Accelerating Renewable Connections (ARC)

ARC Closedown Report

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Definitions and Abbreviations

AD	Anaerobic Digester
ANM	Active Network Management
ARC	Accelerating Renewable Connections
AVC	Automatic Voltage Control
BAU	Business as Usual
BEGA	Bilateral Embedded Generation Agreement
BEIS	Department for Business, Energy and Industrial Strategy
BELLA	Bilateral Embedded License Exemptible Large Power Station Agreement
CES	Community Energy Scotland
CT	Current Transformer
DG	Distributed Generation
DNO	Distribution Network Operator
DSR	Demand Side Response
ENA	Energy Networks Association
ERF	Energy Recovery Facility
EV's	Electric Vehicles
GIS	Geographical Information System
GPRS	General Packet Radio Service
GSP	Grid Supply Point
ICE	Incentive of Connections Engagement
LCNF	Low Carbon Network Fund
LCT	Low Carbon Technology
LIFO	Last In First Off
LMS	Load Management System
MP	Measurement Point
MW	Mega Watt
NGET	National Grid Electricity Transmission
OCAT	Online Curtailment Assessment Tool
OCC	Operational Control Centre
OHL	Overhead Line
OLTC	On Load Tap Changer
POC	Point of Connection
PV	Photovoltaic
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SO	System Operator
SPD	SP Distribution
SPEN	SP Energy Networks
UoS	University of Strathclyde
VPW	Virtual Private Wire

1. Project background

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. Further, the Scottish Government set targets for at least 500MW of local and community based renewable generation by 2020. However, the network in some DNO areas has reached network limits as a consequence of a large volume of renewable generation that has already connected. This means that the network and capacity available for future connections, which traditionally would be facilitated through a programme of network reinforcement, can be substantially constrained. Furthermore, the penetration of higher volumes of embedded generation on the distribution network has already had an impact upon the transmission system to the effect that, within some DNO areas, relatively small generation projects are unable to connect ahead of major reinforcement works being completed on the transmission system.

Between 2009 and 2011 the volume of generation applications in SPD increased by circa 700%. In 2011 in excess of 90% of connection offers in SPD, 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. This was achieved by:

- **Empowering customers** to make informed choices relating to their connection requirements;
- **Applying novel commercial and technical approaches** that have developed new learning that can be applied to implement flexible connection solutions;
- **Informing the development of Flexible Connections Policy and Connection Design processes** required to facilitate a greater level of renewable generation; and
- **Building upon the learning** developed from previous and existing LCN Funded projects to date through collaborating with other DNO partners.

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.

2. Executive summary

SPD committed as part of the ARC project to deliver nine successful delivery reward criteria to provide robust learning that would inform future DNO network policies and processes and aid the deployment of a range of flexible and alternative connection solutions.

SPD was awarded second tier Low Carbon Network Funding (LCNF) of £7.62M in 2012 to carry out Accelerating Renewable Connections (ARC) with the project commencing in January 2013. A further £0.84M was invested by SPD with some additional contribution, through benefits in kind, from project partners to deliver the project and raised the total project funding to £8.46M.

The Scottish Borders and East Lothian area of the SPD network was chosen as the trial location as it had reached or was close to network limits in respect of DG connections. Using conventional planning assessment methodologies, this had already resulted in a number of developers wishing to connect distributed generation being constrained or subject to prohibitively expensive network reinforcement options.

The specific issues faced by SPD in the trial area location are mirrored across UK electricity distribution networks and the project provided the opportunity to implement a range of flexible technical and commercial solutions to address these. For the learning to be relevant, representative and robust, it was essential that there was a strong focus on verification of the trial and its ability to produce learning on the implementation of new technical and commercial solutions to facilitate flexible connections. These were critical factors in the trial site selection process as well as partnering with University of Strathclyde; Smarter Grid Solutions and Community Energy Scotland.

The ARC project aimed to implement a range of flexible technical and commercial solutions to accelerate the process and time to connect for distributed generation. It is recognised that there are some inherent conflicts between the ideal design, operation and management of a distribution network when seeking to implement new ways of delivering capacity. A significant advantage of applying a holistic approach has been that it has facilitated and recognised the requirement for greater interaction between business functions including planning, delivery, operations and asset management, to optimise the tools and techniques trialled.

The objectives of the various activities (work packages) were as follows:

- Empowerment of customers and improvement of their ability to 'optioneer' potential connection opportunities ahead of formal connection application through provision of improved network information and identification of a range of alternative connection solutions
- Review of current internal design policies and processes to facilitate the connection of distributed generation and inform on advancements required to deploy the application of flexible connection solutions.
- Identification and implementation of necessary network enablers in order to facilitate flexible connection solutions and connection trials
- Trial the application of a range of flexible connection solutions that demonstrate how additional distributed generation can be enabled within network limits in network areas considered to be at full capacity

- Disseminate learning to multiple industry stakeholders to enable sustainable user adoption and implementation of the techniques trialled as part of the project

Facilitating quicker and cheaper means of connection has resulted in investments estimated to be worth £283M in project construction and will generate in the order of £333k p.a. in community fund payments for local residents/communities.

Tracking benefits extends beyond that of MWh's generated from clean renewable energy sources. Many of the projects cross multiple energy vectors and contribute toward the concept of the circular economy, examples include;

- Dunbar Energy Recovery Facility will service a £700-million waste contract with the Clyde Valley Residual Waste Project putting an end to landfill in central Scotland, create 55 full time jobs once complete and is estimated that it will create a £10millon in economic boost to the area of East Lothian. https://www.viridor.co.uk/our-developments/dunbar-erf/
- Hoprigshiels Community Wind Farm where all operating profits will be shared between two charities, allowing Berwickshire Housing Association to invest in much-needed new homes for social rent in the area, and Community Energy Scotland to support community groups across the country to develop new renewable energy projects. https://hoprigshielswindfarm.wordpress.com/
- Standhill Farm AD Plant has already commenced with an investment of £2m to develop a new glasshouse to produce tomatoes for the Scottish market - the size of one-and-a-half football pitches. The energy and heat generated from the new AD plant will feed directly into this activity and will also create and sustain jobs at the Farm. http://www.renewableenergyonfarms.co.uk/project/standhill-farm

  Jim Shanks, Proprietor of Standhill Farm said *"I'm sorry to hear that the ARC project is coming to an end as I'm sure without it I'd never have managed to get to first base. We've managed to create a lot of jobs and we've turned an average dairy farm into a hub of production both in terms of food and energy"*

3. Details of the work carried out

3.1 Additional and more frequently updated network information to customers

Heat maps detailing known transmission constraints at the GSP boundary

Prior to the commencement of the ARC project, SPEN had already produced heat maps that detailed constraints and available capacity relating to 33kV and 11kV distribution circuits and substations available to customers. During the early stages of the ARC project it was quickly established that whilst this information was helpful in providing developers with information about known constraints and opportunities for connection to the distribution network, a significant barrier to connection still remained due to the constraints that cumulative levels of distributed generation were having on the transmission network.

In order to facilitate improved heat maps that included information of transmission constraints, we undertook analysis as part of the project to collate information relating to each GSP location within the trial area. The information gathered included the current contracted generation position under each GSP to establish if there was a known constraint and if reinforcement works had been identified to alleviate those constraints. If works were identified forecast completion dates were obtained. This information was retrieved by working with our commercial and design colleagues to review the existing contractual information already in place between GB System Operator NGET (GBSO) and SPD. Information was collated very quickly and it was agreed within SPEN that the exercise would be repeated across all GSPs within the SPD distribution franchise area.

This exercise delivered the publication of a new heat map that included information relating to transmission constraints. Figure 1 below provides an example of the information that has been available for over a year on our website www.spenergynetworks.co.uk and which details those transmission GSP that are constrained or have available capacity.

Figure 1: Representation of the Accelerating Renewable Connections toolbox

Connection date advised within original distribution generation connection offer

In parallel to the provision of enhanced heat map information, a review of the existing information that was included within the distribution connection offer to customers was undertaken, in respect of known transmission constraints.

It was established that when connection offers were being made the proposed date of connection only related to delivery of the distribution connection works. Whilst reference was made to potential transmission reinforcement, no details were included within the original distribution connection offer regarding when those transmission works were likely to be completed.

Following completion of a review of connection offers it was agreed that when transmission reinforcements from a GSP boundary were known and could be referenced in the original distribution connection offer, this information would be made available, ahead of the formal application process to the GBSO. This allows distributed generators to be in receipt of all information relating to their proposed connection to enable them to undertake an informed assessment of the connection offer. Inclusion of this information in distribution connection offers has formed part of the business as usual process from early 2015 and represented a quick deliverable for the project.

Online Curtailment Assessment Tool (OCAT)

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 have 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.

To develop OCAT, the following activity has been undertaken;

- 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;

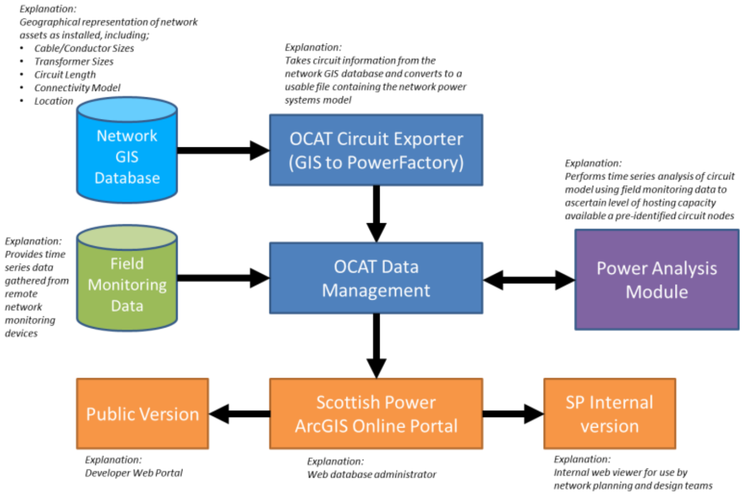


Figure 2: OCAT System Architecture Overview

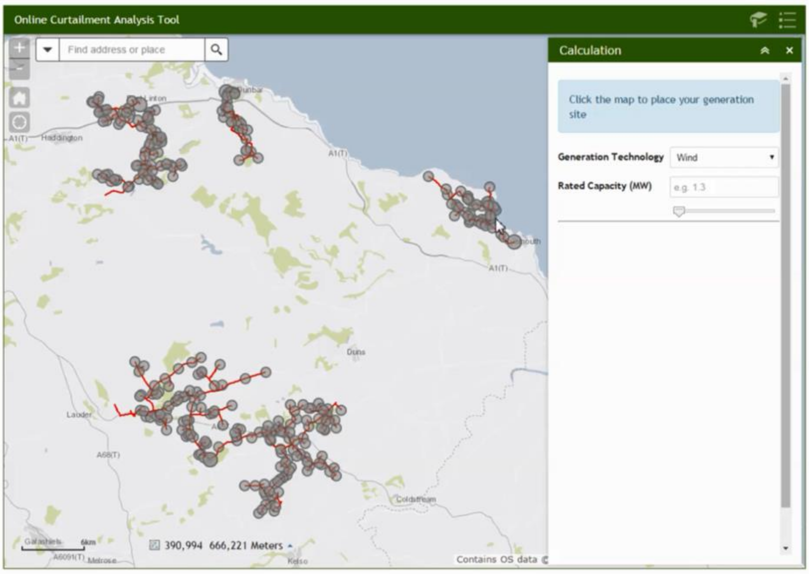


Figure 3: Example of Developer OCAT Web Portal Interface

Development of customer and DNO interface to provide information on constraint events

As part of the ARC project deliverables, we deployed a Local ANM flexible connection solution at Penmanshiel Farm, detailed further in Section 3.3 Project B, which used an alternative technical solution delivered by Nortech.

Deployment of Local ANM schemes provides the ability for DNOs to accelerate customer connections through alternative connection solutions that may not be realised through the application of conventional network reinforcement. Whilst there are obvious benefits to developers by gaining access to the network at an improved cost and timeframe, once operational it is natural that both network operators and customers may wish to view and interrogate data captured by those schemes to understand why a particular constraint event has occurred.

Compared with previous post energisation interaction with customers, as more flexible connection solutions are deployed across distribution networks, greater interaction with customers is likely to be required. In recognition of this we explored the potential to provide a customer interface that could be accessed via a web portal to allow the customer to 'self-serve' when seeking to understand way a particular curtailment event occurred.

Since the Local ANM scheme, managing both a wind turbine and PV array, has been operational at Penmanshiel Farm, we have witnessed several curtailment events where the turbine output has been reduced by 20% due to an identified voltage rise. We have also observed dips, on several occasions, of the availability of the GPRS communications platform that supports the Local ANM solution, meaning that the communications signal is lost between the remote constraint monitor and the central ANM iHost platform. The consequence of this is that the generator's output is programmed to reduce to zero export on the grounds of ensuring continued safe operation of the network.

Naturally when such events occur the customer seeks information on reasons for the curtailment event. Working with Nortech, we have provided a user interface whereby a subset of the information that is being collected from the site is made available to the customer. The customer is able to access the information via a secure web-based log in and retrieve information regarding the performance of the distributed generation and times and durations of curtailment events. Figure 4 & 5 below provides an overview of the Customer Interface Dashboard that has been developed as part of the project to enable the customer at Penmanshiel Farm to directly access information relating to the performance of the scheme. The customer has read only access and is unable to affect the settings of the Local ANM scheme.

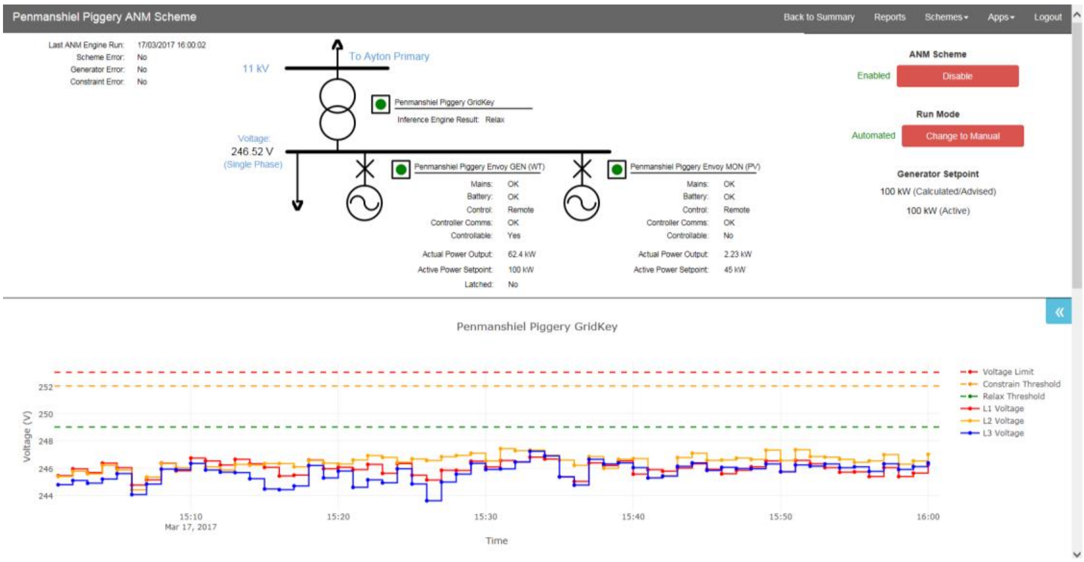


Figure 4: Penmanshiel Farm – Customer Interface Overview

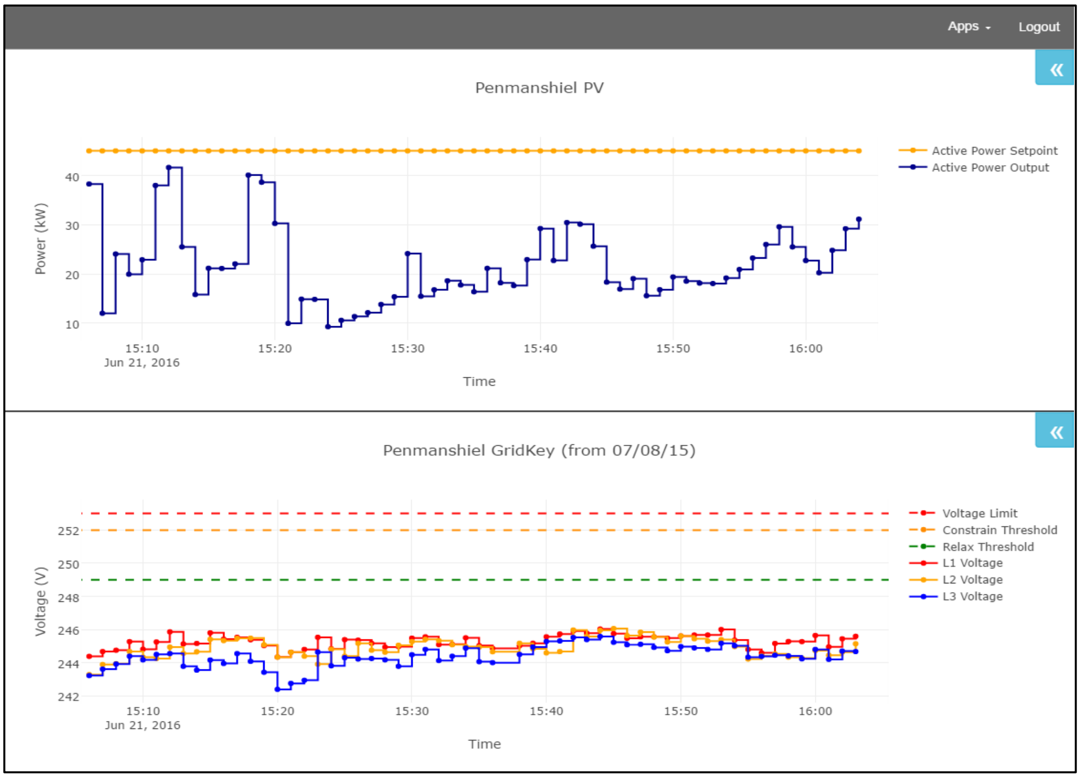


Figure 5: Penmanshiel Farm – Active Power & Three Phase Voltage Profile

The above provides an example of the ongoing interface and customer service provisions that need to be considered when seeking to rollout a suite of flexible connection solutions such as Local or Wide Area ANM schemes.

3.2 Demonstration of commercial and technical solutions which accelerate connections at exporting GSPs

A key deliverable of the ARC project was the implementation of Active Network Management enablement at a minimum of two Grid Supply Points. This was achieved during the project through the deployment of ANM at both Dunbar and Berwick GSPs respectively.

The Exporting GSP

Dunbar GSP comprises two 60MVA, 132/33kV transformers that are owned and operated by SP Transmission. Prior to the commencement of the ARC project connected within the Dunbar distribution network, were two existing wind farms connected at 33kV.

Minimum demand connected under the GSP was estimated to be 10MVA, with total connected levels of distributed generation at 110.5 MW. Under conventional design standards, one of the two existing wind farms was subject to an overload intertrip scheme to prevent any risk of asset overload during N-1 network operating conditions. Analysis undertaken during the development of the ARC Final Submission Pro-forma identified that under minimum demand, maximum generation conditions, reverse power flows across the transmission/distribution boundary at the GSP was approaching 100MVA.

Prior to the implementation of the ARC trial, four additional generators had or were in the process of requesting a connection to the SPD distribution network with a combined connection capacity of 50MW.

