Conservation Voltage

A Low-Risk, High-Return Opportunity for Electric Utilities

Prepared by

THE SHPIGLER GROUP
STRATEGY MANAGEMENT CONSULTING SERVICES

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Executive Summary

Conservation voltage offers the potential for electric utilities to utilize controls over the voltage levels of the distribution network to enable real operational gains. While utilities typically operate in the upper range of the ANSI voltage band under normal circumstances, voltage can be compressed during key periods in a way that benefits utilities and consumers. Numerous studies have shown that for each 1% drop in voltage levels, mean energy consumption for residential and commercial loads can be reduced by .8%, although this value can vary depending on load mix and distribution system configuration.

One of the reasons that this field offers so much value to utilities is the high benefit potential relative to implementation cost. While many system automation programs can take many years to achieve payback, many voltage management programs offer payback in 2-3 years, and many are even more cost effective than that.

Another benefit stems from the varied system approaches that can be employed, with potential program targets including load reduction, improvement in voltage profile, voltage quality improvement, and other areas of operational benefits. As such, utilities can develop their own approaches to build a program that best suits their needs.

The Concept of Voltage Management

Electric utilities have historically extracted as much value and efficiency as possible with manual controls. Today, however, we see a major shift in the thinking within the electric utility industry as it approaches the issue of building the electric infrastructure to ensure reliable and cost effective service delivery given a rapidly changing industry. One of the areas of focus for many electric utilities involves the active and automated management of voltage levels.

Many smart grid programs involve the ability to maintain more constant voltage levels throughout the system. This is critical for digital equipment, which is a characteristic of our post-industrial information economy and is expected to grow further in the years ahead. Advanced Voltage and VAR optimization (VVO) technologies can help drive value creation by improving electric distribution system operations. Advanced VVO is made possible through dramatic improvements in sensors, communications, control algorithms, and information processing technologies that monitor and control voltage levels across the distribution system. Broadly speaking, voltage management programs offer utilities the potential to lower voltage during peak periods to achieve demand reduction, support energy conservation efforts, and reduce energy losses. Doing so provides the potential to defer capital investments, improve asset utilization, reduce generation requirements, and support more efficient utility operations.

The Department of Energy reported that 26 out of 99 projects in the Smart Grid Investment Grant program involved some element of voltage management. Some of the key findings included:[1]

- The majority of the projects reporting hourly load data demonstrated line loss reductions of up to 5%, with 16% exceeding 5% line loss reductions. The DOE concluded that industry estimates of the potential for reductions of 5-10% were possible.
- Feeders with the worst baseline power factors (i.e. those with the highest amount of inductive loads) showed the greatest reductions in line losses.
- Overcompensation for reactive power was observed in a number of feeders. The potential line loss increases were mitigated by operating capacitor banks for voltage support rather than reactive power compensation.
- Overall, peak reduction potential was generally found to be in the range of 1.0% to 2.5%.

Studies have shown that a typical electric customer in the United States experiences 40 to 60 sag events per year with those events resulting in the voltage dropping between 60 to 90%, each lasting several cycles to more than a second.[2] Digital quality power represents 30% of the total electric load and could reach 50% with power system upgrades. Integrated Volt/VAR control (IVVC) throughout the supply delivery system can help to identify the cause of line losses and ultimately reduce them over time. In response to measurements, load tap changers

