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PG&E Stabilizes Network During Peak Loads

Static var compensators provide voltage support in Silicon Valley.

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Deregulation and the high cost of building new transmission lines have put many owners of North American transmission systems under increasing pressure to maximize asset utilization and, at the same time, to maintain present levels of reliability. Utilities are constantly faced with assessing the economics of major investments to refurbish aging infrastructure for improved asset static var compensator (SVC) management.

In this article, Pacific Gas & Electric Co. (PG&E; San Francisco, California, U.S.) addresses reliability related issues arising from aging infrastructure and summarizes the successful application of FACTS (Flexible Alternating Current Transmission Systems) technology equipped with smart digital control systems to sustain system performance upon retirement of existing synchronous condensers. PG&E found that SVCs offer an economic alternative to maintain and enhance bulk system dynamic reactive reserve margin and address voltage stability-related challenges.

A Need For Voltage Support

Rapid load growth in California’s Silicon Valley has reduced system reactive margin considerably, thus increasing the risk of voltage collapse. For this reason, voltage support at Newark Substation is vital for the operations of the 115-kV and 230-kV system at peak loads, because the 115-kV and 230-kV systems approach voltage collapse levels for a single line outage.

Synchronous condensers at the 230-kV Newark Substation now provide voltage support for the South Bay and Silicon Valley. PG&E is experiencing serious technical, operational and environmental problems with the six condensers installed at Newark Substation. The advanced age (60-plus years) of the equipment substantially increases the probability of a catastrophic electrical failure. PG&E will replace the aging condensers with a SVC to provide increased reliability, while maintaining an acceptable and necessary reactive reserve margin to prevent voltage instability and avoid blackouts in the Bay Area.

Bay Area Transmission System

The San Francisco Bay Area has some local generation but also imports electricity from outlying 500/230-kV substations and their connecting 230-kV transmission lines. The figure above shows the existing generation and transmission system in the Bay Area. Most of the existing generation is concentrated in the northeast Bay Area (the Pittsburg/Contra Costa region). Major generating units in San Francisco are the Hunters Point and Potrero power plants, which also are major sources of reactive power support in the area. Tesla, Metcalf and Vaca Dixon 500/230-kV substations are the three major bulk transmission sources that provide additional load-serving support for the Bay Area. Various 230-kV interconnections from Moss Landing Power Plant and The Geysers geothermal plants to the Bay Area also result in higher power...
import capability for load serving purposes.

In addition to the voltage support provided by generation in the area, there are several synchronous condensers (dynamic devices) and shunt capacitors (static devices) available for voltage support at 115-kV and 230-kV voltage levels. Newark Substation is a major source in the Bay Area because of its location and strong electrical interconnections with neighboring substations via 230-kV and 115-kV networks.

**Aging Assets at Newark Substation**

The six synchronous condensers were installed between 1934 and 1943. Two of them have been derated from 15 MVA to 10 MVA because of cable failure and several other breakdowns requiring repair. The collateral equipment is largely original, including breakers, oil pumps, regulators and controls. Maintenance and water treatment are of increasing concern, and their unreliability is another primary cause for possible retirement. It is becoming increasingly difficult to keep the units operating and to know they will be on-line to respond whenever a system disturbance occurs.

The six Newark synchronous condensers are closely coupled to the tertiary windings of the 230-/115-kV transformers at Newark. This close coupling makes the banks vulnerable when synchronous condensers or associated switches and breakers fail.

Historically, the cooling water has been chemically treated to control scale formation and biological growth in the heat exchangers, piping and cooling towers; cooling water blow-down was discharged into an open field. As a result of stricter environmental regulations, this practice was discontinued. Today bio-fouling and scale are of great concern, and no matter what method is used to treat or flush the systems, it is now an expensive proposition.

All synchronous condensers are expensive to maintain compared with traditional substation equipment. Periodic overhauls are expensive because the condensers are large horizontal salient-pole machines, but the overhauls are required to ensure reliability. A mobile crane is used to disassemble the condenser for inspection and repair. In addition, the cooling water system is high maintenance. The condensers are cooled using open cooling towers, requiring makeup water. The cooling towers also need periodic cleaning and their relatively short life means added refurbishments or replacement expenses.

