SP Energy Networks

Low Carbon Networks Fund

Second Tier Reward

Second Tier Reward Application for the Accelerating Renewable Connections Project

£7.62m

Initial investment in project of **£7.62m** from LCNF Tier 2 mechanism

The project successfully connected

13 low carbon

projects compared to the initial **aim of 5**

376

A minimum of **376 FTE years** added to the UK economy

In total the excess generator capacity which has either been enabled or seen a reduction in constraint is

153.53 MW,

compared to initial project aims of **55 MW**

Over 653 GWh

of additional renewable energy generation through the 6-year life of the scheme

£200m

The project has facilitated **£200m** of capital investment, resulting in over **£61 million of GVA** added to the economy from the Dunbar project alone

Over £2m

in energy cost savings for domestic homes (this was through 2.2 MW of additional rooftop PV installations) and as well as savings for small scale connection customers over **£1.5 million** in connection costs

The aim was to examine up to 5 different processes for alternative connections – through the study 7 different methods were used succesfully

Reference documents

Table 1 Table of Reference documents

Document name	Source	Version	Published
ARC Closedown Report	Online	Final	17/3/2017
Economic evaluation of the Active Network Management (ANM) scheme at the Dunbar GSP	Online	Draft	24/09/2021
SPEN ARC Learning Report 1	Online	Final	17/3/2017
SPEN ARC Learning Report 2	Online	Final	17/3/2017
SPEN ARC Learning Report 3	Online	Final	17/3/2017
Dumfries and Galloway INM Project Fact Card	Online	Final	-
SPEN ED2 Business Plan	Online	Final	December 2021
Linking Local Power and Local People: VPW Report for ARC Project	On Request	Final	2017

Table 2 Summary of Tier 2 Project

Tier 2 Project name	Licensee	Project summary (2 sentences)	Tier 2 funding £k*	Licensee compulsory contribution £k*	Other contributions £k*	Link to Close-Down Report
Accelerating Renewable Connections (ARC)	SP Distribution (SPEN)	The aim is to help new green energy projects connect to the local power network earlier by working with local communities and electricity consumers. The project trialled a range of flexible connection solutions including Active Network Management (ANM) — a system which allows us to connect new generators to the power network more quickly and cheaply where previously the network was believed to be at fully capacity.	7,620	846	0	https://www.spenergynetworks.co.uk/userfiles/file/ARC_Closedown_Report.pdf

Executive Summary

SP Energy Networks are proud to present this submission for the Accelerated Renewable Connections (ARC) project for Second Tier Reward and would like to apply for the maximum possible reward for this project through the Second Tier Reward mechanism.

This ARC project was a 6-year study – costing £8.46 million of which £7.62 million was provided via OFGEM through the Low Carbon Network Funding Tier 2 mechanism. It took a holistic approach to enable connection of renewable generation onto already constrained or congested areas of the network. Innovative Active Network Management (ANM) systems were trialled to better coordinate generation assets in constrained areas and allow early connections prior to network upgrades.

The ARC project as a significant 'flagship' innovation project under the Second Tier of the LCN Fund, pioneered a number of alternative network connections, performing well beyond its original objectives whilst also fulfilling the initial aims to an exceptional level. The project successfully connected 13 low carbon projects compared to the initial aim of 5 as described in initial application. The aim was to examine up to 5 different processes for alternative connections – through the study 7 different methods were used. The savings seen by most of the developers for connection costs were significant – with multiple connections entirely mitigating the requirement for transmission upgrades and the other solutions, allowing connection in time to achieve RoC compliance or guaranteed generation and income whilst waiting for network upgrades. In total the excess generator capacity which has either been entirely enabled or seen a reduction in network constraint is 153.53 MW, compared with initial project aims of 55 MW.

In addition, the project has facilitated Cir. £200m of capital investment associated with the generation connections, resulting in over £61 million of GVA added to the GB economy from the Dunbar GSP ANM project alone. The project led to over 653 GWh of additional energy generation through the 6-year life of the scheme, over £2 million in energy cost savings for domestic homes and a minimum of 376 FTE years added to the economy as well as cumulative savings for 3 smaller scale direct connection customers of over £1.5 million in connection costs compared with the previous business as usual (BAU) methodology for connection assessment.

The outcomes and learning from the project and in the period of trialling following project completion, have been incorporated into a number of SPEN policy developments and projects. In particular the Dumfries and Galloway Integrated Network Management (INM) project which is a direct successor to the ARC project on a larger scale covering 11 GSPs.

Customer empowerment was a key success factor in the project. This was achieved through greater information transparency and availability, increased customer engagement and interactive online tools to assess viability of projects. Two-tier connection agreements ensured the customers had a level of surety in their applications up to the point where transmission system upgrades carried out, before transition to firm agreements.

The project has clearly demonstrated that the toolbox developed through ARC is an incredibly cost-effective method of connecting or releasing additional low carbon generation in congested network areas with multi-fold pay-back for customers and local communities compared to the level of investment. The significant and detailed level of learning achieved during the project had resulted in more optimal ANM solutions being developed and deployed by SPEN (in the D&G INM project for example), as well as by other DNOs in the UK with the UKPN £15m STRATA project, WPD ANM roll-out across 10 GSPs and inclusion as a case study in the ENA Good Practice Guide for ANM

SPEN is proud to have carried out exceptional work, in collaboration with its customers, the system operator and its project partners including Smarter Grid Solutions, Community Energy Scotland and Strathclyde University. This project further enables the UKs Net Zero Strategy and SPEN's own net zero targets by tackling obstacles to distributed renewable generation connections in a technically innovative, cost effective and customer first approach.

We believe that the achievements delivered by the ARC project fully satisfy the requirements by Section Three of the LCN Fund Governance Document (2 April 2015) and Reward Criteria set by the guidance (Ofgem letter 13 June 2022) for the Low Carbon Network Fund Second Tier Reward. This report details the exceptional level of performance the project achieved in surpassing its initial aims during the project duration, as well as the significant level to which it has informed SPEN current and forward policy through the INM project and beyond.

Contents

Table 3: Table of Acronyms

AD	Anaerobic Digestion
ANM	Active Network Management
ARC	Accelerating Renewable Connections
AVC	Automatic Voltage Control
BELLA	Bilateral Embedded Licence Exemptible Large Power Station Agreement
BHA	Berwickshire Housing Association
CES	Community Energy Scotland
DECC	Department for Energy and Climate Change
DG	Distributed Generation
DNO	Distribution Network Operator
DSO	Distribution System Operator
EHV	Extra High Voltage
ENA	Energy Networks Association
EV	Electric Vehicle
FTE	Full Time Employee
GB	Great Britain
GBSO	GB System Operator
GSP	Grid Supply Point
GVA	Gross Value Add
GW	Giga Watt
HV	High Voltage
INM	Integrated Network Management
LCNF	Low Carbon Network Fund
LIFO	Last In First Out
LMS	Load Management Scheme
LV	Low Voltage
MW	Mega Watt
NCEWS	Network Constraint Early Warning System
NGET	National Grid Electricity Transmission
OCAT	Online Curtailment Assessment Tool
OLTC	On-Load Tap Changer
PNDC	Power Networks Demonstration Centre
PV	Photo-Voltaic
ROC	Renewable Obligation Certificate
SGS	Smarter Grid Solutions
SP	Scottish Power
SPEN	Scottish Power Energy Networks
SSE	Scottish And Southern Electricity
UKPN	UK Power Networks
VPW	Virtual Private Wire
WPD	Western Power Distribution

1. Description of project and a summary of how the evidence put forward in the STR application align with each Reward Criterion

SPEN looked to carry out this project to meet and mitigate a number of issues seen by the network in the UK at the time of project inception through alternative network connections. In total the cost of the project was £8.009 m, made up of £7.62m in second tier funding and £0.84m invested by SPEN but coming in underbudget by £450k. SPEN are looking to receive the maximum reward through the second tier mechanism due to the exceptional work carried out in the project in the technical and commercial innovations, advanced learning delivered and the way the project was carried out – on time and under-budget whilst over delivering in each of the original aims of the project as well as a wealth of additional achievements and learnings.

The DECC Carbon Plan requires an increased contribution from low carbon generation to support the long-term carbon reduction targets which has a significant bearing on the distribution network. The Scottish Government had also set ambitious targets for at least 500MW of local and community based renewable generation by 2020.

However, the network in some DNO areas had reached network limits as a consequence of a large volume of renewable generation that had already connected. This means that the network and capacity available for future connections, which traditionally would be facilitated through a programme of network reinforcement, was substantially constrained. Furthermore, the penetration of higher volumes of embedded generation on the distribution network had impacted upon the transmission system to the effect that, within some DNO areas, relatively small generation projects were unable to connect ahead of major reinforcement works being completed on the transmission system.

Between 2009 and 2011 the volume of generation applications in SPEN increased by circa 700%. In 2011 in excess of 90% of connection offers in SPEN, with a combined generation capacity of approximately 270MW at 33kV and below were not accepted by customers due to a variety of reasons including time to connect and cost. The licence application process, regulatory and industry code obligations as well as conventional design standards can limit the range of alternative technical connection solutions available to DNOs and restrict them from taking a more holistic approach to connecting renewable generation. This approach was becoming increasingly restrictive given the high volume of additional generation seeking a connection.

The ARC project aimed to address these issues by creating and demonstrating a range of technical and commercial solutions for accelerating renewable connections in a controlled manner to avoid the network from being a barrier to the transition to a low carbon economy. The ARC project has facilitated new renewable generation projects gaining access to the distribution network in a timely manner. The solutions developed through the ARC project have provided developers with greater information in respect of the potential for flexible connections; examined the role that communities can play in balancing local generation with demand; advanced thinking in an attempt to solve the commercial and technical issues associated with exporting Grid Supply Points (GSPs) and sought to provide evidence to inform the debate on investment strategies of smart grid solutions, as identified by WS3 of the Smart Grid Forum at the commencement of the project in 2013. This was achieved by Empowering customers, applying novel commercial and technical approaches to implement alternative connections, informing the Flexible connections policy and connection design process to facilitate a greater level of renewable generation and building upon learning from previous LCNF projects.

The project covered a variety of innovative technical methodologies for connecting or releasing additional capacity on the distribution network including network solutions through ANM at GSPs, single connection ANM solutions, virtual private wire solutions and innovative monitoring and voltage control methods. In tandem with this the project showcased how greater interaction with the customer can result in the optimal solutions, utilising local and community loads to maximise the potential of low-carbon local generation. In line with the new technology new connection agreement contracts were created which were as important as the implementation of hardware and software to ensuring the customers could connect as early as possible.

Figure 1: SPEN targets for 2020

The learnings from the project will be taken forward within SPEN and other DNOs to not only allow greater penetration of low-carbon generation at the distribution level but allow historic projects to increase their capacity factor in constrained grid conditions. Through the level of monitoring performed and the assessments carried out of different technologies, from specific ANM or OLTC transformer hardware to the usage of local load to balance export and advanced monitoring of areas with high concentrations of renewables not only will this project provide learnings for future low-carbon connections but can provide information about how the network behaves under reverse power flow conditions or the impact of increased EV roll-out.

