PRS-778

Transformer Protection

Instruction Manual

CYG SUNRI CO., LTD.

Preface

User's Guideline

This instruction manual contains full information of the equipment, including function descriptions, logic diagrams, input signals, output signals, setting parameters and technical parameters. It also lists the operations on safe handling, commissioning and maintaining of this equipment. The instruction manual can be used as a technical reference during the whole product life cycle.

Documentation and manufactured equipment purchased from CYG SUNRI CO., LTD. are dispatched separately due to the necessary manufacturing period. Therefore, they sometimes may not reach the recipients at the same time. Therefore, this manual is provided as a technical reference to commission the equipment.

The installation and commissioning personnel should read all relevant chapters carefully and get a thorough knowledge of the contents of this manual, before conducting any operation to the equipment. In this way, the personnel can get the required knowledge in handling electronic equipment.

This manual contains a security chapter which describes the safety precautions recommended when using the equipment. Before installing and using the equipment, this chapter is recommended to be thoroughly read and understood.

Personnel Security

The content in this chapter specifically describes to prevent and reduce the safety accidents in electric power production and construction procedures, to ensure the personal safety and health of employees in production activities and to ensure the power grids stable operation and reliable power supply.

Any kind of directly touching with the metal parts of the electrical equipment should be avoided when electrical equipment is on operation, because of the potential electric shock risk. Neglecting warning notices should be prevent because the improper operation may damage the device, even cause personnel injury.

The good operating condition of the equipment depends on proper shipping and handling, proper storage, installation, commissioning and maintenance. Therefore, only qualified personnel should be allowed to operate the equipment. Intended personnel are individuals who:

- Have a thorough knowledge of protection systems, protection equipment, protection functions and the configured functional logic in the IEDs;
- Have a basic knowledge in the installation, commissioning, and operation of the equipment;
- Are familiar with the working field where it is being installed;
- Are able to safely perform operations in accordance with accepted safety engineering steps;
- Are authorized to energize and de-energize equipment, and to isolate, ground, and label it;

- Are trained in the maintenance and use of safety apparatus in accordance with safety engineering regulations;
- Have been trained in first aid if any emergency situations happen.

Warning Indications

The following indicators and standard definitions are used:

DANGER! Means that death, severe personal injury and considerable equipment damage will occur if safety precautions are disregarded.

WARNING! Means that death, severe personal and considerable equipment damage could occur if safety precautions are disregarded.

CAUTION! Means that light personal injury or equipment damage may occur if safety precautions are disregarded.

NOTICE! Is particularly applies to damage to device and to resulting damage of the protected equipment.

DANGER!

NEVER allow the current transformer (CT) secondary circuit connected to this equipment to be opened while the primary system is live. Opening the CT circuit will produce a dangerously high voltage.

WARNING!

ONLY qualified personnel should work on or in the vicinity of this device. This personnel **MUST** be familiar with all safety regulations and service procedures described in this manual. During operating of electrical device, certain part of the device is under high voltage. Severe personal injury and significant device damage could result from improper behavior.

WARNING!

Do **NOT** touch the exposed terminals of this device while the power supply is on. The generated high voltage causes death, injury, and device damage.

WARNING!

Thirty seconds is **NECESSARY** for discharging the voltage. Hazardous voltage can be present in the DC circuit just after switching off the DC power supply.

CAUTION!

- **Earthing**

  Securely earthed the earthing terminal of the device.

- **Operating environment**

  ONLY use the device within the range of ambient environment and in an environment free of abnormal vibration.

- **Ratings**

  Check the input ratings **BEFORE** applying AC voltage/current and power supply to the device.

- **Printed circuit board**

  Do NOT attach or remove printed circuit board if the device is powered on.

- **External circuit**

  Check the supply voltage used when connecting the device output contacts to external circuits, in order to prevent overheating.

- **Connection cable**

  Carefully handle connection cables without applying excessive force.

NOTICE!

The firmware may be upgraded to add new features or enhance/modify existing features, please **MAKE SURE** that the version of this manual is compatible with the product in your hand.

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Documentation Outline

The manual provides a functional and technical description of this relay and a comprehensive set of instructions for the relay's use and application.

All contents provided by this manual are summarized as below:

1 Briefly Introduction

Briefly introduce the application scope, the selectable functions and product features about this equipment.

2 Technical Specifications

Introduce the technical specifications about this relay, including electrical specifications, mechanical specifications, ambient temperature and humidity range, communication interface parameters, type tests, setting ranges and accuracy limits etc.

3 Protection Functions

Provide a comprehensive and detailed protection function description of all protection modules.

4 Supervision Functions

Introduce the automatic self-supervision function of this equipment.

5 Monitoring&Control

Introduce the measurement, controlling, signaling, recording and other functions of this relay.

6 Hardware

Introduce the main module functions of this relay and describe the definition of all terminals of each module.

7Human Machine Interface

Include all the menus of device.

8 Configuration Function

Introduce the configurable function (such as protection function configuration, LED configuration, binary input configuration and binary output configuration, analog quantities channels etc.) of this relay.

9 Communication Protocol

Introduce the communication interfaces and protocol that this relay contains. IEC60970-5-103 and IEC61850 protocols are introduced in details.

10Commissioning

Introduce how to commission this relay, check the calibration and test all the function of this relay.

11 Installation

Recommend on unpacking, handling, inspection and storage of this relay. A guide to the mechanical installation and electrical wiring of this relay is also provided, including earthing recommendations. Some typical wiring connection is demonstrated in this manual as well.

12 Maintenance

A general maintenance steps for this device is outlined.

13 Decommissioning and Disposal

A general decommissioning and disposal steps for this relay is outlined.

14 Connection Diagrams

List the connection diagram examples including all types of modules.

15 Manual Version History

List the instruction manual versions and their corresponding modification history records.

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1 Briefly Introduction

1.1 Application Scope

The PRS-778 is a numerical distributed transformer protection intended for protecting and monitoring various transformers of various voltage level, ranging from 1000kV to 110kV. PRS-778 can detect and clear all types of internal faults.

PRS-778 provides fast and selective protection, monitoring and control for two and three-winding transformers, auto transformers, step-up transformers and generator-transformer block units, phase shifting transformers, special railway transformers, shunt reactors, etc. The relay can operate correctly over a wide frequency range in order to accommodate power system frequency variations during disturbances and generator start-up and shut-down.

This relay can sample the analog values from the traditional instrument transformers, or receive the sampled values from the electronic current and voltage transformers (via a merging unit). The binary inputs and outputs of this relay can be configured according to the demands of a practical engineering through the PRS IED Studio configuration tool auxiliary software, which can meet some special requirements of protection and control functions.

This relay can fully support the IEC61850 communication protocol and GOOSE function, and can completely meet the demands of a modern digitalize substation.

1.2 Product Function

Table 1.2.1 Functions included in the IEDs

Description	IEC 60617	ANSI	CYG Code
Transformer differential protection	3Id/I	87T	87T
Winding Differential Protection	3Id/I	87W	87W
Mho Impedance protection	Z<	21	21M
Quadrilateral Impedance protection,	Z<	21	21Q
Power swing detection	Zpsb	68	68PS
Four stage directional overcurrent protection	3I>	67P	67P
Three-phase thermal overload protection	-	49	49
Earth Fault protection	IN>	51G_67G	51G
Restricted Earth Fault protection	IdN/I	87NL	64REF
Non-directional Instantaneous earth fault protection	IN>>	50N	50/51N
Breaker Failure Protection	3I0> I>	50BF	50BF
Threestage residual overvoltage protection	3U0	59N	59N

Description	IEC 60617	ANSI	CYG Code
Two stagethree-phase overvoltage protection	3U>	59P	59P
Two stagethree-phaseundervoltage protection	3U<	27P	27P
Overexcitation protection	U/f	24	24
Overfrequency protection	f>	81O	81O
Underfrequency protection	f<	81U	81U
Rate-of-change frequency protection	Df/dt<>	81R	81R
Reactor differential protection	3Id/I	87R	87R
Reactor zero-sequence differential protection	IdN/I	87N	87N
Reactor interturn Protection	-	21IT	21IT
Current circuit supervision	-	CTS	CTS
Fuse failure supervision	-	-	VTS

The function diagrams for protecting a 3-windings transformer, an auto-transformer and a reactor are respectively shown below.

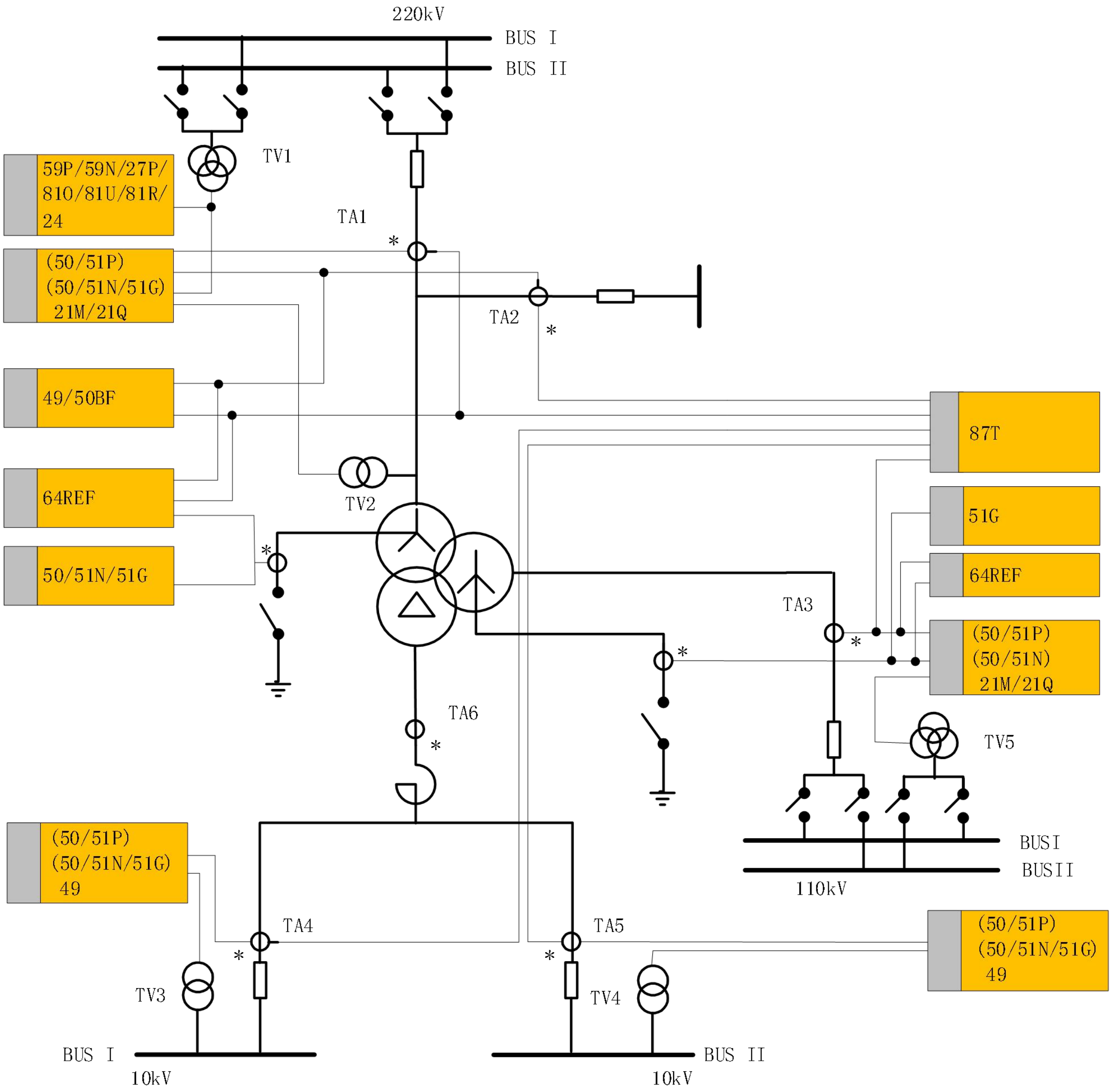


Figure 1.2.1 Typical application of a 3-windings transformer

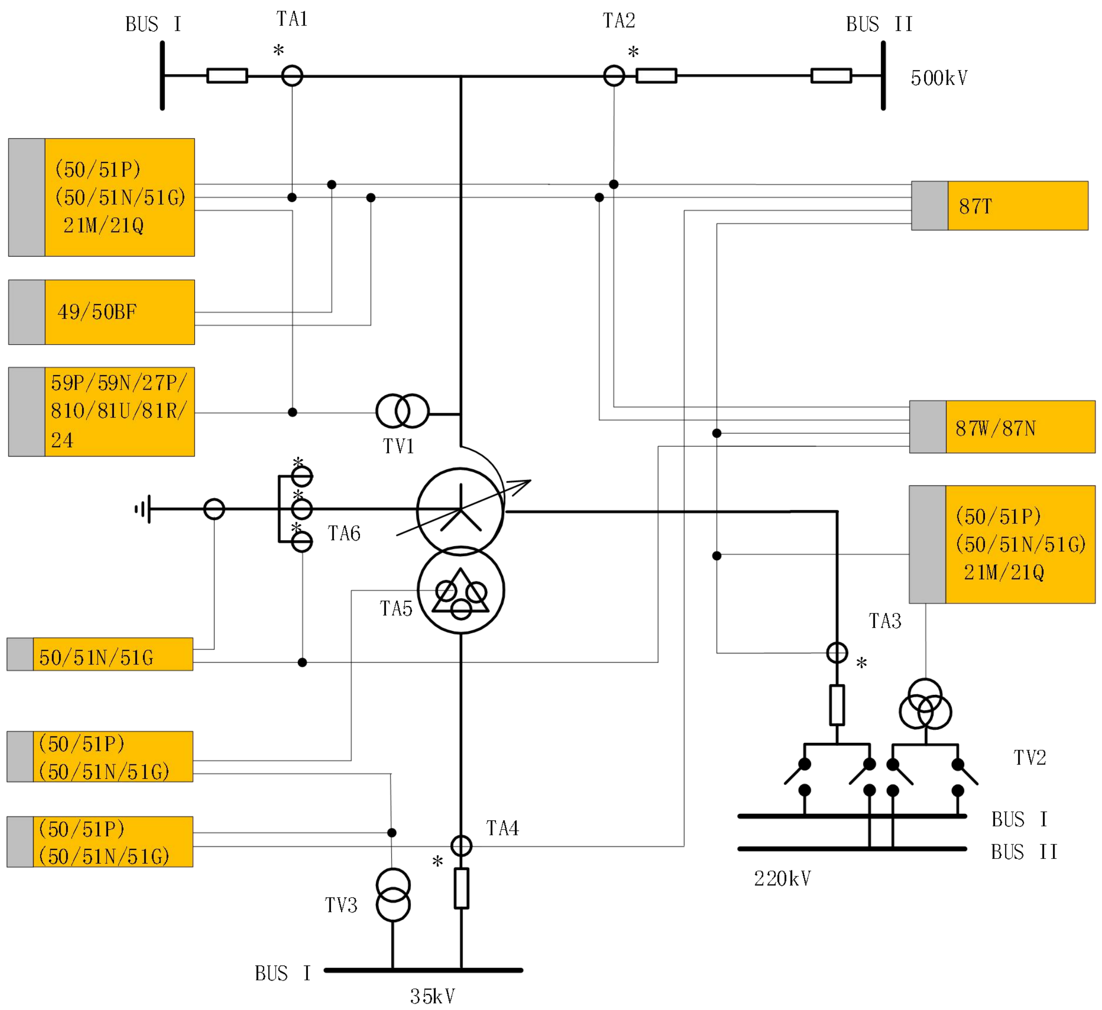


Figure 1.2.2 Typical application of an auto-transformer

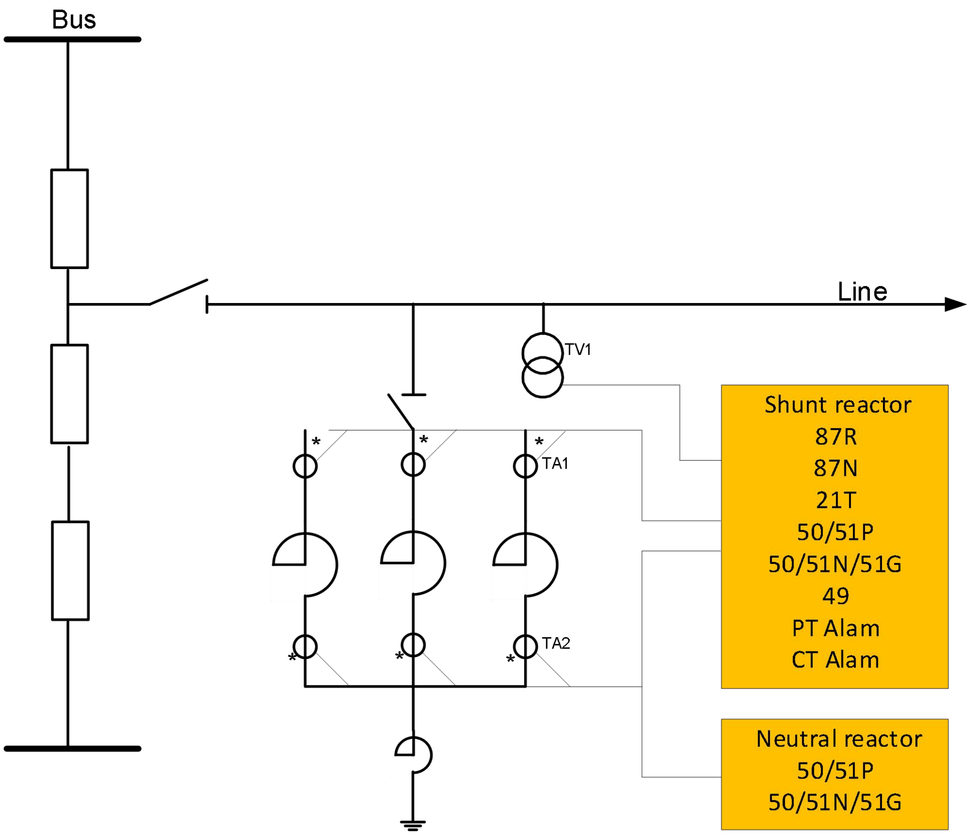


Figure 1.2.3 Typical application of a shunt reactor

1.3 Product Features

- This device is based on a 32-bit high performance dual-core processor, internal high speed bus and intelligent I/O ports, and the hardware is in modularized design and can be configured flexibly, featuring interchangeability and easy extension and maintenance.
- Modularized hardware design makes this relay to be easily upgraded or repaired by a qualified service person. Various function optional modules can satisfy various situations according to the different requirements of the users.
- The adoption of 16-bit A/D converter and the dual-channel sampling technology can ensure the accuracy and reliability of protection sampling and the correctness of protection operation. It also provides dedicated current transformers for metering, and ensures the high accuracy of telemetering with 48-point high speed sampling rate per cycle.
- This device can sample the analog values from the traditional instrument transformers, or receive the sampled values from the electronic transformers. It can support the protocol IEC60044-8, IEC61850-9-2 and GOOSE.
- Various algorithms for protection and measurement have been completed in this device for the feature of electronic transformer sampling, such as the error prevention method of multi-algorithms data anomaly for the digital channels, to realize high accuracy and reliability under various conditions of network faults or communication interruption.

- This device has powerful GOOSE functions, and the connection and cooperation between some devices can be realized without using electrical cables, to facilitate the realization of such functions as simple bus differential protection, overload interlock shedding function and backup automatic transfer function etc.
- This device has fully realized the technology to integrate six functions into one device: protection, measurement, control, remote signaling, merging unit function and remote module functions, to improve the reliability.
- Various methods of GPS time synchronization are supported in this relay, including SNTP, pulse per second (PPS) and IRIG-B synchronization.
- The protection modules are completely separated from other modules, and are independent in both hardware and software. The protection functions do not depend on the communication network, so the failure of communication network will not affect the normal operation of the protection functions.
- Mature protection configuration, fast speed and high security performance can meet the practical requirements. Each protective element is independent, so it is very convenient for whether adopting the selected protective element.
- This device constantly measures and calculates a large amount of analog quantities, such as phase voltage, phase-to-phase voltage, neutral voltage, phase current, neutral current, active power, reactive power, power factor and frequency etc.
- The human machine interface (HMI) with a small control module (a 240×128-dot LCD, a 9-key keypad and 21 LED indicators) on the front panel is very friendly and convenient to the user.
- This device can communicate with a SAS or RTU via different communication intermediates: Ethernet network, RS-485 serial ports. The communication protocol of this device is optional: IEC61850, IEC60870-5-103, DNP3.0.
- This device can detect the tripping circuit of the circuit breaker and monitor the operation (close or trip) time of a circuit breaker by checking the auxiliary contacts of the circuit breaker.
- Complete event recording function is provided: 512 latest protection operation reports, 512 latest warming records, 128 latest user operation records and 2000 latest records of time tagged sequence of event (SOE) can be recorded.
- Disturbance recording function is supported: 36 latest fault or disturbance waves, the duration of a wave recording is configurable.

2 Technical Specifications

2.1 Electrical Specifications

2.1.1 Current Transformer Ratings

Reference		IEC 60255-1,IEC 60255-27
Rated frequency (fn)		50Hz, 60Hz
Nominal range		fn ± 5Hz
Rated current (In)		1A and 5A adaptive (settable)
Thermal withstand capability	continuously	3×In
	for 10s	20×In
	for 1s	100×In
Burden		<0.05VA/phase @1A, <0.2VA/phase@5A

2.1.2 Voltage Transformer Ratings

Reference		IEC 60255-1, IEC 60255-27
Rated frequency (fn)		50Hz, 60Hz
Nominal range		fn ± 5Hz
Rated voltage (Un)		100V ~ 120V (phase-to-phase voltage)
Thermal withstand capability	continuously	240V
	10s	360V
	1s	400V
Burden at rated voltage		< 0.03VA/phase @57.7V

2.1.3 Auxiliary Power Supply

Reference	IEC 60255-1, IEC 60255-26	
Rated voltage	24VDC~250VDC,48V~250VAC	
Variation	80% ~ 120%	
Frequency	50/60Hz, ± 5Hz	
Maximum interruption time in the auxiliary DC voltage without resetting the IED	0%Un,100ms; 40%Un,200ms; 70%Un,500ms At the Un=DC220V	
Gradual shut down / Start up	Class C (60s shut down ramp, 5 min power off, 60s start up ramp)	
Ripple in the DC auxiliary voltage	Class A (15% of rated @200Hz, 220VDC)	
Maximum load of auxiliary voltage supple	1/2 19” Case:	≤20W (normal state) ≤35W (maximum state)
	1/1 19” Case:	≤30W (normal state) ≤40W (maximum state)

2.1.4 Binary Input

Reference	IEC 60255-1, Clause:6.10.5
Binary input number	1/2 19" Case:Up to 18 1/1 19" Case:Up to 36
Rated voltage	24VDC~250VDC,
Pickup voltage	55% ~ 70% rated voltage
"ON" value voltage	70% ~ 120% rated voltage
"OFF" value voltage	< 55% rated voltage
Maximum permitted voltage	120% rated voltage
Resolution of binary input signal	≤ 1ms
Resolution of SOE	≤ 1ms

2.1.5 Binary Output

Reference	IEC 60255-1	
Item	Tripping output	Signal output
Binary output number	1/2 19" Case:Up to 12 1/1 19" Case:Up to 24	1/2 19" Case:Up to 11 1/1 19" Case:Up to 27
Output model	Potential-free contact	Potential-free contact
Max system voltage	380Vac, 250Vdc	380Vac, 250Vdc
Voltage across open contact	1000V RMS for 1min	1000V RMS for 1min
Continuous carry	10A @ 380Vac; 10A @ 250Vd	5.0A @ 380Vac; 5.0A @ 250Vdc
Short duration current	30A, 3s 50A, 1s	30A, 1s
Breaking capacity	1.00A @ 48Vdc, L/R=40ms 0.35A @ 110Vdc, L/R=40ms 0.30A @ 125Vdc, L/R=40ms 0.20A @ 220Vdc, L/R=40ms 0.15A @ 250Vdc, L/R=40ms	0.60A @ 48Vdc, L/R=40ms 0.10A @ 110Vdc, L/R=40ms 0.05A @ 220Vdc, L/R=40ms
Pickup time	<5ms	< 10ms
Dropout time	< 5ms	< 8ms

2.2 Mechanical Specifications

Mounting Way	Flush mounted
Weight per device	1/2 19" Case: Approx. 9.9kg (fully equipped) 1/1 19" Case: Approx.19.5kg (fully equipped)
Merchanical size (width×high×deepth)	1/2 19" Case: 260mm*266 mm *217.7 mm 1/1 19" Case:482.6mm*266 mm *217.7 mm
Hole size (width×high)	1/2 19" Case:227 mm *267 mm 1/1 19" Case: 450 mm *267 mm
Display language	Optional: Chinese, English,Russian, French, Spanish
Housing material	Metallic plates, parts and screws: Steel Plastic parts: Polycarbonate

Housing color	Silver grey	
Location of terminal	Rear panel of the device	
Protection class	IEC60225-1: 2009	Front side:IP40 (IP52 with seal strip) Rear side, connection terminals: IP20 Other Sides: IP40

2.3 Ambient Temperature and Humidity Range

Standard	IEC 60255-1:2009
Operating temperature range	-40°C ~ +70°C
Transport and storage temperature range	-40°C ~ +70°C
Damp heat steady	+40℃ 93%humidity 16h
Damp-heat test, cyclic	6 cycles, +25℃ to +55℃, Humidity 97% to 93%

2.4 Communication Interfaces

2.4.1 Ethernet Port

For Station Level			
Medium		**Parameters**	
Ethernet: Electrical or Optical	Electrical	Port number	3
		Connector type	RJ-45
		Transmission rate	100Mbits/s
		Transmission standard	100Base-TX
		Transmission distance	≤ 100m
		Protocol	IEC60870-5-103:1997, IEC61850 etc.
		Safety level	Isolation to ELV level
	Optical	Port number	3
		Connector type	LC
		Transmission rate	100Mbits/s
		Transmission standard	100Base-FX
		Optical fiber type	Multi-mode
		Wavelength	1310nm
		Transmission distance	≤ 2000m
		Protocol	IEC60870-5-103:1997, IEC61850 etc.
For Process Level (If required)			
Medium	**Parameters**		
Optical	Port number	4	
	Connector type	LC	
	Transmission rate	100Mbits/s	
	Transmission standard	100Base-FX	
	Optical fiber type	Multi-mode	
	Wavelength	1310nm	
	Transmission distance	≤ 2000m	

2.4.2 Serial Port

Medium	Parameters	
RS-485 (EIA)	Port number	2
	Baud rate	4800 ~ 115200bps
	Transmission distance	≤ 500m @ 4800bps
	Maximal capacity	32
	Protocol	IEC60870-5-103:1997, DNP3.0 etc.
	Safety level	Isolation to ELV level

2.4.3 Time Synchronization

Medium	Parameters	
RS-485 (EIA)	Port number	1
	Transmission distance	≤ 500m
	Maximal capacity	32
	Timing standard	IRIG-B
	Safety level	Isolation to ELV level
Optical Ethernet	Port number	1
	Connector type	ST
	Transmission distance	≤ 2000m
	Timing standard	IRIG-B
IEEE 1588	Accuracy	≤ 1ms

2.4.4 Ethernet Port for Debugging

Medium	Parameters	
Electrical Ethernet (in front panel)	Port number	1
	Connector type	RJ-45
	Transmission rate	100Mbits/s
	Transmission standard	100Base-TX
	Transmission distance	≤ 100m
	Safety level	Isolation to ELV level

2.5 Type Tests

2.5.1 Environmental Tests

Dry heat operation test	IEC 60068-2-2, IEC 60255-27	16h, +70℃
Cold operation test	IEC 60068-2-1, IEC 60255-27	16h, -40℃
Dry heat storage test	IEC 60068-2-2, IEC 60255-27	16h , +70℃
Cold storage test	IEC 60068-2-1, IEC 60255-27	16h , -40℃

Damp heat steady state test +Verification of function	IEC 60255-1 IEC 60068-2-78	+40℃ 93%humidity
Damp-heat test, cyclic	IEC 60068-2-30, IEC 60255-27	6 cycles, +25℃ to +40℃, Humidity 97% to 93%
Change of temperature test	IEC 60068-2-14	5 Cycles , 1℃/min, -40℃ to +70℃

2.5.2 Mechanical Tests

Vibration response test	IEC 60255-21-1, IEC 60255-27	Class 1： Vibration Response: Class 1 (10-59Hz: 0.035mm, 59-150Hz: 0.5gn)
Vibration Endurance:	IEC 60255-21-1, IEC 60255-27	Class 1 (10-150Hz: 1gn)
Shock Response	IEC 60255-21-2, IEC 60255-27	Class 1 (5gn)
Shock Withstands	IEC 60255-21-2, IEC 60255-27	Class 1 (15gn)
Bump	IEC 60255-21-2, IEC 60255-27	Class 1(10gn)
Seismic +Verification of function	IEC 60255-21-3, IEC 60255-1	Class I

2.5.3 Electrical Tests

Impulse Voltage Tests.	IEC 60255-27	Impulse test: 5kV (rated insulation voltage ≤ 63V);Impulse test: 1kV (rated insulation voltage ＞ 63V);
AC or DC Dielectric Test	IEC 60255-27	dielectric 50,60Hz 5/60s DC 2.8KV AC 2KV
Insulation Resistance	IEC 60255-27	>100Mohm @500Vdc
Protective Bonding Resistance	IEC 60255-27	Test current DC20A, >12 Vac /Vdc, >60s,< 0.1 ohm

2.5.4 Electromagnetic Compatibility

Burst Disturbance Test / Damped Oscillatory Wave Immunity Test	IEC 60255-26, IEC 61000-4-18	For Power Supply, Binary Input / Output:Common Mode: 2.5kV, Differential Mode: 1kV;For Communication Port:Common Mode: 1kV
Electrostatic Discharge test	IEC 60255-26, IEC 61000-4-2	Contact Discharge: 8kV, Air Discharge: 15kV

Fast Transient test	IEC 60255-26, IEC 61000-4-4	(Power / Earth Port: 4kV, Signal / Control Port: 2kV)
Surge Immunity Test	IEC 60255-26, IEC 61000-4-5	For Power Supply, BI: L-E: 4kV, L-L: 2kV, voltage waveform: 1.2/50μs, current waveform: 8/20μs；Communication Port: L-E: 1kV, L-L: -, voltage waveform: 1.2/50μs, current waveform: 8/20μs)
Conducted radio interference test	IEC 60255-26, IEC 61000-4-6	150kHz~80MHz(Uo: 140dB μV or Uo: 10V)
Electromagnetic fields immunity	IEC 60255-26, IEC 61000-4-3	Test Field Strength:10V/m , Sweep frequency: 80MHz – 1000MHz, Spot frequency: 80MHz, 160MHz,450MHz,900MHz@80% Modulation& Pulse
immunity to conduct, common mode disturbance in frequency range 0 Hz to 150KHz	61000-4-16	Level 4： continuous 30V,short duration 300V at 50/3,50,60Hz; 15Hz~150Hz:30-3 decreases at 20dB/decade; 150Hz~1.5kHz:3 constant; 1.5kHz~15kHz:3-30 increases at 20dB/decade;
Power frequency magnetic fields	IEC 61000-4-8, IEC 60255-26	Continuous: 100A/m, Short Duration 1s to 3s: 1000A/m)
Pulse magnetic field immunity test	IEC 61000-4-9	Class 5: Current 6.4/16μs, 1000A/m
Damped oscillatory magnetic field immunity test	IEC 61000-4-10	Class 5: 0.1MHz&1MHz, 100A/m
Power frequency immunity tests	IEC 60255-26	Input: Class A, Common Mode: 300V, Differential Mode: 150V
Ring wave immunity test	IEC 61000-4-12	Ring Wave Class 4,4kV
Conducted RF interference on power supply terminals	IEC 60255-26, CISPR 22	Conducted Emission Limit for Auxiliary Power Supply Port： Frequency range: 0.15MHz – 0.5MHz, Frequency range: 0.5MHz – 30MHz；

Radiated interference	IEC 60255-26, CISPR 22	Radiated Emission Limit on Enclosure Port： Frequency range: 30MHz - 230MHz, Frequency range: 230MHz - 1000MHz

2.6 Terminals

Connection Type	Wire Size
CT and VT circuit connectors	Screw terminals,4mm^{2}lead
Binary I/O connection system	Screw terminals, 2.5mm^2 lead

2.7 Measurement Range and Accuracy

Metering Item	Range	Accuracy
Phase range	0° ~ 360°	≤ 0.5% or ±1°
Frequency	35.00Hz ~ 70.00Hz	≤ 0.01Hz
Current (three phase 3Ip)	0.05In<I<4.00In	±1.0%In, 0.05In~1.00In ±1.0%I, 1.00In~4.00In
Voltage (Phase 3Up, Phase-to-Phase 3Upp)	0.05Un<U<1.50Un	±0.5%Un, 0.05Un~1.00Un; ±0.5%U, 1.00Un~1.50Un

2.8 Protection Function Features

2.8.1 Transformer differential protection

2.8.1.1 Biased Differential Protection

Function	Accuracy
Tolerance of 2 nd harmonic settings	0.01
Tolerance of 5 th harmonic settings	0.02
Tolerance of operating current	≤2.5% of operating current or 0.02In., whichever is greater
Operating time (without blocking criteria)	50Hz: ≤ 30ms (Id>2 times current setting) 60Hz: ≤ 25ms (Id>2 times current setting)

2.8.1.2 Instantaneous Differential Protection

Function	Accuracy
Tolerance of current setting	≤2.5% of setting or 0.02In., whichever is greater
Operating time	50Hz: ≤ 20ms (Id>1.5 times current setting) 60Hz: ≤ 20ms (Id>1.5 times current setting)

2.8.2 Impedance Protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.02In, whichever is greater
Time delay accuracy	≤25ms(at 4 times current setting)

2.8.3 Breaker Failure Protection

Function	Accuracy
Tolerance of current setting	≤ 2.5% Setting or 0.02In, whichever is greater
Reset ratio	98%
Reset time	≤ 12.5ms
Tolerance of time setting	≤ 1% Setting + 40ms

2.8.4 Directional Over current Protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.02In, whichever is greater
Reset ratio	98%
Time delay accuracy (definite-time characteristic)	≤1%Setting+30ms (at 2 times current setting)
Time delay accuracy (inverse-time characteristic)	≤ 2.5% of operating time or 30ms, whichever is greater (start value multiples in range of 1.2…20 when I> In) ≤5.0% of operating time or 40ms, whichever is greater (start value multiples in range of 2…20 when I≤ In)

2.8.5 Thermal Overload Protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.02In, whichever is greater
Rese ratio	98%
Time delay accuracy	≤ 2.5% of operating time or 30ms, whichever is greater (start value multiples in range of 1.2…20 when I> In) ≤5.0% of operating time or 40ms, whichever is greater (start value multiples in range of 2…20 when I≤ In)

2.8.6 Directional Earth Fault Protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.02In, whichever is greater
Reset ratio	98%
Time delay accuracy (definite-time characteristic)	≤1%Setting+30ms (at 2 times current setting)
Time delay accuracy (inverse-time characteristic)	≤ 2.5% of operating time or 30ms, whichever is greater (start value multiples in range of 1.2…20 when I> In) ≤5.0% of operating time or 40ms, whichever is greater (start value multiples in range of 2…20 when I≤ In)

2.8.7 Restricted Earth Fault Protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.02In, whichever is greater
Time delay accuracy	≤20ms(at 4 times current setting)

2.8.8 Non-directional Instantaneous Earth Fault Protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.02In, whichever is greater
Reset ratio	98%

2.8.9 Residual Over voltage Protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.01Un, whichever is greater
Reset ratio	98%
Time delay accuracy (definite-time characteristic)	≤1%Setting+30ms (at 1.2 times voltage setting)
Time delay accuracy (inverse-time characteristic)	≤ 2.5% of operating time or 30ms, whichever is greater (for voltage between 1.2 and 2 multiples of pickup)

2.8.10 Over voltage protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.01Un, whichever is greater
Reset ratio	98%
Time delay accuracy (definite-time characteristic)	≤1%Setting+30ms (at 1.2 times voltage setting)
Time delay accuracy (inverse-time characteristic)	≤ 2.5% of operating time or 30ms, whichever is greater (for voltage between 1.2 and 2 multiples of pickup)

2.8.11 Under voltage Protection

Function	Accuracy
Accuracy	≤ 2.5% Setting or 0.01Un, whichever is greater
Reset ratio	102%
Time delay accuracy (definite-time characteristic)	≤1%Setting+30ms (at 0.8 times voltage setting)
Time delay accuracy (inverse-time characteristic)	≤ 2.5% of operating time or 30ms, whichever is greater (for voltage between 0.5 and 0.8 multiples of pickup)

2.8.12 Over excitation Protection

Function	Accuracy
Multiple setting of definite time	1.0~1.6
Multiple setting of inverse time	1.0~1.7
Tolerance of Multiple setting	≤2.5% of setting or 0.01, whichever is greater
Drop-off to pickup ratio	≥97%
Operating time	50Hz: ≤25 ms (at 2 times current setting)
	60Hz: ≤23 ms (at 2 times current setting)

Function	Accuracy
Time delay setting	0.1~9999 (s)
Tolerance of time setting	≤1% of setting +30ms (at 2 times setting)
Drop-off time	≤30ms

2.8.13 Over frequency protection

Function	Accuracy
Accuracy	≤0.02Hz
Time delay accuracy	≤1%Setting+30ms (at 1.2 times frequency setting)

2.8.14 Under frequency protection

Function	Accuracy
Accuracy	≤0.02Hz
Time delay accuracy	≤1%Setting+30ms (at 0.8 times frequency setting)

2.8.15 Rate-of-change frequency protection

Function	Accuracy
Frequency setting	45~60 (Hz)
Tolerance of frequency setting	≤ 0.02Hz
Time setting	0~100 (s)
Tolerance of time setting	≤1%Setting+100ms (at 1.2 times frequency setting)

3 Protection Functions

3.1 Overview

The PRS-778 relay is a microprocessor based relay which can provide mature protection for various primary equipments (generally all types of transformers etc.). The following sections detail the individual protection functions of this relay.The glossary will be listed in the below form.

Category	Profession Vocabulary	Abbreviation
Electricity	Time	T
	Phase	Ph
	Direction	Dir
	Overcurrent	OC
	Curve	Curve
	Temperature	Temp
	Characteristic	Char
	Polarity	Pol
	Quantity	Qua
	Factor	Factor
	Current	Cur
	Residual Current	ResCur
	Negative Current	NegCur
	Positive Current	PosCur
	Voltage	Vol
	Residual Voltage	ResVol
	Negative Voltage	NegVol
	Positive Voltage	PosVol
	High Voltage	HigVol
	Low Voltage	LowVol
	thermal	Therm
	Overload	OL
	Negative	Neg
	Sequence	Seq
	Residual	Res
	Beta	Beta
	harmonic	Harm
	Power	Pow
	Earth-fault	EF
	Failure	Fail
	Impedance	Imp
	Reactance	React
	Induction	Induct

Category	Profession Vocabulary	Abbreviation
	Positive	Posi
Operation	Block	Blk
	Enable	Ena
	Operation	Op
	Trip	Tr
	Protection	Prot
	Mode	Mod
	Forward	Fwd
	Reverse	Rev
	Constant	Const
	External	Ex
	Internal	In
	Number	Num
	Selector	Sel
	Measurement	Meas
	Parameter	Para
	Multiplier	Mult
	Minimum	Min
	Alarm	Alm
	Reclose	Recls
	Counter	Counter
	Correction	Correction
	Available	Avai
	Initial	Init
	Reference	Ref
	Normal	Norm
	Restraint	Restr
	Slope	Slope
	deblock	Deblk
	Winding	Wnd
	Elimination	Elim
	Nominal	Nom
	Connection	Connection
	Hysteresis	Hyst
	Compensation	Comp
	Check	Chk
	Synchronize	Syn
	Synchronization	Syn
	Energize	Energ
	Weigh	Weig
	Activation / Activate	Activ
	Error	Err

Category	Profession Vocabulary	Abbreviation
	Configuration	Cfg
	Parameter	Para
	Management	Mana
	Interrupt	Intr
	SelfCheck	SelfChk
	Start	Str
Apparatus	Generator	Gen
	Motor	Motor
	Rotor	Rotor
	Stator	Stator
	Busbar	Bus
	Transformer	TF
	Transmission Line	TL
	Line	Line
	Capacitor	Cap
	Reactor	Reac
	Resistor	Resis
	Switch	Sw
	Component	Comp

3.1.1 System Setting

Table 3.1.1 Settings of System

NO	Name	Range	Unit	Step	Default	Description
1	Sn	0.1~3000	MVA	0.1	200	Transformer or reactor capacity
2	Un_HV	0.1~1200	KV	0.01	110	Rated voltage at HV side
3	Un_MV	0.1~1200	KV	0.01	35	Rated voltage at MV side
4	Un_LV	0.1~1200	KV	0.01	10	Rated voltage at LV side
5	Phi_HV	0~1	-	1	0	Y/△Type at HV side 0: Y Type 1:△Type
6	Phi_MV	0~11	-	1	0	Clock connection at MV side： When it is consistent with Phi_HV/Phi_LV,Y/△Type at MV side is the same as HV side/LV side
7	Phi_LV	0~11	-	1	11	Clock connection at LV side: When it is set to an even number,Y/△Type at LV side is consistent with HV side; When it is set to an odd number,Y/△Type at LV side is inconsistent with HV side
8	VT1n_HV	0.1~1200	KV	0.01	110	Primary value of VT at HV side
9	VT1n_MV	0.1~1200	KV	0.01	35	Primary value of VT at MV side
10	VT1n_LV	0.1~1200	KV	0.01	10	Primary value of VT at LV side

NO	Name	Range	Unit	Step	Default	Description
11	VT2n	30~300	V	0.01	100	Secondary value of VT
12	I1n_H1V	1~12000	A	1	1200	Primary value of CT at H1V side
13	I1n_H2V	0~12000	A	1	1200	Primary value of CT at H2V side
14	I1n_M1V	0~12000	A	1	2000	Primary value of CT at M1V side
15	I1n_M2V	0~12000	A	1	2000	Primary value of CT at M2V side
16	I1n_L1V	0~12000	A	1	4000	Primary value of CT at L1V side
17	I1n_L2V	0~12000	A	1	4000	Primary value of CT at L2V side
18	I1n_GV	0~12000	A	1	4000	Primary value of CT at GV side
19	I1n_LTV	0~12000	A	1	4000	Primary value of CT at LTV side
20	I2n_H1V	1 or 5	A	4	1	Secondary value of CT at H1V side
21	I2n_H2V	1 or 5	A	4	1	Secondary value of CT at H2V side
22	I2n_M1V	1 or 5	A	4	1	Secondary value of CT at M1V side
23	I2n_M2V	1 or 5	A	4	1	Secondary value of CT at M2V side
24	I2n_L1V	1 or 5	A	4	1	Secondary value of CT at L1V side
25	I2n_L2V	1 or 5	A	4	1	Secondary value of CT at L2V side
26	I2n_GV	1 or 5	A	4	1	Secondary value of CT at GV side
27	I2n_LTV	1 or 5	A	4	1	Secondary value of CT at LTV side
28	I1n_HVN	0~12000	A	1	1200	Primary value of zero-sequence CT at HV side
29	I1n_MVN	0~12000	A	1	2000	Primary value of zero-sequence CT at MV side
30	I1n_LVN	0~12000	A	1	4000	Primary value of zero-sequence CT at LV side
31	I1n_GVN	0~12000	A	1	4000	Primary value of zero-sequence CT at GV side
32	I2n_HVN	1 or 5	A	4	1	Secondary value of zero-sequence CT at HV side
33	I2n_MVN	1 or 5	A	4	1	Secondary value of zero-sequence CT at MV side
34	I2n_LVN	1 or 5	A	4	1	Secondary value of zero-sequence CT at LV side
35	I2n_GVN	1 or 5	A	4	1	Secondary value of zero-sequence CT at GV side
36	I0_Rem_LV_Ena	0,1		1	0	Whether the Zero sequence current is filtered off the low voltage side 0: disable 1: enable

Example for Connection Scheme：

1） If the project uses Yyd-11.The setting Phi_HV=0,Phi_MV=0,Phi_LV=11；

2） If the project uses Ydd-11.The setting Phi_HV=0,Phi_MV=11,Phi_LV=11；

3） If the project uses Dyy-11.The setting Phi_HV=1,Phi_MV=11,Phi_LV=11；

4） If the project uses Ddy-11.The setting Phi_HV=1,Phi_MV=1,Phi_LV=11；

3.2 Transformer Differential Protection (87T)

3.2.1 Overview

In electrical power system or electrical power industry, power transformer is the one of the most precious and main important primary equipment. For this main point of view, the protection of power transformer is very important task. If some kind of trouble or fault situation happen in the protected zone of the power transformer, then need to clear this trouble or fault as soon as possible. Transformer differential protection (87T) is specially designed for such kind of trouble or fault situation to protect transformer from maximum cause of injuries or harm and operate the protection as quick as possible.

Transformer differential protection (87T) have two dependable operating function of element likes biased differential element and instantaneous differential element.

1) Biased differential element is operation based on with three characteristics slope.

2) Instantaneous differential element increase the operating speed of protection during internal fault of transformer without three characteristics slope of biased differential element and blocking function (CT saturation, CT failure and Harmonics effect).

3) Some other important and superior special functions of 87T protection are:

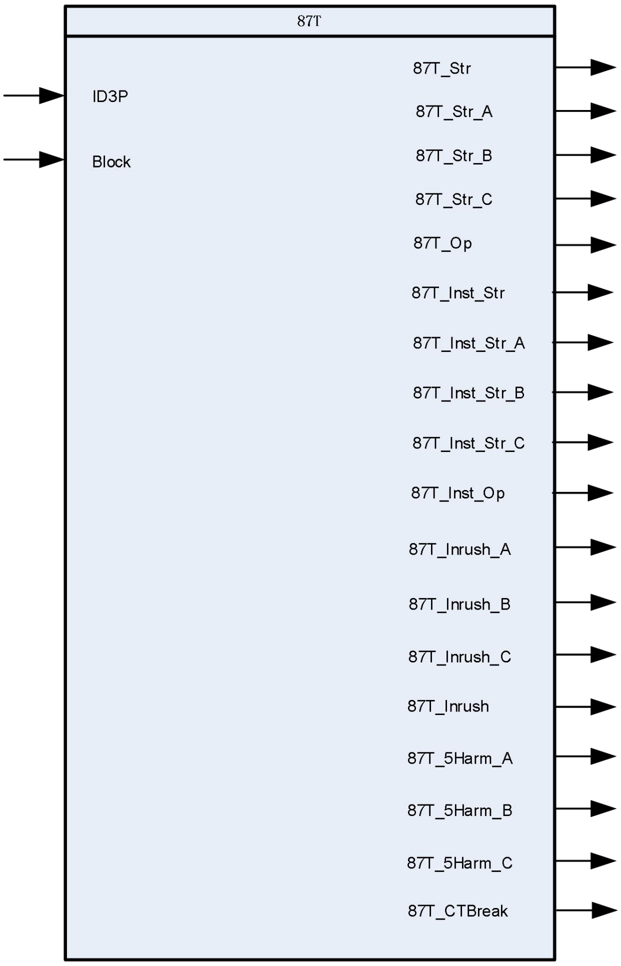
- Meticulousphase compensation IED calculation criteria.
- Accurate and fast fault tracking capability.
- Inrush current distinguish operating principle.
- Special capability to detect over excitation condition of transformer.

Above mentioned these four element of transformer differential protection function are highly proved to sense quickly any abnormal situation in protected zone of transformer and in case of any abnormalty is detected then very fast trip command is issued.

Notice!

Point of view of user’s project and real time experience, some of the protection function of transformer differential protection (87T) are enable or disable according to the customer’s or user’s demand of situation.

3.2.1.1 Function Block



3.2.1.2 Signals

Table 3.2.1 87T Input Signals

NO.	Signal	Description
1	ID3P	Three phase differential current of 87T
2	Block	Block signal of 87T

Table 3.2.2 87T Output Signals

NO.	Signal	Description
1	87T _Str	Start signal of differential from 87T
2	87T _Str_A	Start_A signal of differential from 87T
3	87T _Str_B	Start_B signal of differential from 87T
4	87T _Str_C	Start_C signal of differential from 87T
5	87T_ Op	Operation signal of differential from 87T
6	87T_Inst_Str	Start signal of instantaneous differential from 87T

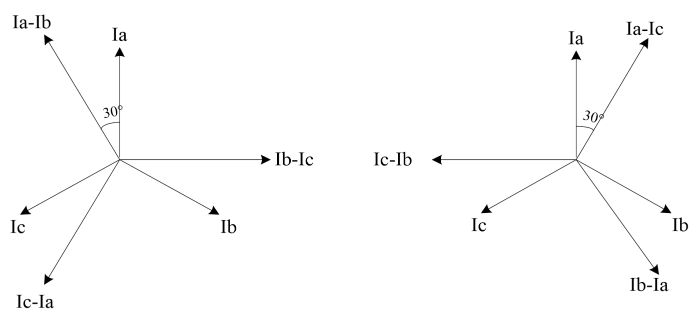
NO.	Signal	Description
7	87T_Inst_Str_A	Start_A signal of instantaneous differential from 87T
8	87T_Inst_Str_B	Start_B signal of instantaneous differential from 87T
9	87T_Inst_Str_C	Start_C signal of instantaneous differential from 87T
10	87T_ Inst_Op	Operation signal of instantaneous differential from 87T
11	87T_Inrush_A	Inrush_A Block signal from 87T
12	87T_Inrush_B	Inrush_B Block signal from 87T
13	87T_Inrush_C	Inrush_C Block signal from 87T
14	87T_Inrush	Inrush Block signal from 87T
15	87T_5Harm_A	5Harm_A Block signal from 87T
16	87T_5Harm_B	5Harm_B Block signal from 87T
17	87T_5Harm_C	5Harm_C Block signal from 87T
18	87T_CTBreak	CT fail signal from 87T

3.2.2 Protection Principle

3.2.2.1 Phase compensation

To simplify field wiring and improve (phase current) inrush current restrained characteristics, this device requires Y shaped connection for CT at each side of transformer and the connection for CT at each side based on the same polarity. Bus bar side is taken as polarity end as shown in application configuration diagram in below figure.Inside the device, phase shift is performed at Y connection side of transformer and its performance will be identical with the performance of CT with Δ shaped connection. The relay device can be applicable for all kinds of winding connection types and the phase shifting can be internally automatically performed according the clock number setting.

Schematic diagram of Y→Δ current conversion at secondary side of CT is as below:



11 o'clock connection	1 o'clock connection
Iab=Ia-Ib Ibc=Ib-Ic Ica=Ic-Ia	Iac=Ia-Ic Iba=Ib-Ia Icb=Ic-Ib

Figure 3.2.1 11 o'clock connection and 1 o'clock connection

In addition, the device also regulates the difference in transformation ratio between CTs at each side of transformer. Each side is provided with a CT transformation ratio regulation coefficient which is multiplied by current quantity collected by the device to get the quantity after regulation of CT transformation ratio. By simply entering relevant parameters of transformer (refer to the table of settings), it's possible to automatically obtain regulation coefficient of CT at each side without the need for external connection with auxiliary CT. Such type of regulation is more reliable when compared with regulation performed using hardware circuit.

This device only performs phase shift for current at Y connection side. In case of 11 o'clock connection at △ side, phase shift at Y side could be performed as below:

$$\dot{I}_A' = (\dot{I}_A - \dot{I}_B)/\sqrt{3}$$

$$\dot{I}_B' = (\dot{I}_B - \dot{I}_C)/\sqrt{3}$$

$$\dot{I}_C' = (\dot{I}_C - \dot{I}_A)/\sqrt{3}$$

In case of 1 o'clock connection at △ side, phase shift at Y side could be performed as below:

$$\dot{I}_A' = (\dot{I}_A - \dot{I}_C)/\sqrt{3}$$

$$\dot{I}_B' = (\dot{I}_B - \dot{I}_A)/\sqrt{3}$$

$$\dot{I}_C' = (\dot{I}_C - \dot{I}_B)/\sqrt{3}$$

[Note]: For transformers with Y connection on each side, although there is no phase difference in the CT secondary current on each side, in order to eliminate the influence of the zero sequence current on the differential protection on the Y-side(using phase-to-phase subtraction method to filter out the zero-sequence current), all Y-side currents should also be performed as Yd11 connection.

Table3.3.3 Matrix of phase compensation

Yy0	$\begin{bmatrix}\dot{I}'_A\\ \dot{I}'_B\\ \dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1 & -1 & 0\\ 0 & 1 & -1\\ -1 & 0 & 1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\ \dot{I}_B\\ \dot{I}_C\end{bmatrix}\begin{bmatrix}\dot{I}'_a\\ \dot{I}'_b\\ \dot{I}'_c\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1 & -1 & 0\\ 0 & 1 & -1\\ -1 & 0 & 1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_a\\ \dot{I}_b\\ \dot{I}_c\end{bmatrix}$
Yd1	$\begin{bmatrix}\dot{I}'_A\\ \dot{I}'_B\\ \dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1 & 0 & -1\\ -1 & 1 & 0\\ 0 & -1 & 1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\ \dot{I}_B\\ \dot{I}_C\end{bmatrix}$

Yy2	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1&-1&0\\0&1&-1\\-1&0&1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}\begin{bmatrix}\dot{I}'_a\\\dot{I}'_b\\\dot{I}'_c\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}0&-1&1\\1&0&-1\\-1&1&0\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_a\\\dot{I}_b\\\dot{I}_c\end{bmatrix}$
Yd3	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}0&1&-1\\-1&0&1\\1&-1&0\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}$
Yy4	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1&-1&0\\0&1&-1\\-1&0&1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}\begin{bmatrix}\dot{I}'_a\\\dot{I}'_b\\\dot{I}'_c\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}-1&0&1\\1&-1&0\\0&1&-1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_a\\\dot{I}_b\\\dot{I}_c\end{bmatrix}$
Yd5	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}-1&1&0\\0&-1&1\\1&0&-1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}$
Yy6	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1&-1&0\\0&1&-1\\-1&0&1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}\begin{bmatrix}\dot{I}'_a\\\dot{I}'_b\\\dot{I}'_c\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}-1&1&0\\0&-1&1\\1&0&-1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_a\\\dot{I}_b\\\dot{I}_c\end{bmatrix}$
Yd7	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}-1&0&1\\1&-1&0\\0&1&-1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}$
Yy8	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1&-1&0\\0&1&-1\\-1&0&1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}\begin{bmatrix}\dot{I}'_a\\\dot{I}'_b\\\dot{I}'_c\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}0&1&-1\\-1&0&1\\1&-1&0\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_a\\\dot{I}_b\\\dot{I}_c\end{bmatrix}$
Yd9	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}0&-1&1\\1&0&-1\\-1&1&0\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}$
Yy10	$\begin{bmatrix}\dot{I}'_A\\\dot{I}'_B\\\dot{I}'_C\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1&-1&0\\0&1&-1\\-1&0&1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_A\\\dot{I}_B\\\dot{I}_C\end{bmatrix}\begin{bmatrix}\dot{I}'_a\\\dot{I}'_b\\\dot{I}'_c\end{bmatrix}=\frac{1}{\sqrt{3}}\cdot\begin{bmatrix}1&0&-1\\-1&1&0\\0&-1&1\end{bmatrix}\cdot\begin{bmatrix}\dot{I}_a\\\dot{I}_b\\\dot{I}_c\end{bmatrix}$

Yd11	$\begin{bmatrix} \dot{I}'_A \\ \dot{I}'_B \\ \dot{I}'_C \end{bmatrix} = \frac{1}{\sqrt{3}} \cdot \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \dot{I}_A \\ \dot{I}_B \\ \dot{I}_C \end{bmatrix}$
Dy1	$\begin{bmatrix} \dot{I}'_a \\ \dot{I}'_b \\ \dot{I}'_c \end{bmatrix} = \frac{1}{\sqrt{3}} \cdot \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \dot{I}_a \\ \dot{I}_b \\ \dot{I}_c \end{bmatrix}$
Dy3	$\begin{bmatrix} \dot{I}'_a \\ \dot{I}'_b \\ \dot{I}'_c \end{bmatrix} = \frac{1}{\sqrt{3}} \cdot \begin{bmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \dot{I}_a \\ \dot{I}_b \\ \dot{I}_c \end{bmatrix}$
Dy5	$\begin{bmatrix} \dot{I}'_a \\ \dot{I}'_b \\ \dot{I}'_c \end{bmatrix} = \frac{1}{\sqrt{3}} \cdot \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix} \cdot \begin{bmatrix} \dot{I}_a \\ \dot{I}_b \\ \dot{I}_c \end{bmatrix}$
Dy7	$\begin{bmatrix} \dot{I}'_a \\ \dot{I}'_b \\ \dot{I}'_c \end{bmatrix} = \frac{1}{\sqrt{3}} \cdot \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix} \cdot \begin{bmatrix} \dot{I}_a \\ \dot{I}_b \\ \dot{I}_c \end{bmatrix}$
Dy9	$\begin{bmatrix} \dot{I}'_a \\ \dot{I}'_b \\ \dot{I}'_c \end{bmatrix} = \frac{1}{\sqrt{3}} \cdot \begin{bmatrix} 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \dot{I}_a \\ \dot{I}_b \\ \dot{I}_c \end{bmatrix}$
Dy11	$\begin{bmatrix} \dot{I}'_a \\ \dot{I}'_b \\ \dot{I}'_c \end{bmatrix} = \frac{1}{\sqrt{3}} \cdot \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \cdot \begin{bmatrix} \dot{I}_a \\ \dot{I}_b \\ \dot{I}_c \end{bmatrix}$

3.2.2.2 Magnitude Compensation

- **Rated primary current at each side of transformer**

$$I_{1e} = \frac{S_n}{\sqrt{3}U_{1n}}$$

Where:

S_n means maximum rated capacity of transformer nameplate, and U_{1n} represents rated primary voltage at calculated side of transformer.

The formula above applies to calculation of rated primary current of switch CT at HV, MV and LV sides; as for bushing CT at LV side, the rated primary current is given by:

$$I_{1eLT} = \frac{S_n}{\sqrt{3}\sqrt{3}U_{1n}} = \frac{S_n}{3U_{1n}}$$

CT transformation ratio at each side of transformer

$$K_{TA} = \frac{I_{1n}}{I_{2n}}$$

Where, I_{2n} rated secondary current of CT is 5A or 1A; I_{1n}"primary side of CT" is dependent on corresponding settings of system parameters.

Rated secondary current at each side of transformer

$$I_{2e} = \frac{I_{1e}}{K_{TA}}$$

CT balance coefficient at each side of differential protection

With HV side as reference, the balance coefficient at HV side is fixedly set to 1.

Balance coefficient at MV side:

$$K_{phM-ZC} = \frac{I_{2e-H}}{I_{2e-M}} = \frac{I_{1eH}/K_{TAH}}{I_{1eM}/K_{TAM}} = \frac{S_n/\sqrt{3}U_{1nH}}{S_n/\sqrt{3}U_{1nM}} \times \frac{K_{TAM}}{K_{TAH}} = \frac{U_{1nM}}{U_{1nH}} \times \frac{K_{TAM}}{K_{TAH}}$$

Balance coefficient at LV side (switch CT):

$$K_{phL-ZC} = \frac{I_{2e-H}}{I_{2e-L}} = \frac{I_{1eH}/K_{TAH}}{I_{1eL}/K_{TAL}} = \frac{S_n/\sqrt{3}U_{1nH}}{S_n/\sqrt{3}U_{1nL}} \times \frac{K_{TAL}}{K_{TAH}} = \frac{U_{1nL}}{U_{1nH}} \times \frac{K_{TAL}}{K_{TAH}}$$

In the formula, K_{TAL} means CT transformation ratio of CB at LV side, while U_{1nL} represents rated voltage at LV side.

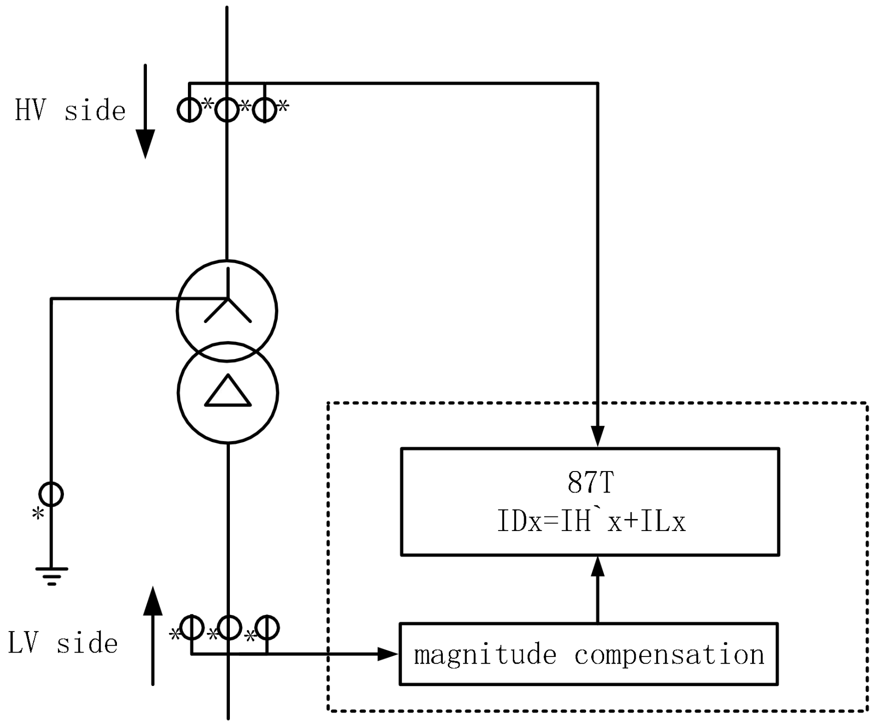


Figure 3.2.2 87T principle diagram for Yd-11

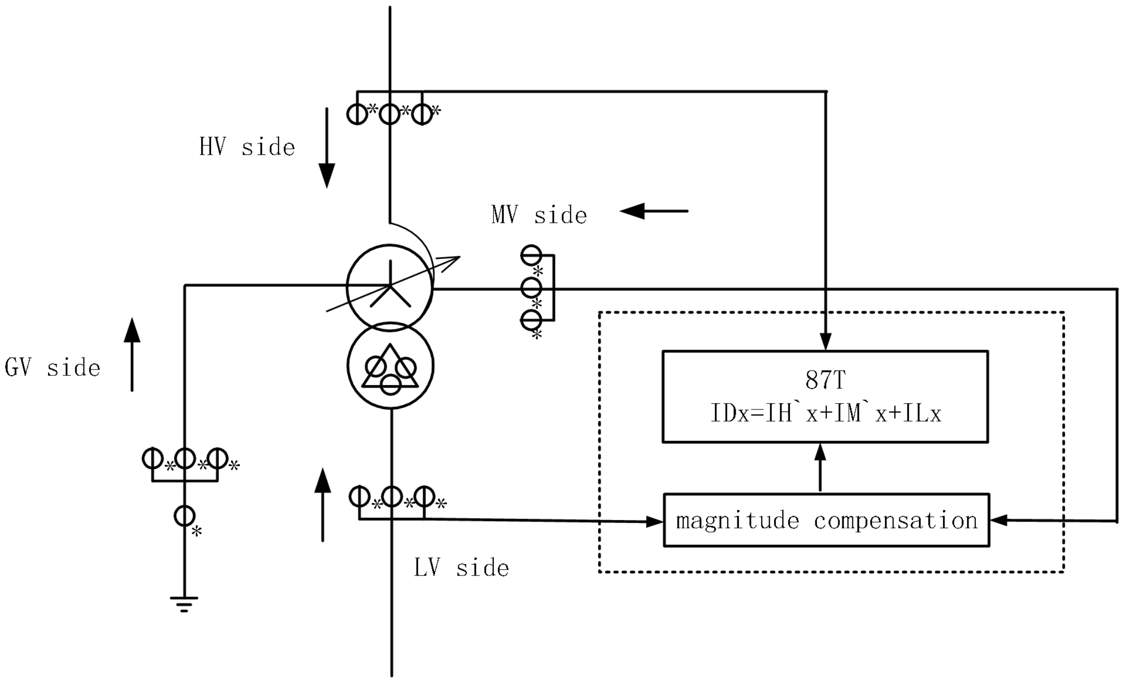


Figure 3.2.3 87T principle diagram for YNa0d-11

3.2.2.3 Fault detector based on biased differential current

The fault detector can initiate biased differential element, and its operation equation is shown as below.

Idmax>0.9*87T_Cur_Str

Where:

Idmax is the maximum value of three phase differential currents.

3.2.2.4 Fault detector based on instantaneous differential current

The fault detector can initiate instantaneous differential element, and its operation equation is shown as below.

Idmax>0.9*87T_Cur_Inst

Where:

Idmax is the maximum value of three phase differential currents.

3.2.2.5 Calculation of Differential and Restraint Currents

The equation of calculating differential current is:

$$\begin{cases} I_{dA} = \left| I'_{A1} + I'_{A2} + I'_{A3} + I'_{A4} + I'_{A5} + I'_{A6} \right| \\ I_{dB} = \left| I'_{B1} + I'_{B2} + I'_{B3} + I'_{B4} + I'_{B5} + I'_{B6} \right| \\ I_{dC} = \left| I'_{C1} + I'_{C2} + I'_{C3} + I'_{C4} + I'_{C5} + I'_{C6} \right| \end{cases}$$

The equation of calculating restraint current is:

$$\begin{cases} I_{rA} = \frac{1}{2} \times \left(\left| I'_{A1} \right| + \left| I'_{A2} \right| + \left| I'_{A3} \right| + \left| I'_{A4} \right| + \left| I'_{A5} \right| + \left| I'_{A6} \right| \right) \\ I_{rB} = \frac{1}{2} \times \left(\left| I'_{B1} \right| + \left| I'_{B2} \right| + \left| I'_{B3} \right| + \left| I'_{B4} \right| + \left| I'_{B5} \right| + \left| I'_{B6} \right| \right) \\ I_{rC} = \frac{1}{2} \times \left(\left| I'_{C1} \right| + \left| I'_{C2} \right| + \left| I'_{C3} \right| + \left| I'_{C4} \right| + \left| I'_{C5} \right| + \left| I'_{C6} \right| \right) \end{cases}$$

Where:

I'_{Am}, I'_{Bm}, I'_{Cm} are corrected secondary current of branch m (m=1, 2, 3, 4, 5, 6).

I_{dA}, I_{dB}, I_{dC} are differential currents.

I_{rA}, I_{rB}, I_{rC} are restraint currents.

3.2.2.6 Biased Low Stage

The currents for following calculation are the results of the actual secondary current of each side multiplying its own correction coefficient. The biased low stage with low start setting and restraint slope is much more sensitive for a slight internal fault. The function includes four blocking elements: CT saturation, inrush current, overexcitation and CT circuit failure (optional) to prevent it from the unwanted operation during the short circuits outside the protected area, the large currents fed by the transformer in motor startup or the transformer inrush situations.

$$I_d > K_1 \times I_r + I_{Str} \quad (I_r < K_{nee1})$$

$$I_d > K_2 \times (I_r - K_{nee1}) + K_1 \times K_{nee1} + I_{Str} \quad (K_{nee1} \le I_r < K_{nee2})$$

$$I_d > K_3 \times (I_r - K_{nee2}) + K_2 \times (K_{nee2} - K_{nee1}) + K_1 \times K_{nee1} + I_{Str} \quad (I_r \ge K_{nee2})$$

$$I_d = \left| \sum_{i=1}^{m} I_i \right|$$

$$I_r = \frac{1}{2} \sum_{i=1}^{m} | I_i |$$

Where：

I_d and I_r are respectively the differential current and the restraint current.

I_{Str} is the start setting of biased differential protection (i.e., 87T_Cur_Str).

“Knee1” and “Knee2” are respectively current settings of knee point 1 and knee point 2, the corresponding set value: 87T_Cur_K1 and 87T_Cur_K2).

“K1”, “K2” and “K3” are three slopes of biased differential protection, the corresponding set value: 87T_Slope1, 87T_Slope2, 87T_Slope3.

Operation characteristic of sensitive biased differential element is shown below.

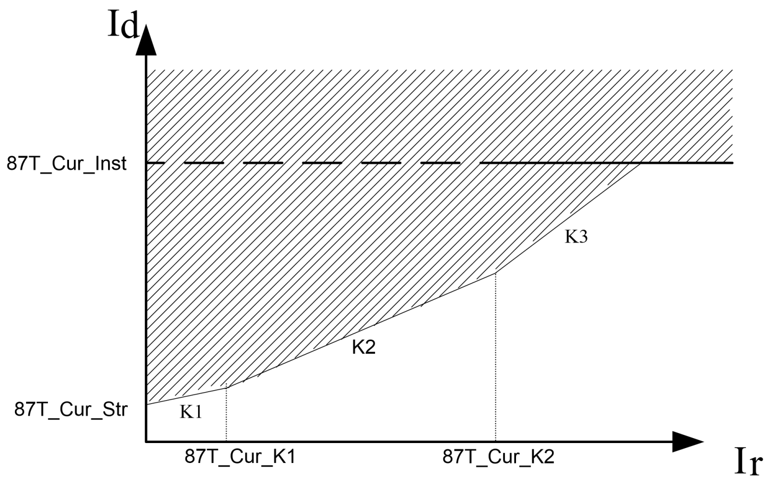


Figure 3.2.4 Operation characteristic of differential protection

3.2.2.7 Instantaneous High Stage

Instantaneous high stage for transformer is to accelerate the operation speed for transformer's internal fault. The operation of the instantaneous high stage is not biased and has no blocking element. Instantaneous high stage shall operate to clear the fault when any phase differential current is higher than its setting. Its operation criterion is:

Idmax> 87T_Cur_Inst

Where：

Idmax is the maximum value of three phase differential currents.

3.2.2.8 Inrush Current Discrimination

The device provides optional inrush current distinguished principles: harmonic principle (second harmonic) or waveform symmetry principle. The logic setting 87T_Opt_Inrushis used to select distinguished principle.

- **Inrush current discrimination based on harmonics**

The ratio of second harmonic in three-phase differential current to fundamental harmonic is taken as criterion for blocking of inrush exciting current, and the operating formula is given as below:

$$I_{2nd} > K_{2xb} \bullet I_{1st}$$

Where：

I_{2nd} means second harmonic in differential current at each phase;

I_{1st} represents fundamental harmonic of differential current at corresponding phase;K_{2xd} is second harmonic restraint coefficient.

This device incorporates our proprietary second harmonic compound logic restraint principle which has been proven through substantial operation cases. Details are described as below:

- As for transformer with Y/Δ connection, differential current reflects the difference of current phasor between two phases at Y shaped connection side. In case of charging of no-load transformer at Y shaped connection side, the relatively obvious in rushing characteristic (second harmonic content or intermission angle) in single-phase current may be weakened after currents at two phases subtract each other. If this is the case, the traditional method (that is, to realize restraint by extracting second harmonic component from differential current) may not work. Since CT at Y side of transformer is connected in the Y shape, second harmonic in the original two phase currents could be used for restraint when second harmonic of differential current fails to perform the restraint. This could significantly improve the reliability of inrush restraint.
- With respect to conventional second harmonic inrush restraint, biased differential protections at all the three phase will be blocked in case of inrush restraint if with differential current at any phase, and this is referred to as "or" logic. If restraint is performed simply as "or" logic, differential protection may operate at a relatively low rate in case of charginga faulty transformer with no load. This device conducts a complex inrush current restraint logic based on the differential currents,which is distinguished in the inrush current and fault current at three phases.If there is no fault in the transformer, "or"restraint logic is used to reliably block tripping even large inrush current is generated. In case that a faulty transformer without any load is switched on, split-phase restraint mode would be automatically activated. The split-phase restraint mode ensures that percentage differential protection can still operate rapidly and sensitively when a faulty transformer without any load is switched on.

➢ **Inrush current discrimination based on waveform symmetry principle**

In case of fault, differential current basically displays power frequency sine wave, while in case of inrush exciting current, waveform would be subjected to distortion, interruption and asymmetry due to the existence of substantial harmonic components. It's possible to identify inrush exciting current by identifying such distortion using algorithms.

In case of fault, the following formulais fulfilled:

$$S_{+} \leq K_{b} * S_{-}$$

Where:

S_+ means half-wave integral quantity of $| I'_i+I'_{i+T/2} |$;

S_-represents the half-wave integral quantity of $| I'_i-I'_{i+T/2} |$;

K_b is waveform asymmetry coefficient.I'_i represents the numerical value of differential current derivative at some certain point of first-half wave, while $I'_{i+T/2}$ means the numerical value of differential current derivative at the corresponding point of second-half wave. K_b is normally set to be 0.1~0.2 and this device takes 0.2.

