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UK power: an ever-changing challenge for civil engineers

This paper provides an overview of Britain's continually evolving electricity supply industry and how it got to where it is today. In an ever-changing social, political and technical environment, the industry has gone from private to public ownership and back again, and the benefits of a partial return to distributed generation are now becoming apparent. Continually rising demand and an increased emphasis on sustainability and security are now leading to further restructuring. All of this continues to supply a rich variety of challenges and opportunities for civil engineers, whose role in developing, upgrading and maintaining the nation's power-system infrastructure remains as vital as ever.

The first industrial application of electricity was probably in the electroplating industry, developed in Russia by Jacobi in the 1830s[1] and using primary batteries as its power source. Later power systems involved a simple generator connected directly to a user's application, such as the Gare du Nord in Paris, which was lit by arc lights in 1875.[2]

Such systems were valued for their utility rather than efficiency. Electricity replaced gaslights in public places, at work and in the home, and later went on to replace steam power, hydraulics or compressed air for turning machinery. The early power systems needed no extensive strategic planning because as soon as customers saw the benefits of electricity, demand increased and could be relied upon to match the output of the generating sets, at least during daytime and working hours. As demand fell at night, the proprietors of the early systems would turn off the generating sets and restart the system in the morning.

Early networks were unsynchronised, being either direct current (DC) based systems, or alternating current (AC) with only one generating machine. Later, as demand for lighting during the silent hours increased, supply would be switched across to storage batteries. Connection was easy using DC networks, some of which survived until the 1940s and even later (pers. comm.).

Although rotary converters for transforming electricity from DC to AC were in service by 1892[3] there was an economic incentive to avoid additional expenditure on rectification. Even today, the power conversion unit is still one of the highest value components of an energy storage system.

The use of storage to meet the night-time minimum load was superseded by the development of local grids. Small networks offered a higher standard of supply, as reserve-generating sets were available in the event (often likely) of failure of an operating generator. Increasing the network size allowed averaging of the load to match the generation and simplifying load following, at least for individual machines if not for the central control.

Local authorities take over

In the UK there were many power companies, which provided power to the industries, businesses and domestic properties in their local area. The 1882 Act for the Promotion of Electrical Undertakings provided for a municipal authority to take over a power company

Fig. 1. The 509 MW Battersea power station in London started producing electricity in 1933 with 69 MW generating sets

after 21 years, and a recurring option at seven-year intervals after that. As a result, many private power companies were transferred into public ownership.

The predominant fuel was coal or coke, with hydropower providing a substantial contribution where suitable resources existed. In many areas, there was an integrated energy portfolio. Coal from a local mine was moved by coal-fired railway trains to a gasworks. The gasworks produced town gas and coke by heating the coal, and useful by-products such as bitumen were also produced and sold. The unwelcome environmental legacy of these processes is still being cleared today as the sites of redundant gasworks are restored and redeveloped for other uses. Coke was moved straight from the gasworks to a local power station where steam turbines generated electricity. The typical generating unit in the 1930s was in the 50–100 MW range and the conversion efficiency was 20–25%. For example, Battersea A power station, commissioned in 1933, used 69 MW sets (Fig. 1).[4]

Centralisation and nationalisation

In 1926, The Electricity (Supply) Act introduced the first effective national coordination of electricity supplies from the fragmented municipal companies and undertakings. It created a public corporation, the Central Electricity Board, to concentrate the generation of electricity in a limited number of selected stations, interconnecting the stations by linking up the existing regional systems into a high-tension main transmission system, which later became the national grid. The first national grid was completed in 1931. A new act of parliament in 1935 brought the non-selected power stations under the direction of the Central Electricity Board for peak load and standby purposes.

The Second World War placed additional strain on power systems because of the effects of enemy action. The national transmission system at 110 kV provided some security of network operation, with the capability of transferring power despite damaged equipment.

After the war, social changes followed changes in governments throughout Europe. France nationalised its electricity industry in 1946, and in 1947 the electricity supply industry in England, Wales and southern Scotland was brought under public ownership. A total of 560 separate undertakings were grouped into 14 area electricity boards.

The British post-war structure of the power industry was based on the creation of the British Electricity Authority, which was later renamed the Central Electricity Authority (CEA) to avoid its acronym being confused with a national airline. Subsequently the structure was rationalised with the formation of the Central Electricity Generating Board (CEGB), which was responsible for generation and transmission in England and Wales. The CEGB sold its output to the distribution boards, and a handful of very large industrial consumers who were connected directly to the high-tension network of 220 kV.

In Scotland, the structure was organised on a vertically integrated basis, with both the South of Scotland Electric Board (SSEB) and the North of Scotland Hydro Electric Board (NSHEB) having responsibility for generation, transmission, distribution and sales to customers in their franchised areas. The structure in Northern Ireland also provided for a vertically integrated nationalised industry. Offshore, the Isle of Man, Jersey and Guernsey had power systems that had developed from private companies to companies or authorities administered by the islands' governments.

