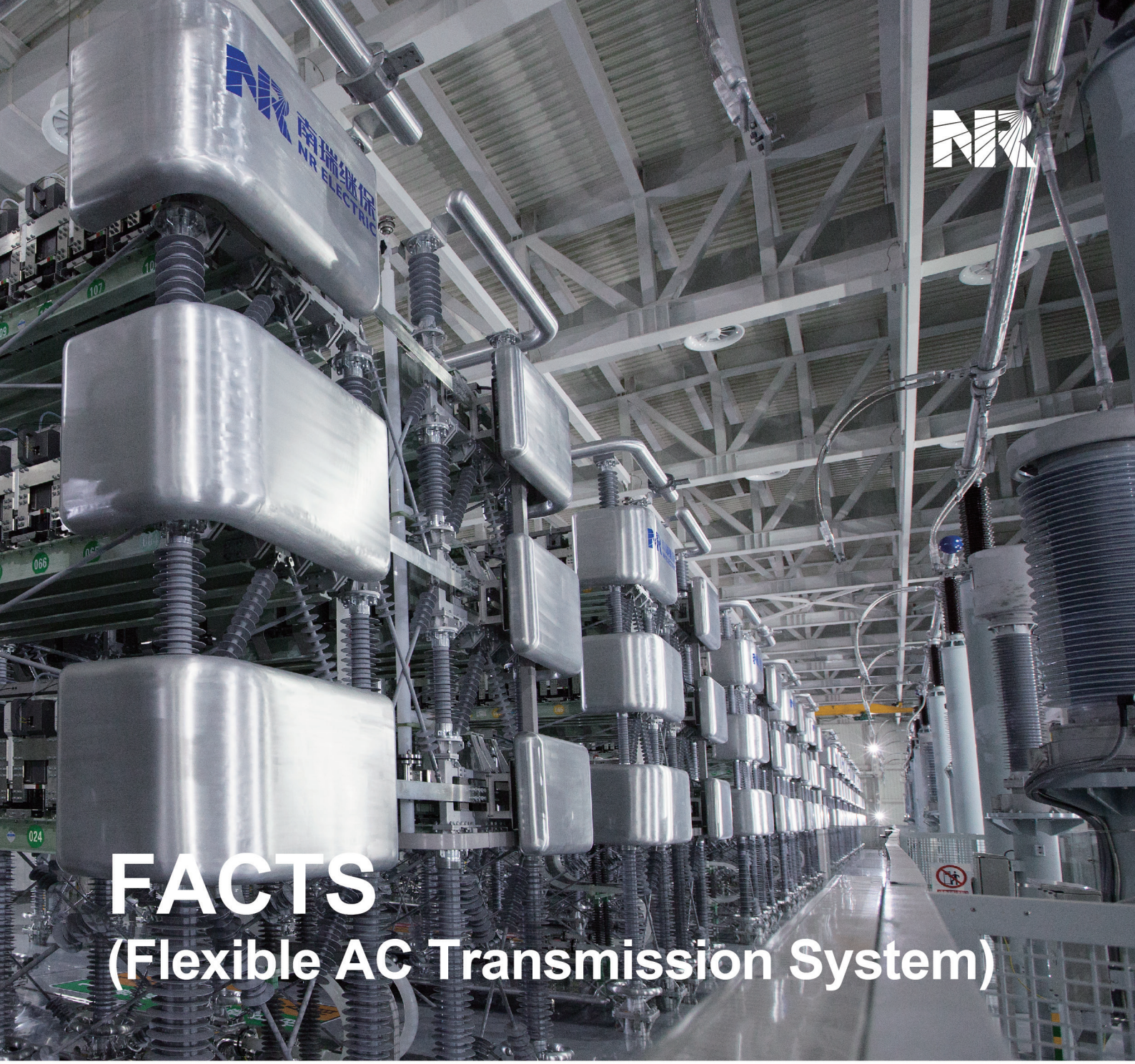

FACTS
(Flexible AC Transmission System)

2019 Catalogue

NR Electric Co., Ltd.

NR engineered innovative Flexible AC Transmission Systems (FACTS) that contribute to enhanced grid stability and power quality. Over the past 20 years, NR has successfully accomplished diverse FACTS milestones with technological breakthroughs that can benefit the consumer by reducing voltage fluctuations and balancing power system.

Growing electricity demand and application require to keep increasing power transmission, distribution capacity and power quality. NR Flexible AC Transmission Systems (FACTS), which is built on power electronics integration, system analysis and control technology, could increase transmission capacity, improve stability & dynamic behavior of the system ensuring better power quality and stability. FACTS family comprises of dynamic shunt & series compensation and dynamic energy storage. Our specialized devices offer series and parallel compensation. NR devices actively injecting or absorbing reactive power for parallel compensation influence the network voltage at their common coupling point while essentially series compensation employed for enhancing the power transfer capability.

NR delivers a wide range of IEC, IEEE and other international standards compliant FACTS solutions inclusive of various communication protocols that offers grid operators the ability to improve controllability and increase power transfer capabilities for optimum grid interconnection and expansion. Our portfolio is to produce cutting edge FACTS devices in order to meet strict requirements from industries, power utility and renewable energy access to execute projects with high reliability all over the world.

Table of Contents

PCS-9580

Static Var Compensator (SVC)

SVC is a set of electrical devices for adjusting reactive power fast and effectively in high-voltage power grid, which can regulate voltage and power factor, keeping voltage stable and improving power quality. It is widely used in power transmission, HVDC converter station, industrial field and wind farm, and so on.

Operating Principle

The SVC can be seen 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.

Typically, there is one or more banks of fixed or switched shunt capacitors or reactors in one SVC system, of which at least one bank is switched by thyristors. The widely applied elements in SVCs include: thyristor controlled reactor (TCR), thyristor switched reactor (TSR),thyristor switched capacitor (TSC), breaker switched capacitor/ filter capacitor (BSC/FC).

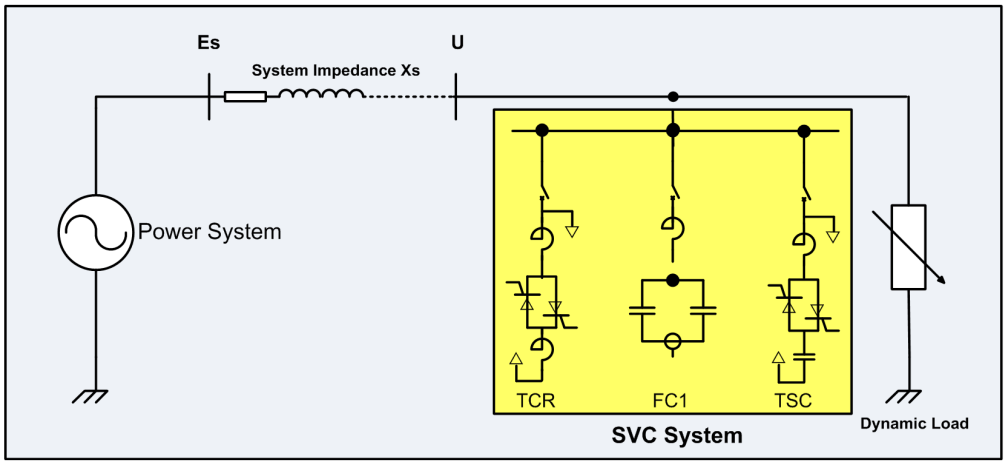

Figure 1 SVC Operating Principle

Functions

- Power Transmission
  - Regulating system voltage.
  - Increasing static stability and transient stability of power system.
  - Increasing line transmission capacity.
  - Restraining power oscillation and sub-synchronous resonance.
  - Restraining transient overvoltage.
  - Balancing three-phase voltage.
  - Controlling the voltage in DC converter station and providing reactive power.
- Industrial Consumers
  - Reducing power fluctuation and voltage flicker.
  - Balancing three-phase load.
  - Reducing harmonic current and harmonic voltage.
  - Improving power factor.
- Electrified Railways
  - Balancing three-phase voltage.
  - Improving power factor.
  - Eliminating harmonics.
  - Suppressing voltage fluctuation and stabilizing grid voltage.

System Configuration

The PCS-9580 SVC system mainly consists of the following components:

- 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.
- Medium Voltage Switchgear
  The medium voltage switchgear typically includes isolating switches, grounding switches and transformers. It can be installed indoors or outdoors.
- 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 connected in series to the thyristor valve in delta-connection, and then connected to the power grid.

