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Magnetically Controlled Shunt Reactor System - MCSR

A dynamic reactive compensator in magnetic saturation core method for improved voltage stabilization and increased transmission capacity

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Version R2.00

Contents

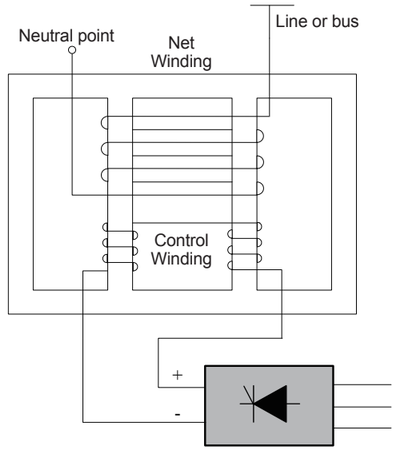
Advantages

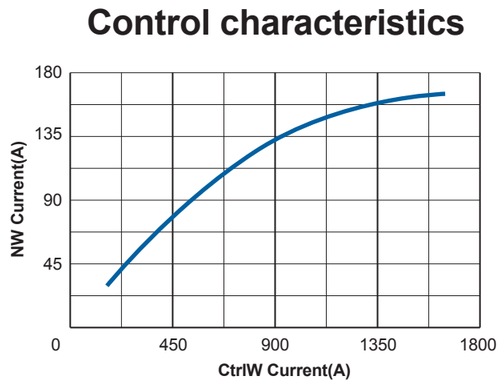
- Supply a quick response reactive power compensator with good static, dynamic and transient stability to adapt different grid voltages and various network scale.
- Continuously regulate reactive power from 5% to 100% of rated capacity, together with a shunt capacitor bank to implement capacitive reactive power output.
- Furnish one-button start/stop design, comprehensive monitoring of the reactor & control system and the automatic operating control.
- Employ the compound control model with multiple electrical variables, to ensure fast capacity regulation under high forced excitation voltage and to guarantee excitation current & reactive power in safe range.
- Produce less harmonic at network side by installation of 5th and 7th filters at medium voltage.
- Regulate the output capacity of the high-voltage reactor through changing the excitation current in the low-voltage control winding using the easy-achievable and high-reliable rectifying facility.
- Improve observability, controllability and maintainability of the excitation system with intelligent excitation control architecture design.
- Configure the intelligent measurement and control unit for the rectifier in order to realize the intellgent exiting of rectifier cabinet (to support on-line maintenance), the intelligent current equalization (to support component-level dynamic current equalization) and intelligent protection.

Functions

It is a conventional way to install fixed shunt reactors into high-voltage long-distance transmission lines for limiting Faraday effects at light loads. However such way will the limit power transfer capacity, since transmission line voltage may be over low at heavy loads.

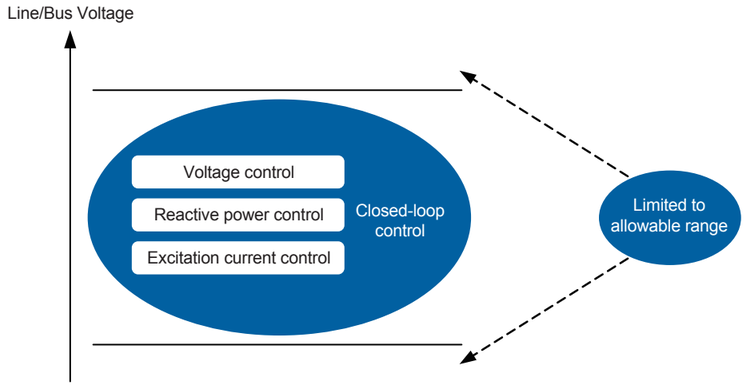
The magnetically controlled shunt reactor (MCSR) can be installed at line terminals or any substation bus and regulate its absorbed inductive reactive power through changing its equivalent impedance according to line voltage or reactive power fluctuation. It will be able to stabilize the line voltage and boost the line power transfer capacity by adjusting the contradiction between overvoltage suppression and reactive power compensation. When installed on the line, it can work together with a small reactor at the neutral point of primary side to suppress secondary arc current and raise the successful rate of auto reclosing.





The MCSR can realize continuous capacity regulation through changing iron core’ s saturation extent, i.e. equivalent magnetic conductivity, by controlling the value of DC current flowing in the control winding. The control system samples the reactor’ s electrical variables and control commands to regulate the excitation voltage & current output by the rectifier in real time according to the change of electrical variables so as to realize the closed-loop regulation with the line voltage or reactive power as its control target. Finally, the voltage level of the line can be maintained and the stability of the power system can be improved.

