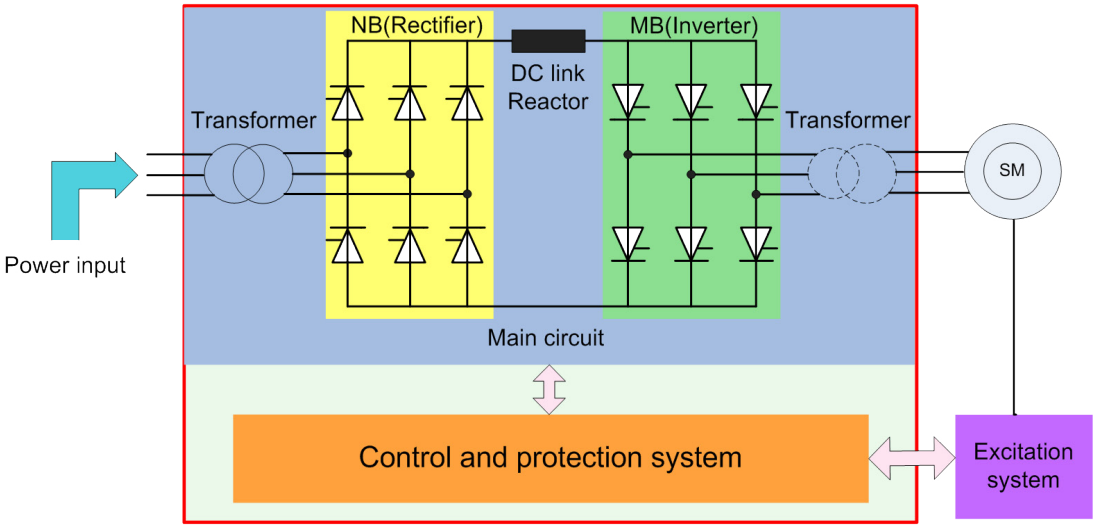
PCS-9575 Static Frequency Converter

Fast startup of large generators without inrush current

NR Electric Co., Ltd.

PCS-9575 static frequency converter (SFC) provides startup and rotation speed control of large synchronous motor. It quickly drags the motor to the rotation speed according to the control requirement. Meanwhile, the PCS-9575 also can be used as speed governing equipment to control motor operation at the required rotation speed.



Application

SFC is mainly used for the startup of pumped storage power plant, gas turbine unit, and large synchronous motor. So far, it has been applied to most of large pumped storage power generation units and gas turbine power generation units.

Startup of Pumped Storage Power Generation Units

With constant increase in intermittent power generation, such as nuclear power generation, wind power and solar power generation, pumped storage power plants need to be constructed. The power plants can run in two operating conditions: water pump and water turbine. The water pump mode is selected during power load valley. It uses surplus electric energy generated by fossil fuel power (or nuclear power) units to pump water from lower reservoir to upper reservoir. The water turbine mode is adopted during power load peak. It generates power via the water head by lowering of stored water.

The pumped storage power plant has unique functions of shifting the peak load and filling the valley load, and fast and flexible unit startup/shutdown characteristics, and has become an important method to guarantee safe and high quality operation of power grid and to improve power system economy.

The most common startup mode of large pumped storage power plants is static frequency conversion startup. The frequency conversion speed governing system features soft startup performance, small disturbance to grid, smooth increase in speed, high automation and high reliability. One set of frequency conversion system is high efficient that one set converter can control the startup of many units.

Startup of power generation units for gas turbine

For the startup of gas turbine units, the external torque power must first be used to drive the rotor through different rotation speed stages of turning gear, light blow, coasting, ignition, warm-up, and acceleration etc. When self-sustained speed is reached, the power will be supplied by the turbine. NR's PCS-9575 Static frequency conversion system (referred to as Load Commutated Inverter, LCI) is perfect matched with the requirements of startup process for gas turbine units.