Improving system efficiency

The CEGB set itself some ambitious targets for increasing system efficiency and many notable achievements in the power industry took place during this period. At the time, the UK had many strong electrical engineering companies and these were able to sell their new products into a receptive nationalised industry.

Gains in efficiency followed two routes: improvements in the design, manufacture and operation of generating plant, and a continued drive towards larger generating unit sizes. The unit sizes increased throughout the 1950s and 1960s. Success points were the commissioning of a fleet of 500 MW generating sets at a number of power stations (e.g. Fawley, Didcot (Fig. 2), Pembroke and Ratcliff). Many of these generating sets are still in operation today. The

Fig. 2. The 2000 MW Didcot A power station in Oxfordshire, commissioned in 1970, was among the first to use 500 MW generating sets. It has been converted for oil and gas firing as well as coal

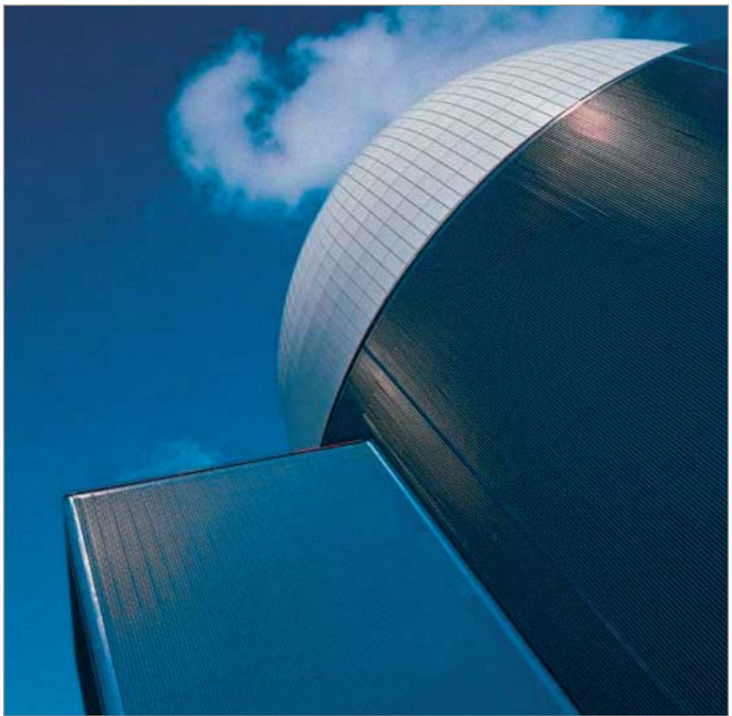

Fig. 3. The 1188 MW Sizewell B pressurised-water reactor power station in Suffolk, commissioned in 1995, is the Britain's newest nuclear power station (courtesy of British Energy, www.british-energy.com)

Table 1. Britain's 14 nuclear power stations provide approximately 22% of its electricity, reducing CO_2 emissions by up to 24 Mt a year, though all but three will have closed within the next 10 years

Operator		Capacity: MW	Published lifetime
BNFL Magnox	Calder Hall	194	2003
	Chapelcross	196	2005
	Sizewell A	420	2006
	Dungeness A	450	2006
	Oldbury	434	2008
	Wylfa	980	2010
British Energy	Dungeness B	1110	2008
	Hartlepool	1210	2014
	Heysham 1	1150	2014
	Heysham 2	1250	2023
	Hinkley Point B	1220	2011
	Hunterston B	1190	2011
	Sizewell B	1188	2035
	Torness	1250	2023
	Total:	**12242**	

gas will provide in excess of 70% of the UK power sector fuel mix by 2020

final stage of this development was the 660 MW sets used at Drax. These will continue to be used as the station has subsequently received a retrofit of flue-gas desulphurisation in order to meet increased environmental conditions for coal-fired plant.

The CEGB and its Scottish counterparts had an obligation to run the power system at the lowest overall cost on an ongoing basis. This meant that they could maintain an interest in the installation and development of modern plant, especially generating plant, which represented their largest single cost. Improving the efficiency of generating plant gave substantial cost savings and so there was a constant drive to seek improvements in plant design, operation and maintenance. Even a fraction of a percentage point improvement in efficiency could save tens of millions of pounds in fuel costs each year.

A coal-fired power station had an expected life of about 40 years and, from the 1960s to the late 1980s, there was a steady stream of power station replacements. New power stations with generating capacities of 1000–2000 MW were being commissioned at the rate of one a year. This regular workload helped power system equipment suppliers plan their future developments and gave British engineers a strong home base to serve an important export market.

Rise and stall of nuclear power

The use of nuclear power as a heat source to raise steam for electrical generators was a logical civilian application of military technology.[5] Various British Government departments were involved in the nuclear programme and there were many overlapping interests. Magnox stations were opened at Calder Hall and Chapelcross in 1956 and 1959 and the CEGB's first nuclear power station was built later at Bradwell in Essex. This was followed by similar stations using Magnox fuel on the shores of the Severn estuary, the Kent coast and the North East and North West. The SSEB also had a nuclear programme.

