Reactive Power Services

Review

Open Networks | WS1A P6

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Related documents

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Reference 2	

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Introduction

About ENA

Energy Networks Association represents the companies which operate the electricity wires, gas pipes and energy system in the UK and Ireland.

We help our members meet the challenge of delivering electricity and gas to communities across the UK and Ireland safely, sustainably and reliably.

Our members include every major electricity and gas network operator in the UK and Ireland, independent operators, National Grid ESO which operates the electricity system in Great Britain and National Grid which operates the gas system in Great Britain. Our affiliate membership also includes companies with an interest in energy, including Heathrow Airport and Network Rail.

We help our members to:

- Create smart grids, ensuring our networks are prepared for more renewable generation than ever before, decentralised sources of energy, more electric vehicles and heat pumps. Learn more about our Open Networks programme.
- Create the world's first zero-carbon gas grid, by speeding up the switch from natural gas to hydrogen. Learn more about our Gas Goes Green programme.
- Innovate. We're supporting over £450m of innovation investment to support customers, connections and more.
- Be safe. We bring our industry together to improve safety and reduce workforce and public injury.
- Manage our networks. We support our members manage, create and maintain a vast array of electricity codes, standards and regulations which supports the day-to-day operation of our energy networks.

Together, the energy networks are keeping your energy flowing, supporting our economy through jobs and investment and preparing for a net zero future.

About Open Networks

Britain's energy landscape is changing, and new smart technologies are changing the way we interact with the energy system. Our Open Networks programme is transforming the way our energy networks operate. New smart technologies are challenging the traditional way we generate, consume and manage electricity, and the energy networks are making sure that these changes benefit everyone.

ENA's Open Networks programme is key to enabling the delivery of Net Zero by:

- opening local flexibility markets to demand response, renewable energy and new low-carbon technology and removing barriers to participation
- providing opportunities for these flexible resources to connect to our networks faster
- opening data to allow these flexible resources to identify the best locations to invest
- delivering efficiencies between the network companies to plan and operate secure efficient networks

We're helping transition to a smart, flexible system that connects large-scale energy generation right down to the solar panels and electric vehicles installed in homes, businesses and communities right across the country. This is often referred to as the smart grid.

The Open Networks programme has brought together the nine electricity grid operators in the UK and Ireland to work together to standardise customer experiences and align processes to make connecting to the networks as easy as possible and bring record amounts of renewable distributed energy resources, like wind and solar panels, to the local electricity grid.

The pace of change Open Networks is delivering is unprecedented in the industry, and to make sure the transformation of the networks becomes a reality, we have created six workstreams under Open Networks to progress the delivery of the smart grid.

2022 Open Networks programme Workstreams

- WS1A: Flexibility Services
- WS1B: Whole Electricity System Planning and T/D Data Exchange
- WS2: Customer Information Provision and Connections
- WS3: DSO Transition
- WS4: Whole Energy Systems
- WS5: Communications and Stakeholder Engagement

Our members and associates

Membership of Energy Networks Association is open to all owners and operators of energy networks in the UK.

- Companies which operate smaller networks or are licence holders in the islands around the UK and Ireland can be associates of ENA too. This gives them access to the expertise and knowledge available through ENA.
- Companies and organisations with an interest in the UK transmission and distribution market are now able to directly benefit from the work of ENA through associate status.

ENA members

ENA associates

- Chubu
- EEA
- Guernsey Electricity Ltd
- Heathrow Airport
- Jersey Electricity
- Manx Electricity Authority
- Network Rail
- TEPCO

Executive Summary

As the electricity networks evolve to adapt efficiently to the challenges and opportunities a net zero energy system brings, novel methods or innovative development of existing technologies can help unlock valuable service to the whole system.

Reactive power has always been a fundamental technical parameter of the electricity system. Its control supports the balancing of the system's voltage. As the sources of electricity generation on the system have diversified, new markets will evolve to ensure adequacy of reactive power provision to support the management of system voltage at the transmission level.

In the Open Networks Workstream 1a Flexibility Services product group (P6), the team have been considering the value of a reactive power flexibility product for procurement at the distribution level.

A review of the innovation from a range of past and present Ofgem funded Network Innovation studies on this topic has been carried to assist in the consideration of network need and the market readiness for such a service.

Projects reviewed

- Reactive Power Market Design
- Power Potential (Transmission & Distribution Interface 2.0)
- Virtual Statcom
- Q-Flex
- Reactive Power trial

The review also seeks to provide some technical background to reactive power, its need and its existing markets.

