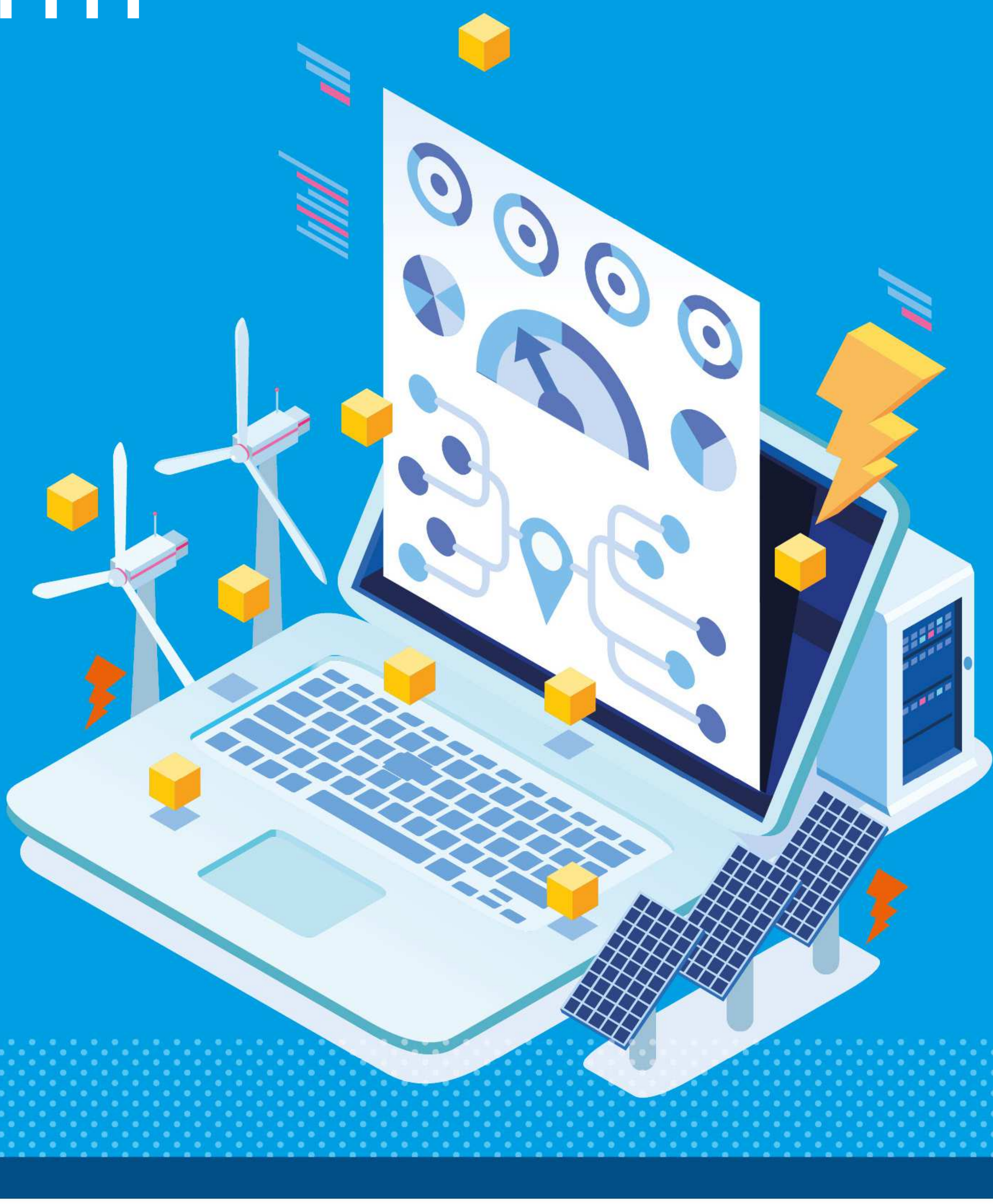
Energy Networks Innovation Process

Project Close Down Form



The voice of the networks

Notes on Completion: Please refer to the NIA Governance Document to assist in the completion of this form.
Do not use tables

Step 1 - Initial Project Details

Project Title

Q-Flex

Project Reference

WPD_NIA_072

Project Contact(s)

Laurence Hunter

Project Start Date

09/22

Project End Date

06/23

Scope (15000 Characters max)

This project demonstrated that the provision of flexible reactive power is technically possible, and assessed how flexible reactive power could offer a solution to forecasted network constraints. Through engagement with potential reactive power suppliers, an understanding of which participants are willing to provide reactive power as a flexibility service was obtained, along with potential market designs.

