PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Introductory Remarks

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Introductory remarks

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The development of public electricity supply started about 1880, less than a century ago. In this country the first Electric Lighting Act was promulgated in 1882, but the terms of this Act were too restrictive to encourage development, and it was not until an Amendment Act was passed in 1888 that real progress started. Since then the demand for energy, and in particular for electrical energy, has been steadily increasing. A doubling period of 10 years, i.e. an increase of 7 % per year, is often used as a typical indication of future demand, and figure 1 shows the demand in England and Wales during the last 14 years. There is, however, some evidence that

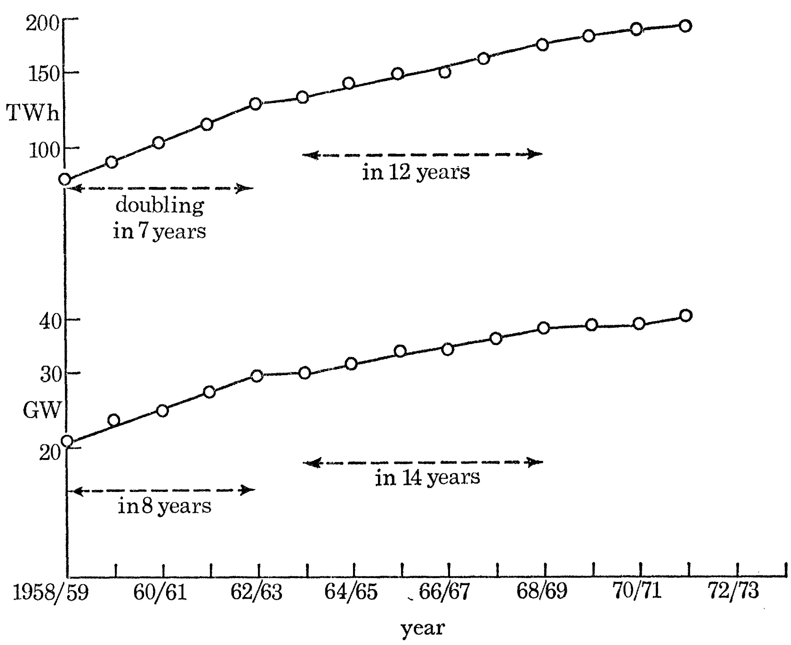

Figure 1. C.E.G.B. electricity supplied (TWh) and maximum demand (GW).

the rate of increase is slowing down in countries where the amount of electricity per head of population has already attained high levels. Nevertheless, even allowing for this factor it is still essential to plan for greatly increased supplies of electricity. This has led to the steady development of larger generators to take advantage of the economies resulting from increase in size. Thus in the last 30 years the maximum size of generators has increased from about 100 to 1500 MW, and the corresponding power station capacities have increased from hundreds to thousands of megawatts.

In order to transmit the loads from these large power stations to the load centres, and to achieve the lowest costs compatible with a high standard of reliability, the generating stations and load centres are interconnected with a network of transmission lines. Here again there has been a continuing need for greater capacity, and as the power-carrying capacity of a transmission line is proportional to the square of the voltage, this has led to higher and higher transmission voltages. In fact maximum transmission voltages have roughly doubled every 20 years, and taking into account the associated increases in the current-carrying capacity of the conductors, an increase in power transmission capacity of some twenty times has been achieved in the last 30 years, and a further tenfold increase is possible with future systems now under study (figure 2). Corresponding advances have been made in other plant such as transformers and switchgear.

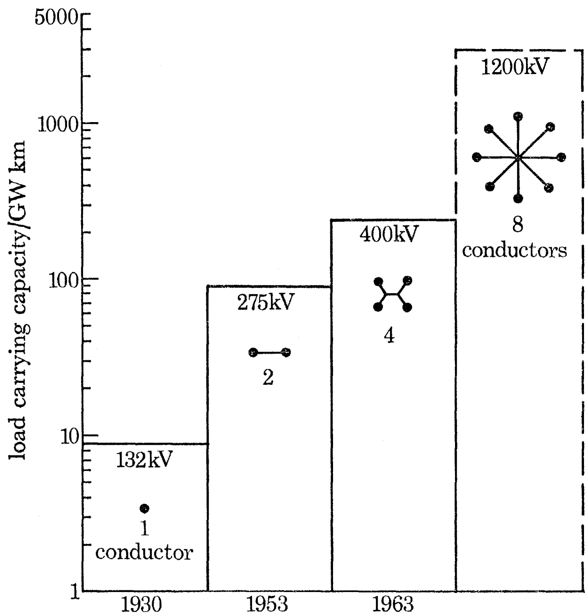

Figure 2. Transmission development in England and Wales.

In making these advances there have always been basic limiting factors which have prevented further progress at the time, and have had to be overcome before the next step could be taken. For example, the early paper-insulated underground three-phase cables operated satisfactorily at 10 to 20 kV, but great difficulties were met when attempts were made to raise the voltage to 33 kV and above. This barrier was eliminated by the development of the screened cable in which the individual cores were electrostatically screened to ensure a purely radial stress in the insulation. At higher voltages a further barrier was encountered due to ionization of the gas in voids in the insulation leading to complete electrical breakdown. This was overcome by the development of the oil-filled and gas-pressure cables in which ionization was prevented by ensuring that any spaces were kept filled with oil, or that the pressure of the gas in voids was kept above the discharge inception value. Cable voltages could then be increased to hundreds of kilovolts. The next step was to increase the current limits by water cooling to keep the conductor temperature at a safe value, and in the future we may succeed in developing the superconducting cable in which the basic limiting factor, conductor resistance, is eliminated!

Similar examples could be given with regard to other types of plant; the basic problems of underground cables and, for example, machine and transformer windings have much in common. There is much to be said for a multidiscipline approach to basic electrical plant problems in general instead of narrow specialized treatment for each specific type of plant.

Perhaps this discussion will be helpful in showing how similar fundamental phenomena are involved in the various specialist fields discussed.

It is the main object of this meeting to show how recent advances in large electrical plant are contributing to the solution of the problem of increasing energy demand and how research and development continue to push forward the current and voltage limits.

Most large electrical plant is used to meet the needs of large-scale generation and transmission for public, or even national, electricity supply systems so that the heavy plant we are going to discuss is mainly for such systems. It must be emphasized that the main justification for technological advances is an economic one and that they will be adopted only if they achieve at least the same reliability and a lower unit cost than a replication of existing plant. However, circumstances could arise, such as a future supply to a large city, or the development of a very large generating station, in which the present technology would have severe limitations and the use of advanced systems would be justified even at an increased initial cost.

We have not included a specific paper on environmental problems in this discussion but they sometimes present a further limiting factor; for example acoustic or radio noise or the effect on amenity may have to be taken into consideration when assessing different schemes. However, the overall advantages of electrical energy environmentally far outweigh any disadvantages; in fact it is only with the help of adequate supplies of electricity that present and future populations can maintain a high standard of living and amenity with a minimum of interference with the desirable aspects of the natural environment. Moreover, any environmental requirement can be met if society is prepared to pay the additional cost.

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