Interim Conclusions

There is a growing body of research, innovation and demonstration to the value of reactive power services at a distribution level as a valuable tool in supporting voltage at transmission and distribution level.

At this point, there is not a definite recommendation for the technical specification has yet been identified and as such, no market product can yet be developed successfully.

It is recommended that this conclusion is reviewed once again by Open Networks on the conclusion of the Q-Flex project due for completion in March 2023.

Background to Reactive Power

The definition

In alternating current (AC) circuits, such as the GB electricity transmission and distribution grids, when the frequency of the current and voltage are in phase with each other, all of the resulting power flow is known as **real** power. As the frequency phase delay between current and voltage increases, so does the amount of **reactive** power. Reactive power is present whenever the current waveform either "lags" or "leads" voltage.

Real Power (P)	The product of the voltage and current in an AC circuit. Sometimes known as the active power.
Apparent Power (S)	The apparent power of an AC circuit is the product of the root mean squared (RMS) value of the voltage and the current, expressed as volt-amperes (VA).
Phase Angle (ϕ)	The difference between the phase angle of the alternating voltage and current waveforms
Reactive Power (Q)	The product of voltage and current and the sine of the phase angle between them measured in units of voltamperes reactive (Var).
Power Factor (PF)	The ratio of real power to apparent power

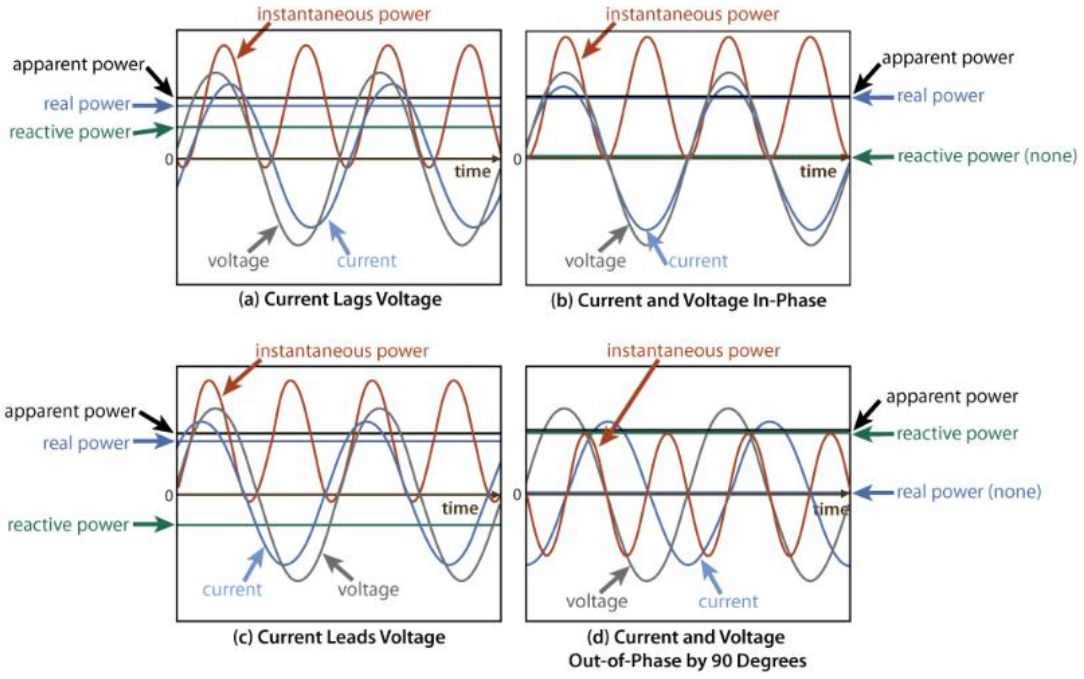


*Figure 1: **Phases of current, voltage and power in an AC system**[1]*

[1] MIT Electric Grid of the Future Report

Reactive Power management

Reactive power management is a key element of voltage support on the GB national electricity transmission and distribution systems. Too much reactive power on the system increases voltage levels, and too little reduces it. The frequency of both voltage and current are controlled carefully as part of the management of power quality. This minimises losses and ensures the electricity is maintained within safe, controllable levels preventing damage to generation and network assets and other equipment connected to the system.