Under conventional network design analysis it was deemed that network limits were such that no additional capacity for new generation to connect was available under Dunbar GSP as a consequence of reverse power flow across the transmission/distribution boundary. Following an application to National Grid, in their role as GB System Operator, a network connection solution was developed via the transmission system owner that would permit all four generation projects to connect upon completion of the following transmission network reinforcements;

- Installation of two additional 90 MVA 132/33kV transformers at Dunbar GSP
- Installation of a second 33kV Switchboard at Dunbar GSP
- Upgrading of the existing 132kV transmission overhead line circuit to Dunbar GSP to provide a minimum summer rating of 165 MVA pre-fault

The forecast upgrade costs for those works were circa £20M in total with a forecast completion date of 2021. The total costs would be apportioned between direct charges to those generators seeking to connect and for wider transmission works, the costs that would be socialised across all network users.

As part of the deliverables of the project, SPD sought to facilitate early access and deliver the additional generation projects by developing a technical solution that would rely upon Active Network Management (ANM) and develop new commercial arrangements that would support the introduction of ANM at Dunbar GSP between SPD, developers, SP Transmission and GBSO National Grid.

Multiple Issues for N-1 Contingencies

Berwick GSP comprises two 60MVA, 132/33kV transformers owned and operated by SP Transmission. Prior to the commencement of the ARC project, two existing distribution connection wind farms were operational with a combined connection capacity of 43.6MW. During the ARC project a further three wind farms sought connection to the distribution network under Berwick GSP with a combined connection capacity of 54.6MW.

Following receipt of these three new connection applications, network studies were undertaken in line with the existing conventional design and connection application process. The studies identified that following connection of the proposed new generation under Berwick GSP there was a risk of a thermal overload of the existing network during either a planned or unplanned outage at Berwick GSP and the wider transmission network i.e. an N-1 constraint was identified.

To address this issue the transmission system owner identified the requirement to implement a wide area Load Management Scheme (LMS) to ensure that no thermal overload of the existing network assets could occur during an outage event. As part of the ARC project, system analysis identified that additional capacity could be released through the implementation of an ANM solution at Berwick GSP during N-1 operating conditions. This would enable real-time management of the generators within an agreed network limit whilst complementing the protection afforded to the network through the implementation of the LMS, mitigating its requirement to operate in the first instance when an outage event occurred.

The implementation of an overload intertrip protection scheme such as the LMS at Berwick GSP is a fundamental network requirement. The protection of network assets is paramount however, due to their binary nature of operation they lack the sophistication of a modern ANM scheme to flex export limits and manage generation in real-time. Furthermore to manage a constraint they can remove significantly more generation than necessary.

ANM control schemes can complement and support existing network protection solutions to enable a greater export of distributed generation to be realised during outage conditions. As the development of ANM schemes continues their interaction with existing overload protection arrangements should be explored further. The next step in the leaning journey would be to have both systems interface with one another whereby a dynamic signal could be presented from the transmission network to a distribution ANM scheme which would respond by taking appropriate action to limit either generation export or net load flows across the transmission/distribution boundary.

In addition to the implementation of the ANM scheme at Berwick GSP to manage export during N-1 system operating conditions, in 2015 we retrofitted an existing 48 MW wind farm with ANM control capability that had connected to the distribution networks under Dunbar GSP in 2008. The generator had been permitted to connect to the distribution network by means of the implementation of an overload intertripping scheme governed by a BELLA connection agreement. The benefit of retrofitting ANM control at the generator was to reduce the customer's overall risk of disconnection from the system during an N-1 outage, and to ensure that the GBSO did not issue a generation turn down instruction directly to the generator in isolation of the existing ANM scheme. Once the ANM scheme perceived a level of network capacity it would allocated it across those generators subject to ANM control thus negating the balancing instruction issued by the GBSO to the BELLA connected generator.

During the project trial period an N-1 outage did occur at the Dunbar GSP which enabled operational experience of the ANM scheme to be gained and recording in its ability to manage the existing 48 MW wind farm's export during an N-1 outage. 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.

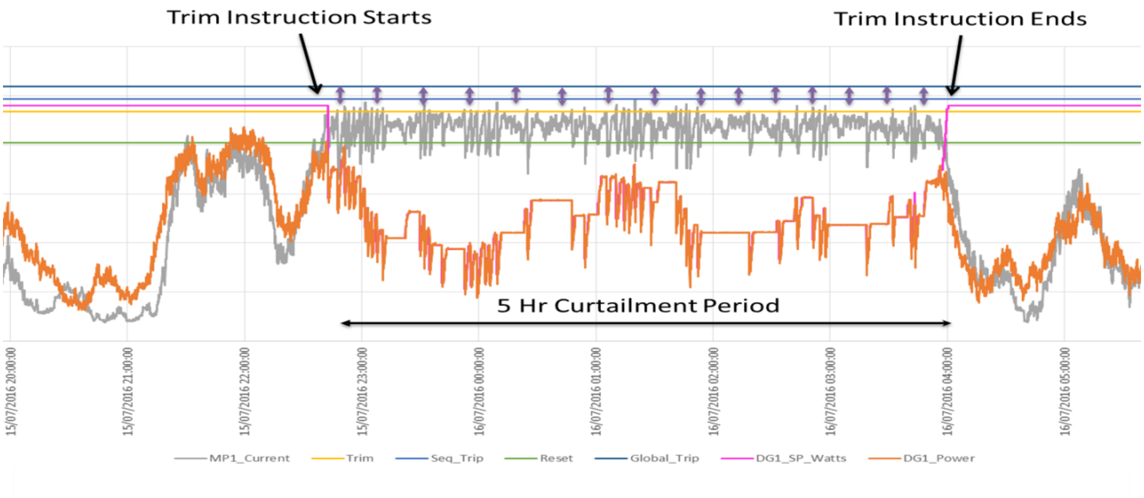


Figure 6: ANM Enabled Wind Farm Managed During N-1 Constraint

Commercial mechanisms and connection agreements implemented

The development of commercial and connection arrangements implemented to permit acceleration of generation gaining access to the distribution network ahead of transmission reinforcements, relied heavily upon positive interaction with GBSO National Grid. With respect to those customers seeking connection under Dunbar GSP, initial engagement with National Grid commenced on 31st January 2013 when we introduced the requirement to development a connection offer and agreement that would permit generation projects to connect ahead of identified grid reinforcements. At the commencement of the project it was both our view and those of developers seeking access to the network, that the implementation of ANM under Dunbar GSP would facilitate an enduring network connection solution and negate any requirement to reinforce the transmission network. However as will be discussed, this proved not to be the case and we worked with the GBSO, as well as our own transmission and distribution commercial colleagues, to develop a two-staged connection agreement. This facilitated both the implementation of ANM but also provided a clear investment signal and governance arrangements to reinforce the transmission network.

- **Stage 1** – An ANM solution offered to the connecting party to facilitate connection of distributed generation ahead of identified transmission network reinforcements. The ANM solution provides an interim non-firm connection against the transmission network and manages network flows within agreed network capacity limits, releasing capacity to each connecting party in line with agreed Principles of Access.
- **Stage 2** – Follows similar arrangements offered under conventional connection agreements whereby all new generators connecting under Dunbar GSP realise a Firm connection against the transmission network following completion of identified transmission reinforcement works. After completion of reinforcement works, ANM control and contractual Principles of Access fall away and each generator benefits from unconstrained generation export.

As stated previously the requirement to implement a two-staged connection agreement was based upon the identified risk that each generator could face from the implementation of an enduring

ANM solution under Dunbar GSP. Within the Dunbar GSP group there is currently a significant industrial demand operating. Following completion of network analysis and review of network demand sources, to inform and provide each generator with a constraint forecast, it was clear that should future demand under Dunbar GSP reduce significantly, each new generator would be exposed to significant constraints and operating restrictions under normal system intact conditions. Working openly with each generator both individually and as a collective group, we presented the potential risks and the benefits of investing in the planned transmission reinforcements to ensure the longer term viability and economics of their respective generation projects. Following this engagement generators were able to clearly understand the requirement for completion of the planned transmission reinforcements. Therefore it was agreed that the most appropriate commercial mechanism to introduce was a two-stage connection agreement.

An extract, redacted appropriately to protect commercial confidentiality, from the two-stage connection agreement implemented at Dunbar GSP is included within Appendix C. In total this agreement has been used to facilitate the connection of four new generators connecting under Dunbar GSP.

The commercial connection offer and connection agreement implemented as part of the ARC project at Berwick GSP differs from that implemented at Dunbar. The main difference is that under Berwick GSP the application of ANM has been implemented to facilitate an increase in available export capacity during those times when the network is operating with an N-1 constraint. As the level of proposed new generation under Berwick GSP was only considered constrained under conventional design rules during an N-1 outage, network reinforcement was considered unnecessary. In the absence of the ARC project, a traditional BELLA connection agreement would have been issued and as discussed above, network export capacity would have been monitored and limited via the implementation of the LMS scheme.

By implementing ANM at Berwick GSP and interfacing with each new distribution connected generator, the export of each site can be managed within the limits of the existing network to maximise the level of export in line with Principles of Access included within the connection agreement. The ANM scheme provides for an enhanced level of transmission asset protection as it can take export limiting actions to mitigate wider transmission constraints without the requirement to disconnect generation from the network. This also provides both a technical and economic benefit to the relevant generator. The implementation of ANM at Berwick GSP has enabled an enduring ANM connection agreement to be implemented in place of the conventional BEGA/BELLA agreement that would have been offered under the conventional network solution.

In parallel to the development of new commercial arrangements to govern the implementation of ANM schemes at Dunbar and Berwick GSPs respectively, we undertook an assessment of the appropriate Principles of Access that could be adopted for those generators connecting as part of the ARC project. This used SSEN's Orkney RPZ trial and UKPN's Flexible Plug and Play LCNF project findings which had had already advanced leaning associated with adoption of Principles of Access arrangements.

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. Figure 7 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 a 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.

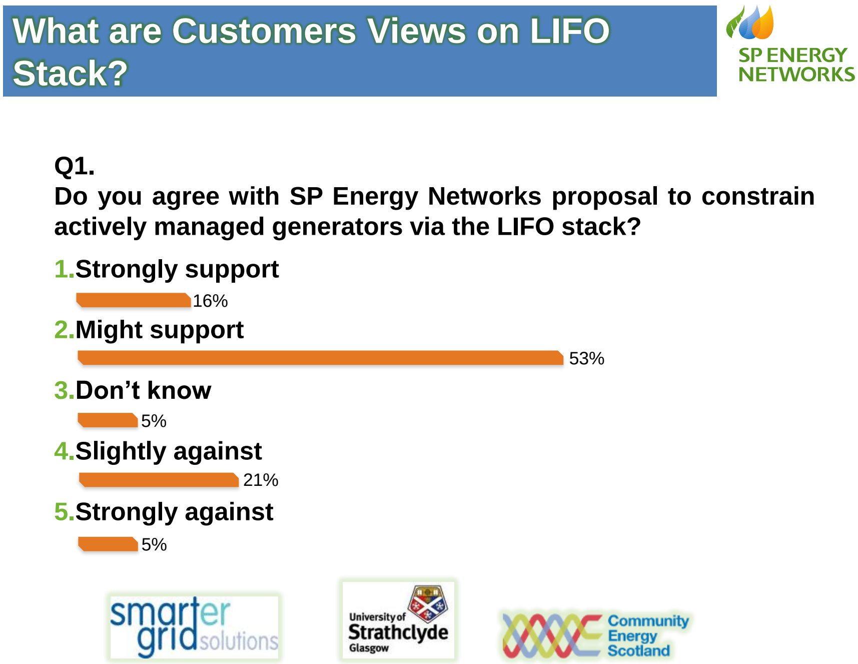


Figure 7: Stakeholder Engagement, Live Feedback on Principles of Access Arrangements

In addition to gaining feedback on our proposals to introduce the LIFO Principles of Access, feedback was also sought from Stakeholders at our June 2014 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 8, 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.

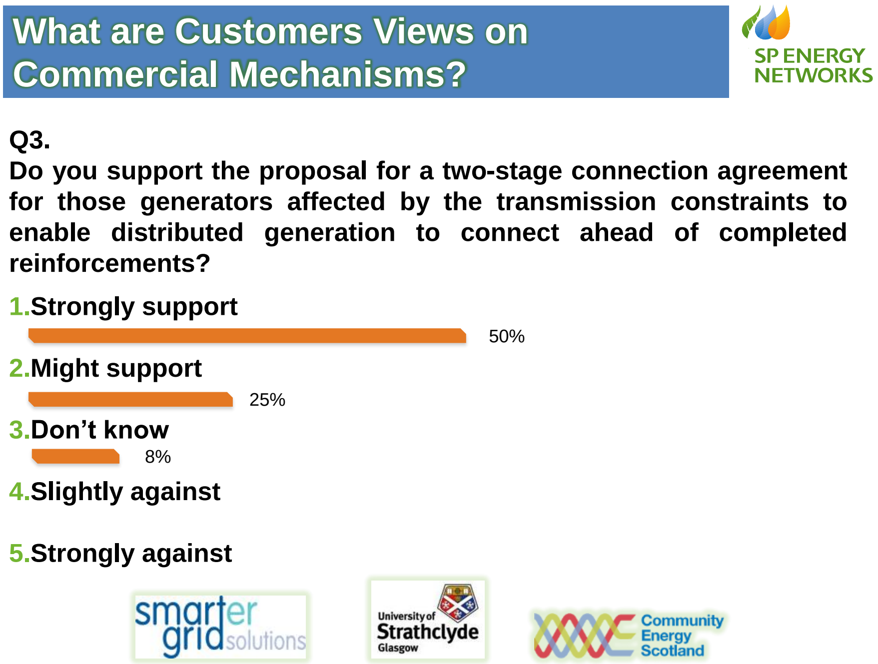


Figure 8: Stakeholder Engagement, Proposed Introduction of Two-Staged Commercial Offer

Technical architecture implemented and delivered

The technical architecture deployed and trialled as part of the ARC project at Dunbar and Berwick GSPs respectively is detailed within figure 9 and 10 provided below.

The principle function of the ANM scheme is to provide a 'soft' curtailment instruction to generators in accordance with pre-defined Principles of Access. Curtailment events are triggered following a breach of pre-defined thermal limits detected, summarised within Table 1.

Action	Limit %	Value (Amps)	Constraint Location	Description
Trim Instruction	90%	945A	132/33kV Grid Transformer(s)	Curtailment of generation in accordance with LIFO
Sequential Trip	95%	998A	132/33kV Grid Transformer(s)	Sequential Trip of generation in accordance with LIFO

Global Trip	100%	1050A	132/33kV Grid Transformer(s)	Global Trip of all generation under ANM scheme

Table 1: Summary of ANM Thresholds

For the Dunbar and Berwick ANM schemes, constraint point measurements were obtained via current transformers (CT) installed within the 33kV transformer circuit breakers, and presented to the central ANM control scheme, which for the purposes of the trial was located within the transmission substation, via a set of dedicated iSTAT M232 multi-functional metering units installed within the transmission network protection relay cubical. To enable this installation the project relied upon engagement with the transmission owner and upon transmission protection engineers to install the necessary equipment within the transmission substation.

A key deliverable of the ARC project was the exploration and application of ANM control to manage distributed generation behind a transmission network constraint. The trial required that the ANM central controller was installed within the transmission substation, decentralised from the main distribution operational control centre (OCC).

Remote terminal units (RTU) installed at each generator substation communicates directly with the central ANM controller via a fibre optic network. Communication between the central ANM controller and each generator managed by the ANM scheme is processed via the remote substation RTU. This has the ability to trip and disconnect the generator from the network following loss of communications or failure to respond to a curtailment instruction within an agreed time limit.

Visibility of the ANM system is communicated back to the transmission owner's control room over the existing SCADA infrastructure and displayed on the transmission Energy Management System (EMS). This provides transmission control room engineers with real-time visibility of system health and curtailment actions. A separate 3G communication link was also established to provide remote technical support for the vendor of the ANM control infrastructure. As further applications are rolled out, visibility of the ANM system would also be made available to distribution control room engineers but for the purposes of the trial and due to the ANM scheme being implemented to manage transmission network constraints, visibility was limited to the transmission control room.

The technical architecture of the ANM system deployed at Dunbar GSP during the project detailed in figure 9 shows the information exchange at the transmission/distribution boundary. This was implemented to meet the objective of the ARC project to trial and demonstrate an operational example of the application of ANM to managed and accelerate the connection of distributed generation and manage power flows across the transmission/distribution boundary.

The existing Dunbar GSP was already subject to an overload intertrip scheme deployed previously to facilitate the connection of existing generation. The ANM scheme was therefore commissioned to operate below the current overload intertrip thresholds with ANM trim thresholds set accordingly. This allowed the trial to proceed by limiting the risk of existing assets being subject to a thermal limit overload should a failure of the ANM scheme occur or a generator fail to respond to a curtailment instruction. However as more ANM schemes are deployed in the future, learning from the project would suggest that protection and ANM schemes should complement one another and enable a greater penetration of distributed generation to connect and export during times where a network constraint is experienced.

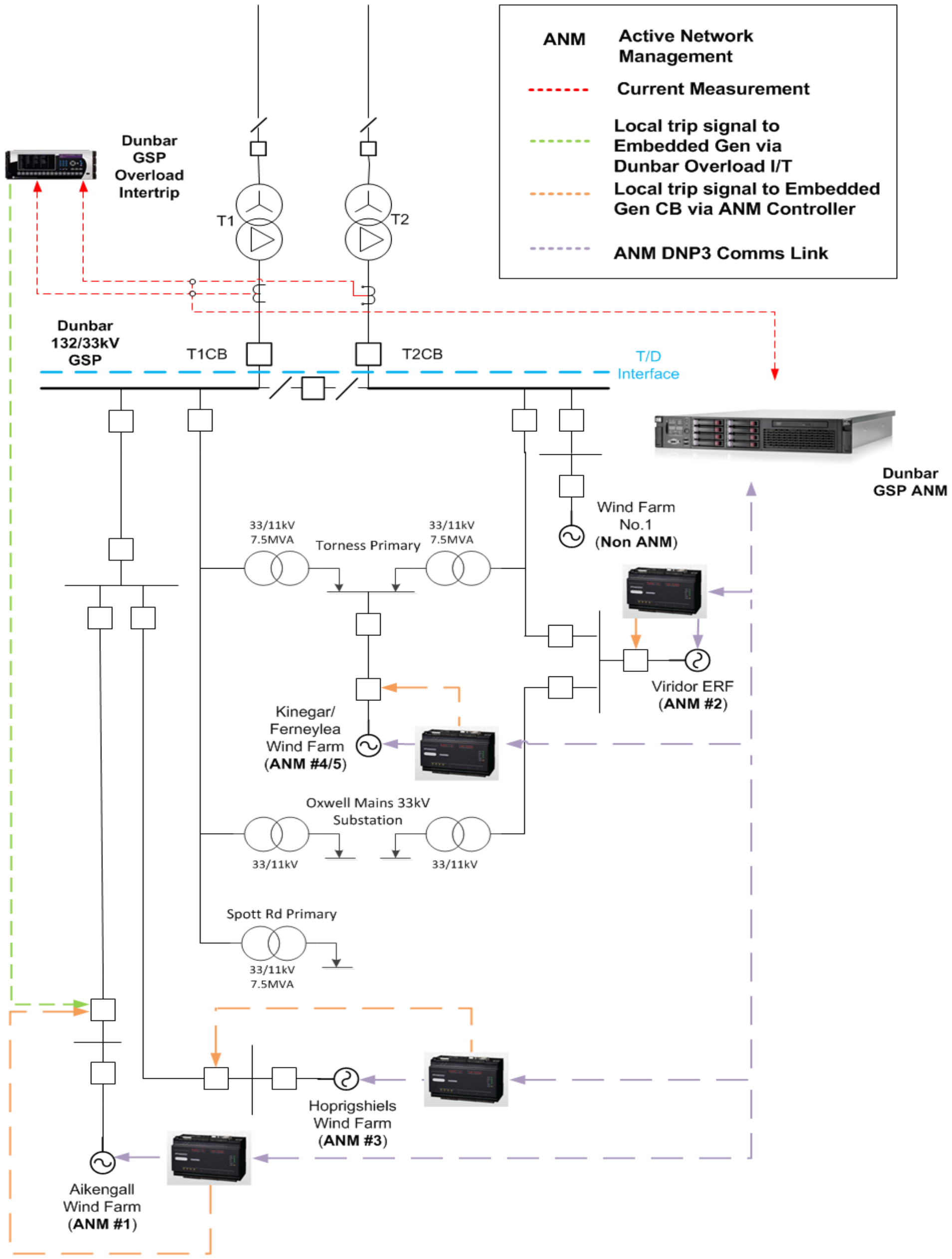


Figure 9: Dunbar GSP ANM Scheme Technical Architecture

Similar to Dunbar, the ANM scheme at Berwick GSP operates under an almost identical system architecture with respect to the collection of network measurement data (i.e. iSTAT M232) and the dispatch of curtailment instructions to connected generators i.e. fibre. One technical difference between the schemes is that the ANM hardware installed at Berwick GSP utilises industrial grade servers, manufactured by Amplicon, that were considered more appropriate for deployment and situ within a substation environment, compared to the commodity based servers deployed as part of the Dunbar ANM scheme.

