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Ireland's Smart Grid Demonstration Projects

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1 Introduction

Electricity networks are complex and expensive to build. It is estimated that the European transmission and distribution (T & D) system has over 230,000 km of transmission lines (220 kV or above) and five million kilometres of distribution lines. The investment value in these networks exceeds €600bn with another €500bn of investment required over the next 20 years.

In Ireland the Electricity Supply Board, Networks (ESBN) owns and operates the Distribution System in the Republic of Ireland, serving a population of over 4 million people with 2.2 million electricity customers. It also owns the Transmission system which is operated by a separate company EirGrid. Due to the dispersed population the average electricity line length, per customer, is almost four times per capita the European average. The investment in these networks in the period 2001- 2010 will exceed €6bn.

Electricity networks are a vital national infrastructure in terms of supporting economic development. In addition, electricity networks are also fundamental to the delivery of EU and national sustainability targets. For success in this role radical change is needed in the design, operation and embedded intelligence of electricity networks – a development sometimes described as smart networks or smart grid. Networks of the future will need to be smarter, more accessible and more efficient. In the US, the new administration has included almost \$5bn to promote smart grid. In Europe the SmartGrids Technology Platform has set out deployment priorities for smart networks [1]. In Ireland many of the building blocks for smart networks are already in place or are being developed. Three areas of particular focus are electricity generation, transportation and energy end use.

2 Smart Network Elements

2.1 Electricity generation

Electricity generation in Europe accounts for 33% of CO₂ production [2]. Governments and utilities everywhere recognise that addressing this issue means a major change in generation technology. The vast resources of coal on the planet, particularly in the US and China, have created an imperative to solve the technology challenge of removing CO₂ emissions from coal-fired generation. For some countries nuclear generation is back on the agenda. In the last decade the development and deployment of wind generation has exceeded all expectations: Europe had 65,000 MW of wind installed by the end of 2008. Ocean and tidal energy are finally getting serious attention. Ireland has set a target of 40% of electricity from renewable sources by 2020 [3], a challenge that all the players in Ireland's electricity sector are focused on making happen. Currently there is over 1,200MW of wind generation connected. It is planned to connect 6600MW connected with approximately half this quantity to be connected at Distribution voltage level, at or below 38kV.

The Electricity Supply Board (ESB) has set out a timeline and targets to reach a position of net carbon neutral by 2035, one of the first utilities in Europe to do so.

2.2 Electric Vehicles

Road transport in Europe accounts for 23% of CO₂ emissions with an even higher figure for Ireland (29%) [4]. Governments and the major car manufacturers recognise that the current energy model for transport is no longer tenable and all are seriously looking at the electric vehicle (EV) in some shape or form. Particularly in Ireland, the scale of available wind energy offers the potential to fuel an

emissions free transport fleet of the future. The EV has the additional advantage that the energy supply infrastructure it requires is largely there. There are however, significant challenges and the networks of the future must adapt to address these.

2.3 Energy in buildings

Energy use in residential and commercial buildings accounts for c. 30% of CO₂ emissions in Europe. Building design, new materials, new standards and major investment in the upgrade of buildings will transform the energy performance of this sector over the next few decades. The installation of local generation, buildings/home area networks (HAN) and smart appliances are all part of this transformation. Eventually, the net energy requirements of the sector suggest that ‘carbon free’ electricity will be the only external energy source needed.

3 Smart networks – an enabler

Ensuring society can leverage from the increasing advantage electricity will bring as a decarbonised energy source presents a major challenge to Electricity Network Operators. ESB Networks’ vision of how all these developments come together is best captured by the model in Fig. 1 [5]. Smart networks are simply a key link in the integration of clean and renewable generation all along the electricity value chain to customers and their energy devices. It is critical that developments in each area are advanced in an integrated way.

