

Open Networks Project Workstream 1: Product 1 Key learnings from trial projects

16 August 2017

Energy Networks Association

Document Ref: ON-WS1-P1 Key Learnings-170816

Restriction: None

Document Control

Version Control

| Version | Issue Date | Author | Comments |
|---------|------------|-----------------------|-----------------------|
| | 16/08/17 | Open Networks Project | Issued for Publishing |

Table of Contents

| | | |
|----------|---|-----------|
| 1 | Introduction | 2 |
| 2 | Customer Load Active System Services Project - CLASS | 3 |
| 2.1 | Description of the project..... | 3 |
| 2.2 | Key learnings | 3 |
| 3 | Statements of Work Trial | 5 |
| 3.1 | Statement of Works..... | 5 |
| 3.2 | Key learnings from Trials..... | 7 |
| 3.2.1 | Learnings from an English DNO trial | 7 |
| 3.2.2 | Learnings from a Scottish DNO trial | 8 |
| 4 | Regional Development Program | 10 |
| 4.1 | Data sharing | 10 |
| 4.2 | Modelling Enhancements..... | 10 |
| 4.3 | Other Learning Points | 12 |
| | Appendix 1: Glossary | 13 |

List of Figures

| | |
|--|----|
| Figure 1: Original Statement of Works process..... | 5 |
| Figure 2: Revised Statement of Works process trialled in England & Wales | 6 |
| Figure 3 Revised Statement of Works process trialled in Scotland | 6 |
| Figure 4: Voltage profile during a fault event | 11 |
| Figure 5: Phase Angle during a fault event | 11 |

List of Tables

| | |
|--|---|
| Table 1: CLASS project – key outcomes..... | 3 |
|--|---|

Executive Summary

This report is part of the ENA Open Networks Workstream 1 – Product 1: Mapping current SO, TO and DNO processes. It seeks to capture important learnings from key projects and programmes of work that have been developed by DNOs and National Grid. The report is focusing on the following three projects and provides the outputs to date:

Customer Load Active System Services (CLASS): The project was run by Electricity North West & National Grid and investigated the effects on the electricity demand by controlling network voltage. One of the key findings of the project was that there was a mathematical relationship between voltage and demand. In summary, the project proved that DNOs can deploy voltage control equipment to provide alternative, low cost, carbon saving and flexible solutions to support National Grid for frequency and demand control, as well as reactive power regulation, without compromising the customers' quality of supply. Additional benefits may include potential reinforcement deferrals and a considerable reduction in carbon emissions.

Statement of Works Trial: Following the work undertaken by the ENA Statement of Works Working Group, trials to test a revised process were launched by National Grid, with a number of DNOs taking part: Western Power Distribution, UK Power Networks, Scottish & Southern Electricity. SP Distribution launched a separate trial with National Grid which sought to trial a streamlined Statement of Works process, developed from the established methodology. The overall aim was to modify the Statement of Works process with the intention of reducing timescales and costs; removal of invoicing issues; providing increased visibility of Distributed Generation (DG)¹ to National Grid; and including details of the transmission impact, where possible, within the DNO offer. According to the proposed process, DNOs would make a Modification Application and provide the SO with technical details about existing and contracted DG. The TO would then study the implications of DG connections, evaluate the impact on the transmission system and provide technical limits as well as a materiality headroom (in the SP Distribution trials this was a Planning Limit rather than materiality headroom) for every Grid Supply Point (GSP). DNOs would be aware of transmission impacts in advance and would be able to expedite the connection process for customers. Work is continuing through the Open Networks Project: WS1: Product 7, to further refine and improve the process.

Regional Development Programs (RDPs): National Grid is running RDPs with UK Power Networks and Western Power Distribution to assess the potential for increasing the network capacity for DG and consider whole system solutions to managing constraints. The RDPs review and update operational and planning approaches in the study areas, by improving interfaces, data models, planning assumptions and processes. The project focuses on data sharing and system modelling enhancements. It looks to improve the connection process for customers and considers the optimisation and coordination of Active Network Management (ANM), a whole system approach to managing Loss of Mains protection issues and resolutions to service conflicts. Both programmes of work are still continuing.

¹ Otherwise referred to as Embedded Generation (EG)

1 Introduction

This report is part of the ENA Open Networks Workstream 1 – Product 1: Mapping current SO, TO and DNO processes. It seeks to capture important learnings from key projects developed by DNOs and the SO/TO; the report is focusing on the following three projects:

1. Customer Load Active System Services (CLASS): The project was run by Electricity North West and National Grid.
2. Statement of Works Trial: Trials to test a revised process were launched by National Grid, with a number of DNOs taking part: Western Power Distribution, UK Power Networks, Scottish & Southern Electricity and Scottish Power Distribution.
3. Regional Development Programs (RDPs): National Grid is running RDPs with UK Power Networks and Western Power Distribution DNOs to assess the potential for increasing the network capacity for DG and consider whole system solutions to managing constraints.

