PRS-7860 Static Var Generator Technical User Manual

Ver 1.00

CYG SUNRI CO., LTD.

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V 1.00

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CYG SUNRI CO., LTD.

Please read this chapter carefully before using the product!

This chapter describes safety precautions for using the product. All contents of this chapter must be read and fully understood during installation and use.

CYG SUNRI CO., LTD. shall not be liable for any damage caused by improper operation due to ignoring the warning instructions in the manual.

Before performing any operation on this device, relevant professionals must carefully read this manual and be familiar with the operation-related contents.

Operation Guidelines and Warnings

The following indication marks and standard definitions will be used in this manual:

DANGER!

Means that if safety precautions are ignored, it may result in death, serious personal injury, or severe equipment damage.

WARNING!

Means that if safety precautions are ignored, it may result in death, serious personal injury, or severe equipment damage

CAUTION!

Means that if safety precautions are ignored, it may result in minor personal injury or equipment damage.

This clause is particularly applicable to damage to the device and possible damage to the protected equipment.

WARNING!

To enhance or modify existing functions, the hardware and software of the device may be upgraded. Please confirm that this version of the user manual is compatible with the product you have.

WARNING!

When electrical equipment is in operation, some components of these devices may carry high voltage. Incorrect operation may cause serious personal injury or equipment damage.

Only qualified professional staff are allowed to work on or near the device. Staff must be familiar with the precautions, work procedures, and safety regulations mentioned in this manual.

In particular, some general working rules for high-voltage live equipment must be followed. Failure to comply may result in serious personal injury or death or equipment damage.

⚠WARNING!

- Exposed Terminals

Do not touch exposed terminals, etc., when the device is live, as dangerous high voltages may be present.

- Residual Voltage

After the device power is turned off, dangerous voltages may still exist in the DC circuit. These voltages will disappear after a few seconds.

⚠CAUTION!

- Grounding

The grounding terminal of the device must be reliably grounded.

- Operating Environment

The device is only allowed to operate in the atmospheric environment specified in the technical parameters, and the operating environment must be free from abnormal vibrations.

- Rated Values

When connecting to the DC power circuit, ensure that they comply with the rated parameters of the device.

- Printed Circuit Boards

Do not insert or remove printed circuit boards when the device is live, as this may cause unexpected failures of the device.

- External Circuits

When connecting the contacts output by the device to external circuits, carefully check the external power supply voltage used to prevent overheating of the connected circuits.

This instruction manual is compiled and published by CYG SUNRI CO., LTD. Therefore, we reserve the right to the final interpretation of related products.

We are sincerely sorry for that related products subsequently upgraded may be slightly different from those in the manual and the commissioning manual may be upgraded without prior notice.Please pay attention to the discrepancy between actual products and corresponding description in this commissioning manual.

For more information about the products, please visit the website: http://www.sznari.com

Free customer service hotline: 400-678-8099

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Chapter 1 Overview

1.1. Background Description

With the development of China's economy, the contradiction between economic growth and the lag in distribution network construction has become increasingly acute, resulting in a large gap between China's distribution network power quality technical indicators and those of developed countries. The existing problems are as follows: The rapid growth of non-linear and impact loads such as electrified railways and steel smelting has greatly increased voltage distortion in the distribution network, reducing the power quality of the distribution network, leading to increased network losses, and easily causing adverse effects on a large number of sensitive equipment in production and operation; The large-scale construction of distributed new energy power stations such as wind power and photovoltaic power generation is prone to causing significant disturbances in the distribution network system at their access points; The distribution network system at the end of the large AC power grid is relatively weak, requiring a large amount of dynamic reactive power to support its voltage stability.

To address the above problems, it is necessary to enhance the voltage control capability of the distribution network and increase its dynamic reactive power reserve, so the role of dynamic reactive power compensation equipment becomes obvious. The development of power electronics and other technologies and the large-scale application of related load equipment have continuously improved the performance requirements for reactive power compensation equipment in the distribution network, such as requiring faster response time, a wider voltage compensation range, and harmonic suppression.

Compared with traditional reactive power compensation devices (SVC), Static Var Generators (SVG) have technical advantages such as a wide compensation range, fast response time, diversified compensation functions, and small floor space. They have broad application prospects and can generate significant social and economic benefits, making them a research hotspot in the field of reactive power compensation.

1.2. Application Scope

SVG is mainly used in transmission systems, distribution networks, new energy power generation, and other fields. In long-distance AC transmission, due to the Ferranti effect, the voltage on the no-load line will increase significantly; at the same time, from the perspective of system stability, the transmitted energy will also be limited. Therefore, to reduce voltage rise and maximize the transmission energy of the line, it is often necessary to consider installing SVG at the midpoint or several intermediate points of the transmission line.

Relatively weak distribution networks have greater reactive power demand. Previously installed synchronous condensers are neither economical nor easy to maintain. However, after installing appropriate SVG, the requirements can be fully met with faster response and more convenient maintenance.

For weak systems at the end of large power grids, such as remote photovoltaic power stations or wind power stations, since the system cannot provide a large amount of reactive power, it is necessary to install SVG at the access point. It can not only stably maintain the voltage at the access point within the required range but also minimize the adverse impact of power grid faults on the weak system. At the same time, the access of SVG also enables the weak system to give full play to its own power supply efficiency.

SVG can also be widely used in industrial fields such as steel plants, chemical plants, electrified railways, urban subways, mines, ports, and heavy processing enterprises to improve power quality and reduce power consumption costs.

The use of AC arc furnaces for steelmaking will have a significant impact on the power grid. Due to the constantly changing ferromagnetic characteristics of the electric furnace, many harmonic currents are injected into the power grid. At the same time, due to the asymmetry in the initial stage of steelmaking, the negative sequence current also increases significantly. A large amount of reactive power demand and changes cause voltage fluctuations and flicker, and also greatly reduce the steelmaking efficiency of the arc furnace itself. Among all current industrial loads, arc furnaces may have the greatest impact on the power quality of the power grid. With the help of SVG, most harmonics can be filtered out, the negative sequence current can be reduced, voltage fluctuations can be limited to the specified range, and voltage flicker almost disappears.

Electrolysis power supplies in chemical plants or rolling mills in steel plants require a large amount of reactive power during operation due to their large capacity and the use of power electronic rectifiers. Although multi-pulse and phase-splitting technologies are adopted in power supplies, the harmonics generated during operation cannot be ignored. At the same time, obvious reactive power fluctuations occur in the initial stage of electrolysis and the biting period of rolling mills, which directly lead to fluctuations in system voltage.

Such voltage fluctuations not only affect surrounding electrical equipment but also adversely affect their own work quality. After installing SVG, the above problems can be well solved.

In recent years, electrified railways have undertaken increasingly heavy transportation tasks. Due to the actual traffic volume far exceeding the designed traffic volume, some existing lines, especially sections with large slopes, often experience slow operation, slope parking, tripping, and other phenomena during operation, seriously affecting the normal transportation of railways. Through research and a large number of tests, it is found that with the increase of load, the voltage loss in the system, traction transformers, catenary, etc., caused by reactive current increases, leading to a serious reduction in the terminal voltage of the traction network, which cannot meet the minimum voltage required for the normal operation of locomotives. The reactive power of electric locomotives changes rapidly during operation, and the voltage fluctuates greatly, which seriously affects the power quality of the public power grid and threatens its own safety. Large voltage fluctuations will affect the line capacity, insufficient reactive power compensation will increase additional losses, and low power factor will lead to fines. These factors cause huge direct and indirect losses to the railway system. Therefore, it is imperative to put SVG devices into operation to improve the power factor of substations and enhance their power supply capacity.

In addition, in occasions such as mining and ore hoisting, seaport cranes, industrial grinders, large wood processing plants, and places with numerous welding machines, the application of SVG will greatly improve work efficiency.

The SVG system of CYG SUNRI CO., LTD. adopts an H-bridge cascaded chain topology, which is the main development direction of current SVG technology and can be widely used in the above scenarios.

1.3. Product Introduction

1.3.1. Product Features

The SVG complete system developed and produced by CYG SUNRI CO., LTD. adopts internationally advanced technologies in the design and manufacturing of primary equipment and the development of secondary control and protection systems, ensuring the overall compensation effect of the SVG system is ideal and the equipment quality is reliable.

The SVG complete system includes the following main equipment:

- Connection Reactor/Connection Transformer
- Power Unit Module
- Equipment Incoming Line System
- SVG Control and Protection System

The starting device of the SVG complete system is applied in 6kV direct-connected/boost-type and 10kV direct-connected/boost-type scenarios, and the 35kV direct-connected type is in the form of a starting cabinet.

The PRS-7860 Static Var Generator not only has all the advantages of traditional SVG but also has its unique advantages:

- Using multi-level modular technology, it effectively avoids the strict requirement for consistency of voltage stress on devices due to direct series connection, greatly saving costs and construction period;
- The output multi-level voltage waveform can eliminate the filter branch, while effectively reducing the total harmonic distortion rate of the grid-connection point voltage and reducing the injection of harmonic current into the power grid;
- It is beneficial to solve the inter-phase balance problem of the system and better provide voltage support when the system is disturbed;

- The turn-off devices have few on-off times in each cycle, and low-loss absorption circuits are adopted to minimize losses;
- All chain links have the same structure, enabling modular design, facilitating capacity expansion and maintenance of the device;
- It uses ordinary transformers or reactors to connect to the system, without the need for multi-pulse transformers, reducing the floor space and lowering the device cost;
- It has redundant operation capability.

1.3.2. Connection Reactor/Connection Transformer

For application scenarios with different voltage levels, SVG can be connected to the system side through a connection reactor or a connection transformer. The output of SVG is directly connected to the 6kV, 10kV, or 35kV system side through a connection reactor, which can realize energy buffering and reduce output current ripple.

The output of SVG can also step down 35kV, 110kV, or higher voltage levels to 6kV, 10kV, or 35kV systems through a connection transformer, which not only reduces the rated operating voltage of SVG but also uses the leakage inductance of the transformer as a connection reactor to realize energy buffering and reduce output current ripple.

1.3.3. Power Unit Module

The power unit module is the basic component of the SVG system, consisting of high-power power electronic device IGBT and its drive circuit, support capacitor, control board, and related auxiliary devices. The IGBT drive circuit adopts an advanced optical triggering method, with low loss and high reliability.

The power unit module of the PRS-7860 Static Var Generator comprehensively considers issues such as electrical connection and insulation, heat dissipation layout, space size, and electromagnetic compatibility, and adopts a modular combined design. It has a compact structure, light weight, and strong versatility, greatly facilitating production, installation, and maintenance. In case of failure, only spare parts need to be replaced to continue operation, simplifying fault handling and gaining valuable time for resuming production. The power unit modules are assembled and installed in the factory. On-site, only the installation and connection busbars need to be fastened, the cables connecting them to the reactor or transformer, and the optical fiber connections to the control and protection equipment need to be connected, which greatly reduces the on-site installation and testing workload.

The main circuit of the entire SVG system adopts a chain series structure. Each phase consists of several power unit modules and adopts a redundant design to meet the "N-1" operation requirement. The star connection structure is shown in Figure 1-1.

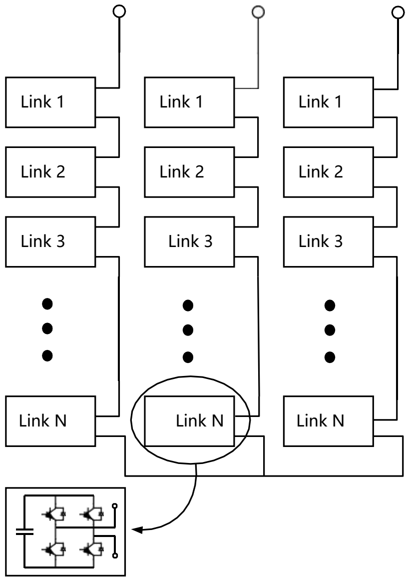

Figure 1-1 Star-connected SVG Power Valve Group Connection Diagram

- **The power unit adopts a closed compact structure, with strong versatility, complete protection, small size, and high power density.**

The power unit adopts a compact structural design, which can realize large-capacity power output, has strong versatility and complete protection functions, and can greatly improve the stability and reliability of the series H-bridge SVG system composed of it.