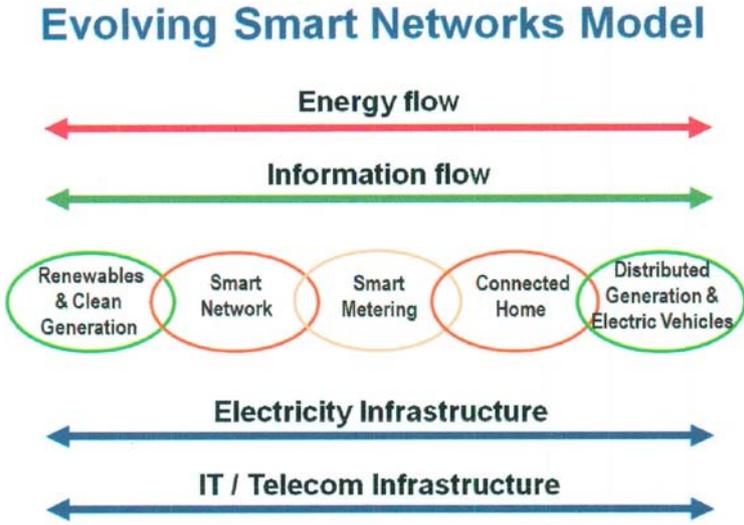


Fig. 1 Smart Network Model

3.1 Renewables and distributed generation

Delivering on Ireland’s target of over 40% of electricity from renewable sources requires over 6,000 MW of renewable generation to be connected to the electricity network. The nature and scale of Ireland’s system means large numbers of relatively small wind farms. Approximately half of the total capacity will be connected to the distribution system, a unique development compared to most other countries. Over 1,200 MW of wind plant is already connected, 1,400 MW of projects are at contract approved stage and a further 3,900 MW have recently been approved by the Commission for Energy Regulation (CER) [6]. The national target for increased penetration of micro-generation with export facility could result in many small generators being connected at low voltage levels. ESB has announced support for the first 4,000 installations by way of a top up of 10 c per kWh on the ESB Customer Supply export tariff of 9 c and free installation of smart metering. These measures, as well as strong support and promotion by Sustainable Energy Ireland (SEAI), are driving interest and applications. Networks of the future will have bidirectional power flows at different voltage levels, with generators at customer sites exporting energy on to the system. Resolving these challenges in ways that are economically viable and enhance security of supply are critical elements of the smart networks journey.

3.2 Electric vehicles

Governments in Europe and the US have signalled a major commitment to developing the electrification of transport. In Ireland, a target of 10% penetration of passenger electric vehicles by 2020 has been set. Ireland should be particularly suited for electric vehicles since the average travelling distance for private cars of 47 km/day is less than the EU average of 60 km/day [4]. In addition the % of house ownership and properties with secure parking driveways is higher in Ireland than other Europe. However, there remain significant challenges and turning this target into reality is not going to happen without major national commitment and industry leadership. Many challenges lie ahead including:

- Roll out of national public charging infrastructure
- Standardisation of charging connections and interoperability between cars changing infrastructure and electricity networks
- Smart charging to minimise system peak implications of high penetration of EVs
- Open and flexible IT and data management systems to enable all electricity suppliers to compete for EV charging.

This project will examine the potential impact of various levels of penetration of EV's on existing distribution networks. Two typical electricity circuits will be examined, one Urban Circuit and one rural group circuit. It is planned to trial EVs on each sample circuit in combination with smart meters to demonstrate the impact of charging on the network. Key factors to be determined are the impact of charging point location on the network and confirm the simulation and modelling software through the physical demonstration. Through a verified model, the project will assess the level of EV penetration that these two typical circuits can take. Such data and a verified modeling tool will be invaluable in terms of characterising EVs as a resource for the electricity system of the future.

3.3 Smart metering

Developments in the areas of smart metering and utility advanced metering infrastructure (AMI) are seen as a gateway between electricity networks and customers. Smart meters are simply intelligent two-way communications devices with digital real-time power measurement. Apart from the obvious advantages of remote operation and remote meter reading they also offer the potential for sophisticated time-of-use and real-time pricing, and demand side management (DSM) and an interface with home area networks (HAN). They also have the potential to act as intelligent nodes on the electricity system. Their deployment offers uniquely valuable information for improved management of voltage, supply quality, outages and networks assets. Roll-out is expensive and complex, and decisions on functionality are critical. For example, including water and gas in the AMI is technically feasible but would add significantly to project and IT risks. ESB Networks is currently operating two evaluation trials for smart meters in conjunction with the Commission for Energy Regulation (CER) and the industry here in Ireland. One trial involving 6,000 customers is well advanced and will look at the potential to influence customers' behaviour in terms of demand/energy levels when offered different price/tariff incentives. The baseline data (minimum 6 months data) of the customer behaviour trial have now been collected. Since January, customers have been encouraged to manage their load through the pricing incentives, more informative bills and an in home display. The Economic and Social Research Institute (ESRI) are independently carrying out the assessment of measuring the impact of the incentives on customer's behaviours. The project is expected to finish in q1 2011. A second trial will look at various smart metering systems including different meters, communications technologies like power line carrier (PLC) technology, radio technologies and IT interfaces. The trials will inform a full business case analysis for a final decision on national roll-out. The challenges are complex – the final system should ideally:

- be able to integrate with existing enterprise systems and emerging smart network systems and have a lifespan of 15-20 years;
- incorporate open standards and interoperability between meter and system vendors; and
- be capable of handling the massive data flows and high levels of cyber security.

