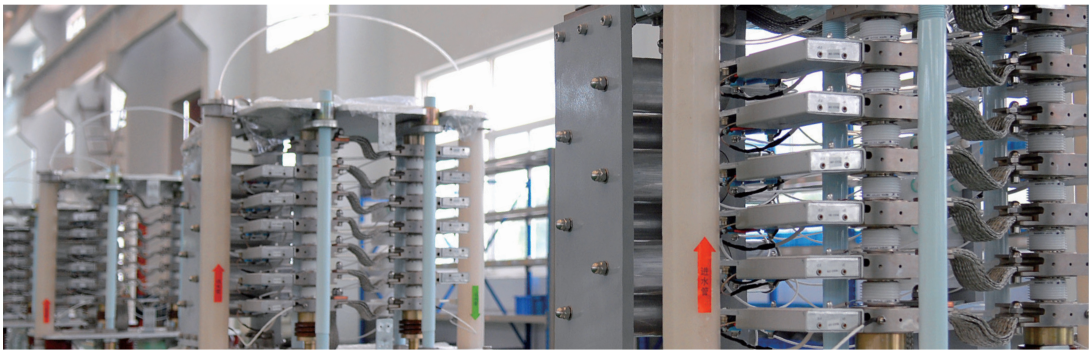
Solutions for Static Var Compensator



SVC -- brings reliable and high-quality power to consumers

NR Electric Corporation

Introduction

Modern society has relied consistently on electrical power, requiring higher demands of power stability and power quality. High-power rapid impact loads, rapid growth of asymmetrical impact loads, e.g. electrified railway, increase in distributed wind power generation equipment, connections/disconnections of large load and inevitable power system faults, are adverse factors which can lead to considerable reactive disturbances in power system and affect power stability, power quality and economy of power grid operation. The overcurrent and overvoltage sequences caused by these disturbances may damage the associated electrical apparatus.

To solve this problem, it is essential to adjust reactive power in the power grid expeditiously to achieve a reasonable power flow distribution, which is also very important in phase modulation, voltage regulation and overvoltage restriction.

The traditional reactive power regulation methods before the invention of SVC are:

- Reconfiguration of system structure
- Generator excitation regulation
- Synchronous compensator
- Change of voltage by transformer tap to adjust the power flow in the grid
- Series compensation capacitor
- Switching in/out of the shunt reactor or shunt capacitor
- Magnetic controlled reactor

Compared to these traditional reactive power compensation methods, the Static Var Compensator (SVC) has extensively gained a significant market value. This is as a result of its efficiency in supplying dynamic reactive power with fast response time and low-cost maintenance scheme.

The Static Var Compensator has different application topology, such as ***Thyristor Controlled Reactor*** (TCR), ***Thyristor Switched Capacitor*** (TSC), ***Thyristor Switched Reactor*** (TSR), and ***Breaker Switched Capacitor*** (BSC).

In this brochure, unless otherwise stated, the SVC mentioned in the following is composed of TCR and BSC.

Why need SVC System

Brings benefits to different industrial field

A complete set of SVC system can be used to generate a constant varying inductive and capacitive reactive power with fast response time. So far, SVC system has been extensively used in electric power system and industrial fields.

Power Transmission

In the case of long-distance AC transmission, due to the influence of Ferranti Effect, the voltage in the middle of transmission lines will rise which will limit the transferred power. Therefore, to reduce the voltage rise and maximize the transferred power, the SVC is normally installed at the midpoint or several points in the middle of transmission line.

In addition, an SVC system installed on the AC side of DC converter station can provide sufficient reactive power with fast response and easy maintenance.

Benefits

- Regulate the system voltage.
- Increase the static stability and transient stability of power system.
- Increase the line transmission capacity.
- Restrain the power oscillation and the sub-synchronous resonance.
- Restrain the transient overvoltage.
- Balance the three-phase voltage.
- Control the voltage in DC converter station and provide reactive power.