➢ **Inrush current discrimination based on comprehensive principle**

When the transformer is empty filled, the inrush current contains DC component, second harmonic, third harmonic and interruption angle. The inrush current can be identified by comprehensive calculation of these characteristic parameters.

The formula for the comprehensive criterion is as follows:

$$K_{set} \leq (C_0 \times K_0 + C_2) \times K_2 + C_3 \times K_3 + C_d \times D$$

Where：

K_0: DC component proportion; C_0 The DC component increases the second harmonic coefficient.

K_2: second harmonic proportion; C_2 The second harmonic coefficient of differential current should consider the sensitivity of slight fault.

K_3 : third harmonic proportion; C_3 Third harmonic coefficient of differential current.

D: waveform asymmetry component; C_d Asymmetry coefficient of differential current waveform.

K_{set}: Setting of magnetizing inrush current coefficient.

3.2.2.9 CT Saturation Detection

To prevent incorrect tripping of differential protection caused by CT saturation in case of external fault, CT saturation detection element of the device would judge the saturation of CT and determine whether to block relevant differential protection.

In case of internal fault:

$$\sum_{i=1}^{n} \left| D\dot{I}_i \right| = \left| \sum_{i=1}^{n} D\dot{I}_i \right|$$

Where：

"n” means the number of sides shared by transformers.

The left part of above equation is restraint current, while the right part is differential current.The equation is not fulfilled in case of either external fault or external fault under the condition of saturated CT. As a matter of fact, since CT saturation induced differential current always comes into being after a certain period of time of CT saturation, the device determines if saturation has occurred by taking advantage of the temporal consistency between restraint current and differential current.If saturation has occurred, the percentage differential restraint coefficient would be automatically driven up so as to assure the reliability of differential protection and the quick operation in case of conversion of external fault saturation into internal fault.

3.2.2.10 Over excitation Detection

When a transformer is overexcited, the exciting current will increase sharply which may result in an unwanted operation of differential protection. Therefore the over excitation shall be discriminated to block differential protection. The fifth harmonic of differential current can be selected to determine over excitation.

$$Id\_5th > 87T\_K\_Hm5 \times Id\_1st$$

Where:

Id_1st is the fundamental component of differential current.

Id_5th is the fifth harmonic of differential current.

The fifth harmonic is recommended to be selected for over excitation calculation.

3.2.2.11 Differential CT circuit abnormality

If the differential current in any phase is continually greater than the alarm setting 87T_Cur_Alm over 10s, the differential current abnormality alarm will be issued, but this alarm will not block differential protection.

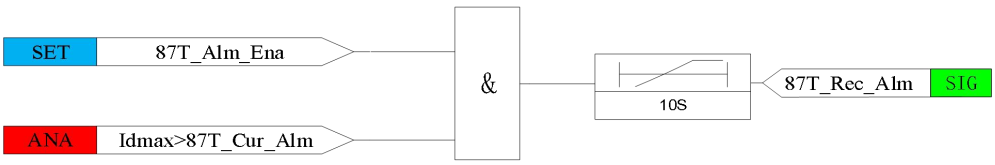


Figure 3.2.5 Differential CT Circuit Abnormality

3.2.2.12 Differential CT circuit failure

This is a differential protection CT circuit failure criterion.

First of all, the possibility of concurrence of multi-side CT line-break and fault is not taken into consideration. Under this premise, it’s possible to distinguish between CT circuit failure and fault based on the following characteristic.In case of CT circuit failure, it’s necessary to specifically identify circuit failure phase.

Single-phase or two-phase CT circuit failure:

	CT circuit failure	Fault
Current variation	Abrupt change of current at line-break side only	Abrupt change of current at multiple sides
Current variation tendency	From high to low	From low to high
Current amplitude	$\leq 0.08\ In$	$\geq\ In$

In case the abrupt current variation is greater than 5~10%IN, abrupt current variation would be deemed to have occurred.

Alarm signal will be issued when CT circuit failure lasts for 10s, and in such a case, whether or not to instantaneously block relevant differential protection is determined by setting.The condition for reset of CT circuit failure is that there's no negative-sequence current at this side.The negative-sequence current at this side is lower than threshold of CT line-break negative-sequence current (fixed value).

Blocking of biased differential protection by CT circuit failure follows the following principle:

- When “CTS_Blk_Ena” is set to “1”, biased differential protection would be blocked in case of CT circuit failure (as for longitudinal percentage differential protection and split-phase percentage differential protection, differential protection would be blocked when differential current is less than 1.2Ie and would not when more than 1.2Ie; with respect to cell differential protection, differential protection would be blocked when differential current is less than 1.2ILe and would not when more than 1.2ILe. Here, Ie means rated secondary current at HV side of transformer, while ILe represents rated secondary current at LV side of transformer).
- When “CTS_Blk_Ena” is set to “0”, biased differential protection would not be blocked in case of CT circuit failure.

Where：

"CTS_Blk_Ena” is effective for Biased low stage.

It should be noted that CT circuit failure induced blocking is principally designed to prevent malfunction of differential protection caused by CT circuit failure and follows the following principles:

Firstly, concurrence of multi-side CT circuit failure is not taken into account; secondly, differential protection trip is allowed in case of concurrence of failure and CT circuit failure; thirdly, relevant protection should be blocked when fault occurs after CT circuit failure; fourthly, protection shall operate if CT circuit failure occurs after the occurrence of fault.

3.2.3 Logic Diagram

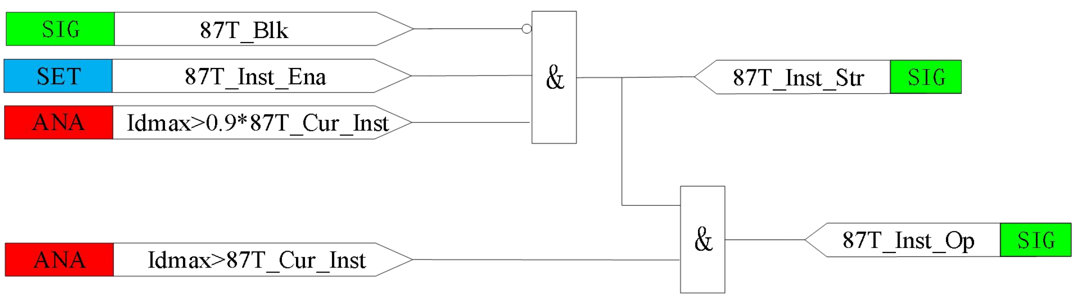


Figure 3.2.6 Logic diagram of 87T_Inst protection

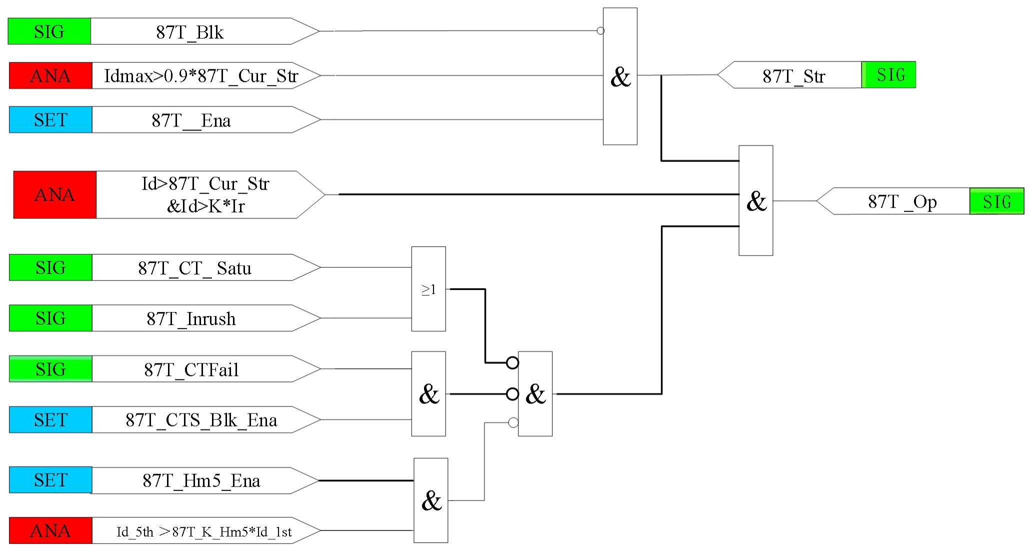


Figure 3.2.7 Logic diagram of 87T protection

Where:

I_{dmax} is the maximum value of three phase differential currents.

“87T_CT_Satu” means that the flag of CT Saturation.

“87T_Inrush” means that the flag of Inrush current

“87T_CTFail” means that the flag of CT circuit failure.

3.2.4 Settings

Table 3.2.4 Settings of Transformer differential protection

No.	Name	Range	Unit	Step	Default	Description
1	87T_Cur_Str	0.05~20.00	PU	0.01	0.40	Pickup setting of biased differential element
2	87T_Cur_Inst	0.05~20.00	PU	0.01	6.00	Current setting of instantaneous differential element
3	87T_Cur_Alm	0.05~20.00	PU	0.01	1.00	Current setting of differential circuit abnormality alarm
4	87T_K_Hm2	0.05~0.50	-	0.01	0.15	Coefficient of second harmonics for inrush current detection
5	87T_K_Hm5	0.05~0.50	-	0.01	0.35	Coefficient offive harmonics for inrush current detection
6	87T_Cur_K1	0.05~20.00	PU	0.01	1.00	Current setting of knee point 1 for transformer differential protection

No.	Name	Range	Unit	Step	Default	Description
7	87T_Cur_K2	0.05~20.00	PU	0.01	6.00	Current setting of knee point 2 for transformer differential protection
8	87T _Slope1	0~0.90	-	0.01	0.00	Slope 1 of biased differential element
9	87T _Slope2	0~0.90	-	0.01	0.50	Slope 2 of biased differential element
10	87T _Slope3	0~0.90	-	0.01	0.75	Slope 3 of biased differential element
11	87T_Opt_Inrush	0~3	-	1	0	Option of inrush current discrimination principle: 0: waveform symmetry 1: Harmonic principle 2: Comprehensive principle 3:Without Inrush Current Block
12	87T _Ena	0,1	-	1	0	Logic setting of enabling/disabling conventional biased differential element 0: disable 1: enable
13	87T_Inst_Ena	0,1	-	1	0	Logic setting of enabling/disabling instantaneous differential element 0: disable 1: enable
14	87T_Alm_Ena	0,1	-	1	0	Logic setting of enabling/disabling differential Alam element 0: disable 1: enable
15	87T_Hm5_Ena	0,1	-	1	0	Logic setting of enabling/disabling block overexcitation 0: disable 1: enable
16	87T_CTS_Blk_Ena	0,1	-	1	0	Logic setting of enabling/disabling block biased differential element during CT circuit failure 0: disable 1: enable

3.3 Distance Protection 21

3.3.1 Overview

The main function of Distance protection (21) is to provide very sensitive and accurate operation of protection where overcurrent protection and earth fault protection cannot meet the required high standard of protection. Such kind of protection operates based on the ratio of voltage and current is known as impedance or distance protection. The ratio of current and voltage directly measured by current transformer (CT) and voltage transformer (PT or VT) respectively.

Distance protection (21) relay device provide forward or reverse five settable zone.

Every zone of distance protection is providing dependable settings and full design scheme of measurement phase to phase (line value) and phase to earth (phase value). The characteristics of distance protection zone are:

- Mho characteristics
  - ○ Phase to phase (line value) distance element
  - ○ Phase to earth (phase value) distance element
- Quadrilateral characteristics
  - ○ Phase to phase (line value) distance protection
  - ○ Phase to earth (phase value) distance protection
  - ○ Reactance line element
  - ○ Direction line element
  - ○ Resistance line element
- Power swing blocking releasing (PSBR)
  - ○ Each zone can be easily configuring PSBR setting

When VT circuit fails, VT circuit supervision logic will output a blocking signal to block all distance protection.

Distance protection can select line VT or bus VT for protection algorithm by a settingVTS_LineVT.

3.3.2 Parameters

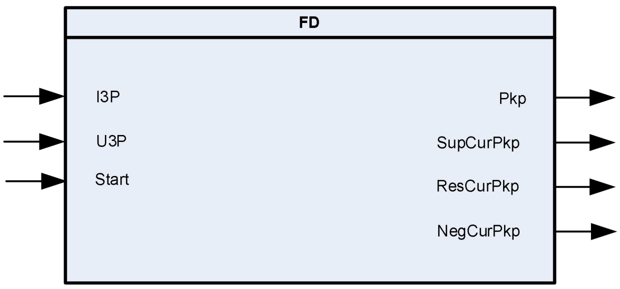
Table 3.3.1 Parameters

No.	Name	Range	Unit	Step	Default	Description
1	Z1_X	(0.05~655)/In	ohm	0.01	10	X-side(X=H,M) Positive-sequence impedance of the whole line (secondary value)
2	Z1Ang_X	10~89	deg	0.01	85	X-side(X=H,M) Positive-sequence impedance angle

No.	Name	Range	Unit	Step	Default	Description
3	Z0_X	(0.05~655)/In	ohm	0.01	30	X-side(X=H,M) Zero-sequence impedance of the whole line (secondary value)
4	Z0Ang_X	30~89	deg	0.01	80	X-side(X=H,M) Zero-sequence impedance angle
5	Kz_X	0~10.000	-	0.001	0.67	X-side(X=H,M) Zero-sequence compensation coefficient magnitude
6	KzAng_X	0~360.00	deg	0.01	0	X-side(X=H,M) Zero-sequence compensation coefficient angle

3.3.3 Fault Detector FD

3.3.3.1 Function Block



3.3.3.2 Signals

Table 3.3.2 FD Input Signals

NO.	Signal	Description
1	I3P	Three-phase current input
2	U3P	Three-phase voltage input
3	Start	Other protection start signal

Table 3.3.3 FD Output Signals

NO.	Signal	Description
1	Pkp	The device picks up

NO.	Signal	Description
2	SupCurPkp	Superimposed current fault detector element operates
3	ResCurPkp	Residual current fault detector element operates
4	NegCurPkp	Negative-sequence current fault detector element operates

3.3.3.3 Fault Detector Based on Superimposed Current

Superimposed phase current is obtained by subtracting the phase current from that of acycle before.

$$\Delta I = I(k) - I(k - N)$$

I(k) is the sampling value at a point.

I(k-N)is the value of a sampling point before a cycle.

Operation criteria:

$$\Delta I_{\Phi} = 1.25\Delta I_{Th} + \Delta I_{Set}$$

Where:

ΔI_{Φ}: Superimposed phase current (Φ=A, B, C)

ΔI_{set}: The fixed threshold value (i.e. the setting FD_X_SupCur_Str)

ΔI_{Th}: The floating threshold value

This element adopts adaptive floating threshold varied with the change of load current continuously. The change of load current is small and steadily under normal or power swing condition, the adaptive floating threshold with the ΔI_{Set} is higher than the change of current under these conditions and hence maintains the element stability.

The coefficient 1.25 is an empirical value which ensures the threshold always higher than the unbalance output value of the system.

If operation condition is met, the fault detector based on superimposed current will operate to provide DC power supply for output relays, the pickup signal will maintain 7s after the fault detector based on superimposed current drops off.

3.3.3.4 Fault Detector Based on Residual Current

In case of long distance fault or big resistance fault, superimposed current is relative small, so, residual current is used to judge pickup condition.

The operation condition will be met when 3I0 is greater than the setting FD_X_ResCur_Str. The fault detector based on residual current is always in service.

Where:

3I0: residual current calculates from the vector sum of Ia, Ib and Ic

If operation condition is met, the fault detector based on residual current will operate to provide DC power supply for output relay, and the pickup signal will maintain 7s after the fault detector based on residual current drops off.

3.3.3.5 Fault Detector Based on Negative-sequence Current

The operation condition will be met when I2 is greater than the setting FD_X_NegCur_Str. It can be enabled or disabled by the logic setting FD_X_Neg_Ena.

Where:

I2: negative-sequence current calculates from the vector of Ia, Ib and Ic

If operation condition is met, the fault detector based on negative-sequence current will operate to provide DC power supply for output relay, and the pickup signal will maintain 7s after the fault detector based on negative-sequence current drops off.

3.3.3.6 Logic

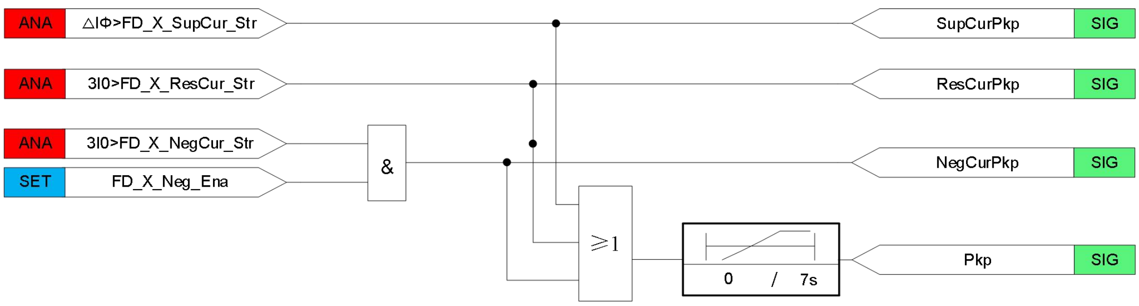


Figure 3.3.1 Logic Diagram for Fault Detector

3.3.3.7 Settings

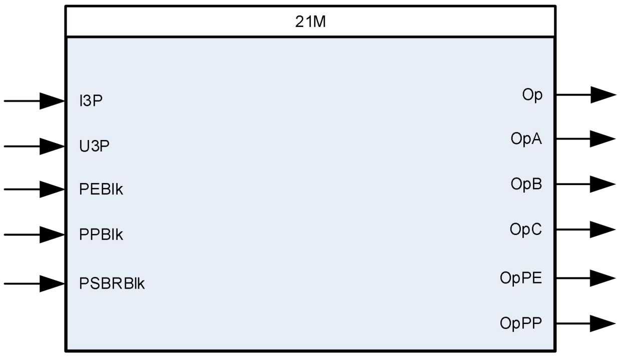
Table 3.3.4 Settings of fault detector

No.	Name	Range	Unit	Step	Default	Description
1	FD_X_Neg_Ena	0 or 1	-	1	0	X-side(X=H,M) Enabling/disabling negative-sequencecurrent fault detector element 0: disable 1: enable
2	FD_X_SupCur_Str	(0.04~0.5) ×In	A	0.01	0.5	X-side(X=H,M) Current setting of superimposed current fault detector element
3	FD_X_ResCur_Str	(0.04~30.00) ×In	A	0.01	0.5	X-side(X=H,M) Current setting of residual current fault detector element

No.	Name	Range	Unit	Step	Default	Description
4	FD_X_NegCur_Str	(0.04~30.00) ×In	A	0.01	0.5	X-side(X=H,M) Current setting of negative-sequence current fault detector element

3.3.4 Mho Distance Protection 21M

3.3.4.1 Function Block



3.3.4.2 Signals

Table 3.3.5 21M Input Signals

NO.	Signal	Description
1	I3P	Three-phase current input
2	U3P	Three-phase voltage input
3	PEBlk	Block signal of phase-to-earth 21M
4	PPBlk	Block signal of phase-to-phase 21M
5	PSBRBlk	Blocking power swing blocking releasing of 21M

Table 3.3.6 21M Output Signals

NO.	Signal	Description
1	Op	Operation signal
2	OpA	Operation signal from phase A
3	OpB	Operation signal from phase B
4	OpC	Operation signal from phase C
5	OpPE	Operation signal from phase-to-earth fault
6	OpPP	Operation signal from phase-to-phase fault

3.3.4.3 Protection Principle

1. Phase-to-phase distance element

Phase-to-phase positive sequence voltage is used as polarized signal for phase-to-phase distance protection.

Operation voltage:

$$\dot{U}_{op\phi\phi} = \dot{U}_{\phi\phi} - \dot{I}_{\phi\phi} \times Z_{ZD} \quad \phi\phi = AB, BC, CA$$

Polarized voltage:

$$\dot{U}_{p\phi\phi} = \dot{U}_{1\phi\phi} \angle\theta$$

Where:

Z_{ZD}: the impedance setting zone x of phase-to-phase distance protection, set by the setting 21Mx_X_PP_Imp_Op(x=1, 2, 3, 4 ; X=H,M)

$U_{\Phi\Phi}$ is the phase-to-phase voltage

$U_{1\Phi\Phi}$ is the positive sequence voltage

$I_{\Phi\Phi}$ is the phase-to-phase current

Phase comparison equation is:

$$270° > \arg\frac{\dot{U}_{p\phi\phi}}{\dot{U}_{op\phi\phi}} > 90°$$

In short line, phase shift θ could be applied to the polarized voltage to improve the performance against high resistance fault. The device provides an angle-shift setting, 21Mx_X_PP_Phi_Shift(x=1, 2, 3, 4 ; X=H,M), to set value of θ among 0°, 15° and 30°

For the three-phase close up short-circuit fault, the positive sequence voltage is lower, and the memorized positive sequence voltage is used.When the memory fades out, the operation characteristic will be reverse offset a little to enclose the origin to ensure keeping operating of distance protection until the fault being cleared. The phase comparison equation is:

$$270° > \arg\frac{\dot{U}_{\phi\phi} + 0.1 \times \dot{I}_{\phi\phi} \times Z_{ZD}}{\dot{U}_{\phi\phi} - \dot{I}_{\phi\phi} \times Z_{ZD}} > 90°$$

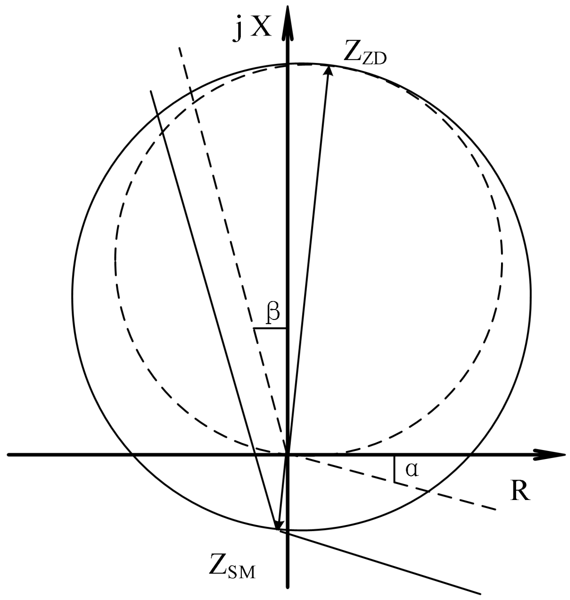


Figure 3.3.2 Phase-to-phase operation characteristic of mho distance protection

2. Phase-to- earth distance element

Operation criteria:

$$270° > \arg\frac{\dot{U}_{1\phi}\angle\theta}{\dot{U}_{\phi} - \left(\dot{I}_{\phi} + k \times 3\dot{I}0\right) \times Z_{ZD}} > 90° \quad \phi = A, B, C$$

Where:

Z_{ZD}: the impedance setting zone x of phase-to-ground distance protection, set by the setting 21Mx_X_PE_Imp_Op(x=1, 2, 3, 4; X=H,M),U_{Φ} is the phase voltage

$I_{\Phi}$is the phase current

$U_{1\Phi}$is the positive sequence voltage

3I0 is the zero-sequence current

K is zero-sequence compensation coefficient

In short line, phase shift θ could be applied to the polarized voltage to improve the performance against high resistance fault. The device provides an angle-shift setting, 21Mx_PE_Phi_Shift, to set value of θ among 0°, 15° and 30°

To improve the operation characteristics of phase-to-ground distance element so as to allow them to cover ground fault with high resistance. without overreach, the device adopts zero sequence reactance relays to further solve the problem of overreach operation of phase-to-ground distance element. The operation criterion of zero sequence reactance relays is:

$$360° > \arg\frac{\dot{U}_{\phi} - \left(\dot{I}_{\phi} + k \times 3\dot{I}0\right) \times Z_{ZD}}{\left(\dot{I}_{\phi} + k \times 3\dot{I}0\right)\angle - \beta} > 180°$$

Where:

β: the angle of zero sequence compensation reactance, set by 21Mx_X_X0Comp_Ang.(x=1, 2, 3, 4 ; X=H,M)

The operation characteristics of above equation on impedance planes are a straight line at the set impedance vector end, shown as figure 3.3.3. In the operation criterion of zero sequence reactance relays, i_0 phase moves backward for β degree to appropriately limit its operation area to improve safety.

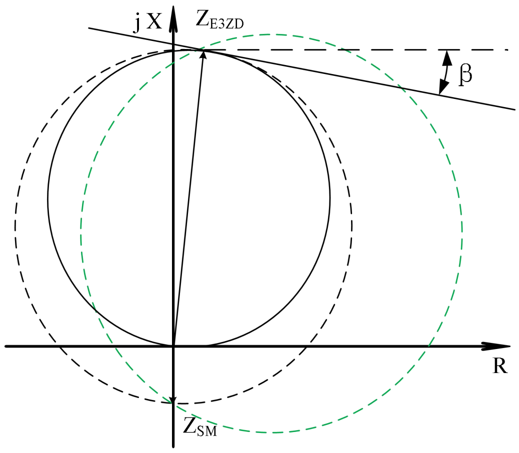


Figure 3.3.3Phase-to-ground operation characteristic of mho distance protection

3.3.4.4 Logic

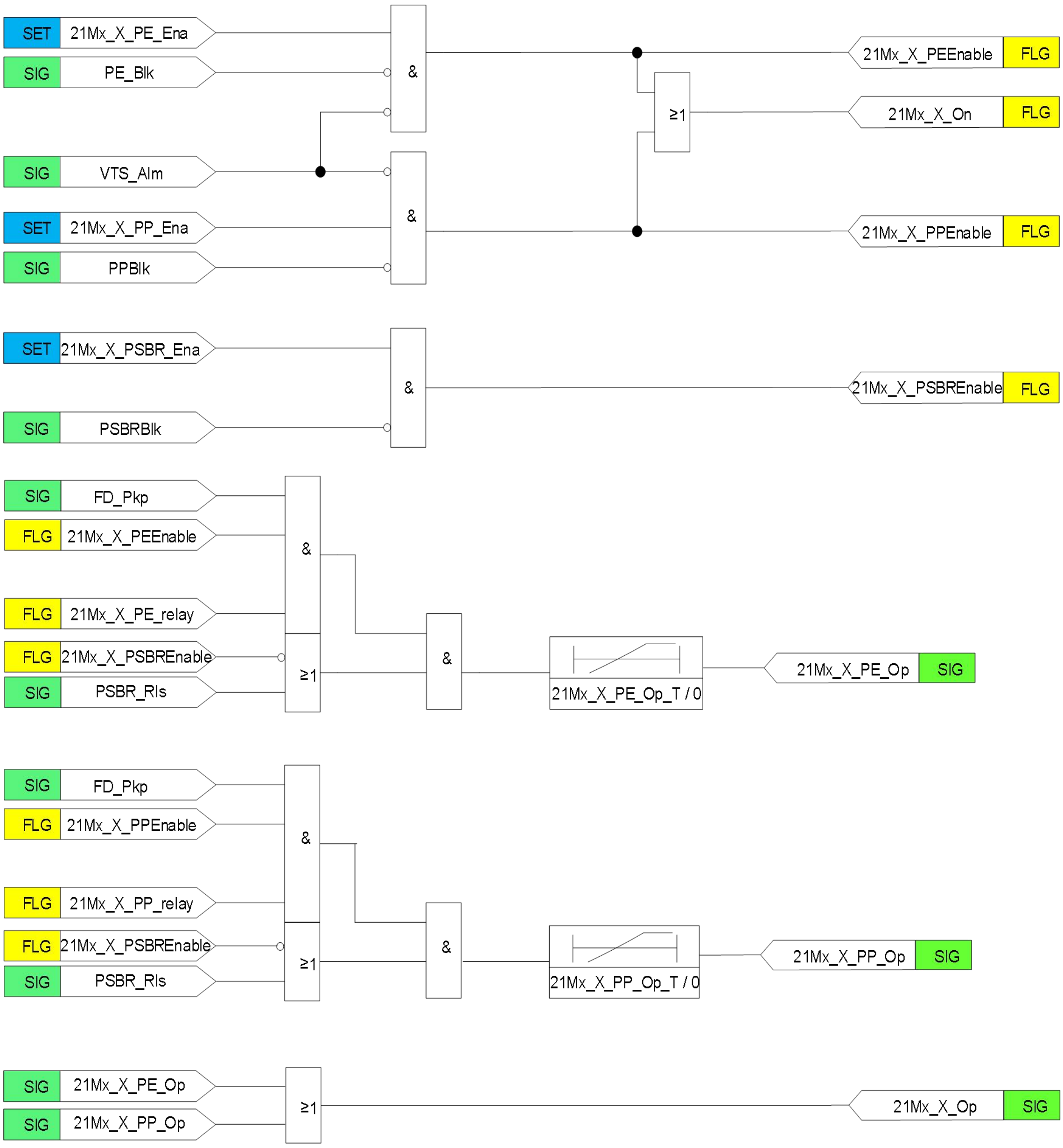


Figure 3.3.2 Logic diagram of distance protection (Mho zone x)

Where:

x=1,2,3,4

21Mx_X_PE_relay means that measured impedance by zone x of X-side phase-to-earth distance protection is within the range determined by the setting 21Mx_X_PE_Imp_Op.

21Mx_X_PP_relay means that measured impedance by zone x of X-side phase-to-phase distance protection is within the range determined by the setting 21Mx_X_PP_Imp_Op.

3.3.4.5 Settings

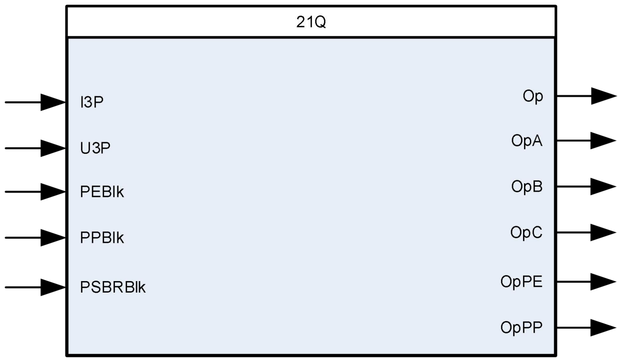
Table 3.3.7 21M Settings

NO	Name	Range	Unit	Step	Default	Description
1	21Mx_X_Dir_Mod	0 or 1	-	1	0	Direction option for zone x of X-side distance protection (x=1,2, 3, 4; X=H,M) 0: Forward 1: Reverse
2	21Mx_X_PE_Ena	0 or 1	-	1	0	Enabling/disabling zone x of X-side phase-to-earth distance protection (x=1, 2, 3, 4; X=H,M) 0: disable 1: enable
3	21Mx_X_PP_Ena	0 or 1	-	1	0	Enabling/disabling zone x of X-side phase-to-phase distance protection (x=1, 2, 3, 4; X=H,M) 0: disable 1: enable
4	21Mx_X_PSBR_Ena	0 or 1	-	1	0	Enabling/disabling zone x of X-side distance protection controlled by PSBR (x=1, 2, 3, 4; X=H,M) 0: disable 1: enable
5	21Mx_X_PE_Phi_Shift	0, 15 or 30	deg	15	0	Phase shift of X-side phase-to-earth distance protection for zone x (x=1, 2, 3, 4; X=H,M)
6	21Mx_X_X0Comp_Ang	0~30	deg	0.01	12	Zero sequence reactance compensation angle for zone x of X-side distance protection(x=1, 2, 3, 4; X=H,M)
7	21Mx_X_PE_Imp_Op	(0.05~500)/In	ohm	0.01	8	Impedance setting of zone x of X-side phase-to-earth distance protection (x=1, 2, 3, 4; X=H,M)
8	21Mx_X_PE_Op_T	0.000~10.000	s	0.001	10	Time delay of zone x of X-side phase-to-earth distance protection (x=1, 2, 3, 4; X=H,M)
9	21Mx_X_PP_Phi_Shift	0, 15 or 30	deg	15	0	Phase shift of X-side phase-to-phase distance protection for zone x (x=1, 2, 3, 4; X=H,M)
10	21Mx_X_PP_Imp_Op	(0.05~500)/In	ohm	0.01	8	Impedance setting of zone x of X-side phase-to-phase distance protection (x=1, 2, 3, 4; X=H,M)

NO	Name	Range	Unit	Step	Default	Description
11	21Mx_X_PP_Op_T	0.000~10.000	s	0.001	10	Time delay of zone x of X-side phase-to-phase distance protection (x=1, 2, 3, 4; X=H,M)

3.3.5 Quadrilateral Distance Protection 21Q

3.3.5.1 Function Block



3.3.5.2 Signals

Table 3.3.8 21Q Input Signals

NO.	Signal	Description
1	I3P	Three-phase current input
2	U3P	Three-phase voltage input
3	PEBlk	Block signal of phase-to-earth 21Q protection
4	PPBlk	Block signal of phase-to-phase 21Q protection
5	PSBRBlk	Blocking power swing blocking releasing of 21Q protection

Table 3.3.9 1Q Output Signals

NO.	Signal	Description
1	Op	Operation signal from 21Q protection
2	OpA	Operation signal from phase A
3	OpB	Operation signal from phase B
4	OpC	Operation signal from phase C
5	OpPE	Operation signal from phase-to-earth 21Q protection
6	OpPP	Operation signal from phase-to-phase 21Q protection

3.3.5.3 Protection Principle

Features available with quadrilateral distance protection include 4 settable forward or reverse zones phase-to-ground or phase-to-phase distance element. Each zone can respectively enable or disable power swing blocking releasing.

1) The reactance line element

Operation criteria:

phase-to-ground:

$$180° < \arg\frac{\dot{U}_{\phi} - \left(\dot{I}_{\phi} + k \times 3\dot{I}0\right) \times Z_{ZD}}{\left(\dot{I}_{\phi} + k \times 3\dot{I}0\right) \angle - \delta} < 360° \quad \phi = A, B, C$$

phase-to-phase:

$$180° < \arg\frac{\dot{U}_{\phi\phi} - \dot{I}_{\phi\phi} \times Z_{ZD}}{\dot{I}_{\phi\phi} \angle - \delta} < 360° \quad \phi\phi = AB, BC, CA$$

Where:

Z_{ZD}: the impedance setting zone x of quadrilateral distance protection, set by the setting 21Qx_X_PE_Imp_Op or 21Qx_X_PP_Imp_Op(x=1, 2, 3, 4;X=H,M)

$U_{\Phi\Phi}$ is the phase-to-phase voltage

$I_{\Phi\Phi}$ is the phase-to-phase current

U_{Φ} is the phase voltage

I_{Φ} is the phase current

3I0 is the zero-sequence current

K is zero-sequence compensation coefficient

δ: the angle of zero sequence compensation reactance, set by 21Qx_X_X0Comp_Ang.

2) The directional line element

Operation criteria:

phase-to-ground:

$$-\alpha < \arg\frac{\dot{U}_{p\phi}}{\dot{I}_{\phi}} < 90° + \beta$$

phase-to-phase:

$$-\alpha < \arg\frac{\dot{U}_{p\phi\phi}}{\dot{I}_{\phi\phi}} < 90° + \beta$$

Where:

$\dot{U}_{p\phi\phi}$ is the phase-to-phase polarized voltage

$\dot{U}_{p\phi}$ is the phase polarized voltage

α: the angle of directional line, set by the setting 21Qx_X_Ang_Alpha(x=1, 2, 3, 4;X=H,M)

β: the angle of directional line, set by the setting 21Qx_X_Ang_Beta(x=1, 2, 3, 4;X=H,M)

3) The resistance line element

Operation criteria:

phase-to-ground:

$$\varphi < \arg\frac{\dot{U}_{\phi} - (\dot{I}_{\phi} + k \times 3\dot{I}0) \times R_{ZD}}{(\dot{I}_{\phi} + k \times 3\dot{I}0)} < 180° + \varphi$$

phase-to- phase:

$$\varphi < \arg\frac{\dot{U}_{\phi\phi} - \dot{I}_{\phi\phi} \times R_{ZD}}{\dot{I}_{\phi\phi}} < 180° + \varphi$$

Where:

R_{ZD}: the resistance setting zone x of quadrilateral distance protection, set by the setting 21Qx_X_PE_R_Op or 21Qx_X_PP_R_Op(x=1, 2, 3, 4;X=H,M)

φ: line positive-sequence characteristic angle

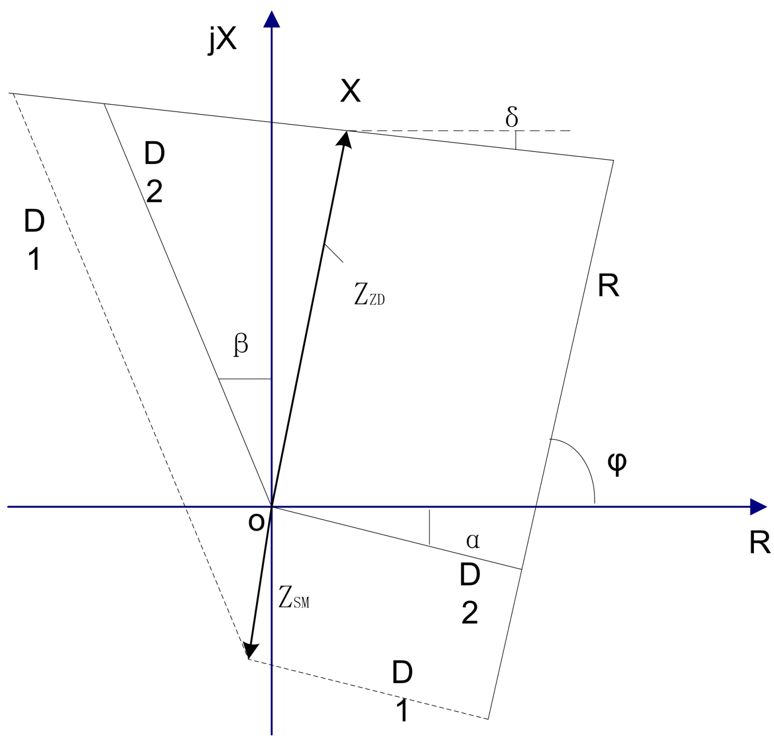


Figure 3.3.5 Impedance characteristic of quadrilateral distance protection

In the figure 3.3.5,the X element completes the fault location,adopt the reactance line element, characteristic is like X line, downward offset angle of the R axis; the D element completes the direction judgment,adopt the directional line element, characteristic is like D broken line; the R element reflect high-impedance-grounded faults,adopt the resistance line element, characteristic is like R line.

3.3.5.4 Logic

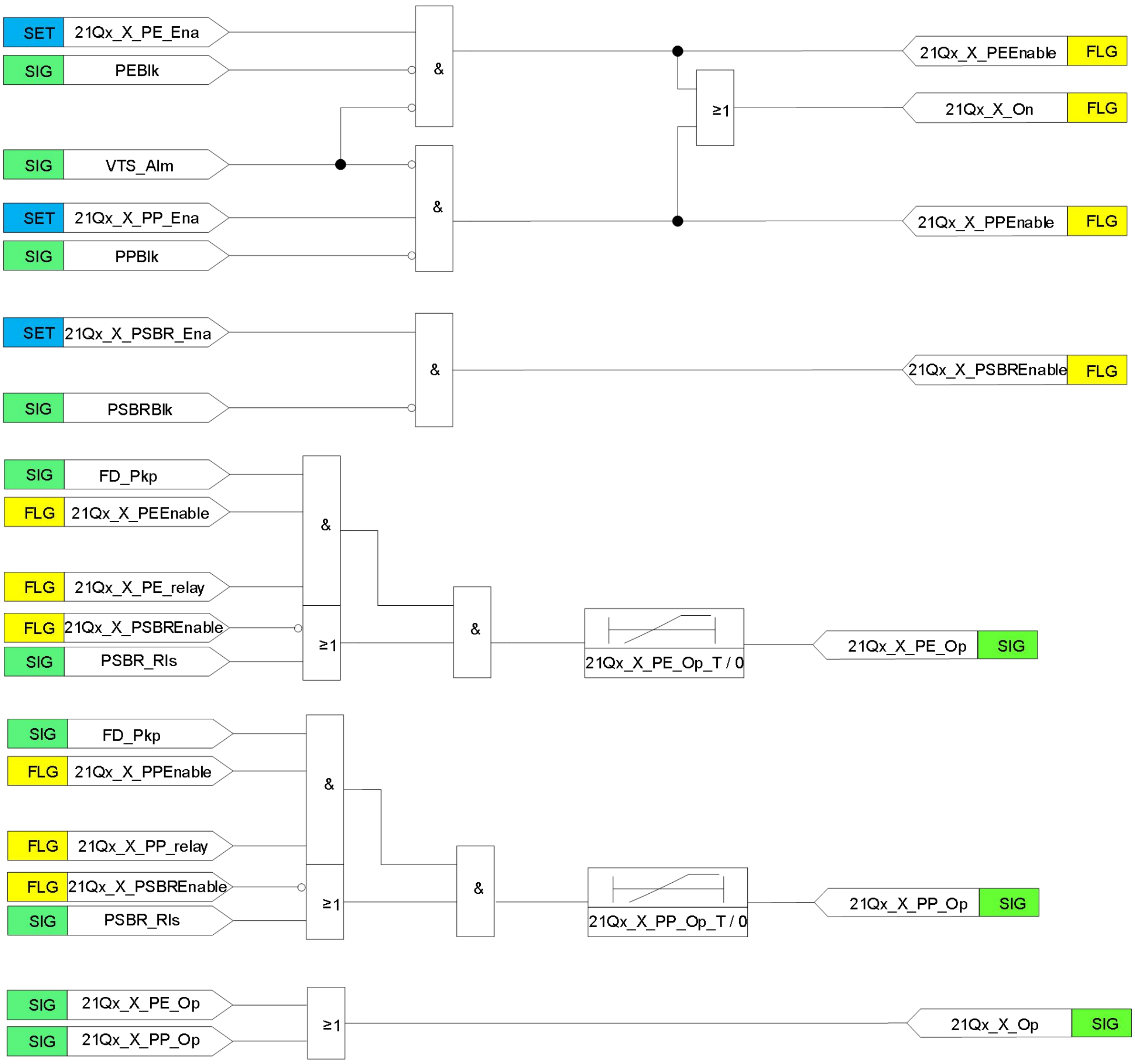


Figure 3.3.6 Logic diagram of distance protection (Quad zone x)

Where:

x=1,2,3,4

21Qx_X_PE_relay means that measured impedance by zone x of X-side phase-to-earth distance protection is within the range determined by the setting 21Qx_X_PE_Imp_Op and 21Qx_X_PE_R_Op.

21Qx_X_PP_relay means that measured impedance by zone x of X-side phase-to-phase distance protection is within the range determined by the setting 21Qx_X_PP_Imp_Op and 21Qx_X_PP_R_Op.

3.3.5.5 Settings

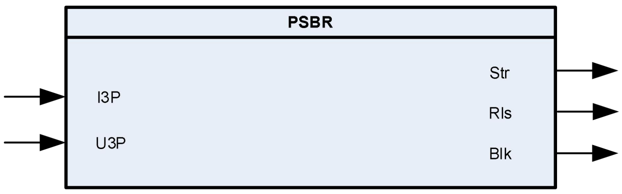
Table 3.3.10 21Q Settings

NO	Name	Range	Unit	Step	Default	Description
1	21Qx_X_Dir_Mod	0 or 1	-	1	0	Direction option for zone x of X-side distance protection (x=1,2, 3, 4;X=H,M) 0: Forward 1: Reverse
2	21Qx_X_PE_Ena	0 or 1	-	1	0	Enabling/disabling zone x of X-side phase-to-earth distance protection (x=1,2, 3, 4;X=H,M) 0: disable 1: enable
3	21Qx_X_PP_Ena	0 or 1	-	1	0	Enabling/disabling zone x of X-side phase-to-phase distance protection (x=1,2, 3, 4;X=H,M) 0: disable 1: enable
4	21Qx_X_PSBR_Ena	0 or 1	-	1	0	Enabling/disabling zone x of X-side distance protection controlled by PSBR (x=1,2, 3, 4;X=H,M) 0: disable 1: enable
5	21Qx_X_Ang_Alpha	5~45	deg	0.01	25	Angle of blinder in fourth quadrant for forward direction
6	21Qx_X_Ang_Beta	0~85	deg	0.01	30	Angle of blinder in second quadrant for forward direction
7	21Qx_X_X0Comp_Ang	0~30	deg	0.01	12	Zero sequence reactance compensation angle
8	21Qx_X_PE_Imp_Op	(0.05~500)/In	ohm	0.01	8	Impedance setting of zone x of X-side phase-to-earth distance protection (x=1,2, 3, 4;X=H,M)
9	21Qx_X_PE_R_Op	(0.05~500)/In	ohm	0.01	20	Resistance setting of zone x of X-side phase-to-earth distance protection (x=1,2, 3, 4;X=H,M)
10	21Qx_X_PE_Op_T	0.000~10.000	s	0.001	10	Time delay of zone x of X-side phase-to-earth distance protection (x=1,2, 3, 4;X=H,M)

NO	Name	Range	Unit	Step	Default	Description
11	21Qx_X_PP_Imp_Op	(0.05~500)/In	ohm	0.01	8	Impedance setting of zone x of X-side phase-to-phase distance protection (x=1,2, 3, 4;X=H,M)
12	21Qx_X_PP_R_Op	(0.05~500)/In	ohm	0.01	20	Resistance setting of zone x of X-side phase-to-phase distance protection (x=1,2, 3, 4;X=H,M)
13	21Qx_X_PP_Op_T	0.000~10.000	s	0.001	10	Time delay of zone x of X-side phase-to-phase distance protection (x=1,2, 3, 4;X=H,M)

3.3.6 Power Swing Blocking Releasing PSBR

3.3.6.1 Function Block



3.3.6.2 Signals

Table 3.3.11 PSBR Input Signals

NO.	Signal	Description
1	I3P	Three-phase current input
2	U3P	Three-phase voltage input

Table 3.3.12 PSBR Output Signals

NO.	Signal	Description
1	Str	Start signal from PSBR
2	Rls	PSBR operates to release distance protection
3	Blk	Block signal from PSBR

3.3.6.3 Protection Principle

When power swing occurs on the power system, the impedance measured by the distance measuring element may vary from the load impedance area into the operating zone of the distance element. The distance measuring element may operate due to the power swing occurs in many points of interconnected power systems. To keep the stability of whole power system, tripping due to operation of the distance measuring element during a power swing is generally not allowed. Our distance protection adopts power swing blocking releasing to avoid maloperation resulting from power swing. In another word, distance protection is blocked all along under the normal condition and power swing when the respective logic settings are enabled. Only when fault (internal fault or power swing with internal fault) is detected, power swing blocking for distance protection is released by PSBR element.

Power swing blocking for distance element will be released if any of the following PSBR elements operates. Each distance zone elements has respective setting for selection this function.

1) Swing detector element (SD)

2) Unsymmetrical fault PSBR element (UF PSBR)

3) Symmetrical fault PSBR element (SF PSBR)

1. Swing detector element

If the device picked up before swing condition is met, PSBR will operate for 160ms.

This detection is based on measuring the voltage at power swing center, during power swing, swing condition is shown as below:

$$\begin{cases} -0.7U_N < U_{OS} < 0.7U_N \\ \Delta U_{OS} > 1V \\ U_1 > 18V \ \& \ U_2 < 3V \ \& \ 3U_0 < 8V \\ 3I_0 < I\_Line \ \& \ I_1 > \mathrm{PSBR.I} \end{cases}$$

If operation condition is met, the swing detector will operate.

2. Unsymmetrical fault PSBR element

The operation criterion:

I0+I2>m×I1

The “m”, an empirical value, is internal fixed coefficient which can ensure operation during power swing with internal unsymmetrical fault, while no operation during power swing.

3. Symmetrical fault PSBR element

This detection is based on measuring the voltage at power swing center, during power swing, U1cosΦ will constantly change periodically.

$$U_{OS}=U1\times COS\Phi$$

Where:

Φ: the angle between positive sequence voltage and current

U1: the positive sequence voltage

1) Releasing element 1

During power swing, power swing center voltage U1cosΦ has the following characteristics: When electric potential phase angle difference between power supplies at two sides is 180o, U1cosΦ＝0 and change rate dU1cosΦ/dt is the maximum. When this phase angle difference is near 0, power swing center voltage change rate dU1cosΦ/dt is the minimum. During short circuit, U1cosΦ remains unchanged and dU1cosΦ/dt＝0.

2) Releasing element 2

For these reasons, the method to release distance protection on condition that power swing center voltage U1cosΦ is less than a setting and after a short delay can be used as symmetric fault discriminating element. This element can accurately differentiate power swing and 3-phase short circuit fault, and constitute a complete power swing blocking scheme with other elements. The element to open distance protection if U1cosΦ is less than a certain setting and after a delay is easy to realize and has short delay, and can trip fault more quickly and accurately trip 3-phase short circuit fault during power swing.

- when -0.03UN<UOS<0.08UN, the SF PSBR element will operate after 150ms.
- when -0.1UN<UOS<0.25UN, the SF PSBR element will operate after 500ms.

3) Releasing element 3

To reduce the time delay for SF PSBR element during power swing, the change rate of voltage at power swing center is also used which can release SF PSBR element quickly for the fault occurred during power swing. The typical release time is less than 60ms.

3.3.6.4 Logic

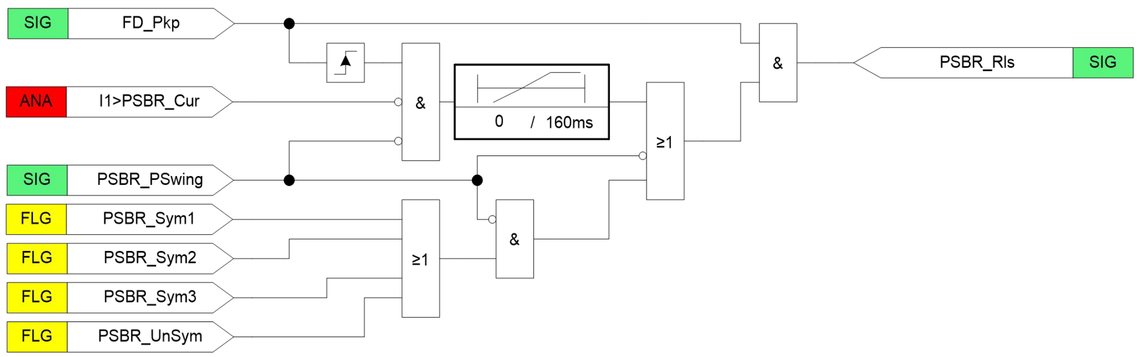


Figure 3.3.7 Logic diagram of PSBR

3.3.6.5 Settings

Table 3.3.13 Settings of PSBR

No.	Name	Range	Unit	Step	Default	Description
1	PSBR_Cur_X	(0.05~30.00) ×In	A	0.01	20	Current setting for X-side power swing blocking

3.4 Directional Over current Protection (67P/50/51)

3.4.1 Overview

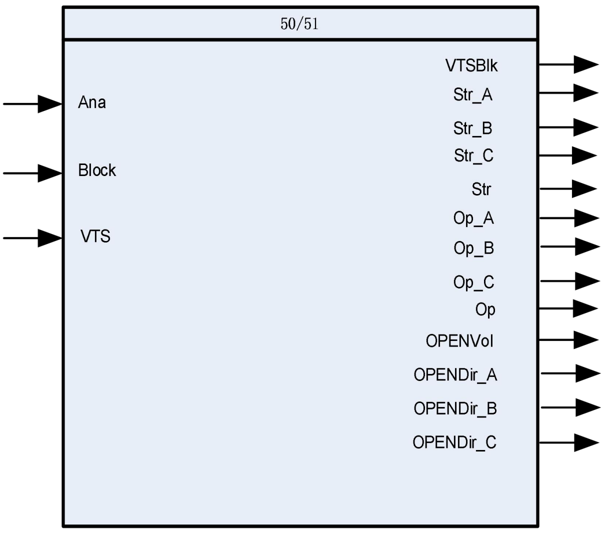
The main and important function of Four stage phase overcurrent protection OC4_PTOC (50/51) is to continuously track the electrical power system current. For the point of view of continuously power supply and minimum damage during fault condition (at the time of fault the normal current value is increases suddenly and this current is too harmful for primary equipment's). If the detected or measured current value is greater than the set level, the Four stage phase overcurrent protection OC4_PTOC (50/51) will operates or gives alarm signal with dependable four stage definite time delay (DT) or inverse definite minimum time (IDMT) delay characteristics and each stage have same logic of operation settings.

Notice!

In case of both side feed transmission lines or ring power system the Phase overcurrent protection ensure the more sensitive and precise operation with directional element. Direction element define the operating angle (direction) range.

In addition, the 50/51 can be configured on the high-voltage side, middle-voltage side or low-voltage side of the transformer as a backup protection for each side.

3.4.1.1 Function Block



3.4.1.2 Signals

Table 3.4.1 50/51 Input Signals

NO.	Signal	Description
1	Ana	the three phase current and voltage
2	Block	Block signal of 50/51 protection
3	VTS	Block signal from VTS Alarm

Table 3.4.2 50/51 Output Signals

NO.	Signal	Description
1	VTSBlk	Block signal of VTS
2	Str_A	Start signal of phase A
3	Str_B	Start signal of phase B
4	Str_C	Start signal of phase C
5	Str	Common start signal
6	Op_A	Trip signal of phase A
7	Op_B	Trip signal of phase B
8	Op_C	Trip signal of phase C
9	Op	Trip signal of 50/51 protection
10	OPENVol	Voltage open signal
11	OPENDir_A	Directional open signal of phase A
12	OPENDir_B	Directional open signal of phase B
13	OPENDir_C	Directional open signal of phase C

3.4.2 Protection Principle

Phase over current protection has following functions:

1) Four-stage phase over current protection with independent logic, current and time delay settings.

2) Four-stage can be selected as definite-time or inverse-time characteristic. The inverse-time characteristic is select able among IEC standard inverse-time characteristics.

3) Direction control element can be selected to control each stage phase over current protection with three options: no direction, forward direction and reverse direction

3.4.2.1 Phase Over current Start Element

The start criterion for each stage of over current element is:

$$I_{\varphi} > \min\{Kret * 50/51\_x\_X\_Cur\_Str, 1.2In\}$$

Where:

I_{φ} is measured phase current.

K_{ret} is the Reliability coefficient of constant current.

50/51_x_X_Cur_Str is the current setting of stage x (x=1, 2, 3, or 4) of X-side overcurrent element(X=H,M,L1,L2,LT) .

The actual normal operation of the transformer current will not exceed the rated current Ie, in order to distinguish the transformer operation abnormal and normal state, is the protection can quickly enter the protection logic operation, start setting the minimum threshold of 1.2 In.

3.4.2.2 Phase Over current Element

The operation criterion for each stage of over current element is:

$$I_{\varphi} > 50/51\_x\_X\_Cur\_Str$$

The measured current values are compared to the set operation current value of the function (50/51_x_X_Cur_Str). If the measured value exceeds the set 50/51_x_X_Cur_Str, the level detector reports the exceeding of the value to the phase selection logic.

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the 50/51_x_X_Str_Ph_Num setting, the phase selection logic activates the output signal of 50/51_x_X_Op_n (n=A,B,C).

3.4.2.3 Direction Control Element

The directional operation can be selected with the 50/51_x_X_Dir_Mod setting. The user can select either "(Non-Dir)", "(Forward)" or "(Reverse)" operation. By setting the value of 50/51_x_X_Dir_Mod to "0", the non-directional operation is allowed when the directional information is invalid.

The 50/51_x_X_ANC_RCA setting is used to turn the directional characteristic. The value of 50/51_x_X_ANC_RCA should be chosen in such a way that all the faults in the operating direction are seen in the operating zone and all the faults in the opposite direction are seen in the non-operating zone. The value of Characteristic angle depends on the network configuration

The cross-polarizing quantity is used to determine the fault direction(Ia→Ubc/Ib→Uca/Ic→Uab). The evaluation of the forward directionality is according to the equation:

$$-90^\circ(+5^\circ) < \arg \frac{\dot{I}_r e^{j(RCA-90^\circ)}}{\dot{U}_r} < 90^\circ(-5^\circ)$$

Also, it can be calculated by following equation:

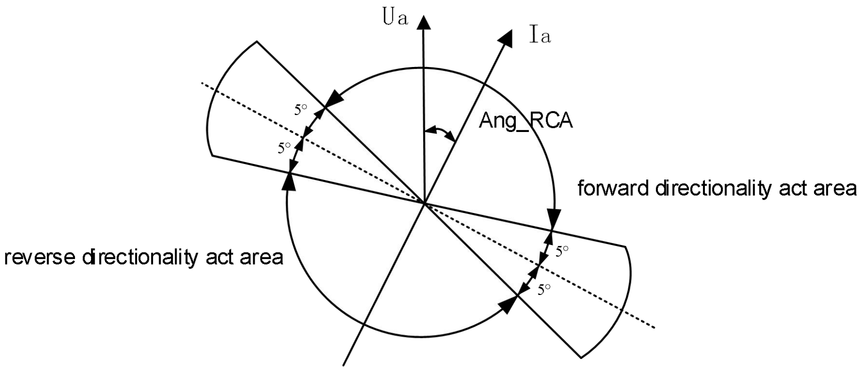
-90° (+5°)< angle(Ir) + RCA - 90° - angle(Ur)< 90° (-5°)

The evaluation of the backward directionality is according to the equation:

$$90^\circ(+5^\circ) < \arg \frac{\dot{I}_r e^{j(RCA-90^\circ)}}{\dot{U}_r} < 270^\circ(-5^\circ)$$

Also, it can be calculated by following equation:

90° (+5°)< angle(Ir) + RCA - 90° - angle(Ur)< 270° (-5°)



±5° is the max angle margin.I_r and U_r are the polarizing current and voltage. RCA is the Relay characteristic angle.

The polarized voltage is available as long as the phase-phase voltage exceeds 12V.If the phase-phase voltage reduces to less than 12V, the device uses memory voltage as polarized voltage.

If the polarized voltage is invalid, the direction element endures until the phase current decreases below the I_LINE(0.05In).

Table 3.4.3 Direction description

Direction	Current	Polarized Voltage
Phase A	Ia	Ubc
Phase B	Ib	Uca
Phase C	Ic	Uab
Phase A - B	Ia - Ib	Ubc - Uca
Phase B - C	Ib - Ic	Uca - Uab
Phase C - A	Ic - Ia	Uab - Ubc

3.4.2.4 Second harmonic detecting element

For harmonic detecting element, the harmonic blocking mode can be selected through the setting 50/51_x_X_Hm2_Mod, it can support phase blocking, cross blocking, and maximum phase blocking. The corresponding relationship is shown in the following table.

Table 3.4.4Harmonic detecting element description

Harmonic blocking mode		Harmonic blocking criterion		
		Phase A	Phase B	Phase C
1	Phase blocking	Ia2nd /Ia1st>	Ib2nd /Ib1st>	Ic2nd /Ic1st>
2	Cross blocking	(Ia2nd /Ia1st >) or (Ib2nd/Ib1st >) or (Ic2nd /Ic1st>)		
3	Maximum phase blocking	Max(Ia2nd,Ib2nd, Ic2nd)/Ia1st>	Max(Ia2nd ,Ib2nd, Ic2nd)/Ib1st>	Max(Ia2nd ,Ib2nd, Ic2nd)/Ic1st>

When the fundamental current is greater than the setting 50/51_x_X_Hm2_IRls, the corresponding phase will be unblocked by harmonic control element.The logic of harmonic control element is shown in Figure 3.4-1.

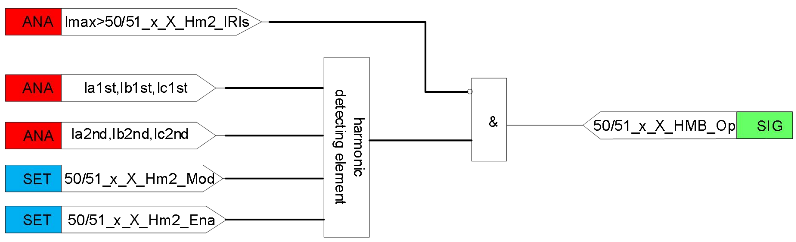


Figure 3.4.1 Logic Diagram for harmonic detecting element

Where:

Ia1st, Ib1st, Ic1st are the fundamental current.

Ia2nd, Ib2nd, Ic2nd are the secondary harmonic current.

Imax is the maximum phase current.

3.4.2.5 Characteristic Curve

All stages can be selected as definite-time or inverse-time characteristic.Inverse-time operating characteristic is as follows.

$$t = \left(\frac{k}{(I/I_p)^{\alpha} - 1} + C \right) \times T_p$$

Where:

I_p: Current setting 50/51_x_X_Cur_Str

T_p: Time multiplier setting 50/51_x_X_T_Mult .

α： A constant setting 50/51_x_X_Alpha.

k： A constant setting 50/51_x_X_K.

C： A constant setting 50/51_x_X_C .

I： Measured phase current.

Table 3.4.5 Inverse-time curve parameters

Curve_Type	Time Characteristic	K	α	C
0	Definite time	--	--	--
1	IEC Normal inverse	0.14	0.02	0
2	IEC Very inverse	13.5	1.0	0
3	IEC Extremely inverse	80.0	2.0	0
4	IEC Long-time inverse	120.0	1.0	0
5	User-defined time inverse	User-defined	User-defined	User-defined
6	IEC Short Time Inverse	0.05	0.04	0
7	ANSI Extremely Inverse	28.2	2	0.1217
8	ANSI Very Inverse	19.61	2	0.491
9	ANSI Normal Inverse	0.0086	0.02	0.0185
10	ANSI Moderately Inverse	0.0515	0.02	0.1140
11	ANSI Long Time Extremely Inverse	64.07	2	0.250
12	ANSI Long Time Very Inverse	28.55	2	0.712
13	ANSI Long Time Inverse	0.086	0.02	0.185

The timer model is determined by the setting 50/51_x_X_Op_Curve_Type. The details are as follows.

When the 50/51_x_X_Op_Curve_Type=0, the operation is activated after the operation timer has reached the value set by 50/51_x_X_Op_T. If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the operation will reset.

When the 50/51_x_X_Op_Curve_Type=1~5. the operation is activated after the operation timer has reached the value set by IDMT curve. However, 50/51_x_X_Min_Op_T defines the minimum desired operate time for IDMT.If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the operation will reset.

NOTICE!

The 50/51_x_X_Min_Op_T setting should be used with great care because the operation time is according to the IEC curve, but always at least the value of the 50/51_x_X_Min_Op_T setting.

3.4.3 Logic Diagram

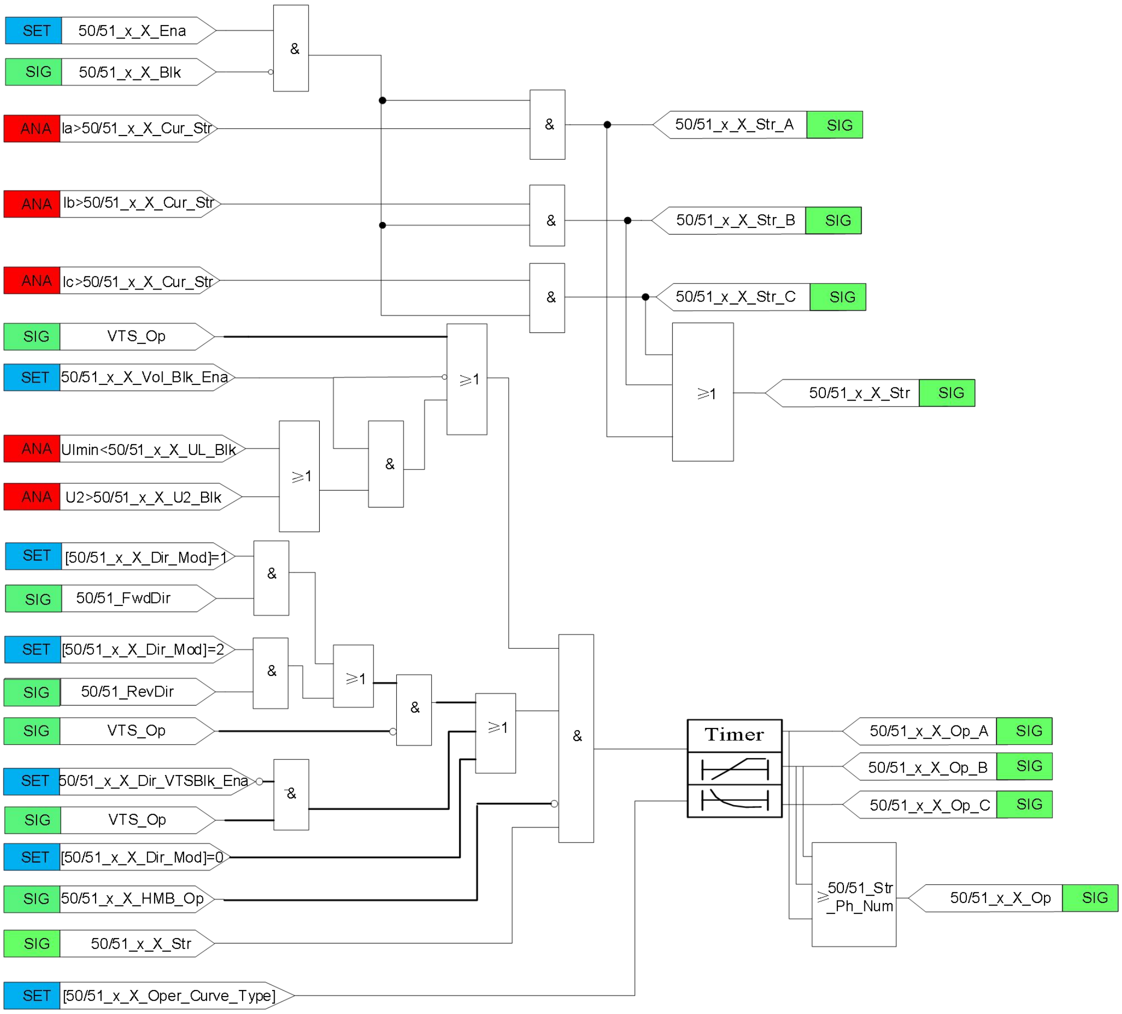


Figure 3.4.2 Logic Diagram for 50/51

3.4.4 Settings

Table 3.4.6 Settings of Four-stage directional over current protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	50/51_x_X_Cur_Str	0.02In~20In	A	0.01	20.00	X-side(X=H,M,L1,L2,LT) Operating phase current level for stage x(x=1,2,3,4)
2	50/51_x_X_Op_T	0.020~100.000	s	0.001	10.000	X-side(X=H,M,L1,L2,LT) Def time delay or add time delay for inverse char of stage x(x=1,2,3,4)
3	50/51_x_X_UL_Blk	0.00~100.00	V	0.01	70.00	X-side(X=H,M,L1,L2,LT) Stage x setting of blocking voltage(x=1,2,3,4)
4	50/51_x_X_U2_Blk	0.00~100.00	V	0.01	20.00	X-side(X=H,M,L1,L2,LT) Stage x setting of Negative voltage(x=1,2,3,4)

No.	Name	Values (Range)	Unit	Step	Default	Description
5	50/51_x_X_Str_Ph_Num	1 out of 3 2 out of 3 3 out of 3	-	1	3	Number of phases required for op (1 of 3, 2 of 3, 3 of 3)
6	50/51_x_X_Ang_RCA	0.0~360.0	Deg	0.1	270.0	Relay characteristic angle (RCA)
7	50/51_x_X_Dir_Mod.	0~2	-	1	0	Directional mode:0-2 for "Non-directional", "Forward" or "Reverse"
8	50/51_x_X_Dir_VTSBlk_Ena	0/1	-	1	0	Enabling/Disabling phase over current protection with direction control element is blocked by VT circuit failure when VT circuit supervision is enabled and VT circuit fails
9	50/51_x_X_K_Hm2	0.00~1.00	-	0.01	0.10	Coefficient of second harmonics for inrush current detection
10	50/51_x_X_Hm2_IRls	2.00~30.00	A	0.01	20.00	current setting for inrush current detection
11	50/51_x_X_Hm2_Mod	0~2	-	1	0	The option of harmonic blocking mode: 0:phase blocking 1:cross blocking 2: maximum phase blocking
12	50/51_x_X_Op_Curve_Type	0~13	-	1	0	Characteristic curve for 50/51. including Definite time, IEC and ANSI typical curve and user programmable curve. The detail is defined in Table 3.4.5 Inverse-time curve parameters.
13	50/51_x_X_T_Mult	0.050~200.000	-	0.001	10.000	Time multiplier for the inverse time delay for stage x(x=1,2,3,4) of X side(X=H,M,L1,L2,LT)
14	50/51_x_X_Min_Op_T	0.000~60.000	s	0.001	0.050	Minimum operate time for inverse curves for stage x(x=1,2,3,4) of X side(X=H,M,L1,L2,LT)
15	50/51_x_X_Alpha	0.00~3.00	-	0.01	1.00	X-side(X=H,M,L1,L2,LT) constant α of 50/51 Stage x(x=1,2,3,4)

No.	Name	Values (Range)	Unit	Step	Default	Description
16	50/51_x_X_C	0.000~10.000	-	0.001	0.000	X-side(X=H,M,L1,L2,LT) constant C of 50/51 Stage x(x=1,2,3,4)
17	50/51_x_X_K	0.001~100.000	-	0.001	1.000	X-side(X=H,M,L1,L2,LT) constant K of 50/51 Stage x(x=1,2,3,4)
18	50/51_x_X_CurMul	20~40.0	-	0.1	30	It is used to IDMT with I=CurMul*Ip.when I> CurMul *Ip, the IDMT time delay is calculated by CurMul . It is invalid if it is not configured or the CurMulEna is disabled.
19	50/51_x_X_CurMulEna	0 or 1	-	1	0	Enable: CurMul is effective. Disable: CurMul is ineffective
20	50/51_x_X_Hm2_Ena	0/1	-	1	0	Stage x Operation setting of X-side(X=H,M,L1,L2,LT) harmonic detecting element Enable/Disable(x=1,2,3,4)
21	50/51_x_X_H_SubIO_Ena	0/1	-	1	0	Whether the overcurrent needs to filter the zero sequence current Enable/Disable
22	50/51_x_X_Vol_Blk_Ena	0/1	-	1	0	Stage x Operation setting of X-side(X=H,M,L1,L2,LT) voltage Enable/Disable(x=1,2,3,4)
23	50/51_x_X_Ena	0/1	-	1	0	Operation 0/ 1

3.5 Thermal Overload Protection (49)

3.5.1 Overview

The relay incorporates a current based thermal calculation, using load current to model heating and cooling of the protected plant.The heat generated within an item of the plant, such as a cable or a transformer, is the resistive loss. Thus, heating is directly proportional to current squared. The thermal time characteristic used in the relay is therefore based on current squared, integrated over time. The relay automatically uses the largest phase current for input to the thermal calculation.

Equipment is designed to operate continuously at a temperature corresponding to its full load rating, where heat generated is balanced with heat dissipated by radiation etc.If the temperature of the protected object reaches the warning level, the alarm signal is given out. If the temperature continues to increase to the maximum allowed temperature value, the protection issues a trip signal to the protected line.

In addition, the 49 can be configured on the high-voltage side, middle-voltage side or low-voltage side of the transformer as a backup protection for each side.

3.5.1.1 Function Block

The function block of the protection is as below.

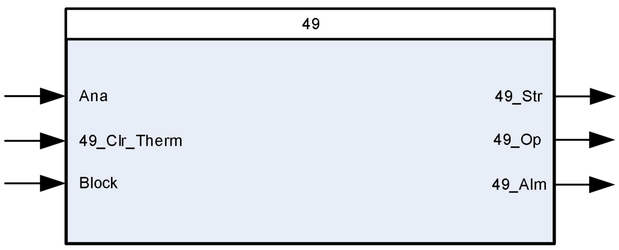


Figure 3.5.1 Function block

3.5.1.2 Signals

Table 3.5.1 VTS Input Signals

NO.	Signal	Description
1	Ana	The current in all the three phases
2	49_Clr_Therm	The input signal of clearing therm
3	49_Str	The start signal
4	49_Op	The operate signal
5	49_Alm	The alarm signal

3.5.2 Logic Diagram

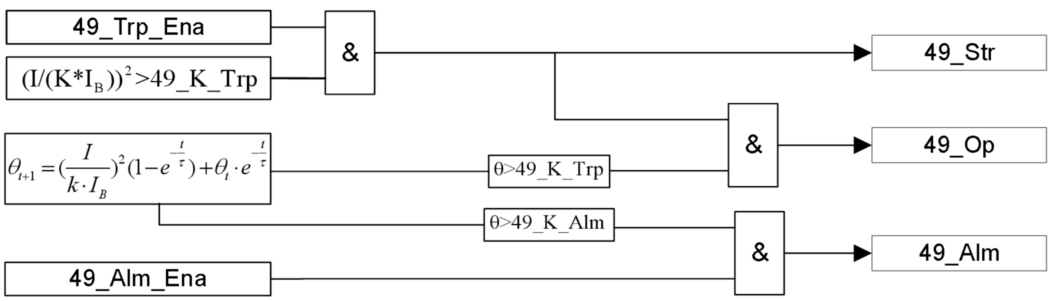


Figure 3.5.2 Functional module diagram

3.5.3 Protection Principle

The thermal overload protection function has two stages: one for alarm and two for tripping, which can be enabled or disabled by setting the corresponding 49_Alm_Ena and 49_Trp_Ena parameter values as "1" or "0".