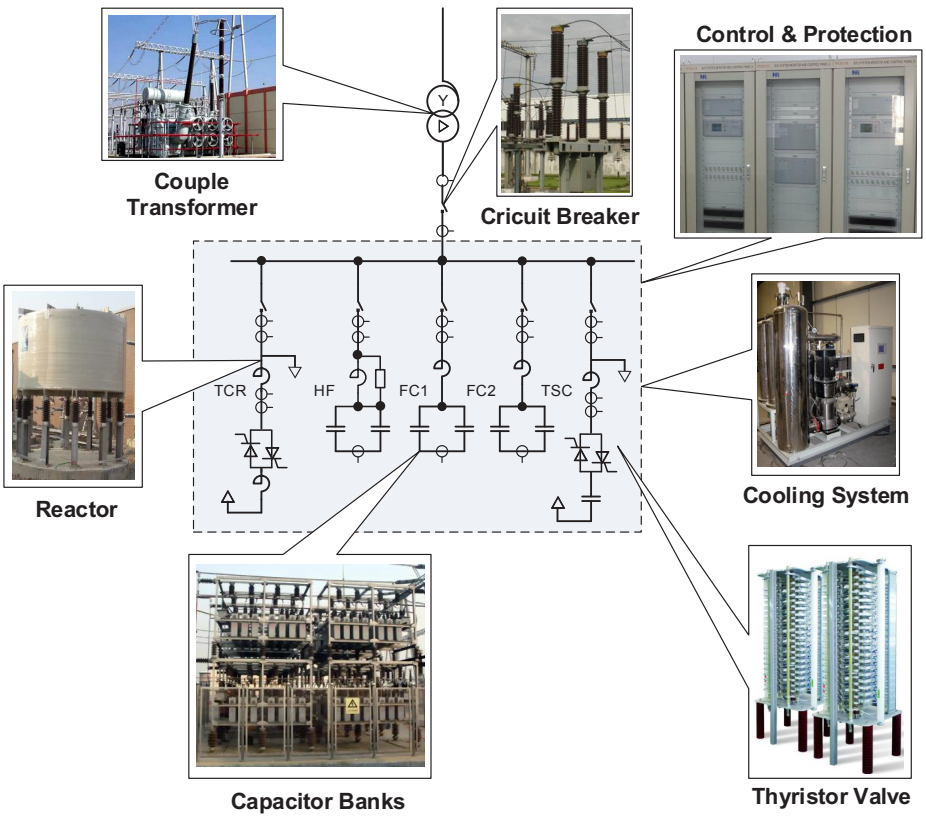

Figure 2 SVC System Configuration

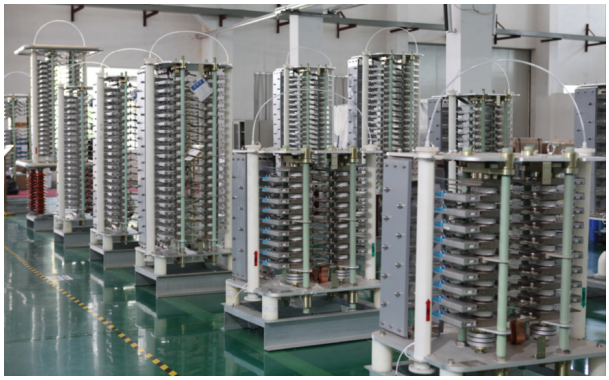

Figure 3 Thyristor Valve

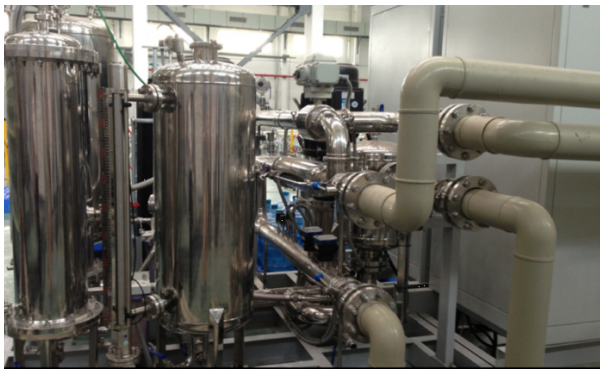

Figure 4 Cooling System

- 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 photoelectric triggering system and it adopts water cooling as the main cooling method.

- Capacitor/Filter Bank
  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 by mechanical breakers or other electrical switches according to the actual situation.

- Cooling System
  The heat produced by thyristor valve will be harmful to thyristors if the heat is not dissipated in time. The 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 airwind for outdoor cooling.

- 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 the FCs in order
  - Protecting each component to ensure the safe operation of SVC
  - Friendly Human-Machine Interface

Features

- Fast system response time (the measured open-loop response time is below than 10ms) .
- High-precision control angle (0.01 °), wide control range (102 ° -165 °).
- Vertical and free-floating press-stack structure for the valve. A valve block features: small size, convenient layout, low costs of infrastructure, simple valve block structure, high reliability and simple installation and maintenance.
- Advanced electro-optical trigger mode employs a high-voltage fiber-optic one-to-one trigger. This technology provides strong anti-interference performance, reliable operation and fast trigger speed.
- Patented water-cooling technology with high reliability and high thermal efficiency. This cooling method has been widely used for the locomotive and aerospace industries. It has also been used in one million kilowatts generating units, and high-pressure and UHVDC transmission.
- High-performance control and protection system. NR Electric SVC system adopts a high-performance decentralized and distributed structure to facilitate functional expansion and remote maintenance.

PCS-9583

Static Synchronous Compensator (STATCOM)

The Static Synchronous Compensator is a voltage regulating device based on voltage source converters. It acts as a source or a sink of reactive power which is independent of AC system voltage. The STATCOM can adjust reactive power of power grid, improve power quality, and reduce grid losses and the impact on electrical equipment. It is extensively applied to power grid, renewable energy generation, steel mill, chemical plant, electrified railway, city subway, mine and so on.

Operating Principle

PCS-9583 STATCOM system adopts voltage source converter and the most advanced reactive power compensation technology, not needing large-capacity capacitors and inductors. The H-bridge circuit is connected to the grid via connection transformer or reactor, by suitably adjusting the phase angle and amplitude of output voltage at AC side of the bridged circuit or directly controlling its AC current, this circuit can absorb or generate reactive current as required and realize dynamic adjustment of voltage or reactive power.

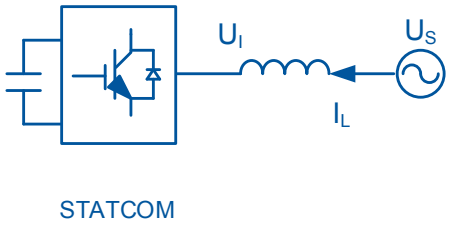

Figure 1 STATCOM Operating Principle

The cascading scheme of multi-level topology is used in the PCS-9583 STATCOM system. This topology consists of several H-bridge power units with monopole multiplier modulation to achieve three-level output on the AC side. Each phase adopts the carrier phase modulation method to obtain better voltage output waveform with much more level numbers. The cascading scheme can output phase voltage with 2N +1 levels if each phase comprises N +1 links (i.e. the H-bridge power unit).

Functions

- Power Transmission Substation
  - Compensate line reactive power and stabilize system voltage
  - Reduce transmission losses
  - Increase line transmission capacity through the dynamic support of line terminal voltage
  - Improve transient stability to prevent against transient voltage collapse
  - Provide power oscillation damping
- Mining Hoists and Industrial Mills
  - Improve power factor, reduce reactive power loss and energy-saving
  - Solve serious harmonic pollution problems, and improve power quality by active power filtering
  - Enhance line terminal voltage, improve voltage stability and power supply security
  - Reduce voltage fluctuation and flickers caused by heavy load during startup
- Electrified Railway
  - Provide power factor control to reduce power loss
  - Supply voltage regulation to weak grid
  - Compensate negative sequence/unbalance current or voltage
  - Provide harmonic filtering
- Wind Farm and Solar Energy
  - Correct system power factor
  - Reduce voltage fluctuation and flicker
  - Filter harmonic current
  - Balance three phase power
  - Enhance voltage stability and improve low-voltage ride through (LVRT) capability
- Steel Plant and Rolling Mill
  - Provide harmonic filtering

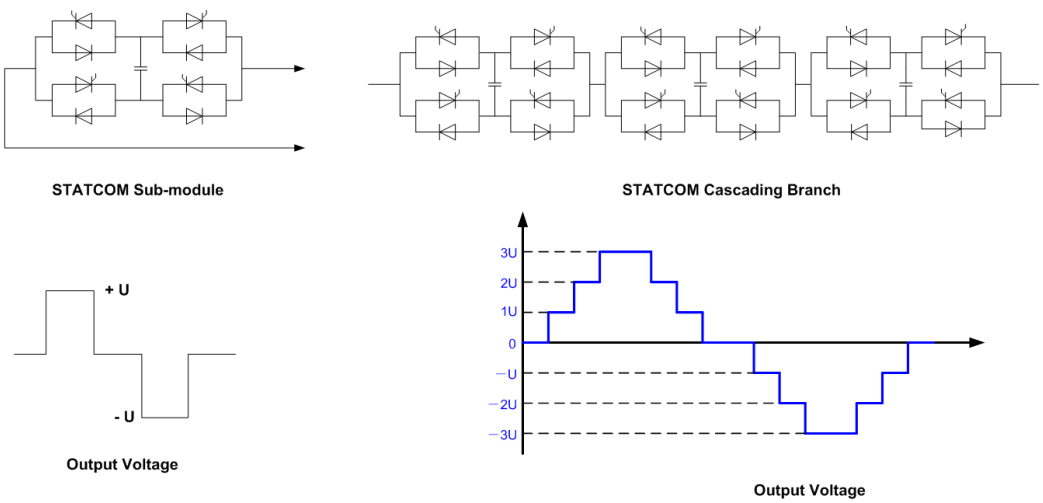

Figure 2 Chain Circuit STATCOM

- Compensate unbalanced voltage
- Significantly reduce voltage fluctuation and flicker
- Improve productivity
- Reduce reactive power impact
- Control power factor

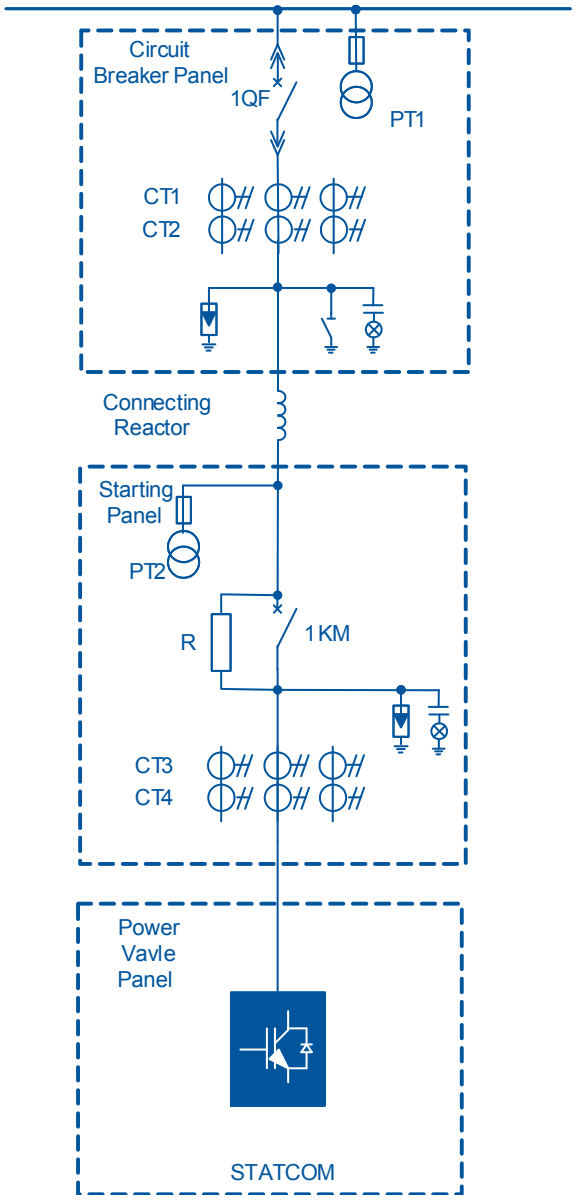

Figure 3 STATCOM System Configuration

System Configuration

This complete set of STATCOM system mainly includes the following main equipments:

- Interface Reactor/Converter Transformer
  The interface reactor/converter transformer is used to connect the converter with the AC power networks, realizing the active power and reactive power exchange between the converter and the AC power networks.

