The Institution of Engineering and Technology

Modelling Requirements for GB Power System Resilience

during the transition to Low Carbon Energy

IET report for the Council of Science and Technology

Part 1: Main Report




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The Institution of Engineering and Technology

Energy

About this report

The Institution of Engineering and Technology was commissioned by the Council of Science and Technology (CST) to research the emerging challenges for modelling electricity systems and how Britain's capabilities would need to be adapted to assess electricity system resilience as GB makes the transition to a low carbon electricity system.

This project commissioned, and received, fifteen individual papers from GB-based specialists of international standing in power system modelling. The authors of the papers worked with a wide stakeholder base of network companies, academics and others, who provided review and challenge. Professor Graham Ault CEng FIET was contracted to provide technical co-ordination and drafting. The emerging conclusions were further validated by means of an industry and academic workshop sponsored by Government Office for Science. The entire project was conducted under the direction of an independent steering committee composed of senior IET Fellows, two of whom were also CST nominees.

The report is composed of three parts:

- Part 1: Main report
- Part 2: Summary of Commissioned Papers
- Part 3: IET Special Interest Publication – Academic & Industry Papers

All three parts of this report are available from the IET website at:

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ISBN: 978-1-78561-023-3

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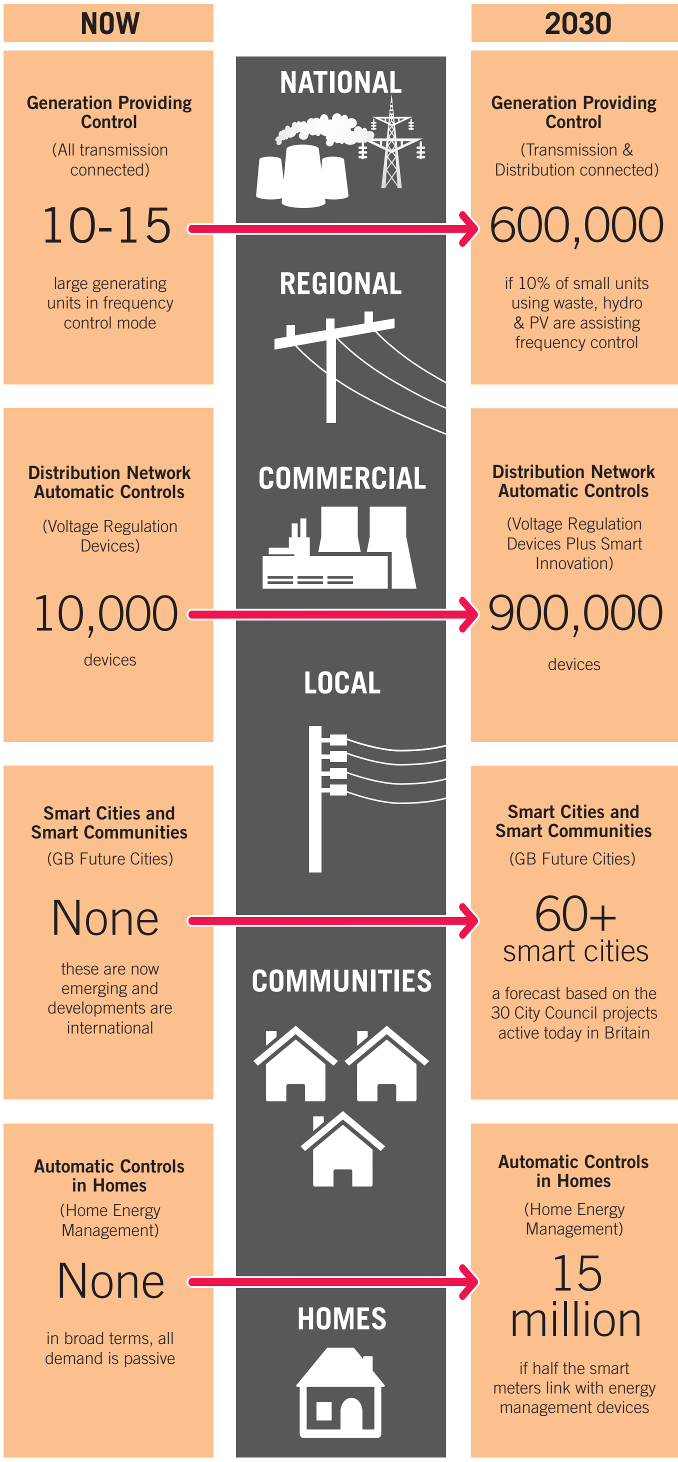
As engineering and technology become increasingly interdisciplinary, global and inclusive, the Institution of Engineering and Technology reflects that progression and welcomes involvement from, and communication between, all sectors of science, engineering and technology.

Contents

1 Headlines

- Changes to the power system due to the take up of low-carbon technology will present significant challenges to the planning and operation of an economic and secure electricity system in Great Britain.
- In particular, four electricity system modelling challenges have been identified and are highlighted in the graphic. These require action in the near-term.
- An ever-increasing number of generating units are being connected to the grid, rising to potentially 600,000 in 2030. Analysing, quantifying, and aggregating the contribution of these distributed power sources at different scales is particularly problematic. Developing the capability to model the impact of decoupled and distributed intermittent generation on system inertia, source impedance, power flows, voltage levels, power quality and protection integrity is key.
- A future smart grid will lead to a massive scale-up in smart technologies and automated equipment in distribution networks to regulate voltage, fault current, power and reactive flows, and to dynamically reconfigure networks. The models and the processes to guide the application of these new technologies are yet to be developed.
- Smart cities and smart communities, containing autonomous zones embedded within the electricity system, could have a large impact on local and national power system requirements and opportunities. Modelling such autonomous behaviours, which will likely change over time, will be a key issue to resolve.
- Automatic or remotely controlled controls in homes, leading to consumers and intermediaries interacting with new energy devices, controls and incentives (including dynamic time-of-day tariffs) present new modelling challenges. Current modelling approaches reflect the end user only at a highly aggregated and simplified level.



- **Failure to address the identified modelling gaps could have serious consequences for system resilience in the near-term and the delivery of low-carbon targets in the mid-term.**
- **The importance of system resilience was highlighted by a recent report by the Royal Academy of Engineering "Counting the Cost" which examined the economic and social costs of electricity shortfalls.**
- **The complexity and connectivity of the identified issues requires a coordinated response from stakeholders across the electricity supply chain.**
- **To address the need for a coordinated response, options have been explored with suggestions to take forward the system modelling agenda, this includes resources and skills issues.**
- **A key recommendation is the importance of agreeing and establishing new coordination and leadership arrangements for electricity system modelling.**

2 Executive Summary

Action is required to address the impact of the nature, scale and pace of the challenge to the GB power system

- Changes to the GB power system are emerging at a scale, pace and type that will present significant challenges to the planning and operation of an economic and secure electricity system, in Great Britain.
- While there is uncertainty on precise timing, there is broad consensus that the changes anticipated are significantly different from those that have characterised the electricity system to date. This raises important and urgent issues for the modelling capabilities that inform crucial decision-making.
- From the earliest days of the grid, modelling has under-pinned investment and operational management, and has been an important contributing factor to performance, efficiency and resilience. It is evident that modelling must keep up with material system changes: for example, the challenges of large scale renewable power sources, the widespread adoption of distributed generation, new sources of electricity demand, energy storage and more active consumers using smart meters and home energy automation.
- The changes already taking place are altering the character of the system, creating not only variable power flows but also reverse flows on distribution networks. This in turn can give rise to material impacts for system balancing, line loading, voltage control, and protection system integrity. Active consumers have less predictable demand patterns, adding to the need for new probabilistic and behavioural modelling capabilities.
- Failure to address the issues in a timely way has potentially serious consequences. These range from a degraded understanding of the behaviour of the system and its critical limits (in the worst case increasing the risk of wide area interruptions), to a failure to address emerging constraints such that limits have to be applied to the numbers of new generation and demand connections while primary reinforcements are undertaken (resulting in delays and losses for customers plus impediments to achieving decarbonisation targets).
- Inadequate modelling capability could lead to unnecessary conservatism, with additional costs being placed on new generation and loads that more comprehensive modelling might show to be unnecessary. These threats have adverse consequences for national economic activity, as well as for the costs of system investment and operation.
- From a substantial and authoritative evidence base, this project has identified a number of power system modelling developments that are taking place nationally and internationally, but there is nevertheless a recognition of the need for new interventions, greater forward-looking capability, and a more holistic approach that spans the electricity supply chain and extends into other energy vectors (e.g heat) and sectors (e.g transport). There is also a need to agree and implement new mechanisms to ensure that overall responsibility and accountability are clearly allocated.

Modelling gaps and priorities have been identified

- From a wide set of detailed evidence, gaps and priority modelling challenges have been identified. These highlight the need for power system modelling developments that address:
  - **The end-to-end electricity system**, embracing the transmission and distribution networks and the changing characteristics of end users and load types.
  - **Active consumers**, utilising smart meters and including home energy automation and localised energy management (e.g. in smart communities and future smart cities).
  - **Markets and commercial externalities**, including the availability of Time of Day tariffs.
  - **New ranges of data**, arising from both smart meters and actively managed networks, together with requirements for data analytics and data sharing.
  - **Interoperability**, including interactions between modelling tools and across a wider range of device and equipment types.
  - **New third party participants**, such as the impact of network service providers, and aggregators of active customers and micro-generators.

Table 2 of the report expands on these headline challenges, identifies new requirements and suggests practical mechanisms to address these priority areas. A key recommendation is that these required modelling capability developments are considered and acted upon with some urgency to address key areas of concern.

Cross-sector co-ordination is required

- The project focused on modelling capabilities, requirements, challenges and gaps and has prioritised several areas for immediate attention. In conducting this work it became apparent that cross-sector coordination and leadership of modelling development would be a fundamental enabler for responding to the modelling challenge. While modelling leadership is provided in various ways in the industry at present, the Steering Group considered there is a need for an enhanced approach, given the nature and scale of the challenge.
- From these additional considerations, a key recommendation is the importance of agreeing and establishing new coordination and leadership arrangements for electricity system modelling. This report offers some initial thoughts that have arisen from the project, which in summary follow a staged approach:
  - **STAGE-1**: Establish a Modelling Leadership Group (initially under a Joint Code Panel[1]).
  - **STAGE-2**: Reposition the Modelling Leadership Group to better facilitate its further development (for example aligning it within a future System Architect function where Modelling Leadership[2] might fit effectively in its remit).
  - **STAGE-3**: Expand the Modelling Leadership activity to include cross-vector and cross-sector capabilities (conceivably by forming a Centre of Excellence within a System Architect function, where a number of synergies can be anticipated).

[1] The ‘Code Panels’ noted here refer to the Distribution Code Review Panel and the Grid Code Review Panel. These bodies are part of the existing sector technical governance arrangements and have oversight by Ofgem.

[2] A System Architect might need to undertake some modelling to fulfil its responsibilities but the wider remit would be to ensure that the industry as a whole has (or is developing) the necessary models and modelling capability consistent with delivering system security and performance. The capabilities within the new Energy Systems Catapult may be helpful here.

