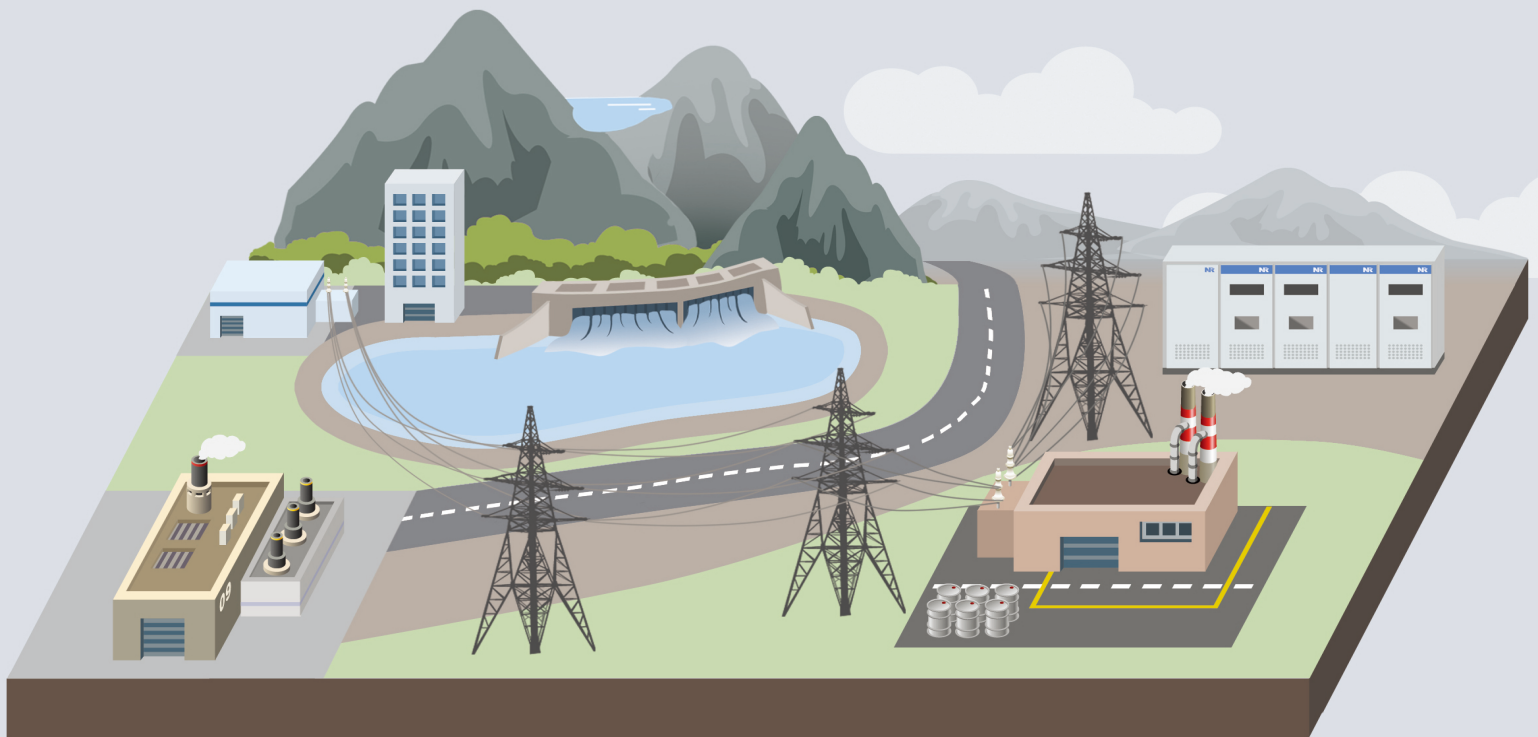




Power Stability Expert

Static Frequency Converter

Outstanding controllability for perfect startup of large motors



NR Electric Co., Ltd.



