# PRS-778

# TransformerProtection

# Instruction Manual

CYG SUNRI CO., LTD.

# Preface

## User's Guideline

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

Documentationand manufactured equipments purchased fromCYG SUNRI CO., LTD.are dispatched separately due to the necessary manufacturing period.Therefor, 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 carefullyand get a thorough knowledge of the contents of this manual, before conducting any operation to the equipment. In this way, the personnel cangetthe required knowledge in handling electronic equipment.

This manual contains a security chapter whichdescribes 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 processures, 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 direcily touching with the metal parts of the electrical equipment should be avoided when electrical equipment is on operation, because of thepotential electric shock risk. Neglecting warning notices should be prevent because the improperly 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 allowedto 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 theIEDs;
- Have a basic knowledgein 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 maintanence 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 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 Manual Version History

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

# Table of contents

Preface....................i
User's Guideline....................i
Personnel Security....................i
Warning Indications....................ii
Documentation Outline....................iv
Table of contents....................1
1 Briefly Introduction....................11
1.1 Application Scope....................11
1.2 Product Function....................11
1.3 Product Features....................12
2 Technical Specifications....................15
2.1 Electrical Specifications....................15
2.1.1 Current Transformer Ratings....................15
2.1.2 Voltage Transformer Ratings....................15
2.1.3 Auxiliary Power Supply....................15
2.1.4 Binary Input....................15
2.1.5 Binary Output....................16
2.2 Mechanical Specifications....................16
2.3 Ambient Temperature and Humidity Range....................17
2.4 Communication Interfaces....................17
2.4.1 Ethernet Port....................17
2.4.2 Serial Port....................17
2.4.3 Time Synchronization....................18
2.4.4 Ethernet Port for Debugging....................18
2.5 Type Tests....................18
2.5.1 Environmental Tests....................18
2.5.2 Mechanical Tests....................19

2.5.3 Electrical Tests ........ 19

2.5.4 Electromagnetic Compatibility ........ 19

**2.6 Terminals ........ 21**

**2.7 Measurement Range and Accuracy ........ 21**

**2.8 ProtectionFunction Features ........ 21**

2.8.1 Transformer differential protection ........ 21

2.8.2 Impedance Protection ........ 21

2.8.3 Directional Overcurrent Protection ........ 22

2.8.4 Thermal Overload Protection ........ 22

2.8.5 Directional Earth Fault Protection ........ 22

2.8.6 Restricted Earth Fault Protection ........ 22

2.8.7 Non-directional Instantaneous Earth Fault Protection ........ 22

2.8.8 Residual Overvoltage Protection ........ 22

2.8.9 Overvoltage protection ........ 22

2.8.10 Undervoltage Protection ........ 23

2.8.11 Overexcitation Protection ........ 23

2.8.12 Overfrequency protection ........ 23

2.8.13 Underfrequency protection ........ 23

2.8.14 Rate-of-change frequency protection ........ 23

**3 Protection Functions ........ 25**

**3.1 Overview ........ 25**

3.1.1 System Setting ........ 27

**3.2 Transformer Differential Protection (87T) ........ 28**

3.2.1 Overview ........ 28

3.2.2 Protection Principle ........ 31

3.2.3 Logic Diagram ........ 41

3.2.4 Settings ........ 42

**3.3 Distance Protection 21 ........ 43**

3.3.1 Overview ........ 43

3.3.2 Parameters ........ 44

3.3.3 Fault Detector FD ........................................ 45
3.3.4 Mho Distance Protection 21M ........................................ 48
3.3.5 Quadrilateral Distance Protection 21Q ........................................ 54
3.3.6 Power Swing Blocking Releasing PSBR ........................................ 59
**3.4 Directional Overcurrent Protection (67P/50/51) ........................................61**
3.4.1 Overview ........................................ 61
3.4.2 Protection Principle ........................................ 65
3.4.3 Logic Diagram ........................................ 69
3.4.4 Settings ........................................ 69
**3.5 Thermal Overload Protection (49) ........................................75**
3.5.1 Overview ........................................ 75
3.5.2 Logic Diagram ........................................ 76
3.5.3 Protection Principle ........................................ 76
3.5.4 Settings ........................................ 77
**3.6 Earth Fault Protection (67N/50/51N) ........................................78**
3.6.1 Overview ........................................ 78
3.6.2 Protection Principle ........................................ 79
3.6.3 Logic Diagram ........................................ 82
3.6.4 Settings ........................................ 82
**3.7 Restricted Earth Fault Protection (64REF) ........................................87**
3.7.1 Overview ........................................ 87
3.7.2 Protection Principle ........................................ 88
3.7.3 Logic Diagram ........................................ 91
3.7.4 Settings ........................................ 91
**3.8 Winding Differential Protection (87W/N) ........................................92**
3.8.1 Overview ........................................ 92
3.8.2 Protection Principle ........................................ 94
3.8.3 Logic Diagram ........................................ 97
3.8.4 Settings ........................................ 98
**3.9 Non-directional Instantaneous Earth Fault Protection(50N) ........................................99**

3.9.1 Overview ... 99
3.9.2 Protection Principle ... 100
3.9.3 Logic Diagram ... 100
3.9.4 Settings ... 101
**3.10 Breaker Failure Protection (50BF) ... 101**
3.10.1 Overview ... 101
3.10.2 Protection Principle ... 102
3.10.3 Logic Diagram ... 103
3.10.4 Settings ... 103
**3.11 Residual Overvoltage Protection (59N) ... 104**
3.11.1 Overview ... 104
3.11.2 Protection Principle ... 106
3.11.3 Logic Diagram ... 107
3.11.4 Settings ... 107
**3.12 Three-phase overvoltage protection (59P) ... 111**
3.12.1 Overview ... 111
3.12.2 Protection Principle ... 112
3.12.3 Logic Diagram ... 113
3.12.4 Settings ... 114
**3.13 Three-phase Undervoltage Protection (27P) ... 116**
3.13.1 Overview ... 116
3.13.2 Protection Principle ... 117
3.13.3 Logic Diagram ... 119
3.13.4 Settings ... 120
**3.14 Overexcitation Protection (24) ... 122**
3.14.1 Overview ... 122
3.14.2 Protection Principle ... 123
3.14.3 Logic Diagram ... 125
3.14.4 Settings ... 126

**3.15 Overfrequency Protection(81O) ........................................................127**

3.15.1 Overview ........................................................................................................ 127

3.15.2 Protection Principle ........................................................................................ 129

3.15.3 Logic Diagram ................................................................................................ 129

3.15.4 Settings .......................................................................................................... 130

**3.16 Underfrequency Protection(81U) ...................................................................131**

3.16.1 Overview ........................................................................................................ 131

3.16.2 Protection Principle ........................................................................................ 132

3.16.3 Logic Diagram ................................................................................................ 133

3.16.4 Settings .......................................................................................................... 133

**3.17 Rate-of-change of frequency protection (81R)..............................................134**

3.17.1 Overview ........................................................................................................ 134

3.17.2 Protection Principle ........................................................................................ 135

3.17.3 Logic Diagram ................................................................................................ 136

3.17.4 Settings .......................................................................................................... 136

**3.18 Reactor differential protection (87R) ...........................................................136**

3.18.1 Overview ........................................................................................................ 136

3.18.2 Protection Principle ........................................................................................ 138

3.18.3 Logic Diagram ................................................................................................ 143

3.18.4 Settings .......................................................................................................... 143

**3.19 Reactor zero-sequence differential protection (87N) ...................................145**

3.19.1 Overview ........................................................................................................ 145

3.19.2 Protection Principle ........................................................................................ 145

3.19.3 Logic Diagram ................................................................................................ 148

3.19.4 Settings .......................................................................................................... 148

**3.20 Reactor interturn Protection (21IT) ..............................................................149**

3.20.1 Overview ........................................................................................................ 149

3.20.2 Protection Principle ........................................................................................ 150

3.20.3 Logic Diagram ................................................................................................ 152

3.20.4 Settings ........ 152

**3.21 Out-of-Step Protection 78O ........ 153**

3.21.1 Overview ........ 153

3.21.2 Protection Principle ........ 154

3.21.3 Logic ........ 158

3.21.4 Settings ........ 160

**3.22 Mechanical Relay Protection (MR) ........ 161**

3.22.1 Overview ........ 161

3.22.2 Protection Principle ........ 162

3.22.3 Settings ........ 163

**4 Supervision ........ 164**

**4.1 Overview ........ 164**

**4.2 Supervision Alarm and Block ........ 164**

**4.3 Current circuit supervision(CTS) ........ 166**

4.3.1 Overview ........ 166

4.3.2 Logic Diagram ........ 167

4.3.3 Protection Principle ........ 167

**4.4 Reactor Current circuit supervision(CTS) ........ 168**

4.4.1 Overview ........ 168

4.4.2 Logic Diagram ........ 169

4.4.3 Protection Principle ........ 169

**4.5 Fuse failure supervision(VTS) ........ 169**

4.5.1 Overview ........ 169

4.5.2 Logic Diagram ........ 171

4.5.3 Protection Principle ........ 171

**4.6 Reactor Fuse failure supervision(VTS) ........ 171**

4.6.1 Overview ........ 171

4.6.2 Logic Diagram ........ 172

4.6.3 Protection Principle ........ 172

5 Monitoring&Control ........ 173
5.1 Overview........ 173
5.2 Measurement ........ 173
5.2.1 Protection Sampling........ 173
5.2.2 Metering ........ 173
5.3 Apparatus Control ........ 174
5.4 Signaling ........ 174
5.5 Event Recording ........ 175
5.6 Fault and Disturbance Recording ........ 175
6 IED Hardware ........ 177
6.1 Overview........ 177
6.2 Hardware Module........ 180
6.3 Human Machine Interface Module........ 181
6.4 Power Supply Module ........ 181
6.5 Main CPU Module ........ 183
6.6 AD module........ 185
6.7 Transformer Module ........ 185
6.8 Binary Input Module ........ 188
6.9 Binary Output Module ........ 190
6.10 Binary Input/Output Module ........ 192
6.11 MR Plug-in Module (Mechanical Relay Input/Output) ........ 194
7 HUMAN MACHINE INTERFACE ........ 196
7.1 Overview........ 196
7.1.1 Design Structure ........ 196
7.1.2 Function mode ........ 197
7.1.3 Operating panel keypad and keys ........ 197
7.1.4 Indication of LED ........ 198
7.1.5 Configurable keys ........ 200
7.2 LCD Diplay description of HMI ........ 201
7.2.1 Oiverview ........ 201

7.2.2 Normal display structure of LCD........ 201
7.2.3 Main menu display........ 202
**7.3 Sub menu functions of main menu........203**
7.3.1 Physical Information........ 203
7.3.2 Review Information........ 205
7.3.3 Monitoring Information........ 209
7.3.4 Event Information........ 212
7.3.5 Record Information........ 217
7.3.6 Setting Information........ 218
7.3.7 Configuration Information........ 221
7.3.8 Test Information........ 224
7.3.9 Clear Information........ 227
7.3.10 Language Information........ 228
**8 Configurable Function........230**
**8.1 General Description........230**
**8.2 Introduction of PRS IED StudioSoftware........230**
**9 Communication Protocol........230**
**9.1 Overview........230**
**9.2 Rear Communication Interface........230**
9.2.1 Ethernet Interface........ 230
**9.3 Network Topoloty........231**
9.3.1 Star Topology........ 231
9.3.2 PRP Topology........ 231
9.3.3 RSTP Topology........ 231
**9.4 IEC61850Protocol........231**
9.4.1 Overview........ 231
9.4.2 Communication Profiles........ 232
9.4.3 Data set and control block........ 236
9.4.4 Logic nodes and data modeling........ 238
**9.5 DNP3.0 Protocol........240**

9.5.1 Overview ........ 240
9.5.2 Link Layer Functions ........ 240
9.5.3 Transport Functions ........ 240
9.5.4 Application Layer Functions ........ 240
**9.6 IEEE 1588-2008 Protocol ........ 242**
9.6.1 Overview ........ 242
9.6.2 Time Synchronization ........ 242
**10 Commissioning ........ 243**
**10.1 General ........ 243**
**10.2 Safety Instructions ........ 243**
10.2.1 Safety Identification ........ 243
10.2.2 Safety Identification Examples ........ 243
**10.3 Commission Tools ........ 245**
10.3.1 Instrumentation and Meters Notice: ........ 245
10.3.2 Tools Requirement: ........ 245
**10.4 Commission Preparation ........ 245**
10.4.1 Basic Knowledge ........ 245
10.4.2 Operation Preparation ........ 246
**10.5 Product Checks ........ 246**
10.5.1 Document Check ........ 246
10.5.2 Appearance Inspection ........ 246
10.5.3 Insulation Check ........ 247
10.5.4 External Wiring Check ........ 247
10.5.5 Test Category ........ 247
**10.6 With the Relay Energized ........ 248**
10.6.1 LCD Display Check ........ 248
10.6.2 Date and Time ........ 248
10.6.3 Light Emitting Diodes (LEDs) ........ 248
10.6.4 Test the AC Current Circuit ........ 249
10.6.5 Test the AC Voltage Inputs ........ 250

10.6.6 Test the Binary Inputs ........ 251

10.6.7 Test the Binary Onputs ........ 251

10.6.8 Protection Function Checks ........ 251

10.6.9 Printing Function Checks ........ 251

10.6.10 On-load Checks ........ 251

10.6.11 Final Checks ........ 252

**11 Installation ........ 253**

**11.1 General ........ 253**

**11.2 Safety Instructions ........ 253**

**11.3 Checking the Shipment ........ 253**

**11.4 Material and Tools Required ........ 254**

**11.5 Device Location and Ambient Conditions ........ 254**

**11.6 Mechanical Installation ........ 255**

**11.7 Electrical Installation and Wiring ........ 257**

11.7.1 TACircuit Connection ........ 257

11.7.2 Power Supply, VT, BI and BO, Signal Wiring ........ 257

11.7.3 Grounding ........ 258

11.7.4 Shielded cable connection ........ 258

11.7.5 Install the optical cable ........ 258

11.7.6 Install the communication cable ........ 258

**11.8 Installationcheck ........ 259**

11.8.1 Checktheinstallation ........ 259

11.8.2 Confirm the hardware and software version ........ 259

11.8.3 Devicestart ........ 259

**12 Maintenance ........ 261**

**12.1 Maintenance General ........ 261**

**12.2 Regular Testing ........ 261**

**12.3 Failure Maintenance ........ 261**

12.3.1 Hardware Failure ........ 261

12.3.2 Software Failure ........ 262

**12.4 Replace Failed Modules ......................................................................262**

**13 Decommissioning and Disposal ............................................ 263**

**13.1 Decommissioning..........................................................................263**

13.1.1 Switching off.......................................................................................... 263

13.1.2 Disconnecting cables............................................................................ 263

13.1.3 Dismantling ........................................................................................... 263

**13.2 Disposal...........................................................................................263**

**14 Manual Version History ....................................................... 267**

# 1 Briefly Introduction

1.1

## 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, autotransformers, 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 digitalized 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 |

| Description | IEC 60617 | ANSI | CYG Code |
|---|---|---|---|
| Winding Differential Protection | 3Id/I | 87W | 87W |
| MhoImpedance 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 | 67N |
| Restricted Earth Fault protection | IdN/I | 87NL | 64REF |
| Non-directional Instantaneous earth fault protection | IN>> | 50N | 50N |
| Breaker Failure Protection | 3I0><br>I> | 50BF | 50BF |
| Threestage residual overvoltage protection | 3U0 | 59N | 59N |
| 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 |

## 1.3 Product Features

1.5

- 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 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.. 2.11

- 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 40-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, IEEE1588,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 20 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: thernet network, RS-485 serial ports. The communication protocol of this device is optional: IEC61850, IEC60870-5-103, DNP3.0 or ModBus.
- 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: 64 latest protection operation reports, 1024 latest supervision records, 1024 latest control operation records, 1024 latest user operation records and 1024 latest records of time tagged sequence of event (SOE) can be recorded.
- Powerful fault and disturbance recording function is supported: 64 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) | | 1/5A |
| 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；<br>40%Un,200ms；<br>70%Un,500ms<br>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 supply | 1/2 19” Case: | ≤20W (normal state)<br>≤35W (maximum state) |
| | 1/1 19” Case: | ≤30W (normal state)<br>≤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<br>1/1 19” Case:Up to 36 |
| Rated voltage | 24VDC~250VDC, 64VAC~250VAC |
| 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

2.4

| | | |
|---|---|---|
| Reference | IEC 60255-1 | |
| Item | Tripping output | Signal output |
| Binary output number | 1/2 19” Case:Up to 12<br>1/1 19” Case:Up to 48 | 1/2 19” Case:Up to 11<br>1/1 19” Case:Up to 54 |
| 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；<br>10A @ 250Vd | 5.0A @ 380Vac；<br>5.0A @ 250Vdc |
| Short duration current | 30A, 3s<br>50A, 1s | 30A, 1s |
| Breaking capacity | 1.00A @ 48Vdc, L/R=40ms<br>0.35A @ 110Vdc, L/R=40ms<br>0.30A @ 125Vdc, L/R=40ms<br>0.20A @ 220Vdc, L/R=40ms<br>0.15A @ 250Vdc, L/R=40ms | 0.60A @ 48Vdc, L/R=40ms<br>0.10A @ 110Vdc, L/R=40ms<br>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)<br>1/1 19” Case: Approx.19.5kg (fully equipped) |
| Merchanical size (width×high×deepth) | 1/2 19” Case: 260mm*266 mm *217.7 mm<br>1/1 19” Case:482.6mm*266 mm *217.7 mm |
| Hole size (width×high) | 1/2 19” Case:227 mm *267 mm<br>1/1 19” Case: 450 mm *267 mm |
| Display language | Optional: Chinese, English |
| Housing material | Metallic plates, parts and screws: Steel<br>Plastic parts: Polycarbonate |
| Housing color | Silver grey |
| Location of terminal | Rear panel of the device |

2.8

| | | |
|---|---|---|
| Protection class | IEC60225-1: 2009 | Front side:IP40 (IP52 with seal strip)<br>Rear side, connection terminals: IP20<br>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~~ 2.7 |
| Damp heat steady | +40℃ 93%humidity 16h 2.10 |
| Damp-heat test, cyclic | 6 cycles, +25℃ to +55℃, Humidity 97% to 93% |

## 2.4 Communication Interfaces

### 2.4.1 Ethernet Port

| 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 reqired)** | | | |
| **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 +Verifcation of function | IEC 60255-27,Clause10.5.1.5 IEC 60255-1,Clause | +40℃ 93%humidity |

| | | |
|---|---|---|
| &dielectric (10 days） | 6.12.3.6<br>IEC 60068-2-78 | |
| 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<br>+Verifcation of function | IEC 60255-21-3<br>IEC 60255-1, Clause 6.13.3 | 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, Binary Input / Output: 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; 15kHz~150kHz:30 constant |
| 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 (Quasi Peak: 79µV, Avg: 66µV), Frequency range: 0.5MHz – 30MHz (Quasi Peak: 73µV, Avg: 60µV)； |

| | | |
|---|---|---|
| Radiated interference | IEC 60255-26, CISPR 22 | Radiated Emission Limit on Enclosure Port： Frequency range: 30MHz - 230MHz (Quasi Peak: 40µV), Frequency range: 230MHz - 1000MHz (Quasi Peak: 47µV) |

## 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

1.11

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

## 2.8 ProtectionFunction Features

### 2.8.1 Transformer differential protection

#### 2.8.1.1 Biased Differential Protection

| | |
|---|---|
| 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)<br>60Hz: ≤ 25ms (Id>2 times current setting) |

#### 2.8.1.2 Instantaneous Differential Protection

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

### 2.8.2 Impedance Protection

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

### 2.8.3 Directional Overcurrent Protection

| | |
|---|---|
| Accuracy | ≤ 2.5% Setting or 0.02In, whichever is greater |
| Resetting ratio | 98% |
| Time delayaccuracy (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) |

### 2.8.4 Thermal Overload Protection

| | |
|---|---|
| Accuracy | ≤ 2.5% Setting or 0.02In, whichever is greater |
| Resetting 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) |

### 2.8.5 Directional Earth Fault Protection

| | |
|---|---|
| Accuracy | ≤ 2.5% Setting or 0.02In, whichever is greater |
| Resetting ratio | 98% |
| Time delayaccuracy (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) |

### 2.8.6 Restricted Earth Fault Protection

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

### 2.8.7 Non-directional Instantaneous Earth Fault Protection

| | |
|---|---|
| Accuracy | ≤ 2.5% Setting or 0.02In, whichever is greater |
| Resetting ratio | 98% |

### 2.8.8 Residual Overvoltage Protection

| | |
|---|---|
| Accuracy | ≤ 2.5% Setting or 0.01Un, whichever is greater |
| Resetting ratio | 98% |
| Time delayaccuracy (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) |

### 2.8.9 Overvoltage protection

| | |
|---|---|
| Accuracy | ≤ 2.5% Setting or 0.01Un, whichever is greater |

| | |
|---|---|
| Resetting ratio | 98% |
| Time delayaccuracy (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 Undervoltage Protection

| | |
|---|---|
| Accuracy | ≤ 2.5% Setting or 0.01Un, whichever is greater |
| Resetting ratio | 102% |
| Time delayaccuracy (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) |

## 2.8.11 Overexcitation Protection

| | |
|---|---|
| Multiple setting of definitetime | 1.0~1.6 |
| Multiple setting of inversetime | 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) |
| Time delay setting | 0.1~9999 (s) |
| Tolerance of time setting | ≤1% of setting +30ms (at 2 times setting) |
| Drop-off time | ≤30ms |

## 2.8.12 Overfrequency protection

| | |
|---|---|
| Accuracy | ≤0.02Hz |
| Time delayaccuracy | ≤1%Setting+30ms (at 1.2 times frequency setting) |

## 2.8.13 Underfrequency protection

| | |
|---|---|
| Accuracy | ≤0.02Hz |
| Time delayaccuracy | ≤1%Setting+30ms (at 0.8 times frequency setting) |

## 2.8.14 Rate-of-change frequency protection

| | |
|---|---|
| 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 golssary 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 |
| | Impedence | Imp |
| | Reactance | React |

| Category | Profession Vocabulary | Abbreviation |
| --- | --- | --- |
| | Induction | Induct |
| | 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 |

| Category | Profession Vocabulary | Abbreviation |
|---|---|---|
| | Error | Err |
| | 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<br>0: Y Type<br>1:△Type |
| 6 | Phi_MV | 0~11 | | 1 | 0 | Clock connection at MV side |
| 7 | Phi_LV | 0~11 | | 1 | 11 | Clock connection at LV side |
| 8 | VT1n_HV | 0.1~1200 | V | 0.01 | 110 | Primary value of VT at HV side |
| 9 | VT1n_MV | 0.1~1200 | V | 0.01 | 35 | Primary value of VT at MV side |
| 10 | VT1n_LV | 0.1~1200 | V | 0.01 | 10 | Primary value of VT at LV side |
| 11 | VT2n | 30~300 | V | 0.01 | 100 | Secondary value of VT |
| 12 | I1n_H1V | 0~12000 | 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 |

| NO | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 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 | I2n_H1V | 1 or 5 | A | 4 | 1 | Secondary value of CT at H1V side |
| 19 | I2n_H2V | 1 or 5 | A | 4 | 1 | Secondary value of CT at H2V side |
| 20 | I2n_M1V | 1 or 5 | A | 4 | 1 | Secondary value of CT at M1V side |
| 21 | I2n_M2V | 1 or 5 | A | 4 | 1 | Secondary value of CT at M2V side |
| 22 | I2n_L1V | 1 or 5 | A | 4 | 1 | Secondary value of CT at L1V side |
| 23 | I2n_L2V | 1 or 5 | A | 4 | 1 | Secondary value of CT at L2V side |
| 24 | I1n_HVN | 0~12000 | A | 1 | 1200 | Primary value of zero-sequence CT at HV side |
| 25 | I1n_MVN | 0~12000 | A | 1 | 2000 | Primary value of zero-sequence CT at MV side |
| 26 | I1n_LVN | 0~12000 | A | 1 | 4000 | Primary value of zero-sequence CT at LV side |
| 27 | I2n_HVN | 1 or 5 | A | 4 | 1 | Secondary value of zero-sequence CT at HV side |
| 28 | I2n_MVN | 1 or 5 | A | 4 | 1 | Secondary value of zero-sequence CT at MV side |
| 29 | I2n_LVN | 1 or 5 | A | 4 | 1 | Secondary value of zero-sequence CT at LV side |
| 30 | I0_Rem_LV_En | 0,1 | | 1 | 0 | Whether theZero sequence current is filtered off the low voltage side<br>0: disable<br>1: enable |

Example for Connection Scheme：

1）If the project uses Yyd-11.The setting Phi_HV=0,Phi_MV=12,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=12,Phi_LV=11；

## 3.2 Transformer Differential Protection (87T)

3.1

### 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:

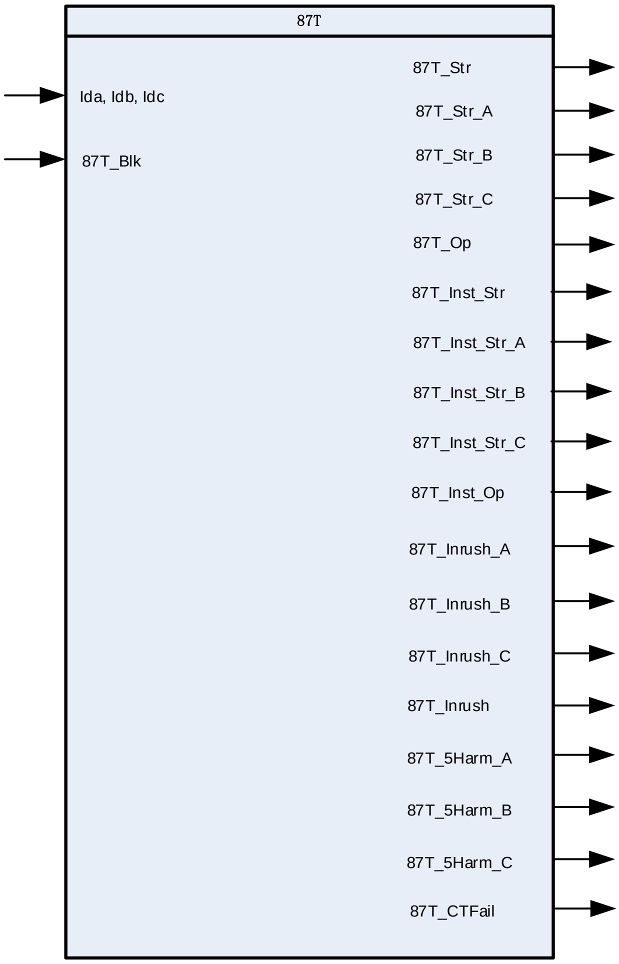
- Meticulousphase compensation IED calculation criteria.
- Accurate and fast fault tracking capability.
- Inrush current distinguish operating principle.
- Special capability to detect overexcitation condition of transformer.

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 pretection 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 3.2-187T Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Ida, Idb, Idc | Three phase differential current of 87T |
| 2 | 87T_Blk | Block signal of 87T |

**Table 3.2-287T Output Signals**

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

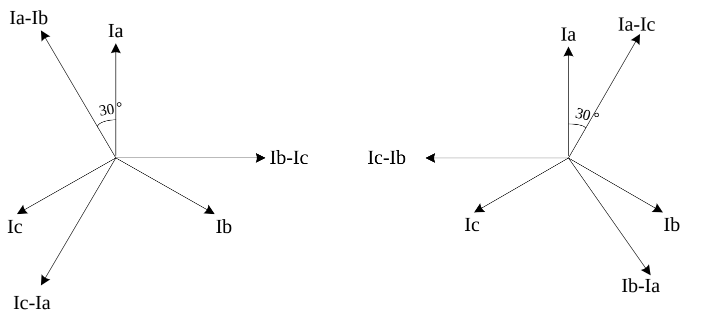
| NO. | Signal | Description |
|---|---|---|
| 7 | 87T_Inst_Str_A | Start_A signal of instantaneous differential from 87T |
| 8 | 87T_Inst_Str_B | Start_B signal of instantaneous differential from 87T |
| 9 | 87T_Inst_Str_C | Start_C signal of instantaneous differential from 87T |
| 10 | 87T_ Inst_Op | 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_CTFail | CT failsignal 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. Busbar 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<br>Ibc=Ib-Ic<br>Ica=Ic-Ia | Iac=Ia-Ic<br>Iba=Ib-Ia<br>Icb=Ic-Ib |

**Figure 3.2-111 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:

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

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

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

**Table3.3-3 Matrixofphasecompensation**

| | |
|---|---|
| **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.

### 3.2.2.3 Fault detector based on biased differential current

The fault detector can initiate biased differential element, and its operation equation is shownas 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 shownas 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:

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

***Where:***

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

IdA, IdB, IdC are differential currents.

IrA, IrB, IrC 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 shortcircuits outside the protected area, the large currents fed by the transformer inmotor startup or the transformer inrush situations.

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

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

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

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

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

***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.

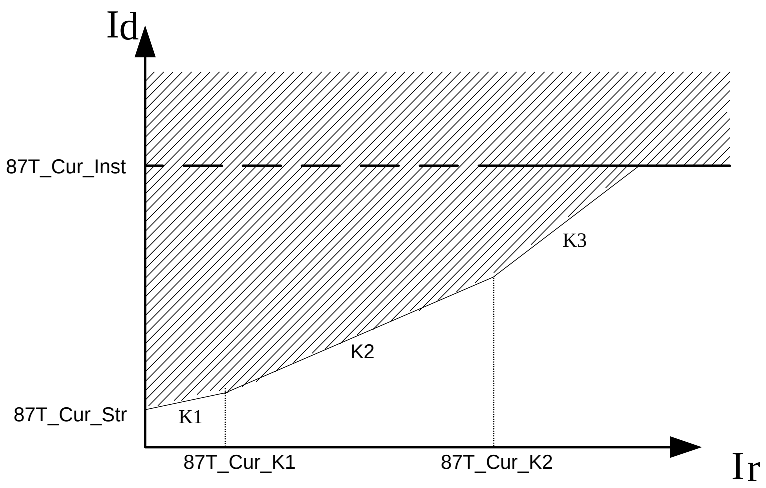



**Figure 3.2-2 Operation characteristic of differential protection**

### 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 biasedand has no blocking element. Instantaneoushigh 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; $K_{2xb}$ 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 inrushing 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 ofcharginga 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 trippingeven large inrush current is generated. In case that a faulty transformer withoutany loadis switched on, split-phase restraint mode would be automatically activated. The split-phase restraint modeensures 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 basicallydisplays 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:

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

***Where:***

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

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

$k_b$ iswaveform asymmetry coefficient. $I'_i$ represents the numerical value of differential current derivative at some certain point of first-half wave, while $I'_{i+\frac{T}{2}}$ 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.

### 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.Theequation 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 Overexcitation Detection

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

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

***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 overexcitation 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.

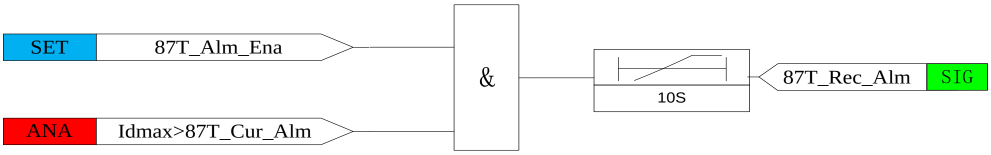



**Figure 3.2-3Differential CT Circuit Abnormality**

#### 3.2.2.12 Differential CT circuitfailure

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 CTcircuit 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** | $\leq 0.08In$ | $\geq In$ |

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 bysetting.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 failureis 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

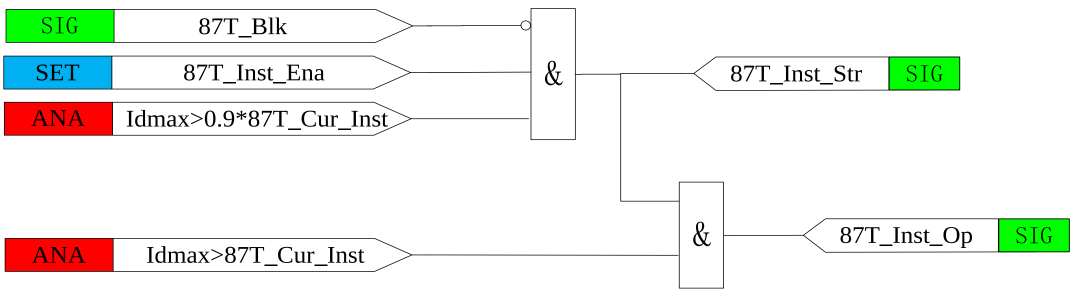



**Figure 3.2-4 Logic diagram of 87T_Inst protection**

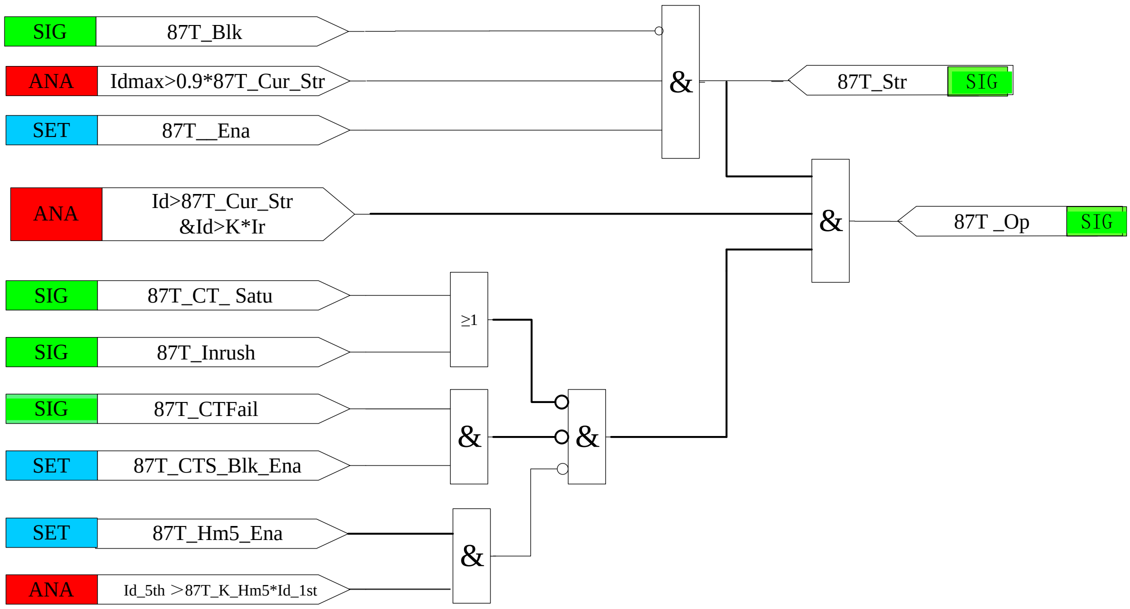



**Figure 3.2-5 Logic diagram of 87T protection**

***Where:***

Idmax 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 3.2-3 Settings of Transformer differential protection**

| No. | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 87T_Cur_Str | 0.05~20.00 | IE | 0.01 | 0.40 | Pickup setting of biased differential element |
| 2 | 87T_Cur_Inst | 0.05~20.00 | IE | 0.01 | 6.00 | Current setting of instantaneous differential element |
| 3 | 87T_Cur_Alm | 0.05~20.00 | IE | 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 | IE | 0.01 | 1.00 | Current setting of knee point 1 for transformer differential protection |
| 7 | 87T_Cur_K2 | 0.05~20.00 | IE | 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 |

| No. | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | 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:<br>0: waveform symmetry<br>1: Harmonic principle<br>2: Comprehensive principle<br>3:Without Inrush CurrentBlock |
| 12 | 87T _Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling conventional biased differential element<br>0: disable<br>1: enable |
| 13 | 87T_Inst_Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling instantaneous differential element<br>0: disable<br>1: enable |
| 14 | 87T_Alm_Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling differential Alam element<br>0: disable<br>1: enable |
| 15 | 87T_Hm5_Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling block overexcitation<br>0: disable<br>1: enable |
| 16 | 87T_CTS_Blk_Ena | 0,1 | | 1 | 0 | Logic setting of enabling/disabling block biased differential element during CT circuit failure<br>0: disable<br>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 distanceprotection.

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

### 3.3.2 Parameters

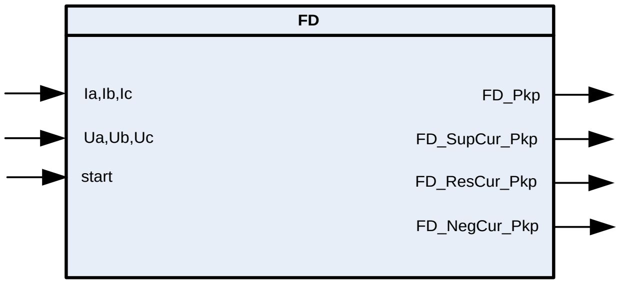
**Table 3.3-1 Parameters**

| No. | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | Z1 | (0.05~655)/In | ohm | 0.01 | 10 | Positive-sequence impedance of the wholeline (secondary value) |
| 2 | Z1Ang | 10~89 | deg | 0.01 | 85 | Positive-sequence impedance angle |
| 3 | Z0 | (0.05~655)/In | ohm | 0.01 | 30 | Zero-sequence impedance of the wholeline (secondary value) |
| 4 | Z0Ang | 30~89 | deg | 0.01 | 80 | Zero-sequence |

| No. | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | impedance angle |
| 5 | Kz | 0~10.000 | | 0.001 | 0.67 | Zero-sequence compensation coefficient magnitude |
| 6 | KzAng | 0~360.00 | deg | 0.01 | 0 | 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 | Ia,Ib,Ic | Three-phase current input |
| 2 | Ua,Ub,Uc | Three-phase voltage input |
| 3 | start | Other protection start signal |

**Table 3.3-3 FD Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | FD_Pkp | The device picks up |
| 2 | FD_SupCur_Pkp | Superimposed current fault detector element operates |
| 3 | FD_ResCur_Pkp | Residual current fault detector element operates |
| 4 | FD_NegCur_Pkp | 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.

$I(k\text{-}N)$ is the value of a sampling point before a cycle.

Operation criteria:

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

Where:

$\Delta I_{\phi}$: Superimposed phase current (Φ=A, B, C)

$\Delta I_{Set}$ : The fixed threshold value (i.e. the setting FD_SupCur_Str)

$\Delta I_{Th}$: The floating threshold value

This element adopts adaptive floating threshold varied with the change of load currentcontinuously. The change of load current is small and steadily under normal or power swingcondition, the adaptive floating threshold with the $\Delta I_{Set}$ is higher than the change of currentunderthese conditions and hence maintains the element stability.

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

If operation condition is met, the fault detector based on superimposed current will operate to provide DCpower supply for output relays, the pickup signal will maintain 7s after the fault detector based onsuperimposed 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 isrelative small, so, residual current is used to judge pickup condition.

The operation condition will be met when 3I0 is greater than the setting FD_ResCur_Str. Thefault 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 DCpower supply for output relay, and the pickup signal will maintain 7s after the fault detector basedon 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_NegCur_Str. It can be enabled or disabled by the logic setting FD_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 DCpower supply for output relay, and the pickup signal will maintain 7s after the fault detector basedon negative-sequence current drops off.

### 3.3.3.6 Logic

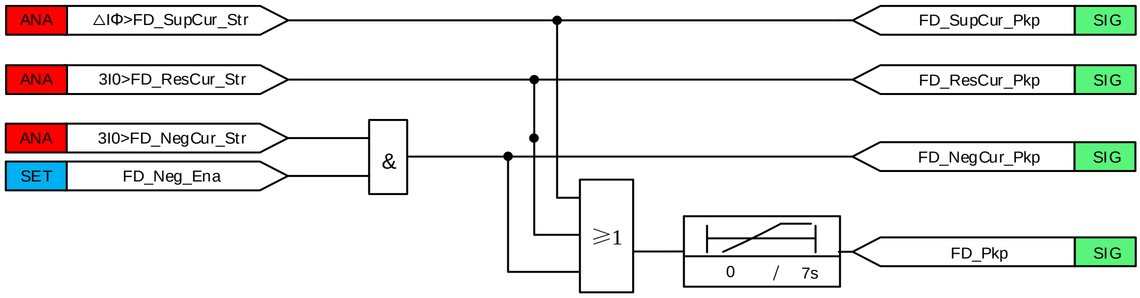



**Figure 3.3.1 Logic Diagram for Fault Detector**

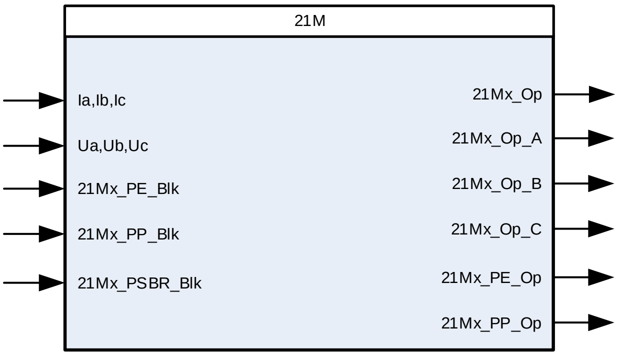
### 3.3.3.7 Settings

**Table 3.3-4 Settings of fault detector**

| No. | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | FD_Neg_Ena | 0 or 1 | - | - | 0 | Enabling/disabling negative-sequencecurrent fault detector element<br>0: disable<br>1: enable |
| 2 | FD_SupCur_Str | (0.04~0.5) ×In | A | 0.01 | 0.5 | Current setting of superimposed current fault detector element |
| 3 | FD_ResCur_Str | (0.04~30.00) ×In | A | 0.01 | 0.5 | Current setting of residual current fault detector element |
| 4 | FD_NegCur_Str | (0.04~30.00) ×In | A | 0.01 | 0.5 | 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 | Ia,Ib,Ic | Three-phase current input |
| 2 | Ua,Ub,Uc | Three-phase voltage input |
| 3 | 21Mx_PE_Blk | Block signal of phase-to-earth 21M zone x (x=1,2,3,4,5) |
| 4 | 21Mx_PP_Blk | Block signal of phase-to-phase 21M zone x (x=1,2,3,4,5) |
| 5 | 21Mx_PSBR_Blk | Blocking power swing blocking releasing of 21M zone x (x=1,2,3,4,5) |

**Table 3.3-6 21M Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 21Mx_Op | Operation signal from zone x (x=1,2,3,4,5) |
| 2 | 21Mx_Op_A | Operation signal from phase A zone x (x=1,2,3,4,5) |
| 3 | 21Mx_Op_B | Operation signal from phase B zone x (x=1,2,3,4,5) |
| 4 | 21Mx_Op_C | Operation signal from phase C zone x (x=1,2,3,4,5) |
| 5 | 21Mx_PE_Op | Operation signal from phase-to-earth zone x (x=1,2,3,4,5) |
| 6 | 21Mx_PP_Op | Operation signal from phase-to-phase zone x (x=1,2,3,4,5) |

### 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-phasedistance protection.

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

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 setting21Mx_PP_Imp_Op(x=1, 2, 3, 4, 5)

$U_{\phi\phi}$ 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 $\theta$ could be applied to the polarized voltage to improve the performanceagainst high resistance fault. The device provides an angle-shift setting, 21Mx_PP_Phi_Shift, toset value of $\theta$ 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 operationcharacteristic 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:

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

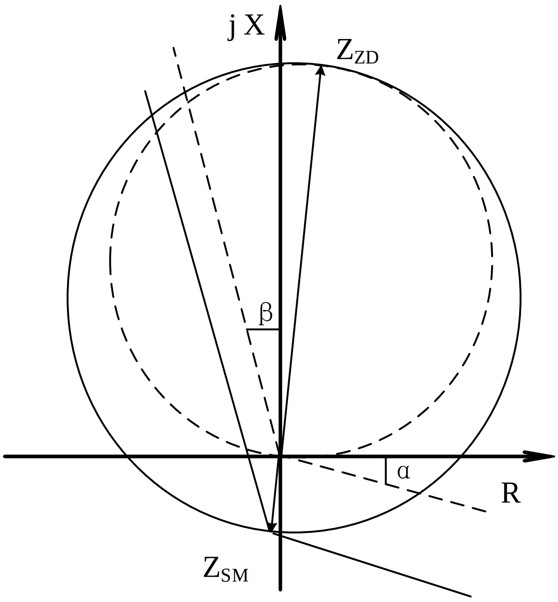



**Figure 3.3.2 Phase-to-phase operation characteristic of mho distance protection**

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 setting21Mx_PE_Imp_Op(x=1, 2, 3, 4, 5)

$U_{\phi}$ is the phase voltage

$I_{\phi}$ is the phase current

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

$3I0$ is the zero-sequencecurrent

k is zero-sequence compensation coefficient

In short line, phase shift $\theta$ could be applied to the polarized voltage to improve the performanceagainst high resistance fault. The device provides an angle-shift setting, 21Mx_PE_Phi_Shift, toset value of $\theta$ among 0°, 15° and 30°

To improve the operation characteristics of phase-to-ground distance elementso 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_X0Comp_Ang.

The operation characteristics of above equation on impedance planes are a straight line at the set impedance vector end, shown as figure3.3.3. In the operation criterion of zero sequence reactance relays, $\dot{I}0$phase moves backward forβ degree to appropriately limit its operation area to improve safety.

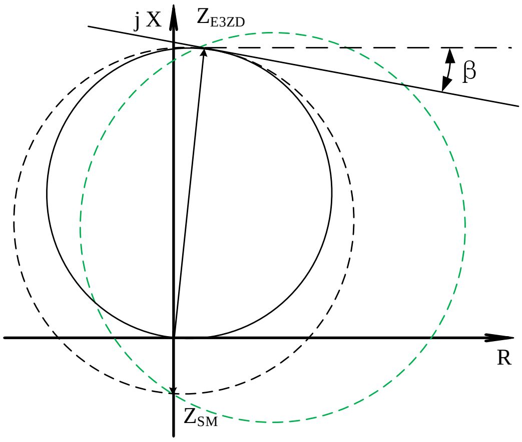



**Figure 3.3.3Phase-to-ground operation characteristic of mho distance protection**

### 3.3.4.4 Logic

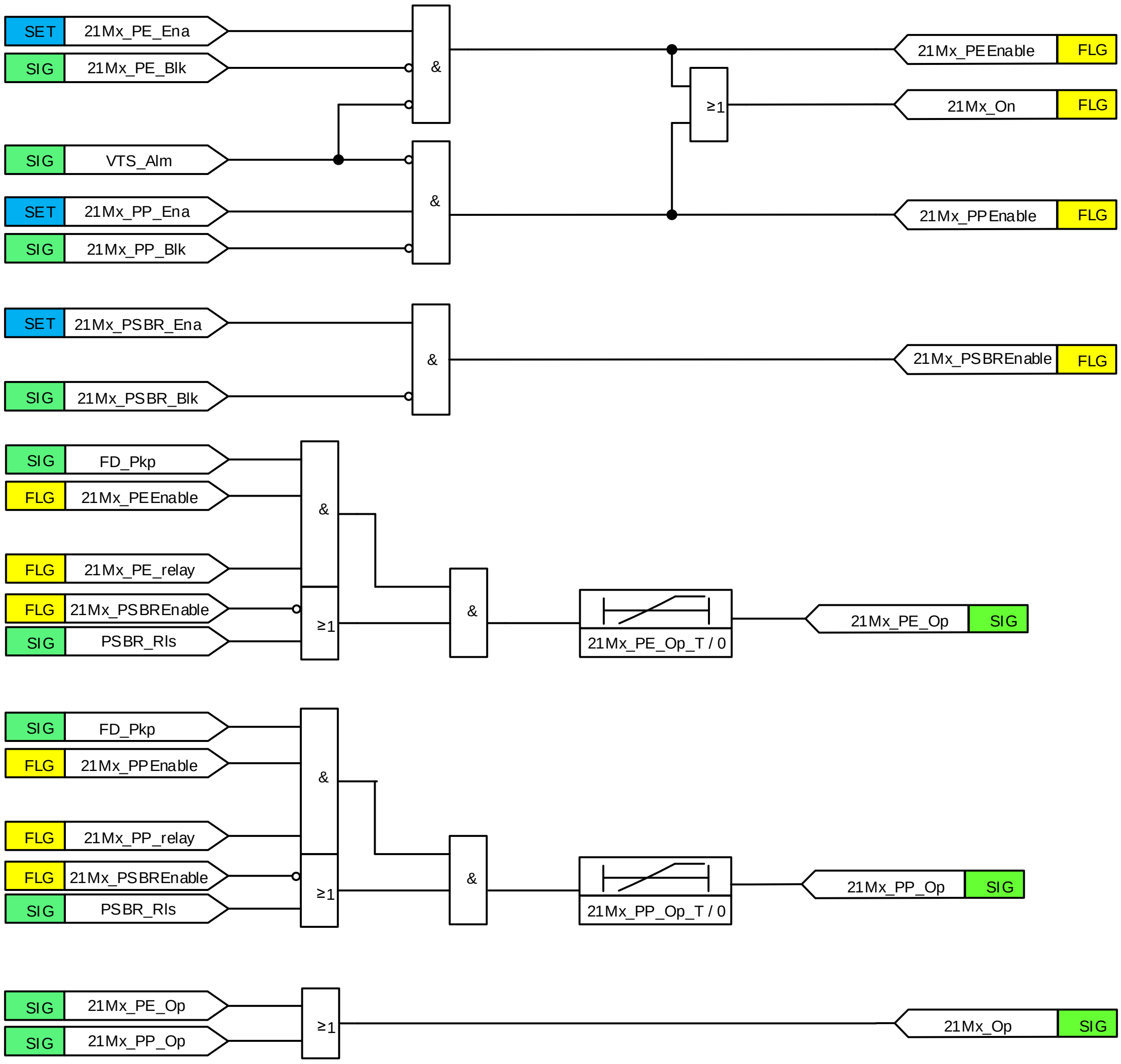



**Figure 3.3.2 Logic diagram of distance protection (Mho zone x)**

Where:

x=1,2,3,4,5

21Mx_PE_relay means that measured impedance by zone x of phase-to-earth distanceprotection is within the range determined by the setting 21Mx_PE_Imp_Op.