Through all of these methodologies the project has clearly aligned with the second-tier reward criteria, facilitating the carbon plan and clean growth strategy directly through the project and indirectly through the exceptional learnings and dissemination of learnings made during and after the project all whilst delivering financial benefits to the customers and wider communities. Outcomes of the project have included a significant amount of new generation being able to connect, a significant amount of new generation capacity released, and the output of existing assets being optimised compared to previous operating conditions, new connection agreement methods built, customer empowerment through development of tools to increase the amount of information available to developers. In addition to this there has been significant savings made by developers in connections and community benefit through local developments and savings for clients of the Berwickshire Housing association and local benefits through employment and community revenue. Multiple reports have been made available from SPEN, community engagement Scotland and Regen detailing the methods and benefits of the technologies trialled.

The project has led directly to SPEN incorporating advanced heat maps into their information offerings for developers across all of the GSPs in their remit and the Dumfries and Galloway Integrated Network Management project which rolls out active network management across 11 GSPs and will help release future capacity in one of the most constrained regions in the UK.

1.1. Exceptional Performance of the Project (Criterion A)

The ARC project delivered almost three times the expected capacity of connections with over 150 MW of low-carbon generation connected through the project operational period. The assets connected vary over medium and small-scale wind, PV arrays, distributed domestic PV, anaerobic digestion plants and combinations of all of the above through a total of 14 connected developments. The performance of the project considering the aims of increasing the ability to connect and reducing the number of declined connection applications can be seen in that over the 6-year period 14 projects were considered and every single one was connected in a way which mitigated at least one key obstacle: time to connect being unfeasible, cost of connection being unfeasible, constrained connection or technical restrictions.

All of the projects were implemented through forms of ANM – with the Dunbar and Berwick GSP projects being the flagships for this with the largest connected generation allowing significant release of capacity through mitigation of the requirement for multi-million pound transmission level investment allowing generators to connect in a timely manner and release previously constrained capacity prior to transmission system upgrades which were performed several years after the projects wished to connect in the case of the Dunbar GSP. Alternatively, as was showcased in the Berwick GSP case the provision of the ANM solution allowed for the generators to connect with no requirement for network upgrades, saving the customers several million pounds in development costs and reducing the cost for all customers through socialised funding. In addition to these large-scale projects ANM was used to facilitate smaller scale connections through mitigating the requirement for network upgrades altogether and enabling methods such as voltage control using OLTCs on the secondary at

11kV and 33kV levels to counter voltage rise issues at local and transmission level for single and distributed PV schemes, Virtual Private Wire solutions to allow excess capacity to be utilised via local demand control. Whilst providing these technical connection solutions commercial agreements were developed to allow two tier connections with an initial ANM enabled connection and then a firmer connection enabled by network upgrades, online tools such as the OCAT and advanced heatmaps which were developed to allow more customer empowerment and reduce the number of unsuccessful connections. These methods performed so exceptionally during the project that they have been rolled out as part of the Business-as-Usual approach for SPEN with advanced heatmaps now available across all of the GSPs within SP Distributions regulatory area, two tier connection agreements utilised as standard and changes to the process which applications are assessed against, with a tiered approach to facilitate as much capacity as possible prior to triggering network upgrades.

In addition to this SPEN has embarked on the Dumfries and Galloway INM project, whereby they will roll out ANM across 11 GSPs in the Dumfries and Galloway area which is one of the most congested areas in terms of the ratio of generation to demand. This will help enable over 200 MW of contracted connections and reduce the level of constraint on an already connected 90 MW. The results from the project have also enabled other DNOs to carry out more informed ANM solutions, as exemplified through the inclusion of the project in the ENAs good practice guide for ANM, UKPNs £15m STRATA project with ARC project partners Smarter Grid Solutions to roll-out ANM across their region and the 10 GSPs which have had ANM applied across the region under WPD ownership.

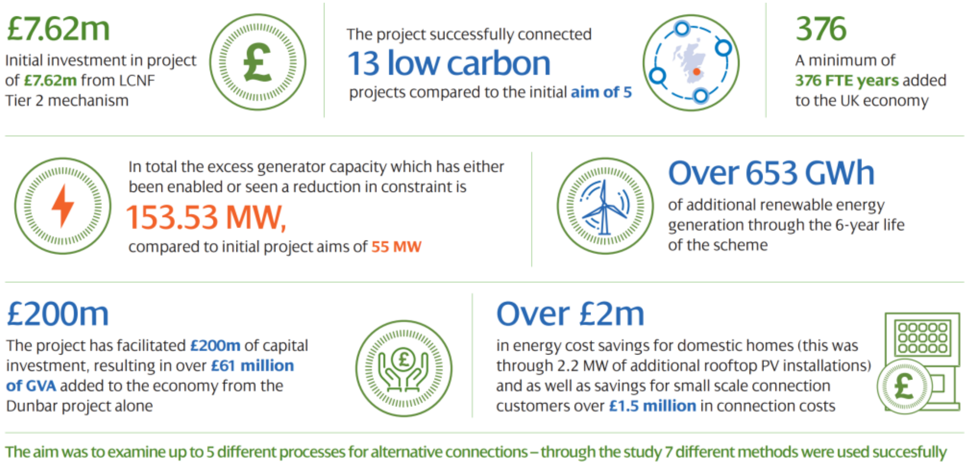

Figure 2: Exceptional Achievements Through the Project

1.2. Additional Investment by SPEN (Criterion B)

SPEN invested an additional £840k into the project as part of the mandatory 10% contribution from the DNO. Due to exceptional work from SPEN significant labour costs compared to the initial budget were saved. This saving was reinvested in ways to maximise the results of the project through additional equipment to facilitate more connections, extending the data-collection period for the BHA PV developments, continuing the Berwick GSP solution through decommissioning of the local ANM hardware and relocation to a centralised control room.

Although the project did not require additional investment from SPEN due to the exceptional performance and effort of the project team out with the project itself SPEN has had to make significant investment to roll out the solutions into BaU. This includes IT costs to implement advanced heatmaps, development of internal processes for reviewing voltage variation allowances and the new tiered approach to connections.

1.3. Exceptional effort (Criterion C)

It is clear from the results, underspend and timely completion of the project that exceptional effort was made by all of the project team including project partners SGS and Strathclyde University in carrying out the project, bringing the technologies into the business at large and in attaining and disseminating learnings. With additional learning through extended monitoring and additional connections compared to the initial project plan and a significant increase in the level of quality and quantity of information dissemination across the industry.

2. Description and evidence of project compliance with reward criteria

2.1. Reward Criterion A

Table 4: Summary of Criterion A Achievements

A1	Develop up to 5 approaches for alternative connections Provide alternative connections for up to 5 developments Make it easier for developers to assess feasibility of projects at an early stage through available information.	Delivered 14 developments through the project with a total capacity of over 150 MW. Developed 7 techniques for alternative connections. Built a more advanced heatmap tool but also developed an online curtailment assessment tool
A2	Release network capacity across at least one constrained GSP to allow additional connections	Capacity was released at both of the GSPs trialled to connect the initial generator considered. In addition to these multiple connections were enabled at each GSP and the constraint of an existing windfarm was managed to allow greater export during constraint conditions.
A3	Release capacity to allow connections leading to investment and employment in the areas.	Significant investment was made amounting to over £200m at one site alone. At the Berwick GSP the ANM solution mitigated the requirement for network upgrades at that time reducing the cost for all GB consumers. Anticipated to deliver more than £2m in savings for customers in the BHA housing developments over a 25-year period.
A4	Showcase the various tools that can accelerate the number of connections	Advanced heat maps rolled out across all of the GSPs in the SPEN distribution area. Development of the Dumfries and Galloway INM project
A5	Allow early connection for one windfarm at a GSP to allow RoC compliant connection and attain some revenue prior to transmission network upgrades Enable one project to connect where the primary obstacle has been the cost of connection	Dunbar GSP allowed 3 generators to connect in time for RoC claims and reduced the cost of connection for all connections across both GSPs as less network modification was required. Enabled 3 projects in the Ruchlaw Mains, Penmanshiel Piggery and Standhill Farm to a total estimated cost reduction of more than £1.5m across the three projects.
A6	Showcase ways to connect quickly and mitigate the requirement for waiting on transmission scale upgrades	The project successfully trialled a number of technologies and methods for connecting which reduced the waiting time to connect whilst providing the commercial solution to accommodate this.

2.1.1 Aspects of the Carbon Plan and/or Clean Growth Strategy that have been facilitated (Reward Criterion A1)

The ARC project facilitated aspects of the Carbon Plan beyond what was initially envisioned in the release of 155 MW compared to an initial target of 53 MW. 14 Developments were connected compared to the original aim of 5 and a wider range of technical applications were applied due to exceptional efforts from the DNO and have led directly to the D&G INM project. Smart systems for assessment by customers have been developed and rolled out into Business as Usual in advanced heat maps.

Table 5: Summary of the released or connected low carbon generation through the project

Area	Projects	Type	Capacity (MW)	Released or Connected Capacity
Dunbar	Aikengall wind Farm	Wind	48	Released
	Dunbar ERF	Energy From Waste	36	Connected
	Hoprigshiels	Wind	7.5	Connected
	Kinegar	Wind	5	Connected
	Ferneylead	Wind	1.5	Connected
Berwick	Penmashiel	Wind	28.7	Connected
	Quixwood	Wind	24	Connected
	Unnamed	Wind	1.9	Connected
Individual Connections	Ruchlaw Mains	PV	0.08	Connected
	Penmanshiel	PV and Wind	0.15	Connected
	Standhill Farm	Anaerobic Digestion	0.047	Released
	Bowhill	Anearobic Digestion	0.1	Released
	BHA	PV	2.2	Released
Total			155.177	

When it was conceptualised the ARC project had aspects of the Carbon plan and the Clean Growth Strategy at its heart; it aimed to increase the penetration of low carbon generation and enable a smarter system, particularly at a distribution level. SPEN identified that two barriers to connection offer acceptance were a) time to connect and ii) costs. The development of a tool to simplify the process for both the customer and the network designers would help alleviate both of these by reducing time spent on planning and optioneering. Implementation of solutions to increase capacity through flexible connections would help reduce the time to connect by mitigating the requirement for long term network upgrades to be installed and the cost would be reduced as existing network assets could be used where previously additional cost would have been incurred for the customer for line or cable installations.

In 2011 over 90% of connection offers were not accepted by customers due to a variety of reasons including time to connect and the overall cost. This amounted to around 270 MW of generation which was not added to the system, the majority of which was of low carbon nature. Through discussions with Community Energy Scotland, it was identified that two issues which were seen as barriers for many of their projects were cost due to the minimal spare capacity on the network or delays due to transmission system constraints.