2 Customer Load Active System Services Project - CLASS

2.1 Description of the project

Electricity North West's (ENW) Customer Load Active System Services (CLASS) project investigated the effects on the electricity demand by controlling network voltage. The CLASS project installed new voltage control equipment in 60 of their primary substations and monitored them over a year, looking at the effects of varying the primary substations tap changer position to control real and reactive power demands, as well as the effects of switching out primary transformers for frequency response. All of this data and control was enabled back to National Grid through the use of an Inter-Control Centre Communication Protocol (ICCP) link so both control rooms, ENW and National Grid, could monitor the system effects and for National Grid to activate them.

The following table presents the main outcomes of the project:

| Output | Description |
|---|---|
| Load characteristics | Methodology to characterise substation load, based on customer type using the Common Distribution Charging Methodology and Elexon load profiles |
| Voltage controlled demand capabilities | The Project has shown that the use of innovative voltage control techniques can provide demand response services and the Solution can be deployed by all DNOs GB-wide |
| Monitored data | Full year's data from all trial substations |
| Voltage/demand relationship | The results of the CLASS trials have produced a mathematical quantification of the relationship between voltage and demand which supports the hypothesis |
| Voltage/demand matrix | From the results of the trial data the University of Manchester have constructed a demand/voltage matrix which will become part of the planning engineer's tool kit |
| Voltage control technology | The retrofitting of new technology onto old technology has been deployed successfully |
| ICCP link between Electricity North West and NG control centres | The ICCP link has provided NG with enhanced visibility of Electricity North West demand data and opportunity to access services through the ENW switching its network assets. |
| Regulatory impact | Assessment of the methodology and trial results have demonstrated that no changes are required to regulatory standards, namely SQSS, DCODE, GCODE |
| Ancillary services market | The trials have shown that DNOs could provide ancillary services for demand reduction during frequency events and reactive power absorption to reduce high voltage on the NG transmission system during minimum load periods |
| Asset health | The CLASS methodology will cause increased tap change switching and shock loading of transformers when providing frequency response. The studies carried out by the University of Manchester and University of Liverpool have indicated a negligible impact on asset health |
| Customer engagement | Robust customer research has demonstrated that the use of voltage reduction techniques does not cause any detriment to customers' perception of quality of supply |
| Carbon impact | The carbon impact of the deferment of traditional network reinforcement has been identified through modelling, along with the carbon benefits of the CLASS service to the frequency and reactive power markets |

Table 1: CLASS project – key outcomes

2.2 Key learnings

This section describes the key learnings derived from the CLASS project.

One of the key findings of the project was a mathematical relationship between voltage and demand, allowing the estimation of the demand response for different load compositions:

- Mainly domestic
- Mainly industrial/commercial
- Mixed

This relationship, although theoretical, is quite useful for estimating the available demand response in operational timescales.

During the trials, it was found that a 1% voltage reduction at a primary substation resulted in an average real power reduction of around 1.3%. Extended to a national level, the total demand reduction could go up to 3.3GW. Moreover, a similar voltage reduction led to an average reactive power reduction of around 5.5%, which could scale up to 2GVAR if applied at the entire GB system. However, further work is needed to explore this areas as other voltage reduction tests suggest much lower reactive power impacts.

Another key finding of the project was the recognition that the CLASS methodology can be used to offer balancing services to NG, namely fast reserve (FR), frequency control management demand (FCDM) and firm frequency response (FRF), using automatic relay operation for a non-dynamic response.

Potential compliance issues were identified at the start of the project. However, a review of the National Electricity System Security and Quality of Supply Standard, SQSS, and other relevant standards and codes (e.g. Distribution and Grid Codes) showed that no amendments are required for DNOs to apply the proposed methodology.

In summary, the project was successful in proving that DNOs can deploy the proposed technology to provide alternative, low cost, carbon saving and flexible solution to support National Grid for frequency and demand control as well as reactive power regulation without impacting the customers' quality of supply. Additional benefits may include potential reinforcement deferrals and considerable reduction in carbon emissions.

More information about the project and its key learning can be found in the close down report available on the project's website.

