'Linking Local Power and Local People':
A Review of potential commercial arrangements for facilitating 'Virtual Private Wire' grid connections

Prepared for SP Energy Networks as part of the 'Accelerating Renewable Connections' Project

With grateful recognition of the contributions from Smarter Grid Solutions, SP Energy Networks and the University of Strathclyde

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Date issued: 20/02/2017

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LIST OF ACRONMYS

ANM	Active Network Management
ARC	Accelerating Renewable Connections
CfD	Contract for Difference
DER	Distributed Energy Resource
DG	Distributed Generation
DNO	Distribution Network Operator
DSO	Distribution System Operator
DUoS	Distribution Use of System charge
ESC	Energy Supply Contract
GSP	Grid Supply Point
ICT	Information and Communications Technology
LIFO	Last-In First-Off
NFG	Non-Firm Generation (as part of an ANM scheme)
OPC	Open Platform Communication
PPA	Power Purchase Agreement
PW	Private Wire
VPW	Virtual Private Wire
ROC	Renewable Obligation Certificate
RTU	Remote Terminal Unit
SGS	Smarter Grid Solutions
SO	System Operator
SPEN	SP Energy Networks

INTRODUCTION

This work builds on the previous ARC report prepared by the University of Strathclyde "Coupling Demand and Distributed Generation to Accelerate Renewable Connections[1]" and should be read in conjunction with it, particularly sections 6.1 ("Commercial arrangements"), and 7.2 ("Virtual Private Wire") as they provide relevant background.

The previous report identified a number of potential technical and commercial arrangements for linking local demand and generation within an Active Network Management system. Virtual Private Wire systems were described as '[the] most effective way of linking demand and Distributed Generation' (Gill, Plecas and Kockar, 2013: 40) where an on-site solution was not viable.

While physical private wire is a technically and commercially proven approach, in rural areas its replicability is limited due to the relatively dispersed nature of renewable generation and loads- for example wind turbines are normally cited some distance from homes and businesses. The report identified no major technical barriers to Virtual Private Wire systems, with the main constraint being a DNO's willingness to consider an approach that represents a radical departure from the traditional 'passive' network design philosophy.

The potential value of reliable, affordable and scalable solutions for facilitating the balancing of local demand and generation has become even clearer since the report was written, in light of a number of changes to the regulatory and market frameworks for the UK electricity system, which we consider more fully in section 3.

The main shift has been a dramatic deterioration in the level and availability of government support mechanisms for renewable energy, as well as the wholesale price of electricity. The combination of reduced subsidy and reduced commodity value represents a significant challenge for renewable energy developers, which the ARC team recognised as a threat to the goals of the project.

One of the main objectives of the Accelerating Renewable Connections project was to increase the range of options for renewable generators to connect to the distribution network, even where there were local or wider constraints that would limit a conventional connection. In terms of MW capacity, the 'top down ANM' approach of enabling key GSPs has been very successful in releasing significant volumes onto the local and national electricity systems.

However the team also sought to develop lower cost Active Network Management (ANM) systems that would be feasible for smaller generators to implement, and that would permit a generator to mitigate its level of 'curtailment' (i.e. reductions in output due to network conditions) by directly linking to specific demand sites on the DNO network.

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[1] **Coupling Demand and Distributed Generation to Accelerate Renewable Connections : Options for the Accelerating Renewable Connections Project.** / Gill, Simon; Plecas, Milana; Kockar, Ivana. Glasgow : University of Strathclyde, 2014. 47 p. Available at: https://pure.strath.ac.uk/portal/files/38906382/Gill_Plecas_Kockar_ARC_coupling_demand_and_distributed_generation_final.pdf

As with other aspects of the ARC project, this thinking drew heavily from the learning from other ANM projects such as the Orkney RPZ in the SHEPD area, which showed the difficulty of curtailment forecasting over a 20-25 year project lifetime, and consequently the importance for ANM connected generators to have some means of mitigating curtailment due to wider changes in network conditions beyond their control.

The specific requirement therefore was a Virtual Private Wire system that:

a) Could be integrated with an ANM control system, and
b) Could be deployed on a commercial basis under current regulatory frameworks.

It is important to emphasise that while both components are important, without a safe and scalable control solution no commercial model would be viable.

It is also important to note that while Virtual Private Wire does not have a uniformly agreed meaning (which we discuss in section 2), in the context of the ARC project the emphasis was specifically on the direct linking of demand and generation within *a constrained network area*, primarily for the purposes of reducing the level of constraint on the generator, in order to increase the generator output. A secondary benefit of adding value to generation by creating local supply chains for electricity is also considered in the analysis of commercial models below.

The ARC team took up the challenge and agreed an approach that would allow for a full demonstration of how a Virtual Private Wire system could work, including both technical and commercial aspects, while protecting existing generators from any unintended impacts arising from the trial system.

The ARC VPW project included three elements:

1. An 'end to end' hardware and software demonstration in a lab environment
2. An evaluation of practical commercial arrangements
3. Knowledge sharing as part of the ARC dissemination strategy

This report represents the main deliverable of the second element, while also incorporating a description of the demonstration system developed by Smarter Grid Solutions. It is intended to complement the dissemination events held in the course of the ARC project, particularly the event held at the Power Networks Demonstration Centre in September 2016, as well as the other published material prepared by the ARC team.

THE VIRTUAL PRIVATE WIRE CONCEPT

The principle of a virtual private wire network is to reproduce one or more aspects of a physical private wire network, without the need to construct new network infrastructure. In this sense, a virtual private wire network substitutes 'silicon', in the form of ICT systems, for the copper that would otherwise be required for physical network infrastructure. This is consistent with the objectives of the ARC project in leveraging networks sensors and machine intelligence to increase the safe carrying capacity of existing network infrastructure. The key differences between the topologies are illustrated in the diagrams below:

