Q-Flex Project: Work Package 1 Report

For: National Grid Electricity Distribution

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0	23/11/2022	Draft submission to NGED
1	07/12/2022	Addressing NGEDs comments and suggestions

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0	23/11/2022	Mahmoud Elkazaz	James Wilson	Adam Maloyd
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1. Introduction

1.1. Introduction to Q-Flex NIA project

National Grid Electricity Distribution (NGED) has engaged Power Systems Consultants UK Ltd (PSC) to deliver an innovation project known as the Q-Flex Network Innovation Allowance project. The Q-Flex project seeks to demonstrate that reactive power flexibility is needed and can form a key component in the transition to net zero 2050.

NGED continually look for innovative ways to overcome power system constraints and operational challenges without the need for costly network reinforcements. This project aims to meet this need with the following project objectives:

- Demonstrate that the provision of flexible reactive power is technically possible.
- Show that flexible reactive power is a solution to forecasted network constraints.
- Prove that participants are willing to provide reactive power as a flexibility service.

The high-level scope of the Q-Flex Project is as follows:

- Undertake technical feasibility assessments of existing and emerging technology's capability to provide dispatchable reactive power.
- Undertake power system studies to demonstrate that optimised reactive power dispatch has the ability to defer network reinforcements and minimise network losses.
- Undertake economic Cost Benefit Analysis to determine the financial and environmental costs/benefits of deferred network reinforcements and minimised losses.
- Undertake a market assessment to determine the interest of asset owners and operators in providing flexible reactive power as a service.
- Undertake an initial market design for the procurement of reactive power from technology asset owners.

The project is structured into the following 5 main work packages:

- **Work Package 1 (WP1):** Current & Emerging Technologies Reactive Power Capability
- **Work Package 2 (WP2):** Q-Flex Reactive Power Studies
- **Work Package 3 (WP3):** Q-Flex Cost Benefit Analysis
- **Work Package 4 (WP4):** Reactive Power Flexibility Market Engagement & Development
- **Work Package 5 (WP5):** Q-Flex Project Report

1.2. Introduction to Work Package 1

Work Package 1 is a desktop-based package for Q-Flex project. This WP includes the literature review for the reactive power capabilities for different technologies, as well as developing questionnaires to survey both the existing and emerging connected technologies in the NGED network. Both the literature review and the answers from the questionnaires are used to develop a Reactive Power Technology Catalogue which provides a summary of the reactive power capabilities of different existing and emerging technologies including P-Q capability curves and controllability information.

The objectives of WP1 are as follows:

- Summarise the reactive power capability of different technology types to be used in the Work Package 2 power system studies.
- Summarise how different technology types can control their reactive power output at the point of connection. (e.g. wind/solar farm reactive capability rather than individual wind turbines or solar inverters)
- Determine the viability of controlling the reactive power from the different technologies at the point of connection.

There are a number of deliverables for WP1 as follows:

- **WP1.D1 – Literature Review Technology Reactive Power Capability:**
  Undertake a literature review of current and emerging technologies reactive capability/controllability, trial results, Power Park Module control systems etc.
- **WP1.D2 – Existing Technologies Questionnaire:**
  Develop a questionnaire to survey existing technologies connected to NGEDs network.
- **WP1.D3 – Emerging Technologies Questionnaire:**
  Develop a questionnaire to survey emerging technology providers and manufacturers.
- **WP1.D4 – Reactive Power Technology Catalogue:**
  The Reactive Power Technology Catalogue provides a summary of the reactive power capabilities of different existing and emerging technologies connected to the NGED network. It also provides the P-Q capability plots of the existing and emerging technologies and the common reactive power control methods of the existing and emerging technologies.
- **WP1.D5 – Work Package 1 Report:**
  The WP1 report documents all the work completed for all deliverables of Work Package 1.

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2. Q-Flex NIA project background

Significant growth in the number of Low Carbon Technologies (LCTs) connected to distribution networks is expected, as the UK moves toward net zero carbon by 2050. This is both in terms of renewable generation and new loads such as from the electrification of transport and domestic heating. Additionally, the UK Government announced in November 2020 that the sale of petrol/diesel vehicles will be banned from 2030, this will accelerate the uptake of electric vehicles (EVs) and investment in charging infrastructure.