The nature of the constraint at Berwick GSP is such that the ANM scheme will only issue a controlling action when a thermal overload is witnessed during an outage N-1 condition, i.e. loss of a transformer at Berwick Grid for either planned maintenance or system fault. Therefore the ANM at Berwick is expected to be deployed on an enduring basis until such times as future generation projects seek connection and a conventional network solution is implemented to reinforce the current transmission infrastructure.

Another difference between the two GSP ANM schemes is that for generators connecting under Berwick, a second constraint was identified during the system planning phase. Due to the collective impact of transmission and distribution connected generation within the Scottish Borders; a wide area transmission protection scheme has been required which monitors an existing super grid substation. This protection scheme been designed to operate when a thermal limit is detected across two 400/132kV super grid transformers and a trip signal is provided to generation connected at both transmission and distribution voltages across a number of grid supply points. As future ANM schemes are deployed to manage the interface between transmission and distribution voltages, leaning from the project highlights the importance of establishing a dynamic export limit across a GSP boundary which can be supplied to an ANM system to manage export and support the balancing actions across the transmission network.

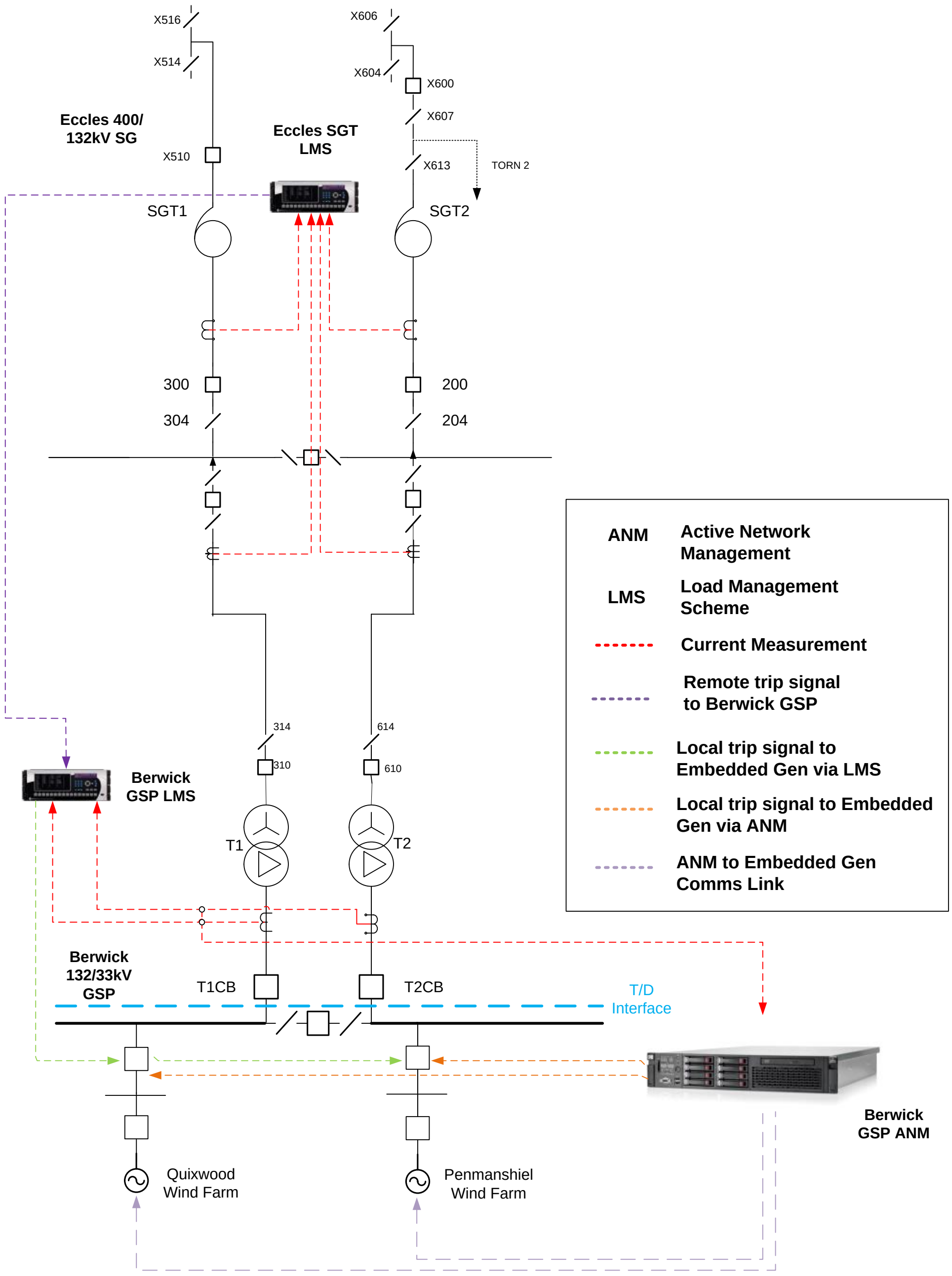


Figure 10: Berwick GSP ANM Scheme Technical Architecture

3.3 Demonstration and trial of new technical and commercial solutions for constrained connections across distribution voltages

Voltage rise constraint requires uneconomic reinforcement works at 11kV – Alternative solutions delivered

Project A – Ruchlaw Mains farm is a rural agricultural business that is supplied via a local 11kV overhead line and which consumes a significant demand of electricity annually in order to run its farming enterprise. The management of the farm see renewable energy as a natural and necessary progression of their business in order to stabilise costs and improve the overall efficiency of the operation.

Prior to the ARC project's involvement with the farm, a 275kW Wind Turbine had been developed in 2012, followed by 60kW of PV in 2014. The turbine provides 40 per cent of the energy for the 1000 sow pig unit at the farm and any additional generation output is exported to the distribution network.

A decision by the business to expand their farming operation and further improve efficiencies of the enterprise led to the development of a new feed mill which is capable of producing 1,200 tonnes of feed per month and required a new demand connection of 250kVA. Part of the project included the installation of an additional 80kW PV array that was to be located on the roof of the proposed new mill.

The original connection application for the 80kW PV array assessed under minimum circuit demand conditions identified a potential voltage rise constraint. The result being the customer receiving a connection offer that required construction of a new 1.3km 11kV wood pole overhead line back to the nearest primary substation, with a forecast connection cost of around £160k. Furthermore the route of the proposed line would require crossing existing arable farmland and require navigating through or round an existing woodland and disused quarry operation. Based upon this offer, the proposed new 80kW PV array proved uneconomic and the customer at that point gave up hope of connecting the new generation.

In 2014 we engaged with the customer to assess whether a connection could be realised through the application of a flexible connection solution. The first task that was undertaken was to understand the businesses existing energy consumption and how this interfaced with the existing on-site generation. An assessment was undertaken to understand the operating regime of the new feed mill and how the forecast power export from proposed 80kW PV array would serve this new demand. The customer informed us that the operating regime of the feed mill would be Monday – Friday, 9am – 5pm, with no feed manufacturing or milling taking place at weekends.

Once all the information had been gathered we considered which alternative connection solutions could be deployed. Whilst on-site demand would exist during week days, there still remained the risk that during a hot summer weekend, the export of the generation from the PV could raise the local distribution voltage out with statutory operating limits.

To establish the most appropriate connection solution, network monitoring was installed at the local secondary transformer that supplied the site to validate system models and the existing export and demand levels. In parallel to the monitoring activity the ARC project considered two flexible connection solutions including;

- Fixed export limitation of zero kW, whereby the new 80kW PV array would only be permitted to generate up to the level of the demand or load present within the customers new mill location
- Curtailment of the new PV array if an actual voltage rise on the surrounding network was detected

Following discussion with the customer and project partner Smarter Grid Solutions, it was decided that a Local or Standalone Active Network Management solution be installed at the site to manage export from the PV and mitigate any voltage rise out with statutory limits.

The Local ANM solution deployed and commissioned during May 2015 was based upon the Connect+ product delivered by Smarter Grid Solutions. Having decided upon the solution, we had to understand how it would be commissioned and integrated at Ruchlaw Mains. The illustration in figure 11 provides a high level overview of the Local ANM scheme deployed.

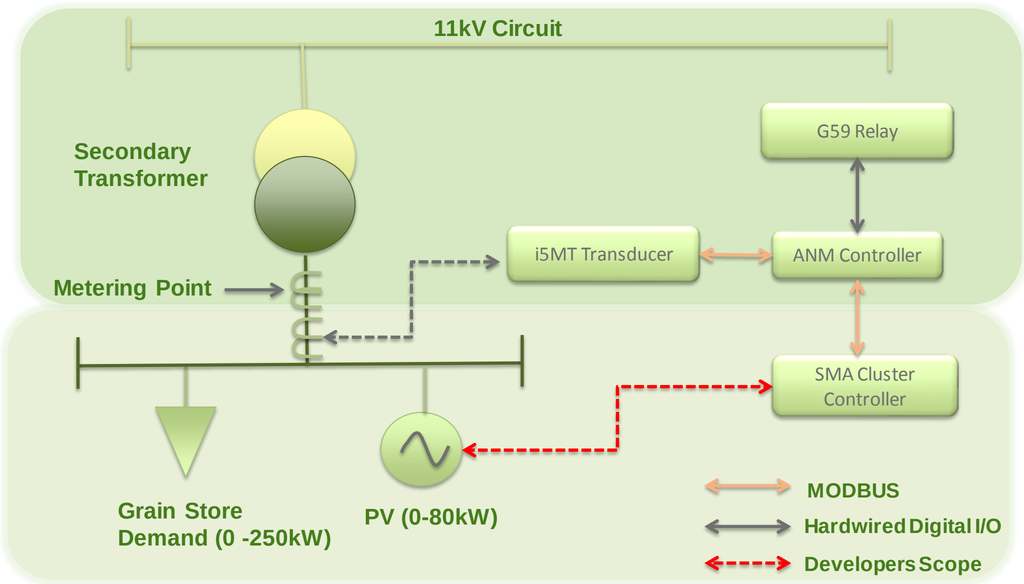


Figure 11: Ruchlaw Mains Farm – Local ANM Overview

The local ANM solution developed at Ruchlaw Mains Farm uses similar principles to active management of a generator output following breach of a pre-defined network limit. In the example of Ruchlaw Mains, the constraint was identified as being voltage rise due to the injection of power onto a section of overhead line network with low demand.

The local ANM control scheme measures power output from a set of dedicated current transformers installed within a CT metering cubical and then converts this real-time measured value to a Modbus signal via an iSTAT M232 transducer. A three phase low voltage measurement is also directly collected from the metering cubical and wired to the same transducer.

With this information the local ANM controller monitors and instructs the PV array to disconnect strings to PV cells upon breach of a predefined voltage limit (252V). This is communicated over a Modbus link between the local ANM controller and a SMA cluster controller installed within the customer's PV installation. In the event of non-compliance, a signal instructs the customers G59 relay to disconnect the PV from the network as a fail to safe.

To record the performance of the scheme a network monitor was installed within the ground mounted secondary substation to capture and record network voltage profiles throughout the peak summer period. Learning from the project concluded that no voltage rise was detected and that minimum demand within the mill shed was of sufficient size to absorb all power generation from the PV array.

Smart Grid Solutions worked directly with SMA to ensure that their local ANM control equipment could interface with the proposed cluster controller and invertors that formed part of the PV array.

By working with SMA and trialling the cluster controller, greater control over the 80kW PV array was achieved. Any requirement to constrain the PV array to mitigate a network voltage rise event can be completed in 5kW increments as opposed to a minimum of 25% of the total connected capacity as was considered when the project was initially implemented.

The engagement between SMA, Smarter Grid Solutions, SPEN and the customer was positive throughout out the process. The desire to implement a workable solution led to an exchange of equipment between SMA and Smarter Grid Solutions with the Local ANM controller being sent to SMA's German production facility. This enabled Factory Acceptance Testing of the integration of the Local ANM controller and SMA cluster controller to take place ahead of full deployment on site.

Project B – Penmanshiel Farm in the Scottish Borders is supplied via an existing 11kV overhead line approximately 11km from the primary substation which splits into a number of supply points served by pole mounted transformers close to the farm.

Prior to the ARC project's involvement with the company, a 50kW PV array was already operating at the site. Similarly to Ruchlaw Mains, the business wished to mitigate their energy costs and therefore was considering the installation of an additional 50kW PV array and 100kW wind turbine.

The original connection application in September 2013 for the new 100kW wind turbine was assessed under minimum circuit demand conditions, and identified a potential voltage rise constraint resulting in the customer receiving a connection offer that required the construction of a new 11km 11kV wood pole overhead line back to the nearest primary substation, at an estimated cost in excess of £600k. Following receipt of this connection offer the installation of the new wind turbine was considered to be uneconomic and the application was cancelled by the customer.

However during 2014, the customer approached SPEN to explore the opportunity for a connection to be realised through the ARC project. In seeking to find an alternative connection solution, we initially deployed two network monitors at each of the secondary transformers that supplied the Penmanshiel Farm. The monitoring was implemented during the spring of 2014 to provide a real-time voltage measurement profile over the summer and autumn period of that year. In parallel to the deployment of monitoring, the customer made an application to the local authority for the construction of the proposed wind turbine with planning consent being granted during September 2014.

Following our experience in deploying the Local ANM scheme at Ruchlaw Mains Farm the flexible connection solution deployed at Penmanshiel Farm was similar however this time we implemented a solution from Nortech. This made use of the existing monitoring equipment and explored the correlation between actively managing two renewable generation sources behind a single point of connection (the 100kW wind turbine and 50kW PV array)

The ARC project trialled the use of a Nortech Envoy (RTU) and iHost ANM platform. The system was commissioned to monitor the voltage rise and export current every minute. It uses a GPRS communications platform to supervise and instruct a constraint action against either the wind turbine or PV array, if the voltage at the monitored constraint location has the potential to exceed network limits. Figure 12 below illustrates the ANM solution deployed;

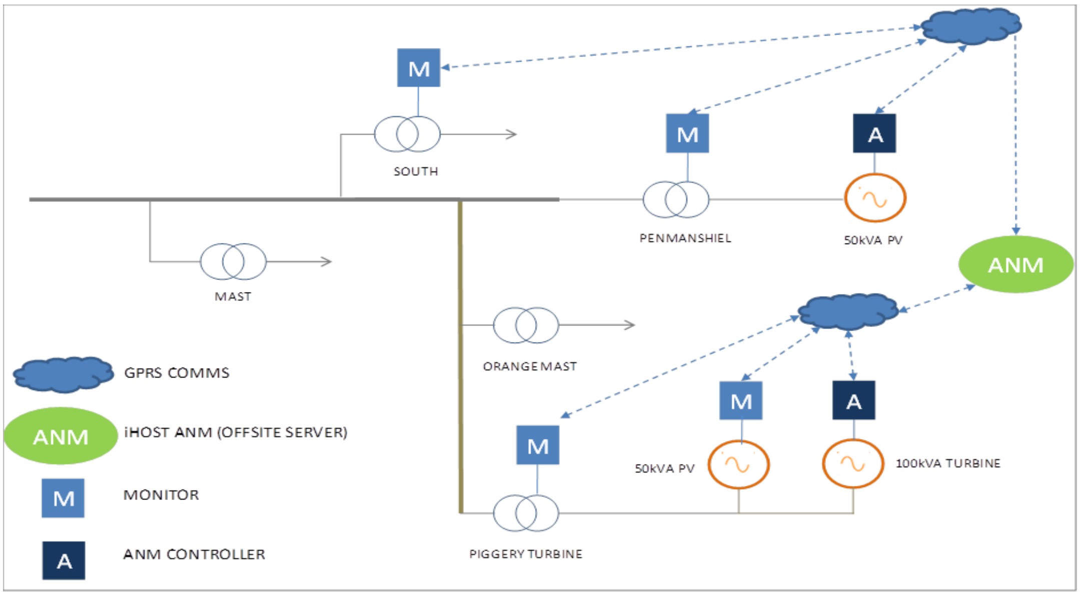


Figure 12: Penmanshiel Farm – Local ANM Overview

The deployment of local ANM connection solutions to managed voltage rise constraints at both Ruchlaw and Penmanshiel Farm respectively, has allowed both of these renewable generation schemes to gain access to the network that would otherwise have not have been realised. Furthermore we have been able to test two Local ANM systems from two separate suppliers during the project, each of which have proven successful in managing export at the respective sites.

Project C – The proprietor of Standhill Farm near Hawick in the Scottish Borders sought to construct and operate a 200kW Anaerobic Digestion (AD) plant to complement his existing dairy and farming enterprise. The benefits to the business of the new plant would be that it would produce electricity to serve the existing energy requirements of the farm with any excess being transported to the grid; produce heat that could be used to dry both arable crops and wood chip for application in biomass facilities and provide the farm with a natural field ready fertiliser reducing annual costs and reliance on chemical applications.

The original concept that was explored at Standhill involved installing a moderately sized wind turbine alongside the AD plant however this was quickly dismissed due to a concern that the cost of grid connection would render the dual scheme uneconomic. In addition, planning for a wind turbine in that part of the country was also unlikely therefore the preferred approach was to construct just the AD plant.

A number of wind turbines had already connected within the area and due to an existing voltage rise constraint the connection offer for the full export capacity of the AD plant required construction of a new 11kV overhead line at an estimated cost of £821k. Further engagement and dialogue with the customer established that the existing 11kV network could accommodate a maximum export of 153kW and that the costs to realise this connection option would be in the order of £22k. The customer accepted this offer and the connection proceeded with a maximum export limit of 153kW.

As part of the ARC project we considered what alternative connection solution could be implemented in order to realise the full export capacity of the AD plant. As the key constraint had been a voltage rise, the first task was installation of monitoring equipment at the farm's supply transformer prior to commissioning of the AD plant. This is illustrated in figure 13.

Over a period of nine months, data extracted from the monitoring confirmed the results of the original network design studies that voltage levels were at the upper limits of the within statutory network operating limits with the site commissioned under a restricted export of 153kW, illustrated in figure 14.