These stages, which might sensibly have review points between them, are further explained in the report, and Appendix 2 provides an initial view of possible institutional options.

Skills in new modelling capabilities are required

- A further finding from the project concerns the skills needed to develop new modelling capabilities. These will embrace the skills required in the network companies and the wider range of academic and sector skills. These will need to be far broader than traditionally deployed, including social sciences for stochastic behaviour analysis, power electronics, control systems expertise, and data analytics. There is relevance here to a wider energy systems skills agenda, but the new depth and range is a distinct concern. Advanced skills will be needed for development, but, the models and techniques will need to be readily deployable in day-to-day operational environments. This will be a challenge for developing user interfaces, data and modelling validation, knowledge retention, and for training.

3 Introduction

This document presents the findings from the IET project on electrical power system modelling in Great Britain, undertaken for CST (Energy) and GO-Science. The project scope was agreed as:

- GB (including offshore systems) but taking account of existing and potential future interconnectors.
- Electricity system (generation, supply, networks, electricity storage, demand response).
- Credible levels of user engagement and behaviour.
- Low carbon generation scenarios (based on National Grid's Electricity Ten Year Statement and Future Energy Scenarios).
- Electrification of transport and heat scenarios (based on DECC's scenarios underpinning the CCC 4th carbon budget – as applied to the Smart Grid Forum WS3 study).
- Study period to extend to 2030 but with a particular focus on the period 2016 – 2024, which may identify some shorter-term challenges.

The project objective is to assess the modelling capability required to ensure the on-going delivery of a secure, resilient and efficient electricity system for Britain through its low carbon transition and to recommend actions to address the issues identified. The project was informed by the parallel strand of work being undertaken by the IET Power Network Joint Vision (PNJV) group, which is examining the challenges arising from future system complexity and the case for establishing a System Architect function for the national electricity system.

The project has been led by a stakeholder Steering Group that scoped the project, commissioned and reviewed evidence papers from subject experts, and presented the results to CST (Energy) and GO-Science.

The Steering Group members, who are listed in Appendix 1, have contributed as individual professionals and their respective employers do not necessarily endorse the conclusions of this report. The Steering Group also convened a workshop day to engage with sector stakeholders, including industry and academia. The Steering Group has valued the engagement of observers from DECC, BIS, Innovate UK and Ofgem.

The project was structured on the basis of four specific tasks:

Task 1: to create the network of key stakeholders to refine the scope of the work by identifying the key modelling challenges and questions for the study;

Task 2: (concurrent with Task 1) to map the existing modelling landscape;

Task 3: to determine the extent to which current models are capable of assessing the performance and resilience of the electricity network and with what degree of confidence;

Task 4: to produce a mapping of the whole suite of models (existing and future) and to recommend whether the use of these models in combination would be sufficient to deliver an adequate understanding of the issues involved.

This document presents the evidence gathered on modelling capabilities and sets out conclusions, recommendations and pathways to support further detailed consideration of implementation choices to respond to the challenges identified.

The role of power system modelling in planning and operating a resilient electricity system

The power system in GB has a track record of delivering high levels of security and performance, and it is vital that we maintain this position. There are many contributory factors in securing these achievements such as equipment standards / specifications, design standards, asset management practices, and operational management disciplines. Each of these has been supported throughout by the deliberate development and application of a range of key modelling capabilities.

Modelling provides an essential foundation on which investment, design, development and operational options are studied to underpin secure and efficient delivery of electricity to customers. While modelling itself does not deliver system security and performance, it is an essential part of the toolkit along with standards, system design, technology, equipment and operating procedures, real time information and skilled personnel. Modelling helps to assure resilience by enabling the full range of operating conditions to be explored, limits to be understood and undesired outcomes avoided.

Figure 1 provides a high level illustration of today's use of modelling capability to support the network companies in fulfilling their responsibilities for running the GB power system.

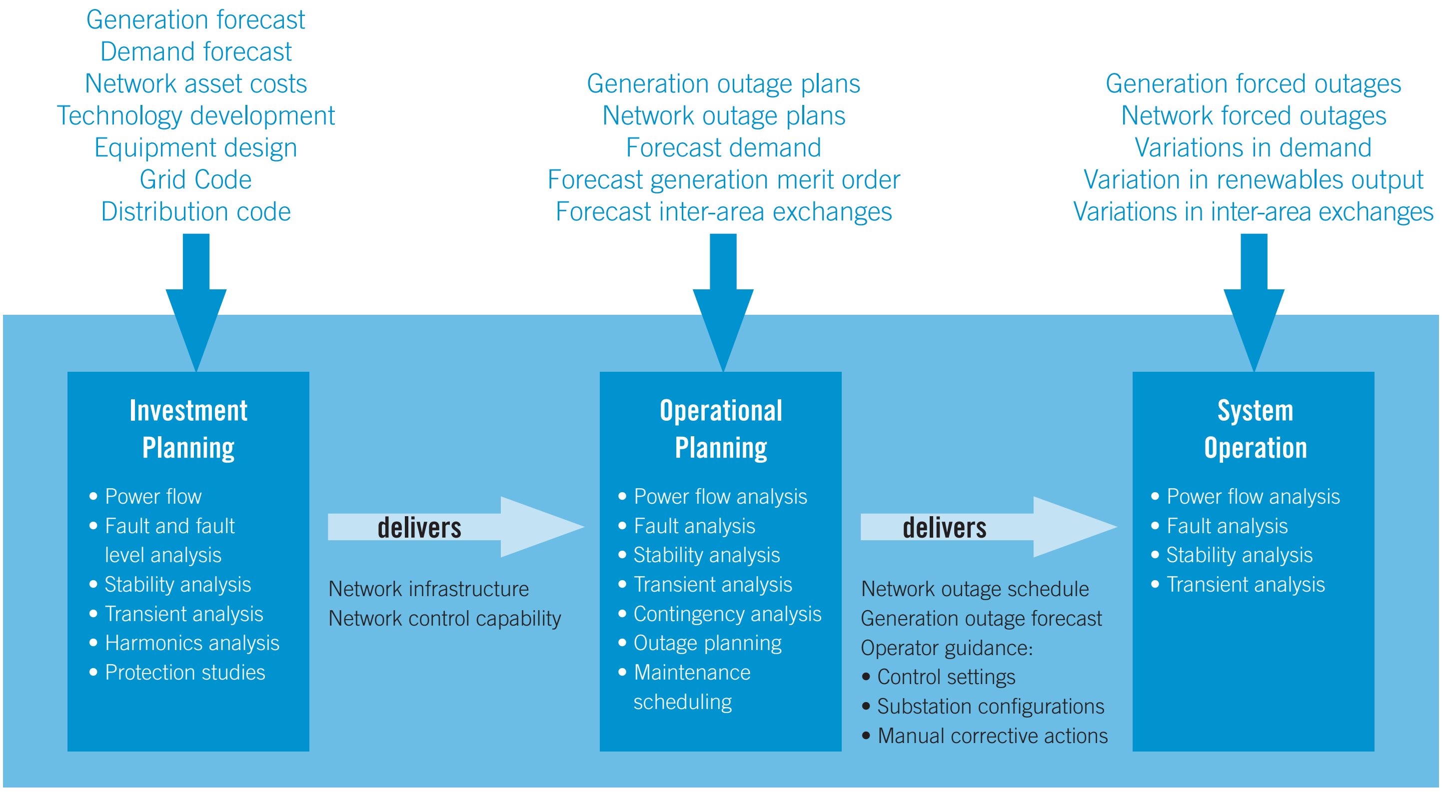


Figure 1: Today's modelling capabilities used to support network company decision making in designing, planning and operating the GB power system[3].

Figure 1 identifies the main modelling capabilities used by the network companies and system operator (and by their vendors, advisers and consultants) in discharging their license obligations. Modelling capability encompasses a wide range of resources required to perform analytical studies of the power system including skilled people, analytical techniques, software platforms and packages, accurate data representing equipment, systems and phenomena, and relevant standards and codes.

These modelling areas are referred to below with reference to how the changes to the power system impact current modelling approaches and present significant new challenges for power system modelling.

[3]Figure adapted from illustration provided by Prof Keith Bell, University of Strathclyde.

Significant power system challenges emerging in GB

The power system that we know today and the modelling tools used to support it, face significant change. The anticipated scale, nature and pace of the changes present major challenges to investing in and operating the power system securely, within the tight performance parameters necessary to ensure supply security. These include the critical limits for line flows, voltages and dynamic interactions.

The expected scale of low carbon technology (LCT) uptake towards 2030, as shown in scenarios such as those published and regularly updated by National Grid[4], present a very different portfolio of generating units of various technologies and new demand technologies compared with today (e.g. Electric Vehicles and Heat Pumps). There is a broad expectation that the power system will have to meet the challenge of greatly increased renewable generation from variable output sources, a greater contribution from small scale and micro-generation, increased demand for heating and transportation, and a greater international interconnection with neighbouring systems. GB electricity statistics (reported by DECC in DUKES) illustrate the continued growth in renewables, early uptake of electric vehicles, and the growth of small-scale generation. GB Distribution Network Operators are currently experiencing extremely high levels of generation connection activity at all scales (e.g. 1.1 GW connected in the first quarter of 2014[5]). Additionally, the GB power system will become subject to European Codes that are driving towards integrated energy markets/balancing mechanisms and more active distribution networks. These networks will have an increasing penetration of automation and intelligent systems, and will deploy entirely new devices featuring power electronics and other advanced, fast-acting control systems.

Under these significant changes, the GB System Operator, along with the Transmission Owners and Distribution Network Operators (together, described as the network companies) will be faced with a significantly more complex system to operate as a result of the development of Low Carbon Technologies, new market arrangements and increased customer participation. The IET PNJV project illustrated these changes to future electricity system interaction and control complexity as shown in Figure 2.

[4]National Grid Future Energy Scenarios (2014).