The operation of three-phase thermal protection can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

The function continuously checks the highest measured phase current valueand reports the highest value to the temperature estimator.

The final temperature rise is calculated from the highest of the three-phase currents according to the expression(the 1st ~ 7th harmonics of the phase current is taken into account):

$$\theta_{t+1} = (\frac{I}{k \cdot I_B})^2 (1 - e^{-\frac{t}{\tau}}) + \theta_t \cdot e^{-\frac{t}{\tau}}$$

I RMS value of the max fault phase current (the 1st ~ 7th harmonics of the phase current is taken into account).

K set value of 49_K_Factor.

I_B the rated current.

τ the set value of 49_T_Mult.

θ_t is the initial thermal state, if the initial thermal state is 30%, the θ_t is 0.3. θ_t is calculated from the following equation:$Ip^2=\theta t^*(k^*I_B)^2$. For the heat rising process, Ip is the previous current 100ms before the heat first rises; for the cooling process, the Ip is the trip current.

θ_{t+1} The trip or alarm thermal state:θ_{Trip}(the setting value 49_K_Trp) or θ_{Alam} (the setting 49_K_Alm). For cooling process, the $\theta_{t+1}$is the return value.

When the component temperature reaches the set alarm level 49_K_Alm, the output signal 49_Alm is issued. When the component temperature reaches the set trip level 49_K_Trp, the 49_Op output is activated.

There is also a calculation of the present time to operation with the present current. This is only calculated if the final temperature is calculated to be above the operation temperature.

The time to operate can be calculated as:

$$t = \tau \times \ln \frac{I^2 - \theta_t (k \cdot I_B)^2}{I^2 - \theta_{t+1} (k \cdot I_B)^2}$$

The time to lockout release is calculated, that is, the calculation of the cooling time to a set value. The calculated temperature can be reset to its initial value via a control parameter that is located under the clear menu.

The temperature calculation is initiated from the value defined with the initial temperature. This is done in case the IED is powered up, the function is turned off and back on or reset through the 49_Clr_Therm input.

The function is cold turned on before 10 min of the IED powered up. If $(I/(k*I_B))^2$ is more than the set value of 49_K_Trp, the 49_Str output is activated.

The temperature is also stored in the nonvolatile memory and restored in case the IED is restarted.

3.5.4 Settings

Table 3.5.2 settings of Three-phase thermal overload protection

No.	Name	Values(Range)	Unit	Step	Default	Description
1	49_Rated_Cur	0.02In~3In	A	0.01	1.00	Rated current
2	49_T_Mult	1~6000	s	1	600	Time multiplier
3	49_K_Factor	1.00~5.00	-	0.01	1.05	Temperature factor
4	49_K_Trp	50~200	%	1	100	Temperature level for tripping
5	49_K_Alm	0~100	%	1	90	Temperature level for alarm
6	49_Trp_Ena	0/1	-	1	0	Trip function disable/enable
7	49_Alm_Ena	0/1	-	1	0	Alarm function disable/enable

3.6 Earth Fault Protection (51G)

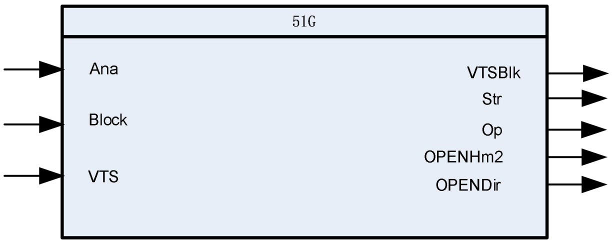
3.6.1 Overview

In electrical power industry, earth fault protection (51G) is very important and need to detect very accurate earth fault value and clear this fault as soon as possible. When earth fault is happening in the power system, according to ohm law current always follow the low resistive path and all current goes into the grounding system and it's a main reason to increase the current level of zero-sequence current.

Earth fault protection (51G) is operation based on zero-sequence current. If the detection level of zero-sequence current is greater than set value, the earth fault protection will operate and protect the system.

In addition, the 51G can be configured on the high-voltage side, middle-voltage side or low-voltage side of the transformer as a backup protection for each side.

3.6.1.1 Function Block



3.6.1.2 Signals

Table 3.6.1 51G Input Signals

NO.	Signal	Description
1	Ana	the three phase current and voltage
2	Block	Block signal of 51G protection
3	VTS	Block signal from VTS Alarm

Table 3.6.2 51G Output Signals

NO.	Signal	Description
1	VTSBlk	Block signal of VTS
2	Str	start signal of 51G protection
3	Op	Operation signal of 51G protection
4	OPENHm2	Hm2 open signal of 51G protection
5	OPENDir	Directional open signal of 51G protection

3.6.2 Protection Principle

The earth fault protection includes four stages of zero sequence overcurrent protection with independent logic function and settings. Each stage can be selected as definite time or inverse time characteristic as required. All IEC standard inverse time characteristics curves are optional. Direction control element can be used to block each stage earth fault protection independently, when the directionality of the fault current should be considered. There are three settable options: no direction, forward direction and reverse direction. The base value, zero sequence current, is selectable. Therefore, both of the externally sampling neutral current and internally calculated residual current can be used as the base value based on the practical situation.

3.6.2.1 Zero-sequence Overcurrent Start Element

The start criterion for each stage of overcurrent element is:

$$3I0 > \min\{Kret * 51Gx\_X\_Cur\_Str, 1.2In\}$$

Where:

3I0 is the calculated residual current.or the sampling neutral current

K_{ret} is the Reliability coefficient of constant current.

51Gx_X_Cur_Str is the zero sequence current setting of stage x (x=1, 2, 3, or 4) of earth fault protection

The actual normal operation of the transformer current will not exceed the rated current Ie, in order to distinguish the transformer operation abnormal and normal state, is the protection can quickly enter the protection logic operation, start setting the minimum threshold of 1.2 In.

3.6.2.2 Zero-sequence Overcurrent Element

The operation criterion for each stage of earth fault protection can be expressed as below:

$$3I0 > 51Gx\_X\_Cur\_Str$$

If the sampling residual current is available for the protection function, that is there is a external residual current wired from the neutral point, the residual current can be used as the operation quantity for the EF protection. Otherwise the internally calculated residual current from the three phase currents will be used instead. The operating quantity is compared to the set 51Gx_X_Cur_Str. If the operating quantity exceeds the set, the start signal will be activated and the timer element will start count the time.

3.6.2.3 Zero-sequence Current Direction Control Element

The directionality of the operation can be selected with the 51Gx_X_Dir_Mod setting. Three options, "Non-directional", "Forward" or "Reverse", are optional for the practical situation.

Self-polarizing is used (I_0-(-U_0)) to determine the fault direction.

The forward directionality is evaluated based on the below equation:

$$-90^0 < \arg\frac{\dot{I}_r e^{j\alpha}}{-\dot{U}_r} < +90^0$$

Also, it can be calculated by following equation:

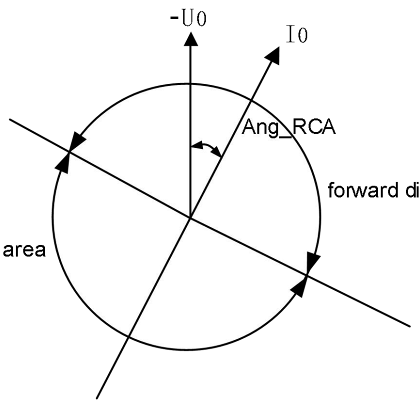
$$-90^0 < angle(Ir) + \alpha - angle(Ur) - 180° < +90^0$$

The reverse directionality is evaluated based on the below equation:

$$90^0 < \arg\frac{\dot{I}_r e^{j\alpha}}{-\dot{U}_r} < +270^0$$

Also, it can be calculated by following equation:

$$-90^0 < angle(Ir) + \alpha - angle(Ur) - 180° < +270^0$$



I_0 and U_0 are the current and voltage of the Self-polarizing. RCA means the characteristic angle.

3.6.2.4 Second harmonic detecting element

The ratio of second harmonic in three-phase current or measured neutral current to fundamental harmonic is taken as criterion for blocking of 51G, and the operating formula is given as below:

$$I_{2nd} > 51Gx\_X\_K\_Hm2 * I_{1st}$$

Where:

I_{2nd} means second harmonic in three-phase current or measured neutral current;

I_{1st} represents fundamental harmonic of three-phase current or measured neutral current at corresponding phase;

51Gx_X _K_Hm2 is second harmonic restraint coefficient.

When the fundamental current is greater than the setting 51Gx_X_Hm2_IRls, the corresponding phase will be unblocked by harmonic control element.

3.6.2.5 Characteristic Curve

Each stage can be selected as definite time or inverse time characteristic depending on the practical demand.

The inverse time calculating equation is listed as follows.

$$t = \left(\frac{k}{(I/I_p)^{\alpha} - 1} + C \right) \times T_p$$

Where:

I_p: Current setting 51Gx_X_Cur_Str.

T_p: Time multiplier setting 51Gx_X_T_Mult.

α: A constant setting 51Gx_X_Alpha.

K: A constant setting 51Gx_X_K.

C: A constant setting 51Gx_X_C.

3I0 is the operating quantity, the selected neutral current or calculated residual current.

The user can select the operating characteristic from various inverse-time characteristic curves by setting 51Gx_X_Op_Curve_Type (x=1,2,3,4;X=H,M,L) corresponding A column of table 3.4.5, and parameters of available characteristics for selection are shown in the table 3.4.5 Inverse-time curve parameters.

NOTICE!

> The 51Gx_X_Min_Op_T setting should be set very cautiously because at least the operating time should exceed the 51Gx_X_Min_Op_T setting even though the operation time is calculated according to the IDMT curve.

3.6.3 Logic Diagram

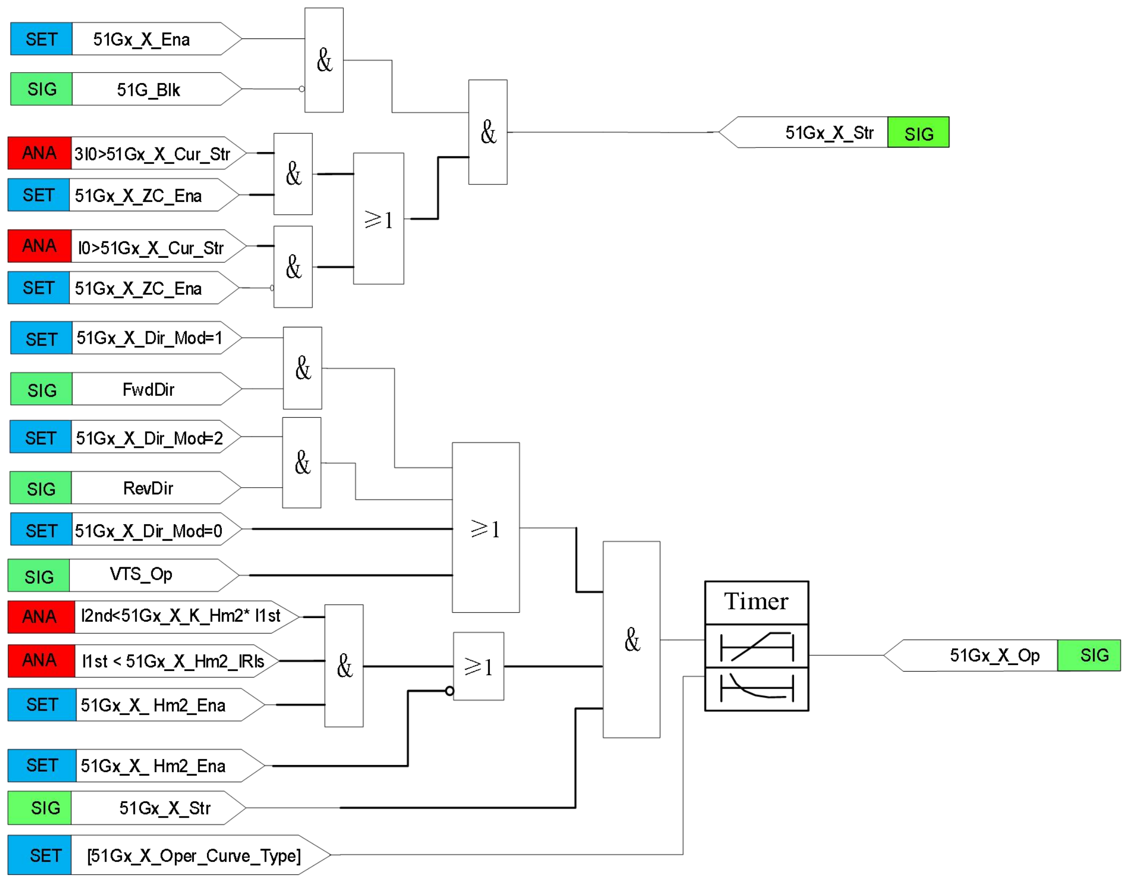


Figure 3.6.1 Logic Diagram for 51G

3.6.4 Settings

Table 3.6.3 Settings of earth fault protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	51Gx_X_Cur_Str	0.02In~20.00In	A	0.01	20.00	X-side(X=H,M,L1,L2) Operating current level for stage x(x=1,2,3,4)
2	51Gx_X_Op_T	0.020~100.000	s	0.001	10.000	X-side(X=H,M,L1,L2) Def time delay or add time delay for inverse char of stage x(x=1,2,3,4)
3	51Gx_X_Ang_RCA	0.0~360.0	Deg	0.1	90.0	Relay characteristic angle (RCA)
4	51Gx_X_Dir_Mod	0~2	-	1	0	Directional mode:0-2 for "Non-directional", "Forward" or "Reverse"
5	51Gx_X _K_Hm2	0.00~1.00	-	0.01	0.10	Coefficient of second harmonics for inrush current detection
6	51Gx_X_Hm2_IRls	2.00~30.00	A	0.01	20.00	current setting for inrush current detection
7	51Gx_X_Op_Curve_Type	0~13	-	1	0	Characteristic curve for 51G. including Definite time, IEC and ANSI typical curve and user programmable curve. The detail is defined in Table 3.4.5 Inverse-time curve parameters.
8	51Gx_X_T_Mult	0.050~200.000	-	0.001	10.000	X-side(X=H,M,L1,L2) time multiplier of the inverse time delay for stage x(x=1,2,3,4)
9	51Gx_X_Min_Op_T	0.000~60.000	s	0.001	0.050	X-side(X=H,M,L1,L2) Minimum operate time of inverse curves for stage x(x=1,2,3,4)
10	51Gx_X_Alpha	0.00~3.00	-	0.01	1.00	X-side(X=H,M,L1,L2) constant α of 51G Stage x(x=1,2,3,4)
11	51Gx_X_C	0.000~10.000	-	0.001	0.000	X-side(X=H,M,L1,L2)constant C of 51G Stage x(x=1,2,3,4)
12	51Gx_X_K	0.001~100.000	-	0.001	1.000	X-side(X=H,M,L1,L2)constant K of 51G Stage x(x=1,2,3,4)
13	50/51_x_X_CurMul	20~40.0	-	0.1	30	It used to IDMT with I=CurMul*Ip, when I> CurMul *Ip, the IDMT time delay is calculated by CurMul . It is invalid if it is not configured or the CurMulEna is disable.

No.	Name	Values (Range)	Unit	Step	Default	Description
14	50/51N_CurMulEna	0 or 1	-	1	0	Enable: CurMul is effective. Disable: CurMul is ineffective
15	51Gx_X_ Hm2_Ena	0/1	-	1	0	Enable second harmonics detection：1 Disable second harmonics detection：0
16	51Gx_X_ZC_Ena	0/1	-	1	0	Zero-sequence current comes fromthree-phase current : 1 Zero-sequence current from the external : 0
17	51Gx_X_Ena	0/1	-	1	0	Operation 0/ 1

3.7 Restricted Earth Fault Protection (64REF)

3.7.1 Overview

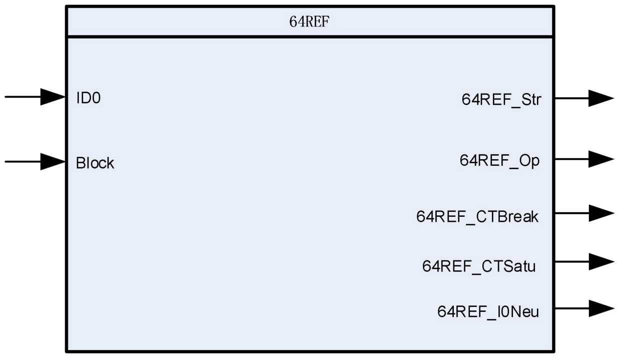
The single-phase or two-phase grounding fault with high resistance occurs when the load of the transformer is low, and the sensitivity of the Transformer differential protection（87T） is limited. Therefore, the restricted Earth Fault protection (64REF) is set as the main protection for single-phase and two-phase grounding fault in the area.The operation calculation of limited earth fault protection (64REF) is based on differential current and limited current.

- The vector sum calculated by the zero sequence current external to the neutral point and the zero sequence current generated by the switch CT is the differential current.
- The maximum value of the zero sequence current external to the neutral point and the zero sequence current generated by the switch CT is the protective braking current

When the internal fault is happening in the winding of power transformer and the total earth fault current is equal to the deference of current. To increase the high operated accuracy of Restricted Earth Fault Protection (64REF) is dependently operate only fault current without any interference of load current. When an internal fault occurs in a power transformer winding, the total ground fault current is equal to the difference of zero sequence current.Limited ground fault protection (64REF) only depends on fault current and will not be affected by load current, so the operation speed will be greatly improved.

This protection can be configured using any type of transformer, such as two - winding, three - winding, auto transformer.In addition, 64REF can be configured on the high voltage side, middle voltage side or low voltage side of the transformer.

3.7.1.1 Function Block



3.7.1.2 Signals

Table 3.7.1 64REF Input Signals

NO.	Signal	Description
1	ID0	Differential current of 64REF
2	Block	Block signal of 64REF

Table 3.7.2 64REF Output Signals

NO.	Signal	Description
1	64REF_Str	Start signal from 64REF
2	64REF_Op	Operation signal from 64REF
3	64REF_CTBreak	CT Break signal from 64REF
4	64REF_CTSatu	CT Saturation signal from 64REF
5	64REF_I0Neu	I0>B0×I Signal from 64REF

3.7.2 Protection Principle

3.7.2.1 Fault Detector

REF's pickup criterion is:

$$I_{0d} = 64REF\_Cur\_Str$$

Where:

I_{0d} is the residual differential current of some side.

3.7.2.2 Amplitude Compensation

If CTs used for REF have different primary rated values, the device will automatically adjust the currents with respective correction ratio shown as below.

$$K_{lph-X} = \frac{K_{TA-X}}{K_{TA-H}}$$

Where:

K_{TA-X} primary side sampled zero-seq CT ratio.

K_{TA-H} primary side CT ratio. Primary side is reference and Kp is 1.

Transformer balance factor is calculated by this formula. When compensation, multiply current and Kp.

3.7.2.3 Calculate Differential and Restraint Current

REF differential current and restraint current are calculated as the following formulas :

$$I_{0d} = |\dot{I}_{0Cal} + \dot{I}_{0Neu}|$$

$$I_{0r} = \max\left\{\left|\dot{I}_{0Cal}\right|, \left|\dot{I}_{0Neu}\right|\right\}$$

Where:

I_{0d} is the REF differential current;

I_{0r} is the residual restraint current;

I_{0Cal} is the residual current of the phase currents;

I_{0Neu} is the neutral measured current;

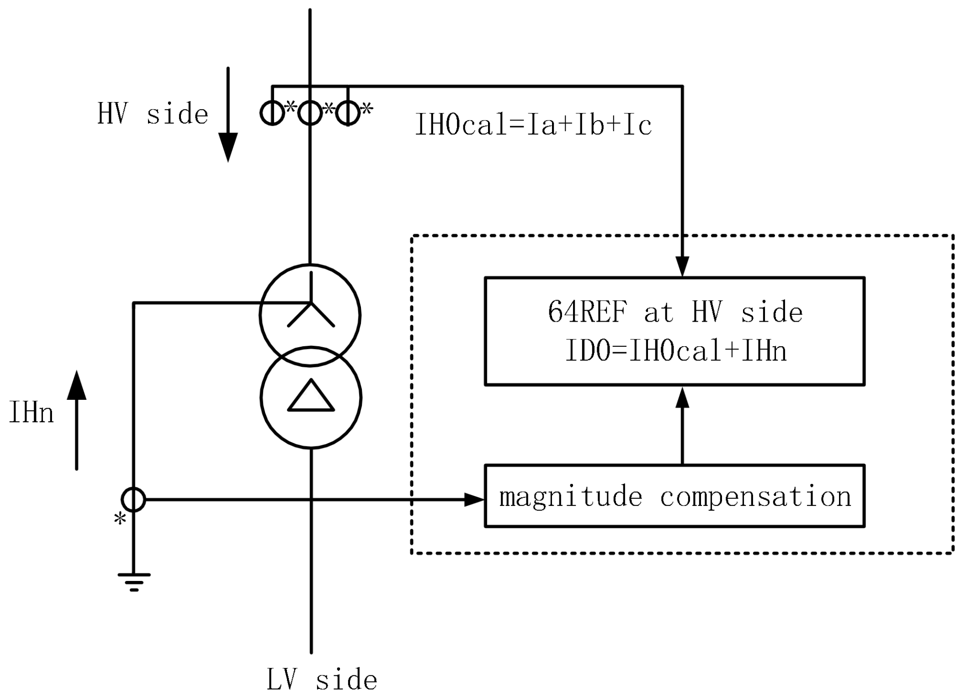


Figure 3.7.1 64REF principle diagram

3.7.2.4 Operation Criterion

The operation criteria of REF protection are as follows:

$$\begin{cases} I_{0d} > I_{0cdqd} \\ I_{0d} > K * I_{0r} \\ I_{0Neu} > I_{0cdqd} / 4 \end{cases}$$

Where:

$I_{0d} = |\dot{I}_{0Cal} + \dot{I}_{0Neu}|$, $I_{0r} = \max\{|\dot{I}_{0Cal}|, |\dot{I}_{0Neu}|\}$. $\dot{I}_{0Cal}$ 、 $\dot{I}_{0Neu}$ are respectively residual current of the phase currents and neutral measured current.For this device, the ratio restrainted coefficient fixedly takes 0.6.

3.7.2.5 Operation Characteristic

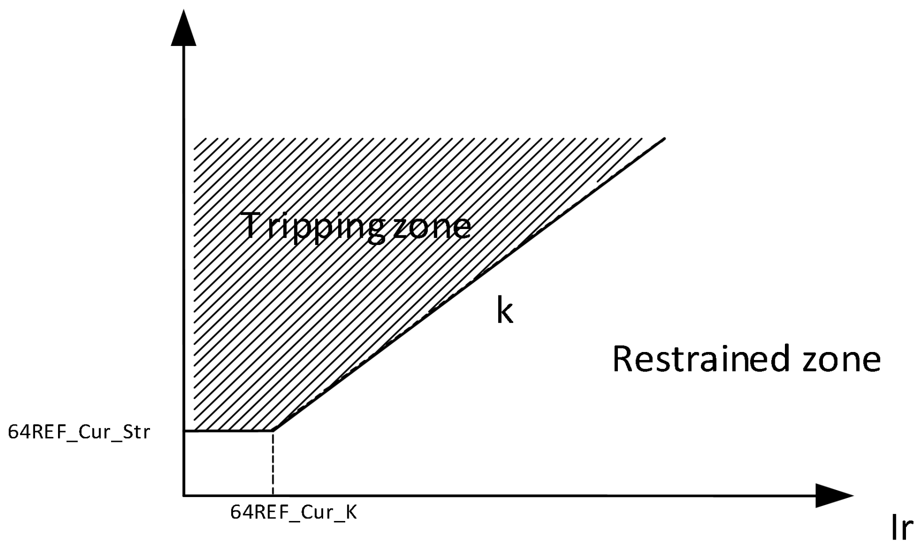


Figure 3.7.2 Operation characteristic of REF

Where:

Id is the differential current; Ir is the restraint current; 64REF_Cur_Str is the start of differential current.

3.7.2.6 CT Transient Characteristic Difference Detection

To prevent the effect of incorrect differential circuit zero-sequence current on DIFF_REF in case of CT transient characteristic difference and CT saturation induced by external faults, the device integrates CT saturation criterion with positive-sequence current restraint at each side. When DIFF_REF protection trips, zero-sequence current at each side must fulfill the following formula.

$$3I_0 > B_0 \times I_1$$

Where:

3I0 is the zero-sequence current at a side.

I_1 is its corresponding positive-sequence current.

B_0 is a proportional constant and the value is 0.6.

3.7.2.7 CT Saturation Detection

Please refer to Section 3.2.2.9 for details.

3.7.2.8 CT Circuit Failure

Please refer to Section 3.2.2.12 for details.

3.7.3 Logic Diagram

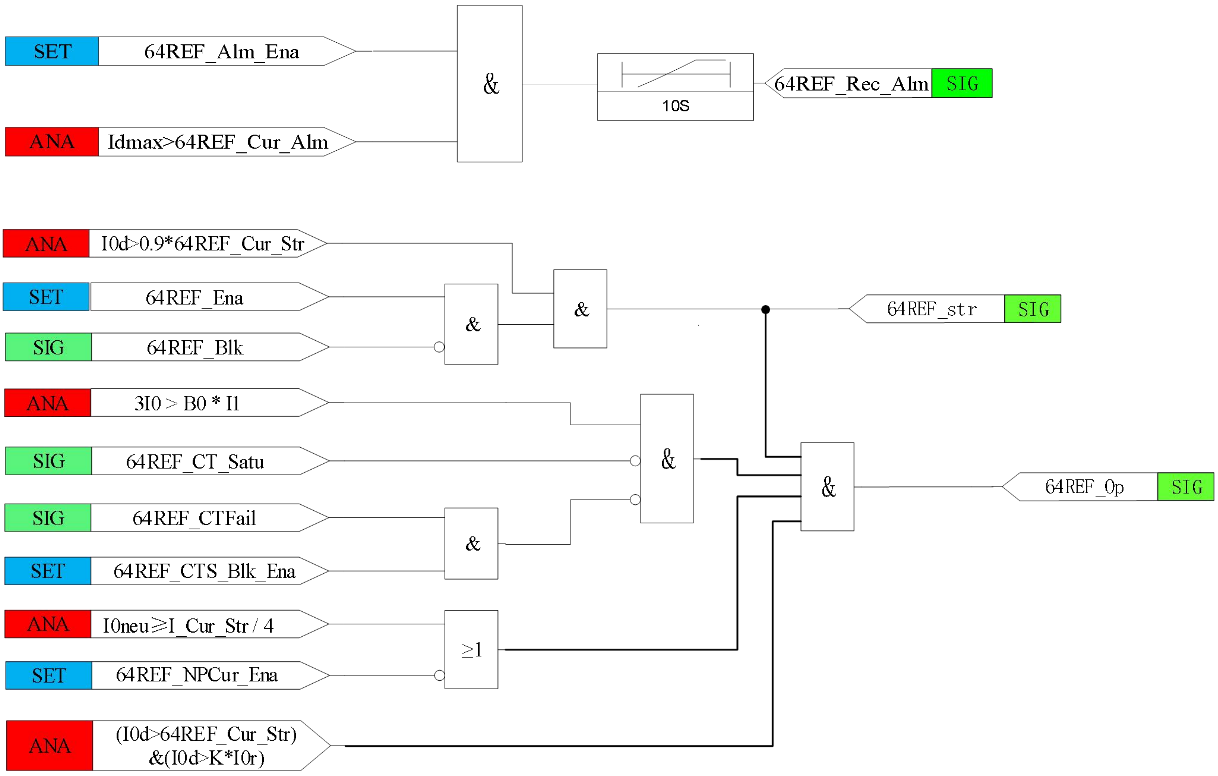


Figure 3.7.3 Logic diagram of restricted earth fault protection

Where:

I0neu is the neutral measured residual current

3.7.4 Settings

Table 3.7.3 Settings of restricted earth fault protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	64REF_X_Cur_Str	0.05~20.00	PU	0.01	0.40	Pickup setting of X-side REF （X=H,M,L）
2	64REF_X_Cur_Alm	0.05~20.00	PU	0.01	1.00	Alm setting of X-side REF （X=H,M,L）
3	64REF_X_Slope	0~0.9	-	0.01	0.6	Percentage restraint coefficient of X-side REF （X=H,M,L） 0.5 is recommended.
4	64REF_X_Ena	0/1	-	1	0	Logic setting of enabling/disabling X-side REF （X=H,M,L） 0: disable 1: enable
5	64REF_X_Alm_Ena	0/1	-	1	0	Logic setting of enabling/disabling X-side REF_Alm（X=H,M,L） 0: disable 1: enable
6	64REF_X_NPCur_Ena	0/1	-	1	1	Logic setting of enabling/disabling X-side neutral current criterion （X=H,M,L） 0: disable 1: enable
7	64REF_X_CTS_Blk_Ena	0,1	-	1	0	Logic setting of enabling/disabling block biased differential element during CT circuit failure 0: disable 1: enable

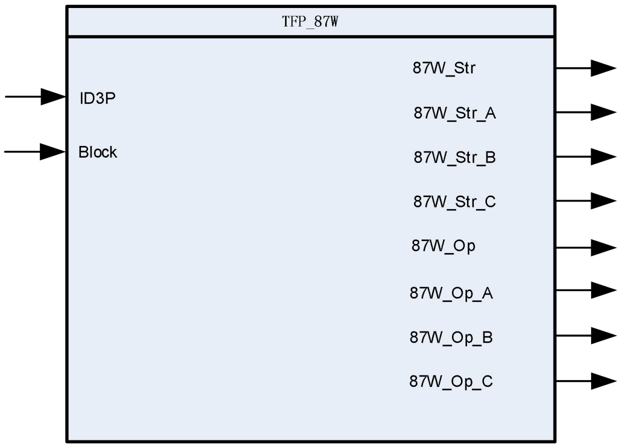
3.8 Winding Differential Protection (87W/N)

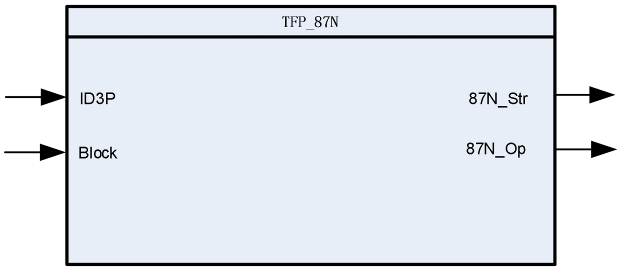
3.8.1 Overview

When each side and common winding of auto-transformer are installed with three phase CTs, winding differential protection can be equipped. Winding differential protection is based on Kirchhoff's law, so inrush current has no effect on it. Winding differential protection consists of phase winding differential protection(87W) and residual winding differential protection(87N).

Residual winding differential protection adopts the calculated residual current of each side and common winding for the protection calculation and three-phase CT polarity is easy to be checked. The operation principle of which is similar to that of REF, but compared to REF, winding differential protection can operate not only during internal earth faults but also during phase-to-phase faults.

3.8.1.1 Function Block





3.8.1.2 Signals

Table 3.8.1 87W/87N Input Signals

NO.	Signal	Description
1	ID3P	Three phase winding differential current from 87W Residual winding differential current from 87N
2	Block	Block signal of 87W/87N

Table 3.8.2 87W/87N Output Signals

NO.	Signal	Description
1	87W_Str	Start signal of differential from 87W

NO.	Signal	Description
2	87W_Str_A	Start_A signal of differential from 87W
3	87W_Str_B	Start_B signal of differential from 87W
4	87W_Str_C	Start_C signal of differential from 87W
5	87W_Op	Operation signal of differential from 87W
6	87W_Op_A	Operation_A signal of differential from 87W
7	87W_Op_B	Operation_B signal of differential from 87W
8	87W_Op_C	Operation_C signal of differential from 87W
9	87N_Str	Start signal of differential from 87N
10	87N_Op	Operation signal of differential from 87N

3.8.2 Protection Principle

3.8.2.1 Fault Detector

87W/87N's pickup criterion is:

$$I_{wd} > 87W/87N\_Cur\_Str$$

Where:

I_{wd} is the winding differential current.

3.8.2.2 Amplitude Compensation

If CTs used for 87W have different primary rated values, the device will automatically adjust the currents with respective correction ratio shown as below.

$$K_{lph-X} = \frac{K_{TA-X}}{K_{TA-H}}$$

Where:

K_{TA-X} primary side sampled CT ratio.

K_{TA-H} primary side CT ratio. Primary side is reference and Kp is 1.

Transformer balance factor is calculated by this formula. When compensation, multiply current and Kp.

3.8.2.3 Calculate Differential and Restraint Current

Winding differential current and restraint current are calculated as the following formulas :

The differential current is as follows.

$$\begin{bmatrix} I_{wdA} \\ I_{wdB} \\ I_{wdC} \\ I_{wd0} \end{bmatrix} = K_{\text{wph1}} \cdot \begin{vmatrix} I_{A1} \\ I_{B1} \\ I_{C1} \\ I_{01} \end{vmatrix} + K_{\text{wph2}} \cdot \begin{vmatrix} I_{A2} \\ I_{B2} \\ I_{C2} \\ I_{02} \end{vmatrix} + K_{\text{wph3}} \cdot \begin{vmatrix} I_{A3} \\ I_{B3} \\ I_{C3} \\ I_{03} \end{vmatrix} + K_{\text{wph4}} \cdot \begin{vmatrix} I_{A4} \\ I_{B4} \\ I_{C4} \\ I_{04} \end{vmatrix} + K_{\text{wph5}} \cdot \begin{vmatrix} I_{A5} \\ I_{B5} \\ I_{C5} \\ I_{05} \end{vmatrix} + K_{\text{wph6}} \cdot \begin{vmatrix} I_{A6} \\ I_{B6} \\ I_{C6} \\ I_{06} \end{vmatrix}$$

$$I_{wdA} = I'_{A1} + I'_{A2} + I'_{A3} + I'_{A4} + I'_{A5} + I'_{A6}$$

$$I_{wdB} = I'_{B1} + I'_{B2} + I'_{B3} + I'_{B4} + I'_{B5} + I'_{B6}$$

$$I_{wdC} = I'_{C1} + I'_{C2} + I'_{C3} + I'_{C4} + I'_{C5} + I'_{C6}$$

$$I_{wd0} = I'_{01} + I'_{02} + I'_{03} + I'_{04} + I'_{05} + I'_{06}$$

The restraint current is:

$$I_{wrA} = MAX(|I'_{A1}|、|I'_{A2}|、|I'_{A3}|、|I'_{A4}|、|I'_{A5}|、|I'_{A6}|)$$

$$I_{wrB} = MAX(|I'_{B1}|、|I'_{B2}|、|I'_{B3}|、|I'_{B4}|、|I'_{B5}|、|I'_{B6}|)$$

$$I_{wrC} = MAX(|I'_{C1}|、|I'_{C2}|、|I'_{C3}|、|I'_{C4}|、|I'_{C5}|、|I'_{C6}|)$$

$$I_{wr0} = MAX(|I'_{01}|、|I'_{02}|、|I'_{03}|、|I'_{04}|、|I'_{05}|、|I'_{06}|)$$

Where:

I_{wdA},I_{wdB},I_{wdC},I_{wd0} are respectively three phase and residual winding differential currents.

I_{wrA},I_{wrB},I_{wrC},I_{wr0} are secondary values of three phase restraint currents and residual restraint current respectively.

I_{Am},I_{Bm},I_{Cm},I_{0m} are respectively secondary values of three phase currents and calculated neutral current of branch m (m=1, 2, 3, 4, 5, 6).

I'_{Am},I'_{Bm},I'_{Cm},$I'_{0m}$are respectively secondary values of corrected three phase currents and calculated residual current of branch m (m=1, 2, 3, 4, 5, 6).

K_{wphm} is corrected coefficient of each side for magnitude compensation respectively (m=1, 2, 3, 4, 5, 6).

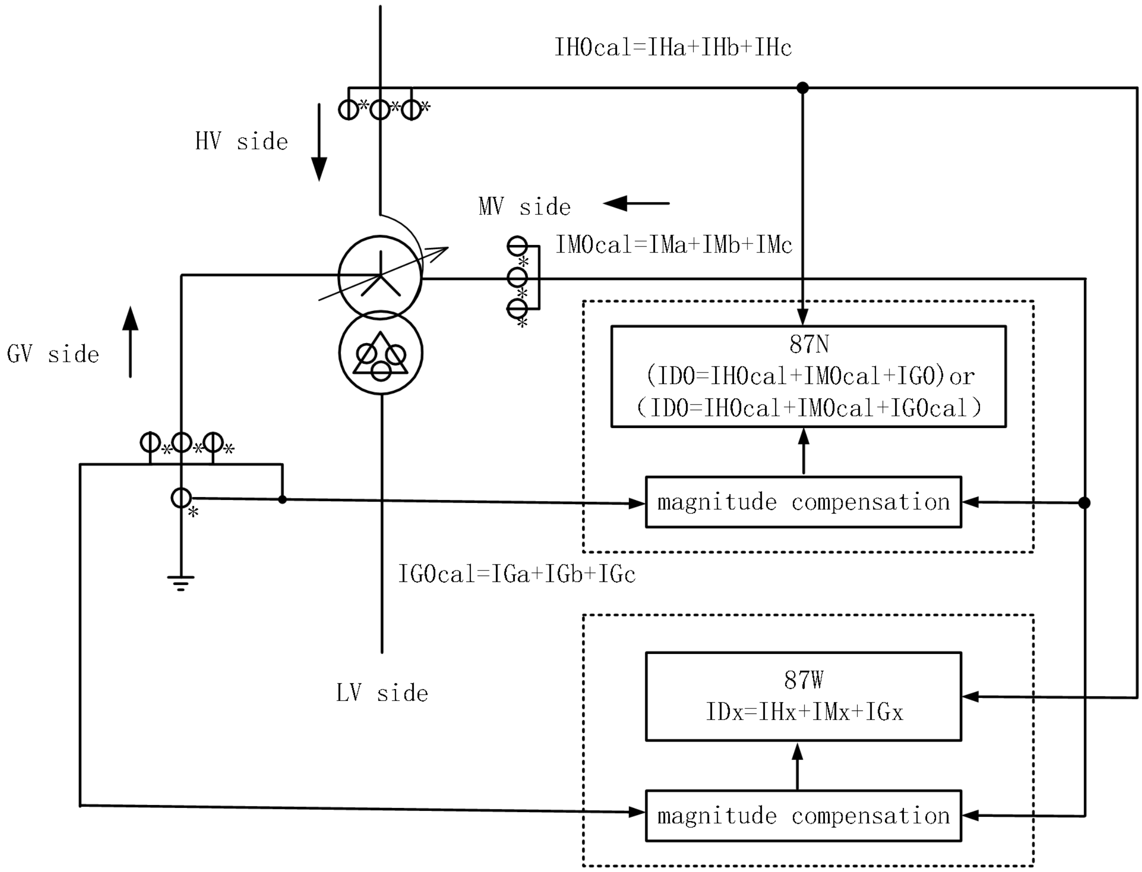


Figure 3.8.1 87W/N principle diagram

3.8.2.4 Operation Criterion

The operation criteria of winding differential protection are as follows:

$$\begin{cases} I_{wd} > 87W/87N\_Cur\_Str \\ I_{wd} > I_{wr} * 87W/87N\_Slope \end{cases}$$

Where:

I_{wd} is the winding differential current.

I_{wr} is the winding restraint current.

3.8.2.5 Operation Characteristic

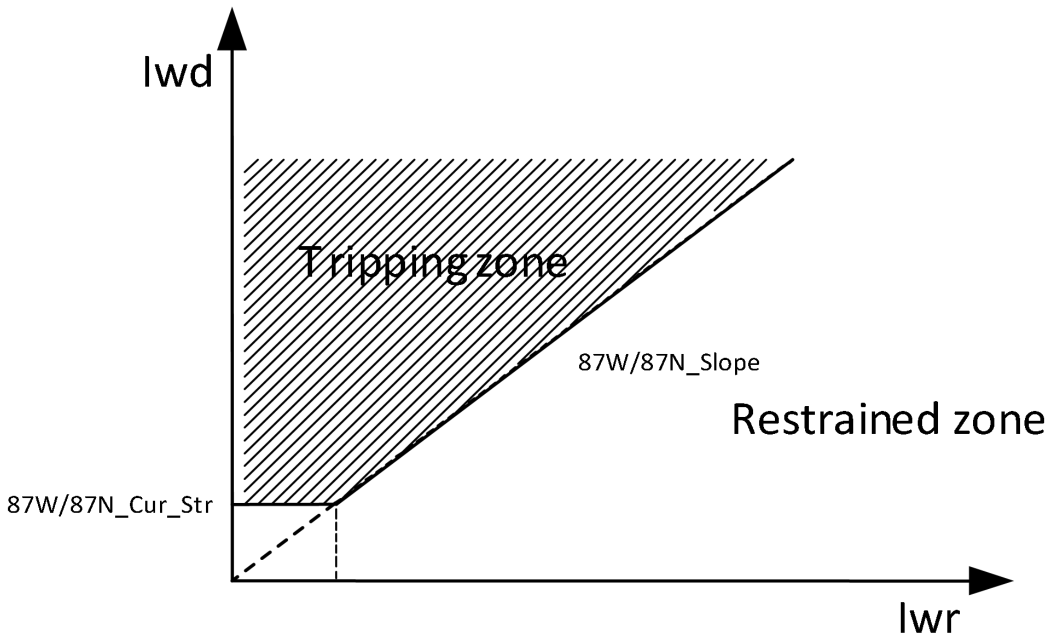


Figure 3.8.2 Operation characteristic of winding differential protection

Where:

I_{wd} is the winding differential current.

I_{wr} is the winding restraint current.

87W/87N_Cur_Str is the start of differential current.

3.8.2.6 CT Transient Characteristic Difference Detection

To prevent the effect of incorrect differential circuit zero-sequence current on 87N in case of CT transient characteristic difference and CT saturation induced by external faults, the device integrates CT saturation criterion with positive-sequence current restraint at each side. When 87N protection trips, zero-sequence current at each side must fulfill the following formula.

$$3I_0 > B_0 * I_1$$

Where:

$3I_0$ is the zero-sequence current at a side.

I_1 is its corresponding positive-sequence current.

B_0 is a proportional constant and the value is 0.6.

3.8.2.7 CT Saturation Detection

Please refer to Section 3.2.2.9 for details.

3.8.2.8 CT Circuit Failure

Please refer to Section 3.2.2.12 for details.

3.8.3 Logic Diagram

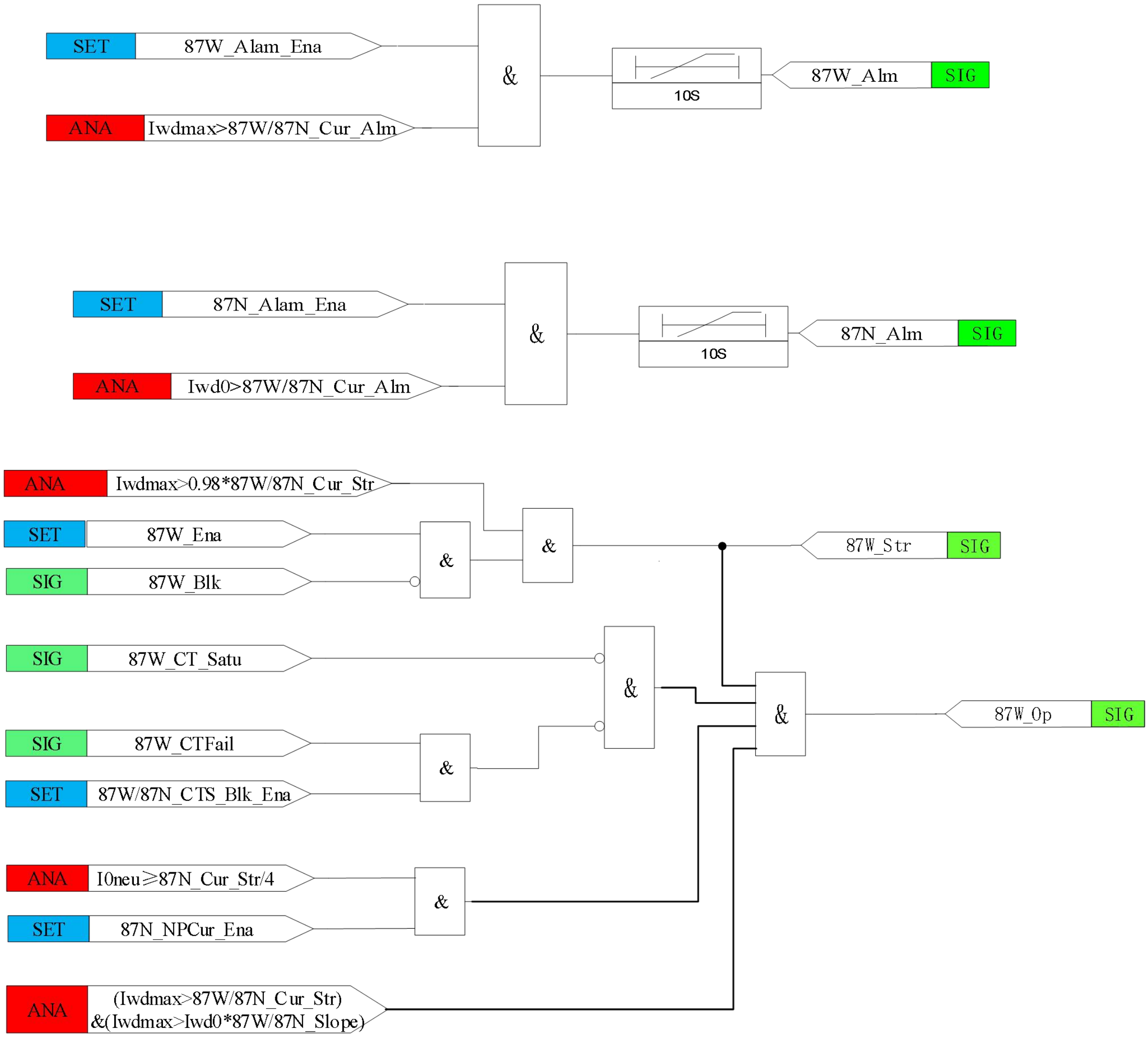


Figure 3.8.3 Logic diagram of winding differential protection

3.8.4 Settings

Table 3.8.3 Settings of winding differential protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	87W/87N_Cur_Str	0.05~20.00	PU	0.01	0.40	Pickup setting of winding differential protection
2	87W/87N_Cur_Alm	0.05~20.00	PU	0.01	1.00	Alm setting of winding differential protection

No.	Name	Values (Range)	Unit	Step	Default	Description
3	87W/87N_Slope	0~0.9	-	0.01	0.6	Percentage restraint coefficient of winding differential protection 0.6 is recommended.
4	87W_Ena	0/1	-	1	0	Logic setting of enabling/disabling phase winding differential protection 0: disable 1: enable
5	87N_Ena	0/1	-	1	0	Logic setting of enabling/disabling residual winding differential protection 0: disable 1: enable
6	87W_Alam_Ena	0/1	-	1	0	Logic setting of enabling/disabling 87W_Alm 0: disable 1: enable
7	87N_Alam_Ena	0/1	-	1	0	Logic setting of enabling/disabling 87N_Alm 0: disable 1: enable
8	87N_IG0_Ena	0/1	-	1	0	Zero-sequence current comes fromthree-phase current : 0 Zero-sequence current from the external : 1
9	87N _NPCur_Ena	0/1	-	1	0	Logic setting of enabling/disabling neutral current criterion 0: disable 1: enable
10	87W/87N_CTS_Blk_Ena	0,1	-	1	0	Logic setting of enabling/disabling block biased differential element during CT circuit failure 0: disable 1: enable

3.9 Non-directional Instantaneous Earth Fault Protection(50/51N)

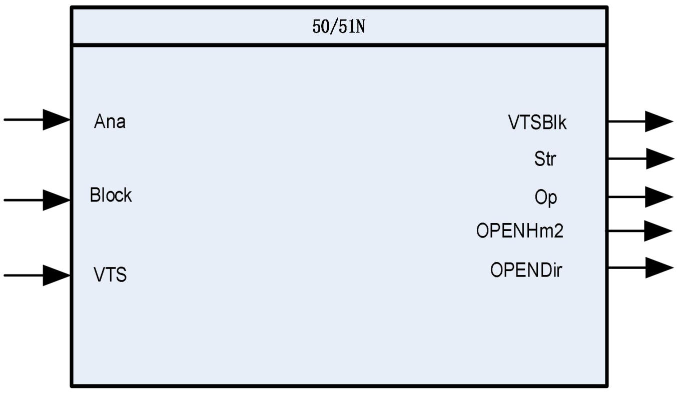
3.9.1 Overview

The main purpose of Instantaneous residual over current protection 50/51N is to continuously monitor the protected network residual current with the combination of zero-sequence instrument transformer (CT). If any kind of trouble happen in protected electrical circuit likes open or short circuit, it brings some type of disturbances. These disturbances will change the value of grounding impedance. If the detected value of restrain current is larger than set value of restrain current the protection will operate instantaneously.

This protection has the capability of current multiplication factor for only transformer inrush condition.

In addition, the 50/51N can be configured on the high-voltage side, middle-voltage side or low-voltage side of the transformer as a backup protection for each side.

3.9.1.1 Function Block



3.9.1.2 Signals

Table 3.9.1 50/51N Input Signals

NO.	Signal	Description
1	Ana	the three phase current.
2	Block	Block signal of 50/51N
3	VTS	Block signal from VTS alarm

Table 3.9.2 50/51N Output Signals

NO.	Signal	Description
1	VTSBlk	Block signal of VTS
2	Str	Common start signal from 50/51N

NO.	Signal	Description
3	Op	Operation signal from 50/51N
4	OPENHm2	Hm2 open signal of 51/51N protection
5	OPENDir	Directional open signal of 51/51N protection (50/51N have no directional components so as no output by default)

3.9.2 Protection Principle

3.9.2.1 Zero-sequence Over current Element

The operation criterion for earth fault protection is:

$$3I0 > 50/51N\_X\_Cur\_Str$$

Where:

3I0 is the calculated residual current.Or the measured neutral current

50/51N_X_Cur_Str is the current setting of earth fault protection

If the measured residual current is configured to be available for the protection function it will be used as operating quantity. Otherwise the internally calculated residual current is used. The operating quantity is compared to the set 50/51N_X_Cur_Str. If the measured value exceeds the set 50/51N_X_Cur_Str, the level detector sends an enable-signal to the timer module.

3.9.3 Logic Diagram

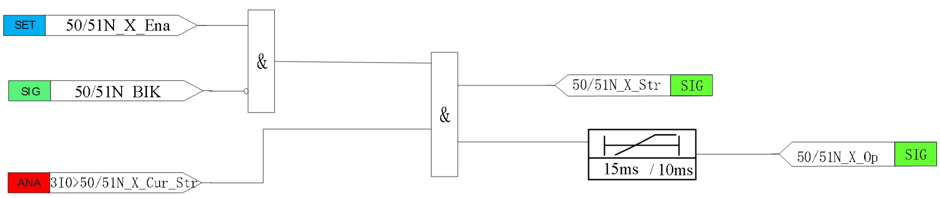


Figure 3.9.1 Logic Diagram for 50/51N

3.9.4 Settings

Table 3.9.3 Settings of earth fault protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	50/51N_X_Cur_Str	0.02In~20In	A	0.01	20.00	Current setting of X-side 50/51N
2	50/51N_X_K_Hm2	0.00~1.00	-	0.01	0.1	Coefficient of second harmonics for inrush current detection

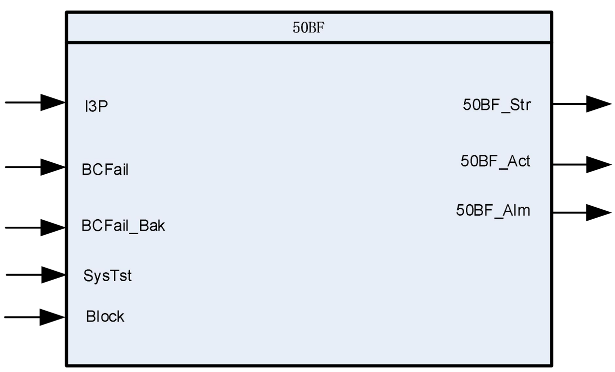
No.	Name	Values (Range)	Unit	Step	Default	Description
3	50/51N_X_Hm2_IRls	2.00~30.00	A	0.01	20.00	current setting for inrush current detection
4	50/51N_X_Hm2_Ena	0/1	-	1	0	Enable second harmonics detection：1 Disable second harmonics detection：0
5	50/51N_X_ZC_Ena	0/1	-	1	0	Zero-sequence current comes from three-phase current : 1 Zero-sequence current from the external : 0
6	50/51N_X_Ena	0/1	-	1	0	Enabling/disabling of X-side 50/51N 0: disable 1: enable

3.10 Breaker Failure Protection (50BF)

3.10.1 Overview

Breaker failure protection is applied to inter-trip each side of transformer when initiation signals of breaker failure protection from busbar protection or other device are received. When the binary input of external tripping is energized and current element picks up, a trip command will be issued with a time delay to trip circuit breakers at each side of transformer. the 50BF can be configured on the high-voltage side or middle-voltage side of the transformer as a backup protection for each side.

3.10.1.1 Function Block



3.10.1.2 Signals

Table 3.10.1 50BFInput Signals

NO.	Signal	Description
1	I3P	the three phase current.
2	BCFail	Input signal of 50BF
3	BCFail_Bak	Input signal of 50BF_Bak
4	SysTst	Input signal of TEST
5	Block	Block signal of 50BF

Table 3.9.2 50BF Output Signals

NO.	Signal	Description
1	50BF_Str	Start signal from 50BF
2	50BF_Act	Operation signal from 50BF
3	50BF_Alm	Alarm signal from 50BF

3.10.2 Protection Principle

The device provides four kinds of current criteria including phase current criterion, zero-sequence current criterion, negative-sequence current criterion and DPFC current criterion. If any current criterion is satisfied, current element of breaker failure protection picks up.

1. Phase current criterion

$$I_{max} > \text{50BF\_X\_Cur\_I\_Str}$$

Where:

I_{max} is the maximum value of three phase-current of some side.

2. Zero-sequence current criterion

$$3I0 > \text{50BF\_X\_Cur\_I0\_Str}$$

Where:

3I0 is three times calculated zero-sequence current of some side.

3. Negative-sequence current criterion

$$I_2 > \text{50BF\_X\_Cur\_I2\_Str}$$

Where:

I_2 is negative-sequence current of some side.

4. DPFC current criteria

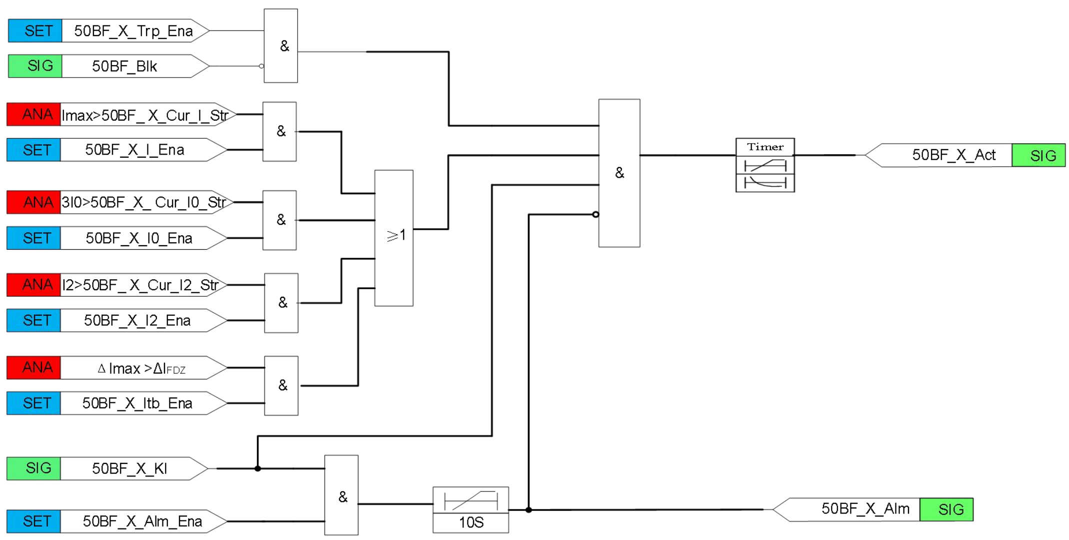
$$\Delta I_{max} > \Delta I_{FDZ}$$

Where:

ΔI_{max} is the floating threshold value which will arise automatically and gradually according to increasing of the output of deviation component.

ΔI_{FDZ} is the fixed threshold and does not need to be set on site.

3.10.3 Logic Diagram



3.10.4 Settings

No.	Item	Range	Unit	Step	Default	Description
1	50BF_X_Cur_I_Str	0.04In~20In	A	0.01	20.00	Operating phase current level of X-side 50BF protection(X=H,M)
2	50BF_X_ Cur_I0_Str	0.04In~20In	A	0.01	20.00	Operating zero-sequence current level of X-side 50BF protection(X=H,M)
3	50BF_X_Cur_I2_Str	0.04In~20In	A	0.01	20.00	Operating Negative-sequence current level of X-side 50BF protection(X=H,M)
4	50BF_X_Op_T	0.00~10.00	s	0.01	10.00	Def time delay or add time delay of X-side 50BF protection(X=H,M)
5	50BF_X_Itb_Ena	0/1	-	1	0	Logic setting of enabling/disabling DPFC current criterion to control breaker failure protection.

No.	Item	Range	Unit	Step	Default	Description
6	50BF_X_I_Ena	0/1	-	1	0	Logic setting of enabling/disabling phase current criterion to control breaker failure protection
7	50BF_X_I0_Ena	0/1	-	1	0	Logic setting of enabling/disabling zero-sequence current criterion to control breaker failure protection.
8	50BF_X_I2_Ena	0/1	-	1	0	Logic setting of enabling/disabling negative-sequence current criterion to control breaker failure protection.
9	50BF_X_Alm_Ena	0/1	-	1	0	Logic setting of enabling/disabling alarm of breaker failure protection
10	50BF_X_Trp_Ena	0/1	-	1	0	Logic setting of enabling/disabling time delay of breaker failure protection

3.11 Residual Over voltage Protection (59N)

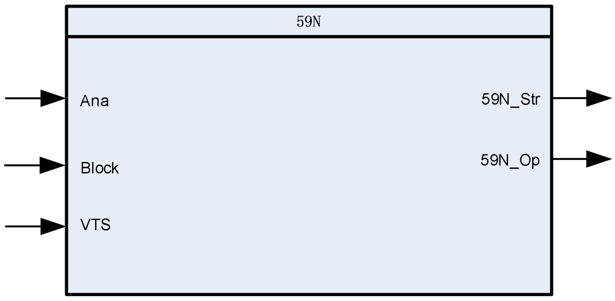
3.11.1 Overview

The main purpose of Three Stage Residual Over voltage Protection (59N) is to continuously monitor the protected network residual over voltage with the combination of zero-sequence instrument transformer (VT). If any kind of trouble happens in protected electrical circuit likes open or short circuit, it brings some type of disturbances. These disturbances will change the value of grounding system impedance cause over voltage in power system. If the detected value of restrain over voltage is larger than set value of restrain over voltage, the protection will operate immediately. This protection provides two stage controlling setting with definite time delay (DT) or IDMT time delay.

In this protection have the capability of blocking function if some trouble happens between VT circuit or IED logic circuit.

In addition, the 59N can be configured on the high-voltage side or the middle-voltage side of the transformer as a backup protection for each side.

3.11.1.1 Function Block



3.11.1.2 Signals

Table 3.11.1 59N Input Signals

NO.	Signal	Description
1	Ana	Three-phase voltage input
2	Block	Block signal of 59N protection
4	VTS	Block signal of VTS alarm

Table 3.11.2 59N Output Signals

NO.	Signal	Description
1	59N_Str	Start signal from 59N
2	59N_Op	Operation signal from 59N

3.11.2 Protection Principle

Residual over voltage protection includes three stages residual over voltage element with independent logic, voltage and time delay settings. All the stages can be selected as definite-time or inverse-time characteristic. The inverse-time characteristic can be selected as IEC or ANSI/IEEE standard inverse-time characteristics and a user-defined inverse-time curve.

Residual over voltage protection can select calculated residual voltage or measured residual voltage according to the setting 59Nx _X_ZC_Ena when calculated residual voltage is adopted, residual over voltage protection can be blocked due to VT circuit failure if the setting 59Nx _X_VTS_Blk_Ena is set as “1”.

3.11.2.1 Operation Criterion

$$3U0 > 59Nx\_X\_Vol\_Str \text{ or } UN > 59Nx\_X\_Vol\_Str$$

Where:

3Uo is calculated residual voltage;

UN is measured residual voltage.

3.11.2.2 Time Curve

The residual over voltage protection can be selected as definite-time or inverse-time characteristic, and inverse-time operating time curve is as follows

$$t(I) = \left(\frac{K}{(\frac{U}{U_{set}})^{\alpha} - 1} + C \right) \times T_P$$

Where:

K, α and C are constants.

U is actual measured or calculated residual voltage.

IDMT Characteristic	K	α	C	Curve Type	Selection
IEC Normal inverse	0.14	0.02	0	1	■
IEC Very inverse	13.5	1.0	0	2	■
IEC Extremely inverse	80.0	2.0	0	3	■
IEC Long-time inverse	120.0	1.0	0	4	■
IEC User inverse	K	α	C	5	■

The user can select the operating characteristic from various inverse-time characteristic curves by setting 59Nx _X_Op_Curve_Type.

In order to prevent it from undesired operation due to VT circuit failure when residual overvoltage protection adopts calculated residual voltage,it is available to block residual overvoltage protection according to the setting 59Nx _X_VTS_Blk_Ena and any of the following criterion is satisfied.

1) The device issues an alarm of corresponding side, Alm_VTS

2) VT of corresponding side is out of service, In_VT

3) Three phase voltages are all smaller than 1.2Un. (Un is secondary rated voltage)

3.11.3 Logic Diagram

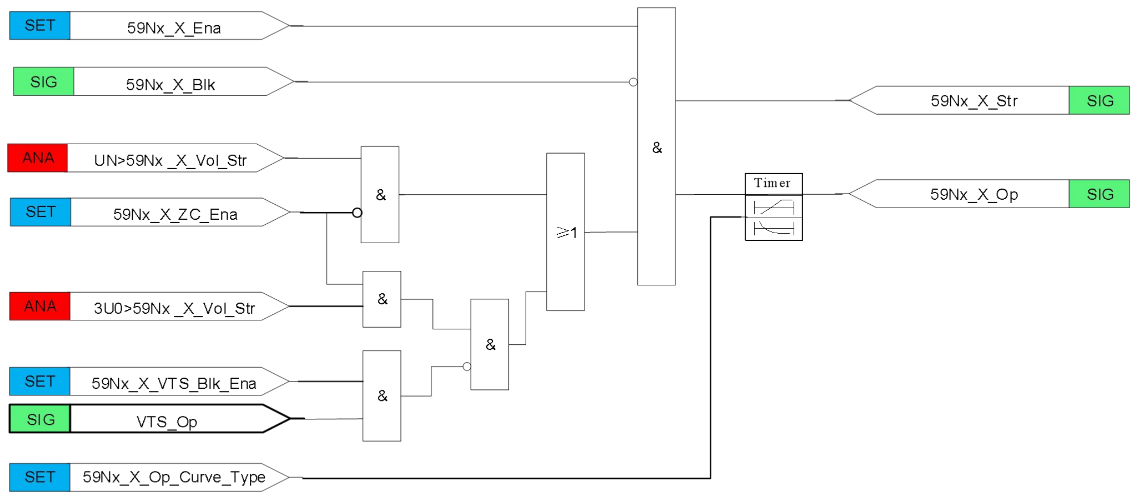


Figure 3.11.1 Logic diagram of residual over voltage protection

Where:

3U0is calculated residual or calculated voltage.

UN is measured residual voltage

3.11.4 Settings

Table 3.11.3 Settings of residual over voltage protection

No.	Item	Range	Unit	Step	Default	Description
1	59Nx _X_Vol_Str	2.00~200.0 0	V	0.01	200.00	Voltage setting of stage x(x=1,2,3) of X-side (X=H,M) residual over voltage protection
2	59Nx _X_Op_T	0.000~300. 000	s	0.001	10.000	Definite time of stage x(x=1,2,3) of X-side (X=H,M) residual over voltage protection
3	59Nx _X_Op_Curve_Type	0~5	-	1	0	Selection of the type of time delay curve:0 for DT, 1~5 for IDMT
4	59Nx _X_T_Mult	0.050~200. 000	-	0.001	10.000	X-side (X=H,M) Time multiplier for the inverse time delay for stage x(x=1,2,3)
5	59Nx _X_Min_Op_T	0.000~60.0 00	s	0.001	0.050	X-side (X=H,M) Minimum operate time for inverse curves for stage x(x=1,2,3)

No.	Item	Range	Unit	Step	Default	Description
6	59Nx _X_Alpha	0.00~3.00	-	0.01	1.00	X-side (X=H,M) constant α of 59N Stage x(x=1,2,3)
7	59Nx _X_C	0.000~10.000	-	0.001	0.000	X-side (X=H,M) constant C of 59N Stage x(x=1,2,3)
8	59Nx _X_K	0.001~100.000	-	0.001	1.000	X-side (X=H,M) constant K of 59N Stage x(x=1,2,3)
9	59Nx _X_ZC_Ena	0/1	-	1	0	X-side (X=H,M) Residual voltage option for the calculation of stage x(x=1,2,3)of residual over voltage protection 0: Measured residual voltage 1: Calculated residual voltage
10	59Nx _X_VTS_Blk_Ena	0/1	-	1	0	When calculated residual voltage is adopted, residual over voltage protection can be blocked due to VT circuit failure if the setting 59N1_VTS_Blk_Ena is set as "1".
11	59Nx _X_Ena	0/1	-	1	0	Logic setting of enabling/disabling stage 1 of residual over voltage protection 0: disable 1: enable

3.12 Three-phase over voltage protection (59P)

3.12.1 Overview

The main operating function of Two Stage Three-phase over voltage protection (59P) is to continuously measure the protected network voltage limit cause by different faults, if the detected voltage limit is greater than set level the Two Stage Three-phase over voltage the protection will operates or gives alarm signal with dependable multi stage definite time delay (DT) or inverse definite minimum time (IDMT) delay characteristics and each stage have same logics of setting. This protection has extra ordinary feature to operate with over current protection.

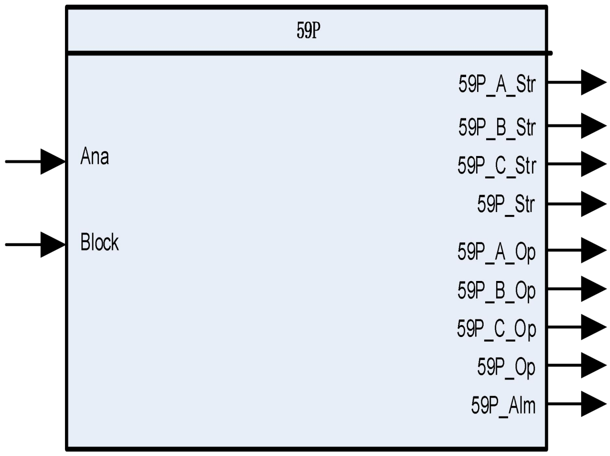
59P can support several kind of VT connection:

- Three phase voltage (Ua, Ub, Uc)
- Three phase-to-phase voltages (Uab, Ubc, Uca)
- Two phase-to-phase voltages (Uab, Ubc)

Two Stage Three-phase over voltage protection 59P is also have blocking function capability.

In addition, the 59P can be configured on the high-voltage side or middle-voltage side of the transformer as a backup protection for each side.

3.12.1.1 Function Block



3.12.1.2 Signals

Table 3.12.1 59P Input Signals

NO.	Signal	Description
1	Ana	the three phase group signal for voltage inputs
2	Block	Block signal of 59P

Table 3.12.2 Output Signals

NO.	Signal	Description
1	59P_A_Str	phase A Start signal from 59P
2	59P_B_Str	phase B Start signal from 59P
3	59P_C_Str	phase C Start signal from 59P
4	59P_ Str	Common Start signal from 59P
5	59P_A_Op	phase A Operation signal from 59P
6	59P_B_Op	phase B_Operation signal from 59P
7	59P_C_Op	phase C Operation signal from 59P
8	59P_ Op	Operation signal from 59P
9	59P_ Alm	Alarm signal from 59P

3.12.2 Protection Principle

The three-phase over voltage protection function can be enabled or disabled by setting the corresponding 59Px_X_Ena parameter values as "1" or "0".

The fundamental frequency component of the measured three phase voltages is compared phase-wise to the set value of the 59Px_X_Vol_Str setting. If the measured value is higher than the set value of the 59Px_X_Vol_Str setting, the phase selection logic detects the phase or phases in which the fault level is detected. If the number of faulty phases matches the set 59Px_X_Str_Ph_Num and no blocking signal input is activated, the phase selection logic activates the timer and the 59Px_X_Str output and the corresponding output of the respective phases (59Px_X_Str_A/B/C).

The 59Px_X_Vol_Opt setting is used for selecting phase-to-earth (59Px_X_Vol_Opt=0) or phase-to-phase(59Px_X_Vol_Opt=1) voltages for protection.

59Px_X_Vol_Str is the preset value to check for the voltage

59Px_X_Str_Ph_Num shows the number of phases required for operate activation.

Depending on the value of the set 59Px_X_Op_Curve_Type corresponding A column of table 3.4.5, the time characteristics are selected according to DT (59Px_X_Op_Curve_Type=0) or IDMT (59Px_X_Op_Curve_Type=1~13). The IDMT operating curve type is shown below :

$$t(I) = \left(\frac{K}{(\frac{U}{U_{set}})^{\alpha} - 1} + C \right) \times T_P$$

When the operation timer has reached the value set by 59Px_X_Op_T in the DT mode or the value set by the IDMT operate time curve, the 59Px_X_Op output is activated. The corresponding output for the respective phases (59Px_X_Op_A/B/C) is also activated. For the IDMT model, 59Px_X_Op_T defines the minimum desired operate time for IDMT.

If a drop-off situation occurs, that is, a fault suddenly disappears before the operation delay is exceeded, the reset state is activated, the timer is reset and the 59Px_X_Str output is deactivated.

The binary input 59Px_X_Blk can be used to block the function. The activation of the 59Px_X_Blk input deactivates all outputs and resets the internal timers. The binary input 59Px_X_Blk can be used to block the start signals and operating signals.

