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Synchronous Condenser Solution - SC

The strong way to support renewable energy integration and stabilize weak network

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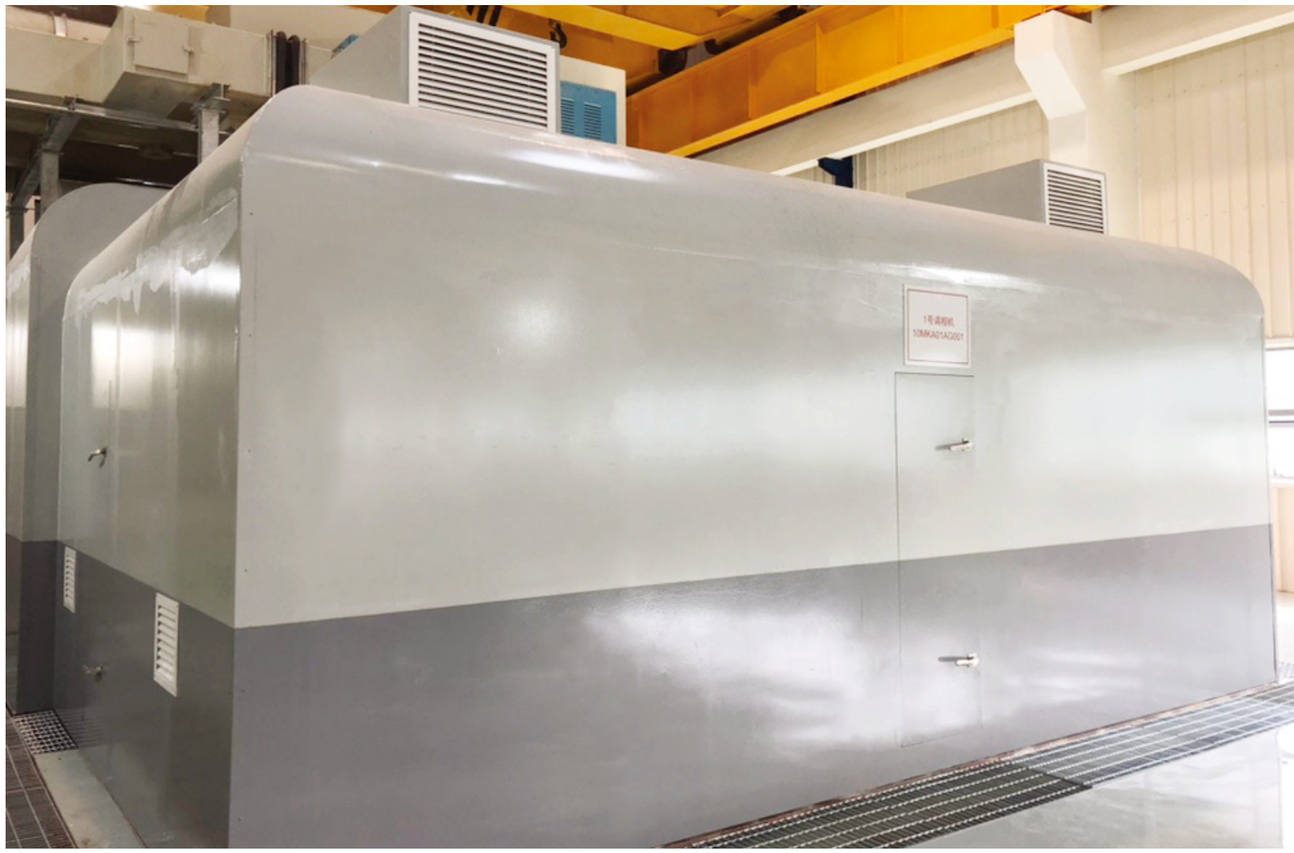


Contents

Advantages

- Compensate reactive power in continuous and rapid way to suppress voltage fluctuation and to give strong voltage support.
- Contribute to more fault current level at installation place and to raise voltage level during fault period.
- Give power grids more inertia to strengthen their frequency stability
- Provide strong short-time overload capacity for good suppression of transient load or other transient process and for saving the cost of stable capacity installation
- Offer strong fault-ride-through capacity to enhance the strength of power system at installation place
- Regulate reactive power, independent of system voltage, with stronger voltage support, as compared with other reactive power compensator

Functions

A synchronous condenser(hereinafter called SC) is a synchronous motor working in special conditions. The SC, in automatic regulating way, is capable of generating more reactive power in lower system voltage and absorbing more reactive power in higher system voltage as required by system conditions, in the event of application in power system. It is used to improve power factor in power grid, sustain network voltage level, raise stability in power system, and better power supply quality. Synchronous condensers operate in the motor state without mechanical load or prime mover and only provide or absorb reactive power to the power system.