Unlike PV or Wind generation, implementation of ANM control over an AD plant was deemed unfeasible as the plant needs to operate at capacity for 24hrs a day. Through deployment of voltage measurement both at the farm's point of connection, and at other locations including the 11kV feeder primary substation (some 12km away), we were able to determine that by reducing the target secondary voltage at the source primary substation, the AD plant could realise the addition 47kW of export required to meet full capacity. This current running arrangement is illustrated in figure 16 with the distribution system measurement points illustrated in figure 17.

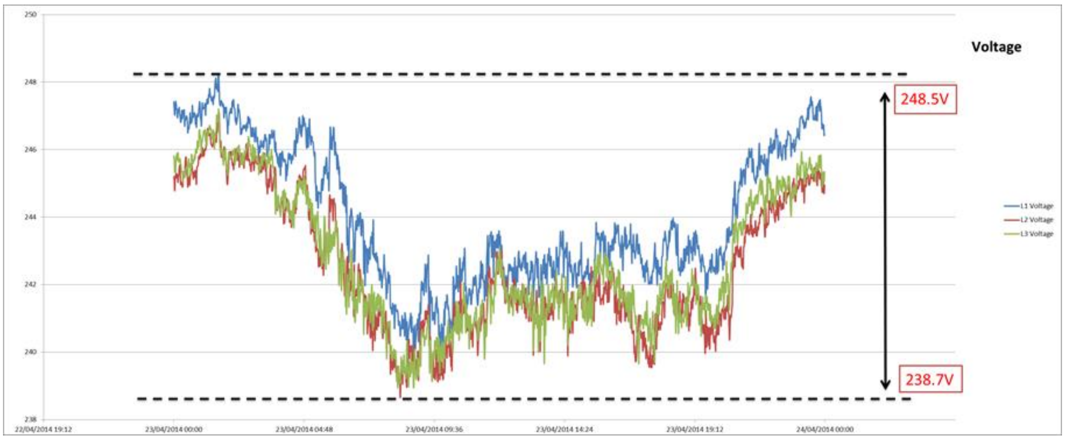


Figure 13: Standhill Farm voltage profile pre-commissioning of AD plant

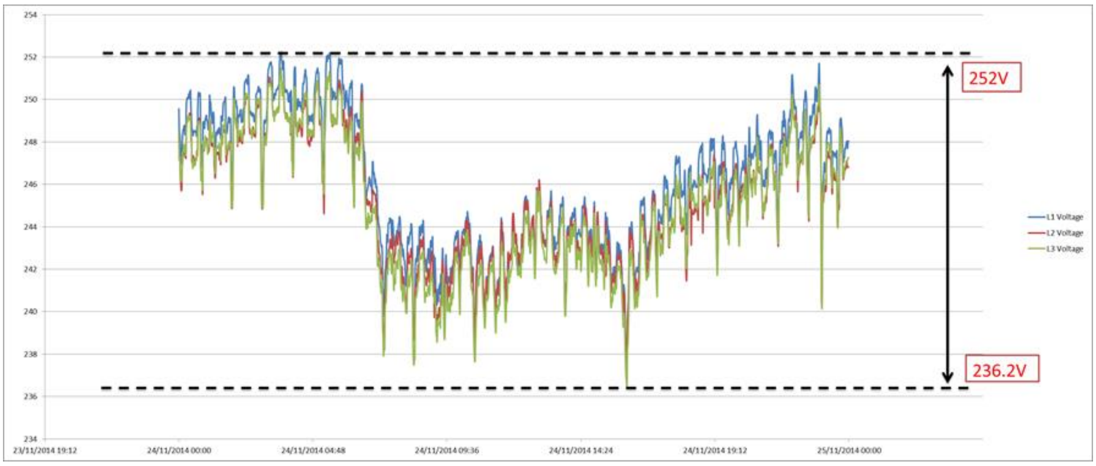


Figure 14: Standhill Farm voltage profile post-commissioning of AD plant with 153kW export limit

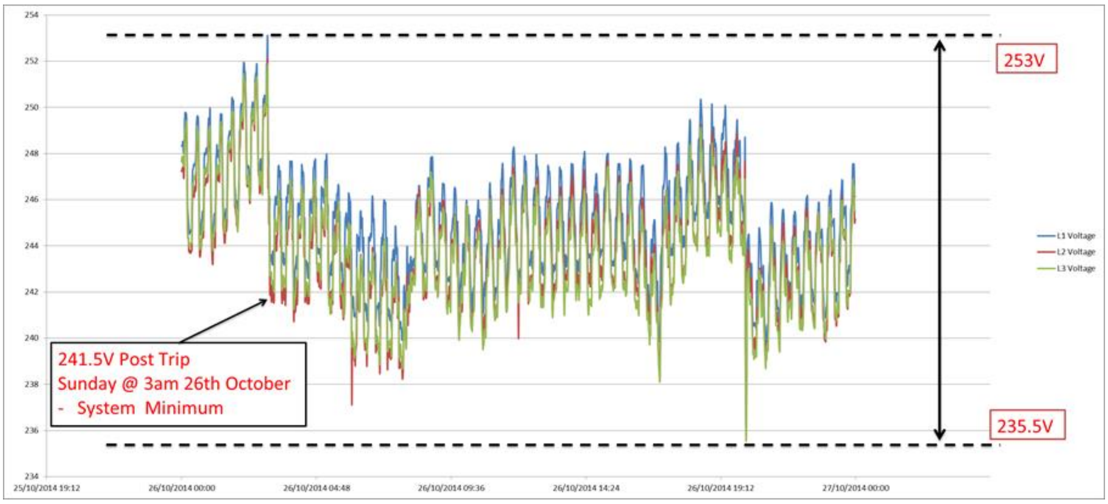


Figure 15: Results of project test to allow export > 153kW – G59 Trip Event Occurred

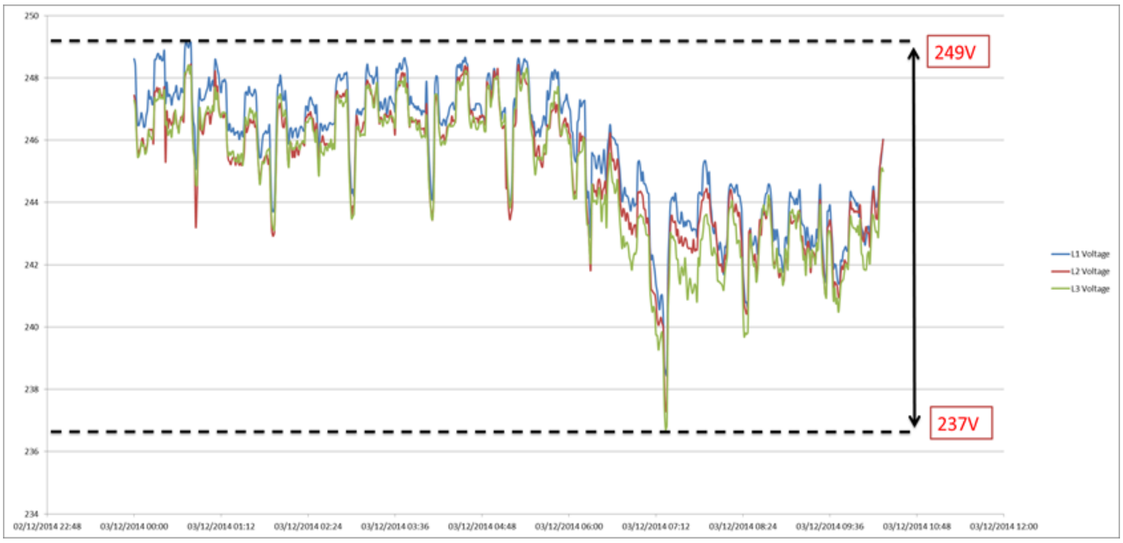


Figure 16: Voltage profile at Standhill Farm with AD plant commissioned at 200kW post wide area network voltage reduction

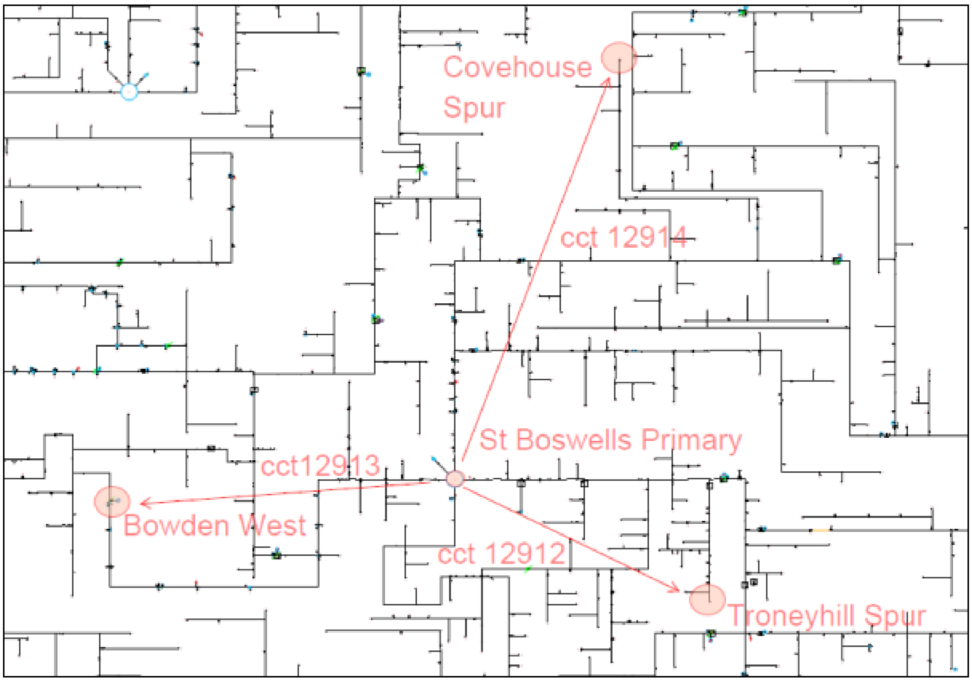


Figure 17: Monitoring installed across various locations to capture voltage profile prior to implemented voltage reduction solution

3.4 Demonstration of the role communities play in accelerating renewable connections

Insufficient Capacity for Small Scale Community Scheme

An application was received by SPD to connect a new 200kW AD plant on the Bowhill Estate near Selkirk. The distribution works that formed part of the original connection offer made provision for a new 11/0.415kV pole mounted transformer and extension of a small proportion of existing OHL to connect the project to the network. However the connection offer also limited the export from the site to an export limitation of 100kW due to an existing transmission network constraint identified as part of the connection design process. Transmission reinforcement works to alleviate constraints in the area were forecast to complete around 2019.

To realise the full export potential of the new AD plant, the customer considered the installation of a private wire network to service the load of the Estate directly from the AD plant. The Estate comprises a number of demand supply points including Poultry Farms, Estate Office, Workers Cottages and Bowhill House, a large country home heated electrically. The original customer proposal was to install a new 11kV private cable network from the new AD plant directly to Bowhill House to service the heating requirements of the property.

The ARC project undertook a review of the actual demands across the various properties in the Estate. This was achieved through the deployment of network monitoring at each secondary supply transformer feeding the Estate so as to capture the overall net power import. After capture of data for around 6-months, a review and analysis of the monitoring results was undertaken, along with a comparison of expected output of the new AD facility. The data demonstrated that the aggregated demand across the estate would be in excess of the expected output of the AD facility and that the customer would remain a net importer of power.

Based upon this analysis we were able to implement a flexible connection solution that adopted the principles of a Virtual Private Wire (VPW) network and permit the full export potential of the AD plant to be realised without reinforcement works. The VPW arrangement is illustrated in figure 18.

To enable the construction of the AD plant, the existing 11kV network was reconfigured to ensure that the export from the AD plant was able to directly serve the various properties that form the Estate’s demand portfolio. In addition, the original monitoring used to obtain network information has remained in place at the various secondary substation locations and a solution developed and agreed with the customer, that should Estate export exceed 100kW back onto the local distribution network, a signal will be provided to the Estate to flex the existing heating load demand in order to absorb all output from the AD plant over and above its 100kW limit already provided for within the original distribution connection offer. However following commissioning of the site during early 2016 there has never been a requirement to rely upon flexible demand following commissioning of the site during early 2016.

Linking local power and local communities via Virtual Private Wire

While physical private wire is a technically and commercially proven approach, the principle of implementing a Virtual Private Wire (VPW) network is a relatively new concept and requires greater consideration and engagement as well as recognising the effect on a variety of industry stakeholders. The ARC project has sought to develop the technical considerations for a single site to deploy a VPW concept, however further exploration of its wider application and impact upon a range of industry stakeholders is required.

Part of the work completed through the project is a report prepared by Community Energy Scotland which reviews the potential commercial arrangements for facilitating ‘Virtual Private Wire’ grid connections. This was enhanced by Smarter Grid Solutions demonstration of the control systems that could be implemented to facilitate VPW networks. The report and demonstration was presented to industry stakeholders at a workshop held at the Power Networks Demonstration Centre during September 2016.

An overview of the drivers and challenges for each industry stakeholder considered in the report is provided in Appendix B. The report entitled ‘Linking Local Power and Local People: VPW Report for ARC Project’ forms part of the suite of learning documents produced as part of the project.

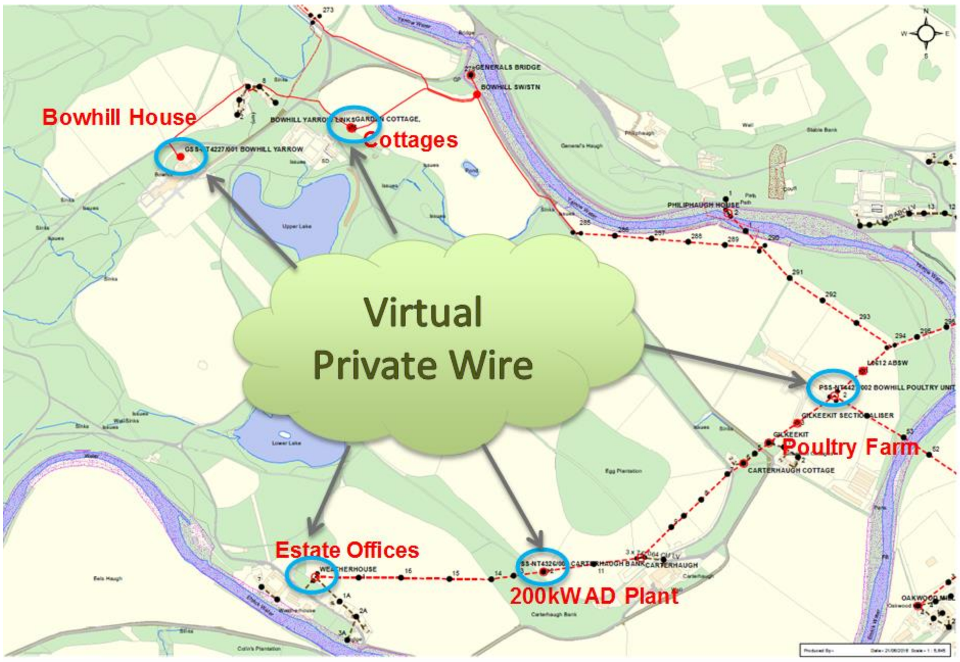


Figure 18: Bowhill House Virtual Private Wire Arrangement

Impact of Small Scale Generation Connecting under A GSP

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 we installed a number of monitors at various network locations to provide data to enable a better understanding of our LV network and its operation.

The University of Strathclyde undertook an initial red, amber, green classification considering both thermal constraints and voltage rise. The process is illustrated in Figure 20. Each proposed installation was mapped onto SPD's GIS system based upon the relevant postcode address. This process enabled the University of Strathclyde to identify the specific secondary substation and LV feeders potentially affected by each PV installation. Heat mapping was undertaken to establish primary and secondary substation clustering and provided a robust means by which to determine where further network monitoring may be required prior to a final determination being made about the connection of the proposed PV installation. This is illustrated in Figures 19 and 22.

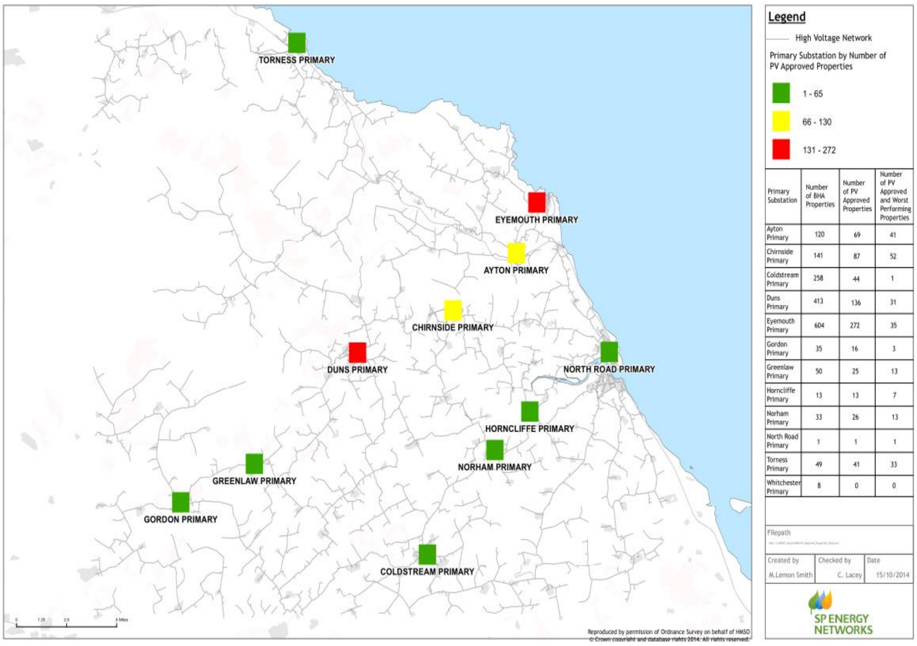


Figure 19: Proposed PV arrays linked to primary substations

Properties categorised as green and therefore considered to have no adverse impact upon the network were released and installed at various locations by July 2015. The benefit the assessment and deploying LV monitoring in the first instance was that we were able to release around 95% of the proposed PV installations originally requested without any requirement for curtailment of network reinforcement.

A combination of three phase voltage and current monitoring and the power system studies were used to assess the potential available capacity at each secondary substation associated with red and amber categorised PC systems. Study methodologies were developed for those cases where the primary voltage was unknown.

Site surveys conducted by network staff identified that only 30% of the current G83 PV connections installed across the trial area had been notified to SPD. However with accurate information on network characteristics being provided by the network monitoring, each circuit cluster was studied to determine if new PV connected generation would exceed either voltage or thermal limits of the existing network. A process was then developed to access how the level of constraint recorded at a particular network location would be treated in respect of approving the new PV installations which is detailed in Appendix 20 along with examples of the outputs from University of Strathclyde LV feeder monitoring exercise.