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Outstanding controllability for perfect startup of large motors



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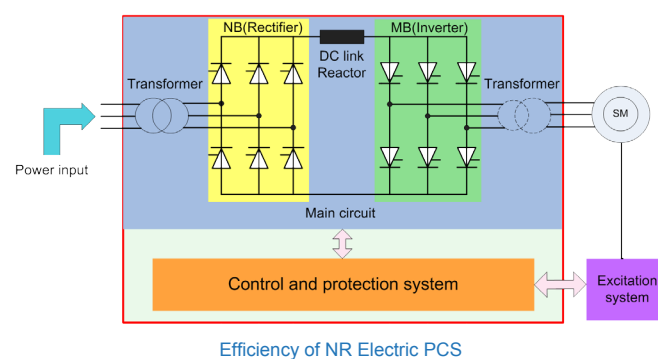
1 Benefits

- *Patented cutting-edge rising speed control tactics to guarantee successful and smooth startup process.*
- *Patented Series-parallel hybrid air flue design for more efficient cooling effect for high-voltage valve bridge.*
- *Redundant and reliable protection scheme with one separate protection and another embedded in SFC controller.*
- *Innovative various frequency differential protection for converter bridge and transformer to guarantee reliability, selectivity and rapidity of protection.*
- *Automatic, seamless and smart interface switch design for easy realizing redundant SFC scheme, especially for refurbishment or upgrade of existing old SFC project.*

2 SFC Function

Rapid market demand over heavy synchronous motors and generators mainly used for hydro-pumping/gas power plants or any other Industrial applications needs a starting and frequency-controlling module for its efficient and reliable operation.

PCS-9575 static frequency converter (SFC) provides an adequate startup control as well as rotation speed control for large synchronous motors by its initial quick-dragging speed control or by its later process-speed governing operation.



3 Core Applications

Wide operation and various field demands make SFC an important and core control equipment over power system. The startup principle and speed adjustment through variable frequency makes SFC a prime factor for pumped storage power plants, gas turbine units, and large synchronous motor. Till now it has been widely applied to the large pumped storage power generation units and gas turbine power generation units.

Pumped Storage Startup

With constant increase in intermittent power generations like , wind and solar power, pumped storage power plants with inherent regulative function need to be constructed correspondingly. Basically the power plants can run in two operating conditions:

- Water pump
- Water turbine

The **water pump mode** is selected during power load valley. The surplus electric energy generated by fossil fuel power (or nuclear power) is generally used to pump water from lower reservoir to upper reservoir. Meanwhile **water turbine mode** generates power from stored water by lowering water head during load peaks. Quick load shifting during peaks or valleys and fast startup or shutdown characteristics of pumped storage power plant guarantees a safe, qualitative and economical operation for power grid. Having frequency conversion startup as the most convenient mode, the speed governing system features a soft startup, low disturbance, smooth operation and high automation & reliability to control single or multi units at once.

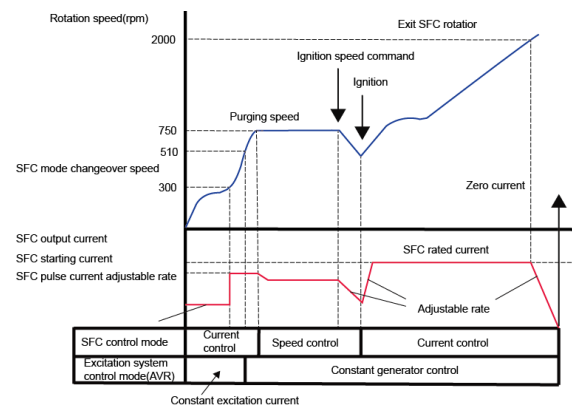




Gas Turbine Startup

As to initiate the startup, SFC provides external torque for rotation of gas turbines through different speed stages like turning gear, light blow, coasting, ignition, warm-up, and acceleration. After achieving of self-sustained speed, the power gets supplied by the turbine. NR Electric's PCS-9575 Static Frequency Conversion system's enhanced operation and controlled output outstandingly match the requirements of startup process for gas turbine units.

Note: PCS-9575 Static Frequency Conversion system also referred as Load Commutated Inverter (LCI).



SFC starting process for gas turbine power generation unit



Extended Applications

Various industrial large power synchronous motors are being operated through PCS-9575 SFC system due to its effective startup and speed governing principle. Included applications are:

- Large power compressors on NG transmission pipelines
- Steel mill large power fans
- Aeronautics wind tunnel test stand etc.



4 Operation Principle

Different from the varying frequency governing principle of ordinary asynchronous and synchronous motor, the output frequency of PCS-9575 SFC is self-controlled through 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.

