NIA ENWL003
Engineering Recommendation (ER) P2 Review

Closedown Report

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REVIEW

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APPROVAL

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1 EXECUTIVE SUMMARY

The review of Engineering Recommendation P2 – Security of Supply has successfully delivered a fundamental review. The project, in particular the analysis undertaken, has produced some significant findings and learning for distribution network operators (DNOs), academics and industry stakeholders.

The work which began in January 2015 and concluded in July 2016 was delivered by a consortium. The consortium included DNV GL, NERA Consulting and Imperial College. The consortium was appointed following a formal tender process. The consortium subsequently reported to a Distribution Code Review Panel (DCRP) appointed working group.

The main objective was to review the requirements for, and function of, a planning standard and, if appropriate, produce an updated version of Engineering Recommendation P2 so the security provided by network assets together with systems and infrastructure provided by others (as appropriate) could be assessed against agreed standards.

The review which was formed of two distinct phases with Phase 1 being essentially a comprehensive research, analysis and modelling engagement and consultation process carried out by the consortium with direction and support provided by the DCRP working group and the Energy Networks Association. The network licensees had no preconceived approach to future security standards. The spectrum of possibilities ranged from a modification and update of the current arrangements, development of a completely new approach starting from first principles, through to recommending removal of any deterministic planning standard, relying instead on distribution network operators' regulatory incentives and other legislation to motivate efficient network design. The essential task of Phase 1 was to identify research, develop and communicate a range of options for the overall approach to structuring and detailing the appropriate level of network security standards and to then propose how such options can be evaluated. The consortium then evaluated these agreed options, and recommended the most appropriate approach that should be taken forward into Phase 2, and ultimately codified.

The Phase 1 analysis work was largely economic and recommended consideration of some potentially quite fundamental changes. It is of note that the time horizon and context for the analysis was not constrained by the structure and policy decisions put in place for RIIO ED1 nor by any assumptions about the level of supply security that would be acceptable to stakeholders in the future.

Phase 1 posed some fundamental questions about the means of providing the most appropriate level of security of supply to customers, via a combination of network assets, customer owned assets, and both technical and commercial operational management techniques, and as such was of great interest to many stakeholders.

To test these proposals with stakeholders Phase 1 also included a series of stakeholder consultation events and DCRP public consultation. Stakeholder feedback did not align with or generally support the conclusions of the economic analysis and concerns were raised about the implications for the underlying reliability and availability of supply. The primary objectives of Phase 1 were to assess the merit and direction of any revision of ER P2/6. It concluded there was a strong economic case to change P2/6 but that there were significant stakeholder issues remaining to be resolved. It is of note that the Phase 1 report contains three somewhat separate sets of recommendations for further consideration:

1. More explicit guidance on the inclusion of Distributed Energy Resources' (DERs) in the assessment of security of supply
2. A change in the minimum level of security of supply, specifically a reduction
3. Additional expenditure not at present in allowances.

Phase 1 suggests that all three of the above are implemented simultaneously; in that it finds them all to be ‘efficient’. However, it does not provide any analysis of the net effect of all three in combination.

This is considered to be an essential step in engaging further with stakeholders in Phase 2. For example stakeholder concerns in respect of item 2 may be alleviated in part or whole by the effect of 3.

It is also of note that the Phase 1 work did not consider the operational aspects of these changes. For example while in isolation the changes in 2 may be attractive, their cumulative effect during periods of severe network depletion such as storms, warrants further analysis. Other operational considerations include the effects on network access for routine maintenance activities and for establishing new connections.

The DCRP has accepted the consortium’s Phase 1 report and endorsed the need to move to Phase 2 which is now underway.

2 PROJECT FUNDAMENTALS

Title	Review of Engineering Recommendation P2/6
Project reference	NIA_ENWL003
Funding licensee(s)	Electricity North West Limited, National Grid Electricity Transmission, Northern Powergrid, Scottish and Southern Energy Power Distribution, Scottish Power Energy Networks, UK Power Networks, Western Power Distribution
Project start date	Jan 2015
Project duration	16 months
Nominated project contact(s)	Dan Randles – Electricity North West

3 PROJECT BACKGROUND

Engineering Recommendation P2 has been in place since the 1950s and has played a major role in the development of secure, reliable distribution networks. While a number of changes have been made over the years, notably the introduction of P2/5 in 1978, the document has served the industry well for over 30 years.

P2 is a ‘deterministic’ standard and is largely focused around ensuring sufficient capacity is available to meet the ‘peak demand’ within a manner and timeframe consistent with the ‘group demand’ (or put simply, the size of network) in question. P2 is also ‘risk based’ to such an extent that larger ‘load groups’ are in general deserving of a higher level of security.

The most fundamental issue regarding the future evolution of the P2 standard is whether it prescribes economically efficient investments, given many changes affecting the energy market at present, including the (anticipated) prolific deployment of non-network technologies and the changing role of the customer. This gave rise to the need for a fundamental review of the baseline philosophy of distribution network operation and design to ensure that the UK Government's energy policy objectives can continue to be met in a cost effective and pragmatic way.

The requirement for a fundamental review of Engineering Recommendation P2 had been recognised by network licensees (ie the electricity distribution network operators (DNO) companies and National Grid) for some time. The licensees therefore believed that it was timely to undertake a comprehensive review of Engineering Recommendation P2 in relation to customer and system requirements and to develop an understanding of what is required to facilitate the long-term development of networks.

The fundamental review of ER P2/6[1] was undertaken by a consortium which included DNV GL, NERA and Imperial College and directed by the Distribution Code Review Panel P2 working group (DCRP P2 WG) through the Energy Network Association (ENA). The consortium was appointed following a rigorous tender process.

The review was formed of two distinct phases. Phase 1 was essentially a comprehensive research, analysis and modelling engagement and consultation process carried out by the consortium with direction and support provided by the DCRP P2 WG and the ENA. Network licensees had no preconceived approach to future security standards. The spectrum of possibilities ranges from a modification and update of the current arrangements, development of a completely new approach starting from first principles, through to recommending removal of any deterministic planning standard, relying instead on DNOs' regulatory incentives and other legislation to motivate efficient network design. The essential task of Phase 1 was to identify research, develop and communicate a range of options for the overall approach to structuring and detailing the appropriate level of network security standards and to then propose how such options can be evaluated. The consortium then evaluated these agreed options, and recommended the most appropriate approach that should be taken forward into Phase 2, and ultimately codified.

Phase 1 posed some fundamental questions about the means of providing the most appropriate level of security of supply to customers, via a combination of network assets, customer owned assets, and both technical and commercial operational management techniques, and as such will be of great interest to many stakeholders. Hence as part of this phase it was important to widely consult with such stakeholders throughout the process.

4 PROJECT SCOPE

Scope of services:

- Workstream 1 – Project initiation
- Workstream 2 – Assessment of P2/6 and identifying options for reform
    - WS2.1 Scope and framework for assessing security performance and measures of characteristic network designs
    - WS2.2 Service quality and cost effectiveness of the present network design practises
    - WS2.3 Risk associated with asset replacement, common mode failures and high impact events
    - WS2.4 Impact of smart grid technologies on service quality risk profile
    - WS2.5 Assessment of impacts of alternative control and operation strategies on security of supply
    - WS2.6 Loss inclusive design of distribution networks and impact on security of supply

[1] P2/6 is the current version of the standard and was published in 2005

- WS2.7 Alignment of security of supply standard in distribution networks with other codes and schemes
- WS2.8 Options for future development of distribution network standard

- Workstream 3 – ER P2/6 options report
- Workstream 4 – Stakeholder engagement workshops
- Workstream 5 – Formal strategy consultation for P2
- Workstream 6 – Detailed review and analysis
- Workstream 7 – Final recommendation
- Workstream 8 – Programme work for Phase 2

5 OBJECTIVES

The objective was to review the requirements for and function of a planning standard and if appropriate produce an updated version of Engineering Recommendation P2 so the security provided by network assets together with systems and infrastructure provided by others (as appropriate) can be assessed against agreed standards.

6 SUCCESS CRITERIA

In order to be sufficiently future proof the revised document will focus on developing a framework against which means of providing security of supply can be evaluated. It is envisaged that a revised standard would not require a further review before, ideally, 2030. DNOs and National Grid will ensure that the means of provision of the appropriate supply security will be executed in an overall economic, efficient and co-ordinated manner.