3 Statements of Work Trial

3.1 Statement of Works

In 2014 National Grid launched a Trial with a number of DNOs with the aim to test proposed changes to the Statement of Works (SoW) process. DNOs are obliged under the Connection and Use of System Code (CUSC) to not energise the connection of a Relevant Embedded Medium Power Station or a relevant Embedded Small Power Station nor permit the Use of its Distribution System unless it has followed section 6.5 of CUSC which includes the SoW process as well as Project Progression. These processes involve assessing the potential impact of embedded generation on the National Electricity Transmission System (NETS). CMP238 permits a DNO to omit the SoW stage of the process and move directly on to Project Progression where there is a known transmission impact. The diagram below is an illustration of the traditional process being followed.

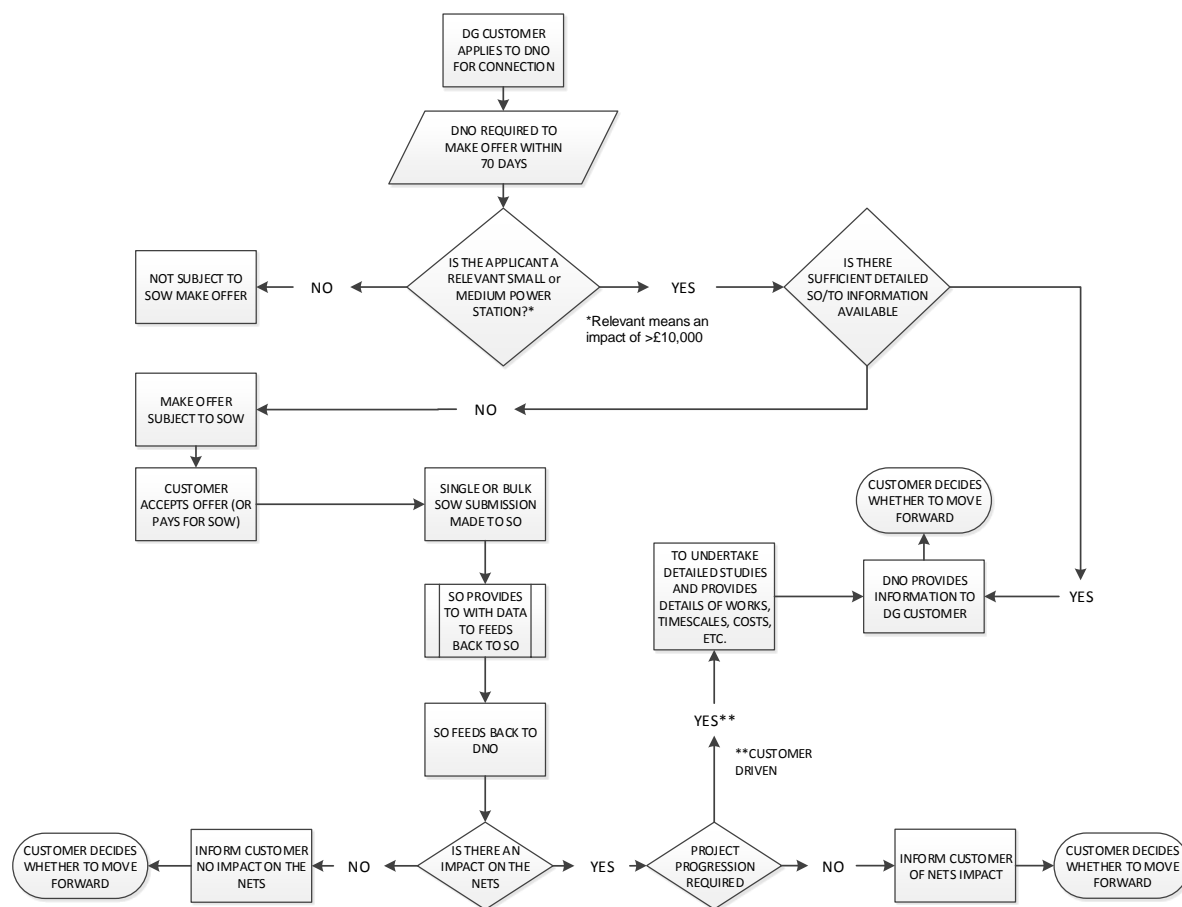


Figure 1: Original Statement of Works process

The proposed changes aim to reduce timescales and costs; removal of invoicing issues; provide increased visibility of DG to National Grid; and include details of the transmission impact, where possible, within the DNO offer.. The DNO will make a Modification Application and will provide the SO with technical details including a list of embedded generators (DG) connected, contracted to connect (and applying/forecast to connect) beneath each GSP along with relevant information such as their size, point of connection, technology type and fault level contribution.