The SFC system mainly consists of thyristor rectifier, reactor, thyristor inverter and controller. The controller has various functions. Such as:

- Adjusts the DC voltage output according to its operating conditions
- Controls the inverter to supply AC with varying frequency to the stator through rotor position feedback
- Regulates the excitation equipment to provide DC to the rotor and drags the motor rotation speed to the required value.

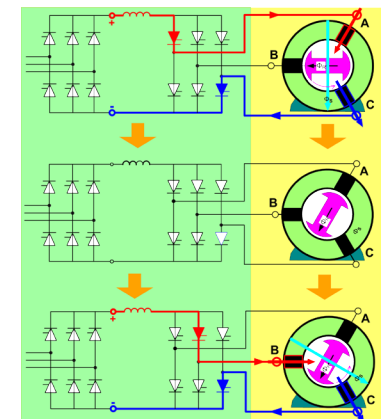
Different inverter control mode divides the working stages of SFC into pulse commutation stage and load commutation stage.

Pulse Commutation Stage

Low motor rotation frequency (e.g. less than 5Hz) leads to low AC voltage and discrete operation of Inverters. This causes On and Off of inverter in sequence to realize output commutation in pulse commutation stage.

Load Commutation Stage

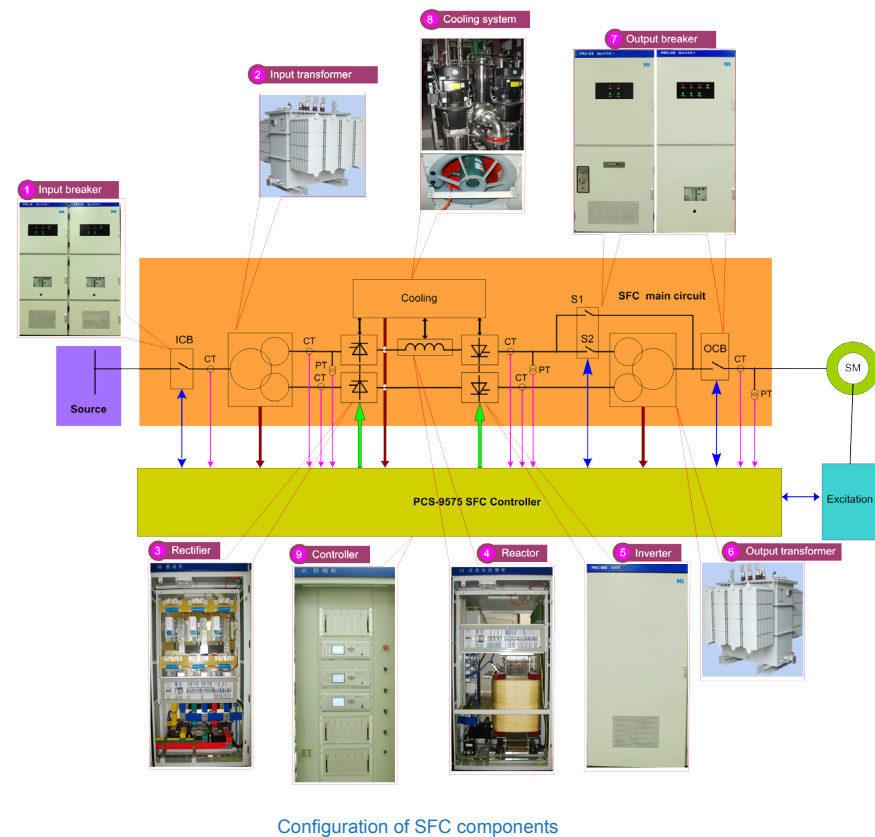
Voltage/Load commutation is realized through high motor rotation speed and high AC voltage of inverter. This provides continuous driving torque and controls motor rotation by keeping the motor speed in linear proportion with the output rectified power.



SFC commutation sequences of Valve

5 Main Components

Precocious primary power equipments and advanced secondary control & Protection equipments makes the PCS-9575 static frequency converter a state-of-art solution for concerning startup. 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 Switchgear Cabinet

It consists of input switches/breakers for SFC system.

Input Transformer

By behaving both as a short circuit current suppressor and an isolation node between SFC and power supply, the input transformer also provides the required secondary voltage at the same time. According to the rectifier pulse number and the voltage ratio, 3-winding transformer, 2-winding transformer, step-down transformer or 1:1 isolation transformer can be adopted .

