Series Capacitors for increased power transmission capacity of regional 230 kV grid in Brazil

Since the end of 2007, Three ABB series capacitors are in operation in the 230 kV power transmission system of Furnas at Rio Verde and Itumbiara 230 kV substations in Brazil. The series capacitors, supplied and installed as a turnkey commitment in just 10 months, have the task of increasing the power transmission capacity of the Rio Verde-Barra do Peixe and Itumbiara-Rio Verde inter-connectors in the regional Mato Grosso grid. Should any infeed of power into this region fail, the series capacitors are there to support the proper function of the power transmission grid. Furthermore, system studies have indicated that due to the build-up of power generation in the region, unless series compensated, the power transmission system would be overloaded.

The series capacitors at Rio Verde are rated at 37 Mvar and 34 Mvar, respectively. The series capacitor at Itumbiara is rated at 34 Mvar at 230 kV.

The series capacitor is equipped with control, protection and supervision to enable it to perform as an integrated part of the power system. Also, as the series capacitor is working at the same voltage level as the rest of the system, it is located on fully insulated steel platforms, one per phase.

The series capacitor protective scheme consists of a Metal Oxide Varistor (MOV), Current Limiting Damping Equipment (CLDE), a 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 purpose of the resistor is to add damping to the capacitor discharge current, and thus quickly reduce the voltage across the capacitor after a bypass operation. The purpose of the varistor is to avoid fundamental frequency losses in the damping resistor during steady state operation.

The FPD scheme is based on a hermetically sealed high power switch, CapThor™, consisting of a very fast acting high power plasma switch and a fast mechanical switch connected in parallel, which replaces conventional spark gaps. The FPD works in combination with the MOV, and allows bypassing in a very controlled way in order to reduce 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-pass possible for a wide range of voltages
- Adds flexibility for future series capacitor upgrading.

Main circuit design
A series capacitor is part of a power transmission system. In this environment, the capacitor bank can be subjected to large load variations and transients of both currents and voltages. The series capacitor must consequently be designed to withstand the highest transient over-voltage and current that may occur for a given disturbance. Therefore, the series capacitor has a sophisticated MOV by-pass protection system.

![Single line diagram.](image)
The CapThor plasma gap is extinguished as the mechanical switch closes, which happens about 5 ms after igniting the plasma gap. Due to this very fast by-passing of the plasma gap, it is not ionized to any significant degree, and cooling and de-ionizing is almost instant. For possible future grid system changes, this may be advantageous for considering by-passing the series capacitor in conjunction with external faults in the power system: the very fast de-ionizing of the CapThor plasma gap enables the series capacitor to be ready for a second by-pass in case the first line re-insertion attempt fails. This decreases possible future needs for MOV extension and thereby also series capacitor footprint.

Control and protection 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 busses.

The Series Capacitors can be controlled from two different locations. Locally in the Series Capacitor control room there is an Operator Work Station based on a personal computer which also manages a Sequence of Events Recorder (OWS/SER). The Series Capacitors can also be controlled via Gate Way Stations (GWS) from a remote control center.

The operator’s interface in the Series Capacitor control room is an InTouch application running on the OWS/SER computer. This computer using an SQL database also performs event handling. All event, alarm and fault lists are displayed on the OWS. The OWS/SER computer is connected to the Main computer through a TCP/IP Ethernet LAN via a network switch.

The following are some of the available protective functions for the Series Capacitors:
- Capacitor unbalance protection
- Capacitor overload protection
- Flashover to platform protection
- MOV overload protection
- MOV failure protection
- Pole disagreement protection
- Bypass switch failure protection
- CapThor protection

Main technical data

<table>
<thead>
<tr>
<th>Item</th>
<th>Rio Verde I</th>
<th>Rio Verde II</th>
<th>Itumbiara</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated system voltage:</td>
<td>230 kV</td>
<td>230 kV</td>
<td>230 kV</td>
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<tr>
<td>Rated reactive power:</td>
<td>34 Mvars</td>
<td>37 Mvars</td>
<td>34 Mvars</td>
</tr>
<tr>
<td>Rated current per phase:</td>
<td>600 A</td>
<td>600 A</td>
<td>600 A</td>
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<tr>
<td>Overload current, 30 min:</td>
<td>810 A</td>
<td>810 A</td>
<td>810 A</td>
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<tr>
<td>Rated phase reactance:</td>
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<td>34.4 Ω</td>
<td>31.4 Ω</td>
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<tr>
<td>Rated MOV energy:</td>
<td>25.1 MJ/3-ph</td>
<td>4.5 MJ/3-ph</td>
<td>26.4 MJ/3-ph</td>
</tr>
</tbody>
</table>

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