3.12.3 Logic Diagram

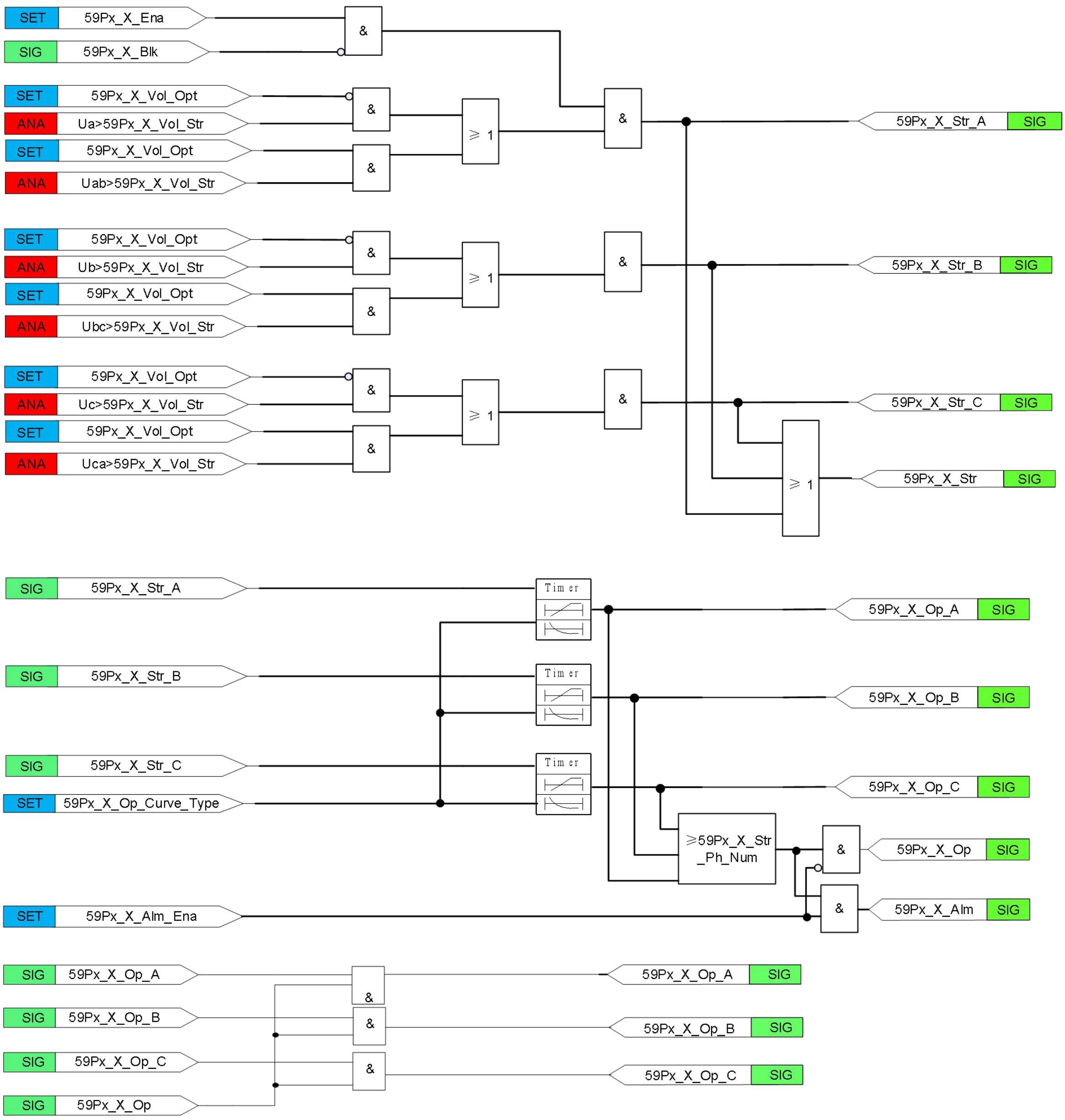


Figure 3.12.1Functional module diagram

Where:

59Px_X_Op_Curve_Type is the selection of the type of time delay curve.

59Px_X_Op_T is the operating time delay for definite time curve.

59Px_X_Min_Op_T is the minimum operate time delay for IDMT curves.

3.12.4 Settings

Table 3.12.3 settings of Two stage Three-phase overvoltage protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	59Px_X_Vol_Str	0.00~160.00	V	0.01	160.00	Start value of over voltage
2	59Px_X_Op_T	0.040~300.000	s	0.001	10.000	Operating time delay for definite time curve
3	59Px_X_Str_Ph_Num	1/2/3	-	1	3	Number of phases required for operate activation:1 for 1 phase, 2 for 2 phases, 3 for 3 phases
4	59Px_X_Op_Curve_ Type	0~13	-	1	0	Selection of the type of time delay curve:0 for DT, 1~13 for IDMT
5	59Px_X_T_ Mult	0.050~200.000	-	0.001	10.000	Time multiplier in IEC curves
6	59Px_X_Min_Op_T	0.000~60.000	s	0.001	0.050	Minimum operate time delay for IDMT curves
7	59Px_X_Alpha	0.00~3.00	-	0.01	1.00	X-side (X=H,M) constant α of 59P Stage x(x=1,2)
8	59Px_X_C	0.000~10.000	-	0.001	0.000	X-side (X=H,M) constant C of 59P Stage x(x=1,2)
9	59Px_X_K	0.001~100.000	-	0.001	1.000	X-side (X=H,M) constant K of 59P Stage x(x=1,2)
10	59Px_X_Vol_Opt	0/1	-	1	0	Parameter to select phase or phase-to- phase voltages: 0 forphase voltages,1 forphase-to- phase voltages
11	59Px_X_Alm_Ena	0/1	-	1	0	Alarm Off/On
12	59Px_X_Ena	0/1	-	1	0	Operation Off/On

3.13 Three-phase Under voltage Protection (27P)

3.13.1 Overview

The main operating function of Two Stage Three-phase under voltage protection (27P) is to continuously measure the protected network voltage limit cause by different faults. if the detected voltage limit is below to set level, the Two Stage Three-phase under voltage protection will operates or gives alarm signal with dependable multi stage definite time delay (DT) or inverse definite minimum time (IDMT) delay characteristics and each stage have same logics of setting. This protection has extra ordinary feature to operate with over current protection.

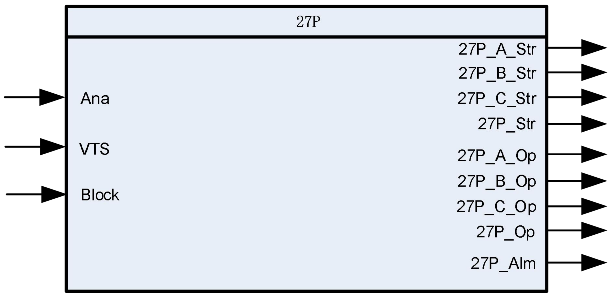
27P can support several kind of VT connection:

- Three phase voltage (Ua, Ub, Uc)
- Three phase-to-phase voltages (Uab, Ubc, Uca)
- Two phase-to-phase voltages (Uab, Ubc)

Two Stage Three-phase under voltage protection (27P) also have blocking function capability.

In addition, the 27P can be configured on the high-voltage side or middle-voltage side of the transformer as a backup protection for each side.

3.13.1.1 Function Block



3.13.1.2 Signals

Table 3.13.1 27P Input Signals

NO.	Signal	Description
1	Ana	three phase group signal for voltage inputs
2	VTS	Block signal of VTS alarm
	Block	Block signal of 27P

Table 3.13.2 27POutput Signals

NO.	Signal	Description
1	27P_A_Str	phase A Start signal of 27P
2	27P_B_Str	phase B Start signal of 27P
3	27P_C_Str	phase C Start signal of 27P
4	27P_Str	Common Start signal of 27P
5	27P_A_Op	phase A Operation signal of 27
6	27P_B_Op	phase B Operation signal of 27P
7	27P_C_Op	phase C Operation signal of 27P
8	27P_Op	Operation signal of 27P
9	27P_Alm	Alarm signal of 27P

3.13.2 Protection Principle

The three-phase under voltage protection function can be enabled or disabled by setting the corresponding 27Px_X_Ena parameter values as "1" or "0".

The fundamental frequency component of the measured three phase voltages are compared phase-wise to the set value of the 27Px_X_Vol_Str setting. If the measured value is lower than the set value of the 27Px_X_Vol_Str setting, the phase selection logic detects the phase or phases in which the fault level is detected. If the number of faulty phases matches the set 27Px_X_Str_Ph_Num and no blocking signal input is activated, the phase selection logic activates the timer and the 27Px_X_Str output and the corresponding output of the respective phases (27Px_X_Str_A/B/C).

The 27Px_X_Vol_Optsetting is used for selecting phase-to-earth (27Px_X_Vol_Opt=0) or phase-to-phase(27Px_X_Vol_Opt=1) voltages for protection.

27Px_X_Vol_Str is the preset value to check for the voltage

27Px_X_Str_Ph_Num shows the number of phases required for operate activation.

Blocking for low current levels is activated by setting. The desired blocking level can be adjusted by the 27Px_X_I_Blk_Ena setting.

For example:If the measured current level decreases below the 0.05A, either the trip output of stage 1, or both the trip and the START outputs of stage 1, are blocked. Blocking for low voltage levels is activated by default.

Depending on the value of the set 27Px_X_Op_Curve_Type corresponding A column of table 3.4.5, the time characteristics are selected according to DT (27Px_X_Op_Curve_Type=0) or IDMT (27Px_X_Op_Curve_Type=1~13). The IDMT operating curve type is shown below:

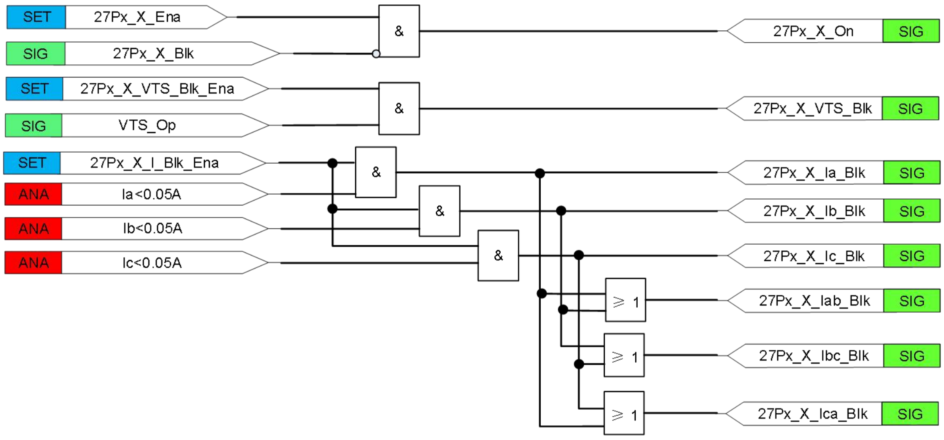
$$t(I) = \left(\frac{K}{1-\left(\frac{U}{U_{set}}\right)^{\alpha}} + C \right) \times T_P$$

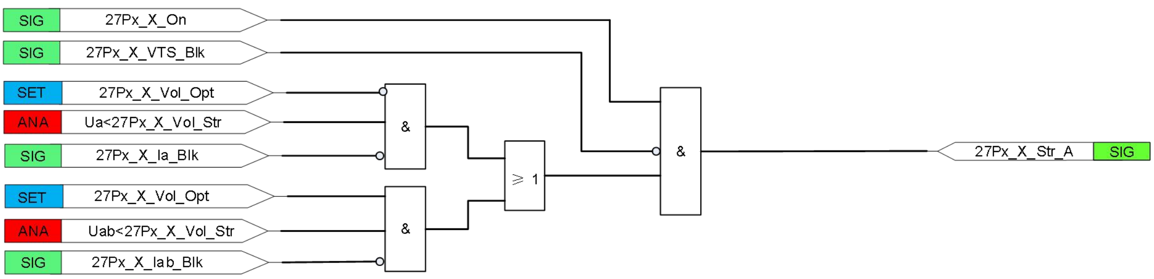
When the operation timer has reached the value set by 27Px_X_Op_T in the DT mode or the value set by the IDMT operate time curve, the 27Px_X_Op output is activated. The corresponding output for the respective phases (27Px_X_Op_A/B/C) is also activated. For the IDMT model, 27Px_X_Min_Op_T defines the minimum desired operate time for IDMT.

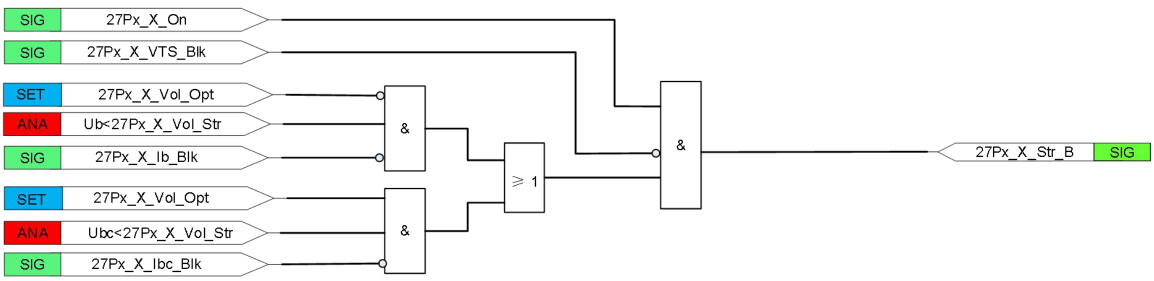
If a drop-off situation occurs, that is, a fault suddenly disappears before the operation delay is exceeded, the reset state is activated, the timer is reset and the 27Px_X_Str output is deactivated.

The binary input 27Px_X_Blk can be used to block the function. The activation of the 27Px_X_Blk input deactivates all outputs and resets the internal timers.

3.13.3 Logic Diagram







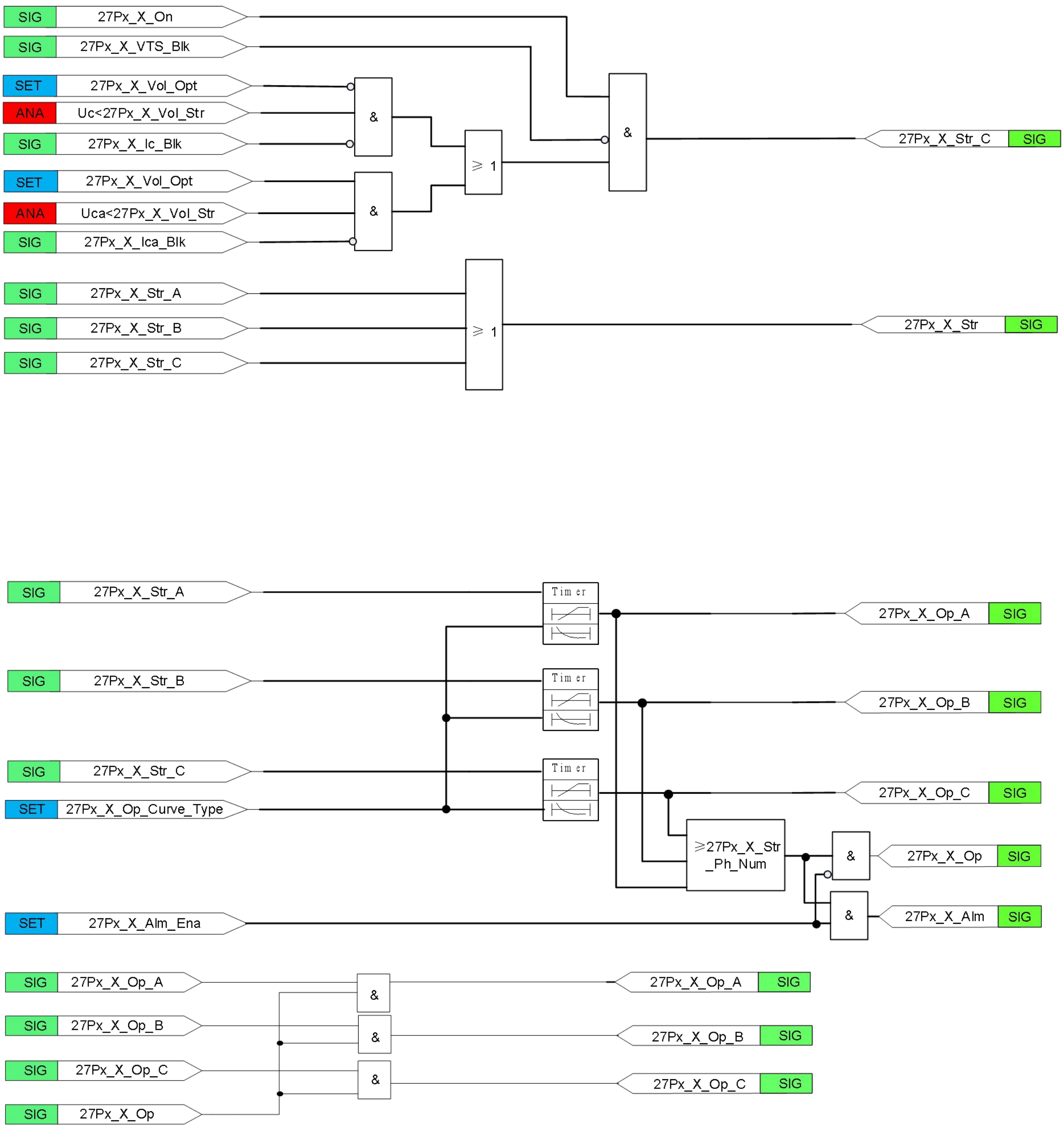


Figure 3.13.1 Functional module diagram

3.13.4 Settings

Table 3.13.3 Settings of Two stage Three-phase undervoltage protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	27Px_X_Vol_Str	0.00~160.00	V	0.01	40.00	Start value of under voltage
2	27Px_X_Op_T	0.040~300.000	s	0.001	10.000	Operating time delay for definite time curve
3	27Px_X_Str_Ph_Num	1/2/3	-	1	3	Number of phases required for operate activation:1 for 1 phase, 2 for 2 phases, 3 for 3 phases

No.	Name	Values (Range)	Unit	Step	Default	Description
4	27Px_X_Op_Curve _Type	0~13	-	1	0	Selection of the type of time delay curve:0 for DT, 1~13 for IDMT
5	27Px_X_T_ Mult	0.050~200.000	-	0.001	10.000	Time multiplier in IEC curves
6	27Px_X_Min_Op_T	0.000~60.000	s	0.001	0.050	Minimum operate time delay for IDMT curves
7	27Px_X_Alpha	0.00~3.00	-	0.01	1.00	X-side (X=H,M) constant α of 27P Stage x(x=1,2)
8	27Px_X_C	0.000~60.000	-	0.001	0.000	X-side (X=H,M) constant C of 27P Stage x(x=1,2)
9	27Px_X_K	0.001~100.000	-	0.001	1.000	X-side (X=H,M) constant K of 27P Stage x(x=1,2)
10	27Px_X_Vol_Opt	0/1	-	1	0	Parameter to select phase or phase-to- phase voltages: 0 forphase voltages,1 forphase-to-phase voltages
11	27Px_X_VTS_Blk_ Ena	0/1	-	1	0	Under voltage protection can be blocked due to VT circuit failure if the setting is set as “1”.
12	27Px_X_I_Blk_Ena	0/1	-	1	0	Under voltage protection can be blocked due to CT circuit failure if the setting is set as “1”.
13	27Px_X_Alm	0/1	-	1	0	Logic setting of nabling/disabling under voltage protection for alarm purpose 0: disable 1: enable
14	27Px_X_Ena	0/1	-	1	0	Operation Off/On

3.14 Over excitation Protection (24)

3.14.1 Overview

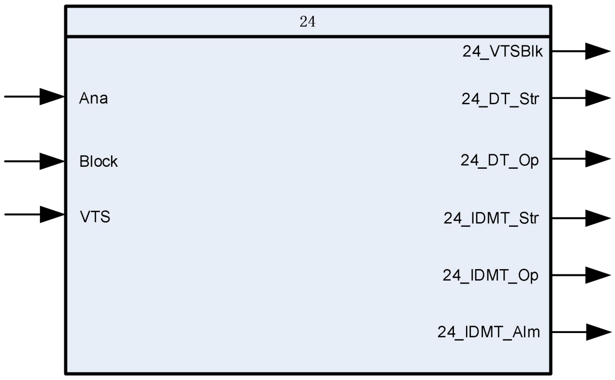
In fact, the primary devices are stationary likes power transformer and some are rotating like generators or motors. They are very expensive and need to work properly from the point of view of continuous power supply . Over excitation disturbs the proper operation of these primary devices and harms the internal structure and leads to major damages. The main function of over excitation protection is to check the level of over excitation of protected devices. If the relay detects the level of over excitation is greater than the set value, the over excitation protection will operate.

The operating range of power system fundamental frequency for 50Hz system is 45~55Hz and for 60Hz system is 55~65Hz.

Notice!

For the point of view of suitable operation of protection, overexcited protection can be configuring at any side of power transformer.

3.14.1.1 Function Block



3.14.1.2 Signals

Table 3.14.1 24 Input Signals

NO.	Signal	Description
1	Ana	“UA,UB,UC” is the three phase group signal for voltage inputs
2	Block	Block signal from 24
3	VTS	Block signal from VTS alarm

Table 3.14.2 24 Output Signals

NO.	Signal	Description
1	24_VTSBlk	Block signal from VTS of 24
2	24_DT_Str	Start signal from 24DT
3	24_DT_Op	Operation signal from 24DT
4	24_IDMT_Str	Start signal from 24DMT
5	24_IDMT _Op	Operation signal from 24DMT
6	24_IDMT _Alm	Alarm signal from24DMT

3.14.2 Protection Principle

Over excitation protection consists of one stage definite time protection and one stage inverse time protection,both of which can be used to trip the relevant break error to alarm the users of the urgent situation. The RMS values of three phase voltages are used for protection calculation. Therefore, the calculation result will not be affected by the frequency fluctuation. Overall, the over excitation inverse time curve is a sectional linear curve, which has high adaptability to all types of fault situations.

The over excitation severity can be represented by the over excitation value,the result of voltage dividing frequency. The over excitation value can be calculated according to the following equation.

$$n = \frac{U_*}{f_*}$$

Where:

U_* and f_* are per unit value of voltage and frequency respectively.

The base value for calculating per unit value of voltage is the secondary voltage proportions to the primary voltage of one side of transformer, and the base value for calculating per unit value of frequency is the measured frequency. Hence, if the transformer works under normal operation, n should be equal to 1.

This base voltage calculation is automatically executed continuously and the users only need to enter the corresponding VT ratio when configuring the settings.

1,Definite time operation criterion:

$$U_* / f_* > 24DT\_K$$

2,Inverse time operation criterion:

Inverse time characteristic is a curve that the over excitation value inversely proportion to the time.The value reflects the heat accumulation and radiation exponentially increase as the over excitation situation deteriorates. The over excitation value is calculated according the above equation. After obtaining the over excitation value, the time delay is obtained by matching with the sectional linear insertion.

Several groups of settings corresponding the points on the curve can be configured, which finally determines the inverse time operation characteristics.This protection can adapt to different over excitation conditions of various transformers flexibly.

The below figure shows inverse time characteristic of over excitation protection.

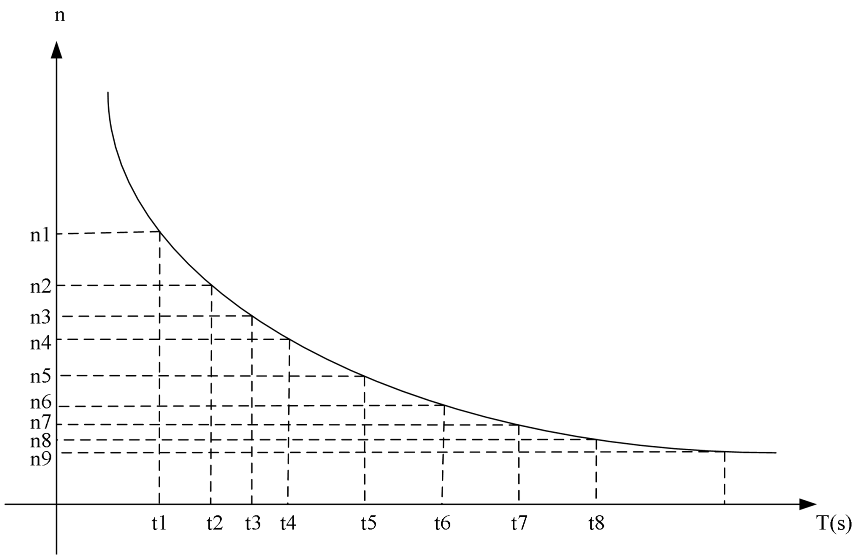


Figure 3.14.1 Inverse Time Characteristic of Over excitation Protection

The main harm of over excitation to transformer is rapidly accumulated heat, so accumulation algorithms adopted and the time delay can be calculated according to characteristic curve basing on the over excitation value. When the accumulated time delay surpasses the operating time delay, inverse time over excitation protection operates.

Dissipating process is also applied to better protect the transformer.When the over excitation value drops less than the minimum over excitation multiple setting, the accumulated value decreases gradually instead of dropping to 0 directly. After the over excitation protection operates to open the breaker and over excitation condition disappears, the accumulated thermal decreases to 0 in 10s.

Over excitation value is the accumulated value by adding the over excitation information at current instant and the over excitation information integrated over various time intervals from its beginning.

Inverse time characteristic curve can be demonstrated by modifying several over excitation value settings showed below.It also should be noticed that each setting of n and t should follow the below rules(n1 ≥ n2…. ≥ n9;t1 ≤ t2…. ≤ t9).

3.14.3 Logic Diagram

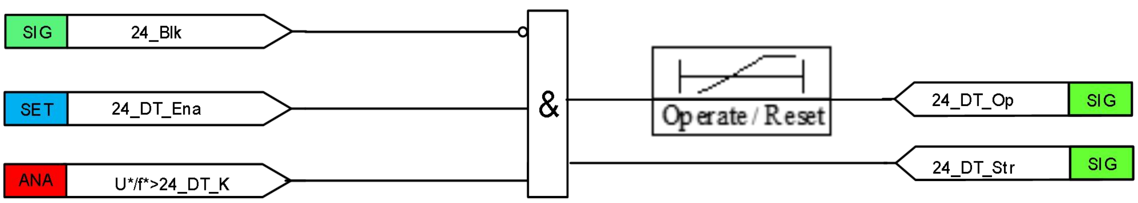


Figure 3.14.2 Logic Diagram of DefiniteTime Over excitation Protection

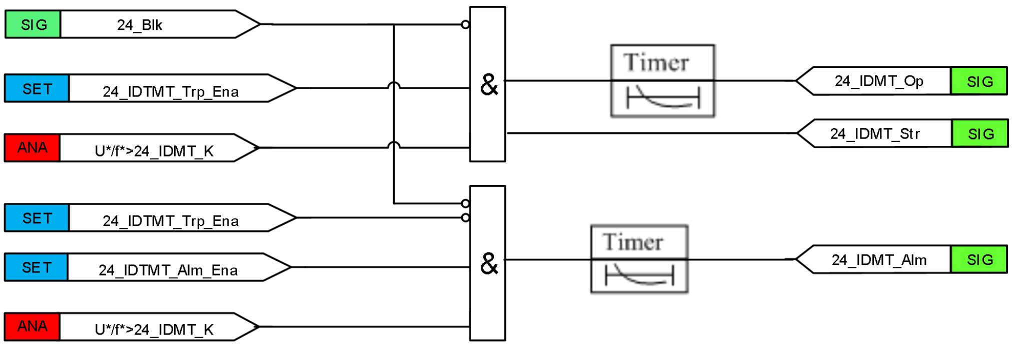


Figure 3.14.3 Logic diagram of inverse-time over excitation protection

3.14.4 Settings

Table 3.14.3 Settings of Over excitation Protection

No.	Item	Values (Range)	Unit	Step	Default	Description
1	24_DT_K	1.00~1.60	-	0.01	1.00	Multiple setting of stage 1 of definite time over excitation protection for trip purpose
2	24_DT_Op_T	0.1~9999.0	s	0.01	9999.0	Time delay setting of stage 1 of definite time over excitation protection for trip purpose
3	24_IDMT_Op_K1	1.00~1.70	-	0.01	1.50	Multiple setting 1 of inverse time over excitation protection: n1
4	24_IDMT_Op _T1	0.1~9999.0	s	0.1	1.0	Time delay setting corresponding to multiple setting 1: t1
5	24_IDMT_Op _K2	1.00~1.70	-	0.01	1.45	Multiple setting 2 of inverse time over excitation protection: n2
6	24_IDMT_Op _T2	0.1~9999.0	s	0.1	1.5	Time delay setting corresponding to multiple setting 2: t2
7	24_IDMT_Op _K3	1.00~1.70	-	0.01	1.40	Multiple setting 3 of inverse time over excitation protection: n3
8	24_IDMT_Op _T3	0.1~9999.0	s	0.1	2.0	Time delay setting corresponding to multiple setting 3: t3
9	24_IDMT_Op _K4	1.00~1.70	-	0.01	1.35	Multiple setting 4 of inverse time over excitation protection: n4
10	24_IDMT_Op _T4	0.1~9999.0	s	0.1	2.5	Time delay setting corresponding to multiple setting 4: t4
11	24_IDMT_Op _K5	1.00~1.70	-	0.01	1.30	Multiple setting 5 of inverse time over excitation protection: n5
12	24_IDMT_Op _T5	0.1~9999.0	s	0.1	3.0	Time delay setting corresponding to multiple setting 5: t5
13	24_IDMT_Op _K6	1.00~1.70	-	0.01	1.25	Multiple setting 6 of inverse time over excitation protection: n6
14	24_IDMT_Op _T6	0.1~9999.0	s	0.1	8.0	Time delay setting corresponding to multiple setting 6: t6

No.	Item	Values (Range)	Unit	Step	Default	Description
15	24_IDMT_Op _K7	1.00~1.70	-	0.01	1.20	Multiple setting 7 of inverse time over excitation protection: n7
16	24_IDMT_Op _T7	0.1~9999.0	s	0.1	10.0	Time delay setting corresponding to multiple setting 7: t7
17	24_IDMT_Op _K8	1.00~1.70	-	0.01	1.15	Multiple setting 8 of inverse time over excitation protection: n8
18	24_IDMT_Op _T8	0.1~9999.0	s	0.1	15.0	Time delay setting corresponding to multiple setting 8: t8
19	24_IDMT_Op _K9	1.00~1.70	-	0.01	1.10	Multiple setting 9 of inverse time over excitation protection: n9
20	24_IDMT_Op _T9	0.1~9999.0	s	0.1	20.0	Time delay setting corresponding to multiple setting 9: t9
21	24_Up/Upp	0/1	-	1	0	Voltage option between phase voltage and phase-to-phase voltage for calculation of over excitation protection 0: phase voltage 1: phase-to-phase voltage
22	24_DT_Ena	0/1	-	1	0	Logic setting of enabling/disabling stage 1 of definite time over excitation protection for trip purpose 0: disable 1: enable
23	24_IDMT_Trp_Ena	0/1	-	1	0	Logic setting of enabling/disabling inverse time over excitation protection for trip purpose 0: disable 1: enable
24	24_IDMT_Alm_Ena	0/1	-	1	0	Logic setting of nabling/disabling inverse time over excitation protection for alarm purpose 0: disable 1: enable

3.15 Over frequency Protection(81O)

3.15.1 Overview

The main and important function of over frequency protection (81O) is to track or monitored the protected zone of electrical power system, where very high accurate and dependable power frequency detection is required. Because over frequency cause many unwanted malfunction operations in power system likes:

- Disturbed the parallel operation of machines (generator or motor)

- Increase the size of conductor (skin effect)
- Increase the size of cores
- Disturbed the metering system capability

In order to prevent the electrical power system from above mentioned malfunctions, over frequency protection (81O) provide 4 different stages with definite time delay to overcome all problems related to cause by over freqency. The operation principle over frequency protection (81O) is based on the following points:

- Abnormal range of frequency
- Line-sequence voltage

Over frequency protection (81O) is also have a blocking capability.

3.15.1.1 Function Block

3.15.1.2 Signals

Table 3.15.1 81O Input Signals

NO.	Signal	Description
1	Ana	Three phase group signal for voltage inputs
2	Block	Block signal of 81O
3	VTS	Block signal of VTS alarm

Table 3.15.2 81O Output Signals

NO.	Signal	Description
1	81O _Str	Start signal from 81O
2	81O_Op	Operation signal from 81O

3.15.2 Protection Principle

Over frequency protection consists of the four stages (stage 1 to stage 4).All stages over frequency protection with independent logic, frequency and time delay settings.

In order to prevent over frequency protection from undesired operation, over frequency protection will be blocked in some cases.

1) Blocking in under voltage condition

If the minimum voltage ULmin<81Ox_UL_Blk, the calculation of protection is not carried out and the output relay will be blocked.

2) Frequency abnormality condition

When f<(fn-10)Hz or f>(fn+10)Hz, over frequency protection will be blocked.

Frequency criterion for each stage is:

$$f > 81Ox\_f\_Str$$

3.15.3 Logic Diagram

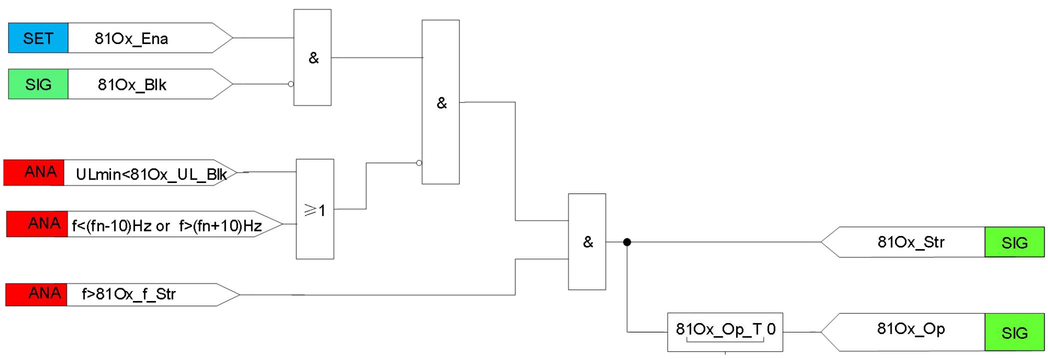


Figure 3.15.1 Over frequency Protection logic diagram

3.15.4 Settings

Table 3.15.3 Settings of Over frequency Protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	81Ox_f_Str	20.00~100.00	Hz	0.01	60.10	Frequency setting for stage x(x=1,2,3,4) of over frequency protection
2	81Ox_Op_T	0.08~200.00	S	0.01	10.00	Time delay for stage x(x=1,2,3,4) of over frequency protection
3	81Ox_UL_Blk	18.00~100.00	V	0.01	30.00	Voltage value of blocking over frequency protection
4	81Ox_Ena	0/1	-	1	0	Enabling/disabling rate of frequency change to block stage x(x=1,2,3,4) of over frequency protection 0: disable 1: enable

3.16 Under frequency Protection(81U)

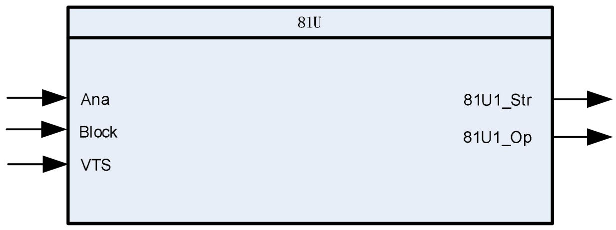
3.16.1 Overview

The main function of under frequency protection (81U) is to continuously track the frequency of protected zone of electrical power system, where very high accurate and dependable power frequency detection is required. Because under frequency cause many unwanted malfunction operations in power system. In electrical power system there are many reason to cause the under frequency likes one of them is active power is not fulfilling match with required power of system. The operation principle over frequency protection (81U) is based on the following points:

- Abnormal range of frequency
- Line-sequence voltage

Under frequency protection (81U) is provide very accurate and reliable operation with four stage definite time delay and each stage have same setting of approach. Under frequency protection (81) is also have a blocking capability.

3.16.1.1 Function Block



3.16.1.2 Signals

Table 3.16.1 81U Input Signals

NO.	Signal	Description
1	Ana	Three phase group signal for voltage inputs
2	Block	Block signal of 81U
3	VTS	Block signal of VTS alarm

Table 3.16.2 81U Output Signals

NO.	Signal	Description
1	81Ux_Str	Start signal from 81U
2	81Ux_Op	Operation signal from 81U

3.16.2 Protection Principle

Under frequency Protection consists of the four stages (stage 1 to stage 4).All stages under frequency protection with independent logic, frequency and time delay settings.

In order to prevent under frequency protection from undesired operation, under frequency protection will be blocked in some cases.

1) Blocking in under voltage condition

If the minimum voltage ULmin<$81Ux\_UL\_Blk$, the calculation of protection is not carried out and the output relay will be blocked.

2) Frequency abnormality condition

When f<(fn-10)Hz or f>(fn+10)Hz, over frequency protection will be blocked

Frequency criterion for each stage is:

$$f < 81Ox\_f\_Str$$

3.16.3 Logic Diagram

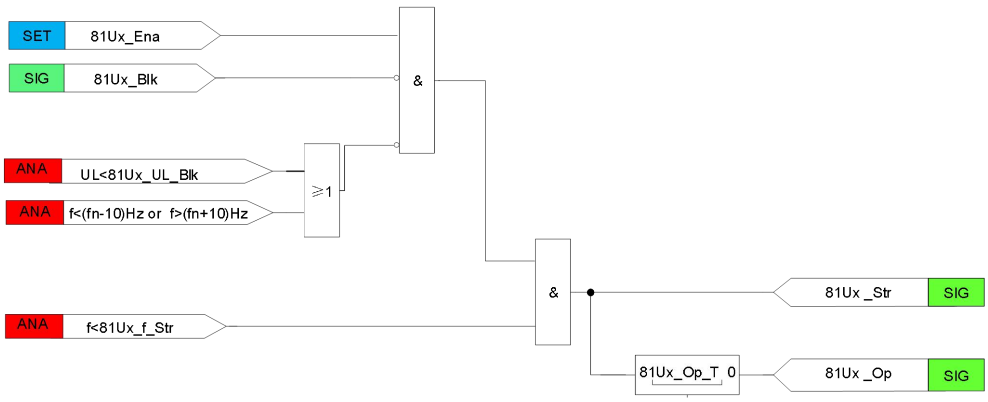


Figure 3.16.1 Logic diagram of under frequency Protection

3.16.4 Settings

Table 3.16.3 Settings of Under frequency Protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	81Ux_f_Str	20.00~100.00	Hz	0.01	59.90	Frequency setting for stage x(x=1,2,3,4) of under frequency protection
2	81Ux_Op_T	0.08~200.00	S	0.01	10.00	Time delay for stage x(x=1,2,3,4) of under frequency protection
3	81Ux_UL_Blk	0.00~100.00	V	0.01	30.00	Voltage value of blocking under frequency protection

No.	Name	Values (Range)	Unit	Step	Default	Description
4	81Ux_Ena	0/1	-	1	0	Enabling/disabling rate of frequency change to block stage x(x=1,2,3,4) of under frequency protection 0: disable 1: enable

3.17 Rate-of-change of frequency protection (81R)

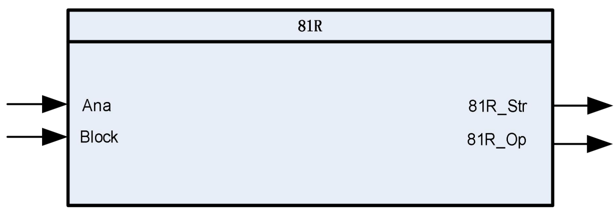
3.17.1 Overview

The chief important function of Rate-of-change of frequency protection (81R) is to continuously check the rate of change of power system fundamental frequency. Because the rate of change of frequency is great impact on electrical power system. The power grid supply frequency is not constant every time and it changes time to time and load to load, If any situation that the variation of power grid frequency is greater than allowable limits of normal operation occurs, it will cause many unwanted fault in power system likes:

- Disturbed the parallel operation of machines (generator or motor)
- Disturbed the metering system capability
- Harm the system

Rate-of-change of frequency protection (81R) is provide very accurate and reliable operation with one stage definite time delay .

3.17.1.1 Function Block



3.17.1.2 Signals

Table 3.17.1 81R Input Signals

NO.	Signal	Description
1	Ana	Three phase voltage inputs.
2	Block	Block signal of 81R

Table 3.17.2 81R Output Signals

NO.	Signal	Description
1	81R _Str	Start signal from 81R
2	81R _Op	Operation signal from 81R

3.17.2 Protection Principle

The rate of change of the frequency of the positive sequence voltage is calculated from phase-to-phase or phase-to-earth voltages and compared to the set 81R_Dfdt_Str. If the measured frequency rate of change is higher than the set 81R_Dfdt_Str and no block signal is activated, the operate timer and 81R_Str signal are activated. However, if the voltage magnitude is below the 81R_UL_Blk set value or the difference between the measured frequency and the rated frequency exceeds 10 Hz, the operate timer and 81R_Str signal are deactivated.

81R_Dfdt_Str is the frequency gradient start value. When the setting 81R_FrUp_Ena=1, it means a positive change in frequency. Otherwise, it means a negative change in frequency.

NOTICE!

81R_Vol_Blk is the setting level compared to the physically connected voltages. For example, if phase-to-phase voltages are physically connected (phase-to-earth voltages virtual), the 10% setting results in ten percent of the normal phase-to-phase voltage. If phase-to-earth voltages are connected (phase-to-phase voltages virtual), the 10% setting results in 17 percent of the normal phase-to-earth voltage. This is assuming the base voltage is set to be the normal/nominal phase-to-phase voltage.

➢ **Timer**

Once activated, the 81R_Str output activates. The time characteristic is according to DT. When the operation timer has reached the value set by 81R_Op_T, the 81R_Op output is activated. If the frequency rate of change condition disappears before the module operates, the operation resets with a set time delay of 81R_Reset_T.

The activation of the $81R\_Blk$ input resets the timer and deactivates the 81R_Op and 81R_Str outputs.

81R_Op_T is the operation delay time setting of the 81R.

81R_Reset_T is the reset delay time setting of the 81R.

3.17.3 Logic Diagram

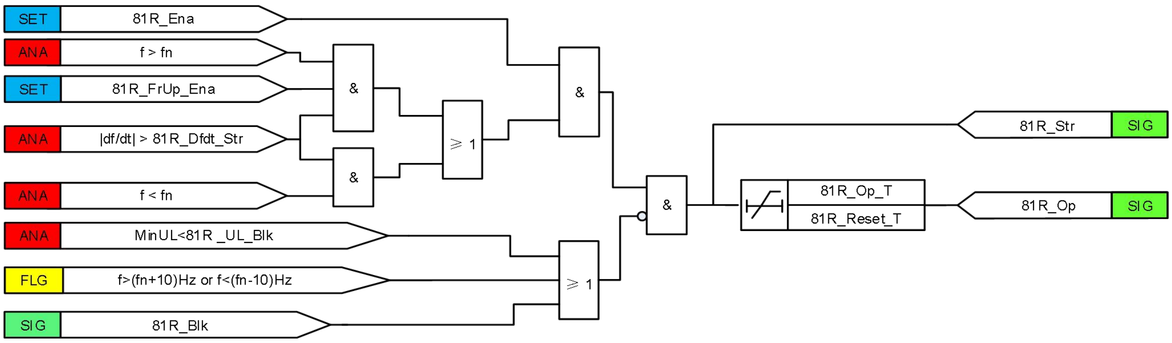


Figure 3.17.1 Rate-of-change of frequency protection logic diagram

3.17.4 Settings

Table 3.17.3 Settings of Rate-of-change of frequency Protection

No.	Name	Range	Unit	Step	Default	Description
1	81R_Dfdt_Str	0.50 - 10.00	Hz/s	0.01	0.50	Frequency gradient start value
2	81R_FrUp_Ena	0/1	-	1	0	Negative/positive change in frequency:0 for negative, 1 for positive
3	81R_Op_T	0.12 - 60.00	s	0.01	1.00	Operate time delay
4	81R_Reset_T	0.00 - 60.00	s	0.01	0.20	Time delay for reset
5	81R_UL_Blk	18.00 – 100.00	V	0.01	30.00	Voltage value of blocking 81R
6	81R_Ena	0/1	-	1	0	Operation disable/enable

3.18 Reactor differential protection (87R)

3.18.1 Overview

In electrical power system or electrical power industry, power reactor is the one of the important primary equipment. For this main point of view, the protection of power reactor is very important task. If some kind of trouble or fault situation happen in the protected zone of the power reactor, then need to clear this trouble or fault as soon as possible. Reactor differential protection (87R) is specially designed for such kind of trouble or fault situation to protect reactor from maximum cause of injuries or harm and operate the protection as quick as possible.

Reactor differential protection (87R) have two dependable operating function of element likes biased differential element and instantaneous differential element.

1) Biased differential element is operation based on with three characteristics slope.

2) Instantaneous differential element increase the operating speed of protection during internal fault of reactor without three characteristics slope of biased differential element.

3) Some other important and superior special functions of 87R protection are:

- Meticulous phase compensation IED calculation criteria.

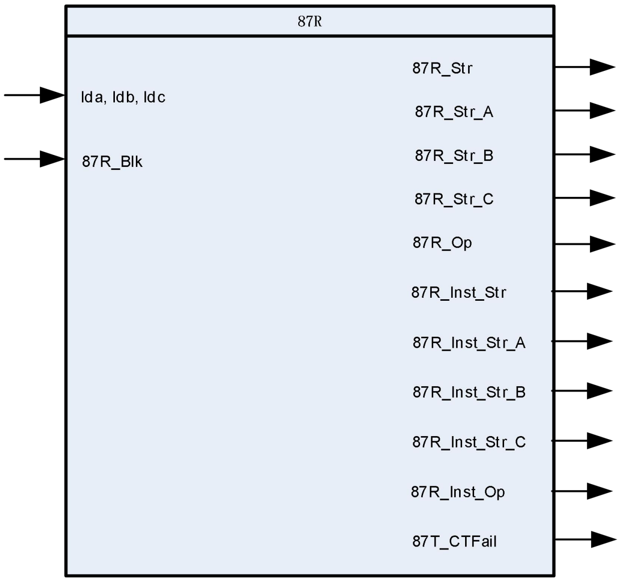
- Accurate and fast fault tracking capability.

Above mentioned these two element of reactor differential protection function are highly proved to sense quickly any abnormal situation in protected zone of reactor and in case of any abnormality is detected then very fast trip command is issued.

Notice!

Point of view of user's project and real time experience, some of the protection function of reactor differential protection (87R) are enable or disable according to the customer's or user's demand of situation.

3.18.1.1 Function Block



3.18.1.2 Signals

Table 3.18.1 87R Input Signals

NO.	Signal	Description
3	Ida, Idb, Idc	Three phase differential current of 87R
4	87R_Blk	Block signal of 87R

Table 3.18.2 87R Output Signals

NO.	Signal	Description
11	87R _Str	Start signal of differential from 87R
12	87R _Str_A	Start_A signal of differential from 87R
13	87R_Str_B	Start_B signal of differential from 87R
14	87R _Str_C	Start_C signal of differential from 87R

NO.	Signal	Description
15	87R_ Op	Operation signal of differential from 87R
16	87R_Inst_Str	Start signal of instantaneous differential from 87R
17	87R_Inst_Str_A	Start_A signal of instantaneous differential from 87R
18	87R_Inst_Str_B	Start_B signal of instantaneous differential from 87R
19	87R_Inst_Str_C	Start_C signal of instantaneous differential from 87R
20	87R_ Inst_Op	Operation signal of instantaneous differential from 87R
21	87R_CTFail	CT fail signal of 87R

3.18.2 Protection Principle

3.18.2.1 Phase Over current Element

The device can regulate the difference in transformation ratio between CT at each side of reactor. Each side is provided with a CT transformation ratio regulation coefficient which is multiplied by current quantity collected by the device to get the quantity after regulation of CT transformation ratio. By simply entering relevant parameters of reactor (refer to the table of settings), it's possible to automatically obtain regulation coefficient of CT at each side without the need for external connection with auxiliary CT. Such type of regulation is more reliable when compared with regulation performed using hardware circuit.

3.18.2.2 Magnitude Compensation

➢ **Rated primary current at each side of Reactor**

$$I_{1e} = \frac{S_n}{\sqrt{3}U_{1n}}$$

Where:

Sn means maximum rated capacity of reactor nameplate, and U_{1n} represents rated primary voltage at calculated side of reactor.

CT transformation ratio at each side of reactor

$$K_{TA} = \frac{I_{1n}}{I_{2n}}$$

Where, I_{2n} rated secondary current of CT is 5A or 1A; I_{1n}"primary side of CT" is dependent on corresponding settings of system parameters.

Rated secondary current at each side of reactor

$$I_{2e} = \frac{I_{1e}}{K_{TA}}$$

CT balance coefficient at each side of differential protection

With HV side as reference, the balance coefficient at HV side is fixedly set to 1.

Balance coefficient at LV side (switch CT):

$$K_{phL-ZC} = \frac{K_{TAL}}{K_{TAH}}$$

In the formula, K_{TAL} means CT transformation ratio of CB at LV side.

3.18.2.3 Fault detector based on biased differential current

The fault detector can initiate biased differential element, and its operation equation is shown as below.

Idmax>0.9*87R_Cur_Str

Where：

Idmax is the maximum value of three phase differential currents.

3.18.2.4 Fault detector based on instantaneous differential current

The fault detector can initiate instantaneous differential element, and its operation equation is shown as below.

Idmax>0.9*87R_Cur_Inst

Where：

Idmax is the maximum value of three phase differential currents.

3.18.2.5 Calculation of Differential and Restraint Currents

The equation of calculating differential current is:

$$\begin{cases} I_{dA} = \left| I'_{HA} + I'_{LA} \right| \\ I_{dB} = \left| I'_{HB} + I'_{LB} \right| \\ I_{dC} = \left| I'_{HC} + I'_{LC} \right| \end{cases}$$

The equation of calculating restraint current is:

$$\begin{cases} I_{rA} = \frac{1}{2} \times \left(I'_{HA} - I'_{LA} \right) \\ I_{rB} = \frac{1}{2} \times \left(I'_{HB} - I'_{LB} \right) \\ I_{rC} = \frac{1}{2} \times \left(I'_{HC} - I'_{LC} \right) \end{cases}$$

Where:

IdA, IdB, IdC are differential currents.

IrA, IrB, IrC are restraint currents.

3.18.2.6 Biased Low Stage

$$I_d > K_1 \times I_r + I_{Str} \quad (I_r < K_{nee1})$$

$$I_d > K_2 \times (I_r - K_{nee1}) + K_1 \times K_{nee1} + I_{Str} \quad (K_{nee1} \le I_r < K_{nee2})$$

$$I_d > K_3 \times (I_r - K_{nee2}) + K_2 \times (K_{nee2} - K_{nee1}) + K_1 \times K_{nee1} + I_{Str} \quad (I_r \ge K_{nee2})$$

Where:

I_d and I_r are respectively the differential current and the restraint current.

I_{Str} is the start setting of biased differential protection (i.e., 87R_Cur_Str).

“Knee1” and “Knee2” are respectively current settings of knee point 1 and knee point 2, the corresponding set value: 87R_Cur_K1 and 87R_Cur_K2).

“K1”, “K2” and “K3” are three slopes of biased differential protection, the corresponding set value: 87R_Slope1, 87R_Slope2, 87R_Slope3.

Operation characteristic of sensitive biased differential element is shown below.

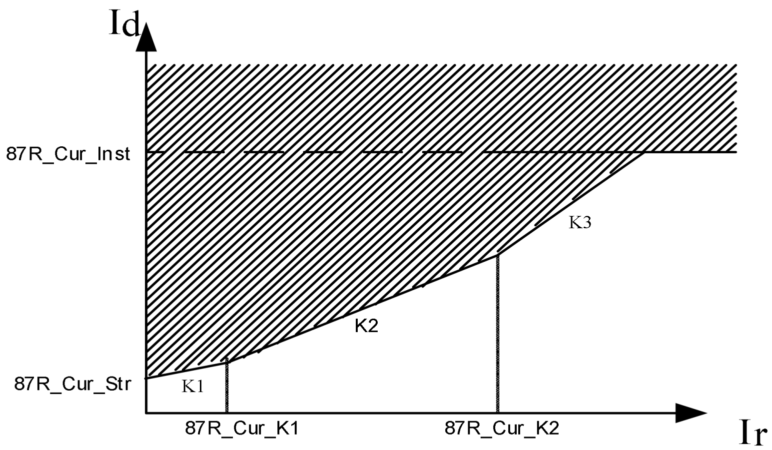


Figure 3.18.1 Operation characteristic of differential protection

3.18.2.7 Instantaneous High Stage

Instantaneous high stage for reactor is to accelerate the operation speed for reactor's internal fault. The operation of the instantaneous high stage is not biased and has no blocking element. Instantaneous high stage shall operate to clear the fault when any phase differential current is higher than its setting. Its operation criterion is:

Idmax> 87R_Cur_Inst

Where:

Idmax is the maximum value of three phase differential currents.

3.18.2.8 Differential CT circuit abnormality

If the differential current in any phase is continually greater than the alarm setting 87R_Cur_Alm over 10s, the differential current abnormality alarm will be issued, but this alarm will not block differential protection.

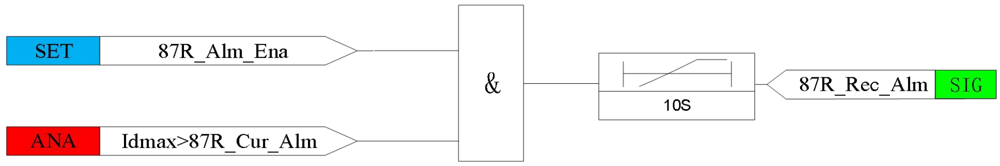


Figure 3.18.2 Differential CT Circuit Abnormality

3.18.2.9 Differential CT circuit failure

This is a differential protection CT circuit failure criterion.

First of all, the possibility of concurrence of multi-side CT line-break and fault is not taken into consideration. Under this premise, it's possible to distinguish between CT circuit failure and fault based on the following characteristic.In case of CT circuit failure, it's necessary to specifically identify circuit failure phase.

Single-phase or two-phase CT circuit failure:

a) min{Ia,Ib,Ic}<0.5Ie
b) max{Ia,Ib,Ic}<1.1Ie
c) Self side:3I0<0.3Ie
d) Other side:3I0<0.2Ie
e) Other side:Imax> 0.04

Blocking of biased differential protection by CT circuit failure follows the following principle:

- When "CTS_Blk_Ena" is set to "1", biased differential protection would be blocked in case of CT circuit failure (as for longitudinal percentage differential protection and split-phase percentage differential protection, differential protection would be blocked when differential current is less than 1.2Ie and would not when more than 1.2Ie; with respect to cell differential protection, differential protection would be blocked when differential current is less than 1.2Ie and would not when more than 1.2Ie. Here, Ie means rated secondary current at HV side of reactor, while ILe represents rated secondary current at LV side of reactor).
- When "CTS_Blk_Ena" is set to "0", biased differential protection would not be blocked in case of CT circuit failure.

Where:

"CTS_Blk_Ena" is effective for Biased low stage.

It should be noted that CT circuit failure induced blocking is principally designed to prevent malfunction of differential protection caused by CT circuit failure and follows the following principles:

Firstly, concurrence of multi-side CT circuit failure is not taken into account; secondly, differential protection trip is allowed in case of concurrence of failure and CT circuit failure; thirdly, relevant protection should be blocked when fault occurs after CT circuit failure; fourthly, protection shall operate if CT circuit failure occurs after the occurrence of fault.

3.18.3 Logic Diagram

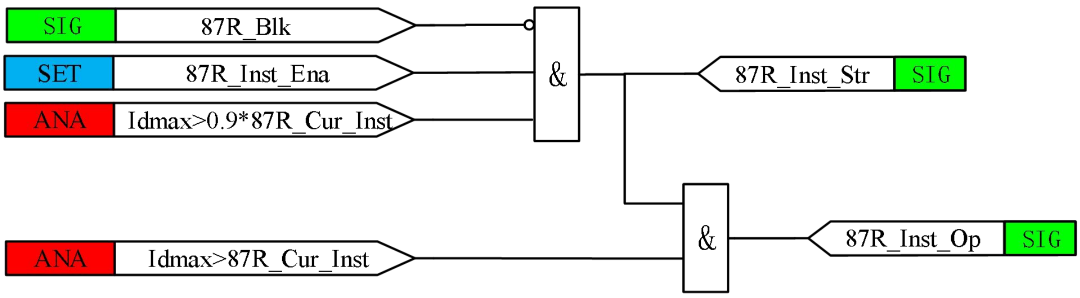


Figure 3.18.3 Logic diagram of 87R_Inst protection

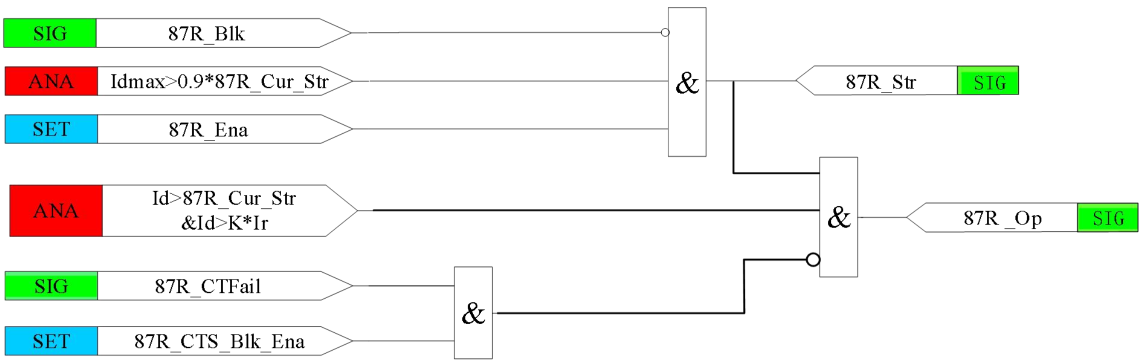


Figure 3.18.4 Logic diagram of 87R protection

Where:

Idmax is the maximum value of three phase differential currents.

“87T_CTFail” means that the flag of CT circuit failure.

3.18.4 Settings

Table 3.18.3 Settings of Reactor differential protection

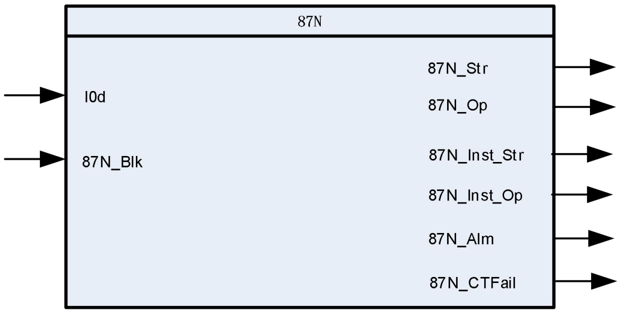
No.	Name	Range	Unit	Step	Default	Description
1	87R_Cur_Str	0.05~20.00	PU	0.01	0.40	Pickup setting of biased differential element
2	87R_Cur_Inst	0.05~20.00	PU	0.01	6.00	Current setting of instantaneous differential element

No.	Name	Range	Unit	Step	Default	Description
3	87R_K_Hm2	0.05~0.50	-	0.01	0.15	Coefficient of second harmonics for inrush current detection
4	87R_Cur_Alm	0.05~20.00	PU	0.01	1.00	Current setting of differential circuit abnormality alarm
5	87R_Cur_K1	0.05~20.00	PU	0.01	1.00	Current setting of knee point 1 for transformer differential protection
6	87R_Cur_K2	0.05~20.00	PU	0.01	6.00	Current setting of knee point 2 for transformer differential protection
7	87R _Slope1	0~0.90	-	0.01	0.00	Slope 1 of biased differential element
8	87R _Slope2	0~0.90	-	0.01	0.50	Slope 2 of biased differential element
9	87R _Slope3	0~0.90	-	0.01	0.75	Slope 3 of biased differential element
10	87R_Opt_Inrush	0~3	-	1	0	Option of inrush current discrimination principle: 0: Without Inrush Current Block 1: Harmonic principle
11	87R _Ena	0,1	-	1	0	Logic setting of enabling/disabling conventional biased differential element 0: disable 1: enable
12	87R_Inst_Ena	0,1	-	1	0	Logic setting of enabling/disabling instantaneous differential element 0: disable 1: enable
13	87R_Alm_Ena	0,1	-	1	0	Logic setting of enabling/disabling differential Alam element 0: disable 1: enable
14	87R_CTS_Blk_Ena	0,1	-	1	0	Logic setting of enabling/disabling block biased differential element during CT circuit failure 0: disable 1: enable

3.19 Reactor zero-sequence differential protection (87N)

3.19.1 Overview

3.19.1.1 Function Block



3.19.1.2 Signals

Table 3.19.1 87N Input Signals

NO.	Signal	Description
1	I0d	zero-sequence differential current of 87N
2	87N_Blk	Block signal of 87N

Table 3.19.2 87N Output Signals

NO.	Signal	Description
1	87N _Str	Start signal of differential from 87N
2	87N_ Op	Operation signal of differential from 87N
3	87N_Inst_Str	Start signal of instantaneous differential from 87N
4	87N_ Inst_Op	Operation signal of instantaneous differential from 87N
5	87N_Alm	Alarm signal of differential 87N
6	87N_CTFail	CT fail signal of 87N

3.19.2 Protection Principle

3.19.2.1 Amplitude Compensation

CT balance coefficient at each side of differential protection

With HV side as reference, the balance coefficient at HV side is fixedly set to 1.

Balance coefficient at LV side (switch CT):

$$K_{phL-LX} = \frac{K_{TAL}}{K_{TAH}}$$

3.19.2.2 Fault detector based on biased differential current

The fault detector can initiate biased differential element, and its operation equation is shown as below.

I0d>0.9*87N_Cur_Str

Where:

I0d is the value of three phase zero-sequence differential current.

3.19.2.3 Fault detector based on instantaneous differential current

The fault detector can initiate instantaneous differential element, and its operation equation is shown as below.

I0d>0.9*87N_Cur_Inst

Where:

I0d is the value of zero-sequence differential current.

3.19.2.4 Calculate Differential and Restraint Current

Zero-sequence differential current and restraint current are calculated as the following formulas :

$$I_{0d} = \left| I_{h0}^{'} + I_{l0}^{'} \right|$$

$$I_{0r} = \frac{1}{2} * \left| I_{h0}^{'} - I_{l0}^{'} \right|$$

Where:

I0d is the zero-sequence differential current;

I0r is the zero-sequence restraint current;

3.19.2.5 Operation Criterion

The operation criteria of 87N protection are as follows:

$$I_{0d} > K_1 \times I_{0r} + I_{Str} \quad (I_r < K_{nee1})$$

$$I_{0d} > K_2 \times (I_{0r} - K_{nee1}) + K_1 \times K_{nee1} + I_{Str} \quad (K_{nee1} \leq I_r)$$

Where:

I0d and I0r are respectively the differential current and the restraint current.

I_{Str} is the start setting of biased differential protection (i.e., 87N_Cur_Str).

"Knee1" is respectively current settings of knee point 1, the corresponding set value: 87R_Cur_K1).

"K1" and "K2" are three slopes of biased differential protection, the corresponding set value: 87R_Slope1, 87R_Slope2.

3.19.2.6 Operation Characteristic

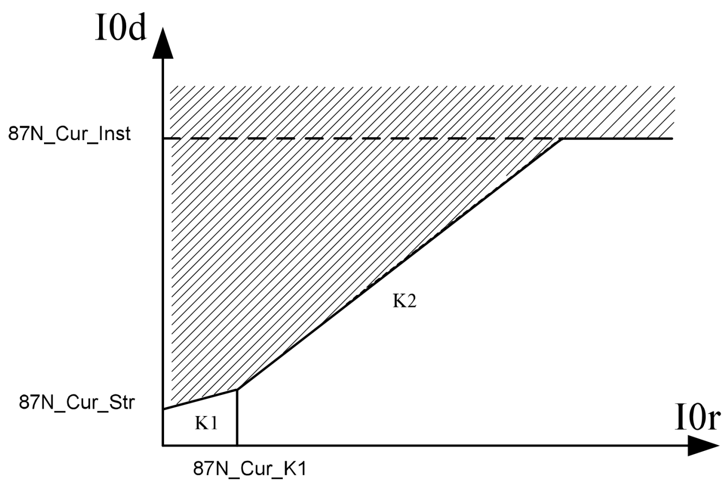


Figure 3.19.1 Operation characteristic of 87N

Where:

I0d is the differential current；I0r is the restraint current；87N_Cur_Str is the start of differential current.

3.19.2.7 CT Transient Characteristic Difference Detection

$$3I_0 > B_0 \times I_1$$

Where：

3I0 is the zero-sequence current at a side.

I_1 is its corresponding positive-sequence current.

B_0 is a proportional constant and the value is 0.2.

3.19.2.8 CT Circuit Failure

Please refer to Section 3.2.2.12 for details.

3.19.3 Logic Diagram

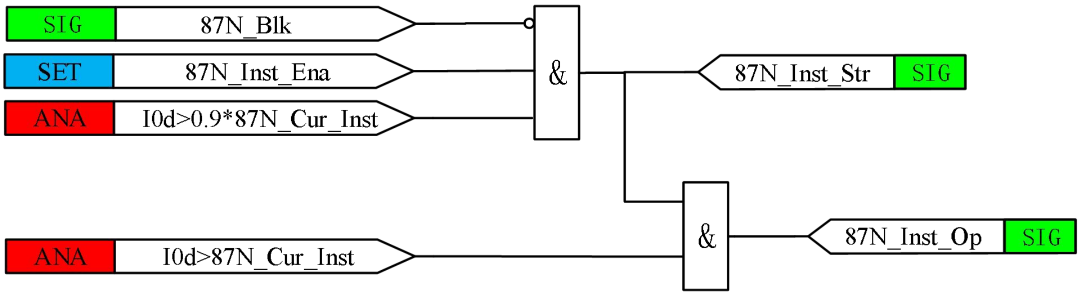


Figure 3.19.2 Logic diagram of 87N_Inst protection

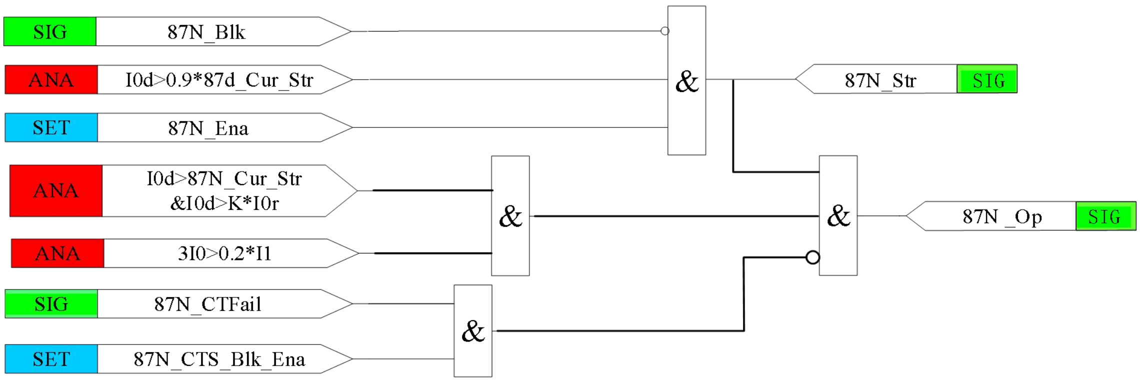


Figure 3.19.3 Logic diagram of 87N protection

Where:

I0d is the value of zero-sequence differential currents.

"87N_CTFail" means that the flag of CT circuit failure.

3.19.4 Settings

Table 3.19.3 Settings of Reactor differential protection

No.	Name	Range	Unit	Step	Default	Description
1	87N_Cur_Str	0.05~20.00	PU	0.01	0.40	Pickup setting of biased differential element
2	87N_Cur_Inst	0.05~20.00	PU	0.01	6.00	Current setting of instantaneous differential element
3	87N_Cur_Alm	0.05~20.00	PU	0.01	1.00	Current setting of differential circuit abnormality alarm

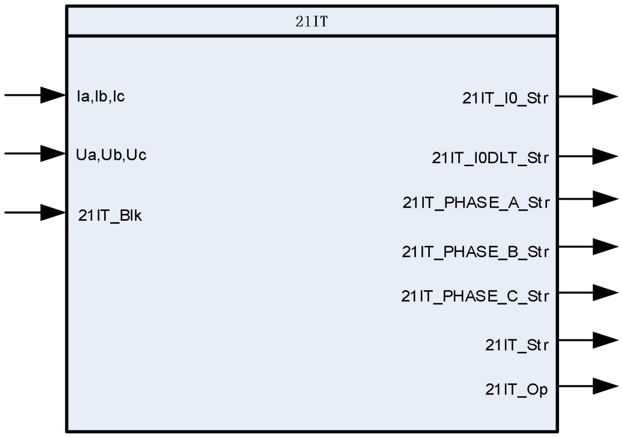
No.	Name	Range	Unit	Step	Default	Description
4	87N_Cur_K1	0.05~20.00	PU	0.01	1.00	Current setting of knee point 1 for transformer differential protection
5	87N _Slope1	0~0.90	-	0.01	0.00	Slope 1 of biased differential element
6	87N _Slope2	0~0.90	-	0.01	0.50	Slope 2 of biased differential element
7	87N _Ena	0,1	-	1	0	Logic setting of enabling/disabling conventional biased differential element 0: disable 1: enable
8	87N_Inst_Ena	0,1	-	1	0	Logic setting of enabling/disabling instantaneous differential element 0: disable 1: enable
9	87N_Alm_Ena	0,1	-	1	0	Logic setting of enabling/disabling differential Alam element 0: disable 1: enable
10	87N_CTS_Blk_Ena	0,1	-	1	0	Logic setting of enabling/disabling block biased differential element during CT circuit failure 0: disable 1: enable

3.20 Reactor inter-turn Protection (21IT)

3.20.1 Overview

The inter-turn short circuit of the reactor is a common form of internal fault. When the number of short-circuit turns is small, the three-phase current imbalance caused by one-phase short-circuit is likely to be small, which is difficult to be detected by relay protection.For this purpose, high-sensitivity, reliable and reliable inter-turn short-circuit protection(21IT) must be considered for high-voltage shunt reactors.The device uses a compensated absolute value comparison type zero sequence directional element and a negative sequence direction, a zero sequence impedance element and an inter-turn short circuit protection starting element.It can improve the sensitivity of the protection action between reactors and ensure that it is not accidentally caused by external faults and any abnormal operating conditions.

3.20.1.1 Function Block



3.20.1.2 Signals

Table 3.20.1 21IT Input Signals

NO.	Signal	Description
1	Ia,Ib,Ic	Three phase current of 21IT
2	Ua,Ub,Uc	Three phase voltage of 21IT
3	21IT_Blk	Block signal of 21IT

Table 3.20.2 21IT Output Signals

NO.	Signal	Description
1	21IT_I0_Str	Zero-sequence current start signal from 21IT
2	21IT_I0DLT_Str	Break current start signal from 21IT
3	21IT_PHASE_A_Str	Impedance A start signal of 21IT
4	21IT_PHASE_B_Str	Impedance B start signal of 21IT
5	21IT_PHASE_C_Str	Impedance C start signal of 21IT
6	21IT_Str	Start signal of 21IT
7	21IT_Op	Operation signal of 21IT

3.20.2 Protection Principle

3.20.2.1 Zero-sequence current start

$$3I_0 > I_{0set}$$

Where:

3I0 is the Zero-sequence current of high side.

$$I_{0set} = 0.2 * I_e.$$

3.20.2.2 Break current start

$$\Delta 3I_0 = \left| |3i_0(t) - 3i_0(t-T)| - |3i_0(t-T) - 3i_0(t-2T)| \right| > I_{0set}$$

Where:

$$I_{0set} = 0.3 * I_e.$$

3.20.2.3 Phase Impedance start

$$Z_\varphi = \left| \frac{U'_\varphi - (I'_{ha} + I'_{hb} + I'_{hc}) * ZL_{s0}}{I'_{h\varphi}} \right| < 0.92 * ZL_1$$

$$ZL_{s0} = \frac{Z_{1n} * K_{AT}}{VT_{1n} * 10}$$

$$ZL_1 = \frac{U_n * 1000}{VT_{1n} * 10 * I_e * \sqrt{3}}$$

Where:

U'_φ is the phase voltage of high side.

I'_φ is the phase current of high side.

I'_{ha} ,I'_{hb},I'_{hc} is the three phase current of high side.

ZL_{s0} is the Zero-sequence Impedance of the neutral point reactor .

ZL_1 is the secondary Impedance of the main reactor .

3.20.2.4 Zero-sequence direction components

$$|U'_0 - I'_0 * 0.9ZL_0| > |U'_0|$$

$$ZL_0 = ZL_1 + 3 * ZL_{s0}$$

Where:

U'_0 is the Zero-sequence voltage of high side.

ZL_0 is the Zero-sequence Impedance of the main reactor .

3.20.2.5 Negative-sequence direction components

$$|U'_2 - I'_2 * 0.9ZL_1| > |U'_2|$$

Where:

ZL_1 is the secondary Impedance of the main reactor .