The process of synchronous condenser’ s operation is divided into three stages: transient process, dynamic process and steady state process.

In the transient process, the synchronous condenser relies on its own damping characteristics to realize fast reactive response. The smaller the secondary transient reactance is, the faster the response is, and the stronger the low-voltage ride-through ability is.

The dynamic process characteristics are determined by its rotor and the excitation system. The forced excitation can realize the short-term overload output of reactive power.

During the steady-state process, accurate reactive power output can be achieved through automatic voltage regulator to maintain the voltage stability of the system.

Applications

In recent years, with the application of HVDC transmission, new energy grid connection and other projects, synchronous condensers can effectively solve the emerging problems due to its unique characteristics, and has been widely used in the following aspects.

HVDC Transmission

The voltage fluctuation of AC busbar will cause the failure of LCC-HVDC commutation, which will lead to a large amount of active power loss and have a great impact on the power grid. The installation of synchronous condenser in converter station is beneficial to suppress the voltage sag caused by transient fault voltage and reduce the possibility of commutation failure.

Renewable Energy Generation Interconnection

Wind, solar and other new energy sources are intermittent power, threatening the stability of the power system. At the same time, most of the renewable energy use power electronic converter as grid-connected means, with poor performance of low-voltage ride-through ability. The installation of synchronous condenser in grid-connected nodes of large-scale renewable energy can provide a large amount of reactive power support for the power system, maintain the stability of the system, and improve the low-voltage ride-through ability of renewable energy power supply.

Long Distance Power Transmission

When the load is far away from the power supply, in order to reduce the line loss, reactive power should be balanced locally as far as possible. Installing synchronous condenser on the load side can not only provide necessary reactive power, but also increase the short circuit capacity of the load side.

Centralized Electricity Consumed Region

As load fluctuation in heavy industry or big city area is big, a synchronous condenser can restrain voltage fluctuation, increase the short-circuit capacity of load side.

Traditional Power Plant Shut Down

After the traditional power plant was shut down, the system short-circuit ratio here is decreased. The installation of synchronous condenser can make up for the short circuit capacity caused by power generators withdrawal.

