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Network Innovation Allowance Closedown Report

Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form.

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Project Closedown

Project Title

Smart Grid Forum Work Stream 7

Project Reference

NIA_NGET0154

Project Licensee(s)

Electricity North West Limited, National Grid Electricity Transmission, Northern Powergrid, Scottish and Southern Energy Power Distribution, Scottish Power Distribution, UK Power Networks, Western Power Distribution

Project Start Date

Jul 2014

Project Duration

14 Months

Nominated Project Contact(s)

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Scope

WS7 of the Smart Grid Forum, through its Steering Group "WS7 SG" for this study, wishes to undertake more detailed electrical power system analysis (using nodal network models) of the electricity system of 2030, with particular focus on the distribution networks, their design and, critically, their operation.

Essentially, this WS7 study is addressing the modelling compromises that are inherent in Transform’s parametric network modelling approach. Transform’s parametric representation of typical distribution networks are to be converted into nodal models in order to explore, through appropriate network studies, how the Transform solutions ‘work’ and what currently unforeseen challenges might emerge.

Objective(s)

A key aim is to establish whether the roles and responsibilities of the parties that own, operate and interface with the electricity supply chain need to change and how.

Success Criteria

The study outputs are likely to have several components. Firstly, there will be a set of generic nodal distribution network models that have been demonstrated to be technically viable to meet the needs of 2030 users. Secondly, there will be a report highlighting the specific methods/solutions that have been used to ensure the technical viability of these networks. This may suggest that early attention should be applied (e.g. specific demonstration projects during ED1) to particular methods/solutions to ensure that they can be successfully deployed when needed. Thirdly, the roles and responsibilities of a DNO in 2030 in terms of supporting whole system optimisation will be described and contrasted with the position today. Again, this would be expected to lead to specific pieces of further development work through ED1.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

Project Overview

The DECC/Ofgem Smart Grid Forum was created by the Department of Energy and Climate Change (DECC) and Ofgem to support the UK's transition to a secure, safe, low carbon, affordable energy system. The main issue discussed within the DECC/Ofgem Smart Grid Forum is how electricity network companies will address significant new challenges as they play their role in the decarbonisation of electricity supply. The Smart Grid Forum has established a number of Work Stream (WS) to examine particular aspects of future networks.

The WS7 study is a continuation of work started by WS2 and continued by WS3 to deepen our understanding of what a future distribution network will be and how it will operate.

The first issue, which was pursued in WS2 was; do smart grids make economic sense? WS2 (ref 2) answered this in the affirmative, albeit it at a very high level, with its cost-benefit analysis (CBA). This was followed by a detailed study into what this smart grid might consist of. WS3 addressed this with the Transform model (ref 3), based on the work of WS2, but providing much more detail about the solutions that might be deployed and in what volume. However, the Transform model was not designed to validate the technical viability of the overall system it foresaw.

WS7 is a natural further progression into the detail, questioning how it can be ensured that the smart grid that Transform has described will be technically viable and to establish how the whole system might operate most efficiently and resiliently in a 2030 scenario with a clear focus on the impacts for our distribution networks. The purpose is to gain knowledge and confidence in our network/system development options to deliver a secure and affordable system and to feed this back into the development of commercial and regulatory analysis.

In summary, this WS7 study is intended to carry out the technical analysis necessary to confirm in more detail how the types of networks described by the Transform outputs will be realised. This will both confirm its technical viability and provide an understanding of its characteristics, for example, to identify what control co-ordination may be required to ensure reliable and robust whole-system operation. Most importantly, it will, from a technical perspective, highlight any new roles and responsibilities that a DNO will need to take on board.

WS7 - DS2030 Project Stages

The WS7 DS2030 Project was split into 6 stages to address a series of questions. All Stages are now complete and reports are available on the ENA website. The Stage 6 report is the final report in the project report collection.

Stage 1 consisted of clarifications on modelling approaches, data sources and deliverables and was completed in early discussions between the Consortium and the WS7 Steering Group.

Stage 2 developed four Base Networks and two Scenarios to be used in the studies, along with the creation of modelling Project Delivery Use Cases (which were reported during Stage 3). A review of international developments in smart grids was conducted and reported separately. Stage 2 also included a stakeholder engagement event to gather feedback on the Base Networks, Scenarios and Project Delivery Use Cases.

