SVC for increased hydro power transmission and power quality improvement in northern Manitoba's 230 kV transmission grid

The Wuskwatim Generation Project in Manitoba, Canada, involves the development of a 200 MW hydropower generating station at Wuskwatim and Taskinigup Falls on the Burntwood River. In addition to the generating station, the project requires new transmission lines and substations to deliver the electricity into Manitoba Hydro's power transmission system. A Static Var Compensator (SVC), commissioned in 2011 by ABB and located at the Birchtree 230 kV substation south of Thompson, Manitoba, is also included in the transmission system. The purpose of the SVC is to enable an increase of the power transfer capability from Manitoba Hydro's northern system by contributing voltage support, preventing excessive first swing transient voltage dips, and power oscillation damping (POD) in the 0.2 Hz to 1.8 Hz range. Due to nearby industrial loads, including a smelter, power quality improvement by means of flicker mitigation is the task of the SVC, as well.

To summarize, the purpose of the SVC is to:
- Control the Birchtree 230 kV positive sequence voltage for steady-state and post-fault conditions
- Mitigate voltage flicker
- Enhance the damping of electro-mechanical oscillations in the 230 kV system

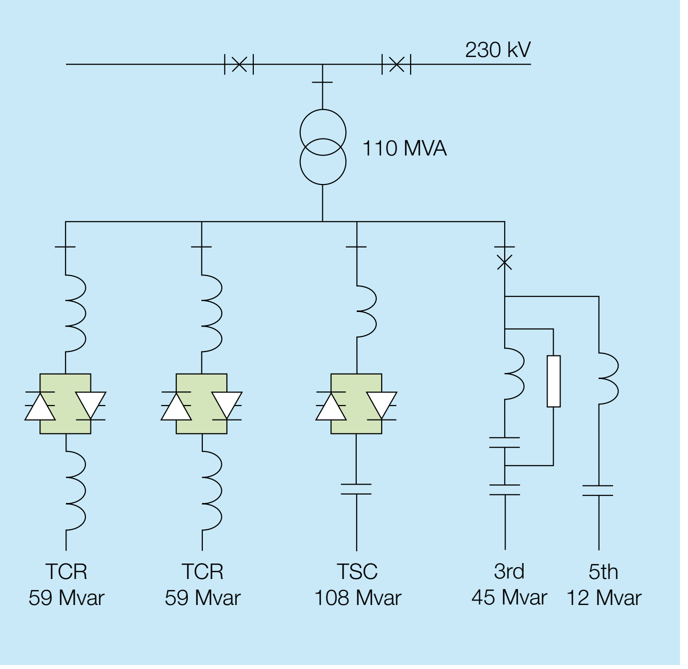
The reliability and robustness of the SVC control system was a major concern due to the weakness of the northern AC power grid in Manitoba. In addition, the Birchtree SVC is within 200 km of another SVC in the grid, as well as several hydro generators, which required careful coordination.

Part of the dynamic range of the SVC is kept in reserve to be available for contingencies. This is implemented as a slow susceptance control towards a pre-set value near 0 Mvar.

Main circuit design

The SVC has a continuous rating of 60 Mvar inductive to 110 Mvar capacitive (-60/+110 Mvar). A short-time rating of +165 Mvar is also provided, to be available for 10 seconds every 30 minutes. This short time capacitive rating is required to prevent excessive first swing transient voltage drops and to assist in damping small signal oscillations. The short time maximum capacitive rating philosophy enables a cost-effective design of the SVC in comparison to having the maximum 165 Mvar continuously available.

The SVC comprises two Thyristor Controlled Reactor (TCR) branches, each rated at 59 Mvar, one Thyristor Switched Capacitor (TSC) branch rated at 108 Mvar, and two harmonic filter branches, rated together at 57 Mvar and tuned to the 3rd and 5th harmonics, respectively. Please see the single-line diagram. The phase-angle control of the TCRs and switching of the TSC result in continuously variable reactive power control over the entire SVC operating range. Splitting the TCR into two parallel branches is required to keep the harmonic generation of the SVC within strict limits for THD (1%) and telephone interference.