This increased LCT penetration on networks exacerbates the likelihood of issues such as increased equipment loading, increased network losses and breaches of regulated network voltage limits. The traditional approach to overcome these constraints is to reinforce the network, or through network flexibility services such as Active Network Management (ANM) or power flexibility services.

2.1. Network Reinforcement

If an electricity network becomes overloaded by load growth or a new generation connection, the capacity of the network will have to be increased. This increase in network capacity is generally termed 'reinforcement'. There are several reinforcement solutions available to a network company, depending on the piece of equipment predicted to be overloaded. Examples are replacing overhead lines, underground cables, transformers, and adding new circuits. The main disadvantage of network reinforcement is the cost and timescales. Network reinforcement needs a lot of investment to be able to upgrade the network capacity. Additional network infrastructure takes time and significant financial investment to build without fully understanding the future network conditions.

2.2. Active Network Management (ANM)

ANM is typically used by system operators to control energy generating schemes, so they can avoid having to upgrade the network, which costs a lot of money. Under this scheme, new energy generators can be instructed, via automated controls, to limit their power output thus avoiding exporting too much power to the network that could otherwise cause overloads, which could lead to outages and system faults. ANM keeps down the connection price for customers, however, as generators may have their output constrained, potential financial losses must be estimated. ANM connects separate components of a smart grid such as smaller energy generators, renewable generation, storage devices, etc., by implementing software to monitor and control the operation of these devices. The connection of these technologies to the main network ensures they are fully integrated into the energy system and thus can be used efficiently, thereby reducing the need to invest in expensive energy network reinforcement.

2.3. Reactive Power Support

The use of flexible reactive power services provides one method to operate the existing network more efficiently, though new services and optimisation in this area are needed to release the capacity for accelerated LCT connections. When designed to do so, modern grid-forming inverter-based Distributed Energy Resources (DERs) can vary their reactive power production, impacting voltage at the point of interconnection. If this function is enabled, DERs potentially can provide the required reactive power as an alternative to installing distribution capacitor banks or reactors.

Reactive power dispatch works by dynamically identifying reactive power needs and then provisioning the need directly from local DERs as a grid service managed through a distributed energy resource management system (DERMS). Modern DERMS are real-time control platforms that enable monitoring and operational control of individual or aggregated DERs, and they typically link to existing utility operational systems. While DERs are often installed by third parties without an in-depth understanding of the grid's operational needs and distributed generation impacts, DERMS have been developed to incorporate those considerations and provide utilities with a platform to manage diverse DERs intelligently and reliably on their networks.

With increased DER penetration, utilities will have to contend with voltage profiles that change drastically throughout the day. Using reactive power dispatch to deliver localised voltage support in addition to or as a replacement for conventional measures can enable DERs to provide grid services.

3. Reactive Power Dispatch and Control.

Reactive power production and consumption by generators allows the network operator to control voltages throughout their system. Network operators may specify requirements in a number of different ways. The simplest of these ways is by having a fixed power factor requirement. The generation plant farm is required to operate at a fixed power factor when generating, frequently near to 1, as requested by the network operator (i.e. According to G99 requirements, For Power Generating Modules between 1MW and 10MW when operating at registered capacity they must be capable of continuous operation between 0.95 lagging to 0.95 leading power factor at the PCC). Often, the required accuracy and integration intervals for the verification of the power factor are not stated. Also, the fixed value may be changed occasionally, for example for winter and summer, or for peak and no-load periods.

Alternatively, the generation plant may have to adjust its reactive power consumption or production to control the voltage to a set point. This is usually the voltage at the Point of Common Coupling (PCC), but other locations may be specified. There may be requirements regarding the accuracy of control and the speed of response. Fast control may be difficult to achieve, depending on the capabilities of the generation plant SCADA system (e.g. communication medium, protocol, other control layers and the parameters of power plant controller). SCADA is used for supervision, monitoring, and control of power plants remotely. The SCADA provides a full remote control and supervision of the entire power plants and individual turbines.

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4. Existing and Emerging Technologies Covered in WP1

WP1 focuses on providing more details about the reactive power capabilities, P-Q capability curves and controllability for two main technology categories: (a) Existing technologies category, and (b) Emerging technologies category. Each category consists of a sub list of technologies as listed below.

