WHAT DOES A DISTRIBUTION SYSTEM OPERATOR NEED TO KNOW ABOUT THE FINDINGS OF THE FUTURE POWER SYSTEM ARCHITECTURE PROJECT?

Olivia CARPENTER
Ricardo Energy & Environment – UK
olivia.carpenter@ricardo.com

John DEVLIN
Frazer-Nash Consultancy Ltd – UK
j.devlin@fnc.co.uk

David MCNAUGHT
Frazer-Nash Consultancy Ltd – UK
d.mcnaught@fnc.co.uk

Roger DUCK
Mapsar Ltd – UK
roger.duck@mapsar.co.uk

ABSTRACT

The Future Power System Architecture (FPSA) project examines the changes to the GB power system expected over the next 15–20 years, and the challenges these will present. The project brief considered functions from a whole system perspective. This paper summarises the key findings and conclusions from the Distribution Systems Operator (DSO) perspective.

INTRODUCTION

With changing customer priorities, development of new technology, diverse energy policy drivers, and emerging business models, the operating environment of Britain's power system will change significantly over the next 15 to 20 years.
However, the functionality required of the future power system is uncertain. The Future Power System Architecture (FPSA) project, which first reported in July 2016, investigated the range of likely future requirements and their implications.
This paper presents the results of this project as they relate to a Distribution System Operator (DSO), considered to be an evolution of the current Distribution Network Operator (DNO) role fulfilled on the UK Power System. DSOs will deliver a role within a smarter, more connected and automated whole system, where customers expect a wider range of service and choice. The table below highlights this difference.

Table 1: Trends which will drive the DSO operating environment

DNO (Today)	DSO (Future)
Stable generation mix with high inertia and largely synchronous generation sources.	Time-varying, unpredictable generation mix with low inertia and a high proportion of asynchronous generation
Passive customers whose demand is stable and driven by predictable diurnal and annual trends.	Prosumers, with generation, large demand (electric vehicles, heating), and energy management technologies, requiring new approaches to optimise the benefits of this
A static distribution network with low automation, relatively simple control schemes and system architecture.	An actively managed distribution system with an increasingly networked and automated control and data architecture.

DNO (Today)	DSO (Future)
Simple two party contractual relationships between the DNO and the transmission system operator and the DNO and customers.	A much more complex contractual environment enabling engaged customers, third-party aggregators, private network operators, on-grid storage and community energy services.
A well understood risk profile enabling a relatively static approach to governance and regulation.	A regulatory environment which needs to respond to a variety of evolving threats to the grid (e.g. cybersecurity, single points of failure, undesirable emergent behaviours.)
Limited whole system management contributions	Potential for contributing to and enabling significant whole system management functionality, such as reserve, frequency response and balancing support

FUTURE POWER SYSTEM ARCHITECTURE

The 'power system architecture' is the underlying structure of the electricity system – how its components and its participants are organised and interact. The project defined the 'power system' to include all assets directly associated with the generation, transport, and use of electricity. This approach specifically includes communication, monitoring and control systems, and 'beyond the meter' customer owned systems. As well as technical considerations it encompasses participant behaviour, commercial and regulatory aspects.
This 'Whole System' focus was a foundational principle of the FPSA project. To achieve this, the project considered functions of the whole system, rather than characterising its constituent parts. This approach allowed the project thinking and conclusions to be independent of organisational structure.

FPSA PROJECT

Background

The FPSA project [1] was commissioned by the then Department of Energy & Climate Change and undertaken through a collaboration between the Institution of Engineering and Technology and the Energy Systems Catapult.

Through the use of a Systems Engineering approach, FPSA examined credible future pathways for the GB power sector, taking into account the changing landscape of user expectations, technology developments, and focus on balancing environmental, cost and security issues. The project identified the technical functionality necessary for the power system to meet security, affordability and climate change mitigation goals in 2030.

The project identified 35 functions for the future power system, including entirely new functions, and functions which exist today but will need to be significantly enhanced to meet future requirements. Each of these was explored, identifying the emerging need for the function, and potential implementation challenges. The functions were then analysed to understand delivery implications, and possible barriers to them being implemented.

There are two further working CIRED 2017 papers related to FPSA; covering the system engineering approach [2], and the international study [3].

Key trends and changes

The change in mix of electricity generation

The rise in renewable electricity generation brings with it technical characteristics such as intermittency and low stabilising inertia that have the potential to reduce the inherent stability and security of the national power system. Today’s power sector can only cope with a certain penetration of such electricity generation technologies.