3.20.3 Logic Diagram

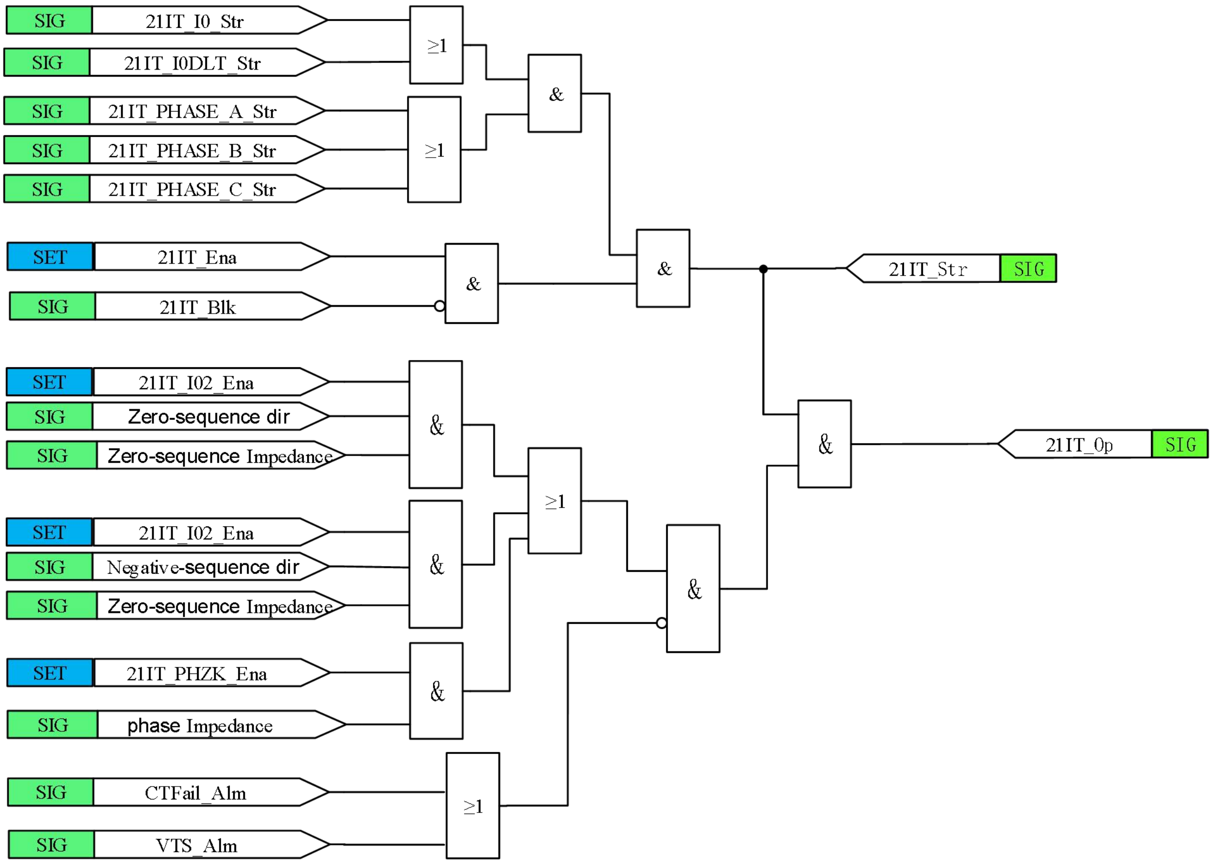


Figure 3.20.1 Logic diagram of 21IT protection

3.20.4 Settings

Table 3.20.3 Settings of Reactor inter turn Protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	21IT_I02_Ena	0/1	-	1	0	Logic setting of enabling/disabling zero / negative sequence directional element 0: disable 1: enable
2	21IT _PHZK_Ena	0/1	-	1	0	Logic setting of enabling/disabling phase impedance element 0: disable 1: enable

No.	Name	Values (Range)	Unit	Step	Default	Description
3	21IT _Ena	0/1	-	1	0	Logic setting of enabling/disabling 21IT 0: disable 1: enable

3.21 Out-of-Step Protection 78O

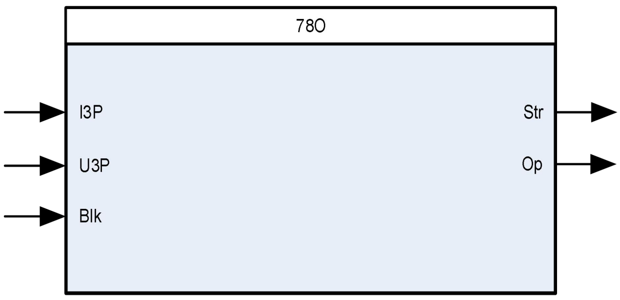
3.21.1 Overview

When the power system loses synchronism, out-of-step protection 78O can automatically disconnect the power plant and the associated load from the power system to prevent damage.

78O use voltage angle criteria and it can adapt to a variety range of power grid structures and operation mode. 78O has the following characteristics:

- Using the criterion of voltage angle, 78O can accurately identifies the system oscillation. The function can operate reliably and correctly if the oscillation period is less than 160ms.
- 78O is not affected by the fault, for example, three-phase symmetrical fault and its recovery, converted fault and power swing which does not lead to system out-of-step.
- When the system is in open-phase operation mode, 78O will not operate even if the system is out-of-step. When the system returns to full-phase operation mode and is still in out-of-step condition, 78O will operate.
- The 78O function can identify the system power angle and avoid disconnecting the circuit breaker when the angle difference is around 180 °.

3.21.1.1 Function Block



3.21.1.2 Signals

Table 3.21.1 78O Input Signals

NO.	Signal	Description
1	U3P	Three-phase voltage input
2	I3P	Three-phase current input
3	Blk	Blocking signal of 78O

Table 3.21.2 78O Output Signals

NO.	Signal	Description
1	Str	Start signal from 78O
2	Op	Operation signal from 78O

3.21.2 Protection Principle

3.21.2.1 Start of the Function

By calculating the voltage at oscillation center of the transmission line, the function can detect whether the system is in power swing or symmetry fault condition.

$$\begin{cases} -0.7Un < U_1 \cos(\varphi) < 0.7Un \\ 3U_1 > 18V \wedge 3U_2 < 8V \wedge 3U_0 < 8V \\ 3I_0 < 300A \wedge I_1 > 500A \end{cases}$$

Where:

Un is the rated voltage.

U_1 is positive-sequence voltage.

U_2 is negative-sequence voltage.

U_0 is zero-sequence voltage.

I_1 is positive-sequence current.

φ is the angle difference between positive-sequence voltage and current.

The function will operate when the criterion is met and last for at least 25ms.

3.21.2.2 Power Swing Detection

The function detects the out-of-step oscillation according to the change of the voltage at oscillation center, and simultaneously evaluates the amplitude and period of oscillation and the power angle to decide whether to operate.

Calculation of the voltage of power swing center can be done through the following formula:

$$U_{\cos} = U_1 \cos(\varphi + \delta)$$

Where:

φ is the angle difference between positive-sequence voltage and positive-sequence current.

δ is the line p**ositive-**sequence impedance angle, set by the setting LinAng.

$U_{\cos}$ have the following wave forms (converted to per unit value):

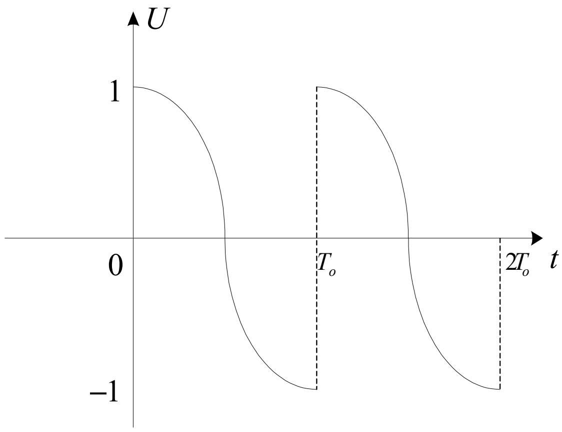


Figure 3.21.1 Voltage at Accelerate Side

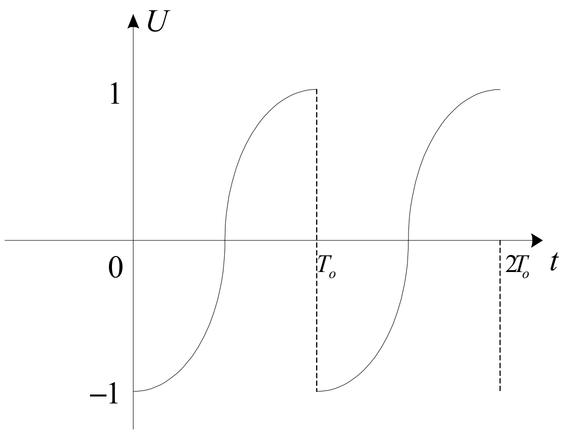


Figure 3.21.2 Voltage at Decelerate Side

The two voltage wave forms above satisfy the following equations:

$$U_{\cos\_accel}(t) = \cos\left(\frac{\pi}{T_0}t\right)$$

$$U_{\cos\_decel}(t) =- \cos\left(\frac{\pi}{T_0}t\right)$$

Where:

T_0 is the oscillation period.

Divide the waveform of $U_{\cos}$ into 6 areas within one oscillation period:

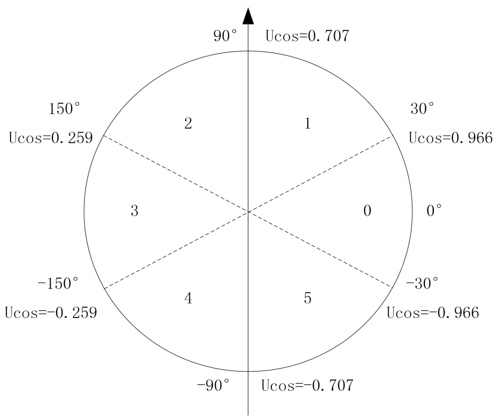


Figure 3.21.3 Phase Division of Vector Diagram

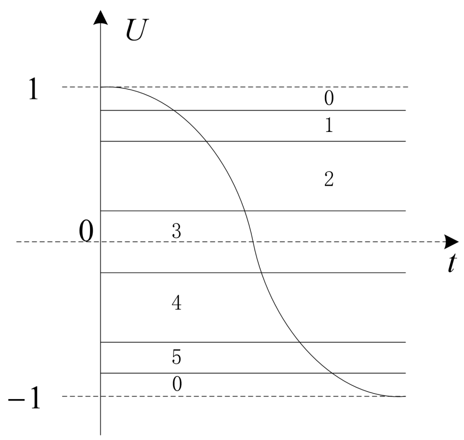


Figure 3.21.4 Division of Waveform

Where in area 0: $|U_{cos}|>0.966$

Area 1: $0.707<U_{cos}<0.966$

Area 2:$0.259<U_{cos}<0.707$

Area 3: $-0.259<U_{cos}<0.259$

Area 4: $-0.707<U_{cos}<-0.259$

Area 5: $-0.966<U_{cos}<-0.707$

U_{cos}falls into each area for an equal time T0/6 in one oscillation period.

In the accelerate side, U_{cos} swing across the areas in the following order:

$$0 \rightarrow 1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 0$$

In the decelerate side, U_{cos}swing across the areas in the following order:

$$0 \rightarrow 5 \rightarrow 4 \rightarrow 3 \rightarrow 2 \rightarrow 1 \rightarrow 0$$

The 78O function records the history of areas that U_{cos}once passed and compare it with the above order. If the order is the same, the function's internal flag Pswing_Cond will be set to 1.

High speed tripping:

In some situations, 78O is required to operate as soon as possible when a loss of synchronization is detected, for which the function provides a high-speed tripping criterion:

The function simply detects if U_{cos} have crossed through area 3 in the above order, for example:

$$5 \rightarrow 4 \rightarrow 3 \rightarrow 2$$

And the absolute value of U_{cos} is greater than 10V.

If the two conditions are met, the function's internal flag Pswing_Inst_Cond will be set to 1.

Notice that high speed trip will only be enable if the setting 78O_InstTrp_Ena is set to 1.

3.21.2.3 Power Swing Center Locating and Direction Determination

Power swing center location determination criterion:

When U_{cos}falls into area 3 and the positive-sequence voltage is below the threshold voltage setting 78O_Op_LowVol for 10ms, the function considered the swing center to be somewhere within the protection zone and the function's internal flag 78O_Pswing_Loc will be set to 1.

Power swing center direction determination criterion:

When the absolute value of U_{cos} is less than 0.1Un, the power swing center is considered to be in the forward direction if the phase angle 30° < Angle(U1/I1)< 150° , and reverse direction if

-150° <Angle(U1/I1)<-30° .

Notice that direction criterion will be automatically satisfied if the direction determination is not enable. And if the setting 78O_Dir_Ena is set to 1, the direction criterion will also be satisfied if 78O_Dir_Mod is set to 0.

3.21.2.4 Tripping Angle Determination

When all the other operation conditions are met, if U_{cos} falls into area 3 while the phase angle 150° <Angle(U1/I1)<210° , tripping signal will be blocked until U_{cos} cross through area 3.

3.21.2.5 Power Swing Cycle Counting

The threshold setting of oscillation cycle number 78O_Op_Pswing_Num is an important parameter in the function. 78O will need more than the setting number of swing cycles counting to operate. 78O_Op_Pswing_Num should be set to 1 if fast disconnecting is required; 78O_Op_Pswing_Num should be set to 3 or 4 in order to cooperate with the out-of-step protection of adjacent lines, which ensures that 78O will not operate before the disconnection of the adjacent line; After the out-of-step oscillation, it is hoped that the out-of-step system can be pulled back into synchronization, in this case, 78O_Op_Pswing_Num should be set to 5 to 10 which can leave enough time for the system recovery. In short, the choice of 78O_Op_Pswing_Num should be based on the actual situation of the system and the cooperation with other protection device.

3.21.2.6 Abnormal Condition Blocking of the Function

78O will be blocked in the following conditions:

- When three-phase fault occurs in the power system.
- When the zero-sequence or negative-sequence voltage or current is in abnormal condition.
- When U_{cos} stays in any area for more than 1.5 seconds.

Notice that all the internal flag will be reset if abnormal condition is detected and the oscillation cycle counting will be set to 0 too.

3.21.3 Logic

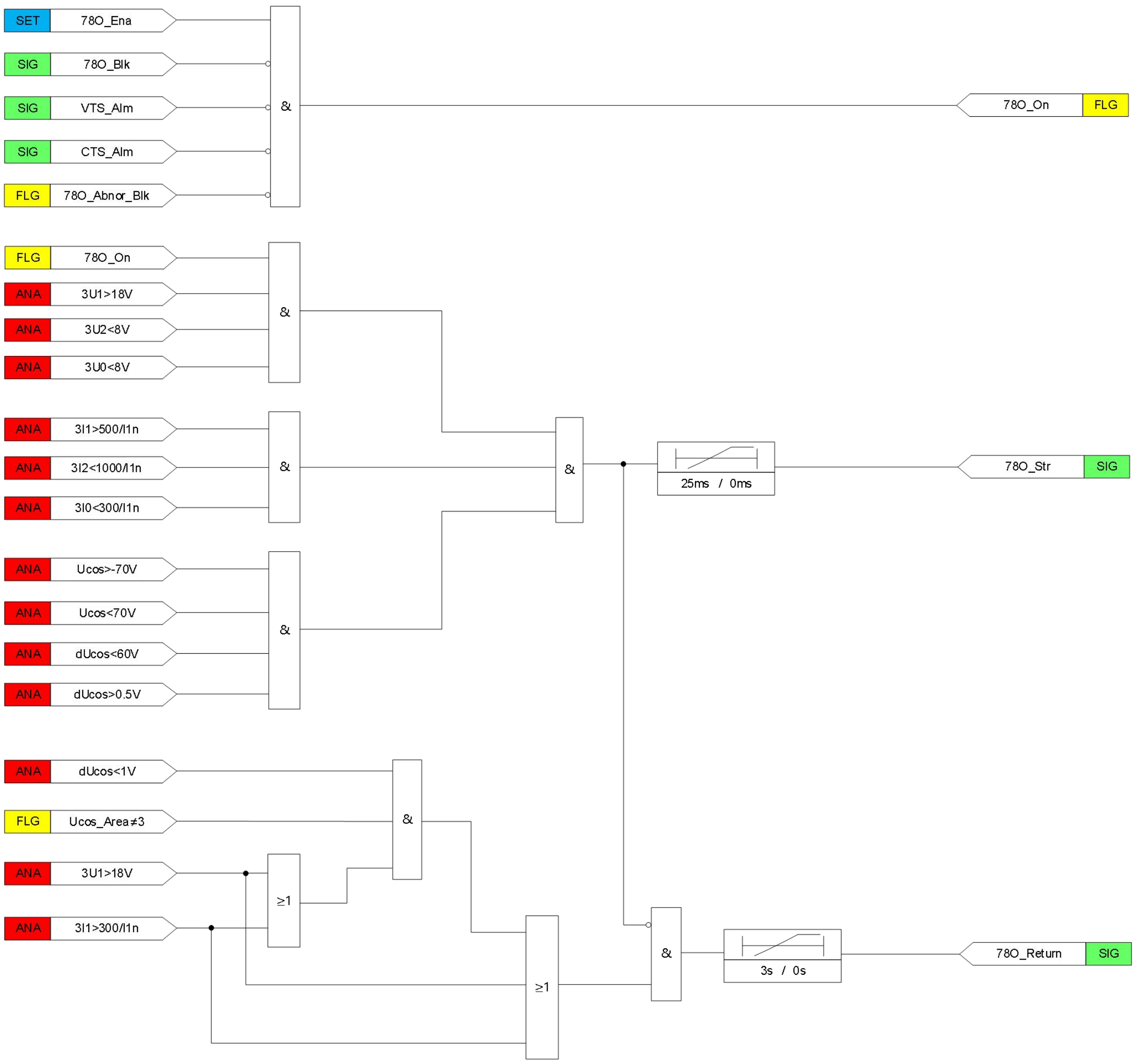


Figure 3.21.5 78O Start

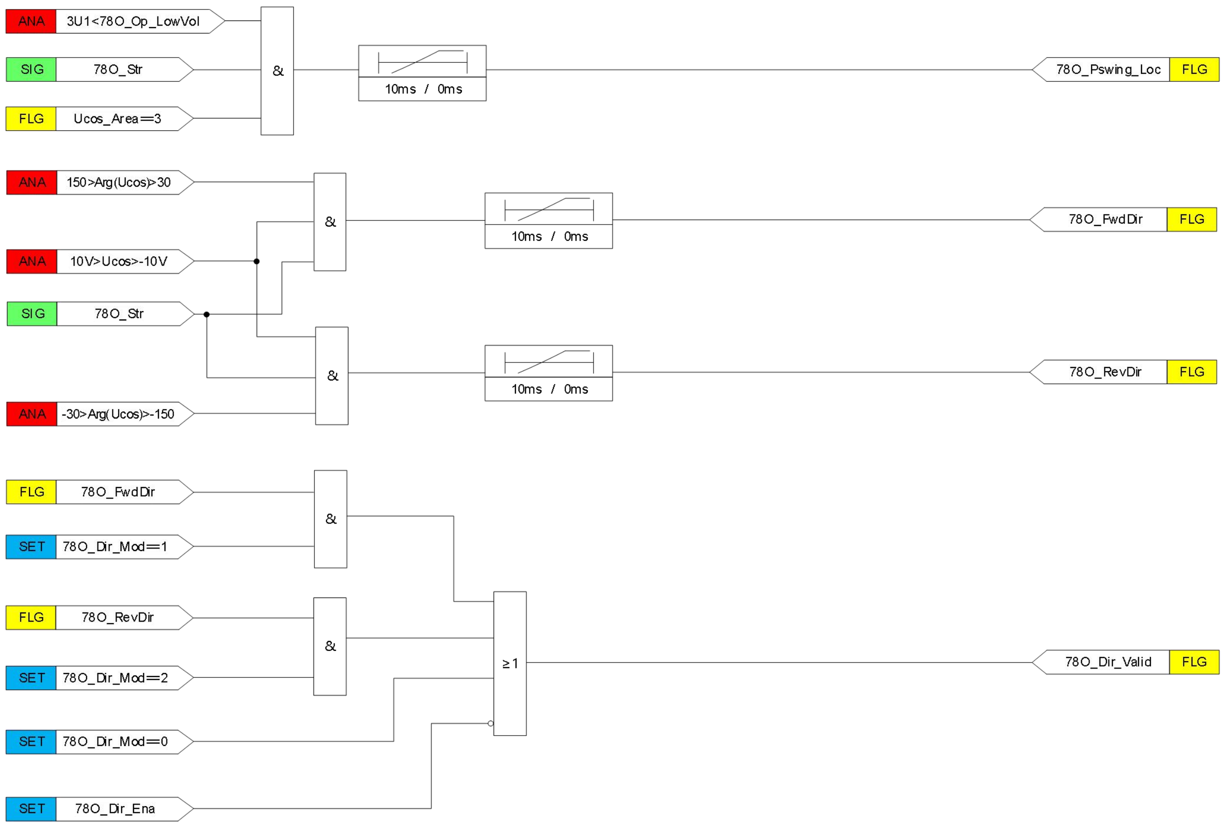


Figure 3.21.6 78O Direction element

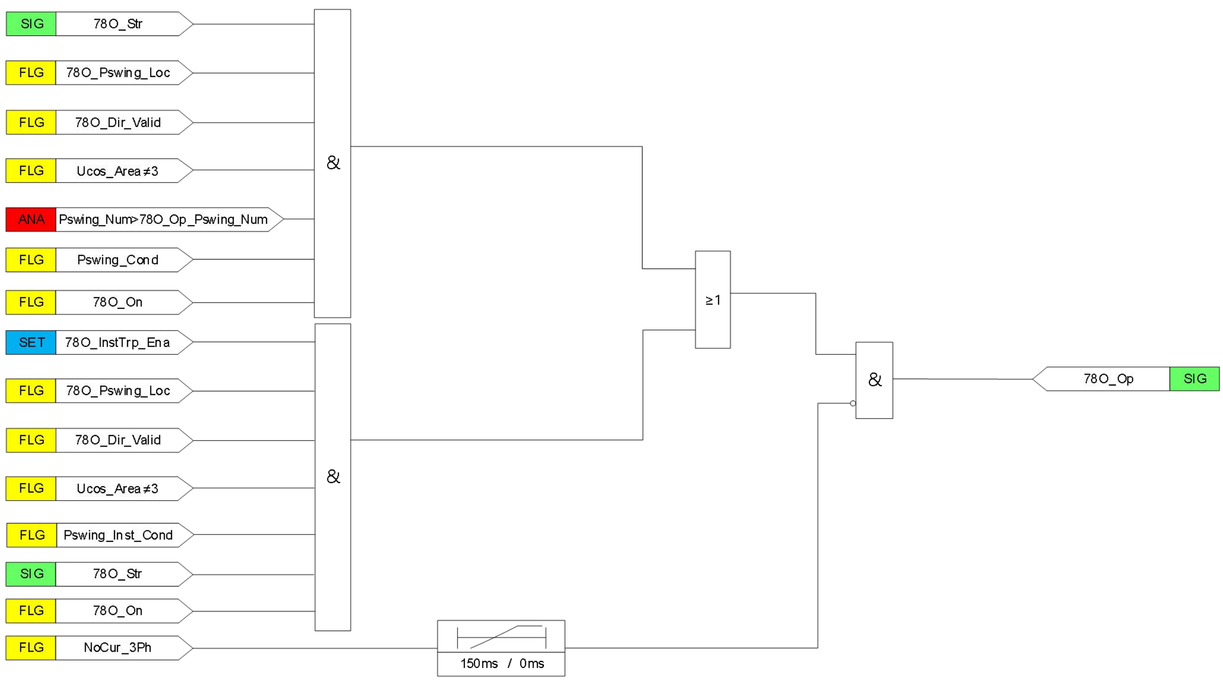


Figure 3.21.7 78O Operation

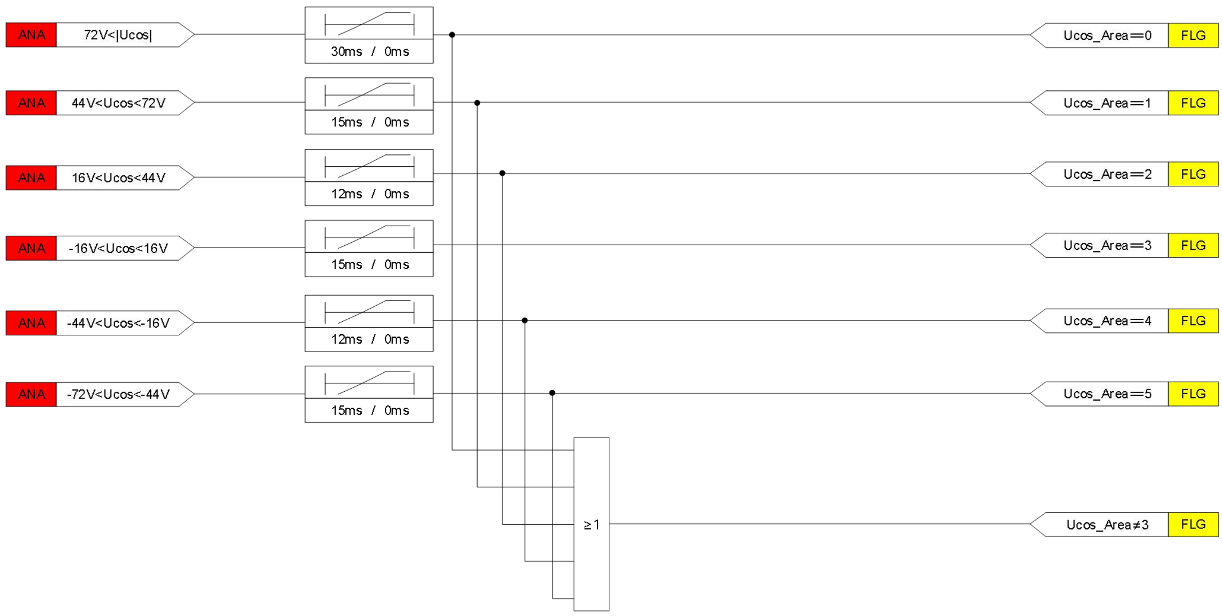


Figure 3.21.8 78O Ucos Area Detection

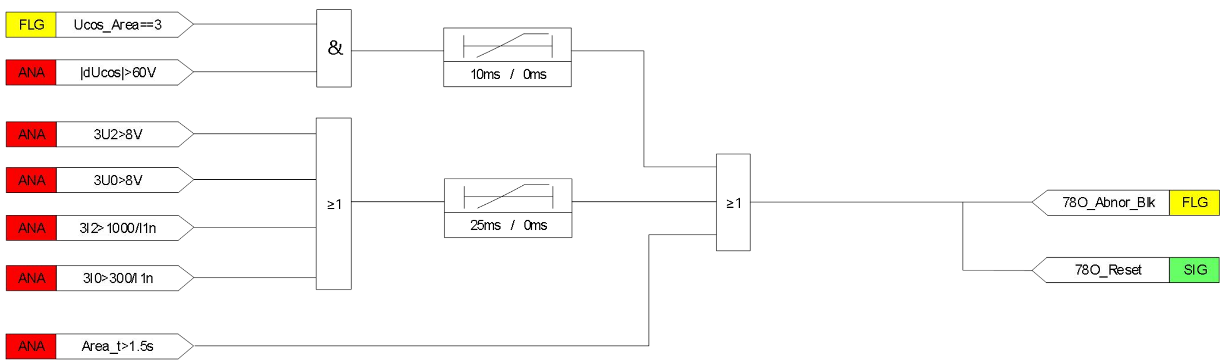


Figure 3.21.9 Abnormal Condition Blocking of 78O

3.21.4 Settings

Table 3.21.3 78O Settings

NO	Name	Range	Unit	Step	Default	Description
1	78O_Ena	0 or 1	-	1	0	Enabling/disabling of out-of-step protection: 0: disable 1: enable
2	78O_InstTrp_Ena	0 or 1	-	1	0	Enabling/disabling high speed trip of out-of-speed protection 0: disable 1: enable
3	78O_Dir_Ena	0 or 1	-	1	0	Enabling/disabling direction determination of out-of-step protection: 0: disable 1: enable

NO	Name	Range	Unit	Step	Default	Description
4	78O_Op_LowVol	0.00~1.00	V	0.01	0.03	Low voltage threshold of out-of-step protection
5	78O_Op_Pswing_Num	1~15	-	1	3	Threshold number of power swing cycle counting
6	78O_Dir_Mod	0, 1, 2	-	1	1	Direction option for out-of-step protection: 0: Non-Directional 1: Forward 2: Reverse

3.22 Mechanical Relay Protection (MR)

3.22.1 Overview

The main transformer protection can provide mechanical protection as the main protection of transformer fault. The mechanical protection includes mechanical protection after delay and mechanical protection without delay.

3.22.1.1 Function Block

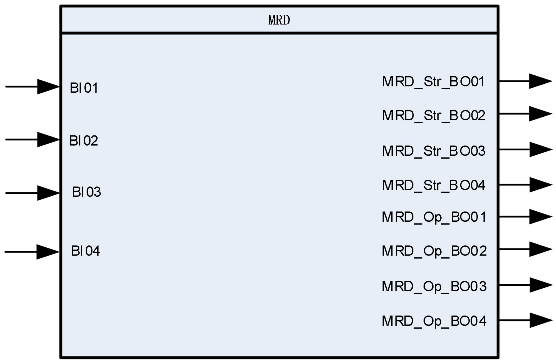


Figure 3.22.1 Delay Of Mechanical Relay

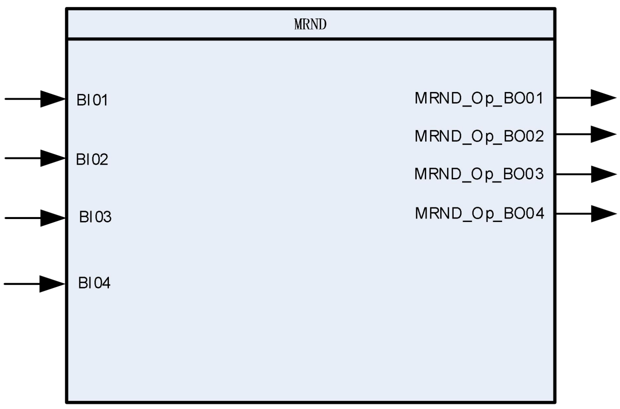


Figure 3.22.2 No Delay Of Mechanical Relay

3.22.1.2 Signals

Table 3.22.1 MR Input Signals

NO.	Signal	Description
1	BI01	Binary Input 01 Of Mechanical Relay
2	BI02	Binary Input 02 Of Mechanical Relay
3	BI03	Binary Input 03 Of Mechanical Relay
4	BI04	Binary Input 04 Of Mechanical Relay

Table 3.22.2 MR Output Signals

NO.	Signal	Description
1	MRD_Str_BO01	Delay Mechanical Relay Start Signal Of BO01
2	MRD_Str_BO02	Delay Mechanical Relay Start Signal Of BO02
3	MRD_Str_BO03	Delay Mechanical Relay Start Signal Of BO03
4	MRD_Str_BO04	Delay Mechanical Relay Start Signal Of BO04
5	MRD_Op_BO01	Delay Mechanical Relay Operation Signal Of BO01
6	MRD_Op_BO02	Delay Mechanical Relay Operation Signal Of BO02
7	MRD_Op_BO03	Delay Mechanical Relay Operation Signal Of BO03
8	MRD_Op_BO04	Delay Mechanical Relay Operation Signal Of BO04
9	MRND_Op_BO01	No Delay Mechanical Relay Operation Signal Of BO01
10	MRND_Op_BO02	No Delay Mechanical Relay Operation Signal Of BO02
11	MRND_Op_BO03	No Delay Mechanical Relay Operation Signal Of BO03
12	MRND_Op_BO04	No Delay Mechanical Relay Operation Signal Of BO04

3.22.2 Protection Principle

3.22.2.1 Delay Mechanical Protection

Delay mechanical protection, with adjustable delay function, trip through the delay operate outlet.

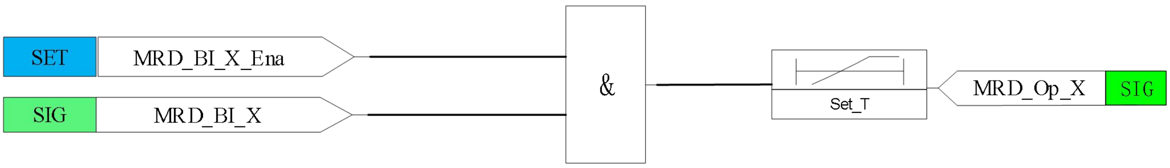


Figure 3.22.3 Logic diagram of MRD Protection

3.22.2.2 Non Delay Mechanical Protection

No delay mechanical protection, direct exit, no delay function, not through the CPU, is completely hardware loop.

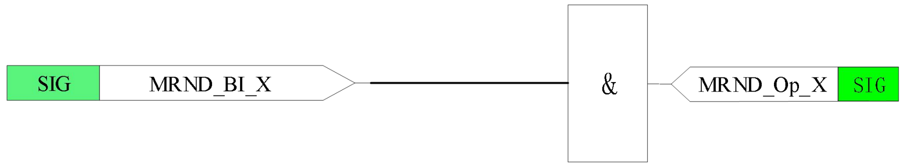


Figure 3.22.4 Logic diagram of MRND Protection

3.22.3 Settings

Table 3.22.3 Settings of Reactor inter turn Protection

No.	Name	Values (Range)	Unit	Step	Default	Description
1	MRD_BI01Op_T	0.00~99.99	s	0.01	99.99	Operating time delay for Delay Mechanical Relay
2	MRD_BI02Op_T	0.00~99.99	s	0.01	99.99	Operating time delay for Delay Mechanical Relay
3	MRD_BI03Op_T	0.00~99.99	s	0.01	99.99	Operating time delay for Delay Mechanical Relay
4	MRD_BI04Op_T	0.00~99.99	s	0.01	99.99	Operating time delay for Delay Mechanical Relay
5	MRD_BI01_Ena	0/1	-	1	0	Logic setting of enabling/disabling Delay Mechanical Relay 0: disable 1: enable
6	MRD_BI02_Ena	0/1	-	1	0	Logic setting of enabling/disabling Delay Mechanical Relay 0: disable 1: enable
7	MRD_BI03_Ena	0/1	-	1	0	Logic setting of enabling/disabling Delay Mechanical Relay 0: disable 1: enable
8	MRD_BI04_Ena	0/1	-	1	0	Logic setting of enabling/disabling Delay Mechanical Relay 0: disable 1: enable

4 Supervision

4.1 Overview

Though the protection system is in non-operating state under normal conditions, it is waiting for a power system fault to occur at any time and must operate for the fault without fail.

When the equipment is in energizing process, the equipment needs to be checked to ensure there are no errors. Therefore, the automatic supervision function, which checks the health of the protection system during startup and normal operation procedure, plays an important role.

The numerical relay based on the microprocessor operations has the capability for implementing this automatic supervision function of the protection system.

In case a fatal fault is detected during automatic supervision, the equipment will be blocked out. It means that this relay is out of service. Therefore you must re-energize the relay or even replace a module to make this relay back into service.

4.2 Supervision Alarm and Block

The relay device has powerful real-time self-check capability. The device will automatically check its own software and hardware running state during the process of operation. If there is any abnormal situation, the abnormal information will be displayed on the LCD, and the corresponding indicator and signal relay will issue prompt. Besides, these abnormal self-check and alarm signal can be uploaded to the SCADA through the IEC 61850 or IEC 60870-103 communication protocol.

Self-check scope of the device is as follows:

1. Self-check about the hardware:
   - Alarm signal of analog quantity circuit self-check
   - Alarm signal of BI circuit self-check
   - Alarm signal of BO circuit self-check
   - Alarm signal of storage self-check
   - Alarm signal of watchdog self-check
2. Self-check about the software and configuration
   - Alarm signal of software running state self-check
   - Alarm signal of configuration self-check
   - Alarm signal of internal communication self-check
3. Self-check about the external communication
   - Alarm signal of external communication self-check

If the relay device is in abnormal status, alarm signal will be issued. Some alarm signals will block the protection function, while some will not. The detailed information is shown as the following table.

Table 4.2.1 Alarm Signal and Block

Alarm Signal Name	Alarm Signal Description	Block Protection or Not
Kernel Comm Abn	Kernel Communication Abnormal	YES
Databus Comm Intr	Databus Communication Interrupt	YES
Databus Data Abn	Databus Data Abnormal	YES
LVDSIO Input Err	LVDSIO Input Error	YES
LVDS Bus SelfChk Abn	LVDSBus Self Check Abnormal	YES
Comp SelfChk Abn	Component Self Check Abnormal	YES
RAM Scan Err	RAM Scan Error	YES
Sys Const SelfChk Abn	System Const Self Check Abnormal	YES
SelfChk Comp Port Err	Self Check Component Port Error	YES
SelfChk Comp Cfg Err	SelfCheck Component Configuration Error	YES
Setting SelfChk Err	Setting SelfCheck Error	YES
Setting CRC Err	Setting CRC Error	YES
Soft Sw SelfChk Err	Soft Switch SelfCheck Error	YES
Soft Sw CRC Err	Soft Switch CRC Error	YES
BO Cfg SelfChk Err	BO Configuration SelfCheck Error	YES
BO Cfg CRC Err	BO Configuration CRC Error	YES
Para SelfChk Err	Parameter SelfCheck Error	YES
Para CRC Err	Parameter CRC Error	YES
Prot Comp RAM Scan Err	Prot Component RAM Scan Error	YES
Databus Longtime Losing Pkg	Databus Longtime Losing Package	NO
Databus Wrong Pkg Alarm	Databus Wrong Package Alarm	NO
A/D Sampling Err	A/D Sampling Error	NO
IRIG-B Syn Abn	IRIG-B Synchronization Abnormal	NO
Mana Bus Comm Intr	Mana Bus Comm Interrupt	NO
Setting Set CRC Err	Setting Set CRC Error	NO
Soft Sw Set CRC Err	Soft Switch Set CRC Error	NO
Para Set CRC Err	Parameter Set CRC Error	NO
Main Cfg Check Abn	Main Configuration Check Abnormal	NO
Cfg File Check Abn	Configuration File Check Abnormal	NO
Comp Cfg Check Err	Component Configuration Check Error	NO
WaveRcd Cfg File Abn	Wave Record Configuration File Abnormal	NO
WaveRcd File Abn	Wave Record File Abnormal	NO

4.3 Current circuit supervision(CTS)

4.3.1 Overview

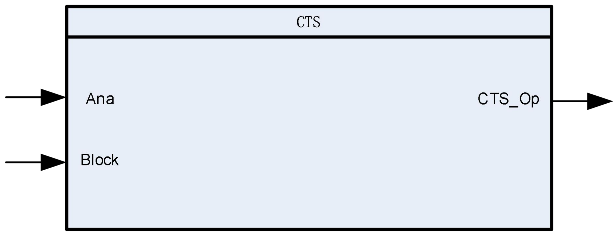
The main purpose of Current circuit supervision (CTS) is to monitor the protected electrical network by the help of instrument transformer (CT).This is a backup function for CT circuit failure. If CT balance coefficient at one side is relatively little, the different current resulting from CT circuit failure is very small. Therefore, the CT circuit failure alarm can not be issued. The function is used to prompt the operator to check and confirm whether the CT is normal or not.

The operation principle criteria of Current circuit supervision CT's based on the following points:

- Three phase zero-sequance current
- Three phase zero-sequence voltage

In addition, the CTS can be configured on the high-voltage side, middle-voltage side or low-voltage side of the transformer as a backup protection for each side.

4.3.1.1 Function Block



4.3.1.2 Signals

Table 4.3.1 CTS Input Signals

NO.	Signal	Description
1	Ana	Residual voltage from the three-phase voltage and current inputs
2	Block	Block signal of CTS

Table 4.3.2 CTS Output Signals

NO.	Signal	Description
1	CTS _Op	Operation signal from CTS

4.3.2 Logic Diagram

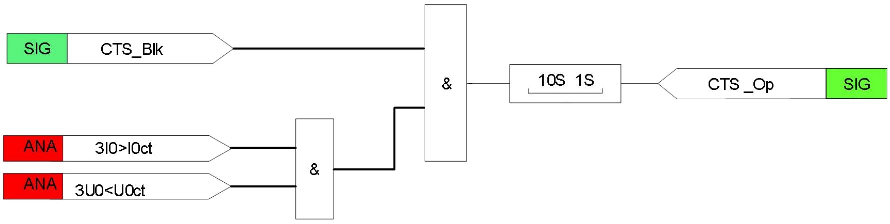


Figure 4.3.1 CTS criterion logic diagram

4.3.3 Protection Principle

This is a backup function of CT circuit failure criterion.

Each side of the device is furnished with CT circuit failure alarm element

To prevent incorrect tripping of zero-sequence overcurrent protection caused by CT circuit failure or anomaly, the device is provided with CT circuit failure judgment element using the following criterion:

$$\begin{cases} 3I_0 > I_{0CT} \\ 3U_0 < U_{0CT} \end{cases}$$

Where:

I_{0TA} and U_{0TA} are respectively internal threshold value of zero-sequence current and zero-sequence voltage for CT circuit failure judgment element.

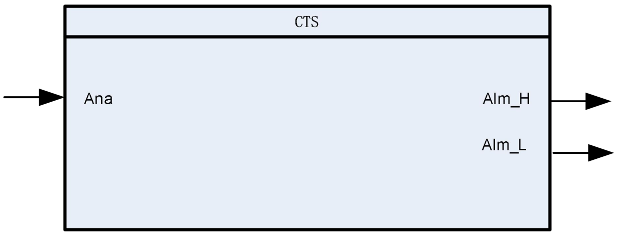
CT circuit failure will be deemed to have occurred once the situation that meets above-noted criterion lasting for 10s.

4.4 Reactor Current circuit supervision(CTS)

4.4.1 Overview

The main purpose of Current circuit supervision (CTS) is to monitor the protected electrical network by the help of instrument transformer (CT).This is a backup function for CT circuit failure. The function is used to prompt the operator to check and confirm whether the CT is normal or not.

4.4.1.1 Function Block



4.4.1.2 Signals

Table 4.4.1 CTS Input Signals

NO.	Signal	Description
1	Ana	Residual voltage from the three-phase voltage and current inputs

Table 4.4.2 CTS Output Signals

NO.	Signal	Description
1	Alm_H	Operation signal from H-side CTS
2	Alm_L	Operation signal from L-side CTS

4.4.2 Logic Diagram

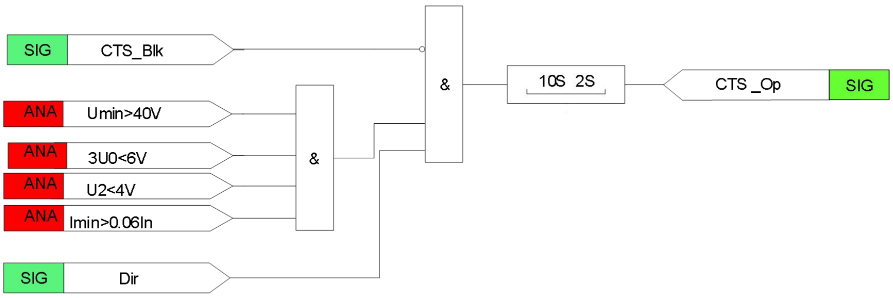
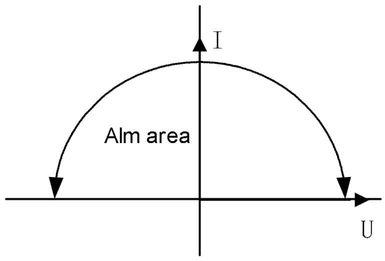


Figure 4.4.1 CTS criterion logic diagram

4.4.3 Protection Principle



4.5 Fuse failure supervision(VTS)

4.5.1 Overview

The main and important function of Fuse failure supervision (VTS) is to continuously supervised the protected electrical network by the help of instrument transformer (VT) and to ensure the stability of accurate operation. If any kind of trouble situation happened in the following circuits between instrument transformer (VT) and intelligence electronic device (IED), cause many un-legal operation of protection function are follows:

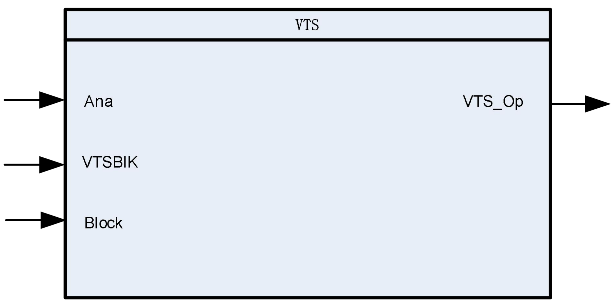
- Overcurrent protection with voltage controlled element
- Synchronization and many other protections

The operation principle criteria of fuse failure supervision VT's based on the following points:

- Negative-sequence voltage is greater than 8V
- Each phase voltage is less than 30V

In addition, the VTS can be configured on the high-voltage side, middle-voltage side or low-voltage side of the transformer as a backup protection for each side.

4.5.1.1 Function Block



4.5.1.2 Signals

Table 4.5.1 VTS Input Signals

NO.	Signal	Description
1	Ana	Three phase group signal for voltage inputs
2	VTSBlk	Block signal of fault
3	Block	Block signal of VTS

Table 4.5.2 VTS Output Signals

NO.	Signal	Description
1	VTS_Op	Operation signal from VTS

4.5.2 Logic Diagram

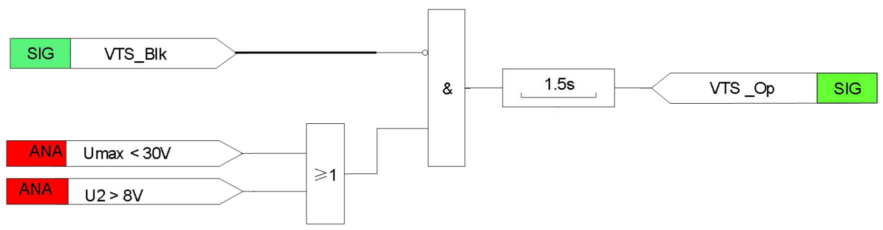


Figure 4.5- 1VTS criterion logic diagram

4.5.3 Protection Principle

Each side of the device is furnished with VT line-break alarm element

In case start-up element fails to activate voltage quantity related protection, VT line-break alarm signal would be given with a delay of 8s once any of the following conditions is satisfied:

- Voltage at each phase is less than 30V;
- Negative-sequence voltage is greater than 8V.

When voltage switch-on hard strap of some certain side is disabled, VT line-break judgment function of this side is automatically lifted.

4.6 Reactor Fuse failure supervision(VTS)

4.6.1 Overview

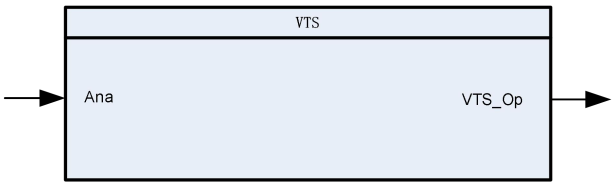
The main and important function of Fuse failure supervision (VTS) is to continuously supervised the protected electrical network by the help of instrument transformer (VT) and to ensure the stability of accurate operation. If any kind of trouble situation happened in the following circuits between instrument transformer (VT) and intelligence electronic device (IED), cause many un-legal operation of protection function are follows:

- Over current protection with voltage controlled element
- Synchronization and many other protections

The operation principle criteria of fuse failure supervision VT is based on the following points:

- Negative-sequence voltage is greater than 8V and Negative-sequence current is less then 0.1Ie.
- Each phase voltage is less than 30V and Three-Phase current is between 0.06In and 1.2Ie.

4.6.1.1 Function Block



4.6.1.2 Signals

Table 4.6-1 VTS Input Signals

NO.	Signal	Description
1	Ana	Three phase group signal for voltage and current inputs

Table 4.6-2 VTS Output Signals

NO.	Signal	Description
1	VTS_Op	Operation signal from VTS

4.6.2 Logic Diagram

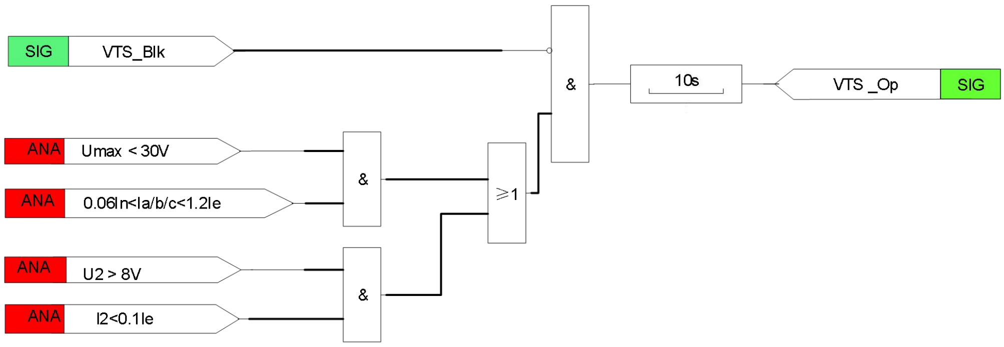


Figure 4.6.1VTS criterion logic diagram

4.6.3 Protection Principle

Each side of the device is furnished with VT line-break alarm element

In case start-up element fails to activate voltage quantity related protection, VT line-break alarm signal would be given with a delay of 8s once any of the following conditions is satisfied:

- Voltage at each phase is less than 30V and three phase current greater than 0.06In and less than 1.2Ie;
- Negative-sequence voltage is greater than 8V and Negative-sequence current less than 0.1Ie.

When voltage switch-on hard strap of some certain side is disabled, VT line-break judgment function of this side is automatically lifted.

5 Monitor&Control

5.1 Overview

Besides the protection and supervision functions, the relay provides some other auxiliary functions, such as protection and metering measurement quantities sampling, remote control, BI signaling, event recording and fault & disturbance recording etc. All these sub-functions are integrated components that fulfill the protection and control functions of the device.

5.2 Measurement

The general measurement quantities include both directly sampling and calculated quantities. These quantities are generally used for protection analyzing and metering calculation. All these quantities can be displayed in the local HMI or transmitted to the PRS IED Studio, SCADA or dispatching center through network communication.

Through the PRS IED Studio configuration tool, the measurement channels in the transformer module can be flexibly connected to any measurement quantity according to the designing requirements.

5.2.1 Protection Sampling

The protection sampling rate is 40 points per cycle. Different protection logics use different measurement quantities, including the RMS value, the phase angle, the frequency, the sequence components and so on. Some protection sampled values are displayed in HMI with 0.5s updating rate.

5.2.2 Metering

The metering rate is 40 points per cycle. Different functions, such as controlling, monitoring and metering, use different measurement quantities, including the RMS value, the phase angle, the frequency, the harmonic content, the sequence components and so on. All these metering values are displayed in HMI with 0.5s updating rate.

5.3 Apparatus Control

The apparatus control is a combination of functions which continuously supervise and control the circuit breakers, switches and earthing switches within a bay.The selection and operation command to control an apparatus is given after the evaluation of other functions' conditions such as interlocking, synchrocheck, operator place selection and the external or internal blockings.

The commands to an apparatus can be initiated from the local self-customized BI, the station HMI or the dispatching center. The local control self-customized BI can be configured on the PRS IED Studio. The control operation can be started by the activation of the corresponding BI signal. The remote control command can be remotely dispatched through the network communication like IEC61850 or DNP.Before executing a remote control command, it is necessary to turn the Local/Remote control switch to the “Remote” position.

The output relays in the BO module can be configured as output contacts so as to close or trip the apparatus.Each control output can be control with an interlock module (which can be configured through the PRS IED Studio) if the corresponding interlock logic setting (see Section 7.4.3) is set to activation.

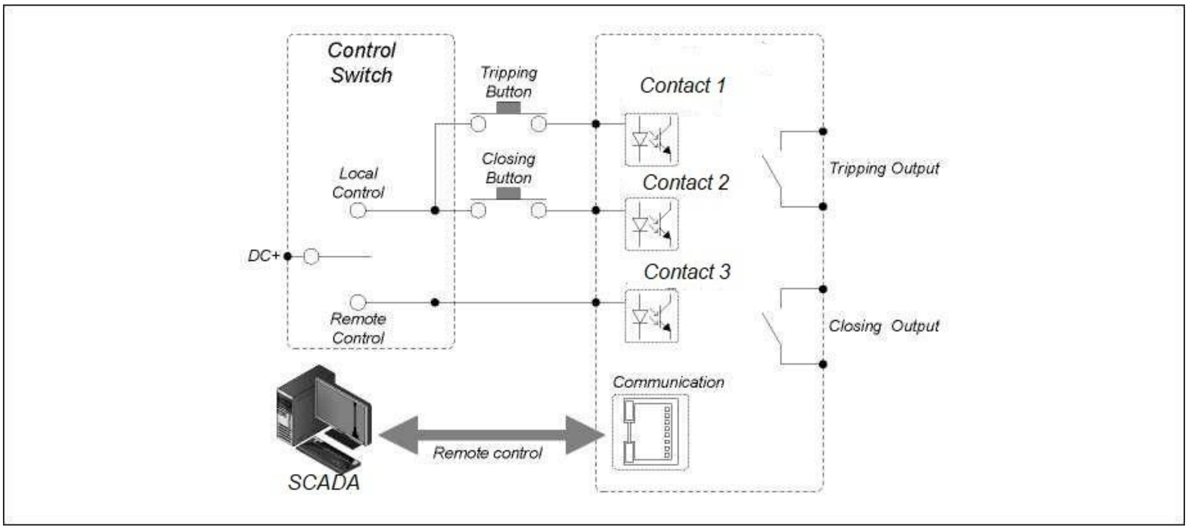


Figure 5.3.1 Demonstration Diagram of The Control Function

5.4 Signaling

All inputs of the protection hardware unit are configurable via PRS IED Studio software. Common binary inputs can be configured for the following purposes:

- Bay primary equipment state acquisition, such as circuit breaker position, insulator position. These signals can be sent to the substation monitoring system or dispatching automation system through the protection device.
- Used for BI condition of the protection logic to achieve the block or release of inner logic.
- Used to monitor the health condition of primary equipment such as SF6 low pressure alarm and transformer high oil temperature. These signals can be used as function input of protection logic, and also can be sent to substation monitoring system or dispatching automation system as separate alarm signals. Achieve remote monitoring.
- Transformer tap position input

All hardware input debouncing time can be set separately. Debouncing time setting can be done through the LCD or PRS IED Studio software.

5.5 Event Records

5.5.1 Overview

The protective device record events in an event log. This allows you to establish the sequence of events that led up to a particular situation. For example, a change in a digital input signal or protection element output signal would cause an event record to be created and stored in the event log. This could be used to analyze how a particular power system condition was caused. These events are stored in the IED's non-volatile memory. Each event is time tagged. The time resolution is 1ms.

The event records can be displayed on an IED's front panel but it is easier to view them through the configuration software. This can extract the events log from the device and store it as a file for analysis on a PC.

The event records are detailed in the EVENTS column. The first event (0) is always the latest event. After selecting the required event, you can scroll through the menus to obtain further details.

5.5.2 Fault Record Events(Fault Records)

An event record is created for every fault the IED detects. This is also known as a fault record.

The IED contains a separate register containing the latest fault records. This provides a convenient way of viewing the latest fault records and saves searching through the event log. You access these fault records using the Select Fault setting, where fault number 0 is the earliest fault.

The event is logged as soon as the fault recorder stops. The time stamp assigned to the fault corresponds to the start of the fault. The fault operating relative time is the subtraction between the fault stop moment and the fault start moment, and the time is in milliseconds.

The IED can store 512 latest time tagged fault record events.

5.5.3 Alarm Record Events

The IED monitors itself on power up and continually thereafter. If it notices any problems, it will register an alarm event. The alarm records include protection alarm records and device self-check records.

5.5.3.1 Protection Alarm Record(Warning Records)

The IED provides self-check alarm information that reflects the communication status between devices, such as carrier channel abnormal, fiber channel abnormal, SV communication abnormal, GOOSE communication abnormal, etc.

The IED provides self-check alarm information that reflects the external circuit such as analog error information (CT disconnection, PT disconnection, etc.) and abnormal information of primary switch state (abnormal trip position, trip signal long time input, etc.)

The IED can store 512 latest time tagged alarm records.

5.5.3.2 Device self-check record(Selfchk Info)

- **Hardware self-check record**

The IED provide hardware health condition self-check alarm, such as analog sampling circuit abnormal self-check, memory status self-check alarm.

- **Software self-check record**

The IED provides software operation status self-check alarm records, such as setting error, parameter verification error and the like.

- **Configuration file self-check record**

The IED provides self-check records that reflect the status of the device configuration file, such as configuration file error, configuration file change, etc.

The IED can store 128 latest time tagged alarm records

5.5.4 Device Record

5.5.4.1 Remote Control Record(Remote Control)

Device control objects include circuit breakers, disconnectors, earthing disconnectors close and open, reset signal, transformer tap adjustment, etc., when the device receives the remote control command, the device will generate control operation record. The remote control contents contain the command source, command time, operation result, failure reason, etc.

The IED can store 128 latest time tagged control records.

5.5.4.2 Device Operation Record(User Records)

The operation record includes the time when the event was generated, the operation object, the content of the operation, and the description of the operation result.

The IED can store 128 latest time tagged device operation records.

5.5.4.3 Device Running Record(Run Records)

The running record is the device power-on, power-off record.

The IED can store 128 latest time tagged device running records.

5.5.5 Sequence of Event(SOE)

The IED provides a sequence of event (SOE) function:

- When the state quantity input signal is from a hard contact, the time tag of the state quantity is marked by the device, and the time is defined before debouncing.
- When the state quantity input is GOOSE signal, the time tag of the state quantity adopts the external input source signal time tag, and GOOSE signal acquisition has no debouncing time.

The IED can store 2000 latest time tagged SOE records.

5.6 Fault and Disturbance Recording

This IED provides the fault and disturbance recorder for recording the sampled values of the fault and disturbance wave when a fault is occurred in the power system, which can be triggered by pickup signals, trip signals and configurable binary signal. The fault recorder feature allows you to record selected current and voltage inputs to the protection elements, together with selected digital signals.

The integral fault recorder has an area of memory specifically set aside for storing disturbance records. The fault memory of the device is automatically updated with every recording. When the fault memory is filled completely, the oldest records are overwritten automatically. Thus, the latest records are always stored safely. The maximum number of time tagged records is 36, contain16 fault disturbance waves, 16 start disturbance waves and 4 manual disturbance waves.

Each fault waveform includes the wave recording data both before and after the fault. Each trigger element operation will extend the wave recording time, until the appointed time delay is over after the trigger element restores, or until the maximum number of wave recording points is reached.

5.6.1 Wave Recording File Format

The wave recording file adopts COMTRADE common format, complying with the requirements of IEC 60255-24. Each COMTRADE record has up to four files associated with it, namely: a title file (xxxxxxxx.HDR), a configuration file (xxxxxxxx.CFG), a data file (xxxxxxxx.DAT), and an information file (xxxxxxxx.INF), where information file is optional file. The wave recording files can be extracted communication with relay.

5.6.2 Fault Wave File

For each fault wave file, the following items are included:

1. Sequence number

Each operation will be recorded with a sequence number in the record and displayed on LCD screen.

2. Date and time of fault occurrence

The date and time is recorded when a system fault is detected. Time & date stamped by relay real time clock. The time resolution is 1ms.

3. Relative operating time

An operating time (not including the operating time of output relays) is recorded in the record. The time resolution is 1ms.

4. Fault information

Including faulty phase, fault location and protection elements.

5.6.3 Waveform Recording Duration

A fault waveform contains all analog and digital quantities related to IED such as currents, voltages, differential current, alarm elements, and binary inputs and etc.

The overall duration of a single fault recording comprises the total duration of the recording criterion, the pre-trigger time and the post-trigger time. With the fault recording parameter, these components can be individually set. The pre-trigger waveform recorded duration is configured via the setting [RecT_PreFault]. The waveform recorded duration after the fault disappears is configured via the setting [RecT_PostFault]. The maximum waveform recorded duration is configured via the setting [MaxT_OneRec].

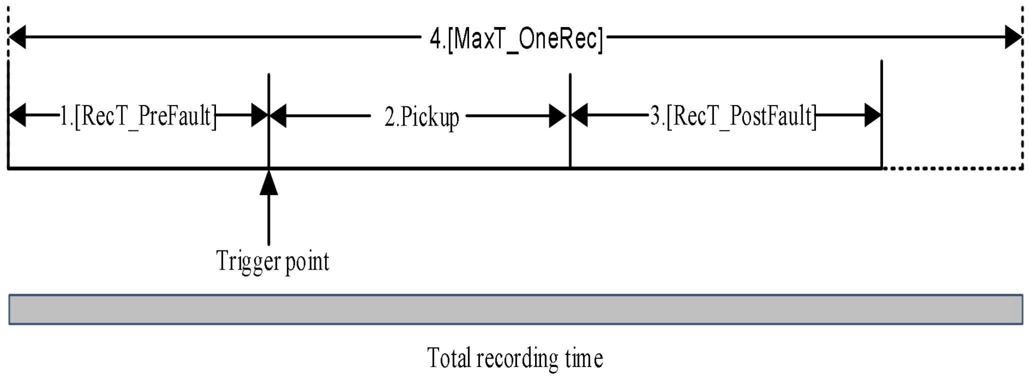


Figure5.6.1 Recording time diagram

1. Pre-trigger recording time

Use the setting [RecT_PreFault] to set this time.

2. Pickup recording time

The pickup recording time cannot be set. It continues as long as any valid trigger condition, binary or analog, persists.

3. Post-fault recording time

The recording time begins after all activated triggers are reset. Use the setting [RecT_PostFault] to set this time.

Maximum recording time

Use the setting [MaxT_OneRec] to set this time. If the summation of wave recording duration is larger than maximum recording time, the one recording time shall be equal to the setting [MaxT_OneRec].

Table 5.6.1 Recording Time Settings

No.	Name	Range	Unit	Step	Default	Description
1	RecT_PreFault	20~1000	ms	1	60	Pre-trigger recording time.
2	RecT_PostFault	20~1000	ms	1	40	Post-fault recording time.
3	MaxT_OneRec	1000~5000	ms	1	5000	Maximum recording time

5.6.4 Fault Wave Recording

You can select any of the IED's analogue inputs as analogue channels to be recorded. You can also map any of the opto-inputs and output contacts to the digital channels. In addition, you may also map a number of DDB signals such as Starts and LED is to digital channels.

The path to the configuration tool:

[IED]->[Const]->[WAVEANA]/[WAVEKI]/[WAVEKO]->[Ana Channel]/[KI Channel]/[KO Channel].

5.6.5 Logic Event Recording(Event Records)

When there is wave recording, the relay will record all of the process signals in logic diagram by Event Records, which configured by manufacture or super (If the permission setting is Show, it means super configuration is available).
The path to the configuration tool: [IED]->[CONST]->[LNDOSOECFG].

6 Hardware

6.1 Overview

The modular design structure of this relay enables a qualified commissioning technician to easily check and locate the damaged hardware modular, so as to eliminate the fault in the very first time. The hinged front panel allows easy access to the HMI modules and the back-plugging design makes it easy to upgrade, maintain or replace any module.

There are several types of hardware modules in this relay, which play different roles in the practical application. The specific modules can be configured flexibly according to the practical engineering demands.

The overall hardware designing frame of this relay is shown as below.

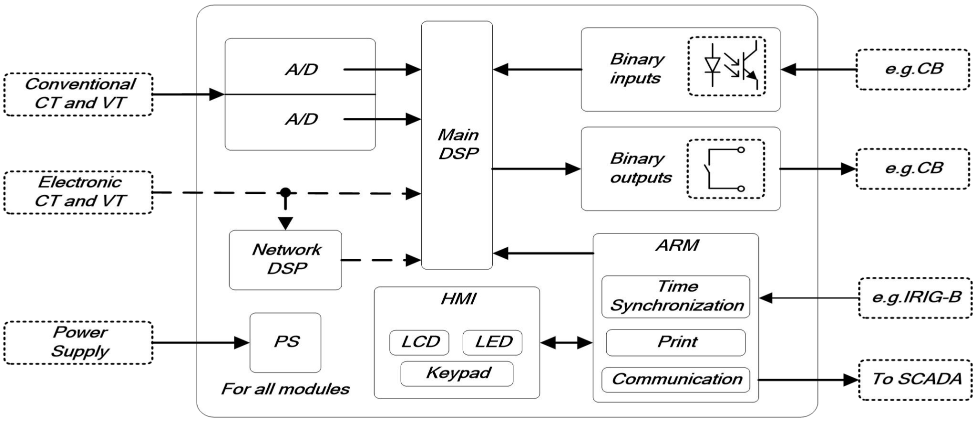


Figure 6.1.1 Hardware Frame of This Relay

The following figures show the front panel and the rear panel of 1/2 19” case.

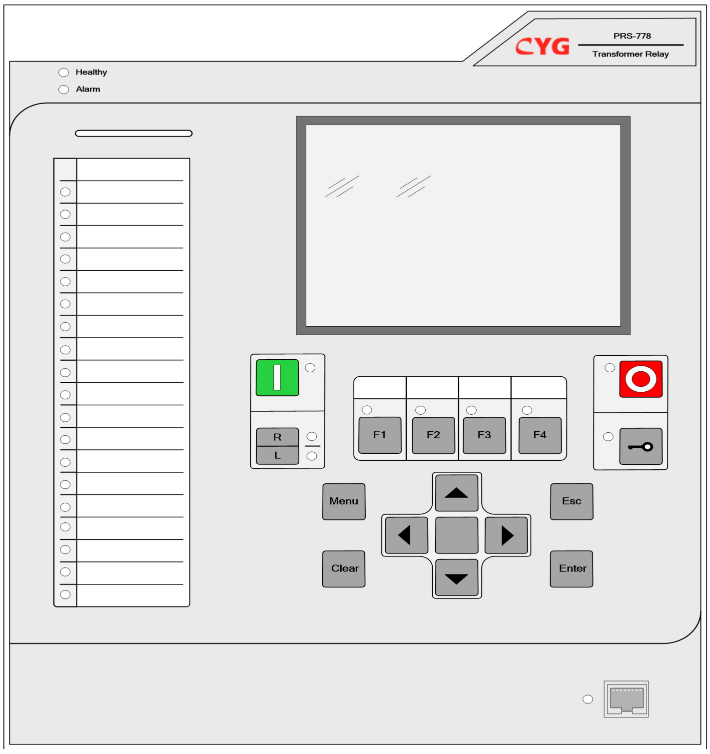


Figure 6.1.2 Front Panel of 1/2 19” Case

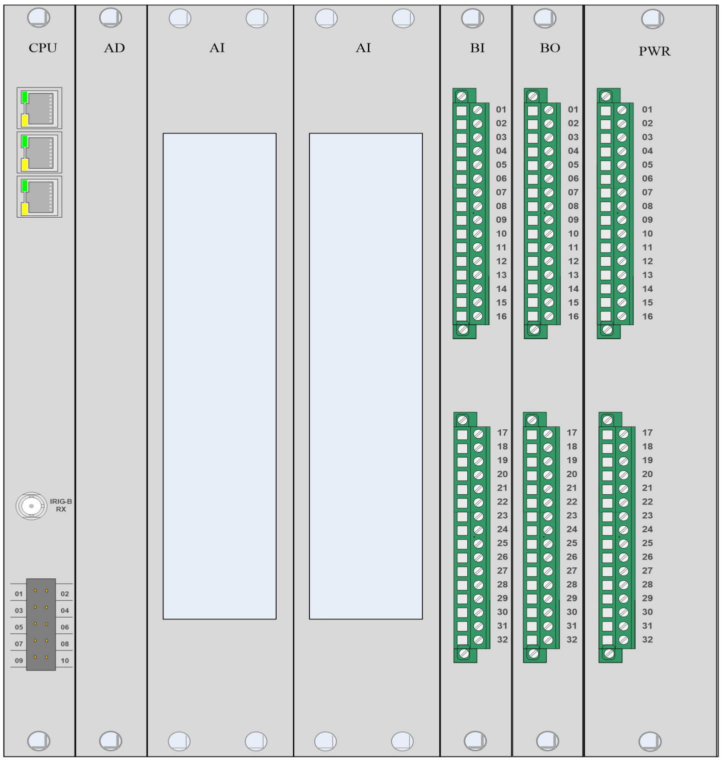


Figure 6.1.3 Real Panel of 1/2 19” Case

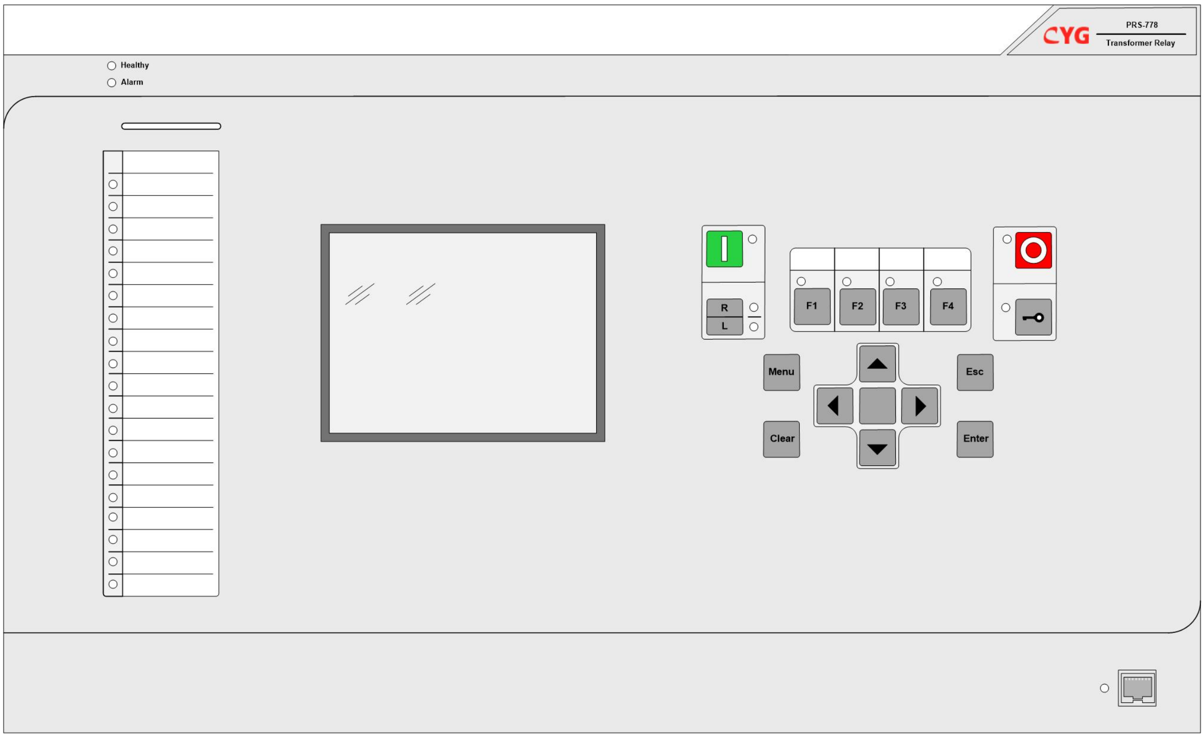


Figure 6.1.4 1/1 19" case front panel of this relay

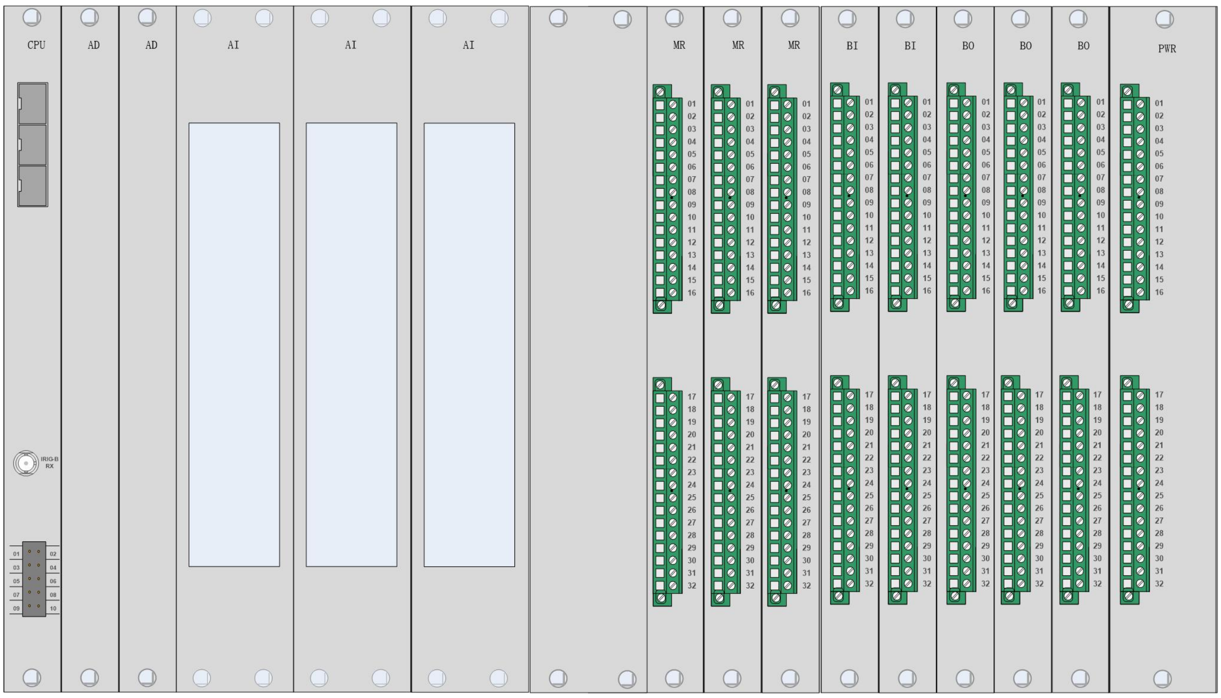


Figure 6.1.5 1/1 19" case real panel of this relay

NOTICE!

The hardware module configuration in the above figure is only for demonstrating one kind of typical configuration. Most oftenly, the configuration have to be modified in most of the project. The hardware module configuration of a practical engineering should be modified based on the practical designing requirement.