The TO will then study the implications of DG connections and evaluate the impact on the transmission system and provide technical limits as well as a materiality headroom (in the SP Distribution trials this was a Planning Limit rather than materiality headroom) for each GSP (or group of GSPs with shared headroom). These limits may be subject to technical or operation conditions agreed between the DNO and SO/TO. The SO will then make a Modification Offer to the DNO in the form of a revised Bilateral Connection Agreement (BCA) and Construction Agreement. The headroom

and other relevant information will be included in Appendix G, which is attached to the Bilateral Connection Agreement (one for each GSP). The BCA and Construction Agreement will be signed by the SO and the DNO. The DNO can then assess DG applications and only initiate a further modification application when the total generation exceeds the materiality headroom.

The following diagram is a representation of the above process as trialled in England & Wales:

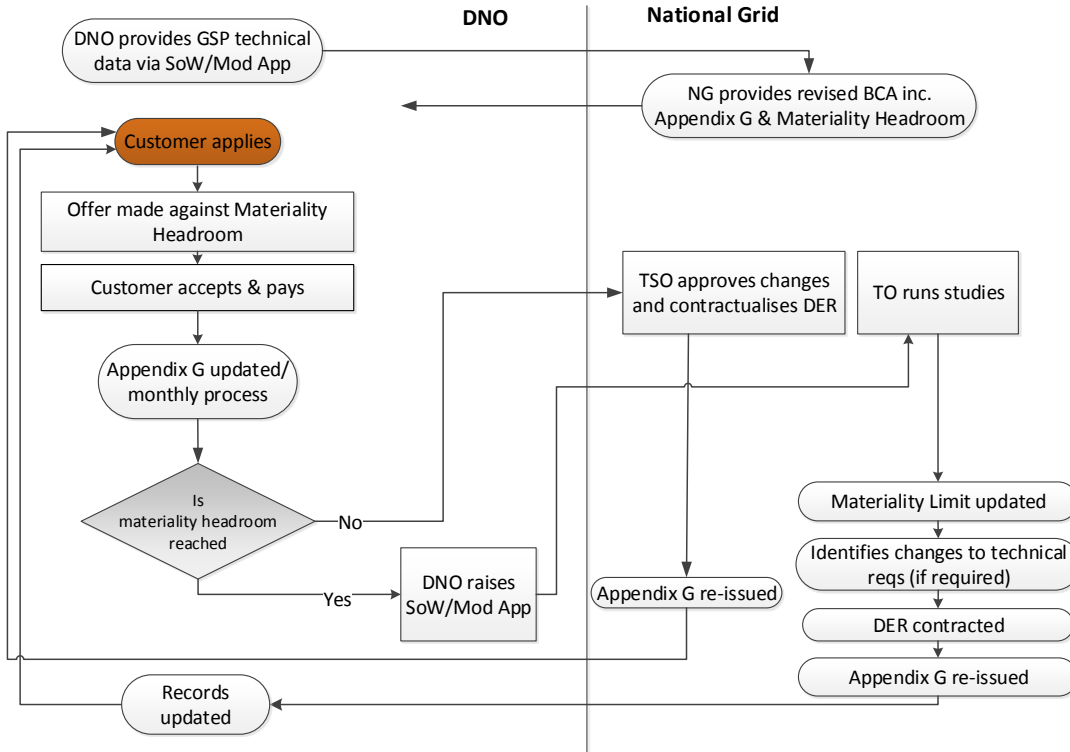


Figure 2: Revised Statement of Works process trialled in England & Wales

The following diagram is a representation of the process as trialled by SP Distribution:

