HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 372 February 2011

Future Electricity Networks

Ongoing reforms of regulation and the electricity market aim to transform the electricity system and its operation. This will require many billions of pounds of investment in the UK's electricity networks. This POSTnote examines the possibilities and challenges for network development.

Overview

- The UK's electricity networks need renewal, reinforcement and reconfiguration to support a transition to a low-carbon energy system.
- By making networks 'smarter', particularly at the regional level, networks can be better used and the need to construct extra network reduced.
- Nevertheless, new or reinforced circuits will often be required, particularly to connect new low-carbon generation at or beyond the extremities of the existing grid.
- Where additional onshore, large-scale transmission circuits are needed, various reforms are underway to reduce delays.
- Offshore circuits will also be required and could form part of a 'super-grid' that increases connection with other countries.

Background

The UK's electricity system is dominated by a centralised delivery model, where power flows from less than sixty large power stations to millions of consumers (POSTnotes 163 and 280). There are two types of electricity network:

- **transmission networks,** which transport power around the country at high voltages, from large power stations to some industrial users and to the distribution networks.
- **regional distribution networks,** which distribute power at lower voltages, generally in one direction from the transmission networks to the majority of consumers.

Electricity supply must be balanced with demand in real time. In Great Britain, National Grid is the transmission system operator responsible for maintaining this balance.[1] As electricity is not stored in significant quantities (POSTnote 306) and most demand is unmanaged, balancing is mainly achieved by controlling the output of flexible generators. The total capacity for power generation has exceeded peak demand by 15–25% in recent years, to ensure that sufficient generation is available at any given instant.[2]

The electricity sector faces three key challenges:

- **the retirement of existing generators.** Up to a quarter (20 GW) of the UK's power-station capacity will reach the end of its operating life by 2020[3] and will need timely replacement. (1 GW is the approximate output of a range of existing coal and nuclear power stations.)
- **the rapid and significant installation of new low-carbon and renewable generators,** as required by legislation (Box 1).
- **a potentially significant increase in electricity demand.** As the greenhouse gas emissions associated with electricity generation decrease, sectors such as heating and road transport may shift to use electricity to reduce their emissions, possibly doubling overall electricity demand by 2050.[4]

Box 1. Legislation and Its Implications for Electricity

The Climate Change Act 2008 commits the UK to reducing greenhouse gas emissions by at least 34% by 2020 and 80% by 2050, compared with 1990 levels. The EU Renewable Energy Directive 2009 requires that 15% of the energy used as electricity and for heating and transport comes from renewable sources by 2020, compared with only 3% in 2009.

These targets present major challenges. A lead scenario of the Department of Energy and Climate Change (DECC) suggests that around 30% of electricity would need to come from renewable generators by 2020,[5] up from only 6.7% in 2009. The Committee on Climate Change (CCC) has suggested that to meet the emissions targets, electricity supplies will need to be almost completely decarbonised by 2030.[6]

Developing the UK's Electricity Networks

Following the Electricity Act 1989 and privatisation of the electricity industry in 1990, the reduction of costs has been a major regulatory driver for the network companies. The Office of Gas and Electricity Markets (OFGEM) indicates that its regulation has benefited consumers: network prices fell by 50% between 1990 and 2010.[7] However, evidence to the Commons Energy and Climate Change (ECC) Committee suggests that because the regulatory regime encouraged the short-term minimisation of operating costs, investment in research, development and deployment for longer-term benefits was insufficient.[8]

OFGEM estimates that £19bn of investment is needed in electricity networks by 2020 to support a lower-carbon economy, at twice the rate of investment during the past 20 years.[7] To support this, it is in the process of introducing a new regulatory regime (the 'RIIO' model)[7] and has also introduced a £500 million "Low Carbon Networks Fund" to encourage trial and demonstration projects.

Investment in the UK's electricity networks is needed for:

- **renewal of ageing network.** Much of the existing network was built in the 1950s-60s and needs replacing.[7]
- **construction of new network.** New or reinforced network is often required to accommodate growth in demand or to connect new generation. The location of generators using ambient energy flows (such as the wind) depends heavily on the location of the resource, in contrast to generators using transportable fuels. Much new generation is expected at or beyond the extremities of the existing grid and will require significant new network.
- **development of 'smarter' networks.** This involves an increased application of information, communications and control (ICCT) technology and could bring a variety of benefits.[9] It can, for example, use existing networks better and thus reduce the need for new network (Box 2).