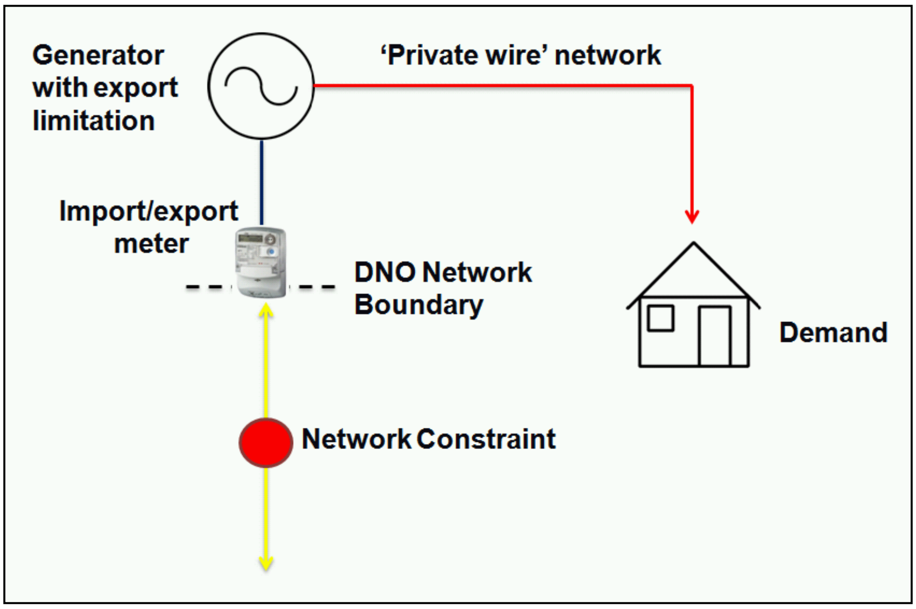

Figure 1Physical private wire network

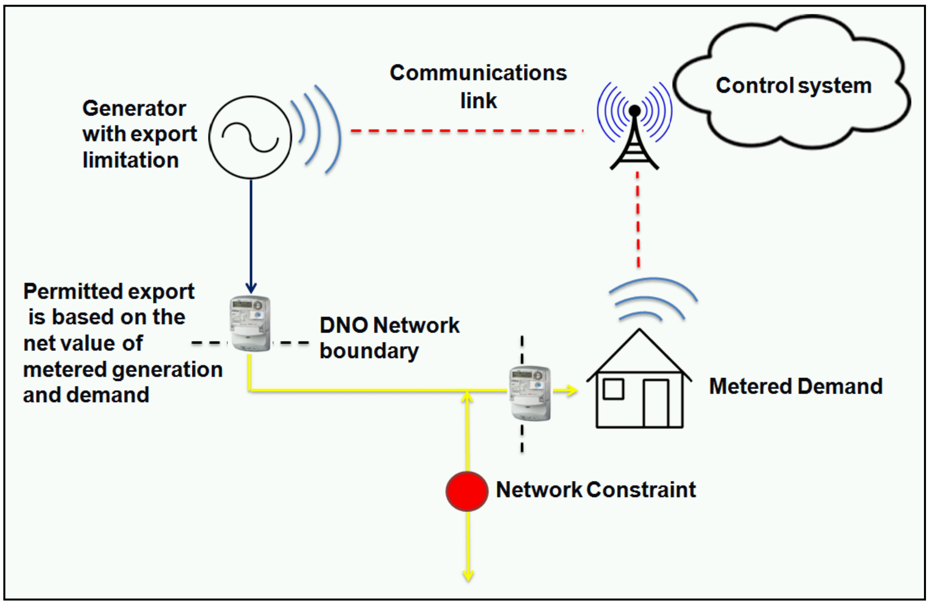

Figure 2 Virtual private wire network

Typically the desired outcomes from a physical private wire network are:

1. The ability to directly supply a load without requiring a licensed supplier as an intermediary.
2. A reduction in the network charges associated with using the public distribution system (although the private wire network operator is still responsible for the maintenance and operational costs of their own system).
3. The ability to generate in an area where generation would otherwise be constrained.

In the context of the ARC project, we are primarily interested in the third outcome, since the main aim is to enable renewable generation which may in turn lead to outcomes 1 or 2 (although some aspects of these are considered in more detail under the commercial arrangements and policy sections below).

The key requirement therefore is to establish a reliable control relationship between a generator and a load (or group of loads), which all have different points of connection to the public distribution network, but are behind the same point of constraint. With the control relationship established, and the principles of access to the distribution network agreed with the DNO (i.e. the ANM connection agreement), a commercial relationship can then be established between a generator and a load (or group of loads) across the same network.

This represents a radical departure from a conventional network architecture where the changes in power flow on the local network caused by a generator are independent of either their permitted network access, or the commercial off-take arrangements for their production. For example a generator with a ‘firm’ grid connection may generate up to their agreed export limit at any time of day, 365 days a year, regardless of local network conditions (barring a network fault). Similarly a generator located in Sunderland may be physically located next door to a factory, while their production is retailed to a supplier whose customers are in Cornwall.

In this sense, a Virtual Private Wire system provides an opportunity to integrate the physical output of a generator, based on real time network conditions, and commercial arrangements with local electricity demand customers.

Drivers for Virtual Private Wire networks

As noted in the introduction, from a generator’s perspective the main drivers for the development of virtual private arrangements are the opportunity to increase generation by mitigating network constraints, and to add value to that generation by enabling commercial relationships with local demand customers. However there are a number of wider considerations for both generators and other system actors, as illustrated in the table below:

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

Virtual Private Wire and Active Network Management

In addition to the considerations noted above, a Virtual Private Wire system offers a specific advantage in relation to Active Network Management (ANM) schemes, namely the ability of a generator to mitigate its curtailment.

Conventional ANM is based on control of generation but not of demand; operationally demand is treated as a passive ‘background’ meaning that the only option in the event of a network limit being breached is to reduce the generation rather than increase the demand. The behaviour of both generators and demand is forecast as part of the curtailment assessment process. If network conditions change (for example, an existing factory is closed) ANM connected generation could be curtailed more than anticipated.

Curtailment is an inevitable feature of any ANM system due to the non-firm basis of the connection, which is the quid pro quo for a quicker and lower cost connection. However where the principles of access are based on ‘Last-in First-Off’ (LIFO)[2] , it is particularly hard for a generator to invest in off-site Demand Side Management as a mitigation strategy, as the generator is unlikely to have any certainty as to when the demand is most likely to benefit their generator, as opposed to other generators higher up the LIFO ‘stack’.

Even if the generator is provided with additional information by the ANM system which allows them to know when they are the ‘marginal’ generator (i.e. at the top of the LIFO stack and therefore likely to benefit from additional demand on the system), this approach limits the usefulness of the demand resource to those times when the generator is marginal, which may be few. This is particularly the case for generators low down in the stack where there will often be several generators ahead of them.

To provide an example, if there is a LIFO stack of three generators of 2MW, and all three generators are fully constrained, generator 3 would have to dispatch demand of 6MW in order to reduce their constraint to zero, effectively giving generators 1 and 2 a free ride. As there is likely to be a cost to dispatching the demand, it is clear that this model is unlikely to be financially viable.

A similar issue arises with other principles of access for ANM schemes, such as the pro-rata model where network capacity is split equally between generators. While the generator is guaranteed some benefit from brining on ‘right time’ demand, the benefit will be shared equally with the other generators as well. While it would be logical to create a single DSM scheme which all three generators invest in, there is no guarantee that they will be able to reach terms as there is no obligation to participate.

Given the rising use of ANM as a means of increasing the volume of DG that can be connected to existing network infrastructure, it is important that generators are able to develop mechanisms for managing the risk of curtailment. The University of Strathclyde study suggested that there was no technical barrier to the integration of Virtual Private Wire in an ANM system and developed a

[2] Reproduced from Gill, Plecas and Kockar, 2013: 19

topology as illustrated on the following page. We will now consider the approach taken by SGS to demonstrate exactly this model using real world hardware and data.

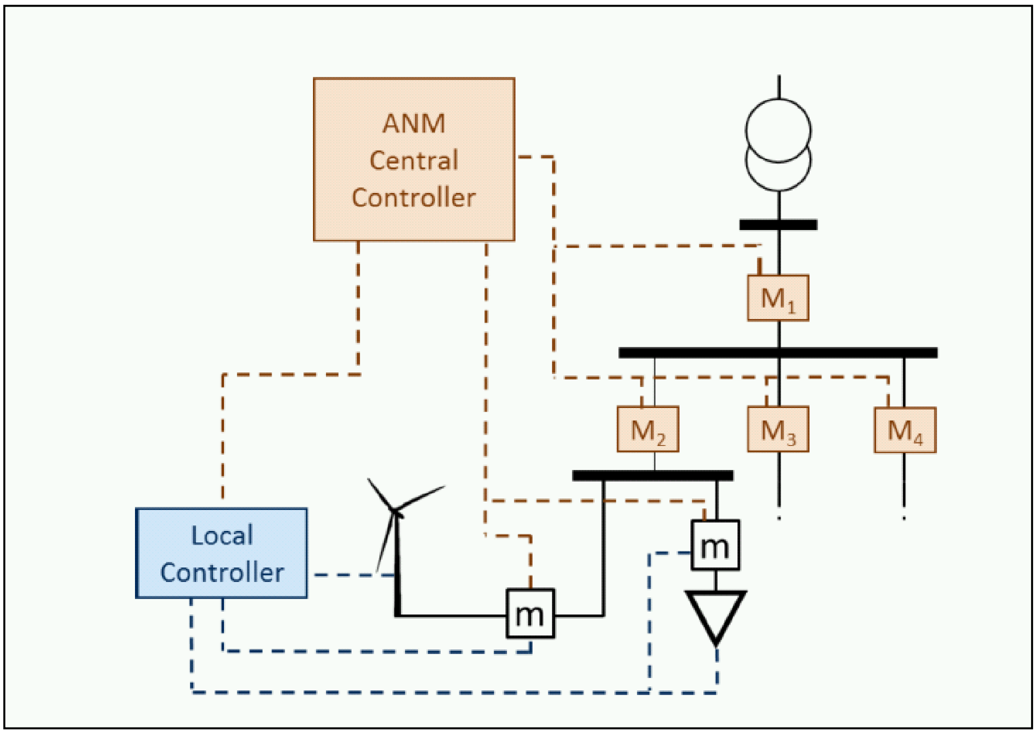

Figure 3 VPW integrated with ANM system[3]

[3] Reproduced from Gill, Plecas and Kockar, 2013: 29

DEMONSTRATION OF CONTROL SYSTEM FOR VIRTUAL PRIVATE WIRE NETWORKS BY SMARTER GRID SOLUTIONS[4]

Management of the constraints in the Accelerating Renewable Connections (ARC) project is achieved by curtailing generator export where there is insufficient network capacity. It is possible for network demand to reduce or avoid DG curtailment by increasing import during constraint breaches.
When new network demand is located at a different site from the generation that will be supporting it, a requirement for Virtual Private Wire (VPW) is created. It is necessary for information sharing to be facilitated between the new demand, the generator supporting it, and the Active Network Management (ANM) system, in order to ensure that capacity can be allocated to the generator.