Other Industrial Occasions

The PCS-9575 SFC system can be used for startup and speed governing of large power synchronous motors in industrial fields, e.g. large power compressors on NG transmission pipelines, steel mill large power fans and aeronautic wind tunnel test stand etc.

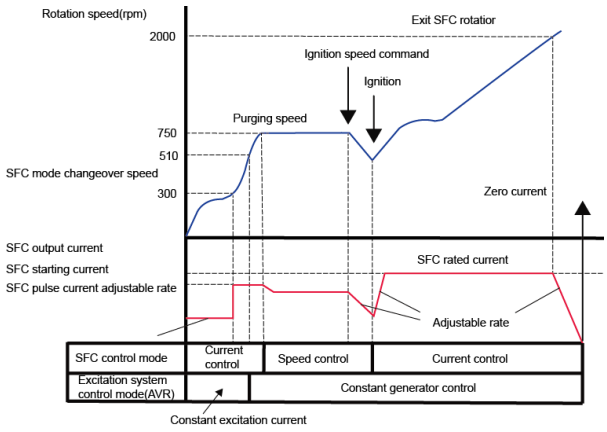


Figure. SFC starting process for gas turbine power generation unit

Operating Principle

SFC system is referred to as self-controlled synchronous motor. The thyristor converter is used to convert DC power to AC power with variable frequency in order to perform the varying frequency governing of synchronous motor. Different from the varying frequency governing of ordinary asynchronous and synchronous motor, the output frequency of self-controlled synchronous motor is controlled by synchronous motor rotor position. Each time the motor rotates passing a pair of magnetic poles, the converter AC output will change by one cycle accordingly, ensuring the synchronization between converter output frequency and motor rotation speed throughout the whole operation period.

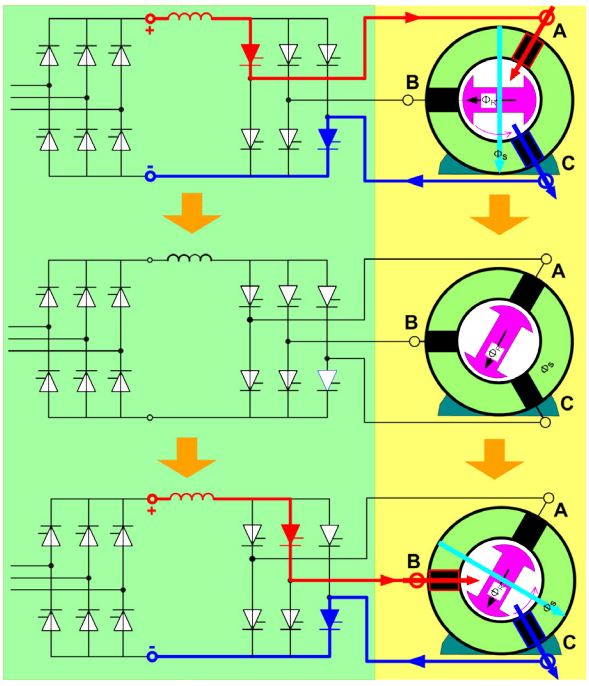
The SFC system consists of thyristor rectifier, reactor, thyristor inverter and controller. The controller adjusts DC voltage output according to its operating conditions, controls the inverter to supply AC current with varying frequency to the stator of synchronous motor according to the rotor position, regulates the excitation equipment to provide DC current to the rotor of synchronous motor, and drags the motor rotation speed to the required value. According to different inverter control modes, the SFC working stages are divided into pulse commutation stage and load commutation stage.

Pulse Commutation

Low motor rotation frequency (e.g. less than 5Hz) leads to low AC voltage of inverter, thus the inverter cannot realize continuous voltage commutation at AC side. In this case, On and Off of inverter need to be controlled in sequence to realize output commutation in pulse commutation mode.

Load Commutation

High motor rotation speed causes high AC voltage of inverter and thereby ensures the realization of voltage commutation at AC side. In this stage, the rectifier is in rectifying state while the inverter is in inverting state. The motor speed is in linear proportion with output of rectification power, so as to provide the motor with continuous driving torque and controls motor rotation speed.



