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Volt/VAR Optimization and Interoperability with other Grid Modernization Initiatives

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SUMMARY

Volt/VAR Optimization (VVO) is a technology that was introduced to the utility world many years ago. Since its introduction, the electric distribution grid has been going through evolutionary changes in the way energy is generated, transmitted, stored, delivered and monitored. Many of these advances are 'Grid of the Future' programs that utilities across the country (and the world) are embracing and implementing to keep pace with technology and customer expectations. They include Advanced Metering Infrastructure Smart Meters (AMI), distributed Solar and Wind Generation, Fault Location and Isolation, Battery Energy Storage, Advanced Distribution Management Systems (ADMS), and others. VVO is a Grid of the Future technology that optimizes the power flow to the customer. It reduces the voltage to the lower level of the acceptable range, and simultaneously, adjusts VAR elements for unity power factor.

When originally introduced, VVO was typically a stand-alone technology. Utilities would install VVO on one substation that did not have any other advanced devices or schemes. At its inception, there were few, if any, Grid of the Future type schemes on distribution feeders, so isolation was easy. As Grid of the Future technologies, devices and schemes were introduced, utilities would still try to separate the feeders with VVO. This was done purposefully because the VVO scheme was often not advanced enough to work in unison with other Grid of the Future schemes. However, with the explosion of smart grid technologies, the philosophy had to change. VVO could no longer be isolated on a feeder, separated from other schemes. It became necessary and desirable to have multiple smart grid schemes running simultaneously on the same feeders. As a result, VVO will have interaction and must have concurrent interoperability with all Grid of the Future technologies.

This paper will discuss how National Grid is expanding VVO across all its jurisdictions, how the VVO interacts with many Grid of the Future technologies, and what National Grid is doing to test and prove the interoperability.

KEYWORDS

Volt/Var Optimization, VVO, Interoperability, Grid Modernization, Grid of the Future, Smart AMI Fault Location, Isolation and System Restoration, FLISR, Distributed Generation, Battery Energy Storage

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National Grid's history with VVO

Volt-VAR Optimization (VVO) is a technology that is designed to deliver the lowest possible voltage (without violating local jurisdictional guidelines for voltage delivered to the customer) and optimize the reactive power (VAR) to near-unity power factor; thus, providing the most efficient energy delivery to the end user. National Grid began introducing Volt/Var Optimization technology (VVO) to the distribution network in 2015 and has been expanding it ever since. Beginning with a pilot in Rhode Island, then a second pilot in NY, the results were favourable enough that it has now expanded to multiple substations throughout Rhode Island and New York. The first substations in Massachusetts were outfitted with VVO in 2019. Through a formal RFP bid process, National Grid selected Utilidata to be the vendor/partner for VVO technology. Utilidata's trade name for their VVO system is AdaptiVolt.

AdaptiVolt is a software application that monitors substation and distribution line activities and executes operational decisions based on real-time data from managed devices and sensors. Simultaneously, AdaptiVolt feeds near real-time status of feeder conditions back to National Grid's Energy Management System (EMS) thus, enabling System Operators to monitor conditions and the health of the distribution system.[1] EMS also has control capability over AdaptiVolt and can perform various functions on the system.

National Grid undertakes a thorough process to evaluate feeders throughout its network to select the feeders that would benefit the most from the VVO technology. Under consideration are feeder characteristics like demographics (residential vs commercial), load, peak load, current operating conditions and planned construction/expansion. After selecting the candidate substation/feeders, National Grid's distribution engineering group conducts a system simulation analysis of the feeders. From this simulation, a plan to upgrade the feeders for optimal VVO operation is developed.

VVO Deployment and Operation Highlights

To enable the VVO System, the substation and distribution network typically require considerable upgrades to the existing equipment. Main-line voltage and var control devices on the feeder need to be retrofitted with advanced controls and must communicate back to AdaptiVolt. Data transmission from the field and substation can be accomplished in several ways. National Grid tested different options and decided on using the cellular network. Each device and substation are retrofitted with a cellular radio that transmits local conditions and receives control commands. Below, is a simple diagram[2] that shows how VVO works as a system.

