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The Voice of the Networks

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# environment briefing02

## transporting electricity

### Overhead Lines or Underground Cables

### Introduction

The Electricity Act 1989 requires electricity companies both to maintain an efficient and economical system of electricity transmission and supply and to have regard to protecting the environment. Since electricity can be transmitted through overhead lines or underground cables, this briefing looks at the pros and cons of these alternatives.

### How Electricity is Delivered to Consumers

Electricity is carried along metal wire conductors; thin conductors have greater resistance and can carry less current than thick ones. The resistance of the conductor to the flow of electric current causes some electrical energy to be lost in heating the conductor and results in a voltage drop along it. The greater the current the more heat is produced and the greater the voltage drop.

If too much heat is produced, this can damage the conductor or cause a safety hazard. Hence any conductor has to be thick enough for its intended purpose to ensure that it does not overheat, whether it is a thin wire feeding a light in a house, or a cable carrying power across the country. It is also a requirement that the voltage does not drop below the legal minimum.

An electricity cable running down the street is therefore thicker than those connecting individual homes; in a large residential and commercial area, there will be several similar cables carrying current in parallel. An even bigger cable or overhead line is required to feed all these circuits. Because there is a practical and economic limit to conductor size, many large conductors may need to be used.

The amount of power transmitted is determined by multiplying the voltage by the current. The solution to the problem of transmitting large quantities of electricity is therefore to increase the voltage, using a transformer. This allows a corresponding reduction in the current, permitting a thinner conductor to be used. However, greater insulation is needed to cope with the increased voltage. The cost benefit of reducing the size and number of conductors is partly offset by the cost of the transformer and the extra conductor insulation.

To convey a given amount of power between two points, there is an optimum voltage which minimises the combined cost of conductors, insulation and transformers. Thus, at power stations in Great Britain supplying large quantities of electricity, the supply voltage for transmission around the country is 275 kV (275,000 volts) or 400 kV. The voltage is then progressively reduced via transformers at the intermediate tap-off points as the power being carried is distributed to different users (see Figure 1).

Electricity is generally supplied to homes, for instance, at 230 volts. In Northern Ireland transmission is at 110 kV or 275 kV and distribution uses voltages from 33 kV down to 230 V.

