The balance of power

Volt/var management improves grid efficiency

GARY RACKLIFFE – The operators of electric power distribution systems are constantly under pressure to increase efficiency, better manage feeder voltages, reduce feeder losses and reduce peak demand. Further, the cost of incremental or peaking generation capacity, as well as siting and environmental considerations, has driven them to find more effective ways to meet capacity requirements using existing equipment. Improving volt/var management on distribution feeders provides an ideal opportunity to meet all these challenges.

Title picture
With increasing numbers of renewable sources coming online and customer loads becoming more demanding, power grids are being pushed to their limits. Advanced volt/var management helps utilities tackle this challenge.

Volt/var control is not a new concept for utilities. A great deal of effort, dating back to the development of distribution systems, has been spent countering the impact of reactive power and voltage drop. The effective management of distribution feeder voltages and losses ensures that voltages are kept within the operating bandwidth defined by standards. This means that consumer equipment will operate properly and the power factor can be optimized, allowing reactive losses to be reduced.

Many factors influence volt/var management, such as the type of consumer load, which can be resistive – like traditional lighting – or inductive, as is found in machine motors, for example. The integration of distributed energy resources such as solar photovoltaic (PV), distributed energy storage, electric vehicle charging infrastructure and microgrids to the complexity of distribution grid operations and volt/var management on distribution feeders.

Effective volt/var control has capital investment implications too: The peak demand in a system usually lasts less than a few hundred hours a year. Active demand management on the distribution system, including controlled demand response and volt/var optimization (VVO), can very effectively reduce the peak demand on the whole electric grid. By shaving these peaks, the need for expensive generation capital investment can be reduced.

However, the complexity and the dynamic nature of distribution feeders makes the management of voltage and reactive power extremely challenging.

> Active demand management, controlled demand response and VVO can very effectively reduce the grid peak demand.

Voltage regulation

Voltage regulation is one of the most important components of volt/var management and involves the management of feeder voltages under varying load conditions. Substation transformers equipped with load tap changers and line voltage

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1 ABB power capacitor banks

regulators help control service voltages, primarily for radial distribution feeder systems. Optimized feeder voltages improve power quality by preventing overvoltage or undervoltage conditions and achieve a flatter voltage profile along the feeder.

Generally, power systems require the supply of both real power (watts) and reactive power (vars). Real power, or the active component, is supplied by a generation source and delivers the active energy that does real work for the customer. Reactive power can be supplied by either a generation source or a local var supply such as a feeder capacitor bank or controllable solar PV inverter. The reactive component does no real work, but it takes up part of the energy delivery bandwidth. Reactive power compensation devices are designed to reduce or eliminate this unproductive component of power delivery and reduce losses. Utilities prefer to address var management locally since the delivery of vars through the power grid results in additional voltage drop and line losses. Because the load on feeders varies, utilities meet the var requirements by switching local reactive power compensation devices such as capacitors, connecting them during high feeder loading and disconnecting them during periods of low feeder loading. The capacitor banks can be located in the substation or on the feeders. Optimized var flow improves power factor and can result in substantial expenditure savings in energy, capacity requirements and infrastructure utilization.

The integration of voltage regulation and var management enables conservation voltage reduction (CVR). Here, system demand is reduced by controlled voltage reduction within approved limits at the customer service points. CVR further reduces losses and lowers overall energy consumed, which also reduces generation capacity requirements and emissions. CVR can typically lower demand by 2 to 4 percent – important for utilities that are capacity-constrained or that face peak demand charges in their power purchase agreements.

The benefits of distribution communications

Centralized radio control systems were introduced into utility systems about 30 years ago and have since evolved to two-way communications that have enabled closed-loop volt/var management systems. In addition, more advanced sensors, and communications-enabled controllers for field devices that manage feeder voltages and reactive power flow, are available. These systems continually sample loads and voltages along feeder circuits and switch compensating devices to improve feeder power factor, manage feeder voltages and reduce demand. They also enable automated CVR.

2 PS vacuum switches

3 ABB CQ900 smart capacitor controller

Model-based volt/var management

There are a number of factors driving the use of distribution system models in the operations environment. In the early 1990s, distribution models started to migrate from planning to the operations environment. System connectivity, the location of protective and switching devices, and knowledge of customer location permitted more accurate outage prediction engines. Shorter customer outage times and more efficient use of field crews were the result.

Additional business drivers include demand reduction, energy efficiency, enhanced asset utilization and better distribution situational awareness. Technical drivers today include improved computational power for handling large distribution models and investments by more utilities in advanced geographic information systems (GISs). These drivers, coupled with the availability of cost-effective sensors, intelligent devices and communications, and grid models, have led to the deployment of effective volt/var management systems.