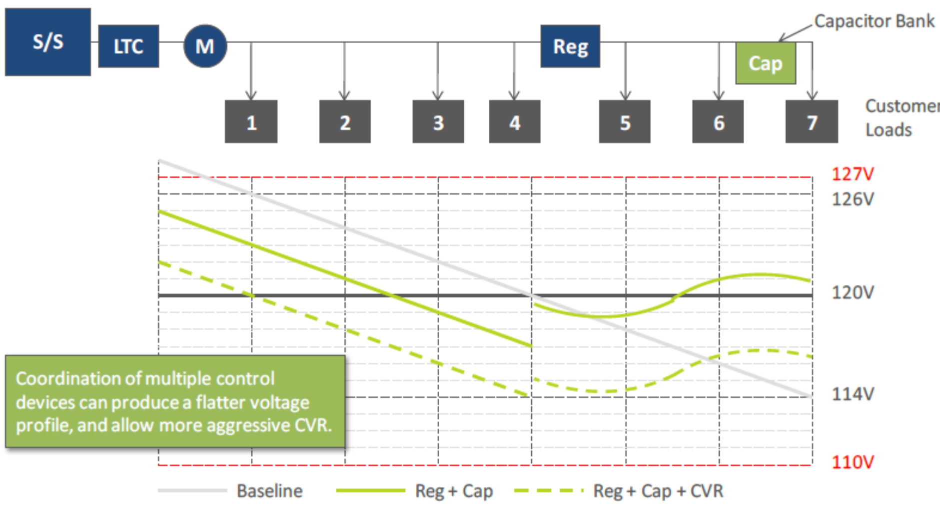
[1] "Application of Automated Controls for Voltage and Reactive Power Management – Initial Results" (December 2012). U.S. Department of Energy.
[2] Mali, V.P., Chakrasali, R. L., Aprameya, K. S., "A Technical Investigation of Voltage Sag" (2015). American Journal of Engineering Research (AJER), Volume-4, Issue-10, pp-60-68.

in substation transformers can reduce voltage to minimize losses. Automated capacitor banks are used for central power factor correction at main and group distribution boards. Power factor correction means that reactive power charges levied by electricity suppliers can be avoided. Improving the power factor has a direct impact on the amount of loss that occurs. With reduced system losses, the emissions and costs of associated generation can also be reduced.

The Value Proposition

Conservation voltage offers fundamental operating support for the distribution network. Volt/VAR control offers the potential to maintain acceptable voltages across all points along the distribution feeder under all loading conditions. In addition, utilities are able to use the system for some key opportunities:

- Improve efficiency by reducing technical losses through voltage optimization
- Reduce system demand through voltage reduction
- Promote a "self-healing" grid
- Support deployments of distributed generation, energy storage, and other distributed energy resources



[3]

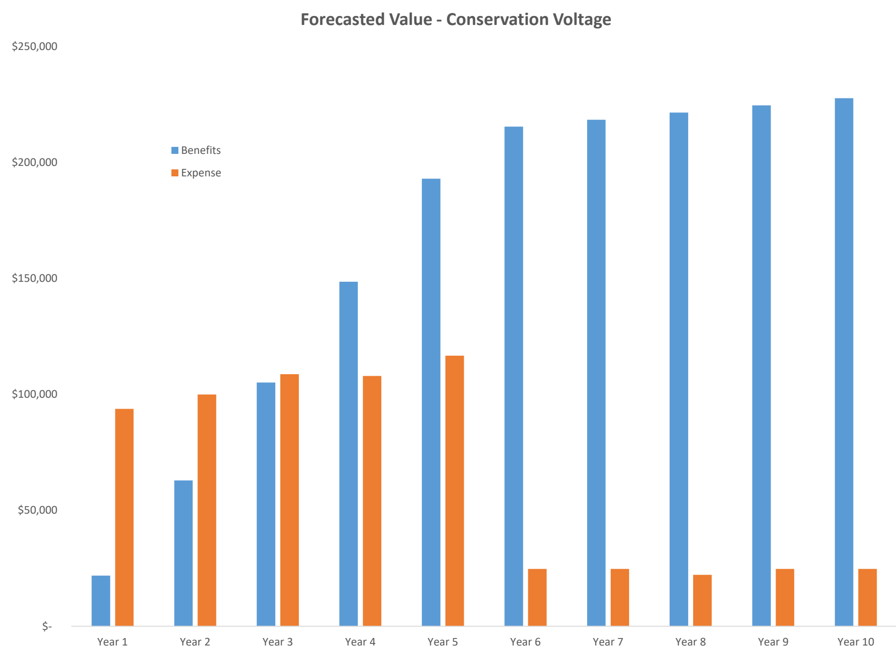
Most utilities operate their distribution feeders in the upper range of allowable voltage levels. As a result, voltage management systems deployed by utilities can often conserve on system demand while still maintaining customers in the lower portion of the range. By doing so, there are a number of potential benefits that can be captured:

- Deployments have demonstrated consistent results in optimization, with demand reduction of 1.5% – 2.1% and energy reduction of 1.3% - 2.0%
- Voltage management often serves as an easy and painless solution for both the utility and its customers
- The system is cost effective because it typically leverages existing equipment
- Implementation is fairly quick relative to many other automation programs

[3] "Application of Automated Controls for Voltage and Reactive Power Management – Initial Results" (December 2012). U.S. Department of Energy.