The second tranche of nuclear stations were based on the advanced gas-cooled reactor (AGR) of which there are five in England and two in Scotland. The final act in the CEGB's nuclear adventure was the construction and commissioning of the pressurised-water reactor (PWR) at Sizewell (Fig. 3).

The early days of nuclear power prompted the message that 'nuclear power would be too cheap to meter.' The irony of such statements can be seen today as the nuclear successor companies strive to decommission closed stations and make provision for future closures.

The UK currently has 31 operating reactors at 14 power stations (Table 1), which provide approximately 22% of the electricity in the UK. Nuclear power plays an important role in helping the UK to meet its climate-change targets. In the absence of nuclear generation, emissions of carbon dioxide (CO_2) in 1999 would have been 12–24 Mt higher, depending on the mix of generation used to replace it,

In addition, three of the older Magnox stations (Berkeley, Hunterston A and Trawsfynydd) have been closed and are undergoing decommissioning. A further two Magnox stations (Bradwell and Hinkley Point A) are being defuelled. The prototype fast reactor at Dounreay is also being decommissioned.[6]

Gas becomes dominant

Gas turbines were first introduced for industrial and utility service during the 1950s. By 1964, approximately 10 GW of open-cycle gas-turbine power plant had been sold worldwide for power generation and mechanical drives.

In the UK smaller power stations using gas turbine technology (for example Letchworth, Ocker Hill and Norwich), were built for peak power duties. These plants had a relatively low capital cost but, as they burnt diesel fuel, their running expenses were high. Their advantage was a relatively rapid start time. They could go from cold to full power (50 or 100 MW) within a few minutes, compared to 3–4 hours

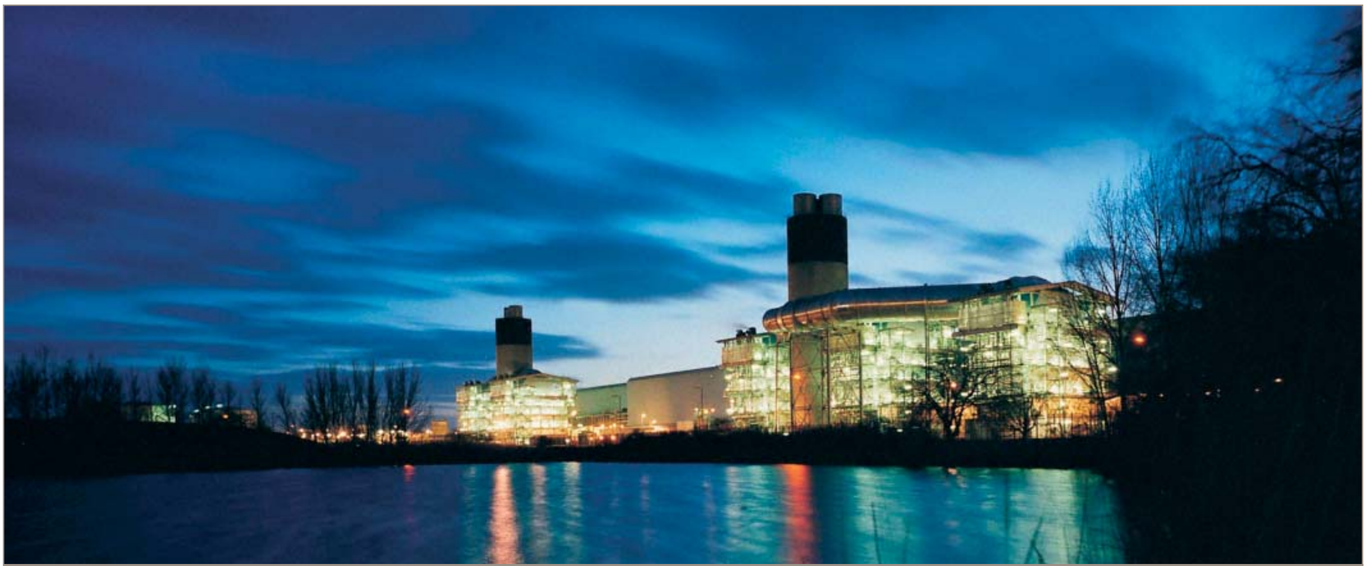

Fig. 4. The 1000 MW Barking power station in Essex, commissioned in 1995, is one of the new generation of highly efficient combined-cycle gas turbine plants (NewsCast)

required for a large coal-fired unit.

The major uptake of gas-turbine technology took place in the early 1990s as a result of a number of changes.

- After the oil embargoes of the 1970s and 1980s, legislation required European power companies to stockpile at least one month's supply of fuel for power stations. This requirement was removed in 1988.
- The emergence of combined-cycle gas turbine (CCGT) technology and its associated dramatic improvement in conversion efficiency has led to lower fuel operating costs (Fig. 4).
- There has been an increase in the availability of low-cost natural gas delivered from the North Sea.