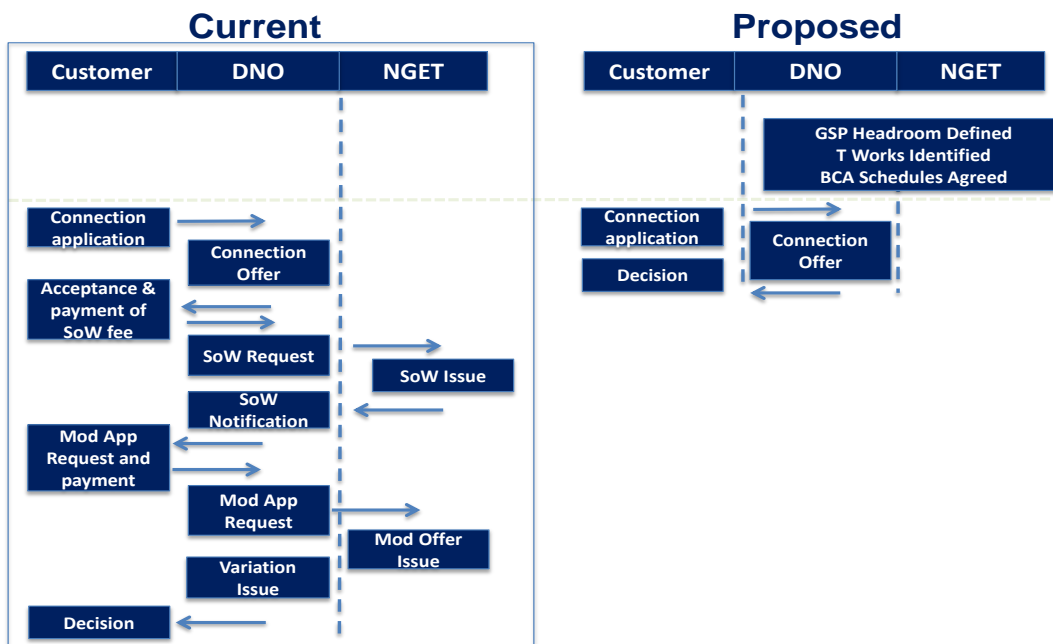


Figure 3 Revised Statement of Works process trialled in Scotland

3.2 Key learnings from Trials

This section lists a number of key learnings from the SoW Trial applied to one DNO in England and one in Scotland. These learnings are taken from the ENA Statement of Works Working Group report dated March 23rd 2017.

3.2.1 Learnings from an English DNO trial

- Most Appendix G's had an initial Materiality Headroom of 50MW, although a few on constrained parts of the network had much lower headroom's. The proposals, with materiality limits, worked quite well on GSPs with a low or modest volume of enquiries, and proved to be a significant improvement in the customer experience.
- Where regional studies have identified transferability of capacity between GSPs, this was seen as beneficial.
- Where GSPs have a high volume of enquiries, then the time it takes to evaluate and obtain a revised materiality limit leaves the DNO in the situation of not being able to provide DG customers with certainty of the transmission impact for a period of time. Where the network is constrained and full studies are required, this is not unreasonable, but where it is known that capacity is spare and a Materiality Limit has been used to avoid sterilising capacity, it does not provide customers with the anticipated improved experience.

Learning point: Consider introducing a quicker process to provide an increased Materiality Limit where it is known that no transmission works are required

Learning point: Develop and make Planning Limits available (requires an effective interactivity process).

- Whilst DNOs can proactively submit modification applications to provide an advanced view of the capability of the system, the need to provide suitable data has led to some DNO's seeing this option as a barrier.

Learning point: An alternative process for DNO's to speculatively apply for a view of future system capability should be considered.

- The Appendix G monthly update cycle includes validation by National Grid. This validation is intended to be a formality and only check that the conditions and limits have been applied correctly. Some DNOs felt the wording on the formal variation to the BCAs facilitating the Appendix G process did not provide them with sufficient comfort to send DG offers that were not subject to this validation, whilst others were able to send firm offers.

Learning point: Review the wording as part of the CUSC process to ensure all parties are comfortable with it.

Learning point: Undertake work across the DNOs to understand the reasons why this clause is viewed differently and work towards common terms in the DNO/DG offer

- DG Customers appear to not be aware of the implications of being on an Appendix G, in particular relating to:
 - Change in Capacity (part 1 vs part 2 customers)
 - Technology Technical details changes
 - Security implication and cancellation charges

Learning point: DNOs to develop communication strategy (e.g. ICE) to raise Customer awareness of the implications of being on the Appendix G Schedules

Learning point: National Grid to work with DNOs to ensure common understanding of Appendix G processes.

- Security charges are currently worked out every 6 months in accordance with CUSC, this can be seen as inconsistent with the rapidly changing DG world

Learning point: Consider this further as part of work on securities.

- There is a lack of understanding on how to show hybrid sites (mixed technology sites), sites with export limiting schemes and GSPs where the DNOs have ANM.

Learning point: Consider this further as part of further development work.

3.2.2 Learnings from a Scottish DNO trial

The Trial was applied at 4 GSPs.

GSP 1 – All 3 offers were issued detailing the known transmission system works, associated charges/securities along with the completion date. All were subject to a further Modification Application to upgrade the GSP as the planning limit had been fully utilised. In addition, a further application was received which triggered the requirement for a new GSP.

GSP 2 – Single offer issued detailing the known transmission system works, associated charges/securities along with the completion date. This GSP is ANM enabled allowing DG to connect whilst being managed against the agreed planning limit.

GSP 3 – Under GSP 3, where the planning limit has been exceeded during the course of the trial, offers have been issued on an interactive basis such that the first offer to be accepted will be able to progress connect without the requirement for any GSP upgrades. Subsequent all remaining offers will be withdrawn and reissued subject to active network management against an agreed planning limit, maximising the available capacity and avoiding the requirement for further transmission system works. Under the trial, in excess of 10 offers have been issued.

