



SVC
Static Var Compensator
An insurance for improved grid system
stability and reliability

It's not the power in that counts... ...it's the power that comes out!

Increased efficiency in power systems

Demand is rising all the time and modern society would cease to function without access to electricity. As the volume of power transmitted and distributed increases, so do the requirements for high quality and reliable supply.

At the same time, rising costs and growing environmental concerns make the process of building new power transmission and distribution lines increasingly complicated and time-consuming. Making existing lines as well as new ones more efficient and economical, then becomes a compelling alternative.

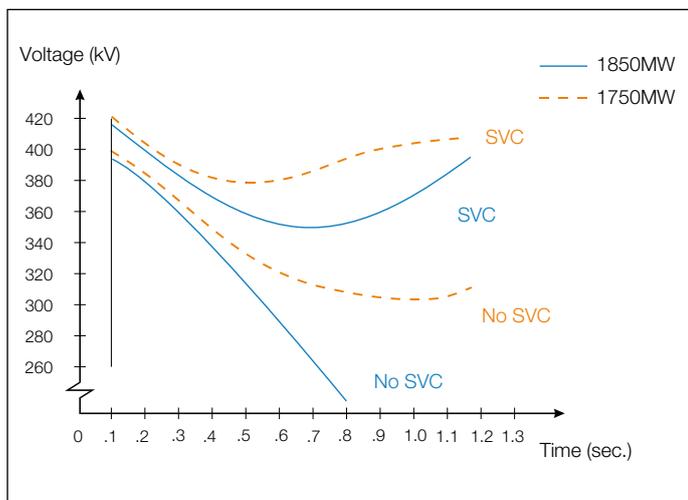
Major savings at reasonable cost

Optimum power transmission and distribution also entails the reduction of transfer losses and provision of adequate power quality and availability at the receiving end.

The SVC is a solid-state reactive power compensation device based on high power thyristor technology.

An SVC can improve power system transmission and distribution performance in a number of ways. Installing an SVC at one or more suitable points in the network can increase transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions. The dynamic stability of the grid can also be improved, and active power oscillations mitigated.

By developing efficient semiconductors (thyristors) dimensioned for high power ratings, ABB has created the perfect environment for reactive power compensation. This technology has also proved highly effective in HVDC applications and thyristor drives for industry.



These voltages demonstrate post fault stabilizing effect of an SVC.



Power Transformer

The ABB static var compensator includes the following major components:



Control System



Thyristor Valves



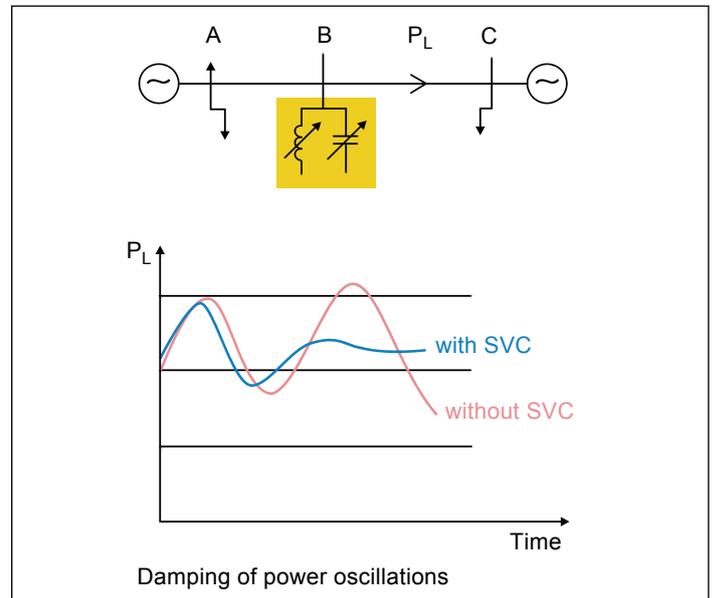
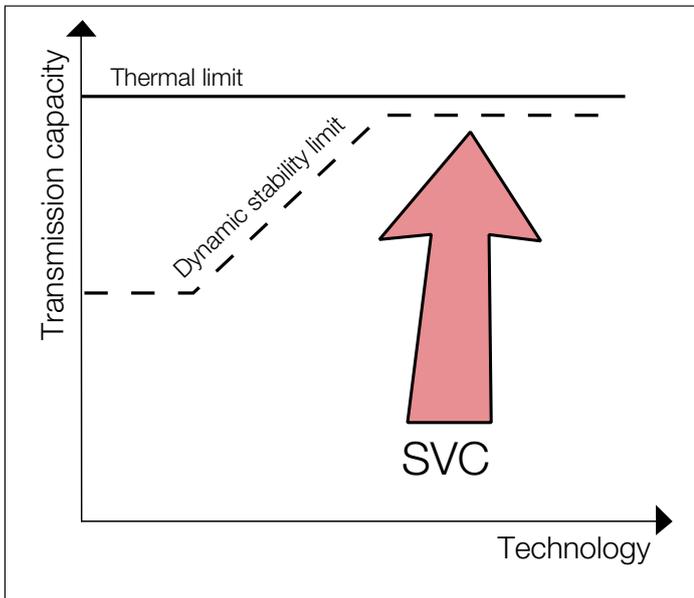
Capacitor Banks