The first CCGT stations opened in the UK in 1993 at Killingholme. These had a conversion efficiency of about 50%. Recent figures suggest that modern plant can have conversion efficiencies of at least 58%, compared to around 35–41% for coal.

CCGT plants can be configured across a range of plant sizes making them well suited to both centralised and distributed generation. Where there is a demand for heat as well as power, the CCGT can be used in a combined heat and power (CHP) role, improving the overall efficiency of the plant dramatically. Many factories, such as paper mills and chemical works have installed CHP plant and reduced their fuel costs substantially.

Gas is now the main energy source in the UK (Fig. 5). In 2000, gas accounted for 43% of energy use compared to 30% for coal. Future predictions from the DTI show that the so-called 'dash for gas'—the construction of substantial numbers of gas fired power stations in the early 1990s—means gas will provide in excess of 70% of the UK power sector fuel mix by 2020. In 2005 the UK will become a net importer of gas as well as coal.

Return to private ownership

The Electricity Act of 1989 was the start of the privatisation process for the CEGB, which formed 12 regional distribution and supply companies, two generating companies, and two vertically integrated Scottish companies. Sales of shares in the Northern Ireland Electricity Service followed later. The AGR and PWR nuclear stations initially remained in public ownership, assigned to two nuclear-generator companies (one in Scotland and one in England), but were privatised later as British Energy in 1996. Although privatised, the National Grid was owned jointly by the regional companies until it was floated in 1995.

The nation's gas industry had already been transformed by the arrival of North Sea gas in the 1970s, severing the need for coking works near power stations. British Gas was privatised in a public share offering in 1986. The British Government's ability to influence the national energy strategy was beginning to wane.

There had been miners' strikes in the 1970s, which resulted in a national emergency and rationing of electricity by region. In 1984, a lengthy miners' strike failed to have a significant impact on electricity production, for reasons attributed to extensive coal stocks at power stations (part of an EU directive on energy sup-

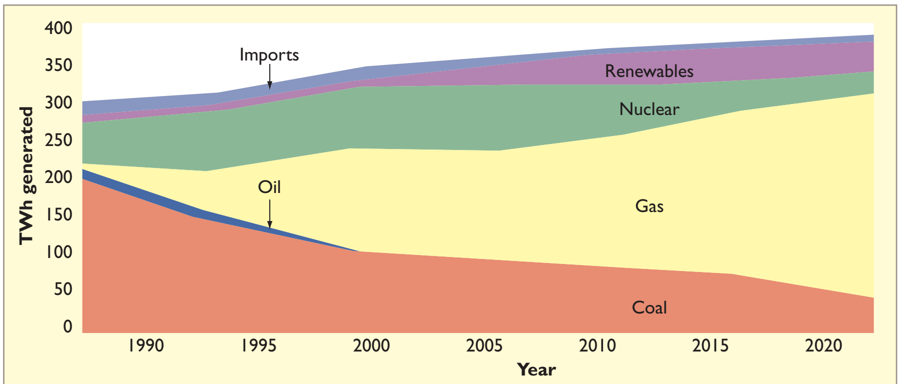

Fig. 5. UK power sector fuel mix from 1990 to 2020. Gas is predicted to account for 70% by 2020 (source DTI 2000, central high scenario)