[5]Finlay Colville, Guest Article in Solar Power Portal, 8th April 2014: http://www.solarpowerportal.co.uk/guest_blog/uk_solar_industry_installs_massive_1.1_gw_in_first_quarter_of_2014_2356

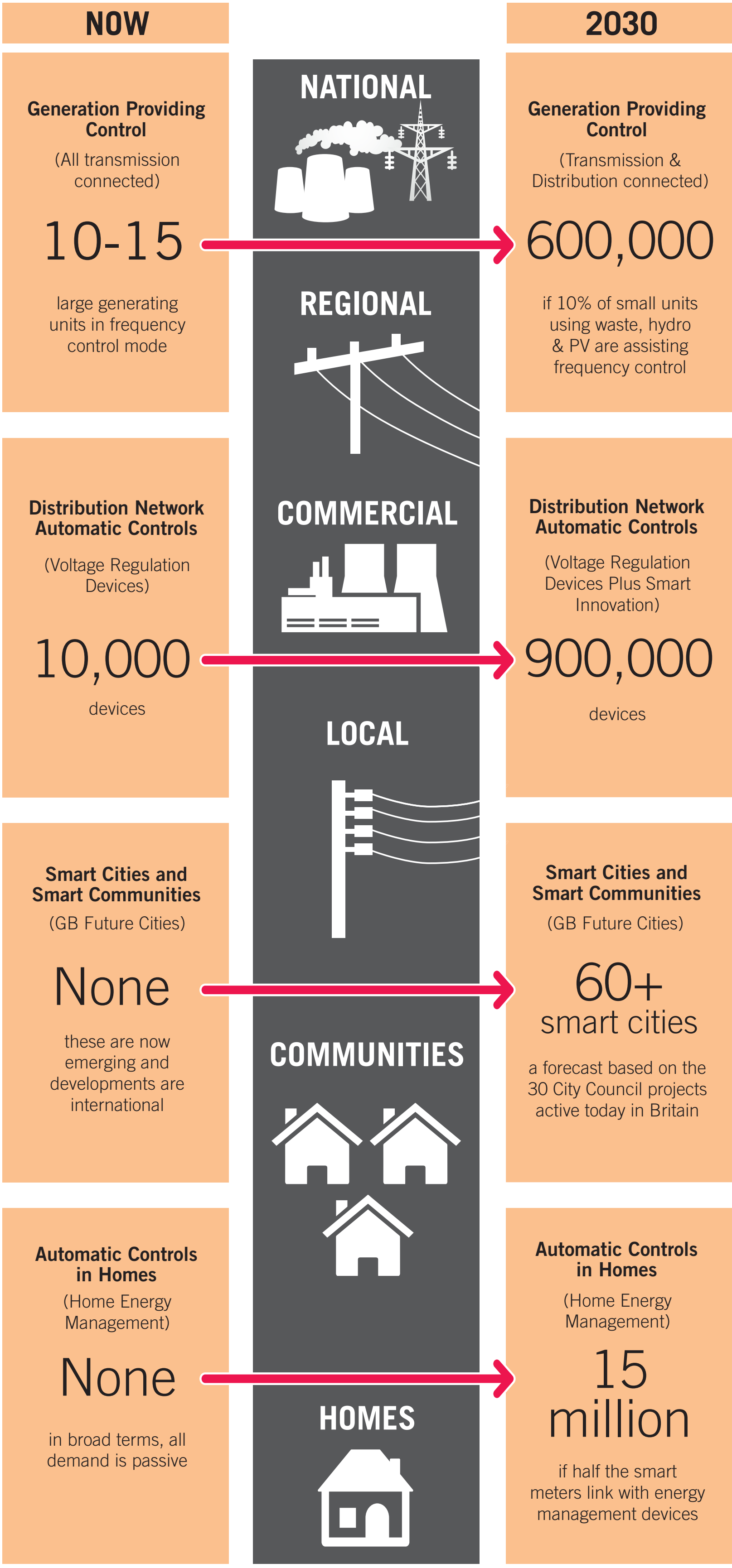


Figure 2: IET Power Network Joint Vision expert group's view of the enhanced opportunity and complexity in the GB power system (adapted from original).

In each of these four illustrated areas of substantial change to the GB power system there are important modelling challenges for which there are yet no definitive routes forward. Each of these four areas are discussed below:

- **Generators providing control** – the ever-increasing number of generating units connected to both transmission and distribution networks and the displacement of conventional synchronous generation is leading to serious issues of falling fault levels and system inertia, and in turn protection coordination, power quality and frequency control (as identified in the National Grid System Operability Framework initiative[6]). The core techniques used to assess the impact of generation control on the system are set out in Table 2. This reflects the types of devices connected, new network technologies, and the inherent unknowns in the equipment characteristics; including their trajectory of deployment into the system and their operation, all of which give rise to challenging issues. The new modelling requirements for analysing, quantifying, and aggregating the contribution of high volumes of smaller scale generating units (and other frequency response resources such as storage and demand response) at different scales is particularly problematic. It is not yet clear how the necessary model validation, aggregation and equivalence process will be achieved. Operating such a system will require enhanced forecasting capabilities to anticipate the availability and capability of all system resources over various time periods including investment planning, operational planning and (within-day to real-time) system operation.
- **Distribution Network Automatic Controls** – with a massive scale-up in automatically controlled equipment in distribution networks (including not only post-fault automated restoration but, increasingly, active network management systems to control distributed generation export and demand response) the modelling of so many systems at the investment planning stage is a challenge that is only really starting to be addressed as smart grid innovation is rolled out. The models and the processes to guide the modelling of these new developments go far beyond the current approaches for modelling as set out in Table 2. Additionally, understanding the aggregate effect of multiple automatic controls on overall system operation is critical for the System Operator to maintain visibility and controllability of a much more complex system. It is particularly timely that CST and GO-Science have commissioned this report as the modelling challenges are only now beginning to be considered by the network owners.
- **Smart Cities and Smart Communities** – with potentially autonomous zones embedded within the GB electricity system (at city or community scale), the behaviours of such zones in response to local resource availability, local customer behaviour and pricing will be less certain but could have a large impact on local and national power system requirements and opportunities. Modelling such autonomous behaviours, which will likely change over time, will be a key issue to resolve. The current modelling approaches set out in Table 2 do not address the technical, commercial or user behaviour issues presented by smart cities and communities.

[6]National Grid has recently published its System Operability Framework and is consulting widely on its approach and content. The document highlights the significant technical changes now starting to be evident on the GB power system and those anticipated for the medium term. See http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/System-Operability-Framework/

- **Automatic Controls in Homes** – the uncertainties, opportunities and challenges from genuinely active consumers with new energy devices, controls, incentives (including time of day tariffs) and behaviours present major stochastic modelling challenges that amplify the issues of monitoring, estimating, forecasting, aggregation, model equivalence and whole system modelling capabilities. The development of such modelling capabilities, to the extent that models and data can be assured and so embedded in network and system operations and planning, is currently at a very early stage and will need to be addressed as these issues emerge and become more significant in the coming years. The results of research projects (for example Low Carbon Network Fund projects) are expected to contribute new insights and will assist modelling validation. None of the current modelling approaches set out in Table 2 reflect the end user except at a highly aggregated and simplified level so the need for new modelling capabilities to fully address active consumers and automated homes or offices is pressing. The smart meter roll out, taking place between now and 2019 to every home will be a catalyst for new consumer engagement and provision of third party services.

If, as seems likely, the security of one network will depend upon the status of other connected networks, this implies a much greater need to share information and co-ordinate actions across network boundaries. This level of inter-operability between network modelling systems does not exist in any comprehensive way at present, as the network operators and system operator can internalise the modelling and planning/operating response with only limited sharing across boundaries. It will be crucial to develop ways of managing this issue so that network operators will be aware as to when they need integrated working with their neighbours, and when they can operate autonomously. It can be envisaged that analysis requirements will arise that need many models to be linked together and expand into other energy vectors and sectors – requiring a “super capability” comprised of comprehensive models of the constituent elements, coordinated across timescales and geographical distributions.

Evidence of the impact of the changes to the power system already emerging

The GB System Operator and the network companies have already started to experience some of the problems associated with these changes in recent years:

(1) In response to the concern for changing system behaviours arising from the reduction in system inertia and the growth of smaller scale distributed generation, along with the potential for adverse response to frequency events from G59 ROCOF protection[7], National Grid with the Distribution Network Operators, the Grid and Distribution Code Review Panels, and the Energy Networks Association have analysed and brought forward proposed changes to the settings of generator protection systems to safeguard system stability and national implementation for >5MW distributed generators is already underway.

Separately, the network companies are addressing emerging concerns in a cross sector approach:

(2) Under the auspices of Smart Grid Forum Workstream 3, the Distribution Network Operators (DNOs) commissioned the ‘Transform’ econometric model from a consortium of third parties led by EA Technology Ltd to understand the business case for smart grid investment strategies over the period to 2050. This new modelling capability has played an important role in developing the Distribution Network Operators’ business plans to be implemented under Ofgem’s RIIO framework from 2015 and covering the period to 2023. Follow-on work under the auspices of Smart Grid Forum Workstream 7 (again with multiple stakeholder inputs and commissioned by the network companies from a consortium) is now undertaking detailed modelling to understand the significant technical challenges associated with these investments. This is termed the DS2030 project and will complete in mid-2015. The models developed by this project will be made available to interested parties in due course, however they will not form a comprehensive new tool set, rather they will make best use of existing tools and include considerable manual intervention to integrate disparate data sets.

[7]G59 ROCOF protection is the mandated protective relaying for distributed generation to ensure that beyond a threshold rate of change of frequency (ROCOF) the generating units would be tripped off the system. The protection is intended to prevent islands being created after a loss of mains event.

Such challenges and responses are expected to become more frequent in the GB power system with the increased scale and pace of change becoming a difficult challenge for the sector to deal with on what is anticipated to be an on-going basis.

This project has gathered evidence of many such challenges, many international reference points that show similar issues elsewhere, and also some of the specific features of the GB power system.

Some of the important differences that are likely to amplify the issues and constrain the mitigations available are the island nature of our AC synchronous power system with only limited DC interconnections to neighbours, different technical standards and design practices, greater proportionate impact of renewables and different energy market arrangements.

4 Main project findings

New modelling capabilities are required to address the changing power system

This project commissioned, and received, fifteen individual papers from GB-based specialists of international standing in power system modelling[8].

The authors of the papers worked with a wide stakeholder base of network companies, academics and others, who provided review and challenge. The project Steering Group, which has defined the scope of the work and managed the delivery of the evidence includes senior representatives from the power network companies, academia, industry, independents, consultants, the regulator and government.

The evidence from the papers (summarised in a separate report) provides a clear picture of the current modelling capabilities and their application by the network and system operation organisations across the full range of requirements set out in Figure 1. While the GB power systems sector has a track record in developing and/or acquiring[9] the necessary modelling capabilities in a timely manner to meet the emerging challenges, the expected challenge now faced is unprecedented in its scale, nature and pace.

It is important to note that many of the modelling platforms and equipment and systems models themselves, have been developed in the, often international, power system analysis and network management vendor community. So why should GB coordinate a modelling response to the power system challenges now? The conclusion of the project is that there are issues of scale, nature and pace of change in the GB power system that make waiting for the open market to provide solutions an unacceptably risky proposition. Furthermore, many of the issues cut across traditional boundaries of responsibility (e.g. the whole system issues noted above) where a measure of industry leadership for resolving these issues will be required. There are also several special characteristics of the British electricity system that, at least, need a locally tailored response even if similar challenges are faced elsewhere (e.g. relatively small network size, with high level of renewables penetration, particular market arrangements and industry structure, etc.). There are undoubtedly opportunities to gain from international initiatives (e.g. ENTSO-E, EERA, CIGRE, etc.) and to provide leadership and export opportunities internationally in turn.

[8]The commissioned papers have been reviewed and revised for publication. The papers have been summarised in an IET Special Interest Publication – Academic and Industry Papers, to provide a detailed summary of the body of evidence on modelling capability as a reference point for industry stakeholders.

[9]Many significant developments in power system modelling capability have been brought forward by vendors of software, equipment and systems or from collaboration between them and the GB network and system operation companies.

The breadth of issues that the current work has revealed gives rise to further detailed questions that should be addressed in due course, but detailing them and testing the validity of the technical detail or the urgency of the need is beyond the scope of the present project. Examples include stability and transient performance issues for the whole system, harmonic and other more local but nonetheless challenging issues, and the modelling of new equipment, technologies and systems at all levels within the GB system and for multiple purposes including equipment approval, system planning and system operation. These specific issues are developed further below.