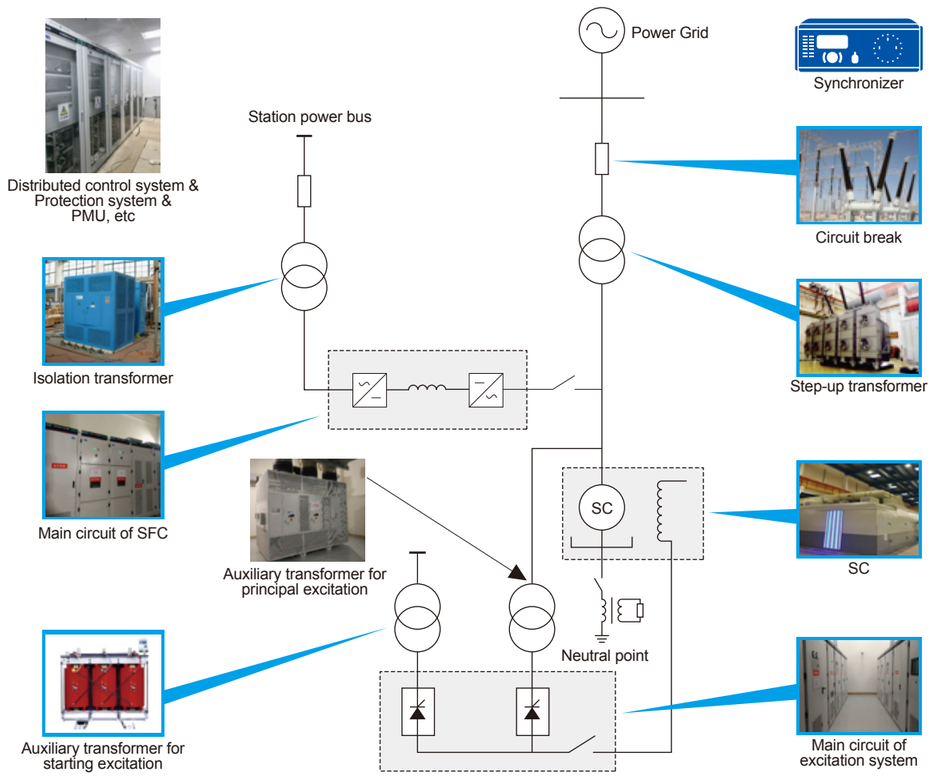
Main Components

Synchronous condenser(SC) system consists of primary equipments and secondary control and protection systems.

Primary equipment include: SC , step-up transformer, circuit break, etc.

Secondary control and protection systems include: excitation system, SFC, protection system, distributed control system(DCS), synchronizer, phasor measurement unit(PMU) , fault recording device, remote diagnosis system, etc.

The above subsystems and devices can be selected according to the specific need of project and user requirements.

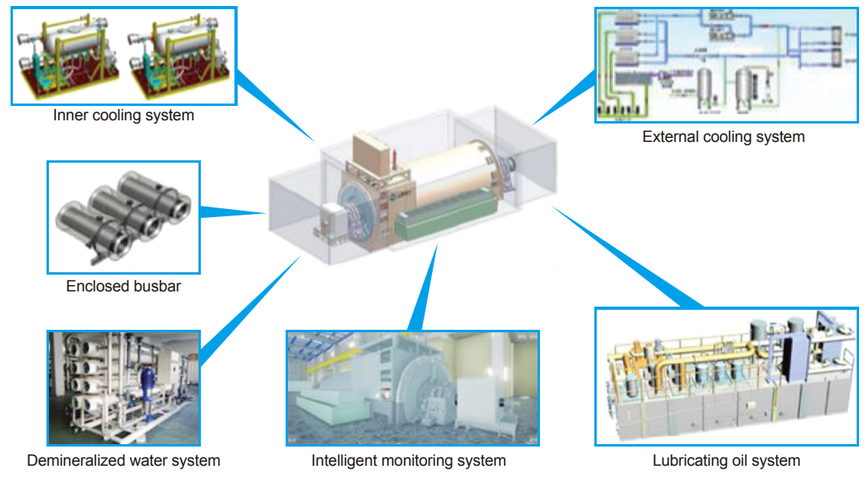


Main components of synchronous condenser solution

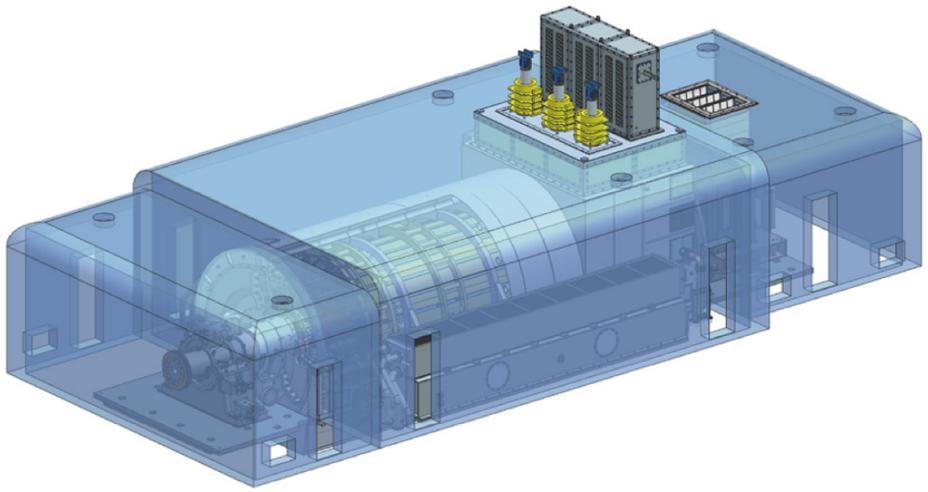
Synchronous Condenser

Photo of on-site SC

The SC includes SC body, lubricating oil system ,cooling system, etc. In order to highlight reactive power compensation ability of SC, the stator and rotor of SC have been specially optimized in many aspects, such as improving the groove shape and turns of stator and rotor, optimizing the cooling structure, and enhancing the insulation of iron core and the shield structure of the end. The SC can be divided into two types: full air cooled and dual water cooled.