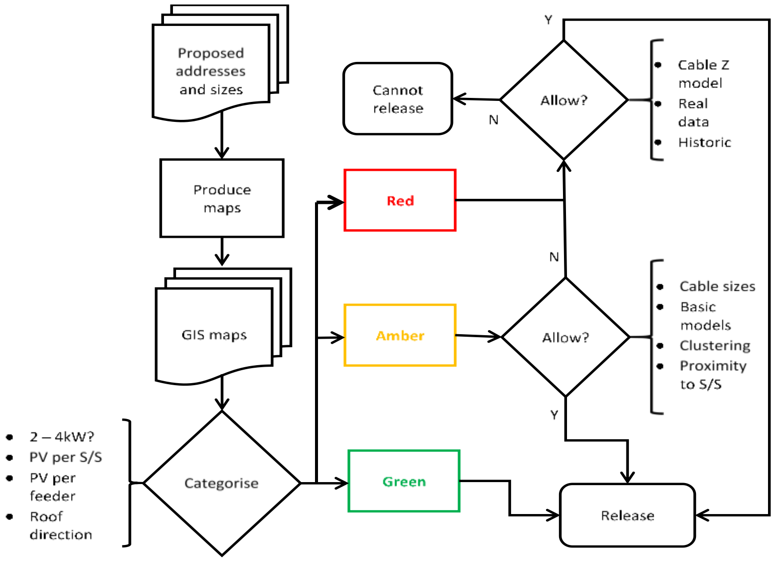


Figure 20: Process Used to Release PV Installation

Properties categorised as red were the most clustered and as such considered to have the greatest impact on the local network. More detailed analysis was carried out by University of Strathclyde to quantify this. In addition to the installation of monitoring equipment at the secondary substation, analysis included detailed power systems modelling of each highly clustered substation, including modelling of LV feeders and the 11kV circuits that were potentially affected. Time series load flow analysis was undertaken based upon both real and historic data to establish the potential risk of any voltage or thermal network limit being breached as illustrated in figure 21.

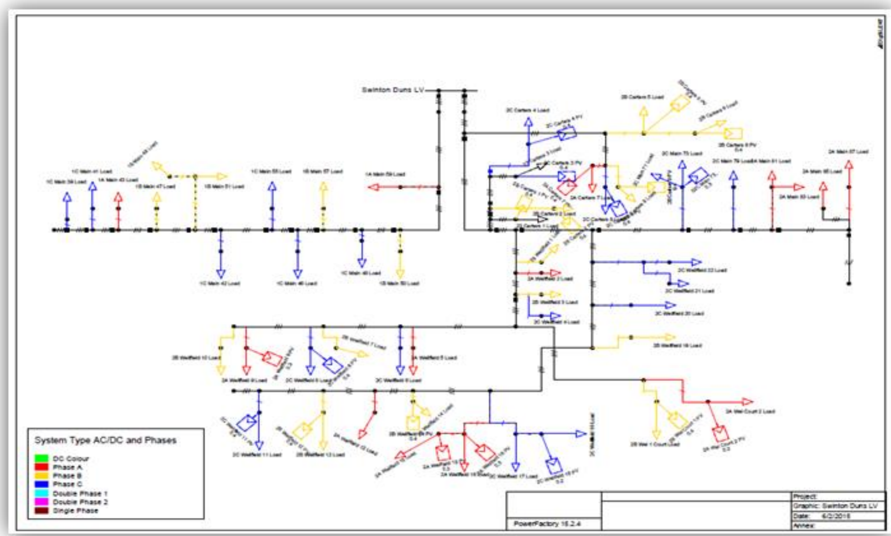


Figure 21: Example of LV Feeder Network Modelling Exercise

For those PV arrays that remained categorised as red, the associated secondary substations were considered at high risk of voltage excursions and therefore secondary on-load tap changer transformers were installed. These have trialled how by advancing the PV arrays and permitting their connection, secondary voltage levels could be regulated during summer months to negate the requirement for network reinforcement. In addition, to develop further learning and meet the projects objectives of developing a suite of flexible connection solutions, two advanced AVC relays were installed at Ayton and Eyemouth primary substations respectively where there was the greatest penetration and capacity of PV connections. 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.

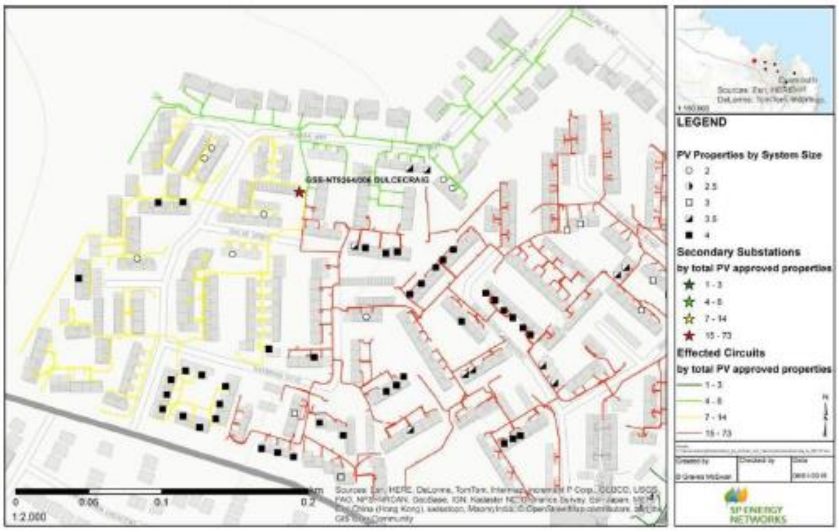


Figure 22: PV Cluster Analysis Categorised as Red, Amber or Green

The deployment of monitoring will remain in place following the end of the project in order to provide SPD with a minimum of 2 years of operational data to analyse the behaviour of the system with high solar irradiance and during lower demand periods of spring, summary and early autumn. An example of the monitoring feeder profiles is given in figure 23.

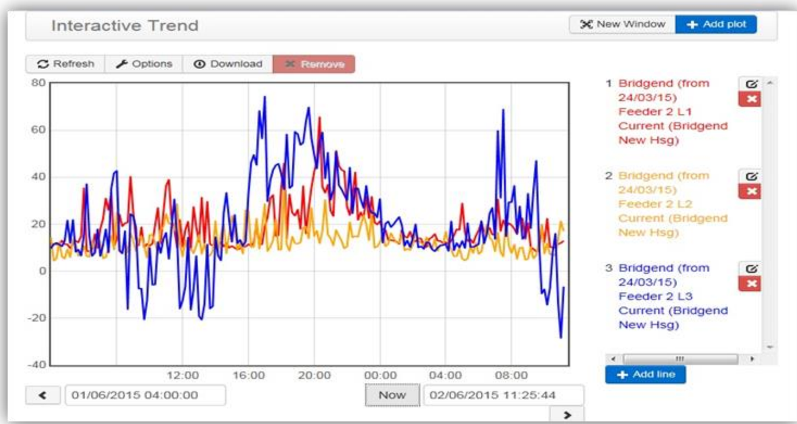


Figure 23: LV Feeder Current (Amps) Profiles Enhanced Network Modelling Data

By enabling the installation of the full 2.2MW of PV arrays across 749 properties, the Housing Association has estimated that over the lifetime of the installations, tenants will see a combined benefit of a £1.9M reduction in energy costs. The Housing Association have intimated the income from deploying this scheme will allow them to continue to make improvements to existing housing stock and invest in new homes across the trial location.

4. Outcomes of the project

Flexible connection solutions

The project has involved the trial of a variety of flexible connection solutions to facilitate an increased penetration of distributed generation gaining access to the distribution network in a timely manner. An overview of the range of network design and technical solutions developed by the project for connection of generation are summarised in Figure 24;

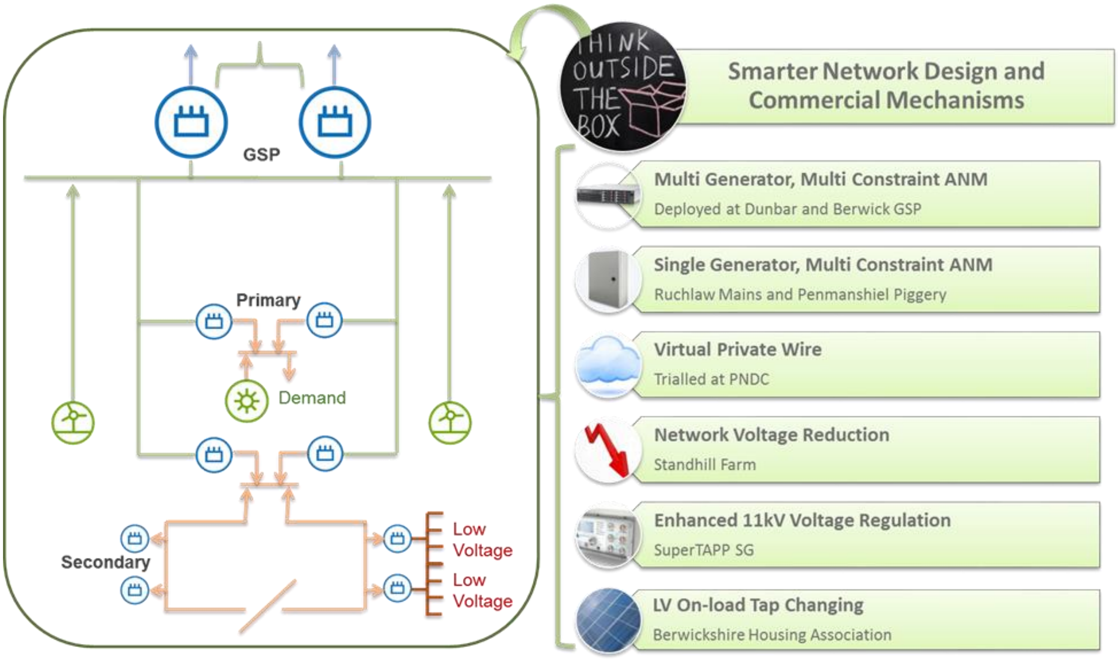


Figure 24: Representation of the Accelerating Renewable Connections toolbox

Through developing a suite of flexible technical and commercial connection solutions, the ARC project has facilitated the connection of 13 distributed generation projects with a cumulative connected capacity of 113MW made up of wind, PV, Anaerobic Digestion and Energy from Waste technologies. This has deferred or saved a significant volume of costs estimated to facilitate those connections following traditional network solutions. Some of this generation has been connected several years ahead of that which would have been possible using traditional connection techniques and some would never have been connected due to prohibitive connection costs.

As well as connecting new plant under ANM schemes we retrofitted and demonstrated the advantage of Active Network Management control to an existing 48MW wind farm to permit an increase in allowable export of renewable generation during an outage on the transmission system. We delivered 2.2MW of solar PV installations across 749 individual homes owned and operated by social housing landlord Berwickshire Housing Association. We examined the relationship between generation, demand and use of Virtual Private Wire. We demonstrated that through greater visibility of the network via the implementation of enhanced network monitoring, simple reductions to the target voltage at primary substations can facilitate generation connection.

We worked closely with the GBSO to develop and implement a commercial mechanism that would permit the application of Active Network Management in order to connect a greater capacity of distributed generation than current planning and design rules would permit ahead of transmission network reinforcements through the active management of load flows across the transmission and distribution GSP boundary in line with existing network limits. We also created an enduring ANM connection agreement that was implemented in place of the existing BELLA commercial arrangements.

Empowering customers

With respect to improving the provision of data to those customers seeking connection to the network, the project developed an Online Curtailment Assessment Tool (OCAT) which can be used by both developers as well as network planners to understand the limits of a particular area of network and inform on potential to implement a flexible connection solution. The project also contributed to the implementation of improved constraint information to customers by providing information on transmission constraints to complement work already delivered by SP Energy Networks in developing on-line 11kV and 33KV heat maps.

Connection process

Our process review identified that management of connection applications by district connection teams with local knowledge and providing early customer engagement is a successful way to manage application and is in line with our newly developed geographical structure implemented at the commencement of RIIO-ED1. Changes being considered or implemented across the industry to the connection application process to which the ARC project has complemented and/or contributed include:

- Updating the electricity distribution charging policy minimum scheme definition to a definition of ‘Least cost’ practical connection to prevent unrealistic applications being issued to customers
- Improving the SoW process that will reduce the number of applications having to be submitted to the transmission owner for system studies
- Connection applications currently incur no charge for all customers and only those who accept the connection offer have to pay the DNO costs of providing all offers. This has previously encouraged multiple and repeat speculative connection applications which increase costs and divert significant planning resources to providing offers that will never connect. Introducing Assessment and Design fees would go some way to alleviate this problem and in March 2016 BEIS undertook a Consultation on Assessment and Design Fees. The outcome of this is awaited.

Provision of new network design tools

To be able to offer flexible connection solutions, network planners and designers require to be supported through the provision of new network data that provides information on the true characteristics and operating regime of the existing network. This would then enable a move away from deterministic worst case network planning to consideration of a probabilistic view of the network. This requires real-time data in the order 10 min granularity and tools to analyse the implications of new connection proposals.

Clearly however this creates a challenge and increase in network operating costs to install the associated network monitoring, communications, IT infrastructure and data storage enabling system requirements.

In respect of clusters of LV PV connections, a new assessment methodology was developed and the following design observations made:

- Maximum PV power output was found to never exceed 90% of installed capacity
- Heavy clusters of PVs at the end of a feeder generally require intervention to permit
- Use of GIS analyst to map properties/cleanse existing data was invaluable
- Future LV mains should be designed with generation in mind, not just demand and be of a 185mm minimum cross section – looking forward potentially 300mm to account for EVs and other LCT unknowns
- Changes in primary voltage and appropriate primary tap changer settings and operation supersedes any LV analysis
- With secondary transformer ratios of 11/0.433kV, it was found during the trial, that generally a voltage at the primary greater than 11.1kV prevents LV PV connections.

Network enablers

The project has demonstrated that investment in monitoring and communication systems is a necessity to enable the DNO to facilitate a greater penetration of flexible connection solutions. Whilst not a specific area of focus for the project, it is worth observing that all IT and communication systems need to take full cognisance of cyber security.

Monitored Data - Providing network planners with greater information to understand the true available capacity of the existing network can be enough to provide DG customers with viable connections. In order to offer a connection solution that reflects the actual available capacity it may be necessary to install the monitoring for a period of time to gather system data before design work is commenced. Hence additional monitoring, communications and data that support the design process are key enablers to the delivery of flexible connection solution and can be solutions in their own right. It may be necessary to monitor across the transmission – distribution boundary to ensure any active network management system has the information required, and both the transmission and distribution businesses have the required visibility of network conditions.

Communications - Where communication between the ANM scheme or the network operator and the generator is required the medium is an important consideration and the reasons for the choice can have many drivers. For large sites fibre optic communication has been a prerequisite and this is unlikely to change. However for generation connecting at 11kV and below there is a balance between the required availability of the communication system and the cost to the project.

The cost of laying a fibre optic cable can be high when land rights are an issue. One recent site with two adjacent generators 400m apart is using a radio signal between the new 11kV generator and the existing 33kV generator which already connected to the network via an existing fibre. The radio link was necessary as the land rights for a fibre optic cable could not be obtained at a reasonable cost.

An alternative communication medium is the mobile phone network, but ongoing support costs and the likelihood that at times the availability may be poor has to be considered. In some cases when a flexible connection solution is not operational due to loss of communication it may be necessary to adopt a failsafe arrangement and guard the network assets by constraining the generator output to zero export. As previously discussed failure of the 3G connection used for the AMN system at Penmanshiel results in the turbine output being reduced.

ANM Platforms - The choice of a centralised or decentralised ANM solution requires the consideration of the whole life cost. This means taking account of the cost of providing reliability and availability compared with the capital, maintenance, and outage costs. Centralised systems are generally easier to specify as they have to withstand less harsh conditions than those in the field and can share back up, support and cyber security systems with other central systems which may be more economic.

As well as installation conditions, access arrangements need to be considered, for example the servers in Berwick GSP have a three hour uninterruptible power supply, have dual redundancy, have been ruggedised and are housed in the transmission substation. This means arrangements have to be made with the transmission owner before the AMN system can be maintained.

5. Performance compared to the original project aims, objectives and Successful Delivery Reward Criteria (SDRC)

The ARC project set out to improve access to facilitate the connection of generation to the network; accelerate the time to connect generation; enable connections to be facilitated around constraints; and create an enduring process and learning that would enable similar schemes to be rolled out across all GB distribution networks.

Through developing a suite of flexible technical and commercial connection solutions, the ARC project has facilitated the connection of 13 individual distributed generation projects with a cumulative connected capacity of 113 MW made up of wind, PV, Anaerobic Digestion and Energy from Waste technologies; retrofitted and demonstrated the advantage of Active Network Management control to an existing 48 MW wind farm to permit an increase in allowable export of renewable generation during an outage on the transmission system; delivered 2.2MW of solar PV installations across 749 individual homes owned and operated by social housing landlord Berwickshire Housing Association; worked collaboratively with GB System Operator National Grid to develop and implement both a two-staged commercial agreement to permit accelerated access to the GB network ahead of the completion of necessary transmission reinforcement, as well as created an enduring ANM connection agreement that was implemented in place of the existing BELLA/BEGA commercial arrangements; delivered an Online Curtailment Assessment Tool (OCAT); examined the relationship between generation and demand and use of Virtual Private Wire; proved that through greater visibility of the network delivered via enhanced network monitoring, simple voltage reductions at primary substations can facilitate generation connections, and finally developed a stakeholder engagement process that empowered developers from the commencement of the project and allowed them to shape and inform the delivery of the overall project and its objectives.

The project 'journey' is illustrated in Figure 25, defining the various key deliverables and milestones.

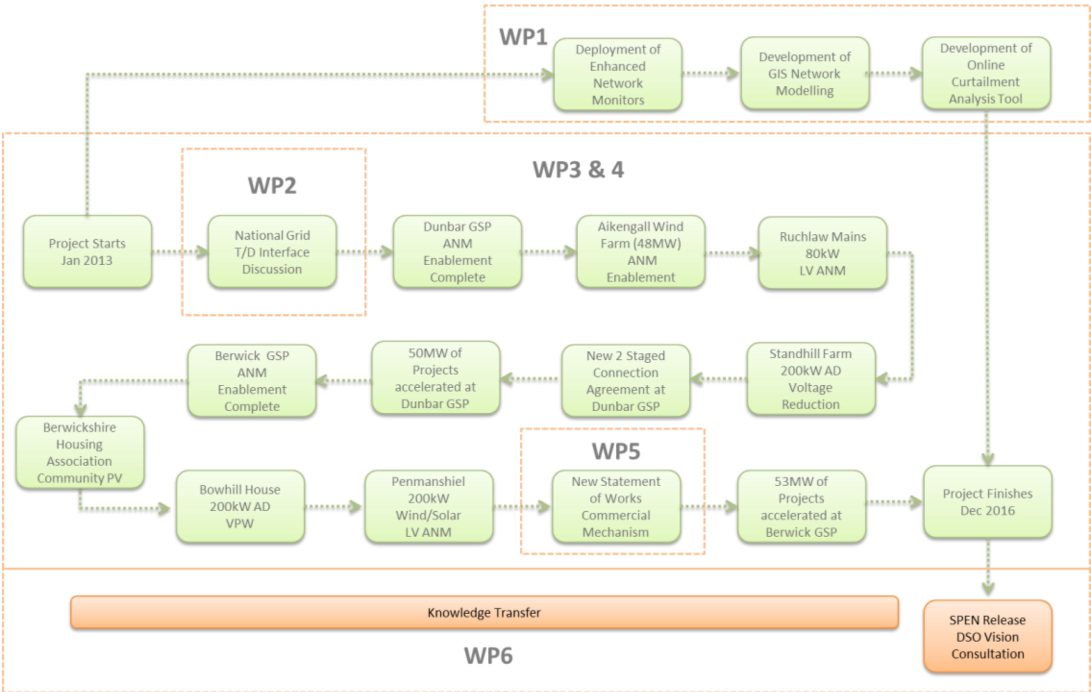


Figure 25: Project Deliverables and Key Milestones

The ARC project has successfully delivered the main SDRC commitments and demonstrated the ability of a suite of flexible connection solutions to accelerate the connection of distributed generation across the various distribution network voltage levels and within areas that were considered to be at full network capacity.

Further details' regarding each SDRC and evidence of its completion is included within Appendix A.

6. Significant variance in expected costs

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.