Inevitably there was some divergence of views across the members of the Industry and Academia Engagement Workshop, but this report is representative of the broad consensus, and the areas that warrant more detailed examination have been noted in a detailed set of notes from the workshop[10].

The main areas where workshop participants did not have a single view concerned whether the case was sufficiently demonstrated for a coordinated approach to modelling capability development, considering the timing, pace and nature of the GB system challenge, and whether third parties in the open market would provide the required modelling capabilities to meet the requirement whenever and in whatever form those challenges emerged.

Evidence has also been gathered through separate initiatives to address the anticipated challenges such as the National Grid System Operability Framework (SOF), Low Carbon Network Fund projects (LCNF), the on-going Smart Grid Forum Workstream 7 'Distribution System 2030' (DS2030) project and relevant academic projects (e.g. HubNet[11]). These are highly valuable contributions to addressing the challenges but are not, in themselves, sufficient for responding to the full scope and scale of the emerging issues and the threats they present.

The evidence gathered also paints a picture of a scale, nature and pace of change in the GB power system that presents substantial new demands for modelling. The new capabilities required and issues yet to be addressed can be summarised broadly as:

- **power system models that span both transmission/distribution networks and active consumers,** enabling the modelling of more facets of power system behaviour in one analysis package or at least compatible interoperable packages.
- **markets and commercial externalities** that have a direct bearing on technical performance and its modelling, noting the potential for active demand responding to time of use prices.
- **new ranges of data** required to support advanced modelling treatment, yet which might be hard to access for reasons of commercial confidentiality or lack of operational experience, and whose accuracy needs to be assured (e.g. GB connection application status/register, operational notifications, effectiveness of smart grid solutions, characteristics of power electronics converters (e.g. harmonic distortion), EV charging behaviour (impact on demand curves), heat pumps (impact on demand curves) and DG fault ride-through capability).
- **transitioning to a less predictable, stochastic world** that can no longer be based upon deterministic system 'givens', incorporating new parameters that will vary depending on wind and sun forecasts, or that depend on consumer choices, behaviours and temperament.
- **optimising demand interaction** with the power system to integrate fully this valuable whole system resource while providing greater flexibility and usability for system users.

[10]Industry and Academia Engagement Workshop Summary, IET, 28th October 2014.

[11]HubNet is the Engineering and Physical Sciences (EPSRC) funded collaboration of power systems academic research groups with one of its main aims being industry interaction.

- **modelling intra-day conditions** and much more frequently changing system conditions, noting that long-established load curves and 'cardinal points' are likely to change significantly and be far less predictable.
- **the dynamic business and operational context** which will be characterised by continual change, new commercial models and services, and new devices and upgrades entering service and changing behaviour at a faster pace than previously experienced.
- **the requirement for interoperability** between power system equipment including a greater dependency on ICT technologies and infrastructure.
- **the interaction between energy vectors:** planning and operating energy-delivery and energy-using infrastructure in an efficient resilient way (e.g. electricity, gas, transport and heat).
- **interaction with smart cities and communities** with multi-faceted public and commercial services, infrastructures and systems.
- **interaction with new third parties,** typically from the ICT and data sectors but also including micro-generators, independent micro-grid operators, and new power network service providers.

In summary, modelling provides us with a self-consistent forecast of what is likely to happen, but it requires a subsequent intervention to steer away from an undesirable outcome. To date this issue has largely been masked by modelling and the interventions both being mainly 'in house' and for an individual network company. However, looking forward, there will be far more cases where the decisions of one party can impose costs on another. At the simplest level, if customers insist on charging their electric vehicles at on-peak times it will drive up investment in distribution, transmission and generation. The models should inform how interventions could be designed and implemented for cross-cutting issues. Such interventions could be technical limits or moves to expose the market participant to the costs that they are imposing on the system. This will broaden the issues from purely technical to commercial issues such as network use-of-system charging. It may also include social considerations such as fuel poverty.

Facilitated by an engagement workshop, Steering Group members, industry and academia have reviewed the detailed evidence, discussed its implications, and explored specific aspects of the recommendations. The questions put to the wider industry and academia workshop were:

- To what extent do the papers and reports capture the main modelling challenges? What might have been overlooked?
- Potential issues have been identified but it has yet to be established which ones will become significant constraints on the operation of the system and when this will happen. Are we able to estimate how the main modelling priorities should be placed on a timeline indicating when they will actually be required (e.g. 1-3 years, 4-9 years, 10-15 years out)?
- What specific modelling capability development initiatives would provide comfort in key areas of concern/risk?
- Who should take responsibility for making sure the right modelling capabilities are in place in time to meet the challenges?
- How should this range of modelling developments be co-ordinated and managed on an on-going basis?

Table 1 presents the results of the workshop straw-poll prioritisation of the modelling challenges.

Modelling Challenges	Timeline (when the issues become significant)		
	1-3 Years	4-9 Years	10-15 Years
Power system models that span transmission/ distribution networks and end users	★★★	★★★	-
Markets and commercial externalities	★★★	★★	★
New ranges of data	★★★★	★★★	★★
A less predictable, stochastic world	★	★★	★
Optimising demand interaction	-	★★	★★
Modelling intra-day conditions	★	★★	-
A dynamic business and operational context	-	-	-
The requirement for interoperability	★★★	★★★	★★★
The interaction between energy vectors	-	★★	★★★
Interaction with smart cities	-	★	★★
Interaction with new third parties	★★	★★★	★

Responses from the groups on 'further challenges' identified the following:
1) Telecoms dependencies for data transfer (e.g. to enable automated and intelligent systems)
2) Skills requirements to support new modelling (e.g. big data analytics and stochastic modelling)
3) New technologies that will require new models, new data, and validation (e.g. power electronic convertors, storage systems, and home energy automation)
The above were seen by participants to be relevant across all timescales.

Table 1: Industry and Academia Engagement Workshop straw poll prioritisation of modelling challenges and gaps (stars show number of workshop groups suggesting the modelling challenge is a priority in the given timeframe).

Mapping of modelling challenges and gaps to development requirements

Taking the detailed evidence of modelling challenges and gaps and the prioritisation of issues provided via industry engagement, a mapping of specific modelling development requirements to address the prioritised modelling challenges and gaps has been developed and is presented in Table 2.

Table 2: Mapping modelling challenges to specific modelling developments required.

Identified Modelling Challenges and Gaps

Power system models that span both transmission/distribution networks and active consumers

Gap: Electrical models of transmission and distribution connected load, generation, storage and network equipment to enable robust steady state, contingency, fault, dynamic, harmonic and system recovery studies to be performed.

Specific Modelling Capability Development Requirements

- Models of lower inertia, power-electronically interfaced, intermittent renewable sources with controllers and HVDC systems at all scales.
- Aggregation of customer behaviour effects, commercial/market responses and meteorological effects on generation and load.
- Robust device / system models of electrical heating and transportation: characteristics, aggregated profiles, diversity, and cold load pick-up.
- Widespread system impacting commercial models such as time of use tariffs, s/meter responses, active device management and scheduling.
- Simplified/aggregated/equivalence models of system components to explore planning and operational issues at appropriate model scales.
- Real time simulation of new equipment / system types including large volumes of independently controlled devices to check dynamic and transient stability.
- Decentralised operation of micro-grids, smart cities and actively managed zones including protection and control systems.
- Models of new system wide transmission equipment including series compensation and wide area monitoring and control.
- Models to assess protection discrimination and co-ordination integrity under increasingly varying network configuration and source impedance conditions.
- Fault ride through capability of DG during system perturbations (requiring a capability to assess voltage transient behaviour under varying network configuration and source impedance conditions).
- Impact of dynamic system conditions and variable fault levels on harmonics, THD and harmonic resonance risk.
- Contingency analysis models to assess power flow, voltage, and fault level changes under plausible generation, demand and outage conditions in both investment and operational planning timescales, and also for operational management (e.g. post-fault); this is a rapidly emerging new requirement for highly utilised active distribution networks.

Addressing the gaps: The response to the prioritised modelling challenges and gaps identified requires several new multi-party initiatives to draw in equipment and system providers, network operators, academic and consulting expertise, modelling platform vendors with contributions to make in this whole electricity system challenge. It is anticipated that the work to deliver these new and advanced modelling capabilities would take some years to deliver in a fully functional and practically usable form to network operators and the system operator.

Identified Modelling Challenges and Gaps

Markets and commercial externalities

Gap: Methods to capture and embed economic and system user and ancillary service provider behaviour characteristics into relevant system planning, operational planning and operations activities.

Specific Modelling Capability Development Requirements

- Modelling of new market mechanisms for capacity, energy and services including dynamic tariffs and system user and network service provider responses to diverse commercial signals – including potential synergies and conflicts arising from multiple supply chain parties contracting with common sources for services (for example DSR and energy storage).
- Model interfaces to economic and commercial modelling environments to provide accurate boundary conditions for the power system.

Addressing the gaps: This challenge requires a cross-industry response to address the extent of the issues but with expected distinct strands of activity to propose, develop and implement data and model exchange solutions for each of the applications scoped above. The opportunity to specify and implement a mandated common data and model exchange mechanism for the GB electricity system requires substantial work. This challenge requires government and regulator input and cross industry coordination (in contrast to others areas where a response from network companies and immediate stakeholders is sufficient) to address possible commercial, regulatory and legislative implications of completely new arrangements and openness in data sharing and use.

Identified Modelling Challenges and Gaps

New ranges of data

Gap: Accessibility to and appropriate analysis for new large volume data sources (e.g. smart meter data), and sharing of data and models to underpin effective and efficient modelling of power system for planning, operations, and policy development.

Specific Modelling Capability Development Requirements

- Protocols, processes and ICT solutions for sharing data between network licensees and system operators on generation, load and storage for planning and operational purposes.
- Characteristics of, and interactions between, new active network assets (e.g. FACTS) under a range of credible operating conditions.
- Sharing of data and modelling results for policy development by the government and regulator.
- Solutions for data security and confidentiality (private citizen and commercial).
- GB-wide generation connection data capture and sharing in appropriate timeframes for effective system planning and operations.
- Load monitoring data to accurately reflect in models the changes in electrical characteristics, volumes and locations of new load equipment.
- Common GB system data model (could be based on CIM and ICCP) to enable full planning and operational phase model and data exchange.
- Real time measurements and estimates to support system operation
- Short term forecasts of weather, demand and other dynamic system operation inputs in an increasingly stochastic environment (including solar PV cloud transients and wind generation ramp rates).
- Failure modes, probabilities and consequences of new network technologies to enable FMEA studies, and hence assess network risk impact.

Addressing the gaps: This challenge requires a cross-industry response to address the extent of the issues but with expected distinct strands of activity to propose, develop and implement data and model exchange solutions for each of the applications scoped above. The opportunity to specify and implement a mandated common data and model exchange mechanism for the GB electricity system requires substantial work. This challenge requires government and regulator input and cross industry coordination (in contrast to others areas where a response from network companies and immediate stakeholders is sufficient) to address possible commercial, regulatory and legislative implications of completely new arrangements and openness in data sharing and use.