21Mx_PP_relay means that measured impedance by zone x of phase-to-phase distance protectionis within the range determined by the setting 21Mx_PP_Imp_Op.

### 3.3.4.5 Settings

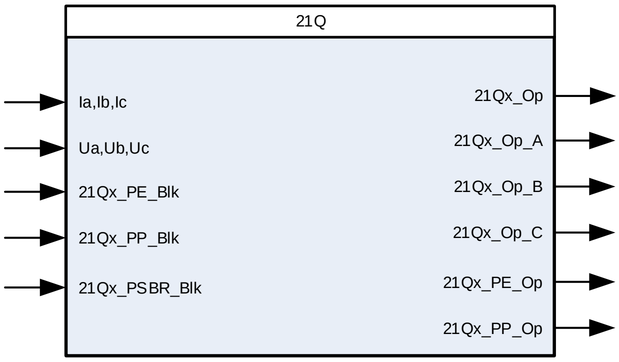
**Table 3.3-7 21M Settings**

| NO | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 21Mx_Dir_Mod | 0 or 1 | - | - | 0 | Direction option for zone x of distance protection (x=1,2, 3, 4, 5) |

| NO | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | 0: Forward<br>1: Reverse |
| 2 | 21Mx_PE_Ena | 0 or 1 | - | - | 0 | Enabling/disabling zone x of phase-to-earth distance protection (x=1, 2, 3, 4, 5)<br>0: disable<br>1: enable |
| 3 | 21Mx_PP_Ena | 0 or 1 | - | - | 0 | Enabling/disabling zone x of phase-to-phase distance protection (x=1, 2, 3, 4, 5)<br>0: disable<br>1: enable |
| 4 | 21Mx_PSBR_Ena | 0 or 1 | - | - | 0 | Enabling/disabling zone x of distance protection controlled by PSBR (x=1, 2, 3, 4, 5)<br>0: disable<br>1: enable |
| 5 | 21Mx_PE_Phi_Shift | 0, 15 or 30 | deg | 15 | 0 | Phase shift of phase-to-earth distance protection for zone x (x=1, 2, 3, 4, 5) |
| 6 | 21Mx_X0Comp_Ang | 0~30 | deg | 0.01 | 12 | Zero sequence reactance compensation angle |
| 7 | 21Mx_PE_Imp_Op | (0.05~500)/In | ohm | 0.01 | 8 | Impedance setting of zone x of phase-to-earth distance protection (x=1, 2, 3, 4, 5) |
| 8 | 21Mx_PE_Op_T | 0.000~10.000 | s | 0.001 | 10 | Time delay of zone x of phase-to-earth distance protection (x=1, 2, 3, 4, 5) |
| 9 | 21Mx_PP_Phi_Shift | 0, 15 or 30 | deg | 15 | 0 | Phase shift of phase-to-phase distance protection for zone x (x=1, 2, 3, 4, 5) |
| 10 | 21Mx_PP_Imp_Op | (0.05~500)/In | ohm | 0.01 | 8 | Impedance setting of zone x of phase-to-phase distance protection (x=1, 2, 3, 4, 5) |
| 11 | 21Mx_PP_Op_T | 0.000~10.000 | s | 0.001 | 10 | Time delay of zone x of phase-to-phase distance protection (x=1, 2, 3, 4, 5) |

## 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 | Ia,Ib,Ic | Three-phase current input |
| 2 | Ua,Ub,Uc | Three-phase voltage input |
| 3 | 21Qx_PE_Blk | Block signal of phase-to-earth 21Q zone x (x=1,2,3,4,5) |
| 4 | 21Qx_PP_Blk | Block signal of phase-to-phase 21Q zone x (x=1,2,3,4,5) |
| 5 | 21Qx_PSBR_Blk | Blocking power swing blocking releasing of 21Q zone x (x=1,2,3,4,5) |

**Table 3.3-9 1Q Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 21Qx_Op | Operation signal from zone x (x=1,2,3,4,5) |
| 2 | 21Qx_Op_A | Operation signal from phase A zone x (x=1,2,3,4,5) |
| 3 | 21Qx_Op_B | Operation signal from phase B zone x (x=1,2,3,4,5) |
| 4 | 21Qx_Op_C | Operation signal from phase C zone x (x=1,2,3,4,5) |
| 5 | 21Qx_PE_Op | Operation signal from phase-to-earth zone x (x=1,2,3,4,5) |
| 6 | 21Qx_PP_Op | Operation signal from phase-to-phase zone x (x=1,2,3,4,5) |

### 3.3.5.3 Protection Principle

Features available with quadrilateral distance protection include 5 settable forward or reverse zones phase-to-ground or phase-to-phase distance element. Each zone can respectivelyenable or disable power swing blocking releasing.

1) The reactance lineelement

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 setting21Qx_PE_Imp_Op OR 21Qx_PP_Imp_Op(x=1, 2, 3, 4, 5)

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

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

$U_{\phi}$ is the phase voltage

$I_{\phi}$ is the phase current

$3I0$ is the zero-sequencecurrent

k is zero-sequence compensation coefficient

δ: the angle of zero sequence compensation reactance, set by 21Qx_X0Comp_Ang.

2) The directional lineelement

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_Ang_Alpha(x=1, 2, 3, 4, 5)

β: the angle of directional line, set by the setting 21Qx_Ang_Beta(x=1, 2, 3, 4, 5)

3) The resistance lineelement

Operation criteria:

phase-to-ground:

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

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 setting21Qx_PE_R_Op OR 21Qx_PP_R_Op(x=1, 2, 3, 4, 5)

φ: line positive-sequence characteristic angle

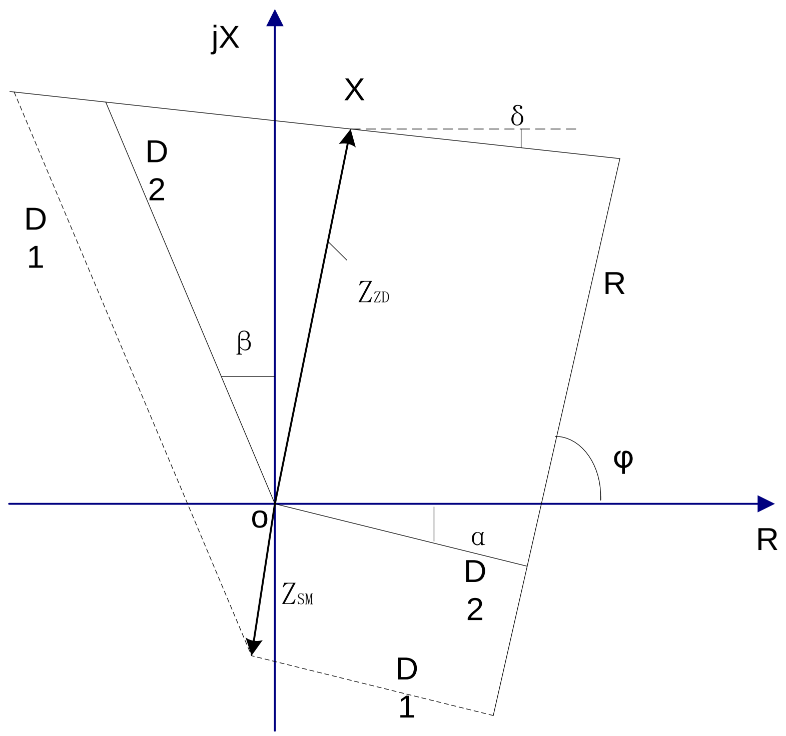



**Figure 3.3.5 Impedance characteristic of quadrilateral distance protection**

In the figure 3.3-5,the X elementcompletes the fault location,adopt the reactance lineelement, characteristic is like X line, downward offset angle of the R axis; the D elementcompletes the direction judgment,adopt the directional lineelement, characteristic is like D broken line; the R elementreflect high-impedance-grounded faults,adopt the resistance lineelement, characteristic is like R line.

### 3.3.5.4 Logic

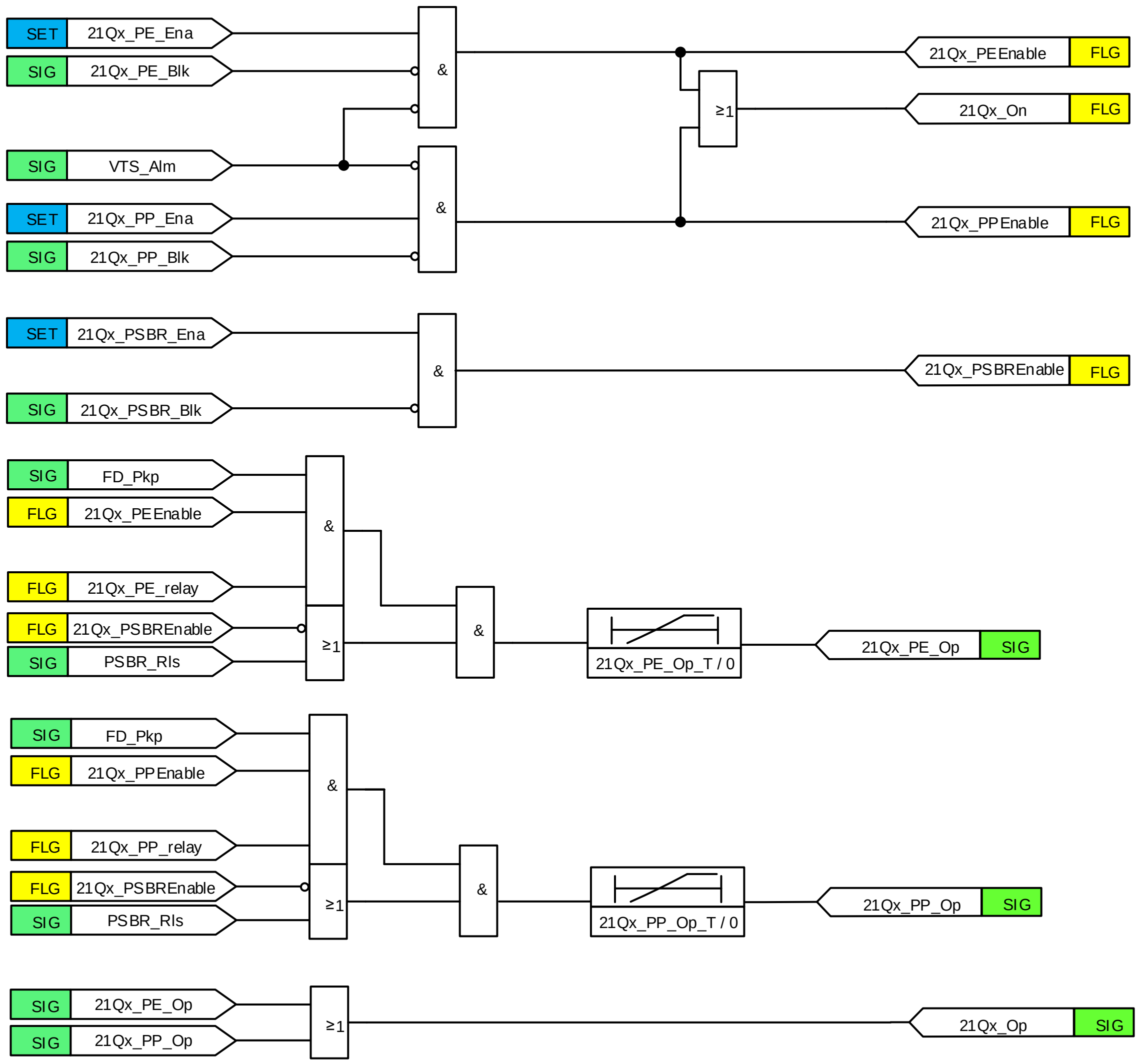



**Figure 3.3.6 Logic diagram of distance protection (Quad zone x)**

Where:

x=1,2,3,4,5

21Qx_PE_relay means that measured impedance by zone x of phase-to-earth distanceprotection is within the range determined by the setting 21Qx_PE_Imp_Op and 21Qx_PE_R_Op.

21Qx_PP_relay means that measured impedance by zone x of phase-to-phase distance protectionis within the range determined by the setting 21Qx_PP_Imp_Op and 21Qx_PP_R_Op.

### 3.3.5.5 Settings

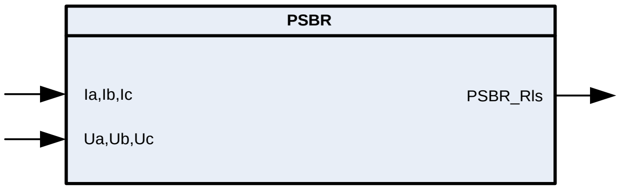
**Table 3.3-10 21Q Settings**

| NO | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 21Qx_Dir_Mod | 0 or 1 | - | - | 0 | Direction option for zone x of distance protection (x=1,2, 3, 4, 5)<br>0: Forward<br>1: Reverse |
| 2 | 21Qx_PE_Ena | 0 or 1 | - | - | 0 | Enabling/disabling zone x of phase-to-earth distance protection (x=1, 2, 3, 4, 5)<br>0: disable<br>1: enable |
| 3 | 21Qx_PP_Ena | 0 or 1 | - | - | 0 | Enabling/disabling zone x of phase-to-phase distance protection (x=1, 2, 3, 4, 5)<br>0: disable<br>1: enable |
| 4 | 21Qx_PSBR_Ena | 0 or 1 | - | - | 0 | Enabling/disabling zone x of distance protection controlled by PSBR (x=1, 2, 3, 4, 5)<br>0: disable<br>1: enable |
| 5 | 21Qx_Ang_Alpha | 5~45 | deg | 0.01 | 25 | Angle of blinder in fourth quadrant forforward direction |
| 6 | 21Qx_Ang_Beta | 0~85 | deg | 0.01 | 30 | Angle of blinder in second quadrant forforward direction |
| 7 | 21Qx_X0Comp_Ang | 0~30 | deg | 0.01 | 12 | Zero sequence reactance compensation angle |
| 8 | 21Qx_PE_Imp_Op | (0.05~500)/In | ohm | 0.01 | 8 | Impedance setting of zone x of phase-to-earth distance protection (x=1, 2, 3, 4, 5) |
| 9 | 21Qx_PE_R_Op | (0.05~500)/In | ohm | 0.01 | 20 | Resistance setting of zone x of phase-to-earth distance protection (x=1, 2, 3, 4, 5) |
| 10 | 21Qx_PE_Op_T | 0.000~10.000 | s | 0.001 | 10 | Time delay of zone x of phase-to-earth distance protection (x=1, 2, 3, 4, 5) |
| 11 | 21Qx_PP_Imp_Op | (0.05~500)/In | ohm | 0.01 | 8 | Impedance setting of zone x of phase-to-phase distance protection (x=1, 2, 3, 4, 5) |
| 12 | 21Qx_PP_R_Op | (0.05~500)/In | ohm | 0.01 | 20 | Resistance setting of zone x of |

| NO | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | phase-to-phase distance protection (x=1, 2, 3, 4, 5) |
| 13 | 21Qx_PP_Op_T | 0.000~10.000 | s | 0.001 | 10 | Time delay of zone x of phase-to-phase distance protection (x=1, 2, 3, 4, 5) |

## 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 | Ia,Ib,Ic | Three-phase current input |
| 2 | Ua,Ub,Uc | Three-phase voltage input |

**Table 3.3-12 PSBR Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | PSBR_Rls | PSBR operates to release distance protection |

### 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

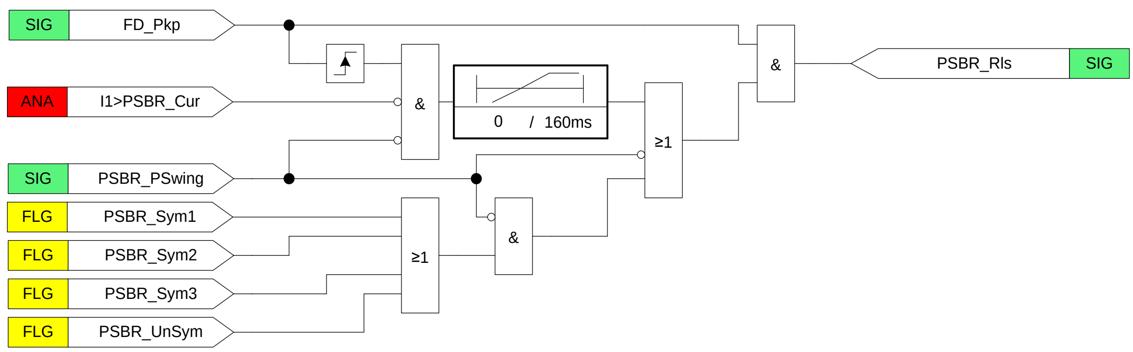



**Figure 3.3.7 Logic diagram of PSBR**

### 3.3.6.5 Settings

**Table 3.3-1 Settings of PSBR**

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

## 3.4 Directional Overcurrent Protection (67P/50/51)

3.4

### 3.4.1 Overview

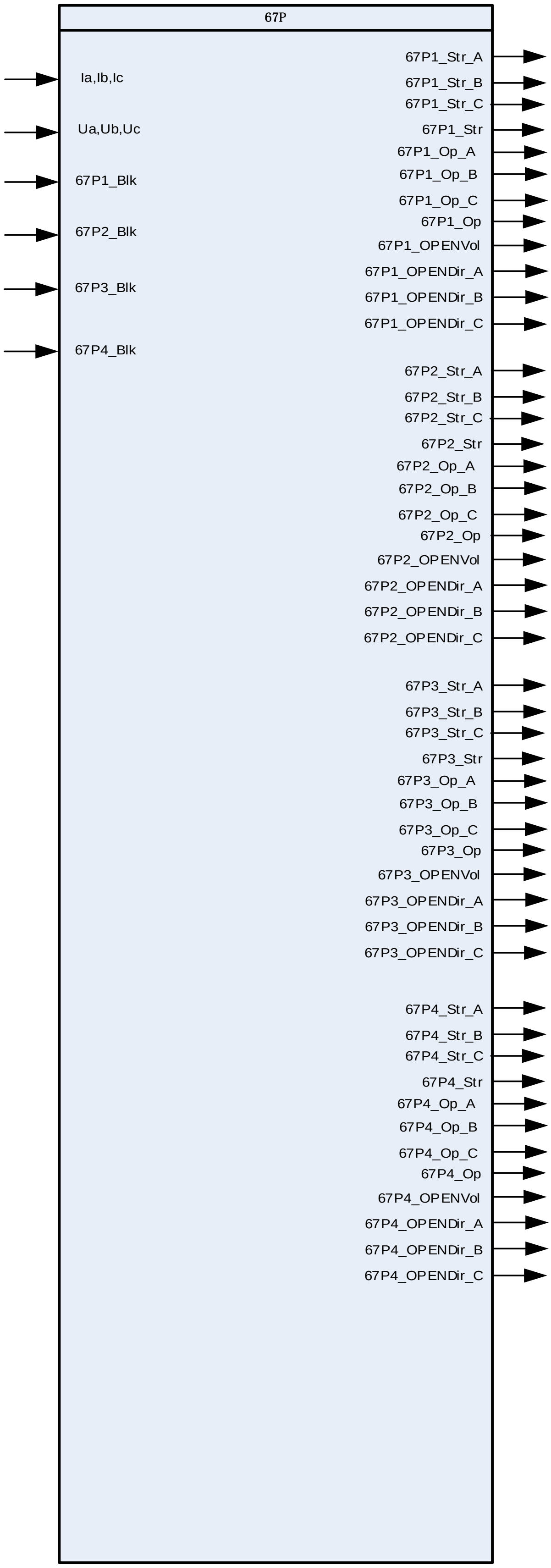
The main and important function of Four stage phase overcurrent protection OC4_PTOC (67P) is to continuously track the electrical power system current. For the point of view of continuously power supply and minimum damage during fault condition (at the time of fault the normal current value is increases 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 (67P) 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 67P 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 3.4-167P Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Ia, Ib, Ic | the three phase current. |
| 2 | Ua, Ub, Uc | the three phase voltage |
| 3 | 67P1_Blk | Block signal of 67P stage1 |
| 4 | 67P2_Blk | Block signal of 67P stage2 |
| 5 | 67P3_Blk | Block signal of 67P stage3 |
| 6 | 67P4_Blk | Block signal of 67P stage4 |

**Table 3.4-2 67POutput Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 67P1_Str_A | Start signal from phase A from 67Pstage1 |
| 2 | 67P1_Str_B | Start signal from phase B from stage1 |
| 3 | 67P1_Str_C | Start signal from phase C from stage1 |
| 4 | 67P1_Str | Common start signal from stage1 |
| 5 | 67P1_Op_A | Trip signal from stage1 phase A |
| 6 | 67P1_Op_B | Trip signal from stage1 phase B |
| 7 | 67P1_Op_C | Trip signal from stage1phase C |
| 8 | 67P1_Op | Trip signal from stage1 |
| 9 | 67P1_OPENVol | Voltage open signal from stage1 |
| 10 | 67P1_OPENDir_A | Directional open signal of phase A from stage1 |
| 11 | 67P1_OPENDir_B | Directional open signal of phase B from stage1 |
| 12 | 67P1_OPENDir_C | Directional open signal of phase C from stage1 |
| 13 | 67P2_Str_A | Start signal from stage2 phase A |
| 14 | 67P2_Str_B | Start signal from stage2 phase B |
| 15 | 67P2_Str_C | Start signal from stage2 phase C |
| 16 | 67P2_Str | Common start signal from stage2 |
| 17 | 67P2_Op_A | Trip signal from stage2 phase A |
| 18 | 67P2_Op_B | Trip signal from stage2 phase B |
| 19 | 67P2_Op_C | Trip signal from stage2phase C |
| 20 | 67P2_Op | Trip signal from stage2 |
| 21 | 67P2_OPENVol | Voltage open signal from stage2 |
| 22 | 67P2_OPENDir_A | Directional open signal of phase A from stage2 |
| 23 | 67P2_OPENDir_B | Directional open signal of phase B from stage2 |
| 24 | 67P2_OPENDir_C | Directional open signal of phase C from stage2 |
| 25 | 67P3_Str_A | Start signal from stage3 phase A |
| 26 | 67P3_Str_B | Start signal from stage3 phase B |
| 27 | 67P3_Str_C | Start signal from stage3 phase C |
| 28 | 67P3_Str | Common start signal from stage3 |

| NO. | Signal | Description |
| --- | --- | --- |
| 29 | 67P3_Op_A | Trip signal from stage3 phase A |
| 30 | 67P3_Op_B | Trip signal from stage3 phase B |
| 31 | 67P3_Op_C | Trip signal from stage3phase C |
| 32 | 67P3_Op | Trip signal from stage3 |
| 33 | 67P3_OPENVol | Voltage open signal from stage3 |
| 34 | 67P3_OPENDir_A | Directional open signal of phase A from stage3 |
| 35 | 67P3_OPENDir_B | Directional open signal of phase B from stage3 |
| 36 | 67P3_OPENDir_C | Directional open signal of phase C from stage3 |
| 37 | 67P4_Str_A | Start signal from stage4 phase A |
| 38 | 67P4_Str_B | Start signal from stage4 phase B |
| 39 | 67P4_Str_C | Start signal from stage4 phase C |
| 40 | 67P4_Str | Common start signal from stage4 |
| 41 | 67P4_Op_A | Trip signal from stage4 phase A |
| 42 | 67P4_Op_B | Trip signal from stage4 phase B |
| 43 | 67P4_Op_C | Trip signal from stage4phase C |
| 44 | 67P4_Op | Trip signal from stage4 |
| 45 | 67P4_OPENVol | Voltage open signal from stage4 |
| 46 | 67P4_OPENDir_A | Directional open signal of phase A from stage4 |
| 47 | 67P4_OPENDir_B | Directional open signal of phase B from stage4 |
| 48 | 67P4_OPENDir_C | Directional open signal of phase C from stage4 |

## 3.4.2 Protection Principle

Phase overcurrent protection has following functions:

1) Four-stage phase overcurrent 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 selectable among IEC standard inverse-time characteristics.

3) Direction control element can be selected to control each stage phase overcurrent protectionwith three options: no direction, forward direction and reverse direction

### 3.4.2.1 Phase Overcurrent Element

The operation criterion for each stage of overcurrent element is:

$$\mathrm{I_{\varphi} > 67Px\_Cur\_Str}$$

***Where:***

$\mathrm{I}_{\varphi}$is measured phase current.

$67Px_Cur_Str$is the current setting of stage x (x=1, 2, 3, or 4) of overcurrent element.

The measured current values are compared to the setoperation current value of the function

($67Px\_Cur\_Str$). If the measured value exceeds the set $67Px\_Cur\_Str$, 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 $67Px\_Str\_Ph\_Num$ setting, the phase selection logic activates the output signal of $67Px\_OP\_n$(n=A,B,C).

### 3.4.2.2 Direction Control Element

The directional operation can be selected with the $67Px_Dir_Mod$setting. The user can select either "(Non-Dir)", "(Forward)" or "(Reverse)" operation. By setting the value of $67Px\_Dir\_Mod$ to "0", the non-directional operation is allowed when the directional information is invalid.

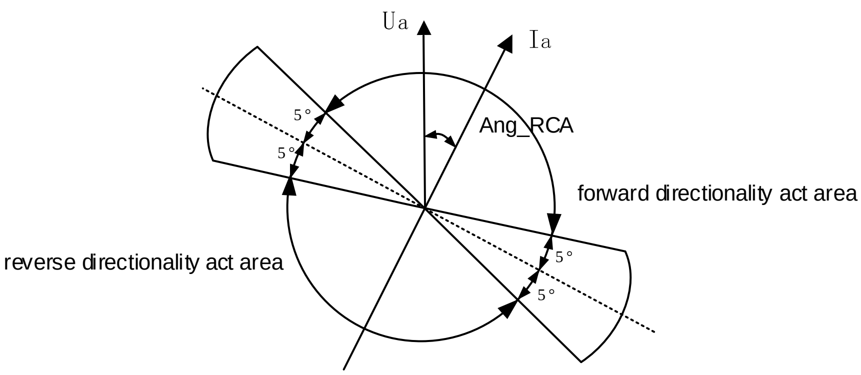
The $67Px\_ANG\_RCA$ setting is used to turn the directional characteristic. The value of $67Px\_ANG\_RCA$ should be chosen in such a way that all the faults in the operating direction are seen in the operating zone and all the faults in the opposite direction are seen in the non-operating zone. The 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:

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

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

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



$\pm 5^o$ 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.Ifthephase-phase voltage reduces to less than 12V, the device uses memory voltage as polarized voltage.

If the polarized voltage is invalid, the direction elementendures 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 |

### 3.4.2.3 Second harmonic detecting element

For harmonic detecting element, the harmonic blocking mode can be selected through the setting 67Px_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 67P_Hm2_IRls, the correspondingphase will be unblocked by harmonic control element.The logic of harmonic control element isshown in Figure 3.4-1.

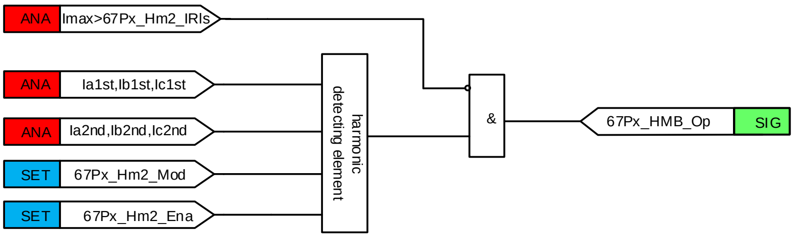



**Figure 3.4-1 Logic Diagram for harmonic detecting element**

***Where:***

Ia1st, Ib1st, Ic1st are the fundamental current.

Ia2nd, Ib2nd, Ic2nd are the secondary harmonic current.

Imax is the maximum phase current.

### 3.4.2.4 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:***

$I_p$ is current setting $67Px\_Cur\_Str$.

$T_p$ is time multiplier setting $67Px\_T\_Mult$.

$\alpha$is a constant setting $67Px\_Alpha$.

$k$is a constant setting$67Px_K$.

$C$is a constant setting $67Px\_C$.

$I$is measured phase current from line CT

| **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 timer model is determined by the setting$67Px_Op_Curve_Type$. The details are as follows.

When the$67Px_Op_Curve_Type = 0$, the operation is activated after the operation timer has reached the value set by$67Px_Op_T$. If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the operation will reset.

When the$67Px_Op_Curve_Type = 1{\sim}5$, the operation is activated after the operation timer has reached the value set by IDMT curve. However, $67Px_Min_Op_T$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 $67Px\_Min\_Op\_T$ setting should be used with great care because the operation time is according to theIEC curve, but always at least the value of the $67Px\_Min\_Op\_T$ setting.

### 3.4.3 Logic Diagram

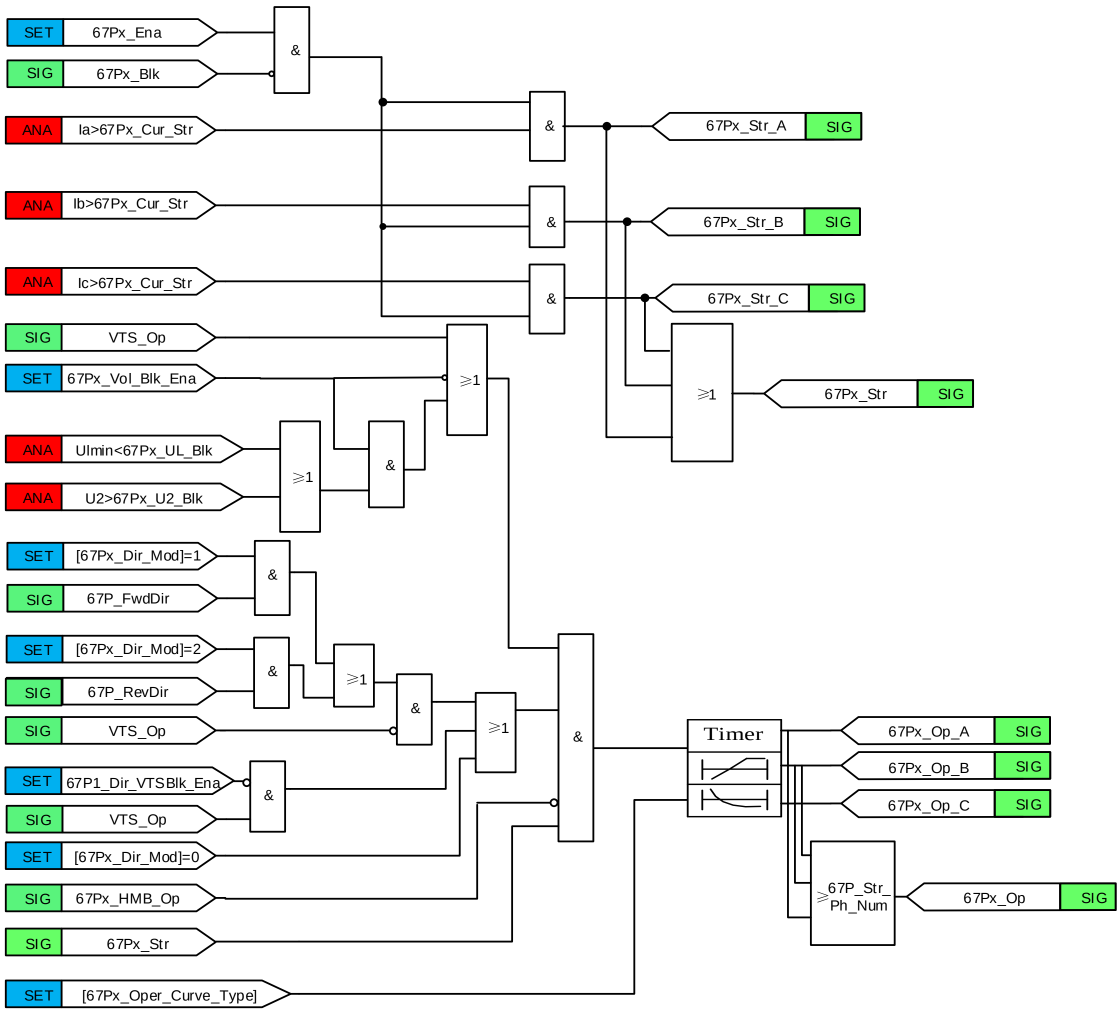



**Figure 3.4-2 Logic Diagram for 67P**

### 3.4.4 Settings

**Table 3.4-5 Settings of Four stagedirectional overcurrent protection**

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 67P1_Cur_Str | 0.02In~20In | A | 0.01 | 20.00 | Operating phase current level |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | for stage 1 |
| 2 | 67P1_Op_T | 0.020~100.000 | s | 0.001 | 10.000 | Def time delay or add time delay for inverse char of stage 1 |
| 3 | 67P1_UL_Blk | 0.00~100.00 | V | 0.01 | 70.00 | Stage 1 setting of blocking voltage |
| 4 | 67P1_U2_Blk | 0.00~100.00 | V | 0.01 | 20.00 | Stage 1 setting of Negative voltage |
| 5 | 67P1_Str_Ph_Num | 1 out of 3<br>2 out of 3<br>3 out of 3 | - | 1 | 3 | Number of phases required for op (1 of 3, 2 of 3, 3 of 3) |
| 6 | 67P1_Ang_RCA | 0.0~360.0 | Deg | 0.1 | 270.0 | Relay characteristic angle (RCA) |
| 7 | 67P1_Dir_Mod. | 0~2 | - | 1 | 0 | Directional mode:0-2 for "Non-directional", "Forward" or "Reverse" |
| 8 | 67P1_Dir_VTSBlk_Ena | 0/1 | - | 1 | 0 | Enabling/Disabling phase overcurrent protection with direction control element is blocked by VT circuit failure when VT circuit supervision is enabled and VT circuit fails |
| 9 | 67P1_K_Hm2 | 0.00~1.00 | - | 0.01 | 0.10 | Coefficient of second harmonics for inrush current detection |
| 10 | 67P1_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush current detection |
| 11 | 67P1_Hm2_Mod | 0~2 | - | 1 | 0 | The option of harmonic blocking mode:<br>0:phase blocking<br>1:cross blocking<br>2: maximum phase blocking |
| 12 | 67P1_Op_Curve_Type | 0~5 | - | 1 | 0 | Option of characteristic curve for stage 1 |
| 13 | 67P1_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay for stage 1 |
| 14 | 67P1_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 1 |
| 15 | 67P1_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 67P Stage 1 |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 16 | 67P1_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 67P Stage 1 |
| 17 | 67P1_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 67P Stage 1 |
| 18 | 67P1_Hm2_Ena | 0/1 | - | 1 | 0 | Stage 1 Operation setting of harmonic detecting element Enable/Disable |
| 19 | 67P1_Vol_Blk_Ena | 0/1 | - | 1 | 0 | Stage 1 Operation setting of voltage Enable/Disable |
| 20 | 67P1_Ena | 0/1 | - | 1 | 0 | Operation 0/ 1 |
| 21 | 67P2_Cur_Str | 0.02In~20In | A | 0.01 | 20.00 | Operating phase current level for stage 2 |
| 22 | 67P2_Op_T | 0.020~100.000 | s | 0.001 | 10.000 | Def time delay or add time delay for inverse char of stage 2 |
| 23 | 67P2_UL_Blk | 0.00~100.00 | V | 0.01 | 70.00 | Stage 2 setting of blocking voltage |
| 24 | 67P2_U2_Blk | 0.00~100.00 | V | 0.01 | 20.00 | Stage 2 setting of Negative voltage |
| 25 | 67P2_Str_Ph_Num | 1 out of 3<br>2 out of 3<br>3 out of 3 | - | 1 | 3 | Number of phases required for op (1 of 3, 2 of 3, 3 of 3) |
| 26 | 67P2_Ang_RCA | 0.0~360.0 | Deg | 0.1 | 270.0 | Relay characteristic angle (RCA) |
| 27 | 67P2_Dir_Mod. | 0~2 | - | 1 | 0 | Directional mode:0-2 for "Non-directional", "Forward" or "Reverse" |
| 28 | 67P2_Dir_VTSBlk_Ena | 0/1 | - | 1 | 0 | Enabling/Disabling phase overcurrent protection with direction control element is blocked by VT circuit failure when VT circuit supervision is enabled and VT circuit fails |
| 29 | 67P2_K_Hm2 | 0.00~1.00 | - | 0.01 | 0.10 | Coefficient of second harmonics for inrush current detection |
| 30 | 67P2_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | current detection |
| 31 | 67P2_Hm2_Mod | 0~2 | - | 1 | 0 | The option of harmonic blocking mode:<br>0:phase blocking<br>1:cross blocking<br>2: maximum phase blocking |
| 32 | 67P2_Op_Curve_Type | 0~5 | - | 1 | 0 | Option of characteristic curve for stage 2 |
| 33 | 67P2_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay<br>for stage 2 |
| 34 | 67P2_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 2 |
| 35 | 67P2_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 67P Stage 2 |
| 36 | 67P2_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 67P Stage 2 |
| 37 | 67P2_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 67P Stage 2 |
| 38 | 67P2_Hm2_Ena | 0/1 | - | 1 | 0 | Stage 2 Operation setting of harmonic detecting element Enable/Disable |
| 39 | 67P2_Vol_Blk_Ena | 0/1 | - | 1 | 0 | Stage 2 Operation setting of voltage Enable/Disable |
| 40 | 67P2_Ena | 0/1 | - | 1 | 0 | Operation 0/ 1 |
| 41 | 67P3_Cur_Str | 0.02In~20In | A | 0.01 | 20.00 | Operating phase current level for stage 3 |
| 42 | 67P3_Op_T | 0.020~100.000 | s | 0.001 | 10.000 | Def time delay or add time delay for<br>inverse char of stage 3 |
| 43 | 67P3_UL_Blk | 0.00~100.00 | V | 0.01 | 70.00 | Stage 3 setting of blocking voltage |
| 44 | 67P3_U2_Blk | 0.00~100.00 | V | 0.01 | 20.00 | Stage 3 setting of Negative voltage |
| 45 | 67P3_Str_Ph_Num | 1 out of 3<br>2 out of 3<br>3 out of 3 | - | 1 | 3 | Number of phases required for op (1 of 3,<br>2 of 3, 3 of 3) |
| 46 | 67P3_Ang_RCA | 0.0~360.0 | Deg | 0.1 | 270.0 | Relay characteristic angle (RCA) |
| 47 | 67P3_Dir_Mod. | 0~2 | - | 1 | 0 | Directional mode:0-2 for "Non-directional", "Forward" or "Reverse" |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 48 | 67P3_Dir_VTSBlk_Ena | 0/1 | - | 1 | 0 | Enabling/Disabling phase overcurrent protection with direction control element is blocked by VT circuit failure when VT circuit supervision is enabled and VT circuit fails |
| 49 | 67P3_K_Hm2 | 0.00~1.00 | - | 0.01 | 0.10 | Coefficient of second harmonics for inrush current detection |
| 50 | 67P3_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush current detection |
| 51 | 67P3_Hm2_Mod | 0~2 | - | 1 | 0 | The option of harmonic blocking mode:<br>0:phase blocking<br>1:cross blocking<br>2: maximum phase blocking |
| 52 | 67P3_Op_Curve_Type | 0~5 | - | 1 | 0 | Option of characteristic curve for stage 3 |
| 53 | 67P3_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay<br>for stage 3 |
| 54 | 67P3_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 3 |
| 55 | 67P3_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 67P Stage 3 |
| 56 | 67P3_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 67P Stage 3 |
| 57 | 67P3_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 67P Stage 3 |
| 58 | 67P3_Hm2_Ena | 0/1 | - | 1 | 0 | Stage 3 Operation setting of harmonic detecting element Enable/Disable |
| 59 | 67P3_Vol_Blk_Ena | 0/1 | - | 1 | 0 | Stage 3 Operation setting of voltage Enable/Disable |
| 60 | 67P3_Ena | 0/1 | - | 1 | 0 | Operation 0/ 1 |
| 61 | 67P4_Cur_Str | 0.02In~20In | A | 0.01 | 20.00 | Operating phase current level for stage 4 |
| 62 | 67P4_Op_T | 0.020~100.000 | s | 0.001 | 10.000 | Def time delay or add time delay for<br>inverse char of stage 4 |
| 63 | 67P4_UL_Blk | 0.00~100.00 | V | 0.01 | 70.00 | Stage 4 setting of blocking voltage |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 64 | 67P4_U2_Blk | 0.00~100.00 | V | 0.01 | 20.00 | Stage4 setting of Negative voltage |
| 65 | 67P4_Str_Ph_Num | 1 out of 3<br>2 out of 3<br>3 out of 3 | - | 1 | 3 | Number of phases required for op (1 of 3,<br>2 of 3, 3 of 3) |
| 66 | 67P4_Ang_RCA | 0.0~360.0 | Deg | 0.1 | 270.0 | Relay characteristic angle (RCA) |
| 67 | 67P4_Dir_Mod. | 0~2 | - | 1 | 0 | Directional mode:0-2 for "Non-directional", "Forward" or "Reverse" |
| 68 | 67P4_Dir_VTSBlk_Ena | 0/1 | - | 1 | 0 | Enabling/Disabling phase overcurrent protection with direction control element is blocked by VT circuit failure when VT circuit supervision is enabled and VT circuit fails |
| 69 | 67P4_K_Hm2 | 0.00~1.00 | - | 0.01 | 0.10 | Coefficient of second harmonics for inrush current detection |
| 70 | 67P4_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush current detection |
| 71 | 67P4_Hm2_Mod | 0~2 | - | 1 | 0 | The option of harmonic blocking mode:<br>0:phase blocking<br>1:cross blocking<br>2: maximum phase blocking |
| 72 | 67P4_Op_Curve_Type | 0~5 | - | 1 | 0 | Option of characteristic curve for stage 4 |
| 73 | 67P4_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay<br>for stage 4 |
| 74 | 67P4_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 4 |
| 75 | 67P4_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of<br>67P Stage 4 |
| 76 | 67P4_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of<br>67P Stage 4 |
| 77 | 67P4_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of<br>67P Stage 4 |
| 78 | 67P4_Hm2_Ena | 0/1 | - | 1 | 0 | Stage 4 Operation setting of harmonic detecting element Enable/Disable |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 79 | 67P4_Vol_Blk_Ena | 0/1 | - | 1 | 0 | Stage 4 Operation setting of voltage Enable/Disable |
| 80 | 67P4_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 andcooling of the protected plant.The heat generated within an item of the plant, such as a cable or a transformer, is the resistiveloss. Thus, heating is directly proportional to current squared. The thermal timecharacteristic used in the relay is therefore based on current squared, integrated over time. Therelay 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 loadrating, 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.

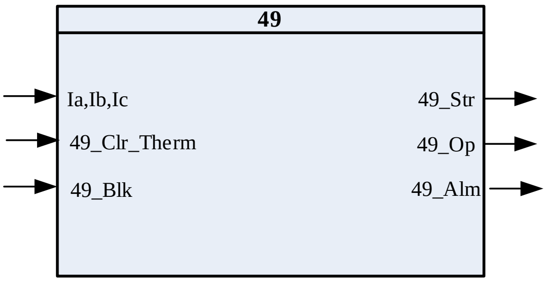



**Figure 3.5-1 Function block**

### 3.5.1.2 Signals

**Table 3.5-1 VTS Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Ia,Ib,Ic | The current in all the three phases |
| 2 | 49_Clr_Therm | The input signal of clearing therm |
| 3 | 49_Str | The start signal |

| NO. | Signal | Description |
| --- | --- | --- |
| 4 | 49_Op | The operate signal |
| 5 | 49_Alm | The alarm signal |

### 3.5.2 Logic Diagram

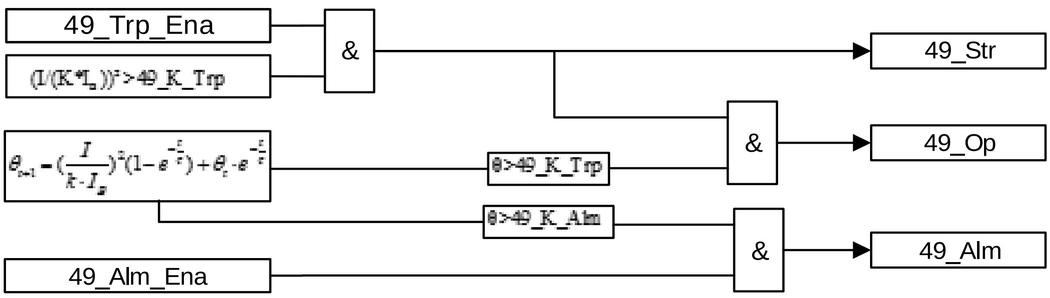



**Figure 3.5-2 Functional module diagram**

### 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.

$\tau$ the set value of $49\_T\_Mult$.

$\theta_t$ is the initial thermal state, if the initial thermal state is 30%, the $\theta_t$ is 0.3. $\theta_t$ is calculated from the following equation: $I_P{}^2 = \Theta_t \cdot (k \cdot I_B)^2$. 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.

