

# Series Capacitors Case Study



# Use of Series Capacitors

Series capacitors are installed to reach a more efficient use of the transmission lines. The diversification of generation, transmission and distribution, in addition to long transmission distances and large generating power plants are resulting in an increased demand for economic and reliable operation of transmission systems. The demand for increasing power transfer means either more transmission lines or compensation of the existing lines. Series compensation is an economic method of improving power transmission capability of the lines.

The cost of a series capacitor bank is approximately 10% of the cost of a new transmission line. Thus, the payback time for the series capacitor bank investment is only a few years.

Quality in series capacitors is the result of a comprehensive design and thoroughly calculated delivery. Full-scale testing of the equipment brings a final touch to the delivery, which proves the design as reliable and capable of performing reliably even in critical conditions.

In countries where vast strips of land separate cities, as in Brazil, Finland, Canada and China, electricity is distributed to customers through high voltage transmission lines. Series Capacitors are used in the HV (High Voltage) and EHV (Extra High Voltage) transmission lines to compensate the inductive reactance of the transmission line.

The AC transmission lines have not been designed for easy and fast control of the voltage and current, which causes problems for the dynamic stability, steady state and for the power transmission capability.

## Series Capacitors will:

- increase power transmission capability
- improve system stability
- reduce system losses
- improve voltage profile of the lines
- optimize power flow between parallel lines



476 Mvar, 735 kV, 2300 A Hydro Quebec, Poste Montagnais, Canada



# Ambient conditions guide the design of Series Capacitors



*Nokian Capacitors of Finland, has delivered compensation equipment and Series Capacitors all around the world for more than 50 years, always taking local requirements into account.*

The company has been a pioneer in developing and implementing the solid-state electronics, fibre optic signal transmission, and non-linear resistor schemes for Series Capacitors.

In 2003, Nokian Capacitors delivered six 500 kV Series Capacitors in China, Brazil and Canada. The equipment was designed to operate reliably in ambient conditions, ranging from extreme cold (Canada  $-50^{\circ}\text{C}$ ) to very hot (Brazil  $+45^{\circ}\text{C}$ ). In previous projects Nokian Capacitors has also takes into account very high wind conditions and seismic conditions for extreme cases, such as North America's west coast and Chile.

*B.C. Hydro 500 kV, 1000 Mvar, 2700 A, 60 Hz, Canada*





## Testing completes design of Series Capacitor equipment

The advantage of the Series Capacitor is that it automatically compensates the line and the compensation power changes according to the line current. The Series Capacitor generates reactive power whenever there is current in the line. The reactive power will increase the power transmission capability and stabilise the system.

Series Capacitors are always tailor-made, taking the customer's special requirements into account. The transmission system (transmission line lengths, short circuit power, compensation degree, stability requirements, duty cycle, etc.) determines the main data, which is then verified in detailed system and equipment studies. After the studies are made, specifications for the Series Capacitor bank are made according to the applicable standards.

Modern software, such as the DigSilent EMTP (Electro Magnetic Transient Program) and the RTDS (Real Time Digital Simulator)<sup>®</sup>, is used for the system and equipment studies, achieving an accurate basis for the design. During and after the manufacturing, different sub-equipments are routine and type tested.

The only way to ensure that the complete delivery fulfils the specifications is to run a full-scale type test and compare its results to the design and simulations of the Series Capacitor. Full-scale type tests are done in a laboratory environment or on site, to verify the appropriate structure for the Series Capacitor being built.

There are different full-scale type tests, such as line fault tests staged fault tests and seismic tests, for complete Series Capacitor banks that verify the electrical and mechanical design. High voltage insulation tests and radio influence voltage tests have also been performed at high voltage laboratories for ready Series Capacitors platforms.



**Nokian Capacitors is currently the only company in the world which has performed verification of the mechanical design by a full-scale site test.**

# B.C. Hydro, Guichon Series Capacitor Bank, 500 kV, 420 Mvar, 2400 A, 60 Hz

The delivery was a turnkey project, which included the design, civil works for a new substation, manufacturing, delivery, installation and commissioning. The bank was taken into operation in November 2003.

## Problem

Increased power transmission from north to south and increased power export from Canada to the United States have led to the situation that the power transmission line capacity was too small.

## Solution

B.C. Hydro decided to increase the compensation level of the existing power transmission line by building a new Series Capacitor bank. Nokian Capacitors Ltd, and B.C. Hydro signed the supply contract of the Guichon Project in May 2002. The Series Capacitor bank was put into commercial use in November 2003, on schedule. The Guichon project increased the current carrying

capabilities from 1600 to 2400 amperes, improved system stability and reduced losses. It also ensured sufficient power supply in the case of faults in parallel lines.