Reactors

To obtain overall control of the reactive power in a network, thyristor controlled reactors and thyristor switched capacitors are often combined with mechanically switched shunt reactors and capacitors, controlled by the SVC.

An SVC can considerably improve grid reliability and availability



The global trend is towards ever larger power networks, longer transmission lines, and higher consumption. Energy is also becoming increasingly expensive. To cope, power transmission and distribution systems have to become more efficient.

In installations all around the world, ABB SVC technology has done exactly this. It has proved second to none in increasing power transmission and distribution capacity at a lower cost.

The benefits of SVC to power transmission:

- Stabilized voltages in weak systems
- Reduced transmission losses
- Increased transmission capacity, to reduce, defer or eliminate the need for new lines
- Higher transient stability limit
- Increased damping of minor disturbances
- Greater voltage control and stability
- Power oscillation damping

Systems interconnected via a relatively weak link often experience power oscillation problems. Transmission capability is then determined by damping. By increasing the damping factor (typically by 1-2 MW per Mvar installed) an SVC can eliminate or postpone the need to install new lines.

In other cases, transient (angular) stability will be a limiting factor on power transmission capacity. SVC will often help to mitigate such situations, as well.

The benefits of SVC to power distribution:

- Stabilized voltage at the receiving end of long lines
- Increased productivity as stabilized voltage means better utilized capacity
- Reduced reactive power consumption, which gives lower losses and improved tariffs
- Balanced asymmetrical loads reduce system losses and enable lower stresses in rotating machinery
- Enables better use of equipment (particularly transformers and cables)
- Reduced voltage fluctuations and light flicker
- Decreased harmonic distortion



The SVC is an excellent tool for achieving dynamic voltage control of power systems.

Voltage stabilisation

SVC is the preferred tool for dynamic reactive power support in high voltage transmission grids. Thanks to its inherent capability for high-speed, cycle-by-cycle control of vars, it will counteract the often hazardous voltage depressions that follow in conjunction with faults in the grid. These highly dynamic events, where the ever increasing use of induction motors (like those in air-conditioning units and wind power turbine-generators) stresses the grid, will need an SVC to maintain the grid voltage and safeguard the fault ride-through capability.

