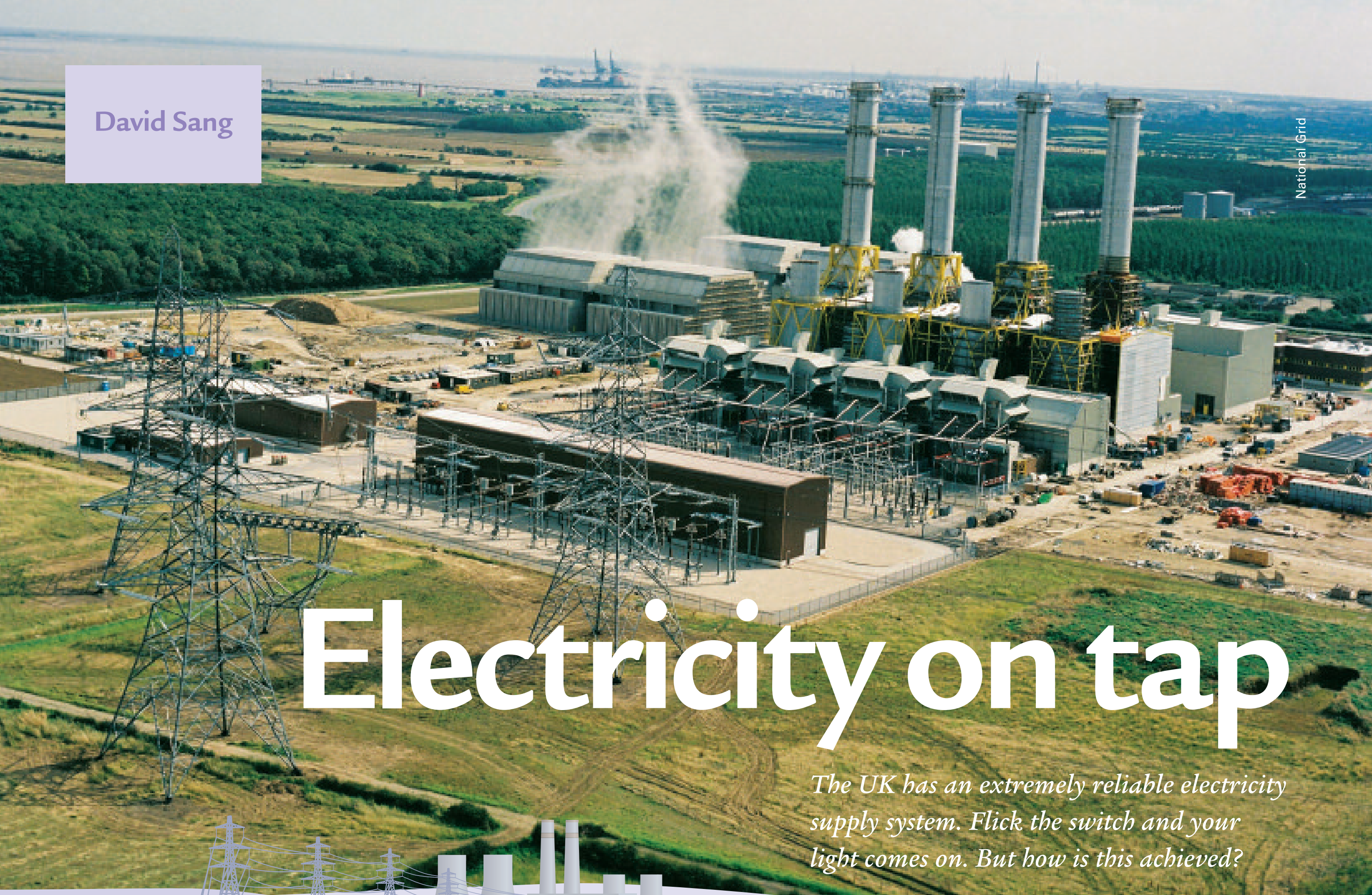
David Sang



Electricity on tap

The UK has an extremely reliable electricity supply system. Flick the switch and your light comes on. But how is this achieved?

