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Research
Smart Grid—Review

An Overview of the Smart Grid in Great Britain

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ABSTRACT This paper presents an overview of the current status of the development of the smart grid in Great Britain (GB). The definition, policy and technical drivers, incentive mechanisms, technological focus, and the industry's progress in developing the smart grid are described. In particular, the Low Carbon Networks Fund and Electricity Network Innovation Competition projects, together with the rollout of smart metering, are detailed. A more observable, controllable, automated, and integrated electricity network will be supported by these investments in conjunction with smart meter installation. It is found that the focus has mainly been on distribution networks as well as on real-time flows of information and interaction between suppliers and consumers facilitated by improved information and communications technology, active power flow management, demand management, and energy storage. The learning from the GB smart grid initiatives will provide valuable guidelines for future smart grid development in GB and other countries.

KEYWORDS smart grid, power system, renewable energy, Low Carbon Networks Fund, smart metering

1 Introduction

The consensus among climate scientists is clear that human-made greenhouse gases (GHGs) are leading to dangerous climate change. Hence, ways of using energy more effectively and generating electricity without, or with limited, production of GHG must be found [1].

In the United Kingdom (UK), the power sector is currently the single largest source of GHG emissions, accounting for 27% of the total [2]. By 2050, emissions from the power sector need to be reduced to close to zero. In Great Britain (GB), the anticipated future decarbonized electrical power system is likely to rely on generation from a combination of renewables, nuclear generators, and fossil-fueled plants with carbon capture and storage (CCS) [2]. This combination of generation is difficult to manage as it consists of variable renewable generation, and large central generators that run at a constant output for both technical and commercial reasons. Meanwhile, the demand for electricity, with the potential electrification of heating and transport, will become more variable. As a result, the power system will need to become smarter at balancing demand and supply. Smart grid is widely recognized as the future of modern electrical power systems. It involves modernizing existing networks, changing the way they operate, facilitating changes in the behavior of energy consumers, providing new services, and supporting the transition to a sustainable low-carbon economy [3].

The UK has made significant progress to date in deploying smart grids and has made a considerable investment in smart grid research and demonstration projects. These projects have been delivered through a range of initiatives, including the Office of Gas and Electricity Markets (Ofgem) price control model, which places great emphasis on supporting network innovation; and the creation of the £500 million Low Carbon Networks Fund (LCNF) and its successor, the Electricity Network Innovation Competition (ENIC). These competitions provide funding for network companies to undertake innovation projects and try out new smart grid technologies and solutions. More limited funding for innovation is available to network companies through the Network Innovation Allowance (NIA) [4] and the previous Innovation Funding Incentive (IFI). GB has also begun the nationwide installations of smart meters, which will help to improve network management and facilitate demand reduction and shifting.

Various actors are involved in the development of the smart grid in GB, including the government (Department of Energy and Climate Change, DECC), a national regulatory authority (Ofgem), network companies, equipment manufacturers, and academia. This paper presents the current status of the development of the smart grid, the roles these actors have played in the past few years, the focus areas and achievements to date, and future work that needs to be undertaken to deliver a low-carbon smart grid. The learning from this work will provide valuable guidelines for future smart grid development in GB and other countries.

2 Smart grid definitions

The future power system is expected to make extensive use of

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modern information and communication technologies (ICT) to support a flexible, secure, and cost-effective decarbonized electrical power system. A smart grid is capable of controlling active networks intelligently to facilitate the integration of renewable energy into the power system [5].

Various definitions of the smart grid have been used by different countries across the globe and no single universal concept has been agreed on. This paper presents two definitions that are often used in GB.

The concept of the smart grid, developed in 2006 by the European Technology Platform, is:

> *A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it—generators, consumers and those that do both—in order to efficiently deliver sustainable, economic and secure electricity supplies.*
>
> *A smart grid employs innovative products and services together with intelligent monitoring, control, communication and self-healing technologies in order to:*
> - *Better facilitate the connection and operation of generators of all sizes and technologies;*
> - *Allow electricity consumers to play a part in optimizing the operation of the system;*
> - *Provide consumers with greater information and options for choice of supply;*
> - *Significantly reduce the environmental impact of the whole electricity supply system;*
> - *Maintain or even improve the existing high levels of system reliability, quality and security of supply;*
> - *Maintain and improve the existing services efficiently; and*
> - *Foster market integration towards a European integrated market.* [1, 5, 6]

The definition provided by the Energy Networks Association (ENA) is:

> *The Smart Grid is everything from generation through to home automation with a smart meter being an important element, with every piece of network equipment, communications technology and processes in between contributing to an efficient and smart grid.*
>
> *A completely Smart Grid of the future will enable appliances in the home to communicate with the smart meter and enable the networks to ensure efficient use of infrastructure, demand response and energy management. These are all critical to making the most of intermittent renewables and keeping the lights on in an affordable low-carbon energy future.* [7]

3 Drivers for smart grid

In GB, the drivers for the smart grid include policy and technical aspects.

3.1 Policy aspects

The *Climate Change Act 2008* [8] established a legally binding target to reduce the UK's GHG emissions to at least 80% lower than the 1990 baseline by 2050. Also, a target was set that emissions should be a third lower than the 1990 level by 2020.

In 2009, the European Commission (EC) passed legislation to ensure that the European Union (EU) meets its ambitious climate and energy targets for 2020. These targets are known as the "20-20-20" Renewable Energy Directive, in which three key objectives are set [9]:

- A 20% reduction in EU GHG emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%; and
- A 20% improvement in the EU's energy efficiency.

Within these overall targets, individual member states have been given different specific targets suited to their climates and circumstances; the target for the UK is to produce 15% of primary energy from renewable energy sources by 2020. Since the adoption of this directive, most member states in the EU have experienced significant growth in renewable energy consumption.

The UK has enjoyed a wealth of energy resources. However, the UK has mainly relied on the natural resources of fossil fuels. Only 1.3% in 2005 and 3.1% in 2009 of primary energy use was from renewable energy [10]. Compared to many other member states of the EU, the UK starts from a very low level of renewable energy consumption and the challenge to meet the 2020 targets is considerable.

The UK Government's Action Plan concludes that delivering 15% renewable energy by 2020 is feasible through domestic action and could be achieved with the following proportion of energy consumption in each sector coming from renewable sources [10]:

- Around 30% of electricity demand, including 2% from small-scale sources;
- 10% of transport demand; and
- 12% of heat demand.

It can be seen that this proposed increase of renewable energy consumption in electricity, transport, and heating sectors is in line with the carbon budgets and will help keep the UK on track to hit the 2050 target of an 80% cut in GHG emissions [11]. In order to meet these targets, major changes in the way GB generates and uses energy, mainly within the electricity, transportation, and heating sectors, are required [2].

In electricity, three parts of the portfolio are renewables, nuclear power, and coal- and gas-fired power stations fitted with CCS. In transportation, ultra-low emission vehicles including fully electric, plug-in hybrid, and fuel cell powered cars are being developed. In heating, the technologies will include air- or ground-source heat pumps, and using heat from power stations.

As can be seen, electricity lies at the heart of these changes. Currently, GB has around 78 GW of generation capacity, leaving around 34% surplus capacity (known as gross capacity margin) over electricity demand at peak times (considered to be 58 GW) [12]. With the potential electrification of heating, transport, and industrial processes, average electricity demand may rise by between 30% and 60% [2]. As much as double today's electricity capacity may be needed to deal with peak demand. Renewable energy will account for approximately half of the estimated capacity needed. The development of CCS technology is expected to bring the costs and risks down to make this technology at scale in a commercial environment.