Additionally, if the SVC includes var absorption capability, it will effectively suppress temporary overvoltages that may appear upon fault clearing. The SVC will make sure the grid

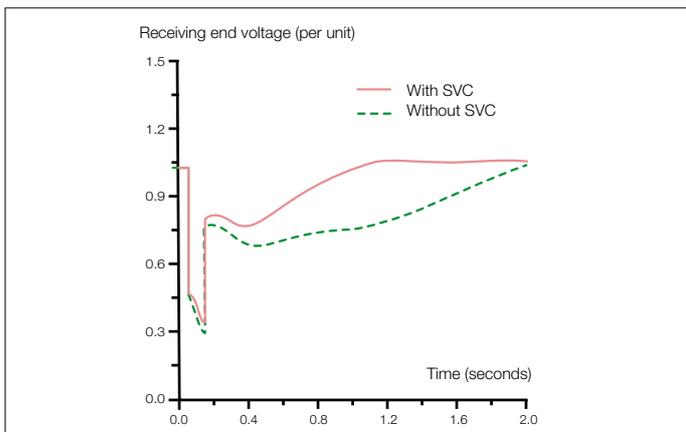
voltage always stays within acceptable limits. In steady-state it will also assist the operators with accurate voltage control so that the voltage profile of the grid is optimized.

Boosting transmission capacity

The SVC will ensure that the system voltage does not sag even when the power flow grows heavy. This means that more power can be transmitted through the system under stable conditions over existing lines.

An ABB SVC has boosted transmission capacity by tens of percent in most cases. Optimum improvement is sometimes achieved in combination with series compensation.

Post fault voltage recoveries with and without SVC.



This SVC has boosted power transmission capacity by over 50 percent in a 230 kV system.



SVC for voltage stabilisation of a large pulsating load.

Basic SVC schemes

Thyristor controlled reactor and fixed capacitor, TCR/FC

A reactor and thyristor valve are incorporated in each single-phase branch. Power is changed by controlling the current through the reactor via the thyristor valve. The on-state interval is controlled by delaying triggering of the thyristor valve relative to the natural zero current crossing.

A thyristor controlled reactor (TCR) is used in combination with a fixed capacitor (FC) when reactive power generation or alternatively, absorption and generation is required. This is often the optimum solution for sub-transmission and distribution.

TCR/FCs are characterized by

- Continuous control
- No transients
- Elimination of harmonics by tuning the FCs as filters
- Compact design

Thyristor switched capacitor, TSC

A shunt capacitor bank is divided into an appropriate number of branches. Each branch is individually switched on or off via a thyristor valve. Switching takes place when the voltage across the thyristor valve is zero, making it virtually transient-free.

Disconnection is effected by suppressing the firing pulses to the thyristors which will be blocked when the current reaches zero.

TSCs are characterized by

- Stepped control
- No transients
- No harmonics
- Low losses
- Redundancy and flexibility

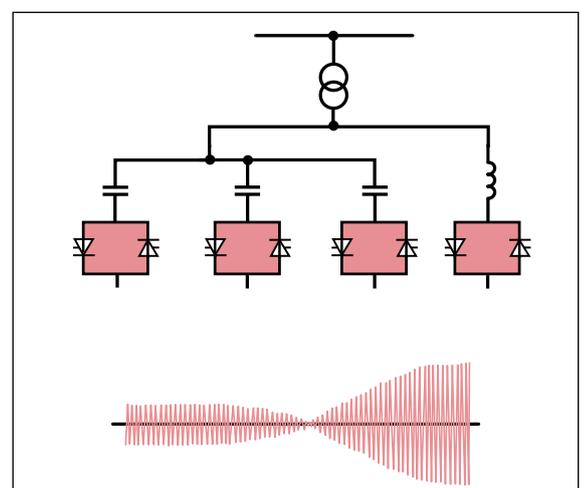
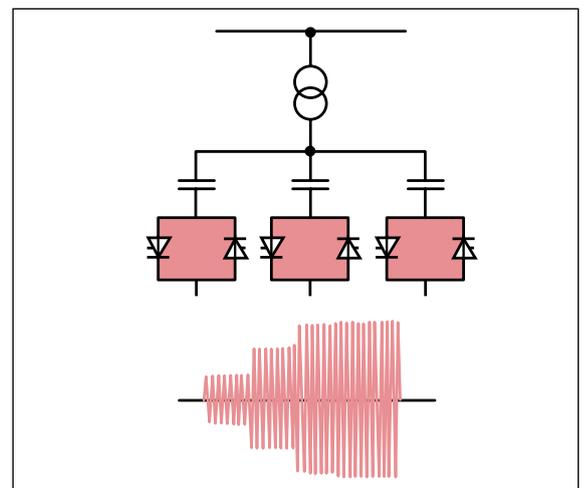
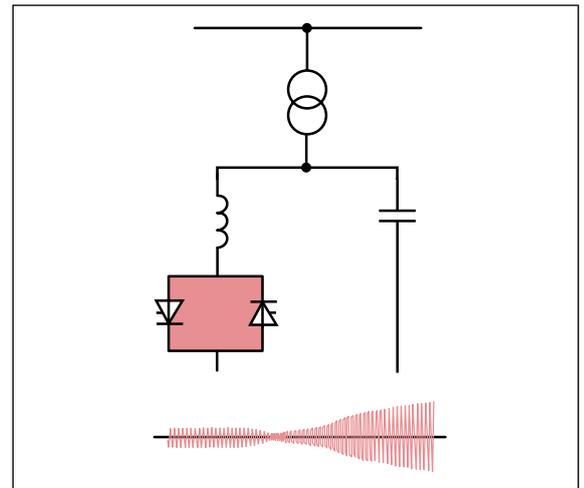
Thyristor controlled reactor/Thyristor switched capacitor, TCR/TSC