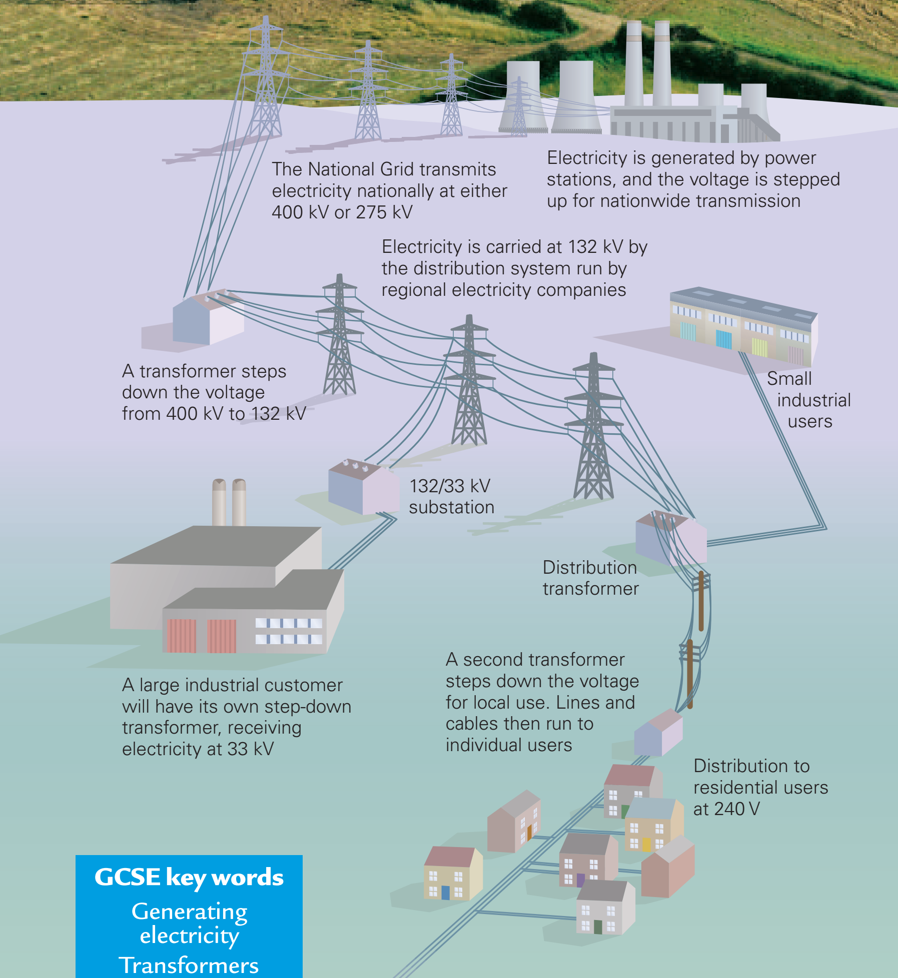


Figure 1 *Typical electricity distribution system, from a power station to homes and factories*

GCSE key words
Generating electricity
Transformers
Electrical power
Efficiency

Most of the UK's electricity is generated in power stations which burn gas or coal, or use nuclear fuel. A gas-fired power station is shown above. A small amount of electricity comes from renewable sources, mainly wind and hydroelectric power. You will be familiar with the cables which hang between giant pylons, and carry power across the countryside, distributing electricity from power station to end user (Figure 1). These cables must have low electrical resistance to prevent energy being wasted.

You might think that copper would be a good material for making cables, because it is a good electrical conductor. In fact, aluminium is often used even though its resistance is greater than that of copper. This is because aluminium has one third of the density of copper. Aluminium cables of the same resistance as copper ones are thicker but lighter, and this means that the pylons can be further apart. In practice, the cables have a steel wire up the middle to act as reinforcement.

