The cost of a series capacitor bank is approximately 10% of the cost of a new transmission line, thus providing a quick return on investment.

**Economic method of improving power transmission**

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 new, additional transmission lines or an increase in capacity of the existing lines.

Global energy demand, meanwhile, continues to increase and is forecasted to nearly double by 2035 (IEA, 2012). As our dependency on continuous electricity supply becomes increasingly critical, series compensation provides an efficient solution to improved power system stability.

Series compensation is an economic method of improving power transmission capability of the lines. The addition of series capacitors will increase power transmission capability and AC system stability while reducing system losses. Series capacitors will improve the overall voltage profile of your transmission lines while optimising parallel line power flow.

**FIXED SERIES COMPENSATION (FSC)**

As part of our global FACTS solution, Alstom offers fixed series compensation (FSC) technology. Fixed series capacitors are the most cost-effective series capacitor scheme used today, with a combination of MOVs (metal oxide varistors), spark gaps and bypass breaker to protect capacitor banks.

**CUSTOMER BENEFITS**

- Efficient method to maximise power transmission capability
- High availability with low maintenance costs
- High reliability with full redundancy
- Designed to endure severe conditions - from frost to heat
- Remote operability and service
- Quick return-on-investment

**BENEFITS OF FIXED SERIES COMPENSATION**

- Increases power transmission capacity
- Improves power system transient and steady state stability
- Improves voltage profile of the lines
- Reduces voltage drops caused by loads
- Optimises power flow between parallel lines
- Reduces transmission losses
- Reduces significantly the need for power generation or transfer line investments
- Savings on dimensioning of power lines
- Maximises power transmission
- Minimises active and reactive power losses
- Allows load sharing between parallel lines
ALSTOM CAPACITOR TECHNOLOGY
For over 50 years, Alstom is recognised as one of the leading manufacturers of high and low voltage capacitors, capacitor banks, air core reactors and control and protection systems for capacitor installations. We have been manufacturing compensation equipment since 1957.

SERIES CAPACITOR INSTALLATION
- Metal oxide varistor scheme (MOV)
- Laser powered signal transmission system for platform to ground communication
- Digital protection and control system, NDP+
- All controls and protection relays on ground level in the control room
- Integrated remote/local control and monitoring features
- Integrated communication software for SCADA communication
- Structural analysis for severe seismic condition verified by full scale seismic tests

MECHANICAL DESIGN
The capacitor bank must be able to withstand the forces caused by short circuit, wind, ice, snow and earthquakes. These mechanical stresses are calculated by using finite element analysis.

In case of severe seismic requirements, it is not possible to design the bank without using special spring dampers in the string insulators. The natural frequency of the series capacitor bank is close to the frequency of an earthquake. The natural frequency of the bank will be reduced by suitable spring damping elements, which are designed for this application.

CONTROL AND PROTECTION SYSTEM
The control and protection scheme for series capacitors is designed as an integrated system consisting of measuring transducers, a signal transmission system, a ground mounted control and protection system complete with human-machine-interface (HMI) and associated auxiliary services. The design philosophy for the control and protection system is to protect the capacitor bank and ensure specified system operating requirements with high reliability and availability of the bank.

The normal protective functions are capacitor unbalance protection, capacitor overload protection, capacitor sustained overvoltage protection, fault-to-platform protection, sustained spark gap protection, MOV single shot energy accumulation protection, MOV accumulated energy protection, MOV rate of energy rise protection, MOV overcurrent protection, MOV failure protection and sub harmonic protection.

For remote operation of the series capacitors, the control and protection system is provided with a remote terminal unit with features based on the IEC 60870-5-101 protocol. The complete control and protection system is duplicated to achieve redundancy for all protective functions.

The control and protection functions are fully implemented as software functions running in a computer system based on embedded controllers on a VME-bus. The software consists of protection relays, programmable control logic, system supervision and user interface modules.

Another goal in the design is to simplify maintenance and trouble shooting work.