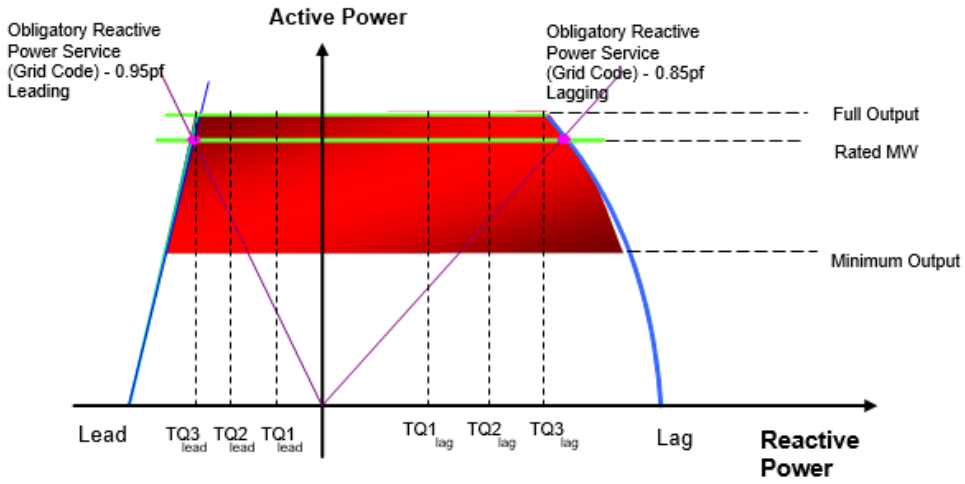
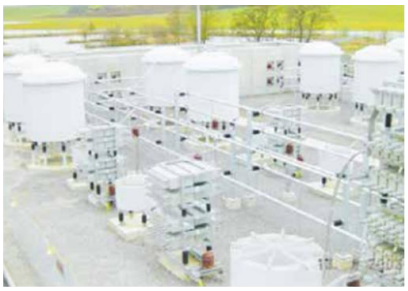


Figure 2 ***Example Capability Breakpoints at Full Output for Leading & Lagging Mvar***[2]

Historically, the reactive power on the system has been managed in one of two ways.

- Large Centralised Electricity Generators (capacity > 50MW)[3] complying with the Grid Code and providing reactive power as well as active power
- additional reactive power supplied by specific ancillary equipment such as Synchronous Compensators, Static Var Compensators (SVC) or STATCOM devices, owned and operated by the Transmission or Distribution Network Operator at strategic network locations

a)



b)

c)

*Figure 3****: Examples of transmission system ancillaries a) Synchronous Compensators / Condensers b) Static Var Compensators c) STATCOM***

[2] Grid Code CC 6.3.2
[3] Grid Code CC 6.3.2

Existing Reactive Power Services as a market

Reactive Power Markets

The primary provision of reactive power supply at a **Transmission** level is facilitated through the obligatory reactive power service (ORPS) as part of the Electricity System Operator's Balancing Services.

Additional provision of reactive power over and above grid code requirements was also historically provided via the enhanced reactive power service (ERPS) market. This service was provided alongside other balancing services. This service was last procured in 2009.

There is also an option to provide absorbance services as well as supply of reactive power. More information on historic reactive power markets can be found on NGESO site[4].

Reactive Power Services at a distribution level

As it stands, there is no industry wide market live at the moment for reactive power at a distribution level on the GB network. However, there have been a several networks innovation projects investigating either the market opportunity, the network benefit and/or the technical feasibility. This review identified four of note (there may be others). A brief review of the scope of these projects and some points of notes from completed studies have been compiled.

Innovation summary

In the main, these innovation projects were desktop studies of the potential of reactive power as a service/market. The most demonstrable reactive power trial was within the Power Potential project where the market was designed and demonstrated in a zone within the Southeast of England.

Summary conclusions

- Only Reactive Power Market Design and Q-Flex were projects solely for the investigation of reactive power
- Power Potential delivered a successful market trial for reactive power provision to support transmission voltage from DERs connected at a distribution level
- Reactive Power Market Design project has identified a range of barriers for procurement of this service from assets connected at distribution level
- It's not clear from publicly available data of the innovations if a definitive technical specification requirement for a reactive power service at a distribution level The Power Potential team have been contacted for more information.

