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Flexible Interconnect Through DERMS-Learning from Practical Deployment

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SUMMARY

DER growth is a key factor in the drive towards net zero, which is being accelerated through introduction of regulatory innovations such as FERC Order No.2222 in the USA. The rapid acceleration of DER interconnection is causing technical challenges to emerge on the distribution network. Where hosting capacity constraints exist, network reinforcement is triggered that can substantially increase interconnection costs for DER developers and establish longer DER interconnection timescales that will slow-down the pace of the net-zero transition.

Flexible Interconnection is gaining traction as a demonstrated and proven solution to the interconnection of DER on constrained distribution networks. Through real-time autonomous control of DER, Flexible Interconnection provides an operational means to manage grid constraints during the infrequent cases where worst-case thermal loading occurs at capacity bottlenecks. Flexible Interconnection presents distribution utilities with an effective tool to address DER interconnection queues and accelerate deployment of low-carbon generation technologies whilst maximizing utilization of their existing network assets

Flexible Interconnection is being rolled-out in utility territories across North America, with established demonstrations in New York progressing the roll-out, triggered by large volumes of large (>1 MW) DER interconnection activity on the distribution system (≤34.5 kV). AVANGRID is deploying Flexible Interconnection processes and has successfully demonstrated its implementation at network sites, facilitating interconnection of greater levels of DER.

AVANGRID has deployed Flexible Interconnection to support the installation of PV generation to Station 113 in Spencerport, NY – a site with existing high levels of generation and capacity constraints at the substation transformer. Deployment of Flexible Interconnection has increased the DER headroom at the substation by 44%, providing a non-firm managed connection to additional PV generation sites, while forecasting curtailment of 0.27% of expected production. The deployment of Flexible Interconnection is facilitated through the installation of a centralized DERMS component with local control software installed at each site.

This paper presents AVANGRID's learning from the demonstration of Flexible Interconnection and deployment of DERMS Infrastructure at the Spencerport substation. The learning derived through the Flexible Interconnection demonstration has informed the strategy for wider deployment of the concept at scale.

KEYWORDS

DERMS, Wind and Solar Integration, DER Integration and Control

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DER GROWTH AND THE GRID CONGESTION CHALLENGE

Over the coming decade utilities across the United States will feel pressure from local & state governments and regulators to drastically increase the amount of renewable energy interconnected to the electrical system. While many of these standards were set in the last few years, as we approach 2030 and beyond utilities must find ways to interconnect Distributed Energy Resources (DERs) in a faster and more cost-effective manner while still maintaining the system reliability all customers depend on.

The two major issues that will stand in the way of utilities achieving these targets are linked by the lack of hosting capacity at the distribution level for new larges DERs:

- triggering high costs as utilities upgrade grade infrastructure and thus increase costing capacity, and
- the timescales for planning and implementing the required grid reinforcements.

As DERs continue to interconnect onto the grid, hosting capacity of grid infrastructure is quickly saturated using conventional interconnection methods. Once the traditional 'passive design' hosting capacity is reached, the utility will need to upgrade the equipment (*reinforcement*) which can cost millions of dollars and many months or potentially years, to complete. The traditional design of a DER interconnection is based upon the worst-case network conditions, reflecting a static operational state that will very rarely, if ever, be realized. The intermittent nature of renewable DER further reduces the likelihood of, but does not fully eliminate, occurrences of these worst-case planning conditions, introducing greater diversity in network operation and thus more available real-time hosting capacity.

While the reinforcement cost is generally borne by the DER developer, the expensive and time-consuming upgrades can make a DER project uneconomical and therefore create a barrier for distribution utilities and the states they operate in to reach their renewable energy targets. It is the desire to address this barrier in a safe and reliable manner that has established Flexible Interconnection as a solution for accelerated and lower-cost interconnection of DERs and allowing the Distribution Utility to deliver greater utilization of its asset base in a demonstrably safe and secure manner.

FLEXIBLE INTERCONNECTION: A SOLUTION TO DER GRID CONGESTION

What are Flexible Interconnections?