7 PERFORMANCE COMPARED TO THE ORIGINAL PROJECT AIMS, OBJECTIVES AND SUCCESS CRITERIA

7.1 Summary of Performance

Outputs of Phase 1

The Phase 1 analysis work was largely economic and recommended consideration of some potentially quite fundamental changes. It is of note that the time horizon and context for the analysis was not constrained by the structure and policy decisions put in place for ED1 nor by any assumptions about the level of supply security that would be acceptable to stakeholders in the future.

To test these proposals with stakeholders Phase 1 also included a series of stakeholder consultation events. Stakeholder feedback didn't align with or generally support the conclusions of the economic analysis and concerns were raised about the implications for the underlying reliability and availability of supply. The primary objectives of Phase 1 were to assess the merit and direction of any revision of Engineering Recommendation (ER) P2/6. It concluded there was a strong economic case to change ER P2/6 but that there were significant stakeholder issues remaining to be resolved. It is of note that Phase 1 contains three somewhat separate sets of recommendations for further consideration:

1. More explicit guidance on the inclusion of distributed energy resources' (DERs) in the assessment of security of supply. This is already permitted by ER P2/6 and hence there are no policy barriers to the realisation of associated benefits.
2. A change in the minimum level of security of supply, specifically a reduction. Such a revision would offer some material future economic benefits but it is clear that

stakeholders have significant concerns over such a move and the economic costs of any reduction in quality or security of electricity supplies.

3. Additional expenditure not at present in allowances. The analysis shows additional expenditure as being efficient in areas such as high voltage network automation and mitigation of high impact low probability events. The case for these was compelling, however there are a number of factors that merit further consideration including; timing of investments versus RIIO ED1 allowances, the assessment of 'efficient expenditure' and the price impacts for customers.

Phase 1 suggests that all three of the above are implemented simultaneously; in that it finds them all to be 'efficient'. However, it does not provide any analysis of the net effect of all three in combination.

This is considered to be an essential step in engaging further with stakeholders. For example stakeholder concerns in respect of item 2 may be alleviated in part or whole by the effect of 3.

It is also of note that the phase 1 work did not consider the operational aspects of these changes. For example while in isolation the changes in 2 may be attractive, their cumulative effect during periods of severe network depletion such as storms warrants further analysis. Other operational considerations include the effects on network access for routine maintenance activities and for establishing new connections.

The DCRP accepted the Phase 1 report and endorsed the need to move to Phase 2 which is now underway.

8 THE OUTCOME OF THE PROJECT

8.1 Summary of Outcome

As indicated earlier in the report the scope of services was delivered by a series of eight workstreams which culminated in the publication of a final report that outlined the key recommendations and a proposed programme of work for phase 2. The following summary of outcomes is provided for each workstream.

8.1.1 Workstream 1 – Project Initiation

Workstream 1 set out the Phase 1 objectives and process, and included an initial engagement with all key industry stakeholders. This was the initial starting up phase of the project and included the following activities:

- The development of an industry Project Initiation Paper (PIP). The PIP highlighted the key objectives of the overall ER P2/6 Review project to industry stakeholders. It was part of the initial communication with all stakeholders and outlined the process as well as the expectations on stakeholder engagement. The PIP was presented at the initial stakeholder event held on Friday 1 May 2015. The paper was aimed at providing some of the supporting documentation around the aims, context, process, and stakeholder engagement. The PIP is referenced as Appendix 13.1 to this report
- Establish a project management office (PMO) activities and a risk register
- Establish a Framework for the Development of Future Network Design Standards.

And the proposal to run two workshops:

- One with the ENA to discuss and agree the content of the PIP, and the Framework for the Development of Future Network Design Standards
- The second with the wider stakeholder community to verify the content of the industry PIP, and the Framework for the Development of Future Network Design Standards.

Workstream 1 deliverables included:

- Industry Project Initiation Paper
  - This document would highlight the key objectives of the overall project to industry stakeholders. It was the initial communication with all stakeholders; outlining the process as well as the expectations on stakeholder engagement. It was developed using PowerPoint so that it could be widely presented to stakeholders.
- PMO activities
  - Project Initiation Document
  - Risk register
  - Workshop write ups
- High-level agreement with industry on the objectives of Workstream S2

8.1.2. Workstream 2 – Assessment of P2/6 and Identifying Options for Reform

The aim of Workstream 2 was to provide the analysis required to (1) understand the impact of ER P2/6 in its current form on the economics of network planning and design, and (2) identify the options for improvement and reform. The key outputs produced through Workstream 2 are summarised and used to assess the future options for the improvement and reform of the ER P2/6 security standard in this report. The analysis performed under Workstream 2 through a number of sub workstreams covers a range of topics, and entailed comprehensive desktop research, modelling of key issues and gathering of stakeholder input activity to identify the current impact of ER P2/6 and possible impacts from alternative security standard options.

Workstream 2.0 related to the gathering of input from stakeholders that supported these elements and also formed the basis for a qualitative analysis relating to the existing ER P2/6 standard and proposed alternative options. The workstream 2.0 report is referenced in Appendix 13.2. Workstreams 2.1 to 2.6 predominantly related to the techno-economic model and quantitative analysis performed by Imperial College. Copy of this report is referenced in Appendix 13.3. Workstream 2.7 introduced the high level options for improvement and reform of the ER P2/6 security standard and reviewed these against a range of regulatory and market mechanisms. Workstream 2.7 also carried out an initial assessment of the pros and cons of the high level options for reform. Workstream 2.7 report is referenced in Appendix 13.4.

8.1.2.1 Workstream 2.0 – Findings of the qualitative review associated with the future development of the P2/6 distribution network planning security standard

The objective of this qualitative study was to support the other mainly quantitative workstreams of this project in reviewing key aspects of the existing ER P2/6 security standard and to highlight potential areas for development of a future UK distribution network security standard.

The results of the qualitative analysis was based on the review and analysis of the consortium's industry questionnaire which contained a set of high level and more detailed questions to seek and gain the input of the many industry stakeholders regarding their opinions and views on the status, usability and adequacy of the existing ER P2/6 security standard and how this could be improved. To ensure that a wide range of inputs and views were captured and opinions recorded, all relevant industry parties and organisations were invited to provide their views and positions through a written response to the questionnaire. This enabled the consortium to build a fully representative understanding from industry stakeholders of their own views and opinions of the strengths and weaknesses of the existing ER P2/6 security standard and identify potential alternative approaches to security standards and regulatory and commercial considerations. Follow-up interviews were also held with key users of the existing ER P2/6 standard to clarify statements and opinions and to provide additional details to their organisations' responses.

The stakeholder responses were analysed and reviewed to identify key themes for input to the development of the draft options report that would consider the benefits and problems associated with a set of high level options for the successor to ER P2/6. The draft options report was developed with the DCRP P2 WG into a final options report for distribution to the wider industry for further formal consultation, leading to a final agreement and set of statements as to the future development path for a potential update to the existing security standard regime.

The stakeholder engagement was the first opportunity for industry stakeholders to input directly to the development of the options review process to identify a successor to the existing P2/6 security standard.

From the analysis of the various stakeholder questionnaire responses and details of the clarifications gathered by stakeholder interviews, a number of key themes emerged relating to the potential reform of ER P2/6. The key themes identified and summarised from this review of the stakeholder responses included:

- Embrace the strengths of the existing standard
- Provide consistency with the regulatory framework
- Remain sufficiently intuitive and easy to audit
- New network technologies must be fully represented
- Provide a clear and consistent set of definitions
- Reflect network user expectations
- Introduction of cost benefit analysis
- Treatment of network losses should not be included
- Statements of requirements should remain prescriptive
- Include the management of construction outages
- Treatment of extreme events

8.1.2.2 Workstream 2.1 – Provision of a scope and framework for assessing security performance and measures of characteristic network designs

Given that the measure of the underlying risk in ER P2/6 is based on expected energy not supplied (EENS), in this task, the consortium investigated a spectrum of alternative measures for quantifying security of supply experienced by customers. The strengths and weaknesses of various customer risk measures, particularly focusing on frequency and duration of outages and customer damage functions, were evaluated. Given its probabilistic nature, the consumer reliability indices were represented by the probabilistic density functions rather than expected values only. This is essential for understanding of the risks profile associated with service quality delivered to network customers and for assessing the robustness of the alternative network design strategies.