A combined TCR and TSC is the optimum solution in many cases. With a TCR/TSC compensator, continuously variable reactive power is obtained across the entire control range plus full control of both the inductive and the capacitive parts of the compensator.

The principal benefit is optimum performance during major disturbances in the power system, such as line faults and load rejections.

TCR/TSC combinations are characterized by

- Continuous control
- No transients
- Elimination of harmonics via filters or TSR (thyristor switched reactor) control
- Low losses
- Redundancy
- Flexible control and operation



Control and protection: MACH 2

ABB's SVC controls are based on a high performance platform called MACH 2. The platform is used throughout FACTS and HVDC applications, and thus becomes a well-known associate to the power transmission industry. The platform is based on standardized hardware, Windows-applications, a user-friendly high-level functional programming tool and open interfaces. MACH 2 is built to be recognized with ease.

The SVC performance requirements are high as sub-cycle action is often needed. MACH 2 uses an industrial PC equipped with state-of-the-art signal processors, powerful enough to ensure accurate switching of the SVC thyristors, even for the most demanding applications. Processor capacity can easily be expanded, and similarly the set of input and output circuitry can be adapted in order to be compatible with local conditions. ABB's vast FACTS experience is behind every application program that is tailored for customers worldwide.

Field proven controls include:

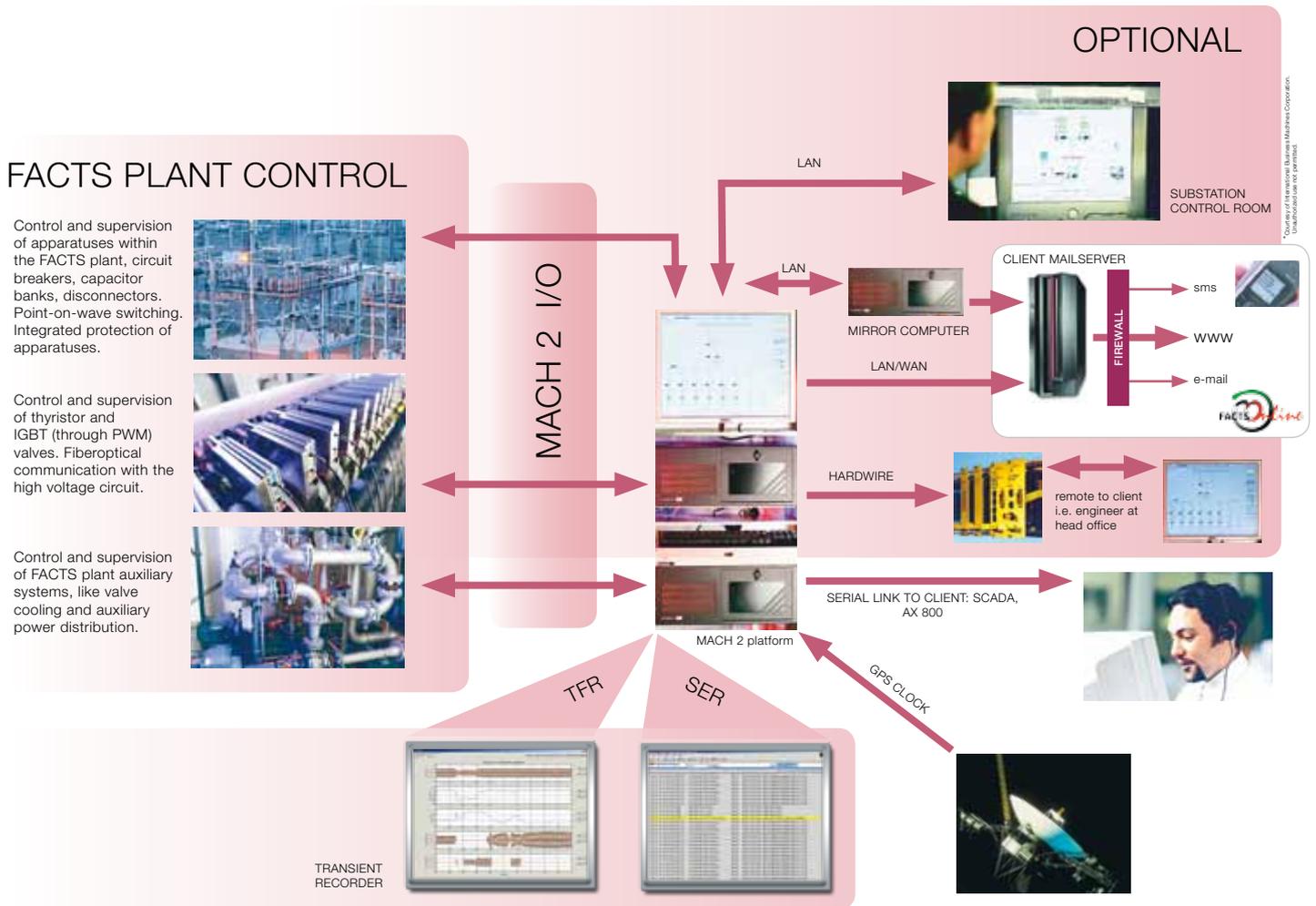
- symmetrical as well as negative-phase sequence voltage control
- adaptive gain control ¹⁾
- transient voltage control strategies ²⁾
- power oscillation damping algorithms