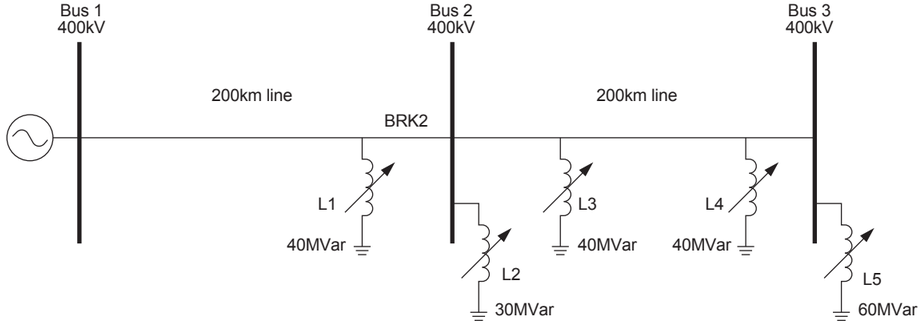
Protection & control Panels rated at 120Mvar



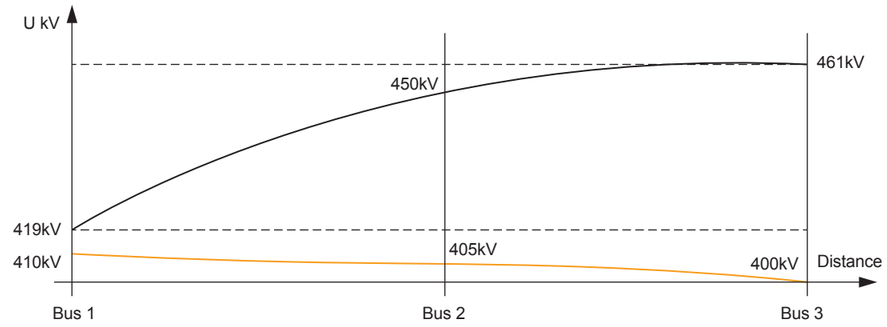
MCSR system is developed as a new generation control system based on the rich experience of NR' s generator excitation system. The system is designed to be reliable, advanced, stable, easy to use and can meet the application requirements on various capacity and voltage. In addition, it can not only implement the protection & control functions, but also realize the on-line real-time measurement & control for the whole system, provide a friendly human-machine interface, support application requirements for digital substations, meet the requirement on IEEE and related standards.

Applications

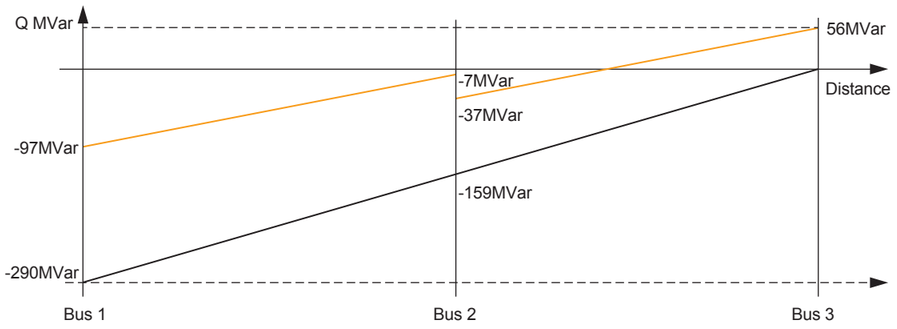
Having improved grid power transmission capacity and reliability, high voltage network also brings some other issues such as transmission line's capacitive charging power getting more, exchanged power among regions becoming loaded. These issues make it more difficult to regulate and control the power system voltage. Specially for outgoing lines in the wind farm, solar power station and hydraulic power station, the above issues are more prominent, because the frequency and amplitude of network voltage have a bigger change caused by fluctuation of the wind farm' s wind force and solar power station' s light density, with transmission line' s Faraday effect getting worse caused by hydraulic power plant' s less power output during dry season. These transmission issues can be effectively resolved by MCSR as a dynamic reactive power compensator.



Typical example of power transmission with/without MCSR



Voltage distribution along transmission line with/without MCSR, where voltage curve in black is without MCSR, and voltage curve in red is with MCSR.