This project consisted of the following five work packages which ran in parallel:

- **Work Package 1 (WP1):** Current & Emerging Technologies Reactive Power Capability (4 months)
  - WP1 consisted of gathering and reviewing literature of current and emerging technologies' reactive power capability and controllability, as well as a review of relevant past trial results and control systems. This was followed by developing and issuing questionnaires to asset owners, and developing a reactive power technology catalogue.
  - The outputs of this WP were questionnaires on both existing and emerging technologies, a reactive power technology catalogue and a final WP1 report.
- **Work Package 2 (WP2):** Q-Flex Reactive Power Studies (4.5 months)
  - WP2 consisted of undertaking power system studies to demonstrate that optimised reactive power dispatch has the ability to defer network reinforcements, required to resolve thermal and/or voltage constraints, and also minimise network losses. These studies include assessment of reinforcement deferment, loss minimisation and the operation of reactive power flexibility.
  - The output of this WP was a report containing the case studies selected, an algorithm called Q-Flex that can be used to calculate optimal power factor set points for distributed generators to resolve voltage and thermal network constraints and results and analysis from the power system studies carried out.
- **Work Package 3 (WP3):** Q-Flex Cost Benefit Analysis (5 months)
  - WP3 involved carrying out economic Cost Benefit Analysis to determine the financial and environmental costs/benefits of deferred network reinforcements and minimised losses achieved from the use of flexible reactive power.
  - The outputs from this WP were a report containing the methodology and findings from the Q-Flex CBA, and the CBA spreadsheets developed.
- **Work Package 4 (WP4):** Reactive Power Flexibility Market Engagement & Development (5 months)
  - WP4 involved carrying out a market assessment to determine asset owners' interest in providing flexible reactive power as a service, as well as developing an initial market design for the procurement of reactive power from technology asset owners.
  - The output of this WP was a report containing assessment of the interest from providers in a reactive power flexibility market, and the market design.
- **Work Package 5 (WP5):** Q-Flex Project Report (2 months)
  - WP5 consisted of a report detailing the summary of learnings, conclusions and recommendations from the project.

A reactive power flexibility market does not currently exist at the distribution level in the UK, but could provide value to our customers and change the way we design and operate our network. The project aimed to gain an understanding on which commercial customers connected to our network are able to provide reactive power flexibility, and understand their willingness to do so through engagement and questionnaires. Following this, the project aimed to design a new reactive power flexibility market or review what might be the best arrangements to achieve our aims.

Objective (15000 Characters max)

- Demonstrate that the provision of flexible reactive power is technically possible
- Assess whether flexible reactive power is a solution to forecasted network constraints
- Understanding if participants are willing to provide reactive power as a flexibility service

Success Criteria (15000 Characters max)

The project will be deemed successful if the following are achieved:

1. A catalogue of reactive power technology produced that has been developed using feedback and information from asset owners and operators.
2. Power studies have been carried out on multiple case studies within the NGED network which have been selected and approved by NGED DSO.
3. Cost Benefit Analysis carried out to determine the financial and environmental costs/benefits of deferred network reinforcements and minimised losses achieved from the use of flexible reactive power.
4. A concept design has been created for a reactive power flexibility marketplace.

Step 2 - Performance Outcomes

Performance Compared to Original Project Aims

Details of how the Project is investigating/solving the issue described in the NIA Project Registration Pro-forma. Details of how the Project is performing/performed relative to its aims, objectives and success criteria. (15000 Characters max)

Objectives

1. **Demonstrate that the provision of flexible reactive power is technically possible - Completed**

Achieved - A literature review has been performed to produce a Reactive Power Catalogue, and engagement with potential providers via questionnaires and workshops has been summarised in a Market Interest Summary Report. Both avenues of research have given clear indications that the provision of flexible reactive power is technically possible.

The Reactive Power Catalogue gives details of the communications technology and infrastructure that could be used for dispatching reactive power, such as applicable network protocols. The Market Interest Summary Report showed that potential market participants believed that Application Programming Interface-links would be the most straightforward method of dispatch.

2. **Assess whether flexible reactive power is a solution to forecasted network constraints - Completed**

Achieved - Modelling has suggested that there are certain network areas where flexible reactive power support could effectively defer network reinforcement.

3. **Understanding if participants are willing to provide reactive power as a flexibility service - Completed**

Achieved - The workshops used for assessing the technical feasibility of reactive power flexibility also investigated the willingness of potential market participants to participate in a hypothetical future reactive power flexibility market. Results were generally positive, particularly for potential providers with incumbent capable assets with periods of non-utilisation for active power provision (notably solar PV at night and wind during still periods).