6.2 Hardware Module

The PRS-778 is comprised of randomly coordinated modules, except that a few particular modules, eg., PWR module, CPU module and HMI module, cannot be replaced in the whole device. The other modules, including TF(current or voltage transformer) module and IO (input and output) module, can be flexibly configured and then placed in the remained slots. The TF module includes AC current transformer, AC voltage transformer, DC current transformer and etc. The IO (input and output) module includes binary input, tripping output, signal output and etc.

Table 6.1 Module Configuration

No.	ID	Module Description	Remark
1	SR7601	Power supply module (PWR module)	standard
2	SR7260	Protection calculation module (CPU module)	standard
3	SR7270	AD conversion(AD module) for 1/1 19" case relay	standard
4	SR7271	AD conversion(AD module) for 1/2 19" case relay	standard
5	SR7100	Current/voltage transformer module (TF module)	standard
6	SR7178A	Current/voltage transformer module (TF module)	standard
7	SR7178B	Current/voltage transformer module (TF module)	standard
8	SR7330	Binary input module (BI module)	standard
9	SR7300	Binary output module (BO module)	standard
10	SR7720	Mechanical relay module (MR module)	option

6.3 Human Machine Interface Module

The human machine interface (HMI) module is installed behind the front panel of this device. It contains an LCD screen to modify the protection settings and system parameters and display information of this device, including the analogue quantities, the running status and event lists.

The menus are showed as tree structure, which facilitates the users to enter any specific menu. After entering the menu, the big LCD shows all the relevant information in one screen, making it easier to get all the information.

6.4 Power Supply Module

The power supply module contains a small voltage converter with enough electrical insulation between the converter and the input/output terminals. A wide range of input voltage is provided due to the sophisticated circuit design. The output voltage from the voltage converter is continuously monitored to ensure stability and safety.

The power supply module provides 10 binary outputs, some dry contacts, which conduct the signal functions showing the operating conditions (device error) or tripping and closing commands (protection, auto-recloser or remote control). The specific function is performed by setting the relevant settings and wiring the external copper cable.

Except for the Dev_Err Cls and Dev_Err Open output contacts (fixed as indication output contacts), all the other binary inputs or outputs can be visually and flexibly configured through the PRS IED Studio configuration tool, which determines what information they transmit between the CPU module and PWR module.

The frame of all the power supply module terminal are shown below.

PWR（SR7601）			
01	POW(+)	TRIP06 Open	17
02	POW(-)	SIGN07 Common	18
03	Dev_Err Common	SIGN07 Open	19
04	Dev_Err Cls	SIGN07 Cls	20
05	Dev_Err Open	SIGN08 Common	21
06	TRIP01 Common	SIGN08 Open	22
07	TRIP01 Open	SIGN08 Cls	23
08	TRIP02 Common	SIGN09 Common	24
09	TRIP02 Open	SIGN09 Open	25
10	TRIP03 Common	SIGN09 Cls	26
11	TRIP03 Open		27
12	TRIP04 Common		28
13	TRIP04 Open		29
14	TRIP05 Common		30
15	TRIP05 Open		31
16	TRIP06 Common		32

Figure 6.4.1 Frame of the Power Supply Module Terminals

The specific terminal definition of the connector is described as below.

Table 6.2 Terminal Definition and Description of PWR Module

Name	Description
POW+	Positive input of power supply for the device.
POW-	Negative input of power supply for the device.
Dev_Err Common	Device abnormality alarm common terminal.
Dev_Err Cls	Device abnormality alarm normal close terminal.
Dev_Err Open	Device abnormality alarm normal open terminal.
TRIP01-06	The No.1 -6 programmable tripping or closing binary output. BOi (i=1-6) Open is the normal open binary output.
SIGN07-09	The No.2 programmable signal binary output. BOi (i=7-9) Open is the normal open binary output, BOi (i=7-9) Cls is the normal close binary output.

6.5 Main CPU Module

The main CPU module, containing powerful microchip processors and some necessary electronic accessories, is the core part of this relay. This powerful processor excecute all the functions of the relay and conduct the commands, including the protection logics, the control function and the internal and external information interfacing functions.

A high-accuracy crystal oscillator is installed on the module as well, ensuring the relay to operate exactly based on the accurate current time.

The main functions of the main CPU module includes as below:

- Sampling information processing

  The values of each sampling point will be stored and then sent to different processing module for different function, including display, calculation, communication.

  The values of each binary IO contacts will also be stored and then sent to different processing module for different function, including display, calculation, communication.

- Protection, measuring and metering quantities calculation

  The CPU module can calculate all the relevant quantities (zero sequence current and voltage, negative sequence current and voltage) on the basis of the directly sampling quantities (phase-to-earth voltages and currents, phase-to-phase voltages and currents) and binary inputs. After the calculation, all the quantities are sent to the protection function module or control module to decide whether the relevant dry contacts trip or close.

- Communication management

  The CPU module can effectively execute all communication procedures parallelly and reliably interface coded messages through the selected communication interfaces. These interfaces are usually used to communicate with a SCADA or a Station Gateway throuth a switcher. The CPU module is also responsible for information exchanging with the HMI module. If any monitoring condition changes or any event occurs (SOE, protection tripping event, device abnormality), this module will send out the relevant event information to all relevant receivers, so as to ensure a first time alarm to notice the users.

- Auxiliary calculations

  Besides all the quantities mentioned above, the CPU module can also calculate the metering values, such as active power, reactive power and power factor, etc., to provide overall monitoring information. All these quantities can be sent to a SCADA or a Station Gateway throuth a switcher.

- Time Synchronization

  The module provides an interface to receive time synchronized signals from external clock synchronization source. This module also has a local crystal oscillator to maintain the internal time accuracy when outside synchronization source breaks down. The synchronization mode includes PPS (pulse per second) mode and IRIG-B mode. Basing on the outside timing message (from SCADA or Station Gateway) or the PPS signal or the IRIG-B signal, this module can adjust its time within the timing accuracy.

The frame of the CPU module terminal is described as below.

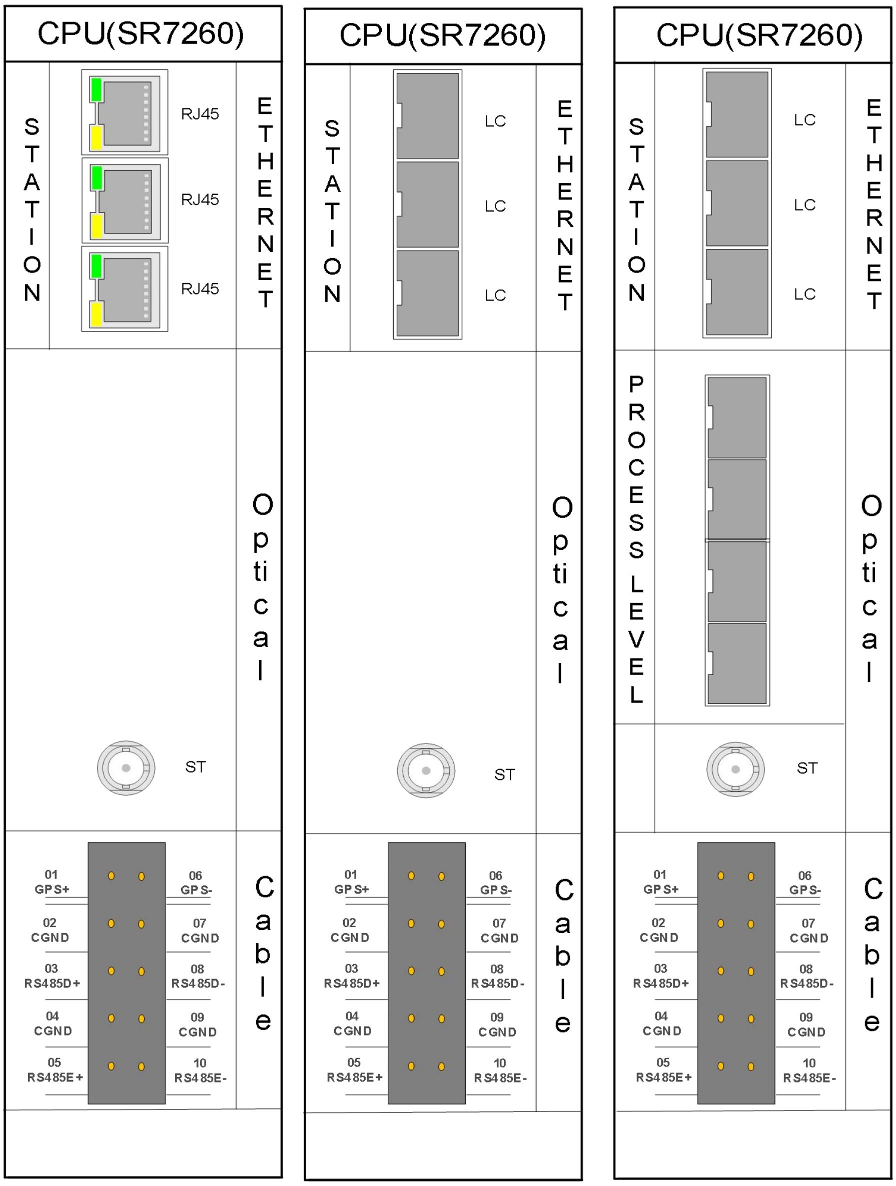


Figure 6.5.1 Frame of Main CPU Module(The third is for digital device)

6.6 AD module

The module consists of a 16-bit high-accuracy AD converter which converters the sampling analog quantities that are continuous in time and amplitude to digital signals channel that are discrete in time and amplitude by channel. After the quick converter, all the digital signals are transmitted to microchip processors for latter application.

6.7 Binary Input Module

The BI module contains 18 binary inputs, the optical isolated input terminals, which can perform different monitoring functions, such as detecting the breaker and switch positions of the corresponding bay. All the BI terminals can be used as general purpose binary inputs or special purpose (protection function or control function) binary inputs. For example, the general purpose binary inputs can be used to indicate the status (0 for normal condition and 1 for abnormal condition) of a certain apparatus. For another example, the special purpose binary inputs can be used to acting as the blocking or start signal for a certain protection function.

All the binary inputs can be visually and flexibly configured through the PRS IED Studio configuration tool, which determine what information do they transmit between the CPU module and BI module.

The frame of the BI module terminal is described as below.

INPUT(SR7330)			
01	BI01+	BI10+	17
02	BI02+	BI11+	18
03	BI01~02 Common-	BI10~11 Common-	19
04	BI03+	BI12+	20
05	BI04+	BI13+	21
06	BI03~04 Common-	BI12~13 Common-	22
07	BI05+	BI14+	23
08	BI05-	BI14-	24
09	BI06+	BI15+	25
10	BI06-	BI15-	26
11	BI07+	BI16+	27
12	BI07-	BI16-	28
13	BI08+	BI17+	29
14	BI08-	BI17-	30
15	BI09+	BI18+	31
16	BI09-	BI18-	32

Figure 6.7.1Frame of Input Terminal

Table 6.3 Terminal Definition and Description of BI Module

Name	Description
BI01+	The No.1 and No.2 programmable binary input.
BI02+	
BI01~ BI02-	
BI03+	The No.3 and No.4 programmable binary input.
BI04+	
BI03~ BI04-	
BI05+	The No.5programmable binary input.
BI05-	
BI06+	The No.6 programmable binary input.
BI06-	
BI07+	The No.7 programmable binary input.
BI07-	
BI08+	The No.8 programmable binary input.
BI08-	
BI09+	The No.9 programmable binary input.
BI09-	
BI10+	The No.10 and No.11 programmable binary input.
BI11+	
BI10~ BI11-	
BI12+	The No.12 and No.13 programmable binary input.
BI13+	
BI12~ BI13-	
BI14+	The No.14programmable binary input.
BI14-	
BI15+	The No.15 programmable binary input.
BI15-	
BI16+	The No.16 programmable binary input.
BI16-	
BI17+	The No.17 programmable binary input.
BI17-	
BI18+	The No.18 programmable binary input.
BI18-	

6.8 Transformer Module

The transformer module can decrease the high input analog values to relevant low output analog values as to the small transformer ratio, acting as an effective isolation between the relay and the power system. The low output analog values, within the range of the AD module after the conversion, are sent to the AD module for further processing. A low pass filter circuit is used to reduce the noise of each analog channel.

The frame of three transformer modules of different specifications are shown below. The first transformer module consists of 6 voltage channels and 6 current channels. The second one consists of 4 voltage channels and 8 current channels. The third one consists of 12 current channels. The current terminal will be automatically short circuited when it is plugged out.

TF1(SR7178A)			
01	Uxa	Uxb	02
03	Uxc	Uxn	04
05	U1	U1'	06
07	U2	U2'	08
09	U3	U3'	10
11	Ixa	Ixa'	12
13	Ixb	Ixb'	14
15	Ixc	Ixc'	16
17	I1	I1'	18
19	I2	I2'	20
21	I3	I3'	22
23			24
25			26

TF2: (SR7178B)			
01	Uxa	Uxb	02
03	Uxc	Uxn	04
05	U1	U1'	06
07			08
09			10
11	Ixa	Ixa'	12
13	Ixb	Ixb'	14
15	Ixc	Ixc'	16
17	I1	I1'	18
19	I2	I2'	20
21	I3	I3'	22
23	I4	I4'	24
25	I5	I5'	26

TF3: 12I(SR7100)			
01	I1	I1'	02
03	I2	I2'	04
05	I3	I3'	06
07	I4	I4'	08
09	I5	I5'	10
11	I6	I6'	12
13	I7	I7'	14
15	I8	I8'	16
17	I9	I9'	18
19	I10	I10'	20
21	I11	I11'	22
23	I12	I12'	24
25			26

Figure 6.8.1Transformer Module of Three Different Specifications

DANGER!

NEVER allow the secondary side of the current transformer (CT) to be opened while the primary apparatus is energized. The opened CT secondary circuit will produce a extremely high voltage and high heat. Although the current terminal will be automatically short circuited when it is plugged out, the safety precaution should be obeyed in order to prevent severe personal injury, person death or considerable equipment damage.

The terminal definition of the connector is described in the below diagram.

Table 6.4 Terminal Definition and Description of TF Module 1

Name	Description
Uxa Uxb Uxc Uxn	The three voltage input channels with inner star connection (Y) for x-side (x=H,M,L) protection and metering.For example, it can be used for over excitation protection (24),three-phase over voltage protection(59P）,three-phase under voltage Protection (27P) and so on.
U1 U1'	The phase/zero voltage input for x-side (x=H,M,L) protection and metering.For example,it can be used for three-phase over voltage protection (59P) / residual over voltage Protection (59N) and so on.
U2 U2'	The phase/zero voltage input for x-side (x=H,M,L) protection and metering,For example, it can be used for three-phase over voltage protection (59P) / residual over voltage Protection (59N) and so on.
U3 U3'	The phase/zero voltage input for x-side (x=H,M,L) protection and metering,For example it can be used for three-phase over voltage protection (59P) / residual over voltage Protection (59N) and so on.
Ixa Ixa' Ixb Ixb' Ixc Ixc'	The three voltage input channels for x-side (x=H,M,L) protection and metering.For example, it can be used for transformer differential protection(87T),directional over current Protection (67P/50/51) and so on.
I1 I1'	The phase/zero current input for x-side (x=H,M,L) protection and metering,For example, it can be used for directional over current protection (67P/50/51) /non-directional Instantaneous earth fault protection(50/51N) and so on.
I2 I2'	The phase/zero current input for x-side (x=H,M,L) protection and metering,For example, it can be used for directional over current protection (67P/50/51) /non-directional Instantaneous earth fault protection(50/51N) and so on.
I3 I3'	The phase/zero current input for x-side (x=H,M,L) protection and metering,For example, it can be used for directional over current protection (67P/50/51) /non-directional Instantaneous earth fault protection(50/51N) and so on.

Table 6.5 Terminal Definition and Description of TF Module 2

Name	Description
Uxa Uxb Uxc Uxn	The three voltage input channels with inner star connection (Y) for x-side (x=H,M,L) protection and metering.For example, it can be used for over excitation protection (24),three-phase over voltage protection (59P),three-phase under voltage Protection (27P) and so on.
U1 U1'	The zero voltage input for x-side (x=H,M,L) protection and metering.For example,it can be used for residual over voltage Protection (59N) and so on.
Ixa	The three voltage input channels for x-side (x=H,M,L) protection and

Name	Description
Ixa’	metering.For example, it can be used for transformer differential protection(87T),directional over current Protection (67P/50/51) and so on.
Ixb	
Ixb’	
Ixc	
Ixc’	
I1	The zero current input for x-side (x=H,M,L) protection and metering,For example, it can be used for non-directional Instantaneous earth fault protection(50/51N) and so on.
I1’	
I2	The zero current input for x-side (x=H,M,L) protection and metering,For example, it can be used for non-directional Instantaneous earth fault protection(50/51N) and so on.
I2’	
I3	The zero current input for x-side (x=H,M,L) protection and metering,For example, it can be used for non-directional Instantaneous earth fault protection(50/51N) and so on.
I3’	
I4	The zero current input for x-side (x=H,M,L) protection and metering,For example, it can be used for non-directional Instantaneous earth fault protection(50/51N) and so on. In half-case three-winding-transformer configuration, this current channel is reserved.
I4’	
I5	The zero current input for x-side (x=H,M,L) protection and metering,For example, it can be used for non-directional Instantaneous earth fault protection(50/51N) and so on. In half-case three-winding-transformer configuration, this current channel is reserved.
I5’	

Table 6.6 Terminal Definition and Description of TF Module 3

Name	Description
I1	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional over current protection (67P/50/51) and so on.
I1’	
I2	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional over current protection (67P/50/51) and so on.
I2’	
I3	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional over current protection (67P/50/51) and so on.
I3’	
I4	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional over current protection (67P/50/51) and so on.
I4’	
I5	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional over current protection (67P/50/51) and so on.
I5’	

Name	Description
I6	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional over current protection (67P/50/51) and so on.
I6’	
I7	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional overcurrent protection (67P/50/51) and so on.
I7’	
I8	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional overcurrent protection (67P/50/51) and so on.
I8’	
I9	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional overcurrent protection (67P/50/51) and so on.
I9’	
I10	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional overcurrent protection (67P/50/51) and so on.
I10’	
I11	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional overcurrent protection (67P/50/51) and so on.
I11’	
I12	The phase current input for x-side (x=H2,M2,L2,LT,G) protection and metering,For example, it can be used for directional overcurrent protection (67P/50/51) and so on.
I12’	

6.9 Binary Output Module

The BO module consists of binary output, dry contacts, which conduct the signal functions showing the operating conditions or tripping and closing commands (protection, auto-recloser or remote control). The specific function is performed by setting the relevant settings and wiring the external copper cable. All the contacts can independently receive tripping or closing commands from the main CPU module and then conduct these commands.

All the binary outputs can be visually and flexibly configured through the PRS IED Studio configuration tool, which determines what information they transmit between the CPU module and BO module.

The frame of the BO module terminal is described as below.

Output(SR7300)			
01	TRIP01 Comon	SIGN09 Comon	17
02	TRIP01 Open	SIGN09 Open	18
03	TRIP02 Comon	SIGN10 Comon	19
04	TRIP02 Open	SIGN10 Open	20
05	TRIP03 Comon	SIGN11 Comon	21
06	TRIP03 Open	SIGN11 Open	22
07	TRIP04 Comon	SIGN11 Cls	23
08	TRIP04 Open	SIGN12 Common	24
09	TRIP05 Comon	SIGN12 Open	25
10	TRIP05 Open	SIGN12 Cls	26
11	TRIP06 Comon	SIGN13 Comon	27
12	TRIP06 Open	SIGN13 Open	28
13	SIGN07 Comon	SIGN13 Cls	29
14	SIGN07 Open	SIGN14 Common	30
15	SIGN08 Common	SIGN14 Open	31
16	SIGN08 Open	SIGN14 Cls	32

Figure 6.9.1Frame of BO Terminal

Table 6.7 Terminal Definition and Description of BO Module

Name	Description
TRIP01-06	The No.1 -6 programmable tripping or closing binary output. TRIPi (i=1-6) Open is the normal open binary output.
SIGN07-10	The No.7-10 programmable signal binary output. SIGNi (i=7-10) Open is the normal open binary output
SIGN11-14	The No.11-14 programmable signal binary output. SIGNi (i=11-14) Open is the normal open binary output, SIGNi (i=11-14) Cls is the normal close binary output.

6.10 MR Plug-in Module (Mechanical Relay Input/Output)

SR7720 is input and output modules for mechanical protection. This module is used to output various signals, issue trip commands and accept reset command.

The terminal definition of the connector is described as below.

MR(SR7720)			
01	PWR+	BO_MR_2_ Common	17
02	BI_MR01	BO_MR1_2	18
03	BI_MR02	BO_MR2_2	19
04	BI_MR03	BO_MR3_2	20
05	BI_MR04	BO_MR4_2	21
06		BO_MR_3_ Common	22
07		BO_MR1_3	23
08		BO_MR2_3	24
09		BO_MR3_3	25
10		BO_MR4_3	26
11	Reset input+	BO_MR_4_ Common	27
12	BO_MR_1_ Common	BO_MR1_4	28
13	BO_MR1_1	BO_MR2_4	29
14	BO_MR2_1	BO_MR3_4	30
15	BO_MR3_1	BO_MR4_4	31
16	BO_MR4_1	PWR-	32

Terminal definition and description is shown as follows:

Table 6.8 Terminal definition and description of MR Plug-in Module

Symbol	Description
PWR+	Positive input of power supply for the device
BI_MR01	Mechanical relay (MR) signal input 1
BI_MR02	Mechanical relay (MR) signal input 2
BI_MR03	Mechanical relay (MR) signal input 3

Symbol	Description
BI_MR04	Mechanical relay (MR) signal input 4
Reset input+	Reset input
BO_MR_1_Common	The first common terminal of negative supply of binary inputs
BO_MR1_1	NO contact, is closed when binary input BI_MR1 is energized.
BO_MR2_1	NO contact, is closed when binary input BI_MR2 is energized.
BO_MR3_1	NO contact, is closed when binary input BI_MR3 is energized.
BO_MR4_1	NO contact, is closed when binary input BI_MR4 is energized.
BO_MR_2_Common	The second common terminal of negative supply of binary inputs
BO_MR1_2	NO contact, is closed when binary input BI_MR1 is energized.
BO_MR2_2	NO contact, is closed when binary input BI_MR2 is energized.
BO_MR3_2	NO contact, is closed when binary input BI_MR3 is energized.
BO_MR4_2	NO contact, is closed when binary input BI_MR4 is energized.
BO_MR_3_Common	The third common terminal of negative supply of binary inputs
BO_MR1_3	NO contact, is closed when binary input BI_MR1 is energized.
BO_MR2_3	NO contact, is closed when binary input BI_MR2 is energized.
BO_MR3_3	NO contact, is closed when binary input BI_MR3 is energized.
BO_MR4_3	NO contact, is closed when binary input BI_MR4 is energized.
BO_MR_4_Common	The forth common terminal of negative supply of binary inputs
BO_MR1_4	NO contact, is closed when binary input BI_MR1 is energized.
BO_MR2_4	NO contact, is closed when binary input BI_MR2 is energized.
BO_MR3_4	NO contact, is closed when binary input BI_MR3 is energized.
BO_MR4_4	NO contact, is closed when binary input BI_MR4 is energized.
PWR-	Negative input of power supply for the device

7 Human Machine Interface

7.1 Overview

HMI is known as the Human Machine Interface. HMI is the main communication interface between the control system and the operator. The friendly LCD facilitates the operator, providing all operating system information in the screen of the front display panel, including binary inputs or outputs, circuit breakers status, version of operating system program, alarm signals, tripping operation, disturbance records, and signal of measuring quantities (voltage, current and angle) etc., Besides these, its also useful for modifying the operating system configuration settings and protection function settings as well. The HMI can also be helpful during commissioning work.

Additionally, the PRS IED studio software helps to conduct all above listed function through communication port (Ethernet cable) on the PC or laptop.

7.1.1 Design Structure

The design structural of Human Machine Interface (HMI) is user friendly and easy to operate in different situations. The design structure details of HMI are follow:

- For monitoring the signal status, fault records and configuration of settings, high quality 320×240 dot matrix LCD with dim lite green back light display is equipped.
- For the access of device functions and control settings. 1 enter and 1 cancel keys, 4 functional keys, 4 arrow keys, 2 remote and local control keys and 2 CB control keys.
- For the indication of different types of alarming and tripping signals. Front panel of HMI includes 21 LED light indicator.
- For the remote access from the PRS IED studio configuration software, Ethernet commissioning interface is available.

The front and back panels of relay shown in figure 6.1.2 and 6.1.3 respectively.

7.1.2 Function mode

- HMI screen is used to monitor the successively status and information of various events, and also helps to configure the protection settings and device operating mode
- Navigation menu keys help the operator to locate the required data or information.
- Data record and printing function is available in relay setting.

In simple words, all functions of PRS-778 are user friendly.

7.1.3 Operating panel keypad and keys

The relay front penal have 9 keypads and 8 function keys help the operator to change the device settings according to the required situation and locate the different kind of data access. These all keys and keypad have different kinds of functions.

Table 7.1.1 Keys information table

Symbol of keys	Description
◀ ▶ ▲ ▼	Arrow keys left, right up and down respectively
F1 F2 F3 F4	Functional keys F1, F2, F3 and F4 respectively. These are configure according to user's demand.
Menu Clear Esc Enter	Different keys like Menu, Clear, Esc and Enter keys
| R|L (key) (◎)	CB close key, Remote/Local control key, User login key and CB opening key respectively.

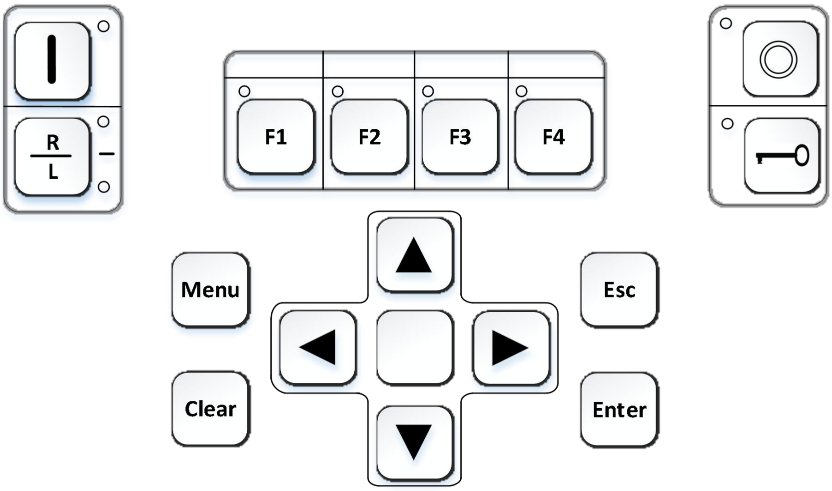


Figure 7.1.1 Overview of Front Panel Keypads and Keys

7.1.4 Indication of LED

The device consists of 31 front panel LEDs. The local view of front panel HMI consists of two relay status LEDs above the display level: healthy and alarm. There are nineteen other configurable LEDs on the front panel of local-HMI and each LEDs can be configured with three colors like green, red and yellow according to user requirement. These LEDs can be configured through local HMI or PRS IED Studio. Additionally, there are nineteen LEDs, each of which can be configured with 3 colors. These LEDs can be triggered by a fault, an alarm event or device record, and they indicate last information.

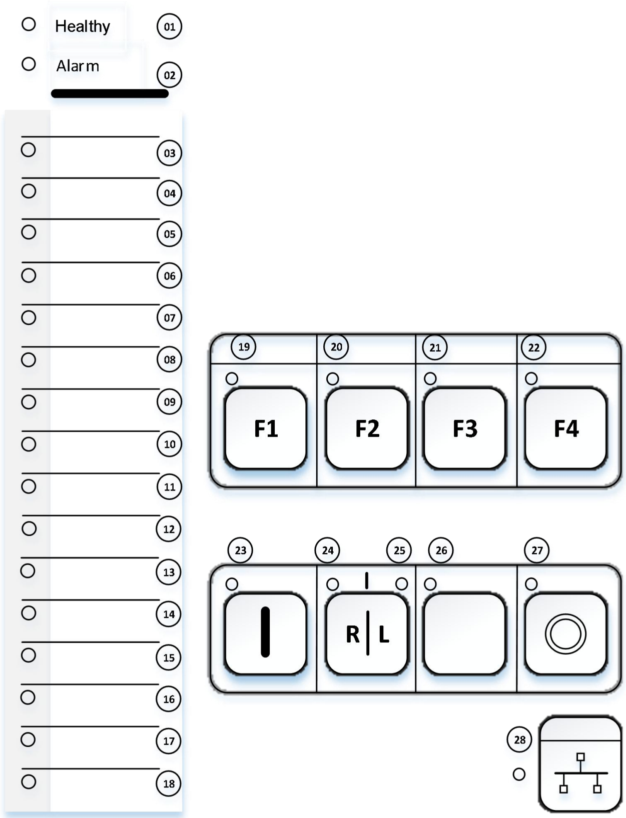


Figure 7.1.2 Overview of Front Panel LED's

Table 7.1.2 LED indications

No.	Key label	Status	Description
01	Healthy	Off	When the device is not energized.
		Green	When the device is in normal working mode and ready to operate
02	Alarm	Off	No alarm signal is energized when the device running normally.
		Yellow	Alarm signal is issued. When any kind of abnormality signal is detected. LED light color is fixed yellow.
03~21	Configurable	Off	None of signal is energized when the device running normally. If state configuration is "hold", it only can be reset by Push button or Keypad.
		Green/Yellow/Red	These LEDs can be configured according to user demand like different operating functions, such as tripping, alarm, reclose, CB open or close and synchro-check etc.
22~25	Configurable	Off	None of signal is energized when the functional key is deactivated.
		Red	These LEDs indicate the functional keys are deactivated
26	CB Close	Off	None of signal is energized when the functional key is deactivated.
		Yellow	This LED indicate the CB Close key is activated.

No.	Key label	Status	Description
27	Remote	Off	The operation mode is determined by the BI.
		Yellow	The device is in the “remote” mode
28	Local	Off	The operation mode is determined by the BI.
		Yellow	The device is in the “Local” mode
29	User login	Off	When user login function is not enable.
		Yellow	When user login function works normally.
30	CB Open	Off	None of signal is energized when the functional key is deactivated.
		Yellow	This LED indicate the CB Open key is activated.
31	Ethernet interface port	Off	When no Ethernet cable is connected with device.
		Green	When it works normally.

NOTICE!

No.01-02 and No.22-31 cannot set status because it is the fixed value.

➢ **General description of LEDs indication**

Healthy

This LED indication shows, device is energized through normal power supply, and ready to work under the normal atmosphere.

Alarm

This LED indication shows, when any abnormality alarm is detected in the system.

Trip

This LED indication shows, when any protection function is operated.

Reclose

This LED indication shows, when auto-recloser function is operated.

CB Open

This LED indication shows, when the circuit breaker is in open position.

CB Close

This LED indication shows, when the circuit breaker is in close position.

7.1.5 Configurable keys

The device HMI front panel consists of four configurable keys. These configurable functional keys provide shortcuts for certain menu or act as a control button. The default view of configurable functional keys (F1, F2, F3 and F4) are shown in above figure 7.1.1. The detail operation of functional keys is listed in below table 7.1.3:

Table 7.1.3 Information of functional keys

Keys	Function	Description	Remarks
F1, F2, F3 and F4	Control	For binary input and output control instantiated according to the configuration tool	This control function, control through three ways like puls, hold and exit.
	Shortcut	"System single line", "Measurement", “Binary input” “Fault record “ “Disturbance” “Clear” “Setting group” 7 selected 1	This shortcut function provide easy access to device operation settings and it is configurable according to user demand.
	Sign out	Do not perform the key function	-

7.2 LCD Display description of HMI

7.2.1 Overview

In this part of HMI, the detail of LCD display function is described.

7.2.2 Normal display structure of LCD

The normal operating condition of local HMI LCD display structure is shown below in figure 7.2.1, the single-line diagram is based on the practical arrangement of equipment, monitoring the position status of CB and Isolator in real time.

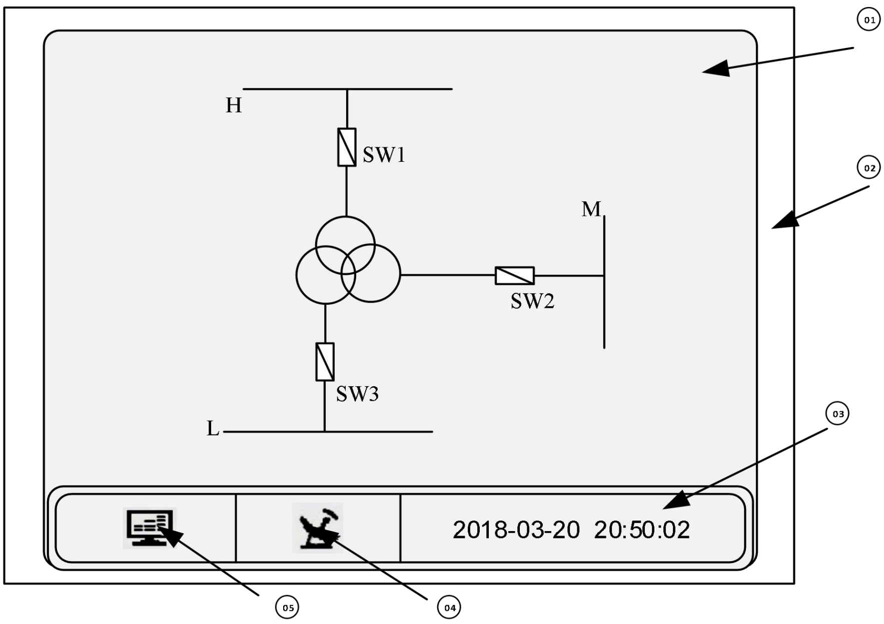


Figure 7.2.1 General Overview Display of Local HMI LCD Screen

According to the overview of local HMI. LCD display is divided into five parts. These parts are listed below:

1. Main data display zone
2. Outer boundary zone
3. Date and time display zone
4. Time synchronization or GPS
5. Data monitoring zone

Main data display zone provides information that the user wants to access like measurement value status, fault records, circuit breaker status, single line diagrams, alarm signals, protection function settings, and synchronization status etc.

Outer boundary zone is known as free text zone and no data display in this zone. It defines the boundary of LCD display zone.

Date and time display zone shows the real monitoring value of date and time. The user can set these date and time value according to requirement. The display format of date and time is yyyy-mm-dd and hh:mm:ss respectively. The time setting format can be easily set to the user time zone demand.

7.2.3 Main menu display

In order to make sure the user can control PRS-778 relay easier, simple and fast, the CYG Co, Ltd designs a flat-panel of main menu LCD display that contain ten main controlling function.

These controlling functions are listed below:

1. Physical
2. Review
3. Monitor
4. Event
5. Record
6. Setting
7. Config
8. Test
9. Clear
10. Language

The main menu display screen is shown in below figure 7.2.2. The main menu will deal with the operation of installation work together with providing basic support and instructions to help user control.

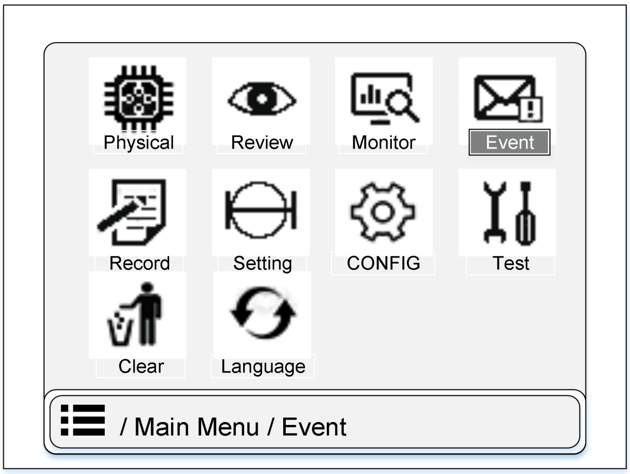


Figure 7.2.2 LCD General Overview Display of Main Menu

7.3 Sub menu functions of main menu

In this part of HMI, the details of menu sub-functions are described. These all sub-functions display on the front panel of HMI LCD.

7.3.1 Physical Information

In this section, describe all the physical information related to device firmware and device communication. The overview display of physical information is shown in below figure 7.3.1.

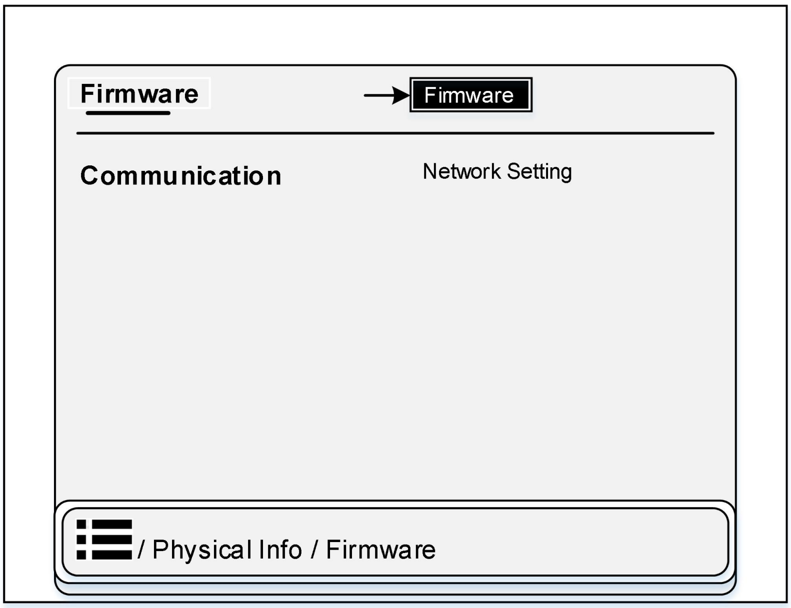


Figure 7.3.1 Overview Display of Physical Information Sub-functions

7.3.1.1 Software

In this sub-section of physical information, the firmware information of the protection relay is described, including the device type, protection relay software, uniqueness code and protection date etc. User can access this function through the following path: "Physical information > Firmware". The Firmware information data divided into two pages and the detail of information is listed in below figure 7.3.2 and table 7.3.1:

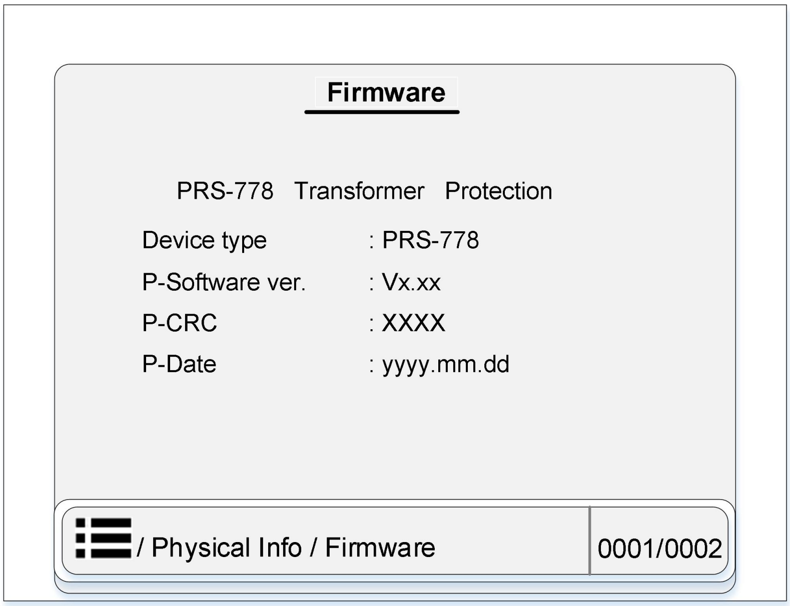


Figure 7.3.2 Overview Display Diagram of Firmware Information

Table 7.3.1 Detail of Firmware information

Name	Function display	Description
Device type	PRS-778	Describe the type of protection relay
P-Software ver	VX.XX	Describe the version of protection relay software
P-CRC	XXXX	Protection Cyclic redundancy check code
P-Date	yyyy-mm-dd	Protection CPU date
M-Software ver.	VX.XX	MCPU software version
M-CRC	XXXX	MCPU Cyclic redundancy check error
M-Date	yyyy-mm-dd	Management CPU date
Device code	CYSR30000000FFFFFFF	S/N Code, serial number of the device
Ordering Code	PRS-778-XXXXX-XXXXXXXX XXXXXX	Ordering Code
Config. Ver.	Vx.xx	The configuration version

For example: the relay used in one project in Thailand, the detail of software information can be display in Table 7.3.2

Table 7.3.2 Detail of Software information example

Name	Function display	Description
Device type	PRS-778	Describe the type of protection relay
P-Software ver	V2.03	Describe the version of protection relay software
P-CRC	5D1B	Protection Cyclic redundancy check code
P-Date	2018.03.07	Protection CPU date
M-Software ver.	V2.03	MCPU software version
M-CRC	1024	MCPU Cyclic redundancy check error
M-Date	2018.03.07	Management CPU date
Device Code	CYSR300000000138495	S/N Code, serial number of the device
Ordering Code	BP-2C-AACAA-BABXCCA AAAABDDD	Ordering Code
Config. Ver.	V2.03	The configuration version

7.3.1.2 Communication

This section, describes the information communication of network setting of the protection relay including IP, MAC and Net Mask of network 1, 2 and 3 respectively. User can access this function through the following path: “Physical information > communication”. The network setting data of communication information is listed in below figure 7.3.3 and table 7.3-3:

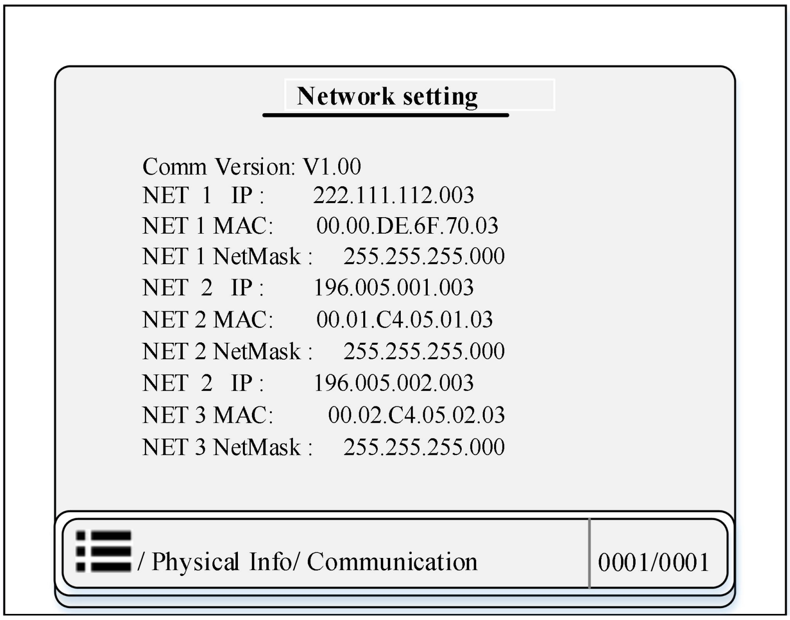


Figure 7.3.3 Overview Display Diagram of Network Setting

Table 7.3.3 Communication data detail

Name	Function display	Description
NET 1 IP	222.111.112.003	IP address of internet protocol for Ethernet port 1

Name	Function display	Description
NET 1 MAC	00.00.DE.6F.70.03	MAC address of internet protocol for Ethernet port 1
NET 1 Net Mask	255.255.255.000	Net Mask address of internet protocol for Ethernet port 1
NET 2 IP	196.005.001.003	IP address of internet protocol for Ethernet port 2
NET 2 MAC	00.01.C4.05.01.03	MAC address of internet protocol for Ethernet port 2
NET 2 Net Mask	255.255.255.000	Net Mask address of internet protocol for Ethernet port 2
NET 3 IP	196.005.002.003	IP address of internet protocol for Ethernet port 3
NET 3 MAC	00.02.C4.05.02.03	MAC address of internet protocol for Ethernet port 3
NET 3 Net Mask	255.255.255.000	Net Mask address of internet protocol for Ethernet port 3

7.3.2 Review Information

This section is divided into two sub-parts, including time mode and the information how to review protection relay settings. This section only provides the setting view display and user can't change the display information of relay. The overview display of review information is shown in below figure 7.3.4.

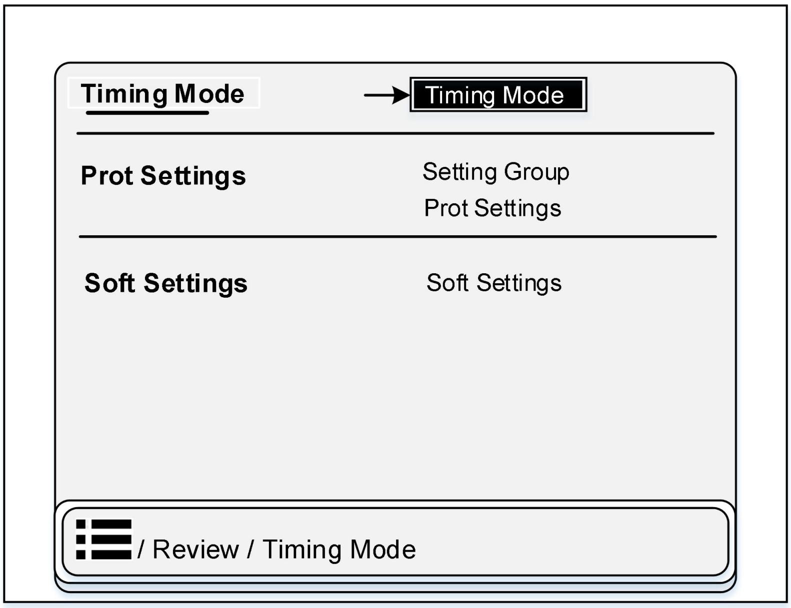


Figure 7.3.4 Overview Display of Review Information Sub-functions

7.3.2.1 Timing Mode

In this section, the user can see the time information like Uart IRIG-B, Opti IRIG-B and SNTP (Simple Network Time Protocol) information and the user can't change any kind of information. Users can access this function through the following path: "Review > Timing Mode". The overview display of timing mode is shown in below figure 7.3.5.

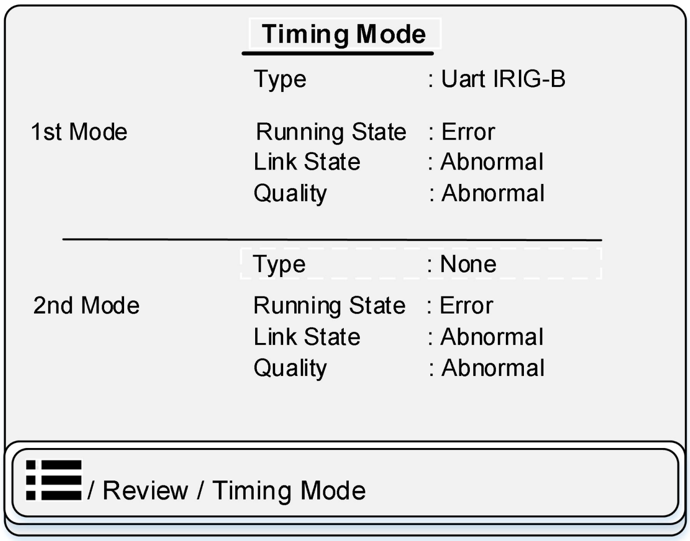


Figure 7.3.5 Overview Display of Timing Mode

7.3.2.2 Prot Settings

This section is divided into two sub-parts like setting group and protection settings.

1- Setting Group

This sub-section the user can see the information about which group is the current group. There are totally 4 groups. and the setting groups can be switched locally or remotely respectively.

2- Prot Settings

This section the user can see the different kind of protection function operation settings . User can access this function through the following path: "Review > Prot Settings". This section contains 01 to 6 pages and 31 parts of relay settings. The information data structure of protection setting is listed in below figure 7.3.6

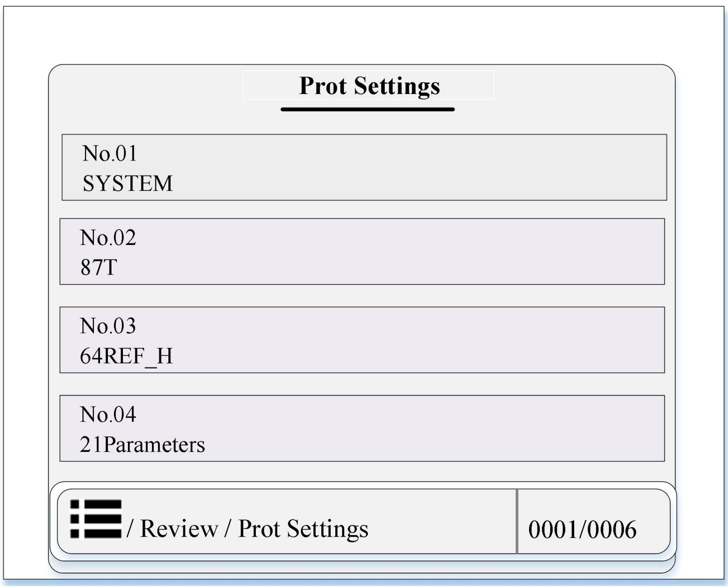


Figure 7.3.6 Overview Diagram of Prot Setting

7.3.3 Monitoring Information

This section divided into three sub-parts and describe the information of real time monitoring data of PRS-778 transformer protection relay. This section only provides the sample, harmonics and BI data information. In this section user can easily access the real-time monitoring data view of relay through arrow keys. The overview display of monitoring information are shown in below figure 7.3.7.

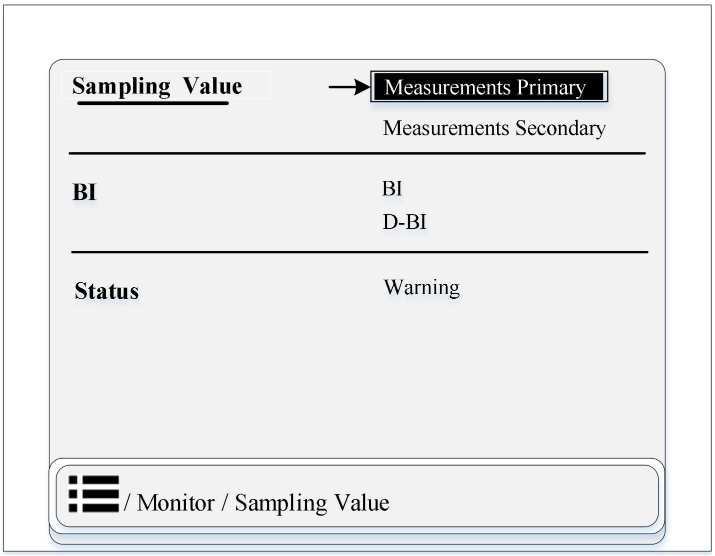


Figure 7.3.7 Overview Display of Monitoring Information Sub-functions

7.3.3.1 Sampling Value

This section is divided into two subpart like Measurements Primary and Measurements Secondary. Both describe the detail information of all measurement values such as current, voltage and angle etc. User can access this function through the following path: “Monitor > Sampling Value”. The measurement data structure of relay is listed in below figure 7.3.8 and table 7.3.4:

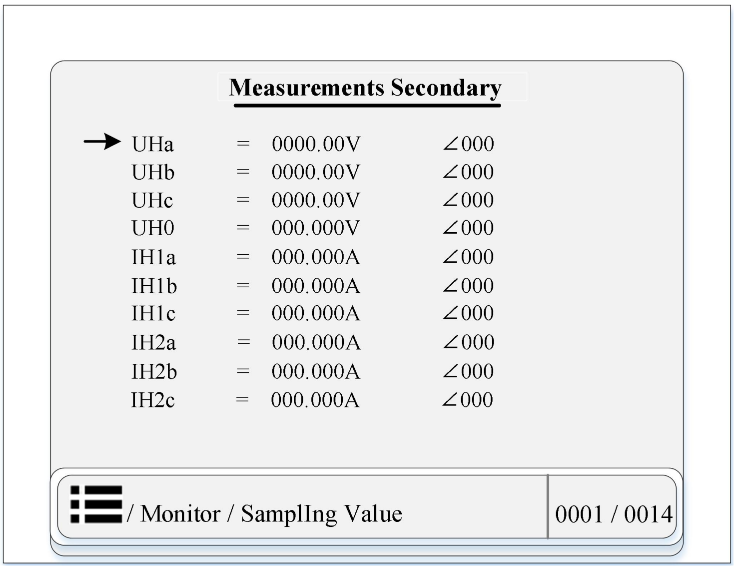


Figure 7.3.8 Overview Display of Measurement Section Quantities

Table 7.3.4 Measurement quantaties

No.	Measurment function	Value (range)	Description
1	UH_a	0000.00V	Phase A measured voltage of H side
2	UH_b	0000.00V	Phase B measured voltage of H side
3	UH_c	0000.00V	Phase C measured voltage of H side
4	UH_0	0000.00V	Ground measured voltage of H side
5	$IH1_a$	000.000A	Phase A measured current of H1 side
6	$IH1_b$	000.000A	Phase B measured current of H1 side
7	$IH1_c$	000.000A	Phase C measured current of H1 side
8	$IH2_a$	000.000A	Phase A measured current of H2 side
9	$IH2_b$	000.000A	Phase B measured current of H2 side
10	$IH2_c$	000.000A	Phase C measured current of H2 side
11	IH_0	000.000A	Ground measured current of M side
12	UM_a	0000.00V	Phase A measured voltage of M side
13	UM_b	0000.00V	Phase B measured voltage of M side
14	UM_c	0000.00V	Phase C measured voltage of M side
15	UM_0	0000.00V	Ground measured voltage of M side
16	$IM1_a$	000.000A	Phase A measured current of M1 side
17	$IM1_b$	000.000A	Phase B measured current of M1 side
18	$IM1_c$	000.000A	Phase C measured current of M1 side
19	$IM2_a$	000.000A	Phase A measured current of M2 side
20	$IM2_b$	000.000A	Phase B measured current of M2 side
21	$IM2_c$	000.000A	Phase C measured current of M2 side
22	IM_0	000.000A	Ground measured current of M side
23	$UL1_a$	0000.00V	Phase A measured voltage of L1 side
24	$UL1_b$	0000.00V	Phase B measured voltage of L1 side
25	$UL1_c$	0000.00V	Phase C measured voltage of L1 side
26	$UL1_0$	0000.00V	Ground measured voltage of L1 side
27	$UL2_a$	0000.00V	Phase A measured voltage of L2 side
28	$UL2_b$	0000.00V	Phase B measured voltage of L2 side
29	$UL2_c$	0000.00V	Phase C measured voltage of L2 side
30	$UL2_0$	0000.00V	Ground measured voltage of L2 side
31	$IL1_a$	000.000A	Phase A measured current of L1 side
32	$IL1_b$	000.000A	Phase B measured current of L1 side
33	$IL1_c$	000.000A	Phase C measured current of L1 side
34	$IL2_a$	000.000A	Phase A measured current of L2 side
35	$IL2_b$	000.000A	Phase B measured current of L2 side
36	$IL2_c$	000.000A	Phase C measured current of L2 side
37	IL_0	000.000A	Ground measured current of L side
38	IG_a	000.000A	Phase A measured current of G side
39	IG_b	000.000A	Phase B measured current of G side

No.	Measurment function	Value (range)	Description
40	IG_c	000.000A	Phase C measured current of G side
41	IG_0	000.000A	Ground measured current of G side
42	ILT_a	000.000A	Phase A measured current of LT side
43	ILT_b	000.000A	Phase B measured current of LT side
44	ILT_c	000.000A	Phase C measured current of LT side
45	ID_a_87T	000.000A	Phase-A differential current of 87T
46	ID_b_87T	000.000A	Phase-B differential current of 87T
47	ID_c_87T	000.000A	Phase-C differential current of 87T
48	IR_a_87T	000.000A	Phase-A restraint current of 87T
49	IR_b_87T	000.000A	Phase-B restraint current of 87T
50	IR_c_87T	000.000A	Phase-C restraint current of 87T
51	ID_REF_H	000.000A	H-side differential current of REF
52	IR_REF_H	000.000A	H-side restraint current of REF
53	ID_REF_M	000.000A	M-side differential current of REF
54	IR_REF_M	000.000A	M-side restraint current of REF
55	ID_a_87W	000.000A	Phase-A differential current of 87W
56	ID_b_87W	000.000A	Phase-B differential current of 87W
57	ID_c_87W	000.000A	Phase-C differential current of 87W
58	IR_a_87W	000.000A	Phase-A restraint current of 87W
59	IR_b_87W	000.000A	Phase-B restraint current of 87W
60	IR_c_87W	000.000A	Phase-C restraint current of 87W
61	ID_0_87N	000.000A	Ground differential current of 87N
62	IR_0_87N	000.000A	Ground restraint current of 87N
63	IHC_A	000.000A	Phase-A resultant current of H side
64	IHC_B	000.000A	Phase-B resultant current of H side
65	IHC_C	000.000A	Phase-C resultant current of H side
66	IMC_A	000.000A	Phase-A resultant current of M side
67	IMC_B	000.000A	Phase-B resultant current of M side
68	IMC_C	000.000A	Phase-C resultant current of M side
69	ILC_A	000.000A	Phase-A resultant current of L side
70	ILC_B	000.000A	Phase-B resultant current of L side
71	ILC_C	000.000A	Phase-C resultant current of L side
72	IHM_A	000.000A	Phase-A resultant current of H and M side
73	IHM_B	000.000A	Phase-B resultant current of H and M side
74	IHM_C	000.000A	Phase-C resultant current of H and M side
75	UH_{ab}	0000.00V	Phase AB measured voltage of H side
76	UH_{bc}	0000.00V	Phase BC measured voltage of H side
77	UH_{ca}	0000.00V	Phase CA measured voltage of H side
78	IH_{ab}	000.000A	Phase AB measured current of H side
79	IH_{bc}	000.000A	Phase BC measured current of H side
80	IH_{ca}	000.000A	Phase CA measured current of H side

No.	Measurment function	Value (range)	Description
81	UM_{ab}	0000.00V	Phase AB measured voltage of M side
82	UM_{bc}	0000.00V	Phase BC measured voltage of M side
83	UM_{ca}	0000.00V	Phase CA measured voltage of M side
84	IM_{ab}	000.000A	Phase AB measured current of M side
85	IM_{bc}	000.000A	Phase BC measured current of M side
86	IM_{ca}	000.000A	Phase CA measured current of M side
87	IL_{ab}	000.000A	Phase AB measured current of L side
88	IL_{bc}	000.000A	Phase BC measured current of L side
89	IL_{ca}	000.000A	Phase CA measured current of L side
90	IG_{ab}	000.000A	Phase AB measured current of G side
91	IG_{bc}	000.000A	Phase BC measured current of G side
92	IG_{ca}	000.000A	Phase CA measured current of G side
93	ILT_{ab}	000.000A	Phase AB measured current of LT side
94	ILT_{bc}	000.000A	Phase BC measured current of LT side
95	ILT_{ca}	000.000A	Phase CA measured current of LT side
96	H_U2	0000.00V	Negative sequence measured voltage of H side
97	H_I2	000.000A	Negative sequence measured current of H side
98	HC_I2	000.000A	Negative sequence resultant measured current of H side
99	M_U2	0000.00V	Negative sequence measured voltage of M side
100	M_I2	000.000A	Negative sequence measured current of M side
101	MC_I2	000.000A	Negative sequence resultant measured current of M side
102	L_I2	000.000A	Negative sequence measured current of L side
103	LC_I2	000.000A	Negative sequence resultant measured current of L side
104	G_I2	000.000A	Negative sequence measured current of G side
105	LT_I2	000.000A	Negative sequence measured current of LT side
106	H_U0_Cal	0000.00V	Zero sequence resultant measured voltage of H side
107	H1_I0_Cal	000.000A	Zero sequence resultant measured current of H1 side
108	HC_I0_Cal	000.000A	Zero sequence resultant measured current of H side
109	M_U0_Cal	0000.00V	Zero sequence resultant measured voltage of M side
110	M1_I0_Cal	000.000A	Zero sequence resultant measured current of M1 side
111	MC_I0_Cal	000.000A	Zero sequence resultant measured current of M side
112	L1_I0_Cal	000.000A	Zero sequence resultant measured current of L1 side
113	LC_I0_Cal	000.000A	Zero sequence resultant measured current of L side
114	G_I0_Cal	000.000A	Zero sequence resultant measured current of G side
115	LT_I0_Cal	000.000A	Zero sequence resultant measured current of LT side
116	H_I02	000.000A	Zero sequence and negative sequence resultant measured current of H side
117	M_I02	000.000A	Zero sequence and negative sequence resultant measured current of M side
118	Fr	000.00 Hz	Frequency
119	Fr_M	000.00 Hz	M-side Frequency

No.	Measurment function	Value (range)	Description
120	U_xF_r	000.00 Hz	Ux voltage frequency
121	U/F	000.00	The over excitation measured value
122	Dfdt	000.000 Hz/S	Rate of change of frequency of phase to phase
123	UxDfdt	000.000 Hz/S	Rate of change of frequency of Ux voltage
124	DU	000.00V	Vlotage difference
125	DA	000.00°	Angle difference
126	DF	000.000Hz	Frequency difference

7.3.3.2 BI

This section is divided into one sub-parts and describe the information of binary input (BI) of this IED seen in the above figure 7.3.7. This section only display all the binary input data. User can access this function through the following path: “Monitor > BI”.

1- BI

This part of single BI monitoring data contains 01 to 10 pages and 73 binary inputs. The BI display diagram of the IED is listed in below figure 7.3.9 :

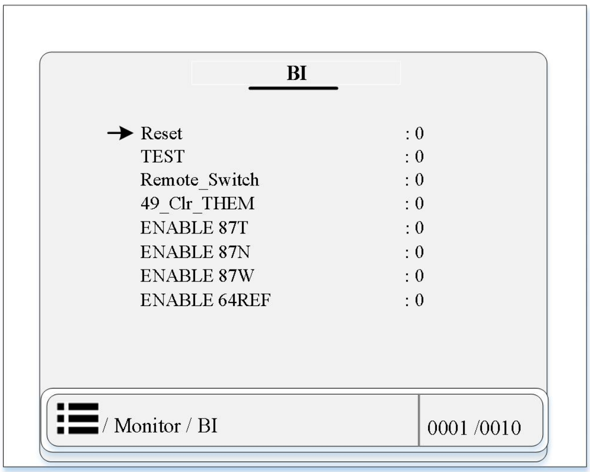


Figure 7.3.9 LCD Display Diagram

7.3.4 Event Information

This section is divided into four sub-section and describe the information of all events, like fault events, alarming information (warning records), selfchk info, SOE, remote control, user records and power records etc. The LCD display event diagram of the IED is listed in below figure 7.3.10:

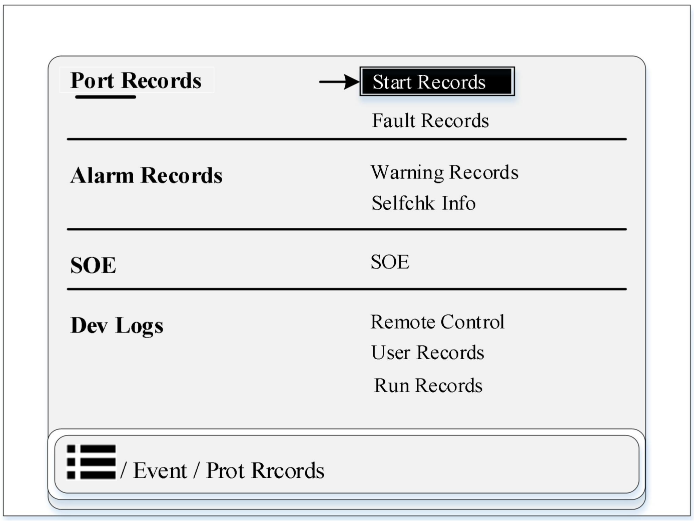


Figure 7.3.10 Overview Display of Event Information Sub-functions

7.3.4.1 Port Records

This section is divided into two sub-function like start records and fault records. This device can store 512 latest protection records. User can access this function through the following path: "Event > Port Records". The detail of this section divided into nine points:

1. Shows date and time
2. Protection function status
3. Shows operation of protection function like which protection function is acted.
4. Shows operated phases information
5. Shows fault clearance delay time
6. Shows slot info like management slot (slot3) or protection slot (slot9).
7. Shows fault number
8. Not reverted
9. Shows fault events page number information, it will be increase or decrease w.r.to numbers of fault.

The diagram of fault event display of relay is listed in below figure 7.3.11:

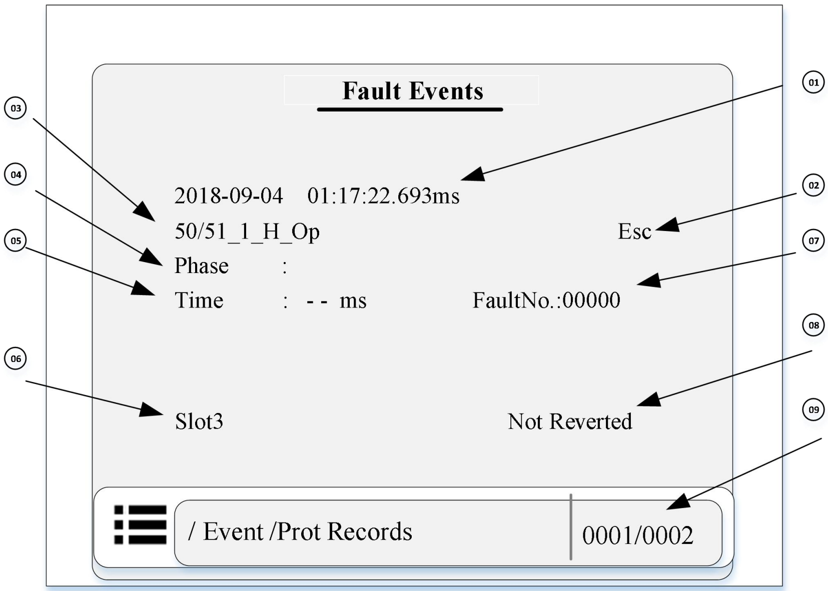


Figure 7.3.11 Overview Display of Fault Events

7.3.4.2 Alarm Records

This section is divided into two sub-functions like warning records and selfchk Info see figure 7.3.10. This device can save latest 512 alarm records.

1- Warning Records

In this section,user can see all warning records like protection warning records and TimingErr warning records etc. User can access this function through the following path: “Event > Alarm Records”. The overview display of warning record is shown in below figure 7.3.12.

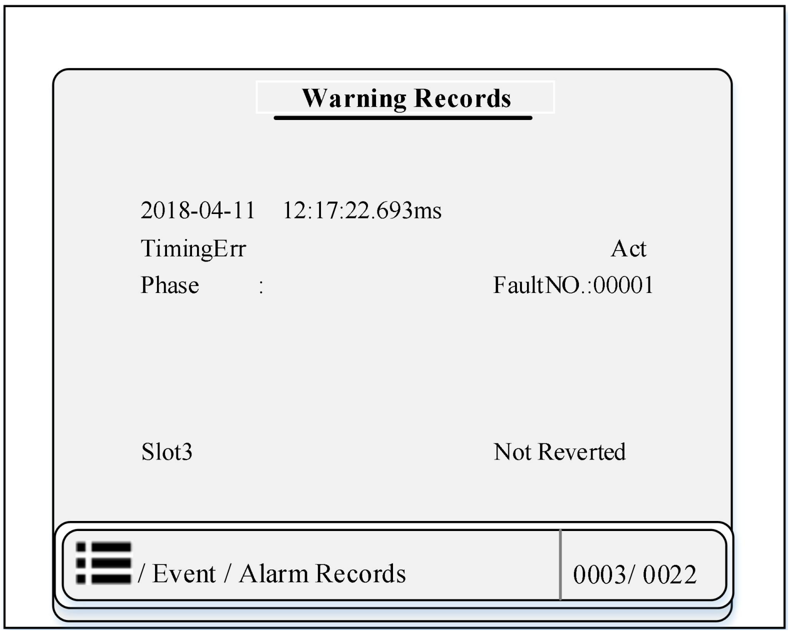


Figure 7.3.12 Overview Diagram of Warning Records Info

2- Selfchk Info

The self-check info checks the communication status between devices, such as carrier channel abnormality, fiber channel abnormality, GOOSE communication abnormality and internal AD sampling abnormality and etc. To summarize, this device also check hardware, software and configuration file and it can totally save latest 128 records. User can access this function through the following path: “Event > Alarm Records”. The overview display of SelfChk info is shown in below figure 7.3.13.

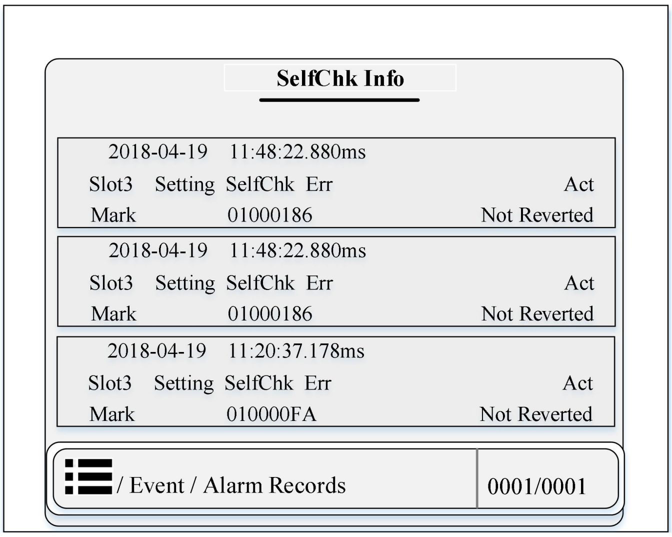


Figure 7.3.13 Overview Display Diagram of SelfChk Info

7.3.4.3 SOE

In this section,SOE checks following condition:

- When the state of binary input signal changes, eg. a hard contact, the time tag of the state quantity is marked by the device and the time is defined after debouncing.
- When the state of GOOSE signal changes, the time tag of the state quantity adopts the external input source signal time tag. The GOOSE signal acquisition has no debouncing time.

User can access this function through the following path: “Event > SOE”. This device can save 2000 latest SOE records. The diagram of SOE record is shown in below figure 7.3.14.

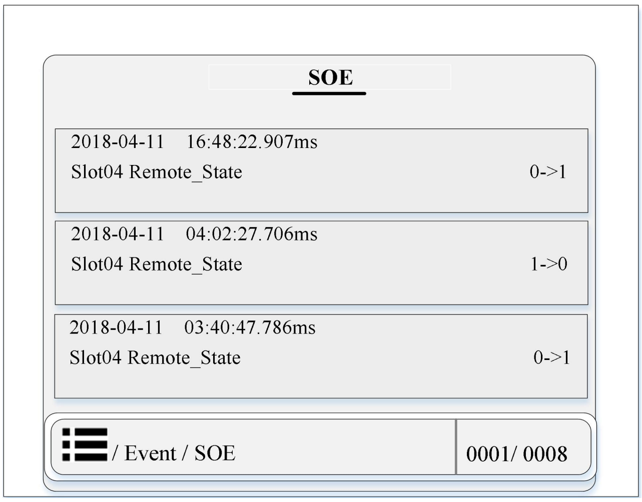


Figure 7.3.14 Overview Display Diagram of SOE

7.3.4.4 Dev Logs

This section is divided into three sub-function like remote control, user records and power records see figure 7.3.10.

1- Remote Control

This part shows the remote control signals like circuit breaker, disconnector, reset signal, transformer tap changer, earthing switches etc. The recorded information includes the command source, command time, operation result and failure reason etc. This device can store 128 latest remote control records. User can access this function through the following path: “Event > Dev Logs > Remote Control”. The diagram of remote control functions are shown in below figure 7.3.15.

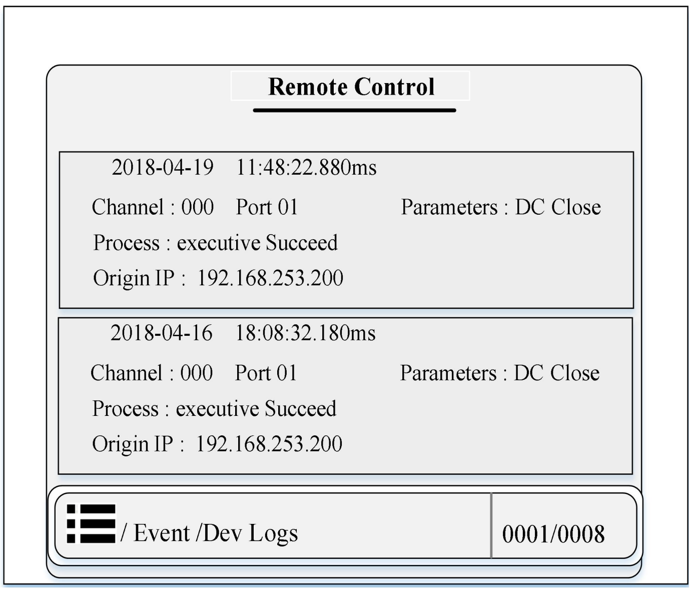


Figure 7.3.15 Overview Display Diagram of Remote Control Access

2- User Records

In this section,user can see the setting of user records with slot number, time and date. User can access this function through the following path: “Event > Dev Logs > User Records”. The diagram of user records are shown in below figure 7.3.16.