Distribution System

The SVC can be connected to the terminal substation in the power distribution system to reduce the reactive power exchange, improve the power factor, decrease the distribution system loss and reduce the damages caused by frequent switch-in of capacitor banks.

Benefits

- Reduce the reactive power exchange with system and improve system stability
- Rapid and continuous compensation of the reactive power, increase in the power factor and improvement in the power quality
- Reduction in the power losses of distribution system
- Used in combination of stepped-switchover capacitor banck to reduce the damage caused by frequent switching of capacitor bank

Wind Power Plant

For small hydro-power plant or wind power plant in some remote locations, the connected large power grid can not efficiently provide enough reactive power, or the excess reactive power may result in a serious voltage drop and large line losses. Installing an SVC system at the connection point can efficiently stabilize the voltage at the connection point to an acceptable level and maximally prevent the harmful impact caused by faults in the power grid.

Benefits

- Increase in the power factor by dynamic reactive power compensation
- Eliminates the harmonics
- Eliminates the voltage fluctuation and voltage flicker
- Provides the local reactive power, stabilizes the voltage and reduces the transmission line losses

Industrial Consumers

The electronic rectifiers applied to the electrolysis power supply and mill machine requires large amount of reactive power. The SVC system can not only supply sufficient reactive power, but also eliminate the harmonics generated by rectifiers and prevent the equipment from the voltage fluctuation.

The use of AC arc furnace usually comes with heavy harmonics and large negative sequence current. Large amount of reactive power demand and reactive power variation result in the voltage fluctuation and flicker, which also reduces the operation efficiency.

Benefits

- Increase in the power factor by dynamic reactive power compensation.
- Eliminates the voltage distortion caused by harmonics.
- Stabilizes the voltage and reduce the voltage fluctuation and flicker.
- Balances the three-phase load current and eliminate the negative sequence current.
- Increases the operation safety of impact loading equipment and its adjacent electrical equipment.

Operating Principles

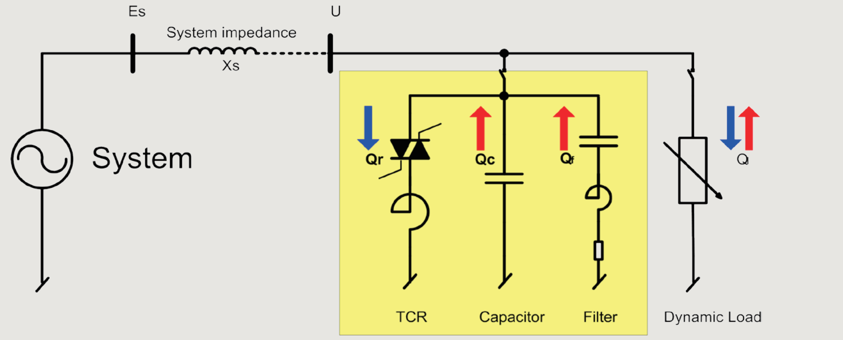
The Static Var Compensator(SVC) is composed of the capacitor banks/filter banks and air-core reactors connected in parallel. The air-core reactors are series connected to thyristors. The current of air-core reactors can be controlled by adjusting the fire angle of thyristors.

The SVC can be considered as a dynamic reactive power source. It can supply capacitive reactive power to the grid or consume the spare inductive reactive power from the grid. Normally, the system can absorb the reactive power from a capacitor bank, and the spare part can be consumed by an air-core shunt reactor.

As mentioned, the current in the air-core reactor is controlled by a thyristor valve. The valve controls the fundamental current by changing the fire angle, ensuring the voltage can be limited to an acceptable range at the injected node(for power system var compensation), or the sum of reactive power at the injected node is zero which means the power factor is equal to 1 (for load var compensation).

Current harmonics are inevitable during the operation of thyristor controlled rectifiers, thus it is essential to have filters in a SVC system to eliminate the harmonics. The filter banks can not only absorb the risk harmonics, but also produce the capacitive reactive power.