Figure 4 Startup Equipment

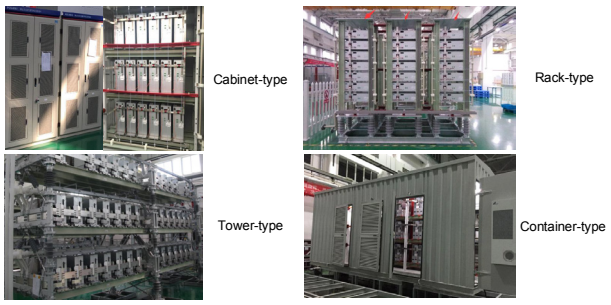

Figure 5 Power Valve

- Startup Equipment
  To start the STATCOM system, the capacitor at DC side needs to be charged firstly. And for reducing the charging current and the impact on the system, the startup equipment is adopted in STATCOM system.

- Power Valve
  Power module, as the basic unit of STATCOM system, consists of IGBT and its drive circuit, supporting capacitor, radiator, equalizing resistance and so on. The power valves adopt H-bridge cascaded structure. Each phase consists of a number of power modules, adopting redundant design and satisfying “N-1” or “N-2” operational requirements.

- Cooling System
  Formation of enormous heat during operation may damage the components if it is not dissipated well. During low system capacity, PCS-9583 STATCOM adopts forced air cooling whereas during large system capacity, it adopts closed-loop water cooling with specialized control system.

- STATCOM Control and Protection System
  The STATCOM control and protection system consists of PCS-9583 PCP (Pole Control and Protection), PCS-9589 VBC (Valve base Control) unit, SMC (Sub-module controller), interposing relay set, network switch and other protection devices.

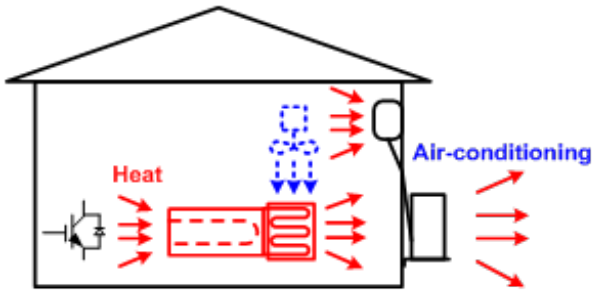

Figure 6 Forced Air Cooling

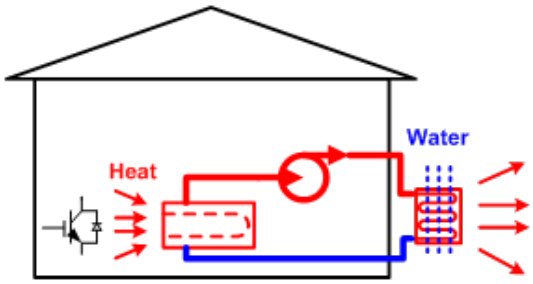

Figure 7 Enclosed Water Cooling

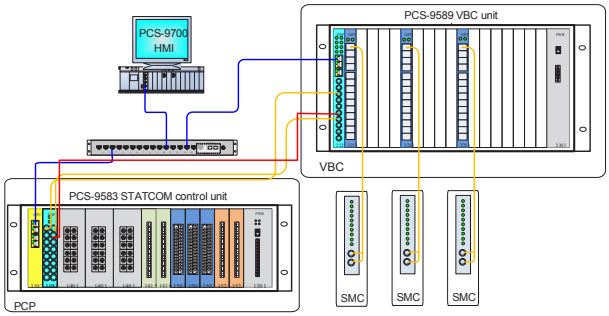

Figure 8 STATCOM Control and Protection System

Features

- Modular design
  Modular power modules with professional design, compact structure, high reliability, and easy to product and maintain. The hot standby redundancy of unique design can ensure operation of redundant unit with zero impulse in case of fault in an operating power module.

- High performance, high reliability of control and protection system
  The UAPC platform of NR is adopted to constitute the control and protection system. Framework is high-performance and high-reliability, and with mature hardware and software. The kernel controller adopts the latest floating controller in the industry, which has high main frequency, large memory, and high operation and control precision. Integral panel and fully enclosed chassis are used so that ingress of dust can be effectively prevented, thus guaranteeing safe and reliable operation of the control system.

- Advanced DC side voltage balance technique
  Adopt advanced DC side voltage balance technique in the industry. Unique innovative balance algorithm between chains and inter-phase balance algorithm have been proposed, effectively control capacitive voltage equalizing between chains, reduce power module complexity, and reduce power loss of the whole system without use of any additional auxiliary hardware equipment.

- Advanced HMI system
  PCS-9700 HMI system is a new generation HMI system developed by NR based on years of SAS research achievements and site operation experiences. This system adopts advanced distributed network technology, object-oriented database technology, cross-platform visualization technology, and latest standards in the industry. It is the achievement of elaborate design and devoted in-depth development. International standards such as IEC60870-5-103 and IEC61850 are fully supported. PCS-9700 can satisfy the demands on HMI system in conventional substations, digital substations, as well as the NCS system in power plants.

- Integrated fault recording function
  This system integrates fault recording function, which can record the whole dynamic process in STATCOM system, including the change process of relevant system electrical parameters after large disturbance and operation behavior of protection modules. Recorded fault data includes data in transient state and steady state. Transient fault recording can record transient disturbance process at a rate of 9.6kHz at highest, without use of triggering conditions. Steady state fault recording continuously records power system status process at a rate 1Hz~1.2kHz. The equipment has a large capacity and high-speed FLASH memory card to ensure safety of dynamic data recording and storage. COMTRADE format of IEEE is adopted to facilitate later acquisition and analysis.

- Complete protection functions
  NR is dedicated to the power system protection, and has obtained a series of patented technologies and proprietary technologies in protection and control of power system. PCS-9583 STATCOM system provides multiple protections, including component level protection, valve unit level protection, and system level protection. The complete set of protection function are provided for power modules, valve banks, lines, and filter capacitor (FC). This hierarchical comprehensive protection strategy greatly improves product reliability.

- Powerful communication functions
  Flexible communication mode is provided and seamless connection with NR PCS-9700 series protection and supervisory control platform can be realized. Power industry communication standard IEC60870-5-103, Modbus protocol and new generation substation communication standard IEC61850 are supported.

PCS-9570

Fixed Series Compensation (FSC)

The fixed series compensation plays an important role in the intelligent network due to its effect on transmission lines, especially with long distances. It can increase the power capacity of the transmission network and optimize power flow dispatching, reduce power losses and make full use of power supply at the minimum generation cost.

NR Electric's PCS-9570 fixed series compensation offers complete FSC solutions. NR's PCS-9570 consists of capacitor, metal oxide arrester (MOV), damping circuit, spark gap, bypass switch, series compensator platform, electronic transducers, FSC protection & control system, etc.

The PCS-9570 series products are designed based on years of experience in the protection and control solutions for HVAC relay protection. The AC digital sampling, based on electronic transformer measurement, effectively solves the interference problem on site. The protection and control model based on IEC61850 standards can implement sequence control of the substation series compensators to automatically switch-in or switch-over capacitor banks with series compensators, so as to optimize the power flows and improve transmission capacity in digital substations. The series products are mainly applicable in the AC transmission lines of 66kV~1000kV.