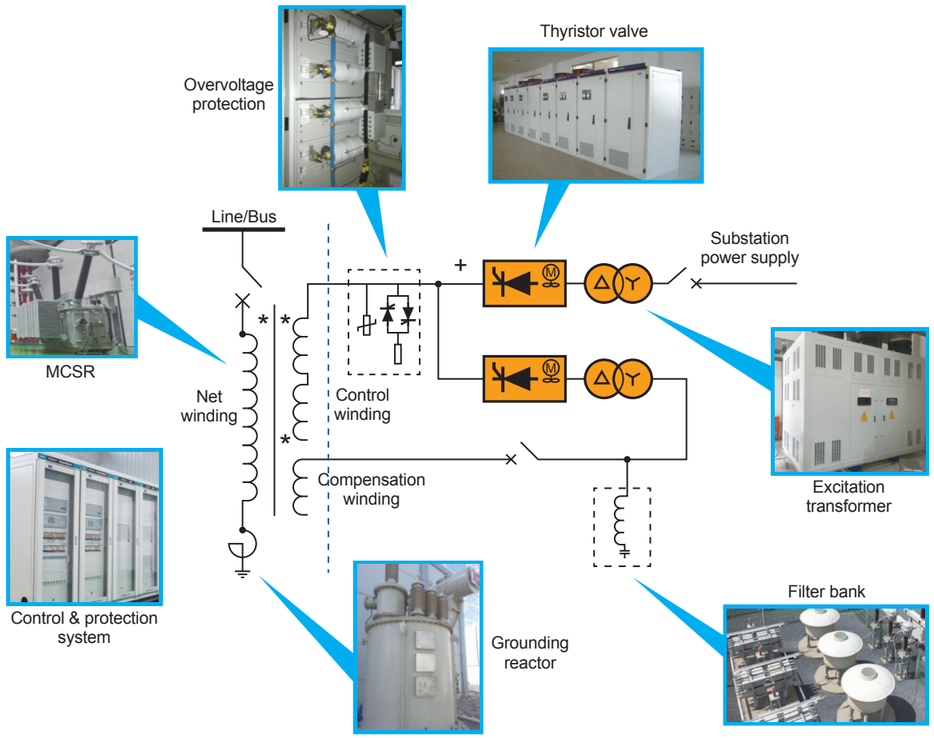


Reactive power distribution along transmission line with/without MCSR, where Q curve in black is without MCSR, and Q curve in red is with MCSR.

MCSR system is suitable for the conventional high-voltage long-distance transmission lines, the transmission lines accessing large-scale wind farm or solar power or other power source and the outgoing lines of hydraulic power plant. The power system voltage range can be from 35kV to 1000kV.

Main Components

MCSR system comprises two parts: one part is a primary power equipment including MCSR body, power rectifier, excitation transformer, overvoltage protection device, filter bank, and auxiliary equipment; the other part is a secondary control devices such as monitoring system, regulation devices, protection devices, coordination control units and so on. These above equipment can be flexibly selected & customized based on site and customer requirements.



Architecture diagram of MCSR system

MCSR Reactor

MCSR body equipment includes network windings, control windings, and compensation windings. The network windings are connected in parallel to the grid. The control windings are connected to the excitation system in order to realize the reactor impedance regulation by changing excitation current. The compensation windings supply AC power to the excitation system and also can be connected to the filter bank.

Power Rectifier

The power rectifier uses three-phase fully-controlled thyristor bridge, receiving firing pluses from excitation regulation device, output dc excitation voltage and current by rectifying the output of ac excitation power source in phase control mode. Because the rectifier can install switchgears or circuit breakers at its ac and dc side with firing pulses turn on and off easily, the rectifier can switch in and out during the system operation period and support online maintenance.

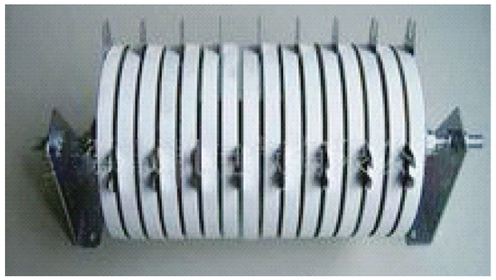
The power rectifier usually adopts the design of one rectifier bridge arranged in one cabinet, and has various rated current level such as 1200A, 1800A, 2400A and 3000A, etc. The current level of single rectifier cabinet can be decided by the MCSR' s excitation capacity requirement and several rectifier cabinets can be configured to run in parallel.

