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A Systematic Approach Using Distribution Data to Optimize the Grid Implementing a Distribution Volt Var Control Algorithm

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SUMMARY

The wealth of data being monitored on the electric distribution system is opening new opportunities for cost savings and improved energy usage efficiency. Applying a combination of two voltage control concepts into a sophisticated algorithm applied systemwide after careful studies is creating value for utilities and their customers.

As the electric utility industry's regulatory models continue to change, one of the major focus areas is creating value for utility customers. How will we create this value? Where will it come from? How can this value be tracked and quantified? Many utilities across the country and the world are looking at dozens of new technology solutions to address these challenges.
The concepts of Volt/VAR Optimization (VVO) and Conservation Voltage Reduction (CVR) have been researched extensively, and the U.S. Department of Energy (DOE) has partnered with multiple national laboratories, universities and dozens of utilities to evaluate the benefits of VVO and CVR as a way to bring value to the customer in the form of energy usage reduction and the associated cost savings. In this paper, we will explore some of the benefits and challenges seen at Southern California Edison behind implementing VVO and CVR beyond the pilot projects and into a new distribution systemwide operating model.

There are many operational benefits that can be realized from DVVC. Because DVVC is a data-driven algorithm, it requires the investigation and verification of assets, equipment settings and operational configurations, which if addressed properly can benefit many other groups within the organization. DVVC can be used for overall energy reduction and savings or just during peak for peak shaving to see benefits. Some of these benefits are:

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- Reduced feeder energy consumption
- Increased power factor at the substation bus
- Lower VAR demands from the sub-transmission or transmission levels
- Lower system losses
- Optimized asset control for line and substation capacitors, LTCs and voltage regulators

Southern California Edison (SCE) has had a communication system for automating distribution assets as well as smartmeter data for years, and in 2016 began using these technologies to apply these Distribution Volt VAR Control concepts. They have worked with vendors to develop a custom algorithm specific to the SCE system to control capacitor banks to fine tune the voltage and VARS on each feeder. After an initial test and measurement, SCE has started to roll out this algorithm using their Distribution Management System (DMS) to hundreds of substations in various regions of their territory.

We will discuss the challenges faced in implementing this algorithm and feeder-specific settings. These challenges include system and feeder characteristics, prioritizing voltage vs. power factor, customer voltage requirements, too much or not enough data, and using system models.

Finally, we will discuss lessons learned from the system rollout, and successes that SCE has had in implementing the program. As we have more data from the system, and we fine-tune the algorithm implementation, we will discuss the long-term forecast for DVVC at SCE.

KEYWORDS

Distribution
Volt/VAR Control
Volt/VAR optimization
Customer Focus
Energy Savings
System Optimization
Conservation Voltage Reduction
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PAIRING CONCEPTS FOR SYSTEMWIDE IMPROVEMENTS

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VOLT/VAR OPTIMIZATION:

VVO is the practice of tightly controlling voltage and volt-ampere reactive (VAR) flow of an entire system to reduce energy losses and shave peak demand.

Studies have estimated VVO could potentially save 2 to 3 percent of annual U.S. electricity consumption. While VVO concepts have been used for decades, only recently have regulators begun to emphasize power quality, energy efficiency and reliability savings. More capacitor banks and voltage regulators are being installed to resolve multiple efficiency issues, including low voltage, high voltage, power factor at the load, as well as power factor at the sub-transmission bus level. More advanced VVO systems use network-based feedback to these devices from a centralized control system that evaluates voltage and VAR flow on a system level as opposed to localized device control. As we continue to build out the grid's communication infrastructure, we can implement these centralized algorithms systemwide. The benefits of VVO are further enhanced by pairing with the benefits and control of a CVR scheme.

CONSERVATION VOLTAGE REDUCTION:

CVR is reduction of the service voltage at the customer connection to reduce energy usage. Most electrical equipment loads consume less power at a lower voltage.

A DOE evaluation of CVR schemes schemes found, on average, a 1 percent reduction in voltage at the customer connection point correlated to a 0.8 percent reduction in energy usage. By pairing VVO with CVR, utilities are utilizing as many assets as possible to reduce the system and end point voltage. The more distribution system assets used to support VVO and CVR control schemes, the greater the value to the utility and end customer.

Together, VVO and CVR have more recently been referred to as Distribution Volt/VAR Control (DVVC). We will use DVVC as an example of the dual-use system, but may reference the individual benefits of each technology for clarity. DVVC is often implemented as a control algorithm programmed to achieve optimal distribution voltage profiles and VAR flows on the distribution system.

These control systems can either be run as a third-party application algorithm that might interface with a Distribution Management System (DMS) or Energy Management System (EMS). Alternatively, the algorithm can be embedded directly into the DMS or EMS. The choice of whether to run a third-party application or an embedded application should be evaluated based on each utility's existing systems. The interface with these management systems can often be difficult to implement in either scenario, and often the technology is new, so it is recommended to bring in outside expertise to help with the challenges.