Historically, electricity networks are planned on the basis that all consumers place the same value on continuity of supply and use of their appliances when required. Furthermore, it has been assumed that the continuity of supply is binary: electricity supply is 100% available under normal operating conditions (all devices can be used) or not at all under outage conditions (no devices can be used). This historic approach usually characterised by valuing avoided interruptions using a single value of lost load (VoLL), although widely understood and recognised, is overly simplistic. First, the estimation of VoLL is subject to considerable uncertainty, driven by the fact that the damage caused by interruptions is different for different classes of consumers, in different locations, and at different times of the year/day. Also, smart metering coupled to in-home energy management devices could change the way customers value supply continuity through facilitating reliability-based consumption choices. By setting design standards that allow networks to be planned in accordance with the differing priorities of different categories of in-house demand, it may be possible to develop and operate networks at lower costs to customers.

In this task Imperial College therefore developed their existing models to allow a range of alternative approaches to valuing interruptions to be taken. For instance, they analysed cases in which the value of interruptions is simply at VoLL, eg drawing on recent studies, such as those prepared for the former DECC, that estimate VoLL[2]. The analysis also considered other cases in which the valuation of avoided interruptions is represented by a customer damage function, such that value depends on the customer type(s) affected, timing and frequency of outages, and duration of the outage. In all cases, the value of reliability-differentiated continuity of supply service was assessed through comparisons with the historical approach to security with having full interruptions and indiscriminate demand curtailment in case of constraints.

In order to support a broad range of network designs with associated network cost characteristics and corresponding performance (which can be found in operation and planning practices), Imperial College developed a high-level probabilistic approach for assessing the security of supply delivered to the end consumer under different conditions. Imperial College also established a set of characteristic network designs, across the range of group demand levels and populated these with relevant technical, cost and performance data.

The key activities of this task included:

- A critical review of recent studies on quantifying costs of interruptions and identify strengths and weaknesses of different customer risk measures including EENS, frequency and duration of outages and different approaches to costing interruptions
- Gathering network and load data (across all voltage levels and demand groups), and statistics associated with network failures, outages and service restoration procedures
- Establishing a set of characteristic network designs, across the range of group demand levels and populating these with relevant technical, cost and performance data. This involved characterisation of failure and repair rates through not only average values but also a range of associated probability distributions
- Based on the range of Imperial College models for assessing distribution network reliability performance, establish key high-level modelling approaches for assessing key load-point focused security indices, including evaluation of the expected values of the key indices based on Markov models and also their distributions through full Monte Carlo based models. This was used to derive equivalent VoLLs from different customer damage functions. A range of studies have been carried out with the of estimating the breakeven value of VoLL at which the existing network would be upgraded cost effectively, and to estimate the least cost redundancy levels. This enabled equivalent cost of interruption to be compared with the cost of interruption when the central VoLL of £17,000/MWh, adopted by the UK government for the Electricity Market Reform, is applied. In order to assess the robustness of the findings, the optimal degree of redundancy is also estimated for higher VoLL of £34,000/MWh (with lower values of VoLL driving lower optimal degrees of redundancy). Sequential Monte Carlo analysis was carried out to determine the impact of reducing the level of network redundancy prescribed by the present standard on the frequency and duration of customer interruptions
- Selected case studies carried out to demonstrate and agree the range of model outcomes to be used in subsequent tasks.

[2] In line with the latest analysis and values used in the Electricity Market Reform carried out by the Department of Energy and Climate Change VoLL of £17,000/MWh was used in Imperial College's studies as the central value. Imperial College has also carried out the analysis using larger value of VoLL (£34,000/MWh) to assess the sensitivity and robustness of identified solutions. A more detailed discussion on Customer Interruption Costs (CIC) and VoLL can be found in Imperial Colleges report "Review of Distribution Network Security Standards", for the Energy Networks Association, February 2016.

The output was a framework for the development of future network design standards.

8.1.2.3 Workstream 2.2 – Analysis of the distribution network service quality performance associated with the present network design standard and alternative options for its update

For developing new network security standards, it is important to understand two key aspects of the present standard (a) the service quality inherent in the present network design practices and implicit in the design standards, including contribution of distributed generation (b) the cost effectiveness of the standard, and its ability to the balance cost of interruptions against the cost of network infrastructure, which involved application of alternative indices such as VoLL and customer damage functions. Imperial College carried out a high-level analysis of average reliability performance, including an examination of the variability of key service quality indicators, and assessed the risk profile implicit in the present network standard across different group demand (GD) levels and selected network configurations. The probability density functions of various measures of reliability performance were estimated by application of suitably designed probabilistic analysis techniques. This facilitated comparisons of the level of security of supply implicit within the present standard with alternative formulations. Furthermore, the reliability analysis was combined with the various forms of customer damage functions, in order to estimate the monetary value of unreliability and to inform the optimal network design. This analysis enabled an evaluation of the magnitudes of VoLL and characterisation of the customer damage functions that are implicit in the present standard. This also included analysis of the appropriateness of demand group definitions and treatment of interconnection/ transfer capacity.

Key activities of this task included:

- (a) Based on samples of real distribution networks and the set of characteristic networks created across all voltage levels and group demands, analysis was carried out to assess service quality delivered to consumers by the present network design practices. This included rural, subrural/urban and urban network topologies and different consumer mixes across different demand groups. Understanding the actual performance of the present network security standard was important when developing alternative network design propositions. This included evaluation of various reliability indices in the form of expected values, and also the risk profile driven by the variability of key parameters
- (b) Cost benefit analysis for the existing network design practices was carried out to assess the efficiency of the present network design standard. A range of studies have been carried out with the aim of estimating the breakeven value of VoLL at which the existing network would be upgraded cost effectively, and to estimate the least-cost redundancy levels. Also, the impact of reducing levels of network redundancy on duration and frequency of interruptions has been determined. Some sensitivity analysis was carried out to demonstrate the impact of various key parameters and assess the robustness of the present practice
- (c) Assessing by how much the assumed cost of interruptions affects the fundamental design of networks, particularly when considering different consumer mixes. According to the London Economics study[3] the central VoLL of £17,000/MWh is attributable to a mix of residential and commercial consumers, while industrial customers would have lower VoLL and hence lower levels of redundancy. On the other hand, predominantly commercial consumers would be characterised with higher values of VoLL and given the conservative approach adopted in the Imperial College work, analysis is also carried out with VoLL of £34,000/MWh. In order to provide the insights of the impact of different values of VoLL on the degree of redundancy, the breakeven value of VoLL at which the existing network would be upgraded cost effectively, is also determined. This can be used to inform the debate regarding the question of “who/what are future

[3] London Economics (2013). ‘The Value of Lost Load (VoLL) for Electricity in Great Britain: Final report for OFGEM and DECC’.

distribution networks being built for"? It was also important in accounting for how uncertainties around the value of avoided interruptions (including how this varies across customer classes) feed through into network planning decisions

- (d) High-level analysis was carried out to establish appropriateness of demand group definitions and treatment of interconnection/transfer capability.

8.1.2.4 Workstream 2.3 – Assessment of risk associated with asset replacement, common mode failures and high impact events

The acceleration of major asset replacement programmes introduces risks not explicitly recognised when the planning standards were developed. Some construction outages will potentially last for long periods, thus exposing potentially large numbers of customers to an increased risk of loss of supply, unless comprehensive contingency measures for emergency restorations are established. The lack of differentiation between construction and maintenance outages in the distribution planning standards represents a significant shortcoming given that a period of potentially considerable asset replacement is underway. Imperial College conducted high-level assessments of materiality of this effect and estimated the risk profiles of supply security for typical configuration characteristics for large demand groups. This included consideration of the appropriateness of the specified return to service periods (outage duration) for a first circuit outage and hence the period at risk of a second circuit outage.

Furthermore, the present standard does not address explicitly common-mode faults. These may be relevant when considering overhead line (OHL) circuits on the same tower or laying multiple cables in the same trench (that are expected to provide redundancy for one another), or especially the loss of a busbar or switchboard. This may be a particularly material issue for large demand groups exposed to potentially high risks of common-mode failures. Furthermore, this task also analysed the significance of high impact low probability events and alternatives for dealing with prolonged outages. Imperial College also considered the cost of interruptions and represented it through a non-linear function of the outage duration.

Key activities of this task included:

- (a) Carrying out high-level assessment of the risk profiles of security of supply associated with typical configurations for large demand groups and impact of different constriction outage durations. This also included establishing the principles of the cost-benefit analysis associated with alternative supply arrangements for construction outages
- (b) Assessment of the driving factors and the importance and materiality of considering common mode failures. Case studies were carried out on the established set of characteristic network designs, particularly associated with large demand groups, with particular focus on parallel circuits and losses of busbars and switchboards[4]
- (c) Carrying out high-level assessment of high-impact low-probability events, such as blackouts of critical districts, outages driven by very extreme weather conditions[5] and consequences of significant reductions in demand diversity following prolonged outages were carried out to identify key indicators, assess their importance and assess the benefits of expenditure on reliability improvements / mitigation measures of reducing their impact on the security of supply.