Power unit modules are usually installed in cabinets or containers according to user needs. Considering the limited floor space and size, a vertical structure is adopted, with radiators and support capacitors arranged up and down, making full use of space, reducing volume, and correspondingly increasing power density. At the same time, assembly is carried out in strict accordance with the process flow to ensure product quality.

The overall structure of the power unit adopts an explosion-proof design, and the internal primary circuit and secondary circuit are separated. On the one hand, it is conducive to electromagnetic shielding and reducing interference; on the other hand, it can effectively isolate failed devices when power devices fail, ensuring that other devices and secondary circuits are not affected, and the unit can normally bypass faults. Figure 1-2 shows the physical diagram of the 6kV/10kV power unit.

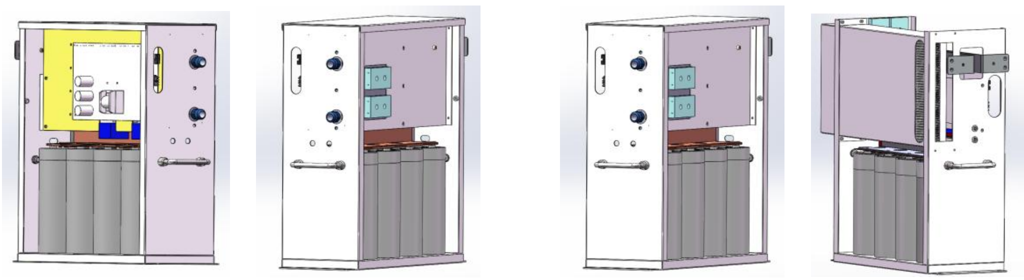

Figure 1-2 Physical Diagram of 6kV/10kV Power Unit (the left two are water-cooled modules, and the right two are air-cooled modules)

- **The electrical structure of the air-cooled power unit is determined by thermal simulation, and forced air cooling is adopted to ensure operational reliability.**

The loss is calculated according to the specifications and parameters of power devices in the power unit and operating electrical parameters. At the same time, the heat dissipation scheme is determined according to the temperature rise requirements of key points. After thermal simulation, the ventilation direction in the cabinet is determined to complete the layout of main power devices. Considering the direction of the primary circuit inside the cabinet, there is no spatial interference between internal devices, and the electrical structure design is finally completed in accordance with the requirements of air gaps and creepage distances.

- **The electrical structure of the water-cooled power unit is determined by thermal simulation, and forced water cooling is adopted to ensure operational reliability.**

The loss is calculated according to the specifications and parameters of power devices in the power unit and operating electrical parameters. At the same time, the heat dissipation scheme is determined according to the temperature rise requirements of key points. The water-cooling scheme has a better heat dissipation effect, can better dissipate heat from the power unit, and can ensure the working stability of IGBT to the greatest extent. With water cooling, no air duct is needed inside the cabinet, which better saves space.

The power unit is mainly composed of a shell, radiator, IGBT module, drive board, support capacitor, power board, sub-module control board, AC busbar, DC busbar, and support plate. In terms of electrical design, the wiring method of the internal and external connections of the valve group is also considered to ensure that it can be disassembled and assembled quickly and conveniently. By selecting appropriate radiators and cooling fans, excessive temperature during operation is prevented, the service life of power devices is prolonged, and the safe and stable operation of the power valve group is ensured.

1.3.4. Starting Device

The SVG system needs to charge the DC-side capacitor first during startup. To reduce the charging current and the impact on the system, CYG SUNRI uses a starting device to reduce the impact on the system. The schematic diagram of the starting device is shown in Figure 1-3, which mainly consists of a charging current-limiting resistor R and a bypass switch KM. During startup, the DC-side capacitor of the SVG system is first charged through the current-limiting resistor R. After the capacitor voltage reaches the predetermined value, the bypass switch KM is closed, and then it can enter the unlocked grid-connection state.

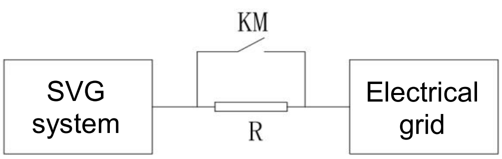

Figure 1-3 Schematic Diagram of SVG Starting Device

The static var generator control and protection system is designed with embedded CPU, ARM, and large-capacity FPGA, which have the most advantages in reliability, functions, and processing capability in the industry. At the same time, it adopts industrial standard high-speed Ethernet and IEC standard optical fiber channels for data acquisition as data transmission links, and uses highly reliable, real-time, and efficient data exchange interfaces internally, making the system have fast response speed and high control accuracy, which can well meet the needs of rapid adjustment of the SVG system.

1.4. Main Functions

The PRS-7860 Static Var Generator provides effective voltage support in case of power system disturbances, with the following main functions:

- Improve the static and dynamic stability of the transmission system;
- Reduce transient overvoltage;
- Damping low-frequency and subsynchronous oscillations of the system;
- Reduce voltage and current imbalance, and suppress asymmetric loads;
- Reduce flicker caused by voltage fluctuations;
- Increase the active power transmission capacity of transmission lines;
- Filter out harmonic currents flowing into the system;
- Improve the power factor of the system incoming line;
- When SVG is applied in HVDC transmission systems, it can quickly compensate for the reactive power required by the converter station, stabilize the fluctuations of weak systems, and ensure reliable commutation.

1.5. Performance Characteristics

The technical characteristics of the PRS-7860 Static Var Generator system are as follows:

1) Modular Design

Professionally designed modular power units with compact structure, high reliability, and easy production and maintenance; The originally designed hot standby redundancy can ensure that the redundant unit switches to operation with zero impact when the operating power unit fails.

2) High-performance and High-reliability Control and Protection Device

The core controller adopts the latest floating-point controller in the industry, with high main frequency, large memory capacity, and high computing and control accuracy.

3) Leading DC-side Voltage Balance Technology

Adopting the industry-leading DC-side voltage balance technology, originally proposing inter-link balance algorithm and inter-phase balance algorithm, without adding any auxiliary hardware equipment, effectively controlling the capacitor voltage balance between links, reducing the complexity of power units and the power loss of the entire system.

4) Integrated Wave Recording Function

The system integrates a wave recording function, which can record the entire dynamic process when the SVG system fails, including the change process of relevant system electrical parameters and the action behavior of protection function modules after a large disturbance occurs. The wave recording data recording method includes both transient wave recording and steady-state wave recording. Transient wave recording can record the transient disturbance process at a maximum rate of 9.6kHz without triggering conditions. Steady-state wave recording continuously records the state process of the power system at a rate of 1Hz~1.2kHz.

5) Powerful Communication Functions

It has flexible communication methods, supporting power industry communication standard DL/T667-1999 (IEC60870-5-103) and the new generation substation communication standard IEC61850, with excellent communication performance.

1.6. Order Notification

As a standard product, the PRS-7860 Static Var Generator device provides various components listed in the standard configuration table. Components in the optional configuration are selected by users according to their needs, not included in the standard product, and need to be purchased separately.

1.6.1. Model and Specification

1) Model Naming of SVG Complete Equipment

Table 1.5-1 Model Naming of PRS-7860 Complete Equipment

PRS-7860	-	H	-	6	-	10	-	W/F	
■									PRS-7860 Static Var Generator (SVG) product series
		■							High-voltage SVG
				■					Rated capacity: indicated by numbers, unit: Mvar
						■			Rated voltage: indicated by numbers, unit: kV
								■	Water-cooled or air-cooled type

2) Standard Configuration

Table 1.5-2 Standard Configuration Table

Component Name	Configuration Quantity	Remarks
Starting Device	1 set	
Power unit	1 set	
Control device	1 set	

Connection Reactor/Connection Transformer	1 unit	1 connection reactor per phase (or) 1 connection transformer
Technical data	See packing list	User manual and necessary drawing data

Chapter 2 Technical Parameters

2.1. Electrical Parameters

2.1.1. System Parameters

Rated operating voltage	6kV, 10kV, 35kV
Rated capacity	-50Mvar～+50Mvar
Output reactive power range	Continuously variable from inductive rated reactive power to capacitive rated reactive power
Response time	≤10ms
Total harmonic distortion rate of output voltage	＜3%, GB/T14549-1993 *Quality of electric energy supply - Harmonics inpublic supply network*
Total harmonic distortion rate of output current	＜3%, GB/T14549-1993 *Quality of electric energy supply - Harmonics inpublic supply network*
Output voltage unbalance degree	＜3%, GB/T15543-2008 *Power quality - Three-phase voltage unbalance*
Efficiency	Power valve group loss ≤0.8% under rated load, complete equipment loss ≤1%
Cooling method	Forced air cooling/water cooling
Overload capacity	1.1 times overload for not less than 3 minutes, 1.2 times overload for not less than 60 seconds
Redundancy	With "N-1" redundant operation capability

2.1.2. PCP Electrical Parameters

➢ DC power supply

Adopted standard	GB/T 8367-1987 (idt IEC 60255-11:2008)
Rated voltage	110VDC, 220VDC
Input range	88~300VDC
Ripple	≤15% of rated voltage
Static power consumption	≤15W
Power consumption during operation	≤25W

➢ Switch quantity input

Adopted standard	IEC 60255-1:2009	
Rated voltage	110VDC	220VDC
Starting voltage	60.5V~77V	121V~154V
Rated current	1.1mA	2.2mA
Return voltage	50% of starting voltage	
Maximum allowable voltage	300Vdc	
Withstand voltage level	2000VAC, 2800VAC	

➢ Switch quantity output

Output contact classification	Closing	Signal
Output form	Passive contact	
Maximum operating voltage	380VAC 250VDC	380VAC 250VDC
Open contact withstand voltage	1000VRMS, 1 minute	1200VRMS, 1 minute
Continuous current-carrying capacity	5A@380VAC	8A@380VAC
	5A@250Vdc	8A@250Vdc
Impact overcurrent capacity	6A@3s 15A@0.5s 30A@0.2s	10A@3s 20A@0.5s 30A@0.2s
Operation time	<8ms (conventional situation) <1ms (parallel fast contact)	<10ms
Return time	<5ms	<10ms
Arc breaking capacity (L/R=40ms)	0.65A@48Vdc 0.3A@110Vdc 0.15A@220Vdc	0.7A@48Vdc 0.3A@110Vdc 0.2A@220Vdc

➢ Fault Wave Recording and Event Recording

Fault wave recording and fault event report	Record all sub-module sampling waveforms and status information 500ms before triggering and 500ms after triggering Can cyclically record 64 protection action reports and 64 fault wave recordings
Abnormal alarm	Can cyclically record 1024 abnormal alarms and device self-inspection reports
Switch quantity change	Can cyclically record 1024 switch quantity changes Switch quantity changes include various input changes and changes of each starting component of the management board, etc.