Some of the factors affecting each implementation scenario could include expected life span of current DMS/EMS implementation, number of automated distribution assets, urgency of implementation and existing dedicated resources. For example, if a utility recently went through a management system upgrade, it may be more challenging to implement the algorithm if it was not included in the original scope of work. The complexity of these systems might require additional engineering resources for implementation, with reductions in resource requirements after the control algorithm has been implemented systemwide. However, it should be understood that DVVC will not be a “set it and forget it” algorithm. Given how dynamic the distribution system is, this algorithm will require consistent maintenance and upgrades, just like many other systems within the utility.

BENEFITING FROM COST SAVINGS AND OPTIMIZATION

There are many operational benefits that can be realized from DVVC. Because DVVC is a data-driven algorithm, it requires the investigation and verification of assets, equipment settings and operational configurations, which if addressed properly can benefit many other groups within the organization.

Average energy reduction is usually about 2 to 3 percent on a systemwide basis. Each individual feeder may see reductions anywhere from zero to 4 percent, depending on existing properties of the feeder.

The main driver for DVVC is usually cost savings for the customer, which are primarily realized through reduced energy consumption. These energy savings are realized by first lowering the average system voltage, then smoothing out the feeder voltage profile to reduce the change in voltage (voltage drop) from the substation to End-of-Line (EOL). For lowering average system voltage, feeders without any existing low voltage issues can see the most energy savings. (For circuits with low voltage problems, DVVC can increase the EOL voltage to reduce violations, but this will lead to reduced energy savings.) The financial savings in the system come from a combination of lowering EOL voltage, reducing energy consumption, smoothing out the feeder voltage profile, optimizing VAR flows and reducing system losses. This allows for additional circuit capacity as well as overall operational efficiency gains.

DVVC OPERATIONAL BENEFITS

- Reduced feeder energy consumption
- Increased power factor at the substation bus
- Lower VAR demands from the sub-transmission or transmission levels
- Lower system losses
- Optimized asset control for line and substation capacitors, LTCs and voltage regulators

To smooth voltage profiles and reduce voltage drop, utilizing more automated equipment like line capacitors and voltage regulators on the feeder will result in increased savings.

Feeder length, conductor size and distribution of load all affect the voltage profile and potential energy savings. DVVC systems that use only automated distribution capacitor control often have lower energy reduction than systems also using voltage regulators and substation load tap changers (LTCs).

Depending on the regulatory environment, DVVC also could be implemented for peak shaving — it would turn on at peak as a demand response mechanism to reduce energy consumption during peak demand, when potential savings have the greatest financial impact. Or the system can be implemented as “normally on” with operational control to disable the algorithm when required. Since voltage drop on the feeder scales with the load level, the largest difference in voltage from substation to EOL is seen at peak loading, and therefore less savings can be seen from lowering average voltage at peak. Because the electric system is designed to maintain voltage for the end customers during these periods of large voltage drop, the average system voltage can be lowered more during off-peak periods, and the utility can see the largest energy savings during these times. However, energy savings realized during peak demand can have larger financial impacts.

DVVC also enables a centralized distribution power factor (PF) control, which can find optimal capacitor and tap changer configurations mathematically to optimize systems. Many DVVC systems allow for programmable input limits of PF (e.g., 0.98 lagging or 0.99 leading as a bandwidth for operation). The algorithm will then review all possible combinations of line equipment settings and select the optimal configuration to achieve an operating scenario within the PF limits.

In most solutions, voltage requirements (i.e., ANSI/IEEE C84.1) also become a limiting factor. For example, if the algorithm finds a solution that would open a capacitor bank, it will only choose that solution if opening the capacitor bank will not cause any localized voltage issues. The utility will need to decide whether the algorithm will prioritize optimizing voltage, which would provide greater financial savings from average system voltage, or power factor. The latter is more common in areas with low PF from large air conditioner or motor loads. The voltage measurements could either be taken from SCADA measurements at the line device or directly from the customer Advanced Metering Infrastructure (AMI) meter.

The PF control on the distribution system is a valuable benefit as it leads to better operational efficiency, as well as providing benefits to better utilize more Distributed Energy Resources (DERs) to the system. Both of these can be huge drivers for creating value for the end customer.

Another benefit of DVVC systems is better asset utilization and operational tracking. The electric system is currently designed to handle those few peak demand days each year. This means many of the assets are underutilized, called upon only a few days a year to meet that peak demand. DVVC aims to increase this asset utilization by finding new operating configurations and tracking operation frequency. DVVC algorithms are able to track the number of operations for each asset and could be integrated to create reports for asset management teams to review for asset maintenance, replacement or relocation. Historically, many distribution assets have been neglected when it comes to maintenance, in part because of the cost to monitor the large number of assets. Increased asset utilization can sometimes lead to additional costs to add monitoring or operational intelligence. The benefits of better reliability, power quality and higher efficiency provide a counterbalance to the added operation and maintenance costs.