Smart metering and/or future energy home area networks will facilitate interaction between the networks/grid demand requirements, appliances and demand levels within the home. The objectives of improved energy efficiency, improved performance and lower costs are all driving developments in this area. This is an area open to new developments and there are clear business opportunities emerging for the creation of exciting new products and services. Smart networks are not simply about enabling

renewables and customer response. Intelligent systems like ESB Networks' SCADA and Operations Management System (OMS) are recognised as being at the leading edge of utility best practice in terms of remote control and system management. Over 1,000 intelligent switches have been installed on medium voltage overhead networks and fully integrated into SCADA over the last three years and further roll-out is planned. These systems along with AMI represent some of the building blocks for smart networks.

It is important, however, to keep a perspective on the Smart Grid concept – the only reason to support a smart grid is to provide worthwhile benefits to customers, i.e. cheap and reliable electricity with lower carbon emissions. Smart grids and distributed generation should not be considered as an end objective in themselves. Accordingly, the term Smart Grid, as used by ESB Networks, not only encompasses ICT technology, but any other development in materials or design (e.g. high temperature conductors) which can deliver customer benefits economically. It is also becoming clear that there are major synergies from the use of different technologies e.g. when a network is sectionalised and automated to improve continuity a by-product is that losses are substantially reduced, thus subsidising the costs of automation.

There are also new opportunities:

- active network management, for example, enable voltage and reactive power control to support increased wind penetration on distribution networks;
- additional distributed intelligence and sensors to help improve load factor, system losses, outage performance and 'self healing' in the event of faults; and,
- leveraging from the latest developments in materials, superconductivity, energy storage and power electronics.

ESB Networks has commenced work on many of these areas already and is linked with the Electric Power Research Institute (EPRI) in the US, the Electricity Research Centre (ERC) in University College Dublin (UCD) and Sustainable Energy Ireland (SEI), along with ESB International, to investigate and research the complex solutions required to bring the many components of smart networks to a successful implementation stage. Smart networks will bring enormous changes in terms of enabling the generation, transportation and utilisation of cleaner electricity – some would suggest not unlike the impact of the internet on telecommunications. However, the real issue is the extent to which they can create value along the entire industry value chain. The bottom line is, of course, the value they create for customers and the economy. Crucially, the roadmap and implementation path for smart networks must be focused on delivering:

- lower electricity prices;
- less carbon emissions;
- Increased quality and security of supply.

Smart networks, as part of a co-ordinated strategy across the energy industry to address national energy efficiency and CO₂ challenges, has the potential to achieve even more in terms of opportunities for the research, development and commercialisation of new systems and products that will be needed to support a more sustainable future.

4 Research Strategy

The ERC together with ESB Networks, EirGrid, and the remaining industrial members of the ERC have developed a number of key research streams to tackle the challenges faced in enabling the smart and sustainable electricity system of the future. These work streams are aligned to ESB Network's smart network roadmap.

ESBN/EPRI and ERC have initiated a Smart Grid Demonstration project which aims to address key research questions on Integration of distributed resources. The demonstrations will include the following components:

- Integrating Distributed Generation Demonstrations
 - A. The control of reactive power at the DSO/TSO interface and the control of voltage at the Distribution point of common coupling through the smart management of Voltage/Var controls at the distribution connected generation
 - B. The management of voltage rise caused by the distribution connected Generator through the use of a voltage regulator.

- C. The economic design of Distribution connected Network Stations.
- Integrating Demand Response Demonstrations
 - D. Carrying out a Customer Behaviour trial to assess the potential for demand responsiveness to pricing and information incentives.
 - E. Demonstrating the impact of EV's on the Distribution system and reviewing the potential for the management of this load to ballast wind. Also to review the potential for Vehicle to Grid.
 - F. Smart operation and design of Distribution Networks.

The ability to control reactive power requirements at large DSO / TSO stations (typically 110 kV/MV or 110/38 kV) requires control over both wind generator power factor and busbar voltage. A range of novel solutions to relieve voltage constraints, incorporating autotransformers, generator reactive power controls, on-load tap changer controls, FACTS devices and other power electronic converters will be investigated. While each option can ease voltage rise constraints, none is sufficient to completely overcome the problem. As a result, co-ordinated control and operation of these resources is required. Active co-ordinated control of these various resources will be assessed, network control options investigated which can accommodate increased wind generation capacity, while also proposing novel wind farm control strategies.

