STATCOM replaces critical urban generation for voltage control and stability

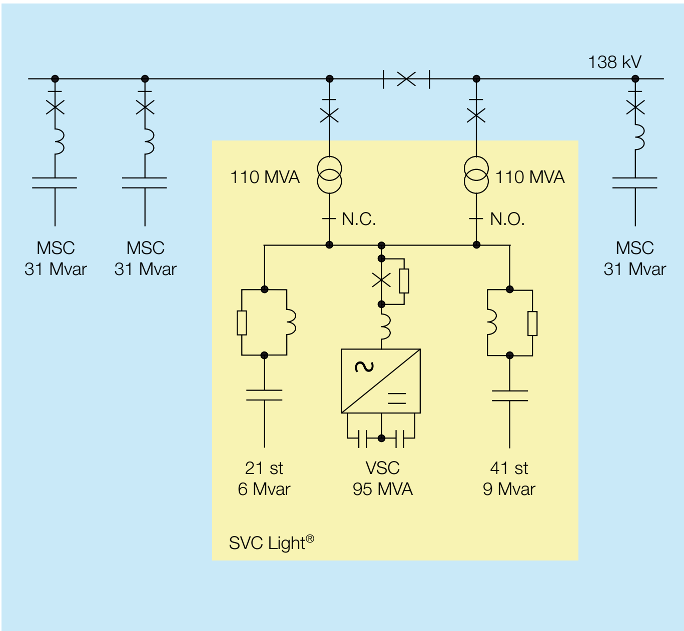
Since 2005, Austin Energy, the public utility serving Austin, Texas and the surrounding area, has been operating an ABB-supplied STATCOM on its 138 kV power system. The STATCOM, rated at 80 Mvar inductive to 110 Mvar capacitive, replaces the Holly oil- and gas-fired power plant near downtown Austin, which was constructed in the 1960s and early 1970s. Due to the plant's age and reduced use, the availability of more cost-effective generation elsewhere, and concerns of nearby residents regarding noise and other environmental factors, Austin Energy decided to close the plant.

Retirement of the power plant without a reliable dynamic reactive power source would be detrimental to the transmission system's voltage stability. Due to the abundance of high-tech sensitive loads in the region, a fast response to help recover from voltage sags is a particular concern for Austin Energy. Flexible AC Transmission Systems (FACTS) technology was considered as a possible solution. To provide the voltage stability and reactive power that would be lost with the closure of the generating plant, Austin Energy initiated a study to determine the size, type, location and connection voltage of a FACTS solution. Space was scarce at the Holly site and ambient noise was a major concern. In addition, some concerns existed about magnetic fields contributing to forces in rebar and in an oil tank beneath the site. For these reasons, the study ruled out an SVC and instead recommended installation of a STATCOM at the Holly 138 kV bus, along with three 31 Mvar mechanically-switched capacitor banks (MSCs) controlled by the STATCOM. Austin selected an ABB STATCOM, also known as SVC Light®, which uses insulated-gate bipolar transistor (IGBT) power semiconductors.

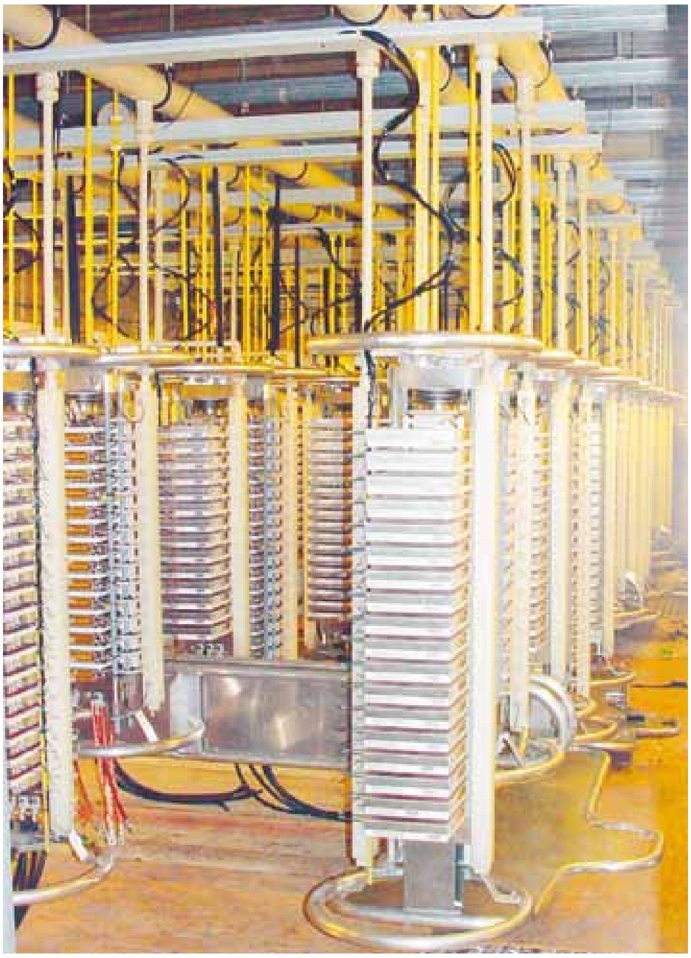
To save space and to address ambient noise concerns, the complete STATCOM, except for the step-down transformers, is housed inside a two-story building. In addition, due to the acoustic noise screening requirements, the phase reactors and harmonic filters are enclosed and the step-down transformers are equipped with additional light-weight sound insulation walls.