Virtual Private Wire Demonstration

In order to demonstrate the effect of a VPW arrangement, Smarter Grid Solutions developed a demonstration system based around a dynamic model of the network area. The network model for part of the ARC trial area was used, and the generators in the network were modified to include dynamic controllers in the DIgSILENT PowerFactory power systems analysis software. The dynamic model is able to receive set points from the ANM system, respond to them, and send generator export information. This was achieved by configuring the model to use OPC[5] for communications. The network model interfaced with an RTU 32 via OPC. The RTU was representing the **sgs connect**[6] element of the ANM system, which is the local controller deployed at the ANM-controller generator site. The RTU 32 interfaces with virtual machines, simulating the ANM system and control algorithms, via DNP3. This is illustrated in Figure 4.

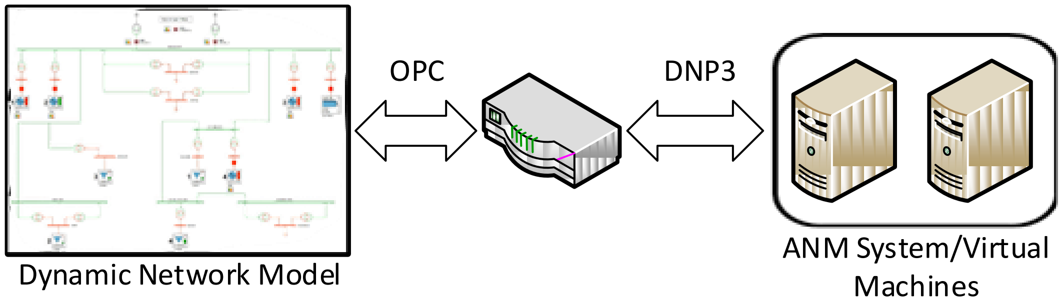

Figure 4 Diagram of Virtual Private Wire Arrangement

Virtual Private Wire Components

A VPW can be installed as a stand-alone solution, or as part of a wider ANM solution. As a result, it uses the same components as set out in the ANM Good Practice Guide[7]:

- Central ANM controller and algorithm;

[4] The text in this section of the report was provided by Smarter Grid Solutions. Their terms and conditions are contained at the end of the report in Annex 1.
[5] https://en.wikipedia.org/wiki/Open_Platform_Communications
[6] **sgs connect** is a field distributed, autonomous and real-time Distributed Energy Resource (DER) controller that manages interaction with the electricity grid and local area.
[7] http://www.energynetworks.org/assets/files/news/publications/1500205_ENA_ANM_report_AW_online.pdf

- Interface to SCADA/Network Management System;
- Measurement Points deployed at constraint locations;
- Local controller deployed at controlled device.

Additional infrastructure is required to monitor the load that the VPW system will associate with specific generation. Monitoring and metering is required to ensure that the network remains operating within limits, and any settlement can be calculated between parties.

In an area which is already enabled for ANM operation, VPW can be integrated with minor updates to the system. The ANM algorithm can be configured on the central platform to apply and preserve the relationship between the export and import of participating parties as if a private wire existed. This allows the netting-off of generation and demand as if it was behind a common metering point, even though it is not.

In areas where ANM has already been deployed, VPW allows new monitored demand to be associated with new generation. For new generation joining an ANM system, it will be at the bottom of the Last-In First-Off (LIFO) stack[8]. An arrangement with a new demand connecting within the ANM system will allow for the new generator to alleviate some of the curtailment it may experience. If the demand is able to absorb all the export from the new generator, and the constraint still exists, curtailment will move to the next generator in the LIFO stack.

ANM operation with Virtual Private Wire

Without a VPW arrangement, the alternatives are for generators to either construct a physical wire to the demand site, which can be very costly, or to experience the full curtailment required for constraint management. In some cases, the possibility of curtailment may result in the loss of financial investment for some developments.
There are several different variants of VPW that can be implemented using existing ANM infrastructure:

- Simple VPW – new load associated with a generator not at the top of the stack. The generator benefits from the new load before the generators ahead of it in the stack;
- Demand Side Response – demand responding without an arrangement with a specific generator to reduce curtailment to generators;
- Load Sharing – an extension of the VPW principle to associate more than one generator to a demand.

With a Simple VPW arrangement in place, as shown in Figure 5, when curtailment at the generator commences, the demand is able to increase import to alleviate the curtailment.

[8] LIFO is the current Principles of Access used by SP Energy Networks. Other Principles for Access are in other ANM schemes across the UK.

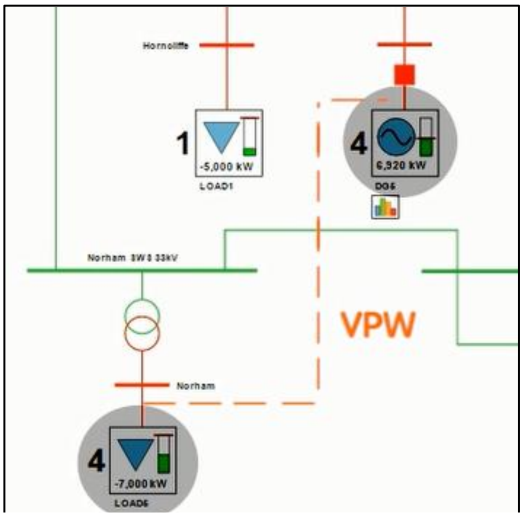

Figure 5 Simple Virtual Private Wire

This project has demonstrated that a specific virtual link between a generator and a demand can reduce curtailment experienced by the generator. It is possible for the ANM system to include responsive demand that does not have an arrangement with a specific generator. When a constraint is breached the ANM system will issue set points to instruct demand to increase in the first instance. If an increase in demand is not enough to clear the constraint, the ANM system will then issue curtailment set points to generators until the constraint breach is cleared.

Load sharing within an ANM system is also possible. This sees a single large demand in an arrangement with multiple generators. Figure 6 illustrates the load sharing concept below. When a constraint is breached the load will increase its import to reduce the curtailment experienced by both generators. If the net export from the generators, after load sharing is 0 MW, then the ANM system will curtail the next generator in the LIFO priority stack.

