

# Power System Modelling Issues and Requirements Identified by the IET Power Network Joint Vision Project

Graham Ault, John Scott  
Smarter Grid Solutions, Chiltern Power  
gault@smartergridsolutions.com, john.scott@chilternpower.com

**Paper 1 of 15, Part 3:** IET Special Interest Publication for the Council for Science and Technology on  
“Modelling Requirements of the GB Power System Resilience during the transition to Low Carbon Energy”



## About this report

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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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## EXECUTIVE SUMMARY

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This paper presents a critical assessment of the modelling implications of the main findings of the IET PNJV Position Statement and Technical Report (published in December 2013) and concludes the following:

- Power system modelling has played a crucial role in supporting the delivery of a secure and efficient power supply system in GB. Power system modelling provides visibility of the implications of decision made by power system planners and operators at various stages of the power production and delivery cycle.
- A number of **new challenges** are emerging and can be expected to have greater implications in future as the sources of power generation transition towards renewable and distributed sources and the uses of electrical power increase particularly in heating and transportation applications. Furthermore, the introduction of energy storage along with enhanced measurement, monitoring, automation and control technologies presents substantial new areas for model development and application. Each of these new developments needs to be modelled fully and embedded into new planning and operational processes and procedures.
- The **scope of power systems modelling** needs to increase to capture a variety of new generation, network, storage and consumption equipment and systems as well as market, customer and regulatory issues in a whole system context, and more responsive/stochastic approaches in the context of a far less deterministic, predictable power system.
- The challenges and opportunities of the available, future, diverse **power systems data** sets have yet to be fully explored and exploited to enhance power system planning and operations. There are numerous capture, access, security, analytics and application challenges

to be overcome to exploit not only the possible, but also the necessary uses of new and diverse data and information sources. Shared data protocols, and data repositories among power network companies and their stakeholders and agreed governance models for data as potential modelling inputs will likely be an area for further development. The sheer volume of input data (and results) will itself require fresh thinking (commonly captured under the banner of 'big data' and 'data analytics'). This will also likely raise serious data privacy and security aspects not previously encountered by power system modellers. Access to, for example, smart meter data and EV location and charge status information, brings with it entirely new responsibilities.

- Cross industry support and coordination is required to address the modelling challenges and in particular to bring forward proposals to support the development of the required power system **modelling skills** to underpin the development of the **modelling platforms, tools and capabilities** required to underpin the continuance, if not improvement, of current levels of security and performance in the GB power system. The future complexity and subtlety of power system modelling, interactions between models, and responses to new developments and devices, will require a depth and continuity of expertise that the network companies might be unable to sustain. Furthermore, this multi-component tool set would need to span users in more than the network companies, and link up seamlessly with modelling of other energy vectors. There are important skill, knowledge and resource questions to address.
- The **System Architect** role proposed by the IET's expert group could include leading the specification and development of power system modelling tools to address the whole-system aspects of the emerging and future challenges to GB system security and performance. The System Architect might also be a key user of the power system analysis tools.

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## 1. BACKGROUND AND METHODOLOGY

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The IET Power Network Joint Vision (PNJV) group comprises industry expertise from across the networks supply chain, academics, consultants and policy makers. It published reports in December 2013 to address a series of questions around the emerging challenges to the ways that electricity is produced, transported and used. The position statement [1] set out the changes and challenges to the electricity system in GB while the technical report [2] provided the underpinning rationale for the position statement and recommendations from the IET PNJV experts on a series of issues that included structure, planning, operations, markets and the impact of new technology.

This paper presents a critical review of the PNJV documents (position statement and technical report) with a focus on modelling issues to provide evidence in line with the objectives of the current IET project for CST on power system modelling.

The IET PNJV reports have been reviewed to identify:

- GB power system modelling challenges
- Existing and emerging power system modelling capabilities
- Evaluation of the current power system modelling landscape
- Recommendations for development of the overall power system modelling capability to meet the challenges.

The IET PNJV reports focus on the challenges with some evaluation of capabilities (mostly in the form of gaps and future needs) and then present recommendations; this paper draws attention to those areas.

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## 2. GB POWER SYSTEM MODELLING CHALLENGES

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This section draws out the main modelling challenges identified in the IET PNJV work in 2013 to focus attention on the requirements for modelling the emerging and future GB power system. Five **new challenges** to power system modelling were identified in [1]:

- **Renewable Generation sources:** The challenge is that in many cases the output of these generators is both variable and uncertain. These variations in output require additional balancing actions.