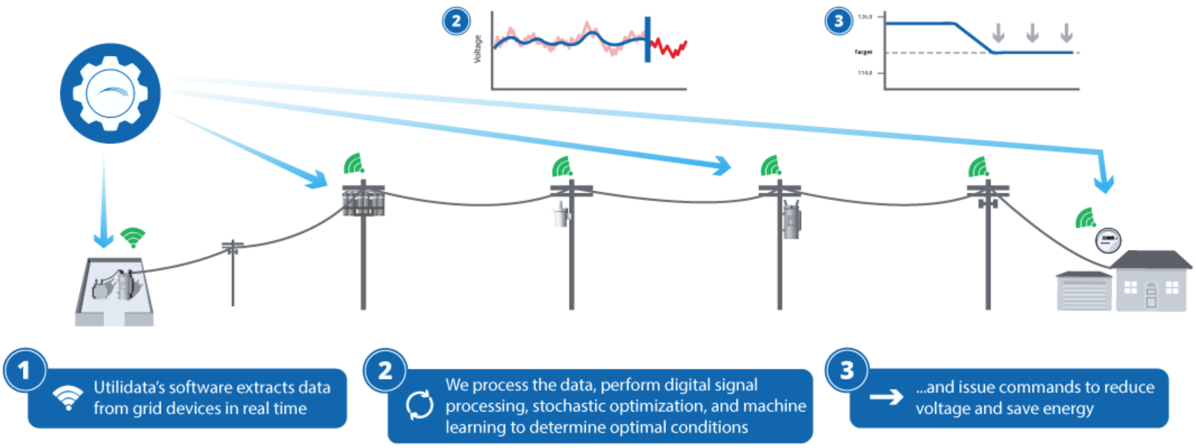

Diagram 1; VVO Operation[2]

When deploying the advanced controls for each asset, the devices are configured for two basic operating modes. When AdaptiVolt is enabled, the controls are in remote mode. When AdaptiVolt is disabled, the controls are in auto mode.

- Remote: the device is communicating with and is being controlled by the VVO system.

This is normal VVO operation.

- Auto: the device operates as an independent unit, running on local settings based on a model. This is needed when VVO is disabled, either by design or due to a fault.

As each device is upgraded, it is set on auto mode until all the work is completed and the system is run through its site acceptance test[3]. Then, VVO is enabled and the devices are switched to remote mode. Additional information about the operation will follow in the sections related to interoperability.

As stated earlier, VVO is designed to deliver the lowest possible voltage and optimize the reactive power (VAR) to near-unity power factor. To accomplish these goals, as demonstrated in Diagram 1, the voltage and VAR are monitored at every field device, and at the end of the 3-phase mainline. By monitoring all of these points in real time, the system is able to react to dynamic load changes and adjust assets based on what's happening now, not what a model says it thinks might be happening.

AdaptiVolt operates based on a hierarchy of control. It will first look at the entire feeder voltage and adjust voltage regulating devices to reduce system voltage to its lowest possible level, while maintaining the ANSI guidelines for minimum voltage at the customer's meter. This is referred to as conservation voltage reduction (CVR). After the voltage is at its lowest operational level, AdaptiVolt will make a decision on the VAR, switching capacitors to attain unity power factor. After each capacitor operation, the system will look back at the voltage and, if needed, make more adjustments to voltage regulating devices.

Monitoring the system voltage and VAR levels is continuous. When enabled, AdaptiVolt will never stop monitoring and optimizing voltage and VAR. The target efficiency gain is 3% to 5%. This continual monitoring and adjusting is necessary to compensate for fluctuations and changes due to normal variations in the load, as well as to account for other technologies that impact the grid. The following sections will show how VVO will act/react to other Grid of the Future technologies.

