INTERNATIONAL REVIEW OF HOW POWER SECTOR DEVELOPMENTS ARE RESPONDING TO CHANGING SYSTEM CHARACTERISTICS

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ABSTRACT

The UK recently undertook an in-depth study (the Future Power Systems Architecture project, FPSA) to identify new and extended functionality that will be required to operate a safe, secure, reliable and affordable system in the future. As part of the project, an international study was undertaken to review various approaches other countries are taking to address similar challenges. It looked in detail at Ireland, Germany, New York and California with a high level review on other areas. This paper summarises key insights from that study. It has helped inform and shape the steps necessary to prepare UK's power system for the transformational change ahead.

INTRODUCTION

Power systems around the world are facing unprecedented challenges that affect both technical designs and business/institutional arrangements. Disruptive changes are emerging, for example due to new technologies, such as distributed generation, electric transportation, demand response, heat pumps, large scale renewable generation, greater interconnection, and home automation. Managing their adoption and integration into the power system requires careful planning and co-ordination to ensure that their value is realised and they do not place unacceptable risks to overall system efficiency and reliability.

PURPOSE

The FPSA [1] project purpose was to "set out, and provide evidence for, what functions will need to be performed in the future power system as a result of its on-going transformative change, and by when". As part of the analysis and evidence gathering, research has been carried out on comparable electricity supply industries from other countries, with the following questions in mind:

- What specific current and future system planning and operational challenges in other countries are relevant and comparable to those in GB?
- Do these challenges require (i.e. in the view of each country) functional changes in planning and operational practices?
- If so, how are these functional changes being conceived, introduced and managed?

The countries chosen for initial analysis by the project steering Group include Ireland, Germany and the United States (California and New York) as the power system challenges in these countries are believed to be sufficiently similar given, for example,

- That they all have stretching renewable targets and there has been notable deployment in their power sectors (and they have seen early effects of the change in generation mix, for example lack of inertia and system control issues).

- There have been notable technology deployments at scales greater than that seen on the GB system and therefore it is believed that there may be some key learnings and advanced thinking around system development.

- They share a similar energy policy in that balancing renewable targets, security of supply and affordability are cornerstones of their policy.

- At a high level, they have similar market structures in that there are levels of competition at various points in the sector, most networks are covered by regulatory frameworks, there is a system operator, there is an active balancing market and there is a degree of separation in retail markets.

The insights and recommendations from that study have been published as an FPSA report [2] and there are two further CIRED 2017 papers related to the main project [3].

COMPARABLE CURRENT AND FUTURE SYSTEM PLANNING AND OPERATIONAL CHALLENGES RELEVANT TO GB

A number of transformational technologies are approaching commercialisation and either are, or likely to be, deployed at scale on the GB network over the next decade or so. These include:

- Distributed generation (primarily PV and wind, but also biomass, gasification, anaerobic digestion, micro and small CHP).
- Heat pumps to support the drive towards decarbonising heat.

- Plug in Hybrid and Electric Vehicles to decarbonise transport and improve air quality.
- Microgrids and community energy schemes promoting more autonomous local grids.
  - Greater deployments of Interconnectors, partly aided by advances in HVDC technology.
  - Large scale renewable deployment which decreases volumes of synchronous plant and reduces system inertia.

A precise comparison is not entirely straightforward, however balancing individual viewpoints, programmes, declared issues, public policies and future plans the table below provides a correlation with the challenges facing the GB system. Three ticks indicates a very strong correlation in that those issues are very relevant through to a cross which indicates that that challenge area is not particularly relevant or not expected at any notable scale.

Challenge Areas	Ireland	Germany	United States		National Grid's Gone Green scenario for the GB system
			New York	California	
Distributed Generation	√	√√√	√	√√√	√√√
Heat pumps	√	√	√	x	√√√
Electric transportation (BEVs & PHEVs	√√	√	√	√√√	√√
Microgrids & Community energy systems	x	√	√√	√√	√√
Interconnections	√√√	√√	√	x	√√√
Large scale renewables and Inertia challenges	√√√	√√√	√√	√√√	√√√

The column 'National Grid Gone Green scenario for the GB system' provides a reference and demonstrates that none of the other countries face all of the challenges to the same degree. On balance, this probably adds to the implementation challenge. Many consulted indicated that their industry structures were often a barrier to taking forward technical solutions to meeting the trend challenges.