- **Distributed Generation sources:** These can connect in large numbers to the distribution networks, right down to the level of individual homes, and result in two-way power flows which the local networks have not been designed to accommodate.
- **New Demands for electricity:** These include heat pumps for low-carbon home heating and charging for low-carbon electric vehicles. Both are capable of increasing the electrical power needed by consumers, substantially exceeding traditional levels of network safe maximum capacity.
- **Demand Response by consumers:** This offers consumers better value if they are willing to use their smart appliances to vary the time of day that they use electricity, for example to align more closely with output from intermittent generation. It can also be very beneficial to alleviating network overloading. However, it creates 'active' consumers, whose actions will at times summate to have impact on the national power system at transmission level. Managing this effectively will require a whole systems approach, spanning both the distribution and transmission networks.
- **Modern Control & Automation:** These and other advanced techniques can provide solutions to enable more power to be carried by the existing networks, and to limit when and where new investment is needed. However, fast signalling and control must always be highly coordinated and integrated across the system to avoid adverse interactions.

It is noteworthy that the above list does not present a once-only challenge for power system modelling. The government's low carbon agenda will require a programme of change over the coming decades, making these topics subject to continuing development to improve effectiveness, costs and service to customers.

Some of the key topics highlighted in these challenges are in dealing with development scale, location and timing uncertainty at the planning stage and then dealing with resource availability, output variation and diversity in operations for generation. The issues with demand are similar at the planning stage (e.g. scale, location and timing) but in operations there are much greater market, commercial models, user behaviour issues and uncertainties. The fifth issue of automation and control will likely increasingly become a challenge to modelling in the planning and operational phases of electricity supply since there are emerging approaches to modelling new technology and solutions for control but few standard

approaches to deal with the issues of resolution of modelling control response in each power system modelling domain, modelling the complexities of interaction and reliable delivery of smart controls, and modelling the surrounding market and commercial drivers behind smart control and automation schemes, to highlight a few key issues. The inter-dependency of the power carrying power system components and ICT infrastructure is crucial and modelling such issues is a new challenge for power system modellers.

The application of power system modelling methods in the day-to-day practice of network operators and the development of these modelling domains to meet future needs is an ongoing process so it is expected that other evidence submitted to the IET project for CST, will highlight those existing and emerging capabilities. It could be expected that the models, tools, techniques, data sets, study cases and assumptions would be developed further in line with the challenges now presenting themselves. This would provide the necessary starting points for modelling such as validated assumptions on the scale, location, behaviour, of new generation and demand technologies and the impact of new control and automation. These new topics for power system modelling would be applicable over different power network timeframes (e.g. investment planning and to operations) and across all modelling domains (e.g. time domain, frequency domain). The inter-play between engineering models and economic, commercial, behavioural and market models is likely to become more important as the linkage of the emerging and future energy supply system into the physical power system becomes much closer.

The need for a **systems engineering approach** to the development and operation of the GB power system was highlighted in the IET PNJV position statement [1]. This has implications for modelling for system design purposes that include the modelling of new equipment and sub-systems but extends to the modelling of whole system behaviour to verify secure and efficient operation of that whole system. The position statement highlights that while the system has been modelled, analysed and designed well in the past, the new power system challenges and requirements are likely to be quite different. The scale and complexity of the transition happening in the power system was illustrated as follows [1]:

The modelling challenges for planning and operating such a system highlight some clear scale (number of devices) and complexity (degrees of freedom in controls) issues for modelling system behaviours.