A key takeaway was a preference from potential providers of reactive power such as solar PV and wind generators for an availability-dominated market due to its higher relative certainty of revenue compared to a utilisation-dominated market.

Success Criteria

1. **A catalogue of reactive power technology produced that has been developed using feedback and information from asset owners and operators.**

Achieved - This has been produced and includes thermal generation, wind and solar PV, electric vehicle, heat pump, battery energy storage, medium-voltage direct current links, and soft open-points.

2. **Power studies have been carried out on multiple case studies within the NGED network which have been selected and approved by NGED Network Strategy.**

Achieved - These have been performed to show benefits on the 33kV and 132kV networks, represented by reduced losses and deferred reinforcement. The potential to reduce losses was found in all areas studied and reinforcement deferral was found possible in two areas studied.

3. **Cost Benefit Analysis carried out to determine the financial and environmental costs/benefits of deferred network reinforcements and minimised losses achieved from the use of flexible reactive power.**

Achieved - Work Package 3 reports demonstrated the financial and environmental benefits of deferred network reinforcement and minimised losses. We found strong performance for the deferral of reinforcement, but weaker performance when addressing network losses.

4. **A concept design has been created for a reactive power flexibility marketplace.**

Achieved - Market structures have been prepared as a part of Work Package 4 that explain how a reactive power flexibility marketplace would interplay with existing Flexible Power services.

Required Modifications to the Planned Project Approach

The Network Licensee should state any changes to its planned methodology and describe why the planned approach proved to be inappropriate. Please confirm if no changes were required. (15000 Characters max)

None

Lessons Learnt For Future Projects

Describe how the project (methodology, stakeholder engagement etc.) changed, or provided opportunities, from your expectation at the start of the project and therefore could be useful for a future project. In addition, please discuss the effectiveness of the research development or demonstration undertaken. (15000 Characters max)

WP1 - Current & Emerging Technologies Reactive Power Capability:

- The Reactive Power Technology Catalogue summarised the reactive power capabilities of different existing and emerging technologies connected to the network, the P-Q capability plots of the existing and emerging technologies and the common reactive power control methods of the existing and emerging technologies.
- The use of flexible reactive power dispatch could provide one means to operate the existing network more efficiently. However, new services and optimisation in this area are needed to release the capacity for accelerated LCT connections.
- Market engagement found that many potential Reactive Power Providers (RPPs), particularly solar PV and wind energy, could provide significant reactive power support with negligible opportunity costs when operating below full active power export during darker and less windy periods, respectively.
- With suitable control systems, modern grid-forming inverter-based Distributed Energy Resources (DERs) can vary their reactive power production, impacting voltage and reactive power flows at the point of common coupling. If this function is enabled, DERs can potentially act as sources and sinks of reactive power with significantly better variability than fixed capacitor banks or reactors at the distribution level.

WP2 - Q-Flex Reactive Power Studies:

- The optimisation algorithm from the Virtual STATCOM project was successfully updated to optimise power factor correction on voltages from 11kV to 132kV, with the primary goal of resolving network constraints and the secondary goal of reducing network losses.
- It may be possible to resolve network constraints and defer future network reinforcement in certain cases, with estimated reductions in thermal loadings of up to 5%. These represent up to 6 years of reinforcement deferral and apply at voltage levels from 33kV to 132kV.
- It may be possible to reduce the power losses of the electricity network, although this was more effective for the historical study than for the studies of future years based on the DFES.
- It was found that many generators were limited by a 3% rapid voltage change limit rather than a reactive power capability limit (the voltage step constraints are given in the Distribution Planning and Connection Code and Engineering Recommendation P28/2).
- Sensitivity studies showed the ability to resolve constraints and reduce network power losses to be highly dependent on nodal effectiveness, making certain generators strategic.

WP3 - Q-Flex Cost Benefit Analysis Studies:

- Cost-benefit analyses were successfully performed using the Common Evaluation Methodology (CEM) tool developed by Baringa to assess flexibility procurement. These produced Net Present Values (NPVs) for all study cases, and where these were positive, ceiling prices for availability payments where the cost would be equal to network reinforcement were calculated.
- There are significant estimated net financial benefits for deferring network reinforcement, varying with the CAPEX to be deferred, the timescale of deferral and the Weighted Average Cost of Capital (WACC).
- There were no estimated net financial benefits for minimising losses in the network unless these were coupled with the deferment of network reinforcement.
- Ensuring reactive power procurement is beneficial for us and our customers depends on the required volumes of reactive power, which depends on the network topology and the cost of deferrable network reinforcements. However, the most important factor is the presence of suitable and willing potential RPPs in the relevant Constraint Management Zone to provide reactive power support, which may depend on their market-entry upfront and opportunity costs.