EPRI has defined Flexible Interconnection *as "a DER Control Strategy used to defer or avoid system upgrades and/or increase distribution system utilization".* [1] In other territories, such as the United Kingdom, Flexible Interconnection is typically referred to as "*Active Network Management*", where in 2015 the UK's Energy Networks Association described it as:

> "*Using flexible network customers autonomously and in real-time to increase the utilization of network assets without breaching operational limits, thereby reducing the need for reinforcement, speeding up connections and reducing costs*".[2]

As reflected in the descriptions above, Flexible Interconnections allow the violations identified in system impact (screening) planning studies to be managed in operational timescales using real-time information, communications, and control technology. Flexible Interconnections work by monitoring the network assets where the constraints identified in the interconnection studies may occur and, as the network nears constraint conditions, curtailing the export from participating generator(s). In cases where the constraint is triggered by high load conditions, the same approach would apply with curtailment of flexible loads.

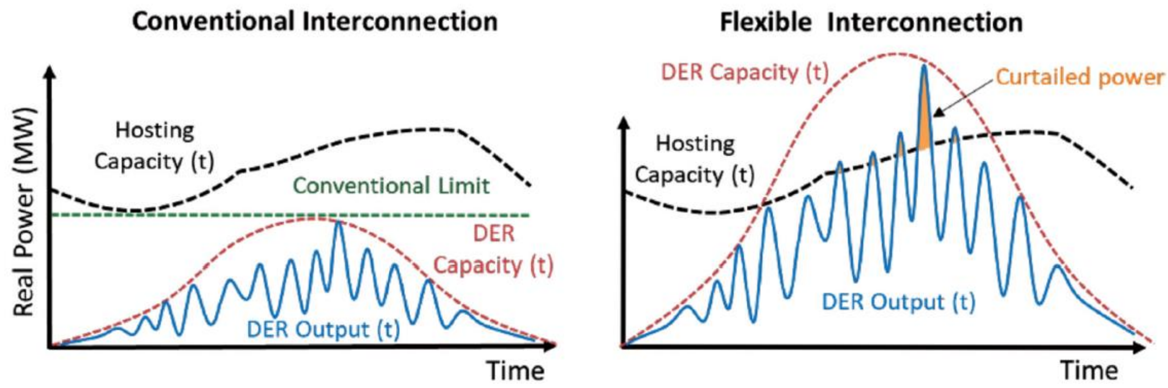

Figure 1: Conventional (Firm) vs Flexible Interconnection- EPRI [3]

Figure 1 illustrates the operational distinctions between a ‘passive’ conventional interconnection and an ‘active’ flexible interconnection:

- The conventional interconnection has a fixed limit and takes no account of intra-day or intra-seasonal variations in load or DER import / export. The fixed, deterministic planning threshold is set based on the worst-case system conditions and limits the DER capacity that can connect to the network before system upgrades are required.
- The Flexible Interconnection removes this fixed limit and manages the DER to the variable real-time hosting capacity of the network. This real-time hosting capacity follows variations in demand and diversified DER export, as well as any network redundancy considerations (e.g. reserved capacity for contingencies). The export from the DER is managed within the real-time hosting capacity, being curtailed only in the periods where DER export exceeds the hosting capacity.

The terms under which curtailment will be applied are written into the interconnection agreement with the DER customer. This allows the DER developer to understand the risks of lost export, model them and build them into their project financial models. The interconnecting DER customer trades the benefits of a lower cost and/or faster connection in exchange for curtailment under specific and well-defined conditions and the associated potential loss of revenues.

Benefits of Flexible Interconnections

Figure 2 summarizes the benefits that Flexible Interconnections provide to DER developers, compiled by EPRI:

Flexible Interconnections provide a tool for states, utilities, and DER developers to achieve their deployment goals, return on investment (ROI) targets, and net-zero timelines. By taking advantage of Flexible Interconnections, DER developers and owners are able to connect DERs at a faster pace for a fraction of the cost in exchange for a marginal percentage of curtailment.