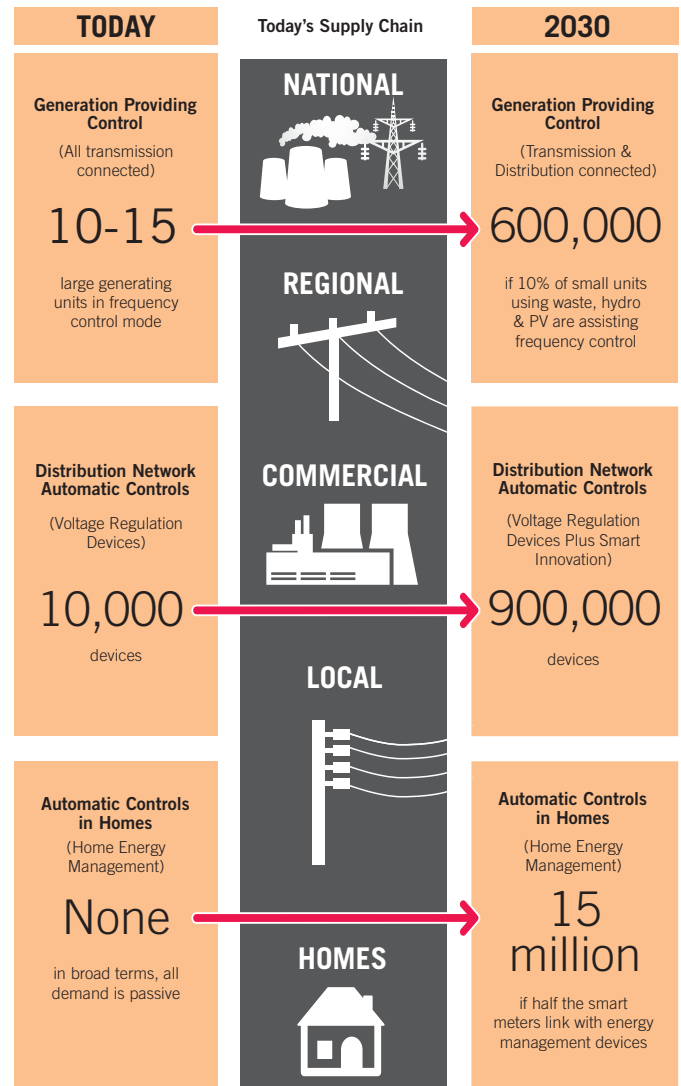


Figure 1: The Anticipated Changes in Complexity by 2030.

Some of the cross jurisdictional data and model exchange requirements are hinted at by this illustration with massively distributed small scale generation having whole system impacts and opportunities at the scale presented and so obvious data and model exchange needs for planning and operations. The same whole system issues arise so data and model exchange is required for the additional controls embedded deep within the system and even at domestic scale and volume where the data access issues through smart meters are a major new opportunity.

The diagram above highlights the rising complexity and potential for interactions between new devices, both within the power system and connected to it by its users. However there would appear to be a further underlying change ahead in the nature of those users – for example the need to integrate smart communities, smart cities, and the societal challenges brought by the Internet of Things.

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The IET PNJV position statement makes strong recommendations around the creation of a **System Architect** role to take responsibility for the technical integration of the future system. The delivery of a system architecture function requires the support of strong modelling capabilities to be able to address the myriad of existing, emerging and future phenomena in power systems. The full scope of the IET project for CST on modelling capability has relevance to the system architect role and it would be expected that any future system architect would wish to take on the findings and recommendations of the IET/CST project.

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### 3. SPECIFIC MODELLING CHALLENGES AND RECOMMENDATIONS FOR POWER SYSTEM PLANNING

