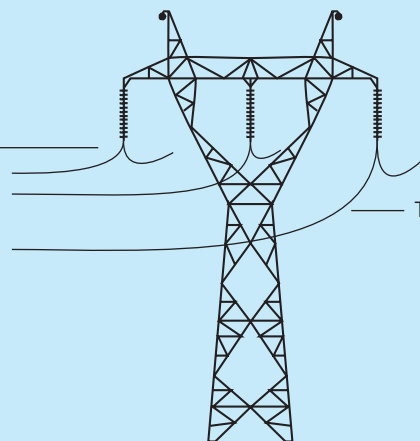
One circuit comprising three phases

#### Single circuit tower

First phase conductor

Second phase

Third phase



Single circuit comprising three phases

At a given location near a transmission line the electric field will be virtually constant, the magnetic field however varies in line with electricity demand.

An energised conductor (with a voltage applied across it) will have an electric field associated with it, irrespective of whether a current is flowing. A magnetic field however will only arise when a current is flowing. The following example may assist in understanding this. Where a TV is switched off but plugged into a live socket, an electric field will be associated with the power lead. It is only when the TV is turned on and current flows in the power lead that a magnetic field will also arise.

The amount of electric power transmitted along a transmission line at any given time is determined by the line's voltage and current. Transmission lines are held at a stable voltage, (in terms of the both the strength and frequency). The current strength varies and reflects changes in electricity use over time.

As electric fields are determined by voltage, the electric field at any given location around a transmission line will, like the voltage, be largely constant. Magnetic fields on the other hand, will change in strength over time in line with the strength of the current.

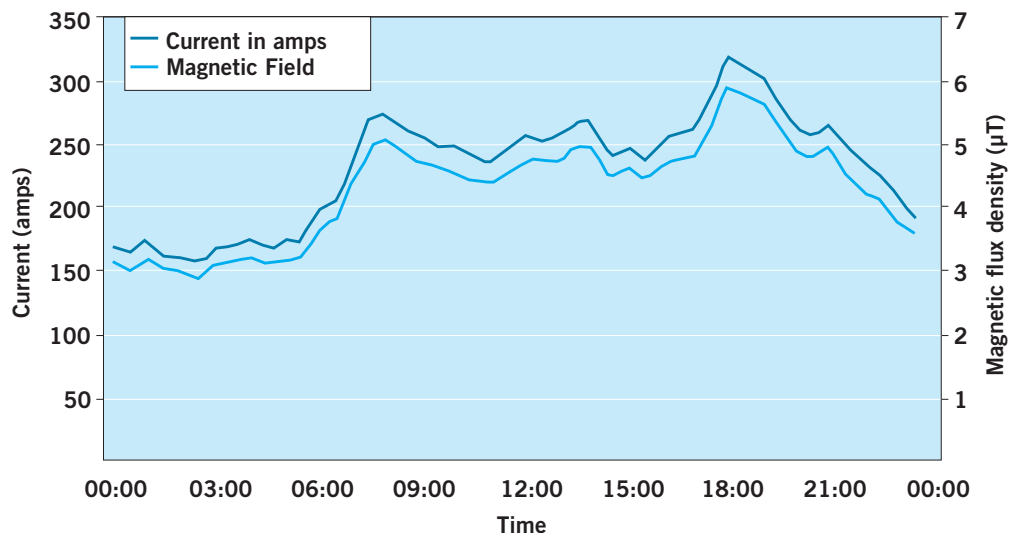
Magnetic fields are normally quantified in terms of the magnetic flux density which is measured in tesla (T). Measurements are most frequently given in microtesla ( $\mu\text{T}$ ), which is 1 millionth of a tesla.

Electric fields are measured in units of volts per metre (V/m) and are normally given as kilovolts per metre (kV/m) –  $1 \text{ kV/m} = 1000 \text{ V/m}$ .

Variations in the current follow fairly typical patterns, with morning and evening peaks, and larger loads in the winter months than during the summer.

