SVC: a cost and time effective option to a 330 kV grid expansion

Power consumption is increasing at a considerable pace in Western Australia due to the resources boom and the associated population increase. Western Power, owner and operator of the grid infrastructure, was studying various options to accommodate increasing levels of power transfer from independent generating facilities in the south-west without destabilising grid voltage levels that may have led to voltage collapse. The challenge was to find a solution within the existing infrastructure that guaranteed power system security in the south west area, while coping with increasing demand from the rapidly expanding metropolitan area of Perth.

A number of options were considered, including:

- Deferring enhancement of the Network that would require additional generation to be located in the metropolitan area.
- Installing a new 330 kV transmission line, this would have been at a high cost and would have taken a considerable time due to environmental approvals and construction period.
- Installing capacitor banks and synchronous condensers. This did not meet the requirements and was too expensive.
- Installing a Static Var Compensator (SVC).

SVC: the optimum solution

The SVC alternative was considered the most appropriate, as:

- It met the required network load growth (connection of approximately 525 MW of new generation in the region without compromising system security)
- It was possible to implement within the required time frame
- It was the most cost effective and practical solution.

The SVC, supplied by ABB and located at the Southern Terminal Station is rated at 132 kV, 100 Mvar inductive to 200 Mvar capacitive (-100/+200 Mvar) and designed to manage grid voltages following an outage of a 330 kV transmission line. It maintains voltage stability, provides flexibility for transmission equipment outages and balances the increased flow of energy entering the network from new generators.

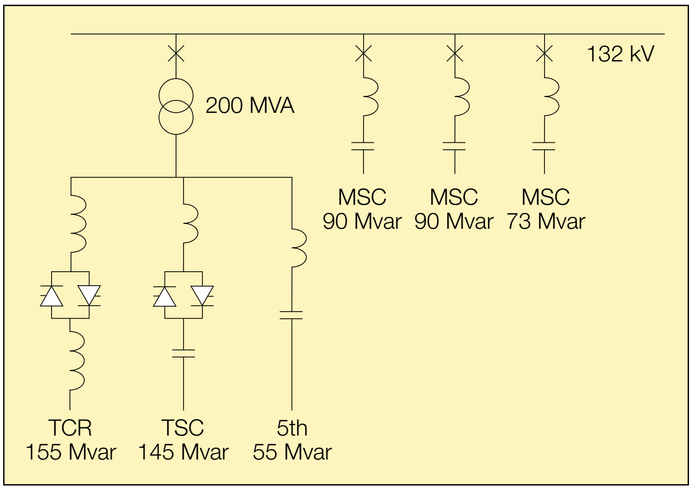
Additionally, the following tasks are performed by the SVC connected to the grid:

- Preventing system over-voltage during load rejection events;
- Enabling the management of power system stability in case of system disturbances/power system faults without resorting to under-frequency or under-voltage load shedding.

Automatic control of external capacitor banks has been integrated in the SVC control system to accommodate 10 capacitor banks, initially four, at 132 kV with a total of 343 Mvar approximately within the Southern Terminal site and at Terminal sites in the Metro area.

Due to space restriction the SVC was incorporated into an area of 50 x 60 m in a corner within the existing Terminal Station boundary. The location was selected to allow future expansion of the site for additional lines with minimum environmental and visual impact.

The SVC was designed and constructed by ABB as a Turnkey Project supported by Western Power and Norman Disney and Young Consultant to Western Power.



Single-line diagram, SVC

Meeting the increased energy demand

The SVC at Southern Terminal has enabled Western Power to meet the state's increased demand for energy in a timely and cost effective manner by optimising the existing infrastructure for both publically owned and private generators. It has created greater capacity for them to supply electricity to the network and maintained a reliable and quality of power supply for Customers.

As the SVC stabilises the voltage on the network it has alleviated voltage disturbances to homes and businesses in the southern area of Western Australia. The more secure power supply enables greater levels of productivity for industry and business across Western Australia.

Installing the SVC has deferred the need for a 330 kV line which would have taken up to seven years to implement and resulted in land clearing for hundreds of kilometres for the line easement. The installed SVC and other associated work cost less than 20 per cent of the cost of building a 330 kV line and saved approximately four and a half years of project time.

Efficient power system control

The SVC has proved to be extremely efficient in controlling transmission voltage levels across the network, particularly during bush fires, two 3 phase faults on the 132 kV Grid about 75 Km from the SVC site and a major storm in the Perth and Metro areas in 2010. Despite these major disturbances the SVC maintained transmission voltage levels and alleviated power supply interruptions for customers connected to the 132 kV grid.