Main Components

PCS-9575 static frequency converter includes primary power equipment and secondary control and protection equipment. The primary equipment consists of input switch cabinet, input transformer, rectifier, DC reactor, inverter, output transformer, output switch, SFC output switch, and cooling equipment for converter.

Input Switch Cabinet

Inside the cabinet, input switches of SFC system are installed.

Input Transformer

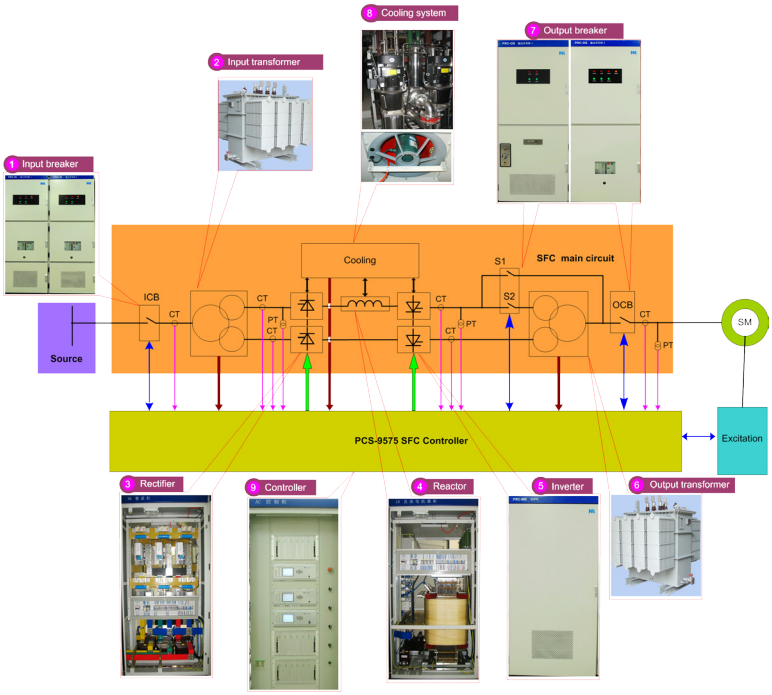
As the isolation node between SFC system and power supply, the input transformer can suppress short circuit capacity and provide the required secondary voltage at the same time. According to the rectifier pulse number and the voltage ratio, the types of input transformer include 3-winding transformer, 2-winding transformer, step-down transformer or 1:1 isolation transformer.

Rectifier

The rectifier generates DC voltage and is taken as current source connected with the reactor in series. The rectifier adopts 3-phase thyristor full bridge structure with 12-pulsewave or 6-pulsewave. The bridge arm of valve block adopts photoelectric triggering using thyristor control unit (TCU). Highly efficient water cooling or air cooling can be applied.

Reactor

The SFC system contains DC reactor and AC reactor. The DC reactor is necessary equipment for current type



Main Components

SFC system. It cooperates with rectifier to constitute a current source. The DC reactor is used to reduce DC current ripple and short circuit capacity. Air cooling equipment is installed for the DC reactors. The AC reactor is configured for AC input and output of SFC system to replace output transformer in LCI system.

Inverter Cabinet

The cabinet adopts 3-phase thyristor full bridge structure with 12-pulse wave or 6-pulsewave bridge. Triggering of bridge arm of valve block adopts photo-electric triggering using TCU. Highly efficient water cooling or air cooling can be adopted.