Stage 3, consisted of a review of the Questions, both in light of the work done in Stage 2 and to ensure a strong agreement between the Consortium and the WS7 Steering Group prior to proceeding with subsequent Stages. Reporting on Stage 3 consisted of the conclusions of the review of Questions, including some proposed modifications to the Questions, as well as presenting the Project Delivery Use Cases, which define the approaches that will be used to generate the outputs that form the basis of the answers to the Questions.

Stage 4 and Stage 5 comprised system planning and analysis of the Base Networks. Simulations examined the impact of the 2030 Scenarios and established how the Base Networks must develop to overcome any issues introduced by the uptake of Low Carbon Technologies, LCTs.

Stage 6 covered final reporting, including answering the project Questions.
Thorough governance mechanisms have been employed during the project to ensure robust and well informed studies and results. Project policy development papers describing the study inputs and methodologies facilitated challenge and guidance at each stage from the WS7 stakeholder group. Further inputs were drawn from wide stakeholder engagement throughout.

Required Modifications to the Planned Approach During the Course of the Project

Additional stakeholder events were required to further disseminate the on-going learning from the project and to make sure that the industry had an input at critical times during the project. The additional stakeholder events increased the costs of the project by approximately £20k.

Lessons Learnt for Future Projects

The headline learning points from DS2030 can be grouped under three headings: 1) Technical Challenges and Solutions, 2) Commercial and Business Challenges, and 3) Wider Insights, as follows:

1. Technical Challenges and Solutions

1.1. By 2030 the networks will be required to accommodate both demand growth and the connection of Low Carbon Technologies (LCTs) comprising new demands and generation. Analysis shows that the associated challenges are material in scale, will manifest themselves in geographic 'hotspots', and will be influenced by network type - notably the different characterisation of urban versus rural systems and radial versus interconnected topologies.

1.2. Network technical constraints to be addressed will include thermal overloading, high voltages, low voltages, waveform quality, and generator stability. The 2030 analysis has considered four representative network types and these provide detailed insights into the issues that can be anticipated. For example, the modelling identified overloads of up to 20% on circuits and up to 175% on transformers. Importantly, the modelling revealed that generalisations are hard to make, for example these unacceptable conditions may vary seasonally, may be off-set by a combination of demand growth and local generation, or may be exacerbated by the presence of LCTs.

1.3. System studies up to the year 2030 examined the four network types (Interconnected Manweb (all levels), Interconnected London (LV interconnected 11kV), Urban, Rural), each for an intact network and contingency (outage) conditions in accordance with system security standards, and checked the technical performance at all intermediate voltages from Low Voltage customers to the transmission connection point (400/132kV). The spread of overload conditions is significant as can be seen from the results for the different network types, voltage systems and transformations: of the 30 categories examined, 10 had no issues, overloads were identified for 11 only under single outage conditions, and the other 9 had overloads in both the intact network and under single outage conditions.

1.4. System voltages were found to be non-compliant with statutory limits, with issues being identified at different voltages for each characteristic network, for example 33kV overvoltage issues associated with distributed generation. In most cases existing voltage control strategies were shown to be adequate for the Scenarios and Base Networks considered, although adjustments and DNO actions will be needed to maintain those studied within acceptable limits. Additional voltage regulation will be required for conditions beyond those studied, i.e. LV voltage control, such as a distribution transformer on-load tap changer or inline voltage regulator. Future co-ordination of voltage control will be important to ensure that multiple voltage control systems do not result in hunting or instability. These study conclusions are based upon existing standards, and simulated voltage issues may become less onerous if these limits are relaxed in the future. Potential future relaxation of voltage limits is being investigated by the ENA, by ENW and by WPD in its Equilibrium project.