Main circuit design

A simplified single-line diagram of the Holly STATCOM including the dual redundant step-down transformers and the three 138 kV MSCs is shown. The STATCOM is based on a voltage source converter (VSC), which inherently has symmetrical operation. It is rated at +/- 95 Mvar, and has 15 Mvar of harmonic filters (all ratings as seen from the 138 kV bus). In total this gives an operating range from 80 Mvar inductive reactive power to 110 Mvar capacitive reactive power. A coupling (phase) reactor that connects the STATCOM to the transformers is also part of the scheme. Furthermore, the three 138 kV MSCs, each rated at 31.2 Mvar, are available to provide steady-state reactive power support to the grid. This results in a total reactive power range for the STATCOM system of 80 Mvar inductive to just above 200 Mvar capacitive. The dynamic capability is twice the VSC rating of 95 MVA, or 190 Mvar.



Single-line diagram, STATCOM and MSC.



VSC: IGBT valve stack.

As indicated earlier, the VSC is inherently symmetrical in its current operating range. This is particularly beneficial in a system of this kind because it allows the system to be optimized for fast response in both the inductive (i.e. over-voltage suppression) and the capacitive (i.e. under-voltage support) modes while minimizing the losses. The passive filters provide harmonic filtering for the higher harmonic frequencies generated by the converter, and marginally offset the STATCOM in the capacitive range. Furthermore, control of external devices such as mechanically-switched capacitor banks and tap changers can be incorporated in the control system. Specifically for the Holly STATCOM, control of one on-line tap changer (OLTC), three 138 kV 31.2 Mvar MSCs and one existing 69 kV 31.2 Mvar MSC have been incorporated in the control system. If necessary in future projects, the controls are capable of controlling more OLTCs and shunt capacitor banks than those currently controlled by the Holly STATCOM.

An interesting aspect of this system is that the entire secondary voltage circuit (at 32 kV) is placed indoors. The IGBT converters are always indoor, air-insulated equipment, but in this installation the phase reactors and the passive harmonic filters are also enclosed. The principal reason for enclosing these components is to provide electromagnetic and acoustic screening. However, the enclosure also made it possible to meet strict requirements on vermin-proofing.

Operating strategy

The STATCOM utilizes the MACH 2 control system, a common control platform used for all ABB FACTS and HVDC projects. The MACH 2 platform is optimized for robustness under disturbed grid conditions, and is designed to be user-friendly and to easily facilitate coordinated control of many objects.

For the Holly application, the MACH 2 controller is configured to automatically switch the three 138 kV MSCs as needed. This operating strategy forces the fixed capacitor banks to be the major producer of reactive power support during slowly-varying conditions in the system. This leaves the STATCOM ready to rapidly respond to power system disturbances by providing dynamic reactive power support. This applies to both over-voltage suppression and under-voltage support.

The MACH 2 controller also switches an existing 69 kV capacitor bank and the tap-changer position of the Holly 138/69 kV auto-transformer. These voltage control mechanisms are slower than the switching controls of the 138 kV capacitor banks and are designed to both improve the slow voltage profile on the 69 kV system and minimize reactive power flow through the auto-transformer.

The STATCOM is able to operate continuously at system undervoltages, with the reactive power capability falling linearly with the voltage. During low-voltage conditions, the STATCOM will supply constant current. At extreme low voltage - down to 0.4 p.u. - operation can be maintained provided that the station auxiliary power supply remains at nominal voltage. For nearby power system faults (with the 138 kV bus voltage dropping severely) lasting up to 100 milliseconds, and the subsequent post-fault voltage recovery sequence, the STATCOM can operate without restriction.