[4] It is recognised that in the future common mode failures could relate to external factors e.g. computer failure of a DSM aggregator.

[5] This relates to weather events that are considerably more extreme than a 1 in 10 year event.

8.1.2.5 Workstream 2.4 – Analysis of the impacts of smart grid solutions on security of supply

A high-level assessment to quantify benefits from flexible generation, responsive demand including storage, to security of supply was completed. A range of generic case studies with characteristic parameters for various flexible generation and demand technologies were carried out to assess the ability of these non-network solutions to substitute network assets without degrading the reliability performance seen by the end consumers. Imperial College's analysis suggests that when assessing the contribution of demand side response contribution to network security, it may be appropriate to consider response time, duration, energy recovery characteristics and cyclic sustainability. In this context, diversity effects associated with multiple demand side response providers/aggregators were considered. This task also included assessment of the role and value of advanced network technologies, such as automation and remote control of switchgear, soft normally open points (NOPs), on-line voltage regulators, in enhancing the security of supply. Imperial College's models were applied with embedded Monte Carlo techniques to estimate effects of these technologies in enhancing security of supply.

This task also considered benefits of permitting islanding-mode operation of the distribution system in order to minimise interruptions in customer supply after the occurrence of severe low probability and high impact events.

The task was carried out in the context of different time frames (2020, 2030 and 2050), considering the future changes in the GB generation mix and the increasing growth in the penetration of distributed generation and demand composition. This involved consideration of effects associated with a lack of system inertia, exports from distributed generation and challenges that electrified heat and transport sector may bring.

Spatial and temporal properties of demand growth are characterised by a significant degree of uncertainty. In this context, non-network technologies may provide flexibility and make the future network reinforcement more certain and hence cost effective in the long run. This would create the option value of non-network technologies, through temporarily postponing investment decisions until more accurate information regarding the spatial and temporal properties of demand growth becomes available, while not compromising the service quality performance experienced by customers. It may be appropriate that such considerations become a part of the future network design standard. Furthermore, this may have implications for the regulatory framework associated with cost recovery for network and non-network solutions, which are considered in this work (see Workstream 2.7 following).

Key activities of this task included:

- Through illustrative case studies on the established set of representative network designs, identifying alternative criteria for incorporating non-network solutions in future network planning standards, on a non-discriminatory basis. This in particular included:
    - Distributed generation of different technologies, response times and availabilities.
    - Responsive demand, considering availability, response time, duration, energy recovery characteristics and cyclic sustainability.
    - Energy storage technologies.
- Identifying alternative approaches to assessing the contribution that these technologies could make to network security in the case when they also provide other system support services, such as different forms of reserve and/or frequency response services. This was supported by relevant case studies.
- Identifying the role and value of advanced network technologies including automation and remote control of switchgear, application of soft NOPs, on-line voltage regulators, in enhancing the security of supply. Alternatives for including islanding-mode of operation were identified.

- Identifying alternative approaches to dealing with uncertainty in future developments when designing distribution networks (particularly in the context of integration of low carbon demand and generation technologies in distribution networks) in order to facilitate the debate of the role and scope of future network security standards. In this context, modelling was carried out to demonstrate possible evolution of the compliance requirement, considering present only, or also a least-cost compliance approach considering uncertainty in future development.

8.1.2.6 Workstream 2.5 – Assessment of impacts of alternative control and operation strategies on security of supply

While the previous task focused on the contribution of various smart grid technologies[6] to security of supply, this task centred on assessing the implications on network control and operation strategies (including those affecting new technology) required to enable these technologies to contribute to security of supply while simultaneously enhancing the ability of the distribution network to accommodate increased levels of demand and generation (and hence power transfers). Hence, in this task the consortium considered alternative control and operation strategies that could be implemented through advanced distribution management systems (DMS) and/or through distributing control functions among various controllers, and accompanying commercial arrangements that would support the use of demand and generation resources in supporting security of supply.

Currently, real time distribution network control is largely preventive with little real-time control (except supply restoration), and security of supply is delivered through preserving sufficient margins in loading of network assets. These margins may be reduced without degrading security of supply, provided that a portfolio of corrective control actions is effectively optimised. Given that a higher degree of integration and participation of corrective control will require an increased reliance on ICT infrastructure, the security risks associated with these technologies need to be assessed. The key aspect of this work is the consideration of both advantages and constraints associated with new monitoring, control and communication technology, reflected in the latency (time to operate), common mode failures and reliability of response.

This task involved:

- Carrying out wide consultation with industry and relevant stakeholders regarding the changes in real time network operation and control facilitated by appropriate software and ICT infrastructures that will be required to facilitate the transition to a smart grid paradigm, focusing on the impact on security of supply. Analysis of experiences and lessons from Low Carbon Networks Fund (LCNF) projects and associated trials also informed this task
- Carrying out high-level case studies to estimate key drivers that will impact the risk profile of future actively managed distribution networks. This includes exposure to common mode failures associated with ICT infrastructure.

8.1.2.7 Workstream 2.6 – Loss inclusive design of distribution networks and impact on security of supply

The present policies for distribution circuit design are driven by security of supply criteria and the cost of losses does not appear historically to have been given adequate consideration. Recent regulation developments through RIIO encourage implementation of minimum life-cycle cost distribution network design that balances the capital investment against the cost of the system losses. Imperial College's recent modelling demonstrates that the optimal peak

[6] These technologies include embedded generation, voltage control technologies (tap-changing transformers, shunt compensation, in-line voltage regulators), energy storage technologies, responsive demand (smart appliances, electric vehicles), dynamic line rating etc.

utilisation of distribution network circuits (LV and HV in particular) should be very low. The implication of this on network reliability may be significant as the optimal network capacity should be much larger than peak demand, which would provide additional headroom and could potentially increase reliability of supply. However this effect has never been quantified and the purpose of this task is to assess the implication of minimum-life cost driven network design on security of supply.

This task involved several activities:

- Based on Imperial College's loss-inclusive, minimum life-cycle cost LV and HV network designs, using the established set of characteristic LV and HV networks, carrying out modelling to assess the impact on network reliability performance.
- Identification of implications on the future network security standards and opportunities that this may open to cost-effectively further improving reliability performance through enhancing flexibility and reconfiguration capabilities of LV and HV networks.

8.1.2.8 Workstream 2.7 – Interface between distribution network standards and the regulatory framework (RIIO), EU codes, capacity mechanism and balancing services significant code review and defining the interface between distribution network standards and Interruption Incentive Scheme and the National Electricity Transmission System Security and Quality of Supply Standard

Network planning standards interact with a wide range of other schemes, codes and regulatory arrangements in the British (and wider EU) electricity market. As part of this task, therefore, the consortium examined the interactions of the high level options for improvement and reform of ER P2/6 with a range of other arrangements. The Workstream 2.7 report which is referenced in Appendix 13.4 covered a range of topics, as follows:

- It discusses the need for regulatory measures to constrain or influence the level of network reliability that DNOs choose to provide for their customers, and discusses the concept of "economically efficient" investment that such regulation should strive to achieve
- It provides historical background and context of ER P2/6, which is one element of the regulatory framework imposed on DNOs that aims to encourage the efficient provision of network reliability to customers
- It describes other regulatory instruments that may affect the British DNOs' decisions regarding the levels of network reliability they provide for their customers
- It describes briefly the range of measures applied in the regulation of electricity distributors in other jurisdictions to encourage them to provide efficient levels of network reliability
- Drawing in part on the range of regulatory measures observed internationally as described, it sets out a range of options for the reform of ER P2/6
- It discusses the advantages and disadvantages of each of the options for the reform of ER P2/6, focusing on interactions with other aspects of the regulatory framework
- It concludes by describing the conditions under which each of the options for reform is most likely to promote the efficient provision of network reliability, and notes what other forms of evidence would be required to make a full appraisal of the options. In particular, the WS2.7 report describes how the evidence produced from the quantitative modelling undertaken by Imperial College through other aspects of this project will inform the overall assessment of the ER P2/6 reform options.

8.1.2.9 Workstream 2.8 – Options for future development of distribution network standard

The aim of Workstream 2 was to provide the analysis required to (1) understand the impact of P2/6 in its current form on the economic efficiency against an idealised standard, and (2) identify the options for improvement and reform considering not just the techno-economic efficiency but also other key influencing factors such as transparency, practicality, usability, performance measurement etc.