$\theta_{t+1}$ The trip or alarm thermal state: $\theta_{Trip}$ (the setting value $49\_K\_Trp$ ) or $\theta_{Alarm}$ (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 (67N/50/51N)

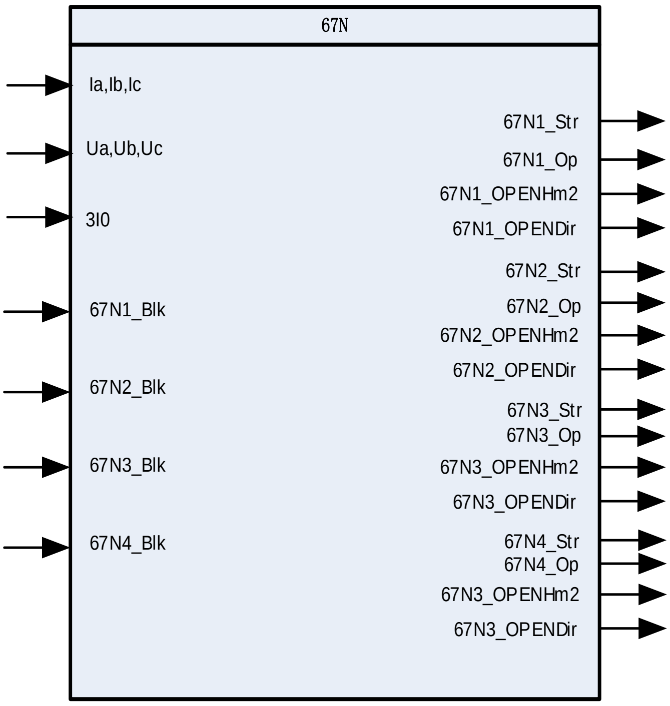
## 3.6.1 Overview

In electrical power industry, earth fault protection (67N) 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 (67N) 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 67N 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 3.6-167N Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Ia, Ib, Ic | the three phase current. |
| 2 | Ua, Ub, Uc | the three phase voltage |
| 3 | 3I0 | The Measured neutral current |

| NO. | Signal | Description |
|---|---|---|
| 4 | 67N1_Blk | Block signal of 67N stage1 |
| 5 | 67N2_Blk | Block signal of 67N stage2 |
| 6 | 67N3_Blk | Block signal of 67N stage3 |
| 7 | 67N4_Blk | Block signal of 67N stage4 |

**Table 3.6-267N Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 67N1_Str | start signal from stage1 |
| 2 | 67N1_Op | Operation signal from stage1 |
| 3 | 67N1_OPENHm2 | Voltage open signal from stage1 |
| 4 | 67N1_OPENDir | Directional open signal from stage1 |
| 5 | 67N2_Str | start signal from stage2 |
| 6 | 67N2_Op | Operation signal from stage2 |
| 7 | 67N2_OPENHm2 | Voltage open signal from stage2 |
| 8 | 67N2_OPENDir | Directional open signal from stage2 |
| 9 | 67N3_Str | start signal from stage3 |
| 10 | 67N3_Op | Operation signal from stage3 |
| 11 | 67N3_OPENHm2 | Voltage open signal from stage3 |
| 12 | 67N3_OPENDir | Directional open signal from stage3 |
| 13 | 67N4_Str | start signal from stage4 |
| 14 | 67N4_Op | Operation signal from stage4 |
| 15 | 67N4_OPENHm2 | Voltage open signal from stage4 |
| 16 | 67N4_OPENDir | Directional open signal from stage4 |

## 3.6.2 Protection Principle

The earth fault protection includesfour 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 Element

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

$$3\mathrm{I0} > 67Nx\_Cur\_Str$$

***Where:***

$3\mathrm{I0}$ is the calculated residual current.or the sampling neutral current

$67Nx\_Cur\_Str$ is the zero sequence current setting of stage x (x=1, 2, 3, or 4) of earth fault protection

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 $67Nx\_Cur\_Str$. If the operating quantity exceeds the set, the start signal will be activated and the timer element will start count the time.

### 3.6.2.2 Zero-sequence Current Direction Control Element

The directionality of the operation can be selected with the $67Nx\_Dir\_Mod$ setting. Three options, "Non-directional", "Forward" or "Reverse", are optional for the practical situation.

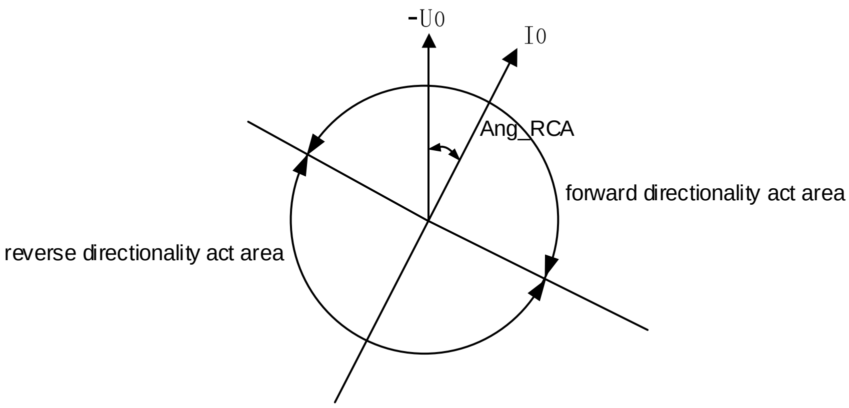
Self-polarizing is used ($I_0$-(-$U_0$)) to determine the fault direction.

The forward directionality is evaluatedbased on the below equation:

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

The reverse directionality is evaluated based on the below equation:

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




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

### 3.6.2.3 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 67N, and the operating formula is given as below:

$$I_{2nd} > 67\mathrm{N\_K\_Hm2} * I_{1st}$$

***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;

$67\mathrm{Nx\_K\_Hm2}$ is second harmonic restraint coefficient.

When the fundamental current is greater than the setting 67Nx_Hm2_IRls, the correspondingphase will be unblocked by harmonic control element.

### 3.6.2.4 Characteristic Curve

Eachstagecan be selected as definite time or inverse time characteristic depending on the practical demand.

The inverse time calculating eqation is listed as follows.

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

***Where:***

$I_p$ is current setting $67Nx\_Cur\_Str$.

$T_p$ is time multiplier setting $67Nx\_T\_Mult$.

$\alpha$ is a constant setting $67Nx\_Alpha$.

$K$ is a constant setting $67Nx\_K$.

$C$ is a constant setting $67Nx\_C$.

$3\mathrm{I0}$ is the operating quantity, the selected neutral current or calculated residual current.

| **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 timer model can be selected by modifying the setting $67Nx\_Op\_Curve\_Type$.

When the $67Nx\_Op\_Curve\_Type = 0$, the operation is activated after the operation timer element has reached the value set by $67Nx\_Op\_T$. If a drop-off situation happens, that is, a fault suddenly disappears and the fault current drop lower than the current setting, before the operate delay is exceeded, the operation will reset.

When the $67Nx\_Op\_Curve\_Type$ $= 1{\sim}5$, the operation is activated after the operation timer has reached the value determined by the IDMT curve. However, $67Nx\_Min\_Op\_T$ limits the minimum possible operate time under IDMT mode, that is, the operation time should not be less than the $67Nx\_Min\_Op\_T$. If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the operation will reset.

***NOTICE!***

The $67Nx\_Min\_Op\_T$ setting should be setvery cautiously because at least the operating time should exceed the $67Nx_Min_Op_T$setting even though the operation time is calculated according to the IDMT curve.

### 3.6.3 Logic Diagram

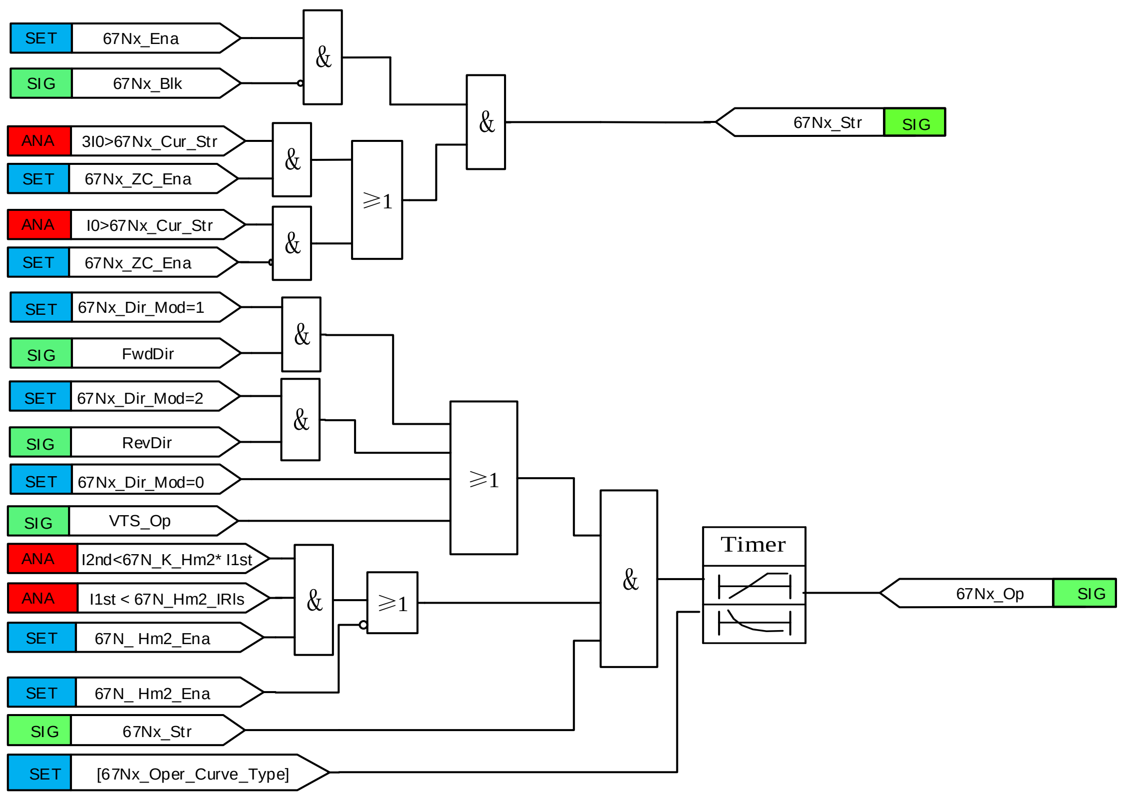



**Figure 3.6-1 Logic Diagram for 67N**

### 3.6.4 Settings

**Table 3.6-3 Settings of earth fault protection**

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 67N1_Cur_Str | 0.02In~20.00In | A | 0.01 | 20.00 | Operating current level for stage 1 |
| 2 | 67N1_Op_T | 0.020~100.000 | s | 0.001 | 10.000 | Def time delay or add time delay for inverse char of stage 1 |
| 3 | 67N1_Ang_RCA | 0.0~360.0 | Deg | 0.1 | 90.0 | Relay characteristic angle (RCA) |
| 4 | 67N1_Dir_Mod | 0~2 | - | 1 | 0 | Directional mode:0-2 for "Non-directional", "Forward" or "Reverse" |
| 5 | 67N1 _K_Hm2 | 0.00~1.00 | - | 0.01 | 0.10 | Coefficient of second harmonics for inrush current detection |
| 6 | 67N1_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush current detection |
| 7 | 67N1_Op_Curve_Type | 0~5 | - | 1 | 1 | Option of characteristic curve for stage 1 |
| 8 | 67N1_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay for stage 1 |
| 9 | 67N1_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 1 |
| 10 | 67N1_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 67N Stage 1 |
| 11 | 67N1_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 67N Stage 1 |
| 12 | 67N1_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 67N Stage 1 |
| 13 | 67N1_ Hm2_Ena | 0/1 | - | - | 0 | Enable second harmonicsdetection：1 Disable second harmonicsdetection：0 |
| 14 | 67N1_ZC_Ena | 0/1 | - | - | 0 | Zero-sequence current comes fromthree-phase current : 1 Zero-sequence current from the external : 0 |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 15 | 67N1_Ena | 0/1 | - | - | 0 | Operation 0/ 1 |
| 16 | 67N2_Cur_Str | 0.02In~20.00In | A | 0.01 | 20.00 | Operating current level for stage 2 |
| 17 | 67N2_Op_T | 0.020~100.000 | s | 0.001 | 10.000 | Def time delay or add time delay for inverse char of stage 2 |
| 18 | 67N2_Ang_RCA | 0.0~360.0 | Deg | 0.1 | 90.0 | Relay characteristic angle (RCA) |
| 19 | 67N2_Dir_Mod | 0~2 | - | 1 | 0 | Directional mode:0-2 for "Non-directional", "Forward" or "Reverse" |
| 20 | 67N2 _K_Hm2 | 0.00~1.00 | - | 0.01 | 0.10 | Coefficient of second harmonics for inrush current detection |
| 21 | 67N2_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush current detection |
| 22 | 67N2_Op_Curve_Type | 0~5 | - | 1 | 1 | Option of characteristic curve for stage 2 |
| 23 | 67N2_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay for stage 2 |
| 24 | 67N2_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 2 |
| 25 | 67N2_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 67N Stage 2 |
| 26 | 67N2_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 67N Stage 2 |
| 27 | 67N2_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 67N Stage 2 |
| 28 | 67N2_ Hm2_Ena | 0/1 | - | - | 0 | Enable second harmonicsdetection：1 Disable second harmonicsdetection：0 |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 29 | 67N2_ZC_Ena | 0/1 | - | - | 0 | Zero-sequence current comes fromthree-phase current : 1<br>Zero-sequence current from the external : 0 |
| 30 | 67N2_Ena | 0/1 | - | - | 0 | Operation 0/ 1 |
| 31 | 67N3_Cur_Str | 0.02In~20.00In | A | 0.01 | 20.00 | Operating current level for stage 3 |
| 32 | 67N3_Op_T | 0.020~100.000 | s | 0.001 | 10.000 | Def time delay or add time delay for inverse char of stage 3 |
| 33 | 67N3_Ang_RCA | 0.0~360.0 | Deg | 0.1 | 90.0 | Relay characteristic angle (RCA) |
| 34 | 67N3_Dir_Mod | 0~2 | - | 1 | 0 | Directional mode:0-2 for "Non-directional", "Forward" or "Reverse" |
| 35 | 67N3 _K_Hm2 | 0.00~1.00 | - | 0.01 | 0.10 | Coefficient of second harmonics for inrush current detection |
| 36 | 67N3_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush current detection |
| 37 | 67N3_Op_Curve_Type | 0~5 | - | 1 | 1 | Option of characteristic curve for stage 3 |
| 38 | 67N3_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay for stage 3 |
| 39 | 67N3_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 3 |
| 40 | 67N3_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 67N Stage 3 |
| 41 | 67N3_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 67N Stage 3 |
| 42 | 67N3_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 67N Stage 3 |
| 43 | 67N3_ Hm2_Ena | 0/1 | - | - | 0 | Enable second harmonicsdetection：1<br>Disable second harmonicsdetection：0 |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 44 | 67N3_ZC_Ena | 0/1 | - | - | 0 | Zero-sequence current comes fromthree-phase current : 1<br>Zero-sequence current from the external : 0 |
| 45 | 67N3_Ena | 0/1 | - | - | 0 | Operation 0/ 1 |
| 46 | 67N4_Cur_Str | 0.02In~20.00In | A | 0.01 | 20.00 | Operating current level for stage 4 |
| 47 | 67N4_Op_T | 0.020~100.000 | s | 0.001 | 10.000 | Def time delay or add time delay for<br>inverse char of stage 4 |
| 48 | 67N4_Ang_RCA | 0.0~360.0 | Deg | 0.1 | 90.0 | Relay characteristic angle (RCA) |
| 49 | 67N4_Dir_Mod | 0~2 | - | 1 | 0 | Directional mode:0-2 for "Non-directional", "Forward" or "Reverse" |
| 50 | 67N4_K_Hm2 | 0.00~1.00 | - | 0.01 | 0.10 | Coefficient of second harmonics for inrush current detection |
| 51 | 67N4_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush current detection |
| 52 | 67N4_Op_Curve_Type | 0~5 | - | 1 | 1 | Option of characteristic curve for stage 4 |
| 53 | 67N4_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay<br>for stage 4 |
| 54 | 67N4_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 4 |
| 55 | 67N4_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of<br>67N Stage 4 |
| 56 | 67N4_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of<br>67N Stage 4 |
| 57 | 67N4_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of<br>67N Stage 4 |
| 58 | 67N4_ Hm2_Ena | 0/1 | - | - | 0 | Enable second harmonicsdetection：1<br>Disable second harmonicsdetection：0 |
| 59 | 67N4_ZC_Ena | 0/1 | - | - | 0 | Zero-sequence current comes fromthree-phase |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | current : 1<br>Zero-sequence current from the external : 0 |
| 60 | 67N4_Ena | 0/1 | - | - | 0 | Operation 0/ 1 |

## 3.7 Restricted Earth Fault Protection (64REF)

### 3.7.1 Overview

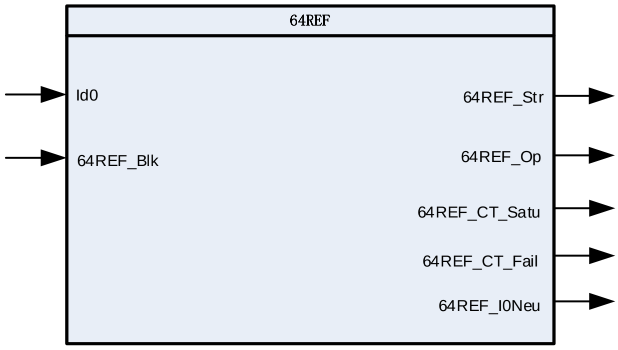
The single-phase or two-phase grounding fault with high resistance occurs when the load of the transformer is low, and the sensitivity of the Transformer differential protection（87T） is limited. Therefore, the restricted Earth Fault protection (64REF) is set as the main protection for single-phase and 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, autotransformer.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 3.7-164REF Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Id0 | Differential current of 64REF |
| 2 | 64REF_Blk | Block signal of 64REF |

**Table 3.7-264REF Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 64REF_Str | Start signal from 64REF |
| 2 | 64REF_Op | Operation signal from 64REF |
| 3 | 64REF_CT_Satu | CT Saturation signal from 64REF |
| 4 | 64REF_CT_Fail | CT fail singal 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:

$$\mathrm{I}_{0d} = 64REF\_Cur\_Str$$

***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 :

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

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

***Where:***

$I_{0d}$ is the REF differential current;

$I_{0r}$ is the residual restraint current;

$I_{0Cal}$ is the residualcurrent of the phase currents;

$I_{0Neu}$ is the neutral measured current;

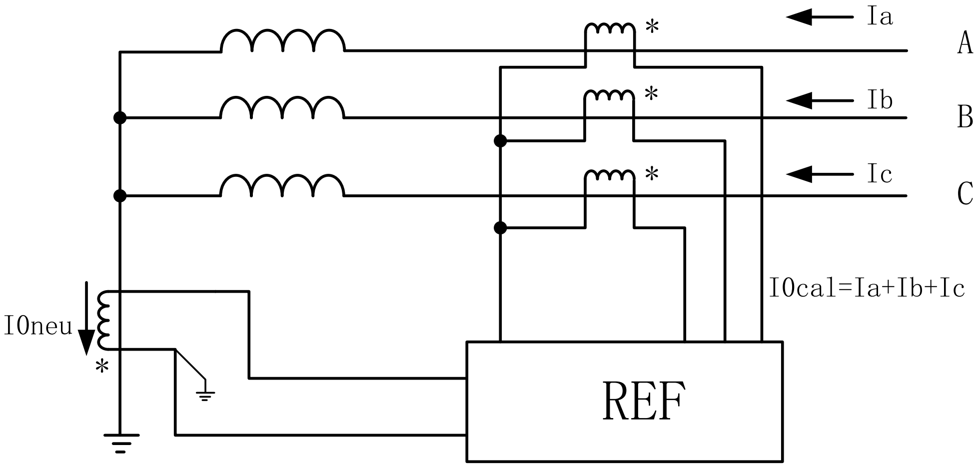



**Figure 3.7-1 REF principle diagram**

### 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:***

$I_{0d} = \left|\dot{I}_{0CaI} + \dot{I}_{0Neu}\right|, I_{0r} = \max\left\{\left|\dot{I}_{0CaI}\right|, \left|\dot{I}_{0Neu}\right|\right\}$. $\dot{I}_{0CaI}$、$\dot{I}_{0Neu}$ are respectively residualcurrent of the phase currentsand neutral measuredcurrent.For this device, the ratio restrainted coefficient fixedly takes 0.6.

### 3.7.2.5 Operation Characteristic

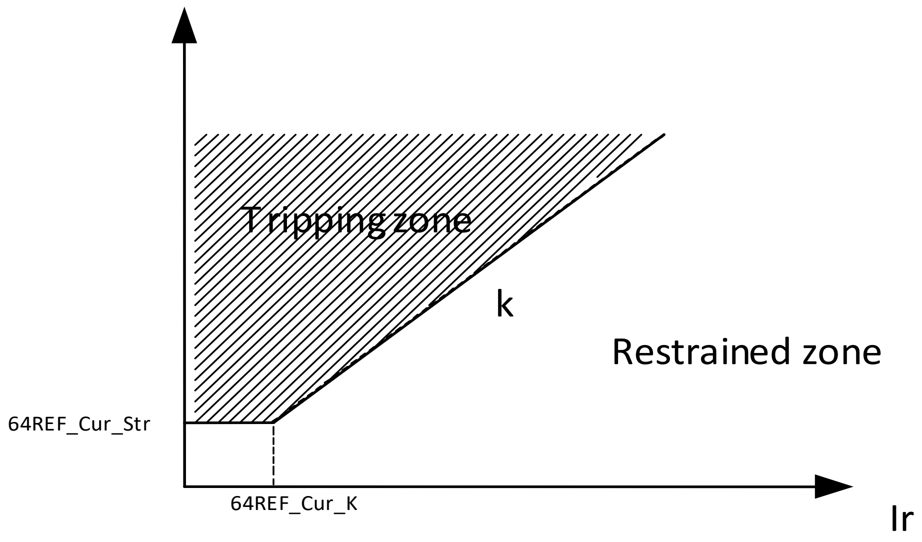



**Figure 3.7-2 Operation characteristic of REF**

***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:***

$3I_0$ 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.

#### 3.7.2.7 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

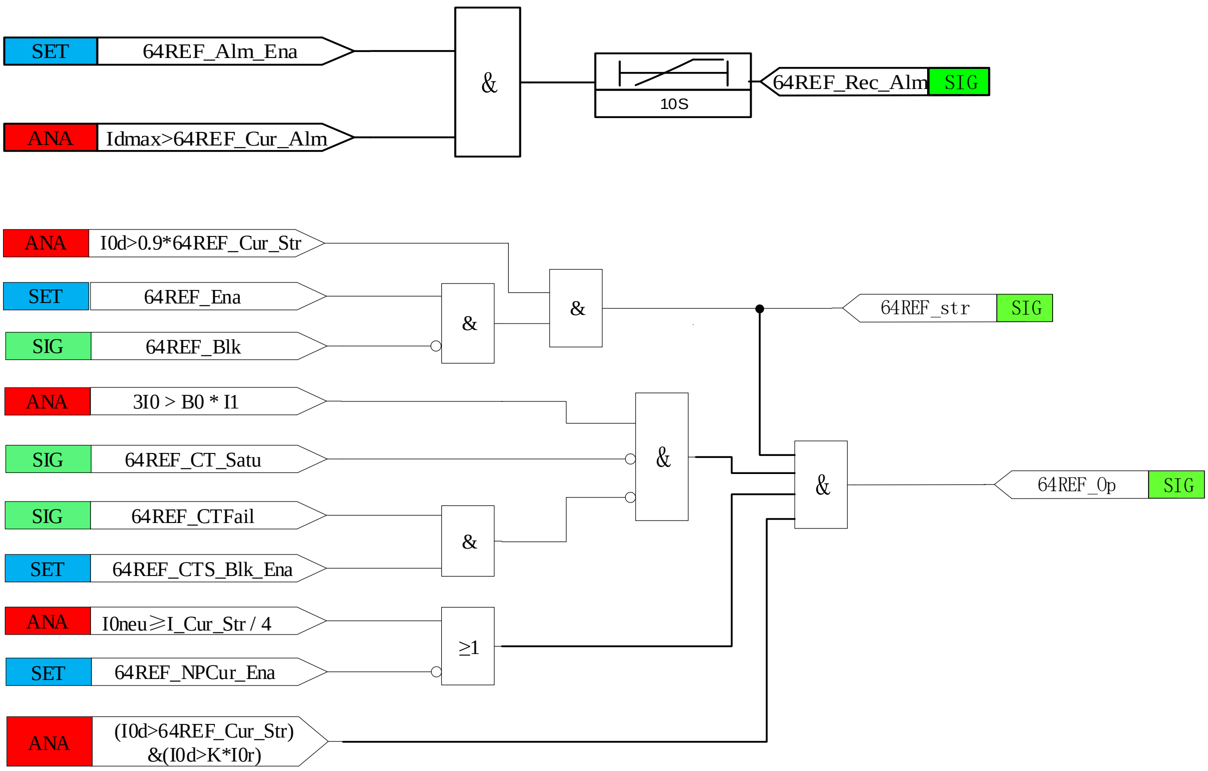



**Figure 3.7-3 Logic diagram of restricted earth fault protection**

***Where:***

I0neu is the neutral measured residual current

### 3.7.4 Settings

**Table 3.7-3 Settings of restricted earth fault protection**

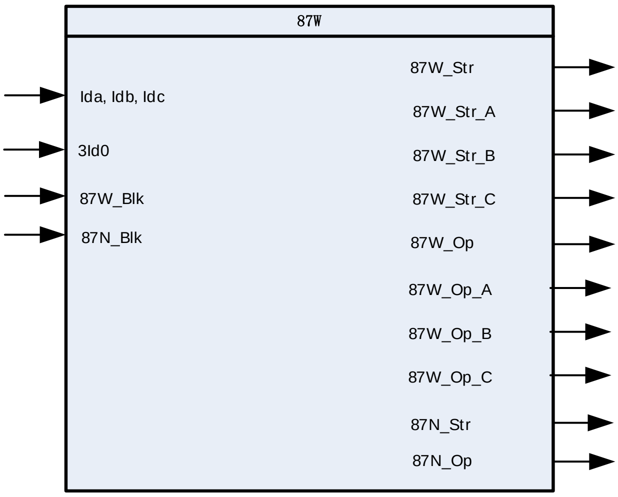
| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 64REF_Cur_Str | 0.05~20.00 | IE | 0.01 | 0.40 | Pickup setting of REF |
| 2 | 64REF_Cur_Alm | 0.05~20.00 | IE | 0.01 | 1.00 | Alm setting of REF |
| 3 | 64REF_Slope | 0~0.9 | - | 0.01 | 0.6 | Percentage restraint coefficient of REF<br>0.5 is recommended. |
| 4 | 64REF_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling REF<br>0: disable<br>1: enable |
| 5 | 64REF_Alm_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling REF_Alm<br>0: disable<br>1: enable |
| 6 | 64REF_NPCur_Ena | 0/1 | - | 1 | 1 | Logic setting of enabling/disabling neutral current criterion<br>0: disable<br>1: enable |
| 7 | 64REF_CTS_Blk_Ena | 0,1 | | 1 | 0 | Logic setting of enabling/disabling block biased differential element during CT circuit failure<br>0: disable<br>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 Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Ida, Idb, Idc | Three phase winding differential current from 87W |
| 2 | 3Id0 | Residual winding differential current from 87N |
| 3 | 87W_Blk | Block signal of 87W |
| 4 | 87N_Blk | Block signal of 87N |

**Table 3.8-2 87W Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 19 | 87W_Str | Start signal of differential from 87W |
| 20 | 87W_Str_A | Start_A signal of differential from 87W |
| 21 | 87W_Str_B | Start_B signal of differential from 87W |
| 22 | 87W_Str_C | Start_C signal of differential from 87W |
| 23 | 87W_Op | Operation signal of differential from 87W |
| 24 | 87W_Op_A | Operation_A signal of differential from 87W |
| 25 | 87W_Op_B | Operation_B signal of differential from 87W |
| 26 | 87W_Op_C | Operation_C signal of differential from 87W |
| 27 | 87N_Str | Start signal of differential from 87N |
| 28 | 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.

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

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

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

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

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

The restraint current is:

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

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

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

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

***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).

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

### 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

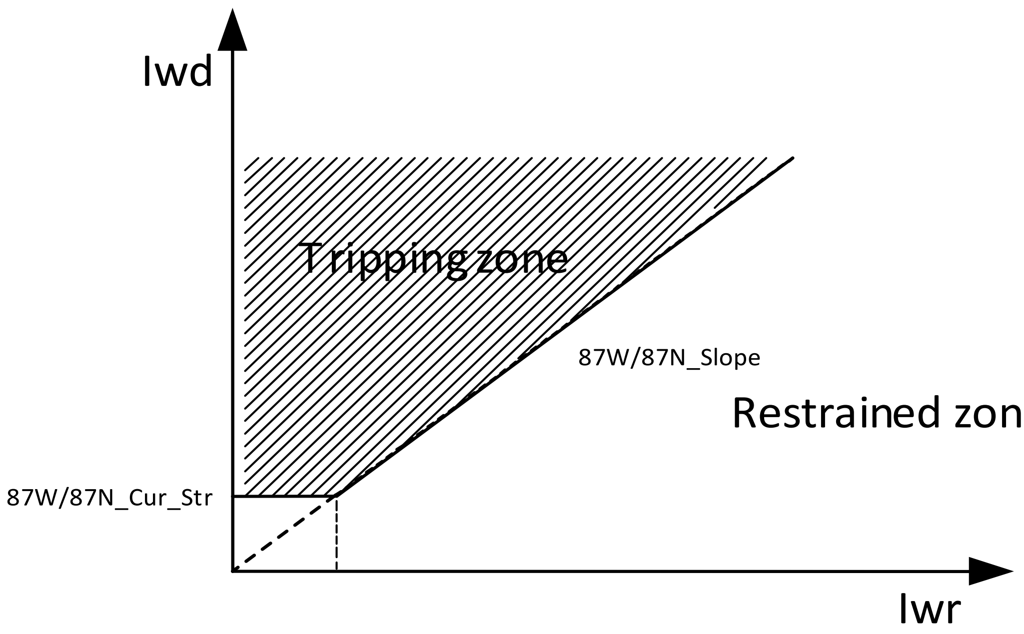



**Figure 3.8 -1 Operation characteristic of winding differential protection**

***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

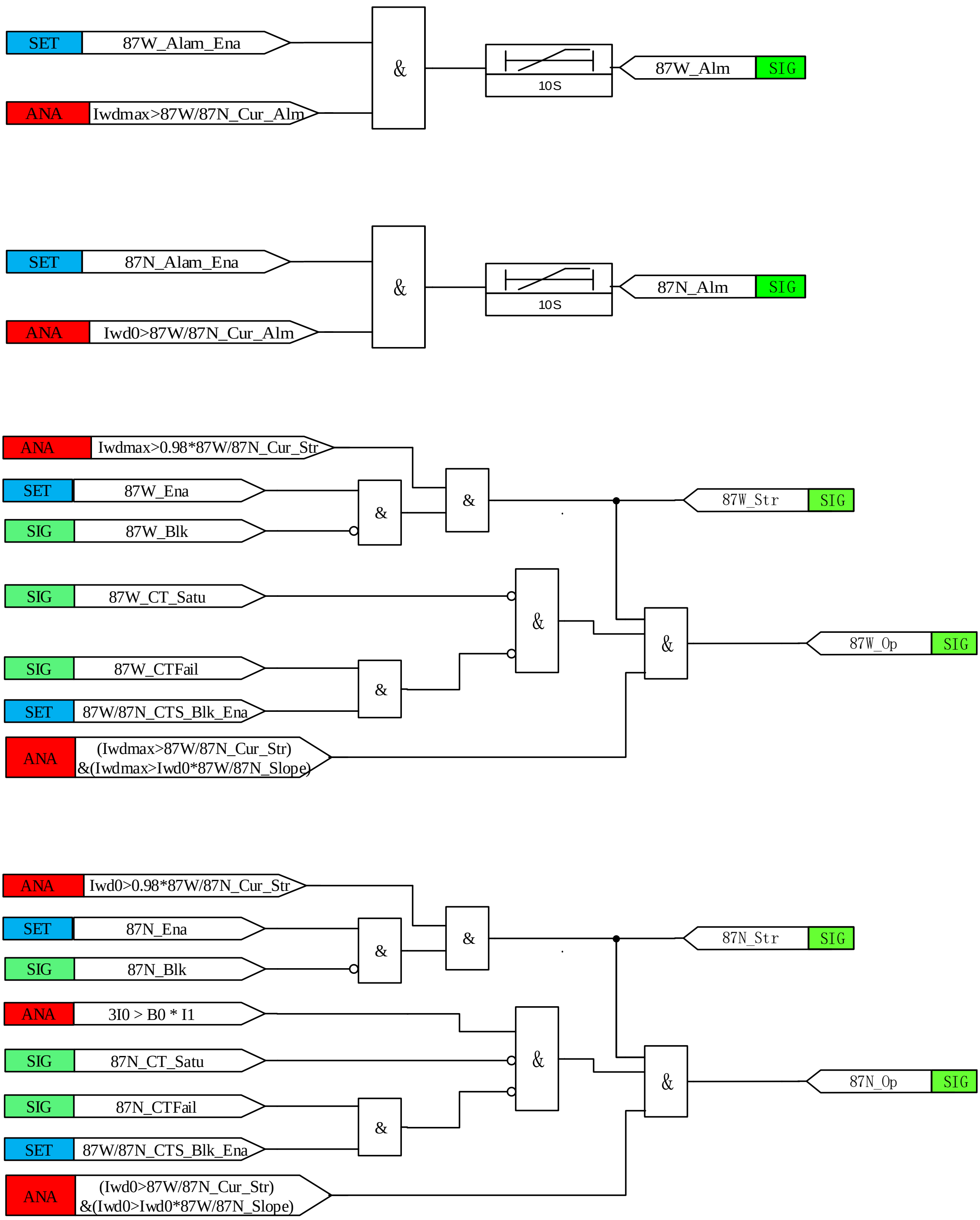



**Figure 3.8-2 Logic diagram of winding differential protection**

### 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 | IE | 0.01 | 0.40 | Pickup setting of winding differential protection |
| 2 | 87W/87N_Cur_Alm | 0.05~20.00 | IE | 0.01 | 1.00 | Alm setting of winding differential protection |
| 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<br>0: disable<br>1: enable |
|  | 87N_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling residual winding differential protection<br>0: disable<br>1: enable |
| 5 | 87W_Alam_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling 87W_Alm<br>0: disable<br>1: enable |
| 6 | 87N_Alam_Ena | 0/1 | - | 1 | 1 | Logic setting of enabling/disabling 87N_Alm<br>0: disable<br>1: enable |
| 7 | 87N_IG0_Ena | 0/1 | - | 1 | 1 | Zero-sequence current comes fromthree-phase current : 0<br>Zero-sequence current from the external : 1 |
| 8 | 87N _NPCur_Ena | 0/1 | - | 1 | 1 | Logic setting of enabling/disabling neutral current criterion<br>0: disable |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | 1: enable |
| 9 | 87W/87N_CTS_Blk_Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling block biased differential element during CT circuit failure<br>0: disable<br>1: enable |

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

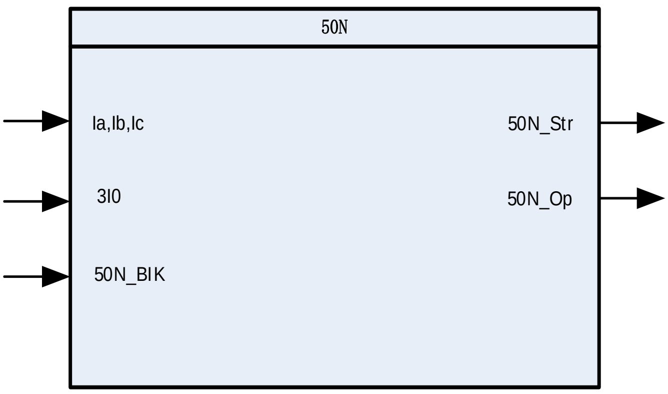
## 3.9.1 Overview

The main purpose of Instantaneous residual overcurrent protection 50N 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's bring 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.

In this protection have the capability of current multiplication factor for use only transformer inrush condition. This protection provides two stage controlling setting with definite time delay (DT) or IDMT time delay and also provide blocking function in case if CT trouble.

In addition, the 50N 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 50N Input Signals**

| NO. | Signal | Description |
|---|---|---|

| NO. | Signal | Description |
|---|---|---|
| 4 | Ia, Ib, Ic | the three phase current. |
| 5 | 3I0 | The Measured neutral current |
| 6 | 50N_Blk | Block signal of 50N |

**Table 3.8-2 50NOutput Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 50N_Str | Common start signal from 50N |
| 2 | 50N_Op | Operation signal from50N |

## 3.9.2 Protection Principle

### 3.9.2.1 Zero-sequence Overcurrent Element

The operation criterion for earth fault protection is:

$$3I0 > 50N\_Cur\_Str$$

***Where:***

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

$50N\_Cur\_Str$ 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 $50N\_Cur\_Str$. If the measured value exceeds the set $50N\_Cur\_Str$, the level detector sends an enable-signal to the timer module.

## 3.9.3 Logic Diagram

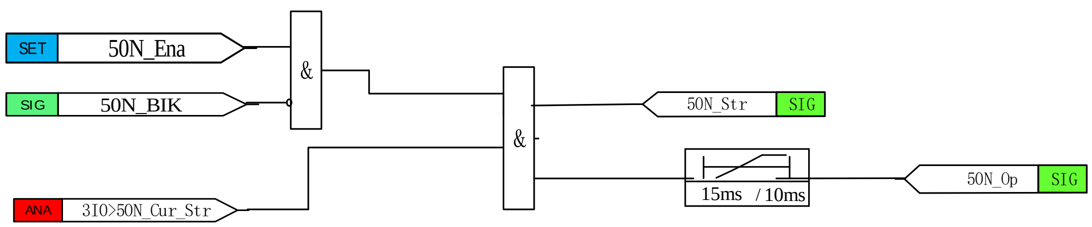



**Figure 3.9-1 Logic Diagram for 50N**

### 3.9.4 Settings

**Table 3.9-3 Settings of earth fault protection**

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 50N_Cur_Str | 0.02In~20In | A | 0.01 | 20.00 | Current setting of 50N |
| 2 | 50N_H_K_Hm2 | 0.00~1.00 | - | 0.01 | 0.1 | Coefficient of second harmonics for inrush current detection |
| 3 | 50N_H_Hm2_IRls | 2.00~30.00 | A | 0.01 | 20.00 | current setting for inrush current detection |
| 4 | 50N_H_Hm2_Ena | 0/1 | - | - | 0 | Enable second harmonicsdetection：1<br>Disable second harmonicsdetection：0 |
| 5 | 50N_ZC_Ena | 0/1 | - | 1 | 0 | Zero-sequence current comes fromthree-phase current : 1<br>Zero-sequence current from the external : 0 |
| 6 | 50N_Ena | 0/1 | - | 1 | 0 | Enabling/disabling of 50N<br>0: disable<br>1: enable |

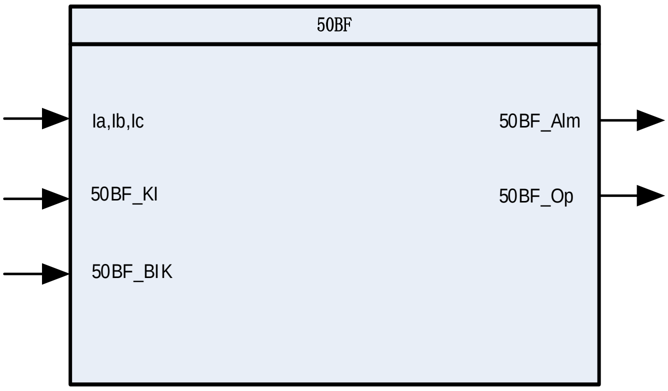
## 3.10 Breaker Failure Protection (50BF)

3.2

### 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, middle-voltage side or low-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 |
|---|---|---|
| 7 | Ia, Ib, Ic | the three phase current. |
| 8 | 50BF_KI | Input signal of 50BF |
| 9 | 50BF_Blk | Block signal of 50BF |

**Table 3.9-2 50BF Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 3 | 50BF_Alm | Alarm signal from 50BF |
| 4 | 50BF_Op | Operation 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

$$I_{max} > \text{50BF\_ Cur\_I\_Str}$$

Where:

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

2. Zero-sequence current criterion

$$3I0 > \text{50BF\_ Cur\_I0\_Str}$$

Where:

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

3. Negative-sequence current criterion

$$I_2 > 50BF\_Cur\_I2\_Str$$

Where:

$I_2$ is negative-sequence current of some side.

4. DPFC current criteria

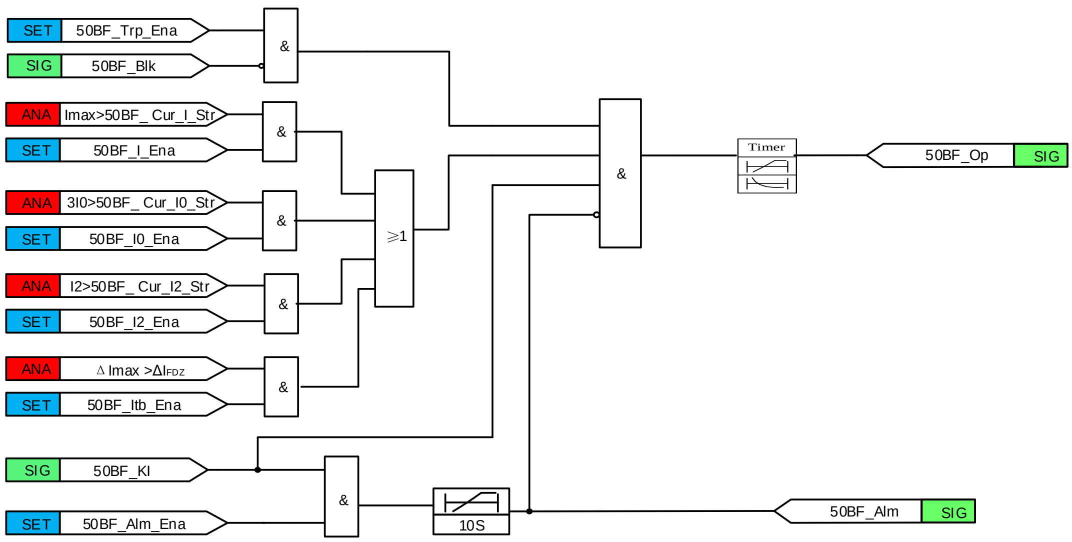
$$\Delta I_{max} > \Delta I_{FDZ}$$

Where:

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

$\Delta I_{FDZ}$ 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_ Cur_I_Str | 0.04In~20In | A | 0.01 | 20.00 | Operating phase current level |
| 2 | 50BF_ Cur_I0_Str | 0.04In~20In | A | 0.01 | 20.00 | Operating zero-sequence current level |
| 3 | 50BF_Cur_I2_Str | 0.04In~20In | A | 0.01 | 20.00 | Operating Negative-sequence current level |

| No. | Item | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 4 | 50BF_Op_T | 0.00~10.00 | s | 0.01 | 10.00 | Def time delay or add time delay |
| 5 | 50BF_Itb_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling DPFC current criterion to control breaker failure protection. |
| 6 | 50BF_I_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling phase current criterion to control breaker failure protection |
| 7 | 50BF_I0_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling zero-sequence current criterion to control breaker failure protection. |
| 8 | 50BF_I2_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling negative-sequence current criterion to control breaker failure protection. |
| 9 | 50BF_Alm_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling alarm of breaker failure protection |
| 10 | 50BF_Trp_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling time delay of breaker failure protection |

## 3.11 Residual Overvoltage Protection (59N)

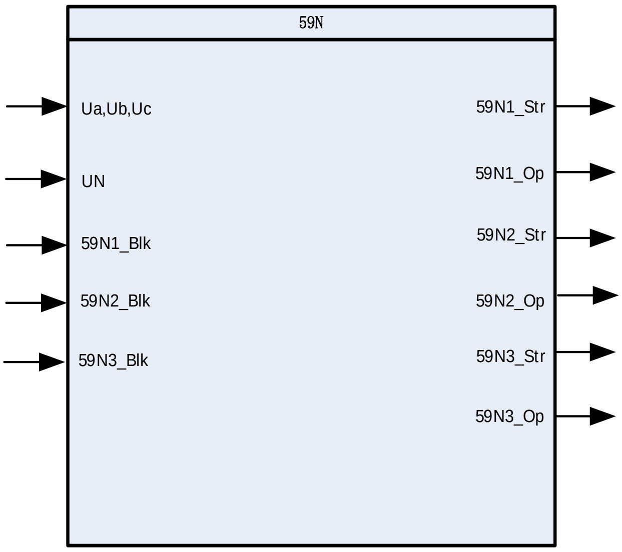
### 3.11.1 Overview

The main purpose of Three Stage Residual Overvoltage Protection (59N) is to continuously monitor the protected network residual overvoltage with the combination of zero-sequence instrument transformer (VT). If any kind of trouble happen in protected electrical circuit likes open or short circuit, it's bring some type of disturbances. These disturbances will change the value of grounding system impedance cause overvoltage in power system. If the detected value of restrain overvoltage is larger than set value of restrain overvoltage 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, middle-voltage side or low-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 | 59N1_Blk | Block signal of 59 stage1 |
| 2 | 59N2_Blk | Block signal of 59 stage2 |
| 3 | 59N3_Blk | Block signal of 59 stage3 |
| 2 | Ua,Ub,Uc | the three phase group signal for voltage inputs |
| 4 | UN | measuredresidual voltage |

**Table 3.11-259G Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 59N1_Str | Start signal from 59G stage1 |
| 2 | 59N1_Op | Operation signal from 59G stage1 |
| 3 | 59N2_Str | Start signal from 59G stage2 |
| 4 | 59N2_Op | Operation signal from 59G stage2 |

| NO. | Signal | Description |
|---|---|---|
| 5 | 59N3_Str | Start signal from 59G stage3 |
| 6 | 59N3_Op | Operation signal from 59G stage3 |

## 3.11.2 Protection Principle

Residual overvoltage protection includes two stages residual overvoltage element with independent logic, voltage and time delay settings. All the stages1 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 overvoltage protection can select calculated residual voltage or measured residual voltage according to the setting $59Nx\_ZC\_Ena$ when calculated residual voltage is adopted, residual overvoltage protection can be blocked due to VT circuit failure if the setting $59Nx\_VTS\_Blk\_Ena$ is set as “1”.

### 3.11.2.1 Operation Criterion

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

***Where:***

$3U0$ is calculated residual voltage;

$UN$ is measured residual voltage.

### 3.11.2.2 Time Curve

Stage 2 of residual overvoltage 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:***

$K$, $\alpha$ 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 $59Nx\_Op\_Curve\_Type$.

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 blockresidual overvoltage protection according to the setting $59Nx\_VTS\_Blk\_Ena$ 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

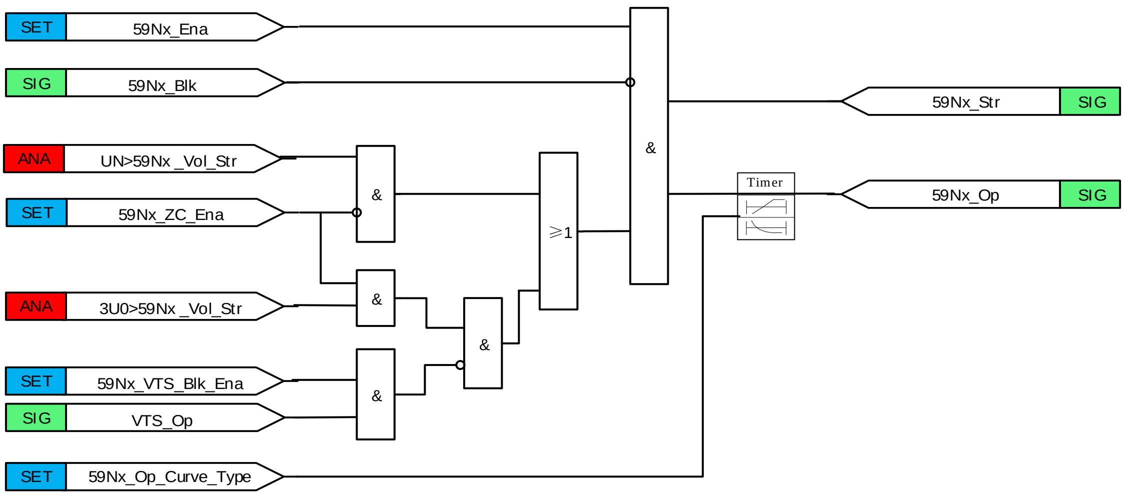



**Figure 3.11-1 Logic diagram of residual overvoltage protection**

***Where:***

3U0 is calculated residual or calculated voltage.