Identified Modelling Challenges and Gaps

The requirement for interoperability

Gap: Interoperation and interfacing of modelling tools at different scales and with a much wider range of interoperable equipment types.

Specific Modelling Capability Development Requirements

- Open and interoperable modelling platforms to enable effective modelling of the power system with all relevant connected equipment for planning and operations studies.
- Open source, common format equipment and system models to enable modelling by different network stakeholders on different modelling platforms.
- Ensuring compatibility to enable the outputs of one model to become the inputs to another, and for there to be confidence in results from different modelling combinations or users.

Addressing the gaps: The interoperability of modelling platforms is mainly a task for the ultimate model users (network companies, system operator and their advisers) and the modelling platform suppliers, but addressing whole system issues in effective and efficient ways requires progress. The interoperability of modelling platforms doing fundamentally different tasks presents a significant challenge that needs to be scoped out and addressed with cross-industry buy-in. The issues arising from the need for interoperable equipment and systems is beyond the scope of modelling but also requires significant cross-industry coordination (including standards and trade bodies).

Identified Modelling Challenges and Gaps

Interaction with new third parties

Gap: Modelling base to capture interfaces and dependencies on new service providers and infrastructures.

Specific Modelling Capability Development Requirements

- Models of new network services and service providers including reliability and response under a full range of system conditions (e.g. intact, contingent, dynamic response, etc.)
- Models of the effects of ICT infrastructure underpinning new customer and service provider interactions with the system.
- Co-simulation of relevant 'third party' systems (e.g. ICT, gas, transport) to ensure full relevance and robustness of studied conditions in power system models.

Addressing the gaps: Although urgent, this challenging area requires models to be specified by the network / system operators (and their coordination mechanisms) in response to anticipated and actual developments of new services, systems, business models and commercial offerings on the electricity system. Developing modelling capabilities in immediately pressing areas (e.g. demand response, ICT infrastructure dependencies) can be taken forward by the licensed network companies and their suppliers/stakeholders in specific model development programmes in an open and coordinated manner.

Table 2 also provides suggestions as to the form of response required to address the prioritised gaps in modelling capabilities. These range from a specific modelling development programme focusing on a single topic for network operators to cross-industry initiatives (including regulator and government) to make more significant changes to the ways models are developed and shared.

The consequences of failing to address the modelling gaps in a timely way are potentially serious:

- **Security:** degraded understanding of the behaviour of the power system and its critical limits that, in the worst case, could increase the risk of wide area supply interruptions.
- **Retarded system development:** failure to address emerging system constraints such that more conservative limits have to be applied to the numbers of new generation and demand connections and their operation, resulting in consumer frustration and delays to meeting government decarbonisation targets.
- **Climate change targets:** slowed deployment of renewable generation and low carbon demand technology through an inability to adequately plan and operate the system as a result of inadequate modelling capability also threatens meeting climate change targets in the challenging timescales set.
- **Loss of economy:** in addition to, and as a result of, system security and developmental targets there would be a loss of economic activity from system users as well as a loss of economy in the operation of the system itself.
- **System performance:** various technical performance parameters such as harmonics, unbalance, and fault levels could also be misunderstood, inadequately anticipated and badly planned for. This could result in poor system performance to the detriment of system users and the network companies.

With lead times of typically 3 to 5 years from model identification, specifying requirements, prototyping, development, validation and adoption, it is evident that the challenges identified in the short term category have a measure of urgency attached to them. The modelling challenges identified in the medium to long term also require initiation of modelling capability development to happen in the near term. Given the lead times for modelling capability development to application, the near term requirements already need to be addressed with urgency.

The conclusions reveal that resting on past success and relying on incremental changes to established capability, is unlikely to be a sustainable position. The risks of inadequate modelling capability are serious as they may conceal surprising and unwelcome developments in the operational characteristics of the power system. In addition to threatening power system security, they can be costly to resolve retrospectively and create barriers to government policy implementation, such as decarbonisation, smart communities, or energy efficiency.

The requirement for modelling capability leadership

In addition to the technical modelling challenges, gaps and required programmes set out above, the Steering Group also considered the need for leadership and coordination of the overall modelling effort, given the multiple parties and complexity involved. Leadership and coordination issues were identified in the commissioned papers, industry engagement and Steering Group discussions and seemed to flow logically from the specific modelling challenges. In response to this, modelling leadership was included in the industry and academia engagement workshop agenda and programme and explored actively there. The Steering Group subsequently undertook some further development of this topic to provide thoughts and suggestions to complement the specific modelling challenges and gaps themselves.

In addition, the Steering Group were keen to embed in this project the related activities on future modelling directions and leadership arising from the National Grid System Operability Framework, the ENA DS2030 and IET PNJV initiatives.

Appendix 2 sets out an initial high-level analysis of options for different ways to address the cross-cutting challenges. The requirement for a joined-up modelling effort leads to a broad recommendation for the creation of some form of Modelling Leadership Group. This analysis draws on thinking that is emerging from parallel initiatives, notably the discussions concerning a System Architect role.

The Modelling Leadership Group would be responsible for conducting the in-depth analysis that a number of workshop members highlighted as having not yet been undertaken, including confirmation of priorities and tasks at a level of detail, and the definition of organisational structure, governance, ownership, funding, and so on. Discussion with DECC, BIS and Ofgem would of course be important.

The cross-industry discussion indicated that a **Joint Transmission and Distribution Code Panel** and a **System Architect** were the two most credible mechanisms for leading the necessary modelling capability development.

There was a widely expressed view that input from academia and the Energy Systems Catapult would be valuable. Alignment of modelling responsibility with the responsibilities already held by the system and network licensees was seen as an important issue. While the System Architect option was explored at a high level at the workshop this was done with clear recognition that closer definition of the role would be required and that other parallel initiatives (e.g. the IET PNJV programme) were addressing this further. The conclusion from the workshop was that Joint Code Panel and System Architect modelling leadership roles were worthy of further thinking (with an open mind to other possibilities).

Further consideration by the Steering Group has resulted in clearer definitions of modelling leadership roles under different options. Three stages for the development of modelling leadership emerged and Table 3 sets out comparison and further thoughts for consideration:

STAGE-1 Modelling Leadership Group under a JOINT CODE PANEL	STAGE-2 Modelling Leadership Group under a SYSTEM ARCHITECT	STAGE-3 Modelling Leadership as part of a Centre of Excellence in an Extended SYSTEM ARCHITECT
IN BRIEF **A prioritising and co-ordinating role,** building on the remit of the Grid Code and Distribution Code Review Panels. (With the agreement of the parties concerned this could be implemented relatively quickly.)	**IN BRIEF** **An accountability role for GB Modelling Leadership,** under the auspices of the (future) System Architect, with a remit to address the whole system, end-to-end, including unregulated third parties. (Establishing Stage-2 would require agreement on authority & resourcing. This could follow logically from establishing a System Architect role.)	**IN BRIEF** **Development to establish a GB Centre of Excellence,** that expands the Stage-2 remit to include other energy vectors and related sectors, with the necessary skills, modelling capability and facilities to examine whole-system and cross-vector energy system impacts. (With Stage-2 established, Stage-3 would be expected to follow once scope is clarified and facilities and resources are in place. Third party facilities and capabilities are likely to be key here.)
HEADLINE TASKS ■ Provide oversight of the Modelling Leadership Group ■ Typically having a shorter-term horizon and probably a more reactive method of working ■ responding in a timely manner to issues as they arise ■ working with and across the network companies and their modelling providers ■ operating within the remit of the DCRP and GCRP panels, i.e. the regulated electricity sector	**HEADLINE TASKS** ■ definition of roles and governance, and perhaps integration of the Code Panels into the System Architect function, would be a first step to move to this next stage ■ the SA could take responsibility and be accountable for the Modelling Leadership activity ■ it would ensure whole-system technical integration and modelling capability ■ it would be well placed to deliver functional designs for power system models and modelling capabilities ■ it could commission work by academia and the E S Catapult	**HEADLINE TASKS** ■ a continuation of the Stage-2 roles ■ lead role for cross vector and wider sector aspects of energy modelling ■ it would be an enabling body to encourage UK entrepreneurship, jobs and exports, working with the Catapult ■ an active role in supporting skills growth, training and knowledge continuity ■ it would address and support the validation of modelling, including through third party simulation and demonstration facilitates ■ the scale and scope of longer-term modelling will require commensurate computing capabilities ■ it would be engaged in supporting and informing the R&D 'supply pipe' for ensuring forward-looking capabilities and facilities
LIKELY KEY STAKEHOLDERS ■ Licensed network companies ■ Academia ■ Software vendor companies	**FURTHER STAKEHOLDERS** ■ Home Energy Mgt vendors ■ Energy Services/TOU providers ■ Energy Systems Catapult	**FURTHER STAKEHOLDERS** ■ Heat, Gas, Hydrogen & EV sectors ■ Third party Test/ Demonstration facilities ■ Third party computing platforms

Table 3: Prospective development of Modelling Leadership through three stages to reflect possible leadership of system architecture development.