CVR further reduces losses, lowers overall energy consumed for generation and reduces emissions.

ABB volt/var control solutions

ABB has three volt/var management systems that manage and control voltages and reactive power flow on the distribution grid.

Volt/var management software (VVMS)

VVMS is a scalable system for closed-loop voltage and var control. It continually samples loads and voltages along feeder circuits and, when appropriate, switches compensating devices such as capacitors, line voltage regulators and transformer load tap changers. VVMS can operate as a stand-alone volt/var control solution or it can be functionally integrated with supervisory control and data acquisition (SCADA) or distribution management systems (DMS). VVMS is interoperable with many different SCADA, DMS, control hardware and communications systems. This gives customers a short lead time, capital investment protection and freedom to use the most appropriate hardware and communications products.

DMS 600 volt/var control system (VVCS)

VVCS provides full SCADA system functionality and a VVO application that uses system information from the DMS 600 database and configured thresholds to

Model-based volt/var management has had a major impact on operations.

In VVO, the as-operated state of the system, including near real-time updates from SCADA and outage management systems, is used.

4 DistribuSense sensors

determine the optimal capacitor bank and voltage regulator configuration. The VVCS application does not require a full DMS model – it uses measured values reported through SCADA and configured setpoints to determine the optimal solution. It implements this solution with remote automatic or manual control of the capacitor banks and tap positions on the voltage regulators. Also, the VVCS provides tools for comprehensive network topology management using standard GIS models, and provides real-time status data, connectivity analysis and distribution topology representation.

The model-based VVO advanced network application in Network Manager DMS

In VVO, the as-operated state of the system, including near real-time updates from SCADA and outage management systems, is used. Distribution companies are then able to maintain the precise voltage control needed to implement CVR without violating customer voltage limits. Model-based systems can consider changes to the network as they occur, including load and capacitor bank transfers between feeders, and changing load conditions. Optimal solutions are developed that account for circuit topology and the feeder distances that affect voltages and var flow throughout the entire feeder.

This application mathematically optimizes the settings for each device using a GIS-derived model of the grid. The application uses switchable capacitor banks, line voltage regulators and the controllable taps of transformers as the optimization control variables.

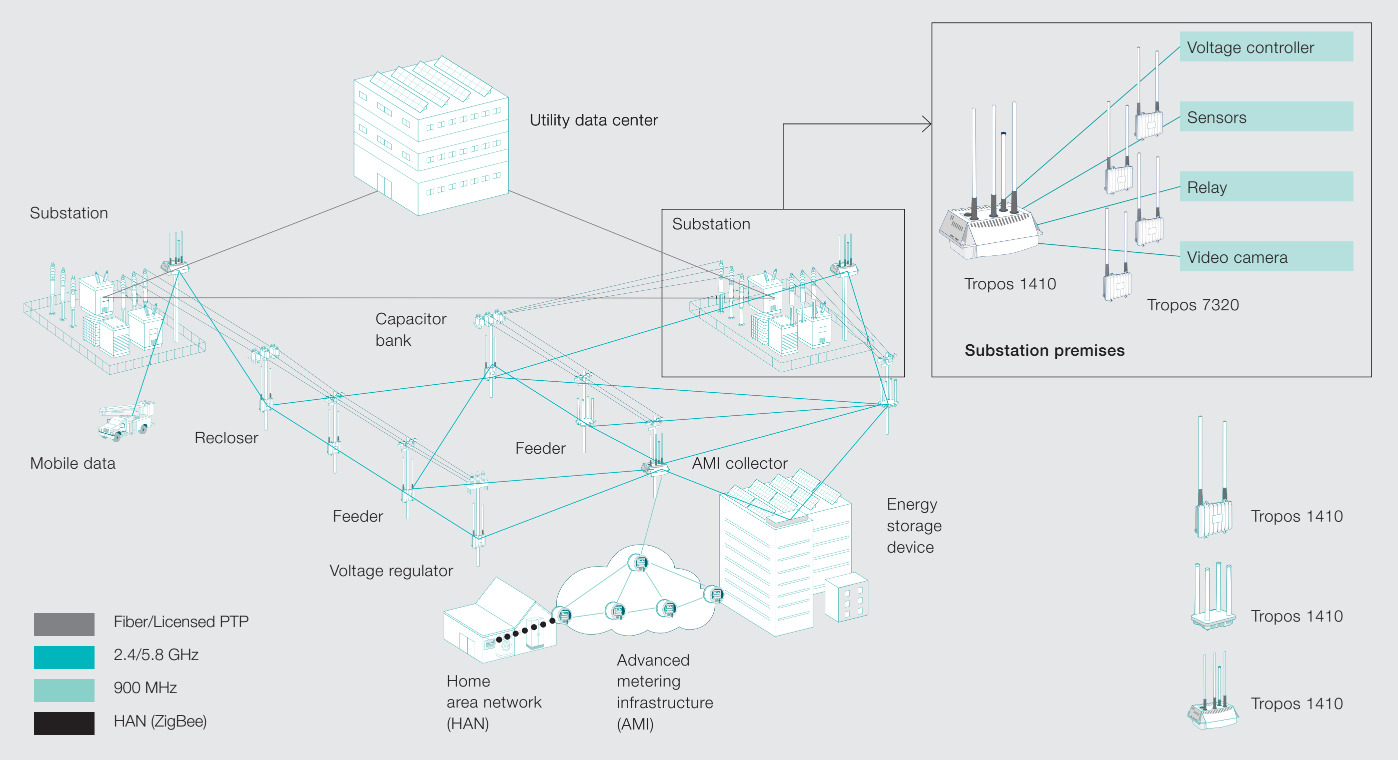
Model-based VVO will also enable distribution operators to accommodate new complexities, including increased renewable generation located at distribution voltage levels, more automated fault location and restoration switching schemes, increased system monitoring and asset management processes, and expansions in electric vehicle charging infrastructure.