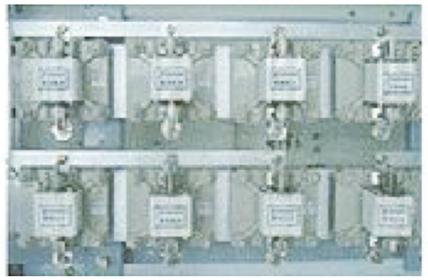
The rectifier cabinet uses air-forced cooling with a parallel air duct. The large-capacity aluminium heat sink or the heat pipe self-cooling heat sink can be used. The fan is installed on the top of the rectifier cabinet and can be replaced online.

Rectifier Cabinet Picture

DC Overvoltage Protection Device

Protecting low voltage equipment of excitation system against overvoltage damage, varistors and linear resistors can be equipped to absorb overvoltage energy and suppress the dc overvoltage at fault.

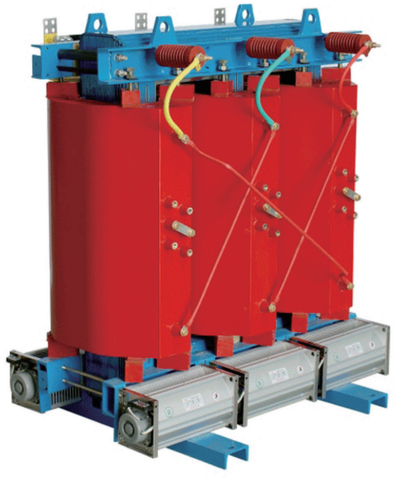




Varistor

Excitation Transformer

The excitation transformer supplies ac power for the excitation system and has self-excitation or external-excitation connection methods. In the self-excitation connection method, the transformer connects to the reactor's compensation windings. In the external-excitation connection method, the transformer connects to the substation power source. Three-phase or single-phase transformer can be used in either epoxy-cast dry type or oil-immersed one.



Excitation transformer

Filter Banks

The 5th and 7th filter banks can be installed at compensation winding side to reduce the influence of harmonics upon the system as generated by the reactor body in operation.

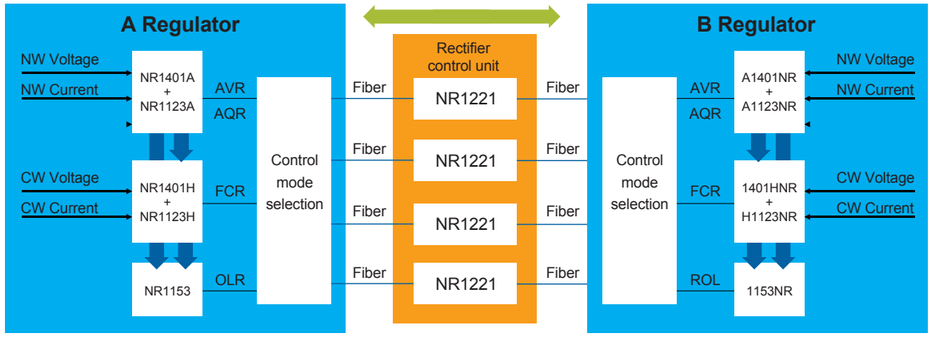
Control System

MCSR control system includes the MCSR control units in master and slave operation modes, the power rectifier with rectifier intelligent measurement and the control unit. The control and communication information of each excitation device is transmitted via double redundant optical fibre link.

MCSR control units employ parallel calculation with CPU and multiple DSP, to shorten adjustment period into 0.25 milliseconds to get more fined regulation model.

With a control regulation function being embedded in the rectifier bridge intelligent measurement and control device, the device can work as a backup auxiliary controller, which will take over the control right during the fault period of double MCSR control units as to maintain the reactor normal operating & protect the reactor from losing the control and isolating the system.

Fully-intelligent control architecture of MCSR control system is shown below.



Fully-intelligent control architecture of MCSR control system

Having an intelligent architecture, MCSR control system can implement the redundant configuration of three regulating channels to increase the switching redundancy of control regulating channel in order to guarantee the reactor's safe operation in maximum possibility.

MCSR Control Unit

With the control unit having a redundant structure of two or multiple channels, each regulating device can work as an independent regulating channel in order to undertake all excitation adjustment tasks. Excitation regulating channels adopt master and slave operation mode.

With complete over-excitation limitation, PT fault judgment and other functions, the operating reliability of the reactor and excitation system can be improved.