- coordinated control of other reactive power elements (Mechanically switched capacitors and reactors (MSC, MSR))
- SVC self-test modes

The MACH 2 concept is built with open interfaces. This elegantly enables remote control and interrogation to be implemented. ABB has developed an internet-based concept for remote control and supervision of FACTS installations, we call it FACTS ON-LINE. This way we are never far away.

¹⁾ To optimize control speed and stability at varying grid strengths

²⁾ Including active voltage support during system faults and mitigation of possible overvoltages at fault clearing





The FACTS control applications within MACH 2 are supported by a Human Machine Interface (HMI). The HMI uses the hardware platform (dedicated industrial PC), into which user friendly databases and information applications are programmed. The customer is provided with precise, relevant and accurate information, either locally or over industry standard communication links. Since an SVC is normally unmanned the

focus of the HMI is to provide simplicity and accuracy when needed, rather than asking for attention on a continuous basis. Extensive diagnostic systems and event handling facilities make sure that the operator and/or the trouble-shooting engineer will always have correct and relevant information. This way the SVC will be reliable, available and perform its best under critical circumstances.

Successful thyristor technology... ...the foundation of ABB's SVC lead

Decades of development work in semiconductor technology, especially in the field of power thyristors, has helped us achieve and maintain our market leading position.

Our high-power thyristors are precision manufactured and subjected to stringent testing. Their dependability has paved the way for further dynamic development of various applications incorporating thyristor technology.

