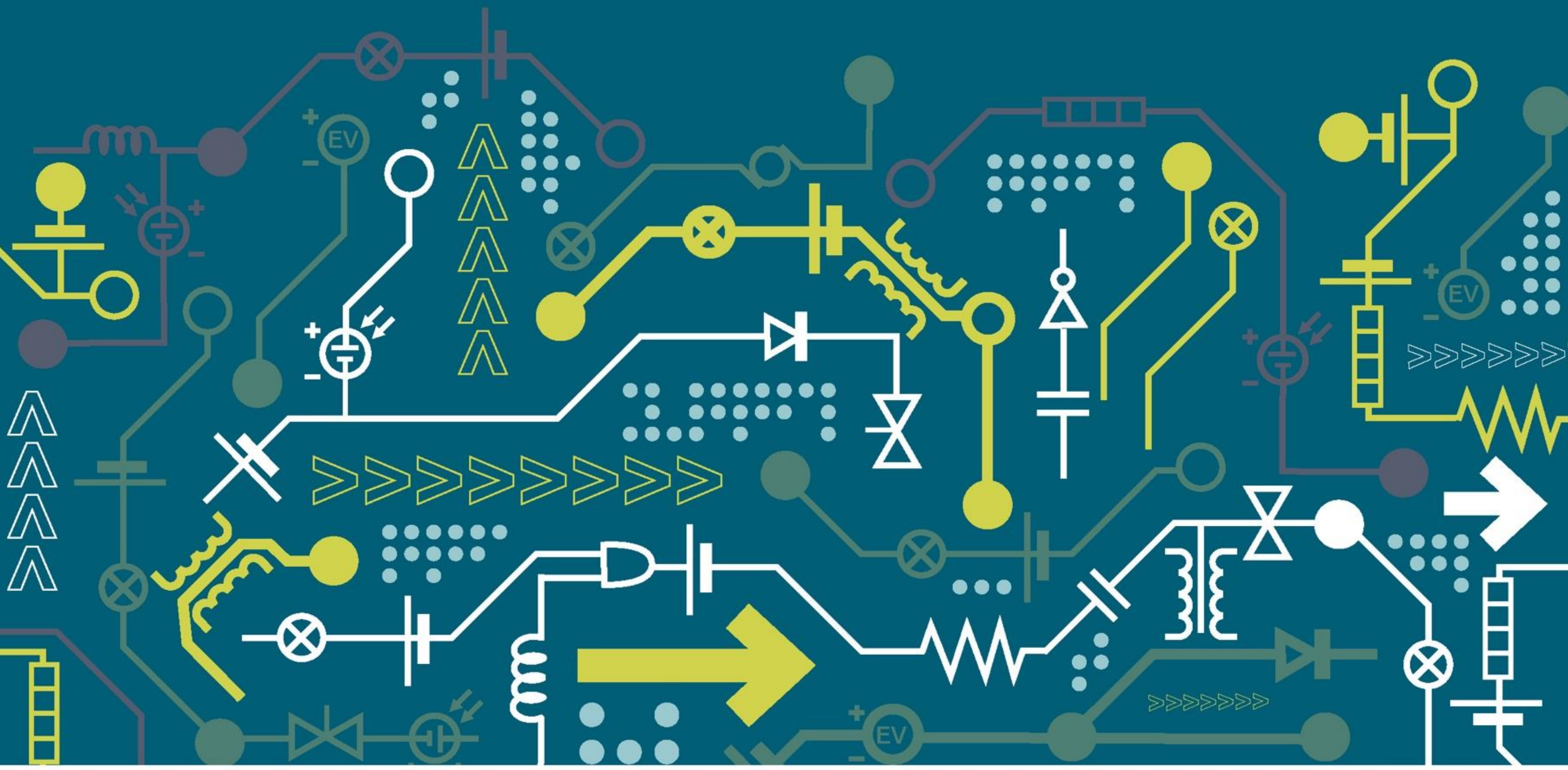
Smart Energy Isles

Closedown Report



WESTERN POWER DISTRIBUTION

Serving the Midlands, South West and Wales

Version Control

Issue	Date
1	02/04/20

Publication Control

Name	Role
Sam Rossi Ashton	Author
Jon Berry	Reviewer
	Approver

Contact Details

Email

wpdinnovation@westernpower.co.uk

Postal

Innovation Team
Western Power Distribution
Pegasus Business Park
Herald Way
Castle Donington
Derbyshire
DE74 2TU

Disclaimer

Contents

1 Executive Summary

Smart Energy Isles was a WPD led NIA funded project that ran from December 2017 to January 2020. The partners at project initiation were ZIV and Nortech but this was subject to change during the project (see Project Changes section). This project was supporting a separate ERDF project being delivered by Hitachi.