The analysis performed under Workstream 2 covered a range of topics, and entailed comprehensive desktop research, modelling of key issues and gathering of stakeholder input activity to identify the current impact of P2/6 and possible impacts from alternative security standard options. In addition to the above predominantly quantitative analysis, Workstream 2.0, provided stakeholder input to assist in the development of the qualitative analysis performed.

High Level Options for Reform of ER P2/6

The analysis of the future distribution network operation and designs under different future development scenarios considered a comprehensive range of high level options for improvement and reform of the present network planning security standard including:

1. Retaining the existing P2/6 standard as is

2. Enhancing P2/6 but retaining the deterministic nature/structure. Enhancements considered included:

    - Non-network solutions – including: generation, energy storage, DSR, advance automation,
    - High impact low probability events,
    - Long term outages for asset replacement,
    - Common mode failures.

3. Replacement of P2/6 with an obligation to perform probabilistic CBAs

4. Development of a hybrid standard with an obligation to perform probabilistic CBAs but retaining some deterministic elements. This is viewed as a hybrid of options 2 and 3

5. Complete removal of P2/6 security standard.

The consortium has evaluated the range of options using the cost benefit framework established by Imperial College. This cost benefit framework considers the (quantitative and qualitative) costs and benefits of:

- Different service quality delivered to end customers, assessing frequency and duration of outages together with risk profile and robustness associated with construction outages, common mode failures and high impact events
- Options for incorporation of demand side response, distributed generation and energy storage technologies in the future network design standards are discussed, while considering application of advanced automatic control schemes and/or area-wide operational measures that might contribute to security.

Furthermore, the consortium has also considered the appropriateness of conducting experiments within present LCNF projects in order to inform the analysis and the development of alternative distribution network standards.

8.1.3 Workstream 3 – ER P2/6 Options Report

The key outputs and conclusions from the analysis carried out under sub workstreams 2.0 to 2.7 that impact on the high level options for improvement and reform of the present security standard are summarised in the consortium's WS3 report published March 2016 – Options for future development of distribution network planning security standard. This report is attached as Appendix 13.5.

8.1.4 Workstream 4 – Stakeholder Engagement Workshops

DCRP P2 Working Group Initial Stakeholder Engagement Workshop #1 – 1 May 2015.

To ensure that the project was successful in delivering a revised standard that would be relevant and fit for purpose for many years to come, the support of all of the stakeholders involved was critical. The ER P2/6 review process was designed to include significant stakeholder engagement to ensure transparency and to gain consensus at each key stage of the project delivery. This first open workshop was the first in a series of planned engagements and provided the opportunity for the consortium and the Distribution Code Review Panel[7] ER P2 working group (DCRP P2 WG) to present its high level approach to the review of the security standards and confirm the methods and approaches that will be adopted to tackle the main questions. This initial workshop was designed to:

- Raise awareness of the overall project and its objectives
- Communicate and detail the approach to be adopted by the consortium, including the key questions and issues to be addressed by the project
- Outline the events and opportunities for stakeholders to engage and support the review process
- Seek and encourage feedback and interaction with wider industry parties and direct users of P2/6, to give all stakeholders a chance to contribute to the final outcome.

DCRP P2 Working Group Initial Stakeholder Engagement Workshop #2 – 9 March 2016.

On 9 March 2016 the ENA held an industry event covering the options identified for reform of P2/6 and an overview of the supporting work and analysis provided by the consortium. This second workshop provided the opportunity for the consortium and the DCRP P2 WG to present their initial conclusions and recommendations regarding the future reform of the P2/6 security standard prior to initiating a formal consultation process.

This second workshop was designed to:

- Raise awareness of the overall project and the potential influence on future network development
- Communicate the initial conclusions and recommendations of options for the potential future reform of the ER P2/6 security standard and provide a brief overview of the supporting study work and the evidence base gathered during the first stages of the review process
- Seek and encourage feedback and interaction with wider industry parties and direct users of ER P2/6, to give all stakeholders a chance to contribute to the final outcome
- Outline future opportunities for stakeholders to engage and support the review process.

8.1.5 Workstream 5 – Formal Strategy Consultation for P2

DCRP Public Consultation – 2 May – 12 June 2016

Following this industry event on 9 March and publication of the reports produced during the review, the DCRP P2 WG sought feedback from industry stakeholders on the potential recommendations for reform of the security standard. This request was part of the Phase 1 review industry consultation process and also ensures compliance with the DCRP

[7] The Distribution Code Review Panel (DCRP) is the body responsible for overseeing the maintenance and development of the Distribution Code and its subordinate documents. Those subordinate documents include Engineering Recommendation P2/6. The ENA is the service provider to the DCRP for the physical maintenance of the Distribution Code and its subordinate documents.

governance process. The consultation questionnaire document[8] was issued to industry by the ENA on the 2 May 2016 with the closing date for responses on the 12 June 2016.

Respondents were asked to provide their views and feedback based on the evidence and analysis provided in the supporting published reports[9] to the consultation as well as their own knowledge and experience.

8.1.6 Workstream 6 – Detailed review and analysis

A report was published (see Appendix 13.6) which summarises the views and feedback received from parties that responded to the consultation questionnaire and assisted in the preparation for developing the final report which would identify and structure the recommendations from the DCRP P2 WG to the DCRP in preparation for the development of the agreed changes or updates or reform to ER P2/6.

The responses to the questions as summarised in the report were used to inform the next part of the process (delivered through workstream 8) in which the consortium worked with the DCRP P2 WG to produce the final Phase 1 recommendations report. This will lay out the arguments and all the supporting evidence for the development route and any final recommendations for any new standard while critically highlighting the benefits of such a route.

8.1.7 Workstream 7 – Final Recommendations

Following the detailed review and analysis of all the work undertaken by the consortium and feedback from industry stakeholders, a report (see Appendix 13.7) was published which provided a summary of the key conclusions encompassing all the research, analysis and stakeholder engagement carried out during Phase 1 of the fundamental review of ER P2/6. The purpose of this report was for it to act as a check point to position the work to date ahead of the DCRP consideration of the case for any Phase 2 work. Through the review of ER P2/6, the P2 working group has examined a range of analysis prepared by the consortium. The work conducted to date leads to the conclusion that – for a range of reasons – there is a strong economic case for the reform of the current standard.

Recommendation 1- Updating the Levels of Physical Network Redundancy Required by P2

The evidence[10] presented to the DCRP P2 WG by the consortium included techno-economic modelling that sought to examine the economically efficient level of network redundancy in case of load growth, making a trade-off between the costs of providing physical network assets to secure demand, as compared to the operational costs/benefits associated with reducing/increasing reliability to end-users and change in network losses and corresponding costs. Among other things, the modelling accounted for the cost of reinforcing network

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[8] Consortium/ENA report "Consultation on future development of distribution network planning security standard", dated 29 April 2016

[9] All supporting documents were made available on the Distribution Code Review Panel website http://www.dcode.org.uk/dcrp-er-p2-workinggroup.html and included:

1. Consortium Workstream 2.0 report "Findings of the qualitative review associated with the future development of the P2/6 distribution network planning security standard", Nov 201
2. Consortium Workstream 2.7 report "Engineering Recommendation P2 Review Workstream 2.7: Alignment of Security of Supply Standard in Distribution Networks with Other Codes and Schemes", prepared for the Distribution Code Review Panel, P2 Work Group, 20 November 2015;
3. Imperial College Workstream 2.1 to 2.6 report "Review of Distribution Network Security Standards, Extended Summary Report", to the Energy Networks Association, March 2016; 4;
4. Consortium/ENA Workstream 3 report "Engineering Recommendation P2 Review (Phase 1), Options for future development of distribution network planning security standard", March 2016.

[10] This evidence primarily emerges from a techno-economic modelling exercise performed by Imperial College. The modelling aims to identify economically efficient investment patterns on representative distribution networks that have been calibrated to represent those in place throughout Great Britain. The data underpinning the analysis (e.g. in respect of network costs and characteristics) was provided by the DNOs through the P2 review process.

assets, the cost of demand curtailment (valued at the Value of Lost Load – VOLL), the failure rates of assets, regular and emergency repair times, performance and cost of alternative supply restoration measures, common mode failures, asset maintenance / replacement duration, use of smart grid technologies and operational measures, load profile, price of electricity and so on.

The modelling shows that, based on the value of VOLL widely used for reliability planning in the British electricity industry (£17,000/MWh), the current standard prescribes minimum levels of network redundancy that are higher than the economically efficient level.

