Series Capacitors for increased power transmission capability over the 765 kV Cape Corridor

A total of six series capacitors are coming on line in 2012 in the 765 kV national grid in South Africa, supplied and installed by ABB. The installations, which form part of an initiative to increase power transmission capacity to the Cape region, will allow Eskom, the national power utility, more flexibility and reduce its reliance on existing local power generation. The ratings of the series capacitors range from 450 Mvar up to more than 1300 Mvar.

The Cape Corridor is a portion of the transmission network that stretches from Mpumalanga down to the Western Cape, approximately 1400 km. The large distance and loading require very high voltages and hence the corridor has 765 kV and 400 kV transmission lines, the current 765 kV network extending half way along the corridor.

With series capacitors, the transmission capability of already existing power systems can be increased considerably, thereby decreasing the need for new lines in cases where the demand for power transmission capacity has grown. Likewise, in green-field projects, the amount of transmission lines to accommodate a certain amount of power transmission can be kept to a minimum.

The series capacitors are located at four sites along the Cape Corridor (Fig. 1):
- Alpha 1 & 2, each rated at 446 Mvar
- Beta 1 & 2, each rated at 1340 Mvar
- Perseus, rated at 893 Mvar
- Mercury, rated at 1119 Mvar

Fig. 1. 765 kV series compensated transmission corridor.
The Alpha and Beta series capacitors compensate the existing Alpha-Beta 765 kV Lines 1 and 2, while the Mercury series capacitor compensates the new 765 kV line Zeus-Mercury. The Perseus series capacitor compensates the new 765 kV line Mercury-Perseus.

**Main circuit design**

The main circuit design is based on single segment schemes in four of the series capacitors (Alpha 1&2, Perseus and Mercury) (Fig. 2).

In the remaining two (Beta 1&2), due to their large ratings (each 1340 Mvar), sub-division into dual segment schemes has been employed (Fig. 3).

The series capacitor protective scheme consists of a Metal Oxide Varistor (MOV), Current Limiting Damping Equipment (CLDE), Fast Protective Device (FPD), and a Bypass Switch. The CLDE consists of a current limiting reactor, plus a resistor and a varistor in parallel with the reactor.

The MOV has been designed to withstand the energy dissipation from external faults, i.e. faults appearing outside the series compensated transmission circuit, without bypassing the series capacitor. The series capacitor may be bypassed for any internal fault, i.e. faults located within the compensated transmission circuit and which is limited by the line circuit breakers for that circuit.

The FPD is based on a hermetically sealed and very fast high power switch, CapThor™, which replaces conventional spark gaps. The FPD works in combination with the MOV, and allows bypassing in a very controlled way in order to limit the energy dissipation in the MOV. The FPD scheme has advantages over previous, conventional schemes with spark gaps such as:

- More compact
- Unaffected by the environment
- Capacitor by-passing possible for a wide range of voltages over the series capacitor, including such voltages as appear over the series capacitor for smaller load flows than would be possible with conventional spark gaps.
- Adds flexibility for future series capacitor upgrading.

The encapsulated design is made possible by a combination of a mechanical switch called Fast Contact (FC) and a forced triggered spark gap called Arc Plasma Injector (API), both shown in Fig. 4.

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Fig. 2. Single segment series capacitor scheme.

Fig. 3. Dual segment series capacitor scheme.

Fig. 4. CapThor: Arc Plasma Injector (API) to the left and mechanical Fast Contact (FC) to the right.
Control system
The control system is based on the ABB MACH 2 concept, which is a system of both hardware and software, specifically developed for power applications. MACH 2 is built around an industrial PC with add-in boards and I/O racks connected through standard type field buses like CAN and TDM.

The series capacitors can be controlled from two different locations. Locally in the series capacitor control room there is an Operator Work Station (OWS) based on an industrial PC. The series capacitors can also be controlled by a remote terminal unit (RTU) from a remote control centre. As an option, control can also be obtained via a Gateway Station (GWS), which is a protocol converter that enables communication with the series capacitor by means of a standard protocol.

The operator’s interface (HMI) in the series capacitor control room is an InTouch application running on the OWS/SER computer (Operator Work Station/Sequence Event Recorder). This computer uses an SQL (Standard Query Language) database for the event handling. Event, alarm and fault lists are displayed on the OWS.

TRV control
Detailed studies of Transient Recovery Voltage (TRV) were performed for the line circuit breakers in Alpha, Beta, Perseus and Mercury. The studies showed that TRV increases could be mitigated by feeding an external bypass order to the series capacitors from the line protections. Due to the speed of the FPD, this allows very fast bypassing of the series capacitors before the line circuit breakers break the fault current. This means the impact of trapped charges in the series capacitors is eliminated, and does not add to the TRV stressing of the circuit breakers. In those cases where series capacitors were installed in existing lines with existing line circuit breakers (Alpha-Beta 765 kV Lines 1 and 2), this is a highly beneficial feature which becomes available when utilizing FPD.

Main technical data of the series capacitors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Alpha (per SC)</th>
<th>Beta (per SC)</th>
<th>Mercury</th>
<th>Perseus</th>
</tr>
</thead>
<tbody>
<tr>
<td>System voltage (kV)</td>
<td>765</td>
<td>765</td>
<td>765</td>
<td>765</td>
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<tr>
<td>Rated reactive power (Mvar)</td>
<td>446</td>
<td>1340</td>
<td>1119</td>
<td>893</td>
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<tr>
<td>Rated capacitor current (A)</td>
<td>3150</td>
<td>3150</td>
<td>3150</td>
<td>3150</td>
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<tr>
<td>Rated capacitor reactance (Ω)</td>
<td>15.0</td>
<td>2 x 22.5</td>
<td>37.6</td>
<td>30.0</td>
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<tr>
<td>Installed MOV, including 10% redundancy (MJ/phase)</td>
<td>20.9</td>
<td>2 x 25.4</td>
<td>62.1</td>
<td>98.1</td>
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