1.1 The challenge

Active Network Management (ANM) connections are being offered in areas of the network where available capacity is limited. Currently, ANM connections can only be offered to generators connected to the 11kV network and above. Being able to manage a group of Low Voltage (LV) generators connected to the same 11kV point of connection in the same way 11kV generators are managed by the ANM system, could allow ANM connections to be offered to distributed generation connected to the LV network. This would require the capability of curtailing those generators when required based on the outputs of the ANM system. Such a system also posed a good situation to consider whether demand side management could be used to alleviate the setpoint of a constrained generator.

1.2 The approach

The scope of the project was to trial the capability of curtailing LV generators based on real-time network constraints and to explore the policies required to enable those generators to take part in ANM in a Business As Usual (BAU) situation.

1.3 Results

The project successfully monitored real-time constraint signals and used them to issue curtailment setpoints to multiple LV generators on the Isles of Scilly.

2 Project Background

Active Network Management (ANM) connections are being offered in areas of the network where available capacity is limited. Currently, ANM connections can only be offered to generators connected to the 11kV network and above. Being able to manage a group of Low Voltage (LV) generators connected to the same 11kV point of connection in the same way 11kV generators are managed by the ANM system, could allow ANM connections to be offered to distributed generation connected to the LV network. This would require the capability of curtailing those generators when required based on the outputs of the ANM system.

The Isles of Scilly is one such location where the number of LV generators may become an issue for the network because the Isles of Scilly are fed by a single subsea cable that, if allowed to go into reverse power-flow could have adverse implications for mainland Cornwall. As such, the project saw this as a good location to test aggregate control of LV generators.

3 Scope and Objectives

Objective	Status
Deliver a system that can issue disaggregated curtailment setpoints to LV generators.	✓
Deliver a recommendations document detailing how ANM connections could be offered to LV generators.	✓
Document the requirements that would allow multiple disparate LV generators to be modelled as a Virtual Power Plant (VPP).	✓

4 Success Criteria

Success Criterion	Status
The project will be deemed a success if real-time constraint signals can be monitored and used to issue curtailment setpoints to multiple LV generators generation on the Isles of Scilly, proving successful curtailment	✓
Documentation of policy requirements	✓

5 Details of Work Carried Out

5.1 Method

To enable the deployment of additional low carbon generation on the Isles of Scilly without adversely affecting the constrained Cornwall mainland, any such generation would need to be curtailed if the subsea cable to The Isles approached reverse power flow. The simplest way to do this is via aggregate control/the creation of a VPP.

A VPP is a cluster of distributed energy resources (DERs) which are aggregated into a single virtual entity and treated as a single power system component for the purpose of technical and commercial operation of the electricity network.

The advantages of implementing such a system include that the geographical spread of assets and generation mix diversity reduces the risk of single points of failure within the system. Also, the short circuit current contribution is reduced, compared to generation of the same aggregated capacity but installed at a single point in the network. Furthermore, if a VPP cluster could participate in an ANM system, this would provide an additional connection option for customers, a cheaper ‘per site’ ANM solution, and faster connection if waiting for network reinforcement can be avoided. All this could culminate in additional LCT connections and faster decarbonisation. However, the response time of VPP, as a whole, to control setpoints can be significantly longer compared to a single installation of the same installed capacity. This is particularly noticeable if different equipment manufacturers and communications protocols / communications carriers are used. In general, for effective and efficient operation, a system is required to coordinate the output of the individual entities that comprise the VPP portfolio.

Hitachi has installed several commercial PV sites as well as controllable demand appliances on the Isles of Scilly and is creating a DSR system as part of its ERDF Smart Energy Islands project. As such, we chose these assets to trial the VPP system and also provided curtailment information to Hitachi to help it best realise its DSR system.

