ABB has installed two series capacitors in Fingrid's 400 kV grid to strengthen the power transmission capacity in northern Finland and to assure power system security. The series capacitors both went on line in 2009.

The contract, comprising two turnkey series capacitor installations was awarded by Fingrid, the Finnish transmission system operator. The series capacitors are an important part of a larger grid investment package in northern Finland. These investments add transmission capacity towards neighbouring Sweden by some 200 MW, and are thereby needed to meet the rising market demand on power transmission between northern Finland and Sweden and also internally in Finland. Series capacitors enable added transmission capacity on existing power lines and help maintain grid stability in the Finnish power system.

Generally, Fingrid is facing a strong increase of investments in the Finnish power grid during the next 10 years period. The planned investments will smooth the path for European market integration and make it possible to connect new generation plants including wind power. Also, the aging of the grid is one reason to rebuild older substations and lines.

**Main circuit design**

Series capacitors require control, protection and supervision to enable them to perform as integrated parts of the power system. Also, as series capacitors are working at the same voltage level as the rest of the system, they are located on fully insulated steel platforms.

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, very fast high power switch, CapThor™, which replaces conventional spark gaps. It comprises a fast acting, high power arc plasma injector working in parallel with a fast mechanical switch. It offers rapid, environmentally robust protection against disturbances in the grid, caused, for example, by strokes of lightning, that could otherwise harm the series capacitor.

The FPD works in combination with the MOV, and allows by-passing in a very controlled way in order to reduce 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
- Adds flexibility for future series capacitor upgrading.

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 a SQL\(^1\) database also performs event handling. All event, alarm and fault lists are displayed on the OWS. The OWS/SER computer is connected to redundant Main computers through a TCP/IP Ethernet LAN\(^1\) via a network switch.

The following are some of the available protective functions for the Series Capacitor:

- 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>Main technical data</th>
<th>Asmunti</th>
<th>Tuomela</th>
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<tbody>
<tr>
<td>Rated system voltage:</td>
<td>400 kV</td>
<td>400 kV</td>
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<tr>
<td>Rated reactive power:</td>
<td>369 Mvar</td>
<td>301 Mvar</td>
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<td>Rated current per phase:</td>
<td>1800 A</td>
<td>1800 A</td>
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<td>Overload current, 30 min:</td>
<td>2430 A</td>
<td>2430 A</td>
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<td>Rated phase reactance:</td>
<td>38 (\Omega)</td>
<td>31 (\Omega)</td>
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<td>Degree of compensation:</td>
<td>70%</td>
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<td>Rated ZnO varistor energy:</td>
<td>130 MJ/3-ph</td>
<td>85 MJ/3-ph</td>
</tr>
</tbody>
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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/FACTS