The Saudi Electricity Company of the Western Region (SEC-WR) operates a power transmission system comprising 380 kV OH lines and underground cables. There are numerous 380/110 kV bulk supply stations, feeding local 110/13.8 kV substations through mostly underground cable circuits. 

Operating conditions in the Saudi power grid are special due to the hot or very hot climate, with up to 80% of the total load consisting of air conditioners. From a grid point of view, air conditioning is a particularly demanding kind of load, with slow voltage recovery, motor stalling or even voltage collapse in conjunction with short circuits in the transmission or sub-transmission network. In the western region in particular, close to the Red Sea and with the major city of Jeddah as well as the holy cities of Makkah and Madinah as dominating load centres, grid stability is sorely strained particularly in summer and during the Hajj pilgrim period. To get to grips with this situation, three large SVCs have been installed in the region, with the explicit purpose of keeping the grid voltage stable as air conditioners all over the place are running at full speed. The SVCs, located at Madinah South, Faisaliyah and Jamia substations and rated each at 110 kV, -60/+600 Mvar (60 Mvar inductive to 600 Mvar capacitive), were taken into service in 2008 and 2009.

Counteracting motor stalling by means of SVC
At a single line to ground fault in the vicinity of the city of Jeddah, on the 380 kV system or directly in the 110 kV system, the positive phase sequence voltage initially drops to 0.7-0.8 p.u. Air conditioner induction motor flux decays and the motors lose electrical torque. Almost instantaneously the motors lose speed. At fault clearing, the motors need to both re-magnetise and re-accelerate. The resulting large active and reactive components in the load current give large voltage drops in the source impedances.

The way to prevent the motors from stalling is obviously to reduce the voltage drop during the fault and to restore the voltage as quickly as possible after fault clearing. Such a task requires a lot of reactive power support during a short period of time, which is precisely the purpose of the SVCs.

Main circuit design
The SVCs are connected to GIS substations at 110 kV. The nominal voltage on the SVC medium voltage bus is 22.5 kV. There are two TSCs (Thyristor Switched Capacitors) rated at 215 Mvar each and one TCR (Thyristor Controlled Reactor) rated at 230 Mvar. The harmonic filters, totally rated at 170 Mvar, are divided into two separate branches. The branches are connected to the MV bus by circuit breakers. Each filter branch is built up by two double tuned filters covering the 3rd, 5th, 7th and 11th harmonics.

Control and protection system
The SVC is controlled by a microprocessor based control system. The control system is based on the 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.
The control system provides facilities for SVC control either from an Operator Work Station (OWS) in the SVC control room or remotely via a SCADA system.

In order to achieve the highest possible availability of the SVC the control system is structured in Automatic Voltage Control mode as well as Manual Control mode. The normal mode of operation is Automatic Voltage Control. The voltage control system is a closed loop system with control of the positive-sequence voltage at the 110 kV bus.

**Fast voltage recovery after system faults**

During a short-circuit in the power grid, the voltage is depressed. The SVC runs fully capacitive. In case of a lightly loaded system, a temporary over-voltage may occur after fault clearing. To improve the situation, a control function has been implemented in the three SVCs, where the TSCs are blocked at the first current zero crossing following fault clearing. The efficiency of this control mode is demonstrated in a recording against a case without the said control mode:

Temporary over-voltage: 1.4 p.u. over-voltage; TSC blocking at the 4th current zero crossing.

**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. In parallel with each thyristor, a snubber circuit (series connected resistors and capacitors) is mounted. The thyristors are liquid cooled using de-ionized water with low conductivity as coolant.

**Operational experience**

Line to ground faults were experienced in the Jeddah as well as Madinah areas in the summer of 2008, i.e. during the peak load season. The SVCs responded quickly and properly to the faults. From this operational experience it can be concluded that the SVCs are efficient in supporting the grid voltage both during and after single line to ground faults.

**Summary**

- Motor stalling or voltage collapse problems are a risk in power systems with a high degree of induction motor loads such as systems with abundant use of air conditioners. Such loads tend to consume large amounts of reactive power, particularly after faults in the grid. This reactive power should not be transmitted over large distances, as it is associated with voltage drops and active power losses.
- SVCs are efficient as a means for maintaining voltage stability in grids feeding large urban areas containing a high degree of air conditioners.
- To maintain voltage stability, particularly in conjunction with fault situations in the grid, fast dynamic response of the SVC is essential. Furthermore, there is typically a trade-off between dynamic response and Mvar rating, i.e. an increase in dynamic response offers a possibility for a saving in Mvar rating to attain the same favourable impact on grid stability.

**Main technical data (one SVC)**

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