"Network access is a major barrier for many of the renewable projects CES are involved in as much of the distribution network has little spare capacity or access is delayed due to transmission system constraints. As a result, the time and cost to connect renewable generation can be prohibitive to these schemes going ahead. Currently the market for new energy storage and management technologies is not mature, cannot be implemented under standard connection agreements with network operators and the installation of such solutions requires careful planning and technical analysis which only add to the overall cost. The double barrier of insufficient grid capacity, and the inability to deploy innovative solutions under current connection methodologies has to be overcome if the community and low carbon sector are to fully deliver in the future"

-Community Energy Scotland (CES)

Dunbar GSP

One methodology the innovation project planned to utilise to increase the level of generation able to connect to the network was via Active Network Management (ANM). This would allow the connection of low carbon generation which would otherwise not have been developed due to a lengthy wait for transmission level upgrades to be carried out. Via ANM the projects would be able to go ahead under certain operating conditions which would allow them to maximise production and export whilst also maintaining the integrity of the wider grid.

One such project was at the Dunbar GSP, which at project inception consisted of two 60 MVA, 132/33 kV transformers. At this GSP there was an existing constraint on a 48 MW wind farm under a non-firm BELLA commercial contract with NGET, this agreement included the implementation of an overload intertrip scheme that would protect the network against thermal overloads during potential N-1 scenarios.

In addition to the existing constrained connections three developments were in the process of seeking a connection at the start of the project totalling 43.5 MW of low carbon generation. Due to constraints on the transmission network these were forecast to be able to connect after significant investment including two additional transformers, a second switchboard at the GSP and upgrading the existing transmission OHL to a 165 MVA pre-fault summer rating. This was predicted to incur costs of c. £20 million with a completion date in 2021 with the projects projected connection dates of between 2017 and 2019.

The delay to connection would have caused these projects to miss the deadline for Renewable Obligation Credits (ROCs) which would have likely caused the developments to get cancelled due to funding issues. As a result of the implementation of ANM these projects were able to secure funding and proceeded.

A solution was provided in a dual method – firstly the technical solution included the implementation of an ANM system, developed by ARC project partners Smarter Grid Solutions, at the Dunbar GSP to facilitate the connection of the three development applications as an interim solution prior to wider network reinforcement and allowed the already connected 48 MW Aikengall wind farm to modify its output to maintain system integrity during N-1 events as opposed to being disconnected.

The solution was enabled through an alternative connection agreement in the form of a two-tier contract whereby they would be non-firm, managed connections until the completion of planned network reinforcement works which would transition to a firm agreement once these upgrades were completed in 2021.

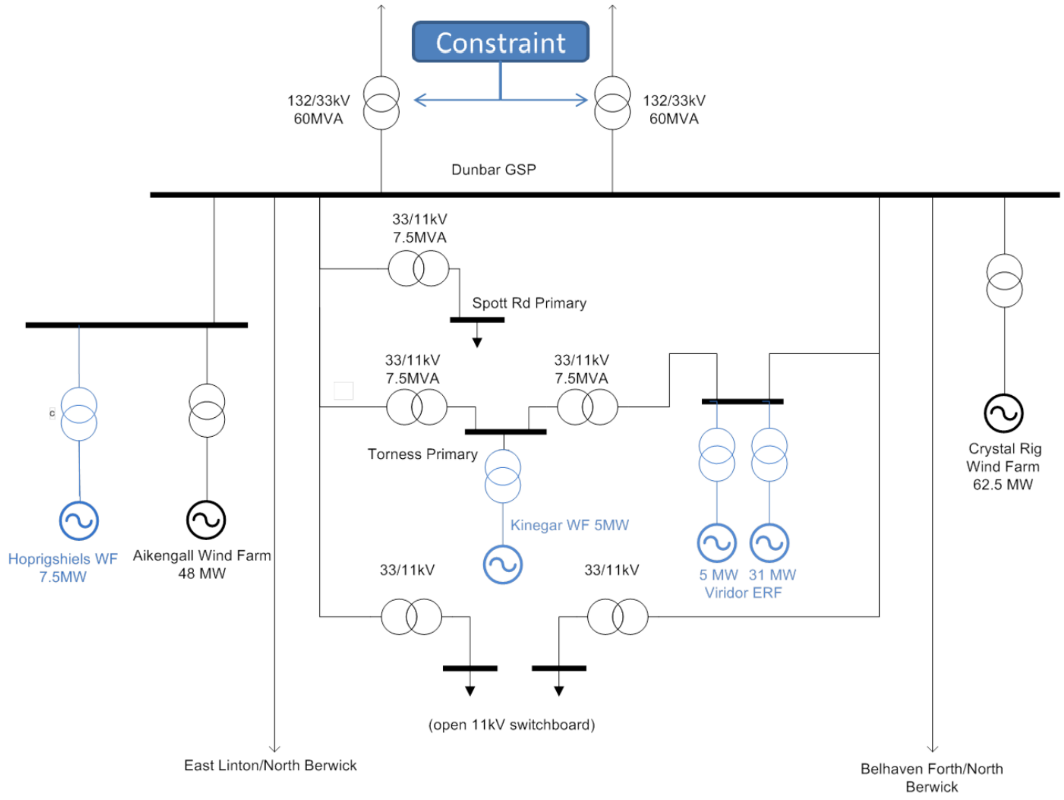

Figure 3: Diagram detailing the constraint seen at the Dunbar GSP

Exceptional value was added to this project compared to the original aims of SDRC 9.3 through the facilitation of a significant amount of generation of a variety of generation types, including wind and, as a UK first, the synchronous generator which was part of the Dunbar Energy Recovery Facility. This steam generator has different operational characteristics than a wind or PV connection and the project has shown that this type of generator can be connected using ANM. The project also showcased the backwards compatibility of the system through another UK first of retro fitting ANM technology onto an existing generator in the Aikengall wind farm. This has shown that not only can ANM be utilised to enable connection in constrained scenarios but that it can be applied to a range of generation technologies and could be utilised to great effect on a number of existing connections which are currently operating under non-firm agreements to optimise their output and increase the level of low-carbon generation on the network.

Empowering customers

One of the described barriers to connection is the difficulty for customers to accurately assess the likelihood of a connection from an early stage. SPEN sought to empower the customers with more information, more connection options and connection offers with better financial impacts. Through the ARC Project SPEN exceeded this target. Exceptional work was carried out whereby more detailed tools were made directly available to the customer through the OCAT tool giving more up-to-date and easier to understand information to customers looking to connect, providing several different connection approaches which led to greater capacity allowance than through conventional methodologies. ANM, virtual private wire (VPW), and alternative network upgrades in the form of tap-changing secondary transformers helped reduce the cost for several projects allowing the customer to connect as they desired in a more feasible way financially.

Customer Service

The ARC project team has put the customer at the heart of the process throughout the project. We recognised from the project's inception that providing an enhanced level of customer service to connection customers participating in trials was essential and complemented our wider customer service approach to getting closer to our customer by moving towards a geographical delivery model. While all participants received the same high level of service as all existing DG connection applicants, DG customers facing barriers to connection in the ARC project area (through either cost, timescales or lack of local network capacity or transmission delays) and who had successfully gained planning permission were invited into an 'optioneering' process with the project team to understand how an alternative smart solution and commercial innovation could be used to resolve the barriers to connection and allow them to realise access to the network.

Core to the 'optioneering' process was the development of a deeper understanding of the connection barriers. In a number of cases, new generation was being connected to provide energy to local demand in the area – and in some cases new local demand. Due to limitations in the standard connection design process, this was on most occasions overlooked or simply never considered and therefore alternative connection solutions had not been offered to customers. In other examples, more detailed analysis or support by monitoring of network flows and voltages was required, which increased the time before a robust connection offer could be provided or managed connections considered. Throughout the ARC project, we offered a tailored rather than a 'one size fits all' approach to customer service. We consider that our approach has been very successful.

This level of engagement went beyond the initial roadmap through the amount of detail and engagement between SPEN and the various developments, this is evidenced by 100% of customers who received an alternative connection offer having accepted the connection terms.

Information availability and Useability

In SDRC 9.8 one of the aims was to empower customers through more information and ease of use. This was initially provided through investigating the transmission level constraints in place and the contracted generation under each GSP and the planned network investments to alleviate any constraints or congestion. This provided up to date information for customers looking to connect, in the form of heatmaps, prior to making any application as shown in figure 3. This helped them streamline their approaches and make applications more likely to be successful when they were made. This was so successful that SPEN decided to take the methodology out with just the specified trial area and agreed to roll it out across all GSPs within the SPEN distribution franchise area.

Figure 4: Illustration of the heatmaps made available to customers

SPEN went further than this initial target with exceptional work to develop the OCAT web portal. In addition to the provision of more frequently updated network information, we committed as part of the project to trial the implementation of a framework that would permit developers to complete a 'viability study prior to submission of a formal connection application. It is widely recognised that whilst the advent of network heat maps has represented a positive step forward, their reliance upon static network data does have limitations when processing high volumes of application requests. The project therefore explored the necessary techniques that would require to be implemented to facilitate the development of a web-based interactive tool that could be made available and allow developers to 'self-serve' or 'optioneer' potential connection opportunities. The principle behind the development of OCAT was that a developer could drag and drop a new generation project onto a map which would in turn identify nearby circuits and following the provision of a few basic details regarding the proposed generation project, obtain information on the estimated time for connection and a high level cost forecast that both a conventional and flexible connection solution would take to complete.

Within the trial area there are 114, 11kV circuits. To enable the OCAT tool to be developed, data from existing network monitoring devices already deployed within the trial area were utilised to establish real-time normal operating conditions. Through the support of a dedicated GIS analyst, validation of existing network models was undertaken to ensure their correctness and accuracy. Where data gaps existed, a data cleansing activity was undertaken, and programming scripts written to substitute missing information with data based upon experienced engineering judgement. The validation process enabled the completion of full data sets for each circuit modelled (circa. 30 for the purpose of the development of OCAT trial). A software tool was developed to extract a circuit's connectivity model from the GIS database and to export a power systems analysis file. Based upon a set of pre-determined criteria, using this power systems file, constraint analysis is calculated for each node along each circuit from the primary substation to the circuit end. This uses information based upon the technology seeking to connect i.e. wind, PV etc. And provides the user with a forecast summary of the level of constraint that would be experienced by connecting via a managed connection vs a conventional network connection solution. Furthermore, a forecast of the likely time that a connection to the network would be realised within is also provided, and any forecast connection date considers the impact of known transmission network constraints. It is envisaged that this information would be refreshed on quarterly basis to account for additional connection applications and developers either accepting or rejecting connection offers. An overview of the OCAT system architecture and web user portal is provided below;