➢ Synchronization Performance

PCP command execution cycle	200.0±0.1us
VBC device and PCP device phase difference jitter range	±0.1us

2.1.3. SMC Electrical Parameters

Rated voltage	15VDC
DC sampling range	0-4000VDC
Power consumption	≤3W

2.1.4. Other Electrical Parameters (Air-cooled)

Cooling fan power supply voltage	380VAC, three-phase
Maximum power consumption of a single cooling fan	<2.5kW

2.2. Environmental Conditions

Temperature	-20℃~+40℃ for normal operation Storage environment temperature -20℃~+40℃

Humidity	Monthly average maximum relative humidity of the wettest month is less than 95%
Atmospheric pressure	80kPa~110kPa (for altitude of 2km and below)
Earthquake resistance	Ground horizontal acceleration: 0.3g Vertical acceleration: 0.2g
Operating environment	Outdoor/indoor
Protection class	IP54 (outdoor SVG) IP3X (indoor SVG)

2.3. Mechanical Structure

2.3.1. Primary equipment mechanical structure (indoor type)

Voltage level (kV)	Capacity coverage (Mvar)	Number of power cabinets (units)	Cabinet size (mm) (width*depth*height)
6	0.5-8 (customizable)	2	4000*1400*2400
			4700*1400*2400
10	0.5-14 (customizable)	2	4300*1400*2400
			5300*1400*2400
35	14-50 (customizable)	6	5850*2000*2660

2.3.2. Device/cabinet mechanical structure

Device color	RAL 7035
Cabinet color	Customized according to user requirements
Pollution level	Level 2
Protection class	Front panel IP40, cabinet side IP50 (chassis without heat dissipation holes), cabinet side IP30 (chassis with heat dissipation holes), rear panel IP30 (GB 4208-2008)

2.4. Communication Ports

2.4.1. EIA-485 interface

Baud rate	9600bit/s
Communication protocol	Modbus
Maximum load	32
Transmission distance	<500 meters
Wiring form	Shielded twisted pair

2.4.2. Ethernet interface

Interface form	RJ-45
	100Mbits/s
Transmission standard	10Base-T/100Base-TX
Transmission distance	<100m
Communication protocol	IEC 60870-5-103:1997

	IEC 61850
Wiring form	Category 5 shielded network cable

2.4.3. Optical fiber interface

Characteristics	Glass optical fiber	
Terminal	ST-ST	LC-ST
Optical cable type	Multimode	
Typical transmission distance	Multimode <2km	
Light wave length	820nm	850nm
Minimum transmit power	Min. -15.0dBm	Min. -17.0dBm
Receiver sensitivity	Min. -30.0dBm	
System reserve	Min. +3.0dBm	

2.5. Anti-interference Performance

- Radiated electromagnetic field interference test complies with national standard: GB/T 14598.9
- Fast transient interference test complies with national standard: GB/T 14598.10
- Electrostatic discharge test complies with national standard: GB/T 14598.14
- Pulse group interference test complies with national standard: GB/T 14598.13
- Immunity to conducted disturbances induced by radio-frequency fields test complies with national standard: GB/T 17626.6
- Power frequency magnetic field immunity test complies with national standard: GB/T 17626.8
- Pulse magnetic field immunity test complies with national standard: GB/T 17626.9
- Surge (impact) immunity test complies with national standard: GB/T 17626.5

2.6. Insulation Withstand Voltage Standard

- Insulation test complies with national standard: GB/T14598.3-93 6.0
- Impulse voltage test complies with national standard: GB/T14598.3-93 8.0

2.7. System Certification

- ISO 14001:2015 Environmental Management System
- ISO 9001:2015 Quality Management System
- ISO45001:2018 Occupational Health and Safety Management System
- GJB 9001C-2017 Military Standard Quality Management System

Chapter 3 Working Principle

3.1. Basic Principle

The PRS-7860 Static Var Generator (SVG) system is based on a voltage source converter and adopts advanced reactive power compensation technology. It no longer uses large-capacity capacitors and inductors. Instead, it connects an IGBT-based bridge circuit to the power grid through a transformer or reactor. By appropriately adjusting the phase and amplitude of the AC-side output voltage of the bridge circuit, or directly controlling its AC-side current, the circuit can absorb or emit the required reactive current, achieving the goal of dynamically adjusting and controlling the voltage or reactive power on the target side. Figure 3-1 shows the basic topology of SVG.

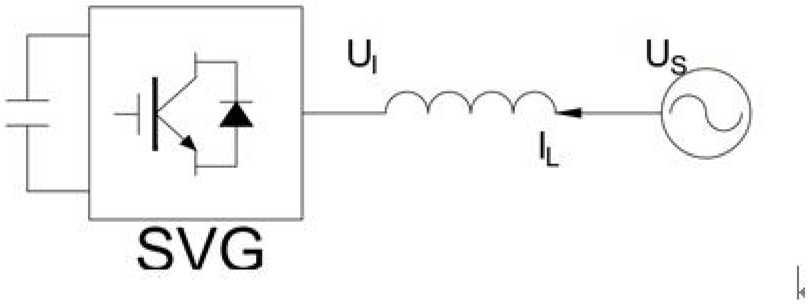

Figure 3-1 Basic Topology of SVG

The PRS-7860 Static Var Generator has three operating modes: no-load operation mode, capacitive operation mode, and inductive operation mode. If SVG is required to suppress load harmonics on the basis of compensating reactive power, it only needs to make SVG output a current opposite to the harmonic current. Therefore, SVG can simultaneously achieve the dual goals of compensating reactive power and harmonic current.

3.2. System Structure

The system structure diagram is shown in Figure 3-2.

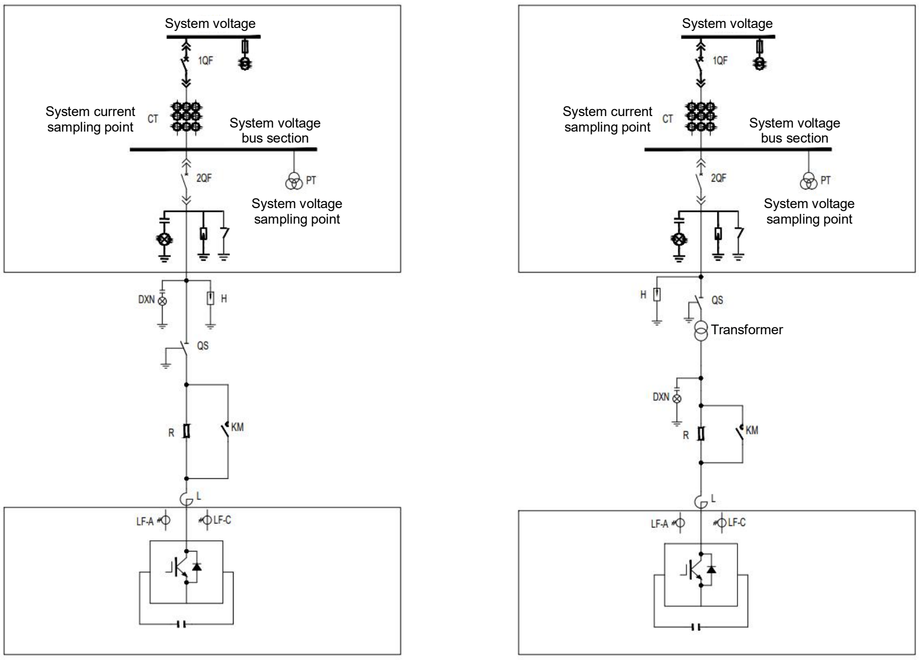

Figure 3-2 Schematic Diagram of System Structure

3.3. Control Modes

The control modes of SVG include constant reactive power control mode, constant voltage control mode, and constant power factor control mode. Local operation and remote operation are supported. For local operation, corresponding control words and control settings need to be set on the device; for remote operation, corresponding operating modes and operating parameters need to be set on the monitoring background.

3.3.1.Constant Reactive Power Control Mode

In the constant reactive power control mode, the command input to the control system is a reactive power command. The control system controls SVG to output reactive power consistent with the given reactive power command according to the reactive power command. This control mode is usually used to directly compensate the reactive power of loads in the station, so as to reduce the loss of the main transformer and improve the active power transmission capacity.

The constant reactive power control mode adopts a dual-loop control method. The current inner loop uses dq decoupling control, and the reactive power outer loop and DC voltage outer loop use PI control. The control target of the reactive power outer loop is to adjust the reactive power output by SVG according to the target value of reactive power control. The control target of the DC voltage outer loop is to ensure that the average DC voltage of the links is consistent with the given reference value by controlling the total active power exchange between SVG and the system.

3.3.2.Constant Power Factor Control Mode

In the constant power factor control mode, the command input to the control system is a power factor command. The control system adjusts the reactive power output by SVG according to the power factor of the target side controlled by the power factor, so as to improve the power factor of the system. This control mode is usually used to compensate the power factor on the low-voltage side of the main transformer.

The constant power factor control strategy is essentially the same as the constant reactive power control. The only difference lies in the calculation method of the given reactive power command. The reactive power command in the constant reactive power control mode is obtained by calculating the reactive power on the load side, while the reactive power command in the constant power factor control mode is obtained by calculating the reactive power compensation required to increase the power factor of the assessment point (such as the bus incoming line) to the command value.

3.3.3.Constant Voltage Control Mode

In the constant voltage control mode, the command input to the control system is a voltage command. The control system adjusts the reactive power output by SVG by controlling the bus voltage on the target side according to the voltage command. This control mode is usually used to compensate the voltage on the high-voltage side of the main transformer or at the substation outlet, so as to reduce the no-load loss of the line.

The constant voltage control mode adopts a dual-loop control method. The current inner loop uses dq decoupling control, and the voltage outer loop and DC voltage outer loop use PI control. The control target of the voltage outer loop is to adjust the reactive power output by SVG according to the voltage control target: output inductive reactive power when the system voltage is high, and output capacitive reactive power when the system voltage is low. The control target of the DC voltage outer loop is to ensure that the average DC voltage of the links is consistent with the given reference value by controlling the total active power exchange between SVG and the system.

3.3.4.Protection Functions

Three levels of protection are set for the static var generator system, mainly providing effective protection for power units and system faults, namely device-level protection, power unit-level protection, and system-level protection. The protection types are shown in Figure 3-3.

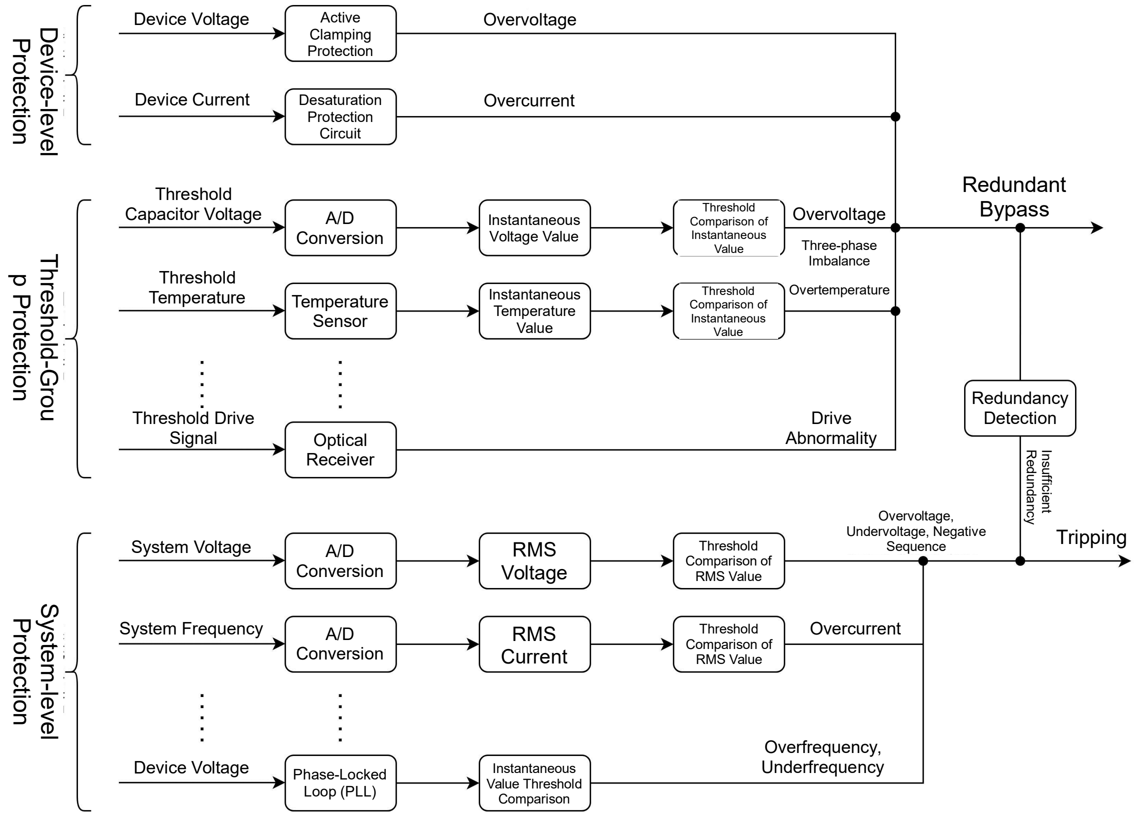

Figure 3-3 Protection Types

Device-level protection detects device-level faults inside the power unit, such as overvoltage protection and overcurrent protection of IGBT by the driver board. Valve group-level protection protects each power unit, including DC-side overvoltage protection, overtemperature protection, drive abnormality protection, and power supply fault protection. The control board inside each power unit implements power unit-level protection functions according to preset settings.

