Changing the face of Scotland’s Power Generation

An Engineering Policy Group
Scotland Holyrood
Briefing given at the Scottish Parliament on 16th November 2016
The Engineering Policy Group Scotland

With a combined membership of 40,000 Scottish engineers and scientists, the Engineering Policy Group Scotland (EPGS) acts as a two way link between the professions and government in Scotland. It aims to provide feedback into government thinking and proactively raise matters of relevance with government.

The EPGS comprises senior members from across Scottish industry academia and professional organisations.

The leadership is provided by a core group of senior professional Engineers and Scientists from key professional bodies in Scotland.

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The Engineering Policy Group Scotland (EPGS) provided a briefing on “The changing face of Scotland’s power generation” which took place on 16th November 2016 at the Scottish Parliament, in Committee Room 1. This event was hosted and chaired by Gordon Lindhurst MSP who is Convener of the Economy, Jobs and Fair Work Committee at the Scottish Parliament.

There were two presentations. The first was from Mr Robin MacLaren, a past managing director and chief engineer at Scottish Power and also a founder chairman of the Electricity Networks Association. The second presentation was from Mr Duncan Botting, Managing Director of Global Smart Transformation based in Scotland and Director of the European Utilities Telecom Council based in Brussels.

First Presentation

The first presentation from Robin MacLaren focussed on the Electricity Grid. He pointed out that:

- The electricity industry is not a single entity. Some elements of the industry are monopolies while others are competitive businesses. Power generation; the transmission of power on high voltage systems and then: the distribution of power at lower voltage to consumers are three different parts of the system, each with a differing set of priorities.

- The over-riding aim in this complex inter-dependent arrangement is to deliver low carbon power, reliably and; at a reasonable cost.

- The grid has been developing for nearly 100 years. Particularly in the last 20 years, a notable recent feature has been the growing importance of renewable power. Typically this is generated from multiple small scale sources which are often intermittent. Problems arise since storing power is difficult although one solution is increased reliance on electricity inter-connectors, connecting our system to foreign grids.

- Traditionally, large generating stations supplied reliable “base load” power, but many of these have now closed or will do so shortly. The coal fired Longannet station was shut down in March 2016 and the two remaining nuclear stations will also be closed in 15 years’ time.

- Patterns of demand for electricity are also changing. Since new power generation capacity, and any reconfiguration of the grid are both major capital investments, plans need to be made well ahead of anticipated changes. A time frame from concept to delivery of around 15 years is typical.

- Not only is storage of electricity difficult, and both demand and supply variable, but transporting power over long distances also results in power loss. Keeping the system balanced, resilient and stable is a considerable technical challenge, particularly in winter when demand is high and problems arising from weather fluctuations are most acute.

- Electricity transmission is planned on a UK wide basis with four licensed transmission areas within the grid which then feed into ten licensed electricity distribution areas. Technical challenges in operating the system include: voltage control; balancing the system in real time; planning for the capacity for electricity to flow between regions and; the need for a resilient system.

- While Scotland’s power network is now more reliable than in the past (in that there are fewer breakdowns), it is however less resilient. It is estimated that the technical recovery process, known as “black start”, could take up to five days! After such a major breakdown, recovery would be protracted, slow and uncertain. This would have severe social and economic consequences far beyond any previously experienced. The likelihood of such a “low probability but high impact event” has increased in recent years.
Second Presentation

The second presentation from Duncan Botting addressed the challenges in planning the electricity system of the future. He demonstrated how this must be done by understanding the inter-dependencies and complexities of the whole energy system. The “whole system” can be viewed as including all physical, commercial, policy, data and regulatory elements as well as the generation, network and end-use aspects.

Duncan Botting is a leading member of the IET Energy Panel and was actively involved working with Government on the recent Future Power Systems Architecture Project (FPSA), a major collaborative venture to address the challenges facing Great Britain’s power networks as the electricity system undergoes a period of transformative change. In his presentation he pointed out that:

- The three main challenges ahead are: to maintain a secure and reliable electricity supply; to deliver on the legal commitment to decarbonise and; to provide value for money, as new technologies are introduced. To address these challenges and also to cope with emerging business models, the underlying structure of the electricity system needs to be reformed by 2030.