Appendix A (14.2) represents the final approved second tier project budget, outturn costs and variance against each cost category. The table identifies that overall expenditure to complete the project has been within the total forecast budget however with respect to specific work packages where any variance has occurred an explanation is provided below.

Labour

The Labour costs incurred in delivering the project represent a total spend of £1.93M. Efficiencies have been driven in respect of total labour charges as a consequence of the original budget forecast making provision for the equivalent to 9.75 Full Time Employees (FTE) to be in post to deliver the project from its inception in January 2013 to conclusion in December 2016.

The reality has been however that the project was delivered with a core project team of 5 FTE supported by existing business departments and external contractor labour resource as required. Furthermore, recruitment delays in the early part of the project led to the core project team of 5 FTE only being in place by March 2014, including the Development Officer appointed by Community Energy Scotland. The project also experienced a churn in core project staff with one employee leaving their post in April 2015 and not being replaced. The total labour charge includes all costs associated with the Community Energy Scotland Development Officer that was funded directly by the ARC project. The benefit of having this direct resource working within the communities of the trial location was the identification of the various community generation projects delivered as part of the trial.

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 to complete the various case studies referenced within the FSP, included for the delivery and demonstration of flexible connection solutions of around 5 individual distribution connections. In the end we have 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 connection across the trial location at 11kV voltage levels. As part of the project we also developed an alternative Active Network Management solution delivered by Nortech which demonstrated an alternative equipment deployment in line with the project objectives as well as 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.

Contractors

As intimated above, due to internal project staff being less than originally forecast to take the project forward, this resulted in a requirement for a greater level of expenditure associated with contracted labour. Again based upon the level of uptake in the number of projects being taken forward and the resource effort associated with the development of our IT solution in respect of OCAT, the final outturn costs for contractors has been delivered at expenditure higher than that originally forecast.

Contingency Cost

The original project direction included contingency costs of £370k. As part of the project we have used some of the contingency to cover some of the additional costs incurred in respect of equipment deployed during the trial period and associated activity and resources to deliver project objectives.

Decommissioning

Final decommissioning costs are 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 but 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.

Bank Interest

The original project direction and funding award made provision for a receipt of funding from bank interest in the order of £195k during the course of the project. Following a review of the ARC bank account the actual monies accrued through bank interest equates to a £48k representing a shortfall in overall project funding of £147k. This means that the total ARC funding award to deliver the ARC project has reduced to £8,314k.

7. Updated business case and lessons learnt from the method

The ARC project has facilitated access to the network for a range distribution connected projects trialling a number of alternative flexible connection solutions. Customers have received a direct benefit through saved costs, early network access or a project going from being abandoned on the bases of the connection charge being uneconomic to realising a network access by implementing a flexible connection solution compared with conventional reinforcement solutions. Notwithstanding the financial benefits, the project has also derived a number of further social and environmental benefits as well as contributing to the notion of the circular economy whereby a number of sectors come together to foster overall benefits.

When developing the ARC project proposal, details on what would be delivered during the project focussed upon a number of defined case studies. As is the nature of distributed generation projects, when the actual delivery of the project commenced a number of these projects failed to progress for a variety of reasons i.e. funding issues, removal or degradation of tariff support for certain technologies or failure to obtain necessary planning consents, all issues out with the control of the DNO.

As a consequent of the uncertain nature regarding the development of distribution generation, the objectives of the various case studies have been trialled however have been based on an entirely different suite of generation and community projects, meaning that the business case from the original submission is derived from a different foundation but still serves to quantify the overall benefits of implementing flexible connection solutions versus conventional reinforcement.

At the commencement of the project it was projected that the implementation of flexible connection solutions would derive an overall cost benefit in connection cost savings of between 18-75% compared to conventional reinforcement. Performance against this forecast is quantified in Appendix E, overview of project benefits.

8. Lessons learnt for future innovation projects

The ARC project has successfully achieved its overall aim to accelerate the connection of renewable generation and engage positively with customers to facility distributed generation connections within constrained area of the network. There are a number of lessons that have been derived from this project around customer engagement, the technical challenges of facilitating flexible connection solutions; co-ordination between distribution and transmission networks to implement a wide area ANM solution and requirement for key enablers such as enhanced network data in order to facilitate the design and offering of flexible connection solutions.

Customer Engagement

The importance of transparency and open engagement with customers from the beginning to the end of the connection application process is paramount when developing a flexible connection solution. Customers understanding of the distribution network constraints and their willingness to work collaboratively to find a flexible connection solution noticeably improved when face to face dialogue was established. We also recognise however that the level of engagement and customer interaction achieved during the period of the project may not be practical to replicate fully within a business as usual context. However there is awareness that the level of engagement between DNOs and customers will increase significantly during both the connection offer and delivery process, with an evolving relationship with the customer akin to key account management.

The project benefited from hosting regular stakeholder workshops that covered a number of topics and engaged a wide range of stakeholder groups. This activity also dovetailed into our business as usual stakeholder engagement process whereby members of the ARC project team regularly attended wider SPEN stakeholder forums to inform on ARC activities and where relevant gain opinions on key deliverables.

On a more practicable level, we also recognise the importance of providing as much data as possible on network capacity options to enable a developer to explore connection opportunities prior to the formal application process. As part of the project we have sought to build upon the availability of network heat maps through the development and trial of the Online Curtailment Assessment Tool (OCAT). The importance of up to date web based tools to maximise the opportunity for customers to 'self-serve' and ensure that the correct smart solutions are identified as 'options' for all DG customers has been recognised throughout the customer engagement process. Flexible connections can provide a suitable alternative to conventional distribution connections which may be considered uneconomic or involve a protracted period of time to be realised.

Commercial Mechanisms

During the project we worked constructively and collaboratively with the GBSO to develop both an interim and enduring ANM connection offer that could be implemented to accelerate the connection of distributed generation within transmission constrained network areas. Since the conception of the ARC project wider industry activity has now evolved significantly to develop new methodologies and processes to improve the interface, information exchange and collaborative working between DNOs, TO and the GBSO. Further advancement of activity in this area now forms a significant part of the outputs of the Transmission Distribution Interface work programme being taken forward under the umbrella of the Electricity Networks Association.

Before seeking to implement any flexible connection solution that involves one or more developers subject to the same constraint or where access is being shared, it is imperative that the commercial arrangements, particularly with reference to Principles of Access, are clear and transparent prior to any connection offer being issued. This ensures that customers have clarity on what they have been offered and how the planned operation of the scheme may impact the economics of their project. Furthermore clear and transparent commercial terms and forecasts around generation export volumes are critical to investors making decisions to finance future distributed generation projects.

Greater visibility of network to aid network modelling and design of flexible connection solutions

Availability of improved and more granular network data is a fundamental requirement to enable implementation of a number of flexible connection solutions and will become a core element of the infrastructure of a modern network to complement conventional assets. This type of network visibility can only be achieved through the deployment of enhanced network monitoring. During the project we reviewed outputs from WPD's LV templates project and considered the adoption of a similar process to inform our decision making and network modelling. However, we considered that the application of this technique within the trial area may not provide network data at the granular level required to make an informed decision on deployment of flexible connection solutions. Different parts of the UK distribution network have unique characteristics and therefore implementation of monitoring proved successful in enabling the deployment of a range of flexible connection solutions and provided network planners with improved data sets than was currently available across the trial area.

Network connection trials

The choice of a centralised or decentralised ANM solution requires consideration of the whole life cost that includes not only initial capital outlay but the ongoing support and maintenance of those systems. During the project we implemented a decentralised ANM solution at Dunbar and Berwick GSPs. Centralised systems are generally easier to specify as they have to withstand less harsh conditions than those in the field and can share back up, support and cyber security systems with other central DNO systems which is likely to drive efficiencies in the longer term. Furthermore a centralised system for ANM could acceleration the application of a greater penetration of managed connections across a wider area of a DNOs electricity franchise area. However, whist there are obvious operational and economic benefits of a centralised system, this has to be balanced with the availability of communications infrastructure that has the ability to optimise the operation of a centralised ANM system and any limitations of the communication infrastructure that the ANM system relies upon will ultimately affect the level of network capacity that is released to accommodate distributed generation.

We have however demonstrated a range of flexible connection solutions which are detailed in Section 3.

Transmission Distribution Interface

The project was successful in advancing both alternative technical and commercial solutions enable the connection of distributed generation that would otherwise have been restricted from accessing the network due to transmission constraints. The activity undertaken in this area represents significant success for the project and was delivered through working collaboratively with the GBSO and wider industry stakeholders. Work however still requires to be undertaken and indeed will be taken forward at part of the ENA's Transmission Distribution Interface work programme.

Learning from the project regarding ANM systems that seek to manage distributed generation against transmission constraints are;

- Visibility of connected generation at distribution level should be available to both GBSO and transmission operator;
- The advent of ANM control to manage distributed generation should not distort the balancing mechanism which could be the case if the GBSO instructs an asset under a relevant GSP within a DNOs network, in isolation of the ANM system. The ANM system could render the balancing instruction obsolete by releasing greater capacity to ANM connected generation;
- ANM systems connected at distribution voltages should complement necessary transmission protection systems and further work needs to be undertaken to establish a methodology of an ANM system receiving a dynamic set point or GSP export limit from the incumbent transmission owner or GBSO; and
- DNOs should be able to connect a greater level of connection capacity to their network and implement flexible connection solutions to manage generation export within existing network limits prior to the need to make an application to the GBSO to upgrade the transmission network. This would only occur when the level of constraint experienced by the distribution connected customers cannot absorb the level of forecast constraint. This relies upon a design methodology that considers the actual contribution of connected generation in respect to MWh as opposed to a design standard that relies upon maximum generation / minimum demand network limits.

9. Project Replication

Section 3 of this report details the technical and commercial solutions which have been successfully deployed and trialled during the ARC project to accelerate the connection of renewable generation within the trial location. Building upon the success of the project and lessons learned from the application of the various flexible connection solutions trialled, replication of key elements of the project have begun to be implemented across the SPEN distribution license areas with further information on this activity included within Section 10.

Other DNOs can use the information in this report and the other key project learning documents detailed in Section 12 of this report to offer and undertaken alternative similar connections.

The technical solutions employed involved both modifications to existing equipment (voltage control), monitoring, active network management or installation of replacement equipment (distribution transformers with automatic tap changers). The solutions comprise commercially available software and hardware components. The ongoing support costs for the monitoring and active network management equipment must be considered.

10. Planned implementation

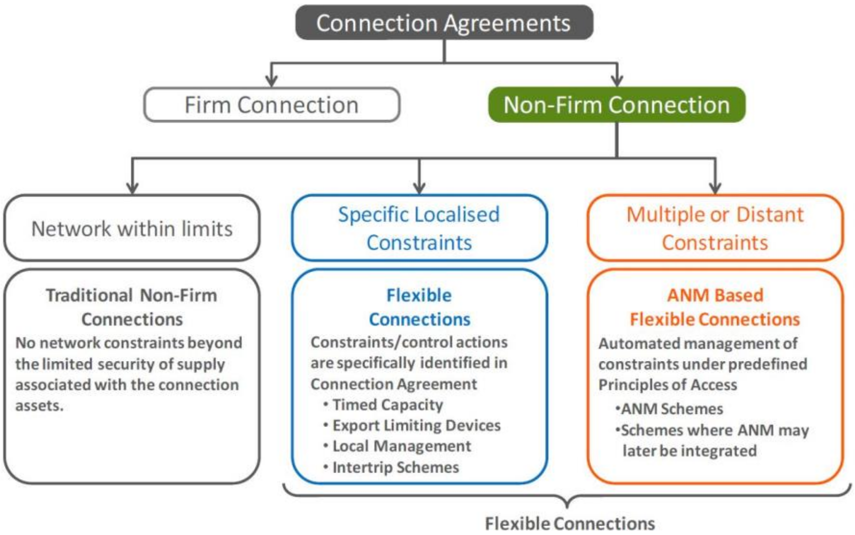
The ARC project has proven that flexible connection solutions are a desirable and viable alternative to conventional connection offers. Furthermore there has been a significant increase in the number of enquiries during the project from developers, operating throughout the SPEN distribution licenced franchise areas of SPD and SP Manweb respectively, wishing to explore the possibility connecting via similar connection solutions. In direct response to the success of the project and wishes of developers, SPEN has committed within our 2016/17 Incentive on Connections Engagement (ICE) plan, to roll out the learning from the Accelerating Renewable Connections project into our Business As Usual connection process.

Actions and commitments included within our 2016/17 ICE plan are;

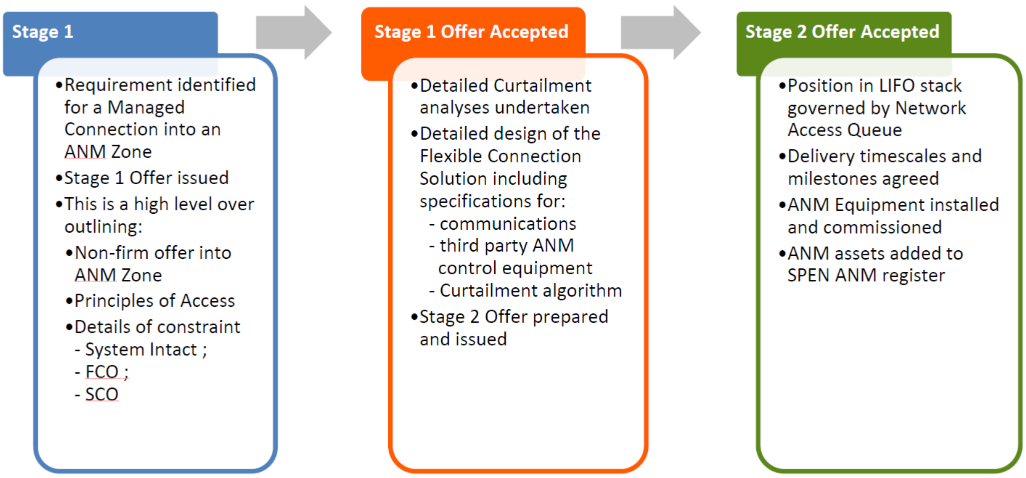
- We will communicate the policy and process for connecting under a flexible connection solution using learnings from our ARC project and roll this out across more suitable areas
- We will educate internal staff on the policy and process for connecting under a flexible connection solution using learnings from our ARC project to ensure this is rolled out to our stakeholders when applicable
- We will launch as awareness campaign to promote the use of flexible connections solutions using learnings from our ARC project to ensure that all stakeholders are aware of the process and benefits to allow them to make effective choices

Progress against those actions within SPEN has been positive to date culminating in the approval during December 2016 for the implementation into Policy of SPEN's Flexible Connections Design Manual that incorporates the **Flexible Connections and Principles of Access Policy**. The manual details a range of flexible connection solutions that may be offered to facilitate low cost and timely connections into constrained areas of network with different levels of constraint complexity. Following receipt of this approval a program of engagement with internal design and delivery staff has commenced and will continue during Q1 of 2017. Furthermore external stakeholders will also be made aware of our Policy around flexible connection solutions whereby we will present on the topic at the 2017 Scottish Renewables Conference in March 2017 and similar stakeholder events throughout the course of 2017.

The development and approval of SPEN's Flexible Connections Design Manual complements our existing Export Limiting Schemes Policy that was approved during January 2016.



Flexible connection solutions will be used to facilitate new generation and demand onto the distribution network in areas where conventional non-firm unconstrained connections would either be slow or prohibitively expensive. The process that SPEN has developed, which forms part of the Flexible Connections and Principles of Access Policy, for triggering a flexible connection offer is shown below;



Considerations in deciding the suitability of a Flexible Connection Offer or solution are:

- Is the connection request for a non-firm connection?
- Is conventional reinforcement either time or economically prohibitive for applicants?
- Is the network at or approaching capacity?
- Is a Flexible Connection Solution likely to be an acceptable alternative
- Are there any technical, regulatory or commercial barriers to using a Flexible Connection Solution that could adversely impact upon the rest of the network?

Should an applicant request a firm connection a conventional connection solution will be offered.

A Flexible Connection Offer should be considered for any non-firm generation connection. Applications will only be offered a Flexible Connection Solution in areas that are (or scheduled to become) an Active Network Management zone.

If an application is made for a non-firm connection and network studies identify that management of constraints is required under System Intact conditions, a traditional non-firm offer should be issued unless otherwise requested by the applicant. Where conventional reinforcement is likely to be either time or economically prohibitive for Applicants, consideration should be given to whether a Flexible Connection Offer could be implemented to allow periods of access despite System Intact constraints.

For any connection application received, we will seek to implement a process whereby guidance will be provided to the customer on how to apply for a Flexible Connection Solution.

11. Learning dissemination

Our approach to stakeholder engagement has been open and transparent communication from the commencement of the project. Our focus during the early years of the project was the establishment of a regular stakeholder forum that met to enable information to be provided on project progress and to obtain the views and opinions of stakeholders when key decisions were to be taken on project direction e.g. implementation of the LIFO Principles of Access.

During the final year of the project our stakeholder engagement activity has focussed more upon dissemination the learning of the trials undertaken and from those generation project that have been commissioned during the ARC project trial period.

Throughout the project we have engaged constructively and positively to exchange learning with DNO, TO and GBSO colleagues. This included joint and individual workshops with colleagues from UKPN, SSE and WPD to exchange learning from our various projects focussed upon implementing flexible connection solutions. We have also held workshops with ENW both to review our activity associated with the application of Virtual Private Wire solutions and general overview of the commercial mechanisms implemented as part of the project.

A full list of Stakeholder engagement activities and objectives of each event is provided in Appendix D.