Flexible Interconnections increase the grid’s capacity to add DERs, which in turn helps states get closer to their renewable energy targets.

Utilities themselves benefit by maintaining revenues associated with the construction of sole use assets, smaller upgrades to interconnect DER and increases in the volume of system use charges, as well as improving customer relations. The utility is able to better utilize its distribution infrastructure. All this can be achieved without adding burden to the ratepayer.

Benefit	Description
Lower interconnection costs	Adding controls and curtailing available generation can be cheaper than conventional network reinforcements. In many cases, conventional upgrades may be prohibitively expensive, constraining DER project development. Flexible interconnection may provide a less costly interconnection option by instituting limited curtailment in lieu of grid upgrades.
Faster interconnection times	Adding controls can be a faster solution than many conventional upgrades (e.g. constructing a dedicated feeder). Flexible interconnection can also be used as a temporary solution for customers who want a firm connection; it allows them to grid connect while they wait for the network reinforcement to occur.
Increased network utilization	Flexible interconnection allows for more DER generation per unit of delivery capacity available, maximizing use of existing grid assets.
Facilitated renewable generation growth	Flexible interconnection can expand renewable generation and meet renewable portfolio standards by using existing network infrastructure, as opposed to building out additional network capacity.

Figure 2: EPRI's Potential benefits of Flexible Interconnections [4]

DERMS INFRASTRUCTURE TO ENABLE FLEXIBLE INTERCONNECTION

What is DERMS?

A DER Management System (DERMS) is a utility platform that bridges the planning and operational timescales of distribution utilities, providing visibility and control of DER assets that facilitate management of network operations such as bi-directional power flows and voltage controls, and help realize the value that DER brings to the distribution grid and market.

While Flexible Interconnection is one of the most prominent Use Cases, DERMS is also deployed to deliver the following Use Cases:

- **Non-Wires Alternatives and Grid Flexibility Services**: Once DER are interconnected to the grid they provide a vital source of 'flexibility' to manage different types of grid constraint. Examples include managing a peak load event on a feeder or substation, and providing local supply to facilitate maintenance outages. Using customer DER flexibility in this way is somewhat like a balancing or ancillary service market where customers are contracted either for utilization only, or availability and utilization for provision of a turn up or turn down energy service. Service requirements can be fixed (e.g. every day between certain hours) or called-off (e.g. day ahead or real-time)
- **Grid Optimization**: DER are not the only flexible assets on the power system; capacitor banks, shunt reactors, on load tap changers, and power electronic devices all offer the opportunity to manage constraints and operate within statutory power quality and security limits. Coordination of these devices with the real and reactive power capability of DER provides new opportunities for grid optimization. Examples include smoothing voltage profiles and managing boundary flows.
- **Market Participation**: DER are increasingly being provided more open access to electricity markets particularly with FERC Order 2222. Most markets require DER to be a certain size or aggregated to reach a minimum capacity. From there on they are treated in the same way as any other market participating merchant asset with financial responsibility to deliver their contracted position or face imbalance charges. Depending on the roles and responsibilities set by regulators within the jurisdiction the distribution utility (as the load serving entity) may be responsible for aggregation and energy delivery, whereas in other markets they may simply be responsible for resolving any service conflicts between market participation and other use cases such as flexible interconnections, non-wires alternatives or grid optimization. The owner and operator of the DER is then responsible for aggregation and market participation from its portfolio of assets.
- **Microgrids**: There are examples of Flexible Interconnections, Non-Wires Alternatives and Grid Optimization solutions being deployed with local DERMS control systems situated in the substation. Furthermore, microgrid applications can also support resiliency objectives such as

preparing DER for potential loss of grid interconnection, for transitioning to an alternate source or islanded operation, black start and sustaining the island by balancing generation and demand with an anchor generator.