Main components of synchronous condenser body



3D Shape of one type of SC Body

Step-up Transformer

Step-up transformer is a kind of three-phase transformer. The low-voltage side of the transformer is connected to the stator of SC, and the high-voltage side is connected to circuit break.

Photo of Step-up Transformer

Excitation System

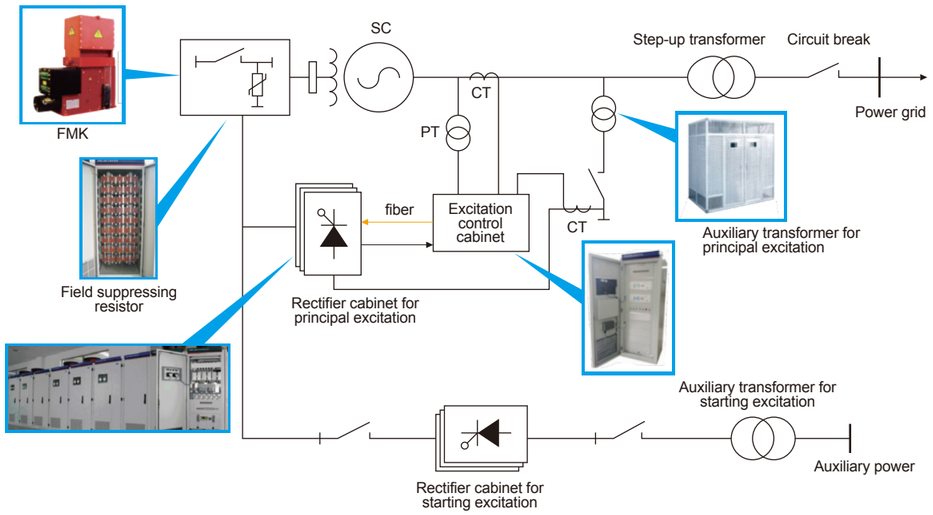
On-site pictures of excitation system

Excitation system is the core control system of SC. SC adopts static excitation system, and the static excitation system includes 2 parts: starting excitation and principal excitation. The starting excitation part cooperates with SFC system for starting SC and the principal excitation part is used to achieve reliable grid-connection with synchronizer and reactive power adjustment after grid-connection.

The excitation system includes auxiliary transformer for starting excitation, auxiliary transformer for principal excitation, rectifier cabinets for starting excitation, rectifier cabinets for principal excitation, field magnetic break (FMK) cabinet, field suppressing resistor cabinet and excitation control cabinet.

The high-voltage side of auxiliary transformer for starting excitation is connected to auxiliary power bus to provide power for starting excitation during the starting period of SC. The high-voltage side of auxiliary transformer for principal excitation is connected to the stator of SC to supply power for the principal excitation. The rectifier cabinets for starting excitation and the rectifier cabinets for principal excitation both adopt three-phase full-controlled bridge structure. The field magnetic break(FMK) cabinet, field suppressing resistor cabinet are common equipment for starting excitation and principal excitation. The excitation control cabinet realizes signal acquisition and command sending of excitation system.

The PCS-9400 excitation system of NREC adopts two independent excitation controllers. The rectifier cabinets for starting excitation and principal excitation are both equipped with redundant configurations, and the excitation system meets the requirements of rated and forced excitation operation when the one rectifier cabinet is out of service.



Schematic diagram of excitation system

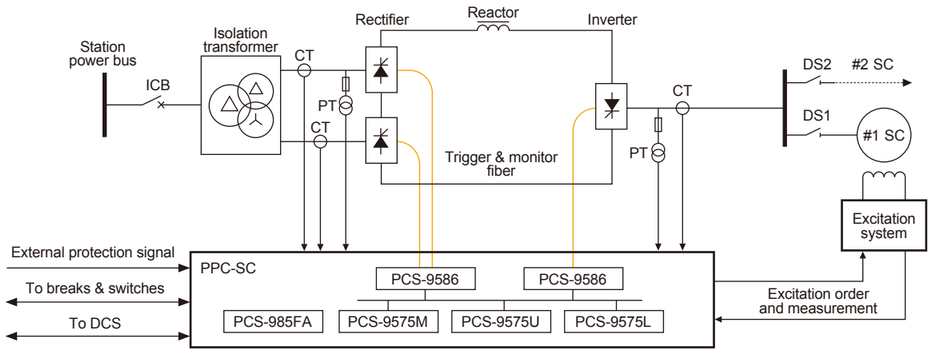
Starting System

Static Frequency Converter (SFC) is used for the startup of SC. SFC includes input circuit breaker, isolation transformer, rectifier, inverter, reactor, switch, etc.