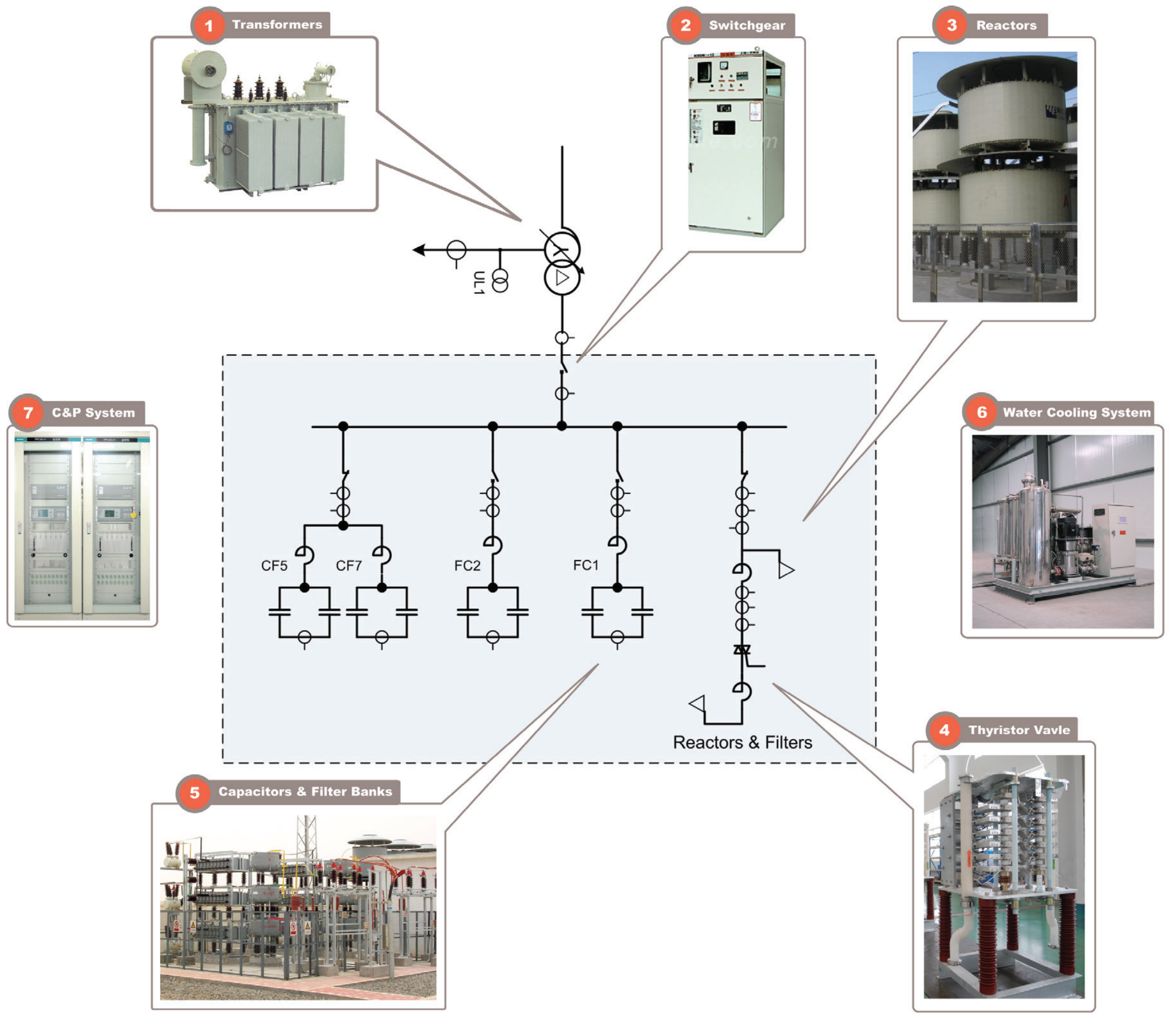
The SVC uses closed loop control system to regulate busbar voltage, reactive power exchange, power factor and three phase voltage balance.