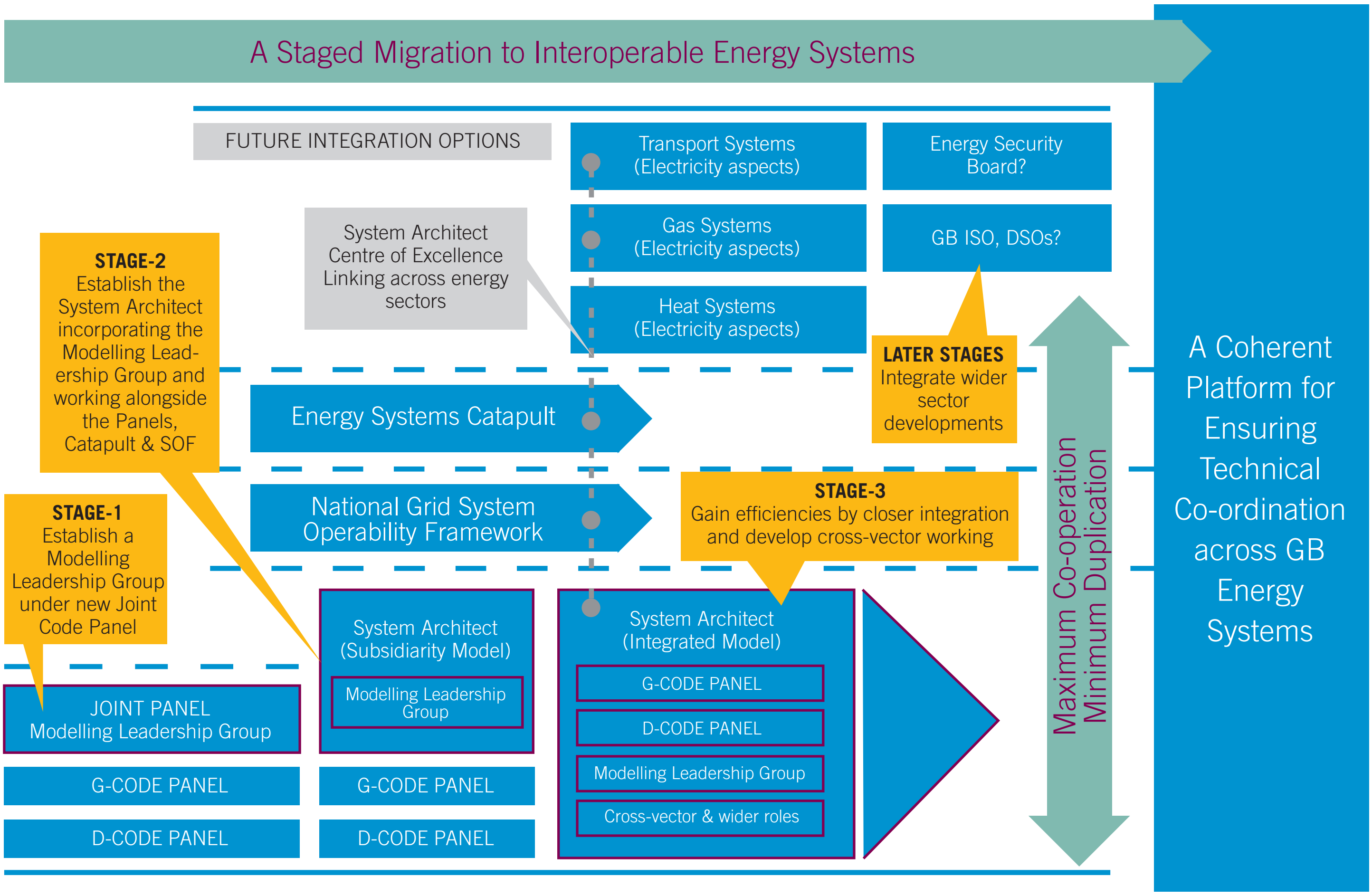


Figure 3: Modelling leadership responsibilities under possible energy system migration paths.

It might be sensible to have review points between the stages to confirm whether to progress and, if so, at what time scale. How these stages for power system modelling leadership might be implemented and the key milestones are important considerations and a graphical representation of the pathways addressing those issues and related issues is provided in Figure 3.

The following conclusions are drawn from the Steering Group's consideration of the requirements for modelling leadership that follow on from the modelling challenges and gaps identified:

- Whilst there is already strong evidence for initiating developmental activities on new modelling capabilities in certain technical areas, it is recommended that the anticipation, prioritisation, specification and commissioning of new modelling capabilities should be focused and co-ordinated by creating a new Modelling Leadership group as a Stage-1 development. Such a group would require appropriate authority and oversight, for example, in a similar way to that established for the Code Panels. It would focus on the regulated company networks, which is consistent with the remit of the Panels.
- The Stage-2 development is envisaged to be a managed transition, incorporating transfer of the Modelling Leadership role into an integral part of a System Architect function. This has many attractions from the perspective of organisational fit and, notably, a remit that is wider than that of the Code Panels, enabling a focus beyond the regulated network companies to include third parties such as EV and heat pump suppliers and providers of home energy automation.

- Stage-3 would be a further expansion of the Modelling Leadership role to create a Centre of Excellence within the System Architect function, addressing integration across other energy vectors such as heat, gas and hydrogen. It is envisaged that this would be likely to require a modelling capability that is both comprehensive in its scope and underpinned with computing facilities of appropriate processing power.
- Stage-2 and Stage-3 activities are seen to benefit from joint working with the new Energy Systems Catapult, national power systems test facilities (such as the Power Networks Demonstration Centre in Glasgow or the proposed Multi-Terminal Test Environment for HVDC), and with multi-party working with all sector stakeholders to develop and validate data sources and modelling outputs. This could form a later stage of development, as and when a System Architect role is established.
- In Stage-1, the early priorities for a Joint Code Panel are likely to be data exchange and interoperability. Data accessibility has become a recognised challenge where working across existing and new network participants will help. This work will need 'back office' support which might be provided by existing groups (organisations that support today's Code Panels, etc.) and resourced / funded through mechanisms available to the licensed network companies and academia. This requires further examination and agreement. Looking ahead, the specific programme within the Energy Systems Catapult to support the development of new modelling tools[12] could be helpful here. Coordination is envisaged to be provided in the interim by a Joint Panel group reporting to the Code Panels. This would be an embryonic Modelling Leadership Group.

5 Conclusions

Action is required to address the impact of the nature, scale and pace of the challenge to the GB power system

The project brought together a substantial and authoritative evidence base of serious emerging system modelling issues and challenging timescales for their resolution. The project concludes that further work and commitments to action are required to address the following:

- **Specific Modelling Gaps and Challenges** to build on the early priorities for modelling capability development set out in Table 2 with further details of the wide array of complex technical modelling challenges in the underlying papers and reports produced in this project:
  - initiate responses to the most urgent modelling capability priorities set out in Table 2 above;
  - a roadmap of when the individual issues will need to be part of the industry's modelling capability with necessary inter-operability established;
  - building the specification for an enhanced modelling capability that spans the parties in the supply chain, utilising the breadth of expertise demonstrated by contributors to this project;
  - a coordinated approach to developing GB modelling capability drawing in relevant stakeholders, expertise and resources to address the scale and scope of the new challenges;

[12] The Energy System Catapult could potentially provide resource and support for modelling capability development in a number of areas such as data derived from testing new network interfacing products as modelling inputs (for example performance characteristics of a power electronics converters).

- recognition of the power systems data and information challenges, with particular attention being paid to issues that include commercial confidentiality, privacy, security, scale and capability;
    - understanding the overall system complexity and the ability of network operators to discharge their obligations in a practicable manner, with particular attention being paid to whole system issues, with much to be gained from the translation of good practice from other sectors where critical infrastructure and mission critical systems are managed effectively.
- **Modelling Skills** emerged as a common theme in the papers, Steering Group discussions and industry engagement:
    - a careful appreciation of the limited pool of specialist skills, the need to make best use of resources, and a way forward that will develop the skills available in key areas;
    - in addition to recognised academic skills in power systems research, the need to ensure that inter-disciplinary aspects such as statisticians, meteorologists, and social scientists can engage effectively in research funding opportunities.
- **Industry Engagement and Buy-In** was also noted as a key issue throughout the project (with initial moves made to initiate such engagement and buy-in through the delivery of the project itself):
    - a continued commitment from the network and system operating companies who own and operate the GB power system to engage and support the development of the required modelling capability in an inclusive, collaborative approach, and to pull this through to application;
    - the engagement of the government and regulator (Ofgem) to support this work, including consideration of any necessary funding and resources.
- **Resources** was noted in several of the project activities and is clearly a logical question when facing substantial new long-term modelling challenges:
    - consideration of the resourcing implications in addressing the scale of challenge anticipated, sustaining the likely on-going resource demand, and meeting the need for depth and continuity of expertise;
    - consideration of the supporting resource requirement for modelling leadership to ensure full contribution from the 'market' (including vendors, academia, Energy Systems Catapult) and specially resourced initiatives.
- **Modelling Leadership** issues followed on naturally when the significant breadth and depth of challenges became clear from the specific modelling questions:
    - effective stakeholder-led governance arrangements for modelling development, building on good practice from recent cross-sector initiatives (e.g. the governance approach for the Transform model cited above[13]);
    - consideration of the related IET PNJV work focussing on a power system architect role in GB with the potential for that role to assist in delivering several of the above objectives;
    - consider further the proposed high-level migration plan to move from Stage-1, to Stage-2 and Stage-3 of modelling leadership (as part of overall system architectural leadership and authority); agreeing with all stakeholders the necessary check-points and dependencies for a managed transition.

[13]Transform is a software tool developed by a third party provider (EA Technology Ltd). Governance of on-going development is managed under the auspices of the Smart Grid Forum, WS3. Page 16 of this presentation provides further information: http://www.energynetworks.org/modx/assets/files/electricity/engineering/SGF%20Seminar%20event%20141013.pdf

Appendix 1

Project Steering Group membership

Member Name	IET Role	Organisation	Steering Group Role
Prof John Loughhead FREng, FIET	Energy Sector Chair	UKERC	Chairman – up until appointment as CSA to DECC (Nov 14)
Dave Openshaw CEng FIET	PNJV Member	UK Power Networks	Distribution expert & Report Reviewer & Approver
Phil Lawton CEng FIET	PNJV Member	National Grid	Transmission expert & Report Reviewer & Approver
John Scott CEng FIET	PNJV Member	Chiltern Power	Stakeholder Management and co-ordination with relevant sector activities
Dr Simon Harrison CEng FIET	PNJV Chairman	Mott MacDonald	PNJV Advisor (invited to join following John Loughhead's retirement as Chairman)
Prof Sir Michael Sterling FREng FIET	Fellow		CST Nominee
Dr Paul Golby FREng FIET	Fellow		CST Nominee
Gordon Graham	Staff	IET	Project Manager and Chairman following John Loughhead's retirement as Chairman
Helen Farr	Staff	IET	Policy Lead

The IET Steering Committee also included Dr Damitha Adikaari (DECC), Gareth Evans (Ofgem), Eric Brown (Innovate UK), Rupert Wilmouth (GO-Science/BIS) and Dr Jenny Moore (GO-Science/BIS) as observers to the project.

The Steering Group members have participated on the basis of their affiliation with the IET and as independent advisers to CST so the views, opinions and recommendations made in this report are provided on a 'best independent professional advice' basis and do not necessarily reflect the views of their employers or of the other organisations they represent.

Contracted technical co-ordination of the project was provided by Professor Graham Ault CEng FIET of Smarter Grid Solutions.

Appendix 2

What form should the response to the modelling challenge take and who should lead?

The conclusion that there is some urgency in the need to act on developing and applying new modelling capabilities, is based on a substantial and authoritative evidence base provided in independently authored papers that point towards emerging and anticipated changes to the power system being substantially more challenging than recent historic developments. The fact that these changes stretch across current licenses for generation, transmission distribution and retail supply and even beyond current regulatory jurisdiction, suggests that the challenges will be difficult to tackle under current governance and coordination mechanisms. The risks from an inadequate response are too great to be left to ad hoc approaches or for third parties alone to provide solutions. There are several promising initiatives in the wider market and in the international arena which need to be assimilated and applied in the GB power system context even if some of the answers are emerging.

If the conclusions, concerns and recommended areas for action set out above are broadly accepted then there is a need to determine where the responsibility should lie to develop the thinking and provide co-ordinated leadership between the stakeholders that will ensure the delivery of the national modelling capabilities required. The evidence gathered through the project points to several key common criteria that require assessment to identify the way forward.

Contribution: What is the appropriate role for network companies, system operators, academic researchers, consultants, innovation projects, commercial power system analysis platform developers, and others in developing the required new modelling capabilities required to underpin the security and performance of the GB power system? What other inputs are required from sector stakeholders? What would the market (e.g. vendors, analysis platform developers) provide without any input from a new mechanism of coordination and leadership?

Resources: How should the developers of the required new power system modelling capabilities be resourced? How much of the resourcing of modelling capabilities will continue to come from commercial software, equipment and systems vendors? What facilities, assets and resources would be required separate from or in response to any coordinated approach? What might the role for academic consortia, the new Energy Systems Catapult and regulated innovation funding be in resourcing the required programmes? Would there be a justification for a national (and/or a virtual) centre of excellence in energy network modelling, drawing together critical sources of expertise? Who would lead and fund the required training and skills development in power system modelling?