- **Existing Technologies**:
  - Wind generation
  - Solar generation
  - Conventional generation (mainly gas power plants)
- **Emerging Technologies:**
  - EV charging
    - Domestic
    - Connected at 11 kV+ (i.e. superchargers)
  - Battery Energy Storage System
    - Domestic
    - Connected at 11 kV
  - Domestic Solar
  - Domestic Heat pumps
  - Medium Voltage DC (MVDC) links
  - Soft Open points

5. Existing and Emerging Technologies Questionnaires Development

PSC in cooperation with NGED has invited a number of stakeholders (i.e. owners, operators, asset managers and manufacturers) to participate in answering two questionnaires to provide more information about the reactive power capabilities of the existing and emerging connected technologies in the NGEDs network.

The two questionnaires: (a) Existing Technologies Questionnaire - Available in **Appendix A**, and (b) Emerging Technologies questionnaire - Available in **Appendix B**, have been developed to obtain detailed information regarding the reactive power capabilities of the existing and emerging connected technologies on the NGEDs network. The questionnaires focus on the following topics:

- Ability of the technology to provide/absorb reactive power to the distribution network.
- What control systems/interfaces are available or planned for the future.
- Are there any real power restrictions caused when providing/absorbing reactive power.
- The ability of the existing technologies to receive control signals/schedules to vary their reactive power output, and what are the expected response times.

- The control mode of the technology.
- The reactive capability characteristic of the generation technology.
- The communication technology/infrastructure used to receive the control signal.
- The end user/customer impact, and aggregation potential.

6. Reactive Power Technology Catalogue Development

PSC has taken the information gathered from stakeholders and from the literature review to undertake a technical assessment of both the existing and emerging technologies. This has been reflected in a reactive power technology catalogue. The reactive power technology catalogue - available in **Appendix C** - has been developed to provide:

- P-Q capability plot (or plots) for the different technology types, and particularly highlight the technology's ability to provide reactive power at zero real power output.
- The common or future planned reactive power control arrangement for the different technology types.
- The reactive capability at the connection point to WPD's network rather than at individual units.

Appendices

Appendix A: Existing Technologies Questionnaire

Existing Technologies Questionnaire

Organization name:	Department:
Responsible Person:	Email address:
Date of the Questionnaire:	

Summary: Power Systems Consultants UK Limited (PSC) has developed this questionnaire in participation with National Grid (NG) to survey the existing connected technologies to their electricity distribution network as a part of Q-Flex Innovation project. The Q-Flex Network Innovation Allowance project seeks to demonstrate that reactive power flexibility is technically possible and whether it can form a key component in the transition to net zero 2050.

PSC asks owners, operators, asset managers and manufacturers who have existing connected technologies to the National Grid electricity distribution network to participate in this questionnaire to provide more information about the capability of their technologies to **provide reactive power to the National Grid electricity distribution network**.

If you have any queries, please contact Mahmoud Elkazaz (power system engineer at PSC) by email mahmoud.elkazaz@pscconsulting.com

Please answer the following questions:

1. Which technology Category (from the following technologies) connected to the distribution network is your company responsible for?
   - Wind generation
   - Solar generation
   - Conventional generation

   Note: please fill a separate questionnaire for each Technology Category

2. What is the connection voltage, rated power, quantity of installations and the installation date (if already connected) of the technology?

3. Can the technology provide reactive power to the distribution network? (Please provide links to manuals or certification)

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4. If the technology can provide reactive power to the distribution network, are there any constraints on the availability through the day? (i.e. can provide reactive power only during certain hours, only during the day, only during the night, anytime of day for a limited duration)

5. If the technology can provide reactive power to the network, are there any real power restrictions caused when providing/absorbing reactive power?

6. If the technology can provide either bi-directional or single directional reactive power to the network, does it operate on a fixed power factor (e.g. 0.95 or any other fixed value) or it can be controlled?

7. If the power factor of the technology can be controlled, what is the applicable range of changing it?

8. If the power factor of the technology can be controlled, what are the existing control systems/interfaces available?

9. What is the control mode of the technology (voltage control, current control, power factor control, volt-var)? Can the control mode of the generation/demand technology be changed?

10. Can the technology receive local and/or remote control signals/schedules to vary their reactive power output? and what is the response time?