Of course, the finding that P2 prescribes more network redundancy than is economically efficient does not hold in all cases; the consortium's work indicated that it would be efficient to maintain the levels of redundancy currently required in P2 in some circumstances (eg customers connected to less reliable networks). However, the conclusion that P2 generally requires more network redundancy than is economically efficient is robust to extremely high levels of VOLL, orders of magnitude higher than the core assumption of £17,000/MWh and to a wide range of other assumptions of efficient investment. Hence, there is a strong economic case for reform of ER P2/2 to update the minimum levels of network resilience that DNOs are obliged to provide through physical network assets.

Alongside this analysis, the consortium has estimated the potential quantum of savings from this reform under specific load growth scenarios considered by the Committee on Climate Change and former DECC, which may be very substantial, in the order of billions of pounds. However, given the limitations of the modelling conducted to estimate the benefits at the GB level from modifying ER P2/6, which was based on representative rather than real networks including a number of assumptions made that would need to be verified, it would not yet be safe to conclude on the precise quantum of savings to customers from this reform. However, the estimated savings appear to be orders of magnitude higher than the costs of developing and implementing a new standard.

Recommendation 2 – Harnessing the Benefits of Distributed Energy Resource

The modelling examined the effect of distributed energy resources[11] on optimal network planning. These technologies may provide a more economically efficient means of providing supply reliability to customers than the provision of capacity using physical network assets, so incorporating them into network planning may reduce the need for conventional network reinforcement, and/or improve reliability for customers.[12]

The conclusion from this aspect of the modelling is that the contribution of distributed energy resources to network security can be markedly different from the contributions defined in the current standard. Specifically, the contribution of distributed energy resources depends on:

- The reliability of the network and the level of redundancy in the network to which they connect
- For technologies such as storage, the amount of energy that can be stored and the duration over which it can be provided
- The reliability of distributed energy sources, risk of common mode failures in case of multiple distributed energy resources (that may be driven by failures of ICT systems) and relative size of connected distributed energy resources as compared to group demand.

Because these factors are not explicitly considered in the current standard, the analysis suggests there is a case for updating P2 to better represent the contribution of these non-

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[11] Distributed energy resources include technologies such as demand side response, electrical storage and distributed generation.
[12] The Consortium modelling determines the effective security contribution of non-network solutions, using a concept known as modelling the "Effective Load Carrying Capability" of distributed energy resources, which is an internationally established concept used to quantify the security contribution of different technologies.

network technologies to network security. This will be important for optimising the potential of these technologies in reducing overall network costs, and harnessing the benefits they bring through increased supply reliability for consumers.

Recommendation 3 – Allowing DNOs to Make an Efficient Use of Operational Measures and Other Smart Technologies

Another aspect of the study was to examine the role of other smart network technologies in system planning:

- ***Automation***: By modelling the performance of real distribution networks, the consortium has demonstrated that it would be cost-effective to increase the deployment of network automation to improve network performance. Hence, there may be a case for providing guidance on the use of automation to improve network performance in any new standard.
- ***Mobile Generation***: The analysis carried out demonstrated that it could be economically efficient to increase the use of mobile generation at distribution sites to enhance network performance. Hence, reducing restoration times through the operational measures would enable further increase in utilisation of network assets and reduction in redundancy without compromise on reliability of supply.
- ***Emergency Loading of Network Assets***: The modelling also suggests that in some circumstances emergency loading of network assets, both transformers and cables, could be utilised more widely as a means of providing additional network capacity in the short-term. In essence, the analysis shows that the cost of reducing the lives of assets that are overloaded in emergency conditions could be economically justified based on both the extra reliability provided to consumers and the avoided costs of providing the same levels of reliability through reinforcement. It may also be efficient to define network capacity in any new planning standard in a way that allows the use of dynamic rating technologies, as recent trials demonstrate they have significant potential. In addition, the definition of capacity in the standard may also allow and guide the use of dynamic line rating technologies, as work carried out within several Low Carbon Networks Funding projects demonstrated they have significant potential.
- ***Managing Network Overloads Through a Wider Use of Demand Side Management***: The modelling also shows that, if DNOs have the ability to manage network overloads through a wider use of demand side management,[13] the overall levels of security of supply can increase and the economic case for redundancy through physical network assets to secure overall demand reduces. The degree of flexibility that consumers will be willing to offer to DNOs and the compensation DNOs will need to offer customers in return for this flexibility remain uncertain at present, not least because enabling technologies such as smart meters have largely yet to be deployed. However, the modelling evidence shows the case for more fully incorporating these measures into planning standards to harness the benefits of these technologies as they emerge.
- ***Advanced Voltage Management***: Increasing the use of advanced voltage management, or allowing voltage reductions beyond the limits prescribed by present standards, may also improve efficiency as network capability is frequently constrained by voltage rather than by thermal current limits, particularly in LV networks. However, the consortium recognised that this finding is probably more relevant to potential reform of voltage standards than ER P2/6 which focuses on planning for security of supply. Any reform of ER P2/6 should therefore consider any potential future reform of voltage standards.

13 This might arise through customers being willing to offer more extensive demand side response services to DNOs than they do at present, for example.

Recommendation 4 – Accounting for Distribution Losses in Network Planning

The analysis also examined the impact of accounting for distribution losses on optimal network planning. The analysis has demonstrated that the minimum levels of network redundancy resulting from the current standard are higher than the economically efficient level. In essence, in the near-term this modelling shows it would be efficient for DNOs to delay reinforcement, “sweat assets” harder than is current practice, and use smart measures such as automation, demand side management, and distributed energy resources, to mitigate the effects on network performance.

The modelling shows that network design should increasingly be driven by the reduction in network losses. When network assets need to be replaced or reinforced, the modelling has shown that it will be efficient to materially oversize distribution network assets compared to the peak demand they are built to serve in order to achieve efficient levels of network losses. For example, the modelling demonstrates that an optimally sized LV cable would be operated at maximum demand no higher than 12-25% of its thermal rating.[14]

While oversizing of assets does not affect network reliability directly, the oversizing of assets would create a large amount of spare capacity in many network assets. In these cases, it will become economically efficient to use this spare capacity to increase redundancy of LV and HV distribution networks beyond the level currently prescribed by ER P2/6. As well as minimising overall costs by achieving an efficient balance between network costs and losses, this approach to network planning would materially increase network performance.

Recommendation 5 – Ensuring Efficient Levels of Resilience during Construction Outages

The modelling also demonstrated that there is a strong economic case for including some guidance for the levels of resilience that DNOs should provide during protracted outages, such as when they are replacing assets. In particular, the modelling demonstrates that it is economically efficient to mitigate the risks of customer interruption during relatively long-lasting asset replacement works, reducing the exposure of customers to the risk of prolonged outages during these periods.

Recommendation 6 – Planning for High Impact Low Probability Events

The studies carried out demonstrate that common mode failures and/or high impact low probability (HILP) events could expose customers to severe risks of interruptions. In this context the modelling has shown that the concept of conditional value at risk could be applied to limit the probability of severe outages. This may result in an increase in network investment, increase in cost of operational measures, increase in cost of applying non-network solutions such as distributed generation, while cost effectively reducing the consequences of high impact outages. A number of options have been identified, including: robust design of distribution substations with a balanced portfolio of network and non-network solutions, deployment of emergency operation and investment actions to deal with HILP events. There is therefore a need to consider the incorporation of HILP events into any new standard.

For a wide range of reasons described above, the work conducted to date has demonstrated that there is a strong economic case for the reform of ER P2/6.

8.1.8 Workstream 8 – Programme work for Phase 2

Phase 1 of the ER P2/6 review has concluded that two high level options for reform of the present ER P2/6 should go forward to Phase 2 for the more detailed review process to

14 Note, there is a link between decisions by DNOs to oversize network assets compared to peak demand in order to achieve an economically efficient level of losses, and the connection charges faced by new network users. We do not discuss these interactions here as they are outside of the scope of this review of P2.

deliver the new ER P2 documents. The final workstream 8 report[15] referenced in Appendix 13.7 also provides conclusions regarding the use of distributed energy resources (DER), operational measures, losses, construction outages and high impact low probability events associated with these options. The two high level options are:

8.1.8.1 Option 1 – A new deterministic standard[16], with updated requirements in respect of the supply security DNOs are obliged to provide:

- The new standard should cover the key drivers of the economic level of network reliability, potentially including:
    - Network load ("group demand")
    - Network type (different mixes of OH and UG)
    - Network failure rates
    - Restoration times
    - Repair times
    - Network upgrade costs
    - Load profile
    - Cost of interruptions
    - Use of smart grid technologies.
- It will also need to enable reliability to be provided in the most efficient way, making an efficient trade-off between network and non-network technologies, accounting for:
    - Network reliability performance
    - Economic levels of network redundancy.