<u>VVO Interoperability with Distributed Generation (DG) Sites:</u>
The amount of DG on the nation's grid is increasing at an exponential rate and is projected to continue for the foreseeable future. There is now no way to avoid having a VVO system without encountering DG, from small behind-the-meter residential installations, to large scale solar farms. The VVO system must be smart and agile enough to account for sudden and significant changes in energy injected onto the grid from these DG sites. A large cloud mass on an otherwise sunny day could introduce significant changes

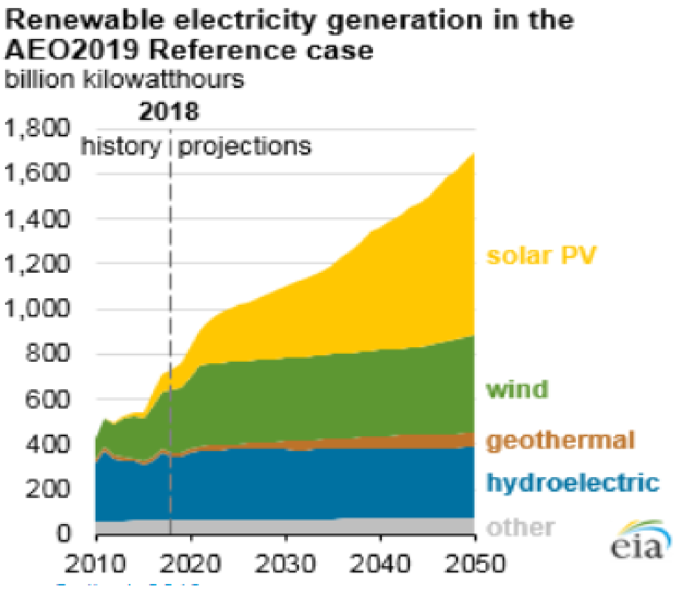

Figure 2: Historical and Projected Growth of DG[4]

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To account for this, the VVO must be able to work in unison with smart inverters and detect and react to these changes. This includes having smart controls that can sense and report on reverse power flow, should that occur. On all VVO feeders, National Grid deploys regulators and smart controls that can detect varying levels of reverse power flow and change the operation of the regulators as needed. In conjunction with this, the VVO system monitors the controls and adjusts its decisions when reverse power flow is detected. This is done automatically and requires no manual intervention. When forward power flow is restored, the VVO system will revert to normal operation. The AdaptiVolt system has been successfully used at other utilities on feeders with high DG penetration. National Grid, in conjunction with the New York State Energy Research and Development Agency, is running tests on a community solar project in Clifton Park, N.Y. where a VVO system is already deployed and actively managing DG.[5] Additionally, National Grid is planning a pilot to test the VVO system under high DG conditions in Western Massachusetts.

<u>VVO Interoperability with Battery Energy Storage</u>
With the ever-expanding electronics and electric vehicle markets, battery technology has rapidly advanced to create smaller devices with a longer lasting charge. At the same time, the price has decreased, making it more attractive for new applications. Recent McKinsey & Company research suggests that, “Low-cost storage could transform the power landscape”.[6]

McKinsey research has found that storage is already economical for many commercial customers to reduce their peak consumption levels. At today’s lower prices, storage is starting to play a broader role in energy markets, moving from niche uses such as grid balancing to broader ones such as replacing conventional power generators for reliability, providing power-quality services, and supporting renewables integration.[6]

Battery energy storage can be used to improve the quality of the distributed energy on the grid and from that standpoint, works seamlessly with VVO. However, two of the applications that intersect with VVO operation are battery back-up for power restoration and energy storage for use during times of peak demand.

Battery back-up, as McKinsey states, is like having an automated generator when power goes down on the grid. A battery back-up system can power up to several homes for several hours, until the grid power is restored. In this application, VVO will typically be disabled, so there is no interaction with VVO.