In addition, data, smart meters, communications networks and information flows have been consistently highlighted as being increasingly viewed as part of the energy system. As the future unfolds these are likely to become critical components of distribution system planning and facilitating integration of distributed energy resources. The task of converting data to information was highlighted as a new function/capability required in the sector, while this has begun, its complexity is likely to significantly increase as more devices connect to and become part of energy systems.

MEETING FUTURE SYSTEM CHALLENGES

Ireland

Ireland initiated (in 2011) a wide ranging programme to look at the many aspects and implications of meeting its renewable targets. The DS3 programme "**D**elivering a **S**ecure **S**ustainable Electricity **S**ystem'' brings together key industry participants (transmission and distribution companies, regulators, system operators (EirGrid and SONI) and generators) to develop solutions to operating the power system in a secure, reliable and economic way. At its core, the programme is about making the necessary operational changes to manage significant levels of renewable generation, but it is also about the evolution of the island's wider electricity system and implementing broad changes in market and regulatory spheres that will ultimately benefit consumers. Holistically it considers technical, commercial and regulatory needs of the system. The programme is chaired by the regulator but follows a very collaborative approach. The programme commission's technical studies and analysis as required with recommendations being discussed openly and taken forward/rejected as required. The programme has the authority to initiate detailed changes such as modifications to the grid code.

The interface between the transmission companies and distribution companies is facilitated by the programme with regular meetings to discuss progress, issues and implications arising from the DS3 programme. This governance arrangement (TSO/DSO plan) ensures transmission originating issues have a formal route to distribution assessment. DS3 complements a number of other distribution oriented programmes, for example ESB's Integrated Vision for Active Demand Management and NIE's Project 40. These are both closely aligned with DS3.

The primary purpose of the programme is to meet the 2020 renewables targets but has found itself dealing with adjacent areas, for example DSR, which whilst not explicitly required to meet 2020 targets is a key enabler. This has led to suggestions that the programme could take on a similar role in looking at 2030 and 2050 targets which could cement it as an enduring body rather than a targets-based transient programme. This is currently being discussed.

Though operationally focussed the programme does often initiate demonstration projects and helps focus on areas for inclusion in the various smart grid programmes in Ireland and Northern Ireland. In some ways it is comparable to that of the GB Smart grid strategy work, however appears to have a wider remit to be able to take decisions and implement changes.

Germany

A new target architecture for Germany to meet its energy goals is described within the 'Energy Transition'. The new target architecture prioritises and structures the objectives of the Energy Concept. In many ways it is a very high level systems architecture which brings together policy, markets and programmes to meet the transition. The update suggests development of the two core market functions, firstly to ensure adequate capacity is available and secondly that it is available at the right time (at the right scale).

The four German TSO's (50Hertz, Amprion, TenneT and TransnetBW) jointly produce a 10 year network development plan that sets out network reinforcements and investments required to meet the energy policy. The plan is co-ordinated by the federal network agency (Bundesnetzagentur). Though primarily to accommodate the transition to renewables, the plan does take account of resilience, European interconnection, security, consumer protection and market access. The plan is developed collaboratively, takes into account future scenarios and is subject to public acceptance. It is considered to be a robust methodology for delivering the plan required to outline the development of the transmission system. There are no plans to extend its remit to cover distribution systems, or private networks/community energy systems.

The German Commission for Electrical, Electronic and Information Technologies (DKE) and Association for Electrical, Electronic and Information Technologies (VDE) have developed the 'German Roadmap, Smart Grids 2.0' with the subtitle 'smart grid standardisation, status, trends and prospects'. A number of industry experts provided input to the work and in many ways it mirrors elements of the FPSA project. The document covers smart grid architecture, security and use cases.

It is believed that a variety of additional measures (functions) will be required on distribution grids to manage storage, demand response, smart inverters, two-way flows, virtual power plants, flexible loads, integration with heat supply and heat storage. For example, some German distribution utilities are starting to forecast local renewables output to better manage the local grid. Others are considering how to integrate local balancing and peak-shaving with local combined-heat-and-power plants and heat storage. Some utilities are experimenting with smart inverters installed on distributed solar power systems as a new way to regulate distribution system voltage and reactive power. And some utilities are thinking about long-term planning and modelling for their local networks. However, there is no evidence of extensive systems analysis highlighting requirements for new or improved functions, though much of the functionality identified in the FPSA (around distribution networks) work is under consideration.