Supporting hardware and infrastructure

ABB supplies a complete portfolio of support hardware and infrastructure for volt/var management.

ABB power capacitor banks provide an economical way to apply capacitors to a distribution feeder system to provide voltage support, lower system losses, release system capacity and eliminate power factor penalties → 1. The banks are factory pre-wired and assembled, ready for installation.

The PS vacuum switch is a solid-dielectric vacuum switch suitable for use in distribution systems up to 38 kV ungrounded (grounded: 66 kV) → 2. The switch has been specifically designed and tested in accordance with ANSI C37.66 for heavy-duty operation in capacitor-switching applications with the harshest climatic conditions.



ABB's CQ900, the next generation of smart capacitor controllers with two-way communications, is designed specifically for capacitor applications and advanced volt/var management applications ➔ 3.

The ABB DistribuSense™ current and voltage sensor product family enables increased feeder intelligence and drives timely decision-making for volt/var control and CVR applications ➔ 4. ABB's latest in outdoor sensing technology, the DistribuSense WLS-110 sensor, combines VLS-110 voltage monitoring with state-of-the-art, precision-cut, split-core current transformer technology.

Wireless communications systems

ABB's Tropos provides an industry-standards-based wireless IP broadband network ➔ 5. It includes outdoor, mobile and indoor mesh routers. The patented Tropos mesh operating system was built from the ground up to meet the challenges of mission-critical outdoor network deployments. It has directional radio for point-to-point and point-to-multipoint communications and a carrier-class centralized management and control system. Using these building blocks, Tropos systems are used to construct the most resilient, scalable, high-performance and secure networks for utilities, municipalities, mining and industrial customers.

Benefits

Volt/var management helps utilities move from blind operation to feeder management with multiple measurement and control points, end-to-end instrumentation on the feeders, and closed-loop control for automated optimization. The increasing penetration of variable, renewable generation sources, and the increasing diversity and variability of loads, are creating fertile ground for volt/var management.

Utilities are also running closer to their limits than ever before, making the ability to optimize within operating parameters extremely important. OG&E, a large American utility, for example, is at the forefront of implementing model-based VVO to combat these challenges. VVO enables OG&E to maximize the performance and reliability of their distribution systems while significantly reducing peak demand, minimizing power losses and lowering overall operating costs.

If a vertically integrated utility can also optimize power factor, they have to generate less power to satisfy demand. This also benefits the environment in terms of reduced fossil fuel consumption. Further, good power factor control avoids having to pay financial penalties for out-of-specification operation. Strategies such as CVR can reduce costs even more: Overall system demand reduces by a factor of 0.7 to 1.0 percent for every 1 percent reduction in voltage. From a consumer perspective, this reduces the energy they consume. From a utility perspective, it reduces the amount of power they need to generate or purchase from a generator. There is an obvious benefit associated with reduced operating costs, but to the extent these strategies can be implemented to defer investment in new generation capacity or to address reduced capacity due to old generating assets being taken offline, the benefits can be enormous.

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