For instance, we have applied this technology to HVDC, which involves both very high currents and ultra high voltages, plus exacting demands for reliability. The development of thyristor valves for Static Var Compensators is based on this know-how.

ABB has chosen to use the ETT (Electrically Triggered Thyristor) concept for both FACTS and HVDC referring to the vast available experience and track records of operation reliability.

Our range of thyristor valves for SVC includes water-cooled valves for different voltages which enables us to offer optimum solutions for the majority of applications.

For SVC applications, ABB has a comprehensive programme of high power thyristors in 4" and 5" sizes, voltage classes up to 6.5 kV, and current handling capabilities of well over 3000 A per device without any need of paralleling.

ABB offers both PCT (Phase control thyristor) and BCT (Bi-directionally controlled thyristor). BCTs are particularly suitable in situations where room is scarce and current handling capability moderate.

In the BCT, anti-parallel thyristors have been integrated on a common silicon wafer and therefore, only one thyristor stack is required instead of two (one for each current direction). With this arrangement, only half the number of thyristor housings is needed. The number of components in a valve is reduced, saving space as well as complexity.



Cooling system

The cooling system consists of a closed loop piping circuit where a mixture of de-ionized water and glycol is pumped through the thyristor valves and outdoor water to air heat exchangers. There are two water-circulating pumps, one is in operation and the other is stand-by. In case of a pump failure an automatic switch over to the stand by unit will be initiated. A small portion of the flow is by passed through a water treatment circuit where the coolant is continuously de-ionized and filtered.

An outdoor dry air blast cooler is used, connected directly over the main circuit. Low noise fans are employed for reducing sound levels. All fans are individually controlled to ensure sufficient cooling with minimum losses.

The cooling system is automatically controlled by the MACH 2 system.

Directly connected SVC

A directly connected SVC is an SVC where there is no need for a step-down transformer to be connected between the SVC and the power system. ABB offers direct connection for system voltages up to 69 kV. This, of course, brings benefits to the project of a variety of kinds:

- A simplified SVC scheme
- A substantial hardware cost saving
- A saving in transportation cost, weight and volume
- A saving of site footprint
- A saving of plant losses
- No need to handle transformer oil
- No fire hazard
- No transformer maintenance costs
- Easy expandability since transformer rating and secondary voltage rise is not an issue when adding branches.
- Shorter lead times, not influenced by long transformer delivery times.



Cooling water pump unit



Dry air blast cooler



Directly connected SVC

Shunt capacitors and reactors



ABB has a comprehensive, high density capacitor programme, with up to 1 Mvar or more in one single can. This ensures a compact build-up of capacitor banks.



Low noise shunt reactors help fulfil the strictest requirements on noise reduction from SVCs.

Relocatable SVC

Power industry deregulation is introduced to meet growing market demands for flexibility. If this is to be the case in practice, technical solutions must also be flexible.

ABB's relocatable Static Var Compensator concept (RSVC) was conceived precisely for this purpose. This SVC mobility means dynamic voltage support can be obtained where it is most needed in the power grid to meet the current demand for network stability.

Modular design

The truly mobile design of the RSVC enables an installation to be fully relocated within weeks. The RSVC is modular and transportable by road by means of standard vehicles. Its compact design and technical excellence guarantee quiet operation and low magnetic interference, thereby lessening the environmental impact.

Easy to erect and commission

The modular design facilitates simple on site erection and commissioning. Prefabricated buswork and cabling ensures quick and easy inter-module connection.

The modular build-up also enables much of the equipment and system testing to be done in the workshop prior to delivery, which also saves time and money.