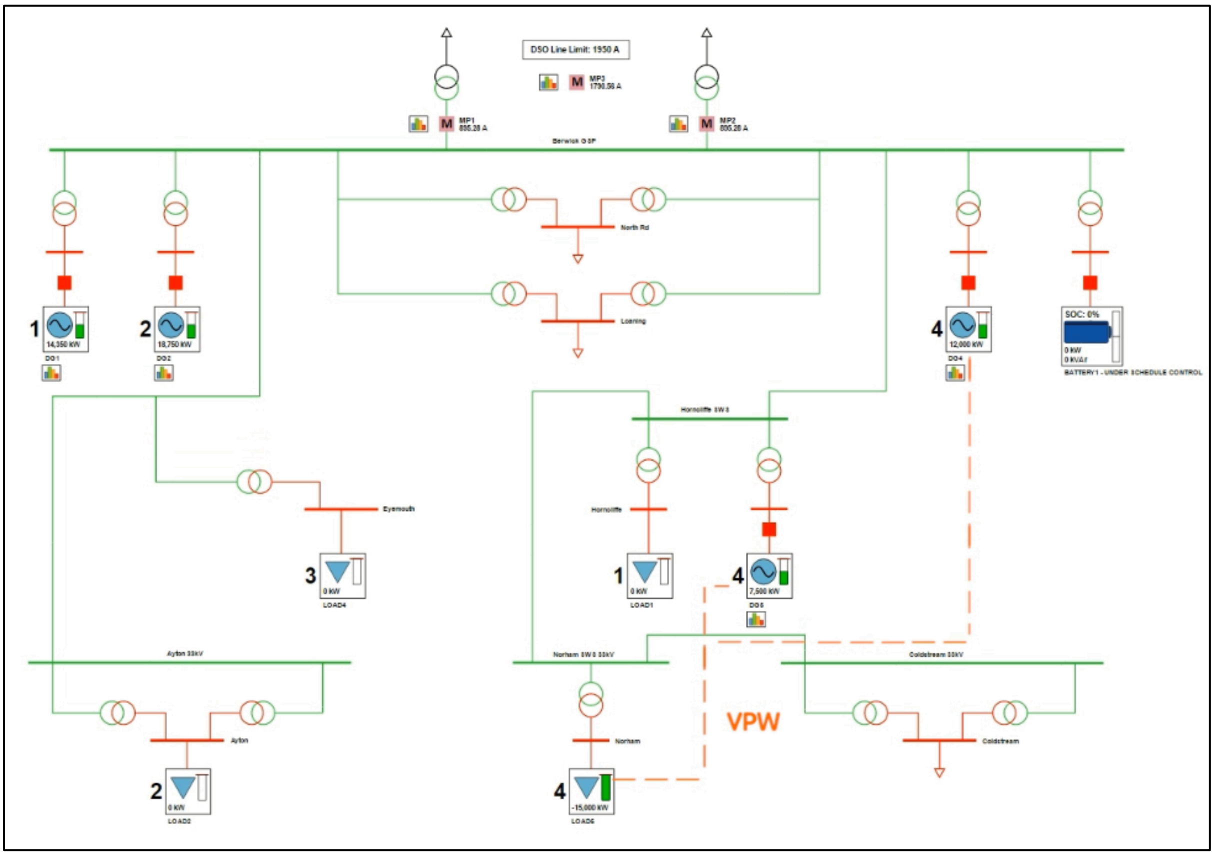

Figure 6 Load Sharing Example

Scalability of the solution

This project has demonstrated a range of different VPW arrangements that could technically be implemented on ANM infrastructure that is available to DNOs today. In the future, it is anticipated that ANM systems will grow and expand, with monitoring and control of hundreds of devices. The SGS ANM platform has been tested with up to 1,000 devices. The implementation of VPW into an ANM system has no detrimental effect of the core constraint management function.

POTENTIAL COMMERCIAL ARRANGEMENTS FOR VIRTUAL PRIVATE WIRE NETWORKS

Contractual requirements for a Virtual Private Wire system

As well as needing a technically acceptable control system, there are a number of contractual agreements which may be required to implement a VPW system depending on the model used.

These may include:

1. Grid connection agreement with DNO
2. Electricity off-take agreement (PPA) with licensed supplier[9]
3. Electricity supply agreement (ESC) with licensed supplier
4. Demand Side Management contract with aggregator
5. Rebate agreement with participating demand
6. In some circumstances, a site specific DUoS calculation may also be required

In the following section, we consider in more detail the commercial arrangements required to share value between participating generators and loads. There are a range of options which have been identified, building on those included in the University of Strathclyde study[10], as well as possibilities that have emerged since. The selection process has focused on those options which are likely to be feasible based on current technology costs and regulatory framework.

In line with the approach developed by SGS in the previous section, there are three types of demand that may be included within the VPW:

1. New demand
2. Pre-existing demand
3. A proportion of pre-existing demand

The decision as to which of these can be included will rest with the DNO, based on the local network conditions and, in the case of a pre-existing ANM scheme, the connection agreements and principles of access that area already in place. In relation to the commercial models, the main implication of the different types of demand is whether there is an additional cost to the generator of making the demand available, as this will affect what level of curtailment reduction is economically viable. This is considered in more detail below (see 'suitable for load increase' row of the table), with worked examples, but it is important to emphasise that this is a key factor in determining both the technical design of the VPW system and suitable commercial arrangements.

It should be noted that these models are presented as archetypes, and are neither comprehensive, nor mutually exclusive since different elements can be combined in many instances. However they represent a distillation of what we see as the most distinctive aspects of each approach, as well as their compatibility with the range of circumstances that are likely to arise in practice.

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[9] Note that in the case of a pre-existing PPA or ESC the generator or demand may need to wait until the agreement expires in order to avoid break-clause penalties

[10] See Gill, Plecas and Kockar, 2013: 30

We have summarized these 'design criteria' in relation to the different models in the table below:

	1	2a	2b	3	4	5	6
Ownership of generation and load(s)							
Single owner	x						x
Different owners		x	x	x	x	x	x
Number of loads							
Single	x	x		x			x
Multiple	x		x		x	x	x
Size of load							
Large (>100kW)	x	x		x	x		x
Small (<100kW)	x		x		x	x	x
Existing metering arrangements							
NHH	x		x		x		x
HH	x	x		x		x[11]	x
Access to ancillary services markets							
Yes			x			x	
No	x	x		x	x		x
Same electricity supplier for PPA and ESC							
Yes				x	x	x	x
No	x	x	x				x
Suitable for load increase[12]							
Yes				x	x	x	x
No	x	x	x				x

Note that the diagrams do not show any of the control or metering arrangements as we are only considering the contractual relationships in this section.

Model 1: Common ownership of generation and demand

The first model is the simplest as it requires no additional commercial arrangements compared to a conventional installation apart from the VPW connection agreement with the DNO. The simplicity derives from the fact that the demand and generation are owned by the same legal person. Therefore any benefit to the generator from increased generation is also in itself a benefit to the load.

Considering the numbered text boxes of the diagram in turn:

[11] Half hourly smart meters
[12] This is only relevant where demand may be turned on specifically to match generator output (DSM). If the demand would be on anyway then this can be ignored.

1. The first step in all the models is for a constrained generator to have its permitted export linked to the level of demand at (in this case) one site on the distribution network. The demand must be located behind the same constraint as the generation.

2. Against a base case where the generator's export was either statically or dynamically limited, the VPW link will increase the permitted export, subject to the demand being available. Provided that the increased network access coincides with a time when the generator is able to generate, its output will increase against the base case.

3. The increased output will lead to increased income for the generator owner, through electricity sales via the PPA agreement as well as any government incentives that the site is eligible for such as FiTs, ROCs etc.

4. The electricity consumed by the loads owned by the generator is supplied by a licensed electricity supplier at whatever standard tariff is already in place. There is no discount or direct benefit to the load in this scenario; all the benefit accrues to the generation by increasing its output.