**Analysis & Recommendation**

PG&E performed a reactive margin sensitivity analysis of the Bay Area transmission system and determined that the dynamic reactive support currently available from these synchronous condensers at Newark is an absolute necessity to maintain system reliability, especially with continued load growth. The VAR support maintains an acceptable and necessary reactive reserve margin to mitigate voltage instability from unscheduled generation and transmission contingencies during high load conditions.

During 1999, an additional 225 MVAR of shunt capacitors were added at Newark Substation at the 230-kV level to improve voltage profile in the area. Because slow-switched conventional capacitors do not provide dynamic reactive support, the system’s dynamic reserve margin (to prevent fast voltage collapse) was not noticeably improved.

The need for dynamic support to minimize the risk of voltage collapse, particularly during disturbances on the 230-kV system, remains critical in the Bay Area. There are also three 50 MVAR 115-kV shunt capacitors at Newark that provide load-serving support in the area. Based upon study results, the recommended plan was to replace the six synchronous condensers with a single SVC system.

**Keeping the Power On**

The most critical failure point of an SVC system is the transformer, which would result in 100% loss of the system. For the SVC system, a “firm bank” comprised of three single-phase units plus a spare unit with associated bus work (typical for PG&E), will be employed. This will allow restoration of service within hours should a transformer phase fail. SVCs are widely used around the world both for their capabilities and for their low maintenance costs; the devices have no moving parts, so repairs are minimal.

PG&E issued a request for proposal to various qualified FACTS suppliers using a competitive bidding process. ABB was awarded the project after completion of a careful bid evaluation process by the PG&E project team. Technically, ABB’s solution offered a robust design ensuring high availability and reliability of the SVC unit. ABB also was able to commit to a 12-month turnkey delivery time to meet the critical in-service date.

The SVC will be connected to the 230-kV system at the Newark Substation and will consist of one 154 MVAR thyristor-controlled reactor (TCR), one 166 MVAR thyristor-switched capacitor bank (TSC) and two 27 MVAR filter branches tuned to the fifth and seventh harmonic respectively, giving the SVC an operating range from 100 MVAR inductive to 220 MVAR capacitive. The SVC is connected to the 230-kV grid via three single-phase power transformers.

The SVC is controlled by a microprocessor-based control system that provides facilities for SVC control, either from the operator workstation (OWS) in the SVC control room or remotely via a conventional RTU/SCADA system.

The normal mode of operation is automatic voltage control. The voltage
control system is a closed-loop system with positive sequence voltage control. The voltage regulator must be fast enough to counteract voltage variations and disturbances and also retain an adequate stability margin. The positive sequence voltage on the 230-kV side of the SVC transformer is compared with a set voltage reference and controlled by the automatic voltage regulator. Since this is a closed-loop voltage control mode, it is not possible to operate in automatic mode if the voltage response is lost. If this happens, the SVC controls will automatically be switched to manual mode.

FACTS Technology Arrives
The SVC was purchased from ABB after a competitive bidding process. The project, which took about a year to deploy, came on line at the Newark Substation in June of 2002. ABB built a separate control room at the Newark Substation for housing the thyristor valves and all associated control systems including the MACH2 computer workstation for controlling the static VAR system.

Capacitors and Harmonic Filters
Three 75 MVAR mechanically switched capacitor (MSC) banks are connected to the 230-kV bus at Newark Substation and incorporated into the SVC voltage control to optimize operation by keeping the SVC operating within ±40 MVAR, thus maintaining the dynamic SVC range for contingencies.

In automatic SVC mode the MSCs are either in or out of service, depending on the capacitive power demand monitored by the SVC. In manual SVC mode, the MSCs are controlled from the OWS in the SVC control room. In remote mode, the MSCs are controlled remotely from the PG&E system operations center via the RTU/SCADA, independently of the SVC control. Should the SVC for any reason trip for an internal fault while the MSCs are in operation and controlled by the SVC, the MSCs will remain in operation and automatically assume remote mode. Harmonic filters (HF) usually are required to keep voltage distortion in the network at acceptable levels. The HF is capacitive at the fundamental frequency and contributes to the net capacitive output of the SVC. Newark SVC meets specified distortion requirements.

Conclusion
Adding the SVC with associated capacitors, filters and controls in the Bay Area will help maintain an acceptable and necessary reactive reserve margin to provide voltage stability during unscheduled generation or transmission contingencies under high load conditions, which otherwise could result in blackouts in the Bay Area.

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