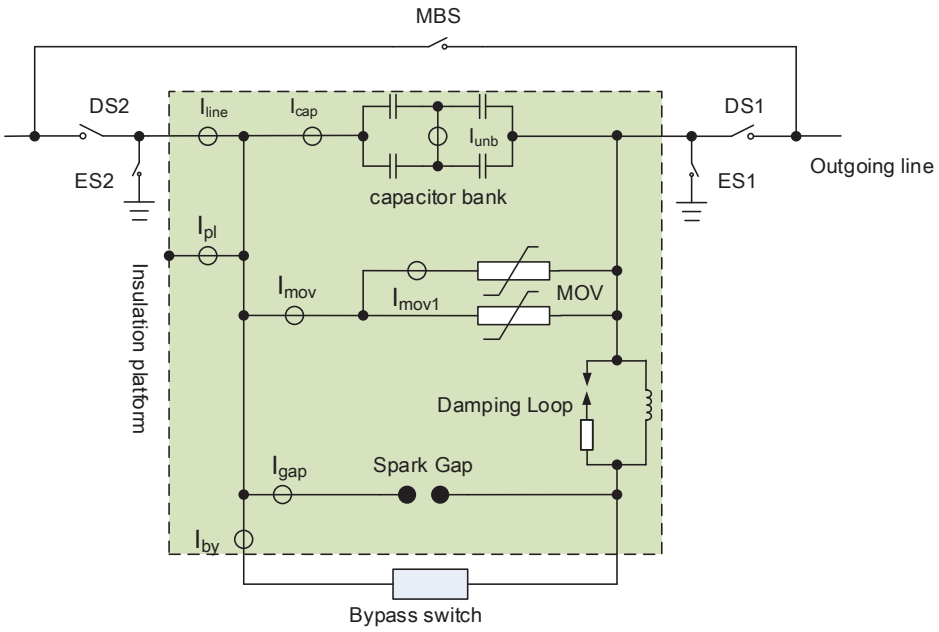

Figure 1 Series Compensation Single Line Diagram

Figure 2 220kV Fixed Series Compensation Site

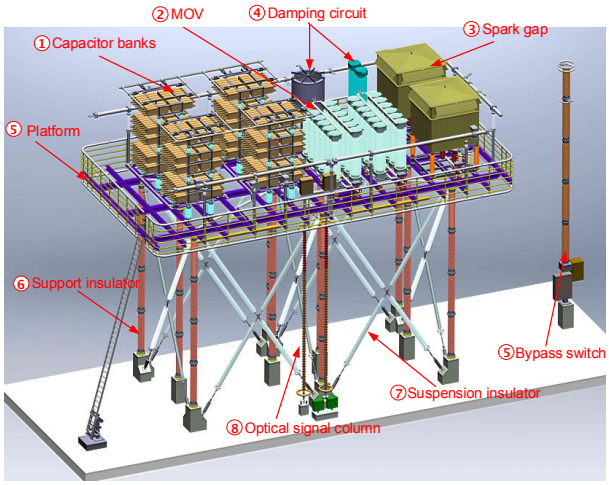

Figure 3 750kV FSC Three-dimensional Layout Diagram

System Configuration

FSC mainly consists of the following components:

- Capacitor Bank
  Capacitor banks are used to achieve the compensation for transmission line inductance so as to reduce the electrical distance between two substations and improve the system transient stability.

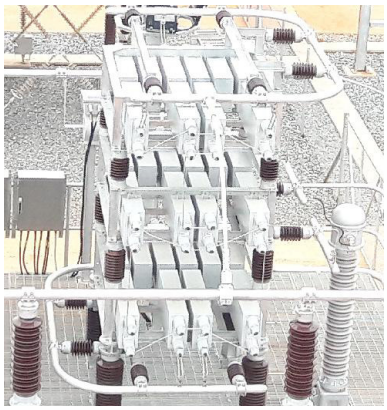

Figure 4 Capacitor Bank

- MOV
  MOV has good non-linear characteristic. It provides overvoltage protection for capacitor banks to limit the overvoltage cross capacitor bank at the protection level 2.0pu ~ 2.5pu (typically) or less, to ensure the safe operation of capacitor bank.
- Spark Gap
  The duration from turn-on command issuing to completely spark gap conduction is less than 1ms. It prevents the MOV against damage due to the excessive absorption of energy.
- Damping Circuit
  The damping device comprises damping reactors and linear resistor string gap (or non-linear resistance). When the series compensation device is in bypass state, the damping circuit can facilitate and speed up the energy storage in capacitor.
- Bypass Switch
  The closing time of bypass switch is longer than the conduction time of spark gap, but it can cause the spark gap interrupted. In addition, it provides normal operation and maintenance functions for series compensation devices.
- FSC Control and Protection System
  The typical configuration of series compensation is shown as below. Protection devices and trigger gap control are in redundant design. The switching control device integrates conventional circuit breaker monitoring and control functions in one rack. The protocol converter and the remote device can be configured according to the actual situation. The remote control unit provides distant sequence control of series compensation to realize free-maintenance station.

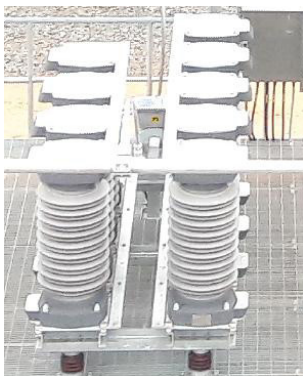

Figure 5 MOV

Figure 6 Spark Gap

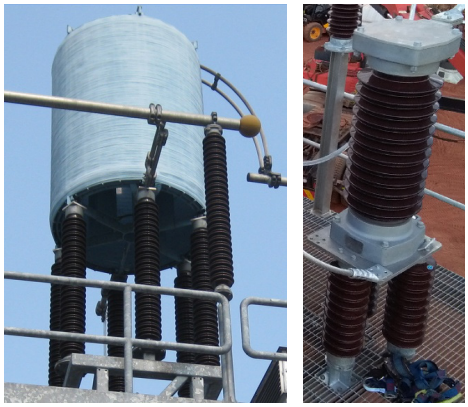

Figure 7 Damping Circuit

Functions

- Support manual enable/disable capacitor banks and sequence enable/disable capacitor banks, support five-maloperation system for switch operation.
- Provides complete protections, including: capacitor protection, MOV protection, gap protection, etc.
- Support the linkage interface with line protection and SSR (Sub Synchronous Resonance) devices.
- Equip with HMI monitoring, clock synchronization, fault recording and other functions.

Features

The PCS-9570 series products are developed based on NR's solid AC high voltage protection principles and years' of experience. It provides protection and control solutions for AC transmission line capacitors in series compensation system. It features:

- Professional design of safe and reliable equipment
  The PCS-9570 system adopts safe and reliable primary equipment such as capacitors, MOV, spark gap, damping device, electronic transformer and protection & control system.
- Unified UAPC platform
  The self-developed UAPC platform has visual programming software and hardware modular configuration. It is flexible for expansion. Communications between hardware modules are fulfilled by internal high-speed bus.
- The operation of duplicated protections are fully independent. The starting components are combined with protection output to increase operation reliability.
- The use of electronic transformer greatly improves its anti-interference capability.
- Interposing relay sets are developed for the closing of bypass switches.
- The control and protection module can facilitate the realization of sequence characteristics of series compensation equipments.
- Measurement and control devices are fully complied with IEC61850. Operators can enable or disable dispatching of series compensation devices through the remote one-touch control function.
- Easy-to-use testing device
  The conventional relay tester can ease the on-site inspection of series compensation system.

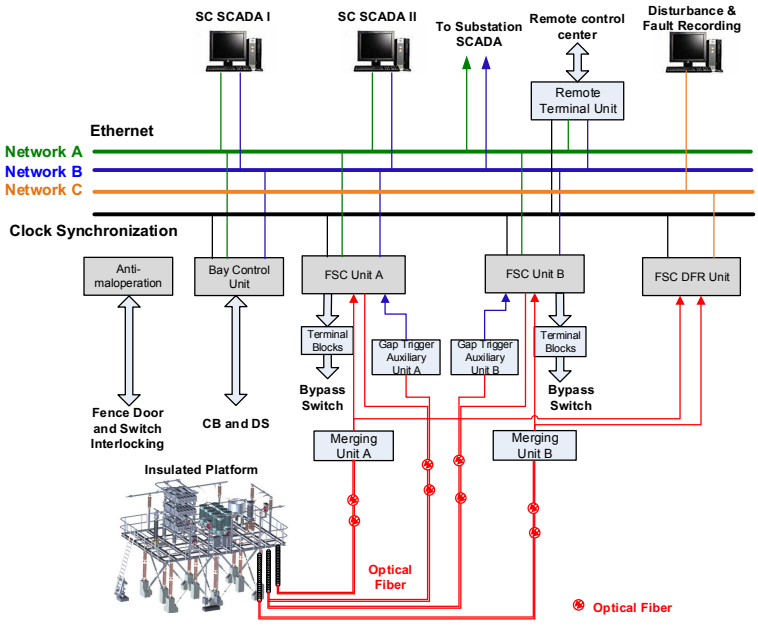

Figure 8 Fixed Series Compensation Network Structure

PCS-9590

Series DC De-Icer

Heavy ice coating can damage transmission lines and towers, ultimately leading to a power supply outage in partial or the entire grid network. To guarantee the safe operation of the power system in severe weather, NR Electric provides consumers with the PCS-9590 fixed DC de-icer and the PCS-9591 relocatable DC de-icer for the protection of transmission lines. The DC output voltage is adjustable. Different DC short-circuit currents can be supplied according to the conductor's diameter and length. In addition, the de-icer device can also be used as SVC to quickly compensate reactive power, stabilize system voltage and improve power quality.

Fixed DC De-Icer

The fixed DC de-icer can be used for long transmission lines with high voltage level. The power supply of PCS-9590 is normally fed by a LV AC bus. The PCS-9590 fixed DC de-icer includes:

- Two standard containers: one is used to install valve banks and water cooling system, the other is equipped with phase switching disconnector and control panels.
- Converter transformer: to offer voltage transformation and commutation reactance