The relationship between current and magnetic field strength is demonstrated in the figure below, where the predicted magnetic field strength directly below the conductor, with assumed maximum sag, can be seen to follow the load on a transmission line. As a rule of thumb, the maximum daily loads normally occur in the morning and early evening.

### Predicted Load Profile and Magnetic Field associated with a typical transmission line



In this example the magnetic field during low demand overnight is approximately half its evening peak value.

For both electric and magnetic fields, field strength reduces rapidly with distance from the source.

The current carried by a transmission line directly influences the magnetic field as identified above. It also indirectly influences the electric field levels experienced below the line. The current has a heating effect on the conductors which increases the conductor sag. Weather conditions such as air temperature, solar radiation, and wind speed also affect line sag. As line sag increases, the electric and magnetic fields experienced below the lines at ground level also increase. This is because the distance between the line (the source of the fields) and the ground decreases.

### Can electric and magnetic fields be reduced?

Transpower keeps itself abreast of the techniques that are available to reduce electric and magnetic field (EMF) exposures associated with transmission. The methods that are available relate to the characteristics of electric and magnetic fields and can be summarised as:

- the reduction of field levels with distance from their source.
- cancellation between the fields of electrical phases.
- shielding of fields.

### The reduction of field levels with distance from their source

Electric and magnetic fields reduce rapidly with distance from their source. For transmission lines, electric and magnetic field reduction will be between one-quarter and one-eighth for every doubling of distance from a line. The range in the level of reduction with distance identified is due to cancellation effects as outlined below.

### Cancellation between the fields of electrical phases

As outlined in the description of the nature of electric and magnetic fields, a single transmission circuit is comprised of three conductors. The strength and direction of electric current and voltage in each conductor alternates. The timing of the alternation in each conductor is out of phase from the other conductors, for example, as the current is at a peak on one conductor, it is rising in the second and falling on the third. As such, a single transmission circuit is said to comprise of three phase conductors.

The electric and magnetic fields associated with the respective voltage and current on each phase conductor also alternate in strength and direction.

The fields associated with each conductor phase, interfere with one another to reduce the field strength overall, which is known as “cancellation”.

Cancellation is enhanced where conductors of different phases are brought in closer proximity to one another. For transmission lines, the ability to reduce conductor-to-conductor distance is restricted by electrical safety considerations. Cables however can be laid in close proximity and in a triangular ‘trefoil’ pattern to enhance cancellation.

Transpower typically applies a number of field reduction techniques including ‘reverse phasing’ of transmission line conductors and the laying of cables in trefoil formation.

Cancellation is also affected by the relative positioning of conductors, or conductor configuration. “Reverse phased” configuration of double circuit transmission lines achieves greater EMF reduction with distance than would otherwise be the case. This configuration, which also achieves electrical efficiency gains, is routinely applied on the National Grid.

### Shielding of fields

Electric and magnetic fields differ considerably in the extent to which they can be shielded.

Electric fields are shielded by vegetation, building facades etc. A person within a house or under tree cover, for example, will not be subjected to an electric field from a nearby transmission line. Similarly, due to shielding by the cable sheath, a buried cable will have no associated electric field at the surface.

Magnetic fields are only shielded by ferro-magnetic materials such as iron and steel, so for most situations, the magnetic field strength is unaffected by the presence of another intervening structure. As such, magnetic fields are found both below transmission lines and above buried cables.

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This is one of five fact sheets produced by Transpower to provide the public with information about electric and magnetic fields. This fact sheet describes the nature of electric and magnetic fields particularly as they relate to electricity transmission. Other fact sheets that are available cover:

- **Fact Sheet 1 on electric and magnetic fields and transpower**
- **Fact Sheet 3 on the typical strength of electric and magnetic fields**
- **Fact Sheet 4 on the guidance on safe levels of electric and magnetic fields**
- **Fact Sheet 5 on electric and magnetic fields and the question of health effects.**

If you have further questions concerning EMF please call Transpower on 0508 526 369 or contact us through our website [www.transpower.co.nz](http://www.transpower.co.nz).