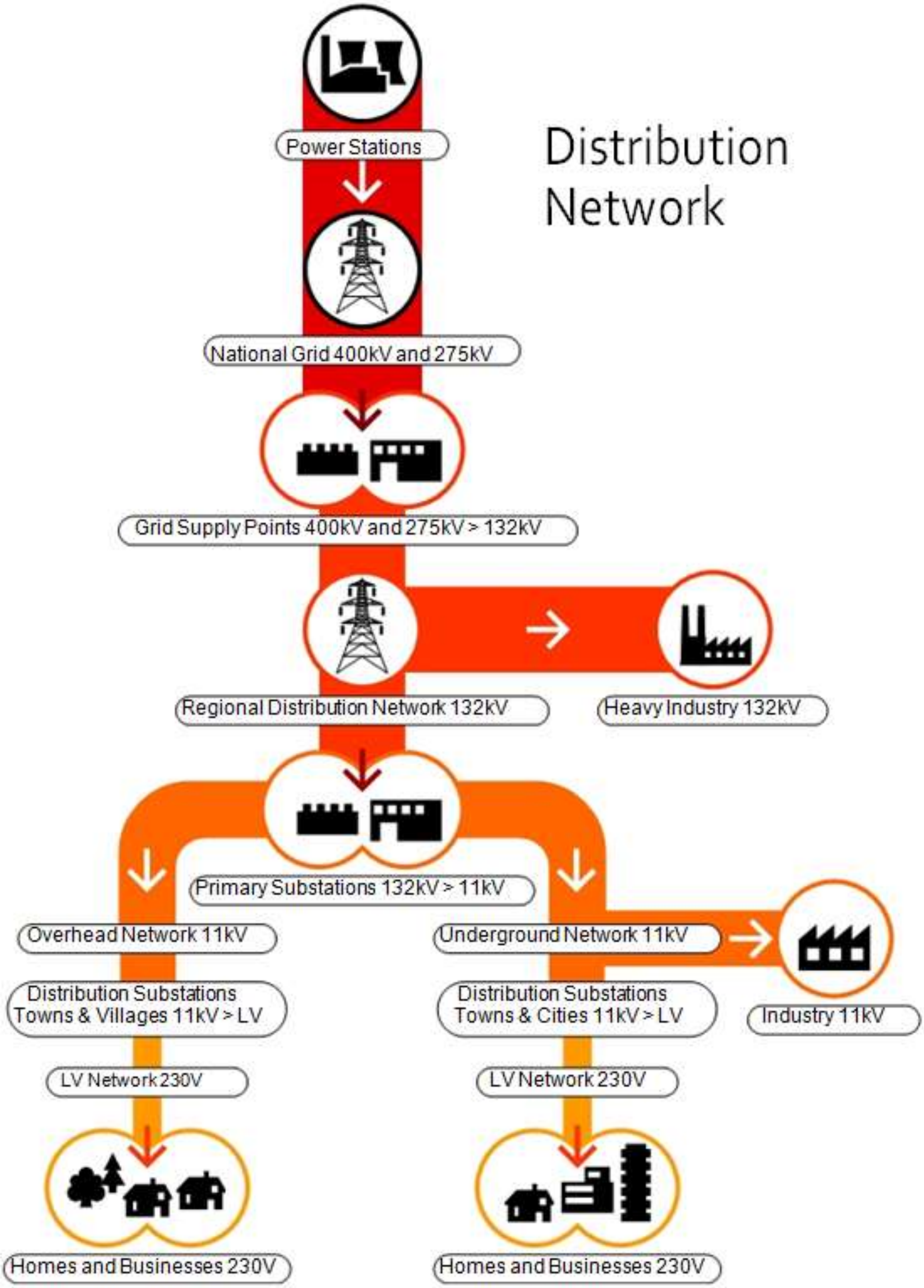


**Figure 1** **Electricity and Transmission Distribution System**

## Differences between Overhead Lines and Underground Cables

The current carrying conductors for both overhead lines and underground cables have to be insulated to reduce losses and hazards. The amount of insulation needed depends on the voltage. Conductors used for transmission (400 kV or 275 kV) need more electrical insulation than those used for distribution (132 kV down to 230 V).

An overhead conductor uses the surrounding air to provide the necessary insulation, with ceramic or glass insulators maintaining the insulation at support structures. High voltage overhead lines are suspended from tall pylons, whereas lower voltage lines can be carried on shorter pylons or wooden poles.

A conductor laid in or close to the ground has to be clad with an insulating material, normally plastic or fluid-impregnated paper. The high voltage applied to the cable causes heat to be generated in the insulation in addition to heating of the conductor by the current. The electrical insulation also has the subsidiary effect of a thermal insulator, slowing the escape of the heat into the ground. At higher voltages, more electrical insulation is required, making heat escape even more difficult. The cable conductor therefore has to be made even larger to prevent it from overheating.

When large cables are buried in the ground they must be kept apart to limit mutual heating and they must be deep enough to provide clearance for activities on the ground surface (the depth increases with voltage). For 33-400 kV cables, trenches wider than 1 metre have to be excavated and the swathe of land required for a number of cables, necessarily spaced, may be as much as 30 metres wide. Where lengths of cable are joined, the area taken up (known as a joint bay) can be up to 20 metres long. Thermally conductive backfill materials may need to be packed around the cables. If the trench is in a street, all excavated material must be removed and the site comprehensively reinstated.

## Environmental Considerations

**Sensitive Areas.** Wherever possible, new lines are routed to avoid sensitive areas such as nature reserves, archaeological sites and leisure amenity areas. (An environmental impact assessment is undertaken for major new routes). Where this is not feasible, however, a balance has to be struck between the visual impact of an overhead line and the much greater site disruption and permanent damage that might be caused during installation of an underground cable at the same voltage. Excavations for overhead lines are limited to the foundations for their pylons or poles. For underground cables, however, soil has to be removed from a large trench, perhaps several km long, and heavier cable drums and associated equipment have to be transported to the site. The trenching activity is particularly disruptive when installing 275 kV and 400 kV underground cables.