5.2 Approach.

The VPP is made up of six photovoltaic (PV) generation systems, which are electrically and geographically distinct, together with a mixture of commercial and domestic load. Each of the distributed energy resources, which are aggregated within the VPP, are controllable individually in terms of their active power export (in the case of the PV systems) and active power import (in the case of the demand-side response loads). This is so that a customer could, if desired, define a curtailment sequence where generators of less financial value are curtailed first.
At each PV generation site, a Low Voltage Connection Controller (LVCC) box is installed and integrated to the PV inverter array. This gives

- Remote visibility of the real-time power output of the generation scheme;
- Connection health status indications; and
- The ability to allow setpoints to be dispatched to control the output of the generation based on real-time power network constraints (such as thermal and voltage excursions).

PV Sites monitored or controlled by the project system		
	Panels	Inverter (kW)
Waste	280	70.00
Desalination plant	48	15.00
St Mary's fire station	32	8.20
Airport terminal roof	36	8.20
Airport fire station	56	10.00
Airport ground mount	160	40.00

The LVCCs and DSR system are integrated into a software platform which sits in WPD Avonbank and receives the real-time power network monitoring information via the DSO’s Network Management System and, together with knowledge of the operational limits of the network, is able to determine how much generation is required to be curtailed (or demand increased) in order to continue to operate the network safely. The software platform uses time-series analytics to forecast the magnitude and duration of power network constraints.

Fundamentally, the system monitored real-time power flow through the subsea cable, if it detected a constraint violation (for example, excess generation leading to reverse power flow in the subsea cable) the generation output was reduced to alleviate the constraint and, at the same time, a signal was sent to a Hitachi DSR system for an increase in load demand. Depending on the commercial viability (weighing up the cost of reactively increasing the load demand versus the cost of the generation constraint) the Hitachi DSR system either responded to the request or remained at the previously scheduled level. If the DSR loading was increased, this could have been detected by a change in power flow through the subsea cable and a signal would have been sent to the PV generation systems to increase their output.

There were no other constrained generators on the islands so the benefit of the DSR would always go to the intended generators. This is a simpler arrangement than for other ANM systems where the difficulty of knowing which generator in the LIFO stack would be constrained at any one time makes it harder to put commercial arrangements in place between DSR providers and generators seeking to increase their output when the value of their additional generation outweighs the DSR costs.