When device-level protection or power unit-level protection occurs, the faulty power unit is first bypassed. If the number of operating power units is insufficient, it enters the fault tripping state.

System-level protection mainly protects the SVG system. Such faults are generally serious. When a system-level fault occurs, SVG trips with delay protection.

1) IGBT Overvoltage and Overcurrent Protection

IGBT overvoltage and overcurrent protection are implemented by the hardware protection circuit built into the driver board. The driver board is equipped with an active clamp circuit for IGBT overvoltage protection and a desaturation circuit for IGBT short-circuit protection.

2) DC-side Overvoltage Protection of Power Units

The control board inside the power unit is equipped with a capacitor DC voltage sampling circuit and sends the sampled value upward. When the control board inside the power unit detects that the DC-side capacitor voltage exceeds the preset setting, it sends the overvoltage protection information to the power unit trigger control unit, and the core main control device sends the protection information. This protection can effectively prevent overvoltage on the DC side of each power unit caused by faults during pre-charging and operation, thus protecting the internal devices of the power unit valve group.

3) Overtemperature Protection of Power Units

The control board inside the power unit uses a PT100 temperature protection circuit. When the control board inside the power unit detects that the temperature of the power unit exceeds the preset setting, it sends the overtemperature protection information to the power unit trigger control unit, and the core main control device sends the protection information. This protection can effectively prevent damage to components caused by overheating of the power unit during operation.

4) Abnormal Drive Protection of Power Units

The control board inside the power unit is equipped with a drive logic generation and verification circuit. When the control board inside the power unit detects an abnormality in the drive signal or the driver board, it sends the drive abnormality information to the power unit trigger control unit, and the core main control device sends the protection information. This protection can effectively prevent damage to components caused by abnormal drive of the power unit during operation.

5) Power Supply Fault Protection of Power Units

The control board inside the power unit is equipped with a power supply monitoring circuit. When the control board inside the power unit detects a power supply fault, it sends the power supply fault information to the power unit valve group trigger control unit, and the core main control device sends the protection information. This protection can effectively prevent damage to components caused by power supply faults of the power unit during operation.

6) Inter-phase DC Voltage Imbalance Protection

Due to the large number of links in the SVG system, when the DC-side three-phase capacitor voltage is unbalanced, it may cause imbalance in the three-phase output of the SVG system, affecting the operational safety of SVG. Its protection logic is shown in Figure 3-4.

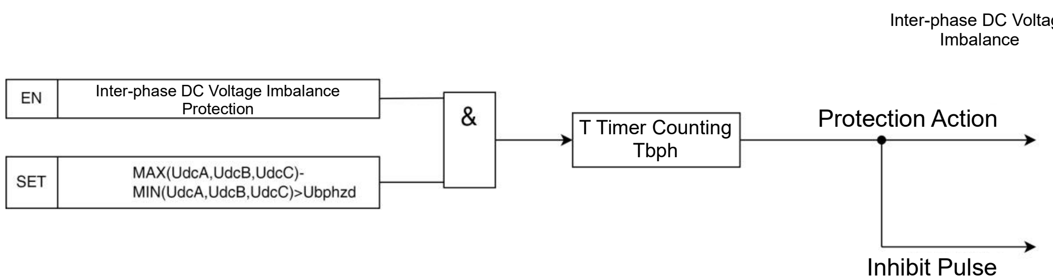

Figure 3-4 Logic Block Diagram of DC-side Three-phase Capacitor Voltage Imbalance Protection

The control and protection device allows the enable/disable of the inter-phase DC voltage imbalance protection soft pressure plate, inter-phase DC voltage protection setting, and protection delay setting. When a DC-side three-phase capacitor voltage imbalance fault occurs in the system, the SVG system protection logic acts, and the device and monitoring background display corresponding action information.

7) System Overvoltage/Undervoltage Protection

When the system voltage is too high or a serious fault occurs, to prevent overvoltage from damaging power unit components due to overvoltage, protection processing for SVG is required. This protection needs to directly trip the switch to disconnect it from the power grid. Its protection logic is shown in Figure 3-5.

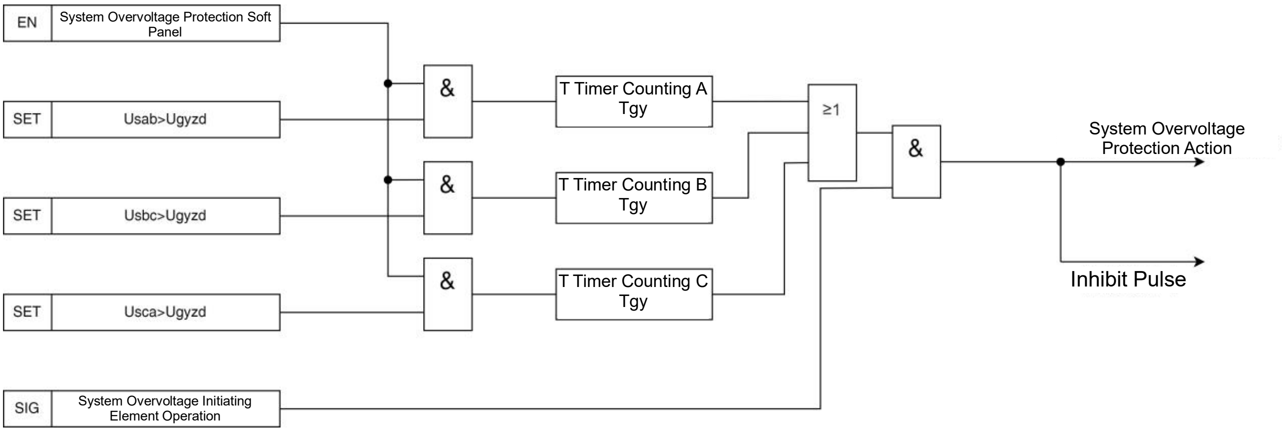

Figure 3-5 Logic Block Diagram of Overvoltage Protection

The control and protection device allows the enable/disable of the system overvoltage protection soft pressure plate, system overvoltage protection setting, and system overvoltage protection delay setting. When an overvoltage fault occurs in the system, the SVG system protection logic acts, and the device and monitoring background display corresponding action information.

When the system has an instantaneous low voltage, the SVG system can quickly output capacitive reactive power to increase the system voltage. However, when the system has a permanent low voltage fault, the capacitor voltage of the SVG power unit will not be able to maintain stability, and tripping operation is required. Its protection logic is shown in Figure 3-6.

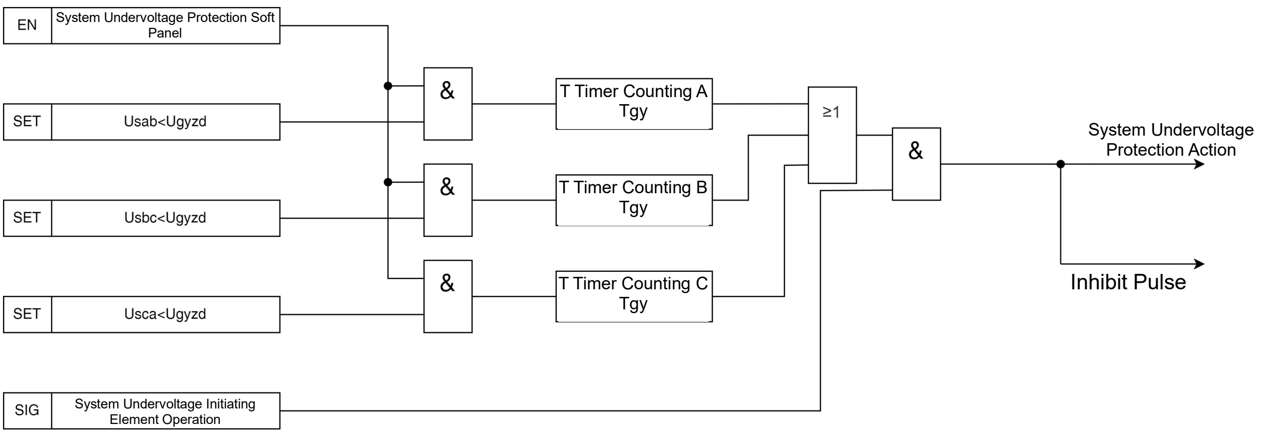

Figure 3-6 Logic Block Diagram of Undervoltage Protection

The control and protection device allows the enable/disable of the system undervoltage protection soft pressure plate, system undervoltage protection setting, and system undervoltage protection delay setting. When an undervoltage fault occurs in the system, the SVG system protection logic acts, and the device and monitoring background display corresponding action information.

8) System Overfrequency/Underfrequency Protection

The standard GB/T 15945-2008 *Power quality - Frequency deviation for power system* stipulates that under normal operating conditions of the power system, the frequency deviation limit is ±0.2Hz. When the system capacity is small, the deviation limit can be relaxed to ±0.5Hz.

When the system frequency is too high or too low, the output current of the SVG system is consistent with the system frequency, which has no impact on the safety of the SVG system within a certain range. For such cases, whether the SVG system trips or only blocks the pulse is selectable via the soft pressure plate, and the block delay time setting is available. If the grid frequency does not return to normal within this time, the SVG system trips. Its protection logic is shown in Figure 3-7.

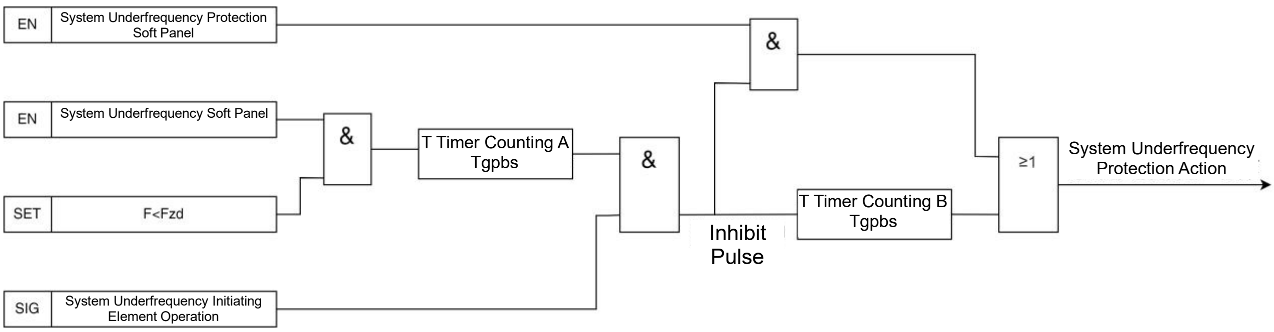

Figure 3-7 Logic Block Diagram of Underfrequency Protection

The control and protection device allows the enable/disable of the system overfrequency/underfrequency protection soft pressure plate, enable/disable of the system overfrequency/underfrequency blocking selection soft pressure plate, system overfrequency/underfrequency protection setting, system overfrequency/underfrequency blocking delay setting, and system overfrequency/underfrequency protection delay setting. When an overfrequency/underfrequency fault occurs in the system, the SVG system protection logic acts, and the device and monitoring background display corresponding action information.

9) Overcurrent Protection

The SVG system can output a maximum of 1.35 times the rated current. When the output current exceeds 1.35 times, it is easy to damage internal components of the system. At this time, protection for the SVG system is required. The SVG system has two-stage overcurrent protection, and its protection logic is shown in Figure 3-8.