Rectifier

A current source series with reactor adopts 3-phase thyristor full-bridge structure having the options of 6/12-pulsewaves. The thyristor valve bridge arm adopts photoelectric triggering using thyristor control unit (TCU) and highly efficient water/air cooling for refined and exceeding output.

Reactor

The current source uses a DC reactor for reducing DC current ripple and short circuit current. It is availed with air cooling for optimum performance. .However the AC reactor is configured for AC input and output of SFC system, and replace output transformer in LCI system.

Inverter

The Inverter adopts a 3-phase full-bridge thyristor structure with the options of 6/12-pulsewaves. Photo-electric triggering and high efficient water/air cooling make it more efficient for Inversion.

Output Transformer

By making an isolation node between SFC system and motor, output transformer changes the output of SFC to required stator voltage. Depending upon inverter pulse number, the output transformer can be 3-winding transformer, 2-winding transformer, step-down transformer and 1:1 isolation transformer. While in LCI system the output transformer is not configured.

Output Switchgear Cabinet

In SFC system, the output switch cabinet is composed of output switch/breaker and output transformer bypass switch. In case of LCI system, the output transformer with bypass switch cabinet is generally not configured.

Cooling system

Formation of enormous heat during operation may damage the components if it is not dissipated well. During low system capacity, PCS-9575 SFC adopts forced air cooling whereas during large system capacity, it adopts closed-loop water cooling with specialized control system.

Control & Protection Panels

As the mastermind of PCS-9575 SFC, the Control and Protection System keeps track of every system through acquiring digital and analog data and issues commands for switching/triggering and controlling of analog quantities. The controller analyzes and processes various input signals to perform the monitoring of system operation.

6 Technical Features

With outstanding performance and extreme reliability, PCS-9575 SFC system adopts a mature power electronics technology aiming the features as:

- Innovative, mature and reliable platform for hardware and software with thousands of applications.
- High reliability and Versatility of Distributed multi-CPU hardware system.
- High resistance to EM interference.
- Highly matured visualized modular-programming.
- Stable and reliable control of frequency variation.
- Complete protection functions of entire system.
- Complete fault recording & analysis/external communication functions and friendly man- machine interaction.
- Highly integrated control system.
- Highly compact and reliable valve design.
- Real time phase-lock control generation technique guarantees stable pulses and strong interference immunity.
- Adherence to Photoelectric triggering technique keeps valve design compatible with IEC61954 and allows long service life of thyristor.
- Strong anti-interference photoelectric triggering provides better consistency and isolation security.
- All kinds of differential protection, over-current protection, and instantaneous protection (di/dt) are being managed by state-of-art protection and control system.
- Guarded by forced air cooling for small/medium capacity system whereas closed-loop circulating water cooling (patented technology) for large capacity systems.
- Simple and reliable design of heat dissipation system.
- Guaranteed long-term supply of system spares and timely after-sales service.



By guarantying a stable and reliable software functions, high EMC level, and good system maintainability, NR PCS-9575 SFC provides an All-In-One solution to its customers.

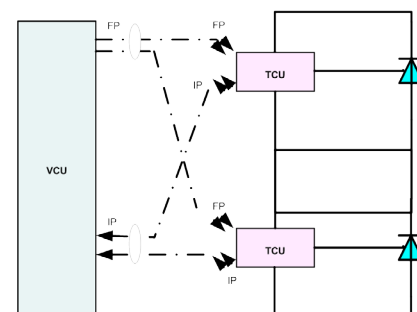
Highly Compact & Reliable Valve Design

Compact valve design with series combination and enhanced core techniques of NR PCS-9575 SFC, makes it more bonded with the respective application. Adding to that the valve strings with forced closed-loop circulating water radiators makes it more suitable for heavy load applications (e.g. LCI system used in gas turbine power plant).

Advanced Photo-Electric Triggering

With implementation of photo-electric triggering into HVDC Power converter valves, the PCS-9575 SFC system simplifies the control of DC power flow through valve control unit (VCU) in control cabinet and thyristor control unit (TCU) on valve itself.

The VCU is used to convert control pulses (CP) to optical signals whereas the TCU does the opposite of VCU and convert it back to firing pulse to trigger the thyristor. Normally, when a valve is energized, TCU acquires energy signal and accordingly issues the indication pulse (IP) optical signal to VCU. After VCU receives indication pulse (IP) signals and control pulse (CP) from control system, it issues firing pulse (FP) to TCU.