The SVC automatically adjusts system voltage levels at the heart of the power network at the Terminal Stations located at Southern Terminal, Northern Terminal, etc. Previously, this process was controlled remotely by a series of different devices at the power stations and switchyards, resulting in much longer response times, increasing the risk for a voltage collapse and a blackout of parts or the whole of Perth depending on the operation of the Network and Generation.

Main circuit design

The SVC comprises a thyristor-controlled reactor (TCR) rated at 155 Mvar, a thyristor-switched capacitor (TSC) rated at 145 Mvar, and a 5th harmonic filter rated at 55 Mvar. This gives the SVC a total, continuously controllable reactive power range from 100 Mvar inductive to 200 Mvar capacitive.

Control system

The SVC is controlled by a duplicated 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 the network parameters employed in the SVC control system.

The control system provides facilities for SVC control either from an Operator Work Station (OWS) in the SVC control room or remotely via the SCADA system.

The SVC performs system control tasks as follows:

- Voltage control
- Damping of system electro-mechanical oscillations by means of POD (Power Oscillation Damper). (Currently not activated at Southern Terminal.)
- Control of mechanically switched capacitors (MSC) in the substation.

The normal mode of operation is automatic voltage control. The voltage control system is a closed loop system with control of the positive-phase sequence voltage at the 132 kV bus. The desired voltage reference is set from the OWS.

The SVC is designed for continuous operation in degraded modes. In such modes, the SVC is available for operation within a limited range even if one or more of its reactive branches are temporarily unavailable.

TSC capacitor bank

5th harmonic filter

Return to service within 48 hours

Western Power's requirement of 48 hours return to service after a total failure of the SVC was complied to with the following features:

1. Installation of 4 x 1-phase power transformers
2. Duplicated control systems
3. Cooling system with duplicated water pumps and spare fan
4. Duplicated 415 V auxiliary supplies from the 21 kV SVC busbar
5. Western Power provided an emergency 415 V supply for a "Black start" of the SVC
6. Removable links on the connection from the 21 kV busbar to the TSC & TCR branches
7. Two redundant thyristors in each thyristor stack
8. Adequate spare parts provided

TSC valve and cooling equipment

Thyristor valves

Each three-phase thyristor valve consists of three single-phase units with PCTs (Phase Control Thyristor) stacked vertically in two anti-parallel stacks per phase. Snubber circuits (series connected resistors and capacitors) are mounted in parallel with each thyristor. The thyristors are electrically fired, with energy for firing taken from the snubber circuits. Thyristor firing orders are communicated via optical light guides from the valve control unit located at ground potential (indirect light firing). The thyristors are liquid cooled, with de-ionized, low conductivity water as coolant.

Loss minimising

Loss minimisation logic has been incorporated into the SVC control system to operate the SVC at the most efficient operating level, meaning that the control system operates the SVC to ensure that its own power losses are minimised while remaining fully operational.

Noise abatement and control of EMF

Stringent noise mitigation strategies were implemented to meet state regulations due to the close proximity of local dwellings to the SVC. To effectively combat noise emission, concrete walls together with noise shields were installed around the transformers and reactors of the SVC. Low noise fans were installed on the thyristor valves and the four single-phase power transformers. Low noise power transformers were also selected for inclusion in the SVC.

The result is an SVC, extremely quiet in operation, the noise emission of which does not exceed 35 dB at the Terminal Station boundary.

It was also a key design feature that the SVC met Western Power's electromagnetic field (EMF) emission requirements.

High reliability
The SVC has been designed to have an availability of 99.6% of the time for operation with a reliability rating of less than one failure per annum.

Summary
The ABB SVC installed at the Southern Terminal Station has optimised the capacity of the existing Western Power infrastructure and deferred the need to build a new 330 kV transmission line from the South West of Western Australia to the Metro area of Perth.

The SVC solution was less than 20% of the cost of an alternative new 330 kV transmission line and saved approximately four and a half years of project time. The SVC maintains voltage stability, provides flexibility for transmission equipment outages and balances the increased flow of energy entering the Transmission Grid from new generators. It is an insurance against **blackouts**.

Main technical data

System voltage	132 kV
SVC rating	100 Mvar inductive to 200 Mvar capacitive
Control scheme	Voltage control by means of a closed loop system with control of the positive-phase sequence voltage; Power Oscillation Damper (POD); Automatic control of external MSCs
Thyristor valves	PCT type thyristors, water cooled, indirect light firing

A02-0223 E, 2011-01

For more information please contact:

ABB AB
FACTS
SE-721 64 Västerås, SWEDEN
Phone: +46 (0)21 32 50 00
Fax: +46 (0)21 32 48 10

www.abb.com