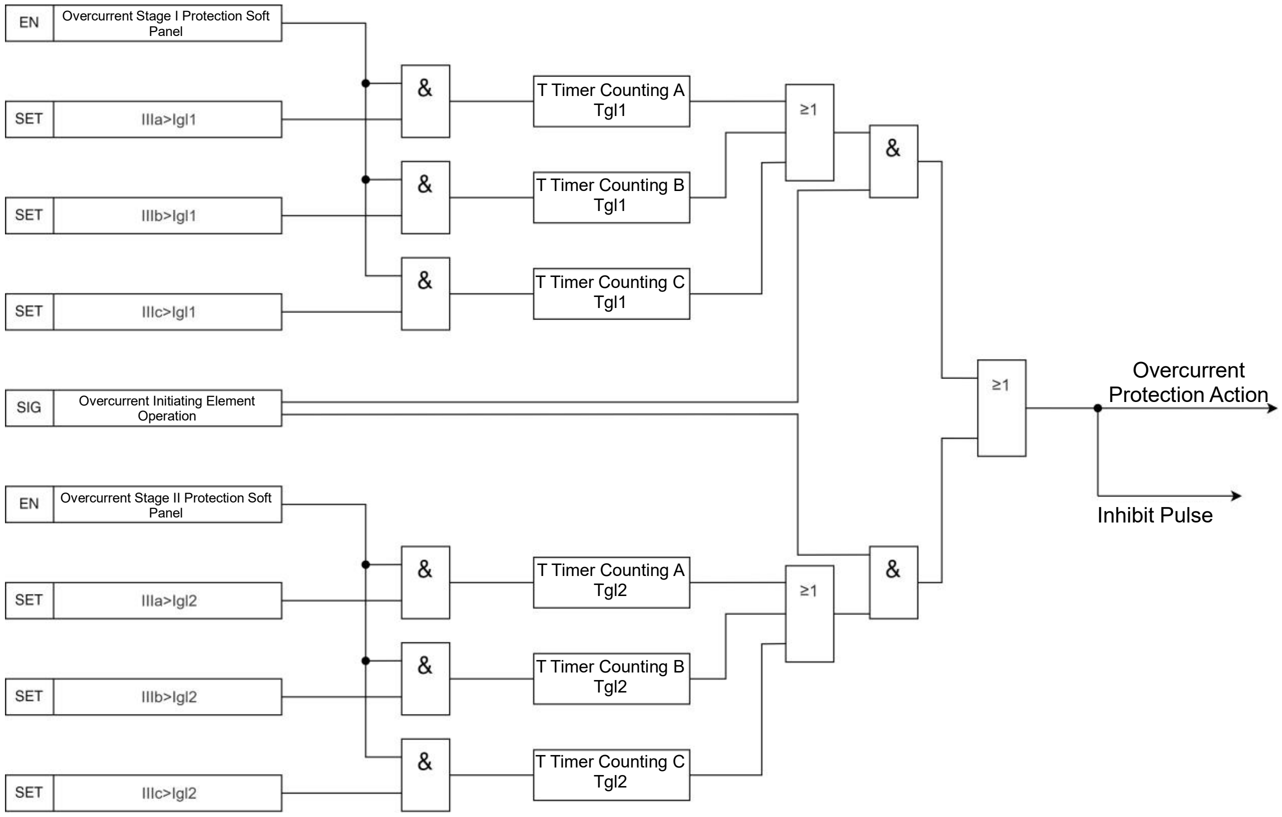

Figure 3-8 Logic Block Diagram of Overcurrent Protection

The control and protection device allows the enable/disable of overcurrent Stage I and II protection soft pressure plates, overcurrent Stage I and II protection settings, and overcurrent Stage I and II protection delay settings. When an overcurrent fault occurs in the system, the SVG system protection logic acts, and the device and monitoring background display corresponding action information.

10) System Negative Sequence Voltage Protection

When an asymmetric fault occurs in the system and the voltage imbalance degree is large, negative sequence voltage will be generated, which may cause inter-phase capacitor voltage imbalance and affect the operational safety of SVG. If an instantaneous severe asymmetric fault occurs in the system, the pulse can be blocked to wait for the grid voltage to recover before restarting. If a permanent severe asymmetric fault occurs in the system, tripping is required. Its protection logic is shown in Figure 3-9.

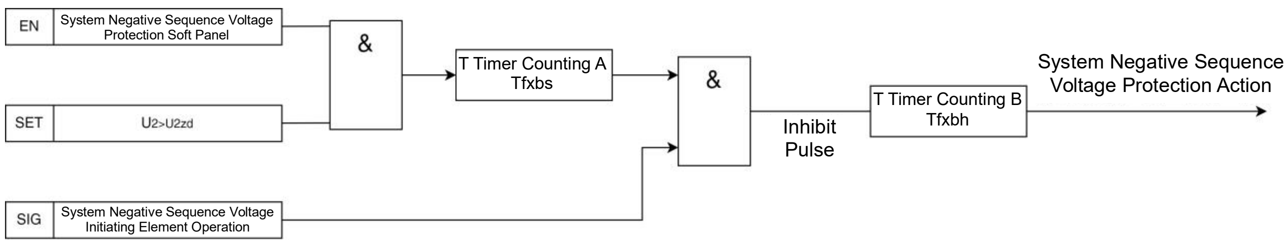

Figure 3-9 Logic Block Diagram of Negative Sequence Voltage Protection

The control and protection device allows the enable/disable of the system negative sequence voltage protection soft pressure plate, system negative sequence voltage protection setting, system negative sequence voltage blocking delay setting, and system negative sequence voltage protection delay setting. When an overvoltage fault occurs in the system, the SVG system protection logic acts, and the device and monitoring background display corresponding action information.

3.3.5.Operating States

The SVG system has four operating states: pre-charging process, operating state, fault tripping state, and normal shutdown state. The description and conversion relationship of each operating state are as follows.

1) Pre-charging Process

After the SVG control system is powered on, it immediately enters the standby state and then performs self-inspection. If there is no fault and the state is normal, after receiving the user's command to close the main circuit breaker, pre-charging is performed through the pre-charging resistor to charge the DC-side capacitor, so as to reduce the impact on the system during startup. When the DC voltage is charged to the DC set value, the control system automatically closes the pre-charging bypass switch to bypass the pre-charging resistor, and switches to the operating state after receiving the unlock command.

2) Operating State

The SVG system is in the grid-connected operating state, and can output reactive power in various control modes to achieve the effects of compensating reactive power and power factor, stabilizing voltage, or suppressing harmonics. It can also switch between constant reactive power mode, constant voltage mode, and constant power factor mode according to user needs. If a link of any phase fails during operation, the system automatically bypasses the link (this condition is for customized bypass devices), without affecting the normal operation of the system. When a serious system fault occurs or the redundant links of a certain phase are insufficient, the control system will issue a tripping command and switch to the fault tripping state.

3) Fault Tripping State

When a system-level serious fault, control device fault, or serious communication fault occurs, tripping processing is required to ensure the safety of the valve group. After the control system issues a tripping command, it disconnects the main circuit breaker and the pre-charging bypass switch, and displays corresponding fault information on the device and monitoring background.

4) Normal Shutdown State

When SVG does not need to be put into operation or needs maintenance, shutdown can be performed through background remote control or local control system. After the shutdown command is issued, the system automatically disconnects the main circuit breaker and the pre-charging bypass switch, and enters the shutdown state.

Chapter 4 Main System Equipment

4.1. Power unit

4.1.1.Overview

SVG power units with a rated voltage of 6kV/10kV are vertical air-cooled or water-cooled, and those with a rated voltage of 35kV are air-cooled or water-cooled.

4.1.2.Main Components of the Power Unit

The main components are described in detail below using the SVG power unit (6kV/10kV) shown in Figure 4-1 as an example.

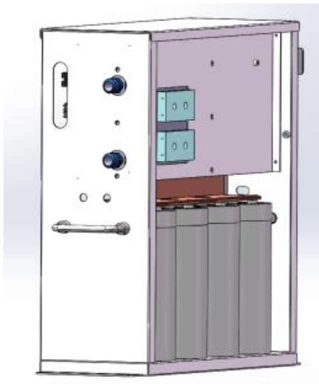

Figure 4-1 Schematic Diagram of SVG Water-cooled Power Unit

1) IGBT

IGBT (Insulated Gate Bipolar Transistor) is the core component of the SVG power unit, so its performance and service life are crucial. Each unit consists of 2 half-bridge IGBTs forming a single-phase full-bridge circuit. Considering the design requirements for voltage margin and the fact that SVG of different capacity levels have different rated currents, IGBTs with different parameter specifications are selected.

2) Driver Board

The driver board is the core device that drives the IGBT to turn on and off, and also protects the IGBT from faults. It mainly completes the following tasks:

Converts the signal sent by the control board inside the power unit to drive the IGBT to work;

Sends trigger pulses of a certain amplitude and width to the IGBT through its own drive circuit;

Monitors the working status of the IGBT, converts the status signal, and transmits it back to the control board inside the power unit;

Once the IGBT has an overvoltage or short-circuit fault, it immediately protects the IGBT through its own detection and protection circuit, and issues a blocking pulse to force the IGBT to turn off, so as to protect the IGBT.

3) Radiator

Since the IGBT in the SVG power unit is frequently turned on and off, and a certain current flows through it when it is on, there are switching losses and on-state losses. Radiators of different specifications are used according to the voltage level and capacity, and water-cooling or air-cooling equipment is added to improve heat dissipation efficiency.

4) Voltage-sharing Resistor

The voltage-sharing resistor adopts a thick-film non-inductive planar resistor, which has a planar square structure, a wide temperature range, and good pulse load capacity. This product has large power, light weight, stable and reliable high-voltage performance, and is easy to disassemble and assemble, and can be directly installed on the radiator.

5) Film Capacitor

The DC-side capacitor is a high-quality special power film capacitor, with a metal shell, full-film, and sealed integral structure, small size, and high capacitance density. The capacitor has the advantages of low equivalent series resistance and low equivalent series inductance, short-term 1.5 times overvoltage capability, long service life, maintenance-free, and excellent performance under high temperature conditions.

6) Busbar

The busbar reliably connects the DC-side capacitor and the IGBT, thereby reducing impedance and line inductance, eliminating wiring errors, improving system reliability, effectively improving thermal characteristics, and providing efficient assembly and a wide range of interconnection methods.

7) Optical Fiber and Guide Slot

The optical fiber is mainly responsible for transmitting optical signals between the valve group trigger control unit and the internal control board. The multimode glass optical fiber used in SVG has excellent characteristics, with an effective transmission distance of up to about 100 meters.

The optical fiber is arranged in the guide slot, which can not only protect the optical fiber from external damage but also ensure that the wiring is neat and orderly.

4.2. Reactor

4.2.1.Structural Features

The reactor used in the SVG system is generally a dry-type air-core reactor or a dry-type iron-core reactor, which consists of windings, metal structural parts, and post insulators as a whole. The reactor windings are wound with aluminum wires or copper wires, each aluminum wire or copper wire is wrapped with an insulating tape, and the required number of turns is wound within a certain diameter range according to the design. Outdoor products usually must be sprayed with anti-ultraviolet paint before leaving the factory, so that they can operate safely under outdoor rain conditions. At the same time, the reactor components are made of non-ferromagnetic materials, which can effectively reduce additional losses caused by electromagnetic induction.

4.2.2.Performance Characteristics

- The inductance value is relatively stable, and the external volt-ampere characteristic is linear;
- High overall mechanical strength, good dynamic and thermal stability;
- Low noise, with operating noise ≤80dB;
- Can be used both indoors and outdoors, especially in occasions requiring linear working characteristics or high dynamic and thermal stability, fire resistance, and outdoor operation, it can better exert its advantages;
- Simple operation management and maintenance-free.

4.2.3.Operating Conditions

- Installation location: both indoor and outdoor are acceptable;
- -40℃～+40℃;
- Altitude: not exceeding 2000 meters. If it exceeds, it can be specially designed according to the specific requirements put forward by the user;
- Maximum wind speed: 35m/s;
- Earthquake intensity: horizontal 0.3g, vertical 0.15g;
- The installation location should be clean, free of harmful corrosive gases and vapors, and free of conductive or explosive dust;
- When installed indoors, the installation location should have good ventilation.