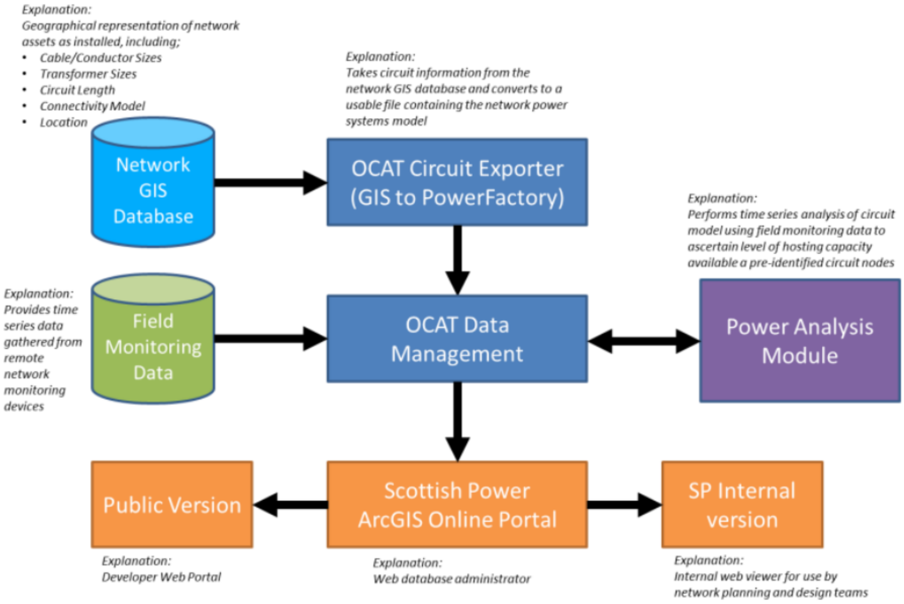

Figure 5: Overview of the OCAT architecture

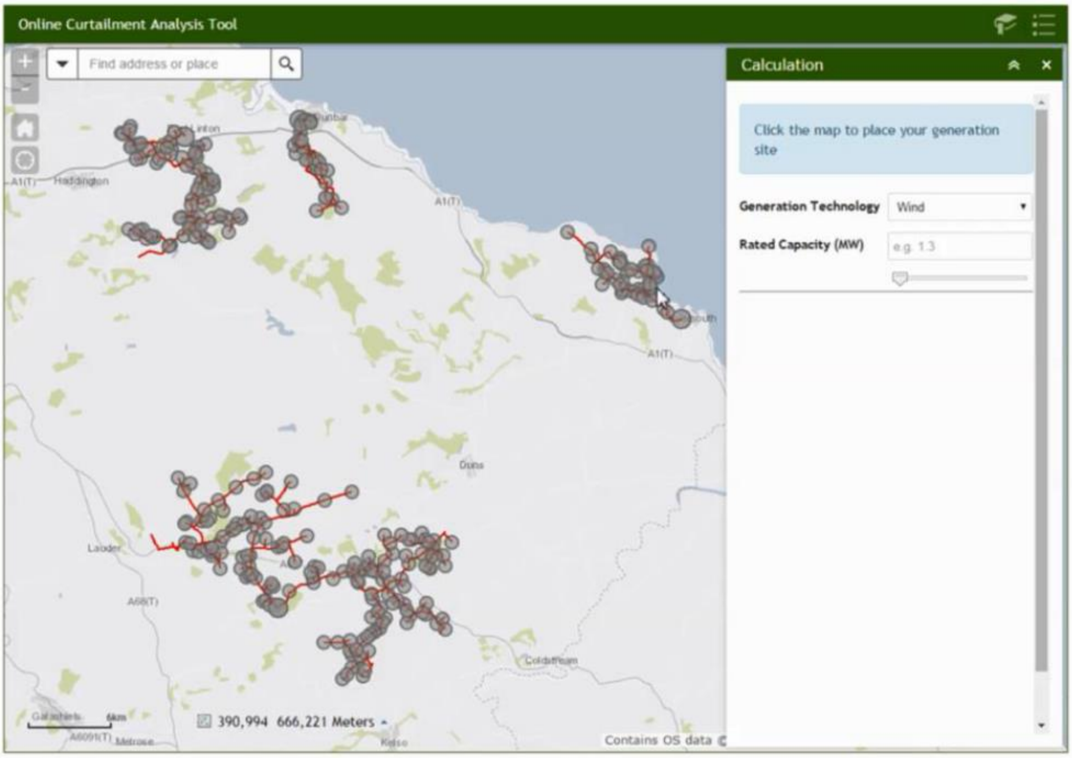

Figure 6:Example of the OCAT tool developer interface.

2.1.2. Releasing network capacity (Reward Criterion A2)

In the initial project direction application of an ANM solution to release network capacity across one of the two GSPs considered was the aim, however through the project both of the GSPs had ANM solutions applied – with different technical methodologies – and the resulting released generation was more than anticipated.

Network Capacity across both of the GSPs considered, which were already under significant constraint due to network congestion at the transmission system level. The Dunbar ANM project allowed an additional 50 MW of generation to be implemented resulting in over 650 GWh of low carbon energy to be produced which otherwise would not have been due to network constraints that were in place at the time due to transmission system upgrades that were planned. Over the 13 projects which the ARC study covered over 150 MW of capacity was released through a range of innovative techniques, some of which are shown in Figure 7.

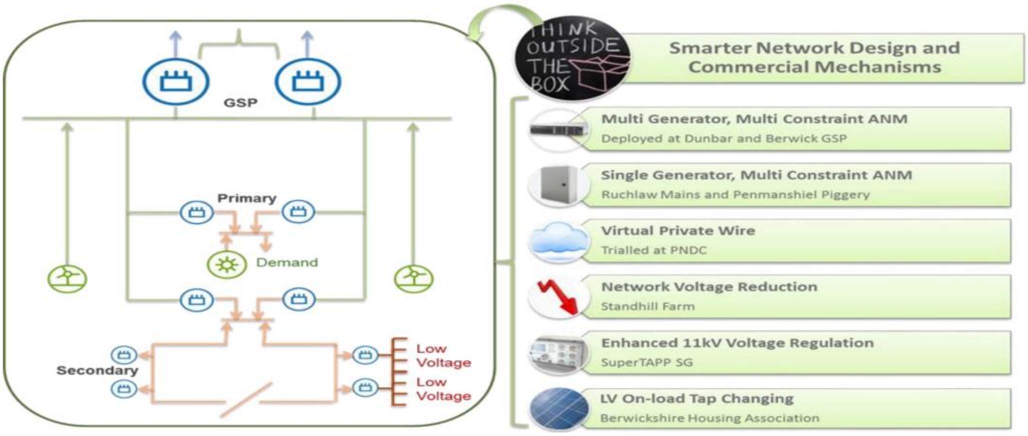

Figure 7: Range of technologies implemented during the ARC project

Bowhill Farm

In one circumstance there was a new 200 kW Anaerobic Digestion plant application received and through the business-as-usual approach the connection offer was to include a new transformer and extension to the existing OHL network in the area. With this connection the capacity would also be limited to 100 kW until 2019 due to transmission system upgrades. To accommodate this extra capacity SPEN carried out an assessment beyond the initial scope of the ARC project to implement an innovative virtual private wire network to enable full output from the AD plant by servicing a local estate directly via an 11kV private wire network whereby the system could export 100kW to the network and any additional power would be used to heat the local estate. Through monitoring at the various secondary substations of the exported power from the estate and implementation of demand side response the system was configured to flex the heating demand on the estate to maintain the export limit to the network to 100 kW whilst allowing the AD plant to generate its maximum potential. This allowed the full capacity of the AD plant to be realised with no transmission system upgrades.

Standhill Farm

Standhill Farm was in a similar situation as Bowhill farm in that the owner wanted to connect a 200 kW Anaerobic Digestion plant but was, initially, only offered a connection of 100 kW due to voltage rise constraints. Following a challenge from the customer and a detailed study it was found that this export could be increased to 153 kW. During the ARC projects Standhill Farm was chosen as a case study to assess if the full export could be realised through an alternative connection solution. During a 9-month monitoring campaign it was found that the voltage limitation was met and exceeded a number of times and was subject to G59 over-voltage protection relay trips and at each occurrence it was found that the AD plant was operating at or above its agreed 153 kW export limit.

> "SP Energy Networks got on board and really helped" and "I cannot stress enough that, without them, it just would not have happened. I believe in the benefits that renewables can bring to a farm, and I've fought like a dog to get what I've got; but it was SP Energy Networks who, in the end, got me a viable grid offer to make this project work."
>
> Jim Shanks – Owner Standhill Farm

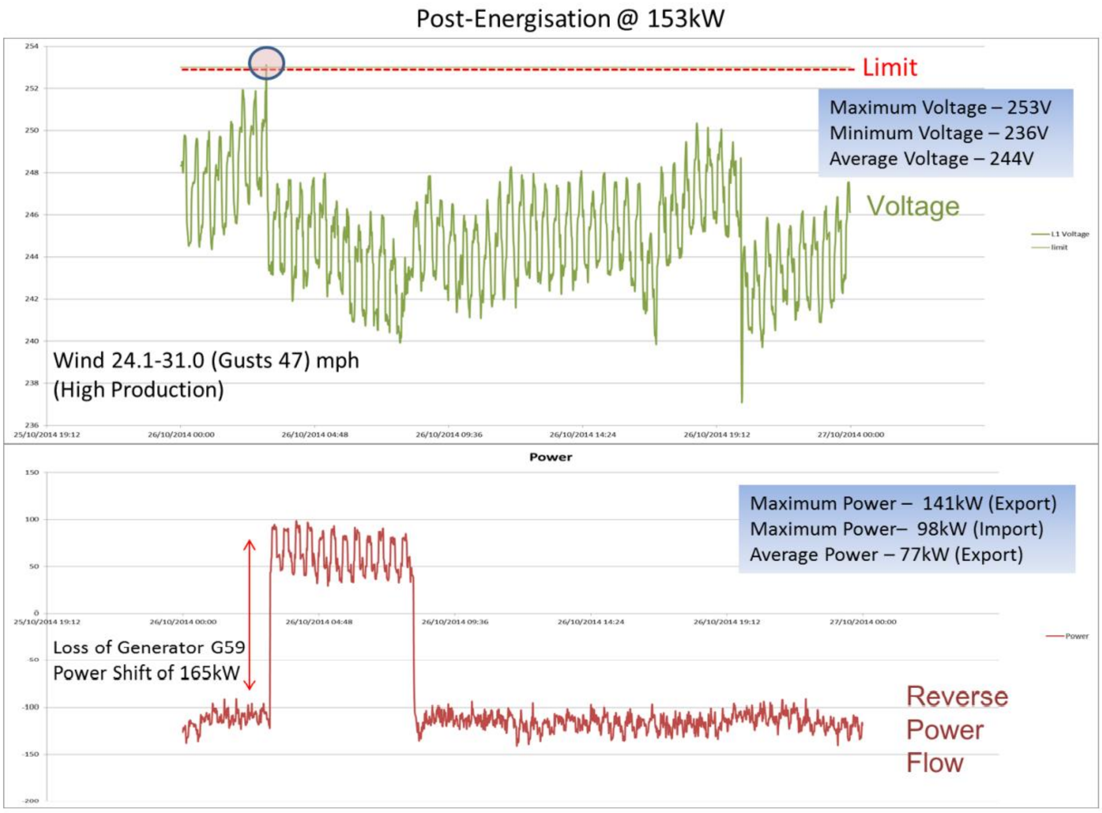

Figure 8: Illustration of voltage limitations seen during operation of the AD plant

Considering this SPEN went to exceptional effort to find a solution through assessing the real time data for voltage level at the furthest points from the feeder and came to the solution whereby the voltage at the 11 kV level at the St Boswells primary feeder would be reduced to 11.0 kV. Whilst this was in breach of current network design policy the case was brought to the design authority and technical review panel within SPEN and the change was implemented. This solution has since been applied a number of times within the ARC project and is something that SPEN can utilise in the post-trial period to allow additional capacity to be released and mitigate the requirement for additional hardware in similar scenarios.