SVC System

System Configuration

A Static Var Compensator mainly consists of following components:



1 Step-down transformer

The static var compensator is normally installed at low voltage side of main transformer, otherwise a step-down transformer is needed to reduce the voltage.

2 Medium Voltage switchgear

The medium voltage switchgear typically includes isolating switches, grounding switches and transformers. It can be installed indoor or outdoor.

3 Linear (Air-core) reactor

The air-core reactor in static var compensator has high stability and high linearity. It is used to absorb reactive power under the control of thyristors. Usually the air-core reactor is series connected to the thyristor valve in delta-connection and then connect the delta bridge to power grid.

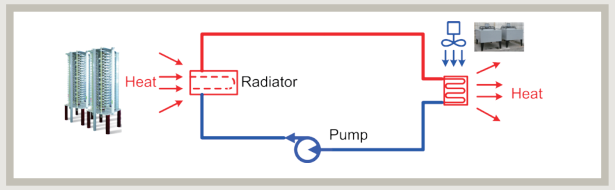
4 Thyristor valve

The thyristor valve is the main control part in a SVC system. It is composed of several series/paralleled connected thyristors and its auxiliary components. The thyristors are triggered by electrical lighting system and it adopts water cooling as the main cooling method.

5 Capacitor/filter banks

The capacitor/filter banks can supply sufficient capacitive reactive power to power grid and filter the harmful harmonics. The filter is composed of capacitors, reactors and resistors, providing capacitive reactive power to the entire system.

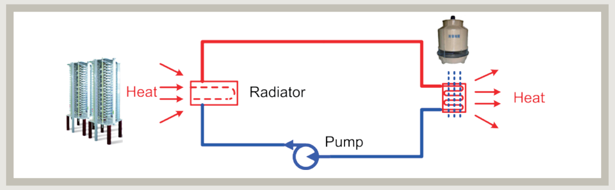
In practical, the capacitor/filter banks are divided into several sub-banks which can be switched-in/switched-off by mechanical breakers or other electrical switches according to the actual situation.



Water-fan cooling method

6 Water cooling system

The heat produced by thyristor valve will be harmful to thyristors if the heat is not dissipated in time. The de-ionized water cooling system is sufficient for the thyristor valves which have a high operating voltage. The cooling system uses the de-ionized pure water for internal cooling and regular industrial recycling water for external cooling.



Water-water cooling method

7 SVC control and protection system

The key functions of SVC control and protection system are:

- Generating the control pulses to the valve at suitable time to fire the thyristors
- Monitoring the SVC system to provide operation condition, fault record or self checking information
- Switching in/out the FC in order
- Protecting each component to ensure the safe operation of SVC
- Friendly Human-Machine Interface

Functions & Features

Professional system design

With professional research teams and world-class manufacturing & testing facilities, NR is always persisting to offering customized and cost-effective solutions to our end users. The advanced testing facilities can help to obtain the most optimized capacity, system configuration and control strategies in the design on the basis of system voltage, active power distribution, reactive power balance and restraint harmonics.

Innovative technologies and new materials

The main pipes of valve cooling system are made of Polyvinylidene Fluoride(PVDF) which has advantages of excellent shock resistance, attrition resistance, corrosion resistance, creep resistance and excellent tensile. The PVDF is noncombustible, high heat resisting and can work in -40°C-150°C for a long term. With these benefits, PVDF has been widely used in NR's SVC thyristor valves. The distributed pipes in each layer of thyristor are made of perfluorinated ethylene-propylene(FEP) which has high mechanical strength,

chemical stability, well electrical insulating property, abrasive resistance, age resistance and incombustibility. The cables and optic fibers of thyristor valve groups are all made of flame-resisting materials that can effectively reduce the possibility of combustion failure for the valve groups.