WP4 - Reactive Power Flexibility Market Engagement & Development:

- Potential RPPs interviewed as part of NERA's stakeholder engagement process generally expressed a preference for alignment between the reactive power market and existing active power flexibility markets.
- Potential providers have differing needs for revenue certainty depending on their technology type; in particular, older windfarms and solar plants may require upfront investment to enable reactive power capabilities.
- Since suppliers will initially likely be monopolists over demand for their reactive power, a pay-as-bid market design has been developed initially. This allows NGED to compare bids against the cost of network reinforcement at the Service Requirement stage. Moreover, the prices RPPs can submit at the Availability Market stage are capped at the prices submitted in the Service Requirement stage.
- We may wish to transition to a pay-as-clear market design in the future if the interchangeability of supply arises in the reactive power market, as defined by an N-2 Liquidity Test for each Constraint Management Zone.

Outcomes of the Project

When available, comprehensive details of the Project's outcomes are to be reported. Where quantitative data is available to describe these ~~outcomes~~outcomes, it should be included in the report. Wherever possible, the performance improvement attributable to the Project should be described. If the TRL of the Method has changed as a result of the Project this should be reported. The Network Licensee should highlight any opportunities for future Projects to develop learning further. (15000 Characters max)

Current & Emerging Technologies Reactive Power Capability

- Gathered literature on existing and emerging technologies' reactive capabilities/controllability, trial results, control systems, etc.
- Developed and issued questionnaires to asset owners/operators.
- Produced a Reactive Power Technology Catalogue.

Q-Flex Reactive Power Studies

- Identified constraint case studies using the Distribution Networks Options Assessment (DNOA) and Shaping Subtransmission Reports. These were modelled in PSS/E.
- Updated the optimisation algorithm developed in the Virtual STATCOM NIA project.
- Undertook Q-Flex reinforcement deferral studies for networks at voltage levels 33kV, 66kV and 132kV.
- Undertook Q-Flex loss minimisation studies.
- Undertook Q-Flex operational studies.
- Undertook Q-Flex sensitivity studies.

Q-Flex Cost Benefit Analysis

- Developed costs and benefits assumptions to feed into the Common Evaluation Methodology (CEM) tool developed by Baringa.
- Undertook cost-benefit analyses (CBAs) for flexible reactive power dispatch.

Reactive Power Flexibility Market Engagement & Development

- Assessed flexible reactive power market interest.
- Developed initial flexible reactive power market design.

Q-Flex Project Report

- Produced this report summarising the work done, learnings, conclusions, and recommendations for the project.

Step 3 - Outputs And Implementation

Data Access Level

A description of how any network or consumption data (anonymised where necessary) gathered in the course of the Project can be requested by interested parties. Please include a link to the publicly available data policy. (15000 Characters max)

All reports and supporting work are published on the National Grid – Q-Flex project page. Additional data can be requested by contacting us directly.
NGED data can be requested via the National Grid Connected Data Portal (https://connecteddata.nationalgrid.co.uk/).
(/www.nationalgrid.co.uk/innovation/contact-us-and-more)

Foreground IPR

A description of any foreground IPR that have been developed by the project and how this will be owned. (15000 Characters max)

New foreground IPR has been created in the project reports. These are published and freely available on the NGED Innovation website. This includes an update to the V-STATCOM algorithm which is available on our website.

Planned Implementation

Please describe the next steps to implement this innovation project. What policies and standards need to be updated or created as part of this implementation. (15000 Characters max)

The outputs from Q-Flex describe the potential market design opportunity for reactive power markets within Distribution networks. In addition, the technology catalogue provides a comprehensive overview of how assets typically connected to the network can provide reactive power control.

Business as Usual roll-out of this learning will include a review of where 132kV reinforcement can be deferred or avoided through the use of reactive power flexibility. The project demonstrated that for reinforcement schemes above £1m, with more than three generators connected downstream, a positive cost benefit analysis can be achieved.

Other Comments

N/A

Standards Documents

Identify any industry standards that may require updating due to the outcomes or understanding developed from this innovation project. If no standards will need to be updated, please state - not applicable

N/A