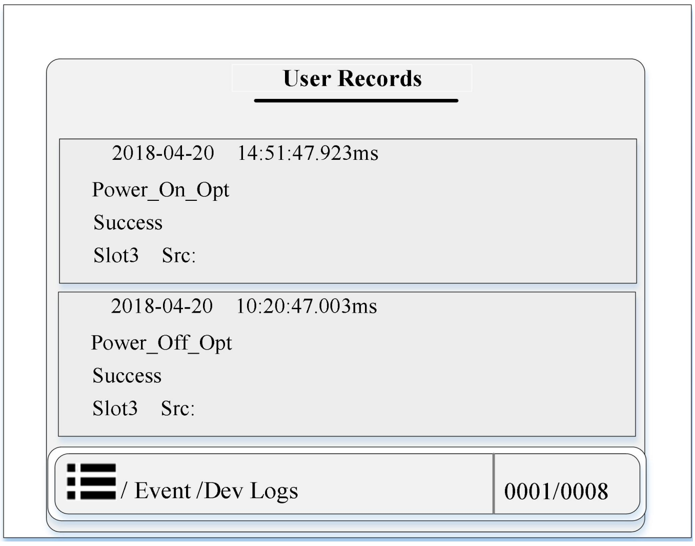


Figure 7.3.16 Overview Diagram of User Records

3- Run records

In this section,user can see the setting of run records date and time with energizing and dis-energizing slot number. The number of pages of this section can be increase or decrease through the storage of run records. User can access this function through the following path: “Event > Dev Logs> Run Records”. The diagram of run record is shown in below figure 7.3.17.

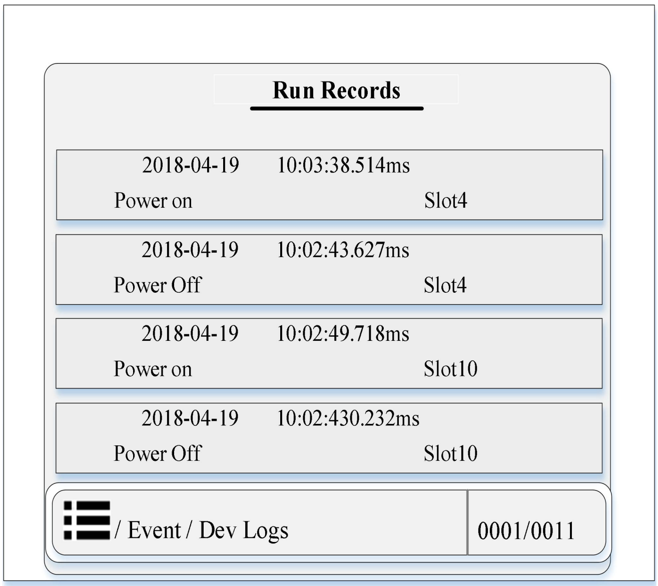


Figure 7.3.17 Overview Diagram of Power Records

7.3.5 Record Information

In this section, user can see the disturbance records and this section is divided into one sub-section. The diagram of disturbance record is shown in below figure 7.3.18.

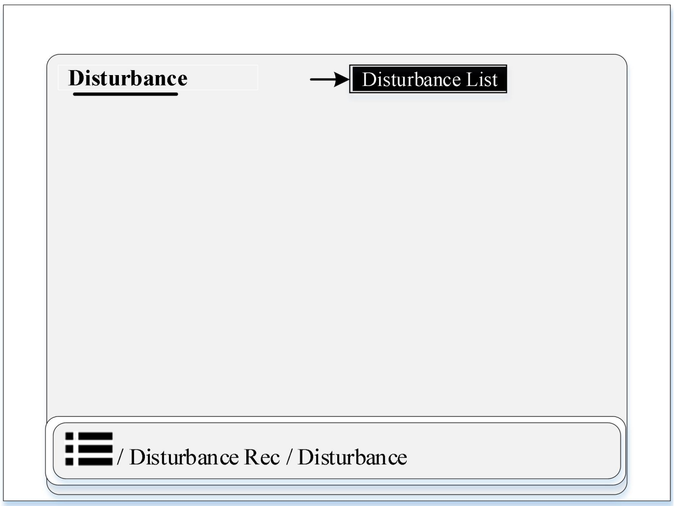


Figure 7.3.18 Overview Display of Records Information

7.3.5.1 Disturbance List

In this section, user can see the disturbance records of all the faults. User can access this function through the following path: “Disturbance > Disturbance List”. The diagram of faulty wave records are shown in below figure 7.3.19.

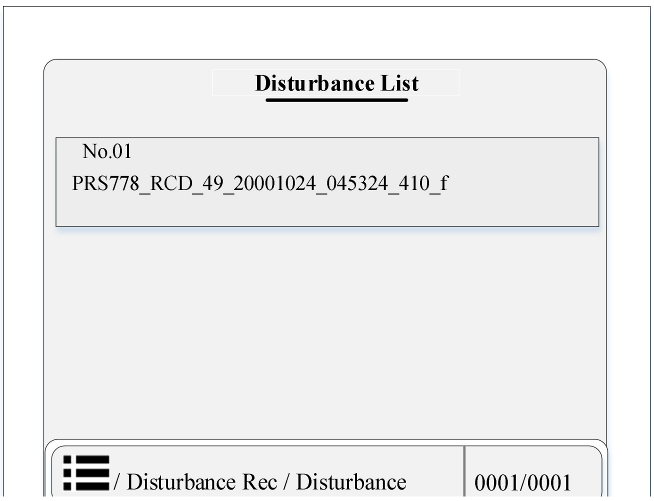


Figure 7.3.19 Overview Diagram of Disturbance List

7.3.6 Setting Information

This section divided into two sub-section like set group and protection settings. In this part user can set the device configuration according to operation demand. The overview display of setting information is shown in below figure 7.3.20.

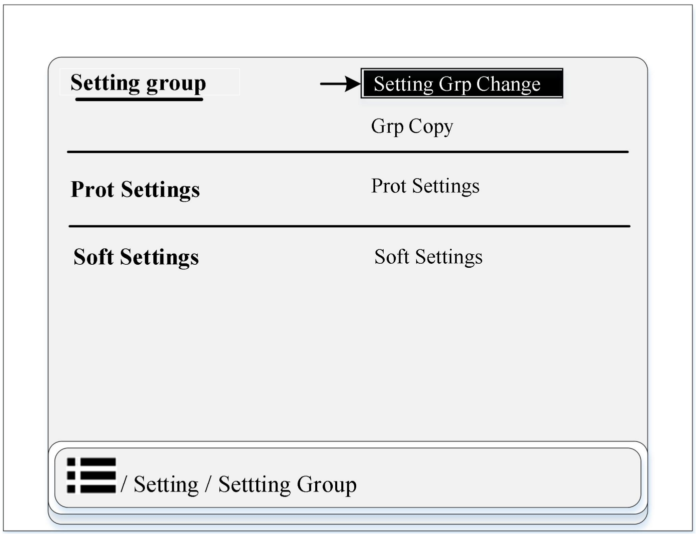


Figure 7.3.20 Overview Display of Setting Information Sub-functions

7.3.6.1 Setting group

This sub-section is divided into two further sub-section like Setting Grp Change and Grp Copy and in this part user can change the group setting.

1- Setting Grp Change

This device has four setting groups and user can easily configure the group setting according to operation demand. This setting is divided into four steps. User can access this function through the following path: "Setting > Set group". The procedure of group setting change is explaining in below figure 7.3.21.

Firstly, enter "Setting > Setting group > Setting Grp Change". Secondly, select group setting. Thirdly, download new configuring setting. Fourthly, cancel to return back or exit.

Figure 7.3.21 Procedure Diagram of Group Setting Change

2- Grp Copy

This device has four setting groups and user can easily copy one group settings and save this same setting in other group. User can access this function through the following path: “Setting > Set group”. The procedure detail of group setting copy is explaining in below figure 7.3.22.

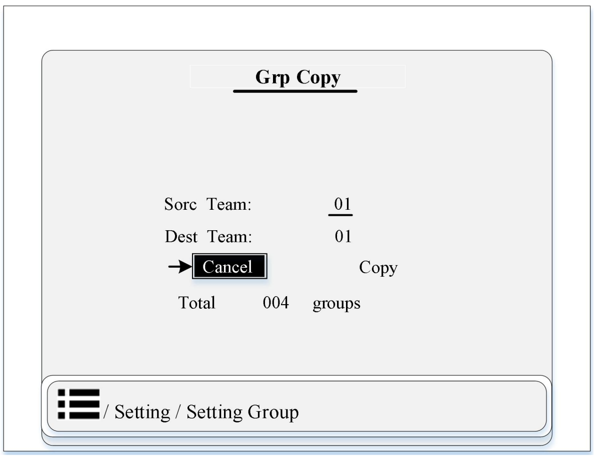


Figure 7.3.22 Procedure Diagram of Group Setting Copy

7.3.6.2 Prot Settings

In this section, user can change the different kind of protection function settings. User can access this function through the following path: “Setting > Prot Settings”. The detail of protection setting is listed below figure 7.3.23:

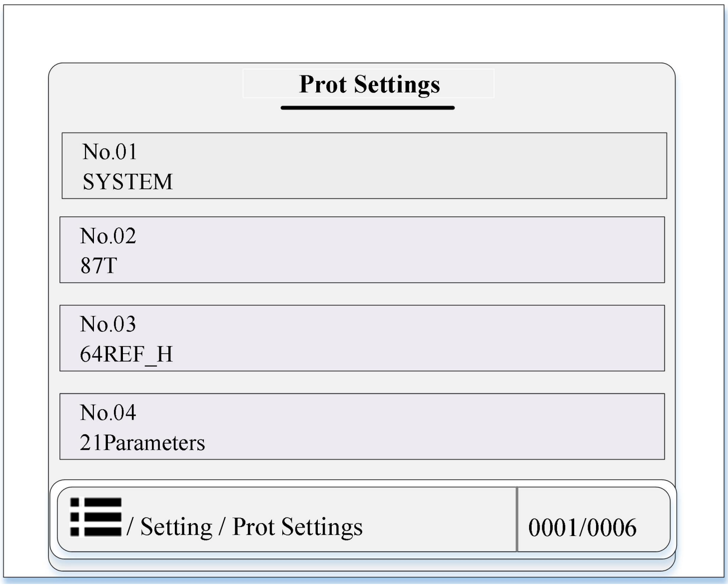


Figure 7.3.23 Diagram of Protection Setting

7.3.7 Configuration Information

This section is divided into two sub-function like time and authorization. In this part, the user can set the device date and time according to the time zone of certain country. Besides that, the monitoring and controlling authorization of different users (of different posts) can also be modified. The diagram of configuration information is shown in below figure 7.3.24.

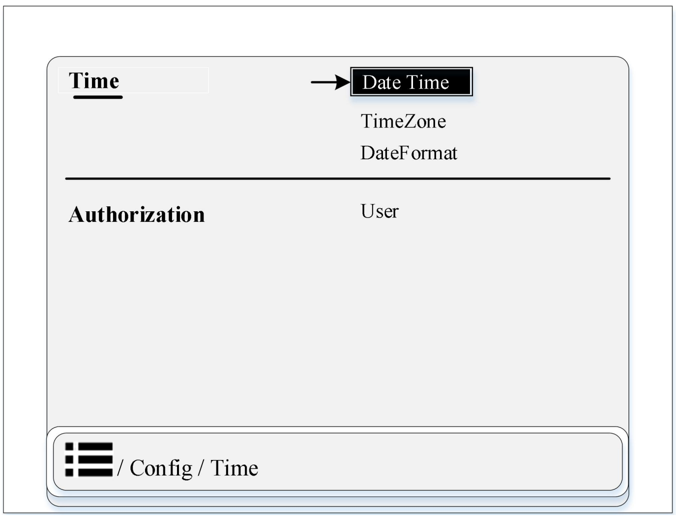


Figure 7.3.24 Overview Display of Configuration Information Sub-functions

7.3.7.1 Time

This part is divided into three sub-section date & time, time zone and date format, see figure 7.3.24. User can access this function through the following path: “Config > Time”.

1- Date and time

In this section, user can easily set date and time according to practical demand. See figure 7.3.25 (a):

2- Time zone

In this section, user can easily set time zone according to their region. See figure 7.3.25 (b):

3- Date Format

In this section user can easily set date format according to their region, such as yyyy-mm-dd, dd-mm-yyyy, MM/dd/yyyy and other 9 date formats. See figure 7.3.25 (c):

Figure 7.3.25 Diagram of (a) Date & Time Setting (b) Time Zone Setting (c) Date Format Setting

7.3.7.2 Authorization

This part is divided into one sub-function, see figure 7.3.26. User can access this function through the following path: “Config > Authorization”.

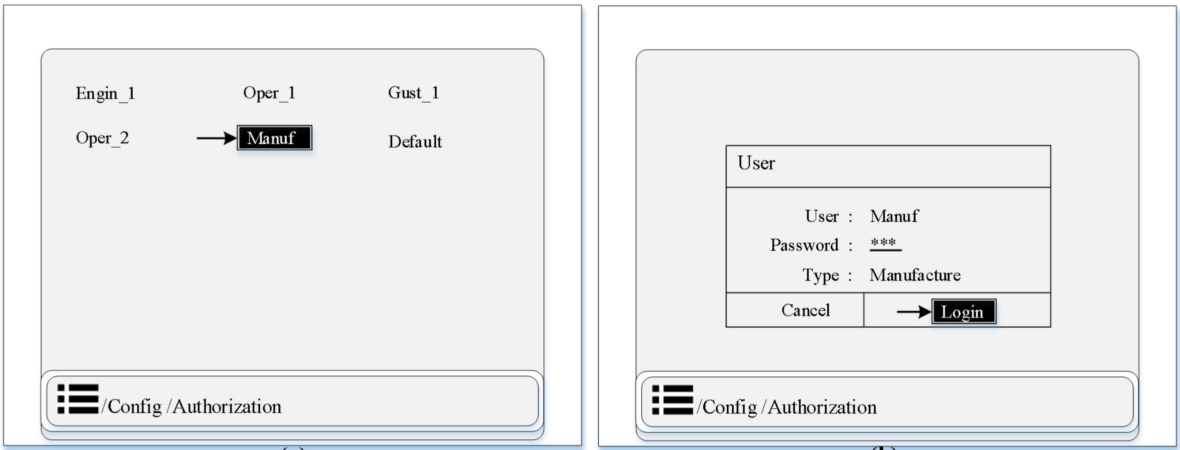
1- User

In this section, user can easily set relay operator setting like operator 1 or 2 or guest 1. See below table 7.3.5 and figure 7.3.26:

Table 7.3.5 User setting detail

User operator selection options	Authorization
Manuf	The manufacturer user has all the configuration functions of access to device setting. At the same time, only the manufacturer's user has the access to hide, read, and write (display) to the logical device LD, logical component LN and logical component data item DO of 61850 protocol and logical picture subgraph. Therefore, as to realize the manufacturer's basic configuration of the device and not be suitable for opening up the correlation. The content settings for users are hidden and should not be opened to users to modify, but the contents they need to view are set to read-only. ***Note!*** None of other users have access to this setting function except manufacturer.
Engin_1	The engineering user staff account has all the general access of configuration (view and modification) functions of the configuration tool, including drawing logical pictures, main wiring diagrams etc. ***Note!*** In this user login section, user cannot create an account configuration of the configuration device setting. 1) The engineering account can only view and modify its own password.
Oper_1 & Oper_2	The operator user account, generally, it can only view the configuration of the device, the logical picture, the wiring diagram and the logical device component. In this section, user can’t create or modify any of its configuration, such as moving the map element position and deleting port association etc.
Guest_1	Guest user account is only for visitors. In this section, user have no rights to change or view any kind of configuration information.

User operator selection options	Authorization
Default	Default user account is only for visitors. In this section, user have no rights to change or view any kind of configuration information.



(a) (b)

Figure 7.3.26 Diagram of Authorization User (a) Operator Selection List (b) Login or Cancel

7.3.8 Test Information

This section is divided into three sub-parts. In this section, user can check the testing accuracy of relay like tripping test, operation test, warning test, Status test, and mandatory wave etc. The overview display diagram of test information is shown in below figure 7.3.27:

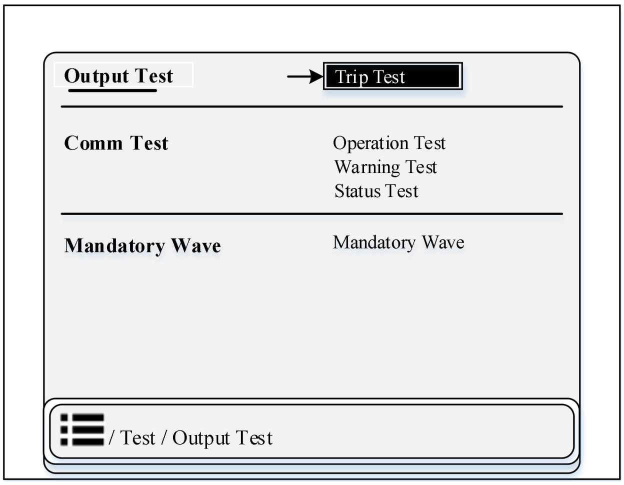


Figure 7.3.27 Overview Display of Test Information Sub-functions

7.3.8.1 Output Test

This section mainly realizes output test, including tripping test and signal test. See figure 7.3.28. User can access this function through the following path: “Test > Output Test”.

1- Trip Test

In this section, user can simulate different trip signal, but the tripping simulation can only be conducted when the IED is under maintenance. See below figure 7.3.28:

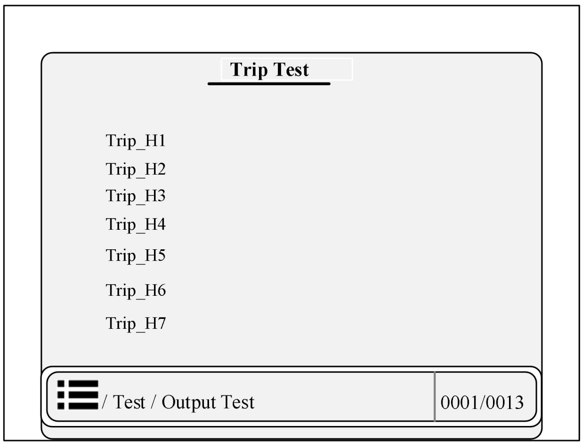


Figure 7.3.28 Overview Diagram of Trip Test

7.3.8.2 Comm Test

Common test is divided into three sub-test like operation test, warning test and status test, etc. User can access this function through the following path: “Test > Comm Test”. The LCD overview display diagram of common test information of every tests is shown in below figure 7.3.29.

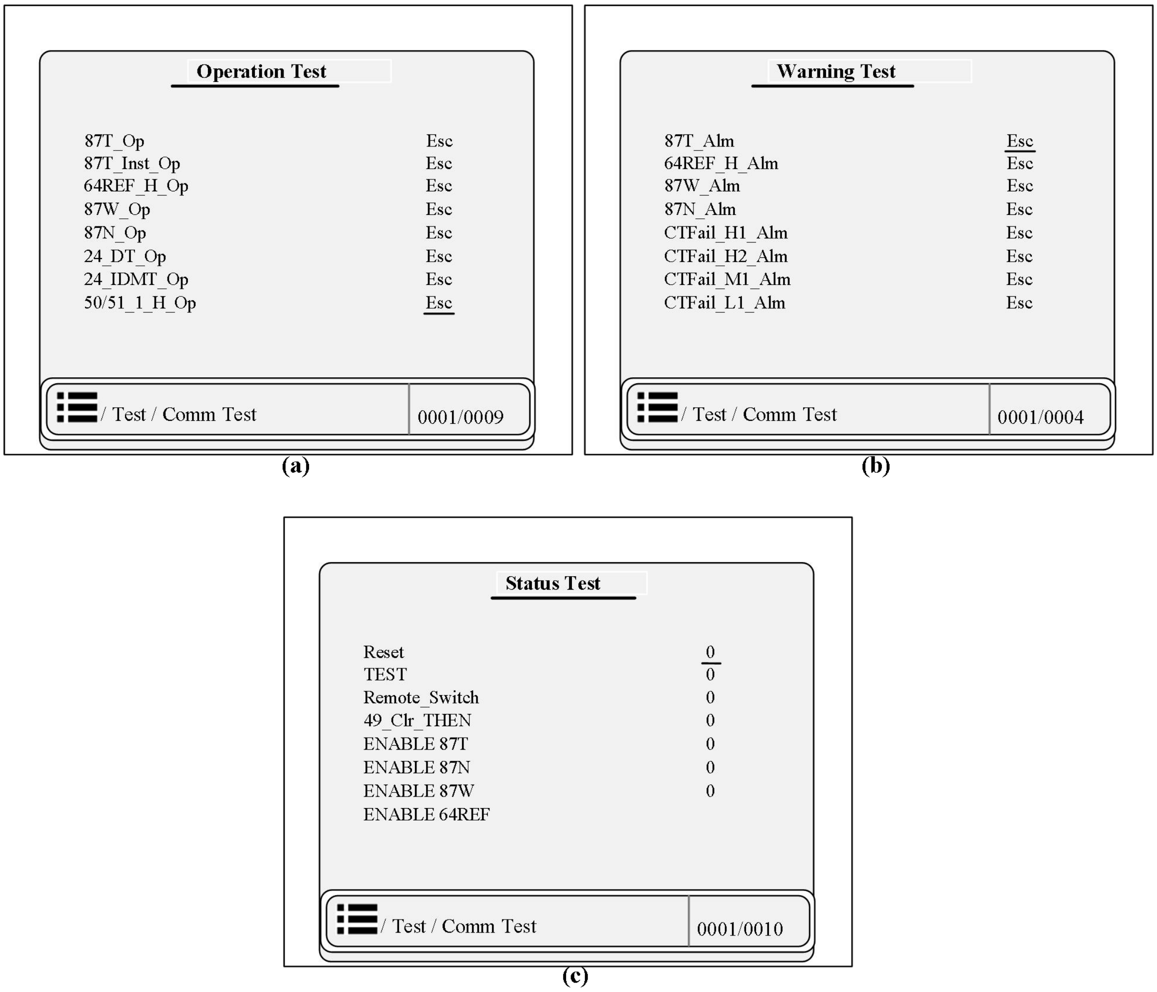


Figure 7.3.29 LCD Display Diagram of (a) Operation Test (b) Warning Test (c) Status Test

1- Operation Test

In this section user can simulate the protection operation event like 51P, 51G and 67P operation function etc. see above figure 7.3.29 (a):

2- Warning Test

In this section user can simulate the warning event like thermal alarm, breaker failure alarm and PTS alarm etc. see above figure 7.3.29(b):

3- Status Test

In this section user can simulate the BI changing status, like reset, remote, CB close or open, CBF, TCS, SOTF start and BI open or close etc. see above figure 7.3.29(c):

7.3.8.3 Mandatory Wave

In this section user can check the mandatory wave function. User can access this function through the following path: “Test > Mandatory wave”. After enter this section user can manually start disturbance recording in disturbance record section. See figure 7.3.27(fault wave):

7.3.9 Clear Information

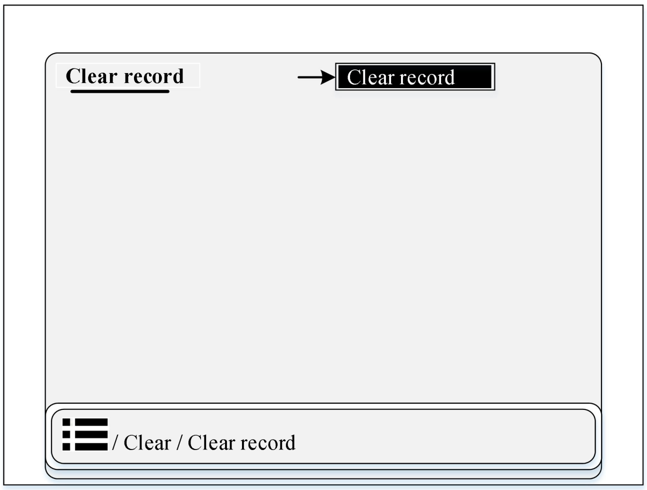


Figure 7.3.30 Overview Display of Clear Information Sub-functions

7.3.9.1 Clear record

In this section user can clear the record history of different functions like Alarm record, LED record and act record etc. User can access this function through the following path: “Clear > Clear Record”. The clear record structure of LCD display is listed in below figure 7.3.31:

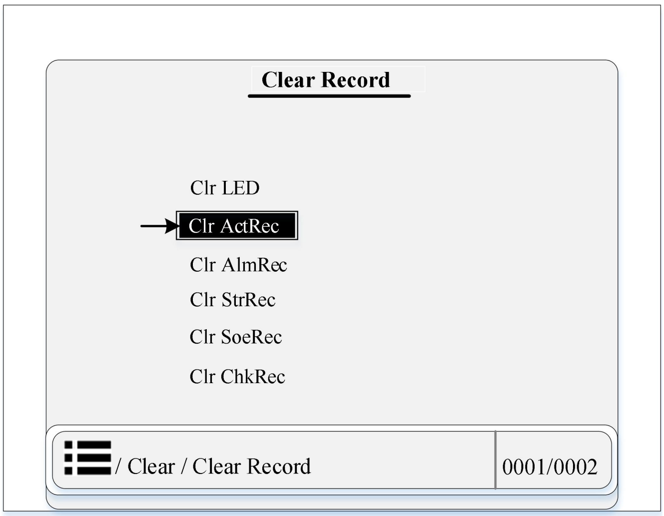


Figure 7.3.31 Diagram of Clear Record Display

7.3.10 Language Information

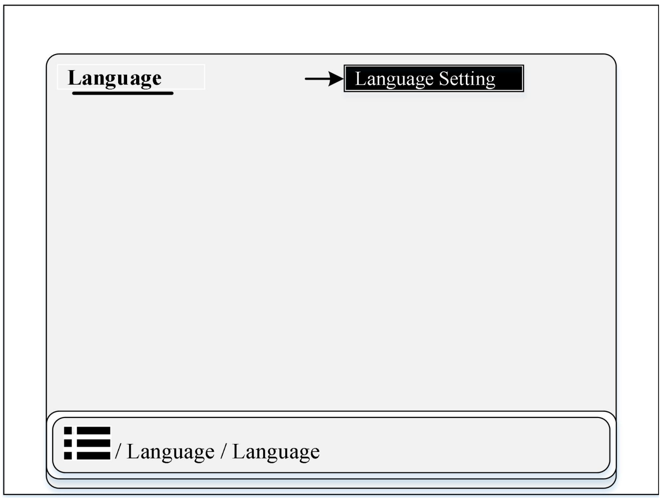


Figure 7.3.32 Overview Display of Language Information Sub-functions

7.3.10.1 Language Setting

In this section user can set the IED language according to their demand like Chinese, English, Hindi, German and Russian etc. User can access this function through the following path: "Language > Language Setting". The language setting diagram of relay is listed in below figure 7.3.33:

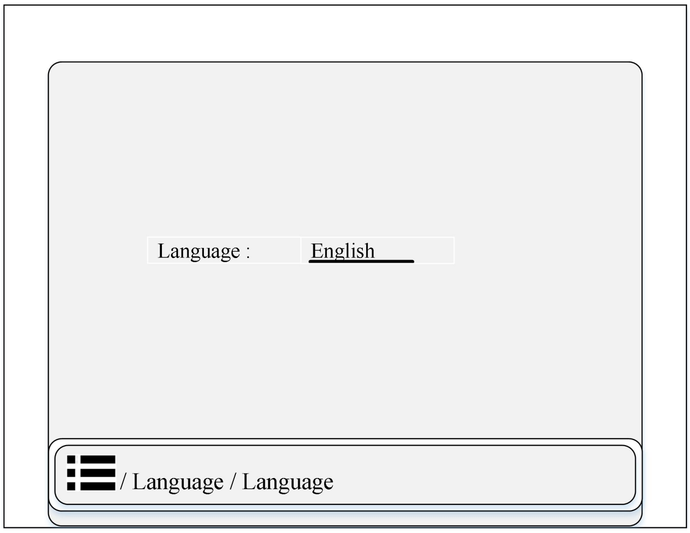


Figure 7.3.33 LCD Display diagram of Language Setting

8 Configurable Function

8.1 General Description

Each product has different configuration parameters according to the functions it has been designed to perform. There is a common methodology used across the entire product series to set these parameters.

The IED is equipped with flexible and powerful configuration functions, including the system configuration, the protection function configuration, the binary input configuration, the binary output configuration, the setting groups selection and the LED indicator configuration through the auxiliary software, which makes this IED meet various practical requirements.

8.2 PRS IED Studio Software

The PRS IED Studio software is developed in order to meet customer's demand on functions of the UAPC platform device, such as device configuration and programmable design. It selects substation as the core of data management and the device as fundamental unit, supporting one substation to supervise many devices.

The software provides two kinds of operation modes: on-line mode and off-line mode. The on-line mode supports the Ethernet connection with the device through the standard IEC60870-5-103 and can be capable of uploading and downloading the configuration files through Ethernet net. The relay parameters and status can be monitored while the device is connected, and the fault wave recording can read and analyzed. The off-line mode supports the off-line setting configuration, including protection logic programming, the binary input configuration, the binary output configuration and etc.

The software provides Online and Off-line comparison function, contain the setting and logic comparison. Online comparison can compare relay configuration and PC backup configuration. Off-line comparison can compare two devices off-line configuration.

8.3 Setting Group Selection

You can select the setting group using binary inputs. You can choose binary inputs through the configuration tool, different binary inputs correspond to different setting groups.You can set the setting group with binary inputs according to the following table:

Table 8.3.1 Recording Time Settings

BI_SETGRP1	setting group01
BI_SETGRP2	setting group02
BI_SETGRP3	setting group03
BI_SETGRP4	setting group04

The path to the configuration tool:

[IED]->[LOGIC]->[PLAT]->[PUB_SetVal].

8.4 Configuration File Introduction

8.4.1 PARAMETER-PUBLIC

8.4.1.1 Macro Set Functions and Parameters

Configuration location: [PARAMETER]-[PUBLIC]-[Macro Set]

This module is used to set the basic functions of the device, such as rated frequency, analog signal transmission type, PRP function disable and enable, device naming, etc.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
System Frequency	Rated frequency (fn): 50/60Hz
If_Comm_Primary_Val	FALSE: send with secondary values TRUE: send with primary values
PRP_Stationbus	OFF: PRP_Stationbus function disable ON: PRP_Stationbus function enable
PRP_Processbus	OFF: PRP_Processbus function disable ON: PRP_Processbus function enable
g_cEquipName	Device name

8.4.1.2 Timing Mode Functions and Parameters

Configuration location: [PARAMETER]-[PUBLIC]-[Timing Mode]

This module is used to set up devices that support two synchronization methods simultaneously.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
TmrType1	The device supports two timing methods: TmrType1 and TmrType2. Normally the first timing method TmrType1 is preferred for timing, while the second timing method TmrType2 is backup. When the first timing method is interrupted, it automatically switches to the second timing method.
TmrType2	

Configuration location: [PARAMETER]-[PUBLIC]- [Timing Mode]-[TmrType1]/[TmrType2]

This module is a timing method supported by the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
SNTP	SNTP timing requires setting the IP address of the timing server on the corresponding timing component

Data item description	The detail explanation
IRIG-B	When checking the B code, it is necessary to set the electrical B or optical B code and verification method on the corresponding timing component
1588	1588 PTP timing requires setting a transparent clock (P2P or E2E) and receiving message network port on the corresponding timing component
None	No timing

8.4.1.3 SR76XX\SR73XX Module with Output Parameters

Configuration location: [PARAMETER]-[PUBLIC]-[SR76XX_XXKO_XX]/[PARAMETER]-[PUBLIC]-[SR73XX_XXKO_XX].

XXKO means XX binary output(BO). XX means supplemental description. SR76XX is power module with BOs, such as: SR7601_11KO_1 is the first power module with 11 BOs; SR73XX is module type with some or whole BOs, such as: SR7300_14KO_1 is the first IO module with 14 BOs.

This module is for setting up the device output board.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
SlotNO	The module number in the device
KOXXIndex	XX means the BO number. The Index means the BO can be associated with output resources in the OUTPUT of the CONST node.
KOXXDspStat	XX means the BO number. The DspStat means maintain condition: Not Hold: the hardware BO is not maintained, it will reset when the associated output resources are reset when there is no fault. Hold: the hardware BO is maintained, it will reset when both the associated output resources and the Start signal are reset when there is no fault, the Start signal is default last for pulse time about 7s. Condition Hold: only used for OC with 79AR functions, when the 79AR reclosed several shots, only the last OC trip phase BO will be hold.

8.4.1.4 SR78X LED module Parameters

Configuration location: [PARAMETER]-[PUBLIC]-[SR780_32LED]

SR78X is an LED module with 32 LEDs.

This module is for setting up the device LED module.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
SlotNO	The module number in the device
LEDXXIndex	XX means the LED number. The Index means the LED can be associated with output resources in the OUTPUT of the CONST node.
LEDXXDspStat	XX means the LED number. Maintain the attribute, Not Hold is not held, and automatically extinguishes if the condition is not met; Hold is held, automatically held when illuminated; Conditional Hold is a condition held, and only a trip after the device coincides will extinguish the lights that do not meet the conditions
LEDXXColStat	XX means the LED number. Select colors, green, yellow, and red are optional

8.4.1.5 SR73XX Input module parameters

Configuration location: [PARAMETER]-[PUBLIC]-[SR73XX-XXKI_XX]

XXKI means the XX binary input(BI), XX means supplemental description. such as: SR7330_18KI_5 is the fifth IO module with 18 BIs.

This module is for setting up the device input module.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
SlotNO	The module number in the device
KIXXIndex	XX means the KI number. The Index means the BI can be associated with input resources in the INPUT of the CONST node.
KIXXHoldSet	XX means the KI number. Debouncing time setting, in milliseconds. If the input power is a DC power supply, the hard switch input debouncing time is usually set to 1000ms, the remote signal input debouncing time is usually set to 20ms, and the protection input debouncing time is usually set to 10ms; If the input power is AC power, the debouncing time is usually set to 6ms

Data item description	The detail explanation
KIXXHoldVol	XX means the KI number. Set the power supply voltage according to the actual situation

8.4.1.6 SR71XX Analog module parameters

Configuration location: [PARAMETER]-[PUBLIC]-[SR71XX]

SR71XX is an analog module with three configurations: 6U6I (6 sets of voltage and 6 sets of current) , 4U8I (4 sets of voltage and 8 sets of current) and 0U12I (0 sets of voltage and 12 sets of current).

This module is for setting up the device analog module.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
SlotNO	The module number in the device
PtXTAIn1	X means the ANA number. Associate PT with primary values, which can be associated with fixed value resources in SET under the CONST node
PtXTAIn2	X means the ANA number. Associate PT with secondary values, which can be associated with fixed value resources in SET under the CONST node.
PtXIndex	X means the ANA number. Associate analog resources, which can be associated with analog resources in ANA under the CONST node
CtXTAIn1	X means the ANA number. Associate CT with primary values, which can be associated with fixed value resources in SET under the CONST node
CtXTAIn2	X means the ANA number. Associate CT with secondary values, which can be associated with fixed value resources in SET under the CONST node
CtXIndex	X means the ANA number. Associate analog resources, which can be associated with analog resources in ANA under the CONST node

8.4.1.7 User Functions and Parameters

Configuration location: [PARAMETER]-[PUBLIC]-[User]

This module is set for device login users.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
UserName	Login user name
Type	Login user type
Password	Login user password

8.4.1.8 DNP_Para Functions and Parameters

When using the DNP protocol as the communication protocol, corresponding communication parameters need to be set;

Configuration location: [PARAMETER]-[PUBLIC]-[DNP_Para]

This module is for setting the DNP parameters of the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
RetryTime	Number of retransmissions, default to 0. If there are no special requirements. The parameter can be set by default
Delay1	The retransmission interval 1, which is set to 0 by default. If there are no special requirements, the parameter can be set by default
Delay2	The retransmission interval 2, which is set to 0 by default. If there are no special requirements, the parameter can be set by default
Infinite	If the main station does not confirm whether to infinitely retransmit the flag, it defaults to 0. If there are no special requirements, the parameter can be set by default
FragSize	The application layer buffer size is set to 0 bytes by default
FlgLastConSet	Whether the last CON is set during multi frame transmission it defaults to 0. If there are no special requirements, the parameter can be set by default
TimeCycle	The DNP timing cycle is set to 0 by default. If there are no special requirements, the parameter can be set by default
IfUTCTime	Send with the UTC or local time flag. True: UTC, FALSE: local time, which defaults to FALSE and takes the local time
UNSEnable	The enable flag for non-request submission, Default setting is FALSE
BufferSizeSOE	Judgment mar of Buffer over Flow，Default setting is 512.
BufferSizeCOS	Judgment mar of Buffer over Flow，Default setting is 256.

8.4.1.9 Com_Para Functions and Parameters

Configuration location: [Parameter]-[PUBLIC]-[Com_Para_1/2/3]

This module is for setting the COM port parameters of the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
PortID	The port name corresponds to the hardware serial port
PortType	Port type, configure according to the type of serial port used
IfUsed	Whether to use, default to True
Protocol	Transport Protocol，default to UDP_INC_103
BaudRate	BAUD,default to 9600
DataBit	Data bits，default to 8
VerfMode	Parity verification type: None, Odd, Even, the default is None
StopBit	Stop bit,default to 1
MasterNo	Main Station Number, which is the address of the monitoring host or RTU, default to 1
StationNo	Substation number，for device address，default to 46

8.4.1.10 Net_Para Functions and Parameters

When using a network port communication protocol other than 61850 protocol, corresponding network port communication parameters need to be set.

Configuration location: [Parameter]-[PUBLIC]-[Net_Para_1/2/3/4/5/6]

This module is for setting the NET port parameters of the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
PortID	Monitoring physical network port selection, with NET_1, NET_2, NET_3, NET_4, NET_5, NET_6 corresponding to the three rear network ports of the CPU board
PortType	Port type, configure according to the type of serial port used
IfUsed	Whether to use, default to True
Protocol	Transport Protocol，default to UDP_INC_103
IfDblMac	Is it a dual MAC address, there is no concept of dual machine dual network in foreign countries, so the parameters related to the dual machine dual network concept do not need to be configured and can be kept as default

Data item description	The detail explanation
IfDblNet	Whether it is a dual network or not, there is no concept of dual machine dual network in foreign countries, so the parameters related to the dual machine dual network concept do not need to be configured and can be kept as default
NetPort	The monitoring number can be flexibly configured according to actual use
MasPortID	Host monitoring port selection, default to NET_A
SlaPortID	The selection of sub machine monitoring port defaults to NET-B
MonIP	Monitor the host IP and configure it according to actual usage needs, with a default value of 222.111.112.200
MonIP2	Monitor the host IP and configure it according to actual usage needs
SlaMonIP	Monitor the IP of the sub machine and configure it according to actual usage needs
SlaMonIP2	Monitor the IP of the sub machine and configure it according to actual usage needs
MasterNo	The main station number, which is the monitoring host or RTU address, defaults to 1
StationNo	The sub-station number is the device address, which defaults to 9

8.4.2 Const

8.4.2.1 INPUT Functions and Parameters

Configuration location: [CONST]-[INPUT]

This module is for setting the input parameters of the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
Index	Resource sequence number
Name	Input Name
COMDef	Resource transmission method USE DNP: DNP protocol submission USE MMS: MMS protocol submission GOOSE IN: GOOSE input GOOSE OUT: GOOSE output STATION GOOSE: As a station goose PROCES BUS: As a process goose SV: Used as SV
DNPClass	Data Class: Class0/ Class1/Class2/Class3

Data item description	The detail explanation
Desc	Input Description

8.4.2.2 OUTPUT Functions and Parameters

Configuration location: [CONST]-[OUTPUT]

This module is for setting the output parameters of the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
Index	Resource sequence number
Name	Output Name
Desc	Output Description

8.4.2.3 ANA Functions and Parameters

Configuration location: [CONST]-[ANA]

This module is for setting the analog parameters of the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
Index	Resource sequence number
Unit	Analog quantity secondary value unit
KiloUnit	Analog quantity primary value unit
Name	Analog quantity name
Related Set	The primary rated value of analog quantity
TAIndex	The secondary rated value of analog quantity
COMDef	Resource transmission method USE DNP: DNP protocol submission USE MMS: MMS protocol submission GOOSE IN: GOOSE input GOOSE OUT: GOOSE output STATION GOOSE: As a station goose PROCES BUS: As a process bus SV: Used as SV

Data item description	The detail explanation
DNPClass	Data Class: Class0/ Class1/Class2/Class3
Desc	Analog quantity description

8.4.2.4 WAVANA Functions and Parameters

Configuration location: [CONST]-[WAVANA]

This module is used to set the parameters for the analog recording of the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
Ana Number	Analog quantity number in waveform recording
Ana Channel	Analog channels in waveform recording

8.4.2.5 WAVAKI Functions and Parameters

Configuration location: [CONST]-[WAVAKI]

The detail explanation of the data item description is as following:

Data item description	The detail explanation
KI Number	Number of input in waveform recording
KI Channel	Corresponding input in waveform recording

8.4.2.6 WAVAKO Functions and Parameters

Configuration location: [CONST]-[WAVAKO]

This module sets the parameters for the recording input of the device.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
KO Number	Number issued in the recording
KO Channel	Corresponding output in waveform recording

8.4.2.7 ACTREC Functions and Parameters

Configuration location: [CONST]-[ACTREC]

This module sets the parameters for device action events.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
Index	Number issued in the recording
Name	Action Event Name
COMDef	Resource transmission method USE DNP: DNP protocol submission USE MMS: MMS protocol submission GOOSE IN: GOOSE input GOOSE OUT: GOOSE output STATION GOOSE: As a station goose PROCES BUS: As a process bus SV: Used as SV
DNPClass	Data Class: Class0/ Class1/Class2/Class3
Desc	Action Event Description

8.4.2.8 ALMREC Functions and Parameters

Configuration location: [CONST]-[ALMREC]

This module sets the parameters for device alarm events.

The detail explanation of the data item description is as following:

Data item description	The detail explanation
Index	Number issued in the recording
Name	Alarm Event Name
COMDef	Resource transmission method USE DNP: DNP protocol submission USE MMS: MMS protocol submission GOOSE IN: GOOSE input GOOSE OUT: GOOSE output STATION GOOSE: As a station goose PROCES BUS: As a process bus SV: Used as SV
DNPClass	Data Class: Class0/ Class1/Class2/Class3
Desc	Alarm Event Description

8.4.2.9 WAVECFGBOOL Functions and Parameters

The device supports monitoring the exit sign output of a certain component as a WAVECFGBOOL, when a change in the flag is detected, it can be set as a wave start flag or a recording action flag. When monitoring the output of a component outlet on site, create a new WAVECFGBOOL in the component and modify the corresponding detection point parameters in WAVECFGBOOL under the CONST node.

Configuration location: [CONST]-[WAVECFGBOOL] -[WaveType/Name/Desc]

The detail explanation of the data item description is as following:

Data item description	**The detail explanation**
WaveType	Note: Recording type： TYPE_STR represents startup type, When the flag is set, it serves as the startup flag in recording. If there is only startup but not operation or action, the startup waveform file will be produced with type "_s". TYPE_ACT represents the type of action, and when the flag is set, it will be used as an action flag in the wave, if there are one or more operation or action, the action waveform file will be produced with type "_f". TYPE_NULL indicates other types, and the state of this type is normally monitored in "_s" or "_f" waveform recording file, but it will not trigger to product a new waveform recording file.
Name	The name of the disturbance wave signal.
Desc	The description of the disturbance wave signal.

Note: After creating the WAVECFGBOOL, the WaveType must be set, otherwise the device will not run.

8.5 Super permissions

This module provides SUPER login permissions.

Main Function Category	Function description	Super	Engineer	Operator
Create new users	Create new users with a lower level than the current user	Engineer, Operator	-	-
Change password	Change the login password	√	√	√
Right click drop down menu for “New interval”	Creating a device through backup files	√	√	√
	Delete device group	√	√	√
Right click drop down menu for "device"	Editing device: create, delete, copy	√	√	√
	Export backup files and driver files	√	√	-
Parameter	Edit parameters: New, Delete, Copy	√	-	-
	ANA module channel association	√	-	-
	IO module channel association, Module channel settings association, Renaming, Language, Timing method, IP address	√	√	-
Const	Edit interface resource properties (such as name, maximum, minimum, step size, setting value, etc.)	√	-	-
	Edit interface resource description	√	√	-
Logic	View logic diagram	√	√	√
	Renaming logical nodes, creating and editing sub graphs and properties, primitives, connections, signals, recording, etc.	√	√	-

Note: “√” means this function is available, and “-” means this function is not unavailable.

9 Communication Protocol

9.1 Overview

This chapter introduces the data communication and the corresponding hardware of the IEDs. The IED supports a wide range of protocols via a communication interface (RS-485 or Ethernet port).The protocols are of international standard for communication in substations and they can be selected by modifying the communication parameters.

Local communication with the IED via a computer is achievable through both the front and back Ethernet ports. Furthermore, remote communication with SCADA or the station gateway is also achievable by choosing the IEC60870-5-103, IEC61850, DNP3.0 communication protocols via RS485 or Ethernet port.

It should be noted that the descriptions contained within this chapter do not aim to fully detail the protocol itself. This section serves to describe the specific implementation of the protocol in the relay.

9.2 Rear Communication Interface

9.2.1 Ethernet Interface

This protective device can provide three rear Ethernet interfaces (optional) and they are unattached each other. Parameters of each Ethernet port can be configured via PRS IED Studio

9.2.1.1 Ethernet Standardized Communication Cable

It is recommended to use twisted screened eight-core cable as the communication cable. A picture is shown below.

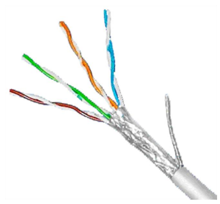


Figure 9.2.1 Ethernet communication cable

9.2.1.2 Ethernet Communication protocol

Ethernet communication protocols are supported by the device including: IEC60870-5-103, PRP, DNP3.0, IEC61850, etc. For more details about these communication protocols, see the correlative standards.

9.3 Network Topology

9.3.1 Star Topology

Each equipment is connected with an exchanger via communication cable, and thereby it forms a star structure network. Dual-network is recommended in order to increase reliability. SCADA is also connected to the exchange and will play a role of master station, so the every equipment which has been connected to the exchange will play a role of slave unit.

9.3.2 PRP Topology

This network topology is supported by the device.

9.4 IEC61850Protocol

9.4.1 Overview

The IEC 61850 standard is the result of years of work by electric utilities and vendors of electronic equipment to produce standardized communications systems. IEC 61850 is a series of standards describing client/server and peer-to-peer communications, substation design and configuration, testing, environmental and project standards. The complete set includes:

- IEC 61850-1: Introduction and overview
- IEC 61850-2: Glossary
- IEC 61850-3: General requirements
- IEC 61850-4: System and project management
- IEC 61850-5: Communications and requirements for functions and device models
- IEC 61850-6: Configuration description language for communication in electrical substations related to IEDs
- IEC 61850-7-1: Basic communication structure for substation and feeder equipment– Principles and models
- IEC 61850-7-2: Basic communication structure for substation and feeder equipment - Abstract communication service interface (ACSI)
- IEC 61850-7-3: Basic communication structure for substation and feeder equipment– Common data classes
- IEC 61850-7-4: Basic communication structure for substation and feeder equipment– Compatible logical node classes and data classes
- IEC 61850-8-1: Specific Communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
- IEC 61850-9-1: Specific Communication Service Mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link
- IEC 61850-9-2: Specific Communication Service Mapping (SCSM) – Sampled values over

ISO/IEC 8802-3

- IEC 61850-10: Conformance testing

These documents can be obtained from the IEC (http://www.iec.ch). It is strongly recommended that all those involved with any IEC 61850 implementation obtain this document set.

9.4.2 Communication Profiles

The PRS-7000 series relay support IEC 61850 server services over TCP/IP communication protocol stacks. The TCP/IP profile requires the PRS-7000 series to have an IP address to establish communications.

9.4.2.1 MMS protocol

IEC 61850 specifies the use of the Manufacturing Message Specification (MMS) at the upper (application) layer for transfer of real-time data. IEC 61850-7-2 abstract services and objects are mapped to actual MMS protocol services in IEC61850-8-1.

9.4.2.2 Client/server

The core ACSI defined by IEC 61850 is mapped to manufacturing message specifications (ISO 9506-1, ISO 9506-2). This is a connection-oriented type of communication. The connection is initiated by the client, and communication activity is controlled by the client.

The rules to map the ACSI services supported by PRS-7000 series units to the MMS are as shown in following table

Table 9.4.1 Mapping of ACSI to MMS service

Name		Range
Server model	GetServerDirectory (read server directory)	GetNameList (read name list service)
Associate model	Associate (associate)	Initiate (initial service)
	Abort (abnormal abort)	Abort (abort service)
	Release (release)	Conclude (end service)
Logic device model	GetLogicalDeviceDirectory (read logic device directory)	GetNameList (read name list service)
Logic node model	GetLogicalNodeDirectory (read logic node directory)	GetNameList (read name list service)
	GetAllDataValues (read all data value)	Read (read service)
Data model	GetDataValues (read data value)	Read (read service)
	SetDataValues (set data value)	Write (write service)
	GetDataDirectory (define read data)	GetVariableAccessAttribute (read variable access attribute service)
	GetDataDefinition (read data directory)	GetVariableAccessAttribute (read variable access attribute service)

Name		Range
Data set model	GetDataSetValue (read data set value)	Read (read service)
	SetDataSetValue (set data set value)	Write (write service)
	CreateDataSet (establish data set)	DefineNamedVariableList (define named variable list service)
	DeleteDataSet (delete data set)	DeleteNamedVariableList (delete named variable list service)
	GetDataSetDirectory (read data set directory)	GetNamedVariableListAttribute (read named variable list attribute service)
Substituting model	SetDataValues (set data value)	Write (write service)
	GetDataValues (read data value)	Read (read service)
Setting group control block model	SelectActiveSG (select activating setting group)	Write (write service)
	SelectEditSG (select edit setting group)	Write (write service)
	SetSGValues (set setting group value)	Write (write service)
	ConfirmEditSGValues (confirm editting setting group value)	Write (write service)
	GetSGValues (read setting group value)	Read (read service)
	GetSGCBValues (read setting group control block value)	Read (read service)
Buffered report control block	Report (report)	InformationReport (information report)
	GetBRCBValues (read buffered report control block value)	Read (read service)
	SetBRCBValues (set buffered report control block value)	Write (write service)
Non-buffered report control block	Report (report)	InformationReport (information report)
	GetURCBValues (read non-buffered report control block value)	Read (read service)
	SetURCBValues (set non-buffered report control block value)	Write (write service)
Log control block model	GetLCBValues (read log control block value)	Read (read service)
	SetLCBValues (set log control block value)	Write (write service)
	QueryLogByTime (query log by time)	ReadJournal (read log service)
	QueryLogAfter (query log after)	ReadJournal (read log service)
	GetLogStatusValues (read log status values)	Read (read service)
GOOSE	GetGoCBValues (read GOOSE control block values)	Read (read service)
	SetGoCBValues (set GOOSE control block values)	Write (write service)

Name		Range
GSSE	GetGsCBValues (read GSSE control block values)	Read (read service)
	SetGsCBValues (set GSSE control block values)	Write (write service)
MSV	GetMSVCBValues (read MSV control block values)	Read (read service)
	SetMSVCBValues (set MSV control block values)	Write (write service)
USV	GetUSVCBValues (read USV control block values)	Read (read service)
	SetUSVCBValues (set USV control block values)	Write (write service)
Control model	Select (select)	Read (read service)
	SelectWithValue (select with value)	Write (write service)
	Cancel (cancel)	Write (write service)
	Operate (operate)	Write (write service)
	CommandTermination (command termination)	InformationReport (information report)
	TimeActivatedOperate (time activated operation)	Write (write service)
File transmission model	GetFile (read file)	FileOpen, FileRead, FileClose (file open, file read and file close service sequence)
	SetFile (set file)	ObtainFile (obtain file service)
	DeleteFile (delete file)	FileDelete (file delete service)
	GetFileAttributeValues (read file attribute values)	FileAttributes (file attribute service)

9.4.2.3 Peer-to-peer

This is a non-connection-oriented, high speed type of communication usually between substation equipment, such as protection relays, intelligent terminals. GOOSE is a method of peer-to-peer communication.

9.4.2.4 Substation configuration language (SCL)

IEC 61850 has defined a series of configuration documents (ICD, IID, SCD, SED, CID), which are prepared with SCL (substation configuration language). The SCL includes the following:

Head: it is used to identify a SCL configuration document and its version, and also to designate relevant names into the mapping option of information (FuntionName)

Substation: it is used to describe the function structure of the substation, and mark the primary devices and their electrical connection relationship.

IED: intelligent electronic device description, to describe the IED pre-configuration, access points, logic devices, logic nodes, data objects, etc.

DataTypeTemplate: the instantiated logic node type, and logic node type is a specific sample of logic node data.

The purpose to define and use SCL is: the description of intelligent electronic device capability and description of substation automation system can be exchanged in a compatible manner between the intelligent electronic device management tools and system configuration tools provided by different manufacturers.

9.4.2.5 GOOSE

GOOSE service is used to transmit fast messages, such as trip and switch position.

The GOOSE service adopts the pear-to-pear transmission or network transmission, and is classified as GOOSE sending and GOOSE receiving.

9.4.2.6 GOOSE sending mechanism

GOCB is automatically enabled when the unit is powered on, when all status of the unit are determined, it performs sending according to the data set shifting mode, to quickly send the initial status of the own GOOSE information;

The time interval for immediate re-sending after shift of GOOSE message is the MinTime parameter (i.e. T1); the “timeAllowedtoLive” parameter in GOOSE message is 2 times the “MaxTime” configuration parameter (i.e. 2T0);

9.4.2.7 GOOSE receiving mechanism

The GOOSE receiving buffer zone of the unit receives the new GOOSE messages, after a strict check of the relevant parameters of GOOSE messages, the receiving side first compares if the StNum (status number) of the newly received frame and that in the GOOSE message of the previous frame are equal. If the StNum of the two frames of GOOSE messages are equal, the SqNum (sequence number) of the two frames of GOOSE messages are compared, if the SqNum of the newly received GOOSE frame is bigger than the SqNum of the previous frame, this GOOSE message is discarded, otherwise the data of the receiving side is updated. If the two GOOSE messages have different StNum, the data of the receiving side are updated;

When receiving GOOSE messages, the PRS-7000 series unit strictly checks if parameters such as AppID, GOID, GOCBRef, DataSet and ConfRev are matching;

In receiving GOOSE messages, it will take into account cases of communication interruption of fault with issuing unit, when the GOOSE communication is interrupted or the configured versions are not identical, the received GOOSE message should maintain the status before interruption.

9.4.3 Data set and control block

PRS-7000 series devices support real-time sending of data. The data objects requiring real-time monitoring are configured into data set, and the data set are associated to report control and

GoCB, so that the change information of monitored objects can be sent in real-time to the background via the report service and GOOSE.

9.4.3.1 Data set

PRS-7000 series devices usually configure data sets in advance in the ICD document, such as protection event, protection digital input and protection measurement. The SCT (system configuration tool) can also add, delete and modify data set configuration according to the needs of existing actual projects.

A data set is an ObjectReference set of orderly DATA or DataAttrubutes. It usually include the following attributes:

- ldInst: the logic device containing the DATA or DataAttrubutes;
- lnClass: the logic node class containing the DATA or DataAttrubutes;
- lnInst: the logic node instant number containing the DATA or DataAttrubutes;
- Fc: all attributes of functional constraint required by DATA or DataAttrubutes;
- doName: name of DATA, or name belonging to the DataAttrubutes;
- daName: attribute name.

9.4.3.2 Report control block

IEC 61850 has defined the report control block, to describe how the changed information is actively submitted via report service when the data set members have changed. Report control blocks are classified into buffered report control block and non-buffered report control block. In case of communication interruption, the newly occurring event will still be stored as buffered report control block, otherwise, it is a non-buffered report control block.

The report control block performs the control of report submission via a series of attribute configurations. Specifically, it has the following important attributes:

RptID

The identity of report control block, globally unique within the scope of LD, if the RptID of the RCB is set by the client side as NULL, in the report submitted by device, RptID is full path.

OptFlds

The option fields OptFlds contained in the report. The PRS-7000 series device supports the following option fields:

— Bit 1: Sequence-number

— Bit 2: Report-time-stamp

— Bit 3: Reason-for-inclusion

— Bit 4: Data-set-name

— Bit 5: Data-reference

- Bit 7: EntryID (for buffered reports only)
- Bit 8: Conf-revision
- Bit 9: Segmentation

When an item is set as 1, the corresponding information will be embodied in the report.

DatSet

The name of the data set associated with the report control block and under the same LD. The members of this data set are monitored by this report control block.

BufTm

Buffer time, it is the buffer time internally prompted by the dchg (data change), qchg (quality change), and dupd (data updating) of the rcb, in ms, with missing value as 0, indicating not using the buffer time attribute, and the maximum value is 1h.

The timer is started when the first internal prompt arrives, after it is reached in timer, all event messages within the buffer time are packed into one report, and submitted to the client side.

When the second change of the same signal arrives in the buffer time, the buffered report is submitted immediately, and the timer is booted again, to start again the subsequent internal prompt buffer.

TrgOps

Trigger option, used to filter the conditions for sending reports. PRS-7000 supports the following trigger options:

- *Bit 1:* Data change
- Bit 2: Quality change
- Bit 3: Data updating (the service follow-up of Ed2)
- Bit 4: Completeness period
- Bit 5: Total call

IntgPd

Completeness period time, to be set by the client side. After successful device enabling (RptEna = TRUE), the timer is started immediately, and after the expiration of completeness period time, the current values of all members in the data set associated by the report are packed and submitted.

The completeness period time set as 0 means the completeness submission function is not enabled.

GI

Total call is launched by the client side with initiative. After the report is enabled, the client side takes initiative to issue GI = TRUE, then the device immediately submit all data values in the current data set.

PurgeBuf

Purge buffer. When the client side sets PurgeBuf = TRUE, all report entries in the IED buffer report are purged.

When the client side modifies RptID, DataSet, BufTime, TrgOps, IntgPd, the device will automatically set purging buffer reports, equivalent to setting PurgeBuf = TRUE.

9.4.3.3 GOOSE control block

The fast messages of the PRS-7000 series device is transmitted via GOOSE, and the transmission characteristics of GOOSE is controlled by the GOOSE control block (GoCB). GoCB has the following important characteristics:

App ID

The application ID, representing the logic device where the GoCB is located. The missing value of App ID is the Object Reference of GoCB.

DatSet

The values of members of the data set associated by GoCB are transmitted by GOOSE.

9.4.4 Logic nodes and data modeling

9.4.4.1 Logic nodes

IEC 61850 7-4 has defined a series of logic nodes, which constitute the minimum communication unit of intelligent electronic devices as classified by functions. There are three types of logic nodes used by the PRS-7000 series unit: management logic nodes (LLN0), physical device logic nodes (LPHD) and application function logic nodes.

LLN0

Management logic nodes provide the management and control functions for all logic nodes and data objects within the logic devices. Some common services are modeled in LLN0, such as setting group control block (SGCB), GOOSE control block (GoCB), SV control block (MsvCB), reported control block (BRCB and URCB) and log control block (LCB); some common data objects are modeled in this node, such as Loc, to represent the local and remote operation enabling of the unit,basing on function soft switch and common settings; some data objects represent the meaning of the whole logic device, such as Beh,which is jointly formed by the Beh value of all logic nodes in the logic device, to represent the behavior and status of the whole logic device.

LPHD

It represents the information of physical devices, including the device manufacturer, unit model, software version, unit serial number, whether agented and the device health status. In this logic node, it is also extended to include device information such as name of protected device and unit time calibration method.

Application function logic nodes

Application function logic nodes include when classified by functions:

A: automatic control logic nodes

C: monitoring related logic nodes, such as CSWI

G: general purpose function logic nodes, such as GGIO, GAPC

I: filing related logic nodes,

M: measurement and metering related logic nodes, such as MMXU

P: protection function logic nodes, such as PDIF, PDIS, PTOC, PTRC

R: protection related functional logic nodes, such as RREC, RBRF

S: sensors, monitoring

T: instrument transducer logic nodes, such as TVTR, TCTR

X: switching device logic nodes, such as XCBR, XSWI

Y: power transformer and related function logic nodes

PRS-7000 series unit uses the corresponding logic nodes according to the functions selected by user. For the corresponding logic nodes, please refer to the instruction manual for unit of the specific model.

9.4.4.2 Data object

IEC 61850 7-3 defined common data types, including:

- Status information: such as SPS, INS, ACT, ACD
- Measured value information: such as MV, CMV, WYE
- Controllable status information: such as SPC, INC, DPC
- Status set values: such as SPG, ING
- Analog set values: such as ASG
- Description information: such as LPL, DPL

The PRS-7000 series unit uses the above common data types, and instantiate the specific data objects according to the need of application functions, to meet the need of application functions. There are the following common data objects in all logic nodes (except for LPHD):

Mod

The model of logic node. It represents the behavior mode of the logic node, such as normal, testing and blocked.

Beh

The performance of the logic node, representing the current performance status of the logic node, the value of the same Mod is read-only and cannot be modified.

Health

Health status, it reflects the status of the relevant software and hardware of the logic node.

NamPlt

The name plate of the logic node

9.5 DNP3.0 Protocol

9.5.1 Overview

The descriptions given here are intended to accompany this relay. The DNP3.0 protocol is not described here; please refer to the DNP3.0 protocol standard for the details about the DNP3.0 implementation. This manual only specifies which objects, variations and qualifiers are supported in this relay, and also specifies what data is available from this relay via DNP3.0.

The DNP3.0 communication uses the Ethernet ports (electrical or optical) at the rear side of this relay.

9.5.2 Link Layer Functions

Please see the DNP3.0 protocol standard for the details about the linker layer functions.

9.5.3 Transport Functions

Please see the DNP3.0 protocol standard for the details about the transport functions.

9.5.4 Application Layer Functions

9.5.4.1 Function Code

Table 9.5.1 Function Code

Function Code	Function
0 (0x00)	Confirm
1 (0x01)	Read
2 (0x02)	Write
3 (0x03)	Select
4 (0x04)	Operate
5 (0x05)	Direct Operate
6 (0x06)	Direct Operate No Acknowledgment
13 (0x0D)	Cold Restart
14 (0x0E)	Warm Restart
20 (0x14)	Enable Unsolicited Responses
21 (0x15)	Disable Unsolicited Responses
22 (0x16)	Assign Class
23 (0x17)	Delay Measurement

9.5.4.2 Communication Table Configuration

This relay now supports 3 Ethernet clients and 2 serial port clients. Each client can be set the DNP related communication parameters respectively and be selected the user-defined communication table.

The user can configure the user-defined communication table through the PRS IED Studio configuration tool auxiliary software. The object groups “Binary Input”, “Binary Output”, “Analog Input” and “Analog Output” can be configured according to the practical engineering demand.

9.5.4.3 Analog Input and Output Configuration

To the analog inputs, the attributes “dead band” and “factor” of each analog input can be configured independently. To the analog outputs, only the attribute “factor” of each analog output needs to be configured. If the integer mode is adopted for the data formats of analog values (to “Analog Input”, “Object Variation” is 1, 2 and 3; to “Analog Output”, “Object Variation” is 1 and 2.), the analog values will be multiplied by the “factor” respectively to ensure their accuracy. And if the float mode is adopted for the data formats of analog values, the actual float analog values will be sent directly.

The judgment method of the analog input change is as below: Calculate the difference between the current new value and the stored history value and make the difference value multiply by the “factor”, then compare the result with the “dead band” value. If the result is greater than the “dead band” value, then an event message of corresponding analog input change will be created. In normal communication process, the master can online read or modify a “dead band” value by reading or modifying the variation in “Group34”.

9.5.4.4 Binary Output Configuration

The remote control signals, logic links and external extended output commands can be configured into the “Binary Output” group.

To an extended output command, if a selected command is controlled remotely, this command point will output a high ~ level pulse. The pulse width can be decided by the “On ~ time” in the related “Binary Command” which is from the DNP3.0 master. If the “On ~ time” is set as “0”, the default pulse width is 500ms.

9.5.4.5 Class Configuration

If the DNP3.0 master calls the Class0 data, this relay will transmit all actual values of the “Analog Input”, “Binary Input” and “Analog Output”. The classes of the “Analog Input” and “Binary Input” can be defined by modifying relevant settings. In communication process, the DNP3.0 master can online modify the class of an “Analog Input” or a “Binary Input” through “Function Code 22” (Assign Class).

9.6 IEEE 1588-2008 Protocol

9.6.1 Overview

The Precision Time Protocol (PTP) is a protocol used to synchronize clocks throughout LAN. On a local area network, it achieves clock accuracy in the sub-microsecond range, making it suitable for measurement and control systems.

9.6.2 Time Synchronization

Time synchronization of the device support IEEE 1588-2008 Protocol via ethernet interface or optical interface.

10 Commissioning

10.1 General

This part contains a brief description about how to verify the function, including functional verification items, functional verification methods and more.

With high degree of self-checking, any fault with the internal hardware and software can be diagnosed by the device itself. So for the commissioning, only hardware interface and the application-specific software function are necessary to verify.

Before carrying out commissioning, users should pay close attention to the safety, technical data and the ratings on the front panel label.

10.2 Safety Instructions

This section contains some safety information, some of which are given warning signs to avoid personal injury or equipment damage, to prompt the user to be careful.

10.2.1 Safety Identification

Electrical warning icon indicating a danger of electric shock.

Notice icon, indicating important information or warnings involved in the article. This icon may indicate a danger of software, equipment or property damage.

Information icons alert readers to important facts or conditions.

Prompt staff not to forget the dangers of static electricity and make prevention.

Forbid to energize the device while not grounded, to avoid endangering the personal safety due to electrical insulation damage!

Although these markings warn of the danger, it is important to note that operating damaged equipment under certain operating conditions can result in reduced process performance and may result in death or personal injury. Therefore, be sure to fully comply with all warnings and cautions.

10.2.2 Safety Identification Examples

For the various safety instructions given in the previous section, the following are examples

10.2.2.1 Warning Signs

Do not touch the circuit during operation. There may be fatal voltage and current.
Strict compliance with safety regulations. Work in high voltage environment need to be serious to avoid personal injury or equipment damage.

When measuring signals in an open circuit, remember to use a properly isolated test clamp that can have fatal voltages and currents.

During normal operation, never disconnect or connect the wires or connectors connected with the terminals. It may cause deadly dangerous voltage and current, may also interrupt the operation of the equipment, damage the terminals and the measuring circuit.

Never disconnect the secondary winding of the current transformer. Current transformers that operate when the secondary windings are open will create strong potentials that may damage the transformers and may cause personal injury.

When the protective device is energized, never plug the module. Hot plug may damage the protection device and measuring circuit, may also result in injury.

10.2.2.2 Caution Signs

Do not connect the protective shell to the live wire, charging the shell may damage the internal circuit.

During installation and commissioning, be careful not to get an electric shock if you touch the leads and connecting terminals

10.2.2.3 Notice Signs

Do not modify the settings in the running protection device. After modify the setting, verify it according to the rules.

10.2.2.4 Anti-static Signs

Remember to avoid touching circuits, including electronic circuits, and the device may be damaged if subjected to static electricity. Electronic circuits may also contain deadly high voltages.

Remember to use a certified conductive bag when transporting the module. Remember to connect the anti-static wristband to the ground when handling the module and remember to operate it on a suitable anti-static surface. Static electricity discharge may cause damage to the module.

Remember to wear the anti-static wristband connected to the ground when replace the module, Static electricity discharge may damage the module and protection device.

10.2.2.5 Earthing Signs

Regardless of operating conditions, remember to connect the protective device to the earth, also needed for special occasions such as testing, demonstrating and off-line configuration on the desk. Operation of the protective device without proper earthing may damage the protective device and the measuring circuit and may also cause an injuring accident.

10.2.2.6 Information Signs

Effective value and step of settings explanation: The protection setting supports as much as 6 significant figures, of which the decimal point occupies one digit (the highest digit can not be a decimal point). The minimum setting step is 0.01.

10.3 Commission Tools

10.3.1 Instrumentation and Meters Notice:

- Instruments, meters must pass the inspection, and within the validity of the inspection
- Instruments, meters should be accurate level higher than the seized equipment related indicators 2 to 4 levels.

10.3.2 Tools Requirement:

- Relay protection testing devices: Multifunctional dynamic current and voltage injection test set with interval timer.
- Regulative DC power: DC output can be adjustable within 0 ~ 240V.
- Accuracy meter: support three-phase voltage, three-phase current output.
- Tong-type ammeter
- Multifunction phase meter
- Multimeter
- Megger
- Laptop: with appropriate software
- Network cable
- Optical power meter
- EIA RS-485 to EIA RS-232 converter

10.4 Commission Preparation

10.4.1 Basic Knowledge

When commissioning this device for the first time, sufficient time should be allowed to become familiar with the manual to understand the basic operation, protection principles, and related basic performance of the devices as much as possible. If find any doubt in the process, consult the manufacturer's field service personnel or technical support staff of our company.

Alternatively, if a laptop is available together with suitable setting software (such as PRS IED Studio software), the menu can be viewed one page at a time to display a full column of data and text. This PC software also allows settings to be entered more easily, saved to a file on disk for future reference or printed to produce a setting record. Refer to the PRS IED Studio Instruction manual for details.

If the application-specific settings have been applied to the relay prior to commissioning, it is advisable to make a copy of the settings so as to allow them restoration later. This could be done by extracting the settings from the relay itself via printer or manually creating a setting record.

10.4.2 Operation Preparation

Check the printer wiring is normal, the print paper is ample, in order to print the test settings, version, and a variety of experiment data.

Attention! The device should be checked before power on. The appearance should be no damage. The module is plugged and fastened, and the insulation of the DC voltage circuit meets the specified requirements. The indicators can refer to the commissioning record of the device.

Attention! Disconnect the external AC circuit of the cubicle before the test to avoid causing a safety accident, which will cause serious damage to the construction workers on site.

Attention! When you need to plug and unplug the device module, you should ensure the device is powered off and make the anti-static measures to prevent the module damage or performance degradation.

Attention! Temporarily open or shorted terminals should be well documented for reliable recovery after the end of the test.

If it has been necessary to disconnect any of the external wiring from the protection in order to perform any of the following tests, it should be ensured that all connections are replaced in accordance with the relevant external connection or scheme diagram. Confirm current and voltage transformer wiring.

10.5 Product Checks

These product checks cover all aspects of the relay which should be checked to ensure that it has not been physically damaged prior to commissioning, is functioning correctly and all input quantity measurements are within the stated tolerances.

10.5.1 Document Check

Document acceptance check include: protection inspection and factory test reports, certificates, drawings, technical manual of related equipment.

10.5.2 Appearance Inspection

Check the front and back of the cubicle of various electricalcomponents, terminal blocks, hard-switch. All should be marked with the number, name, application and operating position. The marked handwriting should be clear, neat, and not easy to bleach.

The device mark inspection shall include the product type, name, manufacturer's name and trademark, date of manufacture and serial number, safety mark, etc., the mark and installation location shall be consistent with the design drawings.

Inspect the surface of the device. There shall not be scratches, bumps, groove marks, rust, deformation and other defects that affect the quality and appearance;

Check the device panel keyboard is complete, flexible operation, the LCD is clear, the indicator shows normal;

Uncharged metal part of the device should be connected as one, and reliable grounding;

Check the cubicle shell of the device must be grounded reliably;

10.5.3 Insulation Check

Disconnect the weak electric link with other devices and short circuit the AC voltage circuit terminal, AC current circuit terminal, DC circuit terminal and signal circuit terminal inside the cubicle terminal block, and measure the insulation resistance value using the tester whose open circuit voltage is 500V. Insulation should meet the following requirements:

Device independent circuit and exposed conductive parts, 500V megger insulation resistance measured value should be no less than 100MΩ;

Between electrically disconnected independent circuits, 500V megger insulation resistance measured value should be no less than 100MΩ;

After the insulation test is completed, make sure that all external wiring is properly connected.