[4] Balancing Services | National Grid ESO

Reactive Power markets innovation trials reviewed

Project Details		Funding
Project Title, Partners and status	**Project Description**	**Budget and source**
Reactive Power Market Design NGESO, AFRY **Complete – Sept 2022**	This 1-year project explored how a reactive power market could be developed to help ESO access more reactive power in the right location, create market access for more providers, incentivise more efficient new technologies and lower the overall spend on reactive power control. (NIA2_NGESO0008)	**£600,000** Network Innovation Allowance
Power Potential (Transmission & Distribution Interface 2.0). NGET, UKPN, **Complete – Dec 2019**	A 3-year project aimed to develop technical and commercial solutions to maximise the use of distributed energy resources (DER) to resolve transmission voltage constraints. Reactive power was only one element of this study, alongside active and active-reactive power aggregation. (NGET_UKPN_TDI2.0)	**£9,560,113** Network Innovation Allowance
Virtual Statcom NGED and PSC **Complete – Dec 2019**	This 21-month desk-top study project investigated new ways of providing additional network capacity in a non-traditional approach to physically extend the network at reduced cost and time. (NIA_WPD_037)	**£293,210** Network Innovation Allowance
Q-Flex NGED, PSC and NERA **Started Sep 2022 (until March 2023)**	The newly kicked-off Q-Flex project will demonstrate if flexible reactive power is possible, assess whether it is a solution to voltage problems, loss minimisation and thermal network constraints, and understand if participants are willing to provide reactive power as a service at the distribution network level. (NIA_WPD_072)	**£538,268** Network Innovation Allowance
Reactive Power trial SPEN (SPM) **Started Sep 2022 (until March 2023)**	Full scale procurement trial utilising the Flexible Power Platform as a proof-of-concept event. Procurement complete and contract now in place to start early 2023.	**Internal**

Points of note by project

Reactive Power Market Design

The Reactive Power Market Design project identified that “future market arrangements will need to facilitate a wide range of providers with diverse cost structures to maximise competition”. The project also established that a wide range of transmission network improvement projects e.g. pathfinder, would change the system need for reactive power. It was noted that there were high technical and regulatory barriers for distribution connected assets to enter the reactive power marketplace with limited current routes to provision outside of direct DNO contracting.

An interesting mapping exercise of expenditure on reactive power market size by voltage region provides some insight to the regions of the GB system was developed (

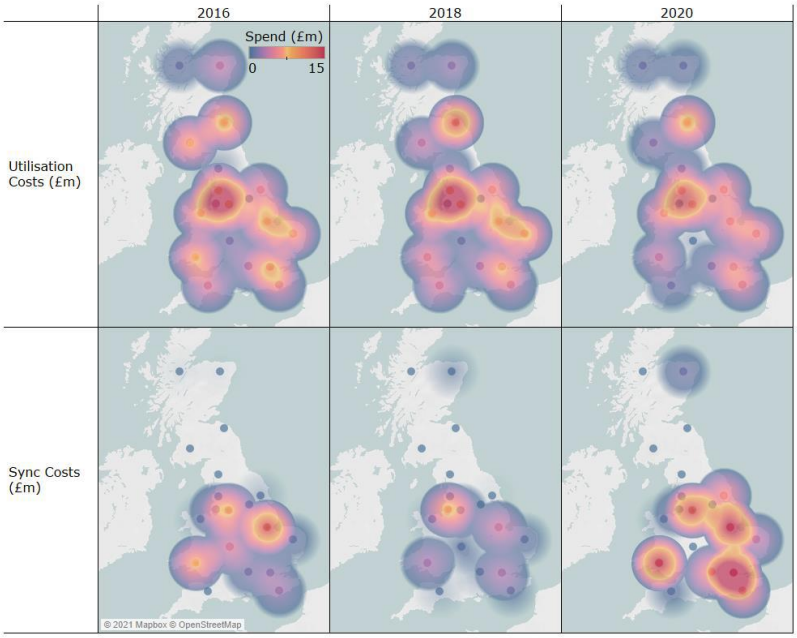


*Figure 4: **Expenditure on Reactive Power by ESO by (voltage) region (ref: AFRY)*** [5]

Power Potential NGET_UKPN_TDI2.0

In the Power Potential project, a reactive power service was designed to provide dynamic voltage support from a Distributed Energy Resources (DER) instead of the traditional use of a Static Var Compensator or STATCOM reactive compensation device or a transmission connected generator.

In the trial, the reactive power service, there were two approaches to ‘service instruction’.