Single-line diagram, SVC

SVC control system

The SVC is controlled by a microprocessor based control system. The control system is based on the ABB MACH 2 concept built around an industrial PC with add-in circuit boards and I/O racks connected via standard type field buses. Dedicated voltage and current transformers provide the control system with information of network parameters employed in the SVC control. The normal mode of operation is automatic voltage control with a closed loop controlling the positive phase sequence voltage at the 230 kV bus system.

The control system provides facilities for SVC control from the Operator Work Station (OWS) in the SVC control room, or remotely via a conventional RTU/SCADA system.

Gain supervision

To prevent possible oscillations in the SVC reactive power output in conjunction with changes in the network configuration of the 230 kV system (a wide range of possible fault levels in the grid), the control system is equipped with a gain supervision function to ensure stability in the closed-loop voltage control for several network configurations. In case of oscillations detected in the system, the gain supervision automatically reduces the voltage regulator gain until the SVC voltage reaches stability. The function operates for oscillations in the 10 Hz to 30 Hz range, which is well outside the frequency range of other modes verified in the power system (< 2 Hz), where a Power Oscillation Damping (POD) control actuates.

Power Oscillation Damping

A Power Oscillation Damping (POD) regulator targets to damp grid system oscillations in the 0.2 Hz to 1.8 Hz range. Due to proximity of the SVC to generation units, the input signal to the regulator is the system frequency deviation, which is calculated by the MACH 2 control system. The POD output is added as an extra contribution to the SVC voltage reference set by the operator. The function is automatically disabled for some scenarios, e.g. system under-/overvoltages and high GIC activity.

Overvoltage strategy

The TCR valves are designed to be controllable up to 1.4 p.u. primary voltage. For primary voltages above 1.4 p.u., the TSC is immediately blocked and continuous pulses are applied to the TCRs. If the primary voltage remains above 1.4 p.u. for more than one second, an SVC trip is initiated. The TSC is designed to be able to block at up to 1.8 p.u. which may occur in weak systems following fault clearing if the TSCs are deblocked during the fault.

TSC self-test

The normal operating mode of the SVC during intact system conditions is zero Mvar output. To minimize the risk of the TSC failing when it is required to go into operation, a two seconds self test is executed every week if the TSC has not been in service during that time.

TSC pre-charge and polarity reversal

In order to minimize TSC energization transients, especially during weak system conditions, the TSC is kept pre-charged via controlled firing of the thyristors. The polarity of the pre-charge is reversed periodically to minimize equipment stress.

GIC precautions

During solar storms, the Birchtree ground grid may experience up to 100 A of DC current or geomagnetically induced currents (GIC) for a period of one minute and up to 30 A for a period up to two hours. The primary concern with GIC is the effect that they have on large power transformers, with increased odd and even harmonics generated by half-cycle saturation and equipment damage caused by stray flux heating. The main SVC transformer is a three-phase transformer with a 3-limb core design connected grounded-wye on the primary and delta on the secondary. With this configuration, any DC flux will leave the core going through the non-magnetic tank walls, resulting in a lower DC shift in the magnetic field density in the core. This type of transformer is the least susceptible to being saturated due to GIC.

GIC can also result in additional second harmonic distortion that potentially can impact the operation of an SVC control system. The second harmonic distortion can impact the measurement, protection and synchronization systems. The Birchtree SVC was tested and confirmed to be immune to second harmonic distortion up to 30%. The POD and negative sequence controller are disabled during periods of elevated GIC.

Degraded mode operation

For increased availability, it is possible to operate the SVC in the following degraded modes:

- TSC failure
- Failure of one TCR branch.

Failure of both TCR branches or of the harmonic filters will result in tripping the SVC.

TCR valve with BCT type thyristors

Main technical data, SVC

System voltage	230 kV
SVC rating	60 Mvar inductive to 110 Mvar capacitive (-60/+110 Mvar); -60/+165 Mvar for 10 sec every 30 min.
Control scheme	Closed loop, three-phase symmetrical control by means of a voltage regulator; Negative-phase sequence voltage control for flicker reduction
Thyristor valves	PCT and BCT type thyristors, water cooled, indirect light firing[1]
Mechanical design	High built, snow and ice clearance 3.2 m
Ambient temperature range	-50º C to +40º C

[1]TCR valves: BCT
TSC valve: PCT

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Application Note, 1JNS013773, 2012-11