Technical Requirements for Flexible Interconnection

Flexible Interconnection requires infrastructure that can provide the following:

- **Autonomous Control:** Flexible Interconnection can result in real-time management of hundreds of devices in response to grid conditions, therefore the enabling systems must operate autonomously with the ability to send alerts or alarms to control room operators under extreme/outage conditions;
- **Scalability**: the ability to easily expand the scheme to accommodate new DER sites and expand to integrate new constraint locations without requiring major overhaul of DERMS infrastructure;
- **Fail-Safe features**: Flexible Interconnection solutions must be resilient to failure of software, hardware or communications infrastructure. Graceful degradation of all DERMS functions is required in the event of any failures or outages;
- **High Availability and Redundancy**: real-time algorithms need high availability to manage grid conditions on a second-by-second basis, otherwise the participating DER must move into fail-safe states. Introducing redundancy to DERMS infrastructure ensures high levels of availability;
- **ADMS/SCADA Integration**: it is essential that DERMS is integrated into the broader distribution system operating environment. This means open standards for secure integration with the ADMS to provide control-room visibility of DERMS operation, enable control-room interventions and facilitate exchange of operational and field datasets.

CASE STUDY: FICS REV DEMO- STATION 113

Project Background

AVANGRID has tested the hypothesis that implementation of its Flexible Interconnection Capacity Solution (FICS) will increase the deployed capacity and density of DERs on a section of the system. AVANGRID operates New York State Electricity & Gas (NYSEG), Rochester Gas & Electric (RG&E), United Illuminating (UI), and Central Maine Power (CMP). NYSEG and RG&E operate in New York and UI in Connecticut. Both New York and Connecticut have goals of 100% carbon-free energy by 2040. CMP operates out of Maine which plans to achieve 80% renewable energy by 2030 and 100% by 2050. To help New York, Connecticut and Maine achieve these goals, AVANGRID deployed Flexible Interconnection at Station #113 in Spencerport, NY, enabled via DERMS infrastructure as part of a New York Reforming the Energy Vision (REV) Demonstration Project.

Due to existing PV plants, Station 113 had unconstrained DG headroom of 2.6 MVA. The 2.6 MVA static headroom is derived from the maximum generation capacity installed on Station 113, where beyond this headroom the reverse-power flow will exceed the design thermal rating of the substation transformer.

A developer sought interconnection of three 5 MW PV plants to the network at Station 113, which under traditional ‘passive’ design principles, would trigger reinforcement of the substation and require the developer to pay for a transformer upgrade. Smarter Grid Solutions and AVANGRID deployed DERMS infrastructure to enable real-time constraint management based on the current flow through the substation transformer via Flexible Interconnection, allowing connection of the 15 MW PV sites and increasing the hosting capacity of the substation by 44 %

The DERMS platform delivered by Smarter Grid Solutions consists of two components: **Strata Grid** and **Element Grid**.

DERMS Components, Functions and Deployment Architecture

Strata Grid is the centralized DERMS component, hosted on server infrastructure at the AVANGRID Energy Control Center. Strata Grid provides the real-time and autonomous monitoring and control functions that enable Flexible Interconnections. The real-time deterministic control algorithms monitor the power flow through the Station 113 transformer and compare this measurement against predefined limits. During periods of high loading on the transformer, when the power flow exceeds the predefined limits, export reduction set-points are calculated and issued to the PV generators to ensure that the power flow through the transformer is maintained within its rating.

Field measurement inputs are monitored by *Measurement Point* state machines, which trigger a request for regulating control actions based on breaches of power flow thresholds at the Station 113 transformer. Additionally, Measurement Points will request releasing actions to allow DER sites to move towards their preferred export set points when the measured value is in a safe operating region.

Element Grid is local control software that is installed onto a DER controller at each of the DER sites. Element Grid sits on the utility side of the meter and delivers the local monitoring and control functions described in **Error! Reference source not found.**.

Function	Description
Measurement of DER Export	The real-time measurement of energy export from the DER site, issued back to Strata Grid to inform control decisions and validate that curtailment set-points have been met.
Issuing Control Signals to DER Site	Receipt of DER curtailment set-points from Strata Grid and issuing these to the DER Site control system for implementation.
Failsafe: Non-Response from DER Site	If DER site fails to meet issued set-point within pre-configured duration, Element Grid will send alarm to Strata Grid and take escalating action (such as opening DER site Circuit Breaker)
Failsafe: Communications outage to Strata Grid	Under communications outage between Strata Grid and Element Grid, DER site will be curtailed to secure fail-safe level.