GSP 4 – Single offer issued detailing the known transmission system works, associated charges/securities along with the completion date. This GSP is ANM enabled allowing DG to connect whilst being managed against the agreed planning limit. A 2 stage offer has been issued, Stage 1 ANM, Stage 2 – firm access upon completion of transmission system works.

Early Findings

- Visibility and understanding of the planning limit and known transmission constraints has provided the DNO with the ability to make a complete offer product minimising the need for referral to the SO

Key learnings from trial projects

- Timescales to provide transmission impact reduced significantly from that experienced by DG under existing SoW process as all information has been included within the DNO offer.
- Reduced capacity reservation from accepted offers awaiting clarification of the transmission impact via the existing SoW Modification Application process (no offers have to date been accepted under the trial)

The SO has provided the DNO with the ability to calculate Wider System Cancellation Charges and associated Security.

4 Regional Development Program

In order to accommodate additional capacity for DER, National Grid has set-up Regional Development Programs (RDPs) with UK Power Networks and Western Power Distribution to focus on areas where significant network reinforcements are necessary to overcome transmission restrictions emerging from the proliferation of DER. National Grid is working with the respective DNOs to find alternatives to costly and lengthy reinforcements. These RDPs will also inform the development of Whole System processes that can be widely used across GB.

The RDPs review and update operational and planning approaches in the study areas by improving interfaces, data models, planning assumptions and processes. Connection and control arrangements for DER are being designed from a Whole System perspective to improve the utilisation of capacity and the connection experience for DER customers. In the different areas, some aspects of the work have greater impact. For example, in the UK Power Networks area, improved dynamic models are being applied. In the Western Power Distribution area, scenario planning is being improved. Through the RDPs, National Grid, UK Power Networks and Western Power Distribution are finding smarter ways to manage the network and increase its DER capacity without compromising its safe and stable operation.

Two specific objectives that have been completed, are i) Data Sharing and ii) Modelling Enhancements. These are discussed further in the following sections.

4.1 Data sharing

A level of data exchange between the SO and the DNOs is carried out as part of defined Grid Code processes (e.g. Week 24, SoW). However, it was identified that more information need to be shared for the SO to be in a better position to study the stability of the system and the impact of embedded generation. The additional data include:

- BSP Net demand data (MW and MVar) – demand net of any embedded generation at agreed timestamps (e.g. minimum summer demand coincident with maximum PV output)
- Demand data split between directly connected at EHV and HV networks
- Embedded generation by technology type (including small generators down to G83) aggregated at EHV and HV networks
- Loss of mains information (MW and technology type). Accurate information on the number of MW per type of LoM and type of technology can be used by the SO to estimate the generation being at risk during transmission events.

4.2 Modelling Enhancements

Another key learning from the RDP projects is the requirement for enhanced modelling of the transmission and distribution network. The benefit of increasing the number of modelling scenarios emerged as key for releasing capacity at the transmission network. Different scenarios reflect different timestamps, such as time of summer minimum demand coincident with maximum PV output.

In addition, it was recognised that it is important to extend the dynamic studies into the distribution networks in order to fully assess and understand the behaviour of embedded generation for events occurring at the transmission level. The importance of such studies was highlighted by an actual event during which a large number of embedded generators were mistakenly disconnected due to a fault on the transmission network in the southern part of the country. Issues like these pose significant risks to the stability of the network and need to be studied and mitigated.

The diagrams below have been extracted from two of the enhanced studies discussed above with the first one corresponding to the voltage profile of an 11kV bar, while the second to its phase angle. The purpose of the studies was to investigate the behaviour of generators connected to the 11kV network under a transmission fault. In particular, it attempted to establish whether the fault would cause the

Loss of Mains (Vector Shift) or Under/Over-voltage protection functions to operate and trip the generators connected to the 11kV network.