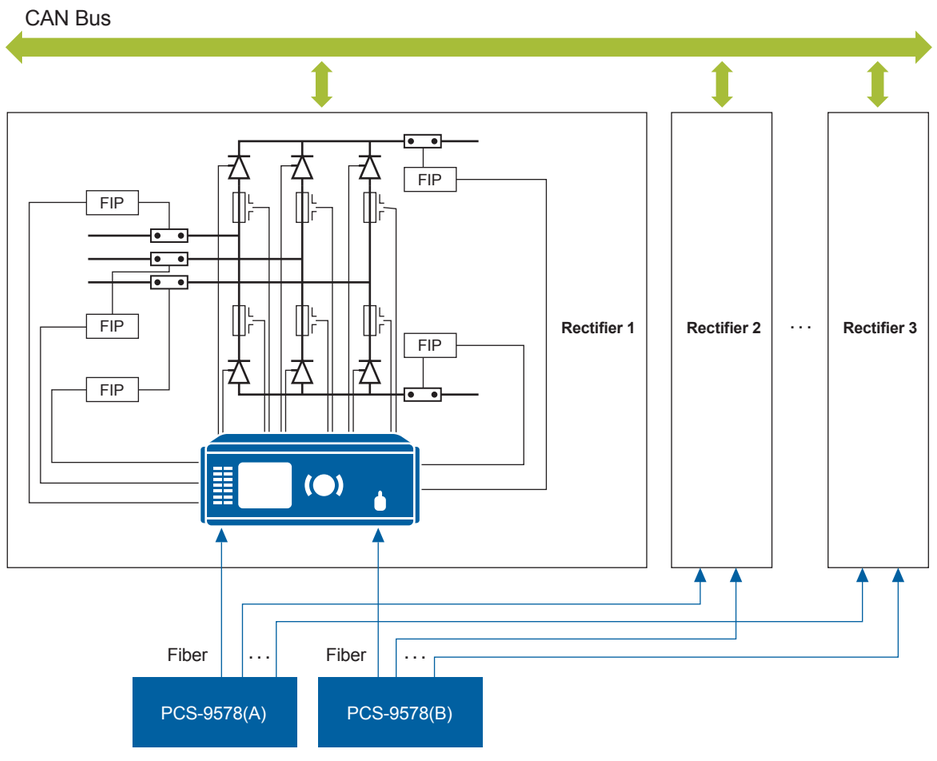
It is to configure background monitoring system and upload the recorded data in real time.

Excitation regulator panel

Rectifier Intelligent Measurement & Control Device (optional)

Each thyristor rectifier can optionally configure one PCS-9425 rectifier intelligent measurement and control device which can implement the following functions.

- Distributed trigger pulses with the pulses between the rectifiers being independent of each other.
- Intelligent choice of master and slave.
- Double synchronization redundant configuration.
- Component-level dynamic intelligent current equalization
- Faulty forced excitation to exit the panels intelligently
- Intelligent control of cooling system
- Status monitoring and alarm