The increase in engagement of electricity customers

There is a trend in customers being directly engaged in the GB electricity system, for example offering services directly or through aggregators. Potential for this to go further can be seen in the uptake of energy management devices, or significant controllable loads such as electric vehicles, small generation, and storage, allowing customers to better engage with their electricity use, as an active part of the power system.

The emergence of new parties within the power system

The whole system view adopted by FPSA means that engaged customers must be seen as a part of the energy system. Energy communities, where groups of customers make coordinated energy decisions, are also an important consideration. These parties are increasing in number, and there is potential for significant further increase.

Unpredictability of change

It is not possible to predict in detail the changing landscape within which the power system will need to operate. Some changes will be fast moving and outside of the control of the power sector, while others may present opportunities which the power sector can leverage if it adapts quickly. There is some flexibility in today’s power sector arrangements, but it is limited and potentially constraining.

Evidence of trends and changes

Within FPSA, there was a focus upon developing a body of evidence to validate the need for functions and the drivers that sit behind them. This body of evidence is available as part of the main FPSA report. [1]

FPSA PROJECT KEY FINDINGS FROM A DSO PERSPECTIVE

The FPSA project developed a number of key themes and findings. This section summarises these findings through the lens of the GB DNO as they evolve to provide DSO services.

Change in core business activities

Managing new loads and intermittent generation

As intermittent renewable sources and distributed generation grow to take up a much larger share of total generation, the system will require new techniques to manage system frequency, stability and reliability.

New technologies and trends in demands also need to be accommodated. These include uptake of electric vehicles and other Low Carbon Technologies (LCTs), but also includes adoption of energy management technologies which give individuals, businesses, and other customers, a way to better understand and engage with their electricity use, and therefore be an active part of the power system.

The active management of networks, generation, storage and demand promise to facilitate growth of intermittent and distributed generation and new loads without unnecessary network constraints or costly upgrades. It could also accommodate, and in some cases support, the increasingly engaged customer base in acting as part of the system as a whole. ‘Smart Grid’ and ‘Active Network Management’ are not new topics when discussing future electricity networks, and significant work has been underway for a number of years exploring what these mean and how they can work.

Evolving challenges in system stability and outage recovery

There is a material increase in technical complexity to move from the traditional predominately passive distribution network to the highly active network of the 2030s. This is in part due to the take up of LCTs and energy management technologies, and also the increase in intermittent electricity generation technologies.

This adds a new dimension to the challenge of managing and coordinating the power network in a way that will benefit its users without jeopardising security, or destabilising the whole system. For example, maintaining system stability can be delivered more efficiently if a system of responsive tariffs, smart meters and appliances with frequency response can be relied upon to deliver demand-side responsiveness.

The recovery from major outages or system collapse (Black Start) will be increasingly challenging as the power system becomes more decentralised, including the need to coordinate between distributed generation sources. However, there is an opportunity to support recovery of the system through coordination of managed loads, to reintroduce them to the system in a manageable way.

This latter functionality will be particularly pertinent after long outages when electric vehicle and other storage may be depleted and homes and workspaces normally heated by electricity (including heat pumps) will be cold. In this situation (Cold Start), energising the system without management of the loads would need to be able to cope with demands that are significantly higher than normal peak load, and therefore careful management of these loads may become an integral part of the recovery procedure.

The need for collaboration with other energy system participants

The need to collaborate across organisational and functional boundaries

The 35 functions that are part of the results of FPSA describe a future where the activities and roles within the power system interact and collaborate continuously, being able to accommodate and adapt to change.

It is imperative to recognise the technical inter-relationships between the new functionality in terms of how these would be delivered, by whom and in what coordinated timeframe.

This drives a need for greater coordination between industry stakeholders, including those that generate, use and store electricity, operate networks, and manage balancing and control.

This collaboration is likely to include sharing of key information and data, joint decision making, coordinating action, and sharing benefits and incentives to allow all parties in the system to be able to act in a coordinated way to the benefit of all system stakeholders.

Much of this coordination and joint action may need to be automated, and rely on IT and communications systems. If the power system evolves to rely on these activities as a part of operating and maintaining stability, then these ICT systems would need to be suitably robust and secure.

FPSA was focused on the power system, but it did touch on the need for some coordination across energy vectors (e.g. electricity, gas, petroleum and heat). The need for this coordination will become inevitable as the UK decarbonisation strategy proceeds with the electrification of heat and transport, and could provide benefits in whole energy system robustness, carbon, and price, being able to optimise between a range of energy sources to deliver the energy needs of society.