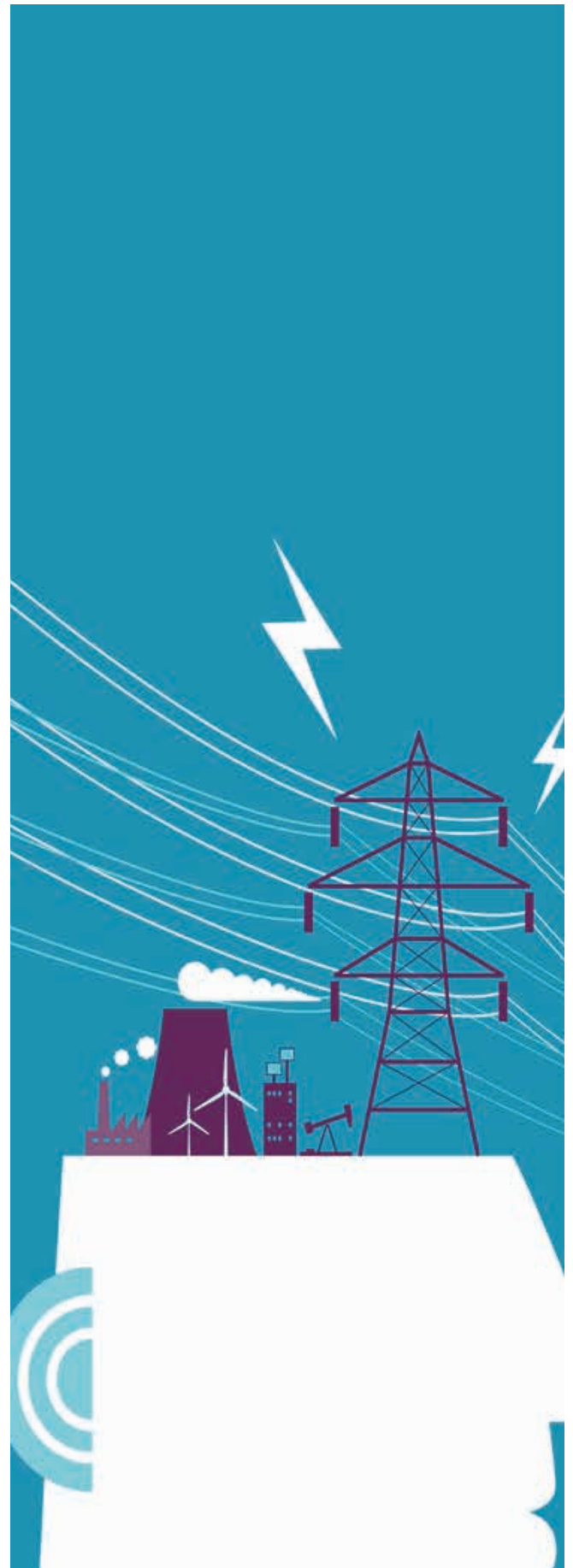
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Three main topics were addressed in the IET PNJV technical report [2] on planning:

- Electricity Demand Change and Information Sharing
- Active Distribution Networks
- Network Planning Tools

The exploration of those topics generated a set of recommendations as follows which are explored further below with some further modelling capability thinking:

- ***Development of specification and governance approach for a GB network planning data repository.*** Access, commercial confidentiality, privacy and other data issues have been thoroughly highlighted in many smart metering and other smart grid data projects internationally. Developing acceptable solutions to those issues is a foundation to providing network planners in different organisations, with different responsibilities with the data required to conduct accurate and effective planning studies leading to the efficient and timely development of the system.
- ***Review of the week-24 planning data submission from DNOs to the GBSO to make it more efficient and effective.*** This is a specific example of DNO to SO data exchange for power system planning and the scope, volume, timeliness and format of data exchange are all issues to be explored further to enhance the effectiveness of system planning.



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- **Commission study (perhaps starting with meta analysis) on emerging and future demand types.** There are specific concerns over the electrical characteristics of new load equipment which has implications for several network calculations such as fault level, frequency response and power consumption voltage response. There are also implications for the overall demand profile of individual and aggregated loads in future. The influence on the overall profile with the complex and uncertain general economic, market, commercial and control response factors are critical for effective exploration of the power system under all of its plausible conditions for both planning and operational power system studies.
  - **Development of the scenario planning based approach now adopted by the GBSO in the ETYS to enhance robustness and track trends and observations in the sector.** The use of scenarios to explore different planning backgrounds provides a valuable means of dealing with development trajectory uncertainty. There are critical uses of background scenarios at both national level (e.g. the scale and location of generation and demand development in the longer term as a major factor in national infrastructure planning) and local level (e.g. the same issues of generation and demand development but with the case by case asset/substation/circuit reinforcement planning implications). The multiple sources of input data for scenarios and the development and iterative development process are areas that can be explored and developed into a wider, enhanced scenario development and application to power system planning.
  - **Develop planning models, standards and processes for treatment of active distribution networks.** The widest definition of active distribution networks including all connected devices, components and systems that are active in themselves but can also be brought under active control provides numerous challenges and opportunities for network planners and operators. The development of standard analytical approaches and the coordination of active network studies across relevant network operators are areas that are starting to be considered but will likely have to be taken much further to address the issues but also exploit the possibilities for efficient network development.
  - **Establish a transmission company and distribution company working group on active distribution networks to tackle the cross-cutting issues.** This could be the mechanism for addressing the challenges and opportunities of active distribution networks noted in the point above.
  - **Develop specifications for planning and analytical tools for network planning to address the new challenges and provide the launch pad for diverse stakeholders to contribute.** The need for new planning tools is being addressed through several innovation projects and by other network operator development and investment activities (e.g. planning tool platform renewal, planning tool functionality enhancement, new analytical methods development and roll-out). Publishing the clear need for analytical tools to support planning provides the opportunity to gain consensus on the requirement as well as informing the technique/tool developer community of the priority areas.
  - **Establish a steering group to lead, oversee and approve tools and models for network planning in GB.** This recommendation would pick up the specific need for wide stakeholder engagement and contribution as well as clear governance of model and method development and approval, but including the assumptions to be made for action and control responses of new load and generation types. Shared development of modelling tool requirements would be an important element of their activity. Establishing a group with real authority to probe, direct and recommend and deliver is a crucial consideration.
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- #### 4. SPECIFIC MODELLING CHALLENGES AND RECOMMENDATIONS FOR POWER SYSTEM OPERATIONS
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- The IET PNJV technical report [2] outlines several areas of substantial challenge to power system operations and those with a modelling relevance are highlighted here with comments on the implications:
- **Operating the system closer to its limits so modelling the implications of the use of corrective controls and the risks of failure of them are required.** This observation suggests some extension of contingency analysis to explore a wider scope of contingencies including primary power plant (generation and network components) as well as failures of the corrective (direct and indirect/aggregate) control schemes spanning technical, commercial, market and other related modelling domains. Control scheme integrity may be highly dependent on data communications and third party providers, making modelling and risk assessment a complex challenge.