Berwickshire Housing Association

As discussed later in this report voltage rise is an issue for a number of newer developments, particularly when there is a high level of concentration. This can particularly affect solar projects where an increasing number of new housings is being built with solar panels installed. One particular case which was covered during the ARC project was the Berwickshire housing association project within the trial area for 2.2 MW of PV installations across 749 new homes.

An initial study was carried out by the University of Strathclyde into both thermal and voltage rise constraints for all of the applications to identify which properties could connect immediately (marked green) as they were relatively low density, medium level of concentration in yellow and in high concentrations which are likely to have an intolerable impact on the grid in red.

Further analysis was performed on the yellow and red properties and a number of these were found to be able to connect with no issues, however there were a number of red properties remaining. The issue at the remaining properties was due to the potential for voltage rise beyond the allowable levels. To combat this secondary on-load tap changers were installed at the affected substations and, to provide learning and further connection enablement, 2 advanced Automatic Voltage Control (AVC) relays were installed at the Ayton and Eyemouth primary substations which saw the greatest penetration of PV connections.

One of the key deliverables from the project has been the utilisation of alternative connection agreements.

2.1.3. Delivering Financial Benefit (Reward Criterion A3)

The ARC project delivered significant financial benefit beyond the expectations of the initial aims due to the exceptional work carried out by the DNO. This included benefit to the Customers through early connections and revenue while waiting network upgrades, community benefits, reduced utility bills for PV customers and significantly reduced connection costs.

The project resulted in significant financial benefit, for the customers seeking connections, for those required to pay socialised costs for connection applications and for wider society. The initial aim of lowering costs for applicants in the trial area by 12-80% was attained across the board. Through exceptional work from SPEN a number of customers were able to connect who would not have been able to at all, whilst others were able to connect a larger capacity and a significant number of full-time employment roles have been opened up in local communities due to work carried out during the ARC project. In the Dunbar project alone, it is estimated that it allowed over £200 million in capital investments, provided 376 FTE years to the economy and provides an additional £75k per year through community benefit.

Dunbar

Five projects were connected to the ANM monitoring and control system on the constrained Dunbar GSP between 2015 and 2019, well ahead of a planned network reinforcement in 2021. Due to funding sources, and in particular the need to secure Renewable Obligation Certificates (ROCs), four out of five of these projects would probably not have gone ahead at all if they had had to wait until 2021 for a firm connection. The remaining project, the Aikengall Community Wind Farm, was upgrading from an existing inter-trip constrained connection to ANM.

Regen’s analysis showed that the implementation of ANM at Dunbar led to some clear economic and carbon benefits including enabling total capital investment of an estimated £200m, the creation of 56 FTE long term jobs, £75k of community benefits funding per year and an estimated carbon saving of 98 thousand tonnes. The economic analysis, summarised in Table 4, has followed the guidelines for Impact Appraisal and Economic Evaluations suggested by Scottish Enterprise.

The export reinforcement work at Dunbar GSP was completed as planned in 2021, many of the benefits however could be extrapolated for the life of the projects since, according to the feedback from project developers, the four new projects would almost certainly not have proceeded if the ANM scheme had not been in place. The benefit contribution of the largest project, Aikengall Community Windfarm, which was commissioned ahead of the ANM scheme, was only measured in terms of the increased energy generation and revenue that the ANM scheme enabled.

A key benefit from an ANM is that it allows projects to connect quickly, rather than waiting for network reinforcement which may be scheduled for several years ahead. For some projects, this delay might mean they lose planning permission or funding streams, making them unviable. Others such as the Aikengall Community Wind farm joined the scheme to replace their existing, intertrip connection with participation in an ANM which could facilitate more export. The table below shows when the schemes connected to the ANM scheme (in green), along with their measured annual export. In the case of Aikengall, only the estimated extra export that was facilitated through connecting to the ANM scheme was considered. This ‘extra-over’ export was estimated by comparing actual export from 2015 onwards to the average annual export experienced whilst on the intertrip arrangement.

The initial aim when looking at the Case Study for the Dunbar ANM scheme was to release a maximum of 27.5 MW of wind generation through a single project. The diagram below showcases where the achievements above and beyond the original intentions of the project have been achieved

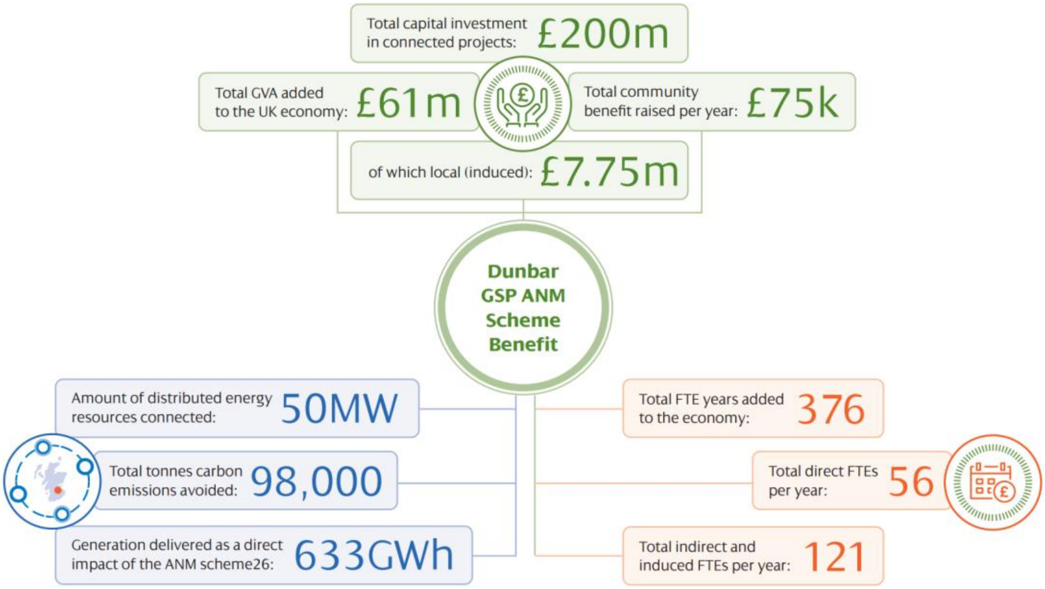

Figure 9: Additional Benefits from the Dunbar GSP ANM Project

Table 6: Summary of the economic benefits seen in the trial area

Total capital investment in connected projects:	£200m
Amount of distributed energy resources connected:	50MW
Total GVA added to the economy:	£61m
. of which local (induced):	£7.75m
Total FTE years added to the economy:	376
Total direct FTEs per year:	56
Total indirect and induced FTEs per year:	121
Total tonnes carbon emissions avoided:	98000
Total community benefit raised per year	£75k
Generation delivered as a direct impact of the ANM scheme26:	653 GWh

Table 7: Summary of the revenues estimated for each of the Dunbar GSP projects purely due to the ANM connection

Development	2015	2016	2017	2018	2019	2020	Total
Aikengall	1.4m	0.2m	1.4m	0.8m	0.7m	0.8m	5.3m
Dunbar ERF					34m	40m	74m
Hoprigshiels			0.8m	1.2m	0.9m		2.9m
Kinegar			0.5m	0.7m	0.6m	0.4m	2.2m
Ferneylea					0.2m	0.1m	0.3m
Total	1.4m	0.2m	2.7m	2.7m	36.4m	41.3m	84.7m

2.1.4. Rollout across the DNO's system and across GB (Reward Criterion A4)

The techniques and methodologies developed during the project have been rolled out through SPEN with the Dumfries and Galloway INM project and the usage of advanced heatmaps across all GSPs within the SP Distribution area. Further afield, since the project's completion WPD has utilised ANM across 10 of their GSPs, starting in 2019, and UKPN has begun the £15M STRATA project to roll out ANM technology across their business area utilising the technology of ARC partners Smarter Grid Solutions.

Connection Assessment Tools

The advanced and updated heatmap development made during the project resulted in system that worked so well that SPEN has now rolled it out across all of the GSPs within their regulatory remit. We have delivered a step change in network analytical capability. Over RIIO-ED1, through our award-winning 12 Network Constraints Early Warning System (NCEWS) innovation project, we have built a full connectivity model of all 48,000km of our LV network. It used advanced machine learning algorithms to extract missing cable assets. We've combined it with our existing HV and EHV network connectivity models, so we now have a complete model of our entire network, from customers' cut-outs up to the transmission network. We call this complete model our ENZ model, and it means we have full analytical capability for our entire network. By combing this with our enhanced forecasting tools, we can precisely identify where, when, and how much additional capacity our customers need. This capability benefits customers as we're able to develop targeted interventions that are tailored to their needs. We reduce the risk of over-specifying solutions (spending more than we needed to), or underspecifying solutions (not providing enough capacity).

This is allowing SPEN to increase the number of connection requests likely to be successful across the entire area. One of the clear benefits found throughout the project was that a greater level of customer engagement not only results in better customer satisfaction, but also increases the likelihood of a successful connection agreement as all of the cases looked at during the study resulted in a successful connection or increase in capacity.

Building on the outcomes of the OCAT tool development SPEN have developed the ConnectMore Interactive Map. The ConnectMore Interactive Map relates to the electrical network within the SP Manweb plc licence area (Merseyside, Cheshire, North Shropshire and North & Mid Wales). The ConnectMore Interactive Map application will provide an indication of the potential Electric Vehicle (EV) charging demand (EV Charging Demand) and high voltage (HV) and low voltage (LV) network capacity (Electricity Network Capacity).

Dumfries and Galloway Integrated Network Management

We are in the process of deploying wide scale ANM across the Dumfries and Galloway network area. This regulates the output of DG to avoid transmission constraints – this type of coordination across transmission and distribution is a UK first. The scale and nature of this project (one of the largest of its type) provides invaluable learning for further developing constraint management zones in RIIO-ED2 and extending their functionality to coordinate a wide variety of DSO functions. Dumfries and Galloway are an area with one of the highest proportions of connected low carbon generation when compared to its level of demand for energy. The INM project directly built upon the learnings from the ARC project and is set to enable significant development or release of renewable generation in the area. There is already 90 MW of renewable generation connected in the area that operates under a Load Management Scheme (LMS) which is not as effective at maximising output as ANM when there is a network curtailment as it simply turns off all or most of the connected generation whereas ANM can maximise utilisation of the existing assets.