- In order to ensure a seamless transition between today’s legacy infrastructure and the transformation required to meet users expectations many elements have to be taken into account including the inter-action of: the market structure of the system (taking into account the commercial organisations involved); the diverse technical requirements; the need for conformity to many different types of regulation and; the necessity to fit in with both present and anticipated societal needs.

- Both the supply and the demand sides of the energy equation are in a period of rapid change. While on the supply side there is likely to be more smaller scale generation and micro-generation, on the demand side innovations such as new smart appliances and electric vehicles will also effect traditional patterns of energy consumption. It is not possible to accurately predict either the degree of uptake of new technology or how, for instance, consumers might adapt to home energy automation but these changes have to be factored into future planning.

- One of the major challenges in Scotland at present is the loss of base load power generation, together with an increase in intermittent generation, provided by renewable energy sources. While the use of inter-connectors to grids outside the UK will help to deal with the intermittency issue, power may not always be available from these sources at the time when it is needed. In future, power demand in part will have to match power supply using mechanisms such as automation, smart technologies and price signals.

- Bearing in mind future developments such as the “Internet of Things”, whereby machines interact with each other automatically, there will be a need to “reach beyond the meter”. The result will be hugely increased complexity involving the aggregate behaviour of millions of devices, with consumers as well as businesses, all interacting in more price-sensitive markets.

- By 2030, the power system will be considerably more complex with a dynamic interaction ranging from within the home right up to the largest power station. New players such as “smart cities” or groups of technology users will require new modes of interaction with the power system. To deal with this new environment, the Future Power Systems Architecture Project identified 35 new or significantly extended functionalities.

- If we are to deliver an orderly transition by 2030, we must start right now! Discussion following the event illustrated how the energy debate
within Scotland is different from that in England. It was noted that there is a tendency for engineering and capacity issues to become muddled. The whole system needs to be viewed not just in terms of the technical issues but also by reference to the market structure and to the commercial realities. Points which arose in discussion included the following:

- The resilience of the grid is different to its reliability. Although the chances of a major break-down in power supply are low, the results would be a catastrophe. Restarting the system is complex.
- Energy investment has to be seen in the long term. The length of time in making decisions can be excessive.
- Some elements in relation to the demand side of the equation (e.g. in relation to policy on promoting energy efficiency) are missing.
- There is a vital need to continue with investment to the National Grid and to have this grid running as effectively as possible.
- Often discussion is dominated by talk of specific technology options. Energy planning is best achieved via a co-ordinated “whole system approach”.
- Policy options in relation to electricity will increasingly dominate general energy policy discussions as this is a major way to decarbonise the economy.
- The provision of an additional modest-sized conventional (probably gas powered) station in Central Scotland would assist in capacity management.
- Often the focus is on power generation rather than demand. In the future much can be done at a community level.
Electricity Transmission
The “Grid” - Our Electricity Backbone
Robin MacLaren

Energy Policy
Who is in charge?
They are all stakeholders to be considered.
Everyone has opinion, no overarching arbiter.

The Energy Trilemma
- Low Carbon
- Low Cost
- Reliability and Resilience

Electricity “Industry” in the UK
- Monopoly and Competitive Businesses
- Regulated – OFGEM agreed Price
  - Competitive – Market Sets Price
  - Generation, Supply, Connections and Metering
- There is no one “industry” – there are at least three
  - Generation
  - Wires
  - Retail
- All have differing priorities,
  - Multiple divisions in the supply chain with limited oversight capability.

Solutions need
- Visionary Thinking
  …and Realistic Expectation!!
- Technology delivery
  …Scale and Timescale
- Economics
  …to encourage investment
- Resilience
  …Keep the lights on at all times!

The Transmission network is a key component

Transmission Network History
The Grid

Development of the Grid

[Diagram showing development stages and key milestones]
Planning is Difficult

- Technology changes
- Flavours of the month may or may not materialise
- Technology sometimes delivers, but costs are too high
- Markets change for electricity – uncertainty for investors, uncertainty for technical planning of grid.
- Scottish Market
- Pricing and Settlement System
- CFDs
- ROCs
- etc.

... and changes to Grid can take 14-15 years from concept to delivery!

Why do we have a Grid?

- Delivering Lowest Energy Cost
- Supported or Taxed Energy Sources compete to provide energy needs at lowest cost
- Competitive contracts provide the essential technical support to operate the grid eg balancing, voltage control
- Prices for 'wires' vary little, energy costs do.