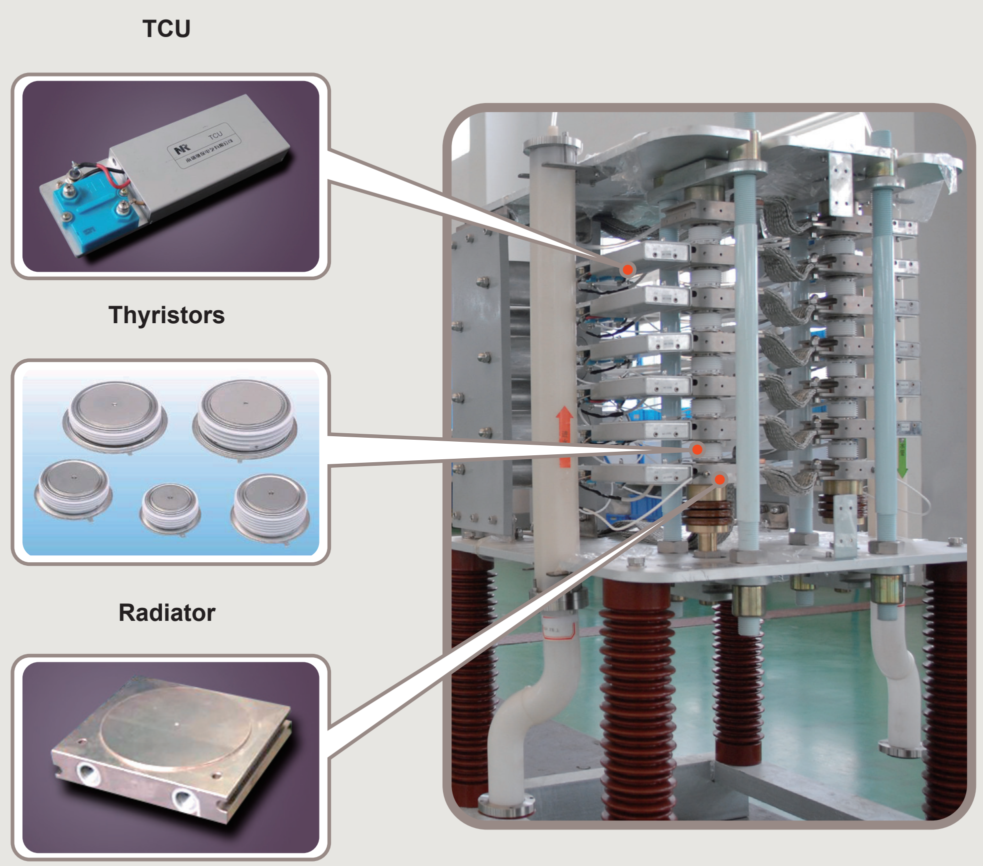
Compact thyristor valve

The core component of SVC system

NR's compact valves are vertical press-mounting configuration. The valve volume is not varying with the increasing current. However, if the valve is composed of bi-directional thyristors, the valve volume will reduce by 25% with current increase.

Benefits of Compact Valves:

- Small space occupation and low construction cost
- Small in size and light in weight
- Easy on-site installation
- High reliability and easy maintenance



Advanced photoelectric triggering system

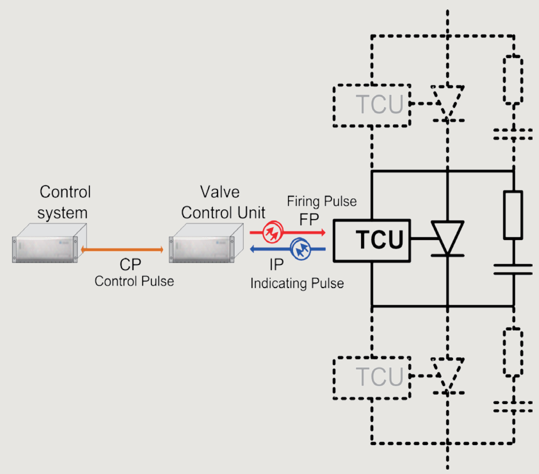
NR's static var compensator adopts photoelectric triggering technology. The triggering system is composed of two parts: one is Valve Control Units(VCUs) installed in control panels or placed in valve room, the other part is Thyristor Control Units (TCUs) which locates upon the main part of valve.