11. If the technology can receive control signals to schedule/vary their reactive power output, what is the communication technology/infrastructure used to receive this signal?

12. Can the technology provide reactive power while generating zero active power and if so what is the range of this?

13. If the technology **cannot** receive control signals to vary the reactive power output, can it be adjusted in the future to receive remote control signal to vary the reactive power generation? What are the required devices for this?

14. What is the reactive capability characteristic of the generation technology (e.g. triangular, rectangular, or D shape)? If applicable, can you provide the P-Q capability curve of the generation technology?

15. Does the technology/plant use any external static or dynamic devices such as a STATCOM or mechanically switched capacitors to keep the reactive power of plant within a certain limits?

16. Does the current technology provide any kind of flexibility services to the distribution network? If yes, please explain.

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Appendix B: Emerging Technologies Questionnaire

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Emerging Technologies Questionnaire

Organization name:	Department:
Responsible Person:	Email address:
Date of the Questionnaire:	

Summary: Power Systems Consultants UK Limited (PSC) has developed this questionnaire in participation with National Grid (NG) to survey the emerging connected technologies to their electricity distribution network as a part of Q-Flex Innovation project. The Q-Flex Network Innovation Allowance project seeks to demonstrate that reactive power flexibility is technically possible and whether it can form a key component in the transition to net zero 2050.

PSC asks owners, operators, asset managers and manufacturers who have emerging connected technologies to the National Grid electricity distribution network to participate in this questionnaire to provide more information about the capability of their technologies to **provide reactive power to the National Grid electricity distribution network**.

If you have any queries, please contact Mahmoud Elkazaz (power system engineer at PSC) by email mahmoud.elkazaz@pscconsulting.com

Please answer the following questions:

1. Which technology category (from the following emerging technologies) connected to the distribution network is your company responsible for?
   - EV charging
     - Domestic
     - Connected at 11 kV+ (i.e. superchargers)
   - Battery energy storage systems (BESS)
     - Domestic
     - Connected at 11 kV or higher
   - Domestic Solar
   - Domestic Heat pumps
   - Medium-Voltage Direct Current (MVDC) links
   - Soft Open points

   Note: please fill a separate questionnaire for each Technology Category

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2. What is the connection voltage, rated power, quantity of installations and the installation date (if already connected) of the technology?

3. Can the technology provide reactive power to the distribution network? (Please provide links to manuals or certification)

4. If the technology can provide reactive power to the distribution network, are there any constraints on the availability through the day? (i.e. can provide reactive power during certain hours, only during the day, only during the night, anytime of day for a limited duration)

5. If the technology can provide reactive power to the distribution network, are there any real power restrictions caused when providing/absorbing reactive power?

6. If the technology can provide either bi-directional or single directional reactive power to the network, does it operate on a fixed power factor (e.g. 0.95 or any other fixed value) or it can be controlled?

7. If the power factor of the technology can be controlled, what is the applicable range of changing it?

8. If the technology can provide reactive power to the network, what control systems/interfaces are available or planned for the future?

9. What is the control mode of the technology (voltage control, current control, power factor control, volt-var)? Can the control mode of the generation/demand technology be changed?

10. Can the technology receive local and/or remote control signals/schedules to vary their reactive power output? and what is the response time?

11. If the technology can receive control signals/schedules to vary their reactive power output, what is the communication technology/infrastructure used for this?

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12. Can the technology provide reactive power while generating zero active power and if so what is the range of this?

13. If the technology can receive control signals/schedules to vary their reactive power output, Can the technology participate in reactive power aggregation schemes? Do the devices have MW/MVAr meters at the interface? Does the participation in power aggregation schemes affect the end user/customer?

14. If the technology **cannot** receive control signals to vary the reactive power output, Can it be adjusted in the future to receive remote control signal to vary the reactive power generation? What are the required devices for this?

15. What is the reactive capability characteristic of the technology (e.g. triangular, rectangular, or D shape)? If applicable, can you provide the P-Q capability curve of the generation technology?

16. Does the technology/plant use any external static or dynamic devices such as a STATCOM or mechanically switched capacitors to keep the reactive power of plant within certain limits?

17. Does the current technology provide any kind of flexibility services to the distribution network? If yes, please explain.

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