- **Prospect of Control interactions.** Emergent behaviour in complex systems is a key concern and, while this may not be modelled in operational timeframes, there is a need for wide scope modelling to be undertaken for the operating states most likely to cause undue system exposure to unintended behaviours, fragility or failure so that effective control and management mechanisms can be identified and implemented. Modelling such complex interactions in operational timeframes or hours would be a very substantial challenge that is not envisaged currently but the application and practicality of such modelling could be usefully explored.

- **Enhanced reliance and impact of failure of ICT on system operations.** Simulation of the impact of ICT failure is already factored into network contingency analysis in the overall functional failure of equipment and systems but this is a narrower view of ICT and its likely significant role in operating the future power system. To address this, a higher number of plausible failure modes of ICT systems in future needs to be further explored and embedded in standard operational modelling processes. Additionally, other approaches to system architecture, design and operation that fully address conventional and ICT component characteristics can benefit from other sectors where high integrity in complex systems is normal (e.g. military, nuclear, aerospace).

- **New information flows.** If new data and information is available to network operating companies in real time (e.g. smart meters, demand response portfolios, commercial/tariff/incentive arrangements, etc.) then integrating these data sets into simulations of network states in operational time frames would require developmental effort.

- **Accurate picture of what equipment is connected and in what state.** The live operational state of a vastly increased volume of connected equipment into operations support modelling to provide operators with enhanced situational awareness (in normal operations and emergencies) may provide substantial benefits but would also require substantial developmental effort and investment.

- **Need for optimisation of the many more (volume and type) of energy producing, storing, controlling and consuming equipment.** Capturing live status data on connected equipment (as noted in the point above), aggregating this into usable model inputs and

then optimising the scheduling and control of those resources in a commercial/market context is a complex, resource intensive task so making the value case for this as well as developing the modelling platform to do it are important tasks.

- **Reflecting the market and customers in the models of system operation.** This extends the commercial/market context (e.g. objectives, contracts, constraints) to include customer requirements with similar factors of objectives and constraints on use of customer equipment to support secure and efficient operation of the power system. Robust techniques to model emerging customer interactions with the system would extend substantially the simpler reflection of customer behaviour used at present.

The IET PNJV technical report [2] provided some specific requirements and suggestions for power system modelling and these are listed below (with some selectivity based to highlight new issues and clarification of the original published list):

- Lack of predictive real-time management tools for efficient operation (including predictivity and anticipatory nature of problems encountered requires self-learning tools).
- Lack of predictive optimal power flow control software and hardware (i.e. smart control), including:
  - New mathematical models and smarter computational tools;
  - State estimation of the power networks;
  - Fault location, isolation and restoration;
  - Volt-var-watt control optimisation;
  - Harmonic detection and mitigation;
  - Coordination of emergency measures;
  - Coordination of intervention teams.
- Current operational models cannot deal with how best to balance supply with demand but also to add in the network constraint dimension.
- Generation, transmission, distribution **and** the demand side need to be addressed in system modelling. This is complicated but a sub-optimal engineered solution would be the highly probable end result from not considering all parts of the electricity supply chain in future.