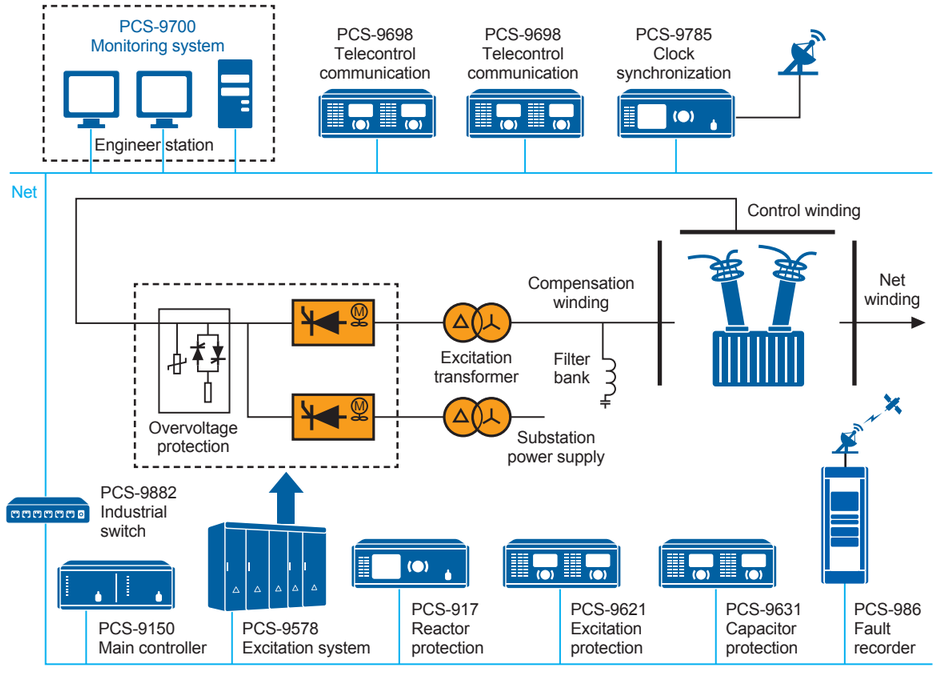
Schematic diagram of devices layout

Technical Features

Integrated Solution

Twenty-years of technical research & product development, manufacturing & engineering service experiences in the protection & control fields of the network and the substation, accumulated the established techniques and products to meet the special requirements on MCSR, NR electric is capable of supplying the protection & control integrated solution to the MCSR system based on unified software and hardware platform as well as unified communication port and system architecture.

NR electric has all the professional technique capacity required by the MCSR protection & control system, including monitoring system and smart substation technique, excitation technique, reactor body protection technique, excitation system protection technique and fault recording etc.



MCSR integrated solution diagram

NR integrated solution has the following advance features.

- Each subsystem such as monitoring system, excitation system, and protection system, is based on UAPC platform with NR’ s independent intellectual property rights, whose hardware board is universal and is large-scale produced with spare parts used each other. It is convenient to implement full lifecycle of operation and maintenance, with each product being similar in operating and maintaining.
- Having the unified platform & model and protocol to fully integrate the information of various equipment with high real-time interaction, it can realize MCSR’ s integrated monitoring, on-line detecting and diagnosis analysing functions so as to reduce the cost in design, operation & maintenance and to improve the whole automation level.

Fully Intelligent Control Architecture of Excitation System

- Implement real-time remote control function using optical fibre and hardware decoding technique.
- Provide built-in backup control function to realize three-channel configuration so as to improve excitation regulation switching redundancy.
- Adopt distributed information measurement and control mode to improve observability and controllability.
- Improve the intelligent level of equipment with the pre-warning function prior to failure.

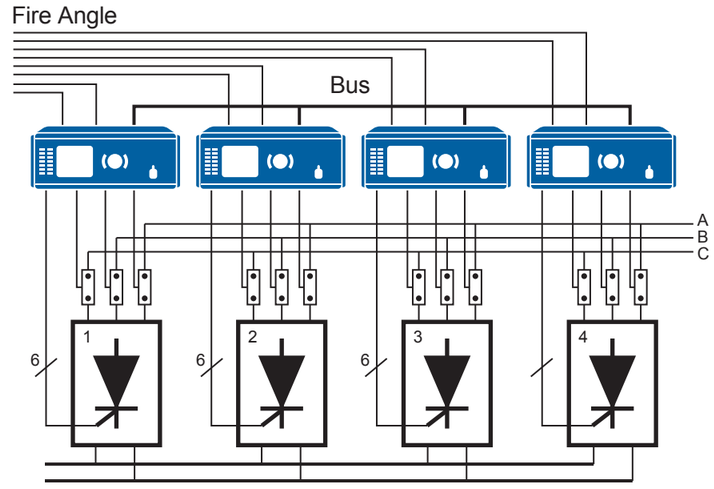
Optical-Fibre Control Distributed Intelligent Triggering Technique

- Triggering pulses with optical fibre coding transmission to improve anti-interference and transmission distance.
- Optical fibre data adding control information to realize intelligent master-slave decision function.
- Distributed phase-shift triggering pulse to improve the rectifier bridge independence from one another.
- Independent intelligent device to implement panel exiting, current equalization and protection.

Intelligent large-power panel picture with single panel output of 3000A

Component-Level Dynamic Intelligent Current Equalization Technique

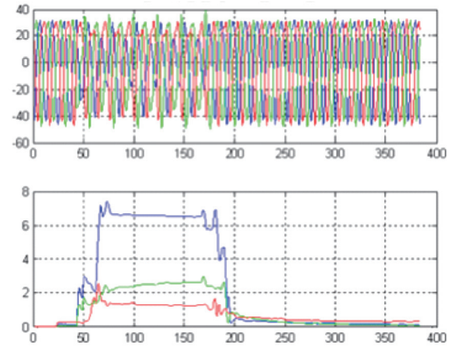
- Current measurement and equalization calculation based on components to implement the rectifier bridge’ s component-level current equalization function.
- Fieldbus technique for intelligent choice of the number of components and troubleshooting components.
- Component-level current-equalization control technique which is the most direct method and is helpful to extend the service life of thyristor.