There are examples of 'smart grid' labelled projects that do incorporate behind the meter technologies and active community involvement. One leading one is in the town of Wildpoldsried, where the local grid operator AUW and Siemens have teamed up for a project to integrate renewables and e-mobility into the local grid. It features a suite of grid edge technologies which managed holistically stabilises local power quality. Elements of the project also cover microgrid architecture and it will test operations in an islanded mode, though at present it is not expected that islanding microgrids will play a significant role in the future energy system.

United States

New York

New York has recognised the many significant changes happening in the industry and embarked on two wide ranging change programmes:

- The Energy Highway – focussing on generation and transmission
- Reforming the Energy Vision (REV) – focussing on distribution networks, distribution system operations, new markets and community engagement

REV aims to better align markets and regulatory frameworks with new technologies and innovation. This ensures that renewable energy is maximised while costs are kept low through enhanced competition whilst maintaining system security. Part of the driver for REV is to enable more resilient networks which are able to cope with more extreme weather events such as superstorm Sandy.

At the heart of the change is the aim to open the distribution network to new market entrants who can provide access to distributed energy resources to utilities. It also aims to promote networks capable of microgrid operation, community energy systems and active involvement by consumers.

Its primary focus is in and around distribution networks, distribution system operations and end user energy efficiency measures. The programme proposes a new entity called the Distributed System Platform (DSP), which will act as an integrator of distributed energy resources (DG, EVs, DSR, storage, and energy efficiency). In European terminology, we would call the DSP a DSO however the DSP has a responsibility to set up and run a competitive market for DER services. Initially the DSP role will be provided by the incumbent utilities as a 'ring fenced entity' however in the longer term the option remains to create a truly independent DSP (mirroring that of the role of an ISO on a transmission system).

It is proposed that the DSPs have a number of new (or enhanced) functions to enable the state to make the best use of distributed energy resources. These are:

- **Distribution planning** – enhanced planning to incorporate DERs, value those resources and improve co-ordination with transmission planning.
- **Distribution grid operations** - improvements to load and network monitoring including effective multidirectional power flow to improve value from DERs.
- **Distribution market operations** – administer RFPs (Requests for Proposals), run auctions, commercial agreements, performance management of DERs and participants.
- **Data access** – collection and provision of customer and distribution system data to facilitate a DER market and spur investment (respecting data privacy and security).
- **Platform technologies** – it is recognised that the different IOUs are at different technology advancement, this function sets a minimum standard to be met to enable a functioning DSP, namely DER management system, geospatial system, optimisation tools and communications network.

California

California's IOUs have developed and publicised long term Distribution Resource Plans (DRPs) as mandated by the CPUC. These plans set out how the utilities pan to integrate a range of DERs (defined as distributed generation, energy storage, energy efficiency, demand response and electric transportation) covering:

- Evaluation of locational benefits and costs of DERs.
- Recommendation for tariff structures, contracts or other commercial mechanisms for deployment of cost effective DER.
- Propose effective co-ordination of existing programmes, incentives and tariffs to maximise locational DER benefits.
- Identify additional utility spending to integrate cost effective DER into distribution planning to yield benefits to ratepayers.
- Identify barriers to deployment of DER (including operation of the distribution system that ensures reliability).

At the core of the DRPs are the methodologies used to establish integration capacity and locational net benefits based on three DER growth scenarios. These are currently under open review with interested parties. The locational benefits assessment seeks to aggregate benefits across a broad spectrum of the energy delivery process which hasn't been attempted before.