Table 1 Element Grid Monitoring and Control Functions

Measurement Points are established at each asset at risk of constraint and are responsible for providing real-time monitoring of power flow or directional current to inform Strata Grid control actions. The real-time measurement inform curtailment actions to address a breach of a defined power flow threshold, and also allow DER devices to release curtailment set-points after resolving a capacity limit breach, once capacity is available on the network.

The Measurement Points utilize directly-measured values or those derived from multiple network measurements, for example the monitoring of power flows through a group of transformers.

The DERMS **Deployment Architecture** is presented in Figure 3, where the *Strata Grid* centralized component is located at the Avangrid Energy Control Center; *Element Grid* local controllers are deployed at each PV site; and the *Measurement Point* is established at Station 113 to provide real-time visibility of power-flow across the substation transformer.

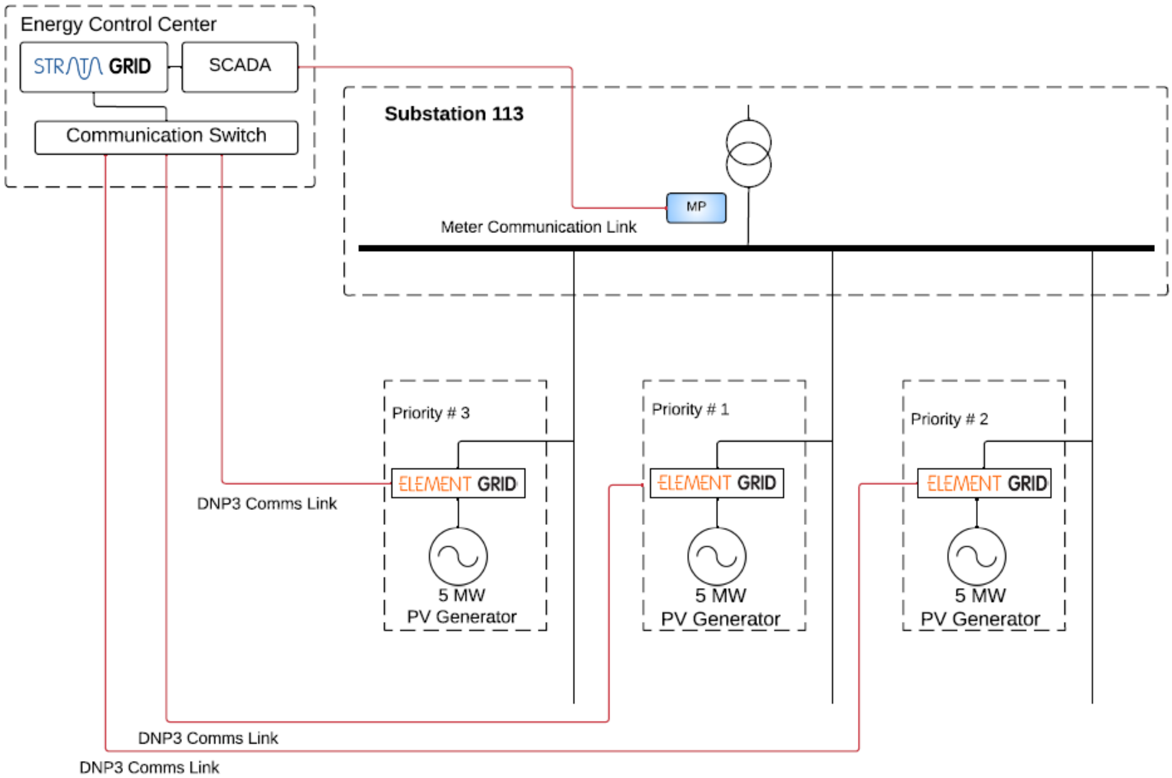

Figure 3 : DERMS Deployment Architecture at Substation 113

Threshold-based Control

The Flexible Interconnection constraint management algorithm hosted on Strata Grid provides active real-time control of DER on constrained grids with the objective of maintaining secure grid conditions within operation limits. It minimizes the curtailment required at each of the three DER sites through fast-acting, deterministic time-bounded control.