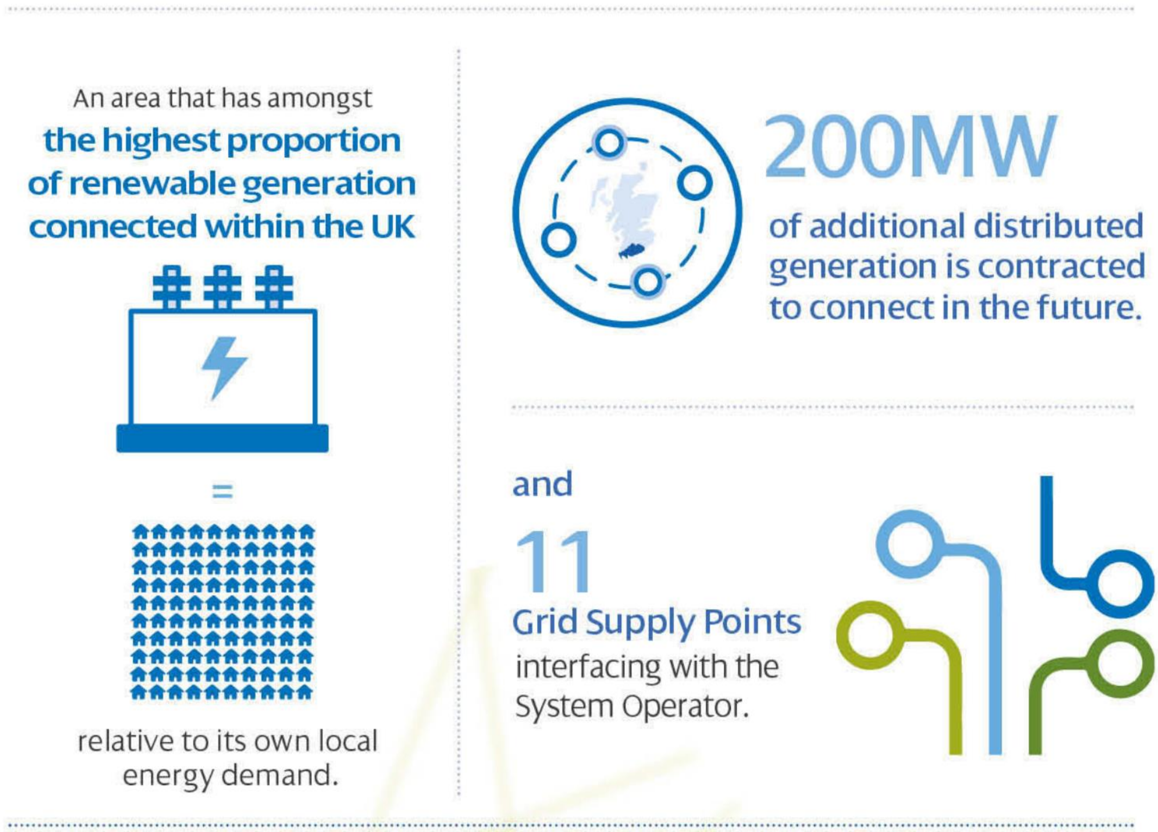

Figure 10: Dumfries and Galloway INM project fact card

Further to this there is 200 MW of capacity contracted to connect by 2023, with the current transmission upgrade plans all DG wishing to connect to the scheme prior to the end of 2023 would be connected via a Restricted Available Access which would limit the potential of these projects and may have prevented them from connecting at all as there would be no guarantee of export capacity and in constrained transmission network conditions would lead to total or majority disconnection of capacity.

Principles of Access

As part of the RPZ trial, SSEN had adopted the principle of Last in First Off (LIFO) access arrangements to govern the connection of distributed generation on Orkney. In contrast UKPN undertook analysis in the development of their Flexible Plug and Play project that led to the development and implementation of the Capacity Quota approach, and which was documented in their Principles of Access Report published in December 2012.The process of implementing the Principles of Access was a key output of the ARC project. As such it was important to understand the pros and cons of each regime. Ultimately the rules surrounding access and allocation of capacity had to be fair, transparent and bankable for those developers seeking to take forward a generation project as part of the ARC trials. Following stakeholder engagement and review of the different options we decided that the ARC project would follow similar Principle of Access arrangements to that adopted by SSE during their Orkney RPZ pilot. Furthermore, at our ARC Stakeholder Forum event held during June 2014 the various Principle of Access arrangements were presented to stakeholders and views sought on the preferred adoption. Figures 10 and 11 provides results of the live feedback session, whereby the majority of Stakeholders preferred the adoption of LIFO. Reasons sighted for this were, transparency, bankability and recognition that as project developed through to construction and connection to the network, any potential delays to the delivery of the project would not adversely affect the agreed LIFO stack position. When all generators were connected, each could take their respective place in the LIFO stack without the economics of their project being adversely impacted by either new generation connecting or eroding expected export capacity as would be experienced under the Capacity Quota arrangements or finding themselves further down the LIFO stack.

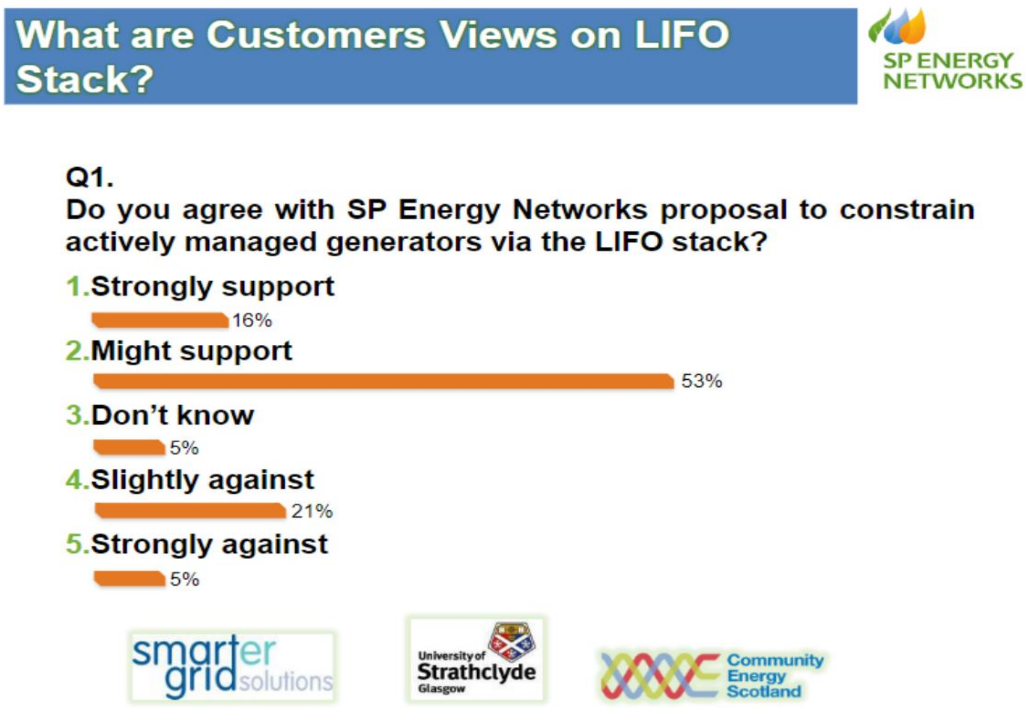

Figure 11: Response to Customer Questionnaire

In addition to gaining feedback on our proposals to introduce the LIFO Principles of Access, feedback was also sought from Stakeholders at our June2014 Stakeholder Forum on the proposals for the introduction of a two-staged commercial agreement developed in conjunction with the GBSO. Again, from the results obtained detailed with figure 10, overwhelming support was gained for our approach and hence the ARC project in taking forward its deliverables can demonstrate that it was meeting the needs and requirements of developers.

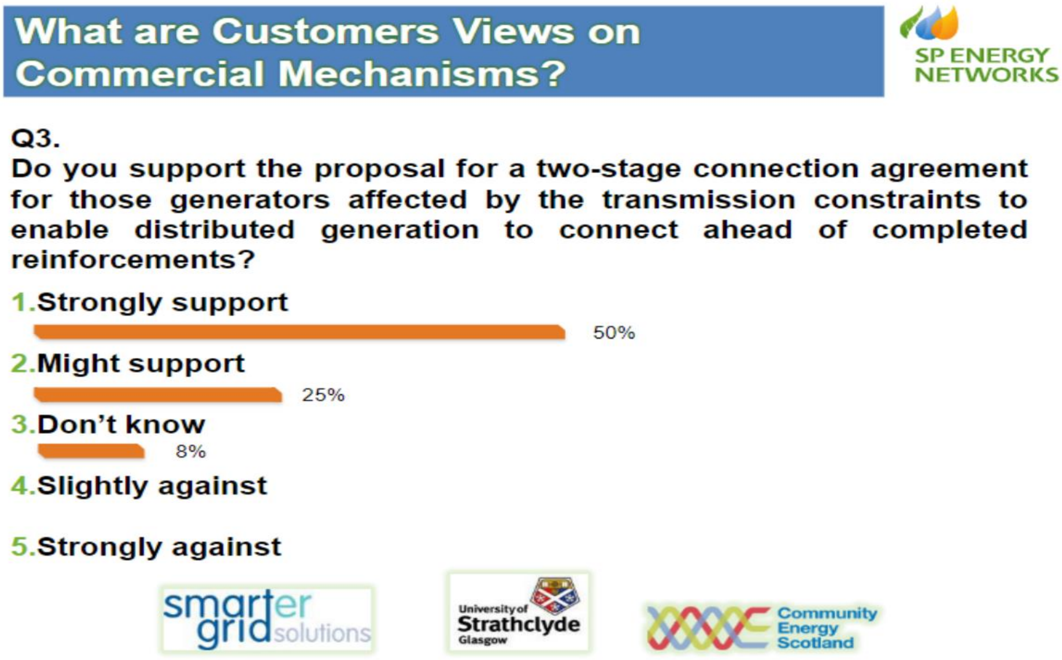

Figure 12: Response to Customer Questionnaire

This has informed the approach SPEN will take forward when applying subsequent ANM projects such as the project in Dumfries and Galloway currently in progress.

Other DNOs

Since the ARC project completion there has been a number of ANM projects across different DNOs such as the WPD project to roll out ANM across 10 GSPs and UKPN £15m STRATA project to apply ANM across their regulatory areas. In addition to this the ARC project was utilised as a case study for the development of the ENA good practice guide for ANM

2.1.5. Value for money to customers (Reward Criterion A5)

The project provided increased value for money to customers by mitigating the requirement for network upgrades. For connecting customers substantial savings were seen compared to the previous method. Reduced time spent going through planning due to the system built to make applications smoother. Customer earnings from the Dunbar ANM case are estimated to be more than £84m. Reduced the need for various 11kV lines/transformers to be implemented resulting in a saving of over £1.5 million over 3 smaller connections.