- non-synchronous DERs were instructed (at their point of connection) using voltage droop control to produce/absorb reactive power
- synchronous DERs were instructed using a voltage target set-point to adjust the generator terminal voltage to produce/absorb reactive power

[5] NIA2_NGESO0008

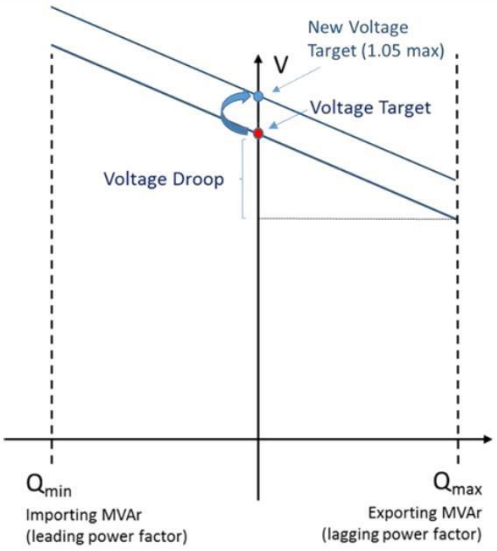


Figure 5 Voltage droop control principles utilised for non-synchronous DERs in Power Potential project

Virtual Statcom NIA_WPD_037

The Virtual Statcom project investigated the technical feasibility (via extensive power systems modelling) of increasing network hosting capacity, for both generation and load, by optimising the reactive power dispatch of distributed generators.

Importantly, the Virtual Statcom optimisation algorithm (developed in the project) demonstrated the ability to resolve or reduce constraints in networks through optimised reactive power dispatch. It was established that this reduction had the potential to reduce the amount of active power curtailment required to manage network constraints. This could have the potential to increasing distributed generation capacity without the need for reinforcement.

Q-Flex NIA_WPD_072 (just started) (Thanks to Ryan Huxtable, National Grid (NGED) for the information)

Q-Flex aims to demonstrate if the provision of flexible reactive power is technically possible, assess whether flexible reactive power is a solution to voltage problems, loss minimisation and thermal network constraints, and understand if participants are willing to provide reactive power as a flexibility service.

To achieve this, it will carry out engagement and literature review to document which current and emerging technologies are able to provide reactive power flexibility and, undertake high level power system studies. It will then develop methods for carrying out Cost Benefit Analysis to determine the financial and environmental costs/benefits achieved from the use of flexible reactive power and carry out a market assessment to determine asset owners' interest in providing flexible reactive power as a service, before developing an initial market design.

Flexibility Services – Reactive Power (FSRP) (contracted) (Thanks to Guy Shapland, SPEN Commercial & Policy Lead – DSO, SPEN for the information)

The trial was funded internally and was a proof of concept working with a Flexibility Service Provider (FSP) (utilising their gas reciprocating engine) to investigate the barriers to entry and the feasibility of managing Reactive Power. The service need was advertised via the pre fault product on Flexible Power platform to manage the trial and to agree the commercial terms and conditions ahead of the technical demonstration.

Phase 1. (Starts early 2023)

- investigate the work needed to prep gas recips to provide reactive power

- configure metering and settings
- run a one-week trial slowly ramping up reactive power to the maximum (2.2MVArs)

Phase 2. (later in 2023)

- investigate the findings to confirm any proven network benefit (site is in a remote network location)
- value the commercial drivers for the product
- report and disseminate the outcome to the industry

Conclusions

Early trials and demonstrations of reactive power service markets have been carried out on the GB network at a transmission and distribution level with promising results.

Reactive power provision can provide valuable voltage support at the distribution level to support voltage within remote rural networks and/or reductions in reinforcement required to provide additional capacity for generation. It can also be used to support voltage across transmission.

However, the definitive technical specification for reactive power to be provided as a flexibility service at a distribution level have not fully been established. The product team therefore conclude that we are unable to recommend a product quite yet.

The feasibility of reactive power as a flexibility service should be reviewed again by the Product Team when the NGED Q-Flex and the SPEN FSRP projects have concluded.

GLOSSARY

Acronym	Term
BSP	Bulk Supply Point
DNO	Distribution Network Operator
LCT	Low Carbon Technology
MW	Megawatts, unit for real power
Mvar	Mega volt-amperes reactive, unit for reactive power
NIA	Network Innovation Allowance
NIC	Network Innovation Competition
PF	Power Factor

Visit our website to find out more about Open Networks

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