Special attention has been paid to the design to minimise equipment maintenance, thus enabling the series capacitor installation to operate unattended.
TESTED AND PROVEN TECHNOLOGY IN DIFFERENT ENVIRONMENTS

- Even in extreme conditions Canada and Finland -50º C, China and Brazil +45º C, India +50º C
- Seismic design for world’s most severe earthquake conditions: Atacama Chile
- Complete set of SC types tests including full size platform voltage withstand and RIV tests
- Spark gap has been tested 40 kA 3 sec.
- Patented capacitor unit fuse, damping circuit, spark gap and platform power supply Total delivered power over 35 000 MVAr in 75 projects since 1964
- The highest system voltage 750 kV

CAPACITOR UNITS

The capacitor units are of an all-film design with environmentally safe, biodegradable impregnation liquid. A large unit size is used for economical reasons and to minimise the size of the platform.

The units are equipped with internal fuses because of their technical and economical advantages.

METAL OXYDE VARISTORS (MOVs)

Metal oxide varistors, which are connected in parallel with the capacitors, provide overvoltage protection of the capacitors during and after power system faults and thus are conducting a large part of the fault current. MOVs are then protected by the spark gap activation against excessive energy absorption.

DAMPING CIRCUIT

The damping circuit consists of an air core, dry type reactor with a parallel-connected damping resistor. In series with the resistor there is a small spark gap which connects the resistor to the circuit only during capacitor bank discharge and thus, minimises the losses when the bank is bypassed.

SPARK GAP

The spark gap is a fast de-ionizing non-self-extinguishing spark gap. In case of operation of the MOV protection relay, the spark gap is force-triggered by the protection and control system via a light signal through the fiber optic signal column to by pass the MOVs. The plasma arc in the trigatron immediately triggers the spark gap.

BYPASS CIRCUIT BREAKER

The bypass circuit breaker is connected in parallel with the capacitor bank and the overvoltage protective circuit. It is used for intentional or emergency bypassing of capacitor bank and its reinsertion.
PROJECT FLOW FOR FSC

Project preparation/bid stage

- Launching phase
- System design & studies
  - Standard specifications
  - Customer specific design requirements
  - Project specification
  - Scope of supply
  - Key milestones
- Detailed engineering
  - System study
  - Insulation coordination study
  - Protection coordination study
  - Performance study
  - Seismic study
  - Capacitor study
  - Breaker study
  - Current transformer study
- Material management
  - HV equipment design
  - Mechanical & structural design
  - Control system design
  - Auxiliary services design
  - Civil design
- Site activities
  - Procurement
  - Manufacturing
  - Quality control
  - Factory acceptance test
  - Delivery to site
- Services
  - Civil works
  - Erection & cabling
  - Site test
  - Commissioning
  - Energising
- Operation
  - Customer training
  - Maintenance
  - Spares
  - Refurbishment

PROJECT PREPARATION/BID STAGE

- Technical proposals
- Commercial submissions
- Prequalification
- Project validation
- Consequences

QUALITY SYSTEM

- Alstom fulfills the requirements of ISO 9001, ISO 14001 environmental standards, and OHSAS 18001.

PRODUCT DEVELOPMENT AND INVESTMENT

Alstom’s investments in research and development have been growing from year to year. Our sophisticated technology includes also a real time digital simulator (RTDS®), which guarantees exact and prompt modelling of customer specific applications.

The development and testing of our systems in the RTDS® environment reduces project risk, accelerates commissioning, saves cost and ensures that the final technical solution meets the customer requirements.

Alstom also carries out complete studies for the design of the series capacitor bank including system transient, fault analysis, seismic studies, protection coordination and other required studies.

ENVIRONMENTAL MANAGEMENT PLAN

Alstom’s environmental management plan policy identifies and finds solutions to any elements of the project that could present a hazard to the environment.

- Drainage and aquatic resources
- Wildlife
- Heritage and archaeological considerations
- Local agencies and public involvement

REFERENCES

Alstom has delivered series capacitors to many power utilities including:
- B.C. Hydro
- Hydro Quebec
- Western Area Power Administration
- Furnas
- Eletronorte
- Fingrid
- PGCIL
- SEC
- Norwegian State Power Board
- Ministry of Energy of Vietnam (Electricity of Vietnam)
- North China Grid Company

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