1.5. Clearly, investment will be needed by the network owners to address network constraints identified in the simulations to the year 2030. The analysis shows that a mix of smart solutions and traditional reinforcement is likely to provide the best outcomes. Smart solutions (such as Demand Response, Real Time Thermal Ratings, Active Network Management, and Energy Storage) can be expected to add flexibility, better utilise existing capacity and so help address uncertainty, as they are generally lower cost and faster to implement than traditional solutions. However, the modelling indicates that some smart solutions may have a relatively short 'life' if applied to the general network rather than to address a specific network issue. For example, depending upon the rates of growth of demand and generation, Demand Side Response applied to the general network could be expected to be effective for approximately four years, compared with traditional reinforcement that can provide significantly greater capacity and a longer life. Smart solutions can, however, bring benefits in terms of deferring reinforcement until it is certain that it is required thus reducing the risk of stranded assets where there is uncertainty in the rate of growth of LCTs on a particular network. A mix of smart and traditional investment types is therefore likely to be advantageous.

1.6. Traditional reinforcement to mitigate the issues identified in the studies up to 2030 are typically more than 10%, and up to 50%, of the existing system capacity at each voltage. The greatest reinforcement needs occur where the loading is already approaching the existing installed capacity, for example the Central London Base Network. The existing capacity margin was seen to be reduced in all networks, except in areas in which reinforcement was proposed. Despite remaining compliant with the security of supply standard, the areas of network with reduced margin will be less flexible and less able to respond to more onerous outage conditions beyond the requirements of the standards, compared to today's network.

1.7. DS2030 studies have shown some smart solutions to be more appropriate to certain network types, highlighting that they must be applied with consideration of the characteristics of the network. Extrapolation of the application of smart solutions highlighted by the project must be undertaken with care since effective network solutions are problematic to generalise, being dependent on factors such as network and demand characteristics.

1.8. The DS2030 analysis has included harmonic analysis (waveform distortion) created by the power electronic interfaces that connect many LCT devices. Challenging issues have been identified that will require further examination as they reveal the potential for low order harmonic voltages to breach standards where the existing background harmonics are already close to limits. Particular problems are likely to arise where LCT devices of the same type are concentrated (eg identical PV panels and invertors across a housing estate, or the clustering of identical EV chargers or Heat Pumps) as this could result in a loss of variability that might otherwise be expected to provide cancellation effects. The potential solutions here require careful attention: at one extreme changing the mandated standards for electrical equipment including LCT devices might be considered (perhaps creating some increment of costs for manufacturers), or alternatively network operators might install filtering devices to reduce harmonic distortion (incurring costs for network companies and their customers). The issue might be treated on a 'polluter pays' approach, but there is the complication of historic levels of harmonic distortion, which in some cases already approach the limits set in standards. The extent of the impact of distorted waveforms on consumers requires further attention, and will need to make allowance for changes to consumer devices in the future.

1.9. Increasingly intelligent protection systems based on existing techniques are expected to be required as the complexity of distribution networks increase and the load and fault flows become more volatile. Transmission protection concepts are likely to be re-designed for application to lower voltage levels.

2. Failure of smart solutions and the effect on network reliability is an important consideration. It needs further examination in terms of the reliability of the different component systems, such as power, communication, software, and new fault modes to inform the most appropriate designs and operation.

2.1. Frequency studies have been performed on the entire GB system model. These have shown the high potential and significance of the contribution from DNO connected equipment towards system frequency containment. It is therefore envisaged that DNOs and generation connected to the distribution system could play an active role in frequency balancing in 2030.

2.2. Consideration has been given to the dynamic behaviour of distributed generators under fault conditions and their interaction with the dynamics of the national power system. This whole system modelling has revealed the potential for generator instability arising from the relatively slow protection clearance times that are typical in distribution systems. This is a complex area of engineering analysis and further work is needed particularly for two aspects: firstly, whether pole slipping of synchronous generators could cause damage to a small generator unit typically connected to 33kV and 132kV levels (say, >40MW), (the initial view is probably not, while noting this is an important consideration for large generators), and secondly, whether in the future a wide area problem might result in the loss of multiple distribution-connected generators causing a reduction of power infeed that is material to the stability of the national power system.