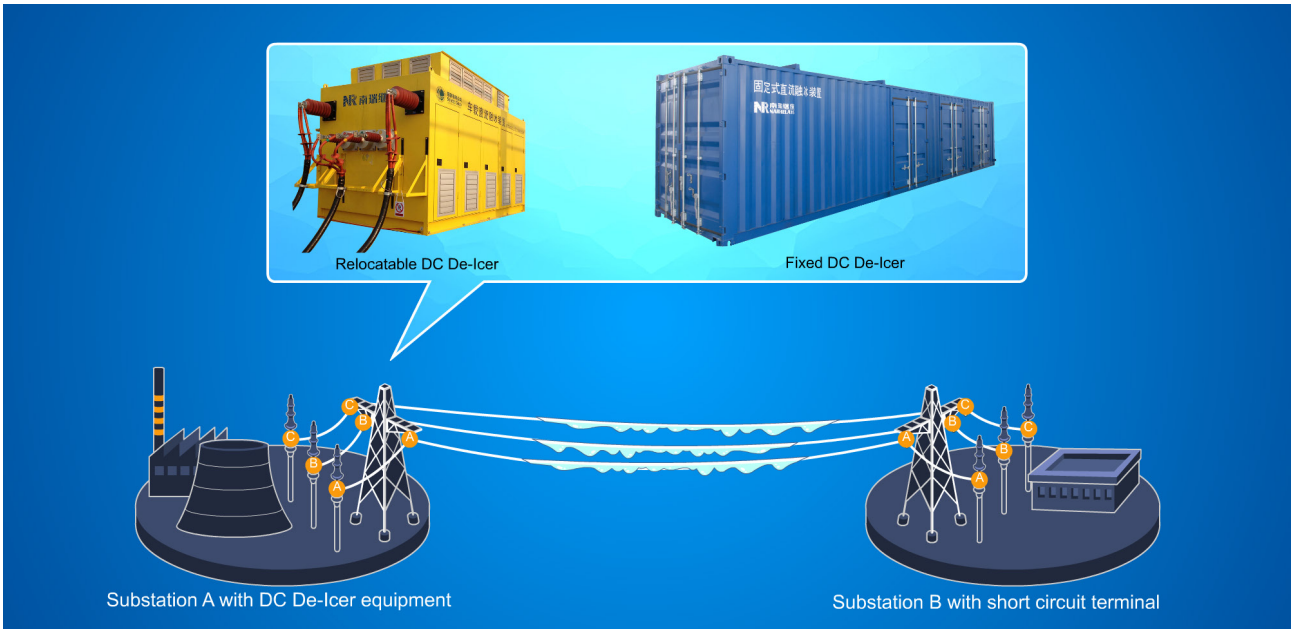

Figure 1 Melting Configuration with DC De-Icer

- 12-pulse conversion valve banks: to convert AC current to DC current.
- Water cooling system: including indoor forced water cooling and outdoor forced air cooling.
- Phase switching disconnector: to select the target AC line and realize balanced de-icing of AC lines.
- Control and protection system: to provide supervision and protection of whole DC de-icer device.

Relocatable DC De-Icer

The relocatable DC de-icer device can be utilized in short- distance lines with low voltage levels. The PCS-9591 relocatable DC de-icer includes:

- One standard container: to install all equipment.
- 6-pulse conversion valve: To convert AC current to DC current.
- Cooling system: including indoor forced water cooling and outdoor forced air cooling.
- Phase switching disconnector: to select the target AC line and realize balanced de-icer of AC lines.
- Control and protection system: to provide supervision and protection functions for the whole DC de-icer device.

Features

- The use of thyristor rectifiers can reduce the impact on the power system during ice melting and ease the switch-over operations.
- The DC de-icer device supports large current and large angle continuous stable operation. It is applicable to transmission lines with different conductor diameters and lengths.
- The PCS-9590/9591 DC de-icer can adopt container type installation and valve hall installation, effectively reducing land occupation, shortening the site construction time frame and easing the equipment transportation.
- The device adopts reliable and compact structure with a water cooling or air cooling system and compact valve banks.
- The PCS-9590/9591 is equipped with 6 phase switching disconnectors enabling the automatic switchover among various ice melting modes and realizing the balanced ice melting for AC lines.
- NR Electric also provides the high performance control and protection system for DC de-icing.
- Primary system of DC ice melting device requires only very small number of operations to realize SVC function.

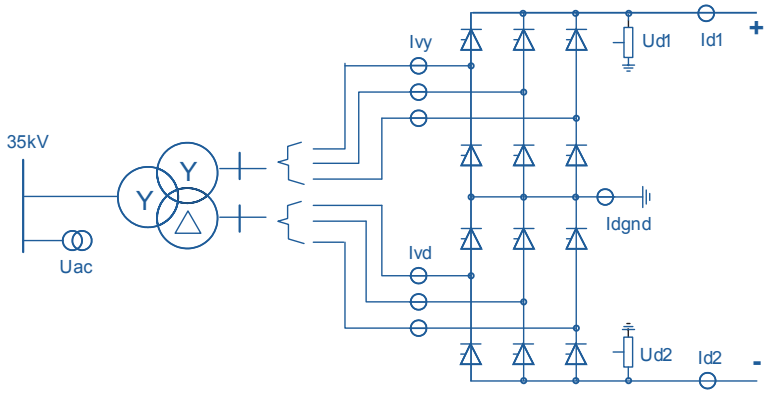

Figure 2 Fixed DC De-Icer Topology

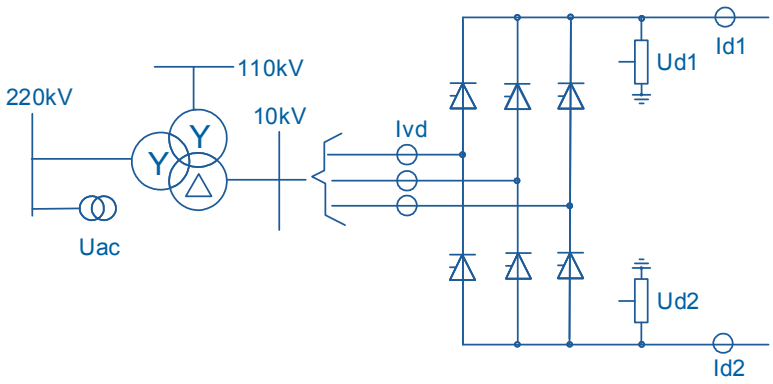

Figure 3 Relocatable DC De-Icer Topology

PCS-9578

Controllable Shunt Reactor (CSR)

NR Electric's PCS-9578 Controllable Shunt Reactor (CSR) is a shunt-type reactive power compensation system for supplying step-changing reactive power with fast response time and low-cost maintenance. It is designed based on high leakage reactance transformer and high-power thyristor semiconductor technology.

CSR is used to solve the contradiction between reactive power compensation and restraining over-voltage especially in an extra-high voltage and long distance power transmission system. It can adjust the reactive power to stabilize the line voltage and achieve a reasonable power flow distribution. Furthermore, CSR can also restrain the secondary arc current to improve reclosing success rate. So far, it has been used successfully in electric power system.

Operating Principle

There are two types of CSRs, multi-stage CSR and magnetically CSR.

For multi-stage CSR, it is connected to the power grid in parallel via by the primary winding of high leakage impedance transformer. Through the combination of thyristor valves and bypass circuit

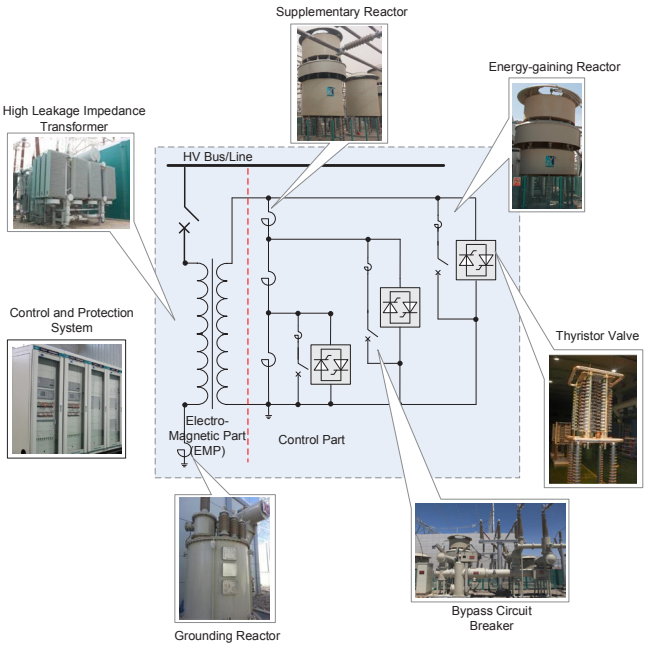

Figure 1 Multi-stage CSR

breakers, the reactance value of the secondary winding of transformer is adjusted step by step, so that the absorbed reactive power can be changed.

For magnetically CSR, by using the non-linear characteristic of magnetization curve of ferromagnetic materials, the saturation degree of the iron core is changed adjusted by adjusting changing the magnitude of dc excitation current of control winding, and then the equivalent magnetic permeability of the iron core is changed to realize continuous regulation of the inductance value and reactive capacity of the reactor.

Functions

- Suppress the overvoltage and compensate the system reactive power
- Adjust and stabilize the system voltage.
- Restrain the secondary arc current and improve reclosing success rate
- Increase the transmission capacity of lines.
- Improve the power flow distribution

System Configuration

- Multi-stage CSR
  - High Leakage Impedance Transformer
    It is the main part of CSR system with high leakage impedance rate over 90%. The primary winding is connected to power grid in parallel, and the secondary winding is connected to the control part.
  - Supplementary Reactor
    The supplementary reactor is used to absorb the reactive power, all supplementary reactors are linked in series and connected with secondary winding of high leakage impedance transformer.
  - Energy-gaining Reactor
    Each energy-gaining reactor is connected with an bypass circuit breaker in series, and provides power supply for thyritor control unit to ensure that the thyristor can be triggered on timely.
  - Bypass Circuit Breaker
    Each bypass circuit breaker is connected to the correponding supplementary reactor in parallel, and they operates when CSR starts to change level. All circuit breakers act in sequence according to a certain control and protection strategy.
  - Thyristor Valve
    As an auxiliary switchgear, the thyristor valve bank is quickly turned on before the bypass breaker operates, avoiding the opening or closing of circuit breaker with current and prolonging its service life. After the operation of the circuit breaker, the thyristor valve bank is turned off and is not used as a long-term flow device.
  - Control and Protection System
    The control and protection system is composed of merging unit, valve control unit, reactor relay and other control and protection devices, and it can cooperate with other FACTS devices and AVC system.