The control pulses generated by control system are converted to fire pulses by VCU. The TCU will then convert the fire pulses to electrical pulses to trigger the thyristor. If the thyristor is not forward biased, or has been damaged, the TCU will check and send the IP signal to the control system via VCU. The control system will issue an alarm or switch-off the thyristor based on the received fault information.

The photoelectric triggering system can brings many advantages in the following aspects:

- The photoelectric triggering system is small in volume and light in weight
- The TCU can be energized by primary circuit under the control dictated by optic fibers
    - Well photoelectric insulation property
    - Strong anti-interference capability
    - Short time delay and fast response
    - Well synchronism property of fire pulse
    - Reliable triggering signal with large gradient
    - Noiselessness
- The TCU integrates forward overvoltage protection and reverse recovery protection for thyristors.

Electrical Triggering System



The TCU modular is in a sealed metal box installed on the wing plate of radiator.

- Strong anti-interference capability and low self radiated interference
- Well operation environment for TCU
- Avoidance of circuit pollution and circuit malfunction
- Compact configuration

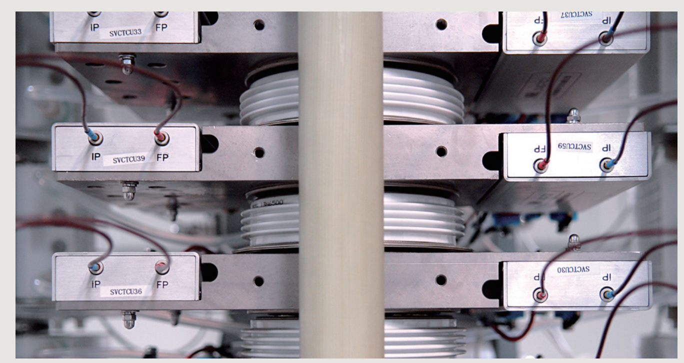
The TCU and the VCU are also used in commutation valves in HVDC transmission projects and integration test for HVDC & UHVDC valves.

Thyristor overvoltage threshold protection

The series connected thyristor will sustain the high forward voltage if it is not properly triggered. To avoid from being damaged, the thyristor shall be forced to conduct before the forward voltage reaches the threshold value.

The conventional forward overvoltage protection is using a Break Over Diode(BOD) to clamp the overvoltage. However, BOD has large volume, and the operation voltage deviation will increase with the amount series connected BODs. These disadvantages can easily result in an increase in the threshold voltage of the entire valve.

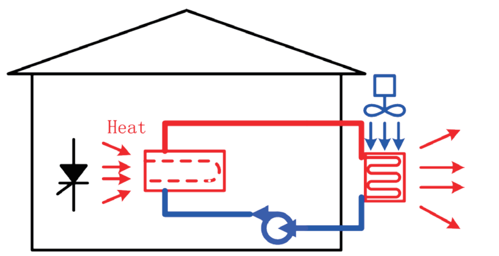
To avoid these disadvantages, NR designed the unique overvoltage protection circuit for thyristor valve. This unique overvoltage protection circuit has small deviation in threshold voltage and the threshold value is editable to adapt to different thyristors. So far, this overvoltage threshold protection circuit has been widely used in HVDC transmission projects and static var compensators due to its stable and reliable performances.