UN is measured residual voltage

### 3.11.4 Settings

**Table 3.11-3 Settings of residual overvoltage protection**

| No. | Item | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 59N1 _Vol_Str | 2.00~200.00 | V | 0.01 | 200.00 | Voltage setting of stage 1 of residual overvoltage protection |
| 2 | 59N1_Op_T | 0.000~300.000 | s | 0.001 | 10.000 | Definite time of stage 1 of residual overvoltage protection |
| 3 | 59N1_Op_Curve_Type | 0~5 | - | - | 0 | Selection of the type of time delay curve:0 for DT, 1~5 for IDMT |

| No. | Item | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 4 | 59N1_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay for stage 1 |
| 5 | 59N1_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage 1 |
| 6 | 59N1_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 59N Stage 1 |
| 7 | 59N1_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 59N Stage 1 |
| 8 | 59N1_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 59N Stage 1 |
| 9 | 59N1_ZC_Ena | 0/1 | - | 1 | 0 | Residual voltage option for the calculation of stage 1 of residual overvoltage protection<br>0: Measured residual voltage<br>1: Calculated residual voltage |
| 10 | 59N1_VTS_Blk_Ena | 0/1 | - | 1 | 0 | When calculated residual voltage is adopted, residual overvoltage protection can be blocked due to VT circuit failure if the setting 59N1_VTS_Blk_Ena is set as “1”. |
| 11 | 59N1_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling stage 1 of residual overvoltage protection<br>0: disable<br>1: enable |
| 12 | 59N2 _Vol_Str | 2.00~200.00 | V | 0.01 | 110.00 | Voltage setting of stage 2 of residual overvoltage protection |

| No. | Item | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 13 | 59N2_Op_T | 0.000~300.000 | s | 0.001 | 10.000 | Definite time of stage 2 of residual overvoltage protection |
| 14 | 59N2_Op_Curve_Type | 0~5 | - | - | 0 | Selection of the type of time delay curve:0 for DT, 1~5 for IDMT |
| 15 | 59N2_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay for stage2 |
| 16 | 59N2_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage2 |
| 17 | 59N2_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 59N Stage 2 |
| 18 | 59N2_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 59N Stage 2 |
| 19 | 59N2_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 59N Stage 2 |
| 20 | 59N2_ZC_Ena | 0/1 | - | 1 | 0 | Residual voltage option for the calculation of stage 2 of residual overvoltage protection<br>0: Measured residual voltage<br>1: Calculated residual voltage |
| 21 | 59N2_VTS_Blk_Ena | 0/1 | - | 1 | 0 | When calculated residual voltage is adopted, residual overvoltage protection can be blocked due to VT circuit failure if the setting 59N2 _VTS_Blk_Ena is set as "1". |
| 22 | 59N2_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling stage 2 of residual overvoltage protection<br>0: disable<br>1: enable |

| No. | Item | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 23 | 59N3_Vol_Str | 2.00~200.00 | V | 0.01 | 110.00 | Voltage setting of stage 3 of residual overvoltage protection |
| 24 | 59N3_Op_T | 0.000~300.000 | s | 0.001 | 10.000 | Definite time of stage 3 of residual overvoltage protection |
| 25 | 59N3_Op_Curve_Type | 0~5 | - | - | 0 | Selection of the type of time delay curve:0 for DT, 1~5 for IDMT |
| 26 | 59N3_T_Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier for the inverse time delay for stage3 |
| 27 | 59N3_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time for inverse curves for stage3 |
| 28 | 59N3_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 59N Stage 3 |
| 29 | 59N3_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 59N Stage 3 |
| 30 | 59N3_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 59N Stage 3 |
| 31 | 59N3_ZC_Ena | 0/1 | - | 1 | 0 | Residual voltage option for the calculation of stage 3 of residual overvoltage protection<br>0: Measured residual voltage<br>1: Calculated residual voltage |
| 32 | 59N3_VTS_Blk_Ena | 0/1 | - | 1 | 0 | When calculated residual voltage is adopted, residual overvoltage protection can be blocked due to VT circuit failure if the setting 59N3_VTS_Blk_Ena is set as "1". |
| 33 | 59N3_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling stage 3 of residual overvoltage protection<br>0: disable<br>1: enable |

## 3.12 Three-phase overvoltage protection (59P)

3.3

### 3.12.1 Overview

The main operating function of Two Stage Three-phase overvoltage 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 overvoltage 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 overcurrent protection.

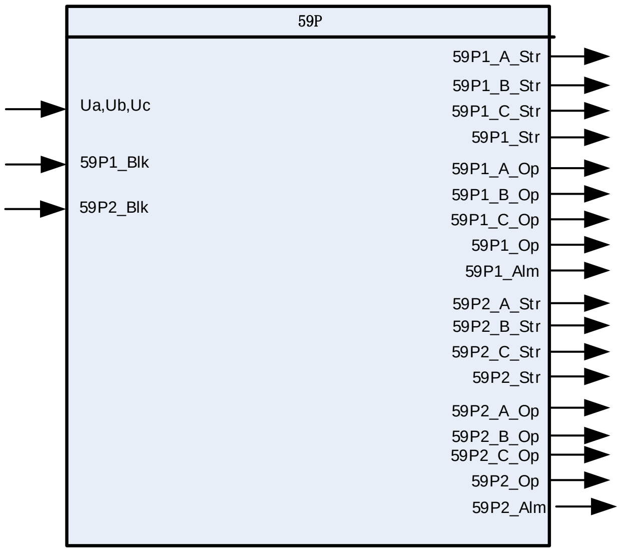
59Pcan support several kind of VT connection:

- 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 overvoltage protection 59P is also have blocking function capability.

In addition, the 59P 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.

#### 3.12.1.1 Function Block




#### 3.12.1.2 Signals

**Table 3.12-1 59P Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 59P1_Blk | Block signal of 59P stage1 |
| 2 | 59P2_Blk | Block signal of 59P stage2 |
| 3 | Ua,Ub,Uc | the three phase group signal for voltage inputs |

**Table 3.12-2 Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 59P1_A_Str | phase A Start signal from 59P stage1 |
| 2 | 59P1_B_Str | phase B Start signal from 59P stage1 |
| 3 | 59P1_C_Str | phase C Start signal from 59P stage1 |
| 4 | 59P1_ Str | CommonStart signal from 59P stage1 |
| 5 | 59P1_A_Op | phase A Operation signal from 59P stage1 |
| 6 | 59P1_B_Op | phase B_Operation signal from 59P stage1 |
| 7 | 59P1_C_Op | phase C Operation signal from 59P stage1 |
| 8 | 59P1_ Op | Operation signal from 59P stage1 |
| 9 | 59P1_ Alm | Alarm signal from 59P stage1 |
| 10 | 59P2_A_Str | phase A Start signal from 59P stage2 |
| 11 | 59P2_B_Str | phase B Start signal from 59P stage2 |
| 12 | 59P2_C_Str | phase C Start signal from 59P stage2 |
| 13 | 59P2_ Str | CommonStart signal from 59P stage2 |
| 14 | 59P2_A_Op | phase A Operation signal from 59P stage2 |
| 15 | 59P2_B_Op | phase B_Operation signal from 59P stage2 |
| 16 | 59P2_C_Op | phase C Operation signal from 59P stage2 |
| 17 | 59P2_ Op | Operation signal from 59P stage2 |
| 18 | 59P2_ Alm | Alarm signal from 59P stage2 |

### 3.12.2 Protection Principle

The three-phase overvoltage protection function can be enabled or disabled by setting the corresponding $59Px\_Ena$ parameter values as "1" or "0".

The fundamental frequency component of the measured three phase voltages iscompared phase-wise to the set value of the $59Px\_Vol\_Str$ setting. If the measured value is higher than the set value of the $59Px\_Vol\_Str$ 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 $59Px\_Str\_Ph\_Num$ and no blocking signal input is activated, the phase selection logic activates the timer and the $59Px\_Str$ output and the corresponding output of the respective phases ($59Px\_Str\_A/B/C$).

The $59Px\_Vol\_Opt$ setting is used for selecting phase-to-earth ($59Px\_Vol\_Opt = 0$) or phase-to-phase($59Px\_Vol\_Opt = 1$) voltages for protection.

$59Px\_Vol\_Str$ is the preset value to check for the voltage

$59Px\_Str\_Ph\_Num$ shows the number of phases required for operate activation.

Depending on the value of the set $59Px\_Op\_Curve\_Type$, the time characteristics are selected according to DT ($59Px\_Op\_Curve\_Type = 0$) or IDMT ($59Px\_Op\_Curve\_Type = 1{\sim}5$). 59P supports the following IDMT operating curve type:

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

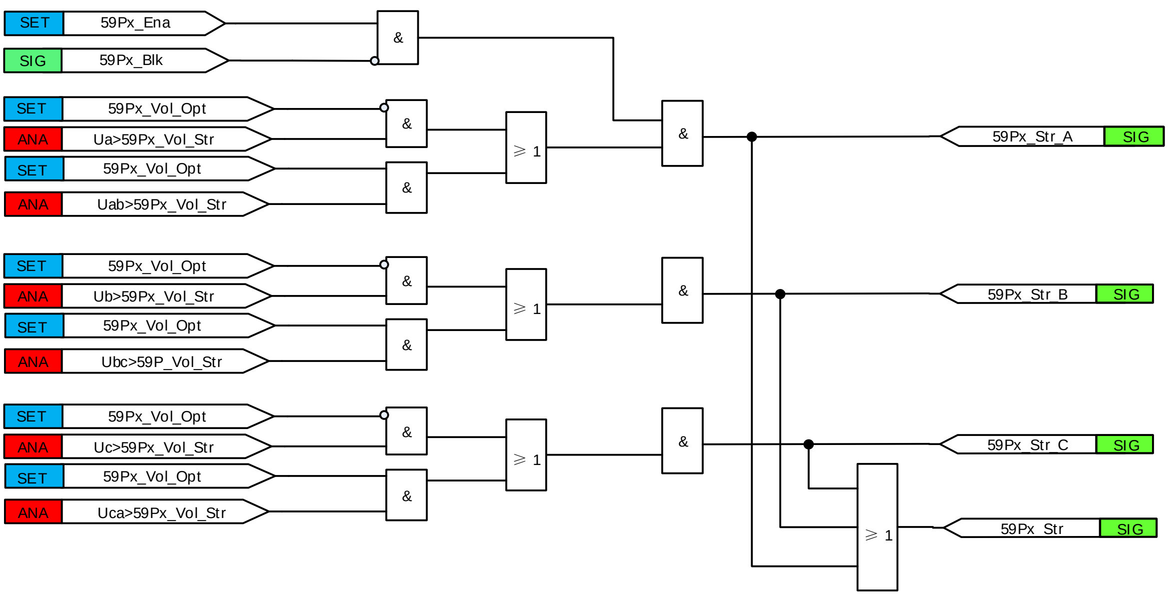
| IDMT Characteristic | K | α | C | Curve Type | Selection |
|---|---|---|---|---|---|
| IEC Normal inverse | 0.14 | 0.02 | 0 | 1 | ■ |
| IEC Very inverse | 13.5 | 1.0 | 0 | 2 | ■ |
| IEC Extremely inverse | 80.0 | 2.0 | 0 | 3 | ■ |
| IEC Long-time inverse | 120.0 | 1.0 | 0 | 4 | ■ |
| IEC User inverse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

When the operation timer has reached the value set by $59Px\_Op\_T$ in the DT mode or the value set by the IDMT operate time curve, the $59Px\_Op$ output is activated. The corresponding output for the respective phases ($59Px\_Op\_A/B/C$) is also activated. For the IDMT model, $59Px\_Min\_Op\_T$ 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 $59Px\_Str$ output is deactivated.

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

### 3.12.3 Logic Diagram



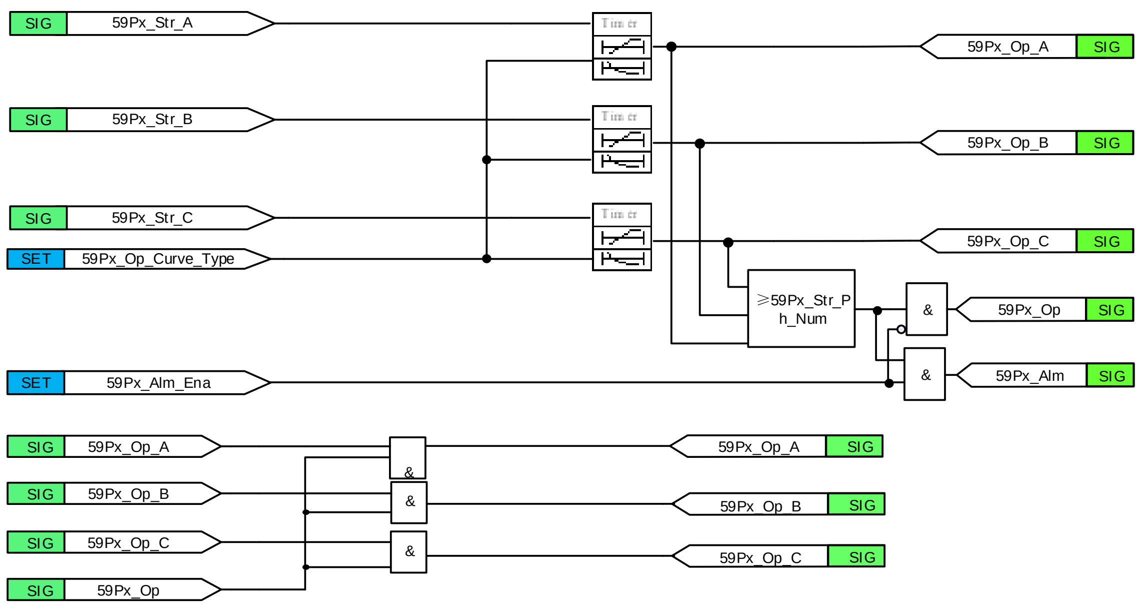



**Figure 3.12-1Functional module diagram**

***Where:***

$59Px\_Op\_Curve\_Type$ is the selection of the type of stage x(X=1,2)time delay curve.

$59Px\_Op\_T$ is the operating time delay for stage x(X=1,2)definite time curve.

$59Px\_Min\_Op\_T$ is the minimum operate time delay for stage x(X=1,2)IDMT curves.

## 3.12.4 Settings

**Table 3.12-3settings of Two stage Three-phase overvoltage protection**

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 59P1_Vol_Str | 0.00~160.00 | V | 0.01 | 160.00 | Start value of overvoltage |
| 2 | 59P1_Op_T | 0.040~300.000 | s | 0.001 | 10.000 | Operating time delay for definite time curve |
| 3 | 59P1_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 | 59P1_Op_Curve_Type | 0~5 | - | 1 | 0 | Selection of the type of time delay curve:0 for DT, 1~5 for IDMT |
| 5 | 59P1_T_ Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier in IEC curves |
| 6 | 59P1_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time delay for IDMT curves |
| 7 | 59P1_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | 59P Stage 1 |
| 8 | 59P1_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 59P Stage 1 |
| 9 | 59P1_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 59P Stage 1 |
| 10 | 59P1_Vol_Opt | 0/1 | - | 1 | 0 | Parameter to select phase or phase-to- phase voltages: 0 forphase voltages,1 forphase-to- phase voltages |
| 11 | 59P1_Alm_Ena | 0/1 | - | 1 | 0 | Alarm Off/On |
| 12 | 59P1_Ena | 0/1 | - | 1 | 0 | Operation Off/On |
| 13 | 59P2_Vol_Str | 0.00~160.00 | V | 0.01 | 110.00 | Start value of overvoltage |
| 14 | 59P2_Op_T | 0.040~300.000 | s | 0.001 | 10.000 | Operating time delay for definite time curve |
| 15 | 59P2_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 |
| 16 | 59P2_Op_Curve_Type | 0~5 | - | 1 | 0 | Selection of the type of time delay curve:0 for DT, 1~5 for IDMT |
| 17 | 59P2_T_ Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier in IEC curves |
| 18 | 59P2_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time delay for IDMT curves |
| 19 | 59P2_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 59P Stage 2 |
| 20 | 59P2_C | 0.000~10.000 | - | 0.001 | 0.000 | constant C of 59P Stage 2 |
| 21 | 59P2_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 59P Stage 2 |
| 22 | 59P2_Vol_Opt | 0/1 | - | 1 | 0 | Parameter to select phase or phase-to- phase voltages: 0 forphase voltages,1 forphase-to- phase voltages |
| 23 | 59P2_Alm_Ena | 0/1 | - | 1 | 0 | Alarm Off/On |
| 24 | 59P2_Ena | 0/1 | - | 1 | 0 | Operation Off/On |

# 3.13 Three-phase Undervoltage Protection (27P)

## 3.13.1 Overview

The main operating function of Two Stage Three-phase undervoltage 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 undervoltage 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 overcurrent protection.

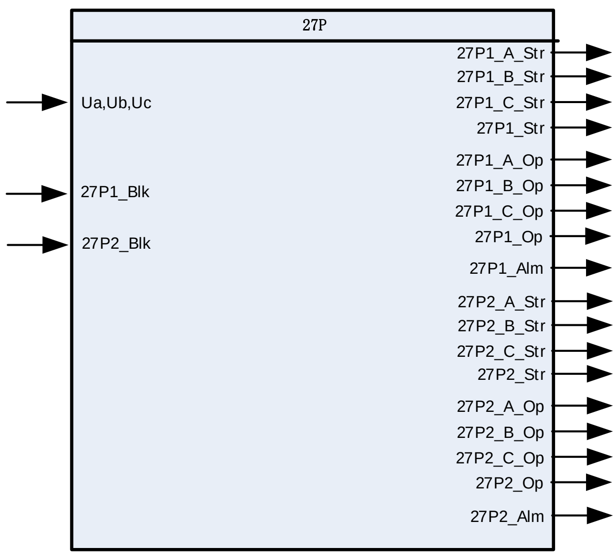
27P can support several kind of VT connection:

- 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 undervoltage protection (27P) is also have blocking function capability.

In addition, the 27P 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.

### 3.13.1.1 Function Block




### 3.13.1.2 Signals

**Table 3.13-1 27P Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Ua,Ub,Uc | “Ua,Ub,Uc” is the three phase group signal for voltage inputs |
| 2 | 27P1_Blk | Block signal of 27P stage1 |

| NO. | Signal | Description |
|---|---|---|
| | 27P2_Blk | Block signal of 27P stage2 |

**Table 3.13-227POutput Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 27P1_A_Str | phase A Start signal from 27P stage1 |
| 2 | 27P1_B_Str | phase BStart signal from 27P stage1 |
| 3 | 27P1_C_Str | phase C Start signal from 27P stage1 |
| 4 | 27P1_Str | CommonStart signal from 27P stage1 |
| 5 | 27P1_A_Op | phase A Operation signal from 27 Pstage1 |
| 6 | 27P1_B_Op | phase B Operation signal from 27P stage1 |
| 7 | 27P1_C_Op | phase C Operation signal from 27P stage1 |
| 8 | 27P1_Op | Operation signal from 27P stage1 |
| 9 | 27P1_Alm | Alarm signal from 27P stage1 |
| 10 | 27P2_A_Str | phase A Start signal from 27P stage2 |
| 11 | 27P2_B_Str | phase BStart signal from 27P stage2 |
| 12 | 27P2_C_Str | phase C Start signal from 27P stage2 |
| 13 | 27P2_Str | CommonStart signal from 27P stage2 |
| 14 | 27P2_A_Op | phase A Operation signal from27P stage2 |
| 15 | 27P2_B_Op | phase B Operation signal from27P stage2 |
| 16 | 27P2_C_Op | phase C Operation signal from27P stage2 |
| 17 | 27P2_Op | Operation signal from 27P stage2 |
| 18 | 27P2_Alm | Alarm signal from 27P stage2 |

## 3.13.2 Protection Principle

The three-phase undervoltage protection function can be enabled or disabled by setting the corresponding $27Px\_Ena$ 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 $27Px\_Vol\_Str$ setting. If the measured value is lower than the set value of the $27Px\_Vol\_Str$ 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 $27Px\_Str\_Ph\_Num$ and no blocking signal input is activated, the phase selection logic activates the timer and the 27P_Str output and the corresponding output of the respective phases ($27Px\_Str\_A/B/C$).

The $27Px\_Vol\_Opt$ setting is used for selecting phase-to-earth ($27Px\_Vol\_Opt = 0$) or phase-to-phase($27Px\_Vol\_Opt = 1$) voltages for protection.

$27Px\_Vol\_Str$ is the preset value to check for the voltage

$27Px\_Str\_Ph\_Num$ 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 $27Px_I_Blk_Ena$setting.

For example:If the measured current level decreases below the 0.05A, either thetrip 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 $27Px\_Op\_Curve\_Type$, the time characteristics are selected according to DT ($27Px\_Op\_Curve\_Type = 0$) or IDMT ($27Px\_Op\_Curve\_Type = 1\sim5$). 27P supports the following IDMT operating curve type:

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

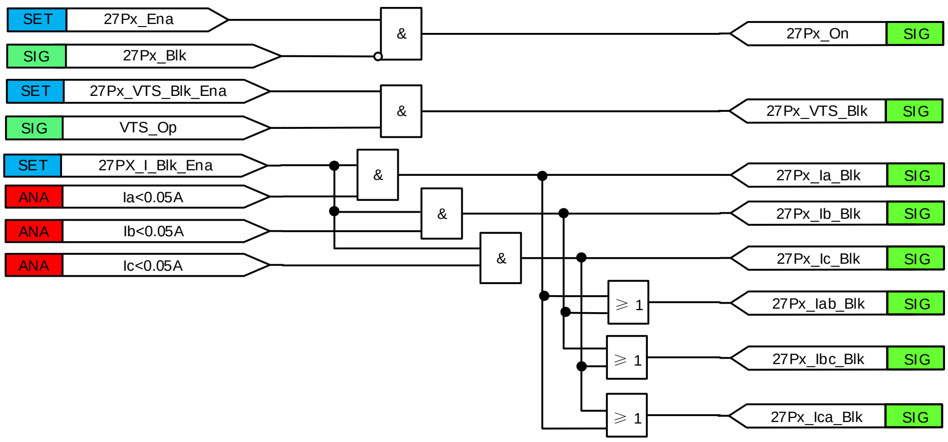
| IDMT Characteristic | K | α | C | Curve Type | Selection |
|---|---|---|---|---|---|
| IEC Normal inverse | 0.14 | 0.02 | 0 | 1 | ■ |
| IEC Very inverse | 13.5 | 1.0 | 0 | 2 | ■ |
| IEC Extremely inverse | 80.0 | 2.0 | 0 | 3 | ■ |
| IEC Long-time inverse | 120.0 | 1.0 | 0 | 4 | ■ |
| IEC User inverse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

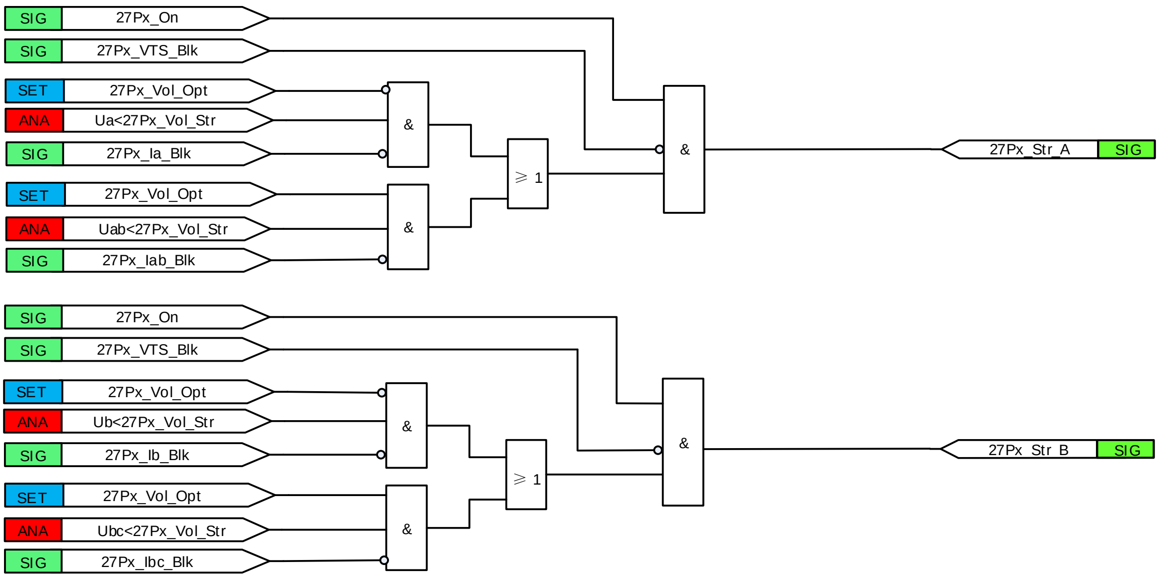
When the operation timer has reached the value set by $27Px\_Op\_T$ in the DT mode or the value set by the IDMT operate time curve, the $27Px\_Op$ output is activated. The corresponding output for the respective phases ($27Px\_Op\_A/B/C$) is also activated. For the IDMT model, $27Px\_Min\_Op\_T$ defines 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 $27Px\_Str$ output is deactivated.

The binary input $27Px_Blk$can be used to block the function. The activation of the $27Px\_Blk$ input deactivates all outputs and resets the internal timers.

### 3.13.3 Logic Diagram



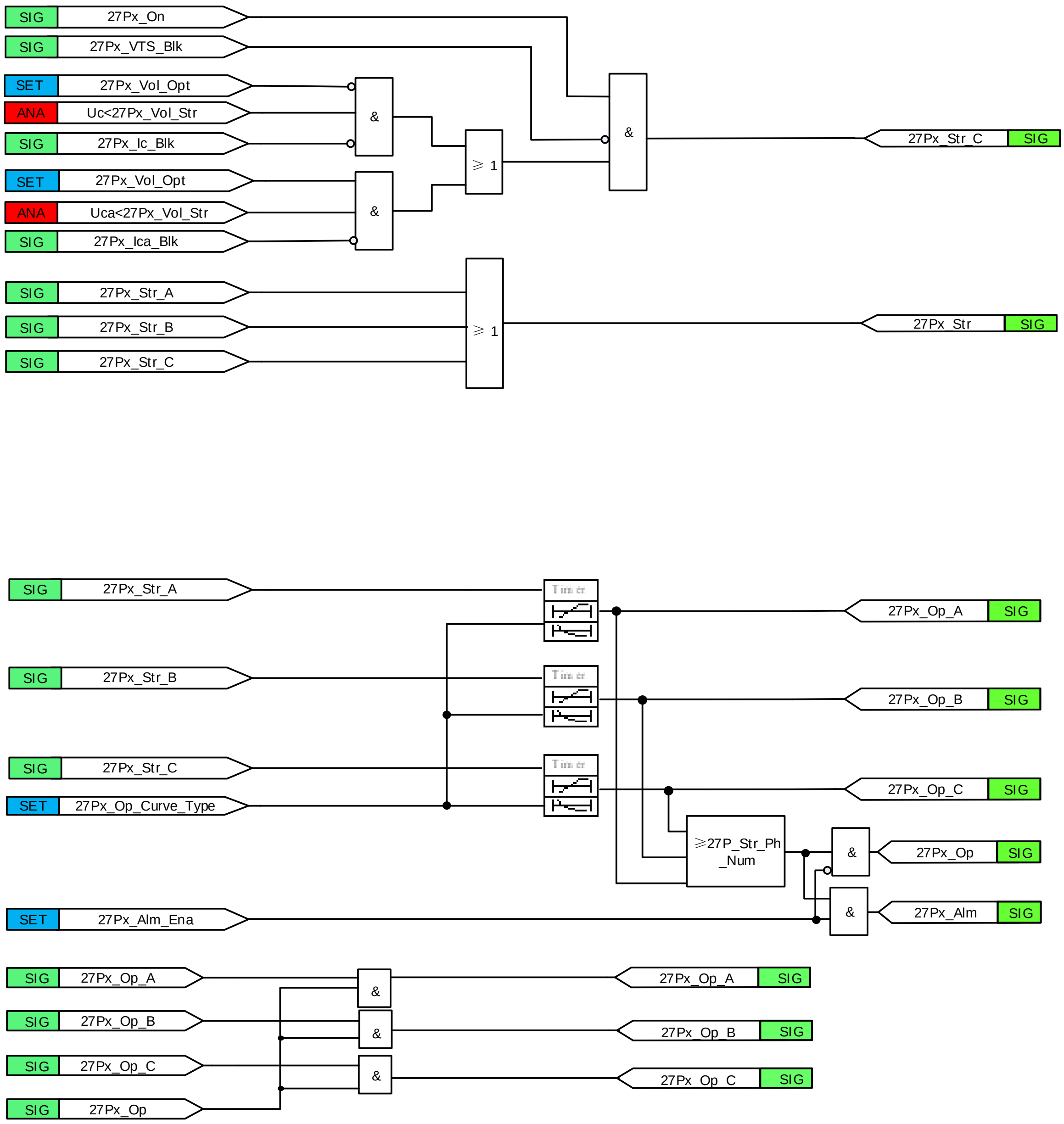



**Figure 3.13-1Functional module diagram**

## 3.13.4 Settings

**Table 3.13-3Settings of Two stage Three-phase undervoltage protection**

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 27P1_Vol_Str | 0.00~160.00 | V | 0.01 | 40.00 | Start value of undervoltage |
| 2 | 27P1_Op_T | 0.040~300.000 | s | 0.001 | 10.000 | Operating time delay for definite time curve |
| 3 | 27P1_Str_Ph_Num | 1/2/3 | - | - | 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 | 27P1_Op_Curve_Type | 0~5 | - | - | 0 | Selection of the type of time delay curve:0 for DT, 1~5 for IDMT |
| 5 | 27P1_T_ Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier in IEC curves |
| 6 | 27P1_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time delay for IDMT curves |
| 7 | 27P1_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 27P Stage 1 |
| 8 | 27P1_C | 0.000~60.000 | - | 0.001 | 0.000 | constant C of 27P Stage 1 |
| 9 | 27P1_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 27P Stage 1 |
| 10 | 27P1_Vol_Opt | 0/1 | - | 1 | 0 | Parameter to select phase or phase-to- phase voltages: 0 forphase voltages,1 forphase-to-phase voltages |
| 11 | 27P1_VTS_Blk_Ena | 0/1 | - | 1 | 0 | undervoltage protection can be blocked due to VT circuit failure if the setting 27P1_VTS_Blk_Ena is set as “1”. |
| 12 | 27P1_I_Blk_Ena | 0/1 | - | 1 | 0 | undervoltage protection can be blocked due to CT circuit failure if the setting 27P1_I_Blk_Ena is set as “1”. |
| 13 | 27P1_Alm | 0/1 | - | 1 | 0 | Logic setting of nabling/disabling undervoltage protection for alarm purpose<br>0: disable<br>1: enable |
| 14 | 27P1_Ena | 0/1 | - | 1 | 1 | Operation Off/On |
| 15 | 27P2_Vol_Str | 0.00~160.00 | V | 0.01 | 40.00 | Start value of undervoltage |
| 16 | 27P2_Op_T | 0.040~300.000 | s | 0.001 | 10.000 | Operating time delay for definite time curve |
| 17 | 27P2_Str_Ph_Num | 1/2/3 | - | - | 3 | Number of phases required for operate activation:1 for 1 phase, 2 for 2 phases, 3 for 3 phases |
| 18 | 27P2_Op_Curve_Type | 0~5 | - | - | 0 | Selection of the type of time delay curve:0 for DT, 1~5 for IDMT |
| 19 | 27P2_T_ Mult | 0.050~200.000 | - | 0.001 | 10.000 | Time multiplier in IEC curves |
| 20 | 27P2_Min_Op_T | 0.000~60.000 | s | 0.001 | 0.050 | Minimum operate time delay for IDMT curves |
| 21 | 27P2_Alpha | 0.00~3.00 | - | 0.01 | 1.00 | constant α of 27P Stage 2 |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 22 | 27P2_C | 0.000~60.000 | - | 0.001 | 0.000 | constant C of 27P Stage 2 |
| 23 | 27P2_K | 0.001~100.000 | - | 0.001 | 1.000 | constant K of 27P Stage 2 |
| 24 | 27P2_Vol_Opt | 0/1 | - | 1 | 0 | Parameter to select phase or phase-to- phase voltages: 0 forphase voltages,1 forphase-to-phase voltages |
| 25 | 27P2_VTS_Blk_Ena | 0/1 | - | 1 | 0 | undervoltage protection can be blocked due to VT circuit failure if the setting 27P2_VTS_Blk_Ena is set as “1”. |
| 26 | 27P2_I_Blk_Ena | 0/1 | - | 1 | 0 | undervoltage protection can be blocked due to CT circuit failure if the setting 27P2_I_Blk_Ena is set as “1”. |
| 27 | 27P2_Alm | 0/1 | - | 1 | 0 | Logic setting of nabling/disabling undervoltage protection for alarm purpose<br>0: disable<br>1: enable |
| 28 | 27P2_Ena | 0/1 | - | 1 | 1 | Operation Off/On |

## 3.14 Overexcitation Protection (24)

### 3.14.1 Overview

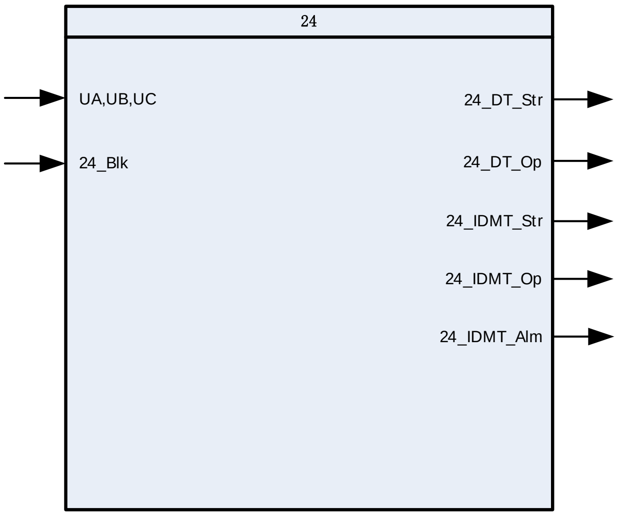
In fact, the primary devices are stationary likes power transformer and some are rotating like generators or motors are very expensive and from the point of view of continuous power supply need to work properly. Over excitation disturb the proper operation of these primary devices and harm the internal structure and lead to major damages. The main function of overexcitation protection is to check the level of overexcitation of protected devices. If the relay detects the level of overexcitation is greater than the set value, the overexcitation 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 3.14-124 Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | UA,UB,UC | “UA,UB,UC” is the three phase group signal for voltage inputs |
| 2 | 24_Blk | Block signal from 24 |

**Table 3.14-224Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 24_DT_Str | Start signal from 24DT |
| 2 | 24_DT_Op | Operation signal from 24DT |
| 3 | 24_IDMT_Str | Start signal from 24DMT |
| 4 | 24_IDMT _Op | Operation signal from 24DMT |
| 5 | 24_IDMT _Alm | Alarm signal from24DMT |

### 3.14.2 Protection Principle

Overexcitation protection consists of one stage definitetime protection and one stage inversetime protection,both of which can be used totrip the relevant breakeror alarm the users of the urgent situation. The RMS values of three phase voltagesare used for protection calculation. Therefore, the calculation result will not be affected by the frequency fluctuation. Overall, the overexcitation inversetime curve is a sectional linear curve, which has high adaptability to all types of fault situations.

The overexcitation severity can be representedby the overexcitation value,the result of voltage dividingfrequency. The overexcitation valuecan be calculatedaccording 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 proportionsto the primary voltage of one side of transformer, and the base value for calculating per unit value of frequency is the measuredfrequency. Hence, if the transformer works under normal operation, n should be equal to 1.

This base voltage calculation is automatically excutedcontinuously and the users only need not enter the corresponding VT ratio when configuring the settings.

**1,Definitetime operation criterion:**

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

**2,Inversetime operation criterion:**

Inversetimecharacteristic is a curve that the overexcitation value inversely proportion to the time.The value reflects the heat accumulation and radiation exponentially increase as the overexcitation situation deteriorates. The overexcitation value iscalculated according the above equation. After obtaining the overexcitation value, the time delay is obtainedby matching with the sectional linear insertion.

Several groups of settings corresponding the pointson the curvecan be configured, which finallydetermines the inversetime operation characteristics.This protection can adapt to differentoverexcitation conditions of various transformers flexibly.

The belowfigure shows inversetime characteristic of overexcitation protection.

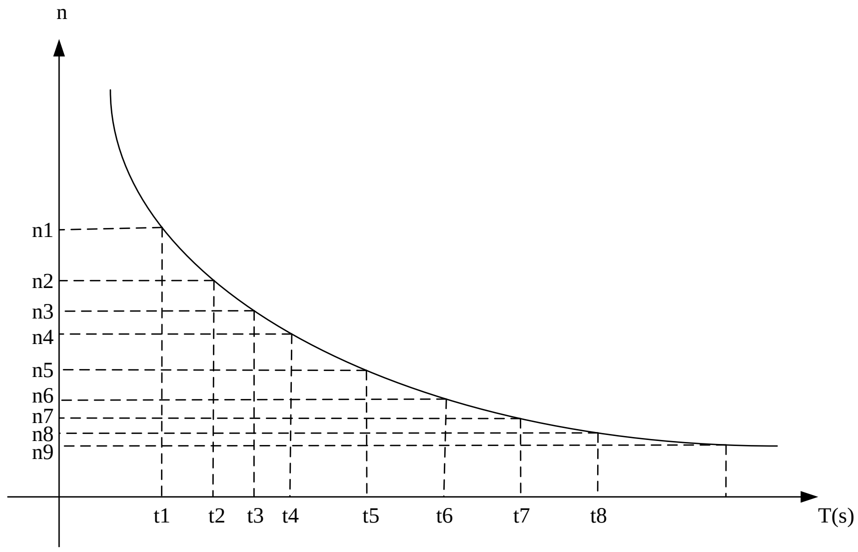



**Figure 3.14-1 Inverse Time Characteristic of Overexcitation Protection**

The main harm of overexcitation to transformer is rapidly accumulated heat, so accumulation algorithmis adopted and the time delay can be calculatedaccording to characteristic curve basing on the overexcitation value. When the accumulated time delay surpasses the operating time delay, inversetime overexcitation protection operates.

Dissipating process is also applied to better protect the transformer.Whenthe overexcitation valuedropsless than the minimum overexcitation multiple setting, the accumulated value decreasesgradually instead of dropping to 0 directly. After theoverexcitation protection operates to open the breaker and overexcitation condition disappears, the accumulatedthermaldecreases to 0 in 10s.

Overexcitation valueis the accumulated value by adding theoverexcitation information at current instant and theoverexcitation information integrated over various time intervals from its beginning.

Inversetime characteristic curve can be demonstratedby modifying several overexcitation valuesettings showed below.It also should be noticed that eachsetting of n and t should follow the below rules(n1 ≥ n2…. ≥ n9;t1 ≤ t2…. ≤ t9).

### 3.14.3 Logic Diagram

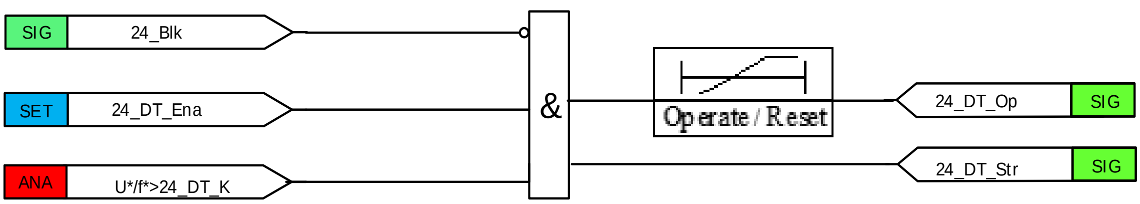



**Figure 3.14-2 Logic Diagram of DefiniteTime Overexcitation Protection**

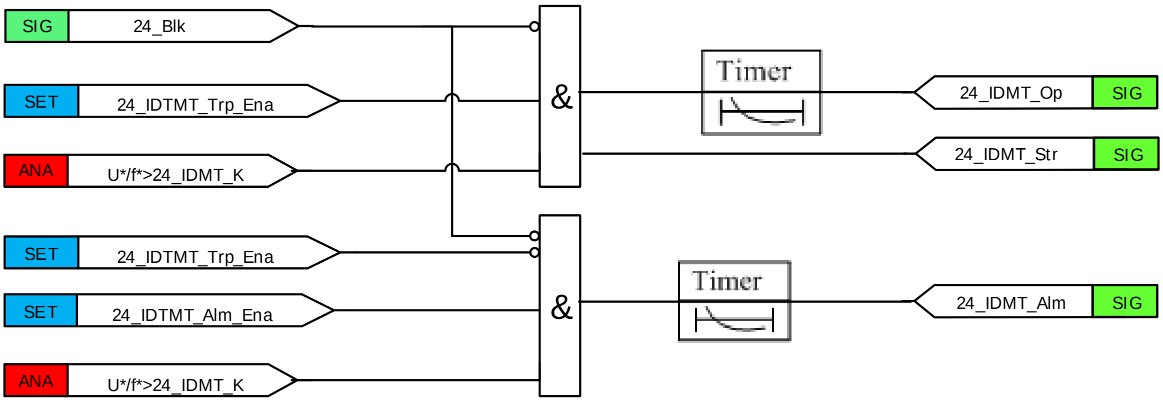



Figure 3.14-3 Logic diagram of inverse-time overexcitation protection

### 3.14.4 Settings

Table 3.14-3 Settings of Overexcitation 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 definitetime overexcitation 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 definitetime overexcitation protection for trip purpose |
| 3 | 24_IDMT_Op_K1 | 1.00~1.70 | - | 0.01 | 1.50 | Multiple setting 1 of inversetime overexcitation 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 inversetime overexcitation 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 inversetime overexcitation 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 inversetime overexcitation 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 inversetime overexcitation 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 inversetime overexcitation protection: n6 |

| No. | Item | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 14 | 24_IDMT_Op _T6 | 0.1~9999.0 | s | 0.1 | 8.0 | Time delay setting corresponding to multiple setting 6: t6 |
| 15 | 24_IDMT_Op _K7 | 1.00~1.70 | - | 0.01 | 1.20 | Multiple setting 7 of inversetime overexcitation 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 inversetime overexcitation 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 inversetime overexcitation 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 overexcitation protection<br>0: phase voltage<br>1: phase-to-phase voltage |
| 22 | 24_DT_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling stage 1 of definitetime overexcitation protection for trip purpose<br>0: disable<br>1: enable |
| 23 | 24_IDMT_Trp_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling inversetime overexcitation protection for trip purpose<br>0: disable<br>1: enable |
| 24 | 24_IDMT_Alm_Ena | 0/1 | - | 1 | 0 | Logic setting of nabling/disabling inversetime overexcitation protection for alarm purpose<br>0: disable<br>1: enable |

## 3.15 Overfrequency Protection(81O)

### 3.15.1 Overview

The main and important function of overfrequecy 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 overfrequency cause many unwanted malfunction operations in power system likes:

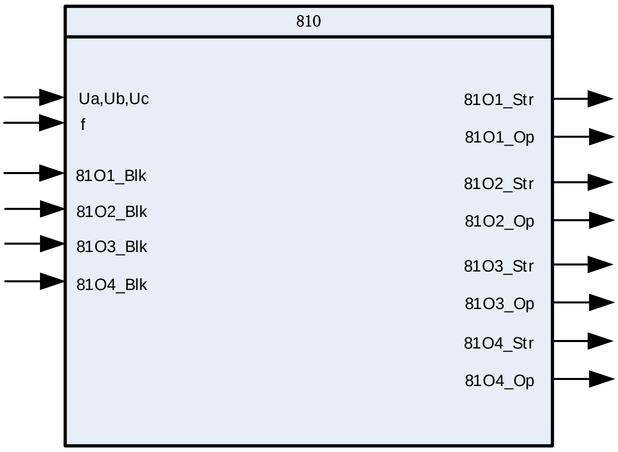
- Disturbed the parallel operation of machines (generator or motor)
- Increase the size of conductor (skin effect)
- Increase the size of cores
- Disturbed the metering system capability

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

- Abnormal range of frequency
- Line-sequence voltage

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

#### 3.15.1.1 Function Block




#### 3.15.1.2 Signals

**Table 3.15-181O Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Ua,Ub,Uc | Three phase group signal for voltage inputs |
| 2 | f | Frequency of protected zone of electrical power system |
| 3 | 81O1_Blk | Block signal of 81O stage 1 |
| 4 | 81O2_Blk | Block signal of 81O stage 2 |
| 5 | 81O3_Blk | Block signal of 81O stage 3 |
| 6 | 81O4_Blk | Block signal of 81O stage 4 |

**Table 3.15-281O Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 81O1 _Str | Start signal from 81O stage 1 |
| 2 | 81O2 _Str | Start signal from 81O stage 2 |
| 3 | 81O3 _Str | Start signal from 81O stage 3 |
| 4 | 81O4 _Str | Start signal from 81O stage 4 |
| 5 | 81O1_Op | Operation signal from 81O stage 1 |
| 6 | 81O2_Op | Operation signal from 81O stage 2 |
| 7 | 81O3_Op | Operation signal from 81O stage 3 |
| 8 | 81O4_Op | Operation signal from 81O stage 4 |

## 3.15.2 Protection Principle

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

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

1) Blocking in undervoltage condition

If the minimalline 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, overfrequency protection will be blocked.