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The report also outlined requirements for modelling and suggestions under headings as ‘system optimisation’ and ‘flexibility of the power system’ with special attention paid to electric vehicles and electric heat pumps as new electrical load types, and system resilience as an issue.

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## 5. CONCLUSIONS AND RECOMMENDATIONS

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The IET PNJV position statement [1] set out six high level recommendations and these are listed below (as originally published in italics) with additional comments added to draw out specific modelling implications:

**1. *DECC should work with industry to establish a System Architect role to achieve a whole systems approach.***

Whole system models as well as high quality equipment models for new technologies would be required to underpin the architecture for the future network and to support the work of the System Architect.

**2. *Government/industry stakeholder groups should explore and address effective interactions between engineering, market and regulatory aspects to determine changes needed.***

Classical power system engineering models must be used alongside or in concert with market, customer and regulatory models.

**3. *DECC/Ofgem should develop the regulatory arrangements that will enable demand response and distributed storage to participate in maximising whole system synergies and the mitigation of risks.***

Modelling of demand response and distributed storage must be further developed and embedded in standard approaches for investment planning and operational modelling of the GB power system.

**4. *Network companies should together determine how to address the impact of a data rich environment, including the mechanisms for improved internal and external data exchange.***

New sources, uses and requirements from data sets that cut across ownership, access, privacy and right of use boundaries will likely be a feature of future power system modelling activities in future and preparatory and developmental work should begin to address these issues.

**5. *Network companies’ procurement arrangements should facilitate greater access for specialist providers to bring benefits in smart grids, demand management and new customer services.*** This provides a clear requirement for modelling of the new technologies and solutions including responsibilities for

new model development, commissioning, verification, testing and embedding into network investment planning and operational processes.

**6. *Network companies, the IET, and other interested parties should work out how to address the requirements for increasing engineering, commercial and business complexity, including the means to access skills and research and test facilities, and the sharing of knowledge.*** It would be expected that attention and resource is targeted towards renewed/enhanced efforts to develop skill and capability in this area as well as coordinating the research and development effort on power system modelling techniques and tools.

**Comment:**

From the modelling perspective, is there also a case for examining the greater automation of output interpretation, the need to provide advice and real-time advice in control timescales, and even the need to work towards the option for more ‘fly by wire’ systems, i.e. without the control engineer being in the loop?

***This short paper highlights a range of emerging challenges that are clearly material in scale. The insights and engagement of the CST will be highly valuable in progressing responses and solutions in the national context.***

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## 6. REFERENCES

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[1] The IET, ‘Electricity networks - handling a shock to the system (position statement)’, December 2013, <http://www.theiet.org/factfiles/energy/elec-shock-page.cfm>

[2] The IET, ‘Electricity networks - handling a shock to the system (technical report)’, December 2013, <http://www.theiet.org/factfiles/energy/pnjv-page.cfm>





The Institution of  
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## IET Offices

### London\*

Savoy Place  
2 Savoy Place  
London  
WC2R 0BL  
United Kingdom  
[www.theiet.org](http://www.theiet.org)

### Stevenage

Michael Faraday House  
Six Hills Way  
Stevenage Herts  
SG1 2AY  
United Kingdom  
**T:** +44 (0)1438 313311  
**F:** +44 (0)1438 765526  
**E:** [postmaster@theiet.org](mailto:postmaster@theiet.org)  
[www.theiet.org](http://www.theiet.org)

### Beijing

Suite G/10F  
China Merchants Tower  
No.118 Jianguo Road  
Chaoyang District  
Beijing China  
100022  
**T:** +86 10 6566 4687  
**F:** +86 10 6566 4647  
**E:** [china@theiet.org](mailto:china@theiet.org)  
[www.theiet.org.cn](http://www.theiet.org.cn)

### Hong Kong

4412-13 Cosco Tower  
183 Queen's Road  
Central  
Hong Kong  
**T:** +852 2521 2140  
**F:** +852 2778 1711

### Bangalore

Unit No 405 & 406  
4th Floor, West Wing  
Raheja Towers  
M. G. Road  
Bangalore 560001  
India  
**T:** +91 80 4089 2222  
**E:** [india@theiet.in](mailto:india@theiet.in)  
[www.theiet.in](http://www.theiet.in)

### New Jersey

379 Thornall Street  
Edison NJ 08837  
USA  
**T:** +1 (732) 321 5575  
**F:** +1 (732) 321 5702

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