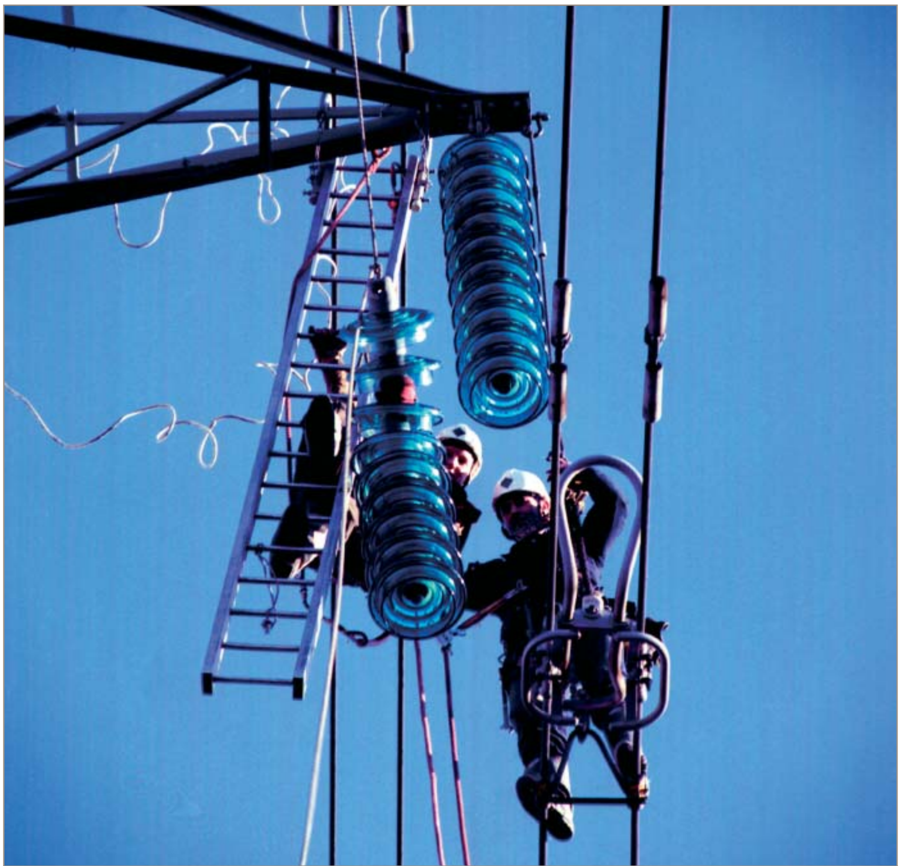

Fig. 6. National Grid owns the 400 kV and 275 kV electricity transmission system in England and Wales (NewsCast)

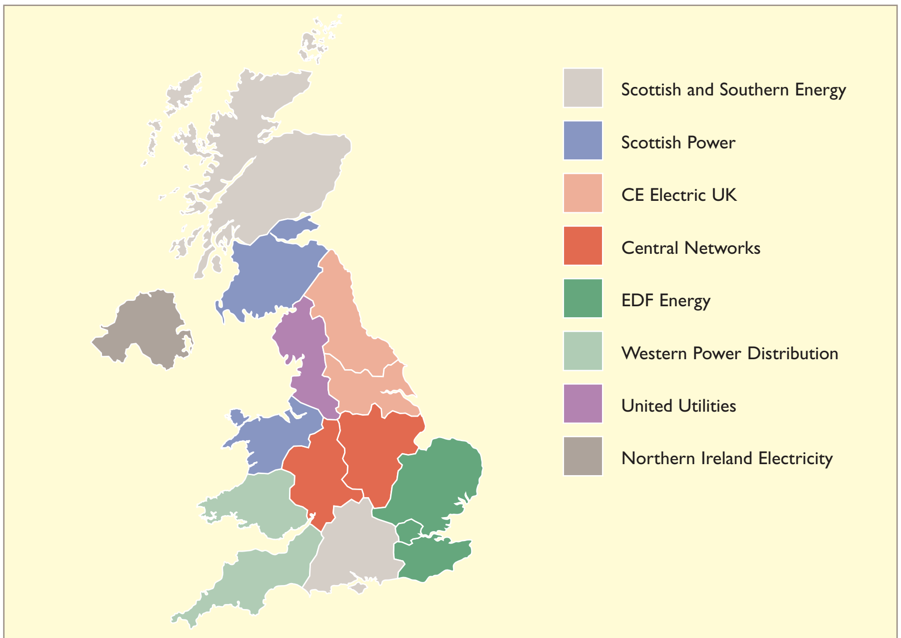

Fig. 7. Current ownership of the UK's electricity distribution networks (source http://www.energynetworks.org/index_map2.asp)

ply), diversity of fuel sources, with oil-fired and nuclear power plant operating almost continuously, and operation of the cross-Channel high-voltage DC link importing power from France. Nevertheless, the socio-economic changes at that time set in train various political moves that contributed dramatically to the organisation of the following privatisation process.

The CEGB annual report for 1986 lists 11 coal-fired power stations with generating units of 500 or 660 MW. All of these stations are still in operation by successor companies. Thirty coal-fired power stations were listed with units less than 500 MW and of these only Tilbury remains in operation today. The oil-fired stations have not fared so well, with closures at Pembroke Ince and Fiddlers Ferry.

Current electricity supply structure

Post privatisation, the UK industry has been separated into a number of companies, controlled by licences under the various electricity and utility acts. There were six major generating companies at privatisation and 35 at the end of 2002.

There is only one transmission company in each area. National Grid (NG) operates in England and Wales (Fig. 6), Scottish Power and Scottish and Southern are the transmission owners in southern Scotland and the Highlands. National Grid also owns the gas transmission network. Transmission has recently been separated into transmission owners and transmission operators. National Grid is the owner and operator of the grid in England and Wales and became the transmission system operator in the Scottish Areas in April 2005, leaving ownership of the transmission assets with Scottish Power and Scottish and Southern. This separation of roles between the owner and operator reflects the desire of the regulator to ensure fairness and transparency in offering all users of the network equal access.

The ten distribution companies are presently arranged geographically, along similar lines to the pre-privatised regional electricity boards (Fig. 7). The distribution network owners and operators are also licensed and regulated. It is possible for new entrants to establish a new network, but a licence would be required to bring it in to operation. It is likely that private networks will be established over the coming years, although mostly in special cases such as industrial and commercial estates, or renewable energy parks.