5.2.1 Architecture

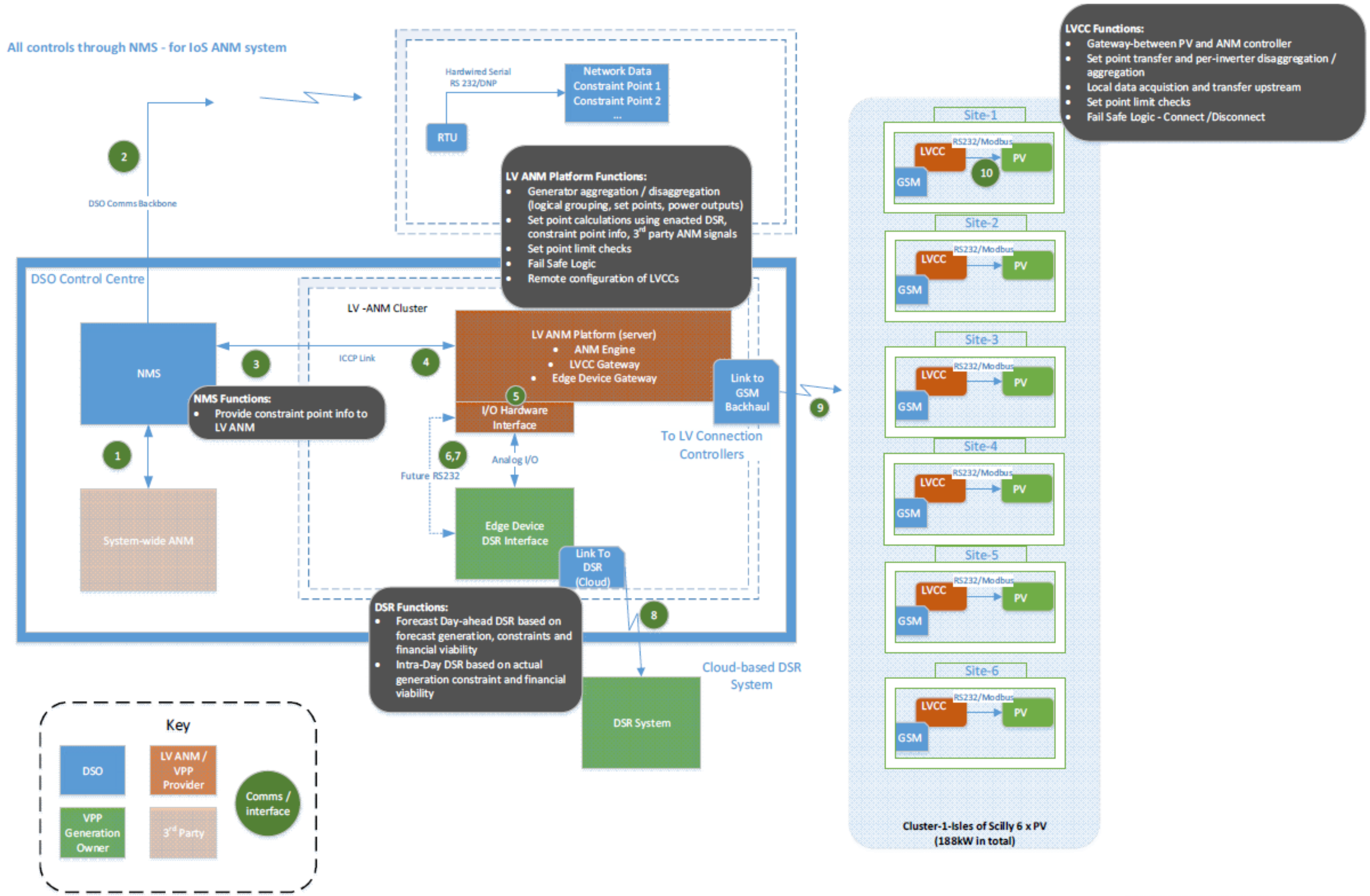


Fig 1. Project architecture diagram

	Interface Number Description
1	Interface between third party (non-project) ANM systems and the WPD NMS (not used in project)
2	Interface between network data acquisition (DSO RTUs) and the WPD NMS (providing real-time constraint point power flow and voltage information)
3, 4	Inter-Control Centre Protocol (ICCP) interface transferring network monitoring signals from NMS to LV ANM System
5	DNP3 over Ethernet interface from LV ANM Platform to I/O hardware (acting as the signal translator and protocol converter for Hitachi DSR system)
6	Analogue I/O between LV ANM Platform and Hitachi DSR system
7	Placeholder for future digital I/O between LV ANM Platform and DSR system (not used in project)
8	IP based communications from Hitachi Edge device to Hitachi DSR system
9	DNP3 over Mobile (3G) communications from LV ANM Platform to LVCC boxes
10	Modbus over Ethernet communications from LVCC boxes to Inverters

5.2.2 Trial Design

The ANM trials were run from June until October 2019. During this period, several modes of operation were trialled. These modes of operation are described below:

1. Cyclic Operation of the Project System
2. Instantaneous
3. “Day ahead” / Forecasted behaviour

Cyclic Operation of the Project System

This is the standard mode of operation for the system. Generator Curtailment is triggered by network loading falling below a specified threshold and therefore risking reverse power flow, DSR is requested due to generator curtailment, an increase in network loading is detected, and generator curtailment is alleviated.

As there was not the expected level of take-up of generation in the trial area, there wasn’t sufficient generation to risk reverse power flow through the constraint point and so new methods were devised to trial the project system.

Instantaneous

Two types of instantaneous operation were trialled so as to best imitate a network constraint situation. These employed the same functionality as the cyclic operation, but mixed simulated data/artificial constraints with the real network data to force a response.

- **Simulated Generator:** A large simulated generator was added to the project system that traced the output of an existing generator and scaled it to replicate a situation where more generation was deployed on the Isles. However, the system was designed to calculate setpoints based on generator capacity and not generator output, in order to protect the network in the event of a large amount of generation suddenly outputting at any time. Due to this, an undesired consequence of the large simulated generator was that all other (real) generators remained constantly curtailed and DSR was perpetually requested.

- **Artificial Cable Limit:** The subsea cable loading threshold at which the system triggered and issued curtailment setpoints to the generators in the project system was increased from 0MW (to prevent reverse power flow to the Cornwall mainland) to a loading that would cause the system to operate daily.