Many issues raised by network development are different for the distribution and transmission networks. For instance, a move to 'smarter' networks will mainly affect the distribution networks, since these are generally 'passive' at present in that they use relatively little ICCT technology. Transmission networks, by contrast, already employ high levels of system monitoring and intelligent control (although scope does remain for increased use). Distribution- and transmission-level issues are discussed in the following sections.

Distribution Networks

Smart Meters

Smart meters (POSTnote 301) could have a key role in the move to smarter networks by providing real-time information to consumers, suppliers and the networks. They could provide a better understanding of demand and enable, for example, Demand Side Management (DSM) as discussed in the following section. The government will require suppliers to install smart meters in every home in Great Britain by 2020.[10] The Department of Energy and Climate Change (DECC) and OFGEM are consulting on the process[10] and are due to publish an implementation plan in April 2011, ahead of a full 'roll out' from summer 2012.[11]

Box 2. Novel Techniques for Network Operation

OFGEM's "Registered Power Zones" scheme has supported novel approaches to network operation that have reduced the need for network reinforcement.[1,9] An example of this is the **Dynamic Line Rating** (DLR) technique applied by EON Central Networks in Skegness, Lincolnshire.[12] The temperature of a power line increases with power flow and is affected by the ambient air temperature and wind speed. Conventionally, the maximum power that is allowed to flow within a line is calculated with fixed values for air temperature and wind speed. When new wind turbines were planned for Skegness, conventional calculations suggested that line reinforcement was required to cope with the increased power generation. Engineers developing the alternative DLR calculation method suggested that such reinforcement was unnecessary. They calculated the power rating of the power lines on a minute-by-minute basis with real-time weather data. They found that this power rating increases at times of high wind generation because the higher wind speeds have an increased cooling effect. By avoiding unnecessary grid reinforcement the project saved an estimated £5m.[12]

However, smart meters do not guarantee smarter networks. That will depend on the smart meters' features, an effective communications infrastructure between the meters and the networks/suppliers, appropriate privacy and security arrangements, and consumer acceptance. The communications issue has been the focus of much recent debate. DECC and OFGEM have proposed to accelerate the roll-out by initially installing meters that meet only basic requirements, prior to establishing a communications infrastructure.[10] However, organisations such as the Institution of Engineering and Technology (IET) have emphasised that communications capabilities are crucial for a smarter grid and should be put in place early in the roll-out programme.[13] They outline the risk that meters might otherwise require (costly) re-visits to change or upgrade them. The IET advocates a more cautious roll-out approach that focuses on specific geographic areas to test and prove principles. In this context, OFGEM and DECC have announced funding for a variety of pilot 'smart grid' projects that include smart meter trials (e.g. Box 3).

Box 3. Low Carbon Network Fund Projects

In November 2010, OFGEM announced the first-round of funding from its £500m "Low Carbon Network Fund" for projects that include:

- **"Customer-led Network Revolution"** (£53.6 million). This project will monitor more than 28,000 residential, commercial and industrial customers with smart meters and 600 smart appliances. It will explore ways for smart meters and network operators to communicate. It will also investigate how new tariffs can encourage customers to engage in Demand Side Management (see below).
- **"Low Carbon London"** (£36.1 million). This will focus on the ten "Low Carbon Zones" in London and integrate with the "Plugged in Places" project (POSTnote 365), which is installing 25,000 electric vehicle charging points by 2015 to support 100,000 electric vehicles. In conjunction with energy retailers, the project will implement new tariffs for vehicle charging. It will install 5,000 smart meters and also receive information about commercial electric vehicle usage.

Demand Side Management (DSM)

DSM is the process of managing demand to suit available supply, a reversal of the current paradigm for electricity. A simple example is the "Economy Seven" tariff, where cheaper off-peak pricing encourages a shift in demand from peak times to night hours to the benefit of generators and networks. Some large industrial users negotiate lower tariffs to accept reductions of supply when necessary.

Smarter technologies could enable more complex DSM to aid system balancing or to avoid network congestion. An unobtrusive example is to interrupt supply to those appliances that will suffer no ill effect, such as fridges. Devices can be installed between the power supply and the appliance to monitor the frequency of the grid, which indicates the balance between supply and demand. These devices then increase or decrease the electricity use of their appliance to suit the networks. Significant numbers would be needed to provide a notable system-balancing service.

