USING STANDARDS TO INTEGRATE DISTRIBUTED ENERGY RESOURCES WITH DISTRIBUTION MANAGEMENT SYSTEMS

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ABSTRACT

Technology advancements in solar photovoltaics (PV) and battery storage have driven sharp increases in their employment by utilities, consumers, and third parties. These Distributed Energy Resources (DER) are often connected to the grid at the distribution level, and distribution operational requirements are being greatly impacted by their presence. Despite the potential impact of DERs on the distribution feeders, the current generation of distribution management systems has few if any available mechanisms for managing the operations of DERs. The proposed paper describes the results of an effort to address the need for enterprise integration of distributed energy resources.

INTRODUCTION

No portion of the electric power grid has been impacted more by grid modernization (the "smart grid") than the electric distribution system. Grid modernization is transforming distribution operations from mostly manual paper-driven processes to automated computer-assisted decision making and control for distribution system optimization. A central part of this transformation is the Distribution Management System (DMS) which integrates numerous remote monitoring and central control facilities with enterprise level systems to optimize distribution system performance and accomplish a variety of business goals.

At the same time, technology advancements in solar photovoltaics (PV) and battery storage have driven sharp increases in their employment by utilities, consumers, and third parties. These Distributed Energy Resources (DER) are often connected to the grid at the distribution level, and distribution operational requirements are being greatly impacted by their presence.

The power inverters that link solar PV and battery resources to the grid are highly-capable devices with advanced message processing and fast power control with nearly instant response to received commands and monitored conditions. Over the last few years, industry efforts have defined a wide range of standard grid-supportive functions that inverters may provide and standard communication protocols that allow these functions to be remotely managed.

These electronic inverter capabilities, if properly exposed and integrated with DMS, can transform high penetration DER from problematic uncertainties to beneficial tools for distribution management. To achieve these potential benefits, DMS must account for the presence of DER in its models and advanced applications. Furthermore, the DMS should take advantage of the advanced DER control capabilities and opportunities for improving the reliability, efficiency, performance and overall quality of service for the electric distribution customers.

INCORPORATING DER CAPABILITIES

The presence of high penetrations of such units on the distribution system is having a profound effect on electric distribution designs and operating practices that have existed for a century or more. On feeders with very high penetrations of customer-owned generating resources, the potential exists for having more power supply than demand on a given feeder, resulting in reverse power flow that can cause unacceptable voltage profiles and possible overloads along the distribution feeder. In addition, some renewable distributed generation units (solar PV and wind power) have highly variable power output which can produce voltage fluctuations that reduce the overall quality of power supply on the feeder and, therefore, must be mitigated.

For these reasons, the distribution system operator and the distribution monitoring and control systems used by the operators must be aware of the current operating status of the DERs at all times and must be able to manage the output of these units. This is necessary to enable the operators to maintain acceptable electrical conditions on the circuits at all times, to guarantee the safety of the workforce and general public, and to protect existing utility-owned electrical assets.

At this time, control of customer-owned distributed generating units is limited to transfer-tripping larger generating units during a circuit outage (anti-island protection). However, DERs that are equipped with smart inverters and other intelligent controllers may be able to provide additional functionality, such as volt-VAR support, to meet the changing feeder requirements on demand. For the purposes of this white paper, any control function that alters the normal operation of the DER (normal operation is, for example, to achieve maximum power output from generator at all times) is referred to in this paper as "Advanced DER Management".

MANAGING DISTRIBUTED ENERGY RESOURCES

Over the past few years, the utility industry has made significant progress in defining common grid-supportive functions for distributed resources such as solar photovoltaics and battery storage, and also in defining the open standard communication protocols needed to connect these devices into utility networks. Figure 1 illustrates a utility enterprise, including a central office application environment (in blue) and field networks and equipment (in green).

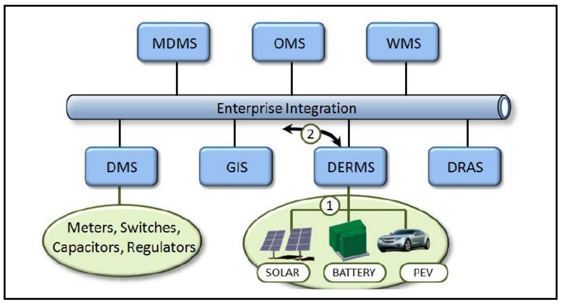

Figure 1: Utility Enterprise Diagram

Industry activities to create DER standards have thus far focused almost exclusively on the behaviors of individual DER units and the communication protocols over the field networks that connect directly to these devices (reference point 1 in Figure 1). The functions include, for example:

- Intelligent Volt-VAR control
- Intelligent Volt-Watt control
- Reactive power /power factor
- Low-voltage ride through
- Load & generation following
- Storage systems charge/discharge management
- Connect/disconnect
- Dynamic reactive current injection (responding to changes in voltage dV/dt)
- Max generation limiting
- Intelligent frequency-Watt control
- Peak limiting function for remote points of reference

In Figure 1, the function of managing the DER devices is shown as an enterprise application called a Distributed Energy Resources Management System, or DERMS. In actual implementations, DERMS functionality may or may not be a dedicated software. Stand alone DERMS products could be developed and deployed, or DERMS functionality could be into DMS, EMS, SCADA, or other applications. Nevertheless, it is beneficial at this early stage of industry consideration to think of a DERMS as a separate logical entity so that the interactions between DER and other utility systems can be identified and supporting information standards developed.