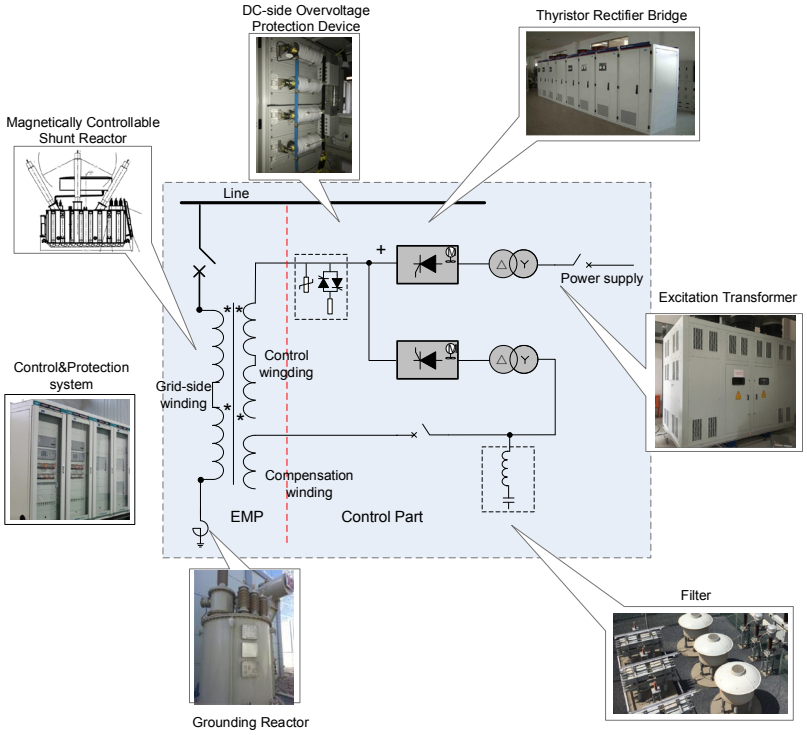

Figure 2 Magnetically CSR

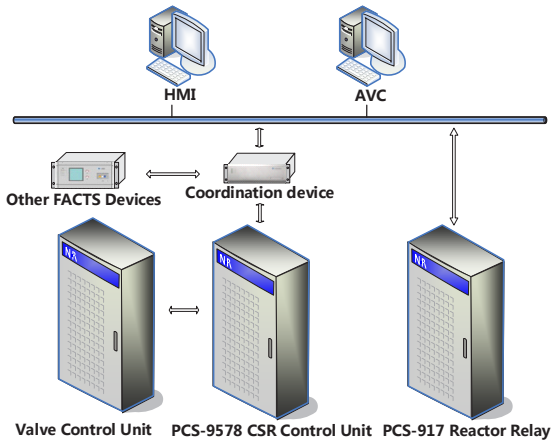

Figure 3 Control and Protection System of Multi-stage CSR

- Magnetically CSR
  - Magnetically Controllable Shunt Reactor
    The magnetron controllable shunt reactor consists of grid-side winding, control winding and compensation winding. The grid-side winding is connected in parallel to the system. The control winding is connected to the excitation system, and it realizes reactor impedance adjustment by changing the current flowing through the winding. The compensation winding is connected to the filter bank or or supplies power to the excitation system.
  - Excitation Transformer
    The excitation transformer is used to provide power for the excitation system. It can be set in two modes: self-excitation and separated excitation: the self-excitation power supply is taken from the compensation winding of reactor, and the separated excitation power is taken from the station power supply.
  - Thyristor Rectifier Bridge
    Through thyristor rectification, the alternating current is converted to direct current to provide a field current for the control winding. Generally, several thyristor valve banks with low-voltage and high-current are used in parallel operation, and the actual number of valve banks is configured according to engineering requirements.
  - DC-side Overvoltage Protection Device
    The large-capacity varistor and the linear resistor are used to provide over-voltage protection for the low-voltage equipments of the excitation rectification system, they can absorb the over-voltage energy and suppress the DC-side overvoltage in case of fault.
  - Filter
    In the side of compensation winding, 5th and 7th filter branches are configured to reduce the influence of harmonics generated by the main body on the system.
  - Control and protection system
    The control and protection system is composed of monitoring system, control devices, protection devices and coordination devices, etc, and it can cooperate with other FACTS devices and AVC system.

Features

- Multi-stage CSR
  - Optimization designed thyristor valve
    Thyristor valve features compact structure, light weight, small land space and easy installation and maintenance. Moreover, the valve adopts self-cooling structure design, no needing additional cooling equipment, with well cooling effect and less land space.
  - Superior harmonic performance
    The phase locking and fast conduction performance of thyristor ensure that the harmonic content of multi-stage CSR is very small during the adjustment process.
  - Extensive coordination and control functions
    There are a variety of coordination and control strategies between multiple sets of CSR, between CSR and other reactive power compensation equipments in station, between CSR and AVC, and between CSR and stability control system, which greatly expands the regulation ability of CSR.
- Magnetically CSR
  - Integrated design of control and protection system
    The integrated control and protection solution is provided based on unified hardware and software platform, unified communication interface and system architecture, covering monitoring system, excitation, protection, recording and other specialties, with improved overall automation level and higher reliability.
  - Reactive power rapid adjustment
    Through the overall optimization design of exctitaion system, the dynamic response time of reactor is effectively shortened, and the magnetically CSR can quickly adjust reactive power output, which has better capability of suppression of voltage and reactive power fluctuation.
  - High current thyristor valve
    The heat dissipation system with forced fan cooling + parallel air duct design + heat pipe radiator is adopted and it effectively improves the cooling efficiency and the output capability of thyristor valve.
  - Intelligent current distribution of thyristor valve
    The component-level dynamic intelligent current distribution technology is adopted to realize the precise current distribution control of thyristor valve banks in parallel operation.
  - Pulse transmission by optical fiber
    Optical fiber communication is used between the excitation devices to improve the anti-interference ability of thyristor valve banks during the process of trigger pulse transmission, and the operation is more reliable.
  - Overvoltage protection trigger for online energy-gaining
    Based on the DC-side over-voltage triggering and protection design scheme of online energy-gaining, the circuit design is simple and the operation is reliable.

PCS-8200

Unified Power Flow Controller(UPFC)

Unified Power Flow Controller (UPFC), as the representative of the third generation of FACTS devices, is by far the most comprehensive FACTS device. In the steady state of electrical system, it can implement power flow regulation, reasonable control of line active power and reactive power and improvement of the transmission capacity of power system. In the transient state of power system, it can realize fast-acting reactive power compensation, dynamical support of the voltage at the access point and improvement of system voltage stability. Moreover, it can improve the system damping and the stability of power angle.

By adjusting the phase angle and amplitude of output voltage of series transformer via converter valve and control system, UPFC can realize the optimal control of power flow and system voltage. According to the injected voltage characteristics, UPFC control functions can be classified into the following four types:

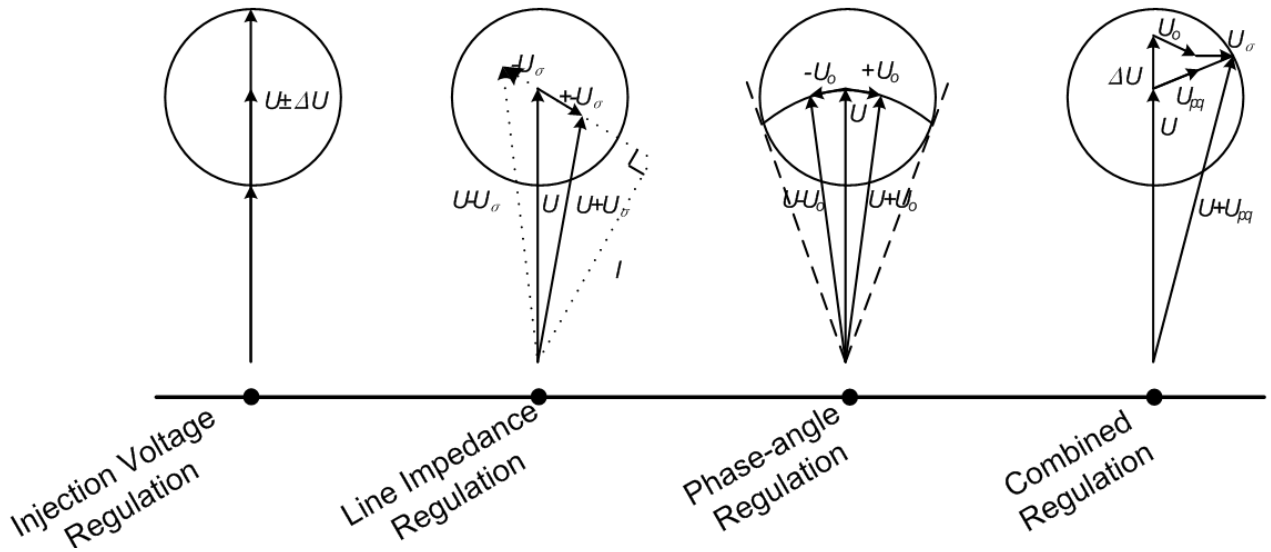

Figure 1 UPFC Control Modes

System Configuration

PCS-8200 UPFC mainly consists of the following three parts:

- Control and protection system
- Thyristor Bypass Switch (TBS)
- Voltage Source Converter (VSC) valve

Control and Protection System

- Adoption of embedded software and hardware technology, distributed architecture and object-oriented approach for function division.
- Realization of all the operation modes of UPFC and switchover between different modes, including UPFC mode, Static Synchronous Series Compensator (SSSC) mode and Static Synchronous Compensator (STATCOM) mode.
- Smooth start/stop function to solve the series converter charging problem, and the series transformer can be put in service without disconnecting the transmission line.
- Proposal of multi-inverter double-circuit line control strategy via automatic selection of master control unit.
- Reasonable distribution of UPFC with full protection for different modes of operation without dead zones.

Thyrisitor Bypass Switch

TBS is installed in valve side of series transformer and is in parallel with the mechanical bypass switch. It is used to bypass the series converter quickly, prevent converter fault from affecting AC line and prevent AC line fault from affecting converter.

Figure 3 Control and Protection System of 220kV UPFC Project in Nanjing, China

- Utilization of fast thyristor switching technology to isolate converter from electrical system in case of fault.
- With high withstand capability of short-term high current, high-power thyristor valves and fast bypass switch technology. So, it is not necessary to use thyristor in parallel or water cooling.
- Adoption of natural cooing for TBS, damping resistance and static equalization resistance for convenient maintenance and high controllability.
- Horizontal structure and three-phase superposition arrangement save installation space.