Output Transformer

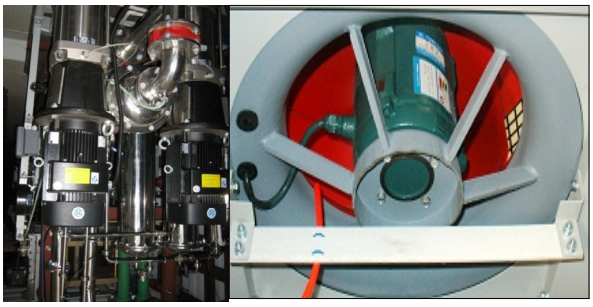
The output transformer is used as the isolation node between SFC system and motor, which changes the output of SFC to be available for stator voltage level. According to the inverter pulse number, the output transformer can be 3-winding transformer, 2-winding transformer, step-down transformer and 1:1 isolation transformer. Normally the output transformer is not configured in a LCI system.

Output Switch Cabinet

The output switch cabinet is composed of output switch and output transformer bypass switch. Normally the output switch cabinet is not configured in a LCI system.

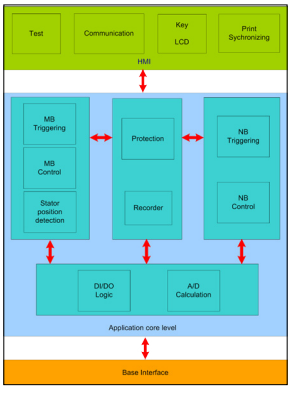
Cooling Equipment

The thyristor valve block generates certain amount of heat during its operation. The components will sustain excessive temperature or even get damaged if the heat is not dissipated in time. When the system capacity is small, PCS-9575 SFC system adopts forced air cooling. When system capacity is large, the power bridge adopts closed-loop circulating water cooling, with special cooling water circulation control system provided.

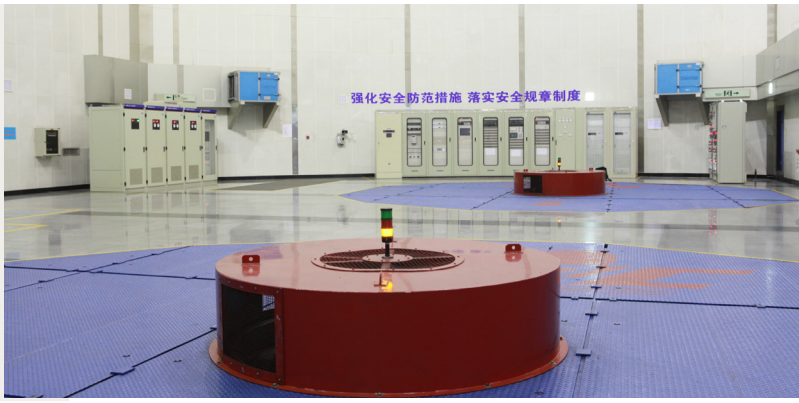


Control & Protection System

PCS-9575 SFC Control and Protection System is the control center and the brain of SFC system. It realizes the control of whole system by acquiring binary and analog quantities (electric and non-electric quantities) of SFC primary system and other systems, and issuing switch operation commands, converter triggering pulse, and control analog quantities. The controller analyzes and processes various input signals to perform the monitoring of system operation.



Technical Features



PCS-9575 SFC control and protection system adopts NR's mature power electronics technology. The whole system features:

- Innovative, mature and reliable platform of hardware and software;
- Distributed multi-CPU hardware system with good versatility and high reliability;
- High resistance to EM interference;
- Visualized modular programming with high maturity;
- Stable and reliable control of frequency variation;
- Complete protection functions;
- Complete fault recording and analysis functions, external communication functions and friendly man-machine interaction;
- High control system integrity;
- Core techniques for high compact and reliable valve block;
- Real time phase locking control pulse generation technique allowing stable pulses and strong interference immunity;
- Photoelectric triggering technique: valve design is compatible with IEC61954 and allows long service life of thyristor;
- Thyristor valves adopt strong anti-disturbance photoelectric triggering, providing good isolation security and consistency of triggering;
- High performance control and protection system to realize differential protection, over-current protection, and di/dt current sudden change protection functions;
- Small and medium capacity system adopt forced air cooling; large capacity system adopts closed-loop circulating water cooling (patented technology);
- Simple and reliable design of heat dissipation system;
- Guaranteed long-term supply of system spares and timely after-sales service

The whole system has advantages of stable and reliable software functions, high EMC level, and good system maintainability etc.