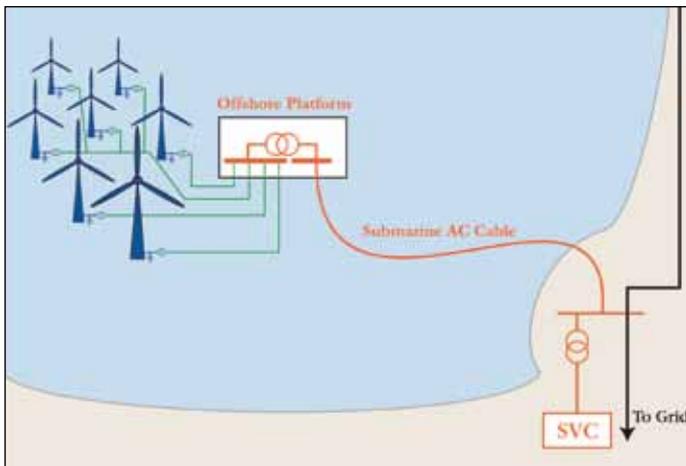


Wind and Railways

For **wind power**, SVC aids in a number of tasks:

- Steady-state and dynamic voltage stabilization
- Continuous power factor control
- Enabling fault ride-through of the wind farm
- Power quality control by mitigation of flicker (caused by tower shadow effect, fluctuating wind, and/or starts and stops of WTGs); also harmonic reduction and reduction of phase imbalance.

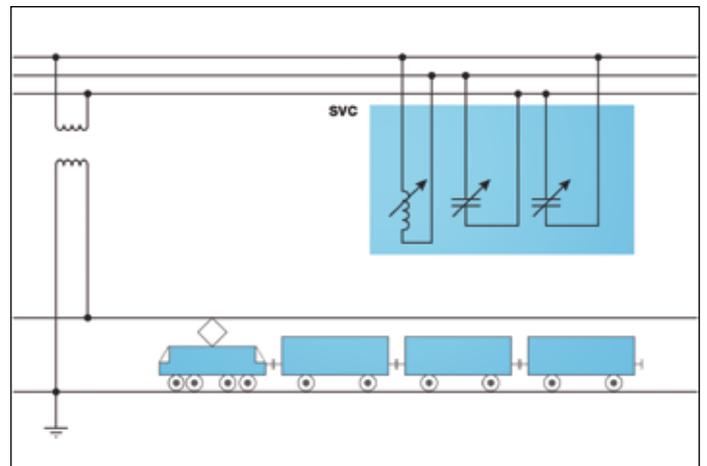
For **off-shore** wind generation, comprehensive AC sea cable networks call for additional elaborate reactive power control. The overall scope of reactive power control should encompass the wind farm just as well as the sea cables, to bring about a well regulated reactive power balance of the whole system, answering to the same demands on reactive power regulation as any other medium to large generator serving the grid.



Railways

The increase in traffic on existing tracks combined with new high-speed rail projects mean rail traction is fast becoming an important load on electrical supply grids. This in turn is focusing a lot of attention on the efficiency of the catenary as well as the power quality of the surrounding grids. Trains taking power from the catenary need to be sure the supply voltages are stable and do not sag.

Voltage and current imbalances between phases of three-phase AC supply systems must also be confined in magnitude and prevented from spreading through the grid to other parts of the system. Likewise, voltage fluctuations and harmonics need to be controlled if they are to stay within the stipulated limits. This is where SVC comes in.



SVCs for all applications



As a result of large power demanding industry development in central Norway, the demand in the region has increased dramatically and is expected to grow further. The power import capacity to the region has previously been limited for system stability reasons. As a remedy, two SVCs were installed in the 420/300 kV grid, each rated at $-/+ 250$ Mvar. With the installation of the SVCs, the power import capacity to the region under stable conditions has increased considerably.

The SVCs are equipped for damping of system electro-mechanical oscillations by means of Power Oscillation Dampers based on active power measurements. They are furthermore equipped with Q Optimizers, which enables coordinated control between the SVCs and mechanically switched shunt capacitors also employed in the grid. This ensures that the SVCs have maximum dynamic capability available to provide fast response to counteract grid disturbances.



A very large SVC was commissioned at the end of 2007 at a key substation near Rawlings, Maryland in USA. The installation enhances the reliability on the 500 kV transmission system – one of the most heavily-loaded in the PJM (Pennsylvania, Jersey, Maryland) Interconnection area – by quickly changing reactive power levels to control the line's voltage.

