SP ENERGY NETWORKS

REACTIVE POWER TRIAL

Phase 1 - 2021

Reactive Power Trial in Partnership with Conrad Energy

Executive Summary

As our electricity network continues to evolve around the daily challenges of a net-zero energy mix, maintaining balance of system voltage has never been so important. Reactive Power is a fundamental element of balancing system voltage and therefore its steady procurement is a priority.

SP Energy Networks's Reactive Power Trial sets out to investigate the feasibility and value of procuring reactive power services at distribution level to enhance our system voltage management and support the growing number of connections to our distribution network.

Introduction

In order to support the projected growth of Low Carbon Technologies (LCTs) and Renewable Energy Resources on the journey to net zero, there is an urgent need to innovate new ways of supporting system voltage to prevent network constraints and mitigate the risk of power outages. Reactive power plays a significant role in maintaining stability and reliability of the network as it ensures voltage levels remain within acceptable limits, preventing harsh voltage fluctuations and consequent damage of connected assets. A well-managed flow of reactive power can improve network efficiency by reducing the amount of reactive power required to be generated and active power transmitted – ultimately reducing the cost of electricity for customers. Despite its integral role, there are an increasingly limited number of traditional sources of reactive power and so alternative sources need to be devised. Though procurement of reactive power to the transmission network is well documented, contracting for reactive power supply at distribution level is a completely novel concept – but arguably something which needs to be tapped into as increasing volumes of embedded generation continue to squeeze network capacity. Successful deployment of reactive power services at distribution level would improve the capabilities for local network management and future planning and can improve the integrity of our system balancing strategies.

Having identified various regions of the SP Manweb network (SPM) operating outside of statutory voltage limits, reactive power support has been tendered for as a flexibility service in recent tender windows - though no providers appeared to actively bid into the competition. This identified key questions regarding how reactive power can be supplied to the distribution network and what changes must be made to encourage providers to participate in this market. In August 2021, SP Energy Networks (SPEN) took the initiative to produce a solution to these questions by conducting a 5-day reactive power trial in partnership with Conrad Energy (CE) to investigate the feasibility of offering reactive power as a flexibility service and define the typical generation requirements of a reliable reactive power provider.

The need for Reactive Power in SPM

Maintaining the operation of the network within statutory voltage limits is a crucial decision-making factor when determining network management and reinforcement plans. Non-compliance with these limits result in heavy fines for SPEN until appropriate voltage levels can be restored. As customer needs evolve, DNO's are innovating smarter ways of managing voltage within these limits including solutions to defer or avoid network reinforcement.

Extensive modelling of profile-based voltage constraints and associated risk durations has been undertaken on the SPM network [1] , identifying several locations where compliance with voltage limits during periods of peak demand is unstable and will only worsen as connected generation increases. As an alternative to costly network reinforcement at these constraint hotspots, voltage control can be improved by procuring a well-balanced flow of reactive-active power support. It is possible to improve control only through active (useful) power resources, though this would require a large volume of active power making it difficult to restore statutory limits in an unforeseen voltage event. The interconnected nature of the SPM network which features several high demand and long circuits mounts additional pressure on making reactive power support readily available. One such primary substation which was identified to be operating outside of statutory limits was in Flintshire, Wales and so was selected as the ideal location to conduct the SPEN-Conrad Energy Reactive Power Trial in August 2021.

Partnership with Conrad Energy

As the UK's largest Independent Power Producer (IPP) [2] specialising in bespoke flexible generation and energy storage, Conrad Energy (CE) were approached as the best suited partner to pilot the innovative reactive power service. With a growing and diverse portfolio of flexible generation projects and ongoing commitment to support the transition to a low carbon economy, CE's expertise would provide invaluable insight and resources for the generation side of the project. The 4-day trial took place at Flint Primary Substation in North Wales, with support from CE's nearby flexible generation site and group of 3 gas reciprocating generators which would be manipulated to generate reactive power imports.

Trial Process

A) OVERVIEW

The objective of the 5-day trial at Flint Primary was to deliver a proof of concept to confirm whether or not reactive power could be provided – and how many MVAr's – as well as investigating the entry requirements to a flexible reactive power market at distribution level. In addition, this pilot phase would allow an opportunity to assess the impact of the service on both the network and connected assets during MVAr fluctuations.