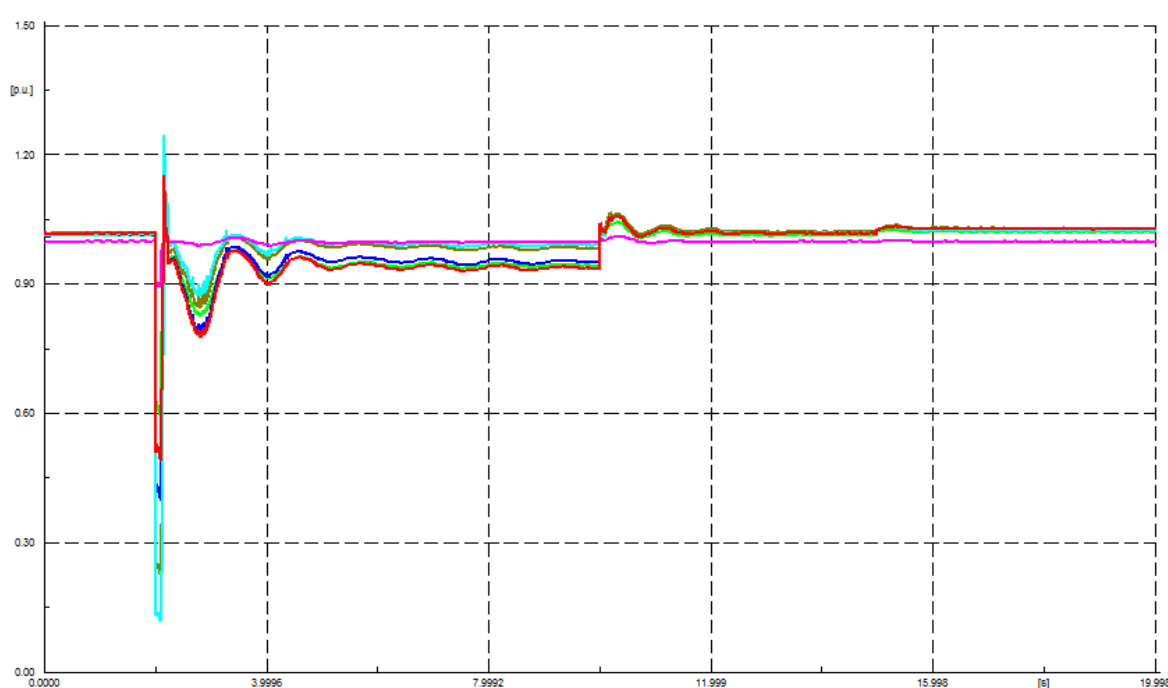


Figure 4: Voltage profile during a fault event

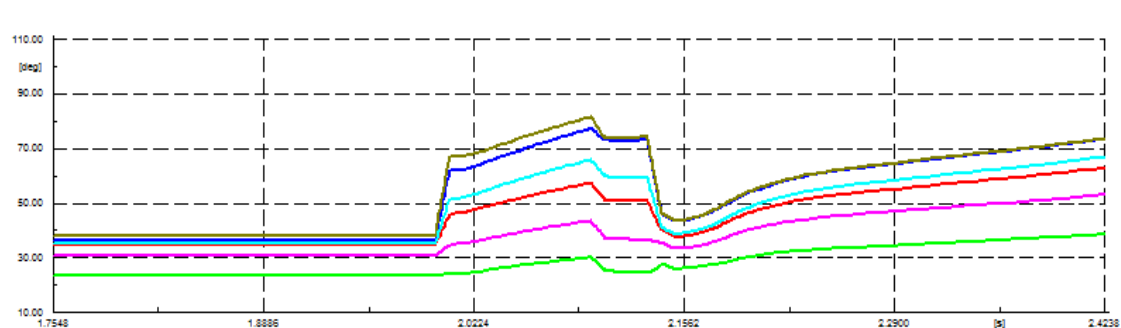


Figure 5: Phase Angle during a fault event

Another key finding of the enhanced studies was the impact of the fault impedance on how far the fault spreads beyond its location. It was found that for a fault at a Grid Supply Point (GSP), the higher its impedance, the furthest the spread of the resulting phase shift at adjacent GSPs. This has particular implications in the extent of the impact that transmission events have on embedded generation.

Despite the importance of the enhanced modelling, it was identified that the current models used by DNOs were not adequately developed to run dynamic studies and this has been identified as a key area that needs improvement.

4.3 Other Learning Points

Through the National Grid-UK Power Networks RDP work, several other learning points are becoming evident as additional capacity is made available to DER customers. These include:

- A Whole System approach to managing Loss of Mains – the work has enabled a much better understanding of how the use of Vector Shift based Loss of Mains protection impacts local risk. A local strategy has been implemented to manage this until wider industry work through the Grid Code GC0079 group is completed.
- Connect & Manage and Active Network Management Design – By utilising a Connect and Manage approach and by approaching the design of an Active Network Management scheme from a whole system perspective, the work will enable further DER connection and the participation of DER in commercial arrangements to manage transmission system constraints.
- Connection Process – the whole system approach implemented through the RDP will enable the completion of connection offers to DER customers that cover distribution and transmission aspects within 90 days. A fair and effective Queue Management process is also being utilised.