The rectifier and inverter both adopt three-phase full-controlled bridge structure. Series 12-pulses rectifier is adopted to minimize harmonics injected at PCC(Point of Common Coupling). The reactor is used to suppress the dc current ripple. Switches are used for direct starting and crossover starting.

PCS-9575 SFC of NREC adopts several patented technology, advanced SCR photoelectric trigger technology and efficient control algorithm to ensure the high successful starting rate. At the same time, PCS-9575 is equipped with redundancy protection, which is independent of the controller.

On-site pictures of SFC system



Schematic diagram of SFC system

Protection System

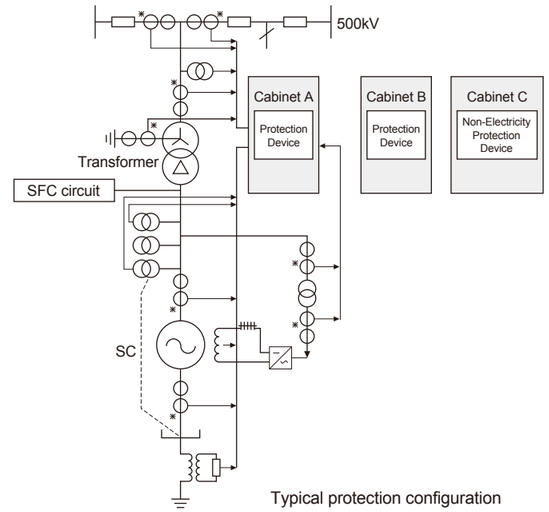
The protection system includes condenser transformer unit protection, non-electricity protection, and isolation transformer protection.

Among them, the condenser transformer unit protection includes condenser protection, step-up transformer protection and excitation transformer protection.

The condenser protection is equipped with condenser differential protection, stator ground protection, and rotor ground protection, etc.

The step-up transformer protection is equipped with transformer differential protection, transformer voltage controlled overcurrent protection, and transformer overexcitation protection.

The excitation transformer protection is equipped with excitation transformer differential protection, excitation transformer overcurrent protection, and excitation transformer overload protection.

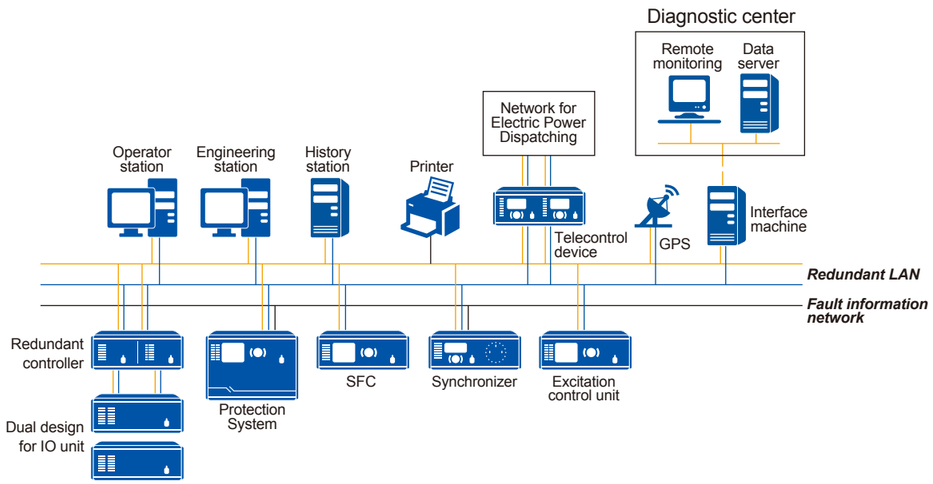


Typical protection configuration

Distributed Control System

PCS-9150 distributed control system(DCS) realizes the following functions: button start and stop of SC, quick restart after disconnection, fast reactive power adjustment, and monitoring auxiliary system operation.