4.2.4.Installation Method

Dry-type air-core reactors have three installation forms: three-phase vertical stacked installation, two stacked and one flat, and horizontal (delta or in-line) installation. Dry-type iron-core reactors have a three-phase integrated structure and are generally installed on a flat ground or in a cabinet.

1) Incoming and Outgoing Line Requirements

The angle between the incoming and outgoing line terminals of a single dry-type air-core reactor is usually 180°. For three-phase stacked installation, the angle between the three-phase incoming and outgoing line terminals is usually 45° or 60°. In addition, attention should be paid to the corresponding phase sequence for the incoming and outgoing lines of dry-type iron-core reactors.

2) Product Hoisting

During hoisting, a special lifting bar should be used to pass through the central shaft holes of the upper and lower conductive arms of the reactor, then insert the bolt into the bolt hole at the lower end of the lifting bar, and lift after the exposed length at both ends is appropriate. For reactors with a weight of more than 2000kg, the lifting holes on the conductive arms should be used for hoisting.

3) Installation Distance

When installing the reactor, the distance between the reactor and the ceiling, ground, wall, and adjacent reactors should meet the corresponding distance requirements.

4) Foundation Installation

According to the reactor foundation drawing, the foundation flat iron should be pre-embedded in the cement foundation first. After the reactor is hoisted and positioned, the foundation supporting iron at the lower end of the post insulator and the pre-embedded foundation flat iron should be welded firmly.

5) Product Stacking Installation

When dry-type air-core reactors are installed in three stacked or two stacked and one flat forms, considering the mutual inductance between the three phases, they must be installed in the order of the product nameplate. First, stabilize the foundation of one reactor, then install the other two one by one.

6) Incoming and Outgoing Line Terminal Connection

The terminals should be flat and smooth, the oxide layer should be removed, conductive paste should be applied, and after overlapping, they should be fastened with specified bolts and sealed with silica gel. Within the range affected by the reactor's magnetic field, metal objects such as protective fences, grounding wires, foundations, and steel bars in the floor must not form a closed loop to avoid circulation losses.

4.2.5.Matters Needing Attention During Installation

- Check the winding leads for any damage or breakage; if damaged, they must be welded well;
- Check the ventilation channels between the winding layers for foreign objects or blockages;
- Check and confirm whether the FRP binding belts of the upper and lower star frames of the reactor are damaged;
- Check the outer surface of the reactor for damage;
- Check whether the installation and wiring of the reactor meet the installation requirements in the product outline drawing;
- Check whether the installation fastening bolts of the reactor are tightened and whether

each support point is compressed;

- After the reactor is installed, the lifting rings should be removed.

4.2.6.Matters Needing Attention During Maintenance

- Check the outer surface and leads of the reactor for damage; if any, repair them immediately;
- Inspect the surface insulating paint of the reactor once a year; if damaged or peeled off, touch it up in time;
- Regularly test the DC resistance and power frequency reactance of the reactor every year; the measured values should be basically consistent each time;
- Check whether the contact between the reactor terminals and the busbar is good; if poor contact is found, treat the contact surface and tighten the bolts;
- Check whether the reactor installation bolts and the bolts on the rain cap and rain shield are loose; if loose, tighten them in time;
- Check whether the ventilation channels between the winding layers of the reactor are unobstructed; if foreign objects are found, remove them in time;
- Regularly clean the inner and outer surfaces of the reactor; the cleaning method can be wiping, blowing with compressed air, or flushing with a low-pressure water gun on a sunny day. Note: If the reactor surface is coated with RTV coating, the best cleaning method is to flush with a low-pressure scattered water gun on a sunny day, which will not damage the hydrophobicity of the RTV surface.
- When the reactor needs to be stored for a long time, it should be placed in a dry and ventilated room or shed to prevent the windings from getting damp. Do not cover the reactor with plastic cloth for a long time.

4.3. Transformer

The main function of the connection transformer is to connect the SVG system to 35kV and 110kV voltage levels, using the leakage inductance of the transformer as a connection reactor to achieve energy buffering and reduce output current ripple.

4.3.1.Operating environment

- Ambient temperature: -20℃~40℃
- Relative humidity: annual average not exceeding 90% (with condensation)
- Pollution level: Class III
- Installation location: indoor or outdoor
- Altitude: <1000m (high-altitude applications need special indication)

4.3.2.Structural Features

- Low-voltage coil: Wound with copper conductors with a purity of 99.9%, with coil ends encapsulated and integrally cast with epoxy resin.
- High-voltage coil: Wound with copper conductors with a purity of 99.9%, formed by static mixing of epoxy resin and vacuum casting. The casting resin adopts imported resin, with film degassing, static mixing, and vacuum casting to ensure the overall quality of the coil.
- Iron core: The transformer iron core is made of imported high-grade, low-loss, high-quality cold-rolled silicon steel sheets. The iron core is processed with Chock line cutting, full miter joints, non-porous binding, and plate-type clamp structure, with pull plates made of stainless steel. The surface of the stacked silicon steel sheets is smooth without burrs.
- Wheels for rolling transportation should be installed at the bottom of the transformer; after the equipment is in place, the wheels are removed, and the transformer base is fixedly installed. Lifting rings for hoisting are set on the top, and traction holes are set on the base with marked load-bearing points for jacking.
- A mounting position for the forced air cooling device is reserved, and an air outlet duct is made inside the transformer, with the duct outlet at the top of the transformer.
- The transformer body is equipped with grounding terminals with obvious grounding marks, accompanied by a terminal box and a transformer temperature controller.

4.3.3.Performance Characteristics

- Harmonic characteristics: Total harmonic distortion rate of secondary winding current ≤10%, among which the 2nd harmonic ≤4%, the 3rd and 4th harmonics ≤2%, and other harmonics ≤1%.
- Connection group: Dy11
- No-load current: ≤0.3%In
- Overload capacity: 200% (1 minute), 110% long-term operation
- Temperature rise limit (ambient temperature +40℃): Average temperature rise of windings (measured by resistance method): ≤100℃; Iron core surface: ≤100℃
- Insulation class: Class F
- Insulation medium: Dry type, epoxy resin, overall vacuum casting
- Cooling method: Natural air cooling (AN), equipped with forced air cooling device, fan voltage AC380V
- Installation conditions: Indoor or outdoor
- Noise: ≤58dB under no-load condition; under 100% load condition with fan started, noise level ≤60dB at 1 meter from the transformer body

- Impedance: 5-12%, deviation ≤±5%

4.4. Starting Device

The main function of the starting device is to charge the DC-side capacitor before the SVG system is unlocked and connected to the grid. Its main technical characteristics are as follows:

- Peak charging current ≤10A
- Loss ≤1kW
- Charging time ≤5s
- Cooling method: Natural air cooling (AN)
- Installation conditions: Indoor or outdoor
- Insulation withstand voltage level: Same as the SVG system
- The device is equipped with grounding terminals with obvious grounding marks, accompanied by a terminal box and a temperature-humidity controller.

Chapter 5 Control and Protection Device

The control and protection device of the Static Var Generator (SVG) system mainly includes a core main control device (main control box) and a valve group trigger control unit.

5.1. Main Control Box

5.1.1.Mechanical Structure and Installation

5.1.1.1. Mechanical Structure

The independently developed main control box by CYG SUNRI is a standard chassis, which has passed the strict EMC (Electromagnetic Compatibility) certification required by the GB/T 17626 series of national standards, as well as temperature shock and vibration tests, with extremely high reliability. It contains functional boards such as a power board, main control board, optical fiber board, and I/O board, realizing card-type interconnection with high uniformity, good stability, and easier maintenance. Chassis structure (unit: mm) and dimensions (unit: mm).

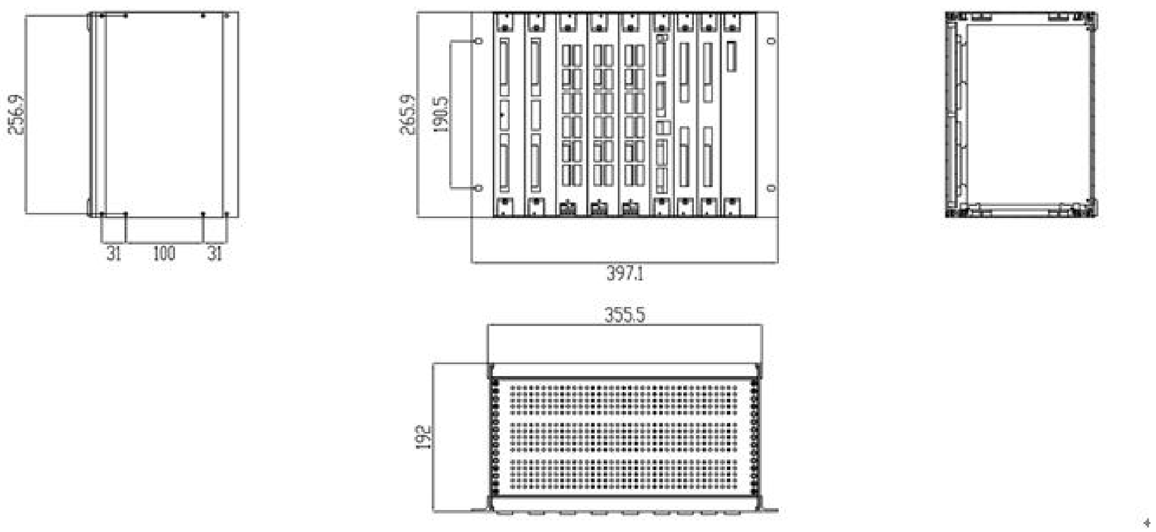

Figure 5-1 Chassis Structure Diagram and Plane Opening Diagram

5.1.1.2. Grounding Instructions

Switching operations of high-voltage devices can generate transient overvoltages in control cables. Devices or circuits at the electrical installation may induce interference currents due to electromagnetic interference. All these may interfere with the normal operation of electronic equipment.

On the other hand, operating electronic equipment can emit interference electromagnetic fields that may affect the normal operation of other electronic equipment. To minimize these effects, certain standards for grounding, wiring, and shielding must be followed.

5.1.1.3. Device Communication Grounding

When using Ethernet communication, if an RJ-45 interface is adopted, the communication line must use standard shielded Category 5 cable, and the network cable sequence must follow the standard when crimping the crystal head; if an optical fiber interface is adopted, when connecting or disconnecting the optical fiber, the connector should be plugged/unplugged, and the optical cable must not be pulled, twisted, or bent. Imperceptible damage may increase fiber attenuation, leading to communication abnormalities.

When the device communicates with communication equipment using an RS-485 interface, carefully confirm that the cable connection is intact; it is recommended to use shielded twisted pair. Communication wiring requirements: Single-end grounding of the shielding layer; for a pair of twisted-pair differential pairs, the other pair of twisted pairs is connected to the signal ground.