Frequency criterion for each stage is:

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

## 3.15.3 Logic Diagram

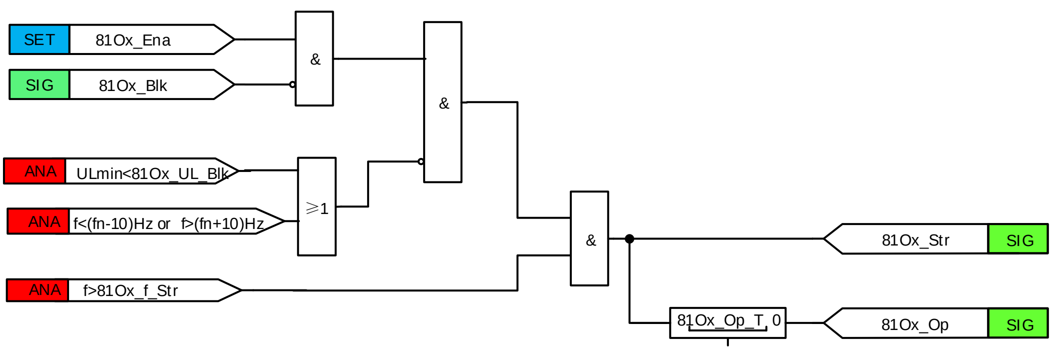



**Figure 3.15-1 Overfrequency Protection logic diagram**

### 3.15.4 Settings

**Table 3.15-3 Settings of Overfrequency Protection**

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 81O1_f_Str | 20.00~100.00 | Hz | 0.01 | 60.10 | Frequency setting for stage 1 of overfrequency protection |
| 2 | 81O1_Op_T | 0.08~200.00 | S | 0.01 | 10.00 | Time delay for stage 1 of overfrequency protection |
| 3 | 81O1_UL_Blk | 18.00~100.00 | V | 0.01 | 30.00 | Voltage value of blocking overfrequency protection |
| 4 | 81O1_Ena | 0/1 | - | 1 | 0 | Enabling/disabling rate of frequency change to block stage 1 of overfrequency protection<br>0: disable<br>1: enable |
| 5 | 81O2_f_Str | 20.00~100.00 | Hz | 0.01 | 60.10 | Frequency setting for stage 2 of overfrequency protection |
| 6 | 81O2_Op_T | 0.08~200.00 | S | 0.01 | 10.00 | Time delay for stage 2 of overfrequency protection |
| 7 | 81O2_UL_Blk | 18.00~100.00 | V | 0.01 | 30.00 | Voltage value of blocking overfrequency protection |
| 8 | 81O2_Ena | 0/1 | - | 1 | 0 | Enabling/disabling rate of frequency change to block stage 2 of overfrequency protection<br>0: disable<br>1: enable |
| 9 | 81O3_f_Str | 20.00~100.00 | Hz | 0.01 | 60.10 | Frequency setting for stage 3 of overfrequency protection |
| 10 | 81O3_Op_T | 0.08~200.00 | S | 0.01 | 10.00 | Time delay for stage 3 of overfrequency protection |
| 11 | 81O3_UL_Blk | 18.00~100.00 | V | 0.01 | 30.00 | Voltage value of blocking overfrequency protection |
| 12 | 81O3_Ena | 0/1 | - | 1 | 0 | Enabling/disabling rate of frequency change to block stage 3 of overfrequency protection<br>0: disable<br>1: enable |
| 13 | 81O4_f_Str | 20.00~100.00 | Hz | 0.01 | 60.10 | Frequency setting for stage 4 of overfrequency protection |
| 14 | 81O4_Op_T | 0.08~200.00 | S | 0.01 | 10.00 | Time delay for stage 4 of overfrequency protection |
| 15 | 81O4_UL_Blk | 18.00~100.00 | V | 0.01 | 30.00 | Voltage value of blocking overfrequency protection |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 16 | 81O4_Ena | 0/1 | - | 1 | 0 | Enabling/disabling rate of frequency change to block stage 4 of overfrequency protection<br>0: disable<br>1: enable |

# 3.16 Underfrequency Protection(81U)

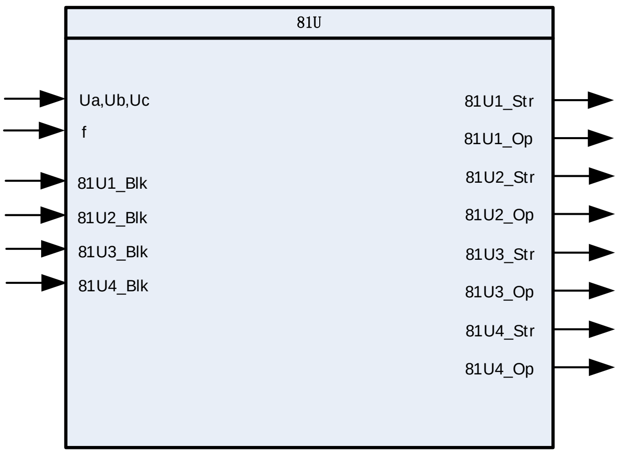
## 3.16.1 Overview

The main function of underfrequecy 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 underfrequency cause many unwanted malfunction operations in power system. In electrical power system there are many reason to cause the underfrequency likes one of them is active power is not fulfilling match with required power of system. The operation principle overfrequency protection (81U) is based on the following points:

- Abnormal range of frequency
- Line-sequence voltage

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

### 3.16.1.1 Function Block




### 3.16.1.2 Signals

**Table 3.16-181U Input Signals**

| NO. | Signal | Description |
|---|---|---|

| NO. | Signal | Description |
|---|---|---|
| 1 | Ua,Ub,Uc | Three phase group signal for voltage inputs |
| 2 | f | Frequency of protected zone of electrical power system |
| 3 | 81U1_Blk | Block signal of 81U stage 1 |
| 4 | 81U2_Blk | Block signal of 81U stage 2 |
| 5 | 81U3_Blk | Block signal of 81U stage 3 |
| 6 | 81U4_Blk | Block signal of 81U stage 4 |

**Table 3.16-281U Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 81U1_Str | Start signal from 81U stage 1 |
| 2 | 81U2_Str | Start signal from 81U stage 2 |
| 3 | 81U3_Str | Start signal from 81U stage 3 |
| 4 | 81U4_Str | Start signal from 81U stage 4 |
| 5 | 81U1_Op | Operation signal from 81U stage 1 |
| 6 | 81U2_Op | Operation signal from 81U stage 2 |
| 7 | 81U3_Op | Operation signal from 81U stage 3 |
| 8 | 81U4_Op | Operation signal from 81U stage 4 |

### 3.16.2 Protection Principle

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

In order to prevent underfrequency protection from undesired operation, underfrequency protectionwill be blocked in some cases.

1) Blocking in undervoltage condition

If the minimalline 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, overfrequency protection will be blocked

Frequency criterion for each stage is:

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

### 3.16.3 Logic Diagram

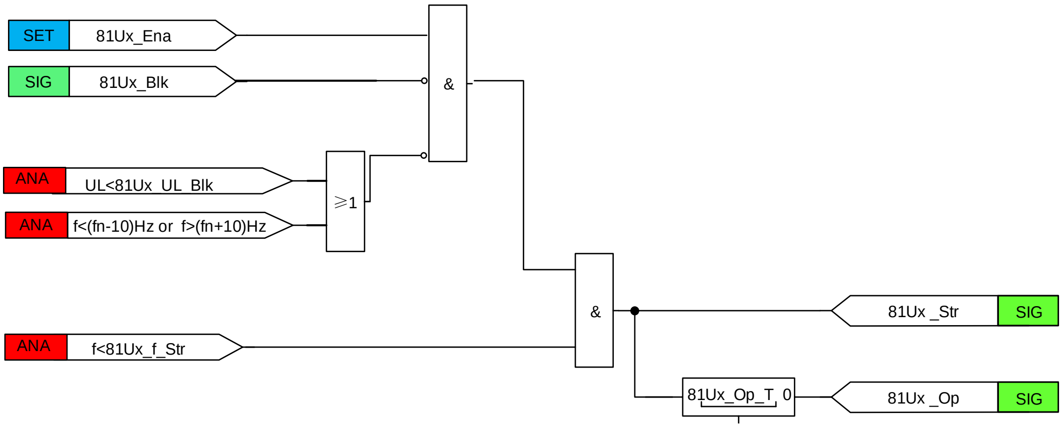



**Figure 3.16-1 Logic diagram of underfrequency Protection**

### 3.16.4 Settings

**Table 3.16-3 Settings of Underfrequency Protection**

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 81U1_f_Str | 20.00~100.00 | Hz | 0.01 | 59.90 | Frequency setting for stage 1 of underfrequency protection |
| 2 | 81U1_Op_T | 0.08~200.00 | S | 0.01 | 10.00 | Time delay for stage 1 of underfrequency protection |
| 3 | 81U1_UL_Blk | 0.00~100.00 | V | 0.1 | 30.00 | Voltage value of blocking underfrequency protection |
| 4 | 81U1_Ena | 0/1 | - | 1 | 0 | Enabling/disabling rate of frequency change to block stage 1 of underfrequency protection<br>0: disable<br>1: enable |
| 5 | 81U2_f_Str | 20.00~100.00 | Hz | 0.01 | 59.90 | Frequency setting for stage 2 of underfrequency protection |
| 6 | 81U2_Op_T | 0.08~200.00 | S | 0.01 | 10.00 | Time delay for stage 2 of underfrequency protection |
| 7 | 81U2_UL_Blk | 0.00~100.00 | V | 0.1 | 30.00 | Voltage value of blocking underfrequency protection |
| 8 | 81U2_Ena | 0/1 | - | 1 | 0 | Enabling/disabling rate of frequency change to block stage 2 of underfrequency protection<br>0: disable<br>1: enable |
| 9 | 81U3_f_Str | 20.00~100.00 | Hz | 0.01 | 59.90 | Frequency setting for stage 3 of |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | underfrequency protection |
| 10 | 81U3_Op_T | 0.08~200.00 | S | 0.01 | 10.00 | Time delay for stage 3 of underfrequency protection |
| 11 | 81U3_UL_Blk | 0.00~100.00 | V | 0.1 | 30.00 | Voltage value of blocking underfrequency protection |
| 12 | 81U3_Ena | 0/1 | - | 1 | 0 | Enabling/disabling rate of frequency change to block stage 3 of underfrequency protection<br>0: disable<br>1: enable |
| 13 | 81U4_f_Str | 20.00~100.00 | Hz | 0.01 | 59.90 | Frequency setting for stage 4 of underfrequency protection |
| 14 | 81U4_Op_T | 0.08~200.00 | S | 0.01 | 10.00 | Time delay for stage 4 of underfrequency protection |
| 15 | 81U4_UL_Blk | 0.00~100.00 | V | 0.1 | 30.00 | Voltage value of blocking underfrequency protection |
| 16 | 81U4_Ena | 0/1 | - | 1 | 0 | Enabling/disabling rate of frequency change to block stage 4 of underfrequency protection<br>0: disable<br>1: enable |

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

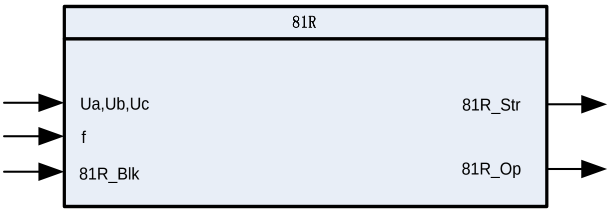
### 3.17.1 Overview

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 its change time to time and load to load, if any situation the variation of power grid frequency is greater than allowable limits of normal operation it's 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 3.17-181R Input Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | Ua,Ub,Uc | Three phase voltage inputs. |
| 2 | f | Frequency of protected zone of electrical power system |
| 3 | 81R_Blk | Block signal of 81R |

**Table 3.17-281R 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 $81R\_Str$ outputactivates. 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

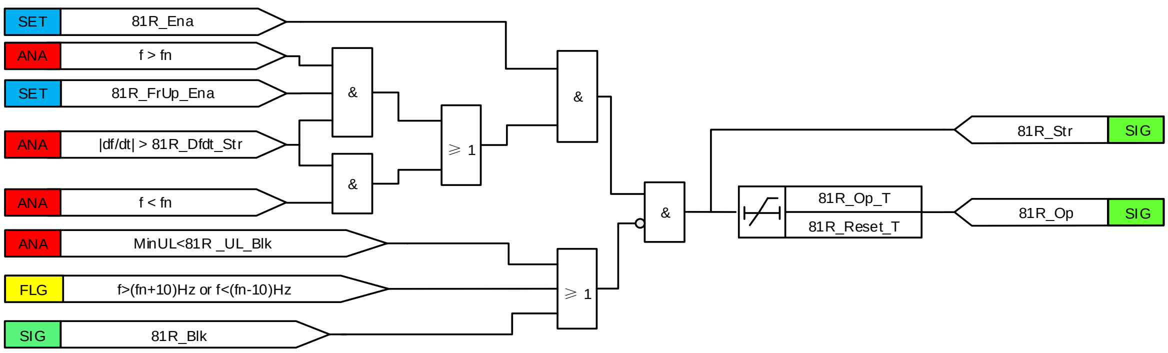



**Figure 3.17-1Rate-of-change of frequency protection logic diagram**

### 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:

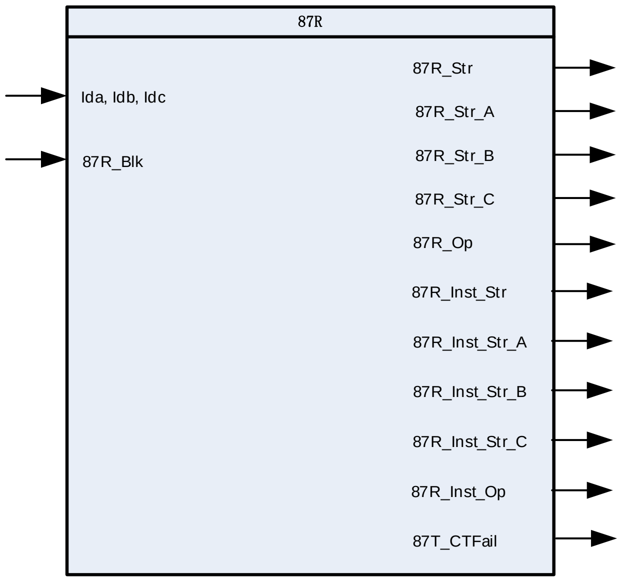
- Meticulousphase compensation IED calculation criteria.
- Accurate and fast fault tracking capability.

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 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 pretection 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 |
|---|---|---|
| 29 | 87R _Str | Start signal ofdifferential from 87R |
| 30 | 87R _Str_A | Start_A signal ofdifferential from 87R |
| 31 | 87R_Str_B | Start_B signal ofdifferential from 87R |
| 32 | 87R _Str_C | Start_C signal ofdifferential from 87R |
| 33 | 87R_ Op | Operation signal ofdifferential from 87R |
| 34 | 87R_Inst_Str | Start signal of instantaneous differential from 87R |
| 35 | 87R_Inst_Str_A | Start_A signal of instantaneous differential from 87R |
| 36 | 87R_Inst_Str_B | Start_B signal of instantaneous differential from 87R |
| 37 | 87R_Inst_Str_C | Start_C signal of instantaneous differential from 87R |
| 38 | 87R_ Inst_Op | Operation signal of instantaneous differential from 87R |
| 39 | 87R_CTFail | CT failsignal of 87R |

### 3.18.2 Protection Principle

#### 3.18.2.1 Phase Overcurrent Element

The device can regulate the difference in transformation ratio between CTs 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:***

$S_n$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 shownas 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 shownas 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

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

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

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

***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.

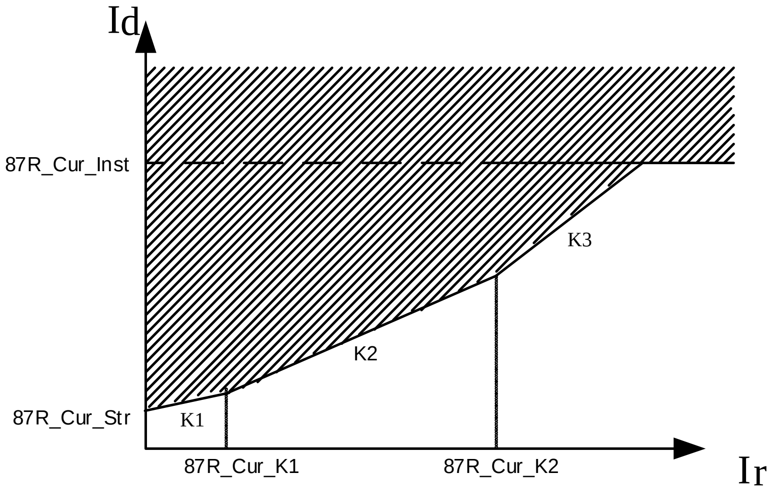



**Figure 3.17-1 Operation characteristic of differential protection**

### 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 biasedand has no blocking element. Instantaneoushigh 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.

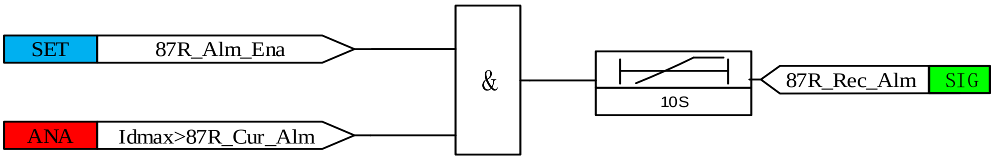



**Figure 3.17-3Differential CT Circuit Abnormality**

### 3.18.2.9 Differential CT circuitfailure

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 CTcircuit failure:

a) $\min\{I_a, I_b, I_c\} < 0.5I_e$

b) $\max\{I_a, I_b, I_c\} < 1.1I_e$

c) Self side: $3I_0 > 0.3I_e$

d) Other side: $3I_0 < 0.2I_e$

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 failureis 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

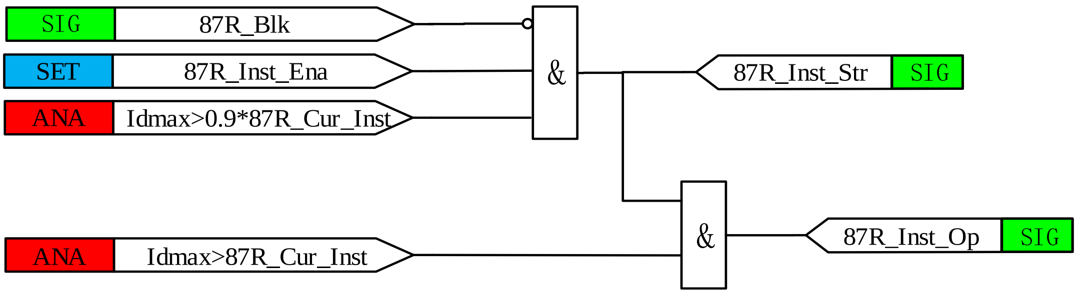



**Figure 3.18-4 Logic diagram of 87R_Inst protection**

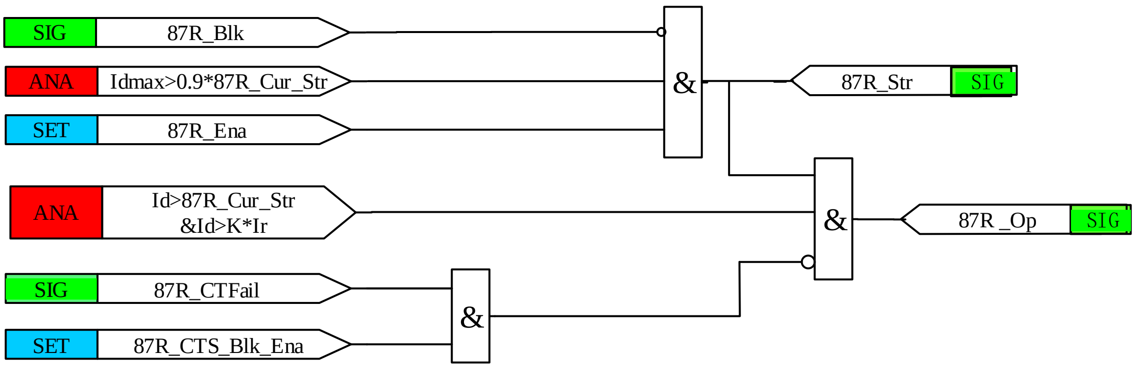



**Figure 3.18-5 Logic diagram of 87R protection**

***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**

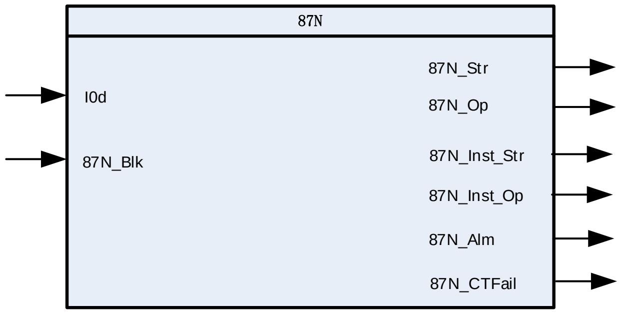
| No. | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 1 | 87R_Cur_Str | 0.05~20.00 | IE | 0.01 | 0.40 | Pickup setting of biased differential element |
| 2 | 87R_Cur_Inst | 0.05~20.00 | IE | 0.01 | 6.00 | Current setting of instantaneous differential element |
| 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 | IE | 0.01 | 1.00 | Current setting of differential circuit abnormality alarm |
| 5 | 87R_Cur_K1 | 0.05~20.00 | IE | 0.01 | 1.00 | Current setting of knee point 1 for transformer differential protection |

| No. | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 6 | 87R_Cur_K2 | 0.05~20.00 | IE | 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:<br>0: Without Inrush CurrentBlock<br>1: Harmonic principle |
| 11 | 87R _Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling conventional biased differential element<br>0: disable<br>1: enable |
| 12 | 87R_Inst_Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling instantaneous differential element<br>0: disable<br>1: enable |
| 13 | 87R_Alm_Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling differential Alam element<br>0: disable<br>1: enable |
| 14 | 87R_CTS_Blk_Ena | 0,1 |  | 1 | 0 | Logic setting of enabling/disabling block biased differential element during CT circuit failure<br>0: disable<br>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 |
|---|---|---|
| 5 | I0d | zero-sequence differential current of 87N |
| 6 | 87N_Blk | Block signal of 87N |

**Table 3.19-2 87N Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 40 | 87N _Str | Start signal ofdifferential from 87N |
| 41 | 87N_ Op | Operation signal ofdifferential from 87N |
| 42 | 87N_Inst_Str | Start signal of instantaneous differential from 87N |
| 43 | 87N_ Inst_Op | Operation signal of instantaneous differential from 87N |
| 44 | 87N_Alm | Alarm signal of differential 87N |
| 45 | 87N_CTFail | CT failsignal 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 shownas below.

I0d>0.9*87N_Cur_Str

***Where：***

I0d is the value of three phase zero-sequencedifferential 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 shownas 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 :

$$I_{0d} = |I'_{h0} + I'_{l0}|$$

$$I_{0r} = \frac{1}{2} * |I'_{h0} - I'_{l0}|$$

***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:

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

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

***Where:***

$I_{0d}$ and $I_{0r}$ 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

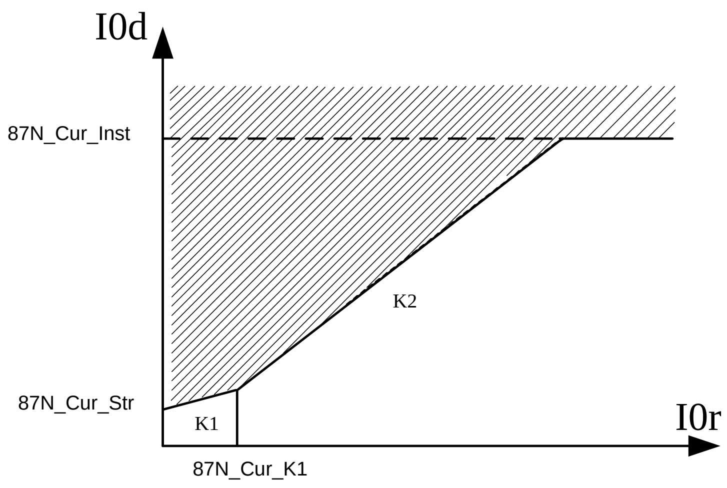



**Figure 3.19-1 Operation characteristic of 87N**

***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：***

$3I_0$ 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 0.2.

#### 3.19.2.8 CT Circuit Failure

Please refer to Section 3.2.2.12 for details.

### 3.19.3 Logic Diagram

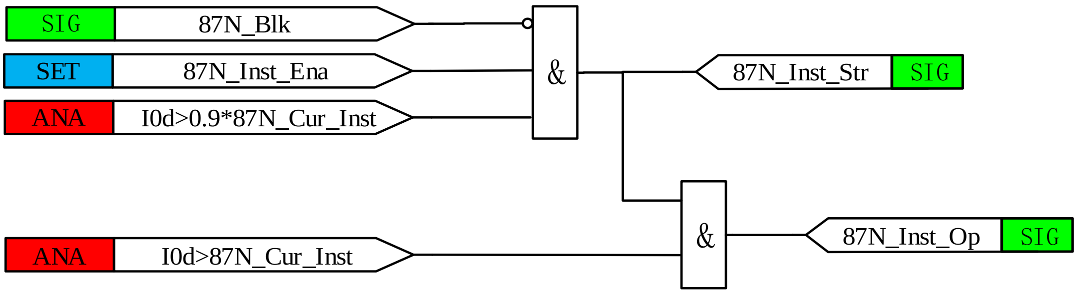



**Figure 3.19-2 Logic diagram of 87N_Inst protection**

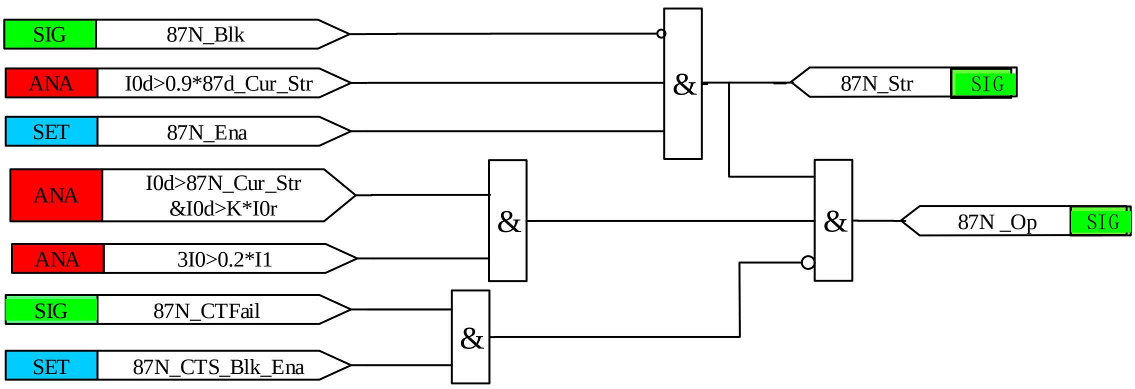



**Figure 3.19-3 Logic diagram of 87N protection**

***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 3.19-2 Settings of Reactor differential protection**

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

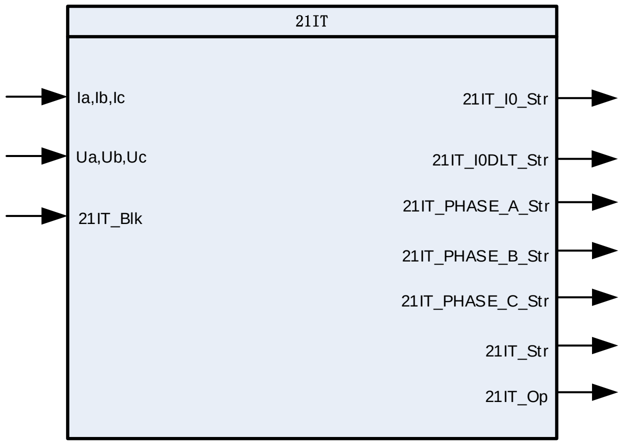
| No. | Name | Range | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| | | | | | | circuit abnormality alarm |
| 6 | 87N_Cur_K1 | 0.05~20.00 | IE | 0.01 | 1.00 | Current setting of knee point 1 for transformer differential protection |
| 8 | 87N _Slope1 | 0~0.90 | - | 0.01 | 0.00 | Slope 1 of biased differential element |
| 9 | 87N _Slope2 | 0~0.90 | - | 0.01 | 0.50 | Slope 2 of biased differential element |
| 12 | 87N _Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling conventional biased differential element<br>0: disable<br>1: enable |
| 13 | 87N_Inst_Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling instantaneous differential element<br>0: disable<br>1: enable |
| 14 | 87N_Alm_Ena | 0,1 | - | 1 | 0 | Logic setting of enabling/disabling differential Alam element<br>0: disable<br>1: enable |
| 16 | 87N_CTS_Blk_Ena | 0,1 | | 1 | 0 | Logic setting of enabling/disabling block biased differential element during CT circuit failure<br>0: disable<br>1: enable |

## 3.20 Reactor interturn 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 interturn 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 3.20-121IT 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 3.20-221IT 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 Astart 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:***

$3I_0$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 Impedancestart

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

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

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

***Where:***

$U'_\varphi$ is the phase voltage of high side.

$I'_\varphi$ is the phase current of high side.

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

$ZL_{s0}$is theZero-sequenceImpedanceof the neutral point reactor .

$ZL_1$is thesecondaryImpedanceof 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 theZero-sequenceImpedanceof the main reactor .

#### 3.20.2.5 Negative-sequence direction components

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

***Where:***

$ZL_1$is thesecondaryImpedanceof the main reactor .

### 3.20.3 Logic Diagram

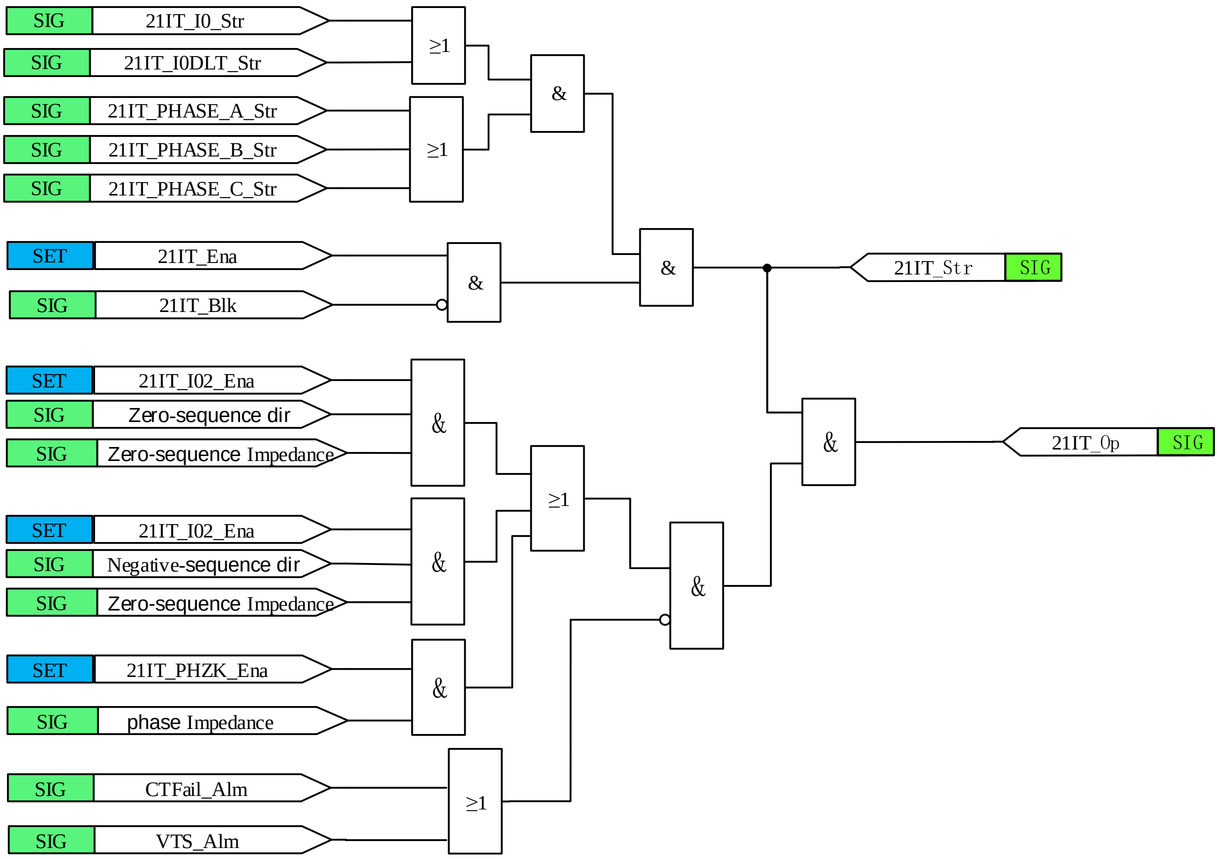



**Figure 3.20-1 Logic diagram of 21IT protection**

### 3.20.4 Settings

**Table 3.20-3 Settings of Reactor interturn 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<br>0: disable<br>1: enable |
| 2 | 21IT _PHZK_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling phase impedance element<br>0: disable |

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

# 3.21 Out-of-Step Protection 78O

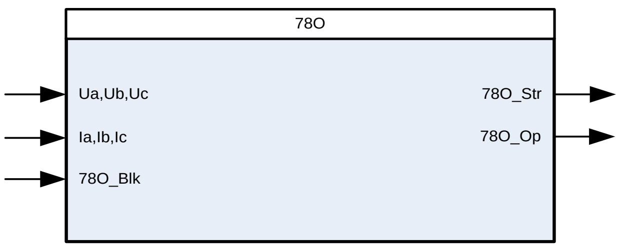
## 3.21.1 Overview

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 | Ua,Ub,Uc | Three-phase voltage input |
| 2 | Ia,Ib,Ic | Three-phase current input |
| 3 | 78O_Blk | Blocking signal of 78O |

**Table 3.21-2 78O Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | 78O_Str | Start signal from 78O |
| 2 | 78O_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:

$\mathrm{Un}$is the rated voltage.

$\mathrm{U_1}$is positive-sequence voltage.

$\mathrm{U_2}$is negative-sequence voltage.

$\mathrm{U_0}$is zero-sequence voltage.

$\mathrm{I_1}$is positive-sequence current.

$\varphi$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 fomula:

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

Where:

$\varphi$is the angle difference between positive-sequence voltage and positive-sequence current.

$\delta$is the line positive-sequence impedance angle, set by the setting LinAng.

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

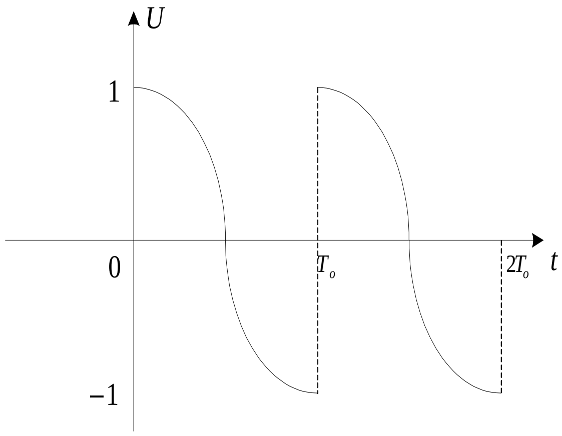



**Figure 3.21.1 Voltage at Accelerate Side**

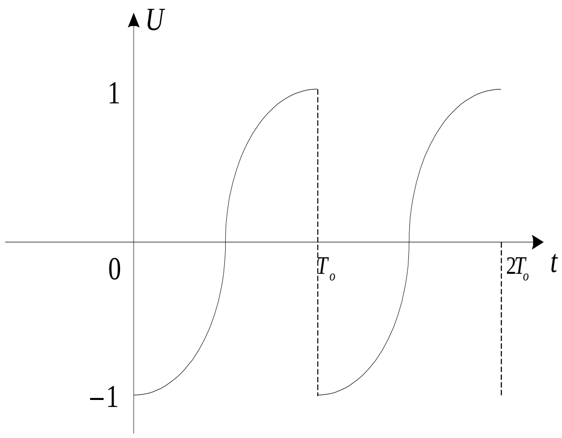



**Figure 3.21.2 Voltage at Decelerate Side**

The two voltage waveforms 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:

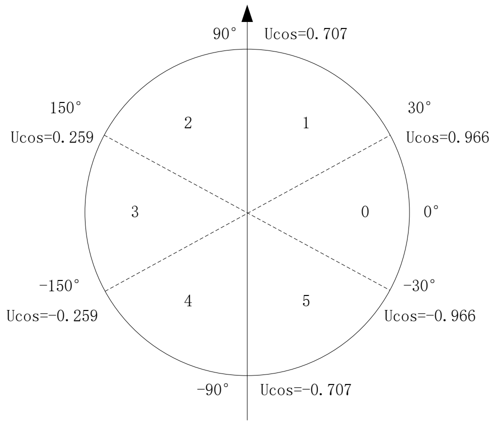



**Figure 3.21.3 Phase Division of Vector Diagram**

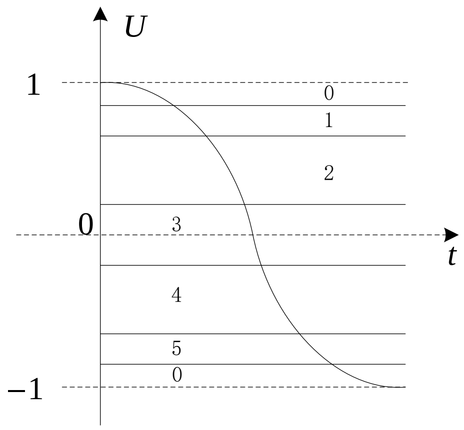



**Figure 3.21.4 Division of Waveform**

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 $T_0/6$in one oscillation period.

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

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

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

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

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 $U_{cos}$havecrossed 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 $30° < \mathrm{Angle}(U_1/I_1) < 150°$, and reverse direction if $-150° < \mathrm{Angle}(U_1/I_1) < -30°$.

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 $150° < \mathrm{Angle}(U_1/I_1) < 210°$, 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

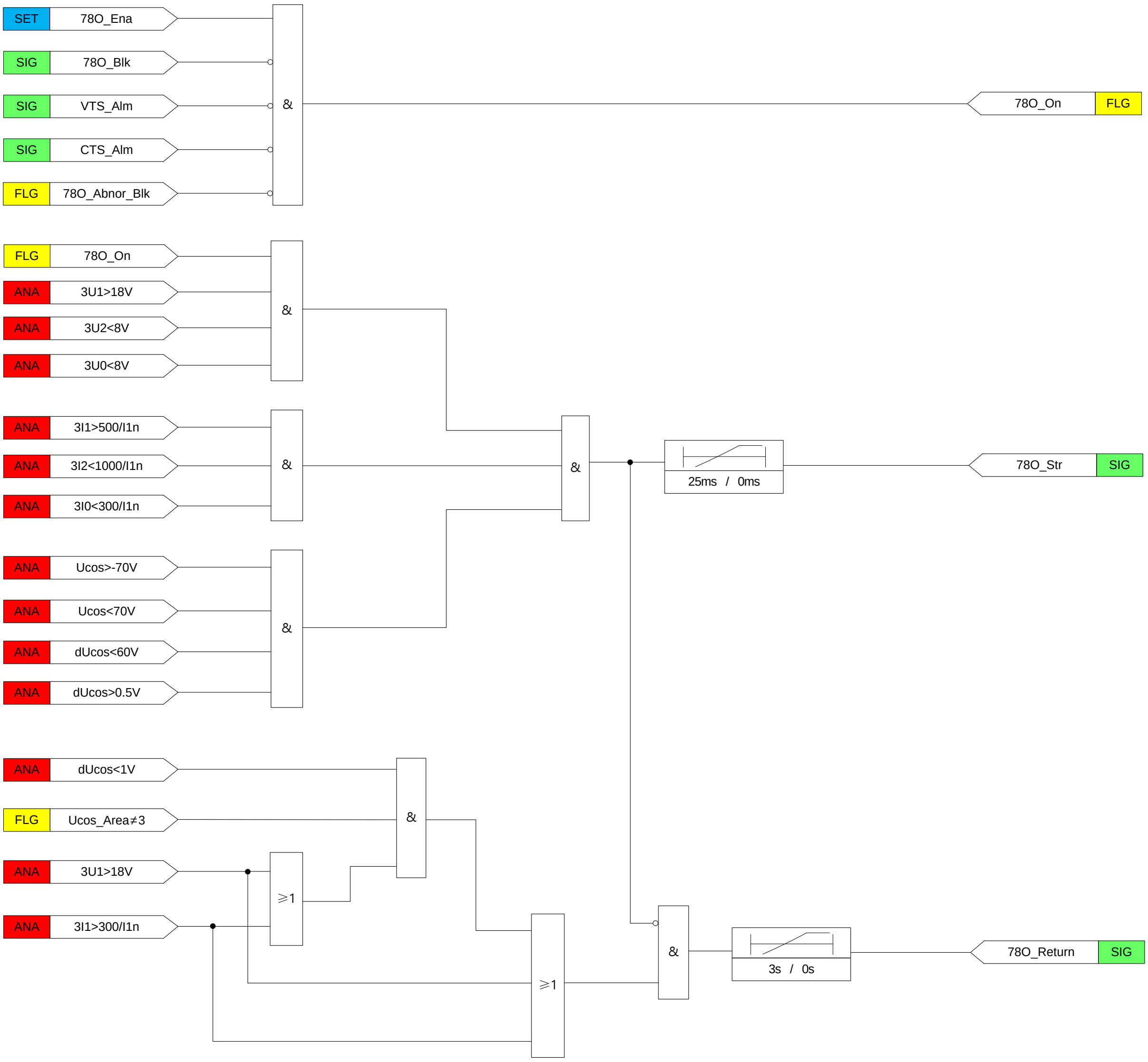



**Figure 3.21.5 78O Start**

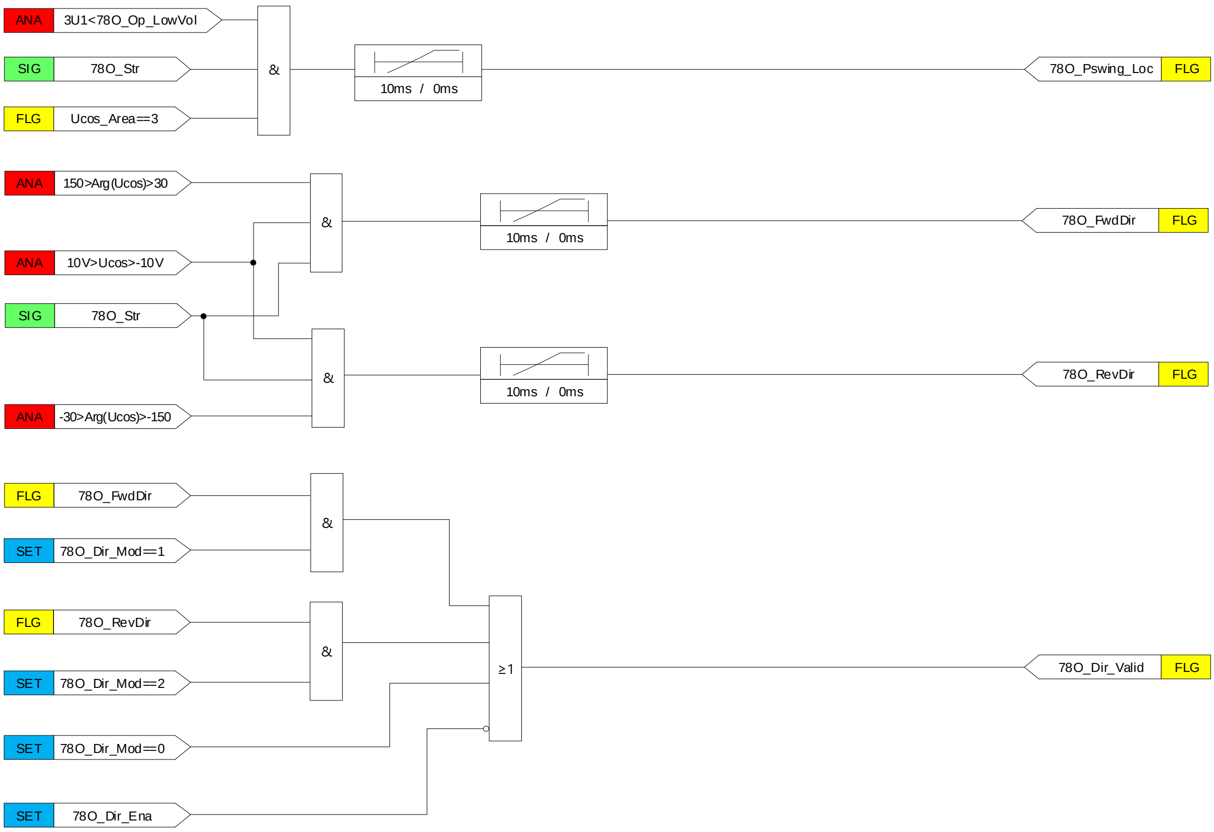



**Figure 3.21.6 78O Direction element**

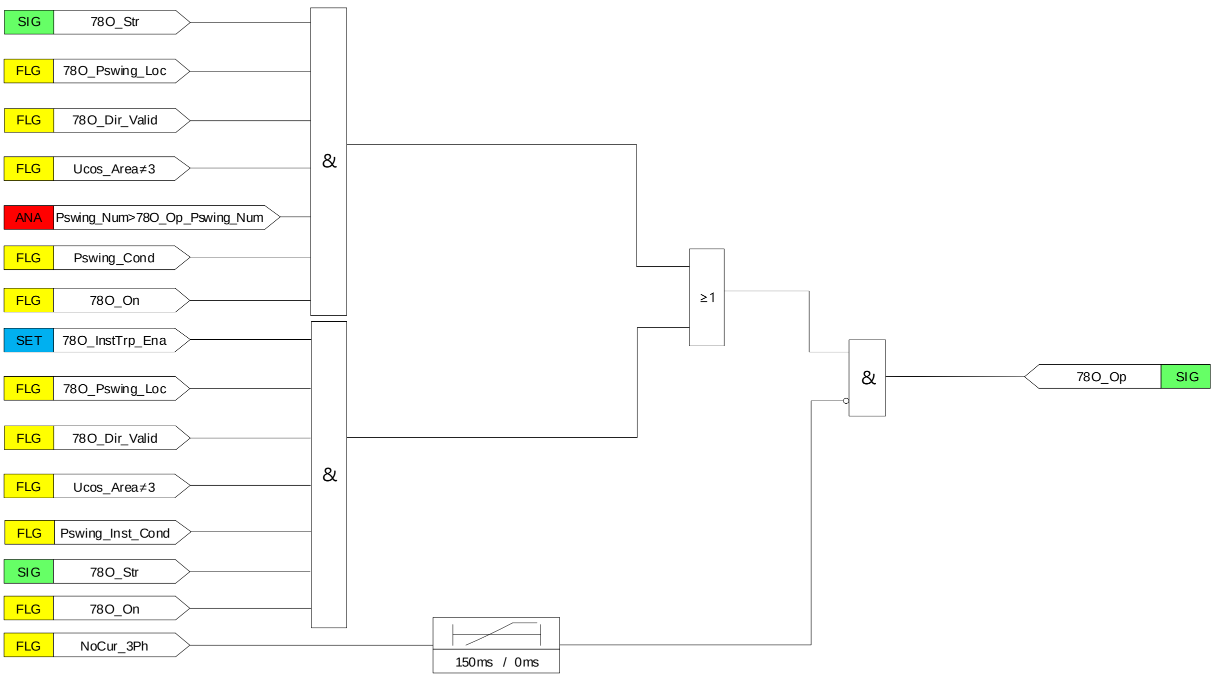



**Figure 3.21.7 78O Operation**

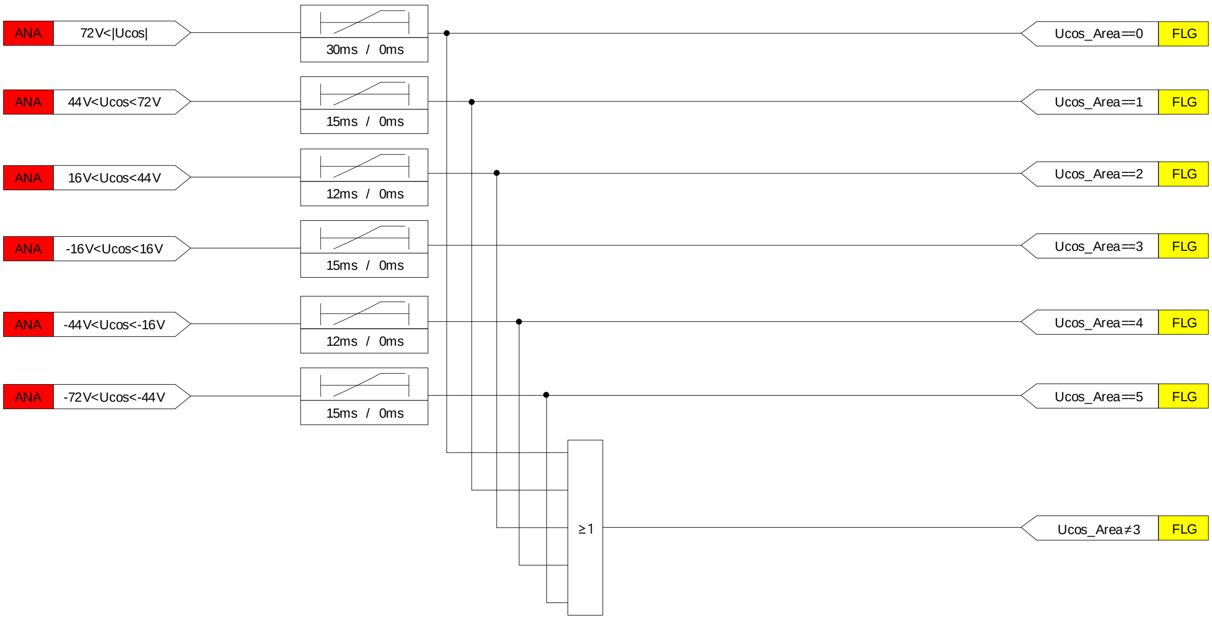



**Figure 3.21.8 78O Ucos Area Detection**

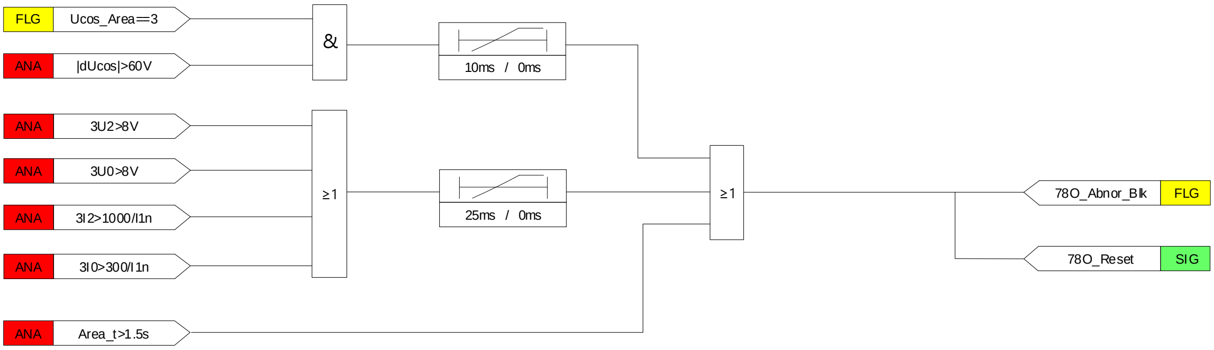



**Figure 3.21.9 Abnormal Condition Blocking of 78O**

## 3.21.4 Settings

**Table 3.21-3 78O Settings**

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

| NO | Name | Range | Unit | Step | Description |
|---|---|---|---|---|---|
| | | | | | 0: disable<br>1: enable |
| 4 | 78O_Op_LowVol | 0.00~1.00 | Un | 0.01 | Low voltage threshold of out-of-step protection |
| 5 | 78O_Op_Pswing_Num | 1~15 | | 1 | Threshold number of power swing cycle counting |
| 6 | 78O_Dir_Mod | 0, 1, 2 | | 1 | Direction option for out-of-step protection:<br>0: Non-Directional<br>1: Forward<br>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

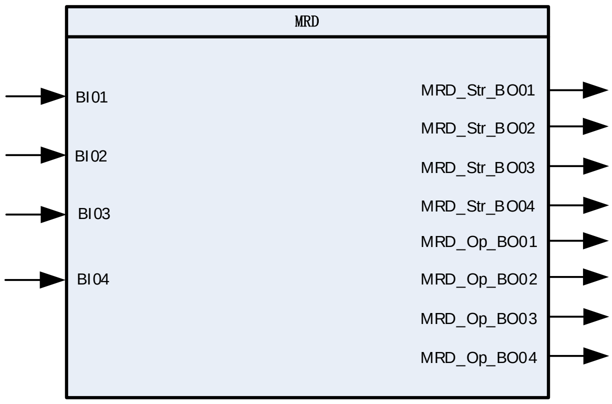



**Figure 3.22-1 Delay Of Mechanical Relay**

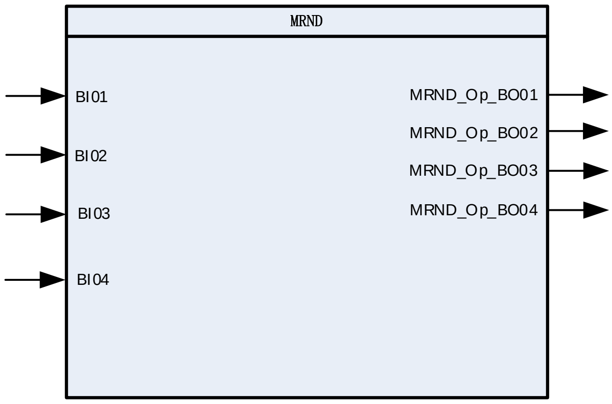



**Figure 3.22-2 No Delay Of Mechanical Relay**

### 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 MROutput 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.