In response to the changing nature of technologies on their networks, two of the IOUs have initiated far reaching programmes to understand the grid required in the future and help with technology understanding. Southern California Edison's programme is called 'Preferred Resources Pilot' and Pacific Gas & Electric's is called 'The Grid of Things'. Whilst the SCE pilot may appear to be a smart grid type project it does have a wider remit which covers distribution engineering and DSO, distributed generation, rate design, Time of Use Tariffs, commercial mechanisms and end user engagement (DSR, EVs etc.). Though not a whole system approach, it does cover many aspects from the distribution network downwards in the electricity delivery network. In parallel they have published an outline architecture for a Grid Management System (GMS), this is positioned as more of a 'system of systems' than a typical DMS that we may first think of in this context. It provides a more defined link between human interface, business systems, grid edge devices, external systems and the physical electricity distribution infrastructure. It covers 8 key systems:

1. Reliability system – facilitates the consistent, reliable and safe flow of electricity.
2. Optimisation system – facilitates optimal generation, consumption and efficient exchange of electricity across the distribution network. It interfaces with devices on the customer side of the meter.
3. Planning system – guidance providing updates and changes to the network.
4. Economic system – interaction with markets and contracts to ensure economic implications of the network are realised.
5. Grid infrastructure management – management of IT and OT that comprise the GMS.
6. Data Repository system – centralised data management and warehousing.
7. Communication system – connectivity across systems and services and behind the meter.
8. Integration system – integration between disparate GMS entities and services.

San Diego Gas & Electric have moved a little further with the concept of 'transactive energy' which aims to provide a platform for distributed energy resources to 'transact' services across a grid infrastructure. Similar to approach to NY's REV, however it doesn't involve the formal DSP role, believing that it is more likely to be executed very locally within a microgrid type framework and probably containing a high degree of automation. They have also defined the functions a microgrid will need to perform (such as voltage regulation, anti-islanding and PF control).

KEY MESSAGES FROM THE INTERNATIONAL STUDY

1. While the challenges faced by the GB electricity sector are similar to those being addressed in the other countries reviewed, none of those countries face them to the extent presented by National Grid's 'Gone Green' scenario. For many varied reasons, not all of these challenges appear in any particular country to the same extent and the impact of the challenges is influenced by the nature of the respective national system. In general it can be observed that the scale of the change anticipated on the GB system is greater and potentially poses a greater co-ordination and integration challenge.

2. There are elements of system wide approaches elsewhere with some good examples on sections of the system, however there was no evidence of true end to end system co-ordination in any of the countries/regions reviewed. Of the countries reviewed, the nearest example to a systems wide approach is Ireland's DS3 programme.

3. Many experts consulted expressed the need for greater system wide co-ordination and indicated that they believed the scale of changes anticipated represented a real risk to system resilience and reliability. Those consulted commonly indicated that they are on a learning journey with respective stakeholders who often believed the 'system' is just large scale generation, wholesale markets, transmission and system operations (neglecting distribution, grid edge and end user components).

4. In the US, the remit and accountability of the Independent System Operator is broader than that of the System Operator in GB. Being closely aligned with their public utility commissions and being not-for-profit entities provides greater responsibility to shape and guide market developments to ensure adequate resources are made available to meet energy needs. At the moment the remit of the ISOs for long term planning typically only covers transmission and generation. However, discussion with ISO staff not infrequently reveals a good awareness of 'whole-system' considerations including distribution and customer issues, which is perhaps a consequence of many ISO staff having a background in Vertically Integrated utilities.

5. Most ISOs and utilities are attempting to remain technology agnostic, however there are signs that some are beginning to mandate a technology portfolio in order to preserve system resilience. For example, the storage mandate in California is an example of the Commission and CAISO selecting a technology (and its sub components) they believe will be required, acknowledging that the current market cannot adequately value it.

6. Distribution systems are highlighted as facing the greatest challenges in defining and implementing comprehensive distribution management systems. In addition, these will need to integrate with ISO systems, Home Area Networks. Microgrid controllers, SCADA systems and market mechanisms to name a few. While many of these have detailed architecture and defined interfaces, there is an absence of a system of systems overview. This is beginning to be actively discussed, with PNNL and EPRI both being cited as thought leaders.

7. There are many new functions that are being developed across the sectors that will need to be incorporated, either into exiting functions or through developing new ones. Examples include modelling of DERs, interconnection rules and standards, situational awareness, data exchange and common information models.

8. Interoperability and standardisation are accepted as best practice. There is evidence of many working groups investing time and effort to agree outputs and it is not being left to vendors and market forces to resolve. Many organisations are helping facilitate this including IEEE, National labs, EPRI, CEN-CENELEC and SGIP (Smart Grid Interoperability Panel) to name a few. Though often time consuming, there was uniform belief that this approach is in the best interests of consumers and the industry at large.

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REFERENCES

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