For transmission system overvoltages, the STATCOM will provide inductive reactive power. For dynamic overvoltages up to 1.3 p.u., the STATCOM is able to operate temporarily at its inductive limit.

Holly STATCOM site

The site view of the Holly STATCOM shows the STATCOM building to the left, and the three 138 kV MSCs in the center and to the right in the picture. The two step-down transformers are located behind the MSCs. One transformer is always in hot standby mode (connected in open circuit).

Operational experience

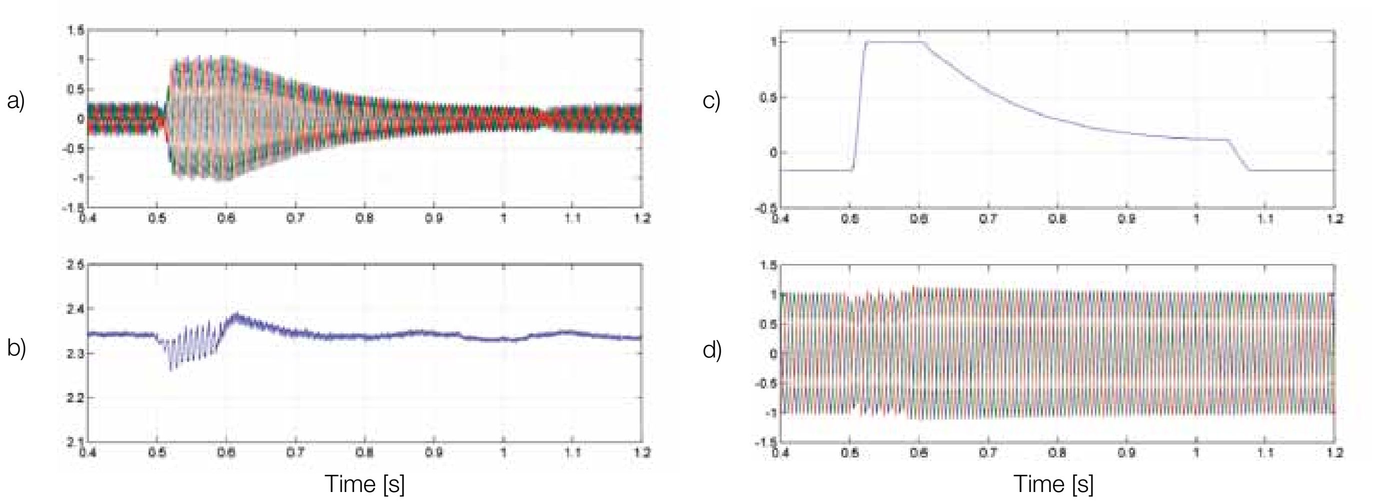
The benefit of the STATCOM's support to the transmission system was demonstrated during severe thunderstorms that hit the central Texas area in November 2004. There were several faults on the 138 kV system, lasting about five cycles each, that resulted in the STATCOM producing its maximum capacitive output. The picture on page 3 shows some plots related to one of these faults. The plots were obtained from a built-in transient fault recorder. The capacitor bank control was disabled at the instant of the disturbance and the initial STATCOM operating point was close to 0 Mvar.

The STATCOM responds to the disturbance by bringing its capacitive output to its maximum in about one cycle. A certain asymmetry in the phase voltages is reflected in the DC side voltage (due to inherent active power fluctuations through the VSC). Despite this, the VSC currents are symmetrical during the fault, which can only be achieved by employing PWM switching. Symmetrical behavior is the optimum for supporting stalling induction motors. After the fault has been cleared, the current is ramped down to the initial, pre-fault value in a controlled manner. The STATCOM is then ready to support the grid if another disturbance occurs.

Main technical data

System voltage	138 kV
Dynamic var rating	80 Mvar inductive to 110 Mvar capacitive.
VSC	3-level, neutral point clamping converter; IGBT based, pulse width modulated; Pulse number: 21.
VSC rating	95 MVA
Control system	Three-phase dynamic positive-sequence voltage control, by means of a closed-loop, high-speed digital voltage controller. The control includes switching of three MSCs, each rated at 138 kV, 31 Mvar, for steady-state system voltage control.

Example of STATCOM response during a transmission line fault:
a) Three VSC phase currents
b) DC voltage
c) VSC reactive current reference calculated by the control system
d) 138 kV system line-to-ground voltages.



Site view of the Holly STATCOM.

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