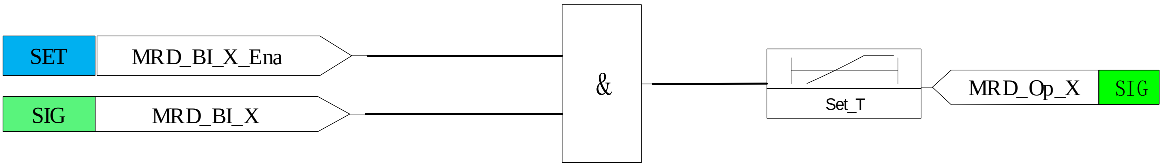



**Figure 3.22-3 Logic diagram of MRD Protection**

### 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.

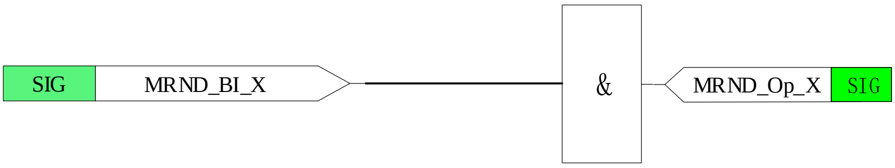



**Figure 3.22-4 Logic diagram of MRND Protection**

## 3.22.3 Settings

**Table 3.22-1 Settings of Reactor interturn 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 |

| No. | Name | Values (Range) | Unit | Step | Default | Description |
|---|---|---|---|---|---|---|
| 7 | MRD_BI03_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling Delay Mechanical Relay<br>0: disable<br>1: enable |
| 8 | MRD_BI04_Ena | 0/1 | - | 1 | 0 | Logic setting of enabling/disabling Delay Mechanical Relay<br>0: disable<br>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

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 Trip Blocking Signal**

| Alarm Signal Name | Description |
|---|---|
| Kernel Comm Abn | Some abnormalityhappen to the internal communication. |
| Databus Comm Intr | Databus communication is interrupted. |
| Databus Data Abn | Some abnormalityhappen to the databus. |
| LVDSIO Input Err | LVDSIO fails to Read BI. |
| LVDSBus SelfChk Abn | LVDS databus is self-detected as abnormal. |
| RAM Scan Err | Some abnormality are found when the RAM is under scan. |
| Sys Const SelfChk Abn | The system constant is self-detected as abnormal. |
| SelfChk Comp Port Err | The communication port isself-detected as abnormal. |
| SelfChk Comp Cfg Err | The communication configuration isself-detected as abnormal. |
| Setting SelfChk Err | The setting CRC code isself-detected as abnormal. |
| Soft Sw SelfChk Err | The soft switch CRC code isself-detected as abnormal. |
| BO Cfg SelfChk Err | The KO configuration file CRC code isself-detected as abnormal. |
| BO Cfg CRC Err | The KO configuration file CRC code is unmatched. |
| Para SelfChk Err | The parameter CRC code isself-detected as abnormal. |
| Prot Comp RAM Scan Err | Some abnormality are found when the BO RAM is under scan. |

**Table 4.2-2 Supervision Alarm Signal**

| Alarm Signal Name | Description |
|---|---|
| Databus LongTime Losing Syn | The databus loses synchronization for a long time. |
| Databus Wrong Syn Alarm | Some abnormality happens to the databus synchronization. |
| A/D Sampling Err | A/Dmodule sampling is abnormal. |
| IRIG-B Syn Abn | IRIG-B synchronization is abnormal. |
| Mana Bus Comm Intr | Management databus communication is interrupted. |
| Set CRC Err | The setting CRC code is unmatched. |
| Soft Sw CRC Err | The soft switch CRC code is unmatched. |
| Para CRC Err | The parameter CRC code is unmatched. |
| Main Cfg Check Abn | Themain configuration file isabnormal. |
| Cfg File Check Abn | The configuration file isabnormal. |
| Comp Cfg Check Err | Thecommunication configuration file isself-detected as abnormal. |

| Alarm Signal Name | Description |
|---|---|
| WaveRcd Cfg File Abn | Thedisturbance configuration file isabnormal. |
| WaveRcd File Abn | The disturbance file isabnormal. |

## 4.3 Current circuit supervision(CTS)

### 4.3.1 Overview

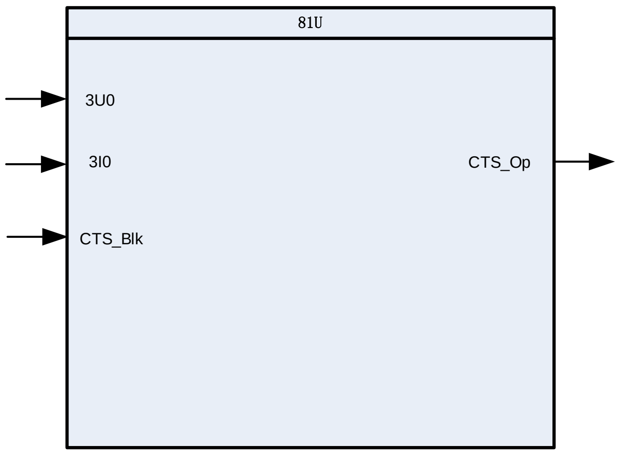
The main purpose of Current circuit supervision (CTS) is to monitor the protected electrical network by the help of instrument transformer (CT).This is a backup function for CT circuit failure. If CT balance coefficient at one side is relatively little, the different current resulting from CT circuit 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 |
|---|---|---|
| 7 | 3U0 | Residual voltage from the three-phase voltage inputs |
| 8 | 3I0 | Residual current from the three-phase current inputs |

| NO. | Signal | Description |
|---|---|---|
| 9 | CTS_Blk | Block signal of CTS |

**Table 4.3-2 CTS Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 9 | CTS _Op | Operation signal from CTS |

### 4.3.2 Logic Diagram

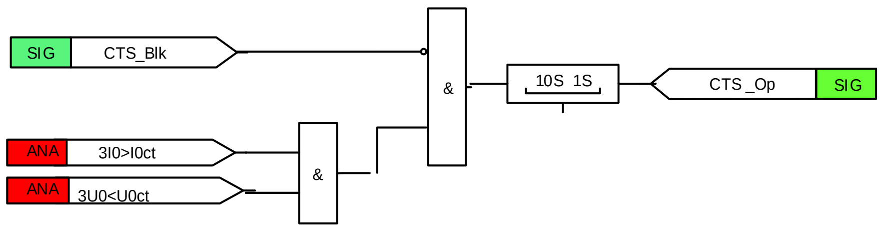



**Figure 4.3-1 CTS criterion logic diagram**

### 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.

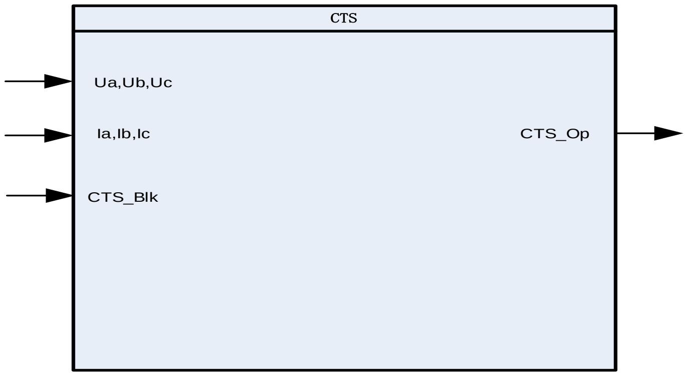
CT circuit failure will be deemed to have occurred once the situation that meets above-noted criterion lasting for 10s.

# 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 |
|---|---|---|
| 10 | Ua,Ub,Uc | three-phase voltage inputs |
| 11 | Ia,Ib,Ic | three-phase current inputs |
| 12 | CTS_Blk | Block signal of CTS |

**Table 4.4-2 CTS Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 10 | CTS _Op | Operation signal from CTS |

### 4.4.2 Logic Diagram

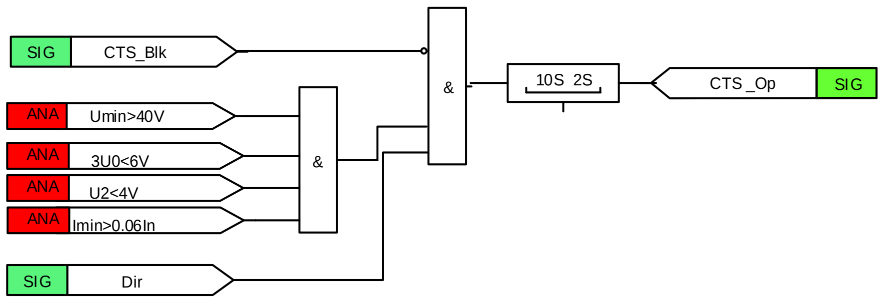
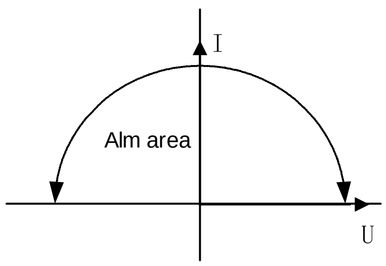



**Figure 4.4-1 CTS criterion logic diagram**

### 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:

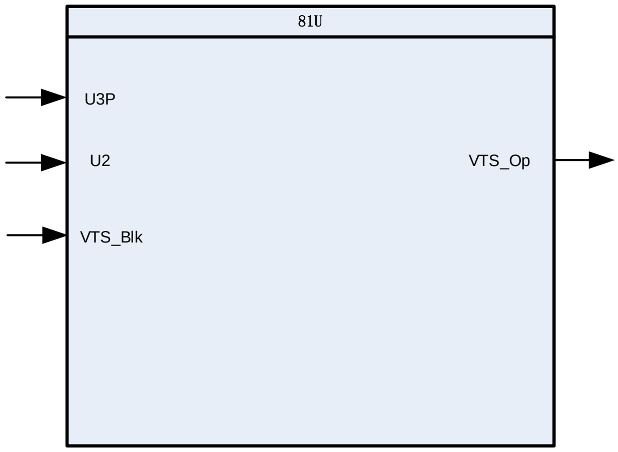
- Overcurrent protection with voltage controlled element
- Synchronization and many other protections

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 | U3P | Three phase group signal for voltage inputs |
| 2 | U2 | Negative voltage inputs |
| 3 | VTS_Blk | 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

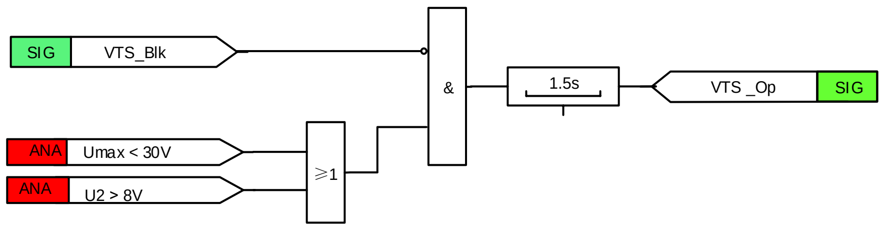



**Figure 4.5-1VTS criterion logic diagram**

### 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

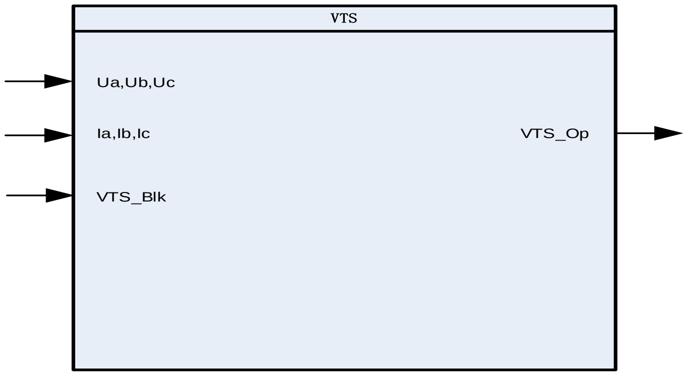
The main and important function of Fuse failure supervision (VTS) is to continuously supervised the protected electrical network by the help of instrument transformer (VT) and to ensure the stability of accurate operation. If any kind of trouble situation happened in the following circuits between instrument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

- 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 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 | Ua,Ub,Uc | Three phase group signal for voltage inputs |
| 2 | Ia,Ib,Ic | Three phase group signal for current inputs |
| 3 | VTS_Blk | Block signal of VTS |

**Table 4.6-2 VTS Output Signals**

| NO. | Signal | Description |
|---|---|---|
| 1 | VTS_Op | Operation signal from VTS |

## 4.6.2 Logic Diagram

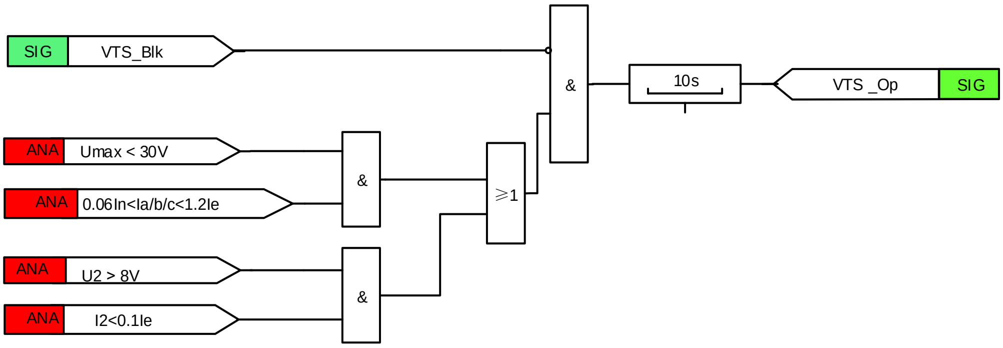



**Figure 4.6-1VTS criterion logic diagram**

## 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 Monitoring&Control

2.17

## 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 to 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 rateis 40 points per cycle. Different protection logics use different measurement quantities,including the RMS value, the phase angle,the frequency, the harmonic content, the sequence components and so on. All these protection sampled values are displayed in HMI with 0.5s updateing 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 updateing rate.

## 5.3 Apparatus Control

The apparatus control is a combination of functions which continuously superviseand 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 otherfunctions' conditions such as interlocking, synchrocheck, operator place selectionand the external or internal blockings.

The commands to an apparatus can be initiated from the local self-customized BI, thestation HMI or the dispatching center. The local control self-customized BIcan 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 tocloseor 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.

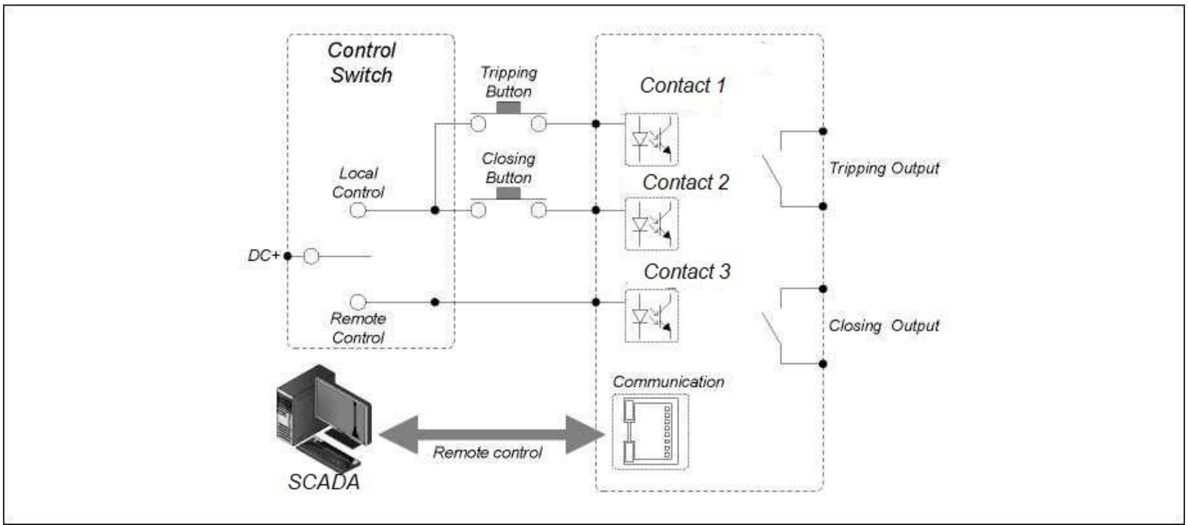



**Figure 5.3-1 Demonstration Diagram of TheControl Function**

## 5.4 Signaling

This relay has some programmable binary inputs which are used to monitor the contact positions of the corresponding bay, or be used in protection logics or for releasing or blocking the relevant protective element, or be used in supervision logics calculation for supervision alarm elements.

The binary inputs can be configured according to the engineering demands through the PRS IED Studio configuration tool auxiliary software.

The binary input state change confirmation time of each binary input is configurable according to practical application through the PRS IED Studio configuration tool auxiliary software, and the default binary input state change confirmation time of the binary inputs is 10ms.

## 5.5 Event Recording

This relay supports the event recording functions which can record all the events happened in this relay. So it is very convenient for the user to view the history records.

The following event information can be recorded.

2.14,2.15

- 64 latest protection operation reports
- 1024 latest supervision alarm records
- 1024 latest control operation records
- 1024 latest user operation records
- 1024 latest reports of time tagged sequence of event (SOE)

## 5.6 Fault and Disturbance Recording

This relay provides the fault and disturbance recording facility for recording the sampled values of the fault and disturbance wave when a fault is occurred in the power system. The 64 latest fault and disturbance records can be recorded in this relay, and each wave record includes up to 10000 fault sampled points (40 sampled points per cycle).

The current and voltage sampled values, the binary input signals and the protection operation signals are contained in the fault and disturbance wave record, and the analog value sampling rate is 40 points per cycle. The format of the wave complies with the “COMTRADE” standard.

Each 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.

# 6 IED 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 configurated flexibly according to the practical engineering demands.

The overall hardware designing frame of this relay is shown as below.

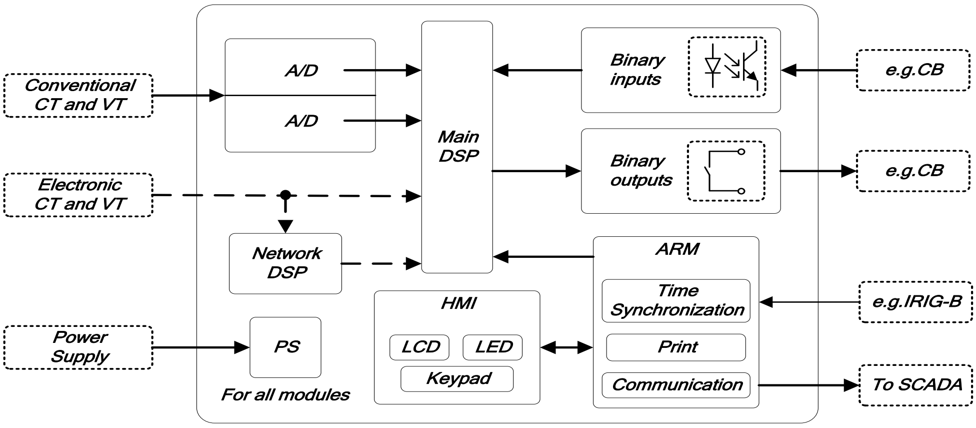



**Figure 6.1.1 Hardware Frame of This Relay**

The following figures show the front panel and the rear panel of 1/2 19” case and 1/1 19” case.

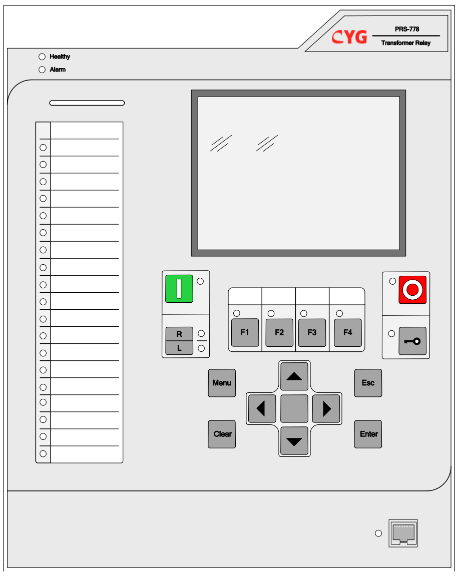



**Figure 6.1.2 Front Panel of 1/2 19” Case**

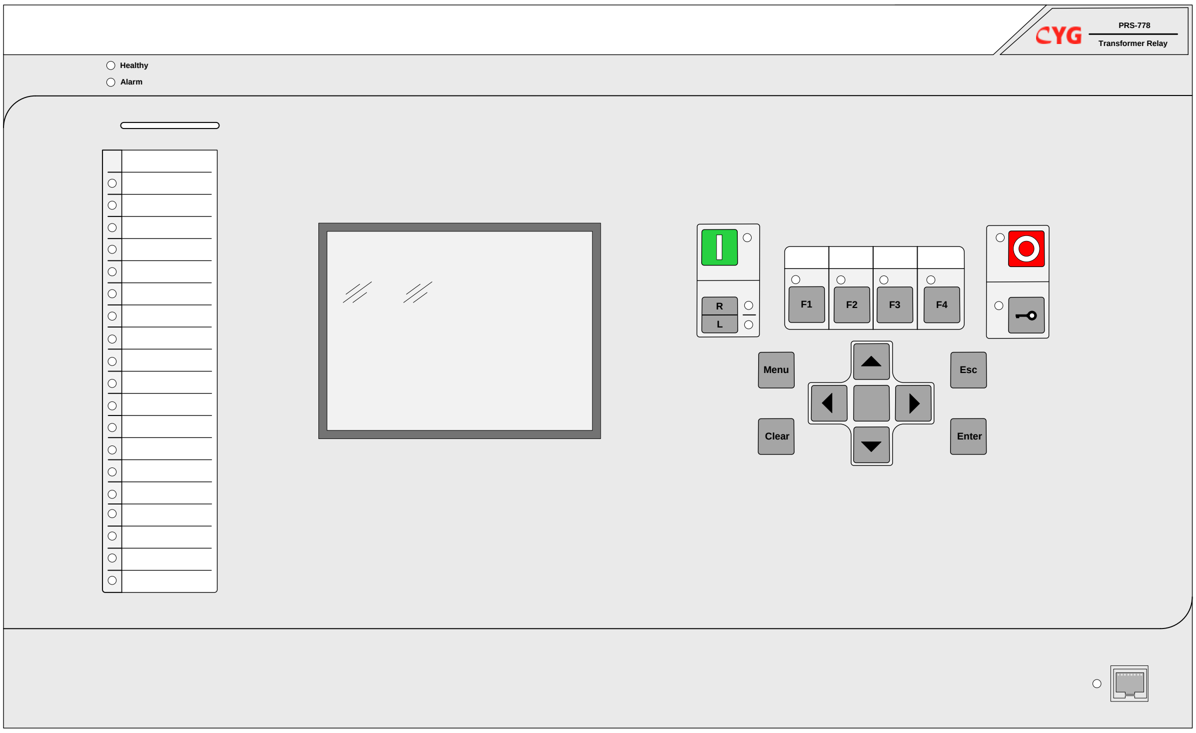



**Figure 6.1.3 Front Panel of 1/1 19" Case**

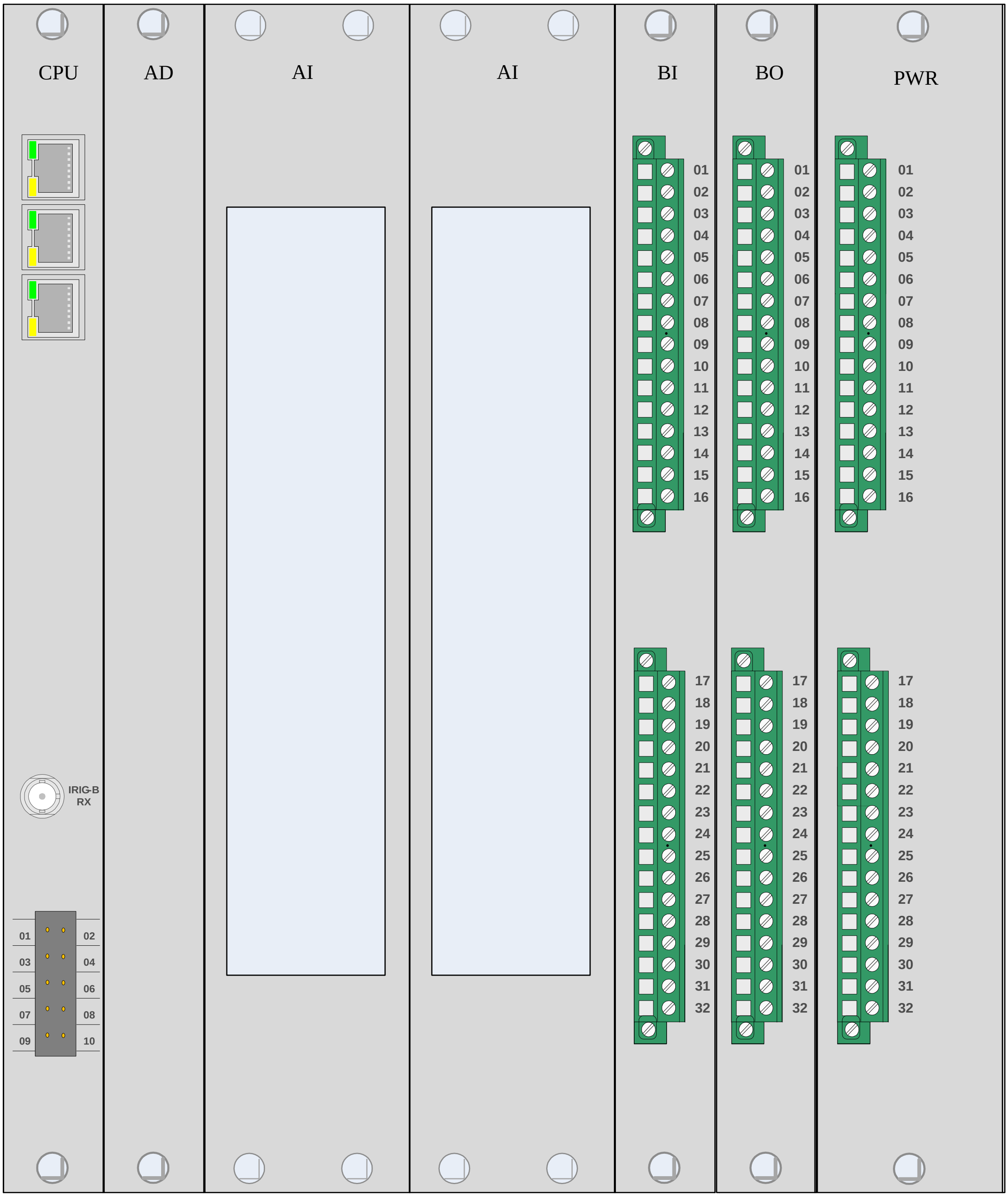



Figure 6.1.4Rear Panel of 1/2 19” Case

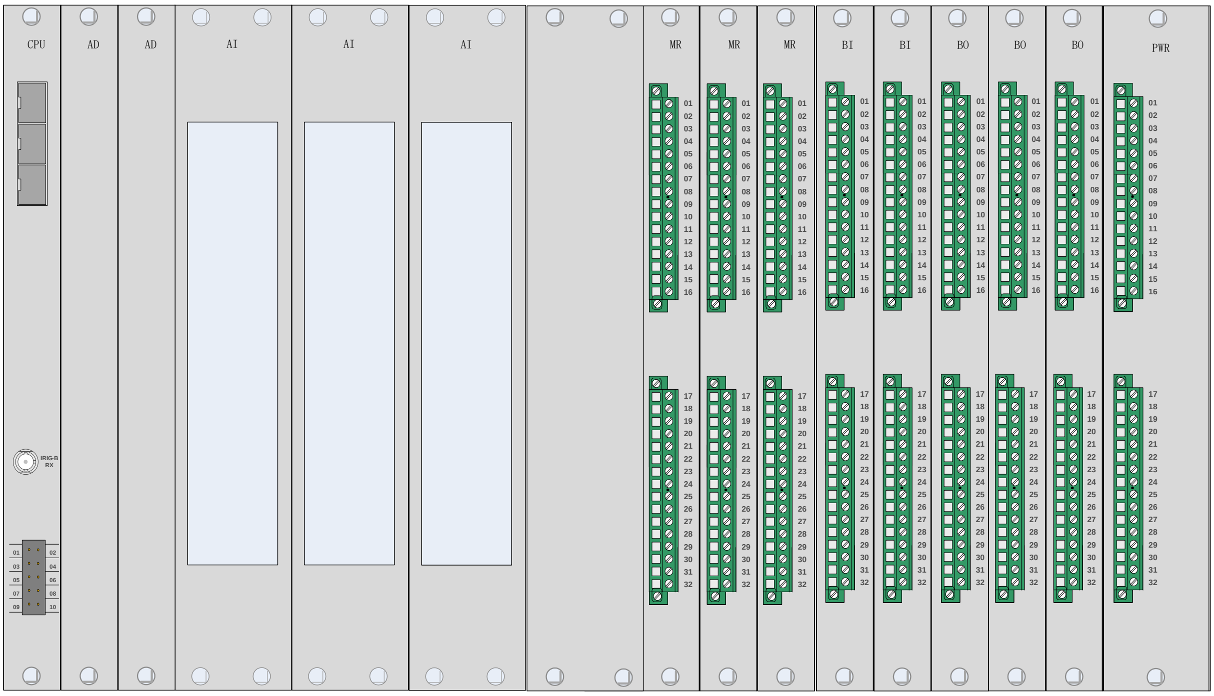



**Figure 6.1.5Real Panel of 1/1 19" Case**

***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 voltgage 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 6-1Module Configuration**

| No. | ID | Module Description | Remark |
|---|---|---|---|
| 1 | SR7910(1/2 19")<br>SR7900(1/1 19") | Human machine interface module (HMI module) | standard |
| 2 | SR7601 | Power supply module (PWR module) | standard |

| No. | ID | Module Description | Remark |
|---|---|---|---|
| 3 | SR7260 | Protection calculation module (CPU module) | standard |
| 4 | SR7270/SR7271 | AD conversion(AD module) | standard |
| 5 | SR7100/SR7178 | Analog input module (AI module) | standard |
| 6 | SR7330 | Binary input module (BI module) | standard |
| 7 | SR7300 | Binary output module (BO module) | standard |
| 8 | SR7302 | Binary output module (BO module) | standard |
| 9 | 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 parametersand display informations of this device, including the analogue quantities, the running status and event lists.

The menus are showed as tree sturcture, which facilitates the users to enter any specific menu. After entering the menu, the big LCD show 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 input voltage is provided due to the sophisticated circuit design. The the output voltage from the voltage converter are continuously monitored to ensure the stability and safety.

The power supply module provides 13 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 determine what information do they transmit between the CPU module and PWR module.

The frame of all the power supply module terminal are shown below.

| PWR | | | |
|---|---|---|---|
| 01 | POW(+) | BO06 Open | 17 |
| 02 | POW(-) | BO07 Common | 18 |
| 03 | Dev_Err Common | BO07 Open | 19 |
| 04 | Dev_Err Cls | BO07 Cls | 20 |
| 05 | Dev_Err Open | BO08 Common | 21 |
| 06 | BO01 Common | BO08 Open | 22 |
| 07 | BO01 Open | BO08 Cls | 23 |
| 08 | BO02 Common | BO09 Common | 24 |
| 09 | BO02 Open | BO09 Open | 25 |
| 10 | BO03 Common | BO09 Cls | 26 |
| 11 | BO03 Open | BO10 Common | 27 |
| 12 | BO04 Common | BO10 Open | 28 |
| 13 | BO04 Open | BO10 Cls | 29 |
| 14 | BO05 Common | BO11 Common | 30 |
| 15 | BO05 Open | BO11 Open | 31 |
| 16 | BO06 Common | BO11 Cls | 32 |

**Figure 6.4.1 Frame of the Power Supply Module Terminals**

The specific terminal definition of theconnector 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. |
| BO01 | The No.1 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO02 | The No.2 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO03 | The No.3 programmable signal, tripping and closing binary output. Specially used for high current interruption. |

| Name | Description |
|---|---|
| BO04 | The No.4 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO05 | The No.5 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO06 | The No.6 programmable signal,tripping and closing binary output. Specially used for high current interruption. |
| BO07 | The No.7 programmable signal, tripping and blocking binary output. |
| BO08 | The No.8 programmable signal, tripping and blocking binary output. |
| BO09 | The No.9 programmable signal, tripping and blocking binary output. |
| BO10 | The No.10 programmable signal, tripping and blocking binary output. |
| BO11 | The No.11 programmable signal, tripping and blocking 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, harmonic quantities of up to 13$^{th}$) on the basis of the directly sampling quantities (phase-to-earth voltages and currents, phase-to-phase voltages andcurrents) 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 excecute 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 moduleis also responsible for information exchanging with the HMI module. If any monitoring conditon 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 metioned 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) modeand 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 terminalis described as below.

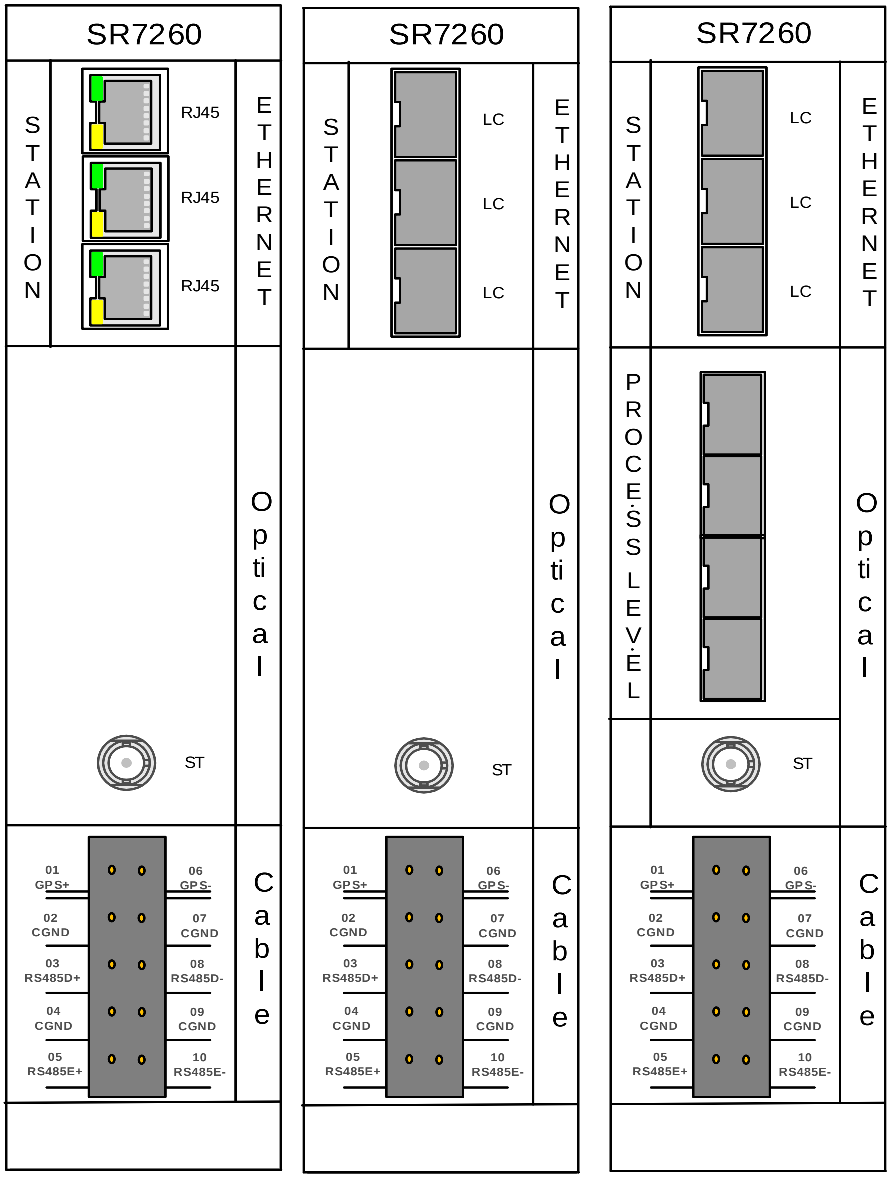



**Figure 6.5.1 Frame of Main CPU Module**

## 6.6 AD module

The module consists of a 16-bit high-accuracy AD converter which converters the sampling analog quantities to digital signals channel by channel. After the quick converter, all the digital signalsare transmitted to microchip processorsfor latter application.

## 6.7 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 pluged out.

| TF1: 6U+6I | | | |
|---|---|---|---|
| 01 | Ua | Ub | 02 |
| 03 | Uc | Un | 04 |
| 05 | U1 | U1n | 06 |
| 07 | U2 | U2n | 08 |
| 09 | U3 | U3n | 10 |
| 11 | Ia | Ia' | 12 |
| 13 | Ib | Ib' | 14 |
| 15 | Ic | Ic' | 16 |
| 17 | Ion | Ion' | 18 |
| 19 | I1 | I1' | 20 |
| 21 | I2 | I2' | 22 |
| 23 | | | 24 |
| 25 | | | 26 |

| TF2: 4U+8I | | | |
|---|---|---|---|
| 01 | Ua | Ub | 02 |
| 03 | Uc | Un | 04 |
| 05 | U1 | U1n | 06 |
| 07 | | | 08 |
| 09 | | | 10 |
| 11 | Ia | Ia' | 12 |
| 13 | Ib | Ib' | 14 |
| 15 | Ic | Ic' | 16 |
| 17 | In | In' | 18 |
| 19 | I1 | I1' | 20 |
| 21 | I2 | I2' | 22 |
| 23 | I3 | I3' | 24 |
| 25 | I4 | I4' | 26 |

| TF3: 12I | | | |
|---|---|---|---|
| 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 6.7.1Transformer 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 pluged out, the safety precaution should be obeyed in order to prevent severe personal injury, person death or considerable equipment damage.

The terminal definition of theconnector is described in the below diagram.

**Table 6-3 Terminal Definition and Description of TF Module 1**

| Name | Description |
|---|---|
| Ua | The three voltage input channels with inner star connection (Y) for protection and metering. |
| Ub | |

| Name | Description |
|---|---|
| Uc | |
| Un | |
| U1 | The phase voltage inputs of line1 for protection and metering. |
| U1n | |
| U2 | The phase voltage inputs of line2 for protection and metering. |
| U2n | |
| U3 | The phase voltage inputs of line3 for protection and metering. |
| U3n | |
| Ia | The three phase current inputs . |
| Ia’ | |
| Ib | |
| Ib’ | |
| Ic | |
| Ic’ | |
| Io | The zero sequence current inputs . |
| Ion’ | |
| I1 | The phase current inputs of line1. |
| I1’ | |
| I2 | The phase current inputs of line2. |
| I2’ | |

**Table 6-4 Terminal Definition and Description of TF Module 2**

| Name | Description |
|---|---|
| Ua | The three voltage input channels with inner star connection (Y) for protection and metering. |
| Ub | |
| Uc | |
| Un | |
| U1 | The phase voltage inputs of line1 for protection and metering. |
| U1n | |
| Ia | The three phase current inputs . |
| Ia’ | |
| Ib | |
| Ib’ | |
| Ic | |
| Ic’ | |
| In | The zero sequence current inputs . |
| In’ | |
| I1 | The phase current inputs of line1. |
| I1’ | |
| I2 | The phase current inputs of line2. |
| I2’ | |
| I3 | The phase current inputs of line3. |

| Name | Description |
|---|---|
| I3’ | |
| I4 | The phase current inputs of line4. |
| I4’ | |

**Table 6-5 Terminal Definition and Description of TF Module 3**

| Name | Description |
|---|---|
| I1 | The phase current inputs of line1. |
| I1’ | |
| I2 | The phase current inputs of line2. |
| I2’ | |
| I3 | The phase current inputs of line3. |
| I3’ | |
| I4 | The phase current inputs of line4. |
| I4’ | |
| I5 | The phase current inputs of line5. |
| I5’ | |
| I6 | The phase current inputs of line6. |
| I6’ | |
| I7 | The phase current inputs of line7. |
| I7’ | |
| I8 | The phase current inputs of line8. |
| I8’ | |
| I9 | The phase current inputs of line9. |
| I9’ | |
| I10 | The phase current inputs of line10. |
| I10’ | |
| I11 | The phase current inputs of line11. |
| I11’ | |
| I12 | The phase current inputs of line12. |
| I12’ | |

## 6.8 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 | | | |
|---|---|---|---|
| 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 6.8-1Frame of Input Terminal**

**Table 6-6 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+ | |

| Name | Description |
|---|---|
| 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- | |

## 6.9 Binary Output Module

The BO module consists of 14 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 outputscan be visually and flexibly configured through the PRS IED Studio configuration tool, which determine what information do they transmit between the CPU module and BO module.

The frame of the BO module terminal is described as below.

| Output | | | |
|---|---|---|---|
| 01 | BO01 Comon | BO09 Comon | 17 |
| 02 | BO01 Open | BO09 Open | 18 |
| 03 | BO02 Comon | BO10 Comon | 19 |
| 04 | BO02 Open | BO10 Open | 20 |
| 05 | BO03 Comon | BO11 Comon | 21 |
| 06 | BO03 Open | BO11 Open | 22 |
| 07 | BO04 Comon | BO11 Cls | 23 |
| 08 | BO04 Open | BO12 Common | 24 |
| 09 | BO05 Comon | BO12 Open | 25 |
| 10 | BO05 Open | BO12 Cls | 26 |
| 11 | BO06 Comon | BO13 Comon | 27 |
| 12 | BO06 Open | BO13 Open | 28 |
| 13 | BO07 Comon | BO13 Cls | 29 |
| 14 | BO07 Open | BO14 Common | 30 |
| 15 | BO08 Common | BO14 Open | 31 |
| 16 | BO08 Open | BO14 Cls | 32 |

**Figure 6.9-1Frame of BO Terminal**

**Table 6-7 Terminal Definition and Description of BO Module**

| Name | Description |
|---|---|
| BO1 | The No.1 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO2 | The No.2 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO3 | The No.3 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO4 | The No.4 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO5 | The No.5 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO6 | The No.6 programmable signal, tripping and closing binary output. Specially used for high current interruption. |
| BO7 | The No.7 programmable signal, tripping and closing binary output. |

| Name | Description |
|---|---|
| BO8 | The No.8 programmable signal, tripping and closing binary output. |
| BO9 | The No.9 programmable signal, tripping and closing binary output. |
| BO10 | The No.10 programmable signal, tripping and closing binary output. |
| BO11 | The No.11 programmable signal, tripping and blocking binary output. Normal open and close contacts are both equipped. |
| BO12 | The No.12 programmable signal, tripping and blocking binary output. Normal open and close contacts are both equipped. |
| BO13 | The No.13 programmable signal, tripping and blocking binary output. Normal open and close contacts are both equipped. |
| BO14 | The No.14 programmable signal, tripping and blocking binary output. Normal open and close contacts are both equipped. |

## 6.10 Binary Input/Output Module

The IO module provides 7 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.

The IO module also contains 9 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.

All the binary inputs and outputs 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 BO module.

The frame of the IO module terminal definition is described as below.

| IO | | | |
|---|---|---|---|
| 01 | BI01+ | BO01 Common | 17 |
| 02 | BI02+ | BO01 Open | 18 |
| 03 | BI01~02 Common- | BO02 Common | 19 |
| 04 | BI03+ | BO02 Open | 20 |
| 05 | BI04+ | BO03 Common | 21 |
| 06 | BI03~04 Common- | BO03 Open | 22 |
| 07 | BI05+ | BO04 Common | 23 |
| 08 | BI05- | BO04 Open | 24 |
| 09 | BI06+ | BO05 Common | 25 |
| 10 | BI06- | BO05 Open | 26 |
| 11 | BI07+ | BO06 Common | 27 |
| 12 | BI07- | BO06 Open | 28 |
| 13 | BI08+ | BO06 Cls | 29 |
| 14 | BI08- | BO07 Common | 30 |
| 15 | BI09+ | BO07 Open | 31 |
| 16 | BI09- | BO07 Cls | 32 |

**Figure 6.10-1Frame of the IO ModuleTerminal**

The terminal definition of the IO module is described as below.