Many possibilities get thrown into planning of the Grid.

- Pelamis
- Nodding Ducks
- Generating Home Boilers
- Smart Meters
- Battery Storage
- Craigroyston
- Electric Vehicles
- Silicon Glen
- Onshore Wind
- Offshore Wind
- Wave
- Tidal
- Lewis Windfarm
- Hyundai in Fife
- Lucky Goldstar
- Interconnectors

Why do we have a Grid?

Energy Transfer

- Large Generators and Energy sources, moving energy to Load Centres such as cities
- Nuclear, Interconnection, Windfarms, tidal, wave
- Changing geographical Energy sources means changes to Grid to transport electricity to customer.

This has been the main driver for recent changes

Long distances from generation source means greater exposure to grid loss

4 Licensed Transmission Areas

Electricity Transmission

UK Transmission Networks

... Like a house of cards. If it all falls over, it takes a long time to rebuild. 'Margin' is only part of it.
The Grid feeds 10 Licensed Distribution Areas

Electricity Distribution

How is all this controlled?

Managing the Network

• Not like wiring your house!
• A ‘house of cards’, balanced second by second
• Multiple boundaries to be actively managed.
• Scotland roughly 10% of the UK electricity demand
• Network Challenged in Northern England

Transmission Operation

CATOS — Competitively Assessed Transmission Owner
TO — SSE Transmission, SP Transmission, National Grid
GBSO — GB System Operator
GBSO Independence to include legal separation and separate licences for GBSO

With this, SO has no interest in assets and is visibly separate.

Engineering Challenges increasing

- Technical performance issues
  - Voltage Control
  - Frequency and Inertia
  - Network operation with Distributed Generation
  - Resilience with Imports and remote generation
  - Low margins reduce flexibility

... Will this need other major plant in Scotland. Coal? Gas? Nuker? New Technology? Or do we accept the increasing risk, while trying to minimise it.

What do we mean by Reliable and Resilient?

- Cars are far more reliable
  - We don’t have as many breakdowns!
- Cars are far more resilient
  - A car crash is much more survivable
- Scottish Electricity supplies are far more reliable
  - Customers suffer fewer power cuts.
- Scottish Electricity supplies are less resilient
  - The car crash has been avoided so far
- Reduced number of large power stations, difficult to restart our networks after a shutdown
- Interconnection crosses weather exposed areas
- Wind Generation may shut down in high winds.
- Technical challenges increasing.

Some history of ‘near misses’ which would be crashes today.

Cabinet Office National Risk Register

- “A nationwide loss of electricity, for which the technical recovery process ‘Black Start’ could take up to 5 days, would affect millions of consumers and critical services. If significant damage is caused to the transmission lines, it could be weeks before some parts of the network are fully recovered and power is restored.”

www.theiet.org/factfiles
Some Scottish History.

1745
- 78 Transmitter Facade, a significant moment in early network.
- Import duty on oil and gas, improved Scottish generation.

1892
- 100 Transmission Facade, mostly located in the central 2000 network.

1990
- 125 Transmission Facade, with significant moment on early 2000 network.
- 2050 Transmission Facade, mostly located in the central 2000 network.
- 2070 Transmission Facade, mostly located in the central 2000 network.

There is a high probability that at least some of these events would, if they were to occur today, close down large parts of Scotland.

Key Message

If this were to happen today:-
- Large areas of Scotland would be impacted (measured in millions of customers) and without power for hours or several days.
- Restoration would be probably reliant of supplies from the south, and restoration or availability of North England Grid to re start the Scottish Grid.
- Current plans leave little room for contingency, and are driven by best efforts rather than a definitive standard.

Possible Actions
- A 'System Restart' standard would one solution.
- Standards drive the planning and requirements.
- South Australia is the one of the most recent Grid Collapses. It has a standard of 40% peak demand within 4 hours.
- Perhaps increased public awareness of risks, to allow family contingency planning?
- .......moving on.

Remember the Energy trilemma?

Energy Trilemma
- Low Cost
- Low Carbon
- High Reliability and Resilience

We are making good progress! ..it is risk and reward.

Solutions are complex across the whole energy spectrum.