Complete MCSR Reactor Protection Scheme

As compared with conventional shunt reactor, MCSR has its particular structure to show different fault features at many kinds of faults with many traditional protections not applicable to MCSR.

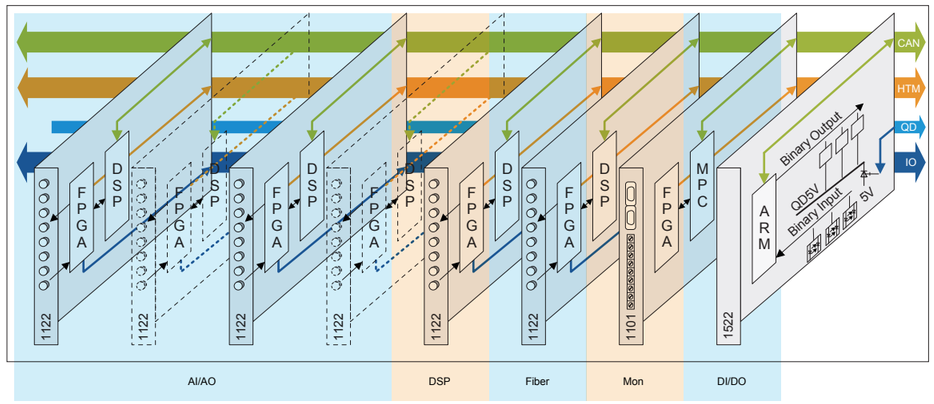
- MCSR turn-to-turn protection based on zero-sequence voltage dynamic compensation and power-frequency variation zero-sequence direction so as to solve the sensitivity issue in various operating conditions.
- MCSR AC winding turn-to-turn differential protection based on time domain translation method to realize the turn -to-turn symmetric differential protection.
- MCSR control winding differential protection based on voltage differential.



Control winding voltage difference and amplitude

Unified Hardware & Software Control Technology Based on UAPC Platform

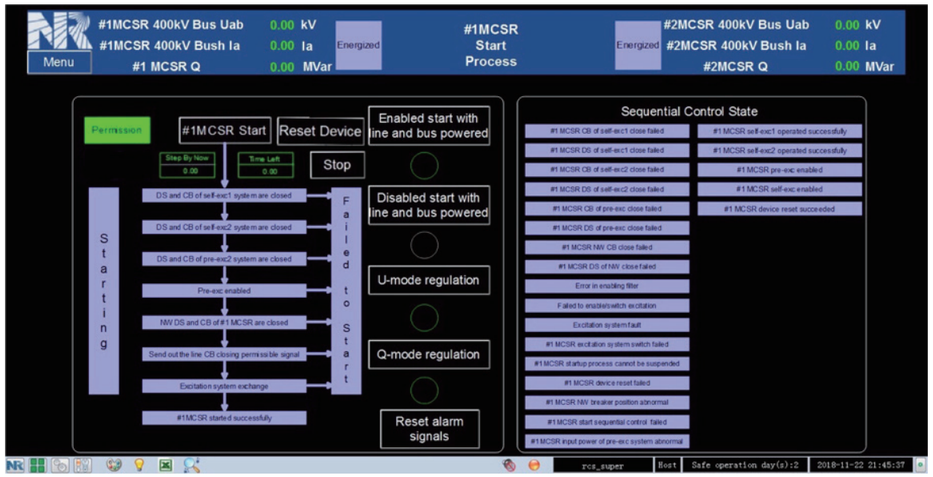
- The unified platform to implement multi DSPs parallel running via HTM bus.
- The regulating speed at 4000 times per second to obtain more accurate model and better adjustment quality.
- The sampling speed at 72 points per period to get fast identifying of the reactor's work condition variation.
- The enhancement of excitation voltage response ratio to strengthen the reactor' s transient and dynamic stability.
- The standardized intelligent plug-ins, production and debugging automation.



One-Button Start/Stop Design

The implementation of one-button start/stop control of the MCSR can get the following benefits:

- Reducing the operation and maintenance cost
- Improving the overall automation level
- Lessening the working intensity of the operators
- Standardizing the procedure of the MCSR start and stop operation
- Mitigating the occurrence of misoperation accidents



Case Study

LAÚCA–HUAMBO Electrical Transmission Project in Angola

There are five sets of MCSRs being installed in two extended substations at 400kV.