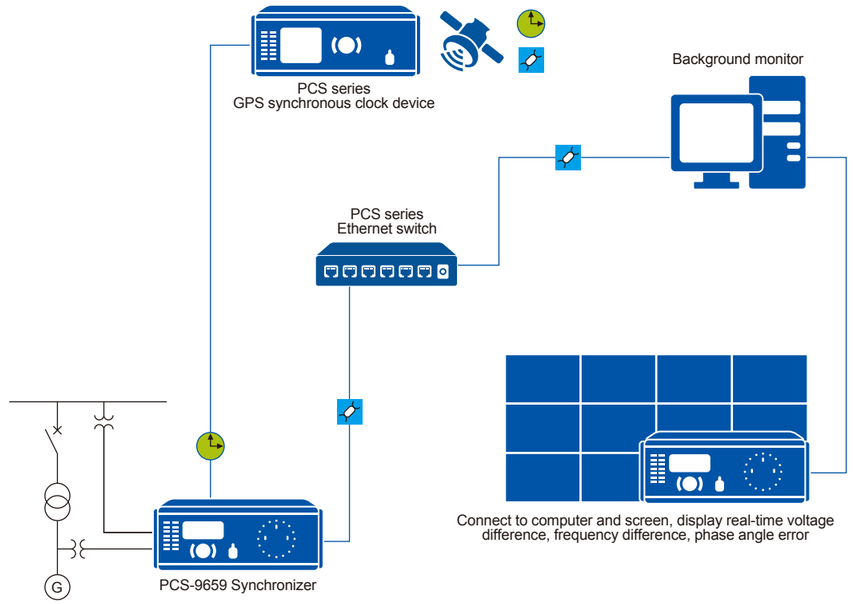
PCS-9150 distributed control system consists of three parts: process control level, communication network and human-machine interface (HMI). It uses redundant fault-tolerant fast Ethernet as the unit high-speed data network (UDH). The unit high-speed data network (UDH) adopts dual-network redundant structure. All sites in station directly access the Ethernet, and the entire unit high-speed data network is effectively connected. Any station site's fault will not affect the normal operation of the system.



Network for distributed control system

Synchronizer PCS-9659 is a digital synchronizer that determines the proper time to initiate closing of circuit breaker to parallel a SC/generator and bus, or to reclose a line. The device adopts "CPU+DSP" dual sampling and mutual calibration technology, and the action components are calculated independently by different algorithms to ensure the reliability of synchronous sampling and the correctness of synchronous closing behavior. The device supports the digital IEC61850 (DL/T860) standard, remote simultaneous process monitoring, multiple communication interfaces and protocols, and multiple timing modes.

During the grid-connection process of SC, the synchronizer could adjust the terminal voltage of SC dynamically and capture the synchronizing point accurately. The voltage difference could be less than 1% and the angle error could be less than 1 degree at grid-connecting moment. At present, the success rate for capture of synchronizing point is 100% in all installed SC project applications.



Schematic diagram of operation for synchronizer

Phasor Measurement Unit

Phasor measurement unit(PMU) can provide accurate, real-time and reliable synchronous phasor data for Wide Area Measurement System (WAMS), and provide strong technical support for grid-connection of renewable energy.