The constraint management algorithm monitors power flows across the transformer at the Station 113 Measurement Point. This Measurement Point was configured with a series of thresholds which trigger control actions to be issued to the DER sites.

If any measurement at the Measurement Point breaches a threshold, a timer is triggered to ensure the breach is not spurious. When the time expires, Strata Grid determines the response required at the Constraint Location to return to a safe level and a control action (usually a DER active power export set-point) is initiated. The FICS REV Demo Case Study employed three key thresholds to provide escalating control actions [5], highlighted in Figure 4 and described below:

- **ANM Trim:** The threshold over which Strata Grid issues a granular set point or set points to reduce the active power export of one or more DER to be controlled according to the Principals of Access (PoA). PoA define the order in which DER are granted access to available network capacity. AVANGRID chose to implement a Last-in First-Out (LIFO) approach to PoA. The set point calculated for the DER is determined using a pre-calculated sensitivity factor which describes the relationship between the DER and Measurement Point for a given network topology. The DER set-point will be calculated such that the Measurement Point power flow goes below the *Trim Target*.

- **ANM Sequential Trip:** The threshold over which Strata Grid sends a trip signal to trip the local DER circuit breaker as a fast-acting escalating control action. This action ensures transformer loading does not near the transformer capacity rating.

- **Release:** The threshold below which the power flow at the Measurement Point must be under for a period before Strata Grid releases the DER set-points. When releasing DER set-points

Strata Grid will calculate the sufficient release to take Measurement Point power flow to the *Release Target*, ensuring the release of set-points does not initiate another *trim* curtailment event.

This approach ensures that curtailment is minimized to the safe operational limits of the network whilst managing the potential ramp rates from renewable generation by limiting the amount of curtailment requests (e.g. a set point rather than a trip signal) and releasing the set point as soon as capacity is available.

Figure 4 : Power Flow Thresholds

Lessons Learned and Next Steps for AVANGRID Roll-Out

Below are some of the key lessons learned from the REV FICS Demo.

Non-Network Curtailment

In the event there is a loss of control or visibility at Station 113, the DERMS automatically curtails the PV site to a fail-safe level. This level is a pre-determined by AVANGRID to ensure that in the event of a communication loss the grid equipment is still operating within its safety limits. However, during the course of the project, there have been communication losses between the DER site and the local DER Gateway. Due to the fail-safe, when there is a communication loss or other malfunction of a system component, the site is automatically curtailed to pre-agreed safe levels. This is known as non-network curtailment and is not included in a curtailment analysis as it is difficult to predict. As the technology matures and Flexible Interconnections roll out as a business-as-usual solution, the amount of non-network curtailment is expected to drop.

Operational Engagement

Compared with a firm connection, Flexible Interconnections require a greater utility engagement in DER operations. The DERMS technology allows the DER curtailment to occur automatically, but appropriate Operating Procedures and proper staffing are critical to ensuring smooth operation and proper communication with DER Operators. [6]

DER Site Controller Interface

Progress is being made on implementing IEEE1547-2018, which lays out the groundwork for utility to DER communications, at the inverter level, issues have risen when communicating to the DER Site Control/Data Acquisition systems which leads to non-network curtailment. [7]

Flexible Capacity Potential

Flexible Interconnections have the potential to reduce the $/W required to interconnect DERs to constrained parts of the grid. The constraints that trigger expensive upgrades such as reconductoring, voltage class upgrade, or substation transformer replacement are the most suitable for deferral by Flexible Interconnections. [8]

Next Steps

AVANGRID will continue to operate the FICS REV demo sites while identifying and implementing additional pilot sites.

Moving forward, AVANGRID will issue guidance documentation on Flexible Interconnections before including Flexible Interconnections as a Business-As-usual option during interconnection. [9]

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