The process of supplying electricity to the end consumer of power is fully competitive with numerous commercial groupings, including supermarkets and phone companies offering to sell electricity to householders.

Another new role in the electricity market is that of the licensed meter reader. Until remote metering is available to all, there will be an ongoing requirement for meter readers to check actual consumption in order that accurate bills can be sent out.

These changes to the market structure are driven by government policy and a view that competition can lower costs. As the market separates into various layers, it has an impact on technical innovation and implementation. There is concern that innovation has slowed, particularly in the heavily regulated area of distribution, where rates of return are relatively low.

In Scotland, the two main companies, Scottish Power and Scottish and Southern Energy, cover the full range of electricity provision. They operate generation, transmission, distribution and supply businesses. The entire output of the two nuclear power stations in Scotland, which are owned by British Energy plc, is sold to these two suppliers under long-term contracts. In addition, there are about 25 small independent hydro stations and some independent generators operating fossil-fuelled stations, which sell their output to Scottish Power and Scottish and Southern Energy.

The electricity supply industry in Northern Ireland is also in private hands. Northern Ireland Electricity plc (NIE) (part of the Viridian Group) is responsible for power procurement, transmission, distribution and supply in Northern Ireland. Generation is in the hands of three private sector companies which own the four major power stations. There is a link (re-established in 1996) between the Northern Ireland grid and that of the Irish Republic, along which electricity is both imported and exported. In December 2001, the link between Northern Ireland's grid and that of Scotland was inaugurated.

Electricity trading arrangements

Privatisation was reliant on a market-based system which grew out from the 'merit order' of the CEGB. Generators submitted bids, for half-hour time periods, for the supply of power during the next 24-hour period. The National Grid Company collated these bids and calculated the least costly method of dispatching the system against their predicted demand curve. Suppliers were paid on the basis of the highest cost unit called on the system for any period and not on the bid price. This mechanism meant that stations running at base load could bid 'zero' for a time period and still be certain that they would receive the market rate for their power. The system also supported smaller generators and renewable generators who could sell power into the 'pool' without incurring substantial transaction costs.

The New Electricity Trading Arrangements (NETA) were introduced in March 2001, as the means of trading electricity in England and Wales and replaced the pool. NETA is based on bilateral trading between generators, suppliers, traders and customers and is designed to offer an efficient and more open market for electricity and at the same time maintain a secure and reliable electricity network. NETA includes forwards and futures markets, a short-term balancing mechanism and a settlement process. The introduction of NETA has placed responsibility on generators to predict their output, or face financial penalties. Wind-power producers have been hit by lower electricity prices as a result.

The NETA market was extended to Scotland under the British Electricity Trading and Transmission Arrangements (BETTA), and trading commenced on 1 April 2005.

Technical performance of the system

The current figure for the UK's generation capacity is 79 562 MW with a maximum system demand of 57 052 MW. Maximum electricity demand so far experienced by the National Grid is 54 430 MW on 10 December 2002. This was 5·3% higher than the previous maximum in January 2002. Maximum demand in 2002/2003 was 87·6% of the capacity of major power producers as measured at the end of December 2002, compared with 80% in 2001/2002, and 81% in 2000. The sharp increase in this percentage is because major power producers have closed or mothballed about 2800 MW of capacity.

Plant load factors measure how intensively each type of plant has been used. The recent trend had been for conventional thermal plant to be used less intensively and CCGT stations more intensively. However, in 2000, increased maintenance and repair at nuclear stations and at CCGT stations, coupled with high gas prices at the end of the year, led to a departure from this trend.

Continuing high gas prices in 2001 and 2002 have brought about lower load factors for 2001 and 2002. Further problems at nuclear stations in 2002 saw nuclear's load factor fall back from the recovery in 2001. The use of coal-fired stations to make up for the nuclear shortfall and in competition with gas is reflected in the increased load factor for conventional thermal stations in 2001 and 2002.

The average load factor of generation plants in the UK was 67% in 2003. This means that, on average, the output from power stations during 2003 was 67% of the total maximum possible from every plant.[7]

Encouraging renewables

Part of the electricity industry's privatisation process in the UK were mechanisms known as the 'non-fossil-fuel obligation' (NFFO) and the nuclear levy. The nuclear levy was a surcharge placed on electricity sales and the NFFO was a surcharge placed on electricity sales from fossil fuels to subsidise the introduction of renewable generation. In Scotland there was a Scottish Renewables Obligation and Northern Ireland had its own NFFO process.

Until the early 1990s renewable energy was not a significant issue in the UK. Hydro was a prevalent energy source and there were also a few geothermal plants but in general there was both little interest and few installations. Wind power was adopted and although the take-up has been slow, wind power has now developed into an important energy source for the UK (Fig. 8).[8] Wind generation is generally connect-

Fig. 8. The 60 MW North Hoyle wind farm in Liverpool Bay, commissioned in 2003, was Britain's first major offshore wind farm (NewsCast)

Fig. 9. The British Army made extensive use of diesel generator sets to provide emergency power after the war in Iraq

The now traditional centralised network is being challenged by the development of distributed energy networks

ed to the system at distribution level and the new offshore wind farms are connected at transmission voltages.