  Due to the high natural loading variation relative to the level of installed generation, the generator curtailment and DSR requests were heavily weighted towards the loading of the cable rather than solar irradiance/generator output. This did not mimic a situation wherein constraints are caused by higher generation deployment on the Isles in future, and caused undesired DSR requests to be made overnight when subsea cable loading was at its lowest (see Fig 2 where a +2.2MW limit (black) caused the system to request DSR not only at 12:00 when the generators would have been curtailed, but also at 00:00 and 03:00 when generator output was zero and so nothing was being curtailed.)

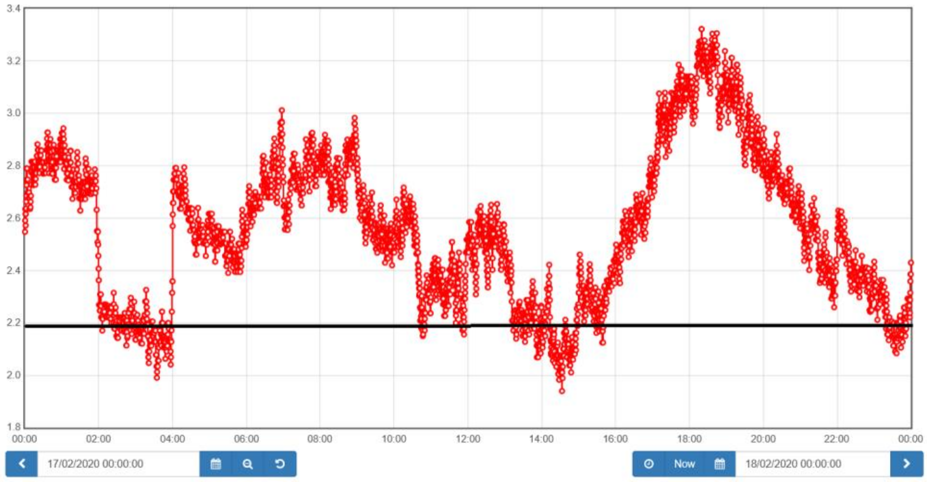


Fig 2. Plot showing subsea cable loading over an average day (red) and where a +2.2MW limit would have triggered system operation.

"Day ahead" / Forecasted behaviour

This mode used historic network data to forecast subsea cable loading that the project system could then use to estimate a constraint magnitude and duration. This enabled Hitachi to take proactive action on its assets (e.g. alter load profiles) to reduce the chance of instantaneous curtailment of the generators. The LV ANM Platform, iHost, used schedules containing predicted constraint duration and magnitude to request DSR from the Hitachi DSR system at the time it was required.

If enough network data could have been provided, the creation of this schedule would have been automated using time-series data analytics, instead for trials the project team drafted schedules and uploaded them to the system. This forward schedule is written into a CSV file which is then uploaded to iHost. Forward schedules can be written for any duration into the future.

5.2.3 Artificial Cable Limit Instantaneous System Operation Example

In the Fig 3, the:

- Blue trace represents the subsea cable loading,
- Red trace represents the aggregate output of the commercial generators on the project system, and

- Black trace represents the curtailment setpoint the system is calculating in accordance with the imposed cable limit.

During this trial the threshold at which the system triggered was changed from 0MW (to prevent reverse power flow), to 2.4MW in the forward direction.

At 14:40, when the power flow drops below this threshold, the required setpoint (black) is calculated to be less than the generator output (red) and as such, the output is curtailed. The system is latched and remains at this level for a few minutes to avoid setpoint hunting, and then the constraint on the generation is relaxed.

Later at 15:20, demand turn-up from a successful DSR trading cycle can be observed. This increases the subsea cable loading (blue) above the system trigger threshold which causes the setpoint (black) to drop well below the generator output (red) allowing them to export art their maximum.