**Farmland.** Care is taken to minimise damage to farmland, which with underground cables could be significant and take a long time to recover, with possible disruption to drainage and water courses. When in service, both overhead lines and underground cables which cross agricultural land impose constraints on farming operations. In the former case, regulations impose height restrictions on buildings and trees and require care in the operation of farm machinery. In the latter case, certain deep ploughing operations must be avoided, crop growth may be adversely affected and no trees or hedges can be permitted along the route occupied by the buried cables.

When repairs are needed to buried cables, vehicle access is necessary and land excavation is inevitable. Overhead line repairs do not usually require any excavation but often require vehicular access.

**Cable Fluid Leaks.** Many city areas are served by high capacity underground cables at voltages between 33-400 kV. The insulation in these is often made of paper impregnated with a low viscosity fluid, which is maintained under pressure from header tanks to prevent air gaps arising. For the last 30 years the fluid used has been biodegradable, which reduces the impact of any leaks. An operating code agreed between the electricity companies in England and Wales and the Environment Agency contains procedures, including continuous monitoring and repair, aimed at reducing the effects of fluid leaks on underground and surface waters. Such leaks are frequently caused by others digging in the highway and further measures have been introduced to reduce the number of such incidents.

**Electric and Magnetic Fields.** There has been some concern about possible health risks from the electric and magnetic fields (EMFs) near overhead lines and underground cables, even though these fields are less than the guideline values published by the National Radiological Protection Board (now the Health Protection Agency Centre for Radiation, Chemical and Environmental Hazards). Further information can be found in the document 'EMFs: The Facts' which is available on the ENA website.

**Interference.** Manufacturers are required to construct electronic equipment such that it conforms to appropriate Standards covering protection from interference from electric and magnetic fields. Magnetic fields from a power line relate directly to the value of the current and fall off with distance from the conductors. Domestic equipment containing cathode ray tubes, such as computer screens and television sets, may be sensitive to magnetic fields exceeding a certain strength. As a general rule therefore, such equipment should be used only in locations which are more than 2m from underground cables, 4m from local distribution substations, 15m from overhead lines operating at voltages below 100kV and 40m from overhead lines operating at voltages above 100 kV. Electric fields, which are only associated with overhead lines, diminish rapidly with distance and are less likely to be of concern to equipment users.

**Noise.** Under certain weather conditions, audible noise can be generated by 275 kV and 400 kV overhead lines. It is therefore normal practice when routeing such lines to undertake a noise assessment to ensure that the route selected will not expose the public to an intrusive level of noise.

**Birds.** An overhead line can be a collision hazard to birds, so the industry works with bird protection organisations to minimise the hazard. By agreement, brightly coloured attachments may be fitted to the top earth wire to make the line more visible to birds, but the increased visual impact is not necessarily welcomed by the local community.

**Visual Impact.** The visual impact of overhead lines is greater than that of buried cables or cables in pipes and is greatest with high voltage lines. Electricity utilities pay considerable attention to the routeing of new overhead lines and, whenever possible, the views of public authorities and local communities are considered in an attempt to arrive at a route which is acceptable to all parties and minimises the impact on the natural environment and cultural heritage.

## Reliability and System Stability

An important consideration in determining the best means of transporting electricity to consumers is the reliability of the system. At voltages up to 11 kV, overhead lines suffer more faults than underground cables since they are more susceptible to wind, snow, ice or falling trees. At higher voltages, however, the more robust towers and conductors of overhead lines are more secure.

Although underground cables may be less prone to faults, they take longer to repair on average than overhead lines, since repair involves locating the fault, excavating the cable, completing the repair and reinstating the cover. The difference in repair times increases with the voltage such that, at 132 kV and above, overhead lines are out of service for a far shorter time than underground cables. At times of low demand, underground cables are also prone to brief overvoltages and system instability which may constrain the operating flexibility of the transmission system.