- There are a number of potential additional benefits, including reduction in the number of tap changer operations, improvement of the overall voltage profile, and support for early detection of voltage quality or regulator issues

The economic impact of these programs can be significant. Consider the case of a municipal utility with 100,000 customers:



The ten-year benefits of the program is estimated to be $12.4 million, while the total cost – including system maintenance – is calculated at $4.9 million. The excess value of $7.5 million can be further augmented when considering the residual long term margins that exist beyond the initial forecast period.

System Architecture Options

There are different approaches that may be considered in the deployment of a voltage management system. These systems should not be considered one-size-fits-all; rather each utility should consider the potential costs and benefits associated with a potential deployment. Broadly speaking, there are three main system approaches a utility might consider:

Approach	Concept	Pros	Cons
Standalone	Voltage control managed by individual Volt/VAR regulating devices	Low cost, limited communications requirements, scalable	Not self-monitoring, poor coordination, suboptimal operation
Rule-Based DA Control	Controlled by SCADA with preset rules	Improved efficiency, self-monitoring, override capabilities	Not scalable, not very adaptable to changing rules, limited efficiency gains
Distribution Model Optimization	Coordinated optimal switching for all voltage control devices	Fully coordinated and optimized, flexible, can support feeder reconfiguration	Higher cost, larger deployment required, learning curve required

For a small utility with simple needs that may be isolated in one or a handful of feeders, the standalone approach can work very well. In this scenario, the utility can deploy resources on a select number of feeders and drop voltage at the feeder bus. This works especially well if the utility has already measured voltage levels across the feeder and found that voltage levels are fairly consistent and do not require regulation. This standalone approach works in isolation, eliminating any need for backend systems to automate or manage the voltage drops. The operator simply monitors load conditions and makes a decision to drop voltage when conditions call for it. Of course, this approach does not offer the benefits of coordination or monitoring; it is all up to the system operator to make sure to lower and appropriately re-elevate voltage levels. However, for a smaller system, this offers a low-cost and simple approach to voltage management.

The rule-based DA control approach calls for a higher level of automation that leverages the existing SCADA system. While early substations required manual switching or adjustment of equipment and manual collection of data for load, energy consumption, and abnormal events, the increasing complexity of distribution networks has resulted in the growth of automated supervision and control from a centrally attended point. This allows for the overall coordination in case of emergencies and to reduce operating costs. Today, standardized communication protocols such as DNP3, IEC 61850, and Modbus are used to allow multiple intelligent electronic devices to communicate with each other and supervisory control centers. Distributed automatic control at substations effectively forms the foundation of the rule-based

DA control system, where the voltage management system is controlled by SCADA with pre-set rules. With this approach, increased coordination can occur as backend systems are integrated into the SCADA system and much of the system operation is managed automatically and without the constant handling of a system operator. Of course, this approach costs more than the standalone approach, but a utility managing a wide variety of feeders at one time can typically justify the added expense due to the higher benefit potential.

Meanwhile, the distribution model optimization approach calls for full coordination. In addition to providing the utility with the capabilities to reduce voltage dynamically to manage the load profile, there are a number of other benefits that can be captured, including dynamic feeder optimization, where the utility can manage reactive power issues, thereby leading to significant reductions in line losses. This approach involves the full complement of equipment integrated into a system that supports feeder reconfiguration capabilities and offers the greatest potential benefit to larger utilities with diverse systems, despite the significantly higher upfront cost.

Summary

The inherent flexibility and potential payback of voltage management systems results in an increasing number of utilities interested in exploring the option. Each utility that is interested in investigating a voltage management option would be wise to consider the following factors before deciding on a set approach:

- What are the key sources of potential benefit that can stem from a conservation voltage program?
- Will feeder lengths and line conditions require significant regulation in order to properly run a program?
- How much control does the utility want to maintain in-house and how much would be better to be outsourced to a third party?
- Is the business case based on realistic system design and the resultant forecasted benefits and costs?