8.1.8.2 Option 2 – A new standard making some limited use of deterministic elements to set minimum reliability requirements, but with an obligation (that would apply in circumstances defined in the standard) to conduct cost benefit analyses (CBAs) to identify the appropriate level of supply security to provide beyond these minimum values. The key drivers listed for option 2 are also applicable to the CBA approach here.

- In developing this option, Phase 2 of the review will need to identify areas where it is possible to codify efficient investment rules in simple tables, and areas where placing more emphasis on conducting CBAs to select optimal investments could improve efficiency.

Option 2 will also need to include work to develop guidance on conducting CBAs[17] as part of the Phase 2 process. Further, through the review of ER P2/6 a range of other conclusions were reached, listed below, which should be carried forward into Phase 2.

- Any new standard **should not** make any requirements in respect of the redundancy that should be built into the direct connection of embedded generation to a shared DNO network
- To ensure efficiency at the transmission and distribution levels, any **new standard** should consider the possible need to align with the provisions in the National Electricity Transmission System (NETS) Security and Quality of Supply Standards (SQSS). However, given the DCRP is conducting a fundamental review of P2/6, Phase 2 should not be constrained by provisions in the current NETS SQSS

[15] Consortium report "Engineering Recommendation P2 Review (Phase 1), Summary Report for the Energy Networks Association", report number 16011094/900, 25 August 2016.
[16] In this context, a deterministic standard is defined to be one in which network reliability requirements are specified based on parameters and criteria defined within the standard
[17] The Consortium recognises that the DCRP P2 Working Group has some considerable experience with conducting CBA. However, some stakeholders have asked that this guidance be provided which may make the CBA process more efficient. For instance, the guidance could specify parameters for which it is hard to form representative assumptions (like VOLL). Guidance on how CBAs should be conducted would also be useful for checking regulatory compliance.

- Any new deterministic standard **should** include guidance on the contribution to system security from non-network technologies
- Any new deterministic standard **should** provide separate guidance as to the measures that DNOs should put in place during construction outages, separately from those measures that DNOs should put in place during maintenance outages and unplanned outages
- The new standard **could** consider extreme events such as common mode failures (CMFs) and high impact low probability (HILP) events. In this context, as demonstrated in case studies carried out in Phase 1, the concept of conditional value at risk could be applied to limit the probability of severe outages. The case for including this concept in the new standard should be considered during the Phase 2 review works.

The aim of Phase 2 is to assist the DCRP P2 working group[18] in selecting the most appropriate option for the new ER P2 Security of Supply and to codify this into the final working documents. This may require translating each of the two recommended options for revision of ER P2/6 into a working format of tables, rules and guidance and then carry out a full economic impact assessment. The impact assessment will require application of the working format for both ER P2 review options against a range of real network scenarios. Further in Phase 2 once again a DCRP P2 working group and wider industry engagement and consultation will support the decision to adopt one of the two revision options to go forward to codification.

Therefore, to deliver the Phase 2 review output a number of fundamental tasks require to be carried out which would consist of a number of workstreams. The outline detail for each workstream forming the overall high level plan for Phase 2 was provided in the report. The plan assumes participation of a DCRP P2 working group and a delivery consortium employed to deliver the majority of the Phase 2 programme. To provide a full high level programme, tasks are included in the plan that would require delivery by parties other than the appointed consortium.

In order to transfer the learning from Phase 1 of the ER P2/6 review, the workstream descriptions contained in the report assume that the DCRP P2 WG is retained to oversee Phase 2 of the review. If a consortium or consultancy is required to support Phase 2 then this selection would be undertaken via a competitive tender process.

9 REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT *

9.1 Modifications to the Planned Approach

With the exception of the project overrun which is explained in section 9.2 there were no major changes required to the planned approach to the review of ER P2/6.

9.2 Cost Variance Table

Workstream/ sub Workstream	Description	Deliverable	Cost	Variation	Registered Value
1.0	Project Initiation	Issue of initiation paper	£29,874		
2.0	Assessment of P2/6 and Identifying Options for Reform	A summary report covering key highlights from the stakeholder engagement / Interview activities	£75,980		

[18] Reference is made throughout this document to a DCRP P2 working group, this was a group of industry stakeholder and customer representatives appointed by the DCRP to oversee the relevant Phases of the review and ensure stakeholder support where required eg provision of data, review of model inputs and outputs, review of output documents etc.

Workstream/ sub Workstream	Description	Deliverable	Cost	Variation	Registered Value
2.1	Framework for assessing security performance and measures and characteristic network designs	Framework for the development of future network design standards	£46,410		
2.2	Service quality and cost effectiveness of the present network design practises	Summary report that will feed into the ‘options’ milestone report	£37,573		
2.3	Risk associated with asset replacement, common mode failures and high impact events	Summary report that will feed into the ‘options’ milestone report	£27,144		
2.4	Impact of smart grid technologies on service quality risk profile	Summary report that will feed into the ‘options’ milestone report	£26,078		
2.5	Assessment of impacts of alternative control and operation strategies on security of supply	Summary report that will feed into the ‘options’ milestone report	£20,140		
2.6	Loss inclusive design of distribution networks and impact on security of supply	Summary report that will feed into the ‘options’ milestone report	£15,834		
2.7	Alignment of security of supply standard in distribution networks with other codes and scheme	Summary report that will feed into the ‘options’ milestone report	£41,808		
2.9	Options for future development of distribution network standard.	Summary report that will feed into the ‘options’ milestone report	£53,643		
3.0	P2/6 Options Report	P2/6 Options Report	£33,166		
5.0	Stakeholder Engagement Report: Workshop	Stakeholder Workshop Report.	£32,968		
6.0	Formal Strategy Consultation for P2/6	Formal Strategy Consultation Paper for P2/6	£39,291		
7.0	Detailed review and analysis of consultation responses	Tabulated view of all question responses and actions to be taken with regards to final Phase 1 report	£34,289		
8.0	Phase 1 recommendations	Phase 1 final report	£34,362		
9.0	Programme work for Phase 2	Work programme for Phase 2 – project plan and supporting documentation	£29,536		
Totals			**£578,096**	**£71,904**	**£650,000**

The original scope of work and costs was based on a 12 month programme and included the project management tasks associated with a 12 month project. The project kick off meeting was on 26 January 2015 with the project programme originally set for completion on 25 January 20161. Programme completed 1 July 2016.

Delays to the delivery of Phase 1 were estimated at 3.5 months and are detailed below.

Delayed WS 2 Data Requested for Imperial College Modelling

A near complete data set was made available to the consortium on 21 June 20153. The initial programme included two weeks for receipt of data. This resulted in a 3.5 month delay to the overall programme.

To assist in the management of the process of data gathering by the DNO WG members, the consortium spent additional (unbudgeted) management time setting up, chairing and summarising and disseminating the actions from four conference call meetings and the follow-up actions (21 and 28 April, 12 and 26 May 2015). The additional consortium project manager time for this task is estimated to be two days in total.

Delayed WS2.0 Questionnaire Responses and Interviews

WS2.0 involved DNO responses to a set stakeholder engagement questionnaire with a follow up one to one interview to clarify the questionnaire responses. This information was part of the WS2.0 qualitative analysis carried out which resulted in a report forming part of the evidence base for the WS2.9 options report.

The questionnaire was issued as planned on 11 May 2015 and the original meeting plan proposed was to have all DNO interviews complete by 22 May 2015 with a fall back completion date of 29 May. This was well communicated at the WG prior to the dates. Some DNOs were late in responding to the questionnaire or to agree interview dates or both resulting in a ten-week delay. In addition the consortium spent additional management time chasing WG members for questionnaire responses and seeking agreement on interview dates estimated at two days.

The impact of both delay sources detailed above on the overall programme was 3.5 months out of the overall estimated programme delay of five months

The remaining 1.5 months delay was predominantly due to a combination of late issue of the Imperial College draft report and extending the review period for WG members to review the report and provide feedback. Imperial College's work required a greater volume of studies and input than expected at the outset, some of which was additional work requested by WG members. The WG members also required additional time to review the Imperial College report. However, the consortium considers that this element of the overall programme delay is a shared issue with the WG and did not request any variation for the associated 1.5 month delay.