Emergence and engagement of new participants

A key conclusion from the FPSA work was the number of new and emerging parties and participants.

The definition of the whole system to include all assets directly associated with the generation, transport, and use of electricity is wider than traditional views of the sector, and most notably includes assets owned and operated by the customers. Therefore, engaged energy customers are now seen as participants which can coordinate activities and information sharing with the rest of the system.

The use of price signals or other incentives will enable customers to save money by managing their power use, storage, and generation, and in doing so, enable cost-effective balancing of load to intermittent renewable generation, increasing the amount that can be added to the supply portfolio. Further to this, a shift in perspective to genuinely understand the customer's viewpoint can move the discussion beyond consideration of price signals and incentives towards a deeper appreciation of the needs and motivations of the ultimate beneficiaries of the power system, with the potential for more creative service design for mutual benefit.

Other new participants emerge when individuals join together into engaged groups, such as energy communities and smart cities. These groups coordinate activity such as buying LCTs, distributed generation, or energy management, and may push for greater autonomy such as peer to peer trading or local balancing of generation and load. These participants require new modes of interaction with the wider power system to achieve their goals.

Aggregation services can coordinate activity across disparate groups of customers to provide services, and signalling and incentives must be managed carefully to exploit benefits of aggregation while mitigating any risks of destabilisation.

The need for a flexible, agile system

It is not possible to predict in detail how the electricity system and the wider environment with which it interfaces will evolve and transform in the future. New challenges and circumstances will emerge through many different processes and activities, many of which may be outside of what is considered the traditional power system. For example:

- New customer technology and behaviour,
- New customer requirements and business models;
- Technology opportunities within the power system; and
- Threats to the power system.

New customer technology and behaviour

New technologies may include new generation, storage, energy management, electrification of other energy loads such as heat and transport. New behaviour may include increased management of energy and engagement in the energy system, or include coordinating or similar behaviour caused by the uptake of new technology, possibly mediated by the developers of these technologies, and wider shifts over time in cultural and social norms.

Notably, it may not be possible to predict the timing, extent, and nature of changes, and they may be out of the control of the DSO or any other single participant in the power system.

From the point of view of the DSO, these may show themselves technically as significant changes in the nature of demand or power quality on the networks.

The technical impacts would be dealt with by today's management and monitoring processes. However, depending on the scale and speed of the change, the reaction may be too slow to prevent network problems.

Alternatively, the reaction may be to restrict these behaviours, resulting in a system that is not fit to meet customer needs.

It is a key requirement of the future power system to be able to react quickly to these changes as they emerge, enabling positive changes in a timely manner, in order to remain fit for purpose and continue to meet the requirements of society. This functionality is combined with a more interactive relationship with electricity users, which allows dialogue to discuss requirements and restrictions, and to coordinate response.

New customer requirements and business models

New customer activities and business models include community energy schemes and smart communities with increased engagement into their local generation, balancing, and local trading.

From the point of view of the DSO, these may become evident by the change in nature of requests and communications from customers and other parties. However, the change in the focus of customers may not be heard due to the minimal communication and collaboration that there is between today's DNOs and the end customers and users of the power system. Where these interactions do exist, for example in connection requests for new loads or distributed generation, the changing needs can be muted by the application of procedural arrangements, rather than direct engagement and dialogue. Again, enabling new activities and business models is key to remaining fit for purpose, and in leveraging the potential benefits that these activities could bring.

This is expected to require significant changes to enable new activities and business models within months of them being posed, combined with a more interactive relationship with electricity users. This relationship may be with particularly engaged customers themselves, or representatives or coordinators such as community energy group coordinators or aggregators.

Technology opportunities within the power network

There will be emerging opportunities created by new system enabling technologies and approaches, including:

- New power system equipment technologies or designs, or new operational approaches within the power system,
- New developments in enabling or related areas, such as IT, modelling, communications, and
- Advancements in other sectors such as health or transport, which have the potential to be used or adapted for the power system.

In order to embrace these opportunities, the power system will need to adapt to enable their implementation, while maintaining safety and stability within the system. There is a need to actively seek out potential technologies and advancements, and to have effective research and development, trialling, and implementation into the evolving system.