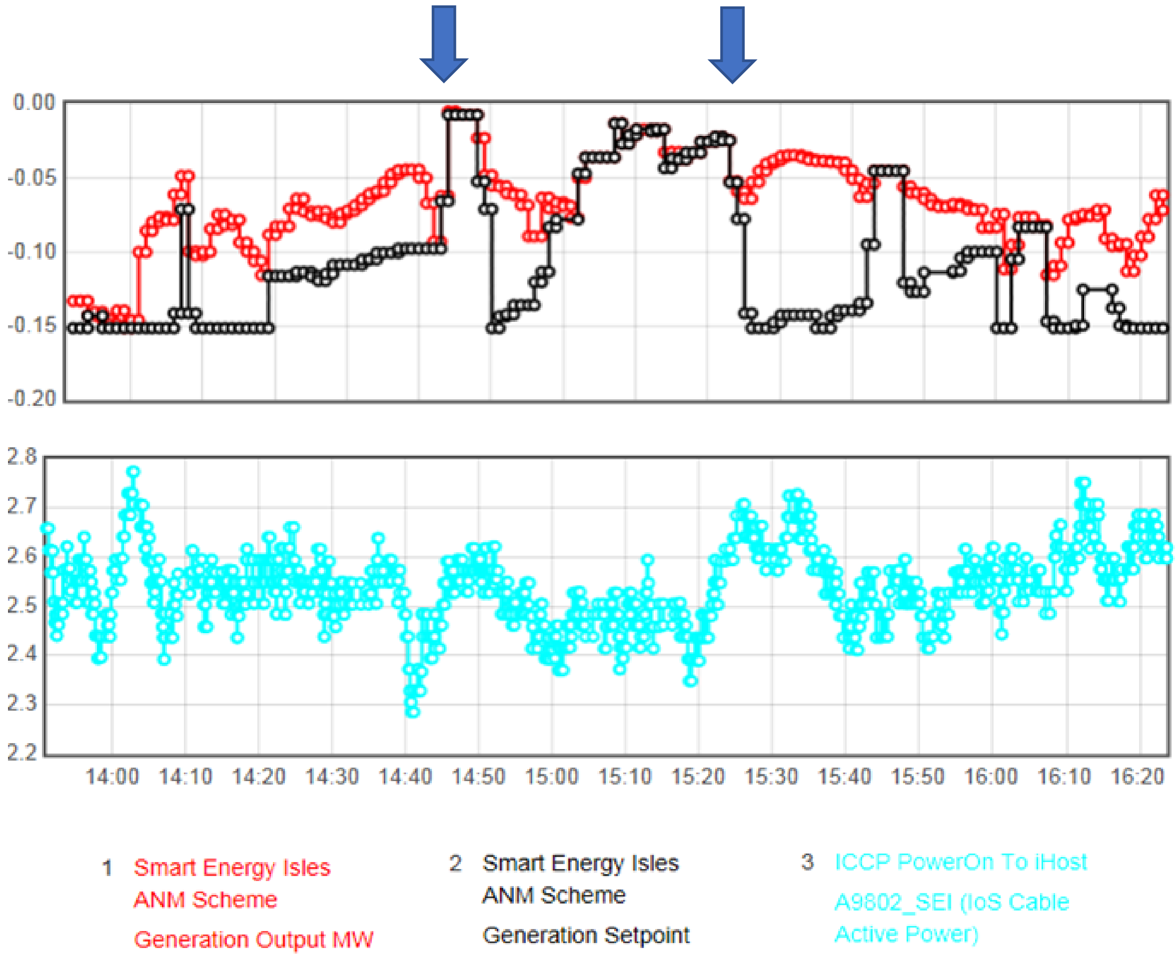


Fig 3. Artificial Cable Limit Instantaneous System Operation Example

5.2.4 DSR Observability for Cyclic System Operation

For cyclic system operation to occur, the demand turn-up effects of the DSR trading cycle needs to be visible at the point of constraint (the subsea cable). The size of the controllable DSR load during the trials, relative to uncontrollable loads on the Isles of Scilly, meant that it was very difficult to differentiate between natural load fluctuations and scheduled load profile changes.

5.2.5 Evidencing Hitachi Trading Success

WPD deployed GridKey units at the two secondary substations on the Isles of Scilly with the most controllable load assets downstream to assist Hitachi with understanding the aggregate behaviour of its demand assets. Note that this monitoring was deployed solely to assist Hitachi's endeavours to validate the impact on the network of their load management system and was not able to assist with cyclic system operation.

5.2.6 Financial Viability for VPPs

The nature of VPPs being clustered LV DERs that can act as a single HV DER and the control system allowing them to be controlled as such means the financial viability can be viewed in a similar way to an HV connection. The potential cost of curtailment for a particular VPP will be reliant on the surrounding HV network, the amount of expected constraint and the number and capacity of higher priority DERs in the LIFO stack. The benefit of any DER connection must be weighed against the installation cost. The VPP solution reduces installation costs while impacting on the benefit of the generation and this should be evaluated on a per site basis. In the case of the Isles of Scilly, as no real constraint is expected on the islands the generators are unlikely to be curtailed and the financial viability of the is improved by not requiring network reinforcement for the installation.