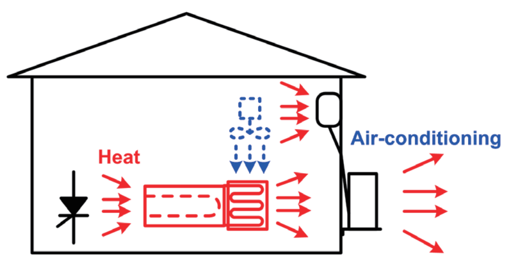
Patented cooling system

A well performed cooling system is a key factor to maintain system's reliability. NR's static var compensators adopt industrial-class sealed de-ionized water cooling system. This reliable cooling system is extensively used in locomotive, aeronautics & astronautics, mega-watt generator sets and HVDC transmission. It has advantages in the following aspects:

- Well proven and experienced technology
- Non-toxic and environmentally-friendly resources
- Large specific heat capacity and high heat transferring efficiency
- Large cooling capacity and low power consumption
- Well control of thyristor junction temperature
- Avoidance of valve hot operation caused by the directly heat dissipation of heat conducting materials.
- Reduce the maintenance cost by replacing the large power air-conditioning in the valve hall
- Lower energy consumption rate compared with other cooling methods



De-ionized watercooling System



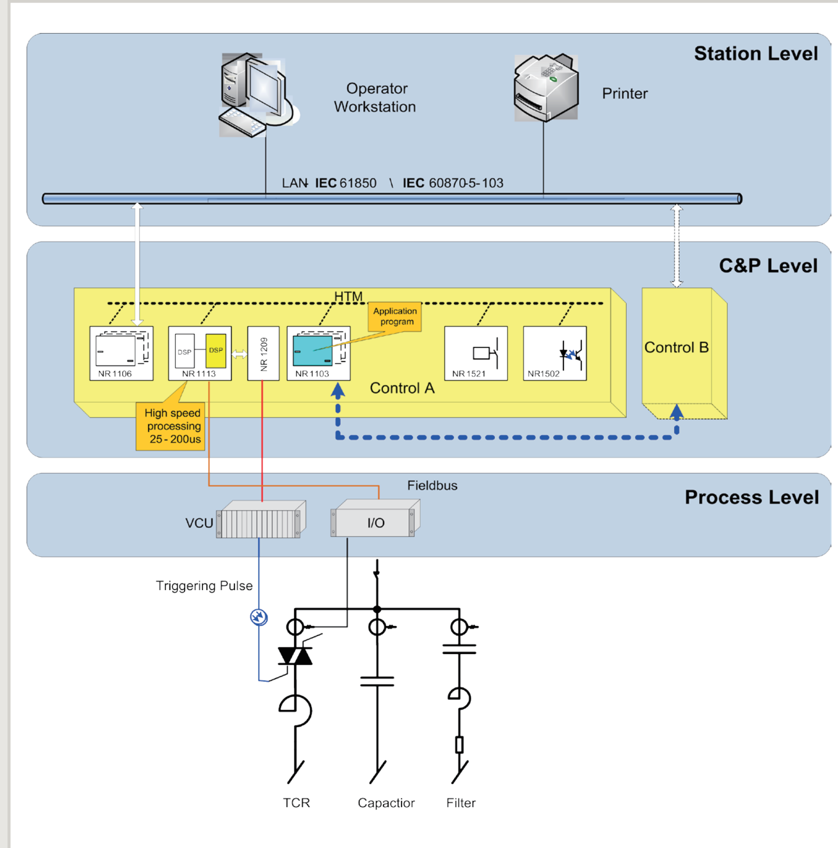
Indirect heat dissipation

The patented core technologies of water cooling system for static var compensator include:

- Parallel waterways design
  - High cooling efficiency
  - Reliable operation
- Patented radiator
  - Direct cooling by unique waterway
  - Small thermal resistance(RSA<7K/kW at rated water flow)
  - Corrosion-resistant and rustproof
- Waterway direct-cooled and voltage-equalized resistor
  - High surge capability
  - Small volume
- High reliable water pipe and joint
  - High environment tolerance of PVDF main pipe
  - Dedicated embedded squeezing leakage-proof structure joint