## Cost Comparisons

The capital cost per km of overhead lines goes up almost in proportion to the voltage, because of the need to provide taller towers and longer insulators so that the higher voltage conductors have sufficient air insulation clearance. However, although high voltage lines are more expensive per km to install than low voltage, their much higher capacity for transmitting electricity means that they are cheaper per unit of power for carrying electricity over a long distance and more efficient in reducing losses.

With underground cables, the heating and trenching problems outlined earlier mean that the capital cost of an underground cable installation increases more rapidly than the increase in voltage.

The capital cost of installing an underground cable is greater than that for an equally rated overhead line, the ratio ranging from about 2:1 at 11 kV to 20:1 or more at 400 kV. However, this is only a guide to relative costs, which depend on many local factors such as the ground conditions.

## Present Use of Overhead Lines and Cables

The changing relative merits of overhead lines and underground cables with increasing voltage are borne out by the lengths of each installed at various voltages in Great Britain. At the lower voltages, the difference in the overall costs of new underground cables and overhead lines does not generally preclude cable use. Indeed, in some particularly favourable areas, undergrounding of new 11kV circuits becomes viable due to access, easily excavated ground and ready routes.. Very few existing overhead lines are later undergrounded although, in some areas, this has been facilitated by joint funding through amenity schemes.

At 33-66 kV, although full undergrounding has been undertaken for amenity reasons in some instances, the high cost and disruption means that each situation is considered on its merits.

At higher voltages, the disadvantages of underground cables in terms of higher capital cost, greater down time due to faults, the potential for greater environmental damage and loss of useful land have precluded their widespread use. High voltage underground cables tend to be reserved for circumstances where overhead lines are impracticable, such as in dense urban areas or sea crossings. In exceptional circumstances, where it has not been possible to avoid routeing lines through areas of designated landscape value, there have been occasions when lengths of underground cable have been installed to preserve the visual amenity.

## Future Trends

The understandable desire to minimise the environmental impact of transporting electricity is directed mainly at reducing the visual intrusion of wires, poles and transmission towers.

At low voltages (below 11 kV) an option increasingly used for overhead lines is to replace the individual bare wires by insulated conductors, bunched together to form one cable known as an ‘aerial bundled conductor’. While this is larger it allows the adoption of shorter poles, and the result is generally considered to be visually less intrusive. Reliability is also improved and the need for tree lopping to maintain clearance is reduced.

Efforts are continually being made to reduce both the costs and the environmental impact of underground cables and to improve their reliability.

Guided boring techniques are being increasingly used to avoid trenching or where trenching is not feasible when installing low voltage service cables and some mains cables. Application at 11 kV will follow once a means of providing suitable protection and a surface warning of the presence of a cable in the ground have been agreed. One solution being considered, which has been adopted elsewhere in Europe, is to install the cables in red, medium density polyethylene pipes.

Most new 33 kV and 132 kV cables use plastic insulation, which dispenses with the need for insulating fluid, and this technology is being extended to higher voltages.

## Summary

- Electricity transmission systems carrying large quantities of electricity over long distances need to operate at high voltage.

- Overhead lines are visually more intrusive than underground cables, but land disruption during installation and repair is greater for underground cables, particularly those operating at high voltage.

- At voltages below 11 kV, overhead lines are more susceptible to weather-related damage and hence less reliable than under-ground cables. At higher voltages, lines are less susceptible in this respect and although high voltage underground cables are even less prone to faults, their complex nature means they take much longer to repair.

- Underground cable installations are more expensive to install than overhead lines, with the capital cost ratio increasing rapidly from about 2:1 at low voltage to around 20:1 at the highest voltage.

- Below 11 kV there is less difference between the overall costs, including maintenance, of lines and cables.

- At progressively higher voltages, the disadvantages of underground cables outweigh their advantages when compared to high voltage overhead lines. They are only installed in dense urban areas and in special circumstances.

- Overhead bundled insulated conductors are increasingly used for low voltages as a way of minimising visual intrusion.