3. Commercial and Business Challenges

3.1. The DS2030 findings point to more extensive technical challenges for network companies. Development of solutions such as Active Network Management (ANM) would appear to be an opportunity for creating Distribution System Operator (DSO) roles and this is discussed in this report. An observation that follows here is the evident need for new skills in network companies, new tools for forecasting and modelling, and new policies and approaches as the nature of business changes. Although future practices will need to be mindful of business needs, it is likely that this will require more than grafting new skills into current teams and processes; the rising complexities, numbers of interfacing parties, and the pace of change brought about by

Community Energy developments, Smart Cities, cross-vector developments, and the Internet of Things can be seen to require some fundamental rethinking. Increased visibility of emerging changes which affect network utilisation will be important, including understanding the geographic penetration of LCT devices, the take-up and characteristics of new consumer devices and energy services, and the emergence and roles of new third parties in the energy sector. In summary, many of these changes can be encapsulated in the shift that is perceived for DNOs as they move from traditional peak demand planning to active management of networks with flexible LCTs and the resulting variable profiles.

3.2. DS2030 has confirmed that demand response is potentially a useful smart intervention. Two issues for further consideration are the business approach to obtaining and deploying this, especially where it is obtained from large numbers of small (domestic and SME) customers, and the obligation for network companies to be able to demonstrate adequacy of their arrangements to the Regulator. Alternative approaches can be explored such as network companies obtaining demand response services from an Aggregator or managing the EV charging profile to reduce peak demand.

3.3. Smart Grid Forum WS6 has recently published its findings. While DS2030 has not formally compared the two projects, there is evidence of good alignment on many issues. An example is the need to resolve the potential for conflicting service requirements from demand response if this is called by the GBSO, by Suppliers, or by the Network companies. Care is required to ensure that the market mechanism ensures services that benefit the network are not conflicted commercially. Similarly, smart solutions may offer benefits in regard to improved flexibility and responsiveness to customers, and it is important that this can be captured in investment cost/benefit analysis.

3.4. DS2030 did not examine cost/benefit cases for different reinforcement options as this was the subject of the Transform Model2; however comparisons were drawn between the Transform and DS2030 analyses. There was alignment as regards the overall need for a mix of smart and traditional reinforcements. In addition the DS2030 studies were able to highlight where certain solutions were most applicable or not suitable (for example limitations in the application of permanent meshing of existing networks as a smart solution). These detailed findings could be used to refine the Transform model. Further work is required to evaluate the economic impact of differences in the applicability and benefits provided by smart solutions

4. Wider Insights

4.1. A review of the detailed findings shows that the 2030 network will be subject to challenges that have an impact on the legacy design concepts of the GB distribution systems. Hence the solutions will require changes to the existing design, planning and operating practice. Examples that can be seen from the studies include: significantly greater 'wholesystem' interactions that span transmission, distribution and customers, the importance of scenario approaches to planning, the need for strategies to manage uncertainty, the need to review the fundamentals of long-standing design and operational standards (ER P2/6, security of supply is currently under review), a re-examination of distribution system protection concepts including automation and clearance times, and new approaches to the treatment of diversity of demands, generation and storage sources.

4.2. A further high level observation from the project is that changes can be anticipated to the control, communications and data systems with which we are familiar today. Centralised control rooms, point to point communications, and bespoke data protocols and archiving will require review. These matters have been addressed at a conceptual level in the project and point towards the need for architecture and strategic road-maps in these areas, so that as smart network solutions and new commercial arrangements increase in penetration, their ICT systems build towards co-ordinated designs that facilitate agreed data sharing, devolved systems integrated with centralised systems, and robust cyber security and data privacy. Piecemeal developments and bespoke systems are an entirely suitable approach at an exploratory stage (for example the successful Low Carbon Network Fund projects), but as these smart solutions become Business as Usual, a co-ordinated development path will be needed if stranded assets are to be avoided and seamless services offered to customers and third parties. Application of smart solutions must consider their interaction and interface with the network and the operation and business context in which they will operate. Some aspects of this may require 'investment ahead of need' and an approach developed jointly between the network companies and the regulator will be helpful. For example, some DNOs are currently installing optical fibre on overhead lines, this will enable better protection and active management.