Other renewable generation types include solar (mostly photovoltaic),[9] and biomass (such as burning short rotational coppice or chicken litter). There is some debate as to whether landfill gas should be categorised as renewable and similar debates are held on the classification of waste to energy.

Returning to distributed generation

Other forms of generation are now included in the UK's portfolio. For example, diesel-generating sets can be used to provide back-up power for critical loads, to supply peaking power or even be run continuously to provide a local supply (Fig. 9). The cost-effectiveness of distributed generation relies on avoiding payment of 'transmission use of system charges' and 'distribution use of system charges' as well as by making small savings of energy losses in the network and gaining separation from variable prices in the market.

Other forms of distributed generation include fuel cells (running on natural gas, reformed natural gas or hydrogen), micro CHP (which uses a small high-efficiency Stirling engine) and micro turbines.

'Micropower' covers a range of technologies that are capable of generating power at a scale suitable for domestic and small commercial or industrial users. It includes thermal solar panels to provide heating and hot water, or photovoltaics to generate electricity. Ground source heat pumps have been in use overseas for some years now, and are just beginning to gain a foothold in the UK market.[10] There are at least three commercial developers of home central-heating systems that also generate electricity (known as micro CHP units). Several companies are about to launch small wind-power generators suitable for wall or roof-mounting to houses in the near future. Many companies are developing hydrogen-powered fuel cells for domestic heat, hot water and power generation.

A micro CHP unit, similar in size, appearance and functionality to a high-efficiency central-heating boiler, will deliver the same comfort levels as a modern boiler but reduce a typical house's emissions by 1·5 t (around 25%) of CO_2 a year. Because of the increased efficiency, the system can reduce energy costs and thereby help relieve fuel poverty as well as provide 1–5 kW of peak electricity generating capacity.

The benefits of using micropower technologies in this way would make a significant contribution to overall reductions in emissions. The so-called ecological footprint of a house can be reduced to its own surface area, leading to the possibility of 'zero carbon residences' for many consumers.[11]

The advent of distributed generation technologies offers a range of alternative options for network planning and infrastructure development. Local generation can be used instead of centralised generation and so avoid reinforcement of grid connections. Power grids may be reconfigured in a cellular structure to increase resilience to disruptions caused by adverse weather, earthquake or man-made physical damage such as terrorist attack.

The now traditional centralised network is being challenged by the development of distributed energy networks. As more CHP and renewable generation is brought on stream, and connected to the distribution network, the traditional power flows from power station to consumers are being reversed. Networks are now sending power 'the wrong way' though the network.

Although flows are relatively small, there is concern that the network does not have the ability to control these new power sources. For example, voltages must be kept within specified ranges. Conventional networks are designed to accommodate a voltage drop towards the end of the network. If a generator is added, feeding back into the network, it will raise the voltage, perhaps above the limit.

Some consumers of power require a high quality and highly reliable source of power. Although the UK has a good record with few interruptions to the public electricity supply (80·2 minutes as an average interruption per customer per annum in 2001/2003)[12] this is inadequate for many businesses. There is an increasing number of owners of uninterruptible power supplies and standby generators to protect against the technical and financial inconvenience of a power cut.

As the number of distributed generation plants increases, a change is expected in the balance of the proportion of centralised generation against distributed generation. In the UK this will depend on the relative capital and operating costs of new generation as well as the nature of existing and planned infrastructure.[13] In contrast, in many developing countries distributed generation is the most likely way to introduce electric power to the large areas not currently receiving mains electricity.

Ensuring security of supply

For the past 100 years the UK has been self-reliant on fuel sources for electricity generation with sufficient reserves of coal, oil and gas. This is set to change. Today electricity is generated from coal (35%), nuclear (22%), gas (38%) and renewables (2%), with 3% from other sources. By 2010 that mix will be very different because of ageing plant and increasing environmental constraints, with coal falling to 17% and nuclear to 16%. By 2020 coal will fall to less than 10% of the total mix and nuclear to under 5%.

Renewables—principally through onshore and offshore wind, energy efficiency and CHP—will be unable to fill the gap left by coal and nuclear. As a result gas-fired generation will be increasingly required, somewhere between 15–20 GW by 2015. This will take the UK's reliance on gas to nearly 60% of the total electricity generation mix.

North Sea gas reserves, however, are facing exhaustion. By 2020, 90% of UK's gas will come from abroad. New gas reserves will enter the UK via long pipelines initially from Norway but later from the Middle East and former Soviet Republics, or shipped as liquid natural gas from West Africa and beyond. The logistics chain will inevitably get longer and gas storage will become a crucial factor for the UK's future energy requirements.