## Result

The Series Capacitor bank was installed to increase power transmission capacity. The compensation level after installation is 51%.

**The Series Capacitor bank was put into commercial use in November 2003, on schedule.**

**The compensation level is 51%.**



*Platform cabinets transmit measurements to the control and protection system on the ground level.*

## Seismic test as proof of design for series capacitor bank in Canada

In 2003, Nokian Capacitors delivered a 500 kV and 420 Mvar Series Capacitor bank for B.C. Hydro to Canada. The bank is located in the seismically active zone of Guichon, British Columbia, Canada. Because of severe seismic, wind and snow loads the bank has special spring dampers in the guy insulators.

The bank was installed during the summer of 2003. In August, a seismic test was done to the fully assembled platform. The tests were carried out by pulling the platform by a wire to simulate an seismic activity. The force of the wire was measured using a force transducer.

A theodolite measured the deflection of the platforms, while the acceleration was measured by accelerometers. The tests were done in longitudinal, transversal and in rotational directions in order to simulate seismic vibrations.

The test results showed that the natural frequency and the critical dampening of the platform corresponded



*Seismic tests*

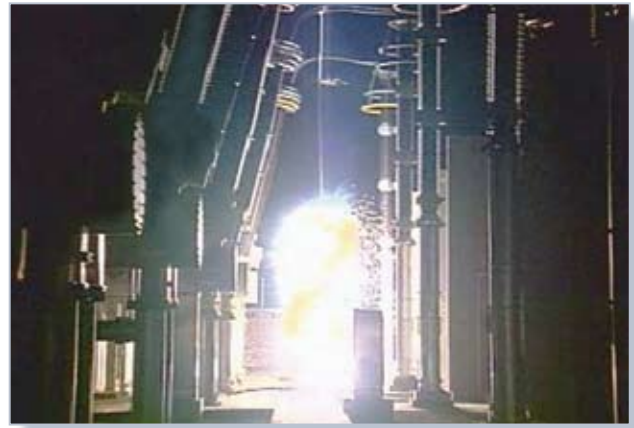
with good accuracy to the seismic structural analysis study made before construction began.

## Line fault tests guarantee availability requirements of a power plant in China



*Wanquan Series Capacitors*

Nokian Capacitors delivered four 500 kV Series Capacitor banks to North China Power Corporation in 2003. The banks are located at the Wanquan substation about 200 km from Beijing. The major part of the electrical supply to the city of Beijing is dependent on the series capacitor bank substation, which sets very high availability requirements for the Series Capacitors. It was thus crucial to run line fault tests, to ensure the reliability and specified design of the system.



*Wanquan Series Capacitors, line fault tests*

The banks were installed during March -May 2003 and tested in June 2003. The line fault tests were carried out on one of the banks by arranging a short circuit from the line to ground at the substation - the protection equipment of the bank operated as planned. The protection system operation was recorded and verified with the system study that was made based on transmission system parameters and simulations. After the successful line fault tests, all four banks were taken into commercial operation.



## End result: a more satisfied customer

Of the many technical possibilities to compensate the long HV and EHV transmission lines, the Series Capacitor has, after technical and economical calculations proved to be the best solution.

Nokian Capacitors has delivered Series Capacitors to many customers at different locations with severe ambient conditions. Because of the diversity of the environments, full-scale testing for the finished Series Capacitor platform has been necessary. In addition to the detailed studies and type tests for the subcomponents, the full-scale tests have given a sense of certainty to the functioning of the end product for our customers.

In all cases the customers have been very satisfied with the proof that the Series Capacitor delivered meets the exact specifications of what the customer has ordered. The verification done through the type tests is the way of ensuring that each Series Capacitor delivered is of the highest quality.

*420 Mvar, 500 kV, 2400 A, Guichon, B.C.Hydro, Canada*



## Other products

In addition to Series Capacitors, Nokian Capacitors also manufactures:

- SVC for utility and industry
- SVC MaxSine
- Railway series capacitors
- Air core reactors
- Shunt capacitor banks
- Filter capacitor banks
- High voltage capacitor units
- Low voltage capacitor units
- Control and Protection System for capacitor banks
- Power factor controllers
- Unbalance relays
- Capacitance meters (clamp type)
- Enclosed Medium Voltage (MV) banks



In line with our policy of ongoing product development we reserve the right to alter specifications.



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