Through the project a number of approaches were taken to optimise the value for money for customers, this included methods to streamline the application process to cut down on application spend and optioneering, reduce the costs to connect by reducing the amount of network upgrades required and enable connections which otherwise would not have connected due to requiring timely and expensive network upgrades.

During the project Berwickshire Housing Association made an application to install 2.2MW of new PV installations across 749 homes within the trial area. The ARC project, working closely with project partner University of Strathclyde sought to use this application to build upon the learning already developed through our Flexible Connections for Low Carbon Future project and investigate further the effect clustering of renewable generation has on LV networks. Initial network studies highlighted that the proposed locations of the new PV systems covered some 59 secondary substations across the ARC trial location feeding into both Dunbar and Berwick GSPs. University of Strathclyde were tasked with undertaking power system analysis to investigate the potential impact on the surrounding network of each new proposed PV installation.

In parallel SPEN installed a number of monitors at various network locations to provide data to enable a better understanding of our LV network and its operation. Through detailed power systems modelling and analysis of the data the project was able to identify which locations could already allow certain connections and which areas would need to wait on network upgrades, through this analysis it was identified that 95% of the applications would already be able to connect with no curtailment. The remaining congested scenarios were further assessed, and a solution was found whereby the installation of secondary on-load tap changer transformers at certain secondary substations which would feed into the Berwick and Dunbar GSPs. This, in tandem with the detailed monitoring, allowed the connection of the entire 2.2 MW of solar which the housing association has estimated will lead to a combined benefit of £1.9 million reduction in energy costs for the tenants over the lifetime of the installations.

In another project where voltage rise was a potential issue, the 200 kW AD plant at Standhill, it was found that following business as usual practice network upgrades with a cost of £821k in the form of a new 11kV line. Through the ARC project further analysis was performed and it was realised that up to 153 kW of the 200 kW could be accommodated with only minor changes to the network which would only cost £22k, a saving of almost £800k which made the project feasible. SPEN went beyond their initial aims in this project by carrying out even more analysis of the voltage rise issue and identifying secondary substation locations where an on-load tap changing transformer could be added which would allow the full 200kW to be connected with no constraint.

Through utilisation of the virtual private wire solution for the Bowhill estate significant savings will be seen through reduced energy costs as well as the reduced heating costs as the power from the AD plant is being used directly to heat the main estate buildings. Further to this up to £70k is being saved annually by the estate as they can now dry waste cattle manure to use as animal bedding as opposed to purchasing from a 3rd party.

2.1.6. Relevance and timing of project (Reward Criterion A6)

The relevance and timing of the project was key – with saturation for additional connection becoming an issue and with connection speed being a significant obstacle for new developers as the RoC scheme was soon to end.

The project is relevant due to the increased saturation at the specific areas targeted during the trial. But also, with a significant number of distribution areas at saturation particularly at the south coast in Cornwall due to solar peaks having a massive impact on capacity where WPD have had to start rolling out constraint management zones.

The ARC project was one of the very first projects in the UK to utilise ANM and it has developed and spread significantly since then – with c. 2% of all distribution connected generation being connected through GSP ANM schemes at 1.3 GW.

The project timing was especially important for the renewable's developments looking to connect to the Dunbar and Berwick GSPs as without the accelerated connection timeframe these projects would have missed the RoC deadline and would have been economically unfeasible.

2.1.7. Methodology robustness and project readiness (Reward Criterion A7)

The methodology throughout the project was of a high level with actions taken based on continual feedback and data acquisition as well as the usage of high-quality project partners. Learning from early stages of the project was directly applied further along in the project timeline.

Thorough work done with engagement with customers and experts in the industry to ensure the best solutions were acquired and the learnings were taken from these case studies to develop further.

Significant steps were taken by SPEN during the project to ensure the project went as smoothly as possible and resulted in the best outcomes and learnings. This involved constant communication with all interested parties, particularly the customers themselves, but also the System operator, the transmission system operator, local individuals and expert industry and academic partners.

The robustness of the project is evident in the range of techniques and scenarios that were assessed during the project and the fact that every single one of the applications taken forward in the project were given successful connection agreements.

2.2. Reward Criterion B

Table 8: Summary of Reward Criterion B Achievements

B1	Details and Significance of SPENs additional contribution	The project was delivered under-budget, and despite additional achievements and exceptional performance there was no requirement for additional contributions from SPEN. Although there were some aspects which had a higher cost than anticipated due to exceptional effort and project management in other areas this additional cost was mitigated.
B2	Issues that justified the additional contribution	There was no additional contribution required during the project operational phase although there was work done to allow additional value through extended monitoring and centralised ANM.
B3	Demonstrable Benefits to Customers	The benefits to customers were all achieved within the initial budget despite exceptional efforts which led to more achievements than stated in the original plan.

The approved project second tier funding was £7.62M, awarded to SPD in 2012 by Ofgem to carry out Accelerating Renewable Connections with the project commencing in January 2013. A further £0.84M was invested by SPD with some additional contribution from project partners to take the total project funding to £8.46M. Overall the project was within the originally forecast project cost although there were some significant variations in cost for specific packages.
Efficiencies in labour usage which were required due to high levels of projects ongoing simultaneously resulted in a core team of 5 FTE instead of the forecast 9.75 FTE. Although some additional contractor work was required overall this resulted in significant underspend in this area and despite lower labour costs, due to the exceptional effort from the SPEN employees the project was able to more than meet the minimum requirements

2.2.1. Details and significance of SPEN's additional contribution (Reward Criterion B1)

Equipment

As described throughout the closedown report our approach to the delivery of the project objectives was structured and driven by those generation projects that sought to connect within the trial area. The original forecast equipment costs for the various case studies referenced within the FSP, allowed for the delivery and demonstration of flexible connection solutions of around 5 individual distribution connections. In the end the ARC project connected 13 projects with further work associated with the delivery of the 2.2MW of PV capacity installed across the 749 properties operated by Berwickshire Housing Association. Furthermore the project required the installation of a greater penetration of network monitoring than originally thought due to the scale of the Berwickshire Housing Association project and increasing numbers of developers seeking connections across the trial location at 11kV voltage levels. As part of the project an alternative Active Network Management solution was also developed and delivered by Nortech to demonstrate an alternative equipment deployment in line with the project objectives. The project team worked with existing manufactures of equipment such as SMA to trial the integration of additional equipment with the local ANM solutions deployed at Penmanshiel and Ruchlaw Farm respectively. Although the actual costs incurred in respect of the deployment of equipment are higher than originally forecast, the outputs from the project in respect of distributed generation projects delivered and MWs connection represent a significant output over and above that originally planned to be delivered and minimum as set out within the SDRC.

Decommissioning

Final decommissioning costs were significantly higher than forecast as a consequence of the ANM equipment being removed from the GSPs at Dunbar and Berwick respectively and being brought to a centralised location. This will allow continued support to be provided to those generators that have connected under the ANM scheme and also provide improvements with respect to efficiencies of operating the scheme. The removal of the ANM equipment from the substation environment also overcomes some practicalities of enabling access for both vendor and distribution operational staff who currently would be unable to access a transmission owned substation.

Implementation of results

SPEN has also had to make significant internal contributions to roll-out the learnings from the project as business as usual practice. This includes significant IT costs to develop the additional heat map development and for the tiered connection approach going forward.

2.2.2. Issues that justified the additional contribution (Reward Criterion B2)

Due to the exceptional effort of the DNO no additional contribution was required.

2.2.3. Demonstrable benefits to customers (Reward Criterion B3)

The project was able to demonstrate exceptional benefits to the customers whilst maintaining the original budget despite increased costs in equipment and decommissioning.

2.3. Reward Criterion C

Table 9: Summary of Criterion C achievements

C1	Develop learning on the 5 methodologies trialled, the different connection agreements approaches.	The project developed significantly more learning due to the number and variety of connections trialled, including several UK firsts. By looking at different approaches for the same solution benefits and drawbacks for each could be developed. Additional learning was found about the network in general and additional ways of freeing up capacity by considering tiered approaches to connections
C2	Develop learning on the 5 methodologies trialled, the different connection agreements approaches.	The DNO went to exceptional lengths to find solutions for a number of connections which allowed greater learning and more techniques were discovered, projects like the BHA PV study, the virtual private wire solution at Bowhill farm and the comparisons found by looking at both remote and local ANM solutions were all due to the exceptional effort of the DNO.
C3	Release case studies on each connection approach including one report on a PNDC trial	Beyond the initial aims the project resulted in a number of academic papers on ANM, inclusion in the ENA guide for ANM and a report on VPW from CES.

2.3.1. Demonstrate where the project has delivered more learning than was expected (Reward Criterion C1)

The project delivered more learning than expected with multiple UK firsts including generation types connected which were not part of the original scope, a larger range of generation assets connected using technical approaches more varied than the initial expectations and longer-term measurements in the BHA project and the Berwick GSP ANM solution extended indefinitely.

Areas of additional learning are where the ARC project really excels. The learning taken from the project far surpassed the initial goals in all areas, technical solutions, commercial approaches and customer empowerment.

The initial aim of the project was to facilitate connections using ANM and novel commercial approaches and the learnings which could be taken from this would allow ANM to be further developed and enabled via different modes of connection agreement. The ARC project provided learnings which far exceeded this by carrying out multiple UK firsts, customer engagement far beyond the initial requirement and thorough assessments of the existing and possible methods for agreeing new connection agreements.

ANM

The ANM projects carried out during the ARC project were some of the first in the UK and at the time the technology was still in its infancy for large scale roll-out. There had been some usage of it in the UK but typically on a small scale and on new solar or distribution connected wind. The ARC project managed to connect systems whereby large- and small-scale wind, anaerobic digestion and even steam generation systems would be connected to the same system. This led to significant learnings as detailed in the report from project partners Strathclyde University. Steam turbines act significantly different to typical inverter connected generators particularly around the ramp-up and ramp-down parameters so the learning gained from this will feed into diversification of the types of generators able to be utilised under ANM.

Another UK first in the project was the retrofitting of ANM control and monitoring systems on an existing windfarm. The 48 MW Aikengall wind farm at Dunbar was connected in 2009 and had been operating under non-firm agreement since construction whereby it would be disconnected under N-1 operating conditions to prevent thermal overload of the transmission network. As part of the Dunbar scheme a Smarter Grid Solutions ANM system was retro-fitted onto the wind farm which allowed it to stay connected during N-1 conditions whilst its output was controlled to ensure there was no risk of thermal overload. During the trial the Dunbar GSP did experience an N-1 outage and the ANM system was utilised to maximise the capabilities of the wind farm whilst maintaining grid integrity. The graph below shows the performance of the ANM scheme at Dunbar GSP and its ability to release a greater level of export during an N-1 outage than would have been realised using conventional network management techniques, whereby if the intertripping scheme had detected a potential thermal overload at the remaining transformer, the wind farm would have been disconnected from the network. The grey line represents the actual power flow across the transmission/distribution boundary with solid yellow line representing the network capacity limit set by the ANM scheme during the N-1 outage. The orange trace shows the actual export of the wind farm. Where the orange trace flattens this represents a period when the ANM scheme was restricting overall export from the wind farm autonomously.