Considerable investment will be required to extend the electricity grid to the best renewables sites and to implement technical innovations to the systems to accommodate its varying generation characteristics. Additionally, investment in the grid will also need to be ramped up to replace time-expired equipment. The situation will become critical over the next 15 years to avoid major power loss incidents, such as those that occurred in London and Birmingham in the late summer of 2003.

Continuing role for civil engineers

The two construction divisions of the CEGB had engineering responsibility within the electricity supply industry in England and Wales for the ordering, construction and commissioning of new power stations as well as the high-voltage system and its associated structures. Immediately prior to the start of the privatisation process, civil engineering works by the CEGB were valued at £100 million a year.

The CEA (predecessor of the CEGB) had recruited engineers in sufficient numbers to allow new stations to be fully engineered by in-house staff. However the leading civil engineering consultants at the time persuaded the CEGB to engage civil and architectural consultants for the design of future stations in order to provide a home showcase for the sale of their professional services overseas. This strategy was largely successful; CEGB was able to manage the peaks and troughs of design work through its consultants, who increased their overseas work on the strength of their domestic expertise.

The CEGB's successor companies have taken a similar attitude, maintaining only a small in-house civil engineering capability, although their in-house resources of mechanical and electrical engineers are much higher. New generation has been largely gas-fired, constructed under turnkey contracts with the turbine manufacturers as the prime contractor. Standardised designs have seen economies of replication both for design and for manufacturing and construction. The outstanding contribution of British engineering overseas has diminished, but still prevails in many areas.

The UK power industry has always been the scene of constant change, whether initiated by technology, politics or commercial activity. As electricity is seen to be one of the fundamental requirements of a modern society, closely following water supply and alongside telecommunications and transport, it will remain an important area for engineers, including civil engineers.

The great coal-fired and nuclear power station construction period has ended, and was briefly replaced by a boom in CCGT construction. As the present fleet of power stations reach their expiry dates, some will be replaced by offshore wind power. Infrastructure developers (such as transport, buildings, industry and commercial estate developers) may begin to take their own responsibility for providing power supplies on a local basis, using the distribution and transmission networks only for a small percentage of their power needs.

Electricity demand has increased by more than 25% since 1990 and is still increasing at more than 1% per annum. Energy efficiency measures should lower primary demand but an increasingly affluent and energy-intensive society may still continue to consume even more power. There is a role for engineers to consider how we plan and run our energy infrastructure with greater responsibility for sustainability.

Conclusions

The UK electricity supply industry has evolved over the past 120 years and has changed with improvements in technology as well as in response to contemporary social and political pressures. For most purposes, the market is regulated by some form of governmental or quasi-automonous non-governmental organisation to provide layers of stability and protection for the end consumer.

Technical changes continue and improvements in technology as well as continuing pressure towards improving sustainability mean there will be continuing changes in the power industry. The industry structure of large, centralised power stations with high civil engineering content and long operating lifetimes has changed. The structure now incorporates many smaller distributed resources operated by independent companies eager to achieve high rates of return, often over shorter timescales.

The role of civil engineers remains as vital as ever.

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References

1. Derry T.K. and Williams T.I. *A History of Technology.* Clarendon, Oxford, 1960.
2. Lord Hinton of Bankside. *Heavy Current Electricity in the United Kingdom: History and Development.* Pergamon Press, Oxford, 1979.
3. Owen E. Origins of the inventor. *IEEE Industry and Applications Magazine*, 1997, **3**, No. 1, 64–66.
4. The Vauxhall Society. Available at: www.vauxhallsociety.org.uk (accessed September 2005)
5. Dagnall S. Nuclear fission: continuing evolution of a future generation. *Proceedings of the Institution of Civil Engineers, Civil Engineering*, 2005, **158**, No. 6, 12–19.
6. http://www.dti.gov.uk/nuclearcleanup/.
7. Department of Trade and Industry. *Digest of UK Energy Statistics 2004.* HMSO, London, 2004.
8. ffrench R., Bonnett D. and Sandon J. Wind power: a major opportunity for the UK. Proceedings of the Institution of Civil Engineers, Civil Engineering, 2005, **158**, No. 6, 20–27.
9. Bahaj A. S. Solar photovoltaic energy: electricity generation in the built environment. *Proceedings of the Institution of Civil Engineers, Civil Engineering*, 2005, **158**, No. 6, 45–51.
10. Batchelor T. Geothermal energy: a major renewable energy resource. *Proceedings of the Institution of Civil Engineers, Civil Engineering*, 2005, **158**, No. 6, 40–44.
11. Sowden D. *The Micropower Council.* Private communication, 2005. See http://www.micropower.co.uk
12. Electricity Association. *Electricity Review 7.* Electricity Association, March, London, 2003.
13. Lovis A.B., Datta E.K., Feiler T., Rabago K.R., Swisher J.N., Lehmann A. and Wicker K. *Small is Profitable.* The Rocky Mountain Institute, Snowmass, CO, 2002.

What do you think?