IEA Implementing Agreement on
Electricity Networks Analysis, Research and Development (ENARD)

Annex I Briefing Sheet

"The Power System of the Future" Challenges & Opportunities

Annex I: Information Collation and Dissemination

Introduction

The architecture of many of today's power systems looks remarkably similar to those installed some 30-40 years ago. It would seem highly unlikely, however, that this system architecture will be able to meet the challenges of distributed generation or the interconnection of renewables and the associated intermittency anticipated over the next 25 years. A growing change in how consumers use electricity, coupled with an increased awareness of the potential environmental impacts of traditional generation technologies, is driving the development of a number of new technologies and systems that could lead to radical changes in the industry.

Some of these technologies and systems, such as Smart Metering, Electrical Energy Storage and Active Network Management, are detailed more fully in separate briefing sheets from this series so are not discussed here.

Shift in Generation Mix

The mix of assets being used to generate electricity is beginning to shift from large fossil fuelled centralized power stations to smaller decentralized units. Whilst nuclear, coal, gas and oil fired power stations are still prevalent, they are increasingly being complemented by a growing array of renewable technologies in many countries. This is largely in response to international and regional targets for emission reductions and growing concerns about security of supply amid increasing concerns over reliance on (expensive) supplies from less politically stable parts of the world.

Internationally, a number of States and Regions have adopted targets for how much of their energy consumption should come from renewable sources in the future. The European Union, for example, has proposed adopting a target of increasing energy used from renewable sources to 20% by 2020. The actual percentage targets are anticipated to vary between the Member States, in relation to their present position, and are due to be finalized in early 2009. Australia has taken a similar approach, with a target to ensure 20% of its electricity comes from renewable sources by 2020[1]. Whilst in the US, many of the States have set their own Renewable Portfolio Standard, which specifies the amount of electricity that retail suppliers need to provide from renewable sources[2]. These range from 4% in Massachusetts to 25% in Minnesota and Oregon. Canada has taken a similar Province led approach.

An increase in the penetration of intermittent generation connected to a system is likely to lead to challenges for balancing the system which could result in System Operators looking for higher levels of reserve or create opportunities for other evolving technologies such as Electrical Energy Storage.

Many of the existing thermal and nuclear power stations are approaching the end of their lifespan. In order to respond to this and increasing concern about the impact of electricity generation, a number of new technologies are being developed to increase the efficiency of these generation methods and reduce emissions.

Example applications of these include the Supercritical Coal-Fired Power Station that E.ON have proposed to build in the UK and the European Pressurized Reactor (EPR) Nuclear Power Station being constructed by EdF at Flamanville in France. Southern Company in the US is also developing gasification techniques to maximize the power production from coal as well as making a cleaner method of combustion.

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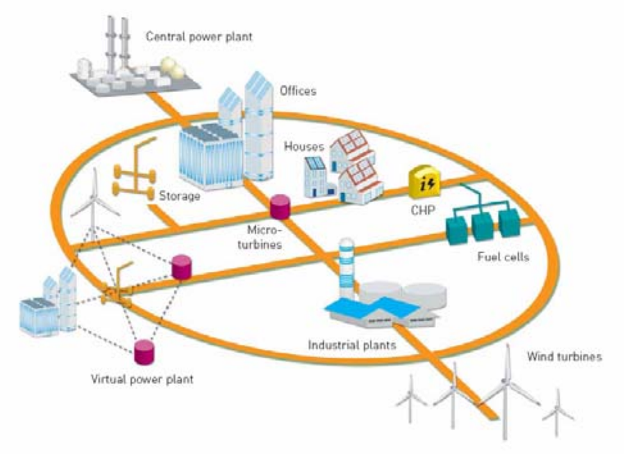
Additionally, concerns regarding emissions are leading to a growth in the market for, and subsequent development of, technologies for Carbon Capture and Storage (CCS). Hydrogen Energy, for example, is looking to combine CCS with new techniques to extract the hydrogen from fossil fuels. The hydrogen would then be burned in a modified gas turbine whilst the CO_2 will be either stored in depleted gas or oil reservoirs or used in Enhanced Oil Recovery. Two projects are currently being developed, one in California, US, and one in Abu Dhabi in the United Arab Emirates.

SmartGrids

A number of forums have been established internationally to investigate the possibilities for the future development of energy networks or SmartGrids. These include the US DOE Federal Smart Grid Task Force, established under Title XIII of the Energy Independence and Security Act 2007[3]; the European SmartGrids Technology Platform supported by the European Commission; and the Ontario Smart Grid Forum.



European SmartGrids Platform – Vision for the Future[4]
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Examples of current SmartGrids projects include Modern Grid Networks, a collaboration between the US DOE and the National Energy Technology Laboratory (NETL), is building upon the framework created by Grid 2030; IntelliGrid, being developed by the Electric Power Research Institute in conjunction with various industry partners; GridWise, an alliance between the US DOE and various private and public stakeholders; and the Danish Cell Controller Pilot Project[5] being a full utility scale "SmartGrid" development with the intention of creating a fully functioning Virtual Power Plant utilizing the already existing high penetration of DER in a Danish 60 kV distribution area.