5.2.7 Demand Turn-Down for Flexible Power

During the trials, WPD's Flexible Power brand published interest in procuring demand turn-down to lop load peaks on the Isles of Scilly (around 0900 and 1830 in April). Where the project had looked at demand turn-up, Hitachi was keen to trial demand turn-down as this posed a strong opportunity to derive additional revenue from its assets. Demand turn-down functionality was evidenced by Hitachi inverting the signal received from iHost.

5.3 Recommendations and Requirements for VPPs

During the project, meetings took place with the WPD Policy Team to ascertain the requirements, were such a system to be connected to the network outside of innovation trials. Below summarises those conversations:

A physical Connection Control Panel (CCP) is required by WPD for an HV connection to participate in an ANM system. A single CCP could service a group of generators or a VPP, the sharing of this asset reduces its 'per site' cost. This CCP could sit at a remote location (next to the VPP control system for example) or in theory be virtualised.

- The VPP is required to all be downstream of the same monitored point of constraint on the network so they could be considered as a single point of connection.
- All generators in a VPP are required to have the capability to physically disconnect when instructed to do so by WPD via CCP.
- Each generation site is required to have an known sensitivity factor relative to the constraint. This is to facilitate functionality wherein a site owner/manager is able to decide in what order/proportions generators within a VPP are curtailed and restored during constraint. (Note: sensitivity factor calculations could be built into a VPP management system)
- Network between disparate assets is required to be non-configurable (disregarding WPD maintenance or fault) as changing the running arrangements will affect generators' sensitivity factors relative to the point of constraint.
- Aggregate ramp-down rates for the VPP must be calculated and must comply with WPD requirements. (as per SD10:2.6)
- A single entity must own/manage all generation sites in a VPP. This entity must submit the connection application for each site to be in the LIFO group simultaneously.

- Once a LIFO position is assigned to a group of generators, no additional generators can join that group or re-join if they leave the group at any time.
- As per existing requirements for a single site, the developer of a VPP must start work on all sites in the group within 12 months of receiving the connection offer and export energy from all sites within 18 months. (as per SD10:13.1)

6 Performance Compared to Original Aims, Objectives and Success Criteria

Objective	Status
Deliver a system that can issue disaggregated curtailment setpoints to LV generators.	As above, the project system successfully monitored the loading of the subsea cable and in-turn sent disaggregated setpoints to disparate LV generators causing them to curtail their output.
Deliver a recommendations document detailing how ANM connections could be offered to LV generators.	These recommendations are outlined in section 5.3.
Document the requirements that would allow multiple disparate LV generators to be modelled as a virtual power plant (VPP).	These requirements are outlined in section 5.3.

Success Criterion	Status
The project will be deemed a success if real-time constraint signals can be monitored and used to issue curtailment setpoints to multiple LV generators generation on the Isles of Scilly, proving successful curtailment	As above, the project system successfully monitored the loading of the subsea cable and in-turn sent disaggregated setpoints to disparate LV generators causing them to curtail their output.
Documentation of policy requirements	These requirements are outlined in section 5.3.

7 Required Modifications to the Planned Approach during the Course of the Project

A change was made to the scope of the project due to issues that became apparent after initiation:

7.1 Cornwall ANM Integration

The project had initially aimed to integrate the VPP within the WPD Cornwall ANM system that has been developed by ZIV. The VPP would have been assigned a LIFO stack position and further trials would have taken place regarding reactions to ANM signals and issues with disparate assets holding one LIFO position. During the project it became apparent that the Cornwall ANM system would not be live in time for project trials. As such, ANM integration was de-scoped from the project which entailed a reduction in budget but an extension in timescales.

8 Project Costs

Activity	Budget (£)	Actual (£)	Commentary
WPD Project Management	81,226	82,526	
Accenture Project Management	130,800	2,970	Accenture was utilised as transitionary project management due to the changing of WPD resource. As such, the projected cost for this was largely underutilised.
ZIV	146,500	78,000	Underspend as ZIV integration with Cornwall ANM system was de-scoped.
Nortech	122,345	125,540	Overspend due to ICCP License required that was not identified during project planning.
Dissemination Costs	3000	0	This was done at the ENA Innovation Forum at no cost
Total	483,871	289,036	

NB. Nortech self-funded the development and demonstration of the VPP dashboard for the project. This represented a contribution of £15k.