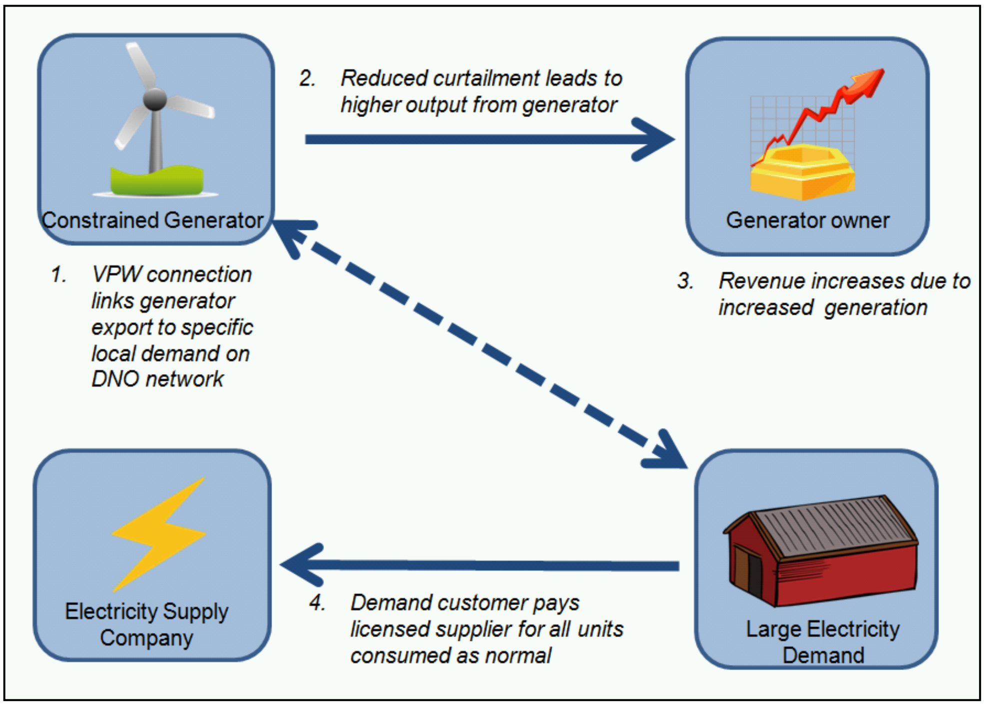

Figure 7 Common ownership of demand and generation

This model, like model 2, is most suitable for a VPW arrangement where the load is pre-existing, as the electricity demand is effectively a sunk cost. If the available load is insufficient for fully releasing the generator, the generator may consider increasing the load, for example by installing additional electrical equipment or replacing fossil fuelled appliances with electric ones- such as storage heaters or electric vehicles.

However as the electricity consumed by the appliances remains at the standard price, this only makes sense if the additional generation is worth more than the additional consumption. This will depend on the terms of the PPA and the ESC, as well as the degree of matching between the demand and generational profiles, and needs careful consideration. In general, models 3-6 are likely to be more suitable for electrifying additional loads, as they actually lower the cost of consumed electricity when it is matched with local generation. Where the demand is on a multi-rate (timed) tariff or half hourly tariff which has large differences in price between peak and off-peak periods this also creates additional complexity in the cost-benefit analysis.

Two illustrative examples are provided below:

1. A farm has a 100kW solar PV array with a VPW connection. There are some milking sheds owned by the same farm but supplied by a different connection point on the same LV network. The milking sheds have an average demand of 20kWe. This means that 30% of the solar generation is still constrained. The farm is considering replacing the oil boiler that provides hot water to the milking shed with an electric boiler. The oil boiler currently costs 5p/kWh to run. The electric boiler would cost 10p/kWh. Additional solar generation is worth 10p/kWh to the farm. Therefore replacing the oil boiler with the electric boiler would save the farm 5p/kWh when it enables additional generation. However when the solar is either unavailable or unconstrained then using the electric boiler costs 5p/kWh more than the oil fired boiler. The farm decides to retain the oil boiler but install a small electric boiler that can be used when the solar PV is constrained.

2. A bakery has a 50kW wind turbine on a nearby hill, connected with a VPW connection. The bakery is operated 24/7 and has an average demand of 40kWe which is linked to the wind turbine via the VPW. The large bakery demand means that only 10% of the wind turbine output is curtailed. The bakery is considering installing an additional electric oven to increase its production and reduce curtailment of the wind turbine. The bakery pays 7p/kWh for electricity at off-peak times and 12p/kWh at peak times. The electricity generated by the wind turbine is worth 9p/kWh. Therefore at off-peak times the additional demand provides a profit of 2p/kW. However at off-peak times it creates a loss of 3p/kWh. As the operational schedule of the oven is not flexible generation is equally likely to occur during an off peak or peak period. The bakery decides to wait until there is a stronger business case for expanding production.

Note that these calculations are only required where the demand is being increased. For pre-existing 'baseline' demand included in the VPW system, there is no additional cost to the generator other than the cost of the VPW equipment and connection agreement.

Case study 1: Bowhill Estate Anaerobic Digestion Plant

Figure 8 Caterhaugh Farm AD Plant

Bowhill Estate has a range of agricultural activities on its farms in the Scottish Borders. The Estate identified an opportunity to develop an Anaerobic Digestion plant to make better use of the cattle, hen and sheep manure produced by their livestock. The technical potential of the feedstock was a 200kWe plant, however after completing network studies SPEN concluded that the local network could not support that level of generation under a conventional connection model. The ARC team installed additional monitoring equipment at the site and across the local network, where the Estate has a number of other properties, farms and businesses.

The ARC team concluded that a 200kW export connection would be feasible provided that the electrical demand from the other properties owned by the estate remained intact. The monitoring equipment has enabled a baseline to be established and allows SPEN engineers to monitor the impact of any future changes in power flows on the network. Compared to the reinforcement that would otherwise have been required, this has lead to a faster and lower cost connection for the Estate, and represents the first instance of a simple Virtual Private Wire system in the UK.

Model 2: Demand Side Management service contract

This model allows a generator to collaborate with third parties who own electrical demand that can be included in the VPW system for that generator. This expands the range of loads that can potentially be associated with a generator in a given area, particularly where the generator does not own any other land or businesses.

The collaboration is enabled by the generator agreeing to share a proportion of the additional revenue that it receives from additional generation enabled by participating demand, in the form of a ‘rebate’ payment. So in the case of the wind turbine mentioned previously, the bakery may decide to share with a local hotel 2p of the 7p/kWh it receives for additional generation *if* the hotel agrees to enter into the VPW scheme for the wind turbine. The payment to the hotel can either be calculated relative to a baseline if the wind turbine has been operational for some time, or by collecting and comparing half hourly metering data for the hotel, bakery and wind turbine.

This is not an electricity supply agreement but a Demand Side Management service contract, as the demand is only providing a service to the generator; the PPA and ESC agreements for the generator and demand remain exactly as they were previously. For the same reasons as model 1, this means that the model is sensitive to the relative price of electricity and the value of additional generation, particularly as the generator cannot retain all the upside but needs to share some with their demand partner.

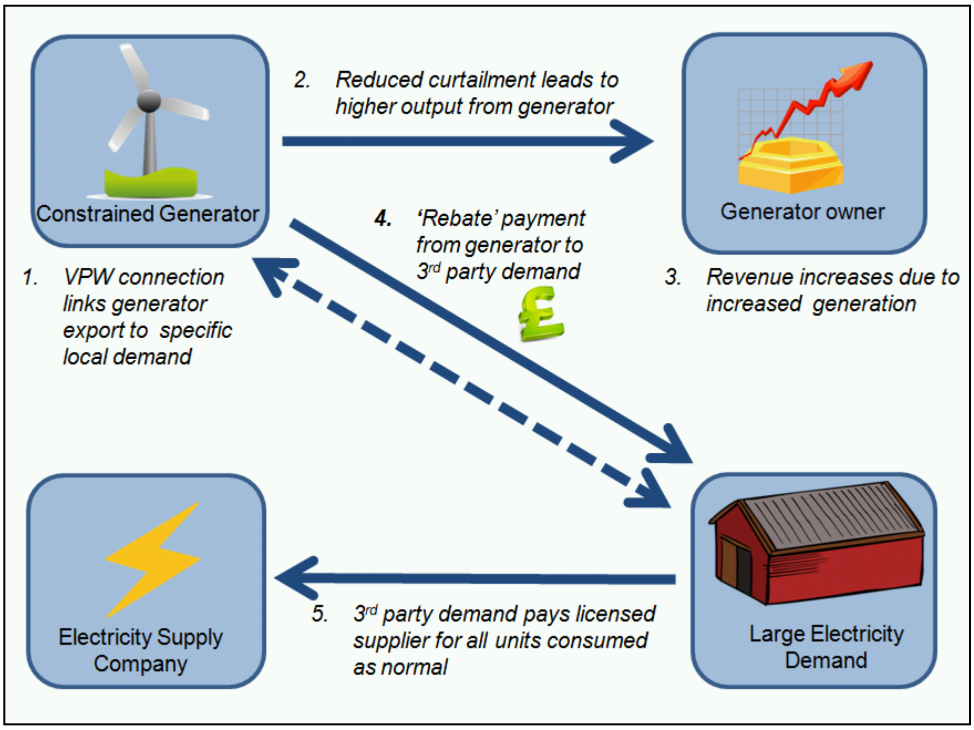

Figure 9 DSM service contract for single large load

The additional challenge with this model is to minimise the transaction costs of recruiting demand partners and agreeing the DSM service contract. Where there is a single suitable demand that is known to the generator this may be relatively straightforward. The variation shown below introduces an aggregator to manage the recruitment and administration of making rebate payments to multiple small demand sites, such as domestic properties and small businesses. The rest of the model remains as before in 2a.