Schematic of thyristor triggering system

The comprehensive techniques for triggering of NR PCS-9575 are:

a) Simple triggering system structure

- Simple and reliable technology
- Good insulation performance
- Small volume, light weight, and compact structure
- Nil radiation disturbance to external equipment
- No noise

b) TCU's auto energy receiving from primary circuit and controlling through optical cable

- Strong anti-interference capability
- Faster response of valves
- Good synchronization of triggering pulse
- High steepness of triggering signal and reliable triggering

c) TCU's integrates forward overvoltage& reverse restoration (dv/dt) protection:

- Ensures optimal safety of thyristor and reliable operation

d) TCU's enclosed module structure fitted with radiator wing panel

- Strong anti-interference capability
- Impeccable operating temperature
- Prevention against dust and moisture
- Compact structure and modular valve design

Patented Water Cooling

NR Electric's large capacity valve system adopts sealed water cooling system, a patented technology widely used in automobiles, locomotives, aeronautics, spaceflight, multi-MW power generation units, and EHVD power transmission.

NR Electric's patented water cooling techniques include:

a) Parallel water path design

- High cooling efficiency
- Reliable operation

c) Water path direct cooling grading resistor

- High overload capacity
- Small volume

b) Patented radiator

- Unique water path design: non-bimetallic direct water path cooling with high cooling efficiency
- Low heat resistance: effective heat resistance (RSA at rated water flow < 7K/kW)
- Al alloy structure: resistant to corrosion and rusting

d) Veritable water pipes and connectors

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

Strong EMC Design

To avoid EM interference in secondary control systems from primary circuit of PCS 9575 SFC, the following anti-interference measures have been taken:

- High EMC level of controller
- Photo-electric triggering
- Shielding of primary and secondary cables
- Metal Shield for secondary circuits
- Adequate grounding for relevant components



Stringent Performance

Equipped with High Voltage and large current laboratories, advanced RTDS laboratory and SFC dynamic simulation laboratories, NR Electric delivers a qualified and high performing SFC product to its customer after testing at various voltage levels.





7 Case Study

NR Electric's advanced & optimal technology with well market penetration over PCS-9575 SFC, has successfully applied for several cases around the world. Some case introductions are:

ShaHe Pumped Storage Power Plant

- Project Name: SFC for ShaHe Pumped Storage system
- Project Capacity: 4 MVA/10.5 kV

ShaHe Pumped Storage Power Plant is located in Jiangsu province of China. The plant has two generator units with 50 MW capacities each. Previously it started its commercial operation in 2002 through Alstom made SFC. But due to uncertainties and to increase further reliability, NR Electric supplied its SFC at owner's requirement.

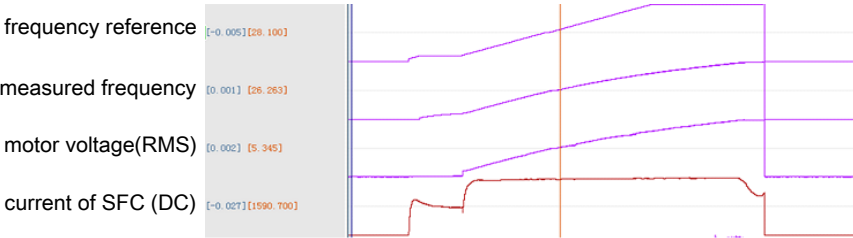
NR Electric SFC successfully operated on later part of 2012 and treated as the master SFC in ShaHe power plant over Alstom's. Till now with 1800 start-ups with a success rate of 100%, NR Electric's PCS-9575 SFC is prominently serving as the first complete intellectual property of China.



ShaHe Pumped Storage Power Plant

Main parameters of the ShaHe SFC project

Capacity of generator Units(MVA)	59.2*2
Capacity of SFC(MVA)	4
Power Bridge Type	12-6 pulses,no serials
Input Voltage of SFC(kV)	10.5
Current Rating(DC, A)	1883
Frequency(Hz)	LS:50Hz;MS:0~52.5Hz
Input transformer (capacity, voltages)	4MVA, 10.5kV/0.7kV/0.7kV
Output transformer (capacity, voltages)	4MVA, 10.5kV/1.4kV



Recorded Curves of Starting Process

The operation and control of installed SFC system delivers the pattern of the reference frequency following and subsequently ease for a smooth and accurate Unit operation. The ShaHe power plant has greatly improved its success rate of starting generator units through NR PCS-9575 SFC.