Coordination: What would be the best mechanisms for coordinating the developmental activities? How could new activities be linked to and coordinated with other initiatives on power system modelling such as the NG System Operability Framework (SOF) and Smart Grid Forum DS2030 initiatives? Who would best anticipate impending challenges and issues for modelling and lead the commissioning of the required work on behalf of the sector?

Integration: How would any new mechanism to lead power system modelling capability development handle increasing whole-system and cross-energy vector working?

Governance: How would governance of the modelling capability development effort be undertaken? What would the role be for existing governance mechanisms such as the Code Panels? What would be the rationale and value of new governance mechanisms?

Specific initiatives: Are there new issues of a sufficient scale and challenge that specific initiatives to tackle them are required? Would system complexity, system stability or data be such topics?

Engagement: How could all of the above benefit from, or even necessitate, strong stakeholder buy-in, steer and contribution?

Alignment: How would a new power system modelling leadership mechanism align with the work of the Grid Code Panel, the Distribution Code Panel, the Smart Grid Forum, the Energy Systems Catapult, the ENSG, academia (including UKERC and HubNet)? How would all of this align with any development towards establishing a System Architect role in GB?

Strategic Fit: How would we ensure that any host organisation has a strategic fit for the nature of work being contemplated (this will help ensure the alignment of priorities and of skills)?

Recommendations:

A new leadership mechanism for modelling capabilities to address the challenges now faced.

The criteria noted above were considered at the Industry and Academia Engagement Workshop along with discussion on some ‘strawman models’ of modelling capability development leadership to promote discussion.

Leadership in a technically complex, multi-faceted and multi-party area such as power system modelling requires certain characteristics of any group taking leadership responsibility. The following list of leadership characteristics are proposed for power system modelling capabilities development:

- Collaborative: working closely with key stakeholders
- Outward facing: need to build engagement, especially into other energy vectors
- Forward-Looking: need for strategic thinking, developing pathways and priorities
- Transparent: agreed and published work plans, best practice governance model
- Knowledge sharing: default would be shared outcomes, subject to IP/Funding details
- Hybrid working: task delivery achieved through both direct and out-sourced working
- Added Value: avoiding duplication, cost-effective choices
- A Centre of Excellence: professional, impartial and respected
- Authority: suitable powers to deliver accountability – but only invoked as a last resort

A range of leadership models were also outlined and discussed at the Industry and Academia Engagement Workshop:

- A newly established, stand-alone, independent body
- Joint Code Panel modelling ‘leadership group’
- Academia

- Energy Systems Catapult
- System Architect (to be more fully defined)
- Ofgem
- DECC
- Others

These modelling leadership options have been evaluated, at a first pass, against the criteria and considerations and these were discussed at the workshop. A key feature of the presented material and discussion focused on the type of governance that a new modelling capability leadership role should have. A ‘liaison role’ would coordinate the perspectives of stakeholders while also coordinating the delivery of the modelling capabilities by other parties. An ‘accountability role’ would take on much greater responsibility for delivery of modelling capabilities while working with, through and for the other stakeholders.

On balance, the workshop discussion pointed towards the challenges to be addressed being most likely to require an ‘accountability’ approach. This conclusion arose from recognition of the scale of the challenges ahead, involving multiple parties (both regulated and non-regulated companies), the breadth of modelling techniques (from steady state to dynamic), and the requirement to develop relationships and work across sectors (including other energy vectors, transport, and home energy management). Furthermore, it appeared inadequate to establish a body with only ‘liaison’ role when the consequence of inadequate modelling could lead to erosion of power system resilience.

However, it was also viewed that to be effective the working methods would have to be highly collaborative in practice and that ‘authority’ would need to be in the form of organisational under-pinning rather than indicating the intention for a directive style.

Figure 4a illustrates the matching of the different modelling institutional options against the criteria for an ‘accountability role’. Following this Figure 4b to Figure 4d add a high-level commentary on the rankings for the two most promising options, namely the Joint Code Panel and the System Architect, plus the merits of a linkage into Ofgem.

An Initial Matching to Criteria

✗ Poor
? Challenging
✓ Promising

	Free Standing (simply 'hosted' somewhere)	**System Architect** (yet to be fully defined)	**Ofgem** (arm's length relationship)	**Code Panels** (New Panel or Joint Working)	**Energy Systems Catapult**	**Academia** e.g. UKERC, HubNet
Contributing Accessing expertise	?	✓	✓	✓	✓	✓
Resourcing Facilities, Staff, Budgets	✗	✓	✓	✗	✓	?
Coordination Other modelling work	?	✓	✓	✓	✓	✓
Integration Whole-system, multi-vector	✗	✓	?	✗	✓	✓
Governance For Accountability role	?	✓	✓	?	✓	?
Specific initiatives Vision & Project Definition	✓	✓	✓	✓	✓	✓
Engagement Policy stakeholders	?	✓	✓	?	✓	✓
Alignment Other sector bodies	?	✓	✓	?	✓	✓
Organisational fit	✓	✓	✗	✓	✗	?

Figure 4a: Matching of Modelling Leadership options to criteria for 'Accountability Role'.

An Initial Matching to Criteria

Explanatory comments on Code Panels option

✗ Poor
? Challenging
✓ Promising

Criteria	Free Standing (simply 'hosted' somewhere)	System Architect (yet to be fully defined)	Ofgem (arm's length relationship)	Code Panels (New Panel or Joint Working)	Energy Systems Catapult	Academia e.g. UKERC, HubNet	Explanatory comments on Code Panels option
Contributing Accessing expertise	?	✓	✓	✓			C/Panel linkage would build on existing technical relationships
Resourcing Facilities, Staff, Budgets	✗	✓	✓	✗			C/Panel has no mechanisms of its own for funding/budgets
Coordination Other modelling work	?	✓	✓	✓			C/Panel linkage would enable this
Integration Whole-system, multi-vector	✗	✓	?	✗			C/Panel present remit is closely defined, so wider engagement would require change
Governance For Accountability role	?	✓	✓	?			C/Panel has Ofgem governance oversight, so development here might establish this
Specific initiatives Vision & Project Definition	✓	✓	✓	✓			C/Panel linkage would be helpful in this role
Engagement Policy stakeholders	?	✓	✓	?			C/Panel at present is deeply technical and does not have strong policy links of its own
Alignment Other sector bodies	?	✓	✓	?			C/Panel linkage would need development in this area to be fully effective
Organisational fit	✓	✓	✗	✓			C/Panel current remit for technical governance would provide a good fit here

Figure 4b: Matching of Modelling Leadership options to criteria for 'Accountability Role' – Explanatory comments on Code Panels option.

An Initial Matching to Criteria

Explanatory comments on System Architect option

✗ Poor
? Challenging
✓ Promising

Criteria	**Free Standing** (simply 'hosted' somewhere)	**System Architect** (yet to be fully defined)	**Ofgem** (arm's length relationship) / **Code Panels** (New Panel or Joint Working) / **Energy Systems Catapult**	**Academia** e.g. UKERC, HubNet
Contributing Accessing expertise	?	✓	S/Architect would build be effective for building technical relationships	✓
Resourcing Facilities, Staff, Budgets	✗	✓	S/Architect would require a funding mechanism, so this would be available	?
Coordination Other modelling work	?	✓	S/Architect linkage would enable this	✓
Integration Whole-system, multi-vector	✗	✓	S/Architect remit would need to be wide, so multi-vector working would be facilitated	✓
Governance For Accountability role	?	✓	S/Architect would require accountability and authority, so a natural fit	?
Specific initiatives Vision & Project Definition	✓	✓	S/Architect linkage would be helpful in this role for modelling	✓
Engagement Policy stakeholders	?	✓	S/Architect would require relationships with policy makers, so a natural fit	✓
Alignment Other sector bodies	?	✓	S/Architect remit would need to be wide, so this would be facilitated	✓
Organisational fit	✓	✓	S/Architect as currently envisaged would provide a good fit here	?

Figure 4c: Matching of Modelling Leadership options to criteria for 'Accountability Role' – Explanatory comments on System Architect option.

An Initial Matching to Criteria

Explanatory comments on Ofgem option

✗ Poor
? Challenging
✓ Promising

Criterion	Explanatory comments on Ofgem option	Free Standing (simply 'hosted' somewhere)	System Architect (yet to be fully defined)	Ofgem (arm's length relationship)	Code Panels (New Panel or Joint Working)	Energy Systems Catapult	Academia e.g. UKERC, HubNet
Contributing Accessing expertise	Ofgem linkage would create strong access			✓	✓	✓	✓
Resourcing Facilities, Staff, Budgets	Ofgem has mechanisms for funding/budgets – provided of course the case is well made			✓	✗	✓	?
Coordination Other modelling work	Ofgem linkage would enable this			✓	✓	✓	✓
Integration Whole-system, multi-vector	Ofgem's present remit is gas and electricity, so wider engagement might require change			?	✗	✓	✓
Governance For Accountability role	Ofgem's frameworks are probably well positioned to provide this			✓	?	✓	?
Specific initiatives Vision & Project Definition	Ofgem linkage would strengthen this role			✓	✓	✓	✓
Engagement Policy stakeholders	Ofgem linkage would enable this			✓	?	✓	✓
Alignment Other sector bodies	Ofgem linkage would enable this			✓	?	✓	✓
Organisational fit	Ofgem's current remit for economics and environment might need to be extended			✗	✓	✗	?

Figure 4d: Matching of Modelling Leadership options to criteria for 'Accountability Role' – Explanatory comments on Ofgem option.

The three most credible stages in developing a modelling leadership function are developed further below. In practice a review point could be included between each:

STAGE-1: A Modelling Leadership Group, overseen by a Joint Code Panel with a specific remit for leading the development of modelling capabilities is judged to have the advantage of being more deliverable in the short term and would have the benefit of more straightforward network and system operator buy-in. It would also have the advantage of providing access to practitioners with network management and modelling expertise. This approach is an extension of current business as usual but with an enhanced focus and new mechanisms for development of modelling requirements. Such a Joint Code Panel would agree and identify the requirements governing new equipment and systems as well as the approaches to modelling them. Enforcement of compliance with codes would also sit with this joint panel. The work of a joint code panel could be enhanced and coordinated through a 'Common Information Model' for data and model exchange. The joint panel would need to include network users such as generators and active demand/consumer representatives. The joint panel would oversee the implementation of the requirements of ENTSO-E, the European Network Codes and other standards and policy setting bodies. A Joint Code Panel might have a shorter-term horizon and perhaps have a more reactive method of working, responding in a timely manner to issues as they arise. An illustration of some of the lines of responsibility (solid) and communication (dashed) under a new Joint Code Panel arrangement are provided in Figure 5.