Professional System Design

An expert and experienced R&D team has spent large amount of time on the system design, primary electric design, electric structural design, and mechanical structural design of PCS-9575 SFC system.

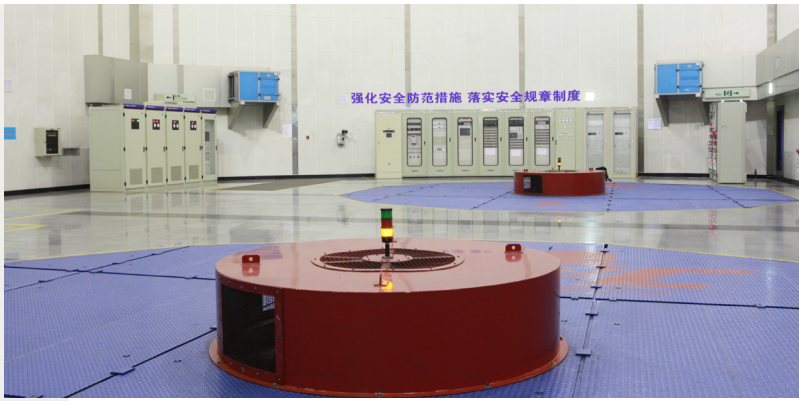
High Compact & Reliable Valve Block

NR possesses all the core techniques of the compact valve block of SFC system. Each bridge arm valve block consists of a number of thyristor connected in series. It adopts forced closed-loop circulating water radiator. The thyristor of each bridge arm and water cooling radiators are assembled to form a complete valve string. This compact valve block structure is suitable for the applications with high requirements of system volume (e.g. LCI system used in gas turbine power plant).

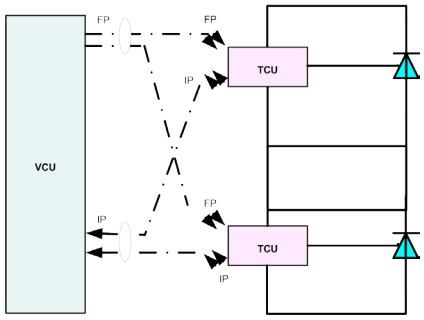
Advanced Photo-Electric Triggering Mode

The PCS-9575 SFC system valve blocks adopt advanced photo-electric triggering technique that is applied to HV/extra-HV DC power transmission converter valves. The triggering system includes 2 parts: the valve control unit (VCU) in control cabinet, and the thyristor control unit (TCU) on valve itself.

Technical Features



The value control unit is used to convert control pulses (CP) to optical signals from control regulator to firing pulse (FP). The thyristor control unit is used to convert triggering pulse optical signals generated by VCU to electric pulse signal so as to trigger thyristor. Normally, when a valve block is energized, TCU acquires energy, when the thyristor is forward TCU will issue the indication pulse (IP) optical signal to VCU. After VCU receives IP signals and CP from control system, it will issue FP to TCU.



Schematic of thyristor triggering system

NR SFC valve block triggering techniques are listed below:

a) Simple structure of triggering system
- Simple and reliable
- Good insulation performance
- Small volume, light weight, and compact structure
- No radiation disturbance to external equipment
- No noise

b) TCU directly takes energy from primary circuit, and is controlled by optic cable.
- Strong anti-interference capability
- Short delay to ensure fast response of valve block
- Good synchronization of triggering pulse
- High steepness of triggering signal and reliable triggering

c) TCU integrates thyristor forward overvoltage protection and reverse restore (dv/dt) protection:
- Ensuring no damage to thyristor and reliable operation

d) TCU module is installed inside the enclosed metal box and fixed on radiator wing panel.
- Strong anti-interference capability
- Good operating temperature and high reliability
- Prevention of TCU circuit against dusty and failure
- Compact structure

The advanced photoelectric triggering mode ensures high reliability and performance of valve blocks.