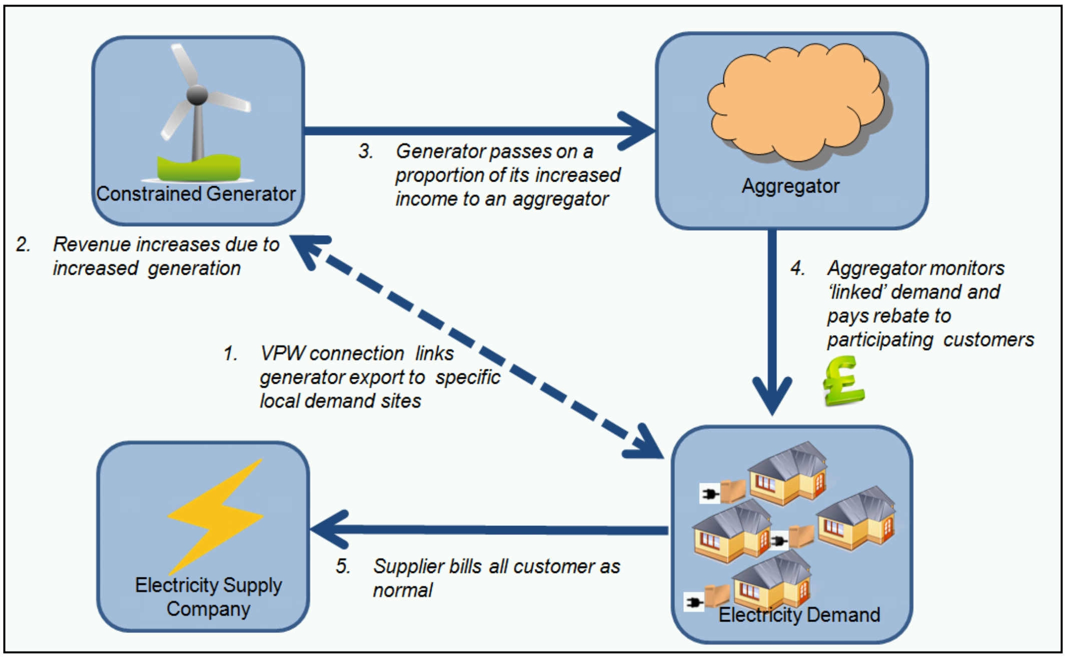

Figure 10 DSM service contract for multiple small loads

While the aggregator streamlines the process of dealing with multiple demand sites, it also represents an additional transaction cost. The inclusion of domestic customers also raises potential risks as they may be more vulnerable in the event of a power cut or less able to manage in the event of an unexpected increase in their electricity bill. While the resolution of these issues would still sit with their licensed supplier, any additional equipment installed by the aggregator could expose them to some liability. Therefore any loads which are to be used flexibly, such as immersion heaters or storage heaters, must be chosen with care to mitigate these risks.

From a system operator's perspective, participation of large numbers of NHH customers in a DSM scheme may increase the perceived imbalance in the system due to changes in the actual demand profile of those customers compared to their settlement class profile. At this time the level of impact is below a materiality threshold, particularly in the context of wider changes to domestic demand profiles due to the installation of new low carbon technologies. However this may place a limit on the long term replicability of this model.

One indirect benefit of an aggregator participating in the scheme is that they may be able to provide the generator or participating demand with access to revenue streams from ancillary services markets, such as Frequency Response for National Grid, which they would otherwise not be able to benefit from on their own. While this is outside the scope of the VPW arrangement itself, it is worth taking into account when assessing the financial benefits that may arise. It would also be important to ensure that any actions for ancillary services do not conflict with the local network requirements, and are fully integrated with the pre-existing control and protection schemes operated by the DNO.

Model 3: 'Sleeved' electricity supply contracts

The third model moves from a purely physical matching of generation and demand within the VPW system, to an integration with the wider electricity supply market.

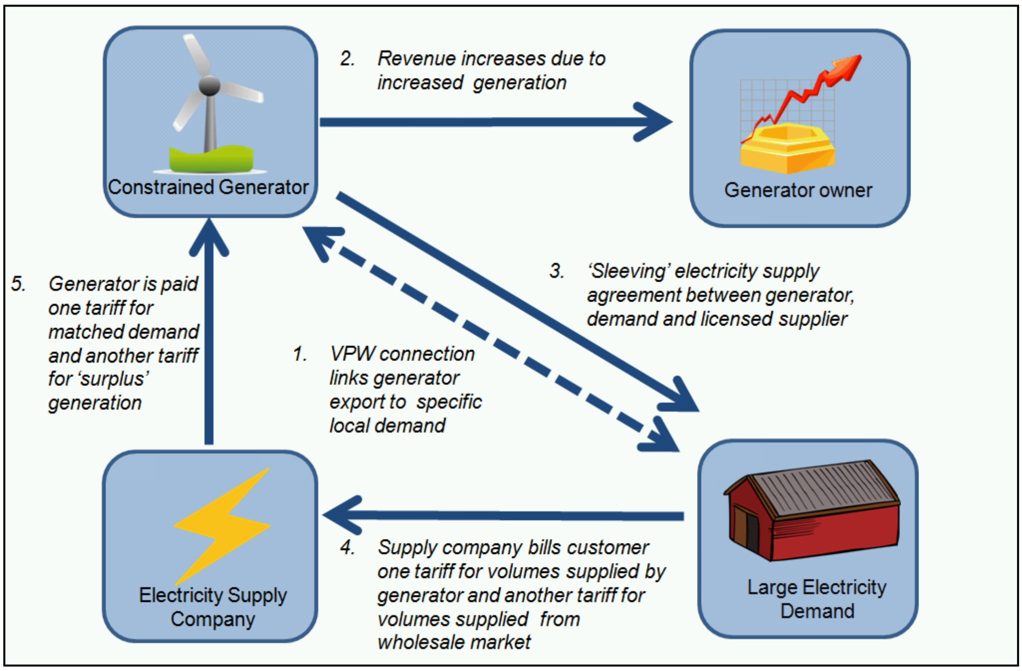

Figure 11 Sleeved electricity supply

This shift is enabled by a bespoke electricity supply contract that sits between the generator and the participating demand, facilitated by a licensed electricity supplier. Traditionally these sorts of agreements, known as a sleeving contract as the electricity supplier simply acts as an intermediary, have been used by large companies to obtain a long term fixed price from their electricity consumption by buying directly from a generator, as well as for CSR reasons by being able to demonstrate the exact provenance of that electricity.

While sleeving contracts have typically been for large energy consumers such as supermarkets and multi MW generators, the market is evolving rapidly with sleeved products now available to generators as small as 30kW.

In the context of a VPW, the sleeving arrangement would need to be modified to create a two tier tariff structure for both the generator and demand, where matched electricity is priced differently to unmatched electricity. In order to do this, both the generator and demand would need to have half hourly metering installed.

Depending on the level of the tariff agreed between the parties, this approach can provide a genuine commercial incentive to maximise the consumption of local generation, and potentially to electrify energy needs previously provided by other fuels such as heating oil or petrol. However its application is currently limited to relatively large loads because of the cost of establishing the supply agreements and the metering requirements. The next two models consider ways of achieving similar outcomes for domestic customers and smaller businesses.