Appendix 1: Glossary

The following terms are used throughout this document:

| Term | Definition |
|---|--|
| Connect and Manage | Connection scheme which allows Generation Customers to connect on the Transmission Network ahead of the completion of any wider transmission system reinforcements required under the security standards. Connecting generators ahead of the completion of wider works are subject to generation constraints. |
| Balancing / Ancillary Services | National Grid procures Balancing / Ancillary Services in order to balance demand and supply and to ensure the security and quality of electricity supply across the GB Transmission System. |
| Bilateral Connection Agreement (BCA) | Each party connected to the GB Transmission System shall enter into and comply with a Bilateral Connection Agreement in relation to such connection. |
| Common Distribution Charging Methodology (CDCM) | The Common Distribution Charging Methodology (CDCM) is used to calculate charges to users who are connected to the LV and HV levels of the distribution network. |
| Connection Agreements | An agreement between the DNO and the User or any Customer setting out the terms relating to a connection with the DNO's Distribution System (excluding any CUSC Bilateral Agreement). |
| Connection and Use of System Code (CUSC) | The Connection and Use of System Code (CUSC) is the contractual framework for connection to, and use of, the National Electricity Transmission System (NETS). |
| Construction Agreement | "Each party who wishes to construct or modify a direct connection to the GB Transmission System or commence or modify use by his Embedded Power Station or Distribution Interconnector, or any Distributor who wishes to connect a Relevant Embedded Medium Power Station or Relevant Embedded Small Power Station to his system shall enter into and comply with a Construction Agreement in respect of any construction works required as a result of that connection or Modification, together with a Bilateral Agreement as identified in Paragraph 1.3.1 or, as appropriate, an agreement to vary such Bilateral Agreement. In any case under the OTSDUW Arrangements, paragraph 1.5 applies to such Construction Agreement." |
| Distribution Code | A code required to be prepared by a DNO pursuant to condition 9 (Distribution Code) of a Distribution Licence and approved by the Authority as revised from time to time with the approval of, or by the direction of, the Authority. |
| Distributed or Embedded Generator (DG or EG) | A Generator including a Customer with own generation whose generation sets are directly connected to the DNO's Distribution System or to an other authorised distributor connected to the DNO's Distribution System. The definition of Embedded Generator also includes the OTSO in relation to any embedded Transmission System. |
| Distribution Network Operator (DNO) | The person or legal entity named in Part 1 of the Distribution Licence and any permitted legal assigns or successors in title of the named party. |
| Distribution System | The System consisting (wholly or mainly) of electric lines owned or operated by the DNO and used for the distribution of electricity between the Grid Supply Points or Generation Sets or other Entry Points to the points of delivery to Customers or Authorised Electricity Operators, or any Transmission Licensee within Great Britain and Offshore in its capacity as operator of the licensee's Transmission System or the National Electricity Transmission System and includes any Remote Transmission Assets (owned by a Transmission Licensee within Great Britain), operated by the DNO and any electrical plant and meters and metering equipment owned or operated by the DNO in connection with the distribution of electricity, but shall not include any part of the National Electricity Transmission System. |
| Generator | A person who generates electricity under licence or exemption under the Electricity Act 1989 (as amended, including by the Utilities Act 2000 and the Energy Act 2004). |

| Term | Definition |
|---|--|
| Grid Code | The code which National Grid Electricity Transmission plc. is required to prepare under its Transmission Licence and have approved by the Authority as from time to time revised with the approval of, or by the direction of, the Authority. |
| Grid Supply Point (GSP) | A point of supply from the National Electricity Transmission System to Network Operators or Non-Embedded Customers. |
| Inter-Control Centre Communication Protocol (ICCP) | Inter-Control Centre Protocol (ICCP) is a standard real-time data exchange protocol which provides a mechanism for real-time data exchange between utility control centres. |
| Loss of Mains protection | Protection to achieve disconnection of the distribution generator from the Distribution System in the event of loss of one or more phases of their supply. |
| Modification Application | Application for requesting modifications to Bilateral Connection Agreements |
| Reactive Power | The product of voltage and current and the sine of the phase angle between them, which is normally measured in kilovar (kVAr) or megavar (MVar). |
| Real Power | The product of voltage and the in-phase component of alternating current measured in units of watts, normally measured in kilowatts (kW) or megawatts (MW). |
| Statement of Works (SoW) | Statement of Works is submitted to National Grid for the purposed of assessing the impact of embedded generation upon the National Electricity Transmission System. |
| System Operator (SO) | The System Operator is responsible for ensuring the stable and secure operation of the whole transmission system. |
| The System Security and Quality of Supply Standard (SQSS) | Transmission licensees – both onshore and offshore – are required by their licences to comply with the National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS), which sets out criteria and methodologies for planning and operating the GB Transmission System. |
| Transmission Owner (TO) | Transmission Operators (TOs) are licensed to develop, operate and maintain the high voltage system within their own distinct onshore transmission areas. |