**Table 6-8 Terminal Definition and Description of IO 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- | |
| BO01 | The No.1 programmable signal, tripping and closing binary output. |
| BO02 | The No.2 programmable signal, tripping and closing binary output. |
| BO03 | The No.3 programmable signal, tripping and closing binary output. |
| BO04 | The No.4 programmable signal, tripping and closing binary output. |
| BO05 | The No.5 programmable signal, tripping and closing binary output. |
| BO06 | The No.6 programmable signal, tripping and blocking binary output. Normal open and close contacts are both equipped. |
| BO07 | The No.7 programmable signal, tripping and blocking binary output. Normal open and close contacts are both equipped. |

## 6.11 MR Plug-in Module (Mechanical Relay Input/Output)

2.18

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 | | | |
|---|---|---|---|
| 01 | PWR+ | BO_MR2_2 | 17 |
| 02 | PWR- | BO_MR2_3 | 18 |
| 03 | BI_MR01+ | BO_MR2_4 | 19 |
| 04 | BI_MR01- | BO_MR2_ Common | 20 |
| 05 | BI_MR02+ | BO_MR3_1 | 21 |
| 06 | BI_MR02- | BO_MR3_2 | 22 |
| 07 | BI_MR03+ | BO_MR3_3 | 23 |
| 08 | BI_MR03- | BO_MR3_4 | 24 |
| 09 | BI_MR04+ | BO_MR3_ Common | 25 |
| 10 | BI_MR04- | BO_MR4_1 | 26 |
| 11 | BO_MR1_1 | BO_MR4_2 | 27 |
| 12 | BO_MR1_2 | BO_MR4_3 | 28 |
| 13 | BO_MR1_3 | BO_MR4_4 | 29 |
| 14 | BO_MR1_4 | BO_MR4_ Common | 30 |
| 15 | BO_MR1_ Common | Reset input+ | 31 |
| 16 | BO_MR2_1 | Reset input- | 32 |

Terminal definition and description is shown as follows:

Table 6.2-9 Terminal definition and description of MR Plug-in Module

| Symbol | Description |
|---|---|
| PWR+ | Positive input of power supply for the device |
| PWR- | Negative input of power supply for the device |
| BI_MR1 | Mechanical relay (MR) signal input 1 |
| BI_MR2 | Mechanical relay (MR) signal input 2 |
| BI_MR3 | Mechanical relay (MR) signal input 3 |
| BI_MR4 | Mechanical relay (MR) signal input 4 |
| 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. |

| Symbol | Description |
|---|---|
| BO_MR4_1 | NO contact, is closed when binary input BI_MR4 is energized. |
| Common 1 | 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. |
| Common 2 | 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. |
| Common 3 | Common terminal of negative supply of binary inputs |
| Reset signal | Reset input |

# 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 PRS-778 Human Machine Interface (HMI) is user friendly and easy to operate in different situations. The design structure detail of HMI is 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 28 LEDs light indicator.
- For the remote access from the PRS IED studio configuration software, Ethernet commissioning interface is available.

The front and back panels of PRS-778 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 PRS-778 relay setting.

In simple words, all functions of PRS-778 are user friendly.

### 7.1.3 Operating panel keypad and keys

The PRS-778 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 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 |
|  | CB close key, Remote/Local control key, User login key and CB opening key respectively. |

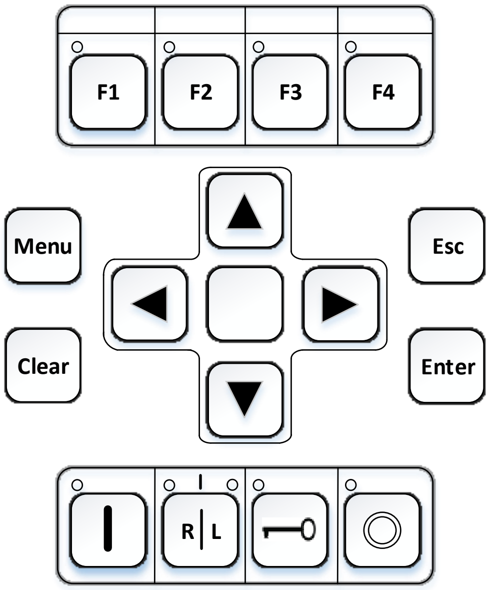



**Figure 7.1.1 Overview of Front Panel Keypad and Keys**

### 7.1.4 Indication of LED

2.16

The PRS-778 device consists of 28 front panel LEDs. The local view of front panel HMI consists of two protection status LEDs above the display level; healthy and alarm. The sixteen 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, sixteen LEDs shows 48 different alarming status.

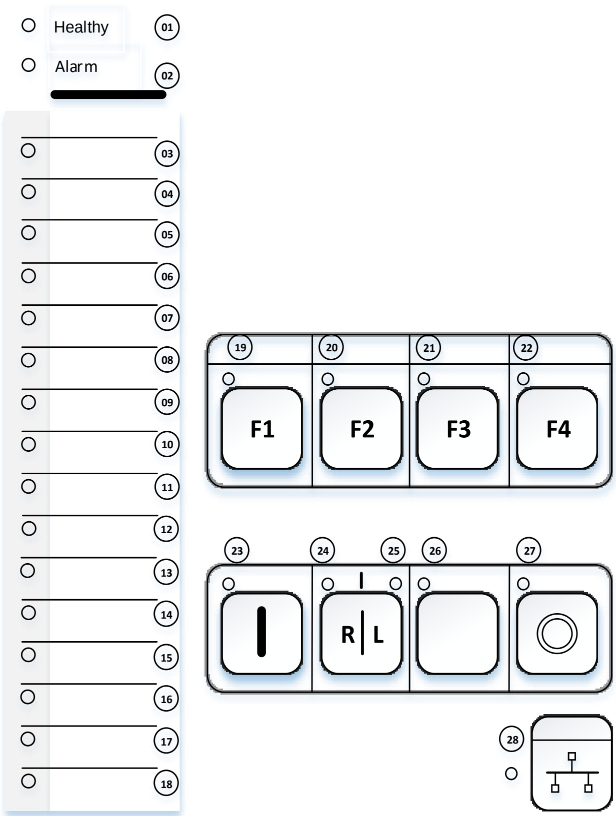



**Figure 7.1.2 Overview of Front Panel LED's**

**Table 7-2 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. |
| | | Green/Yellow/Red | Alarm signal is issued. When any kind of abnormality signal is detected. LED light color is configured according to user demand. |
| 03~18 | Configurable | Off | None of signal is energized when the device running normally. |
| | | 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. |
| 19~22 | Configurable | Off | None of signal is energized when the functional key is deactivated. |
| | | Green/Yellow/Red | These LEDs indicate the functional keys are deactivated and they can be configured according to user demand. |
| 23 | CB Close | Off | None of signal is energized when the functional key is deactivated. |
| | | Green/Yellow/Red | This LED indicate the CB Close key is activated and it can be configured according to user demand. |

| No. | Key label | Status | Description |
|---|---|---|---|
| 24 | Remote | Off | The operation mode is determined by the BI. |
| | | Green/Yellow/Red | The device is in the "remote" mode |
| 25 | Local | Off | The operation mode is determined by the BI. |
| | | Green/Yellow/Red | The device is in the "Local" mode |
| 26 | User login | Off | When user login function is not enable. |
| | | Green | When user login function works normally. |
| | | Yellow/Red | When user login function is not working normally. |
| 27 | CB Open | Off | None of signal is energized when the functional key is deactivated. |
| | | Green/Yellow/Red | This LED indicate the CB Open key is activated and it can be configured according to user demand. |
| 28 | Ethernet interface port | Off | When no Ethernet cable is connected with device. |
| | | Green | When it works normally. |
| | | Yellow/Red | Alarm signal indication, in case of abnormality. LED color can be configured according to user requirement/demand. |

➢ **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 PRS-778 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 are listed in below table 7.1.3:

**Table 7-3 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 | "Main menu", "system single line", "event", "measurement", "fault recording", "device status", "clear" 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 Diplay description of HMI

### 7.2.1 Oviervew

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.

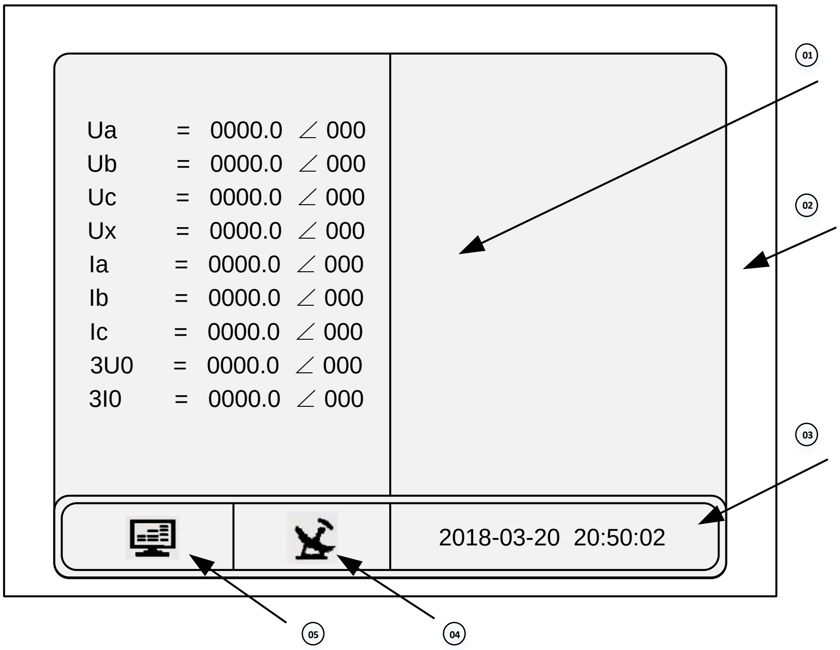



**Figure 7.2.1 General Overview Display of Local HMI LCD Screen**

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.

Time synchronization ….

Data monitoring zone ….

### 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 designes a flat-panel of main menu LCD display that contain ten main controlling function.

These controlling function 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 shown in below figure 7.2.2. The main menu will deal with the operation of installation work togetherwith providing basic support and instructions to help user control.

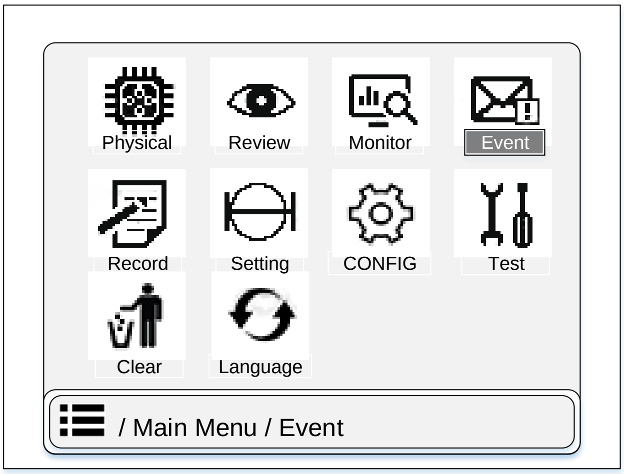



**Figure 7.2.2 LCD General Overview Display of Main Menu**

## 7.3 Sub menu functions of main menu

This part of HMI, the detail of menu sub-functions is 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 software and device communication. The overview display of physical information is shown in below figure 7.3.1.

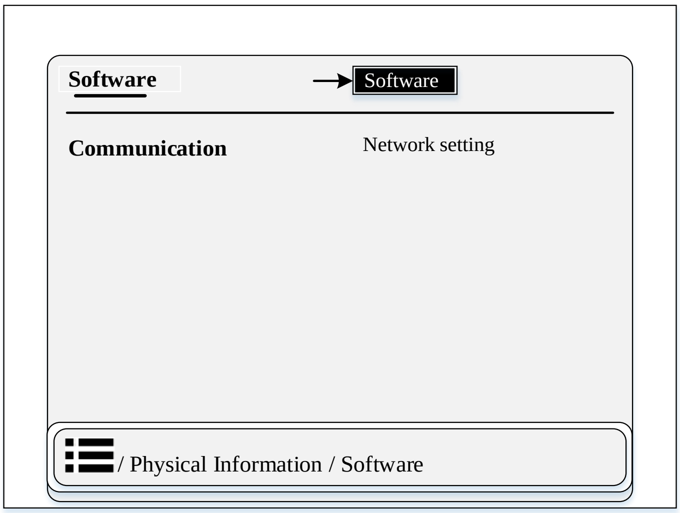



**Figure 7.3.1 Overview Display of Physical Information Sub-functions**

#### 7.3.1.1 Software

In this sub-section of physical information, the software 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 > software”. The software information data divided into two pages and the detail of information is listed in below figure 7.3.2 and table 7.3.1:

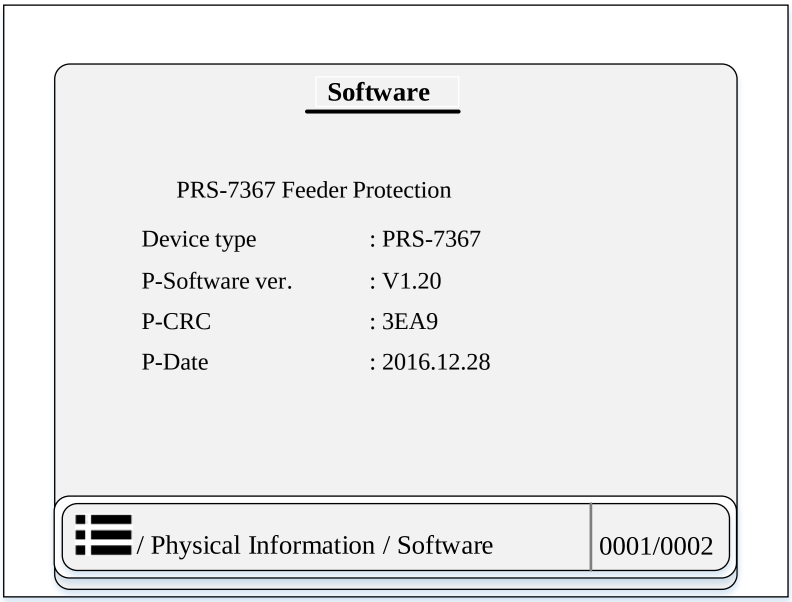



**Figure 7.3.2 Overview Display Diagram of Software Information**

**Table 7-4 Detail of Software information**

| Name | Function display | Description |
|---|---|---|
| Device type | PRS-XXXX | Discribe the type of protection relay |
| P-Software ver | V1.20 | Describe the version of protection relay software |
| P-CRC | 3EA9 | Protection Cyclic redundancy check code |
| P-Date | yyyy-mm-dd | Protection CPU date |
| M-Software ver. | V1.20 | MCPU software version |
| M-CRC | 6F3C | MCPU Cyclic redundancy check error |
| M-Date | yyyy-mm-dd | Management CPU date |
| Uniqueness code | A01-30000000FFFFFFF | |

### 7.3.1.2 Communication

This section, describes the information communication of network setting of the protection relay including IP, MAC and NetMask 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 7.3.2:

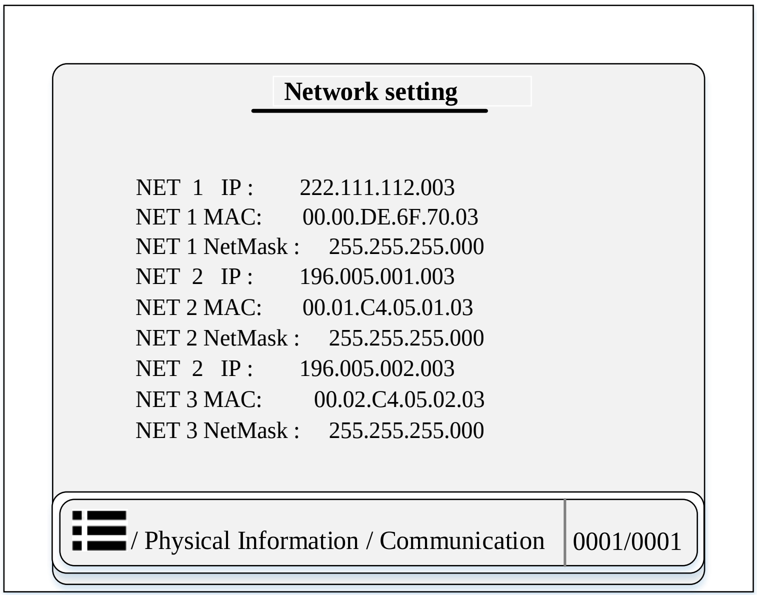



**Figure 7.3.3 Overview Display Diagram of Network Setting**

**Table 7-5 Communication data detail**

| Name | Function display | Description |
|---|---|---|
| NET 1 IP | 222.111.112.003 | IP address of internet protocol for Ethernet port 1 |
| NET 1 MAC | 00.00.DE.6F.70.03 | MAC address of internet protocol for Ethernet port 1 |
| NET 1 NetMask | 255.255.255.000 | NetMask 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 NetMask | 255.255.255.000 | NetMask 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 NetMask | 255.255.255.000 | NetMask 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 monitoring data. 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.

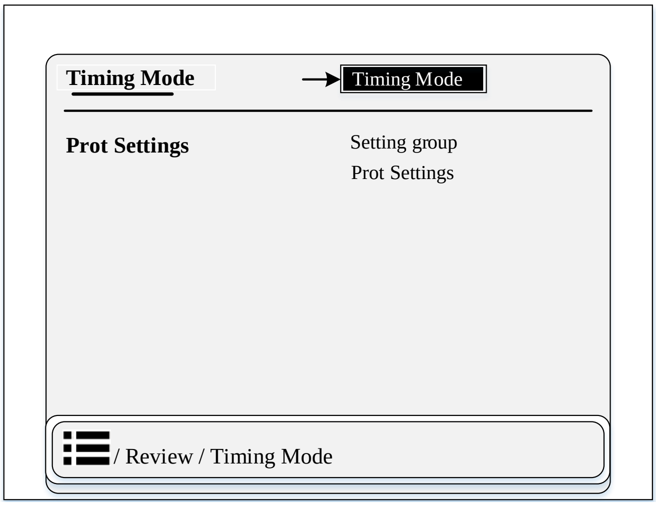



**Figure 7.3.4 Overview Display of Review Information Sub-functions**

### 7.3.2.1 Timing Mode

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.

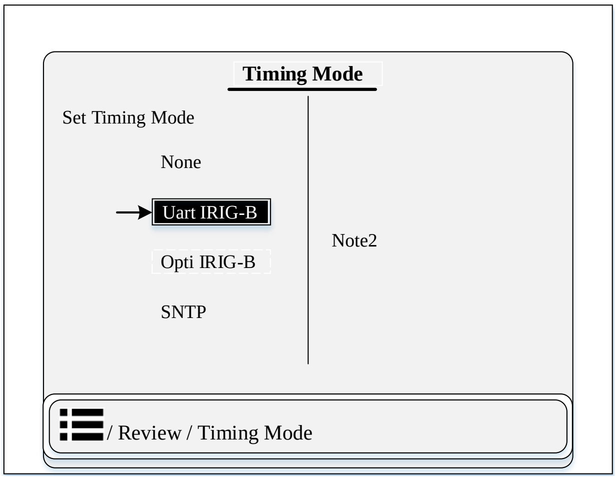



**Figure 7.3.5 Overview Display of Timing Mode**

### 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.

**2- Prot Settings**

This section the user can see the different kind of information like public, measurement and protection function operation settings etc. User can access this function through the following path:

"Review > Prot Settings". This section contains 01 to 11 pages and 42 parts of relay settings. The information data structure of protection setting is listed in below figure 7.3.6 and table 7.3.3:

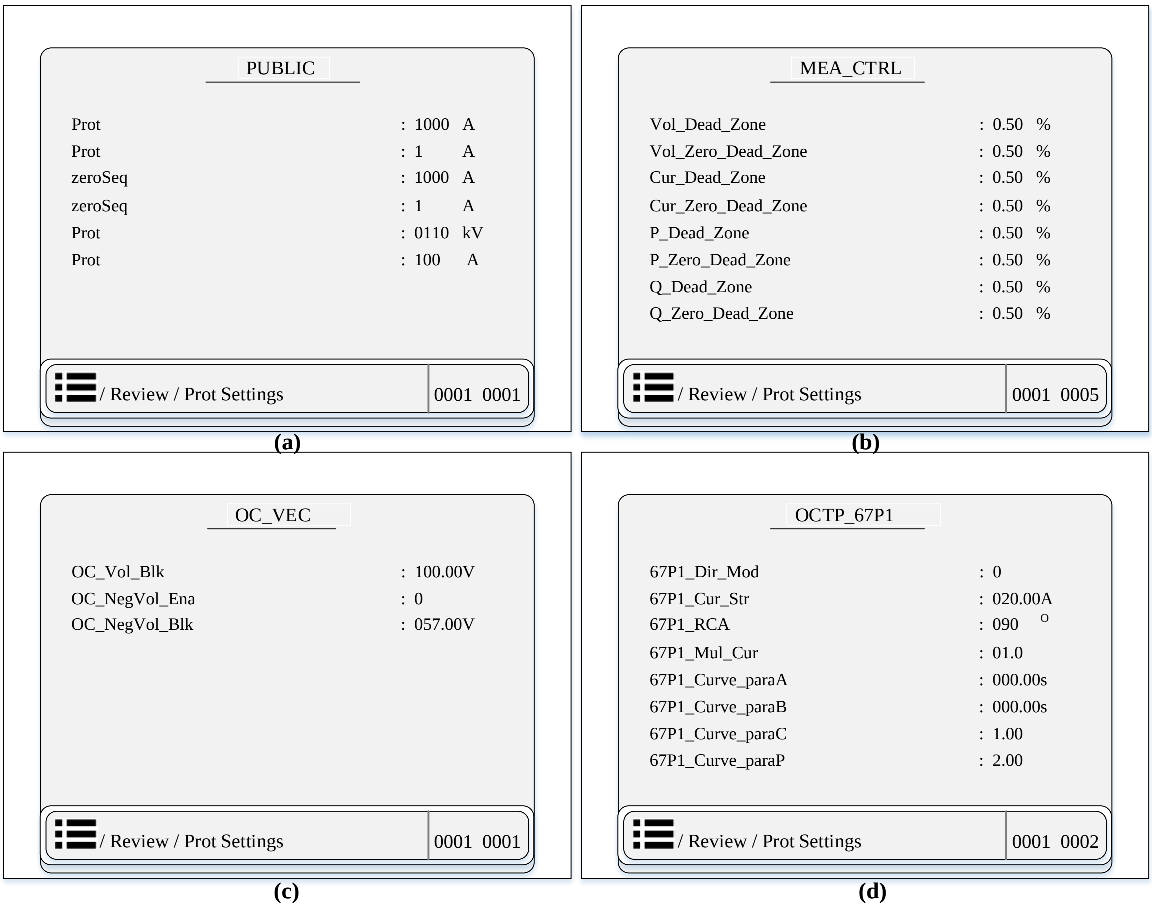



**Figure 7.3.6 Overview Diagram of Prot Setting (a) Public Setting (b) Measurement Control Setting (c) Overcurrent Protection Setting (d) Phase Overcurrent Protection Setting of Stage 1**

**Table 7-6 Protection settings**

| Setting No. | Functionality | Description |
|---|---|---|
| 01 | Public | This part shows the information of primary and secondary ratio of current and voltage respectively. Also shows the value of operating system frequency. |
| 02 | MEA_CTRL | Known as Measurement control and the user can see the different information like dead zone values, synchronism values, bus bar rated operating values, angle difference and remote operating values etc. This part contains into 01-05 pages. |
| 03 | OC_VEC | Known as overcurrent protection with voltage element control and the user can see the relevant setting of OC_VEC in this part. |
| 04-07 | OCTP_67P (1-4) | Known as overcurrent protection 67P (1-4) and user can see the relevant setting of 67P (1-4) like direction mode, current start value, curve setting parameters, RCA angle and minimum protection operating time etc. This part contains into 02 pages. |
| 08-11 | OCTP_51P (1-4) | Known as non-directional overcurrent protection 51P (1-4) and user can see the relevant setting of 51P (1-4) like multiplier current setting, |

| Setting No. | Functionality | Description |
|---|---|---|
| | | current start value, curve setting parameters, reset time and minimum protection operating time etc. This part contains into 02 pages. |
| 12-15 | OCTG-51G (1-4) | Known as non-directional earth fault protection 51G (1-4) and user can see the relevant setting of 51G (1-4) like current start value, multi current setting, curve setting parameters, reset time and minimum protection operating time etc. This part contains into 02 pages. |
| 16-19 | OCTG_67G (1-4) | Known as directional earth fault protection 67G (1-4) and user can see the relevant setting of 67P (1-4) like direction mode, RCA angle, current start value, multi current setting, curve setting parameters, 3phase zero sequence enable/disable and minimum protection operating time etc. This part contains into 02 pages. |
| 20 | OCTN_46N | Known as negative sequence current protection 46N and user can see the relevant setting of 46N like current start value, multi current setting, curve setting parameters, minimum protection operating time and reset time etc. This part contains into 02 pages. |
| 21 | OCPD_46D | Known as phase discontinuity protection 46D and user can see the relevant setting of 46D like the ratio b/w negative and positive current, minimum phase starting current, protection operating time, 46D enable/disable and reset time etc. |
| 22 | OCT_SOTF | Known as switch onto fault SOTF and user can see the relevant setting of SOTF like SOTF operating mode and initiating mode, SOTF dead line current and voltage, SOTF dead line time, SOTF current and voltage detection time and SOTF reset time etc. This part contains into 02 pages. |
| 23 | PTTR_49F | Known as three phase thermal overload protection 49F and user can see the relevant setting of 49F like the rated current setting of 49F, 49F time multiplie, 49F K factor, 49F K trip and alarm setting and 49F trip and alarm enable/disable etc. |
| 24 | UVPR_27P | Known as positive sequence undervoltage protection 27P and user can see the relevant setting of 27P like 27P voltage start setting, 27P operating time, 27P block voltage setting and 27P enable/disable etc. |
| 25 | RBF_51BF | Known as circuit breaker failure protection 51BF and user can see the relevant setting of 51BF like 51BF enable/disable, 51BF retrip enable/disable, 51BF operating residual current, 51BF retrip and fail time etc. This part contains into 02 pages. |
| 26-27 | OFRS_81O (1-2) | Known as overfrequency protection 81O (1-2) and user can see the relevant setting of 81O (1-2) like 81O operating time, 81O blocking voltage setting and 81O enable/disable etc. |
| 28 | PFRC_81R | Known as frequency gradient protection 81R and user can see the relevant setting of 81O (1-2) like 81R frequency gradient start value, 81R Negative/positive change in frequency, 81R operating time, 81R blocking voltage setting and 81R enable/disable etc. |
| 29 | OVPR_59P | Known as positive sequence overvoltage protection 59P and user can |

| Setting No. | Functionality | Description |
|---|---|---|
| | | see the relevant setting of 59P like 59P voltage start setting, 59P operating time and 59P enable/disable etc. |
| 30 | OVNR_59N | Known as negative sequence overvoltage protection 59N and user can see the relevant setting of 59N like 59N voltage start setting, 59N operating time and 59N enable/disable etc. |
| 31 | OVGR_59G | Known as residual overvoltage protection 59G and user can see the relevant setting of 59G like 59G voltage start setting, 59G operating time and 59G enable/disable etc. |
| 32-33 | OVLR-59 (1-2) | Known as three phase overvoltage protection 59 (1-2) and user can see the relevant setting of 59 (1-2) like 59 voltage start value, 59 operating curve setting parameters, 59 time constant multiplier, 59 start phase number, 59 reset time and 59 minimum protection operating time etc. This part contains into 02 pages. |
| 34 | UFRS_81U (1-4) | Known as under frequency protection 81U (1-4) and user can see the relevant setting of 81U (1-4) like 81U frequency start value, 81U operating time, 81U voltage blocking value and 81U enable/disable etc. |
| 38 | UFRE_81U | Known as underfrequency restore protection 81U and user can see the relevant setting of 81U like 81U frequency start value, 81U operating time, 81U valid duration time of operation, 81U voltage blocking value and 81U enable/disable etc. |
| 39 | PREC_79 | Known as auto-recloser 79 and user can see the relevant setting of 79 like 79 enable/disable, 79 synchronous enable/diable, 79 discremination reclosing time for 1 to 5 operation, 79 auto lockout reset time, 79 recovery delay time after blocking and 79 maximum shots etc. This part contains into 03 pages. |
| 40 | ALM_PTS | Known as fuse failure supervision PTS and user can see the relevant setting of PTS enable/diable, PTS Operate level of pos seq undervoltage and PTS check mode of PT failure etc. |
| 41 | ALM_CTS | Known as current circuit supervision CTS and user can see the relevant setting of CTS enable/diable, CTS current start value and CT external zero-sequence current calculation criteria disable/enable. |
| 42 | ALM_TCS | Known as trip circuit supervision TCS and user can see the relevant setting of TCS enable/diable and TCS operate time. |

### 7.3.3 Monitoring Information

This section divided into three sub-parts and describe the information of real time monitoring data of PRS-778 feeder 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.

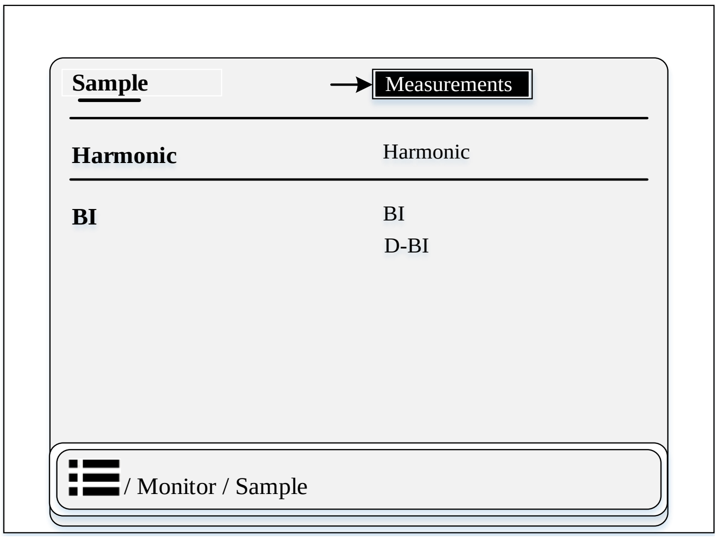



**Figure 7.3.7 Overview Display of Monitoring Information Sub-functions**

### 7.3.3.1 Sample

This section divided into one sub part like measurements and 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 > Sample”. This section contains 01 to 04 pages and 36 measuring quantities. The measurement data structure of relay is listed in below figure 2.3.8 and table 7.3.4:

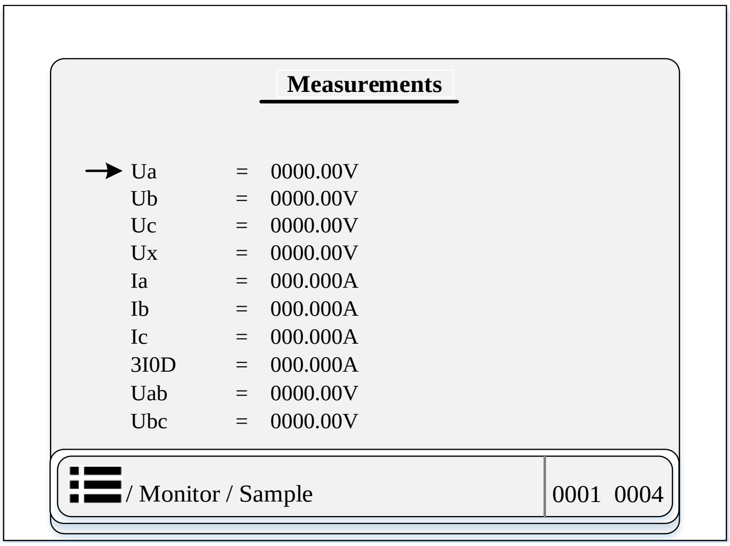



**Figure 7.3.8 Overview Display of Measurement Section Quantities**

**Table 7-7 Measurement quantaties**

| No. | Measurment function | Value (range) | Description |
|---|---|---|---|
| 1 | $U_a$ | 0000.00V | Phase A measured voltage |
| 2 | $U_b$ | 0000.00V | Phase B measured voltage |
| 3 | $U_c$ | 0000.00V | Phase C measured voltage |
| 4 | $U_x$ | 0000.00V | Ground measured voltage |

| No. | Measurment function | Value (range) | Description |
|---|---|---|---|
| 5 | $I_a$ | 000.000A | Phase A measured current |
| 6 | $I_b$ | 000.000A | Phase B measured current |
| 7 | $I_c$ | 000.000A | Phase C measured current |
| 8 | 3I0D | 000.000A | Three phase zero sequence current from external source |
| 9 | $U_{ab}$ | 0000.00V | Phase AB measured voltage (phase to phase measured voltage) |
| 10 | $U_{bc}$ | 0000.00V | Phase BC measured voltage (phase to phase measured voltage) |
| 11 | $U_{ca}$ | 0000.00V | Phase CA measured voltage (phase to phase measured voltage) |
| 12 | Duab/dt | 000.000V/S | Uab rate of change of voltage |
| 13 | Dubc/dt | 000.000V/S | Ubc rate of change of voltage |
| 14 | Duca/dt | 000.000V/S | Uca rate of change of voltage |
| 15 | UxDudt | 000.000V/S | Ux rate of change of voltage |
| 16 | $F_r$ | 000.000 Hz | Frequency |
| 17 | $U_xF_r$ | 000.000 Hz | Ux voltage frequency |
| 18 | Dfdt | 000.000 Hz/S | Rate of change of frequency of phase to phase |
| 19 | UxDfdt | 000.000 Hz/S | Rate of change of frequency of Ux voltage |
| 20 | $U_1$ | 0000.00V | Positive sequence measured voltage |
| 21 | $U_2$ | 0000.00V | Negative sequence measured voltage |
| 22 | $3U_0$ | 0000.00V | Calculated Three phase zero sequence voltage |
| 23 | $I_1$ | 000.000A | Positive sequence measured current |
| 24 | $I_2$ | 000.000A | Negative sequence measured current |
| 25 | $3I_0$ | 000.000A | Calculated Three phase zero sequence current |
| 26 | $UJY_a$ | 000.000V | |
| 27 | $UJY_b$ | 000.000V | |
| 28 | $UJY_c$ | 000.000V | |
| 29 | MUTIME | 000.000 HZ | |
| 30 | P | 0000.00 W | Power |
| 31 | Q | 0000.00 VAR | Reactive power |
| 32 | S | 0000.00 VA | Apparent power |
| 33 | COS | 000.00 | Cos value |
| 34 | DU | 000.00V | Vlotage difference |
| 35 | DF | 000.000Hz | Frequency difference |
| 36 | DA | 000.00° | Angle difference |

### 7.3.3.2 Harmonic

In this section, the user can see the calculated harmonic content data list of all phase voltage and current and also the RMS value of all three phase voltage and current. User can access this function through the following path: “Monitor > Harmonic”. The harmonic overview display diagram of relay is listed in below figure 7.3.9. After the measurement channel is selected, the harmonic data of the channel can be viewed.

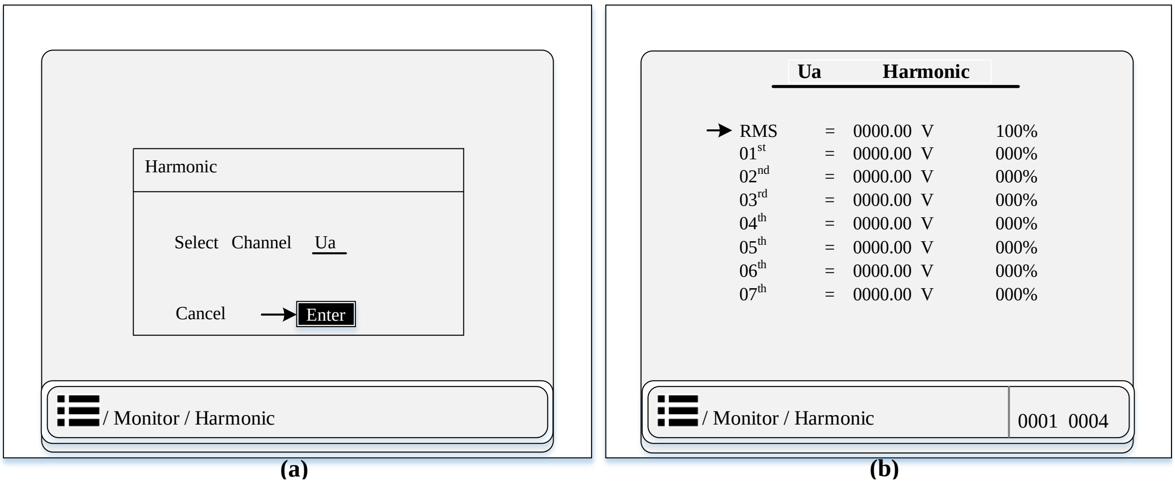



**Figure 7.3.9 LCD Display Diagram (a) Overview of Entrance Harmonic Monitoring Chart (b) Ua Harmonic Content Display Chart of Page 1**

### 7.3.3.3 BI

This section divided into two sub-parts and describe the information of binary input (BI) of this IED seen in the above figure 7.3.5. 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 04 pages and 32 binary inputs. The BI display diagram of the IED is listed in below figure 7.3.10 (a):

**2- D-BI**

D-BI is stand for double binary input function. The D-BI display diagram of relay is listed in below figure 7.3.10 (b):

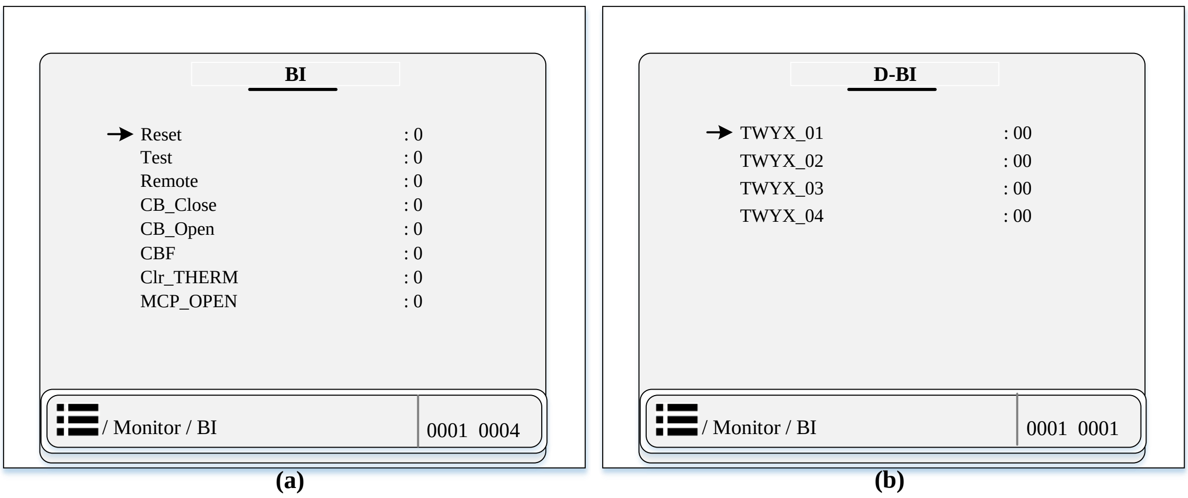



**Figure 7.3.10 LCD Display Diagram of (a) BI Monitored Data (b) D-BI Monitored Data**

## 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 7.3.11:

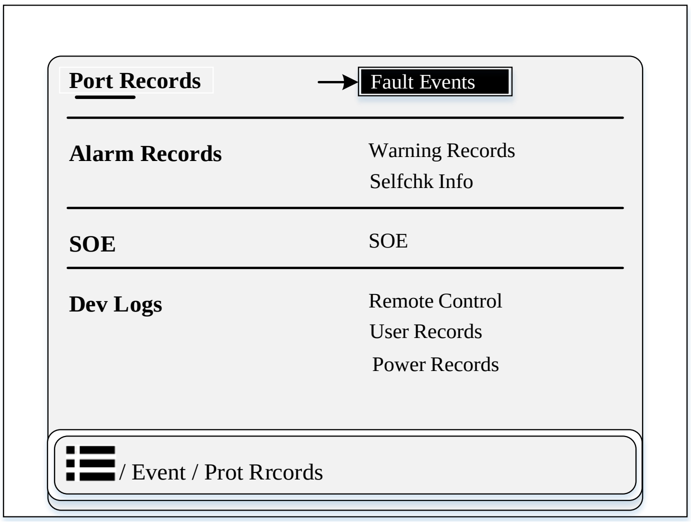



**Figure 7.3.11 Overview Display of Event Information Sub-functions**

### 7.3.4.1 Port Records

This section divided into one sub-function like fault events and this device can store 1024 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 7.3.12:

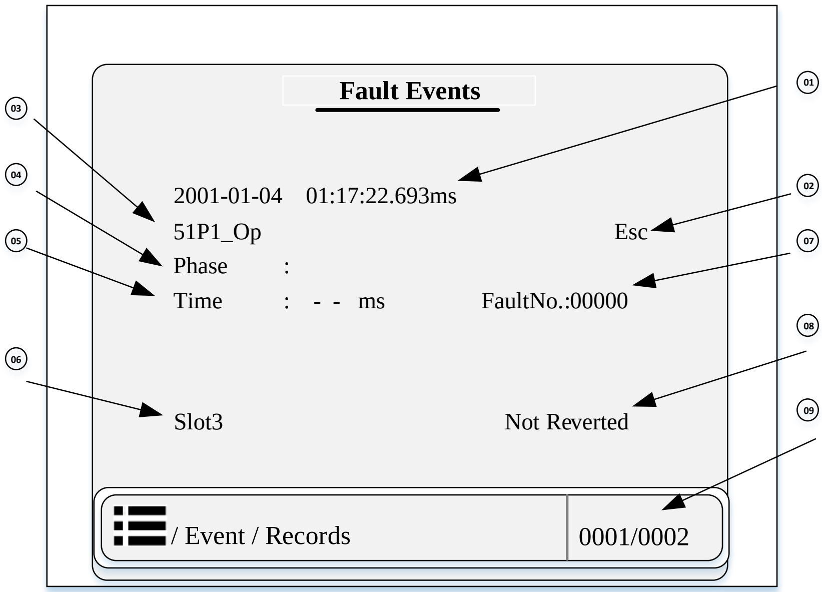



Figure 7.3.12 Overview Display of Fault Events

### 7.3.4.2 Alarm Records

This section divided into two sub-functions like warning records and selfchk Info see figure 7.3.11. This devise can save latest 1024 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 7.3.13.

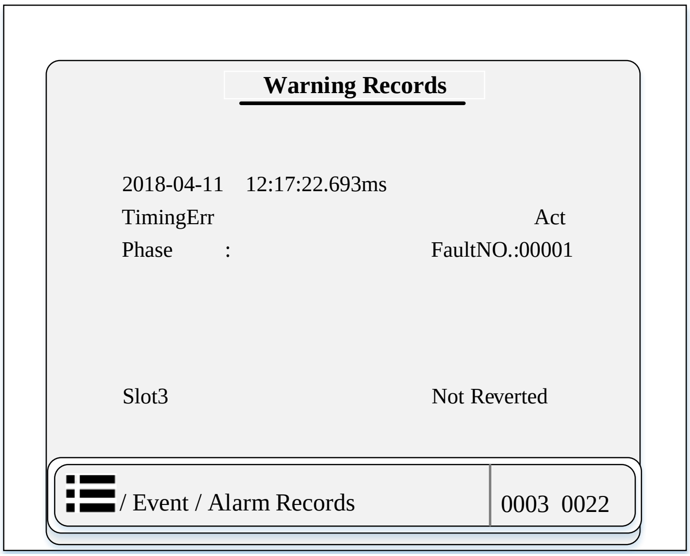



Figure 7.3.13 Overview Diagram of Warning Records Info

#### 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 summarise, this device also check hardware, software and configuration file and it can totally save latest 1024 records. User can access this function through the following path: “Event > Alarm Records”. The overview display of SelfChk info is shown in below figure 7.3.14.

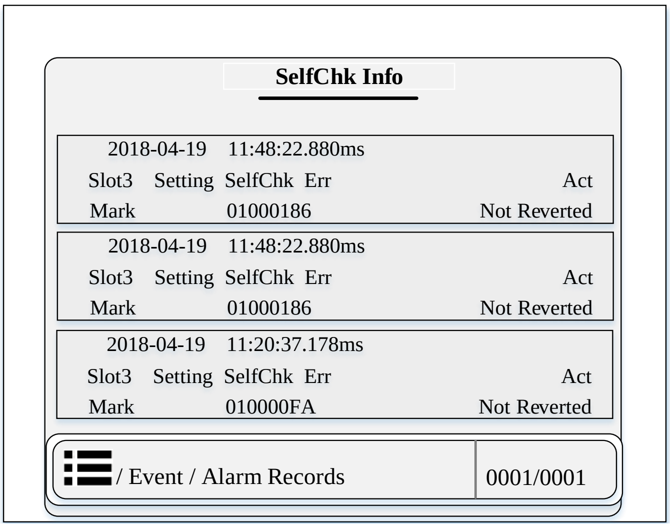



**Figure 7.3.14 Overview Display Diagram of SelfChk Info**

### 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 1024 latest SOE records. The diagram of SOE record is shown in below figure 7.3.15.

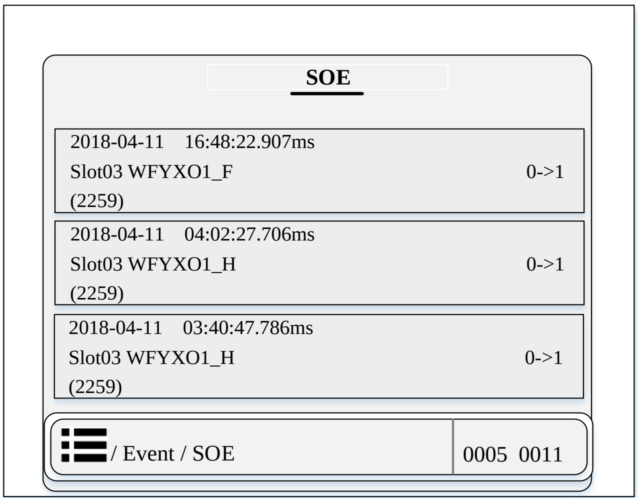



**Figure 7.3.15 Overview Display Diagram of SOE**

### 7.3.4.4 Dev Logs

This section divided into three sub-function like remote control, user records and power records see figure 7.3.11.

#### 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 1024 latest remote control records. User can access this function through the following path: "Event > Dev Logs". The diagram of remote control functions are shown in below figure 7.3.16.

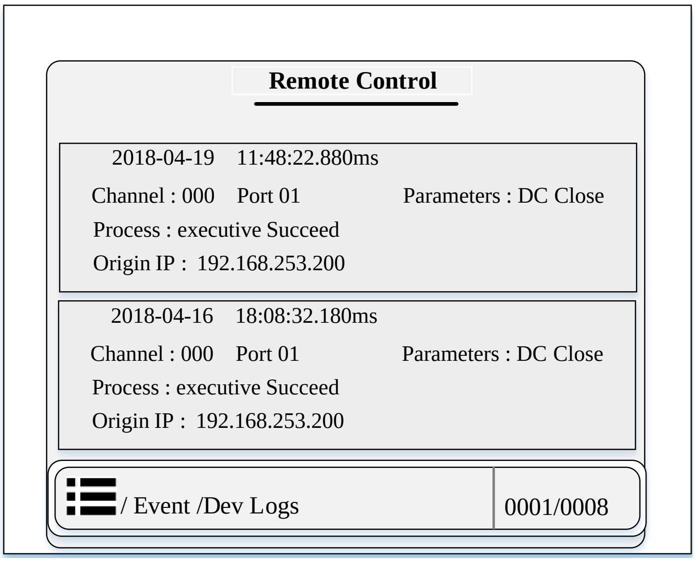



**Figure 7.3.16 Overview Display Diagram of Remote Control Access**

#### 2- User Records

In this section user can see the setting of user reocrds with slot number, time and date. User can access this function through the following path: “Event > Dev Logs”. The diagram of user records are shown in below figure 7.3.17.