Model 4: Local tariff from licensed electricity supplier

In this fourth model, a 'local tariff' incentivises local electricity customers of all sizes to join the VPW scheme and benefit from a reduced tariff:

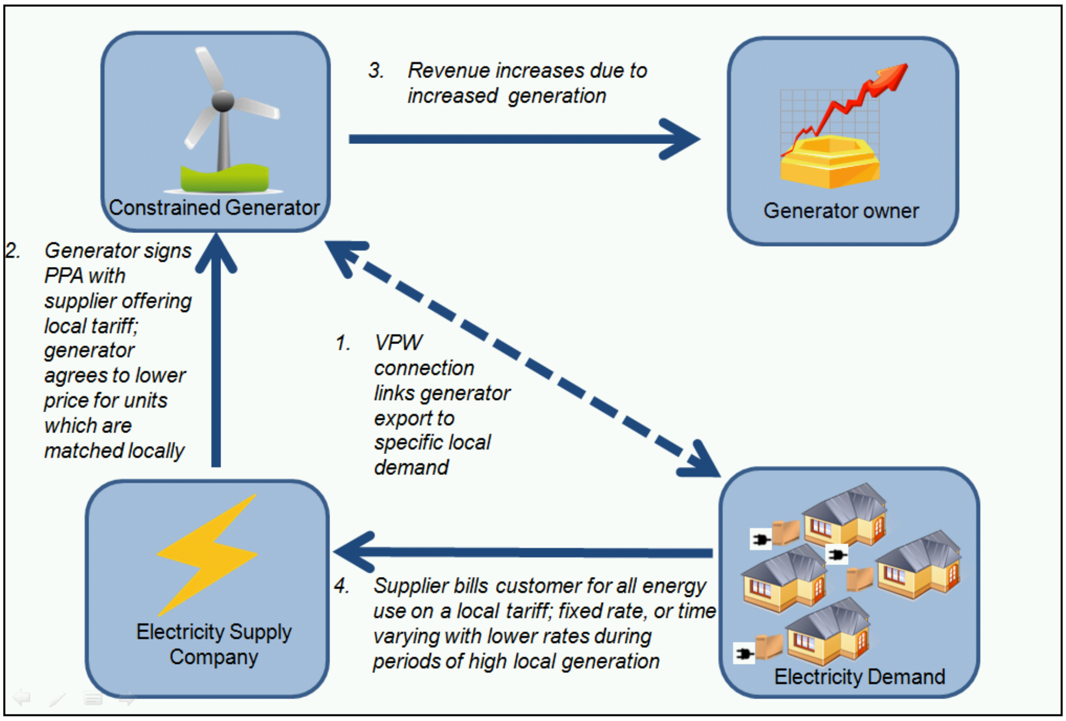

Figure 12Local tariff

The reduced demand tariff is enabled by the discount that the generator agrees to with the supplier offering the local tariff. Like the rebate payments in model 2, the discount is worthwhile for the generator provided that its production is increased sufficiently by the additional demand. However unlike the rebate based models, there is no need for an additional rebate payment- the benefit to the demand is 'priced in' to the reduced tariff. This means that there is a bigger cake to be shared between the generator and demand, increasing the benefit to both.

This model can be implemented using standard customer demand profiles, in which case the supplier compares the actual generation profile against the aggregate profile of the relevant customers, or by using half hourly smart meter data to calculate the actual match between generation and demand.

Because of the setup costs for the supplier in calculating and promoting a local tariff, this model is only likely to be viable where there are a significant number of potential customers, with a threshold of 5-10,000 who actually sign up. This suggests it is currently most suitable for relatively large generation projects, although the customer threshold may fall as the model is standardised and more suppliers begin to offer these sorts of arrangements. 'White label' arrangements and 'License lite' represents can be considered as subsets of model 4 as they would effectively mirror the same contractual architecture. It remains to be seen whether either of these approaches will significantly reduce the customer threshold for local tariff schemes.

Model 5: Local Energy Services Company and 'virtual' MPAN

This model has been developed to provide a route for smaller groups of homes and businesses to link their consumption with local generation.

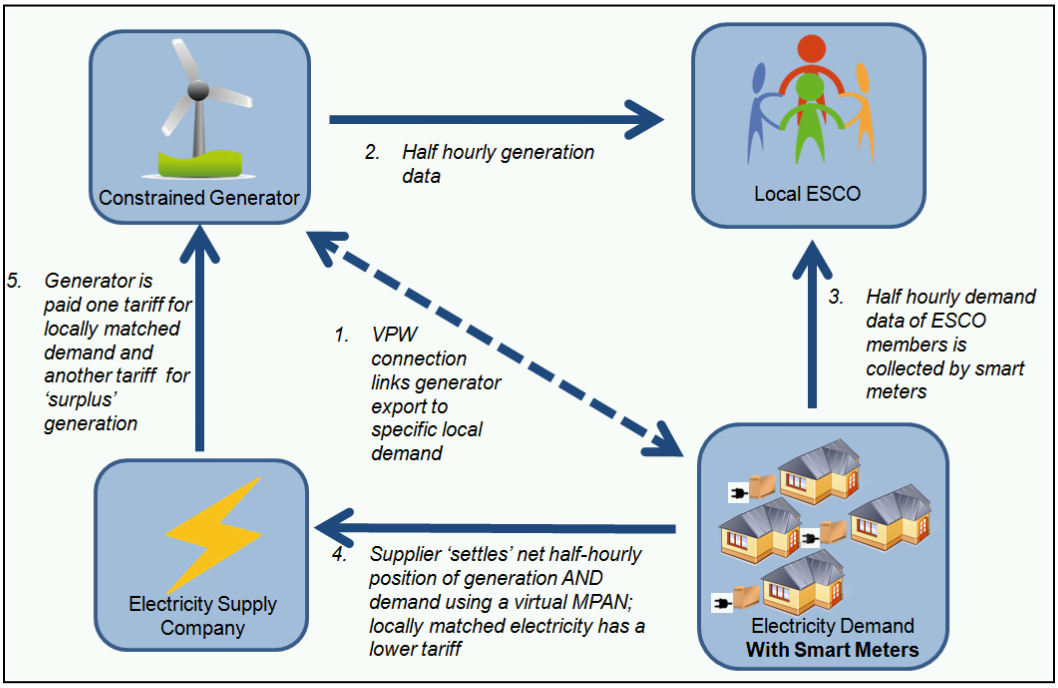

Figure 13 Local ESCO and virtual MPAN

It seeks to reduce the customer threshold for working with a licensed supplier through two routes:

1. Actively recruiting members (either demand customers or generators) in order to streamline the sign up process for the supplier.
2. Half hourly smart meter data is collected and submitted to the supplier via a 'virtual' MPAN that includes all the generation and demand for the ESCO members. This means that the supplier has visibility of the actual imbalance position of this specific group of customers.

The virtual MPAN is established by a supplier under the provisions in the Balancing and Settlement Code, which allow for the metering data for individual customers at different locations on the distribution network to be grouped together under certain circumstances. By enabling the supplier to group customers in this way, the transaction costs for a local tariff are reduced as post facto disaggregation of their portfolio is not required. Depending on the arrangement between the ESCO and the supplier, the ESCO may absorb some of the costs for establishing the virtual MPAN, such as new metering infrastructure.

For the purposes of 'settlement' (i.e. the accounting of electricity generation and demand within the UK electricity market) only the net amount of generation or demand is entered into the settlement system by the supplier. Any surplus generation will be handled through a standard PPA, and a shortfall in generation can also be handled through a standard demand tariff. However an internal price is agreed between the ESCO members and the supplier for generation which is matched with demand from the ESCO members. Typically this will be lower than the cost of standard electricity for demand customers, or higher than the normal price paid for export to generators.

The actual supply relationship can either be between the licensed supplier and individual ESCO members, or between the supplier and the ESCO itself, with the ESCO then acting as a reseller of electricity to individual members. There are provisions for electricity resale under the Electricity Act 1989 and while it can be treated as a license exempt form of electricity supply, the circumstances of individual projects while require independent legal advice.

For the purposes of this report, the ESCO simply acts as a facilitator to bring a group of electricity users and producers together, in order to agree a price for locally matched electricity with a licensed supplier. This represents a significant step in empowering members of a community to come together and work collectively as an active part of the electricity system. However it is important to recognise that this model is innovative and still emerging, with a number of permutations under consideration amid ongoing dialogue between DNOs, Ofgem and Elexon.