The primary site at Flint operates 3 Jenbacher 6-series gensets which need to be generating active power to provide a reactive power service at the same time. The amount of reactive power generation is dependent on the power factor of each of the 3 generators which determines whether reactive power is being generated (imported) or consumed (exported). A leading power factor – where the load current is capacitive in nature – ensures that reactive power is being imported and so each of the generators were configured as such during the scheduled trial periods. If successfully imported, metered readings of reactive power would record the generated MVAr's for each service window. In advance of the trial, a 6 month bilateral contract was agreed and signed with Conrad Energy, outlining the following scheduled flexibility program:

Flexibility Product	Secure, Pre-Fault Scheduled Service (from Flexible Power platform)
Capacity	0.4MVAr Leading Power Factor
Service Window	16:30 – 19:30 over the 5 day period
Cost	£400MVArh

B) PREPERATIONS

One of the key innovations behind the trial was the intention to accurately feed the metered reactive power data straight into our SPEN Flexible Power API. This involved some enhancements to our API and a series of tap changer audits and network assessments in advance of the trial to ensure everything was optimised to accommodate this upgrade. CE had also taken the time to test their own API and ensure that the metering data could be accurately transmitted to the Flexible Power portal. To improve management of the reactive power flow, they also installed and upgraded control equipment to allow automatic setting of the power factor of the generators.

C) SERVICE WINDOW OPERATIONS

During the 3-hour service window each evening, the auto-scheduled dispatch signal was sent to each of the 3 generators to adjust to the desired input power factor. With the gensets running at a leading power factor, a measure of both active power and subsequent reactive power was metered and data transmitted to the Flexible Power portal for analysis. The approach was to adjust the power factor to slowly ramp up reactive power to the maximum (2.2MVAr's) across the 5 days and assess the degree of controllability available and observe any impact on the generators/network.

D) RESULTS

Based on the data received in Flexible Power, the quantities of generation between 16:30 and 19:30 on each day are shown in Table 1.

Trail day	Active Power Generated (MW)	Reactive Power (MVAr)
1	4.7	1.0 (Import)
2	7.0	1.5 (Export)
3	7.0	1.5 (Export)
4	-	2.25 (Import)
5	No Generation	No Generation

Table 1 - Metered data from the 5-day trial

On Day 1, CE discovered that the polarity of the reported data was inverted (measuring import instead of export and vice versa). In addition, there were only 2 out of 3 generators available on this day therefore a comparatively low volume of reactive power was imported.

On Day 2, CE had corrected the polarity error and made available the 3rd generator and therefore we see a largely stable amount of active power being produced and in turn a higher amount of reactive power being absorbed from the network with a power factor of 0.975 leading. This result was consistent for day 3 which yielded identical results.

On Day 4, a power factor of 0.95 leading was achieved, resulting in a maximum daily reactive import of 2.25MVAr. The active power on this occasion was not recorded.

Though the trial was officially scheduled to run for 5 days, CE did not provide any generation on day 5 and so no data was recorded for the final trial day.

Conclusions & Next Steps

The 5-day trial successfully demonstrated that the provision of reactive power at a single primary generating site can be achieved and highlighted the following findings:

1. Ramping up of reactive power can be controlled via tuning of the generators' power factor
2. The power factor of the 3 generators could be controlled via our internal control system
3. The generators could adjust their output to prevent any loss of active power
4. We could successfully feed the reactive power metered data directly to the Flexible Power API
5. The impact on both the generators and the network appeared to be acceptable

The above conclusions lay a useful foundation to explore further the potential for reactive power to provide essential voltage support at distribution level, targeting specifically remote and rural networks and even the prevention of local network reinforcement. However, though the trial results are positive, they do not yet provide enough insight to develop a full technical specification for reactive power to be offered as a distribution flexibility service and further research will be required for such a product to be developed.

Therefore, a 2nd Phase of the project will commence later in 2023 and will focus on valuing the service by confirming any proven network benefit from the 5-day trial results. It will also allow a chance to assess the impact at the remote ends of the feeder, value the commercial drivers for the product and finally report and disseminate the outcome to industry.

References

[1] R. B. e. al, "Flexible Network Planning Process: Case Study," CIRED, Glasgow, 2020.
[2] C. Energy, "The energy company of the future," Conrad Energy, [Online]. Available: https://conradenergy.co.uk/. [Accessed March 2023].