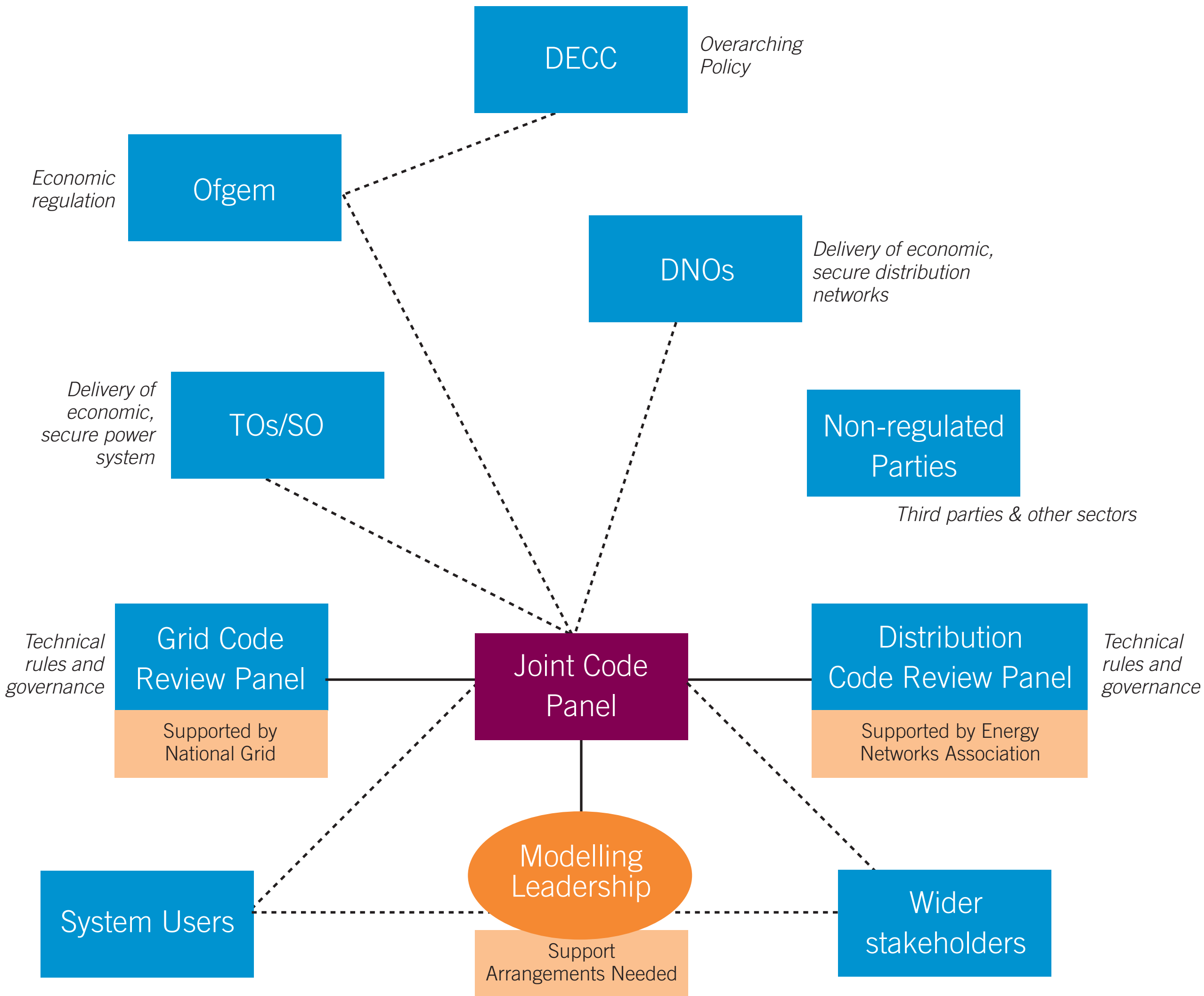


Figure 5: Illustration of modelling Leadership under a new Joint Code Panel.

STAGE-2: Transfer the Modelling Leadership to a System Architect function as this has the potential to lead on modelling capabilities, including the interfacing with parties beyond the regulated companies. Its responsibility for power system modelling and modelling capability development would need to be defined, both in general, as well as specific, terms. The System Architect would be charged with ensuring whole-system technical integration and modelling capability, and would be well placed to deliver functional designs for power system models and modelling capabilities. This would extend to commissioning of work by academia and the Energy Systems Catapult. The System Architect would need 'buy-in' by all industry parties and have authority to coordinate and lead. The System Architect would have to coordinate with a wide group of other stakeholders on modelling matters as well as on wider matters. The System Architect would need to 'enable' rather than 'dictate', and leading on modelling capability development could be a key facet of enabling. In contrast to the Joint Code Panel, the System Architect could be more forward-looking and broader in remit. Whilst this would be a clear advantage in many respects, its terms of reference would need to be carefully drafted to ensure that it did not go beyond its intended remit to develop practical 'fit for purpose' models that combine (or balance) the requirements for comprehensiveness and usability. An illustration of some of the lines of responsibility (solid) and communication (dashed) under a new System Architect arrangement are provided in Figure 6. An important and challenging consideration for the terms of reference of a System Architect is that it would need to operate beyond the boundaries of the regulated electricity companies (which is the remit of the present Code Panels).

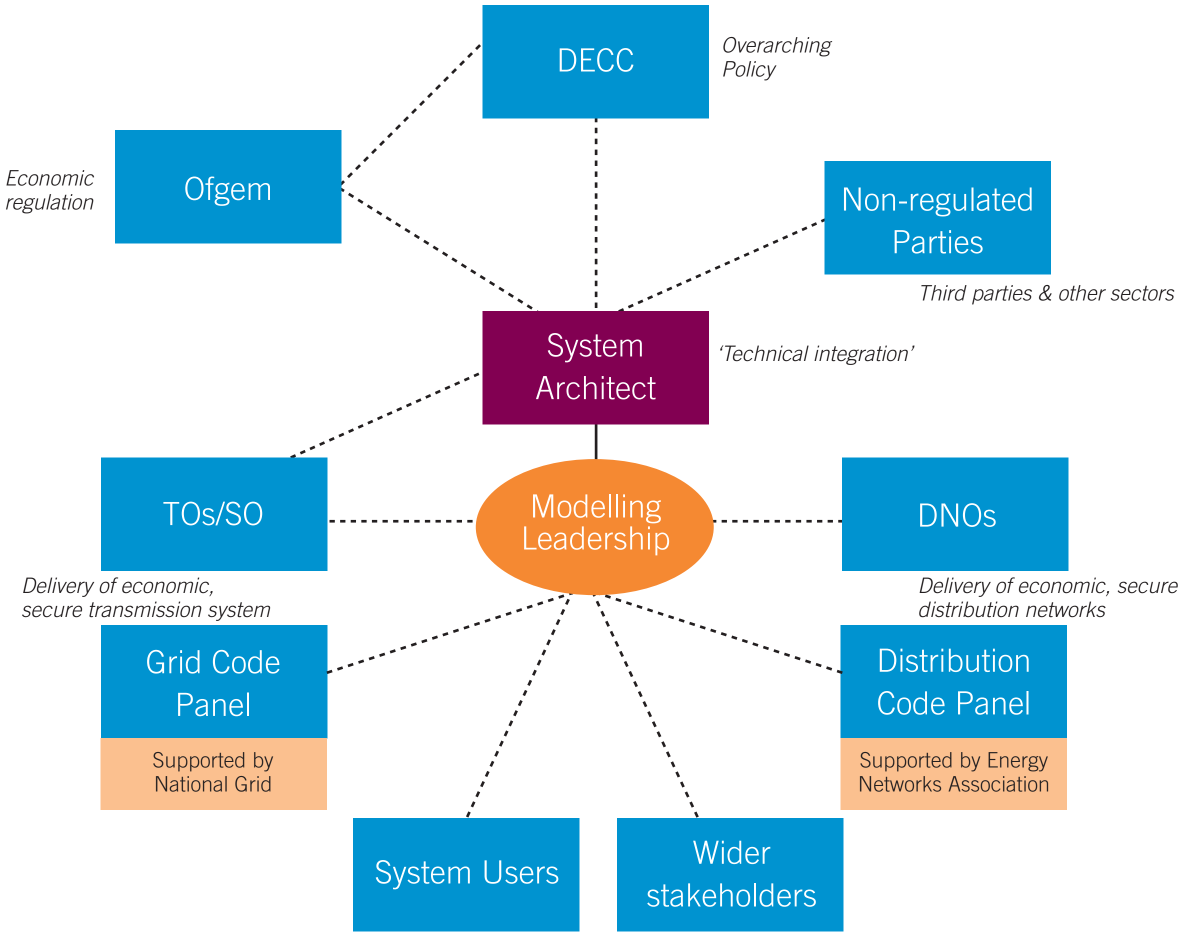


Figure 6: Illustration of modelling Leadership under a new System Architect.

The third stage option extends the System Architect role further:

STAGE-3: Modelling Leadership as part of a Centre of Excellence in an Extended SYSTEM ARCHITECT function. In view of the breadth, scale and challenges highlighted in the modelling field, noting the potential expansion into other energy vectors (e.g. heat, gas and hydrogen) and related sectors (e.g. Transport, Smart Cities and the Internet of Things) it is helpful to consider what scaling-up opportunities might be required for a Modelling Leadership remit in the System Architect organisation.

The following conclusions on modelling leadership can be drawn:

- Whilst there is already strong evidence for initiating developmental activities on new modelling capabilities in certain technical areas, it is recommended that the anticipation, prioritisation, specification and commissioning of new modelling capabilities be focussed and co-ordinated by creating **a new Modelling Leadership Group as a Stage-1 development.** Such a group would require appropriate authority and oversight, for example in a similar way to that established for the Code Panels.
- The second option of Stage-2 would be a managed transition incorporating transfer of the Modelling Leadership role into **an integral part of a System Architect function.** This has many attractions from the perspective of organisational fit and, notably, a remit that is wider than that of the Code Panels, enabling a focus beyond the regulated network companies to include third parties such as EV and HP suppliers and providers of home energy automation.
- Stage-3 would be an expansion of Modelling Leadership to create **a Centre of Excellence within the System Architect function,** addressing integration across other energy vectors such as heat, gas and hydrogen. It is envisaged that this would be likely to require a modelling capability that is both comprehensive in its scope and underpinned with computing facilities of appropriate processing power.
- Stage-2 and Stage-3 activities are seen to benefit from joint working with the new Energy Systems Catapult, national power systems test facilities (such as the Power Networks Demonstration Centre in Glasgow or the proposed Multi-Terminal Test Environment for HVDC), and with multi-party working with all sector stakeholders to develop and validate data sources and modelling outputs. This could form a second stage of development, as and when a System Architect role is established.
- In Stage-1, the early priorities for a Joint Code Panel are likely to address data exchange and, interoperability working with existing network participants, and work with new system participants where data accessibility has become a recognised challenge. This work will need ‘back office’ support which might be addressed provided by existing the groups (organisations that support today’s Code Panels, etc.) and resourced / funded through the price controls of the licensed network companies, innovation funds, and academia. This requires further examination and agreement. Looking ahead, the specific programme within the Energy Systems Catapult to support the development of new modelling tools[14] could be helpful here. Coordination is envisaged to be provided in the interim by a task force reporting to the Code Panels. This task force would be an embryonic Modelling Leadership Group.

[14]The Energy System Catapult could potentially provide resource and support for modelling capability development in a number of areas such as data derived from testing new network interfacing products as modelling inputs (for example performance characteristics of a power electronics converters).

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