This experience allowed the ANM system to be validated and evidenced the level of additional production available through ANM. This is significant as there are a number of N-1 constrained wind farms across the UK and if additional generation can be released through ANM then this could lead to a reduction in the amount of CO_2 released overall and can help build the business case for further windfarms that may have to operate under constrained or non-firm circumstances.

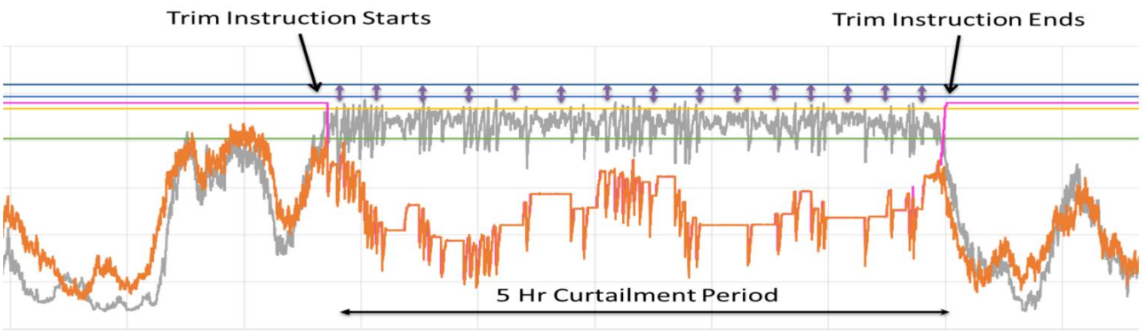

Figure 13: Example of performance of ANM system during curtailment period

During the Dunbar case study significant extra learning was produced compared to a traditional ANM scheme as it facilitated a wide range of technologies including some UK firsts. This included new connection of wind farms over a range of export levels from 5 MW up to 35 MW, and the different impact of managing two different sizes of generator through the same scheme. In addition to this a steam generator was connected via an ANM solution for the first time in the UK. As steam turbines will have different operating performances regarding response times to ANM signals compared to wind or solar connections, through the multi-year period SPEN were able to

Table 10: Pros and Cons of remote or local ANM systems

	Pros	Cons
Substation	Local constraint management system, can be operated as a local or network wide scheme	Non-sterile environment that typically is not suited to commodity based server hardware solutions. Access for installation of vendors who must be accredited/authorised by DNO. More onerous on existing SPEN staff
Centralised	Easier access for repair, upgrade or maintenance	Potential single point of failure for all generators connected to multiple ANM schemes Potential RTU sampling rate restrictions, as all data must pass through RTU and full capability of ANM equipment is not realised Communications failure leads to total shutdown of generation under ANM control

manage this connection without any issues and build up a repository of operating information for the performance of this generator.

Different control methodologies were trialled across the project which allowed learning on the pros and cons of substation vs centralised deployment of ANM. At the Dunbar GSP the ANM system was deployed on commodity computer hardware whereas at the Berwick GSP the same technology was employed on ruggedized substation computers- a summary of the learnings is shown in the table.

Shortcomings in Current Assessments

One area in which additional learning has been found is in the current methodologies for assessing connections and the shortcomings associated. Throughout the project there has been continual comparisons to the methodologies used to assess if a connection request can be successfully granted based on the existing and planned conditions and on a number of occasions it has been found that there are gaps in the process or areas which could be improved upon. One example of this is through the surveys carried out during the BHA PV project, where it was found that in the area concerned the DNO had not been informed of upwards of 70% of the G83 applications which had already been installed, which can cause important gaps in the knowledge the DNO has of its regulatory area. In the BHA project it was also found that with almost no detailed assessment it was possible to release 24% of the applications prior to making detailed system studies – showing that a tiered approach can lead to much quicker processing of applications.

In the Ruchlaw Mains project there was an application made for additional load of 250 kVA and an additional generation through an 80 kW PV array. When the PV array was assessed the additional load application was not considered in tandem and this resulted in both applications being taken forward separately which would have resulted in an initial £160k cost for the PV application which was not feasible at the time, and it was only when the customer raised an appeal. During the subsequent assessment it was also found that there was an assumption that a nearby wind turbine would be operating at full capacity 100% of the time which was not the case, and this led to the there being a voltage constraint which, in reality, did not need to exist.

2.3.2. Additional learning as a result of exceptional effort of the DNO (Reward Criterion C2)

SPEN went to exceptional effort to make many of the projects possible – going beyond the original aims of the project through customer engagement, use of innovative technology and developing new internal reviews to allow network variations which would not typically be allowable and demonstrating the benefits of all of these through a significant level of connection.

Exceptional effort taken by the DNO to facilitate cases which were UK firsts, pertinent to the emerging issues such as EV roll-out and greater solar integration at domestic dwellings and scenarios which covered a range of generation technology. Specific development of solutions that were not widely developed at the time – VPW, Voltage rises solutions, increased GSP capacity.

Berwickshire Housing Association

Throughout the project the team provided exceptional customer service to the customers looking to connect. This not only ensured the customer received the highest level of service, but it also enabled connections which otherwise may not have proceeded. Through the Berwickshire Housing Association project close collaboration between the parties led to the release of additional capacity but learning above and beyond the level that would be expected from this project was found through exceptional efforts from the DNO. In addition to adding OLTCs to a number of substation secondaries SPEN installed two AVC relays at the two substations which seen the highest level of PV development. The implementation and trial of this additional technical solution enables the existing primary substation transformers to manage expected voltage excursions within statutory network limits. Whilst the application of these techniques was to trial their usefulness in managing the existing network to accommodate PV generation, the learning derived from their application will also inform the ability of similar network solutions to manage the impact of a greater penetration of electric vehicles, heat pumps and greater adoption of a wide range of low carbon technologies at lower voltage levels across the UK distribution networks. The monitoring continued beyond the end of the project end date to allow for the collation of a full two-year operational database including the most important summer periods with high irradiation – an example of the data captured from these feeders is shown in figure 13.

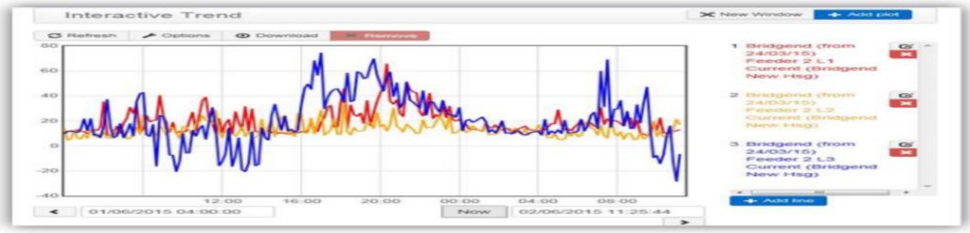

Figure 14: Example of data captured during two years of monitoring

Virtual Private Wire

SPEN went to exceptional lengths to allow the full capacity of the 200 kW Anaerobic Digestion plant at Bowhill farm as seen previously in this report. Although the increase in capacity was only 100 kW the solution itself was innovative in showing how ANM equipment can allow VPN to be developed in local communities. This learning can be taken forward into a number of fields as it shows that a software solution if plausible and leads to significant reduction in costs for hardware that would be required in traditional private wire solutions in addition to simply releasing excess capacity in a generator.

Technology Comparisons

SPEN sought out the opportunity to employ their solutions in a variety of ways to allow learnings of the benefits and drawbacks attached to each methodology. This included using multiple different hardware types such as ANM from Smarter Grid Solutions for the GSPs and utilising Nortech equipment for the Penmanshiel Piggery project.

Figure 15: Smarter Grid Solutions ANM topology

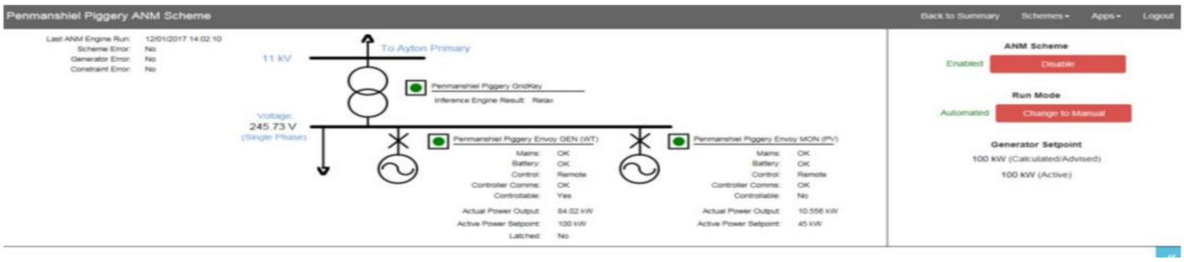

Figure 16:Nortech ANM system topology

Learnings which came from this include the implementation of generation reduction at the Ruchlaw mains site whereas at the Penmanshiels site the output, during the project, was never reduced.

2.3.3. Exceptional capture and dissemination of learning in a way that maximises value for all customers (Reward Criterion C3)

Beyond the initial targets of information capture to allow the specific projects to be carried out and attain feedback on connection and constraint management the ARC project captured data well after the project end date through the BHA and Berwick GSP projects, multiple technology types were trialled in UK first ways with the capture of comparative benefits and drawbacks which was not initially envisioned. Through the project information was disseminated as per the goals but there were also additional academic and research papers published by project partners which will allow better implementation of the technologies and methodologies trialled throughout the project.

One of the cores aims of the project was to capture operational data and customer feedback in a detailed way – however the project went well beyond this. Information was captured as was required to enable all of the solutions and to find the level of satisfaction amongst customers regarding the constraint approach regarding LIFO. However, through additional work from SPEN in finding UK firsts and looking to examine and compare methodologies as much as possible much more learning was found. This has been disseminated not just through the closedown reports and the case study reports but for the VPW solution Community Energy Scotland was commissioned to carry out a report and for the Dunbar ANM scheme Regen was contracted to write a post-trial assessment which gives detailed information on the results multiple years after the project was finished. SPEN ensured information was being distributed to all interested parties through multiple in person events throughout which gave updates on the progress of the project.

Table 11: Academic Papers published on the ARC project

Academic paper title	Authors	Direct Citations in other papers
Coupling Demand and Distributed Generation to Accelerate Renewable Connections: Options for the Accelerating Renewable Connections Project, **April 2014**	Simon Gill, Milana Plecas, Ivana Kockar	7
Distributed Generation on 11kV Voltage Constrained Feeders, **Sept 2014**	Simon Gill, Milana Plecas, Ivana Kockar	3
Background Analysis for Local Power, Local Benefit Project, **Feb 2015**	Simon Gill, Milana Plecas, Ivana Kockar	0

Further than this project partners Strathclyde University published three papers on the ANM scheme results alone which has been further cited numerous times. The ARC project has been directly referenced in the ENA document “Active Network Management Good Practice Guide”

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