In addition to improving reliability, the SVC enables increased transmission capacity across the PJM region. Enabling more power to flow on existing lines is an efficient use of resources and an important step in keeping pace with the region's increased demand for electricity.

The SVC is rated at 500 kV, $-145/+575$ Mvar. The turnkey project was completed in 14 months, a record time given its scope, size, and complexity. The SVC is equipped with an advanced control system capable of controlling not only the operation of the SVC itself, but also the switching of two local 500 kV Mechanically Switched Capacitor banks (MSC).



The Saudi Electricity Company operates a power transmission system comprising 380 kV OH lines and underground cables. Operating conditions are special due to the hot climate, with up to 80% of the total load consisting of air conditioners. From a grid point of view, air conditioning is a particularly demanding kind of load, with slow voltage recovery, motor stalling or even voltage collapse in conjunction with short circuits in the transmission or sub-transmission network. To get to grips with this situation, three large SVCs have been installed in the region, with the explicit purpose of keeping the grid voltage stable as air conditioners all over the place are running at full speed. The SVCs, rated each at 110 kV, $-60/+600$ Mvar, were taken into service in 2008 and 2009.



Two SVCs are in operation in the power grid in Bretagne, France, one rated at 225 kV, -100/+200 Mvar and the other at 225 kV, -50/+100 Mvar. Grid voltage control is a key issue in the region and the SVCs have the following tasks:

- Allow fast supply of reactive power upon the appearing of faults in the grid.
- Absorb reactive power to control the grid voltage during low load or high level of distributed generation.
- Add flexibility and smoothness to grid voltage control.
- Prevent tripping of wind farms located in the region.

The SVCs have proved their usefulness in the power grid. They have sustained the network during situations with low grid voltage and all available MSCs connected. They have also brought increased flexibility into network management, and have increased the voltage stability due to TCR fine adjustment.



A mining complex in Peru, situated in the Andes mountains at an altitude of more than 4.000 meters above the sea level, is a major copper and zinc producer, one of the largest in the world. A prerequisite for production was the development of adequate utility infrastructure to feed the mine complex, as the feeding grid system was too weak to support the loads without proper measures taken. As a solution, an SVC was installed, rated at 45 Mvar inductive to 90 Mvar capacitive. Its purpose is to stabilize the 220 kV voltage at the mine feeding substation to within $\pm 5\%$, permitting safe operation of very large mining machinery even under the most restrictive power system conditions.



Western Texas, USA has an abundance of wind power. Adequate dynamic reactive power support is necessary to maintain system operation at acceptable voltage levels. To improve and maintain voltage stability, ABB has supplied and installed three SVCs in the system. Each SVC is rated at -40/+50 Mvar. Two SVCs are connected directly to 69 kV without any need for step-down transformers. The third is connected to the 34.5 kV tertiary winding of an existing 345/138 kV autotransformer. Each installation was initially scheduled to take 11 months from the time of initiation to the end of commissioning. Two of the SVCs were actually completed in just 10 months.



A total of seven SVCs were supplied to High Speed 1, the 108 km high-speed rail line between London, UK and the channel tunnel at Dover. With this link in operation, it is possible to travel between London and Paris in just over two hours at a maximum speed of 300 km/h. Six of the SVCs, each rated at -5/+40 Mvar single-phase are used mainly for dynamic voltage support. The seventh SVC, rated at -80/+170 Mvar is needed for dynamic balancing of asymmetrical loads between phases.

ABB – the pioneer

...and market leader of SVC





ABB was one of the first companies to identify the importance of effective and rapid control of reactive power. As the market leader in static var compensation, ABB's know-how in this field is acknowledged world-wide.

We commissioned the first large commercial thyristor-switched capacitor installation (1972) and also launched the first combined type Static Var Compensator, TCR/TSC (1979). Many of these are still in operation.

ABB SVCs have been installed by power utilities and industrial plants around the world for all existing voltages between 10 kV and 800 kV. And the technical and economy advantages of this technology are becoming increasingly recognized.

Today, close to 500 ABB SVCs are in operation or under installation all over the world. A selection of these are shown in the world map.

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