The goals of these forums and projects can be broadly described as improving the efficiency, reliability and security of electricity supply, whilst optimising the amount of distributed generation connected to the network. This is likely to be through using new technologies to make the existing systems work more intelligently in conjunction with Active Network Management. Example of technologies that might be part of a SmartGrid include: dynamic circuit ratings; logic scripts incorporated into protection systems and 2-way communication between assets and operators.

Grid 2030[6] highlighted the following as key factors affecting the future of the electricity system:

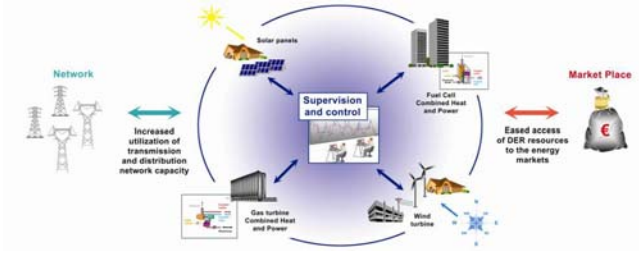
- Electricity Restructuring;
- Environmental Regulations;
- National Security;
- Competition;
- Aging Infrastructure;
- Consumer Demands;
- Information Technologies;
- New Materials;
- High Temperature Superconductors;
- Electricity Storage;
- Advanced Power Electronics;
- Distributed Energy Technologies.

Whilst the focus of Grid 2030 is the development of the US national system, many of these key factors apply to other national systems.

SmartGrids might also incorporate a greater element of automation to facilitate the taking of preventive action to limit faults, for example. They may also use Demand Side Management (DSM) and/or Virtual Power Plants (VPPs) to facilitate a greater level of control of load and generation on distribution networks.

Virtual Power Plants

VPPs are a number of independent generation sites, usually relatively small scale (i.e. 50MW or smaller) that are combined to form a single generation entity. Instructions can then be sent to control the asset, as would be sent to larger generators, and the operator responds by adjusting the various sites accordingly. The generation sites might include wind, photovoltaics, microCHP, back-up generators, fuel cells, storage, or small hydro.



FENIX Project's Model of a VPP[7]

Potentially, VPPs could increase the security of supply by being able to offer Ancillary Services and DSM. They could also make it easier for System and Network Operator to manage the power system by combining a number of small sites, which would usually not be visible, into a single entity that could be controlled. How different sites are controlled and instructed is just one of challenges for the development of VPPs. Other challenges include how VPPs might sit within different regulatory frameworks; identifying the most ideal combination of generation types and how the sites should be connected to the existing networks.

Community Orientated Microgeneration

In some countries, there has already been a move away from large-scale generation to smaller individual and community-orientated projects. In Denmark, for example, decentralised generation makes up over 55% of the country's electricity generation and of its 3150MW of installed wind capacity approximately 58% is owned by individuals and farmers. In Germany, 2.6GW of electricity is produced by domestic photovoltaic cells. Other countries are now looking at following suit.

Community focused microgeneration has a number of benefits including promoting energy awareness; increasing security of supply and helping individuals and communities to reduce their fuel costs.

The extent to which microgeneration has succeeded has often been determined by the regulatory structure of the country involved and the initiatives available. In Germany, for example, operators of the electricity networks are obliged to accept renewable energy fed into the national public grid and pay a predetermined rate as stipulated in the Law for the Priority of Renewable Energy. This gives some certainty to individuals and communities looking to invest in microgeneration as to the economic benefits that they may receive from any specific system.

The reasons for countries to investigate and promote microgeneration vary. For some, it is a response to legislative or regulatory requirements whilst for others it is due to concerns regarding remoteness of supply. The costs and benefits therefore involved vary from country to country, and even between communities. A remote neighbourhood that is dependent on imported energy supplies is likely to receive a greater benefit from achieving some independence than an inner city suburb.

These projects have often involved the use of renewable generation and/or Combined Heat and Power (CHP) systems. Examples of this type of scheme include the district heating scheme in Ringkøbing in Denmark to provide the local town with heat and power; the Harvard Business School's 36kW photovoltaic installation on its sport hall roof in the US; and the Kennermerwind Cooperative in the Netherlands whose members own 10 wind turbines.

Community microgeneration projects may also include the development of a Microgrid. A Microgrid would control the load and generation on a small part of the LV network (below 11kV in the UK, for example) and potentially could run islanded for short periods of time in the event of a disruption to the wider network. One example of this type of project is the microgrid test bed being led by the Consortium for Electric Reliability Technology Solutions (CERTS) in the USA. The concept is intended to enable an unlimited quantity of DG and energy storage to be integrated into the existing electricity grid.

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ENARD Participating Countries:
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