Patented Water Cooling System

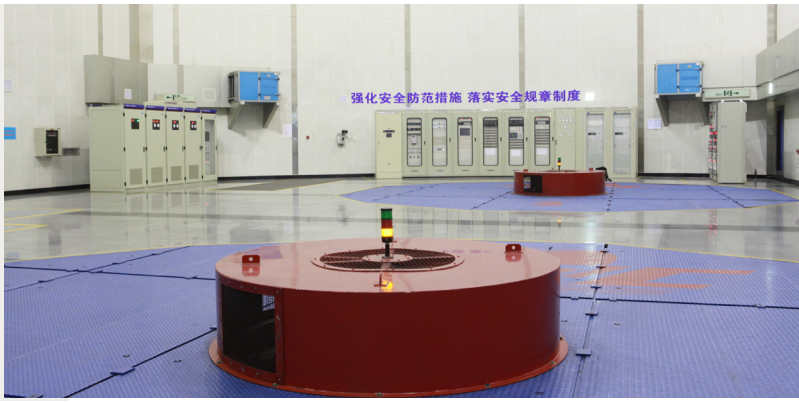
The performance of cooling system is critical for valve block. NR's large capacity valve block system adopts sealed pure water cooling that is widely used in automobiles, locomotives, aeronautics, spaceflight, 1000MW grade power generation units, and HV and extra-HVDC power transmission.

NR possesses the following patented water cooling techniques:

a) Parallel water path design
- High cooling efficiency
- Reliable operation

b) Patented radiator
- Unique water path design: direct water path cooling (non-bimetal structure) with high cooling efficiency
- Low heat resistance: effective heat resistance

Technical Features



RSA at rated water flow less than 7K/kW

- Made of Al alloy: resistant to corrosion and rusting

c) Water path direct cooling grading resistor

- High overload capacity
- Small volume

d) High reliable water pipes and connectors

- PVDF main water pipes of nuclear power grade: excellent performance, good adaptive capability, and high reliability
- The unique patented nested extruded leak-proof structural connectors for HV DC power transmission: reliable connection

The advantages of water cooling system ensure the overall performance, compactness and reliability of valve block.

Strong EMC Design

Normally, SFC control system is placed with primary circuit. During the operation of primary equipment, It may generate electromagnetic interference to secondary control system. In PCS-9575 SFC system, the following anti-interference measures have been taken as follows.

- High EMC level of controller;
- Photo-electric triggering;
- Shielded cables are applied to all primary and secondary circuits;
- All secondary circuits operate in metal shielded channel;
- Relevant components are reliably grounded.

High Performance

The PCS-9575 SFC control and protection system adopts NR's unified UAPC platform, which is also used for HVAC protection, HVDC control and protection system, flexible AC power transmission system (FACTS) control and protection system, SVC control and protection system, and digital substation control and protection system. The platform features high performance distributed structure and easy functional expansion capability.

The PCS-9575 can realize the following functions:

- Stable and reliable control of variable frequency;
- Comprehensive protection of system equipment;
- Complete fault recording and analysis functions;
- Various external communication functions;
- Friendly man-machine interactive functions;
- Complete hardware and software self-check functions.

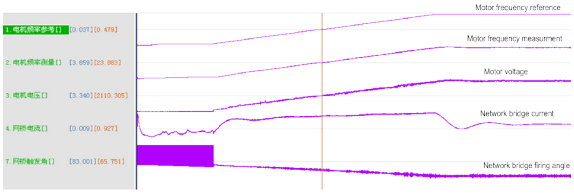


Figure. Starting process test wave

Systematic Experimental Capability

NR has established HV and large current laboratories, advanced RTDS laboratory and SFC dynamic simulation laboratory to perform SFC system tests at different voltage level, ensuring the quality and performance of all SFC products before delivering to site.

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