Smart meters have the potential to introduce more significant DSM. Suppliers could, for example, use smart meters to offer tariffs whose prices vary through the day and night to reflect the overall pressure on the electricity system. This could encourage consumers to alter their non-urgent electricity use to cheaper times. 'Smart' dishwashers and other appliances could be remotely operated or programmed to respond to varying tariffs. Space-heating systems (such as heat pumps) and electric-vehicle charging could be similarly managed (Box 4).

The Electricity Networks Strategy Group (ENSG), a senior industry group chaired by DECC and OFGEM, has emphasised that successful smart metering and DSM will require a concerted approach to security and data privacy as well as the development of common and open smart grid standards.[14] An illustrative timeline from the group suggests that use of DSM could expand from 2015,[14] though this is heavily linked to the emergence of smart appliances and the willingness of consumers to participate.

Box 4. Demand Side Management for Heating and Transport
The potential growth in electricity use for heating and transport (POSTnote 365) presents both a threat and an opportunity to the networks:

- **threat** – if the power demands are unmanaged, large increases in heating demands and vehicle-charging would require significant new generation capacity and network reinforcement.[15]
- **opportunity** – both vehicle-charging and heating are potentially suitable for demand-side management (DSM). A user could leave an electric car plugged in, but its actual charging could be timed to suit the network. Electric-vehicle batteries could even feed power back into the grid. Buildings respond relatively slowing to sources of heating, and thus heating systems could be switched off or on over short time periods without noticeably affecting building temperatures.

Recent research[15] suggests that DSM can significantly reduce demand peaks and the need for system reinforcement. For example, in the long-term scenario of a full take up of electric vehicles and electric heat pumps, unmanaged demand is estimated to increase overall energy use by 50% and the system's peak power demand by 100%. Optimising demand through DSM could, in contrast, restrict the peak power demand to an increase of only 29%, make better use of generation and network capacity, and reduce the need for network investment.[15]

Storage
Energy storage offers another way to reduce the need to balance generation with demand in real time. 'Pumped storage' hydro-electric stations already provide vital system balancing services. (These stations use electricity to pump water to a high-level reservoir, later releasing the water to generate electricity at peak times. In 2009 the UK had 2.7 GW of pumped-storage capacity.) A variety of other technologies could provide storage at all stages within the electricity system: from generation, through transmission and distribution, to the end-users (POSTnote 306). DECC indicates that significant technological advances are required for storage to become a reality on a large scale.[9] The ENSG suggests that widespread deployment is unlikely until at least 2020.[14]

Distributed Generation
Localised electricity generation within the distribution networks, such as with solar photovoltaic arrays and combined heat-and-power (CHP) systems, can provide benefits over the centralised approach.[16] By generating electricity close to where it is used, there is potential to reduce both the need for new network capacity and transmission losses (there would still be losses within the distribution networks). Fuels can be used more efficiently in CHP generators, which capture the heat produced during electricity generation and provide it for local use.

Feed-In Tariffs were introduced in April 2010 to provide financial incentives for small-scale generators up to 5 MW (equivalent to 2,500 kettles of 2kW each). The ENSG suggests that total capacity of such generators will be limited before 2020.[14]

The potential for a large-scale deployment of distributed generators presents a variety of challenges to networks. The current distribution networks were not designed to cope with large numbers of such generators, which at times can turn consumers into producers who feed electricity back into the grid. Research and development is ongoing to address these issues. For example, the "Virtual Power Plant" concept is to aggregate and co-ordinate many distributed generators. The EU FENIX project, amongst others, has been developing and demonstrating the concept, with a UK-based project involving Woking Borough Council, Imperial College London, and a variety of industrial partners.

Transmission Networks
Barriers to New Generation
Two major barriers for new generators have been delays in the planning system (for consenting new network) and delays in getting access to the transmission network.[8]

Reform of the planning system has been ongoing since the Planning Act 2008. In 2010, the Coalition consulted on revised draft National Policy Statements (NPSs) and intends to present final versions to Parliament in May 2011.[11] NPSs are to be "blueprints" for consenting major infrastructure to support a "rapid, predictable and accountable" planning system. Many consultation responses concerned the negative visual impact of overhead lines, particularly in sensitive areas such as Areas of Outstanding Natural Beauty.[17] As part of a wider inquiry into NPSs,[18] the Commons ECC Committee recommended that cables are put underground in such places, though also said that economic or environmental circumstances could sometimes make this impractical. National Grid has commissioned research on the costs of undergrounding, due to report in early 2011.