Transmission Networks are key

Addressing the challenges

The Future Power Systems Architecture Project

FPSA Project
Thinking of Energy as a Whole System

Duncan Botting
MD Global Smart Transformation
IET Energy Sector Chair
FPSA – Project Delivery Board Champion

Introduction

- Understanding the new reality for Energy
- Scotland in the wider GB Energy Landscape
- New work on Whole Energy Systems Analysis
- Summary

Whole Systems

Politics and Regulation mixed in with the Business layer

An attempt to model the whole electricity system!

The customer’s importance is shown here by this pixel!

More of the system.....

BUT - Below the meter now VERY important...

Are we wired for success?

- What business models will impact different parts of the power network – Generation, Transmission, Distribution, Private Networks, Customers, etc.,......
- Is the Market Structure and the governance (Regulation) to provide efficient, safe and reliable energy delivery fit for purpose?

Market Structure

Market Structure (Governance and Regulation)

Not one but communities acting in the same way

Whole System Impacts -

- Do we understand the inter-dependencies and complexities of the whole energy system:
  - Market Structure (Legislation, Policy, etc.)
  - Regulation (Economic, Environmental, Health & Safety, Technical, Commercial, etc.)
  - Commercial (Business Layer)
  - Technical (Functional, Information, Communications, Physical Layers)
  - Societal Behaviour (Needs, Requirements, etc.) –
Smart Conclusions

- There is a need to be "joined-up" in the thinking between Governance, Commerce, Technical and Societal policy implementation
- Today we do not understand the inter-dependencies, inter-relationships of the complex interactions that are now able to take place – inside and outside of the current market, commercial and societal frameworks
- Policy makers need to be informed in easy to digest, pictorial, infomatics and other ways to be able to communicate the complexities to legislators in order not to end up with conflicting regulatory and societal behaviour
- EUTC works to facilitate this understanding in different regions and jurisdictions. Technology and Telecoms can only deliver efficiencies within the bounds that are set by legislation, regulation and societal agreement!

Scotland within the wider GB Energy Landscape

A Need for Whole System Thinking

- Using the system in the way we have traditionally may not be optimal in the new reality
- The Power System is going to be transformed – with or without policy control
- Advanced analysis already in progress

The Reality

- Loss of Base Load Power Generation
- Reduction of inertia on system
- Increase of Intermittent Generation
- Diversity of demand falling
- Community Energy rising
- Cities and communities require different solutions
- Inter-connectors only provide half the solution

New work on Whole Energy Systems Analysis

Vision

To work with the full set of stakeholders to create a platform to determine a system architecture for the whole GB electricity system to be the transformation pathway in its early stages in electricity and energy, and to catalyse the implementation of this architecture.

Whole System is widely defined, to include the physical, commercial, policy, data, regulatory, consumer and other aspects of the complete electricity system including all generation, network and end use aspects, and its interaction with other energy systems at the point of end use.

Stakeholders include existing and new parties: generators of all scales, users of all scales, network, supply chains, service providers, government, wider society, future users, and all those who interact or should interact with the present or future electricity system.
Mandate
What are the functions that will be required to make the future low carbon, power system work?
- Consider a 2030 horizon
- Identify the functions, new or significantly enhanced
- Provide supporting evidence
- Identify sequencing and interdependencies
- Focus on technical challenges, not institutional arrangements
- Do not develop solutions
- Apply whole systems thinking
- Use systematic, systems engineering, open approach

Delivery of FPSA1
- Commissioned by DECC
- Undertaken by a Catapult – IET collaboration
- Supported by specialist experts
- Strengthened by stakeholder engagement
- Applied a rigorous System Engineering approach
- Built a substantial evidence base
- Managed following best practice

Deliverables
- FPSA1 Summary Report
- Main Report and appendices
- International Study
- System Engineering Methodology
- Functional Matrix Spreadsheet
- Function Sequencing Spreadsheet

Key Outcomes
- Substantial new or extended functionalities are needed for the power system by 2030
- Implementation challenges of the new functionality are significant
- Delivery by 2030 is possible but we need to start now

New or extended functionality
- 35 new or significantly extended functions identified
- Heavy interaction between functions, so no simple prioritisation
- Incremental deliver would be risky
- Extra costs
- Breached engineering limits
- Compromised system security
- Policy objectives not met
- A coherent transformation programme is needed
- It’s a whole-system challenge, that involves many parties