XiangShuiJian Pumped Storage Power Plant

- Project Name: SFC for XiangShuiJian Pumped Storage system
- Project Capacity: 20 MVA/15.75 kV

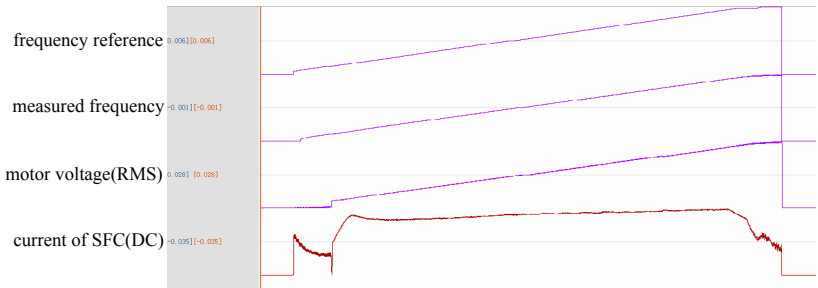
XiangShuiJian Pumped Storage Power Plant, locating in Anhui province of China has four generator units with 250 MVA capacities each. To acquire high reliability of the Power station, NR supplied its state-of-art PCS-9575 SFC equipped with redundant design and guaranteed performance along with ABB. The two redundant SFC's seamless performance and successful start-ups of units, makes the whole power plant highly flexible and competent for peak load performance



Generators of the XiangShuiJian Power Plant

Main parameters of the XiangShuiJian SFC project

Capacity of generator Units(MVA)	250*4
Capacity of SFC(MVA)	20
Power bridge	6-6 pulses,(3+1) in serials
Input voltage of SFC(kV)	15.75
Rate current(DC, A)	2551
Frequency(Hz)	LS:50Hz;MS:0~52.5Hz



Recorded Curves of Staring Process

NR SFC's smooth and accurate frequency reference follow-up and elevated performance makes it more secure and impregnable for pumped storage power plants. Elevated performance through PCS-9575 SFC makes the XiangShuiJian power plant an important and secured power source during valley loads.

Shaoxing Jiangbin Gas Turbine Power Plant

- Project Name: SFC for JiangBin Gas Turbine
- Project Capacity: 7.0 MVA/6.3 kV

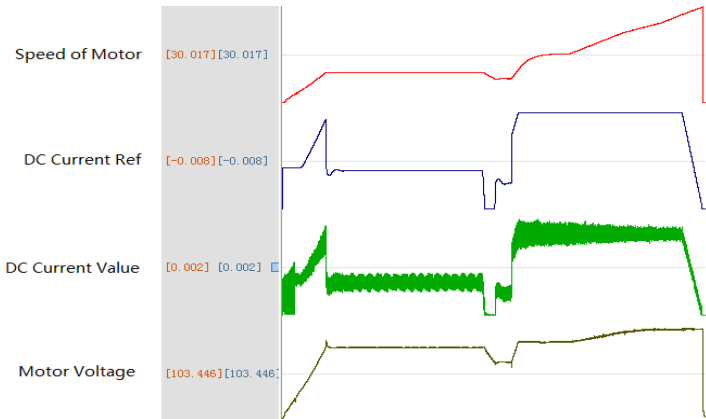
Shaoxing Jiangbin Gas Turbine Power Plant, locating in Zhejiang province of China has two Mitsubishi M701F4 generator units (Rated Power: 450MVA). In order to expand the capacity of original #1 SFC (made by ABB), NR supplied its state-of-art PCS-9575 SFC. The PCS-9575 SFC's superior performance and successful start-ups of units, makes the whole power plant highly flexible and competent for peak load performance.



Shaoxing Jiangbin Gas Turbine Power Plant

Main parameters of the Jiangbin SFC project

Capacity of generator Units(MVA)	450*2
Capacity of SFC(MVA)	7.0
Power bridge	12-6 pulses
Input voltage of SFC(kV)	6.3
Rate current(DC, A)	2569
Frequency(Hz)	LS:50Hz;MS:0~50Hz



Recorded Curves of Staring Process

NR SFC's excellent DC current follow-up and speed regulation performance makes it more secure and impregnable for Gas Turbine power plants. Elevated performance through PCS-9575 SFC makes the Shaoxing Jiangbin power plant an important and secured power source during peak loads.



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