Fault Recording Device

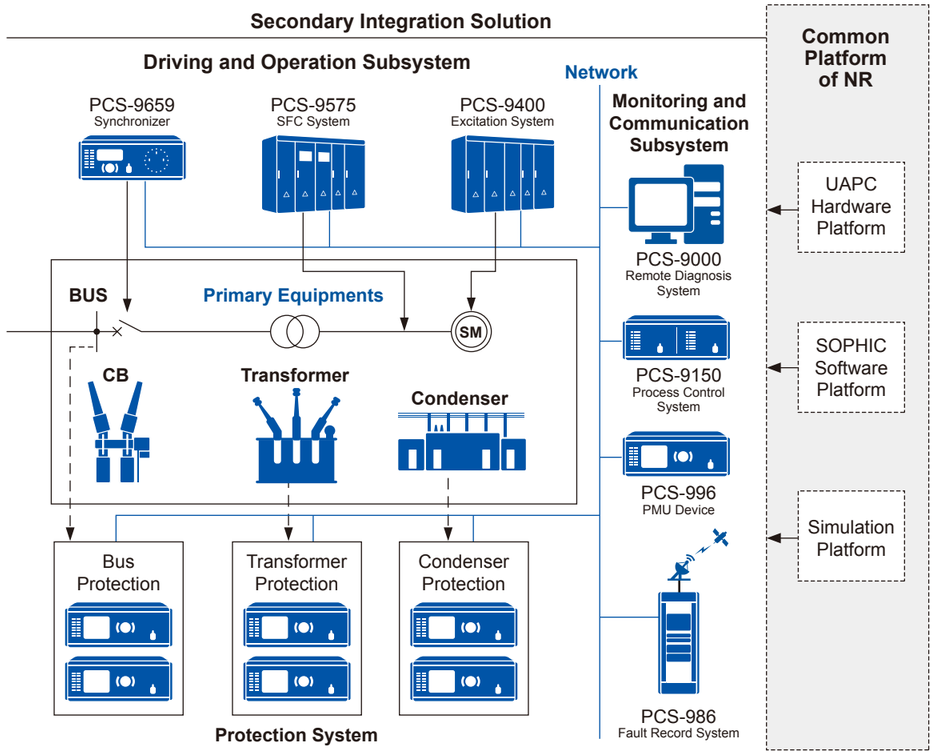
Fault recording system is responsible for the collection, triggering and recording of fault data, as well as the recording configuration, parameter management and data analysis

Remote Diagnosis system

Remote diagnosis system realizes the remote diagnosis of SCs distributed in various areas and the remote monitoring and state analysis of the equipment in substations.

Technical Features

All-in-one Solution



The secondary control and protection system of SC can be divided into three subsystems, namely, the startup and operation subsystem, the monitoring and communication subsystem, and the protection subsystem. They mainly include the following equipments:

Startup and operation subsystem

- PCS-9575 Static Frequency Converter(SFC)
- PCS-9400 Excitation System
- PCS-9659 Synchronizer

Monitoring and communication subsystem

- PCS-9150 Distributed Control System
- PCS-996 Phasor Measurement Unit
- PCS-9000 Remote Diagnosis System
- PCS-986 Fault Recording Device

Protection subsystem

- PCS-985 Protection for Condenser Transformer Unit
- PCS-987 Protection Device for Torsional Stress

Capability Of Overall Design

Depending on NREC's dynamic simulation system, RTDS simulation system and EMC laboratory, it is convenient to test the integrated secondary solution of SC system, and verify system capacity, control parameters, protection settings and anti-interference measures. At the same time, with the help of RTDS and other simulation systems, the joint simulation between SC and power system can be carried out to verify the control strategy of the SC system, so as to achieve the overall optimal performance , improve the debugging efficiency on site and achieve the optimal design of the all-in-one solution.

Dynamic simulation lab

RTDS lab

Unified Reliable UAPC Platform

All devices provided by NREC are based on UAPC platform. Unified hardware boards, high product reliability and high substitution of spare parts are all advantages of NREC. Through unified platform, model and protocol, the information of various professional devices are fully integrated, which leads to high real-time communication, low cost of design, operation and maintenance, improvement of the overall automation level.

Perfect Training System

The provision of comprehensive training, test, experiment and simulation, etc. ensures that the users can master the operation and function of NR Electric products in different views and aspects, know NR products indeed and complete the installation, debugging and operation of those products independently.

NR Electric's training can be offered in many ways, including:

Customized training

A set of training courses is specially designed according to the customer' s training demands. The training courses are pertinent to the customer' s actual demands. The training can advance the customer' s skill level to the maximum extent in a shorter period.

On-site training

The engineers are sent to the customer's site for training so as to save the customer's travel expense.