5.1.1.4. Device Hardware Configuration

The hardware configuration of the main control box is shown in Figure 5-2, with corresponding functional board configurations as listed in Table 5-1:

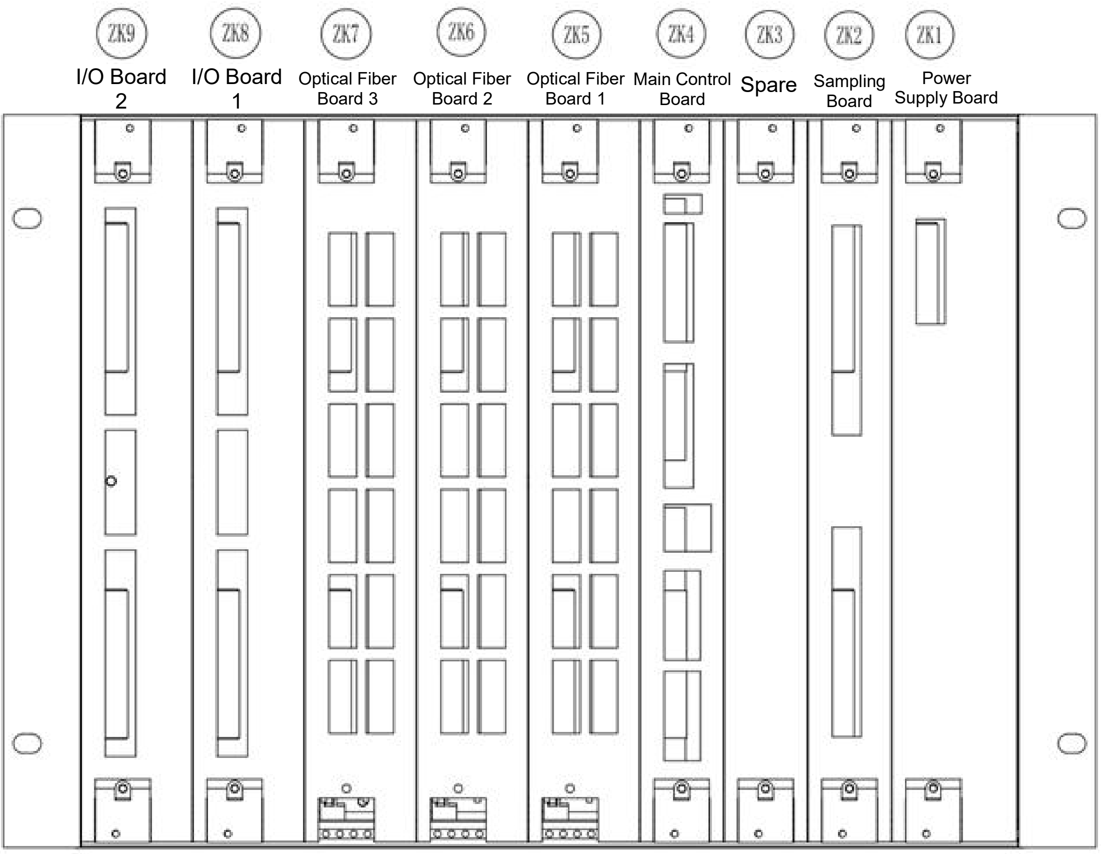

Figure 5-2 Device Hardware Configuration Diagram

The terminal definitions of the main control box are shown in Table 5-1.

Table 5-1 Terminal Definition Table of Main Control Box

Label	Functional Board Name	Function Description

ZK1	Power board	Powers the main control box
ZK2	Sampling board	Samples bus CT/PT data and power cabinet compensation current Hall data
ZK3	Sampling board (spare)	Spare
ZK4	Main control board	Issues a series of operation commands for controlled output devices, and connects the touch screen and background host computer, etc.
ZK5	Phase A optical fiber board	Collects operating parameters of Phase A power unit modules and issues action commands
ZK6	Phase B optical fiber board	Collects operating parameters of Phase B power unit modules and issues action commands
ZK7	Phase C optical fiber board	Collects operating parameters of Phase C power unit modules and issues action commands
ZK8	I/O board 1	Inputs and outputs internal signals
ZK9	I/O board 2	Inputs and outputs external signals

5.1.2.Functional Board Description

5.1.2.1. Main control board

The control board consists of a high-performance embedded processor, memory, Ethernet controller, and other peripherals. The main control board implements core control, coordinates the work of various boards, and communicates externally.

The main control board receives data from other functional boards in the device via an internal bus, and has 1 RJ-45 100M Ethernet interface, 2 RS-485/RS-232 external communication interfaces, and 2 optical fiber interfaces.

The terminal definitions of the main control board are shown in Table 5-2.

Table 5-2 Terminal Definition Table of Main Control Board

Terminal Number	Function Description
I1	Emergency stop input
I2	
O1	Spare
O2	
24V	Provides power
GND	Ground terminal
TRX11	Spare fiber optic port
TRX12	
TRX21	
TRX22	
RJ1	Ethernet port
DB1	RS-485 interface for host computer background communication
DB2	RS-485 interface for touch screen communication

For the 2 RS-485 ports, shielded twisted pair must be used. Connect pin 7 of the DB1 twisted pair to pin 8 of the touch screen's RS-485 interface, and pin 8 of the DB1 twisted pair to pin 7 of the touch screen's RS-485 interface; connect pins 2, 9 of the DB2 twisted pair and the shielding layer to the RS-485 interface of the control cabinet's external terminal block XT4 for fixation.

5.1.2.2. Sampling board

The system sampling wiring method is shown in Figures 5-5/5-6 (for reference only), and the corresponding terminal definitions are as listed in Table 5-3:

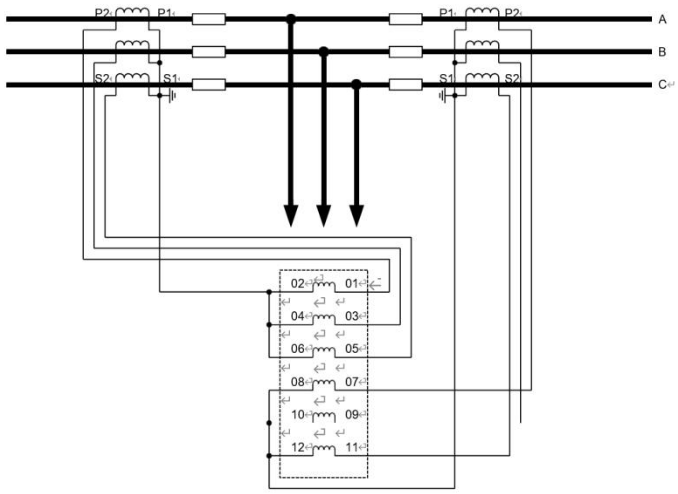

Figure 5-5 Wiring Diagram of Current Sampling Principle (for reference only)

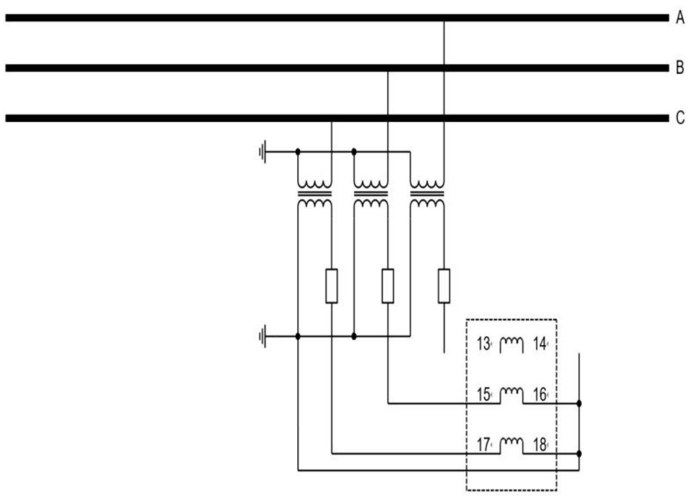

Figure 5-6 Wiring Diagram of Voltage Sampling Principle (for reference only)

The terminal definitions of the sampling board are shown in Table 5-3.

Table 5-3 Terminal Definition Table of Sampling Board

Label	Terminal Number	Description
ZK2	M1	Phase A Hall current sensor sampling signal (power cabinet output)
	V1+	Hall current sensor operating power supply
	V1-	
	M2	Phase C Hall current sensor sampling signal (power cabinet output)

	1N1+	Phase A system target input current signal
	1N1-	
	1N2+	Phase C system target input current signal
	1N2-	
	RUA+	Temperature and humidity signal acquisition port (spare)
	RUA-	
	RUC+	
	RUC-	
	RUU+	
	RUU-	
	RUW+	
	RUW-	
	USA	Auxiliary channel voltage sampling signal
	USB	
	USC	
	UOA	Phase A system voltage sampling signal
	UOB	Phase B system voltage sampling signal
	UOC	Phase C system voltage sampling signal
	EGND	Voltage sampling ground port

5.1.2.3. Optical Fiber Board

The optical fiber board realizes real-time monitoring of each unit module. ZK5, ZK6, and ZK7 correspond to unit modules of Phase A, Phase B, and Phase C respectively.

The main function of the optical fiber board is communication between the main controller and power units, including various commands issued by the main controller and reading the internal DC voltage and temperature of power units.

5.1.2.4. I/O Board

The labels of I/O boards are ZK8 and ZK9, and their terminal definitions are shown in Tables 5-4 and 5-5 respectively.

Table 5-4 Terminal Definition Table of I/O Board (ZK8)

Label	Terminal Number	Description
ZK8	DO1	Interlock tripping of high-voltage circuit breaker in system-side switchgear
	DO2	Spare
	DO3	
	DO4	
	DO5	Closing of SVG vacuum contactor grid-connection switch
	DO6	Opening of SVG vacuum contactor grid-connection switch
	DO7	Spare
	DO8	Permitted closing of high-voltage circuit breaker in system-side switchgear

Label	Terminal Number	Description
	DO9	Spare
	DO10	
	DO11	
	DO12	
	24V	External input DC24V power supply
	GND	
	DI1	Control power supply status signal input
	DI2	Cabinet door switch status signal input
	DI3	Switching On/Off
	DI4	Auto/Commissioning
	DI5	Remote/Local
	DI6	SVG device external fault input
	DI7	Normal status of pressure relief valve
	DI8	Spare
	DI9	
	DI10	Water-cooling power supply signal input
	DI11	Water-cooling/air-cooling mode switching
	DI12	Emergency stop input

Table 5-5 Terminal Definition Table of I/O Board (ZK9)

Label	Terminal Number	Description
ZK9	DO1	Spare
	DO2	
	DO3	
	DO4	SVG operating status output
	DO5	Fan control
	DO6	SVG major fault alarm output
	DO7	Spare
	DO8	Water-cooling remote start (no such output for air-cooling)
	DO9	Water-cooling remote stop (no such output for air-cooling)
	DO10	Spare
	DO11	
	DO12	
	24V	External input DC24V power supply
	GND	
	DI1	SVG isolation switch status signal input
	DI2	SVG vacuum contactor status signal input
	DI3	Water-cooling system tripping signal input
	DI4	Water-cooling system alarm signal input
	DI5	Water-cooling system operating signal input

Label	Terminal Number	Description
	DI6	Spare
	DI7	System-side bus tie switch status
	DI8	Fan status signal input
	DI9	Reactor over-temperature tripping signal input
	DI10	High-voltage incoming line status signal input
	DI11	Reactor over-temperature alarm signal input
	DI12	Emergency stop input

5.1.2.5. Power board

The label of the power board is ZK1. The terminals of the power board are power input terminals, where DC+ and DC- are for DC 220V, and AC+ and AC- are for AC 220V.

Chapter 6 Installation and Commissioning

The following content is the installation instructions for the PRS-7860 Static Var Generator. Please read this chapter carefully to help you correctly install our company's SVG products.

6.1. Transportation and Installation Requirements

The product has undergone careful inspection before leaving the factory, and complete protection measures are provided during transportation. However, damage may still occur during transportation. Before installation, users should carefully check whether the product is intact. If product damage occurs, please provide damage photos and the product factory serial number, and we will provide the fastest and best service. Basic product installation requirements are as follows:

1) The installation environment should be a dry indoor area; avoid direct sunlight and rainy/damp environments.
2) The installation environment must be free from shaking and vibration.
3) The ambient temperature should meet the requirement of -20℃~+40℃.
4) Ensure there is sufficient space (≥80cm) at the top and rear of the cabinet for heat dissipation.
5) When multiple sets of SVG are installed in the same room, ensure good indoor ventilation for heat dissipation and leave sufficient maintenance channels.
6) The installation environment should be as far away from living areas as possible, as there will be certain noise during operation.
7) After wiring is completed, the cable outlet holes of the cabinet should be sealed with fireproof mud or protective sandbags to prevent rodent damage.

6.2. Mechanical Installation

6.2.1.Safety Instructions

⚠DANGER! Ensure the DC side of the power valve group is de-energized before installation and maintenance! The DC side voltage of each power unit may be as high as 800V; direct contact with power unit modules is dangerous!

⚠CAUTION! Installation of this product must be carried out under the guidance of professional personnel!