12. Key project learning documents

Title	**Date**
Ofgem LCNF Submission - ARC - Low Carbon Network Fund FSP	Nov 2012
https://www.ofgem.gov.uk/sites/default/files/docs/2012/11/arc_resubmission_combined_0.pdf	
Ofgem 6 Monthly Progress Reports - ARC - Ofgem Progress Report - June 2013	June 2013
https://www.ofgem.gov.uk/sites/default/files/docs/2013/09/spen_arc_six_monthly_report_june2013.pdf	

Ofgem 6 Monthly Progress Reports - ARC - Ofgem Progress Report – Dec 2013	18/12/2013
https://www.ofgem.gov.uk/sites/default/files/docs/2014/02/arc_-_ofgem_progress_report_-_december_2013_final.pdf	
ARC - Ofgem Progress Report - June 2014	27/06/2014
https://www.ofgem.gov.uk/sites/default/files/docs/2014/08/accelerating_renewable_connections_-_ofgem_progress_report_-_june_2014_0.pdf	
ARC - Ofgem Progress Report – Dec 2014	12/12/2014
https://www.ofgem.gov.uk/sites/default/files/docs/2015/02/arc_-_ofgem_progress_report_-_december_2014_final.docx_0.pdf	
ARC - Ofgem Progress Report - June 2015	12/06/2015
ARC - Ofgem Progress Report – Dec 2015	12/12/2015
ARC - Ofgem Progress Report - June 2016	17/06/2016
ARC Learning Reports	
Stakeholder Mapping Report	March 2014
Stakeholder Forum Summary Report	March 2014
Community Workshop Summary Report	April 2014
Coupling Demand and Distributed Generation to Accelerate Renewable Connections	April 2014
Distributed generation on 11kV Voltage Constrained Feeders	Sept 2014
Background Analysis for Local Power, Local Benefit Project	Feb 2015
Shinnel Glen Hydro Scheme Analysis	October 2015
Berwickshire Housing Association PV Scheme Analysis	April 2016
Linking Local Power and Local People – A review of potential commercial arrangements for facilitating 'Virtual Private Wire' grid connections	Feb 2017
Designing and Operating Alternative Connection Solutions Across Voltage Levels	March 2017
The Changing Nature of the T and D Boundary	March 2017
The Business Case for Top Down Investment	March 2017

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14. Appendices

14.1 Successful Reward Criteria Summary

Identifier	Title	Criterion	Required Evidence	Actual Evidence
9.1	Project budget	The project will be delivered to budget in accordance with the Tier 2 full submission. A 5% variance will be acceptable between work packages but the overall project will be delivered in line with this submission in order to demonstrate effective cost control.	Ongoing cost reporting to monitor progress and publication of a final report to Ofgem will identify costs incurred per work package to assess compliance with the Tier 2 submission. Project completion date of December 2016.	Section 6 and Appendix A (14.2) of this report contains the final project spend incurred.
9.2	Project timeline delivery	The project will be delivered in accordance with the timelines outlined in the Tier 2 submission to ensure timely learning can be disseminated and adopted in advance of RIIO-ED1 commencing. Delivery in accordance with these timelines and in line with budget as per criterion 1 will demonstrate effective project management.	Ongoing project reporting and formal reports to Ofgem will identify the how well the project is being delivered in accordance with the time lines set out within this submission. Should individual work package time lines deviate from plan, a lower reward weighting may be appropriate as long as the overall project is delivered on time. Completion date December 2016.	Section 5 details the project delivery timeline and discussion. The overall deliverables of the project have been completed within the time period agreed commencing January 2013 and completing in December 2016. The Closedown report has been submitted in line with the LCNF Governance criteria being submitted to Ofgem three months following the end of the project on 31st March 2017

9.3	Demonstration of alternative solutions as detailed in case study 1	Implementation of the Active Network management system and interface with National Grid as outlined in Case Study1 for the exporting GSP site.	Implementation of the ANM system at a GSP, demonstrating one of the alternative solutions highlighted in Case Study 1. Evidence: publication of a revised case study evaluating the traditional solution versus the alternative solution which has been deployed detailing cost, time and operational benefits. Learning and details of the processes and technology involved to achieve an interface with NGET and the impact of this on the statement of works process. Completion date December 2016.	Case Study 1 - The exporting GSP (Dunbar) This case study is considered in detail within; Learning Report 1: *Designing and Operating Alternative Connection Solutions across Voltage Levels,* Section 4.1.4 – Dunbar 132/33kV GSP Learning Report 2: *The Changing Nature of the Transmission and Distribution Boundary*, Section 4.2.1 - Two Stage Connection Agreement
9.4	Demonstration of alternative solutions as detailed in case studies 2,3 and 4	Implementation of the Active Network management system and alternative arrangements as detailed in either case studies 2, 3 or 4. Each of these case studies are based on real examples within the trial area which provides us with a high degree of confidence that it will be possible to demonstrate and document the learning from at least one of these examples.	Delivery of at least two connections which utilise the alternative solutions detailed in case studies 2, 3 or 4. Evidence: publication of a revised case study evaluating the traditional solution versus the alternative solution which has been deployed detailing cost, time and operational benefits. Learning and details of the processes and technology involved to achieve such a connection. Completion date December 2016.	Case studies are considered in detail within; Case Study 2 - Learning Report 1: *Designing and Operating Alternative Connection Solutions across Voltage Levels,* Section 4.1.5 – Berwick 132/33kV GSP Case Study 3 – Learning Report 1: *Designing and Operating Alternative Connection Solutions across Voltage Levels,* Section 4.2.2 – Ruchlaw Mains Farm PV Scheme Case Study 4 – Learning Report 1: *Designing and Operating Alternative Connection Solutions across Voltage Levels,* Section 4.2.3 – Penmanshiel Piggery Farm Wind/PV Scheme

9.5	Creation of community energy generation scheme & model for community level generation	Delivery of a minimum of one community level generation scheme to facilitate a new generation connection onto the network and thereafter production of achievements and learning developed through identification of options for community scale active energy management (matching generation with green demand at a local level). In addition ARC will delivery at least one community level generation demonstration project facilitated through the PNDC that will be used to disseminate knowledge to industry stakeholders. Based upon the pipeline of community projects identified by CES in the trial area, it is believed that this will be achievable as 14 projects have already been identified.	Publication of a report detailing the available options for community scale active energy management to facilitate the matching of available generation to local green demand. This will include a review by Community Energy Scotland and a selection of community groups. This will be enhanced through the delivery of a PNDC demonstration event that showcases at least one community energy solution. Furthermore ARC will deliver at least one community energy generation model that facilitates a new generation connection and publish an account of experiences and processes as a follow-up report Criterion 9.5 to be used and adopted by other communities throughout GB. The delivery of this SDRC will involve a presentation to a interested and relevant stakeholders where an opportunity for questions, information gathering and challenge will be provided.	Case studies are considered in detail within; Community Energy Scotland Report – *“Linking Local Power and Local People – A review of potential commercial arrangements for facilitating ‘Virtual Private Wire’ grid connections”* VPW Case Study - Learning Report 1: *Designing and Operating Alternative Connection Solutions across Voltage Levels,* Section 4.1.7 – Power Networks Demonstration Centre – Desktop Trials Case Study 6 - Learning Report 1: *Designing and Operating Alternative Connection Solutions across Voltage Levels,* Section 4.1.8 – Bowhill AD Plant Case Study 7 - Learning Report 1: *Designing and Operating Alternative Connection Solutions across Voltage Levels,* Section 4.3.3 – BHA PV Scheme
9.6	Demonstration of top-down Active Network	Delivery of and deployment of Active Network Management top-down	Publication of report detailing the learning and experience of the deployment of ANM and delivery of a Cost Benefit Analysis (CBA) of the top-	Learning Report 3: *The Business Case for Top Down Investment*

	Management	enabling technology at a minimum of two substations within the trial area as well as associated communication and control system platforms in order to evaluate the benefits of the adoption of this innovation vs. incremental investment plan.	down strategy vs. traditional business as usual solutions, based upon project objectives. Delivery December 2016.	
9.7	Detailed publication and dissemination of learning from project	Effective dissemination of project learning and business processes to ensure that other DNOs and stakeholders can benefit from the delivery of this project.	Publication and dissemination of project learning including: Detailed business process maps for the alternative approaches adopted in the project; Proposals for structure of future generation facilitation incentives framework; Evaluation of triggers for smart investments; and Investment decision based analysis when DNOs invest in network to maximise existing generation; Learning and technical documentation to support the technology demonstrated and how this is reflected in design policies. Completion December 2016	Learning Report 1: *Designing and Operating Alternative Connection Solutions across Voltage Levels* Learning Report 2: *The Changing Nature of the Transmission and Distribution Boundary* Learning Report 3: *The Business Case for Top Down Investment*
9.8	Improved generation connections experience	Improved overall experience for customers connecting within the trial area through: Empowering customers through the facilitation of more information; Alternative options for connections; and Improvements to the time	Stakeholder survey will be undertaken within the first year of the project to determine the baseline of perception of the connections process, time to connect and overall experience - completion date of August 2013. Stakeholder survey will be repeated in 2016 to determine the improvement that has been experienced by customers within the trial area. All surveys will be undertaken by an external	ARC Stakeholder Mapping Report March 2014; *https://www.spenergynetworks.co.uk/userfiles/file/2014_03%20ARC%20stakeholder%20mapping%20Final.pdf* ARC Stakeholder Forum Summary March 2014 https://www.spenergynetworks.co.uk/userfi

	and cost to connect through these alternative options.	agency and a summary of the results made available - completion date of December 2016.	les/file/ARC-stakeholder-forum-report.pdf

14.2 Summary of Project Costs vs Allowances

Accelerating Renewable Connections Cost Categories	Original Project Funding £k	Total Project Expenditure £k	Variance to Original Budget £k
Labour			
Total	**3,279.76**	**1,931.32**	**(1,348)**
Travel & Expenses			
Total	**25.00**	**31.88**	**7**
Equipment			
Work Package 0.0 - Project Mgt	-	-	0
Work Package 1.0 - Empowering Customers	10.00	44.99	35
Work Package 2.0 - Connection Design	-	-	0
Work Package 3.0 - Network Enablers	920.00	1,059.94	140
Work Package 4.0 - Network Connection Trials	560.00	799.68	240
Work Package 5.0 - Project Evaluation	-	-	0
Work Package 6.0 - Knowledge Transfer	55.00	63.68	9
Total	**1,545.00**	**1,968.30**	**423**
Contractors			
Work Package 0.0 - Project Mgt	60.00	44.86	(15)
Work Package 1.0 - Empowering Customers	353.92	453.56	100
Work Package 2.0 - Connection Design	50.00	70.91	21
Work Package 3.0 - Network Enablers	590.00	704.39	114
Work Package 4.0 - Network Connection Trials	682.90	794.81	112
Work Package 5.0 - Project Evaluation	200.00	189.33	(11)
Work Package 6.0 - Knowledge Transfer	85.00	106.19	21
Total	**2,021.82**	**2,364.06**	**342**
IT			
Work Package 0.0 - Project Mgt	-	-	0
Work Package 1.0 - Empowering Customers	200.00	201.81	2
Work Package 2.0 - Connection Design	475.00	544.94	70
Work Package 3.0 - Network Enablers	355.00	339.70	(15)
Work Package 4.0 - Network Connection Trials	160.00	157.49	(3)
Work Package 5.0 - Project Evaluation	-	-	0
Work Package 6.0 - Knowledge Transfer	-	-	0
Total	**1,190.00**	**1,243.94**	**54**
IPR Costs			
Work Package 0.0 - Project Mgt	-	-	0
Work Package 1.0 - Empowering Customers	-	-	0
Work Package 2.0 - Connection Design	-	-	0
Work Package 3.0 - Network Enablers	-	-	0
Work Package 4.0 - Network Connection Trials	-	-	0
Work Package 5.0 - Project Evaluation	-	-	0
Work Package 6.0 - Knowledge Transfer	-	-	0
Total	**-**	**-**	**0**
Payments to Users			
Work Package 0.0 - Project Mgt	-	-	0
Work Package 1.0 - Empowering Customers	-	-	0
Work Package 2.0 - Connection Design	-	-	0
Work Package 3.0 - Network Enablers	-	-	0
Work Package 4.0 - Network Connection Trials	-	-	0
Work Package 5.0 - Project Evaluation	-	-	0
Work Package 6.0 - Knowledge Transfer	-	-	0
Total	**-**	**-**	**0**
Contigency			
Work Package 0.0 - Project Mgt	-	-	0
Work Package 1.0 - Empowering Customers	15.00	14.37	(1)
Work Package 2.0 - Connection Design	55.00	70.04	15
Work Package 3.0 - Network Enablers	205.00	195.95	(9)
Work Package 4.0 - Network Connection Trials	95.00	88.00	(7)
Work Package 5.0 - Project Evaluation	-	2.05	2
Work Package 6.0 - Knowledge Transfer	-	2.65	3
Total	**370.00**	**373.07**	**3**
Decommissioning			
Work Package 0.0 - Project Mgt	30.00	-	(30)
Work Package 1.0 - Empowering Customers	-	-	0
Work Package 2.0 - Connection Design	-	-	0
Work Package 3.0 - Network Enablers	-	-	0
Work Package 4.0 - Network Connection Trials	-	97.00	97
Work Package 5.0 - Project Evaluation	-	-	0
Work Package 6.0 - Knowledge Transfer	-	-	0
Total	**30.00**	**97.00**	**67**
Other			
Work Package 0.0 - Project Mgt	-	-	0
Work Package 1.0 - Empowering Customers	-	-	0
Work Package 2.0 - Connection Design	-	-	0
Work Package 3.0 - Network Enablers	-	-	0
Work Package 4.0 - Network Connection Trials	-	-	0
Work Package 5.0 - Project Evaluation	-	-	0
Work Package 6.0 - Knowledge Transfer	-	-	0
Total	**-**	**-**	**0**
Grand Total	**8,461.58**	**8,009.57**	**(452)**
Review Of Bank Interest Accrued			
Forecast	(195.00)		
Received	48.00		
Total Interest Shortfall	(147)		
Revised Total Project Funding Received	**8,314.58**	**8,009.57**	**(305)**

14.3 Linking Local Power and Communities: Extract from VPW Report as part of ARC project

Stakeholder	Driver	Challenge
Generator	Lower capital cost than physical private wire. Enables non-firm generation to manage constraint through Demand Side Management.	Requires integration of diverse engineering skill sets. No national standards for VPW systems at time of writing.
Consumer	Can create 'peer to peer' trading relationships between local energy users and producers. May reduce the cost of delivered electricity.	Entry and transaction costs of licensed supply are high for small customer volumes; alternatives to license supply remain unproven. May increase exposure to balancing risk.
DNO	Potentially avoids risk of stranded network assets and maintains visibility of the distribution system to the DNO. Gives customers greater choice on availability of flexible connection solutions for the connection and can reduce connection timescales.	Requires installation of network monitoring and ICT systems at LV. Customer is exposed to risk of increased curtailment if they lose the demand associated with their connection.
System Operator	Could assist in balancing demand with generation at local level which may reduce or mitigate needs for wider reinforcement or higher cost to obtain ancillary services.	SO may not have visibility of VPW system within DNO network and such links are important as greater penetration of such schemes come forward.
Ofgem	Could facilitate opportunities for aggregation of demand and generation that can participate in ancillary services markets and increase system flexibility. Complements roll out of SMETS 2 smart meters and elective half hourly metering.	Recruitment of domestic demand customers is typically higher cost than non-domestic; local tariffs may involve Time of Use which most domestic customers are currently unfamiliar with. Rollout is currently behind schedule and SMETS 2 specification not finalised.
UK Government	Creates opportunities for renewable energy development within a low subsidy regime. Supports the development of community and locally owned schemes.	Cost savings/added value remain unproven; therefore some level of subsidy support likely to continue to be required. Increases the complexity of grid connection arrangements compared to a conventional firm connection.

14.4 Example of Two-Stages Connection Agreement

Regulation & Commercial

Generic Generator,

ABC Avenue,

Town,

Local Authority,

Postcode

Date:

... /.... /......

Contact / Extension:

....

Tel: ....

Dear Sir,

CONNECTION OFFER IN RESPECT OF THE AGREEMENT TO CONNECT GENERIC GENERATOR PLANT (THE "DEVELOPMENT") TO THE SP DISTRIBUTION PLC DISTRIBUTION SYSTEM

This connection offer is provided to you in response to your request to be connected in advance of the Stage 2 NGET Transmission Works via an ANM Scheme.

SP Distribution reserves the right to modify the provisions of the Agreement to take account of any works, costs or restrictions imposed upon it by NGET.

NGET Offer Summary

The NGET Offer provides for the connection of Generic Generation Customer Ltd which includes the associated wider works necessary to facilitate the connection, subject to the derogation from the National Electricity Transmission Systems (NETS) SQSS being granted.

Stage 1

Registered Capacity	**Estimated Completion Date**
[X] MW (Active Network Management Basis)	.../...../.....

Stage 2

Registered Capacity	**NGET Completion Date**
[X] MW (Firm Basis)	.../...../.....

Accordingly, SP Distribution hereby exercises it right to revise the terms of the Agreement as follows:-

ACTIVE NETWORK MANAGEMENT SCHEME

DEFINITIONS

The following terms and conditions in this Appendix apply to the management of the Customer's export capacity under an ANM Scheme during that period subject to the derogation from the NETS SQSS being granted, and sets out in particular the basis of constraint of that part of the export capacity identified in the Agreement as being "Non-Firm"

"ANM Scheme"	Means the overall active network management scheme including but without limitation the **"SP Distribution Control Equipment"**.
"SP Distribution Control Equipment"	Means the equipment and technical specification set out in Paragraph 6
"Constrained Location"	Means those locations of constraint as detailed in Table 1 of this Appendix that affect the Connection detailed within this Agreement
"Constraint Measurement Point"	Means the equipment used to monitor Current and Voltage at an identified **"Constrained Location"**
"Curtailment"	(a) Means to limit from time to time the maximum amount of electricity that may flow into the Distribution System from the Connection Point The term **"Curtail"** shall be construed accordingly.
"Curtailment Instruction"	Means an **"Instruction"** given by the **"ANM Scheme"** to action a **"Curtailment"** of electrical power output by the **"Qualifying Generation Plant"**
"Dead Time"	Means a defined time where no action is taken.
"Forecast Constraint"	Means any information, projections, data, estimates or forecasts as to future levels of **"Curtailment"** provided by or on behalf of the Company to the Customer in relation to this Agreement
"Instruction"	Means an instruction given by SP Distribution to the Customer via the **"SP Distribution Control Equipment"** or verbally or in written form in accordance with the technical specifications set out in this Appendix in order to undertake **"Curtailment"**
"LCS"	Means the **"Qualifying Generation Plant"** local control system.
"LIFO Register"	Means of defining **"Qualifying Generation Plant"** position under a **"ANM scheme"** using a Last in First Off Methodology
"LIFO Stack"	Means of applying **"Qualifying Generation Plant"** with a **"Curtailment Instruction"** within an **"ANM scheme"** using a Last in First Off Methodology

"Local ANM Controller"	Means the hardware installed at any **"Qualifying Generation Plant"** metering substation, connected to **"LCS"**
"NETS SQSS"	National Electricity Transmission System Security and Quality of Supply Standard
"Non-Compliance"	Means failure to respond or comply with **"Curtailment Instruction"**
"Qualifying Generation Plant(s)"	Means any Generating plant connected to the **"ANM Scheme"**
"Subordinate Generation Plant(s)"	Means any Generating plant connected to the **"ANM Scheme"** that is behind the Customer in the **"LIFO Stack"**
"System Lockout"	Means the **"Local ANM Controller"** will restrict the energisation of the **"Qualifying Generation Plant"** based upon **"Non-Compliance"**.

1. TECHNICAL REQUIREMENTS FOR CONTROLLING THE INTERRUPTABILITY

1.1 The Customer's Generating Equipment shall be paralleled to the SP Distribution's Distribution System.

1.2 SP Distribution Control Equipment shall be installed at the Connection Points to:

1.2.1 interface the Customer's Installation and/or equipment therein with the SP Distribution's Supervisory Control Alarm and Data Acquisition (SCADA) Systems

1.2.2 conduct measurement of current and/or voltage in real time

1.2.3 convey an Instruction in digital format, to the Customer's control equipment to communicate the new Maximum Entry Capacity that may be utilised. The specification for such instructions is set out in Part 6 of this Appendix

1.2.4 provide volt free trip contacts, for operation upon failure of curtailment of Interruptible Entry Capacity, which shall be connected to the SP Distribution Connection Point isolator or circuit breaker in respect of curtailment Entry Capacity

1.2.5 provide volt free trip contracts, for operation upon failure of curtailment of Interruptible Entry Capacity, which shall be connected to the SP Distribution Connection Point isolator or circuit breaker or if appropriate equipment under control of the Customer that may isolate the Customer's generating equipment

and the specific technical requirements will be set out in Part 6 of this Appendix.

2. CURTAILMENT

2.1 The Customer agrees that in the event that the power flows and/or voltage levels in any Constrained Location exceed the maximum available Entry Capacity as determined by SP Distribution, SP Distribution shall be entitled to give an Instruction in accordance with the technical requirements in Part 6 of this Appendix, to Curtail the flow of electricity through the Connection Point in an amount expressed in kW to bring the power flows and/or voltage levels at the relevant Constrained Location below the maximum available Entry Capacity provided that prior to issuing an Instruction to Curtail the Customer's flow of electricity through the Connection Point SP Distribution has ensured that all flows of electricity onto the Distribution Network from Subordinate Generation Plants have been reduced to zero.