9 Lessons Learnt for Future Projects

The primary lessons that were learned during this project were ones of project development and delivery:

- Ensure project conditions are in place prior to project initiation – As above, the project chose the Isles of Scilly as a trial location as it was working to the assumption that the number of generators that were due to be deployed there was going to push the subsea cable feeding the isles towards reverse power-flow causing potential issues for the network on the Cornwall mainland. This assumption was incorrect and as such the project system is unlikely to be required on this network in the near future.

- Ensure partners and their respective managers have unified direction – Having multiple and different project partners and therefore project managers throughout the duration of the project entailed a slight difference of opinion and directions. These circumstances ultimately led to duplication in scoping conversations and delays in specification documents as new resource got up to speed.

- Ensure development time is left to accommodate for the WPD IR specification process – During development the project team was not fully aware of the WPD IR process whereby, if IR needs to host a project system within the WPD network, it needs to create its own specification for the system. This ultimately led to a delay in project system deployment.

- Ensure that any company that project equipment is being procured from is willing to assist with non-standard configurations. The project LVCCs attempted to control the photovoltaic invertors in a novel fashion. The company that provided these invertors was difficult to contact after purchase which entailed additional effort by a project partner to understand novel configurations from documentation.

- Ensure that the expectations of stakeholders and partners regarding post-trial activity are managed throughout the project. Some project stakeholders were under the impression that the project system would remain in place after the project become a WPD BaU solution. As above the trial area did not suit the solution for BaU and the solution still requires approval by the WPD central business.

- Ensure permissions from asset owners are suitable for the length of the trial with contingency. Delays in solution development meant that trials ended later than first planned. An extension of permissions needed to be sought from asset owners to extend the trial.

- Ensure that enough contingency time is built into project testing and build for projects with some dependency on photovoltaics/seasonal generation. Delays meant that the summer irradiance peak was missed during trials and as such the generators never saw their maximum utilisation during that time.

- Ensure that GSM signal strength is tested on site at the first convenient time and upon installation at the latest. An untested site had low signal issues post-installation and so the site required a revisit to install a larger antenna.

- Ensure that every project stakeholder fully understands the data it requires to achieve its aims. A project partner had not fully considered the data it required to achieve its own aims. This entailed additional effort by entire project team.

10 The Outcomes of the Project

The project successfully

- Developed a scalable system that can take inputs from a network management system, calculate and disaggregate curtailment setpoints, output these setpoints to generators, and request demand turn-up from DSR systems.
- Trialled the developed system over six months utilising six generation sites and one DSR system.
- Proved that the project is suitable for curtailing multiple LV generators which could reduce the per-site cost of connection to a constrained network.

Project findings will also be disseminated at the International CIGRE Conference - the conference is going ahead as an e-conference this year and being re-run next year. A Smart Energy Isles paper written by Nortech will be published and presented at both conferences.

11 Data Access Details

Two secondary substations on the Isles of Scilly were monitored from July 2019 to January 2020 as part of the project. This data is available upon request.

https://www.westernpower.co.uk/projects/smart-energy-isles

www.westernpower.co.uk/Innovation/Contact-us-and-more/Project-Data.aspx

12 Foreground IPR

There was no foreground IPR created as part of this project.

13 Planned Implementation

On the Isles of Scilly

WPD identified the Isles of Scilly as a geographical area that may soon become an issue for the network due to the deployment of low carbon generation and constraints on the Cornwall mainland. At the time of writing, the penetration of such generation has been lower than assumed and as such the perpetuation of the system developed during the project is not required post-trials and is unlikely to be required in the near future.

Elsewhere

The VPP toolkit developed within this project could be of use where a network is connected downstream of a network constraint but wants to deploy LV-connected renewables. Although further work is required to deploy this LV system within an HV ANM system.

Glossary

Abbreviation	Term
ANM	Active Network Management
BaU	Business as Usual
CCP	Connection Control Panel
DER	Distributed Energy Resources
DSO	Distribution System Operator
DSR	Demand Side Response
ICCP	Inter-Control Centre Protocol
LCT	Low Carbon Technology
LVCC	Low Voltage Connection Controller
NMS	Network Management System
PV	Photovoltaics (Solar Panels)
VPP	Virtual Power Plant

wpdinnovation@westernpower.co.uk
www.westernpower.co.uk/innovation

@wpduk