10.5.4 External Wiring Check

External protection wiring should be consistent with the design drawings; Internal and external wiring on the terminal block and cable marking on it is correct, complete, and consistent with the drawings; Secondary circuit wiring should be neat and beautiful, solid and reliable;

All secondary cables and terminal blocks wiring connection should be solid. Cable mark should be complete, correct and clear;

The correct mark should be attached to the optical fiber (including optical cable, pigtail, jumper) and both ends of the device port. Such fiber-optic annotation should include the optical fiber number, destination. The starting point of the fiber should indicate the cubicle number. The content of the port mark should include the port number and destination. The starting point of the port should include the cubicle number, switch number and port number.

10.5.5 Test Category

The following tests are necessary to ensure the normal operation of the equipment before it is first put into service.

These tests are performed for the following hardware to ensure that there is no hardware defect. Defects of hardware circuits other than the following can be detected by self-monitoring when the power supply is energized.

- User interfaces test

- Binary input circuits and output circuits test
- AC input circuits test
- Function tests

These tests are performed for the following functions that are fully software-based. Tests of the protection schemes and fault locator require a dynamic test set.

- Measuring elements test
- Timers test
- Metering and recording test
- Conjunctive tests

The tests are performed after the relay is connected with the primary equipment and other external equipment.

- On load test.
- Phase sequence check and polarity check.

10.6 With the Relay Energized

Check that the input range of the external power supply should meet the power requirements of the "technical data" section within the permissible power supply input voltage range.

Attention! All external circuits connected to the unit must be checked to ensure correct installation before the unit is powered on or the test procedure started.

10.6.1 LCD Display Check

After the device is powered on, the LCD will be lit. After the device is initialized, if the device is in normal operation, the LCD displays the status of the main single line diagram.

Attention! If the device is in the alarm state after power-on, the LCD displays the alarm status information. At this point you can refer to the "Supervision" section to analyze the cause of the alarm and treatment.

10.6.2 Date and Time

If the time and date is not being maintained by substation automation system, the date and time should be set manually.

Set the date and time to the correct local time and date using menu item “Clock”.

For devices using IRIG-B (DC) time code and SNTP, IEEE 1588 time synchronization, you can verify the timing accuracy by modifying the clock setting of the device. For PPM, PPS time synchronization system, through the time synchronization binary input check.

10.6.3 Light Emitting Diodes (LEDs)

The device has two lights that can not be defined. The two lights are as follows:

"Healthy": indicates that the device is in normal operation, no software, hardware failure. When the "healthy" light goes out, it indicates a serious problem with the device, resulting in the device not functioning properly.

"Alarm": indicates that there are some alarm events on the device. On this condition, you can analyze the cause of the alarm and how to handle it by checking the "supervision" section of the manual.

The rest of the indicators are configurable indicators.

If the indicator of the device is set to the self-retaining state, if the signal is not reset before the latest power-off, the signal will continue to be triggered when the device is powered on again, and the indicator can be reset by resetting operation. It is likely that alarms related to voltage transformer supervision will not reset at this stage.

10.6.3.1 Test the HEALTHY and ALARM LEDs

Apply the rated power supply and check that the “HEALTHY” LED is lighting in green. We need to emphasize that the “HEALTHY” LED is always lighting in operation course except that this device finds serious errors in it.

Produce one of the abnormal conditions listed in Chapter 4, the “ALARM” LED will light in yellow. When abnormal condition reset, the “ALARM” LED extinguishes.

10.6.3.2 Test the Other LEDs

Test the other LEDs according to the configuration of the LEDs (through the PRS IED Studio software). If the conditions which can turn on the selected LED are satisfied, the selected LED will be on.

10.6.4 Test the AC Current Circuit

Attention! The wiring must be checked in strict accordance with the AC current connection drawings provided.

The purpose of this test is to check whether the wiring of the AC circuit in the cubicle is correct and whether the sampling precision meets the requirements. The sampling accuracy and polarity of the device can be checked through sourcing rated AC current at the AC current input terminal on the back of the cubicle .

Protection current measurement accuracy requirement shall be no higher than 1% or 0.02In. However an additional allowance must be made for the accuracy of the test equipment being used.

Apply current equal to the current transformer secondary winding rating to each current transformer input in turn, checking the magnitude using a multimeter/test set readout. The corresponding reading can then be checked in the relays menu.

10.6.5 Test the AC Voltage Inputs

Attention! The wiring must be checked in strict accordance with the AC voltage connection drawings provided.

The purpose of this test is to check whether the wiring of the AC voltage in the cubicle is correct and whether the sampling precision meets the requirements. The sampling accuracy and polarity of the device can be checked through sourcing rated AC voltage at the AC voltage input terminal on the back of the cubicle .

Protection voltage measurement accuracy requirement shall be no higher than 1% or 0.02In,However an additional allowance must be made for the accuracy of the test equipment being used.

Apply voltage equal to the voltage transformer secondary winding rating to each voltage transformer input in turn, checking the magnitude using a multimeter/test set readout. The corresponding reading can then be checked in the relays menu.

10.6.6 Test the Binary Inputs

The purpose of this test is to check whether the connection of binary input circuit is correct. During the test, the voltage applied to the binary input terminal must be within the allowable operating range.

Each binary input status can be checked by the device LCD panel, and the status "1" indicates that the binary input has been applied with an input voltage, and the opening status becomes "0" when the input voltage disappears.

10.6.7 Test the Binary Outputs

The purpose of this test is to check whether the binary output circuit connection is correct. According to the protection logic of the device and various kinds of signal output logic, stimulate a fault condition. The corresponding relay contact of the device shall be operated with the corresponding action or alarm signal.

10.6.8 Protection Function Checks

The purpose of this experiment is to verify the correctness of the protection logic. Protection function tests generally include the following types:

- Impedance protection test
- Current protection test
- Voltage protection test
- Frequence protection test
- Secondary system supervision function test

For details on how to implement the protection logic function, refer to "Operation Theory"

10.6.9 Printing Function Checks

Check the printer cable is connected properly before printing, printing paper is complete. Printing method can be set to "automatic" or "manual". When set to automatic printing, the device will print protection action event, self- checking information and other records initiatively in real time.

10.6.10 On-load Checks

The objectives of the on-load checks are:

- Confirm the external wiring to the current and voltage inputs is correct.
- Measure the magnitude of on-load current and voltage (if applicable).
- Check the polarity of each current transformer.

10.6.11 Final Checks

After the above tests are completed, remove all test or temporary shorting leads, etc. Restore the original correct wiring. Tighten the secondary circuit terminals, especially for the current terminals, circuit breaker closing and opening, operating power supply circuit.

If a test block is installed, remove the test plug and replace the cover so that the protection is put into service.

Ensure that all event records, fault records, disturbance records and alarms have been cleared and LED’s has been reset before leaving the protection.

Ensure that the protection has been restored to service.

11 Installation

11.1 General

Design and installation chapter is suit for design, installation, commissioning and maintenance staff.Designers must have a wealth of experience in electrical design.The installer must have the basic knowledge of electronic equipment and cubicle drawing reading.Commissioning and maintenance personnel must have extensive experience in operating protective equipment and test equipment.The equipment must be shipped, stored and installed with the greatest care.

Choose the place of installation such that the communication interface and the controls on the front of the device are easily accessible.

Air must circulate freely around the equipment. Observe all the requirements regarding place of installation and ambient conditions given in this instruction manual.

Take care that the external wiring is properly brought into the equipment and terminated correctly and pay special attention to grounding. Strictly observe the corresponding guidelines contained in this section.

11.2 Safety Instructions

Warning! Only insert or withdraw a module while the device power supply is switched off. To this end, disconnect the power supply cable that connects with the power supply module.

Attention! A module can only be inserted in the reserved slot. Components can be damaged or destroyed by inserting module in a wrong slot.

The basic precautions to guard against electrostatic discharge are as follows:

- Should boards have to be removed from this relay installed in a grounded cubicle in an HV switch gear installation, please discharge yourself by touching station ground (the cubicle) beforehand.
- Only hold electronic boards at the edges, taking care not to touch the components.
- Only works on boards that have been removed from the cubicle on a workbench designed for electronic equipment and wear a grounded wristband.
- Always store and ship the electronic boards in their original packing. Place electronic parts in electrostatic screened packing materials.

11.3 Checking the Shipment

Vehicles, trains, ships and all other means of transport are available, but to prevent snow and rain, shock, impact and collision, to ensure product packaging integrity.

Check that the consignment is complete immediately upon receipt. Notify the nearest CYG SUNRI CO., LTD. Company or agent, should departures from the delivery note, the shipping papers or the order be found.

Visually inspect all the material when unpacking it. When there is evidence of transport damage, lodge a claim immediately in writing with the last carrier and notify the nearest CYG SUNRI CO., LTD.Company or agent.

➢ **Unpacking and checking procedures**

1. Remove the shipping package.
2. Before unpacking, you should first check the equipment packaging intact, whether there are signs of serious collision and phenomenons that equipment in the box may be damaged. If found abnormal, it is recommended to take pictures as a record, confirm and contact with the manufacturer at first time.
3. When unpacking, you should use a claw, and pull out the nails, and then pry off the box lid; If the crowbar is used, never take the device as a fulcrum, and it is forbidden to stick into the wooden box carelessly with the crowbar.Open the box with the greatest care and avoid excessive vibration.
4. Check the appearance of the device is intact.
5. Check the delivery list.Check the device certificate of competency, supporting documents, attachments, spare parts, etc. are consistent with the order requirements, whether the packing list and the type, name, quantity, etc. are consistent and complete. If correct, sign the confirmation.
6. Manufacturer documents and spare parts should be assigned to personal keeping and registration.
7. If any abnormalities occur during unpacking, feedback CYG SUNRI CO., LTD. Company or agent at the first time, so as to avoid the follow-up of unclear responsibilities.

If the equipment is not going to be installed and commissioned immediately, store all the parts in their original packing in a clean dry place and keep air circulation.And to prevent the intrusion of various harmful gases, non-corrosive items stored in the same place.

11.4 Material and Tools Required

The necessary mounting kits will be provided, including screws, pincers and assembly instructions.

A suitable drill and spanners are required to secure the cubicles to the floor using the plugs provided (if this relay is mounted in cubicles).

11.5 Device Location and Ambient Conditions

The mechanical and electrical environmental conditions at the installation site must comply with the requirements of "Chapter 2 Technical Data". Avoid adverse conditions caused by the environment:

- Avoid installing in wet, dark and other places likely to cause damp and rust. If in unavoidable rainy area, install the device in a higher position;
- If the area is an earthquake prone area, fix the protection devicetightly;
- If there is a lot of dust in the installation place, clean it before installing.

The place of installation should permit easy access especially to front of the device, i.e. to the human machine interface of the equipment.There should also be free access at the rear of the equipment for additions and replacement of electronic boards.

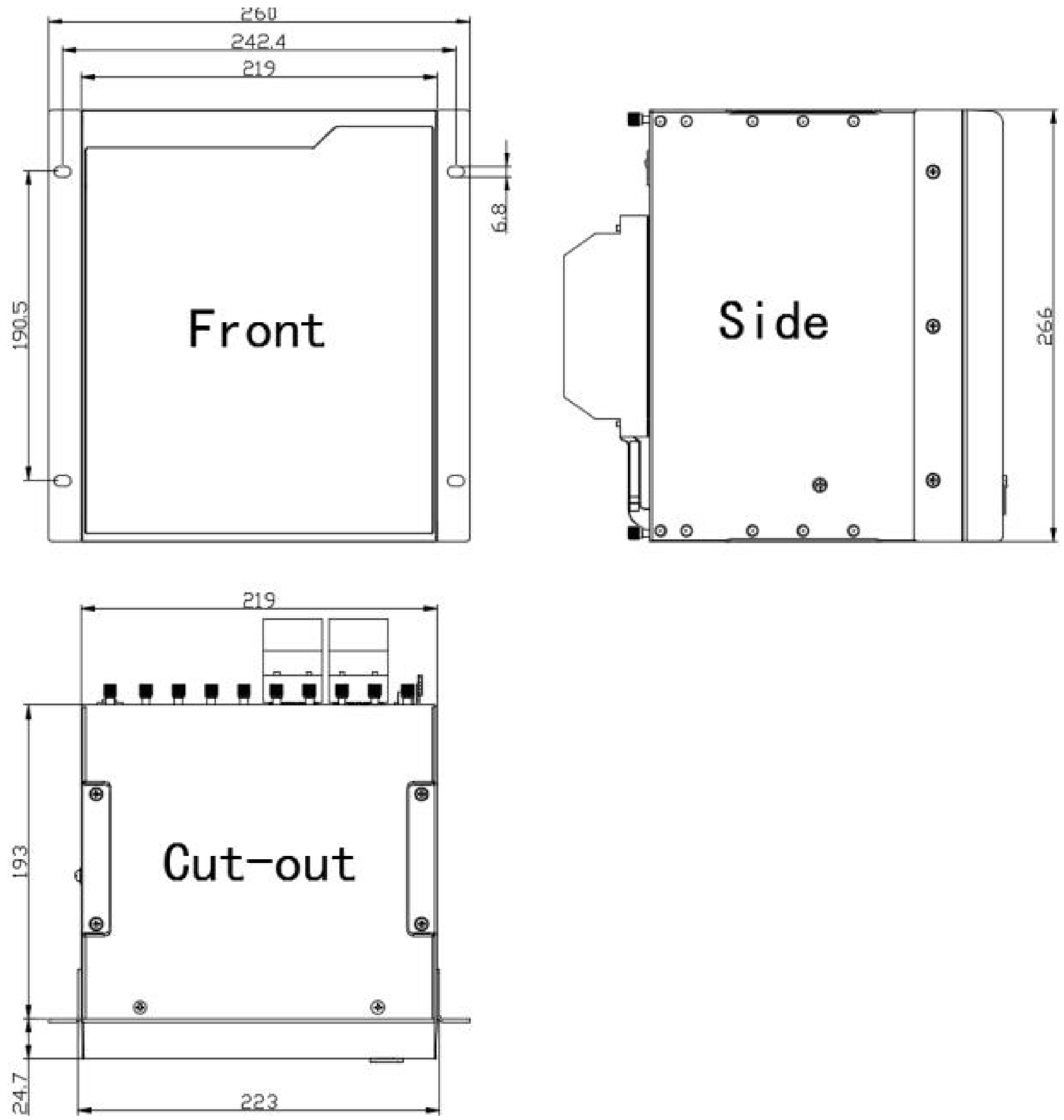
11.6 Mechanical Installation

In the case of equipment supplied in cubicles, place the cubicles on the foundations that have been prepared. Take care while doing so not to jam or otherwise damage any of the cables that have already been installed. Secure the cubicles to the foundations.

The device should be firmly fixed in the cubicle(cabinet),and the connecting screws should be tightened.The grounding wire of each device should be connected with the copper grounding busbar inside the cubicle, and reliably connected with the secondary grounding network. Device wiring should be consistent with the wiring diagram requirements.

The device features a 6Uheight, 1/1 19 "or 1/2 19" width chassis, integral panel and pluggable functional modules with lock. The device is designed conforming to IEC 60297-3.Embedded Installation as a whole, rear wiring. The current/ voltage connector structure are in the same size, and can be expanded, combined flexibly. Installation hole size as below.

Attention! It is necessary to leave enough space top and bottom of the cut-out in the cubicle for heat emission of this relay.


260
242.4
219
6.8
190.5
Front
Side
266
219
Cut-out
193
24.7
223

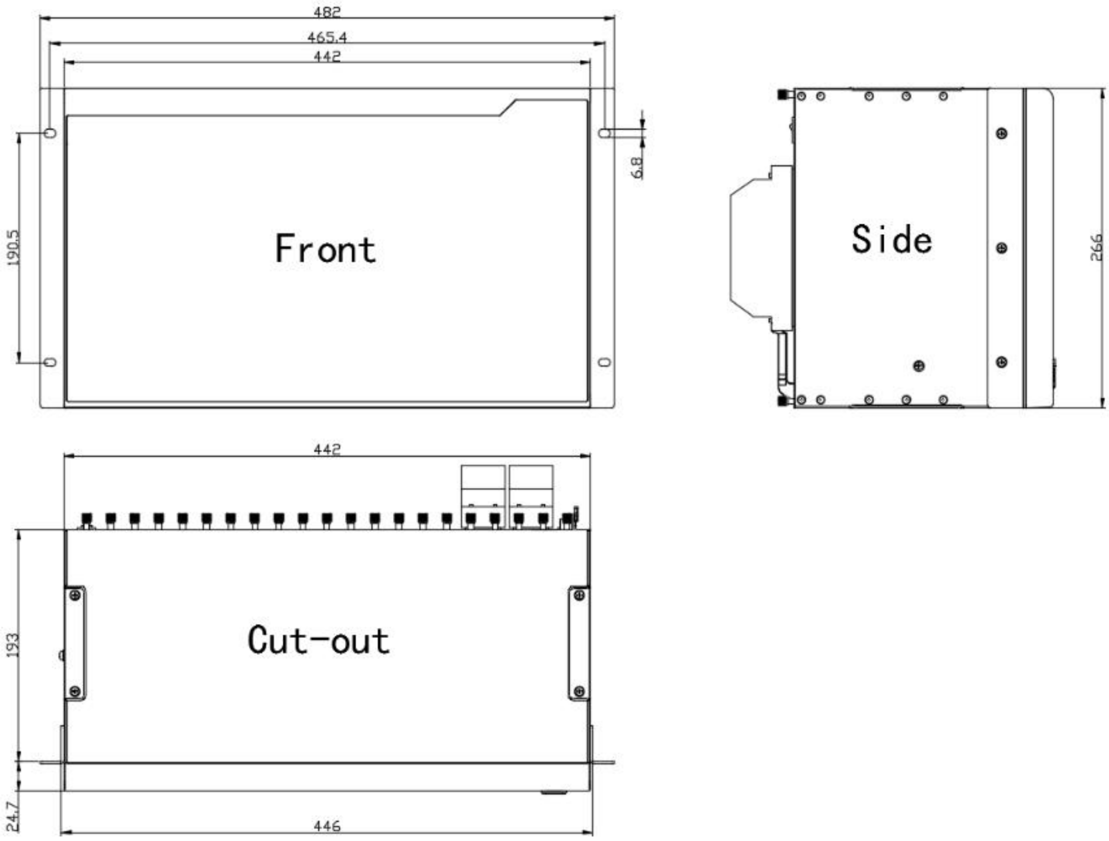


Figure 11.6.1 Dimensions of this relay and the cut-out in the cubicle (unit: mm)

11.7 Electrical Installation and Wiring

11.7.1 TA Circuit Connection

According to the wiring diagram of the device, connect the terminal block of rear AC module with the CT loop using multiple wires, of which the cross-sectional area should be 2.5 ~ 4.0mm^2.

11.7.2 Power Supply, TV, BI and BO, Signal Wiring

According to the wiring diagram of the device, connect the AC, Phoenix terminal of module and the terminal block in the cubicle side with multiple wires.

DC voltage power supply wiring power +, power - should be distinguish indifferent colors, for example power + (brown), power - (blue).

Power supply, binary inputs & outputs: stranded conductor, 1.0mm^2 ~ 2.5mm^2.

AC voltage inputs: stranded conductor, 1.5mm^2.

Grounding: braided copper cable, 2.5mm^2 ~ 6.0mm^2.

For wires connected to two points, there should be no jointin the middle, and the wire core should not be damaged. If the wire length is not enough during the process of wiring or rewiring, the worker must replace it. There should be no excess wire in the slot. If it is required to remove the wire, the whole wire must be completely removed.

When wiring the AC terminal of module, current and voltage wires must adopt 12mmsizecablelug, to avoid loose contact.Strictly prohibit electric screwdriver, so as to avoid terminals damage.

Attention! Never allow the current transformer (CT) secondary circuit connected to this equipment to be opened while the primary system is live. Opening the CT circuit will produce a dangerously high voltage.

11.7.3 Grounding

Use a yellow-green multi-core cable with a cross-section of at least 2.5 mm^2 to connect the grounded copper bars. The cubicle should reliably connected to the secondary ground network.

11.7.4 Shielded cable connection

When using a shielded cable, connect the shielded cable to ground and follow the engineering application method. This includes checking of the appropriate grounding point near the device, such as the grounding point inside the cubicle and the grounding point near the measurement source. Ensure a single shield connection a suitable short cross-sectional wire (maximum 10CM) for ground connection.

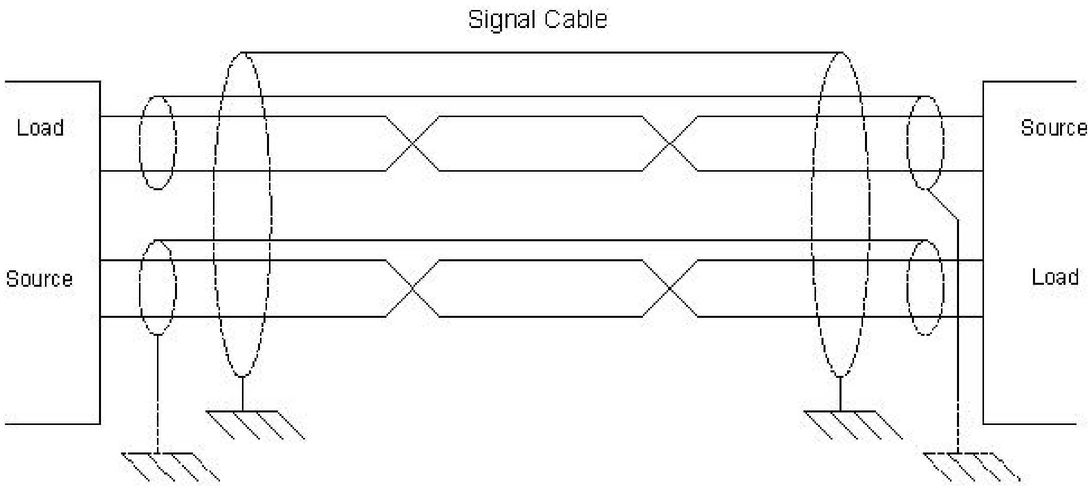


Figure 11.7.1 Shielded cable connection

11.7.5 Install the optical cable

Care should be taken to handle the cable without substantial bending. The minimum curvature radius of the plastic optical fiber is 15 cm and the glass optical fiber is 25 cm. To use the cable clamp, a loose buffer sleeve should be used.

When connecting or removing the optical fiber,please take hold of the connection ends. Do not take the cable. Do not twist, stretch, bend the cable. Invisible damage can increase the attenuation of the fiber and can destroy the communication.

11.7.6 Install the communication cable

When using electrical connections between the protection device and the communication device, or point-to-point electrical connections between the two protection devices, it is important to install the cables carefully. Due to the low electrical level of communication signals, the factors susceptible to noise interference must be considered.

The best way is to use shielded twisted pair(STP), one for each twisted pair and the other for the all twisted pairs for surround shielding. Each signal uses the twisted pair shown in the following figure to shield each individual twisted-pair cable by connecting its internal shielded cable to the device's ground connection or, alternatively, to a device near the signal transmitter Connected, at the receiving end, shielded line let it hang in the air, not connected with the ground. The outer shield surrounding all twisted pairs is physically connected near each end of the equipment.

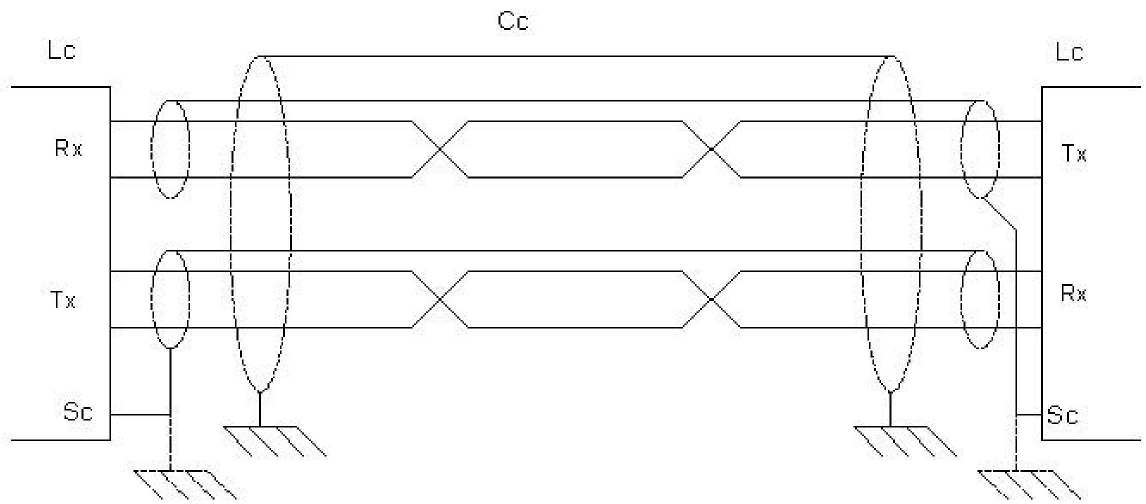


Figure 11.7.1 Communication cable connection

Cc: communication cable

Lc: line connector

Rx: receive signal input

Tx: transmit signal output

Sc: shielded (grounding) connection

11.8 Installation check

11.8.1 Check the installation

Check that all terminal screws with external wiring are tightened, the wiring is neat, and all wiring labels are clearly defined.

11.8.2 Confirm the hardware and software version

Hardware and software version information is available on the device label. After the device is powered on, the software version can also be checked through the LCD interface.

11.8.3 Device start

If confirm that the wiring is correct during the installation check, you can supply device with power and start it.

Configuration file needs to read during device startup process.It needs a certain period of time for the startup process.The startup time is related to the size of configuration file. In general, the startup time is less than 1 minute.

The "HEALTHY" indicator lights up when the unit starts up normally. If a fault is detected during the startup procedure, the "ALARM" indicator is lit and the internal fault code, alarm information can be checked via LEDs.

12 Maintenance

12.1 Maintenance General

A strict and detailed laboratory test is carried out in the development and design of the relay device. All the relay devices are strictly tested according to national or international standards.

The relay device has powerful real-time self-check capability. However, during the long time running of the relay device, there is no real time supervision for the input terminals and output circuits. Therefore, some periodic tests should be done to ensure that the relay is functioning correctly and the external wiring is intact.

The maintenance of the relay device mainly includes the following two conditions:

- Regular testing;
- Failure maintenance

12.2 Regular Testing

Regular testing is to test the normal relay devices in a certain period of time, so as to find potential defects or failures and eliminate hidden dangers to ensure the healthy operation of the devices.

The regular testing cycle depends on a number of factors, such as the environment conditions, the complexity, etc. Advices of CYG are as the following:

- The relay device must be tested for the first time in the first year of operation, mainly including protection logic, AC circuit, tripping circuit and power supply circuit.
- A partial test should be carried out every 3 years, mainly including the inspection of the AC circuit and the tripping circuit.
- An overall test should be carried out every 6 year, mainly including the protection function logic, the AC circuit, the tripping and closing circuit, the power supply circuit.

12.3 Failure Maintenance

Failure maintenance refers to the maintenance of a faulty relay device.

12.3.1 Hardware Failure

1) Check whether the hardware is in trouble or not according to the device alarm signal.
2) visual check of the device
    - Check whether the device has obvious physical fault
    - If you can find a clear physical fault point of the device, please contact CYG for repair or replacement
3) Confirm the scope of the fault
    - Check whether this fault is caused by an external circuit.
    - Carry out the input and output test for the relay device by test instrument.

- If it is determined that the fault belongs to the relay device, please contact CYG for repair or replacement

12.3.2 Software Failure

1) Check whether the hardware is in trouble or not according to the device alarm signal.
2) Try to restart the device and check if the fault is recoverable if possible.
3) If the fault is not recoverable, please contact CYG for repair or replacement

12.4 Replace Failed Modules

If the failure is identified to be in the relay module and the user has spare modules, the user can replace the failed modules to recover the protection device.

Repair at the site should be limited to module replacement. Maintenance at the component level is not recommended.

Before replacement, the user should check that the replacement module has an identical module name and hardware type-form as there moved module. Furthermore, the replaced module should have the same software version. For the replaced analog input module and power supply module, it should be confirmed of the same ratings.

NOTICE!

After replacing modules, it must be checked that the same configuration is set before and after the replacement. If it is not the case, there is a danger of the unintended operation of switch gear taking place or of relay device not running correctly. Persons may also be in danger.

Units and modules must only be replaced while the power supply is switched off and only by appropriately trained and qualified personnel. Strictly observe the basic precautions to guard against electrostatic discharge.

Take anti-static measures such as wearing an earthed wrist band and placing modules on an earthed conductive mat when handling a module. Otherwise, the electronic components may suffer damage. After replacing the main CPU module, check the settings and configurations.

13 Decommissioning and Disposal

13.1 Decommissioning

13.1.1 Switching off

To switch off this relay, break down the cable connected to the power supply module or switch off the external miniature circuit breaker.

13.1.2 Disconnecting cables

Disconnect the cables in accordance with the rules and recommendations made by relational department.

DANGER!

Before disconnecting the power supply cables that connected with the power supply module of this relay, make sure that the external miniature circuit breaker of the power supply is switched off.

DANGER!

To decline the possibility of electrical shock, all current terminal should be shorted before attempting to remove or replace any modules.

13.1.3 Dismantling

The rack of this relay may be removed from the system cubicle, after which the cubicles may also be removed.

DANGER!

When the station is in operation, make sure that there is an adequate safety distance to other operating parts or equipments, especially as dismantling is often performed by unskilled personnel.

13.2 Disposal

In every country there are companies specialized in the proper disposal of electronic waste.

NOTICE!

Each module used in the device is fixed to several specific module type, as oftenly indicated with a label on the backside of the chassis. There are some chances that the modules will be damaged if they are installed in the wrong chassis slot. When removing and replacing modules, it is best to use the label in the chassis as a indicator, so as to make sure each module is installed in the proper slot.

NOTICE!

Strictly observe all local and national regulations when disposing of the device.

14 Connection Diagrams

14.1 Structure drawing of PRS-778(Digital)

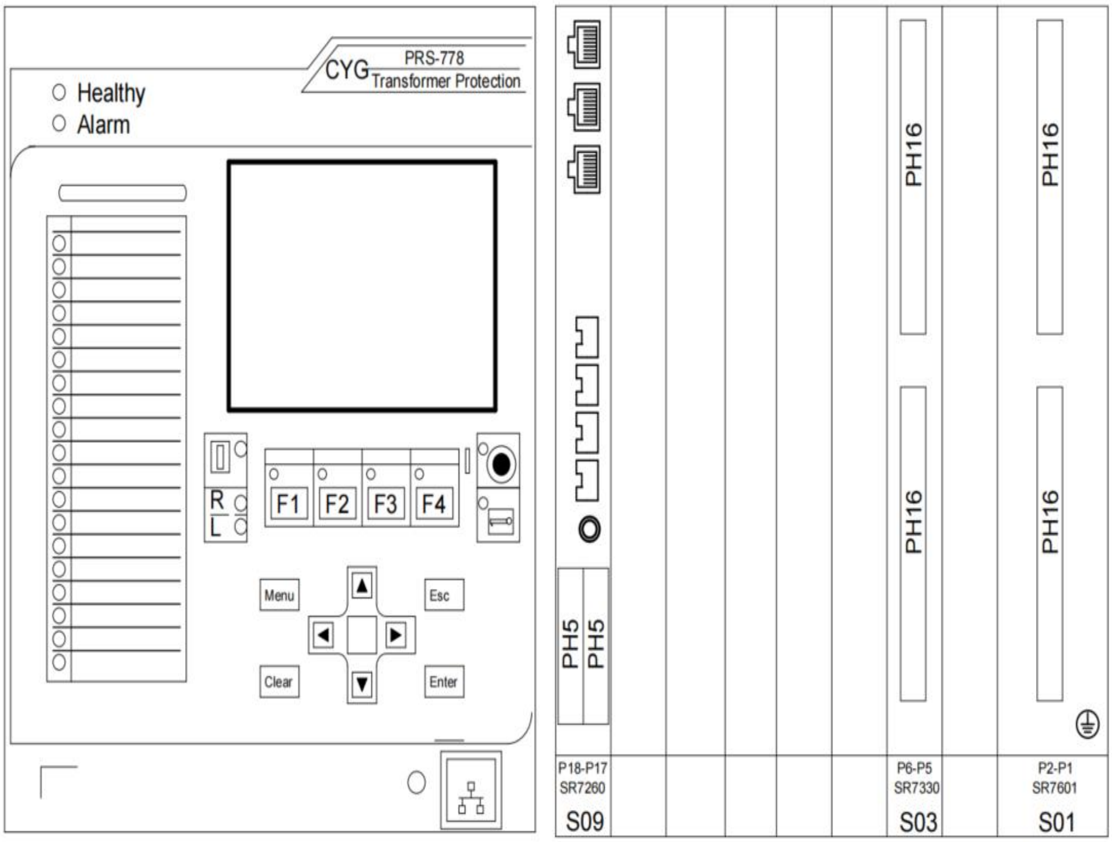


Figure 14.1.1 Drawing of structure

14.2 Modules drawing of PRS-778(Digital)

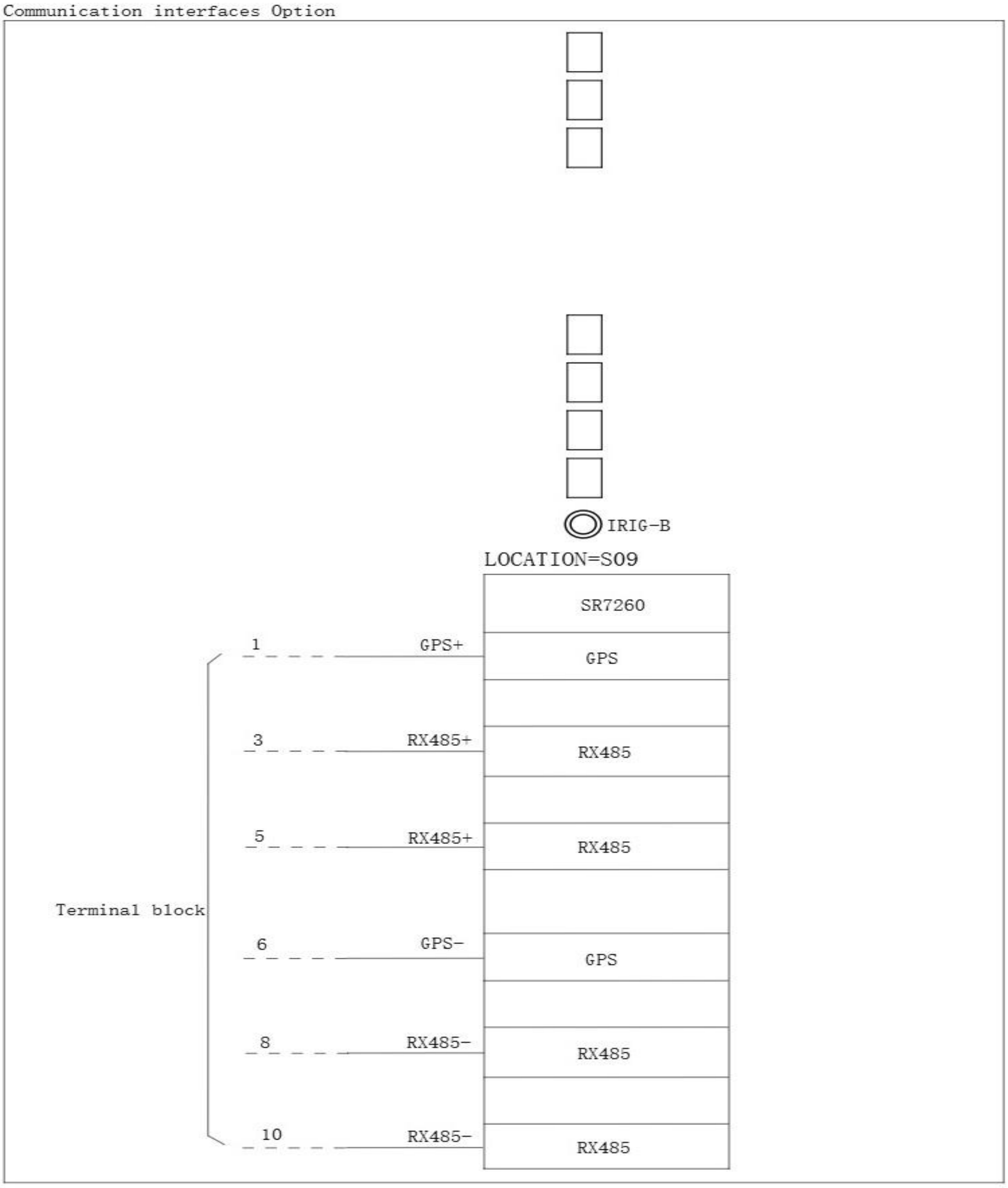


Figure 14.2.1 Communication interfaces: SR7260

14.3 Structure drawing of PRS-778(Three-winding transformer)

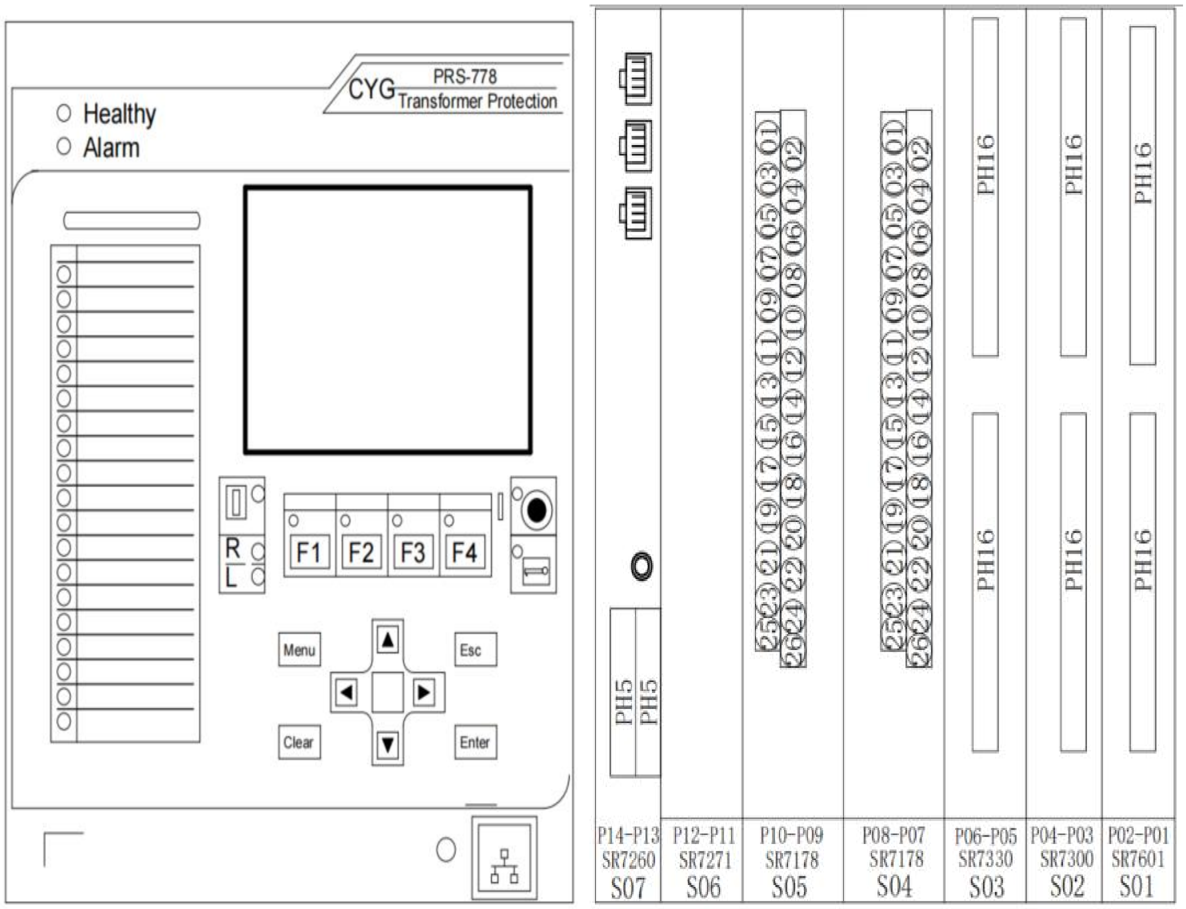


Figure 14.3.1 Drawing of structure

14.4 Modules drawing of PRS-778(Three-winding transformer)

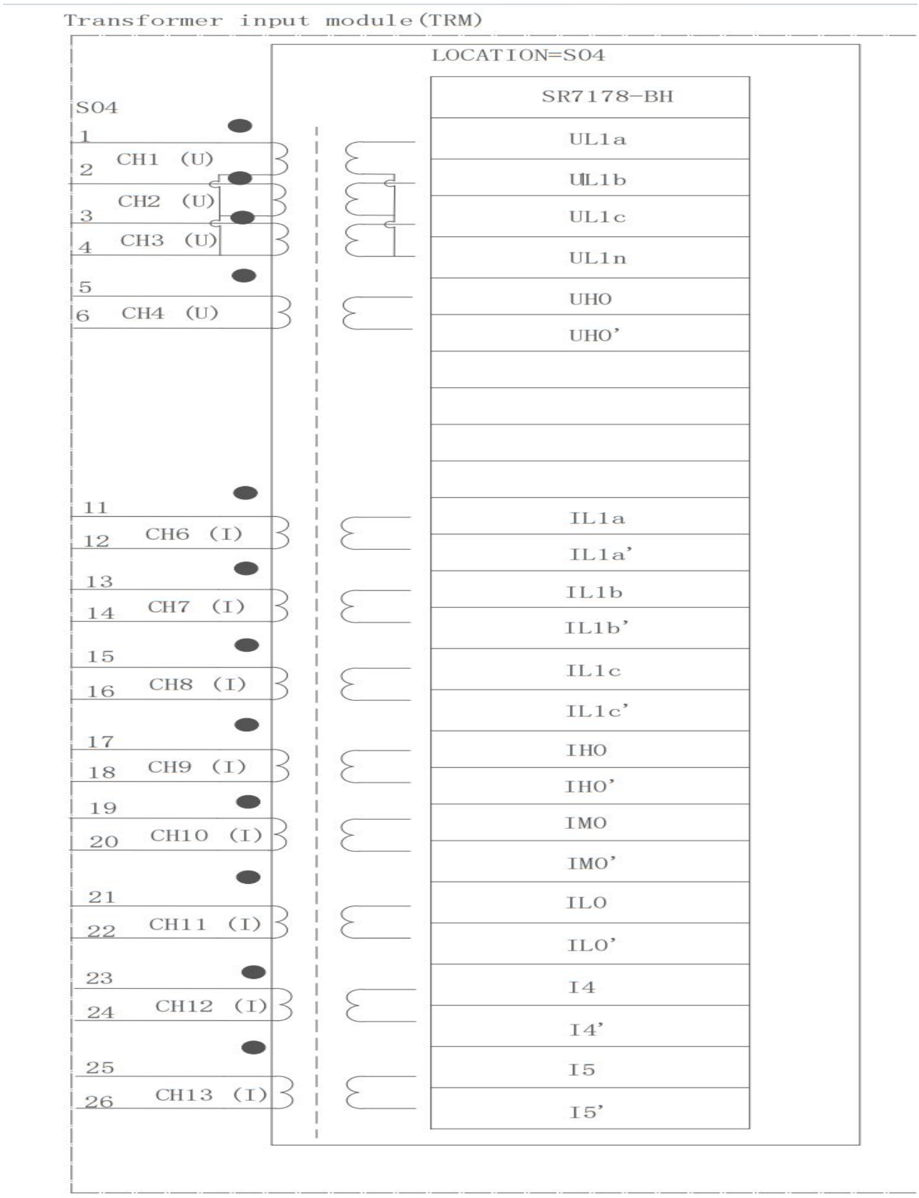


Figure 14.4.1 Transformer input module: SR7178B

Note: in half-case three-winding-transformer configuration, the current channels of I4 and I5 are reserved.

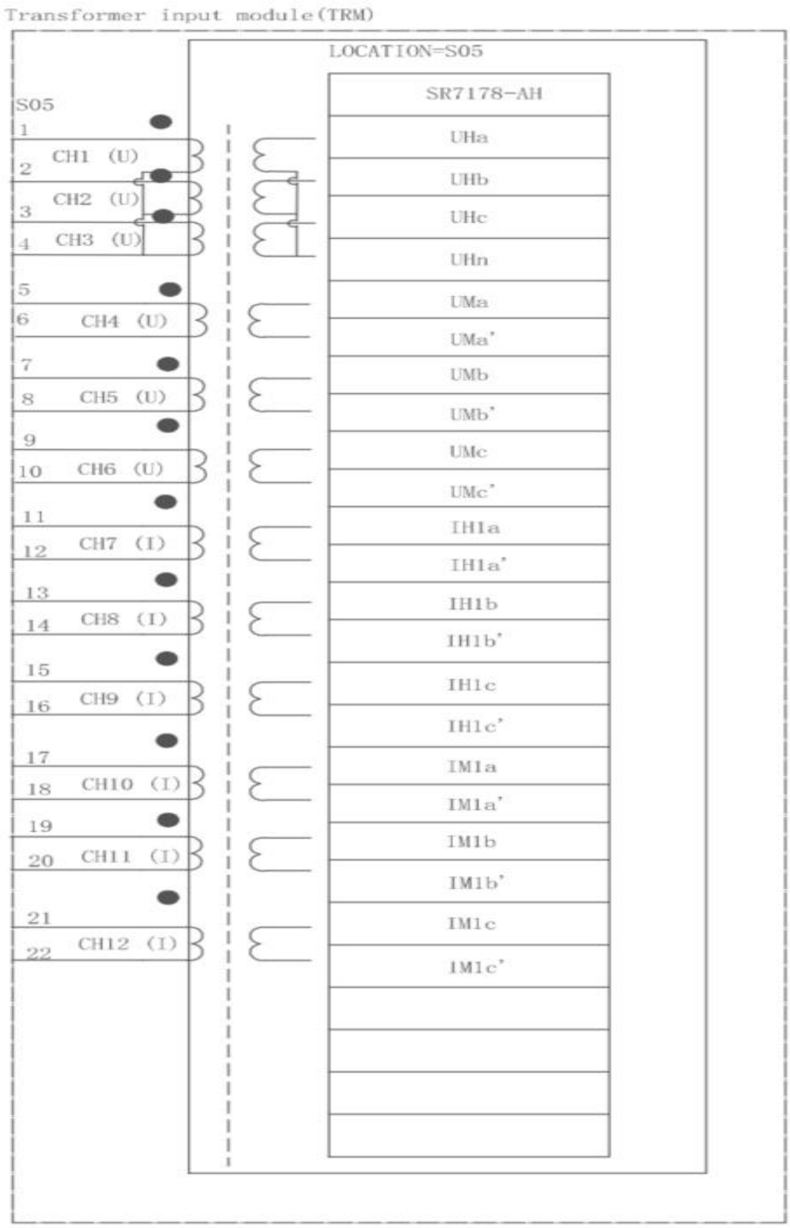


Figure 14.4.2 Transformer input module: SR7178A

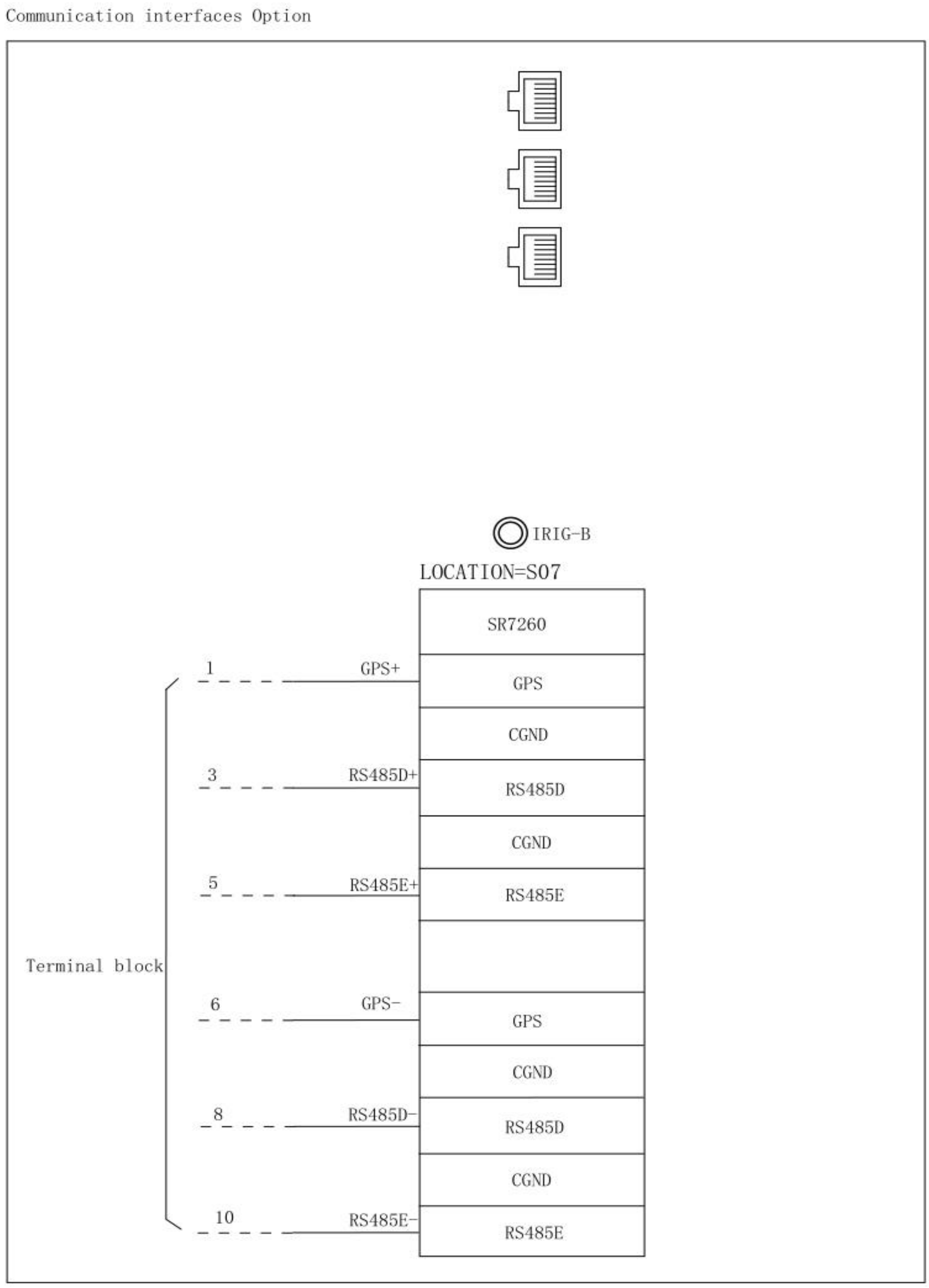


Figure 14.4.3 Communication interfaces: SR7260

14.5 Structure drawing of PRS-778(Transformer + Mechanical IO)

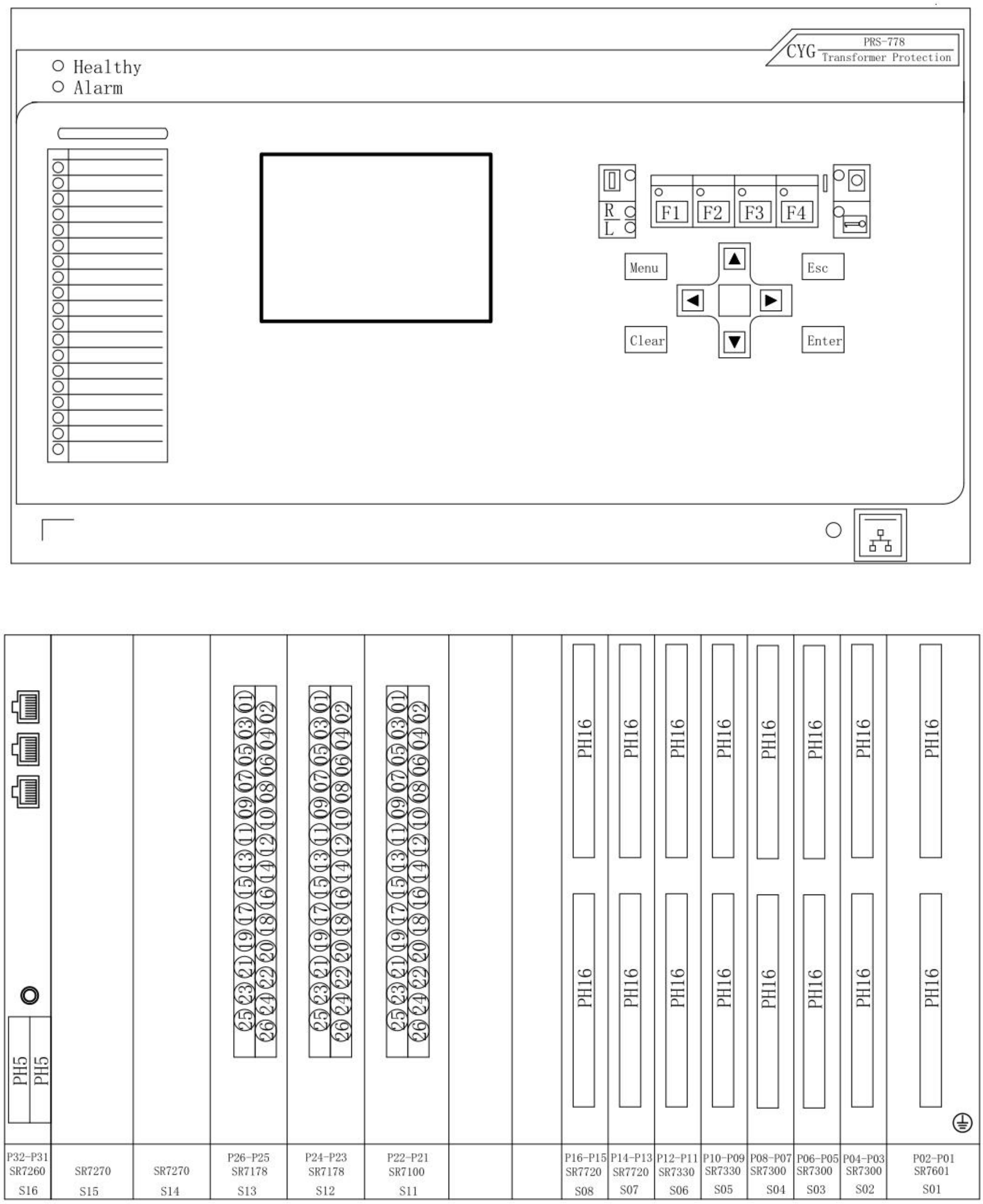
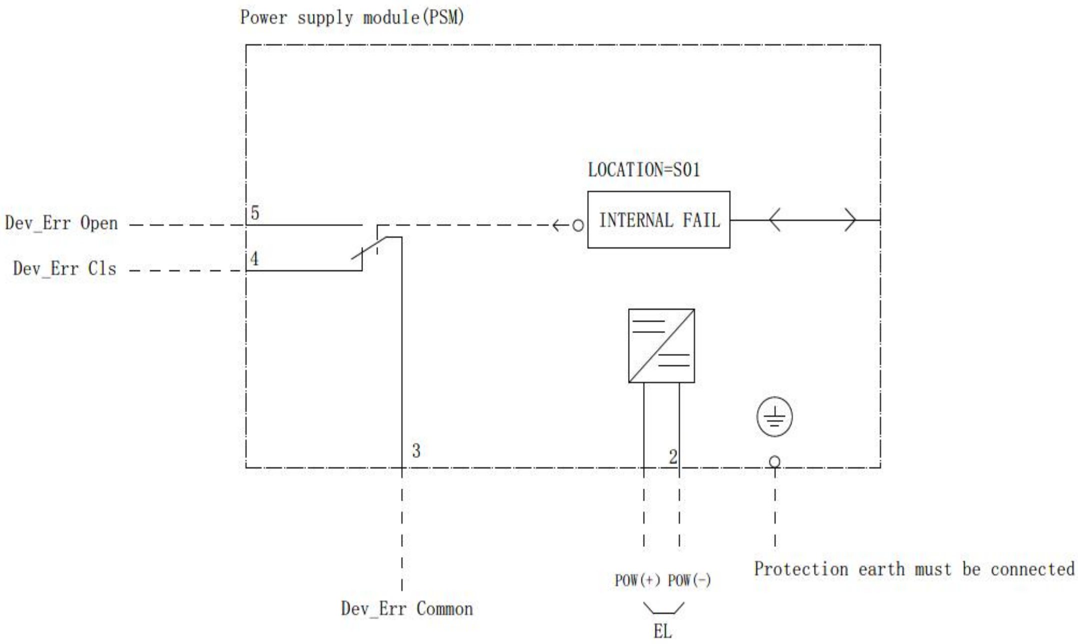
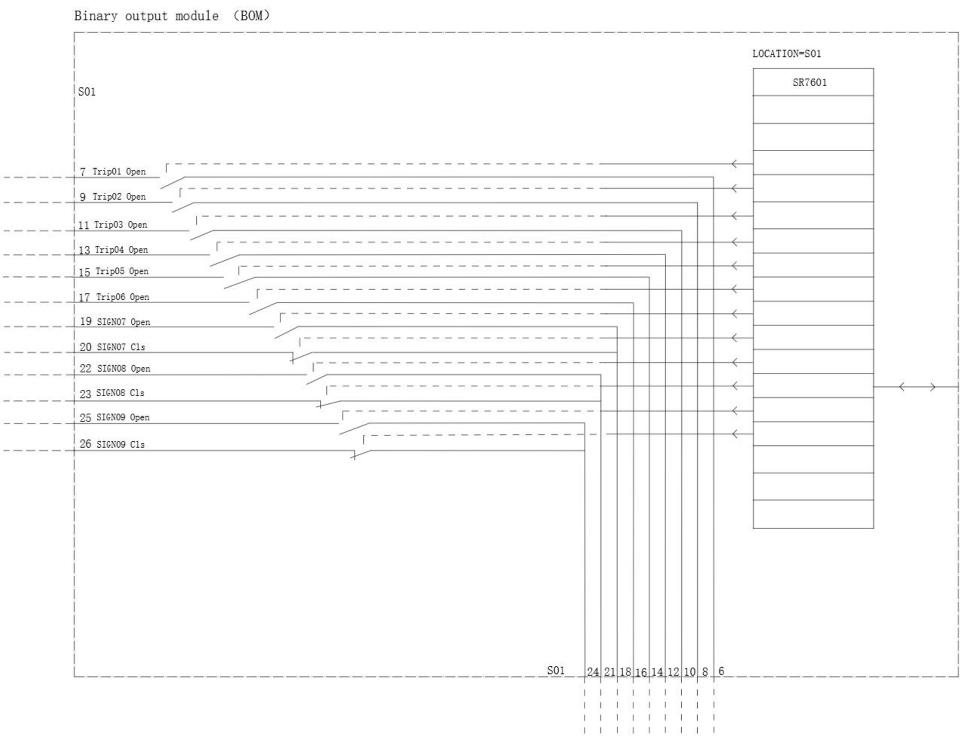


Figure 14.5.1 Drawing of structure

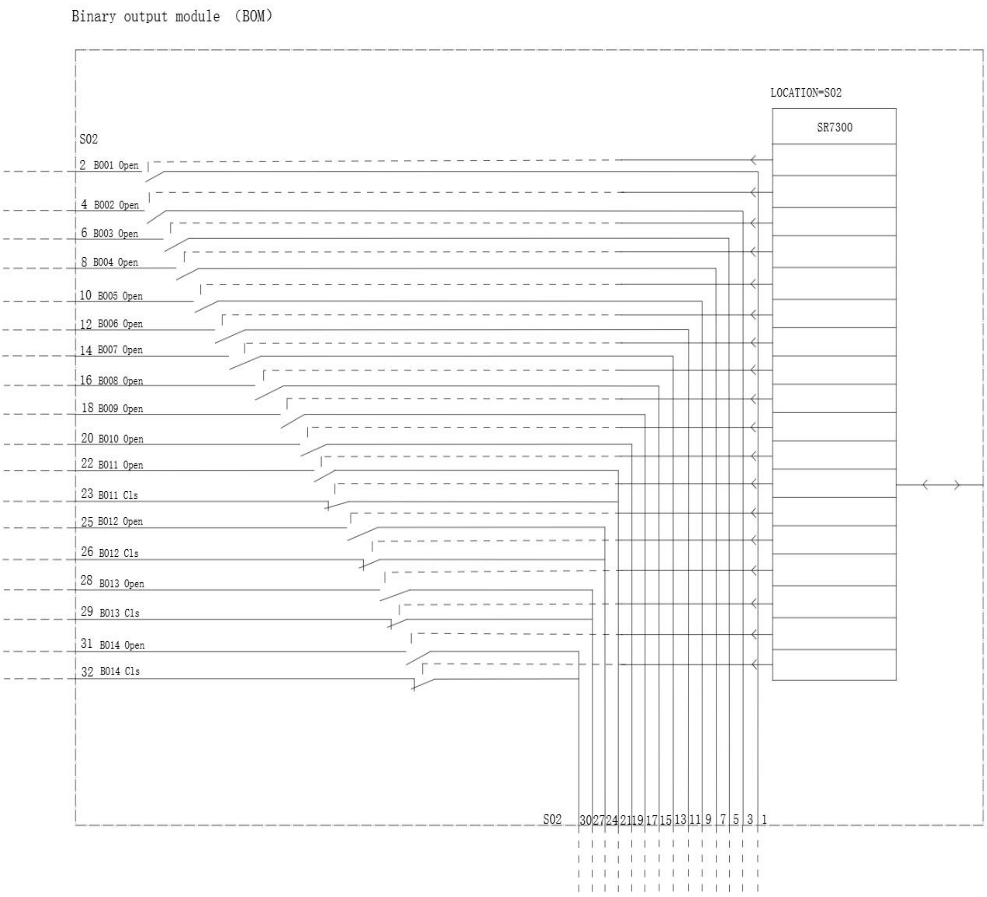
14.6 Modules drawing of PRS-778(Transformer + Mechanical IO)





Designations in correspondance to the location in the rack	
S01=	SR7601
1	PWR+
2	PWR-
3	Dev_err common
4	Dev_err Cls
5	Dev_err Open
6	Trip_H7 com
7	Trip_H7 Open
8	Trip_H8 com
9	Trip_H8 Open
10	Trip_M7 com
11	Trip_M7 Open
12	Trip_M8 com
13	Trip_M8 Open
14	Trip_L7 com
15	Trip_L7 Open
16	Trip_L8 com
17	Trip_L8 Open
18	Sign01 common
19	Sign01 Open
20	Sign01 Cls
21	Sign02 common
22	Sign02 Open
23	Sign02 Cls
24	Sign03 common
25	Sign03 Open
26	Sign03 Cls
27	
28	
29	
30	
31	
32	

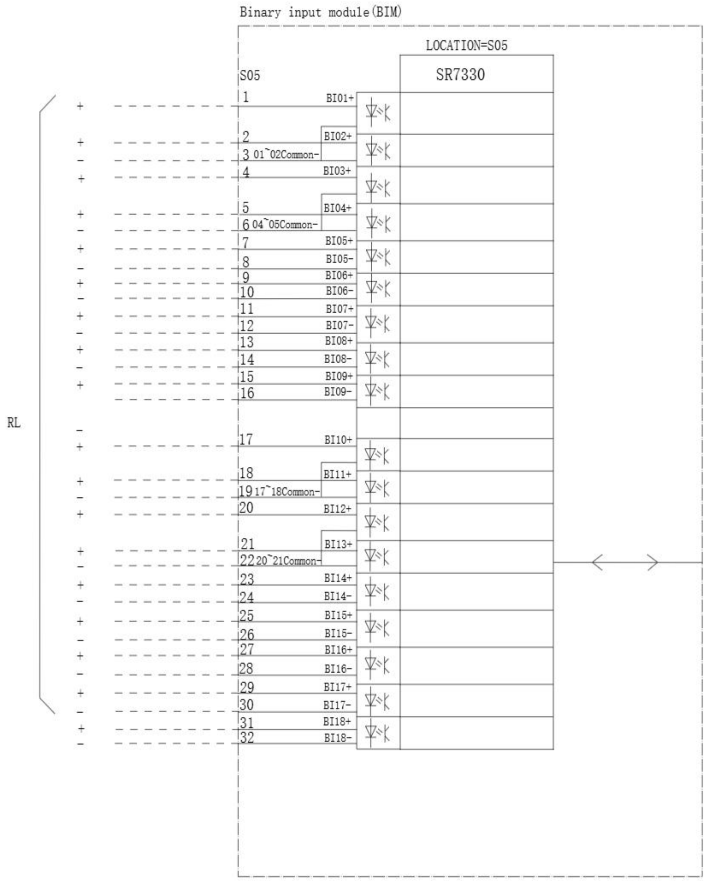
Figure 14.6.1 Power supply module:SR7601



Designations in correspondance to the location in the rack

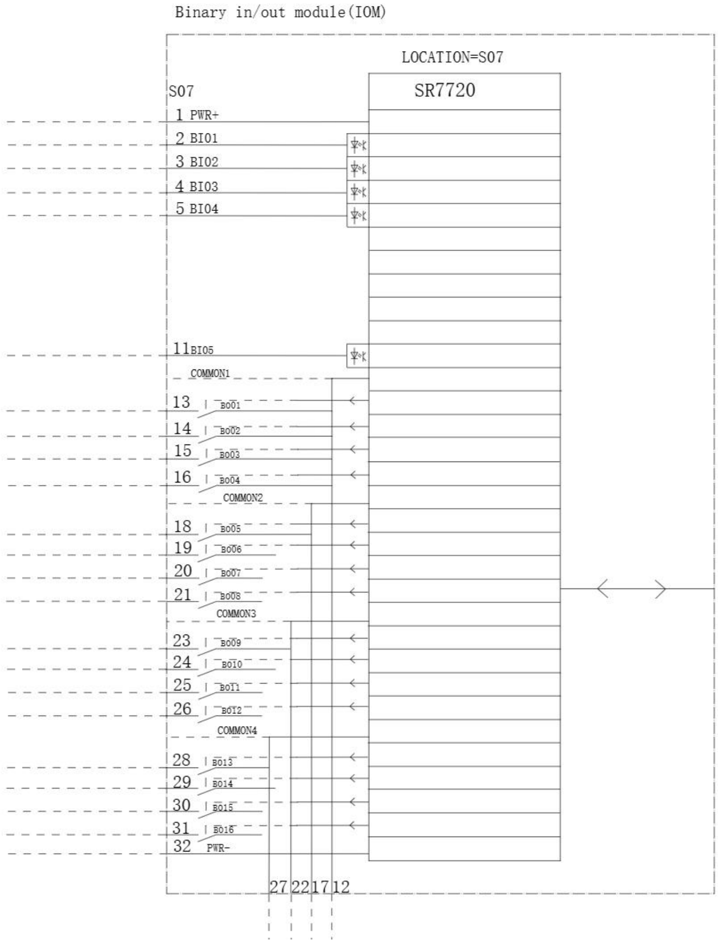
S02=	SR7300
1	Trip_L1 Com
2	Trip_L1 Open
3	Trip_L2 Com
4	Trip_L2 Open
5	Trip_L3 Com
6	Trip_L3 Open
7	Trip_L4 Com
8	Trip_L4 Open
9	Trip_L5 Com
10	Trip_L5 Open
11	Trip_L6 Com
12	Trip_L6 Open
13	Sign 04 Com
14	Sign 04 Open
15	Sign 05 Com
16	Sign 05 Open
17	Sign 06 Com
18	Sign 06 Open
19	Sign 07 Com
20	Sign 07 Open
21	Sign08 Common
22	Sign08 Open
23	Sign08 Cls
24	Sign09 Common
25	Sign09 Open
26	Sign09 Cls
27	Sign10 Common
28	Sign10 Open
29	Sign10 Cls
30	Sign11 Common
31	Sign11 Open
32	Sign11 Cls

Figure 14.6.2 Binary output module: SR7300



Designations in correspondance to the location in the rack	
S05=	SR7330
1	50BF_H+
2	50BF_M+
3	BI19~BI20 Common
4	BI21+
5	BI22+
6	BI21~BI22 Common
7	BI23+
8	BI23-
9	BI24+
10	BI24-
11	BI25+
12	BI25-
13	BI26+
14	BI26-
15	BI27+
16	BI27-
17	BI28+
18	BI29+
19	BI28~BI29 Common
20	BI30+
21	BI31+
22	BI30~BI31 Common
23	BI32+
24	BI32-
25	BI33+
26	BI33+
27	BI34+
28	BI34-
29	BI35+
30	BI35-
31	BI36+
32	BI36-

Figure 14.6.3 Binary input module: SR7330



Designations in correspondance to the location in the rack

S07=	SR7720
1	PWR+
2	MRND_BI01
3	MRND_BI02
4	MRND_BI03
5	MRND_BI04
6	
7	
8	
9	
10	
11	Reset input+
12	MRND_BO_1_COMMON
13	MRND_BO1_1
14	MRND_BO2_1
15	MRND_BO3_1
16	MRND_BO4_1
17	MRND_BO_2_COMMON
18	MRND_BO1_2
19	MRND_BO2_2
20	MRND_BO3_2
21	MRND_BO4_2
22	MRND_BO_3_COMMON
23	MRND_BO1_3
24	MRND_BO2_3
25	MRND_BO3_3
26	MRND_BO4_3
27	MRND_BO_4_COMMON
28	MRND_BO1_4
29	MRND_BO2_4
30	MRND_BO3_4
31	MRND_BO4_4
32	PWR-

Figure 14.6.4 Mechanical IO module: SR7720

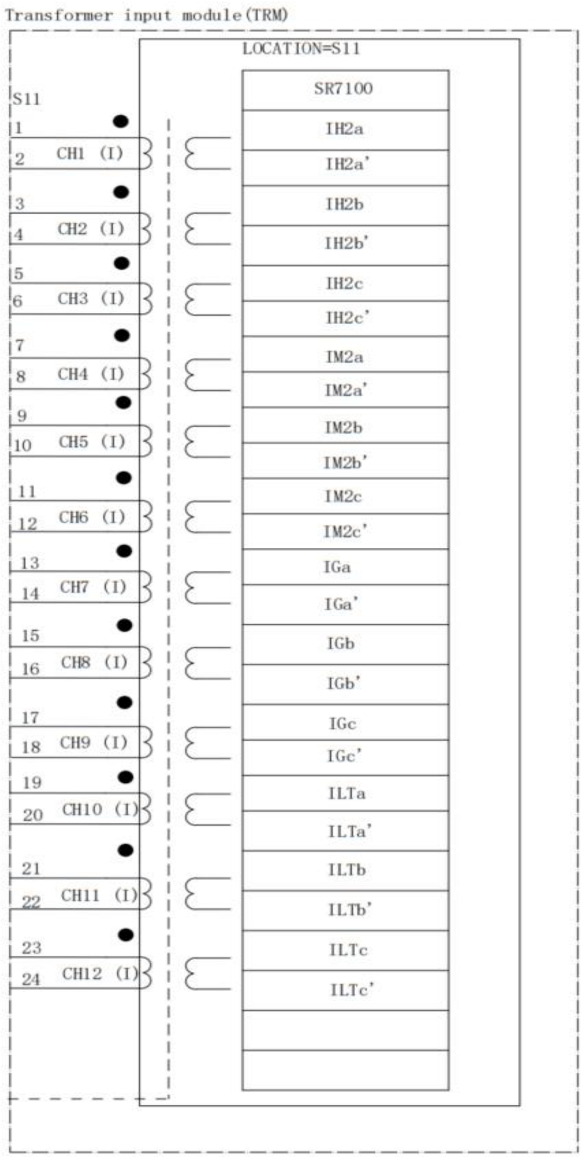


Figure 14.6.5 Transformer input module: SR7100

15 Manual Version History

In the current version of the instruction manual, several descriptions on existing features have been modified.

Table 15- 1Manual version and modification history records

Manual Version		Software Version	Date	Description of change
Source	New			
Beta	1.00	1.00	2014-04-15	Form the original manual.
1.00	1.01	1.01	2015-05-21	Update the number of the binary inputs and binary outputs.. Add the binary input hardware demo diagrams in the binary input tables. Update the description of IEC61850 dual-MMS Ethernet.
1.01	1.02	1.02	2016-01-24	Add parameters of fault location function. Output TEMP_RL is added Internal improvements. Update the configurable signals.
1.02	1.03	1.10	2016-08-16	Update the communication description. Update the mechanical specifications. Update the main CPU module picture. Update the setting list.
1.03	2.01	1.20	2017-12-16	Update all the protection functions. Add the “4.2 Supervision Alarm and Block” chapter Increase the amount of the terminal of BI module. Update the logic diagram of the Three-phase thermal overload protection. Update the content of the “9 Communication Protocol” chapter.
2.01	2.02	2.00	2018-06-09	Update the description of the protection functions. Update the IDMT curves.
2.03	2.03	2.03	2018-08-21	Modify thedrop-off to pickup ratio to 97% Add GPS time synchronization IEEE 1588
2.03	2.03	2.03	2018-09-21	Add chapter 9.6
2.03	2.04	2.03	2024-03-18	Modify the description of hardware. Add Chapter 8.4.and 8.5 Add Chapter 14.