Demand side management can be seen as a potential mechanism to aid in the management of wind variability, particularly as conventional generation is displaced from the system. Implemented strategies have focussed on peak saving (peak reduction due to efficiency measures), peak shifting (deferring peak until a later time) and peak shaving (deferring peak load permanently). These schemes are typically planned in advance and give little opportunity for shorter-term dynamic operational issues. However, the advent of smart metering and its potential for real-time pricing could encourage greater load flexibility. The flexible load resource for Ireland is being investigated, along with its availability to provide system services in a reliable and economic manner.

The implications of wide-scale deployment of electric vehicles on system operation and distribution network development must also be understood. The capability of the existing network to facilitate vehicle charging will need to be assessed and if constraints present themselves methods for optimal use of the existing assets and network investment strategies will need to be devised. From a system operation perspective, it is likely that night-time charging of vehicle batteries will be encouraged, such that system balancing opportunities could exist from the storage capability provided. Since vehicle charging is discretionary rather than essential load, system support services could be provided. In addition, ramp rate limits, e.g. during morning rise, regional load control, e.g. voltage considerations, could all be beneficial. Switching of charging loads could be initiated by smart metering and / or home area networks, by sending controls to on-street chargers or even by in-built car intelligence. Vehicle to home (V2H) or vehicle to grid (V2G) roles could also be feasible, but will require consideration of the domestic supply, local network and vehicle electronics.

As outlined above, ESB Networks has already significant smart technology deployed on the Irish Distribution networks through remote control automation switches, SCADA and OMS. The advent of smart metering in conjunction with this will allow potential for more active management of networks. In addition network design such as the conversion of medium voltage networks to 20 have already led to losses savings of up to 25MW. The demonstration project will show that these savings are true. In the US a number of studies are showing positive results from implementing conservation voltage programmes. Due to the mix of resistive load in Ireland, this is unlikely to be as successful on this side of the Atlantic, however a demonstration trial will be performed with will also give good information on the load mix of our customers.

5 Conclusion

It is evident that the term smart networks spans a range of developing areas within the electricity industry. This paper has set out Ireland's vision of how the proposed benefits of a smarter network can be attained. It will require co-operation and collaboration of industry stakeholders and research institutes but is realistically achievable over the next ten years. A key issue to be remembered is the primary function of the electricity network, that being to deliver a secure and reliable supply of electricity to every customer. The current high standards of supply must be maintained if the development of smarter networks can claim to achieve its stated goals.

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7 Biographies

Mark McGranaghan: Mark McGranaghan is a Director in the EPRI Power Delivery and Utilization (PDU) Sector. His research area responsibilities include overhead and underground distribution, advanced distribution automation, Intelligrid, and power quality. He is also directing EPRI's extensive smart grid demonstration initiative (5 year effort) to help coordinate the industry approach for distributed resource integration with the operation of the grid. Before joining EPRI, Mr. McGranaghan

worked for Electrotek Concepts for 14 years and McGraw-Edison/Cooper Power for 11 years. Mr. McGranaghan has BSEE and MSEE degrees from the University of Toledo and an MBA from the University of Pittsburgh. He has taught seminars and workshops around the world and is very active in standards development and industry activities (IEEE, CIGRE, IEC).

Teresa Fallon: Teresa Fallon received a B.E. degree in Industrial Engineering and Information Systems in 1992. She has worked in the ESB since graduation and has carried out many roles in this organization. She currently is the Networks Investments Manager for north of the country and is moving to a new role of Program Coordinator for the ESB Networks Smart Grid Demonstration Project.

Andrew Keane: Andrew Keane received a B.E. degree in Electrical Engineering in 2003 and a PhD degree in Electrical Engineering in 2007 both from University College Dublin. He is an SFI lecturer in the School of Electrical, Electronic & Mechanical Engineering in UCD with research interests in power systems planning and operation, and the integration of distributed energy resources.

8 Abstract

The electricity system of Ireland is unique as it has no synchronous connections to other systems, while the existing non-synchronous connection provides limited flexibility. When coupled with a target of 40% electricity from renewables by 2020, exceeding any other country, the challenge is truly striking. However, this challenge also gives Ireland the opportunity to be the world leader in this area. The unique experience in solving this problem will provide the technology and knowledge to harness renewable energy sources globally and limit the dependency on petrochemicals. The continued development of the electricity distribution network as a smart network is a critical element of this process which spans electricity generation, transportation and energy end use. This paper described the various elements of ESB Networks' sustainability strategy and the associated research themes being jointly pursued by ESB Networks, the Electric Power Research Institute (EPRI) and the Electricity Research Centre, University College Dublin.