The new system Functions and their drivers
Headlines
- Seven drivers of new functionality identified - leading to 35 new or extended functions for the 2030 power system
- Spread across four functional timeframes:
  - Investment Planning
  - Operational Planning
  - Real-time Operations and Balancing
  - Markets & Settlement
- Drawing on National Grid Future Energy Scenarios (some Green emphasized) and 2º Carbon Budget
- Functions largely independent of future power sector evolutionary pathways (four scenarios)
- Power Sector Adaptation
- Power Sector Leadership
- Customer Empowerment
- Community Empowerment

Drivers of New or Extended Functionality
- The flexibility to meet changing but uncertain requirements
- The change in mix of electricity generation
- The recovery from major events or emergencies
- The active management of networks, generation, storage and demand
- The use of incentives to enable customers to benefit and the system to operate more efficiently
- The emergence of new parties providing new services to customers
- The emerging need for coordination across energy vectors

Examples of New or Extended Functions
- Continuous review of the energy landscape to enable the power sector to respond readily to rapid and continuous change, and ensure the timely introduction and embedding of new functionality (including planning requirements) in an increasingly distributed and weather dependent generation portfolio (investment planning)
- Providing a mechanism for peer to peer trading (intra and inter community) with appropriate charging for use of the power system (markets & settlement)
- Enable restoration of supplies following a prolonged local supply failure - leading to loss of both local generation and diversity in demand (investment planning)

Examples of New or Extended Functions
- Provide automated and secure management of demand, generation and an increasing range of energy resources and ancillary services, including smart appliances, and building and home energy management systems (real-time)
- Collect forecast information from all significant parties within the power sector, identify and resolve constraints and conflicts, with assigned responsibility for security of supply (operational planning)
- Collaborate with other energy sectors across multiple sites to make the best use of available energy resources and to provide the flexibility to meet environmental and financial priorities (markets & settlement)

Overall Conclusions
- A substantial view of extended functionality is required to meet energy policy objectives by 2030
- The new functionality presents substantial implementation challenges and a technical, market and commercial perspective
- It is feasible to deliver the changes required to the scale and complexity within current power systems
- New functionality presents technical barriers and new challenges to traditional power systems

Cross Boundary Challenge
- The new functions are not organizationally aligned
- The power sector comprises many formal and informal organizations
- Boundaries themselves are not a barrier, but the administrative complexities and the behaviours they create can be

Active Management of Networks: Provide automated and secure management of demand, generation and an increasing range of energy resources and ancillary services, including smart appliances, and building and home energy management systems (real-time)
- The green dots highlight the parties (and boundaries) that will be involved
- New electricity grid recommendations
Developing a shared view for implementation

Some common principles to apply:
- Enable beneficial opportunities for all parties, existing and new
- Build on findings from innovation projects and progress already made
- Enhance energy flexibility, promote demand side engagement
- Identify options, recognize uncertainty and ability to respond
- Consider technical + commercial + societal aspects
- Less government, more markets and more industry leadership
- Enable access for entrepreneurial parties, new customer services
- A presumption for Open Systems enabling shared and secure data
- Any wider energy system issues that arise will be noted

Stakeholder:

WP4: Enabling Frameworks
Duncan Cotting
IPSA Project Delivery Board

Why an Enabling Framework?

- Understanding the need for an Enabling Framework
- What is an Enabling Framework?
- How would an Enabling Framework Help?
- What might one look like?

Today’s Industry Change Process

Implementing the detail to enable delivery of the required new system model

Not entirely responsible for these changes
Summarising - an Enabling Framework for new Energy Systems

A Kernel Framework

This framework is designed to maintain the core principles of policy coherence by being:

- Change Coherent
- Agility
- Resilience
- Sustainability
- People
- Security
- Adaptability
- Reliability
- Affordability
- Technology

The biggest challenge?

- Mismatched processes
- Different spin speeds

Many challenges, many unknowns...

The Enabling Frameworks are seen as an iterative process of discovery.

What are the needs of different stakeholder groups?
What processes would be effective and could be adopted more widely?
What technologies will enable these needs?

Outputs should inform policy, regulation, technical deployment and societal engagement

Thank You

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