VOLT-VAR OPTIMIZATION WITH DER

Numerous electric distribution utilities have implemented or are planning to implement an advanced Volt-VAR Control and Optimization (VVO) function as part of their DMS to improve voltage profiles and increase overall efficiency of the electric distribution system. Recent DMS implementations of VVO utilize switched capacitor banks and voltage regulators (including LTCs) to accomplish the VVO application. Additional benefits beyond what can be achieved using these conventional devices are possible by using the smart ac inverter functions. This improved version of VVO is referred to as "DER Enhanced" VVO.

Conventional VVO is accomplished by performing two main steps:

1. Use switched capacitor banks to "flatten" the voltage profile

2. Use voltage regulators to lower the voltage as much as possible

Figure 2 shows the feeder voltage profile before performing any VVO control actions. The voltage at the substation end of the feeder is at the upper end of the acceptable voltage range, while the voltage at the end of the feeder is near the low limit, thus preventing any voltage reduction. Figure 3 shows the effect of performing step 1 of VVO which has the effect of raising the minimum voltage on the feeder and "flattening" the voltage profile. This enables VVO to perform step 2, which uses voltage regulators to lower the feeder voltage, thus accomplishing the overall VVO objective.

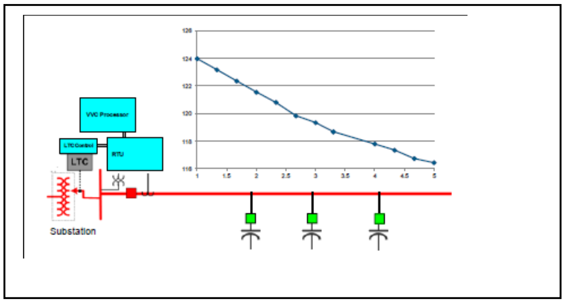

Figure 2: Original Voltage Profile

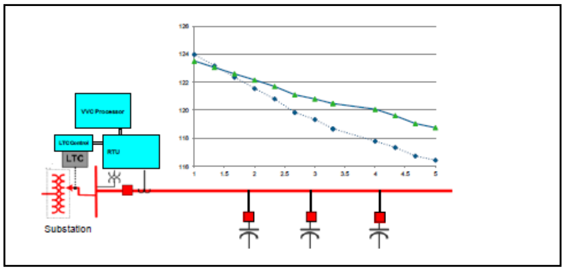

Figure 3: Capacitor Switching

DER Enhanced VVO uses the Volt-VAR function of smart ac inverters to elevate the voltage level (flatten the voltage profile) more than conventional capacitor banks. This enables the voltage regulator(s) to lower the voltage along the feeder even more, resulting in lower average voltage for all customers, and improved overall efficiency. Figure 4 depicts the DER-Enhanced VVO results.

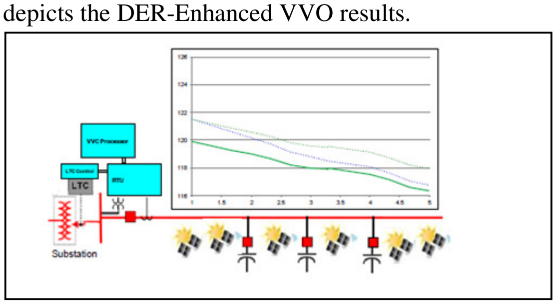

Figure 4: DER Enhanced VVO

FAULT LOCATION AND SERVICE RESTORATION WITH DER

For heavily loaded feeders, some service restoration activities may be blocked due to lack of spare capacity on adjacent feeders. One solution is to install additional automated switches that are able to split the feeder into smaller parts that can be transferred between heavily load feeders. Another solution is to provide more ties to adjacent feeders and thereby split the load transfer between several backup sources. Both of these approaches are expensive solutions.

Another possible solution is to trigger demand response capabilities or use DERs (energy storage, distributed generators, etc) to supply a portion of the load during such emergencies, thus reducing the amount of load that must be transferred following the fault. Figure 5 depicts this proposed solution.

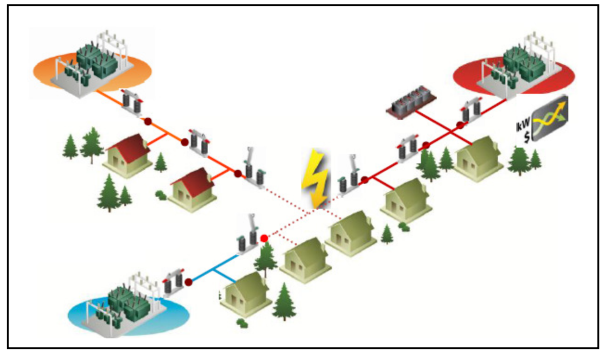

Figure 5: DER Enhanced FLISR

CONCLUSIONS & RECOMMENDATIONS

Distributed Energy Resources of various types are becoming increasingly common in utility distribution systems. Technology improvements continue to add new capabilities and drive down cost, raising the likelihood that higher penetrations of these devices will come. Fortunately, the present levels are low in most circuits, and the utility industry has time and opportunity to develop a framework of standards for multi-vendor interoperability to guide the arrival of these devices and their integration. A proactive approach is much preferred, rather than waiting until penetrations are high, and reacting to the cost and maintenance complexity associated with incompatible devices and applications.

The collaborative work performed by the power industry over the last few years in the area of smart inverter standards and field network protocols was a good first step toward preparing for higher penetration of distributed energy resources.