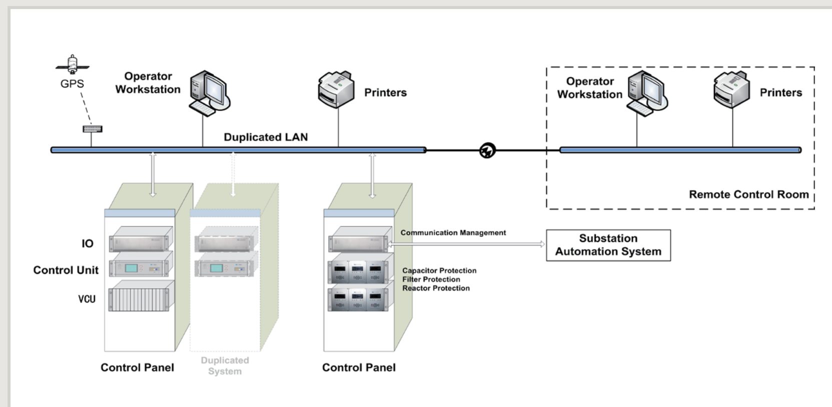
High-performance control & protection system

The control & protection system of static var compensator adopts the breakthrough UAPC platform, which also has been applied to NR's HVDC control & protection system, FACTS control & protection system and digital substation protection & control system.



Operating Principle of SVC Control & Protection System

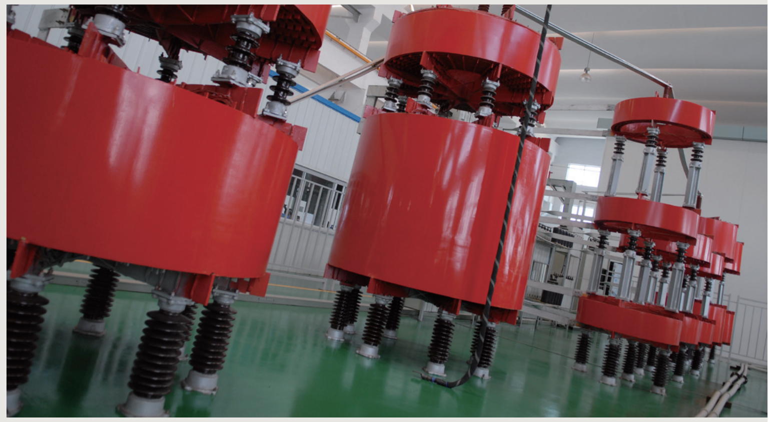
The typical SVC control & protection system diagram is shown below:



SVC Control & Protection System Diagram

Features of SVC control & protection system

- Short response time: interruption time is 25μs; actual open loop response time is less than 7 ms
  - Leading overall performance
  - Voltage flicker can be better controlled if operating with high-performance triggering system.
- High accurate control angle(0.01°) and large control range(102°-165°)
  - Large dynamic range
  - High control precision
  - Larger output range and margin
- Multiple control modes can meet the requirements of different industry fields
  - Voltage control mode
  - Reactive power control mode
  - Reactive power factor control mode
  - Combination control of voltage and reactive power
  - TCR DC control mode
  - Negative sequence control mode
  - Manual susceptance regulation mode
- Redundancy design of the entire control and protection system
  - Ensure reliability requirements of electric power consumers
  - Integration of device information and connection with user monitoring system
  - Easy operation and maintenance
  - Easy to realize information telematics
- Integrated fault record function complied with COMTRADE format
  - Precisely aware of system operation status
  - Timely discovery of abnormal events to ensure the safe operation
  - Flexible fault analysis
- Integrated design of harmonic monitoring system
  - Precisely aware of system operation status
  - Simplified monitoring method
  - Timely discovery of abnormal events to ensure the safe operation
- Modularized system design brings advantages of flexible system updates and long-term spare parts supply
  - Guarantee customers' investigation and reduce maintenance cost
- Flexible and reliable protection configuration
  - Long-term experienced and well-proven protection devices
  - Flexible to install in switch cabinet
- Simulation training system consistent with real equipment operation
  - Improve employees' operation skills
  - Reduce training cost



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Version 2012.03