Overhead and underground

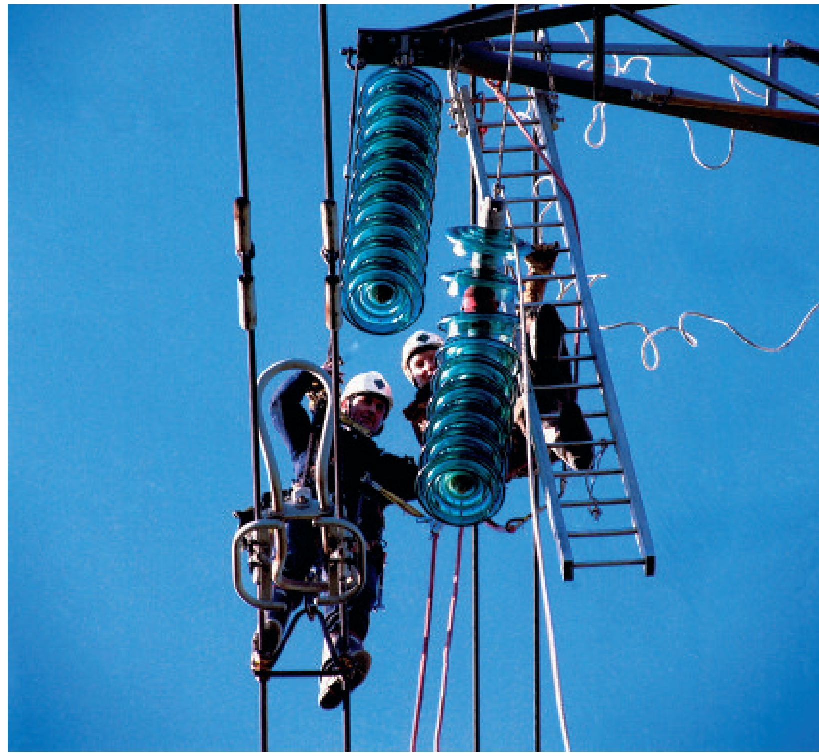
The pylons and cables (power lines) which distribute electricity make up the National Grid. The cables are at a very high voltage (275 kV or 400 kV) — that's one reason why they are held so high above the ground, where they are out of harm's way and are insulated by the air around them. Box 1 discusses how safe these power lines are.

Box 1 Are power lines safe?

High voltage power lines often pass close to housing. The voltages are stepped down to safe levels for distribution to homes, factories and shops. However, some people worry that the alternating currents in the cables produce electromagnetic radiation which may be hazardous.

The National Radiological Protection Board is responsible for advising on all radiation hazards. Visit its website (http://www.nrpb.org) to see its assessment of whether or not there is a link between high voltage power lines and instances of leukaemia in children.

REVOLT (http://www.revolt.co.uk) is an organisation which coordinates groups opposed to new pylons.



National Grid

Above: *At times, engineers repair cables while the power is still switched on. Provided they do not touch any other metal object, they are safe*

As current flows through the cables, some of its energy is lost because of their electrical resistance. This cause the wires to warm up slightly, but the air carries away this heat. About 2% of the energy carried by electricity in the UK grid is lost because of the resistance of the cables.

An alternative is to bury the cables underground. This may be done in areas of great natural beauty, or in built-up areas, but it is very costly. It can add up to £10 million to the cost of 1 km of power line. Cables buried in the ground are also much more difficult to repair than overhead lines.

Why use high voltages?

In the UK, the grid operates at up to 400 kV. In France, the highest voltage is 1000 kV. The voltage tells you about the energy carried by the current. A current of 1 A at 1000 V (1 kV) carries energy at the rate of 1000 W (1 kW). If the voltage is increased to 500 kV, that same 1 A current carries energy at a rate of 500 kW.

Engineers try to keep currents in the grid as low as possible because the greater the current, the more the cables heat up and the greater the loss of energy. To send a lot of energy along the cables, it is best to operate at high voltages so the current is kept low.

power = current × voltage

watts = amps × volts

Transforming voltages

Most power stations generate alternating current (a.c.) at 25 kV (Figure 2). This is high enough to ensure that the currents are not too big, and low enough to enable the cables to be insulated safely. As the cables leave the power station, they pass through a switching and transforming unit. Here, the power is directed to the appropriate power lines, and its voltage is increased by transformers (see Box 2).