BALANCING VOLTAGE POSES VARYING CHALLENGES

As with any new technology, utilities should be prepared to face plenty of challenges along the road to implementation. Numerous resource pieces of the utility puzzle need to fit together for DVVC to work. Data must be aggregated from different platforms such as mapping, metering data, system models, EMS, DMS and Outage Management System (OMS) to a centralized location for analysis. Because this is effectively a new operational technology, everyone from engineers to operators and managers needs to understand how it may affect their business, and might require additional training. The initial design will take additional engineering resources to address the implementation, and afterward the maintenance and updates to the system will require a team of dedicated resources.

The system and feeder properties themselves can be some of the biggest challenges. As discussed earlier, the biggest of these is existing low voltage at the EOL. For example, take a feeder that supplies 5,000 customers with AMI meters. When you look at typical loading profiles, either high or low, you may find that multiple customers saw low voltage during a given day. Sometimes it is a distribution transformer issue, an undersized secondary, or maybe an old cable splice that was never documented. It could be a number of variables that caused the low voltage, but based on the meter data, it is now known that the voltage on that feeder, at that loading level and point in time, cannot be reduced any further. While this voltage data has been available to the utility for as long as it has had an AMI system, utilities often have never investigated the data at the level of detail required for DVVC. The use of a DVVC algorithm and smart meter data can help identify and fix these weak points in the system. A DVVC system can help prioritize maintenance for the distribution system. These investigations take time and often require a lot of work to process and determine the validity of the data. The creation of algorithms to clean and normalize data is essential to the time effectiveness of the solution.

In some cases, these challenges may lead to making more conservative assumptions, limiting the initial effectiveness of the algorithm. However, as data analytics tools continue to advance and as the algorithms become smarter, we will gain greater visibility into our distribution system, which will allow us to react more quickly to address issues in the future. As the system algorithm is implemented, updated and revised, the distribution system will be able to react dynamically. And as more equipment is monitored, it will continue to optimize. It is important to start this process as early as possible to meet the utility's needs as the system grows and becomes smarter.

Existing high voltage can also be another challenge for DVVC implementation. To date, much of the electric grid has operated on the higher end of the voltage profile. This was attributable to many reasons, whether to resolve low voltage issues downstream or to allow for more kilowatt-hours to be delivered to the customer. But times are changing, and the operational focus of utilities is shifting to energy efficiency. The problem is, if the voltage is too high at the distribution substation level — the starting point of the DVVC control — then the algorithm will only be able to reduce the voltage a small amount using line devices. Either it will only be able to push LTCs to their max taps (not able to reduce voltage any more) or it will open all the capacitors to address high voltage concerns. Without all the capacitors playing into the algorithm, the system may not be able to meet the VAR and PF limits that were set. Therefore, for maximum benefit, the system must be analyzed as a whole, rather than from the low side of the distribution substation down. Again, systemwide data analysis and studies can be used to determine ideal substation voltage, which, when addressed, can lead to a more efficient and stable system.

There is a constant balance between voltage and VAR demands, and that is the real benefit of a tried and tested volt/VAR control algorithm. That is, there is a voltage sweet spot — DVVC can fine-tune and optimize the system, but it will only optimize to the specifications created by the system engineers. To avoid these problems, utilities should conduct preliminary studies to understand the design and challenges of their system, and make sure the DVVC software vendor walks through the optimization to make sure it matches how they would prefer to address these challenges.

Often the biggest limitation to ideal energy savings is a lack of accurate system models. As modeling software, documentation and data management systems improve, creating accurate system models is becoming more feasible. As utilities across the country evaluate these new technologies, distribution engineers are frequently asked, "Could we run a study or a simulation for DER (distributed energy resources) planning?" This often receives the response, "It depends." It typically depends on the availability of accurate network models for your system (or how much work it would be to create or update them), and very few have accurate models. With every passing year, it becomes more essential for utilities to maintain these accurate models.

Having these system models benefits all aspects of distribution system design, operation and maintenance. However, the lack of accurate circuit models is one of the top barriers to grid modernization. Engineers fall back on conservative assumptions because of the lack of faith in the data's integrity. Now, with modern technology and data analytics, utilities can use DVVC to push the grid into the next generation. Implementing a DVVC program is a great opportunity to dedicate resources to updating these models, as they will become integral in the future Automated Distribution Management Systems (ADMS) or Distributed Energy Resource Management Systems (DERMS).

CONCLUSION

DVVC concepts have been around for decades, but they were always limited in their effectiveness because of a lack of centralized control, network connectivity to distribution assets, and the availability of network models. As the electric utility industry has begun to invest in networks, communication and automation, the building blocks are being set in place to enable these new technologies.

Especially in an environment where the grid is stressed with increasing application of distributed energy to help address renewable portfolio standards, DVVC provides potential solutions to some challenges that are still coalescing. Once a utility has built an AMI system and has network connectivity to distribution assets, preconditioning and DVVC are logical next steps. Many of the benefits increase value and save money for the customer and the utility, and the inherent challenges help encourage the utility to improve its operations and planning for the next-generation grid.