Under previous arrangements for getting access to the transmission network, potential generators were required to wait for both local connection works and wider system reinforcements before they could connect, often causing significant delays for the waiting applicants. In August 2010, a "Connect and Manage" scheme was formalised to reduce connection times. It enables new generators to connect before wider network reinforcement is completed, in contrast to the previous approach.[19] The costs of managing the additional generation (until the wider works are completed) are spread across all generators. The costs passed to consumers are projected to be 20p per household per year until 2020.[20]

Another way to reduce connection times is to anticipate and begin building new network ahead of need. OFGEM has begun to approve some of the £4.7bn of network investments proposed by the ENSG as necessary for meeting the UK's 2020 targets.[20] The process has been welcomed by many for accelerating the connection of new low-carbon generation. However, the extent of the proposals has been challenged by some, including witnesses to the Commons ECC Committee. Prof. Goran Strbac, for example, described the ENSG proposal as a "business-as-usual" response constrained by existing regulatory and network-access arrangements.[8] He and others acknowledged that new and reinforced network is required but said that alternatives should also be considered.[8] These include novel network operation techniques (e.g. Box 2) and a greater role for DSM, distributed generation and storage.

Offshore Connections

Up to 50 GW of offshore wind generation and other marine technologies is expected in the next 10–15 years.[20] DECC and OFGEM have been developing a regulatory regime to encourage the necessary investment. A prominent debate is whether a co-ordinated approach to network development should be taken, rather than connecting each wind farm individually to land. Some argue[8,19] that such an approach is needed to minimise costs and the number of connection points on land. National Grid, for example, suggests that co-ordination could reduce costs to consumers by 25%.[21] DECC and OFGEM plan to consult on the benefits of a co-ordinated approach in 2011.[22]

Interconnection and Super-Grids

Interconnectors enable the trading of electricity between countries. The UK has links of 2 GW with France and 0.6 GW with Ireland;[2] a further 1 GW link with the Netherlands is due to be commissioned in 2011. The concept of a 'super-grid' is to expand such interconnection to create an international or even intercontinental transmission network. Proposals include one for the North Sea, which was supported by ministers of ten European countries via a memorandum of understanding on 3 December 2010.

Increased interconnection and development of super-grids have a range of potential benefits. They could help to incorporate intermittent generation (such as wind power) and ensure security of supply by enabling power transfers between countries that have insufficient or surplus generation.[8] This would depend technically on the ability of neighbouring countries to increase output or accept input. Consumers could benefit from greater levels of competition, although closer integration with other electricity markets also brings risks.[8] Debate is ongoing as to whether offshore wind networks should form part of a super-grid. One recent report found it more cost-effective, in the short to medium term, to keep interconnection and offshore wind farm connection separate.[23] The Campaign to Protect Rural England, however, argues for a longer-term view and co-ordinated approach, emphasising that decisions taken now for offshore wind connections may affect the future viability of a super-grid. Further evidence is forthcoming, such as the second phase of the European Climate Foundation's "Roadmap 2050" project due to report in summer 2011.

Encouraging Network Development

A range of other legislative and regulatory issues (Box 5) will affect the development of UK electricity networks. Despite these, the government believes that significant reform of the UK's electricity market is needed to deliver investment at the required scale and pace.[4] DECC has launched an Electricity Market Reform (EMR) consultation[4] and aims to publish a White Paper in spring 2011.[11] The Commons ECC Committee is conducting an inquiry into EMR, also due to be published in spring 2011.[24]

Box 5. Overarching Factors Affecting Electricity Networks

- DECC will publish a review of the role of OFGEM in spring 2011.[11]
- OFGEM has launched "Project TransmiT" to review the transmission charging regime and further connection issues.
- The Energy Security and Green Economy Bill 2010/11 aims to make OFGEM responsible for estimating future capacity and assessing the adequacy of plans, by enabling them to collate relevant information from generators and suppliers.
- The EU "Third Package", which aims to deliver a single competitive energy market across the EU, will be implemented in March 2011.

Endnotes

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