Three sets of MCSR with each rated at 40Mvar are three-phase oil-immersed ONAN type, with two of which installed in WACO KUNGO substation and one of which installed in BELÉM DO DANGO Substation.

- Rated voltage: 420/12kV
- Maximum voltage: 420/17.5kV
- Rated capacity in continuous output: 2-40MVA
- Cooling mode: ONAN

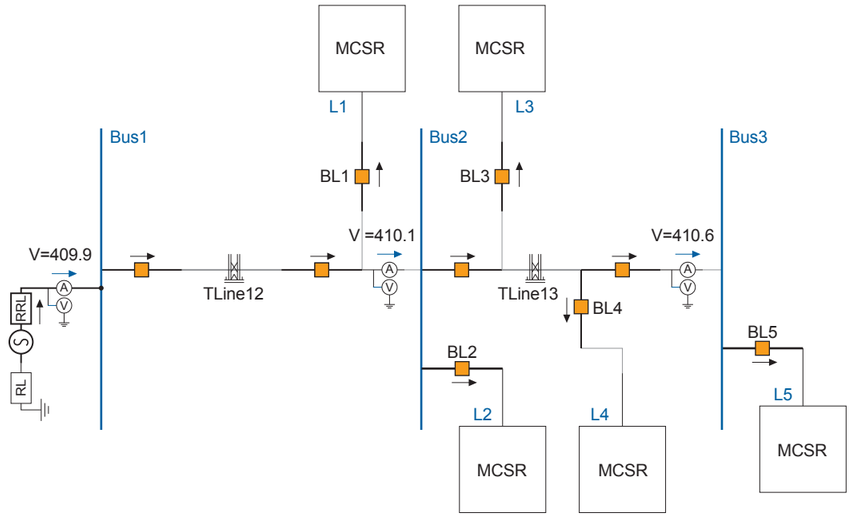
One set of three-phase oil-immersed ONAN type of 60Mvar MCSR is installed in BELÉM DO DANGO Substation.

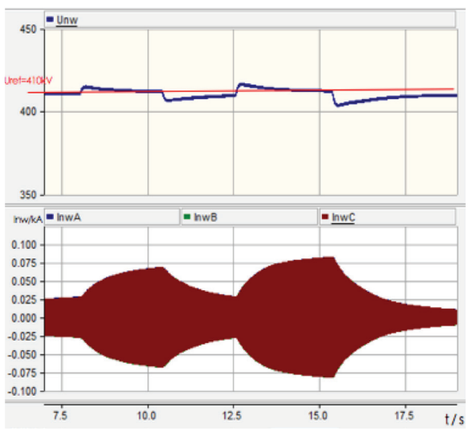
- Rated voltage: 420/12kV
- Maximum voltage: 420/17.5kV
- Rated capacity in continuous output: 3-60MVA
- Cooling mode: ONAN

One set of three-phase oil-immersed ONAN type of 30Mvar MCSR is installed in WACO KUNGO Substation.

- Rated voltage: 420/12kV
- Maximum voltage: 420/17.5kV
- Rated capacity in continuous output: 1.5-30MVA
- Cooling mode: ONAN

NR Solution





Effect after MCSR installation, while Unw is the measured voltage at network side of L1, and Uref as reference setting is 410kV as well as Inw is the measured current at network sideof L1.

- Full-independent double-redundant excitation control system
- Redundant configuration of the excitation power transformer and the power rectifying panel's excitation power circuit so that whichever becomes abnormal to exit cannot affect the reactors operation because of there being on-line maintenance.
- Three-layered dc overvoltage protection design with low-voltage large-capacity zinc-oxide resistor, overvoltage protector and thyristor-bypass circuit so as to ensure low-voltage excitation equipment' s safety.
- Coordination control device configured in each substation to distribute the required capacity output of multiple MCSRs installed at the same substation and to coordinate the work between them according to the grid work condition.

500kV Substation project in Inner Mongolia

There is one set of 120Mvar MCSR in 500kV substation of Wulate Middle Banner of UHV power supply bureau with the following parameters.

- Rated voltage: 500kV
- Maximum voltage: 550kV
- Rated capacity in continuous output: 6-120MVA
- Cooling mode: ONAN

NR Solution

- DCS sequence control device to complete one-button type start/stop control
- Rated current output of strong-forced excitation single power rectifying cabinet to be 3000A under forced air cooling and be 1500A under natural air cooling.
- A full-capacity external excitation power rectifying circuit in high reliability with the same excitation output capacity as compensation winding's excitation system.

Engineering Debugging