6.2.2.Mechanical and Installation Dimensions

For daily maintenance and system heat dissipation, ensure there is at least 100cm of space directly in front of the cabinet, at least 60cm of space on top of the cabinet, and at least 80cm of space at the rear of the cabinet during installation.

⚠CAUTION! Do not place flammable and explosive materials near this product!

6.2.3.Moving and Installation Methods

The cabinet of this product can be moved into position by a forklift from the bottom, or hoisted to the installation position by an overhead crane using the 4 lifting rings on the top of the cabinet. When using the hoisting method, the angle between the hoisting steel wire rope and the horizontal direction of the cabinet top should be greater than 60 degrees.

6.3. Electrical Connection

6.3.1.Input and Output Requirements

- **System AC side input**

  Three-phase grid line voltage range: 6kV/10kV/35kV

  Grid frequency range: 48.5Hz~51.5Hz

- **Fan power input**

  AC line voltage: 380V

- **Wiring Method (AC Side Wiring)**

⚠DANGER! Ensure the incoming line circuit breaker is disconnected, and both the DC side and AC side are de-energized before wiring!

1) Disconnect the AC side incoming line circuit breaker and confirm that the AC terminals are de-energized.
2) Connect the busbars of adjacent power valve groups in Phase A of the power units in sequence.
3) Connect the busbars of adjacent power valve groups in Phase B of the power units in sequence.
4) Connect the busbars of adjacent power valve groups in Phase C of the power units in sequence.
5) Ensure the busbars are securely fastened.

6.4. System Startup

6.4.1.Confirmation Work Before Startup

The following precautions need to be confirmed before starting the SVG system to ensure they are checked before SVG power transmission:

1) Equipment cabinet doors remain closed.
2) SVG isolation switch is in the open position.
3) SVG starting cabinet circuit breaker is in the open position.
4) Check the status of SVG equipment; ensure there are no foreign objects in the control cabinet, power cabinet, and starting cabinet, and that wiring cables are not loose.
5) Check whether the control power supply in the control cabinet is normal; close all power switches in the control cabinet and start the monitoring background.

6.4.2.SVG Startup Operation Instructions

The "Remote" and "Local" knobs on the cabinet door control the device's control mode. When the knob is in the "Local" state, the device is in standalone state, requiring manual operation on the device itself; when the knob is in the "Remote" state, the device is in online state, allowing operators to operate the device from the remote control background.

"Local" state: In the local state, operators operate the device on the device itself. The operation steps are as follows:

1) Check the position status of the cabinet door knobs, which are in "Off", "Commissioning", "Local" states respectively, and the emergency stop is not pressed.
2) Set the device operation mode and operation capacity parameters on the touch screen.
3) Close the isolation switch of the starting cabinet.
4) Energize the device with high voltage and close the upper switchgear cabinet.
5) Operate on the device itself; turn the knobs on the control cabinet door to "Auto" and "On" in sequence. At this time, the device automatically starts to operate. Wait until the running indicator light is on, and the device is normally connected to the grid.

"Remote" state: In the remote state, operators operate the device from the background. The operation steps are as follows:

1) Check the position status of the cabinet door knobs, which are in "Off", "Commissioning", "Remote" states respectively, and the emergency stop is not pressed.
2) Set the device operation mode and operation capacity parameters on the touch screen.
3) Close the isolation switch in the starting cabinet.

4) Energize the device with high voltage and close the upper switchgear cabinet.

5) Operate on the background; click the "Start" button on the background. At this time, the device automatically starts to operate. Wait until the operation feedback signal is normal, and the device is normally connected to the grid.

6.5. SVG System Shutdown

Shutdown of the SVG system is divided into normal shutdown and fault shutdown.

6.5.1.Normal Shutdown

Normal shutdown of the SVG system should minimize the impact on the system when exiting. Therefore, before disconnecting all switches, the total reactive power output by the SVG should be reduced to zero as much as possible. In addition, normal shutdown should be performed in accordance with the following steps:

- In the "Local" operation mode, turn the "On/Off" knob to "Off" and the "Auto/Commissioning" knob to "Commissioning" to stop the SVG system.
- In the "Remote" operation mode, click the "Shutdown" button on the main screen of the monitoring background to stop the SVG system.

Note: When the SVG system needs to be put into operation again, it should be at least 10 minutes after the last shutdown, as the capacitors in the power units require a certain discharge time.

6.5.2.Fault Shutdown

The SVG in operation may shut down due to various protection actions. Fault shutdown proceeds as follows:

- Protection devices act.
- The controller immediately locks up, and optical pulses of power units are blocked.
- The corresponding switches trip without delay, and the bypass contactor trips with delay.

Note: After the SVG system fault is cleared, the device will perform a self-start. If it fails to operate after three self-start attempts, manual intervention is required. To put it into operation again, restart the SVG system in accordance with the aforementioned startup steps.

1. Circuit Breaker

The circuit breaker must be de-energized immediately for handling under any of the following circumstances:

- Severe damage or discharge on bushings.
- Issuance of an operation blocking signal.
- Circuit breaker fault handling after the circuit breaker trips, immediately record the fault

occurrence time and conduct an inspection to determine if there is any fault in the circuit breaker itself.

- If the circuit breaker fails to trip during opening, identify and eliminate the cause of the failure before re-energizing the system.

2. Reactor

Report to the dispatcher to apply for outage immediately if the reactor has any of the following faults, and take corresponding measures based on inspection results:

- Severe overheating of joints.
- Fracture or discharge of supporting porcelain columns.
- Severe inclination of the foundation.

3. Power Unit

Possible causes of power unit faults are mainly:

- IGBT faults (loss of conduction or turn-off capability).
- Driver board faults (no trigger feedback signal, etc.).

Therefore, after a valve group fault, contact the manufacturer or professionals for repair and replacement.

4. Protection

When the SVG control and protection device detects a fault, it issues a fault trip signal. Records should be kept, the dispatcher should be informed, and the manufacturer should be notified for handling.

⚠**CAUTION! Attention should be paid during SVG system operation:**

- **The SVG system is a high-voltage device; pay attention to personal safety during operation and maintenance.**
- **Never open cabinet doors when the SVG system is operating.**
- **Ensure the control circuit is ready before applying high voltage.**
- **After the SVG system shuts down due to a fault, check the background protection action messages, identify and eliminate the cause before re-energizing.**
- **Activate the emergency stop button in case of emergencies during operation.**
- **Do not turn off the control power supply during operation.**
- **Keep the SVG room clean.**

Chapter 7 Maintenance and Overhaul

7.1. Fault Information and Handling Measures

Common faults and handling methods are shown in Table 7-1.

Table 7-1 Fault Content and Countermeasures

Serial Number	Fault Name	Fault Cause	Handling Measures
1.	HMI Communication Fault	Poor contact of connecting wires between the main controller and HMI	Check the connection of 485 communication lines
2.	Cabinet Door Status Fault	Cabinet door is open	Check cabinet door closure and adjust the position of the travel switch
3.	Unit Overheating	1. Fan not running or reversing 2. Excessive dust on cabinet door filters causing poor ventilation 3. Poorly sealed air ducts	1. Inspect the fan 2. Clean cabinet door filters 3. Inspect air ducts and improve sealing
4.	Unit Overvoltage	1. Fault in the communication part after unit bus voltage sampling 2. Excessive on-site electromagnetic interference causing false action	1. Check internal wiring connections of SVG 2. Improve shielding measures
5.	System Overvoltage	Possible grid fault	Wait for recovery and reset
6.	Unit Overcurrent	1. False overcurrent protection of the unit 2. System voltage fault causing sudden changes	Re-energize, reset, and start up to wait for automatic recovery
7.	System Overcurrent	1. Excessive system load impact 2. System voltage fault causing sudden changes 3. Overload due to excessively high SVG operating capacity	1. Check for abnormalities in system voltage and load impact 2. Wait for SVG automatic recovery 3. Check if the wiring of SVG output current transformers is correct and if current direction definitions are correct

7.2. Inspection and Overhaul

⚠**WARNING! During daily inspection and maintenance, do not get too close to live equipment such as the SVG system and reactors.**

Daily inspection and maintenance items for SVG equipment mainly include:

1. Frequently check indoor temperature and ventilation; ensure indoor temperature does not exceed 40°C.
2. Keep the indoor environment clean and equipment surfaces clean and dry.
3. Confirm all cabinet doors are locked.
4. Frequently check for abnormal noise, vibration, or odors from the SVG.
5. Frequently inspect all power cables and control cables for damage, check if power cable terminals are loose, and if high-voltage insulating heat-shrinkable tubes are loose.
6. Frequently check if the dust filter of the power cabinet is unobstructed and if cooling fans are operating normally.
7. Check that equipment frames are not tilted, and that all bolts of equipment frames are securely connected, not loose, and washers are complete.
8. Check that equipment grounding is good and meets specifications.
9. During night patrols, check for discharge or flashover at contacts, insulators, bushings, etc.
10. Check that status indicators match the monitoring system display.
11. Regularly check for abnormalities in AC and DC power supplies.
12. Check that reactor leads are not excessively loose or have foreign objects bridging across them, and that sound and vibration are normal.

7.2.1.Regular Maintenance of SVG System

WARNING! Before regular inspection and maintenance, AC and DC power supplies must be disconnected, and wait for the automatic discharge circuit to reduce the DC bus capacitor voltage to a safe range.

To ensure long-term reliable operation of the SVG system, regular maintenance is required. The maintenance cycle depends on the operating environment of the SVG system, generally once a year. In dusty environments, the number of maintenance sessions should be increased as appropriate. Regular maintenance content of the SVG system is shown in Table 7-2.

Table 7-2 Regular Maintenance Content of SVG System

Serial Number	Inspection Part	Inspection Items	Inspection Method/Judgment Standard
1.	Surrounding Environment	Confirm ambient temperature, humidity, vibration	Visual inspection or instruments; meet technical specifications
2.		Confirm presence of dust, oil stains, or water	Visual inspection

		droplets in the environment	
3.		Check for foreign objects such as tools and dangerous goods in the surroundings	No placement
4.	Power Unit	Check if heat dissipation channels are blocked and air ducts are unobstructed	Visual inspection
5.		Check if incoming/outgoing cables are loose or have burn marks	Visual inspection
6.		Cleanliness; promptly remove dirt	Visual inspection
7.	Cabinet	Check for abnormal vibration or noise	Visual inspection; no abnormalities
8.		Check if fasteners are loose, or if there is dust or dirt	Visual inspection; no abnormalities
9.		Check for deformation or damage	Visual inspection; no abnormalities
10.	Cooling Fan	Check for nearby debris, abnormal vibration, or noise	Visual inspection; no abnormalities
11.	Heat Sink Profile	Check for damage and normal temperature	Visual inspection; no abnormalities

7.2.2.Equipment Overhaul

⚠**WARNING!**

- **Overhauling operators must be familiar with the basic principles, functional characteristics, structure, and operation methods of the equipment. Unauthorized personnel are prohibited from operating, maintaining, or overhauling the equipment!**
- **After the SVG system is shut down, residual voltage remains on the DC bus of power units. Maintenance on power units can only be performed after capacitors are fully discharged. Never touch the interior of units before confirming the correct DC bus voltage!**
- **Do not use high-voltage insulation resistance meters to measure the output insulation of the SVG system, as this may damage power electronic devices inside power units!**
- **For withstand voltage tests on high-voltage cables, power units must be disconnected from the tested devices, and tests should be conducted on the tested devices individually; otherwise, the SVG system may be damaged!**
- **When performing insulation tests on the SVG system, all power unit terminals and both ends of DC-side capacitors must be short-circuited with wires before testing. Never test individual terminals against ground, as this risks damaging power electronic devices in power units!**
- **When performing insulation tests on the starting cabinet, PT fuses must be removed!**

- **During overhaul, prevent foreign objects from falling into the equipment!**

Manual Version History

Records of manual versions and modification history:

Version	Revision Date	Drafter	Revision Content
1.00	2024-04-10	New Energy Department of R&D Center	Initial version