Threats to the power system

System security and resilience against threats must be designed into the system and its activities. However, it is also important that it can react to changing threats. Such threats could come from a range of sources:

- Cyber security threats, including new and evolving attack methods, both to the system as a whole, and to its participates for example through taking payment or other personal data;
- Protection against user error, which becomes more pertinent where the system includes many more participates, with a range of motivations and backgrounds; and
- Robustness against machine or software led adverse effects, including software and technologies within loads and distributed generation; for example, energy management technologies or electric vehicles which can be remotely updated with software changes that can influence how they behave, which when synchronised across the country could then produce a significant impact.

Reacting quickly and appropriately to threats will aim to keep the network and the system as a whole safe, secure, and stable, and procedures in place to enable outage recovery. However, it is also essential not to block progress due to uncertainties associated with risk.

IMPLEMENTATION CHALLENGES

The new system functions required of the DSO have characteristics that suggest it will require significant changes to the distribution system architecture:

- They reach beyond the meter;
- They reflect greatly increased complexity;
- They cross current commercial, organisational and governance boundaries;
- They introduce new data requirements with associated security obligations;
- They require new techniques and capabilities for forecasting and simulation;
- They ultimately span multiple energy vectors;
- They require a level of agility new to the sector.

There is an increase in technical complexity to move from today's partially automated distribution network to the highly active network of the 2030s. There will be a requirement to maintain system stability with rising intermittent and distributed generation, while providing a system of responsive tariffs, smart meters and appliances with frequency response to deliver demand-side responsiveness.

The DSO must work with a large number of stakeholders, both existing today and new, within agile and forward-looking engineering, market and regulatory frameworks established by government and/or the (whole) industry itself.

There will be a need to invest in Research & Development (R&D) and innovation. The full range of technologies, techniques and capabilities required are not yet available to the DSO. Examples include:

- Advanced control systems to balance the use of centralised versus distributed control mechanisms;
- Advanced voltage control and real/reactive power flow management systems;
- Development of new forecasting and modelling techniques;
- New protection systems;
- The mechanisms for implementing peer-to-peer trading; and
- The control and communication regime needed for future Cold Start and Black Start situations.

RISKS OF NON-DELIVERY

Delivery of the 35 functions is considered by the FPSA project to be vital for the system to remain fit for purpose into the future, delivering the requirements of society and carbon reduction goals. There is the potential for DSOs to mitigate risks and realise opportunities. If the new functionality is not delivered, or is delivered late, there could be:

- Compromises to the security, integrity and reliability of the power system at physical, operational and data levels;
- Excessive operational costs or avoidable constraints and related costs;
- Inefficient investment, low utilisation of assets or over-engineering – meeting the policy objectives but expensively;
- Impediments to valuable new commercial models and lost benefits to consumers and the economy; and
- Failure to meet policy targets for carbon reduction.

FPSA NEXT STEPS

The FPSA team is now working on FPSA2, which will report in April 2017.

The vision is to work across the energy industry to create a platform to determine a system architecture for the whole electricity system in Great Britain and to advance implementation of this architecture.

Addressing lessons from the first phase, FPSA2 is continuing to take a whole system approach, engaging with a broad range of stakeholders, including new and emerging players. The project is building from work in the mainstream electricity sector by engaging much more with consumer-facing innovation, and the worlds of smart cities and community energy, and testing the extent to which existing industry arrangements can allow radical change.

FPSA2 will deliver initial views on the implementation frameworks through which future functionality could be delivered.

CONCLUSIONS

The whole system approach used in FPSA – that the power system includes all assets directly associated with the generation, transport, and use of electricity – is a fundamental shift in the view of the power sector. This means that customers are seen as system participants and stakeholders. This view is particularly relevant as the potential for engaged customers and customer groups grows.

The FPSA project describes 35 functions that must be fully implemented in order to meet the future requirements of the power system stakeholders.

Implementation of these has significant implications for future DSO roles and the nature of the interactions between DSOs and other parties. It also represents significant opportunity to maximise benefits of interaction and coordination with a wider group of stakeholders, within a smarter, more connected and automated whole system. There is also opportunity for new revenue streams thorough provision of new and whole system services.

Maximising the opportunity will require a shift in awareness to appreciate the wider system in which the DSO plays an integral part, in order to provide the context and motivation for necessary collaborative action with other market players and with customers.

It is a key requirement of the future power system to be able to react quickly to changes in landscape and stakeholder requirements, opportunities of new technologies and approaches, and emerging threats to the electricity system. This agility must be integrated into the system for it to remain fit for purpose and continue to meet the requirements of society.

DSOs have a critical role to play in maximising the opportunities and mitigating the risks of a whole system approach, which will include engaging in dialogue and explorations that embrace these wider issues.

ACKNOWLEDGMENTS

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