Although the consortium demonstrated a 3.5 month delay to the programme which was outside of their control they agreed that the impact of the five-month delay should be shared equally between the consortium and the WG. Hence they reduced the cost impact on the consortium from a 3.5 month delay to 2.5 months, in revising their variation cost.

10 LESSONS LEARNED FOR FUTURE PROJECTS

Although there were no major changes required to the planned approach to the review of P2/6. There were two specific lessons that would need to be considered in the planning of the Phase 2. They are as follows:

10.1 Stakeholder engagement and feedback and questionnaire responses and Interviews

A key part of the P2/6 Phase 1 review was to gain a detailed understanding of the position of the many industry stakeholders as a starting point for the consortium's qualitative analysis. The most effective way to understand the current status and thoughts of the industry was through engaging with and receiving feedback directly from the industry stakeholders. The qualitative analysis tasks began with a set of high level and then detailed questions to seek and gain the views of the many stakeholders regarding their thoughts and views on the status, usability and adequacy of the existing P2/6 security standard and on the future development of the standard. To ensure that the views and comments for all relevant industry parties were sought and recorded, the stakeholders were split into two broad categories:

Category 1 – stakeholders who make use of ER P2/6 on a regular basis and where P2/6 has a direct impact on their business (DNOs and NGET) and those who have responsibility for oversight (DECC and Ofgem).

Category 2 – the wider group of interested parties and industry participants who do or may have had an interest in the ER P2/6 review. This wider group of stakeholders included representatives from offshore transmission owners, independent DNOs (IDNOs), and trade bodies and organisations covering traditional and renewable resources ie solar, conventional and renewable generation, hydro generation, demand side response and domestic customers.

The questionnaires and interviews were designed to support the review analysis activities, particularly the qualitative analysis, and to ensure that relevant industry stakeholders had the opportunity to provide significant input into the final output.

Of the many dozens of organisations invited to respond to the questionnaire by use of the DCRP mailing list the consortium received completed questionnaires from only 14 respondents plus two organisations that provided verbal responses through interview only. A number of the 14 respondents represented trade bodies and organisations and hence represented the views of a number of their member organisations. The consortium and the DCRP P2 WG believe that all key stakeholders had been invited to respond to the questionnaire and that the views of the majority of key interested stakeholders have been received. The follow up interviews were also a problem to arrange and agree dates due to the busy schedules of those being interviewed.

10.2 Data Requested for Imperial College Modelling

Due to the significant amount of data that was requested by Imperial College from the DNOs the time taken to collate and submit the required data exceeded the timescale set out in the plane. This resulted in a delay in the project and added to the variance in the overall cost of the project. Please see section 9.2 for further details.

11 PLANNED IMPLEMENTATION

Implementation of Phase 2

The scope of the potential changes suggested by Phase 1 is very significant but the final report lacks detail on important implementation issues. As such Phase 1 could not be implemented by the DCRP without additional detailed work being undertaken. The DCRP met in December 2016 to both review Phase 1 and to determine how to structure and expediently progress to implementation. Mindful of the costs incurred in Phase 1, the DCRP asked a DNO sub group to devise the Phase 2 implementation framework.

Two DNO workshops were held in February and a further two in March 2017, Ofgem were invited and attended the first of these workshops. The scope of the four workshops is detailed in Appendix 13.8. The sub group report is currently being compiled and will be submitted to the DCRP P2 working group (including Ofgem BEIS and others) for consideration and approval. It is expected that the DCRP stakeholder working group will test the workshop output against their terms of reference.

It is likely that the Phase 2 implementation work will be structured in two sub phases:

Phase 2a – This will modify a number of the technical aspects of P2/6 and add clarity to the treatment of DER resources to bring benefits to customers. These changes have been the primary focus of the four workshops and in the main the changes are compatible with the overall RIIO-ED1 regulatory package.

Phase 2b – This will address those items requiring more fundamental changes and with which there are potentially associated regulatory discussions needed.

It is expect that the Phase 2a changes will be drafted into a set of formal recommended changes to ER P2/6 and supporting Engineering Technical Report 130 towards the end of

2017. In line with open governance procedures these will be submitted to the DCRP, most likely in December 2017 or March 2018 for approval to proceed to consultation, and then followed by a final report to the Authority. Once the 2a changes have been accepted by DCRP work will commence on phase 2b.

Once this approach has been ratified by the DCRP P2 working group a detailed Phase 2 project delivery plan will be produced including all project milestones and deliverables. For information a high level timeline for Phase 2 is included in Appendix 13.9.

12 FACILITATE REPLICATION

As set out in condition (24.1) of the standard conditions of the Electricity Distribution Licence, DNOs will be required to apply any new requirements set out in revised ER P2, as they have a duty to plan and develop their distribution networks with a standard not less than that set out in Engineering Recommendation P.2/6.

All reports published during the course of the review are available for all DNOs and stakeholders and can be located on the DCode website[19].

13 APPENDICES

Appendices 1 – 8 are available as separate documents at www.enwl.co.uk/niaprojects.

Appendix 1: Project Initiation Paper

Appendix 2: WS 2.0 – Qualitative review – Findings of the qualitative review associated with the future development of the P2/6 distribution network planning security standard

Appendix 3: WS 2.1-2.6 – Imperial College's Report – Review of Distribution Network Security Standards and Extended Report Appendices

Appendix 4: WS 2.7 – Alignment of Security of Supply Standard in Distribution Networks with Other Codes and Schemes

Appendix 5: WS 3.0 – Options for future development of distribution network planning security standard

Appendix 6: WS7.0 – Analyses of Responses to the Consultation on future development of distribution network planning security standard

Appendix 7: WS 8.0 – Summary Report

Appendix 8: WS 9.0 – Phase 2 Outline Programme and Plan

[19] http://www.dcode.org.uk/

Appendix 9: Summary of DNO scoping workshops:

Workshop 1: Defining the purpose of P2/6 and a new/revised P2/7 – held on 13 February 2017

- What is the purpose P2/6? Is it a demand or demand & generation standard and should it include operational standards as well as design.
- Going forward as distribution networks become more active, is P2 fit for purpose if it remains purely demand security based without network capability guidance/ direction?
- Even if P2 does not plan network capacity, should it provide tools to help estimate the increased contribution of generation and other DER within its networks?
- Is it best to change ETR 130/131 or P2 itself?
- How should P2/6 or any revised standard link to and align with SQSS in the future?

Workshop 2: Defining demand – held on 27/2/17

- Defining demand – how is it calculated?
- Impacts of definition on SQSS
- Week 24 data implications
- Visibility of demand/generation (latent)
- Treatment Flexible vs. inflexible demand and the consideration of diversity factors for generation and demand
- Identifying regional aspect to demand and generation. Workshop 3: Automation and Demand/Generation Side Response – 10/3/17
- Assessing the treatment of active network management (ANM)
- Automation and transfer capacity – how are these treated?
- Reliability of DSR, time of use tariffs and other technologies.

Workshop 3: Automation and Demand/Generation Side Response – held on 10/3/17

- Assessing the treatment of active network management (ANM)
- Automation and transfer capacity – how are these treated?
- Reliability of DSR, time of use tariffs and other technologies.

Workshop 4: F-Factor Contribution – held on 17/3/17

- Assessment of existing f-factors
- Evaluation of 2017 persistence supported by a consultant if required
- Identifying the contribution of directly vs. indirectly contracted storage (and other technologies)
- Assessment of the interaction of f-factor and continuous vs. cyclic ratings
- Modifications to ETR 130 and ETR 131 which should be considered.

Appendix 10: High Level Phase 2 timeline

Phase 2a	
DNO scoping workshops report to DCRP	Q2 2017
Review with DCPR	Q3 2017
Open consultation on forward options with stakeholders	Q3 2017
Work up changes to P2 for P2/7 based on stakeholder feedback – using customer panel to validate changes	Q3 2017
Formal DCRP proposal for modification	Q4 2017
Consultation	Q1 2018
Implement P2/7	Q2 2018
Phase 2b	
DNO assessment of potential impacts and savings	Q3 2017
Identify options for future demand security – firm/essential v flexible demands – requirements for future services inc transport and heat	Q1 2018
Establish informed stakeholder panel (academic, customer (Citizens Advice – other social representatives), suppliers, service providers, storage operators, generators, transportation – public and vehicle providers.	Q2 2018
Undertake stakeholder consultations to assess economic and societal values and impacts expressed in feedback from phase 1	Q3 2018
Develop options for P2/8	Q3-4 2018
Consult on options	Q1 2019
Recommendations to DCRP, Ofgem and BEIS	Q2 2019