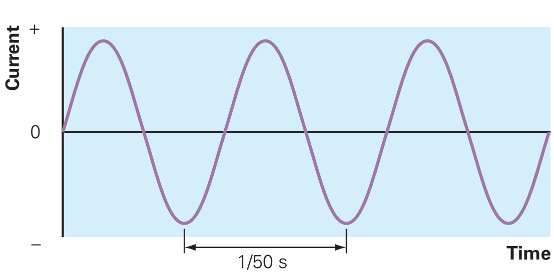


Figure 2 *Alternating current, frequency 50 Hz*

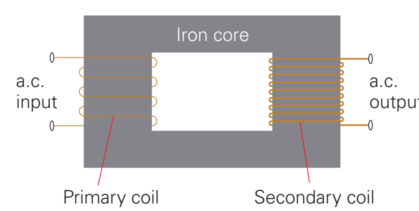


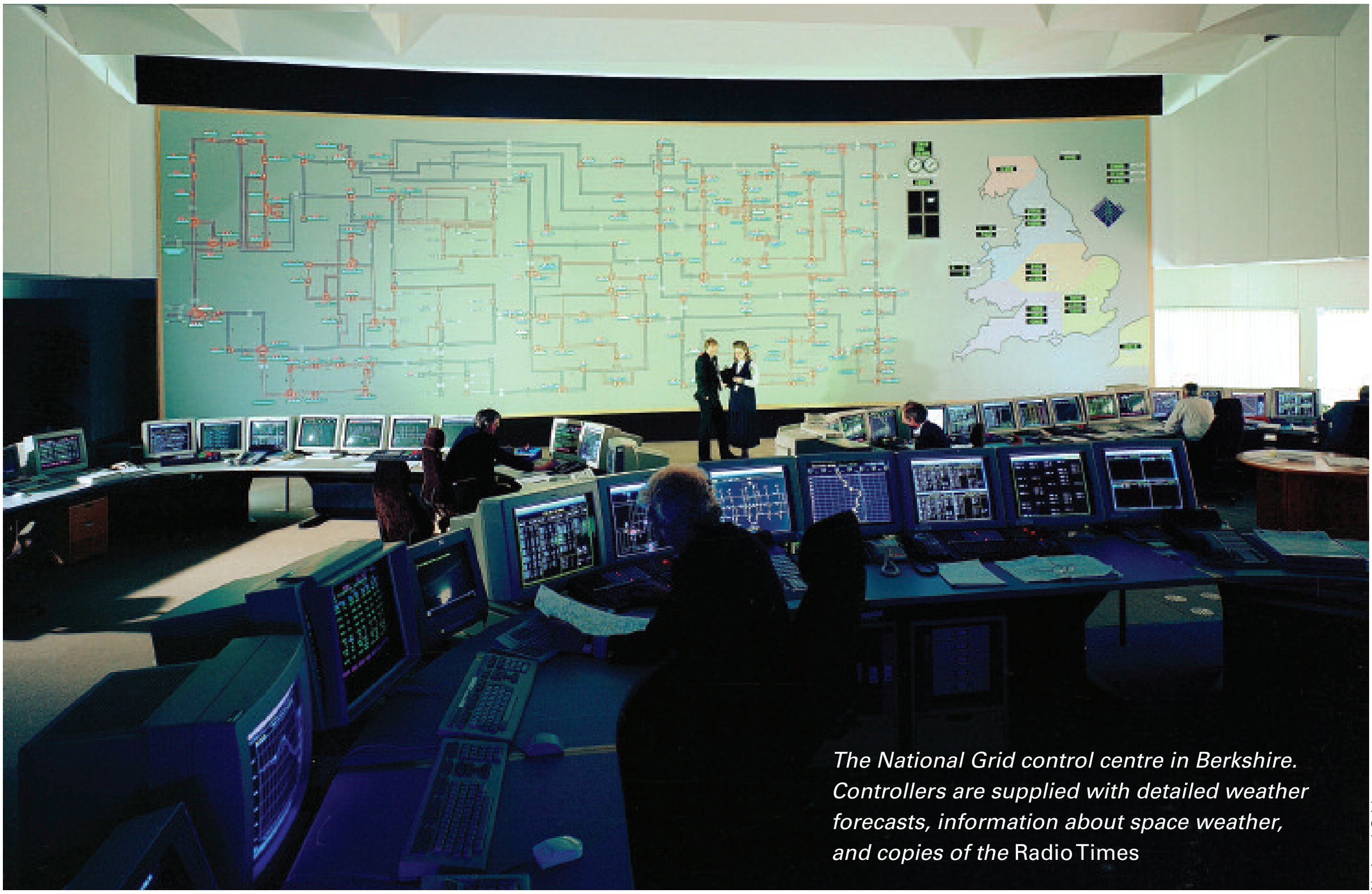
Figure 3 *A transformer is in effect two electromagnets which share a single core. Note that there is no electrical connection between the primary and secondary coils. It is the magnetic field in the core which carries the energy from one coil to the other*

Box 2 How does a transformer work?