Regular training

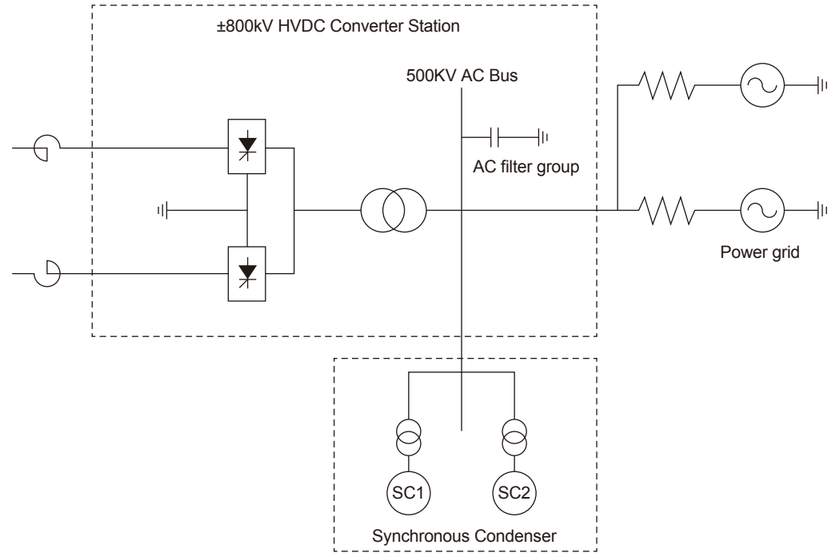
The training courses are issued on our website regularly so that the customer can select the corresponding training courses according to his own demand and time.

Case study

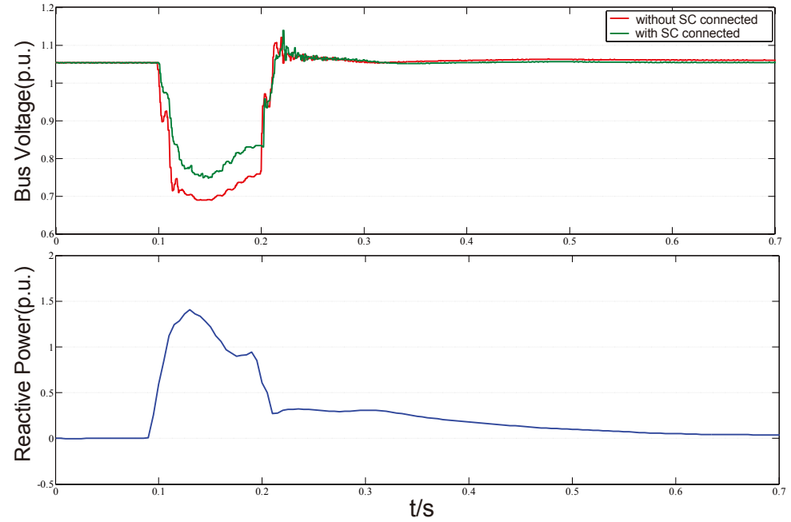
2×300MVA Synchronous Condenser in Xiangtan Station

±800kV Jiuquan-hunan UHVDC transmission project has a transmission capacity of 8000MW. Xiangtan synchronous condenser belongs to the supporting project of the receiving end converter station of the HVDC transmission line, which is located in Xiangtan city, Hunan province, China. It was put into operation on January 5, 2018. After its commercial operation, the system short-circuit capacity can be effectively increased, and emergency reactive voltage support can be provided to the converter station to improve the voltage recovery ability after fault.

Synchronous condenser picture taken on site



simplified connection diagram in Xiangtan HVDC station



Waveforms of the system voltage and the reactive power output of synchronous condenser during fault period

Reference

NR has delivered many synchronous condenser solutions with satisfactory performance, which includes the following references.

- 2 sets of synchronous condenser with each rated 300Mvar, at Xiangtan HVDC station
- 2 sets of synchronous condenser with each rated 300Mvar, at Taizhou HVDC station
- 3 sets of synchronous condenser with each rated 300Mvar, at Linyi HVDC station
- 2 sets of synchronous condenser with each rated 300Mvar, at Nanjing HVDC station
- 2 sets of synchronous condenser with each rated 300Mvar, at ±1100kV GuQuan HVDC station
- 2 sets of synchronous condenser with each rated 300Mvar, at Nanchang HVDC station
- 2 sets of synchronous condenser with each rated 300Mvar, at NanYuan subtation
- 2 sets of synchronous condenser with each rated 300Mvar, at NieGeZhuang substation
- 2 sets of synchronous condenser with each rated 300Mvar, at QingHai ChaiDaMu HVDC station
- 2 sets of synchronous condenser with each rated 300Mvar, at TianShan HVDC station