Hydro One is the largest electricity transmission and distribution company in the province of Ontario, Canada. The company owns and operates substantially all of Ontario’s electricity transmission system, accounting for approximately 96.6% of Ontario’s transmission capacity.

Hydro One is operating two series capacitors supplied by ABB in their 500 kV transmission grid in Ontario. Each series capacitor is rated at 750 Mvar.

In the 500 kV power transmission system of Ontario, the northeastern part is connected to the south mainly by two single circuit lines between Hanmer s/s at Sudbury and Essa s/s at Barrie. Without series compensation, the development of new generation in northern Ontario could result in increased power congestion over the lines. The installation of the series capacitors at Nobel s/s at approximately the midpoint of the lines enhances the use of these circuits by increasing the power transmission capability of the lines by at least 30%. The total length of the corridor is approximately 280 km.

TRV control
Special importance was attributed to avoiding any impact (increase) on the transient recovery voltage (TRV) on existing line circuit breakers following breaker operation for any reason, i.e. during normal load flow just as well as for fault clearing anywhere along the lines. Such increase could otherwise be caused by the voltage over the series capacitors when the line breaker is opened. Avoiding this is enabled by means of ABBs Fast Protective Device (FPD), allowing very fast bypassing of the series capacitors in conjunction with line breaker opening in the transmission lines carrying the series capacitors. 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 fact, studies prior to the project indicated that insertion of a series capacitor in the Hanmer to Essa 500 kV line would have exasperated the TRV on the terminal breakers clearing faults on the line. This emphasized the importance of a fast bypassing mechanism for this project and was one of the factors which led to selection of ABB as supplier of the series capacitors.

Main circuit design
The series capacitor protective scheme consists of a Metal Oxide Varistor (MOV), Current Limiting Damping Equipment (CLDE), the Fast Protective Device (FPD), and a Bypass Switch (B). 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 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 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 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.

Allowance for phase unbalance
The phase impedances in the power corridor are somewhat unequal, due to limited transposing of the 500 kV lines. As a consequence, short circuit currents differ from one phase to another. To make up for this difference, the MOV rating differs between the three phases, in an identical way for the two series capacitors.

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 a personal computer. The series capacitors can also be controlled from a remote control center via a Gateway Station (GWS), which is a protocol converter that enables remote communication by means of a standard protocol.

Current measurements for control and protective functions are attained by use of OCTs (Optical Current Transformers).

The OCT consists of a current transducer in the high voltage busbar and an optical interface module in the control room. Signal transmission between the transducer and the interface is performed by an optical fibre system including platform links, high voltage signal columns and fibre optic cables.

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Main technical data (for one series capacitor)

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System voltage</td>
<td>500 kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>2330 A</td>
</tr>
<tr>
<td>Rated reactance</td>
<td>46 Ω</td>
</tr>
<tr>
<td>Rated reactive power</td>
<td>750 Mvar</td>
</tr>
<tr>
<td>Degree of compensation</td>
<td>50%</td>
</tr>
<tr>
<td>MOV rating (middle phase)</td>
<td>70.5 MJ</td>
</tr>
<tr>
<td>MOV rating (each outer phase)</td>
<td>46.2 MJ</td>
</tr>
<tr>
<td>Ambient temperature range</td>
<td>-50ºC to +40ºC</td>
</tr>
</tbody>
</table>

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