A transformer is a pair of coils of wire, linked by an iron core (Figure 3). Transformers only work with alternating current. The current flows back and forth through the primary coil. This sets up an alternating magnetic field in the core, which in turn induces an alternating current in the secondary coil. If the secondary coil has more turns than the primary, it is a step-up transformer — this increases the voltage and decreases the current, in proportion.

A well-designed transformer wastes less than 0.5% of the energy passing through it, but in practice most are about 98% efficient.

Solar cells generate d.c. electricity. This must be converted to a.c. using devices called inverters, if it is to be supplied to the grid.



The National Grid control centre in Berkshire. Controllers are supplied with detailed weather forecasts, information about space weather, and copies of the Radio Times

National Grid

The biggest ever 'pick up' came after the solar eclipse in 1999, when demand rose from 33 000 MW to 36 000 MW in just 20 minutes.

Meeting the demand

The National Grid Company (NGC) is responsible for ensuring that there is always sufficient electricity to meet demand. You can't store electricity so it must be generated at the time that it is used. This makes the NGC's job rather tricky.

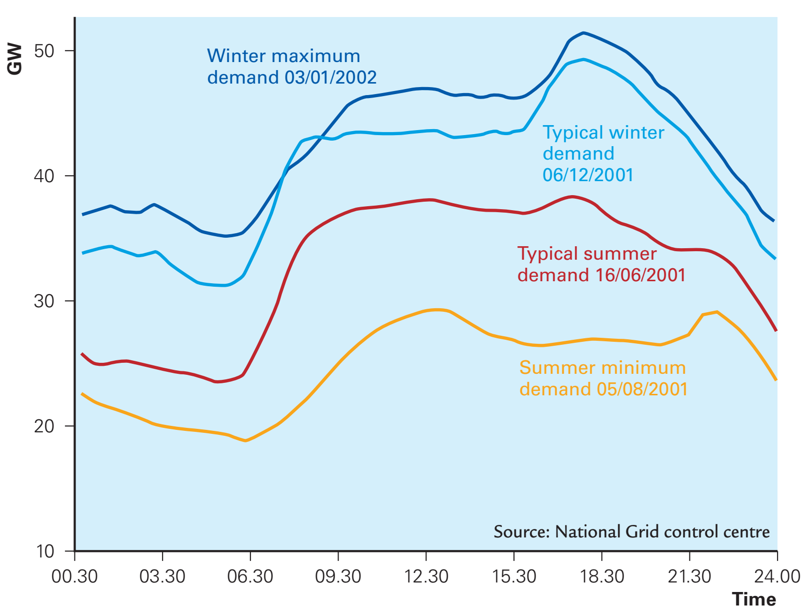


Figure 4 *National Grid actual demand, 2001/02. The greatest demand for electricity (at tea-time on a cold winter's day) is up to three times the smallest demand (at dawn on a summer's day)*

Demand varies greatly during the day, and throughout the year (Figure 4). The grid controllers must ensure that sufficient power stations are up and running, ready to meet any increase in demand. Their task is made more complicated because:

- Nuclear power stations cannot be switched on and off quickly; they are mostly kept running at a steady rate to form the so-called 'base-load'.
- Wind farms give a variable output, depending on how windy it is. Fossil-fuel stations may need to be kept running, ready to take over if the wind drops unexpectedly.

The grid is controlled by five teams of 18 engineers, working in shifts 24 hours a day. They need to anticipate changes in demand caused by factors such as the weather. They also need to be ready for 'pick up', which is when a large number of consumers suddenly increase their demand. Typically, this happens when a popular television show ends, and people rush to put on the kettle. Lots of people flushing the toilet also increases demand as water companies have to pump large amounts of water in a short time.

It is important for consumers that the grid is operated efficiently. There are several companies which supply electricity, and grid operators must ensure that the cheapest combination is in use at any time.

David Sang *writes textbooks and is an editor of* CATALYST.