One of the concerns that have been raised about this approach is the potential to distort the calculation of DUoS. However DUoS can be calculated independently of the volumes that are settled by the supplier, as the gross data is still available and can be submitted to the DNO by the supplier. Therefore there is no inevitable change in the amount of DUoS paid by either the generator or demand customers, although an appropriate methodology for efficient data flows will need to be agreed. As network charging methodologies evolve, arrangements like this will provide a valuable source of data on the costs and benefits of localised balancing of electricity demand and generation at both a local and wider level.

Case study 2: Energy Local trial, Bethesda

Figure 14 View of the Ogwen Valley, North Wales

The virtual MPAN model is currently being trialled in North Wales, which is part of the southern area of SP Energy Networks. Over 100 households from the village of Bethesda and the surrounding valley are participating in the pilot, which is intended to match their demand with the output of a local hydro generator. Energy Local are a non-profit organisation that has brought together the project partnership, which includes Co-operative Energy, local community groups, the National Trust, and the climate change charity 10:10. All of the participating households and generation are members of the local 'energy club' or ESCO, which is structured as a co-operative.

Figure 15 Hydro generator being installed at Hydro Ogwen, near Bethesda

In this instance, the network is not constrained, and it is only the commercial model that is being piloted. The scheme incorporates both a local tariff, where matched local demand is charged 7p/kWh and the generator receives 7p/kWh, as well as a time of use tariff for when the hydro is not available which is intended to incentivise shifting of demand to off-peak times. There has been a high level of interest in the scheme at both a national and local level and Energy Local are currently in discussion with a number of communities regarding potential sites for further trials using different generating technologies, network architectures and demographics.

Model 6: Distribution System Operator and local distribution charging

This final model considers the role that could be played by the DNO in actively coordinating network optimisation as a 'Distribution System Operator' (DSO). It has been included here because it represents the closest integration of physical and commercial flows and therefore conceptually can be seen as the culmination of the previous models. It is also relevant that SP Energy Networks have made a strong commitment to adopting a DSO model in the medium term, which represents a natural evolution of the role played within the ARC project.

While changing network charging methodologies is largely outside the scope of the report since we have focused on the current regulatory framework, they are clearly relevant to the longer term potential of VPW arrangements. In this example, a localised DUoS tariff is used to incentivise local matching of demand and generation:

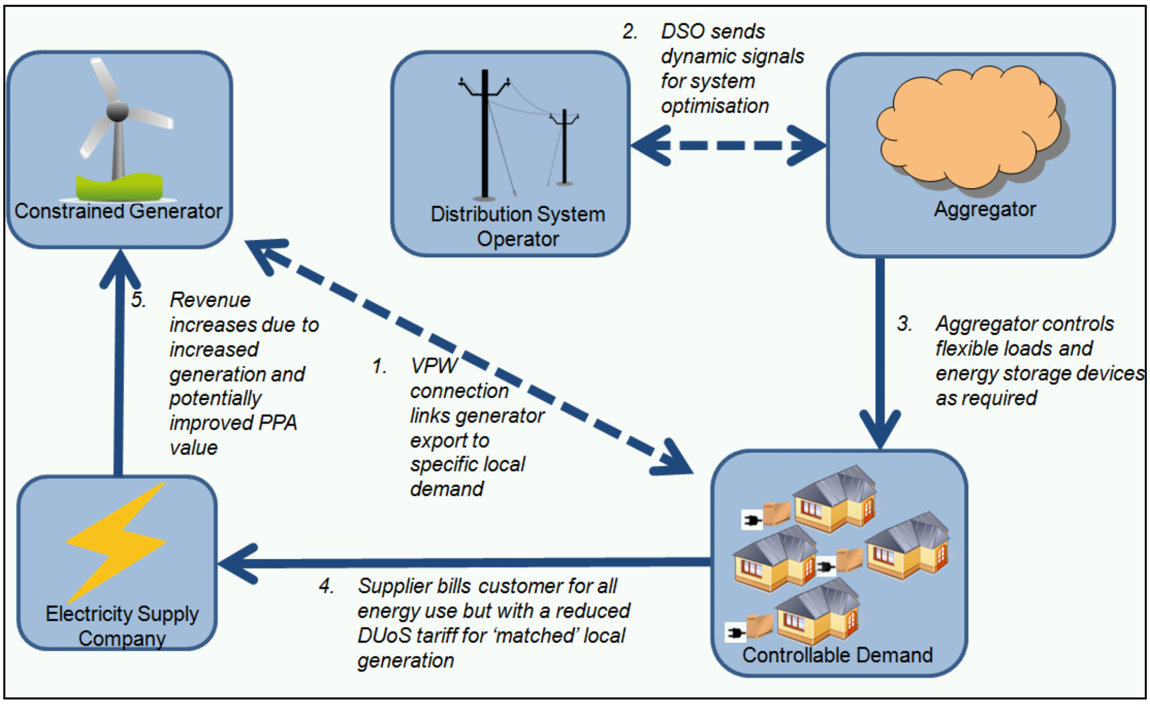

Figure 16 DSO VPW model

Under this scenario, the VPW system would still be intact in that the level of generator curtailment would still depend on the availability of specific linked demand. The key difference to the previous models is the active role of the DNO in monitoring and instructing control decisions to optimise power flows on the local network as a whole. In the prior models the interests of the generation and demand drive the decision making within the VPW scheme, such as whether to dispatch additional demand in response to a curtailment signal.

In this case, the DNO is aiming for an overall optimisation of all controllable assets that are available to them, whether demand or generation. This would still be subject to the terms of connection and any legacy arrangements which are already in place, but represents a significant change to the role of the DNO from a passive gatekeeper to an active participant in real time optimisation of the local network. In the following and final section, we consider some of the policy issues raised by the VPW model, and the broader shift towards more actively managed networks.

POLICY CONSIDERATIONS FOR FUTURE DEVELOPMENT OF VIRTUAL PRIVATE WIRE NETWORKS

There are a range of policy issues that arise from the VPW models that have been considered in this report. These include both industry wide considerations as well as the internal policies of individual DNOs and other stakeholders. The table below provides an overview of some of the issues identified:

Issue	Stakeholders
Metering arrangements for VPW generation and loads	DNO, Elexon, Suppliers, VPW participants
Calculation of DUoS for VPW schemes	Ofgem, DNOs, Suppliers
Connection design methodology for VPW schemes	DNOs, Ofgem, DG
Visibility to DNO of customers participating in a virtual MPAN	DNOs, Ofgem
Electricity licensing requirements for small suppliers	Ofgem, BEIS
Consumer engagement and education in local energy schemes	DNO, BEIS , Ofgem

It is clear that these issues lie at the heart of ongoing changes to our electricity system as new technologies and business models are adopted over time. Historically the pace of change in the electricity sector has been relatively slow compared to other industries, however there is increasing recognition of the need for experimentation as part of the evolution of established practices. Ofgem has recently launched the 'innovation link[13]' to provide regulatory feedback on cross cutting business models, as well as a 'regulatory sandbox'[14] to create test spaces for the real world demonstration of system architectures that are several steps beyond the current regulatory framework.

The ANM systems that VPW is based on have evolved in the context of a relatively high level of government funding for renewable generation. In the current market, generators are under increasing pressure to increase the market value of their generation, while suppliers are encouraged to minimise consumer costs. Against this background, the changing generation mix and national demand profile increases the pressure on DNOs and the SO to balance supply and demand and maximise the flexibility of the system. The work undertaken by the ARC project has established that VPW systems can have a role to play in increasing the flexible use of existing network infrastructure, as well as adding value to generation while reducing consumer costs, and that there are no insurmountable technical or commercial barriers to their implementation. The regulatory position remains complex in many areas, but we expect to see this clarified through practical pilots and ongoing work in industry fora. This suggests that the enabling conditions are already present for the development and wider replication of VPW systems.

[13] https://www.ofgem.gov.uk/about-us/how-we-engage/innovation-link
[14] https://www.ofgem.gov.uk/publications-and-updates/regulatory-sandbox-calling-expressions-interest

ANNEXE 1

Virtual Private Wire Report

Identifier	Date Created	Created by	Description	DUR
	14/12/2016	Rachael Taljaard Euan Davidson	Initial issue	2120

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