VSC Valve

Based on the rich experience on engineering, NR developed the UPFC IGBT converter valve with the advantages of high reliability, small installation space and easy maintenance.

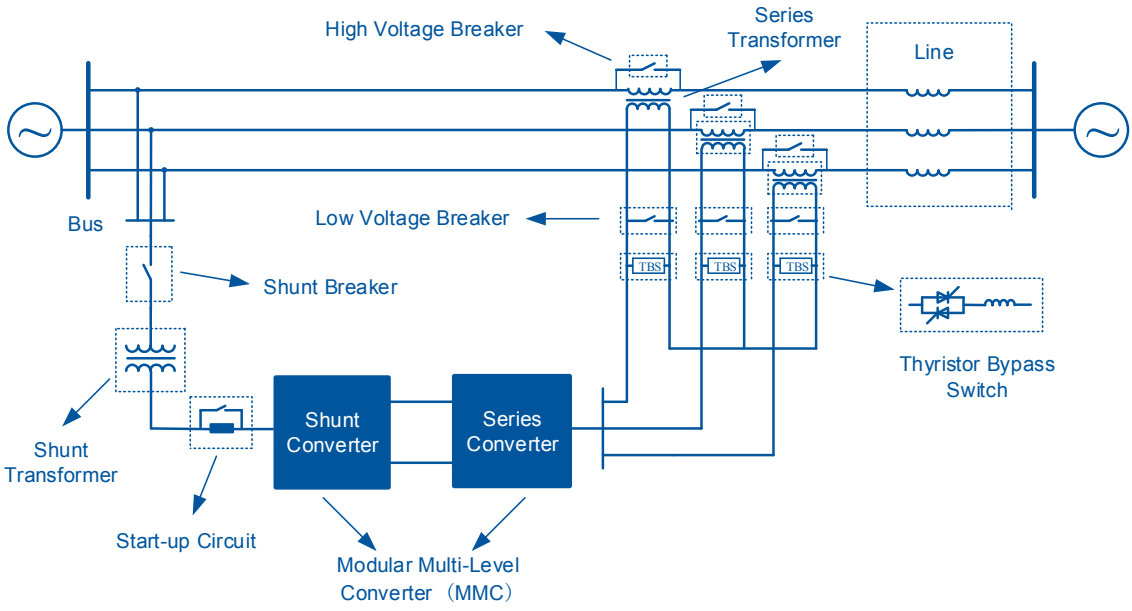

Figure 2 Typical UPFC Connection Diagram

Figure 4 TBS of 500kV UPFC Project in Suzhou, China

- Adopting compact vertical integrated structure for converter valve with hierarchical and phase-segregated design for UPFC low DC voltage applications. This structure promotes electrical symmetry of three-phase arm of converter valve, reduces external electromagnetic radiation and saves installation space.
- According to IGBT valve's charging characteristics during the start of UPFC, an ultra-low supply voltage and active voltage equalization strategy are adopted to prevent the possibility of uncontrolled state during the startup and operation of converter valve.
- For the operational safety margin, an ultra-low leakage inductance and digital driving technology are adopted. This maximizes the rational utilization of the power devices' operating parameters, increases the operational efficiency of converter valve and reduces the electrical stress of core power components.
- Based on hardware detection and state prediction technology, it realizes the monitoring and protection of electrical and non-electrical quantities of IGBT valve in full range. Real-time state information of converter valve and sub-modules is sent to the monitoring system according to IEC61850 protocol.
- The valve control unit with microsecond control precision increases the dynamic response of converter valve, and it provides overvoltage/overcurrent protection for sub-modules according to the complete monitoring.
- The utilization of separable power modules, pluggable boards in the module and standard connectors facilitate troubleshooting and maintenance.

Features

- Flexible adaptation to different electrical network structures.
- Modular structure, easy extension, convenient installation and maintenance.
- Low switching-frequency MMC and low converter loss.
- Flexible control modes.
- In parallel side: controlling AC voltage and dynamic reactive power at grid-connection point.
- In serial side: controlling terminal voltage, phase, impedance and combined flow.
- Support of steady state and transient state analysis for different AC systems.
- Customized system strategies.

Figure 5 VSC Valve of 500kV UPFC Project in Suzhou, China

PCS-9571

Fault Current Limiter (FCL)

PCS-9571 fault current limiter (FCL) is based on fast switch, high-speed sampling and fault identification control system, combined with high-potential isolation power supply equipment to achieve the effective suppression of short-circuit current of the power grid.

During normal operation, the fast switch bypasses the current-limiting reactor, and the entire fault current limiter exhibits a very low impedance state, which does not affect the normal operation of the power system. When a short-circuit fault occurs in the power system, the fault is quickly identified by the control system, and the fast switch is opened in a few milliseconds to transfer the short-circuit current to the current-limiting reactor, thereby limiting the short-circuit current.

The power system can install a fault current limiter to achieve the following objectives:

- No adverse effect on the power system during the startup and normal operation (including returning to normal operation from the fault current limit state);
- Quickly and automatically insert a current-limiting reactance and effectively limit the short-circuit current to the required reasonable level;
- It will not cause system transient oscillation and overvoltage;
- It has a soft-closing function to avoid the secondary impacts due to re-close to permanent fault circuit.

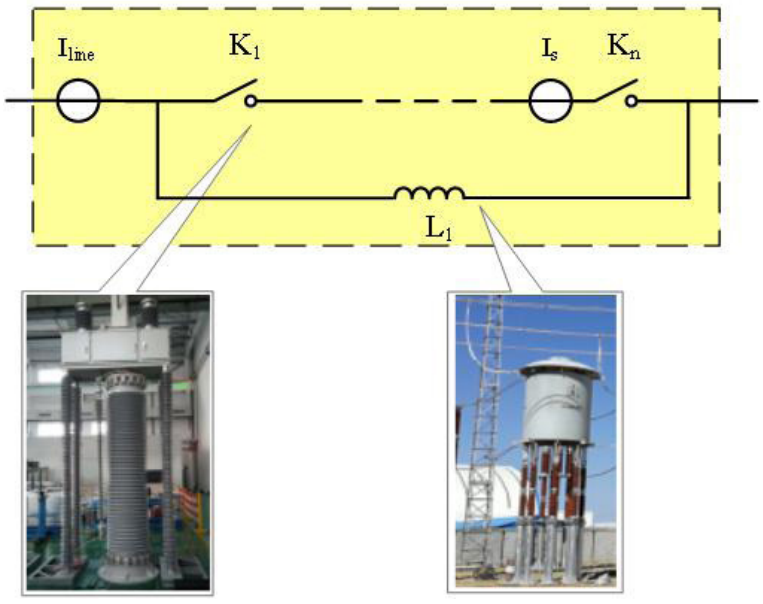

Figure 1 Fault Current Limiter Single Line Diagram

System Components

- Fast switch
  The fast switch adopts the electromagnetic repulsion operating mechanism and isolation transformer for power supply, it can perform the switching operation when the system line is not powered, the rated opening time is less than 5ms, the closing time is less than 20ms, and the mechanical life is more than 2000 times. High voltage level expansion is achieved by series connection of multi-break, and the number of the series-connected break can be flexibly configured according to the actual system requirement.

- Current limiting reactor
  Current limiting reactor adopts air core type, the overall insulation heat-resistance grade is required to be F class, the winding inter-turn insulation heat-resistant material is required to be H class, and the pillar insulator adopts a solid core rod-shaped, non-magnetic porcelain pillar insulator. The impedance value can be flexibly configured according to different current limits, meeting the requirements of dynamic and short-time thermal withstand currents.

- Measurement equipment
  NR provides users with two solutions: electronic current transformer and conventional electromagnetic current transformer. The measurement system has high linearity, no residual magnetism and magnetic hysteresis, and the sampling rate is larger than 10kHz.

- Control system
  The typical configuration of the control system of fault current limiter is as shown in the figure below. It can realize the quick put-into-service and automatic exit of the fault current limiter, the current setting and the time delay setting are settable. Under certain conditions, the enabling or disabling of the fault current limiter can be blocked. It should be equipped with the manual enabling and disabling function of the fault current limiter, the self-supervision function of the status, and the fault recording function, and timely transmits the status and alarm information to the HMI system.

Features

PCS-9571 fault current limiter product is a complete solution for limiting short-circuit current in AC current system. It integrates a series of AC high-voltage measurement, control and protection principles and experience of NR, and it also combines many years of the running experience of high-voltage flexible DC converter valve and hybrid DC circuit breaker etc. power electronic products. It mainly have the following characteristics:

- Comprehensive system-level analysis
  Relying on the technical accumulation of many professional directions of NR, design from the aspects of power system temporary and steady-state performance, over-voltage analysis and relay protection etc., and reasonably select the fault current limiter configuration scheme to effectively achieve the better current-limiting effect.

- Equipotential design of fast switch and operating mechanism
  The operating mechanism and the fast switch break are at a high potential, eliminating the insulation parts between each other, effectively increasing the opening and closing speed and increasing the mechanical life.

- High potential isolation power supply
  The isolation transformer is used for high-potential power supply, which does not depend on the system, so the opening and closing operation when the system line is not powered can be realized.

- Rapid detection and identification of fault
  It can quickly identify line fault for it integrates high-sampling-rate current transformer, through the high-speed and high-integration control, the criteria based on line current instantaneous value and slope etc., are adopted.

- Compact structure
  The primary main device only includes the fast switch and the current limiting reactor, and has a small floor space.