2.2 SP Distribution shall ensure that all Subordinate Generation Plants shall have installed and be connected to the SP Distribution Company Control Equipment and shall be subject to the ANM Scheme.

2.3 SP Distribution shall be responsible for:

2.3.1 holding and maintaining a register of all Qualifying Generation Plants that connect to a Constrained Location (the “LIFO Register”). The Company shall hold a LIFO Register for each Constrained Location

2.3.2 ensuring that all Subordinate Generation Plants on the LIFO Register shall have at all times installed the SP Distribution Control Equipment and shall be subject to the ANM Scheme

2.4 SP Distribution shall ensure that all Subordinate Generation Plants that connects to the Constrained Location shall be added to the LIFO Register.

3. NO LIABILITY FOR FORECAST CONSTRAINT

3.1 The provision of any Forecast Constraint (“Forecast”) related to and/or forms part of this Agreement that provides a view on the likely Curtailment that will be experienced by the Customer through the provision of the Active Network Management Scheme is consistent with current knowledge and practice. The provider of the Forecast and any party on behalf of whom the Forecast has been provided excludes all liability in tort (including negligence), contract and under any statute for any loss or damage arising out of or in connection with any reliance on the Forecast. Subject to the foregoing, to the fullest extent permitted by applicable law, all warranties or representations (express or implied) in respect of the Forecast as excluded.

3.2 The Customer’s use of any Forecast provided by or on behalf of SP Distribution is entirely at the Customer’s own risk. SP Distribution makes no warranty, representation or guarantee that the Forecast is error free or fit for the Customer’s intended use.

4. ACTIVE NETWORK MANAGEMENT SCHEME

4.1 The Active Network Management scheme provides the ability for SP Distribution to manage multiple embedded generators and will issue a Curtailment Instruction to manage power flows within operational limits as calculated by SP Distribution or as instructed by NGET. The ANM Scheme will manage power flows across Constraint Locations through the curtailment of real power output (MW).

4.2 The ANM Scheme shall take the following escalating control actions to protect existing electrical network infrastructure relevant to the connection related to this Agreement.

Scenario	Action
System Intact both **[X]** Grid T1 & Grid T2 CB’s are closed and system is deemed healthy	ANM Scheme will monitor and issue relevant Curtailment instructions to the Customer and curtail real power output of the generator when **[X]** Grid T1 & T2 132/33kV transformers reach 90% of their thermal rating. The ANM Scheme will recalculate generator set points and dispatch at a frequency of 600ms.

System N-1 loss of either **[X]** Grid T1 or Grid T2 transformers or loss of 132kV infeed during Low Generation/High Demand Periods	ANM Scheme will monitor and issue continuous trim instruction to Generic Generation Customer Plant and curtail real power output of generator when the remaining 132/33kV **[X]** Grid transformer reaches 90% of its thermal rating. The ANM Scheme will recalculate set points and dispatch at a frequency of 600ms.
System N-1 loss of either **[X]** Grid T1 or Grid T2 transformers or loss of 132kV infeed during High Generation/Low Demand Period	ANM Scheme will issue trip instruction to Generic Generation Customer Plant if Trip threshold is breached, typically 100% of remaining transformers rating. After a predefined Dead Time the Local ANM Controller will attempt to re-energise the customer once the generators electrical output has dropped to zero. Customer will be released capacity in predefined steps until the remaining transformer reaches 90% of its thermal rating. ANM Scheme will hold the reverse current flow across the remaining transformer to a limit of 90%. The ANM Scheme will recalculate set points and dispatch at a frequency of 600ms.
Communications failure between the Local ANM Controller installed at Generic Generation Customer Plant and the central Dunbar ANM system.	In the case of failure of communication between the central servers and the Local ANM Controller, the Local ANM Controller will fail to safe and limit the output of the generator to a pre-defined level (0MW).
Communications failure between the constraint measurement point and the central ANM system.	In the case of failure of communication between the central servers and the constraint measurement point, the Local ANM Controller will fail to safe and limit the output of the generator to a pre-defined level (0MW).
Management of Generator for **non-compliance** i.e. failure to comply with ANM set-point.	After a defined period of time the ANM Scheme will attempt to unload the generator (reduce output to zero). If the generator fails to respond to the command to unload, after a defined period, the ANM Scheme will trip the network's metering circuit breaker.
Dead Time following generator trip signal being instructed	The ANM controller will wait for a pre-defined number of seconds before attempting to close the circuit breaker and bring the generator back into service. The Dead Time will exceed the time required for the generator to reduce its electrical output to zero on the other side of the breaker.
Trip lockout due to non-compliance	If the system trips the generator 3 times due to non-compliance 3 times within the auto reclose reclaim time, the ANM Scheme will lockout the circuit breaker and not attempt to re-connect the

	generator. Manual intervention is required to reconnect the generator to the system. The reclaim time shall be based upon the SP Distribution auto reclose policy.

5. CONSTRAINT LOCATIONS & LIFO STACK POSITION

5.1. ***Table 1*** of this Appendix provides information relating to the identified Constraint Locations relevant to this Agreement and the position in the LIFO stack of the generation equipment relevant to this Agreement at as the date of this Agreement.

Constrained Location	***Substation or Circuit References***	***Description of Constraint***	***LIFO Stack: Position Number (of Total)***
[X]	[X]	e.g.Thermal Transmission	**[X]** (Of **[X]**)

6. SITE TECHNICAL REQUIREMENTS

6.1 The Customer shall provide a Local Control System (LCS) capable of interfacing with the Local ANM Controller as detailed in figure 1;

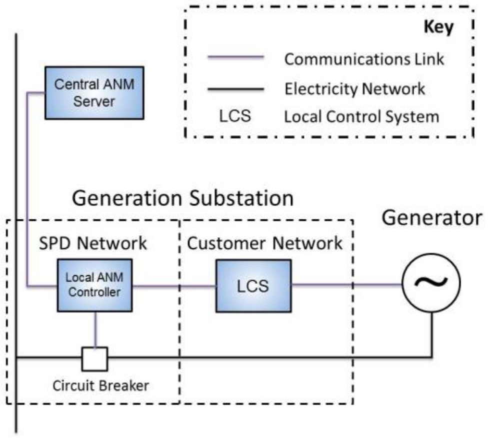

Figure1. ANM to LCS Interface Schematic

6.2 A Local ANM Controller shall be installed within the SP Distribution **[X]** kV Switch Room.

6.3 With the exception of all final terminations at the Local ANM Controller, it shall be the responsibility of the Customer to supply and install all necessary physical connections between the LCS and Local ANM Controller.

6.4 All final terminations within Local ANM Controller shall be carried out by SP Distribution or appointed representatives.

6.5 The Customer shall provide a LCS capable of accepting a physical connection in one of the following formats;

6.5.1 Serial:

- RS-485;
- RS-232;

6.5.2 Ethernet:
- RJ-45;

6.5.3 Analog:
- 0-10V;
- 4 to 20mA;

6.5.4 Digital:
- 10-30 V DC;

6.5.5 Relay Outputs:
- 230V AC (Max);
- 1 A AC Resistive (Max);

6.6 Where a Serial or an Ethernet connection is to be used, the Customer shall provide a LCS compatible with one of the following protocols;
- DNP3.0 (Master/Slave RS-232/485)
- DNP3.0 (Client/Server TCP/IP)
- Modbus Master/Slave (RS-232/485)
- Modbus Client/Server (TCP/IP)
- IEC6870-5-101 Slave (RS-232)
- IEC6870-5-104 Server (TCP/IP)

6.7 The Customer shall provide an LCS with the capability for receiving control signals with a minimum 99.9% reliability and within 1 second of issue from Local ANM Controller.

6.8 The Customers LCS will be issued with a continuous Upper Real Power Set-Point Limit via the Local ANM Controller. The value shall be expressed as a kW value in the range of 0 kW to [X] kW. A continuous set-point shall represent the total allowable real power export from the generator. The Customer's LCS must restrict the total power production of the generators under its control to below this limit.

6.9 The Local ANM Controller shall maintain a watchdog, or heartbeat, with the Customer's LCS. The Customer shall provide a LCS capable of monitoring the watchdog, in order to allow the device to initiate failsafe behaviour upon loss of communication with the Local ANM Controller.

6.10 Upon loss of communication with the Local ANM Controller, the Customer shall ensure that the LCS can assume a failsafe state of operation that satisfies the requirements defined by SP Distribution. The LCS will not be permitted to return the generator to normal state of service until such time as loss of communication is resolved.

6.11 Following the restoration of a communication failure, the Customer shall provide a LCS capable of receiving initialisation data from Local ANM Controller without the need for user intervention.

6.12 An ANM control schedule shall be agreed prior to final commissioning.

6.13 As a minimum, the Customer shall provide a LCS capable of providing the following signal/data exchange as defined within **Table 2**;

Name	Type	Range/Units	Source	Destination	Update/ Frequency	Mandatory
Under	Digital	0 to 1	LCS	ANM	Local ANM	Yes

ANM Control		(1=true)		Controller	Controller Demand	
Local ANM Controller Watchdog Value	Analogue	Site Specific	ANM Controller	LCS	Every Minute	Yes
LCS Watchdog Value	Analogue	Site Specific	LCS	ANM Controller	Every Minute	Yes
LCS Fault Indication	Digital	0 to 1 (1=true)	LCS	ANM Controller	Local ANM Controller Demand	Yes
Upper real Power Set-Point Limit	Analogue	0 to rated real power (kW)	ANM Controller	LCS	Local ANM Controller Demand	Yes
Measured Real Power	Analogue	0 to 120% of rated real power (kW)	LCS	ANM Controller	Local ANM Controller Demand	Yes

Table 2

7. TECHNICAL REQUIREMENTS FOR SP DISTRIBUTION TO GIVE AN INSTRUCTION TO THE CUSTOMER

7.1 SP Distribution shall through its control equipment in an autonomous, semi-autonomous or otherwise in a manual fashion including verbal or written Instructions specify a level of Maximum Entry Capacity which may be less but not greater than the Maximum Entry Capacity as detailed in this Agreement

7.2 Upon receipt from SP Distribution of the specified level of Maximum Entry Capacity, the Customer shall reduce the flow of electricity from the Customer's installation to the SP Distribution's Distribution System in an autonomous, semi-autonomous or manual fashion to not exceed those specified levels and do so within the timescales specified by SP Distribution and detailed in Section 6 of this Appendix.

7.3 Should the Customer fail to act within the period specified by SP Distribution to achieve maximum flows of electricity below the specified levels SP Distribution shall be entitled to De-energise the Connection Points or isolate the Customer's generating equipment as is appropriate.

14.5 Stakeholder Engagement Activities

Stakeholder Event	Date	Purpose
ARC Hosted Events		
First ARC Stakeholder Event – Scotsman Hotel, Edinburgh	27th February 2014	To enable stakeholders to give views on the challenges and opportunities that SPEN might face and what stakeholders would like to see from the implementation of flexible connection solutions. The stakeholder forum brought together representatives from the renewables industry, finance sector, Scottish Government, local authorities, consumers and communities. Richard Jenkins of North Wind Associates provided a presentation on his experience of operating within the Orkney RZP implemented by SSE.
ARC Community Workshop – Dunbar	27th March 2014	Workshop with Local Community Group of Dunbar to inform local people about the purpose of ARC and what the project hopes to achieve. At the time they were seeking to connect a new wind turbine which subsequently failed to obtain planning consent.
Second ARC Stakeholder Event – Scotsman Hotel, Edinburgh	26th June 2014	Presentation of proposed Connection Agreement terms to stakeholders. Sought views on introduction of LIFO and two-staged commercial agreement.
Third ARC Stakeholder Event – Scotsman Hotel, Edinburgh	13th January 2015	Update on the ARC presentation to the SPEN Board of Directors in Dec 14 to move forward in delivering flexible connection solutions into BaU policy. Two Stage Commercial Agreements Online Curtailment Analysis Tool presented. Mid project review. A look back and give an overview of what the project team has been doing to deliver stakeholders' priorities.
Commercial Mechanisms and Constraint Analysis Workshop	17th March 2016	Insight into the requirements of investors when making an assessment on financing /lending capital for a distributed generation project, what value they place on the commercial agreement and how they undertake their due diligence and who provides that service. Experience of obtaining financial closure for the Hoprigshiels development. The process, positives, negatives and the relevance or importance of the connection agreement or offer letter from the Distribution Network Operator (DNO). Overview of commercial arrangements and how they are implemented between TO, DNO, SO and definitions for what is an Alternative Connection ENA ANM working group, best practice guide, and work to interface with grid and develop common

		methodology for constraint analysis Techniques used to develop a constraint analysis
Dissemination Event - Designing and Operating New Alternative Connection Solutions Across Distribution Voltage Levels	7th July 2016	Dissemination of Project Case Studies associated with designing and operating new alternative connection Solutions across distribution voltage levels. Event held in London and attended by industry stakeholders.
Virtual Private Wire Workshop	14th September 2016	Presentation of Virtual Private Wire modelling and integration within an Active Network Management platform, developed by Smarter Grid Solutions and Community Energy Scotland. Review of potential commercial arrangements for practical implementation of Virtual Private Wire connections Discussion of potential national policy implications for emerging connections and system operating models for community schemes and VPW arrangements, presented by UoS. Interactive feedback session from industry panel Consideration of impact on 'local electricity supply' business models
Dissemination Event - The Business Case for Top Down Investment in Smart Solutions	10th November 2016	Dissemination of Project Case Studies associated with the business case for top down investment in smart solutions
<u>Wider Stakeholder and Industry Events</u>		
Renewables UK Annual Conference 2013, Birmingham	5th – 7th November 2013	Attendance as Exhibitor to raise awareness of the ARC Project and engage with interested stakeholders.
Scottish Renewables Annual Conference 2014, Edinburgh	17th – 19th March 2014	Attendance as Exhibitor to raise awareness of the ARC Project and engage with interested stakeholders.
Royal Highland Show 2014	18th – 21st June 2014	Attendance as Exhibitor to raise awareness of the ARC Project and engage with interested stakeholders from the agricultural community.
Renewables UK Annual Conference 2014, Manchester	11th – 13th November 2014	Attendance as Exhibitor to raise awareness of the ARC Project and engage with interested stakeholders.
Solar City Conference, London	4th March 2015	Overview Presentation on ARC Learning
Scottish Renewables Annual Conference 2015, Edinburgh	24th – 25th March 2015	Attendance as Exhibitor to raise awareness of the ARC Project
Royal Highland Show 2015	19th – 22nd June 2015	Attendance as Exhibitor to raise awareness of the ARC Project
Scottish Renewables 2016 Annual Conference	1st - 2nd March 2016	Attendance as Exhibitor to raise awareness of the ARC Project
Royal Highland Show 2016	23rd – 26th June 2016	Attendance as Exhibitor to raise awareness of the ARC Project

14.6 Overview of Project Benefits

Work Complete	Customers Connected	Capacity (kW)	25 Year Projected Lifetime MWh Output	Estimated Displaced Carbon over Project Lifetime	ARC vs Traditional Distribution Cost to Connect £m	ARC vs Traditional Transmission Costs to Connect £m	ARC vs Traditional Time to Connect (Yrs.)	Technique Trialled	Description of Benefit
Exporting GSP	Generator 1 (LIFO 1)	31,000	11,541,300	4,962,759	N/A	£4.5m/£6.33m (29% Saving)	2017/2021 (4Yrs)	Staged ANM	Early network access ahead of reinforcement. Pay as you go arrangement. Consortium approach to triggering wider transmission reinforcement. Sharing of Transmission Costs
	Generator 2 (LIFO 2)	7,500	1,116,750	480,202	N/A	£1.1m/£6.33m (83% Saving)	2017/2021 (4Yrs)	Staged ANM	
	Generator 3 (LIFO 3)	5,000	744,500	320,135	N/A	£0.73m/£6.33m (88% Saving)	2017/2021 (4Yrs)	Staged ANM	
	Generator 4 (LIFO 4	1,500	223,375	96,052	N/A	N/A	2016/2021 (5Yrs)	Staged ANM	

Work Complete	Customers Connected	Capacity (kW)	25 Year Projected Lifetime MWh Output	Estimated Displaced Carbon over Project Lifetime	ARC vs Traditional Distribution Cost to Connect £m	ARC vs Traditional Transmission Costs to Connect £m	ARC vs Traditional Time to Connect (Yrs.)	Technique Trialled	Description of Benefit
N-1 Contingencies:	Generator 1	28,600	4,259,000	1,831,370	N/A	£0.25m/£3.39m (ANM vs Reinforcement)	2016/2018 (2Yrs)	Enduring ANM	Enhanced connection under ANM to manage generation during N-1 periods
	Generator 2	24,000	3,574,000	1,536,820	N/A	£0.25m/£3.39m (ANM vs Reinforcement)	2016/2018 (2Yrs)	Enduring ANM	
Costly Uneconomic Firm Connection	Project A	80	3,850	1,655	£0.02m/£0.16m (87.5% saving with ANM vs Traditional)	N/A	N/A	Local ANM	Reduced infrastructure; Lower cost over traditional solution

	Project B	200	19,750	8,492	£0.02m/£0.74m (97.3% saving with ANM vs Traditional)	N/A	N/A	Local ANM	Reduced infrastructure; Shared infrastructure using multiple generation; Real time access to capacity; Lower cost over traditional solution
	Project C	200	74,500	32,035	£0.015m/£0.82m (98.2% saving Voltage Reduction vs Traditional)	N/A	N/A	Voltage Reduction	Reduced infrastructure; lower cost over traditional solution

Work Complete	Customers Connected	Capacity (kW)	25 Year Projected Lifetime MWh Output	Estimated Displaced Carbon over Project Lifetime	ARC vs Traditional Distribution Cost to Connect £m	ARC vs Traditional Transmission Costs to Connect £m	ARC vs Traditional Time to Connect (Yrs.)	Technique Trialled	Description of Benefit
Role Communities play in Accelerating Renewable Connections	Insufficient Capacity for Small Scale Community Scheme	200	74,500	32,035	N/A	N/A	2015/2019 (4Yrs)	Virtual Private Wire	Coupling Demand and Generation over multiple metering points to accelerate connection behind an existing transmission constraint
	Impact of Small Scale Generation Connecting under a GSP	2,200	106,000	45,580	N/A	N/A	N/A	Enhanced Monitoring + Secondary Substation OLTC	Customer benefits – estimated £1.9m savings in saved energy costs over lifetime of PV

14.7 Copy of DNO Peer Review Confirmation Letter

Bringing energy to your door

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29 March 2017

Dear Euan,

Accelerating Renewable Connections (ARC) – DNO Peer Review

Further to your request that Electricity North West Limited review and comment on the Close-Down report produced in respect of your Low Carbon Network Funded Project – Accelerating Renewable Connections, I can confirm that we have undertaken this review and consider that the objectives and deliverables as agreed in the Project Direction have been satisfied by UK Power Networks.

In addition, subject to the requirements of the governance arrangements. We can confirm that we consider that the Close-Down report as reviewed by Electricity North West Limited is clear and understandable and will provide sufficient information to enable a DNO, not closely involved with the project, with the ability to implement their own range of flexible technical and commercial solutions to release additional capacity to connect in locations were network limits had reached or close to being reached as a Business As Usual offering.

I do hope you find this information of use, but should you wish to discuss anything further or have any additional requirements that you need to address, please do not hesitate to contact me.

Yours sincerely

Mr Stephen Cox

Digitally signed by Mr Stephen Cox
DN: c=GB - UNITED KINGDOM, email=steve.cox@enwl.co.uk, o=Electricity North West Ltd, ou=Network Strategy, cn=Mr Stephen Cox
Date: 2017.03.29 17:44:14 +01'00'

Steve Cox
Engineering and Technical Director
Electricity North West

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