However, for peak shaving applications, battery energy storage is treated like any other DG site. Energy storage systems have control settings that can be used to optimize local power flow conditions and creates a synergy with the VVO’s traditional optimization scheme. The intelligence from the battery storage and other monitoring devices help to predict conditions and can be used to identify optimal charge/discharge operations of energy storage systems throughout the day to co-optimize with primary VVO operations and enhance overall performance.

National Grid is studying the battery storage technology in the context of VVO and currently does not have plans for a pilot. Utilidata is continuing to enhance their algorithm for battery storage applications.

<u>VVO Interoperability with Advanced Metering Infrastructure (AMI)</u>
Like DG, adoption of AMI is also increasing across the country. The advanced metering infrastructure market was valued at USD 7.75 billion in 2019 and is expected to reach USD 17.0 billion by 2025, at a compounded annual growth rate (CAGR) of 14% over the forecast period 2020 - 2025. (See Figure 3) Smart meters represent a transformative technology for the utility industry. These technologically advanced meters provide greater insight into the usage of energy at the point of use (the

Figure 3[7]

customer's site). In the case of smart electric meters, they ensure enhanced control of the electrical grid. Smart meters have been employed as a part of advanced metering infrastructure development initiatives around the world.[7]

Unlike DG, AMI is not disruptive to the grid, in that it doesn't inject changes in the energy profile. Additionally, AMI adds intelligence to the system, providing the means for greater accuracy and more efficient energy delivery.

When AMI is deployed concurrently with VVO, the VVO system can capture all the signal information from the meters and incorporate that intelligence into its decision-making process. There is a difference between the real time data collected by VVO and the AMI Data. The AMI Data is a periodic data dump (usually several hours old). The VVO system will analyse this data over 30 days and build a model of the feeder voltage profile. Using this model in conjunction with the real time data, VVO can gain about 30% improvement in efficiency, from a typical 3% overall voltage reduction, to about 4%. National Grid is in the planning phases of an AMI/VVO pilot in New York.

VVO Interoperability with Fault Location, Isolation and System Restoration (FLISR)

A key driver for upgrading system operation is reliability; minimizing the time customers spend without electricity. A common practice to improve reliability statistics is to incorporate automated techniques to identify, isolate and restore power as quickly as possible. FLISR works just like its name implies: when deployed in the field, it automatically locates a fault and attempts to minimize the impact to customers by isolating the fault to as small of a geographic area as possible and restoring service to as many customers as possible. This scheme is an automated self-healing operation where all the FLISR devices are networked and communicate with each other. The algorithm built into the control allows the network of reclosers to operate independently and automatically.

VVO works seamlessly with FLISR. All control points for the FLISR devices are configured in the VVO system. Whenever a fault occurs and a FLISR device changes state, the VVO does one of two things, depending upon how it's programmed:

a. The VVO system can revert to an Alternate Configuration that is pre-programed in the system. The alternate configuration considers new monitor and control schemes and adjusts decisions accordingly.
b. The VVO system can disable. This is the preference when there are many different options for FLISR reconfiguration.

National Grid is incorporating FLISR across Massachusetts and has multiple locations where FLISR and VVO are deployed on the same circuits. The current operating model uses option (b); VVO is disabled when a fault occurs. Further studies will evaluate incorporating option (a) where possible.

Conclusion / Summary

National Grid is committed to improving the quality and efficiency of delivering energy to the end customer, and VVO, along with all the other Grid of the Future technologies, will continue to be a key player in this effort. To ensure that the full benefits of these technologies are realized, they are all going to have to "play nicely in the sand box" together. That is, they must be interoperable without human intervention.

National Grid has been deploying VVO for several years and working closely with the VVO supplier to develop ways of utilizing VVO in conjunction with new and emerging Grid of the Future technologies. To date, National Grid has evaluated many of them and is either testing or planning to pilot interoperability studies. All results indicate that this will be a successful strategy and VVO will continue to be deployed throughout the National Grid territory.

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