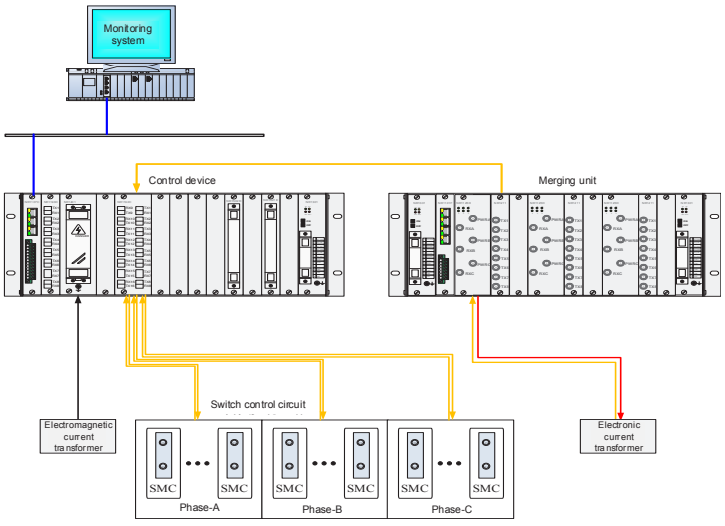

Figure 2 Control System of Fault Current Limiter

PCS-9564A

Dynamic Voltage Restorer (DVR)

With the increasing demand of new power load on power quality, power quality has been greatly concerned by power enterprises and users. When lightning strike, power grid fluctuation, and large-capacity impact load suddenly appear, voltage decline temporally will be inevitable.

Voltage decline can cause sensitive equipment, such as PLC controller, frequency conversion & speed regulation, various digital equipment, being damaged. As a result, production lines or motors are shut down, and many enterprises equipped with precision processing lines suffered economic losses.

PCS-9564A dynamic voltage restorer (DVR) is specially developed by NR to resolve the problem of voltage decline. DVR is installed between power grid and the sensitive load. Under normal conditions, the voltage of power grid is normal, and DVR is in the bypass state. When the voltage of power grid drops temporarily, the switches are quickly separated and the inverter unit is put into operation. The energy storage unit based on super capacitor is used to provide temporarily energy for the load. The system structure is shown as Figure 1.

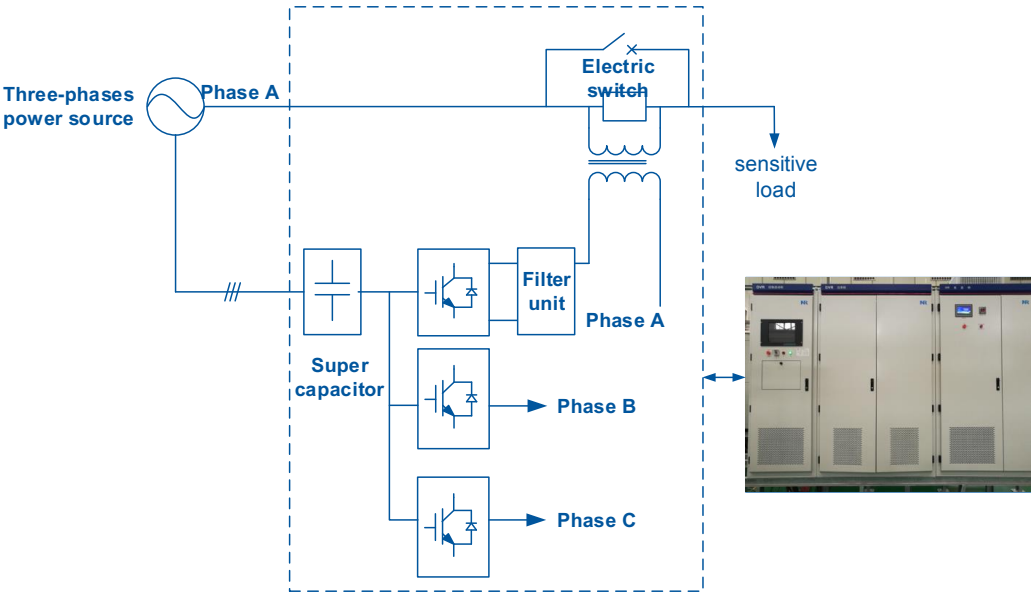

Figure 1 System Structure of DVR

System Structure

PCS-9564A DVR consists of power cabinet, control & startup cabinet and super capacitor cabinet.

- Power Cabinet
  The power cabinet is DVR's core component, which is composed of general converter module, filter and isolation transformer. Each general converter module is composed of power semiconductor components, and the power conversion is realized through flexible series and parallel combination.

- Control & Startup Cabinet
  The control & startup cabinet mainly contains control unit, auxiliary circuit, bypass switch and mechanical switch. The control power supply adopts the duplicated configuration of dual power supplies. The bypass switch and the mechanical switch serve as backup protection for the whole system. When there is a fault happens to the system, the bypass switch and the mechanical switch can be quickly closed to ensure that the power supply to loads is not affected.

- Super Capacitor Cabinet
  The super capacitor cabinet is mainly composed of DVR energy storage unit, which are composed of multiple super capacitor modules in series and parallel. It also contains the management system and the charge-discharge circuit of super capacitors.

Features

- Modular design
  The system adopts the modular design of standard units, which is convenient for maintenance and replacement, and can realize the configuration of multiple capacity through series or parallel modules

- Duplicated configuration
  Multiple bypass functions are provided, including electronic switch bypass (1ms), zero level bypass (1ms) of the inverter unit, fast mechanical switch bypass (3ms) and mechanical switch bypass (60ms). When there is an abnormality in DVR body, various fast bypass methods do not affect the normal power supply of the load.

- Intelligent self-check
  The DVR is in standby state for a long time, and it has intelligent self-check function, which automatically determines whether the core inverter unit in the DVR is in normal state, thus improving the reliability of the equipment.

- Fast compensation
  Low voltage detection technology based on voltage variation and rapid switching compensation technology are adopted. Low-voltage fault detection can be completed within 500us, the voltage can be compensated to the normal range within 2ms, and the total time from voltage incline to compensation completion is <3ms.

PCS-9569

Shore Power System

Shore power system enables vessels to shut down their auxiliary engines and use shoreside electricity power supply while at berth. Auxiliary diesel engines run by vessels consume lots of fuel and produce a large quantity of pollutants, including polluting emissions, noise and vibration. Shore power helps to reduce energy waste and costs and to improve the environment in port.

The PCS-9569 shore power system of NR Electric enables the shore-to-ship power connection. It helps to adjust de the grid electricity to appropriate vessel frequency so as to enable the reliable and high-quality 50 and 60Hz power supply regardless of the local port grid frequency.

Variable Frequency Power Supply

Since vessels may need both 50Hz and 60Hz electricity, whereas local grid may not be able to supply, frequency conversion is necessary. The AC-DC converters are the core of power supply. Besides, other auxiliary equipments, such as transformer and circuit breaker cabinet, are necessary.

There are two types of variable frequency power supplies in the PCS-9569 shore power system:

- Low-voltage PCS-9569L
  Max. 1MVA ;

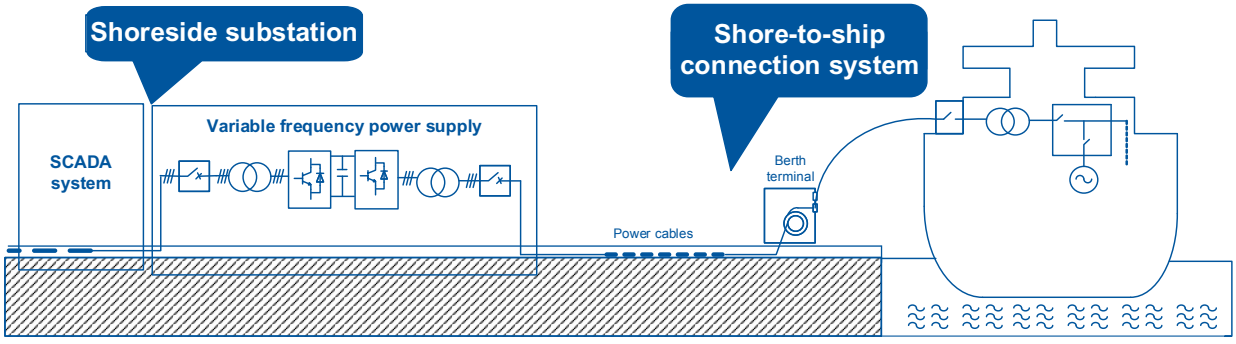

Figure 1 PCS-9569 Shore Power System

Modular design and structure topology in parallel ;
Three-phase controllable AC-DC converter for each module.

- High-voltage PCS-9569H
  2~20MVA ;
  Modular design and structure topology in serial.

SCADA System

Based on the NR Electric's well-proven substation SCADA system, we follow the power dispatching principles and fuse them with the characteristics of shore power system to create the PCS-9700 SCADA system. It provides full monitoring and control functions for frequency converter, transformer, CB cabinet, environment monitoring, etc. it also provides an human-machine interface for rich information with powerful analyze ability and completed alert mechanism.

Shore-to-ship Connection System

The shore-to-ship connection system is laid out along the rail on dock with berth terminal containing connection plugs. the safety interlock mechanism makes sure the shut down of shore power system if there is a disconnection of power cable, an urgent stop command or an unplugging.

The cable reel installation is optional to automatically draw in/out cables depending on the tide level or the draft line. Cable can be released flexibly from reel without exceeding its maximum permissible tensile force.

Features

- Modular design
  System standard modular design for convenient maintenance and replacement ;
  Structure topology in serial or in parallel to realize different power supply capacity.

- Power module redundancy
  Redundancy and fault isolation functions for power module to isolate fault on and bypass single module, to avoid influence on other modules and to realize system continuous operation.

- Rugged dock environment adaptability
  High temperature, low temperature, humidity, salt fog, dust, vibration, etc.

- Advanced control ability
  Automatic voltage and frequency stabilizing ;
  Vector control strategy with high precision ;
  Stabilization : voltage < 5%, frequency < 0.1%.

- Load transfer
  After the synchronization of vessel auxiliary engines and the shoreside power supply, use frequency droop function to realize load transfer without power outage during the shore-to-ship connection.

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