4.3. The challenges revealed by the DS2030 modelling are not unique to the GB power system. Similar issues have been identified through an international review that formed part of the project. However, generalisations can be problematic as the design philosophies of national systems differ, which can make a material difference especially when conditions approach design limits. One example of this is in the French electricity system where a line overloaded into short term ratings will automatically be switched out when the short term rating time period has expired. Other systems leave it in the hands of the operator instead. Fundamental network design reviews for the GB system will need to be cognisant of developments in international standards, most particularly emerging European network code obligations.

4.4. DS2030 findings include a high level examination of network losses. The DS2030 report discusses how deploying smart solutions such as Real Time Thermal Ratings to raise the utilisation of network assets will inevitably mean that losses will be higher than if a conventional reinforcement had been undertaken, whilst others also incur inherent losses due to their operation, for example Energy Storage ac/dc/ac conversion losses. A question for further consideration is how this should be viewed in 2030 under conditions where it is expected that these losses will be supplied from carbon-free renewable generation, having near-zero marginal cost.

4.5. The LCT projections are seen to increase rapidly towards the end of the 2030 study period. If this rate was to continue to 2050 the network implications would be much more severe than highlighted in the studies looking up to 2030. It is to be expected that some smart solutions would be used in the path to 2050 as temporary solutions to manage the uncertainty, in localised areas or alongside traditional reinforcement.

4.6. Finding solutions to the network challenges identified by the modelling is likely to require dialogue between many more parties than has been the case to date. This could involve, for example, network operators, generators, suppliers, aggregators, energy service providers, equipment manufacturers and vendors and standards bodies. Furthermore, the scope of this interaction will extend far beyond traditional power system equipment and will include consumer appliances, home energy management, electric vehicle charging, and in the future, cross-vector interactions with the gas, heat, hydrogen and transport sectors. Today's industry governance frameworks require review for this very different mix of stakeholders and the speed of response that will be expected by customers and third parties. In part this is being done through the Power System Architecture (FPSA) project instigated by DECC. The FPSA project is exploring the future power system requirements for new technical functions and any potential shortcomings in existing governance arrangements to deliver such functions.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

The DS2030 project has undertaken detailed analysis into the operation of the GB power system as projected for 2030. Future needs of the distribution networks were identified with consideration of both traditional and non-traditional reinforcement, with the latter referred to as smart solutions. The analysis has been comprehensive, informed through wide stakeholder engagement, and with challenge and guidance at each stage from the WS7 stakeholder group. This was facilitated by the review and approval of detailed project methodologies.

The conclusions from the work are encouraging and demonstrate that with suitable reinforcement the 2030 distribution power network is expected to be technically viable and capable of serving consumers in line with the national standards for security and quality that are familiar today.

However, attention must be given to important learning points from the studies, if this positive outcome for 2030 is to be attained. Overall, the present power networks operate satisfactorily today, and there is time to address the challenges that may arrive as networks evolve to 2030. It would be helpful to have visibility of emerging issues to enable adequate planning of timely interventions.

Investment will be needed in the networks to respond to the challenges between now and 2030 and a mix of smart and traditional solutions will be necessary.

Detailed power system studies have characterised the performance of different network types, from transmission connection point down to LV. Four Base networks were studied: Urban, Rural, Interconnected Manweb, and Interconnected London. Two Low Carbon Technology (LCT) uptake scenarios were used, one was demand biased, the other was Distributed Generation biased. Whilst there is inevitable uncertainty surrounding the chosen scenarios they provide a good indication of the type of future challenges to distribution networks, understanding that the timing of these challenges may vary depending on actual LCT uptake levels.

Planned Implementation

The outputs from the DS2030 will be two fold.

1. The Transform Model will be updated to reflect the outputs of the DS2030 work, this includes the viability of meshing and the effectiveness of energy storage.
2. Network models of the 4 base networks in Powerfactory format (PFD)

Other Comments

The following reports are available on the Smarter Networks Portal (http://www.smarternetworks.org/Project.aspx?ProjectID=1623#downloads)

Stage 2 Report - Development of the Base Network models, the WS7 Scenarios and Use Cases.
Stage 3 Report - Questions and Use Cases Report
Stages 4 & 5 Report - Project Results
Stage 6 Report - Answering the Questions - Final Study Report
DS2030 Network Models

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