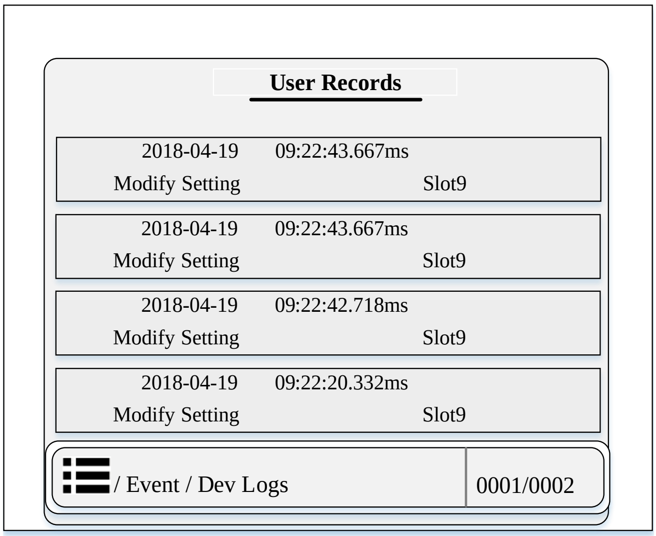



**Figure 7.3.17 Overview Diagram of User Records**

### 3- Power records

In this section user can see the setting of power 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 power records. User can access this function through the following path: “Event > Dev Logs”. The diagram of power record is shown in below figure 7.3.18.

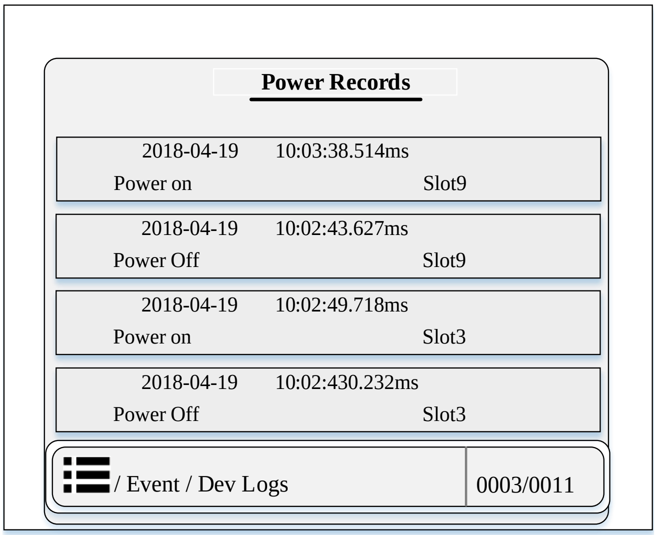



**Figure 7.3.18 Overview Diagram of Power Records**

## 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.

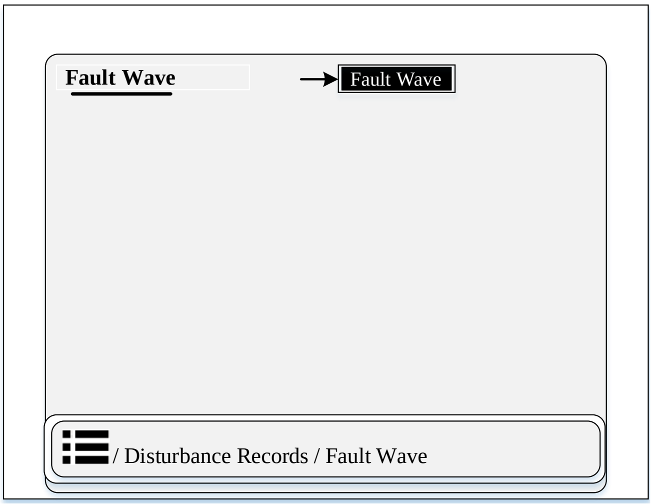



**Figure 7.3.19 Overview Display of Records Information**

### 7.3.5.1 Fault wave

In this section user can see the disturbance records of all the faults. User can access this function through the following path: “Disturbance Records > Fault Wave”. The diagram of faulty wave records are shown in below figure 7.3.20.

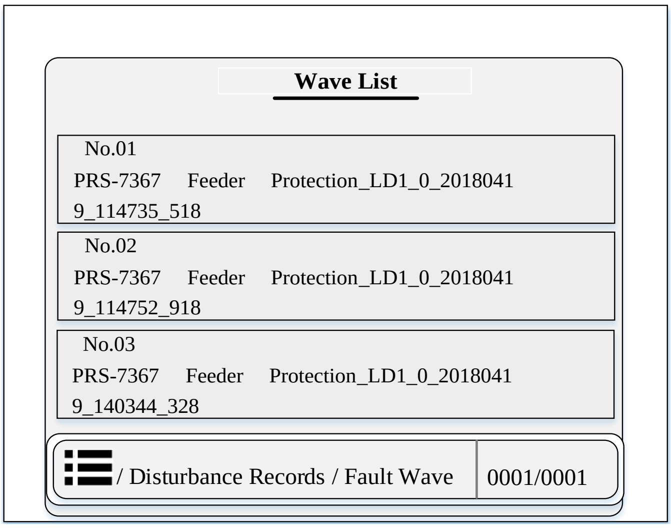



**Figure 7.3.20 Overview Diagram of Fault Wave List**

## 7.3.6 Setting Information

1.8

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 7.3.21.

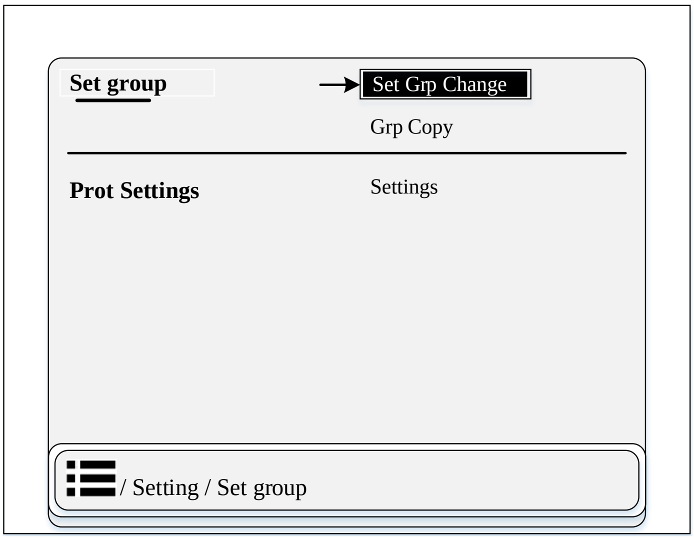



**Figure 7.3.21 Overview Display of Setting Information Sub-functions**

### 7.3.6.1 Set Group

This sub-section is divided into two further sub-section like Set Grp change and Grp Copy and in this part user can change the group setting.

#### 1- Set 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 7.3.22.

Firstly, enter the device login password. Secondly, select group setting. Thirdly, download new configuring setting. Fourthly, cancel to return back or exit.

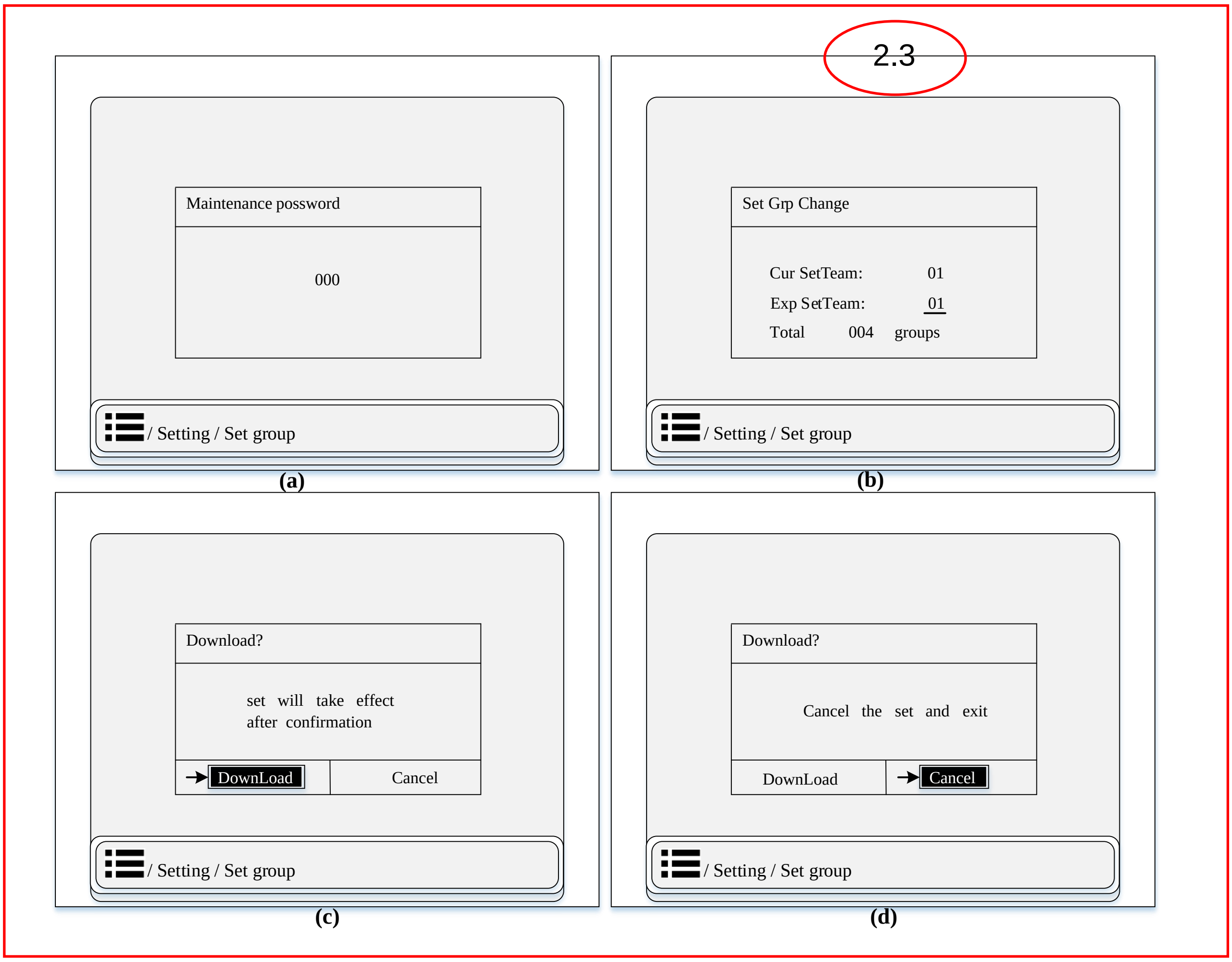



**Figure 7.3.22 Procedure Diagram of Group Setting Change**

## 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 7.3.23.

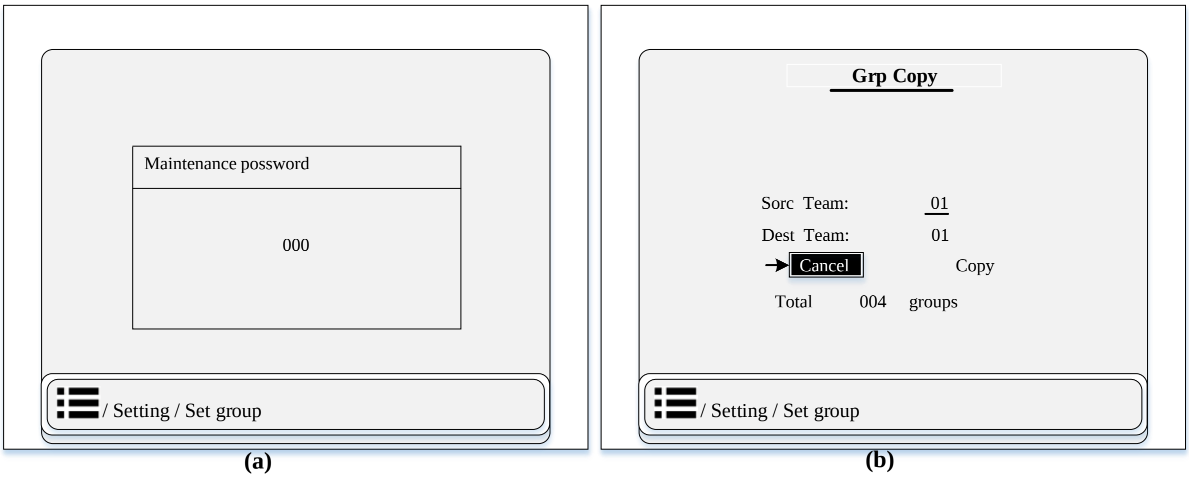



**Figure 7.3.23 Procedure Diagram of Group Setting Copy**

### 7.3.6.2 Prot Settings

In this section user can change the different kind of information like public, measurement and protection operation function settings etc. This section contains 01 to 11 pages and 42 parts of relay settings. User can access this function through the following path: “Setting > Prot Settings”. The detail of protection setting is listed in above table 7.3.3 and below figure 7.3.24:

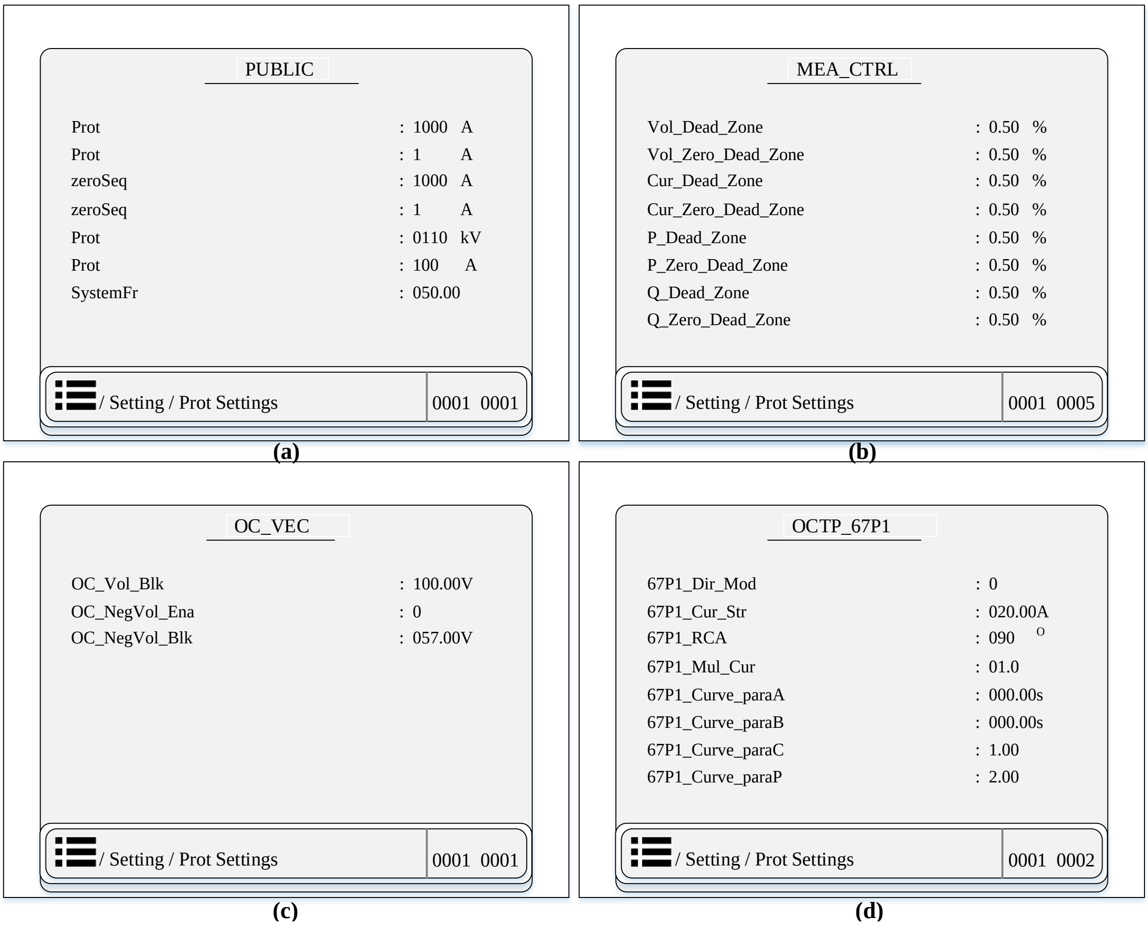



**Figure 7.3.24 Diagram of Protection Setting**

## 7.3.7 Configuration Information

This section divided into two sub-function like time and authorization. In this part 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 post) can also be modified. The diagram of configuration information is shown in below figure 7.3.25.

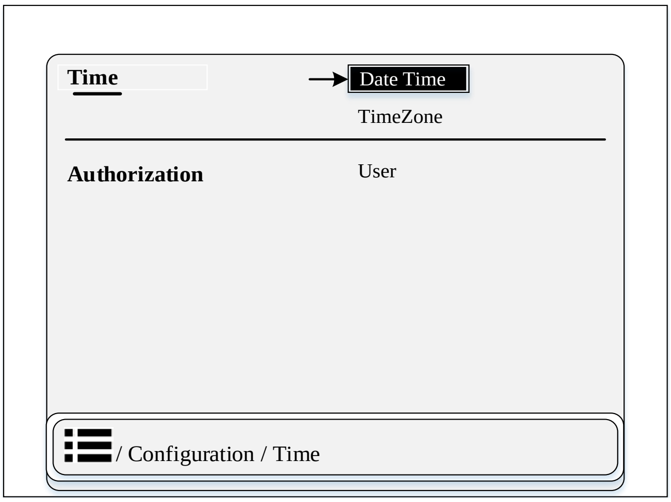



**Figure 7.3.25 Overview Display of Configuration Information Sub-functions**

### 7.3.7.1 Time

This part is divided into two sub-section date & time and time zone see figure 7.3.25. User can access this function through the following path: “Configuration > Time”.

#### 1- Date and time

In this section user can easily set date and time according to practical demand. See figure 7.3.26 (a):

#### 2- Time zone

In this section user can easily set time zone according to their region. See figure 7.3.26 (b):

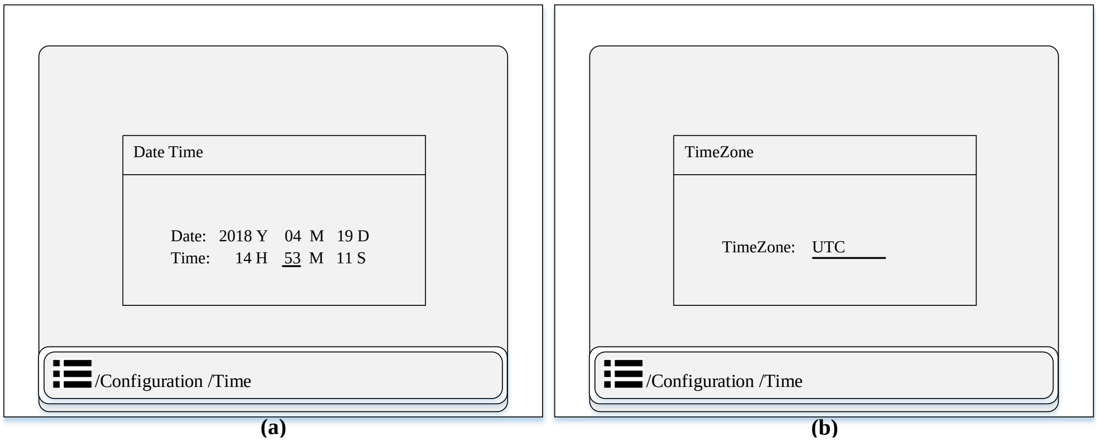



**Figure 7.3.26 Diagram of (a) Date & Time Setting (b) Time Zone Setting**

### 7.3.7.2 Authorization

This part is divided into one sub-function. see figure 7.3.24. User can access this function through the following path: “Configuration > 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 7.3.27:

**Table 7-8 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.<br>***Note!***<br>Non 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.<br>***Note!***<br>In this user login section, user cannot create an account configuration of the configuration device setting.<br>1） The engineering account can only view and modify its own password.<br>2） This account automatically withdraws or logoff after 30 minutes without operation. |
| Oper_1 & Oper_2 | The operator user account, grnerally it can only view the configuration of the device, the logical picture, wiring diagram and the logical device component. In this section user can’t create and 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. |

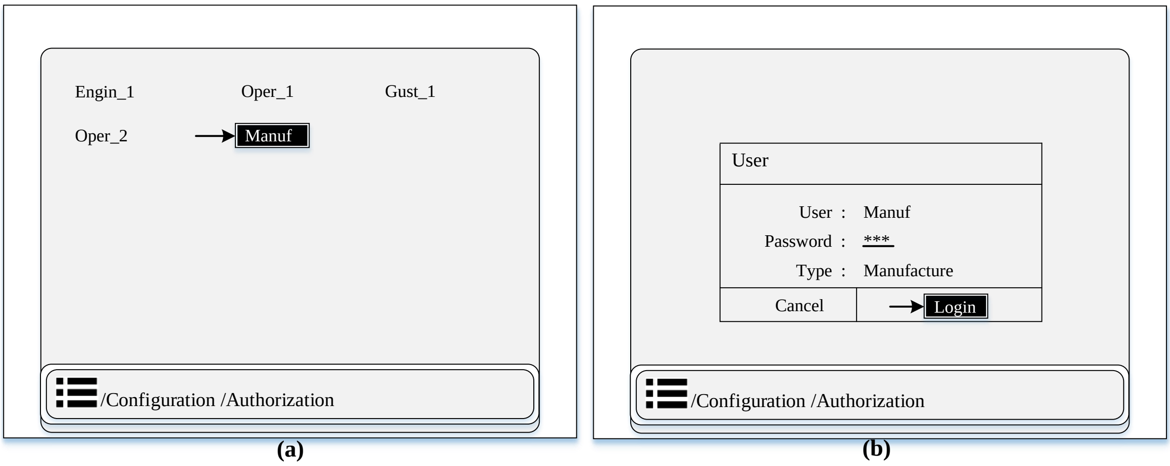



**Figure 7.3.27 Diagram of Authorization User (a) Operator Selection List (b) Login or Cancel**

## 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, signal test, operation test, warning test, block test, measurement test and mandatory wave etc. The overview display diagram of test information is shown in below figure 7.3.28:

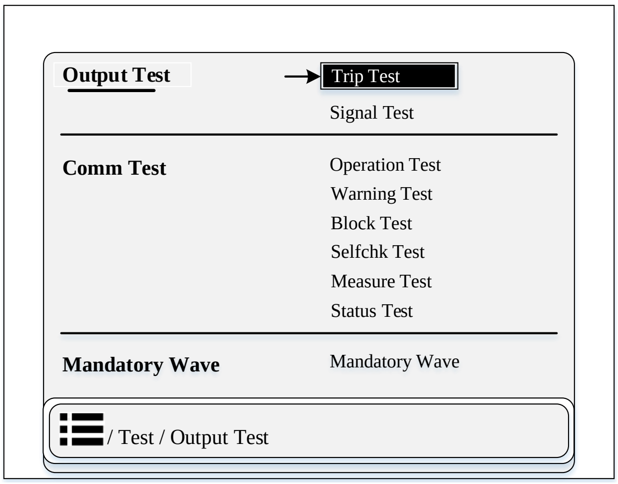



**Figure 7.3.28 Overview Display of Test Information Sub-functions**

### 7.3.8.1 Output Test

Output test is divided into two sub-test like tripping test and signal test. See figure 7.3.27. 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 7.3.29 (a):

**2- Signal Test**

In this section user can simulate all kind of signal test like operation signal, alarm signal and signal reset. see below figure 7.3.29 (b):

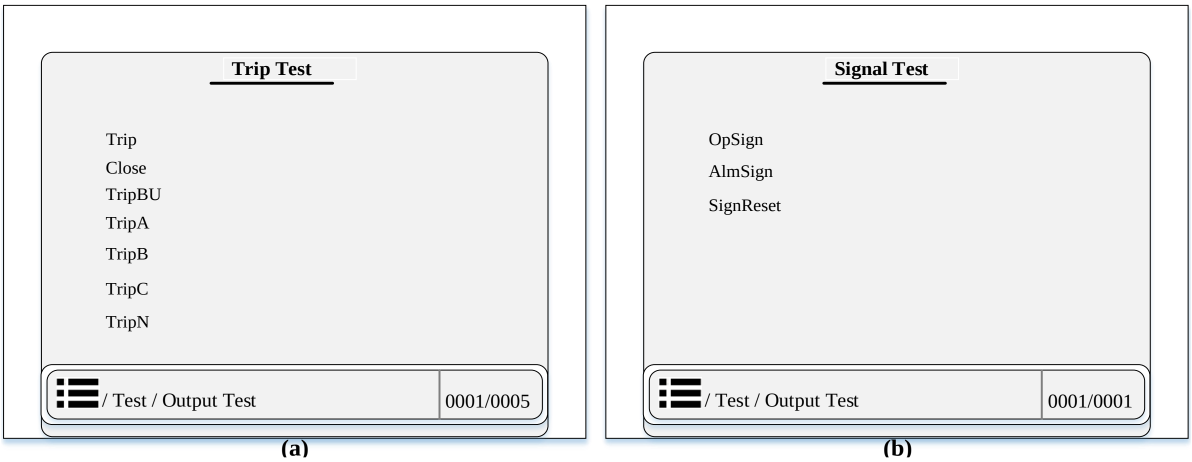



**Figure 7.3.29 Overview Diagram of (a) Trip Test (b) Signal Test**

### 7.3.8.2 Comm Test

Common test is divided into six sub-test like operation test, warning test, block test, SelfChk test, measure 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 7.3.30.

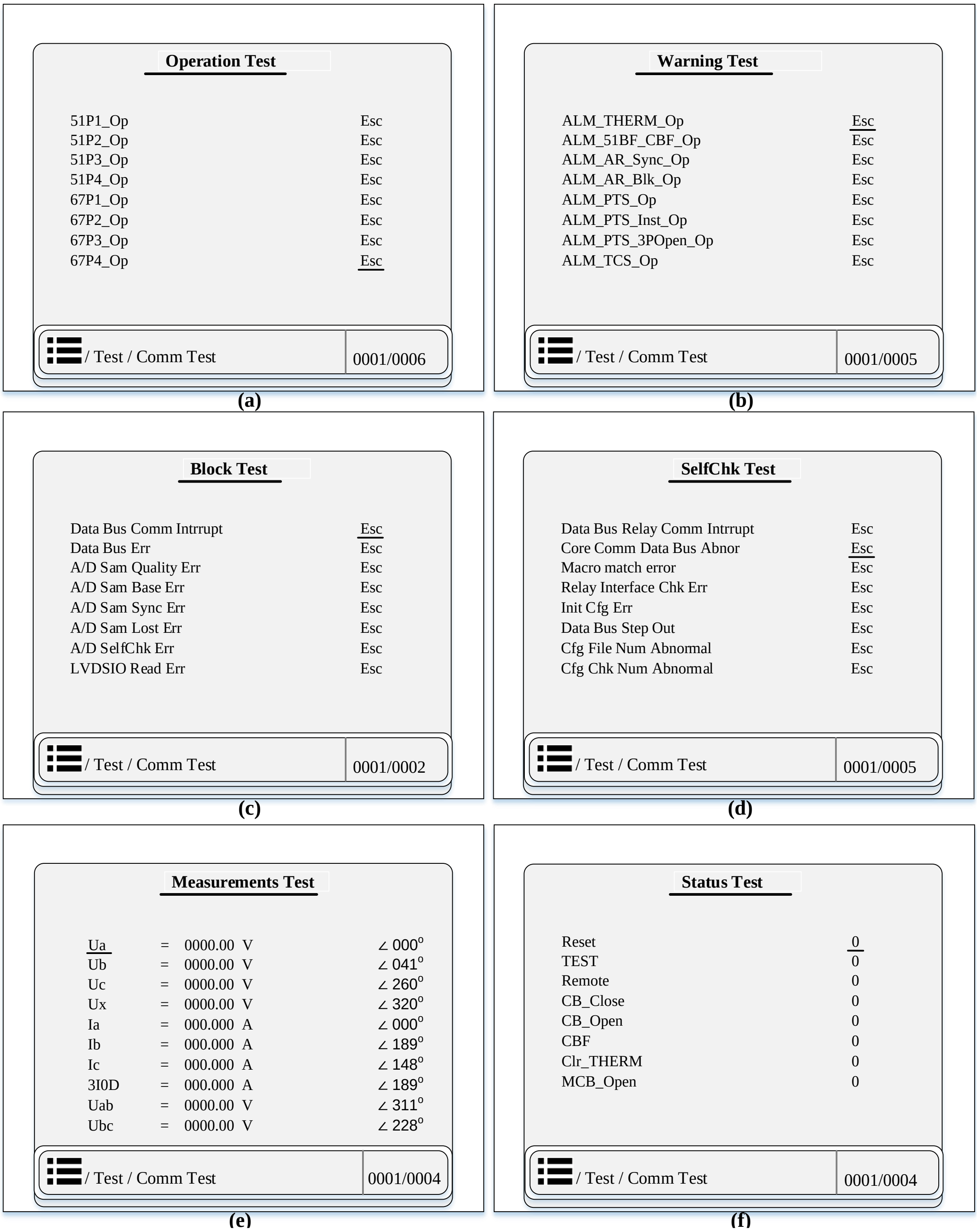



**Figure 7.3.30 LCD Display Diagram of (a) Operation Test (b) Warning Test (c) Block Test (d) SelfChk Test (e) Measurement Test (f) Status Test**

## 1- Operation Test

In this section user can simulate the peotection operation event like 51P, 51G and 67P operation function etc. see above figure 7.3.30 (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 7.3.30 (b):

**3- Block Test**

In this section user can simulate the tripping block event like data bus common interrupt blocking function, data bus Err blocking function, A/D Sam quality Err, A/D SelfChk Err, LVDSIO Read Err, parameter CRC Chk Err and core common data bus abnormal blocking function test etc. see above figure 7.3.30 (c):

**4- SelfChk Test**

In this section user can simulate the SlefChk event like data bus common interrupt SelfChk function, core common data bus abnormal SelfChk function test, relay interface Chk err, initial Cfg err and Cfg (configuration) file number abnormal SelfChk test etc. see above figure 7.3.30 (d):

**5- Measurement Test**

In this section user can simulate the measurement values like voltage and current of phase A, B & C, zero sequence voltage and current, frequency and angle etc. see above figure 7.3.30 (e):

**6- 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 7.3.30 (f):

#### 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 7.3.20 (fault wave):

### 7.3.9 Clear Information

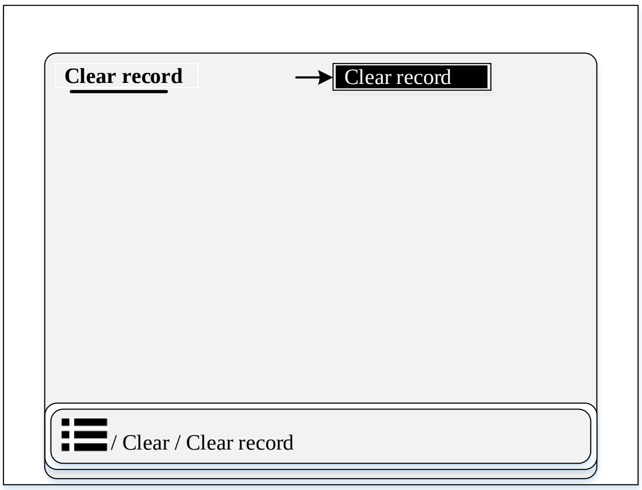



**Figure 7.3.31 Overview Display of Clear Information Sub-functions**

#### 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 7.3.32:

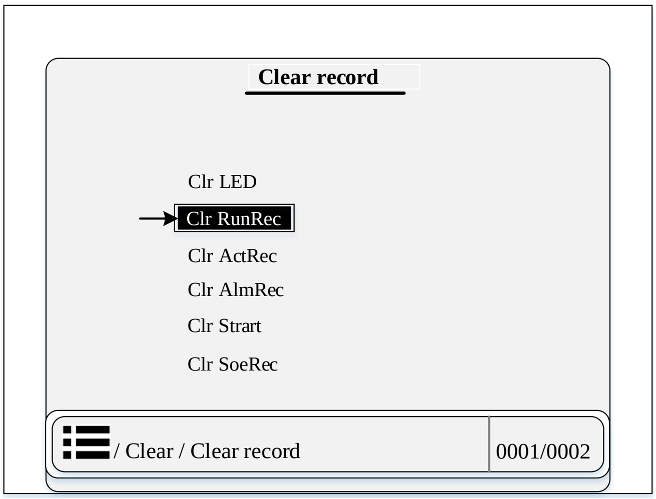



**Figure 7.3.32 Diagram of Clear Record Display**

## 7.3.10 Language Information

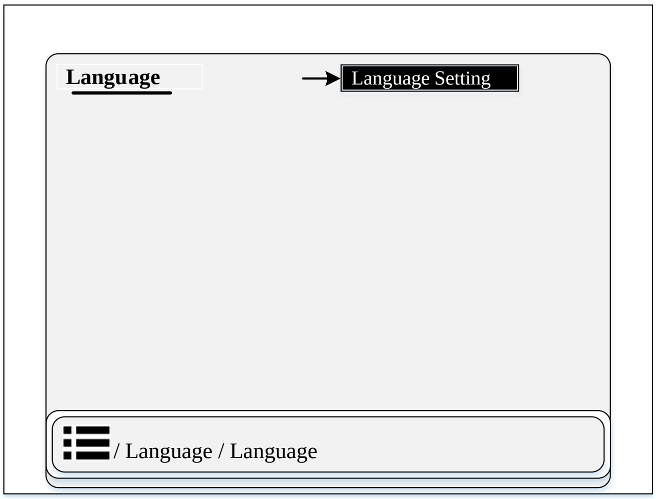



**Figure 7.3.33 Overview Display of Language Information Sub-functions**

### 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 7.3.34:

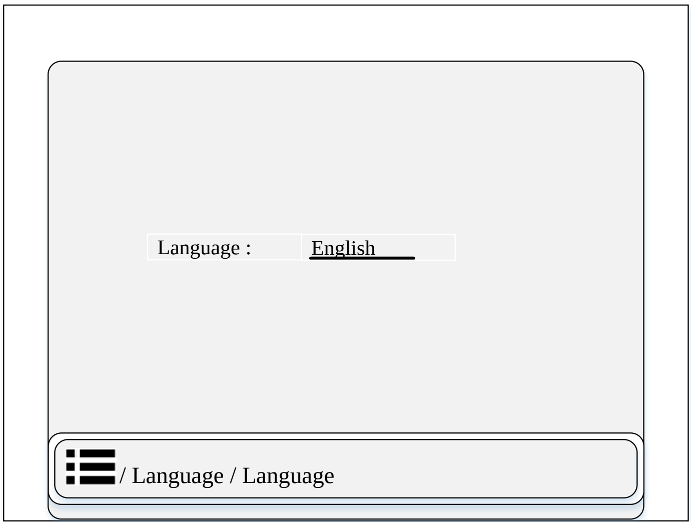



**Figure 7.3.34 LCD Display diagram of Language Setting**

# 8 Configurable Function

2.2

## 8.1 General Description

The IED is equipped with flexible and powerful configuration funtions, including the system configuration, the protection function configuration, the binary input configuration, the binary output configuration and the LED indicator configuration through the auxiliary software, which makes this IED meet various practical requirements.

## 8.2 Introduction of PRS IED StudioSoftware

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 off-line mode supports the off-line setting configuration, including protection logic programming, the binary input configuration, the binary output configuration and etc.

# 9 Communication Protocol

## 9.1 Overview

This chapter introduces the data communication and the corresponding hardware of the IEDs. The IED support a wide range of protocols via communication interface (RS-485 or Ethernet port).The protocols are of international standard for communication in substations andit can be selected by modifying the communicationparameters.

Local communication with the IED via a computer is achievable throught 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 protocol 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 in the menu.

#### 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 bellow.

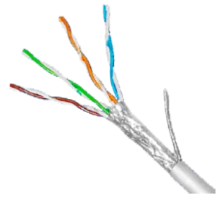


**Figure 9.2.1 Ethernet communication cable**

#### 9.2.1.2 Ethernet Communication protocol

Ethernet communication protocols are supported by the device including: IEC60870-5-103, PRP, RSTP, DNP3.0, IEC61850 etc. For more details about these communication protocols, see the correlative standards.

## 9.3 Network Topoloty

### 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 exchanger and will play a role of master station, so the every equipment which has been connected to the exchanger will play a role of slave unit.

### 9.3.2 PRP Topology

This network topoloty is supported by the device.

### 9.3.3 RSTP Topology

This network topoloty 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 supports 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 9-1 Mapping of ACSI to MMS service**

| ACSI | | MMS |
|---|---|---|
| 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) |
| 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 | Write (write service) |

| | | |
|---|---|---|
| | value) | |
| 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) |
| 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 terminal. GOOSE is the 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, 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, and the based function VEBI and common settings; some data objects represent the meaning of the whole logic device, such as Beh, it 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 No., if it has an agency 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

2.1

**Table 9-2 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 “deadband” 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 “deadband” value. If the result is greater than the “deadband” 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 “deadband” 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 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 weakelectric 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 throughsourcing 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 currenttransformer input in turn, see the following table, checking the magnitude using a multimeter/test set readout. The corresponding reading can then be checked in the relays menu.

**Table 10.6-1 Current channel checkout**

| Group No. | Item | Input Value | Input Angle | Display Value | Display Angle |
|---|---|---|---|---|---|
| Three-phase current 1 | Ia | | | | |

| Group No. | Item | Input Value | Input Angle | Display Value | Display Angle |
|---|---|---|---|---|---|
| | Ib | | | | |
| | Ic | | | | |
| Three-phase current 2 | Ia | | | | |
| | Ib | | | | |
| | Ic | | | | |
| Three-phase current … | Ia | | | | |
| | Ib | | | | |
| | Ic | | | | |
| Residual current 1 | 3I0 | | | | |
| Residual current 2 | 3I0 | | | | |
| Residual current … | 3I0 | | | | |

### 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 throughsourcing 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 0.02UnHowever 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 voltagetransformer input in turn, see the following table, checking the magnitude using a multimeter/test set readout. The corresponding reading can then be checked in the relays menu.

**Table 10.6-2 Voltage channel checkout**

| Group No. | Item | Input Value | Input Angle | Display Value | Display Angle |
|---|---|---|---|---|---|
| Three-phase voltage 1 | Ua | | | | |
| | Ub | | | | |
| | Uc | | | | |
| Three-phase voltage 2 | Ua | | | | |
| | Ub | | | | |
| | Uc | | | | |
| Three-phase voltage … | Ua | | | | |
| | Ub | | | | |
| | Uc | | | | |
| Residual voltage 1 | 3U0 | | | | |
| Residual voltage 2 | 3U0 | | | | |
| Residual voltage … | 3U0 | | | | |

### 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.

**Table 10.6-3 Binary inputs checkout**

| Teminal N0. | Signal Name | States on LCD | Correct? |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

### 10.6.7 Test the Binary Onputs

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 chapterissuitfor 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 cubicledrawingreading.Commissioning and maintenance personnel must have extensive experience in operatingprotective 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!Onlyinsert 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 switchgear 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 phenomenonsthat equipment in the box may be damaged. If found abnormal, it is recommended to take pictures as a record, confirm and contact with the manufacturerat 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. Manufacturerdocuments 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.

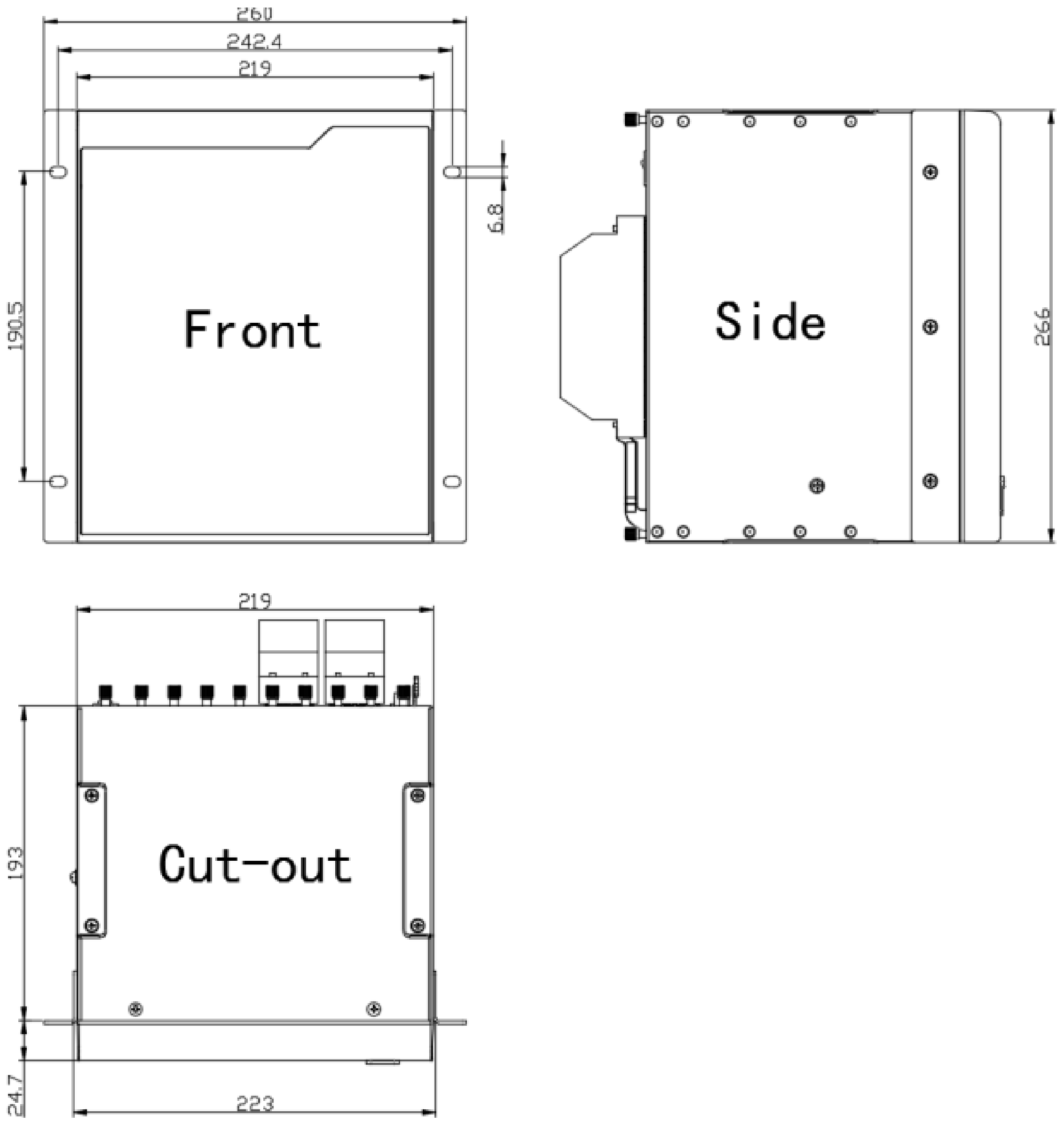
## 11.6 Mechanical Installation

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 inthe cubicle(cabinet),and the connecting screws should be tightened.The grounding wire of each device shouldbeconnected 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 devicefeatures a 6Uheight, 1/1 19 "or 1/2 19" widthchassis, integral paneland pluggable functional modules with lock. The device is designedconformingto 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
193
Cut-out
24.7
223

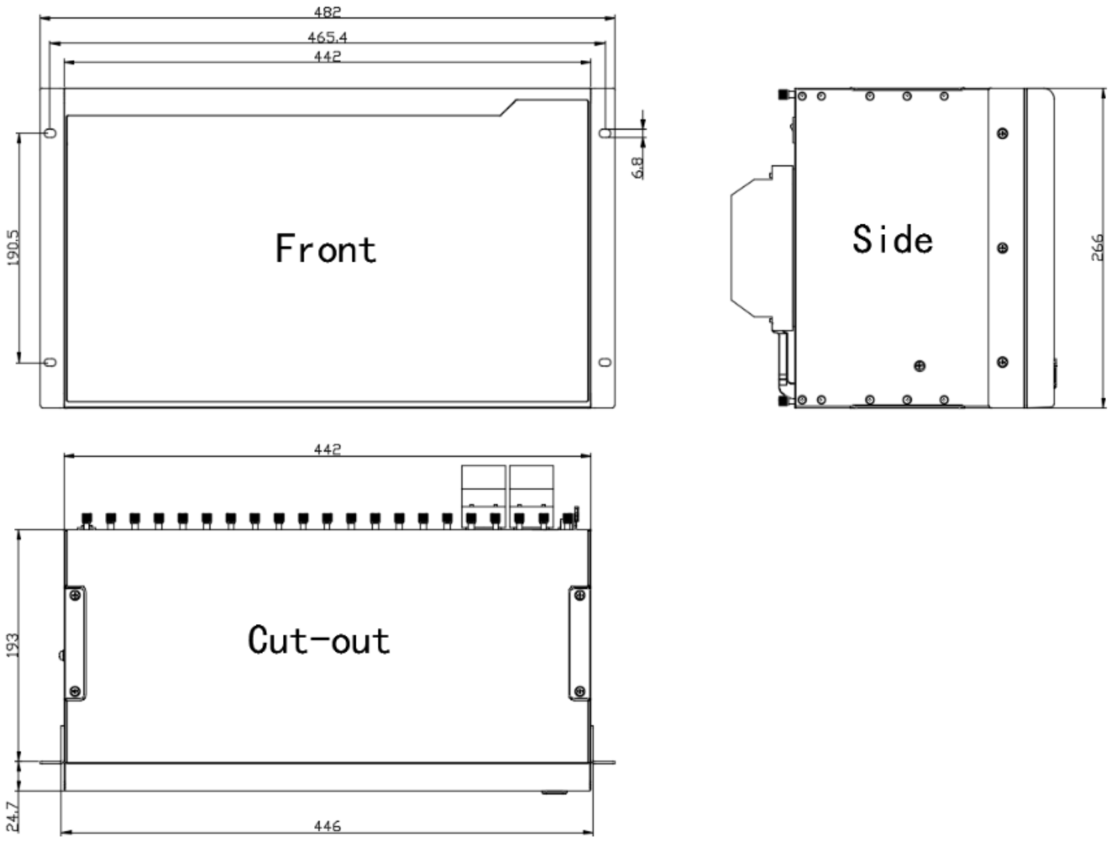



**Figure 11.6-1 Dimensions of this relay and the cut-out in the cubicle (unit: mm)**

## 11.7 Electrical Installation and Wiring

### 11.7.1 TACircuit Connection

According to the wiring diagram of the device, connect the terminalblockofrearAC modulewith the CT loop usingmultiple wires, of whichthe cross-sectional area should be 2.5 ~ 4.0mm$^2$.

### 11.7.2 Power Supply, VT, BI and BO, Signal Wiring

According to the wiring diagram of the device, connect the AC, Phoenix terminal of module and the terminal blockin the cubiclesidewith multiple wires.

DC voltage power supply wiring power +, power - should be distinguish indifferent colors, forexample 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 wiresconnected to two points, there should be no jointin the middle, and the wirecoreshould 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 wiringtheACterminalofmodule, current and voltage wiresmust adopt 12mmsizecablelug, to avoid loosecontact.Strictly prohibit electric screwdriver, so as to avoid terminals damage.

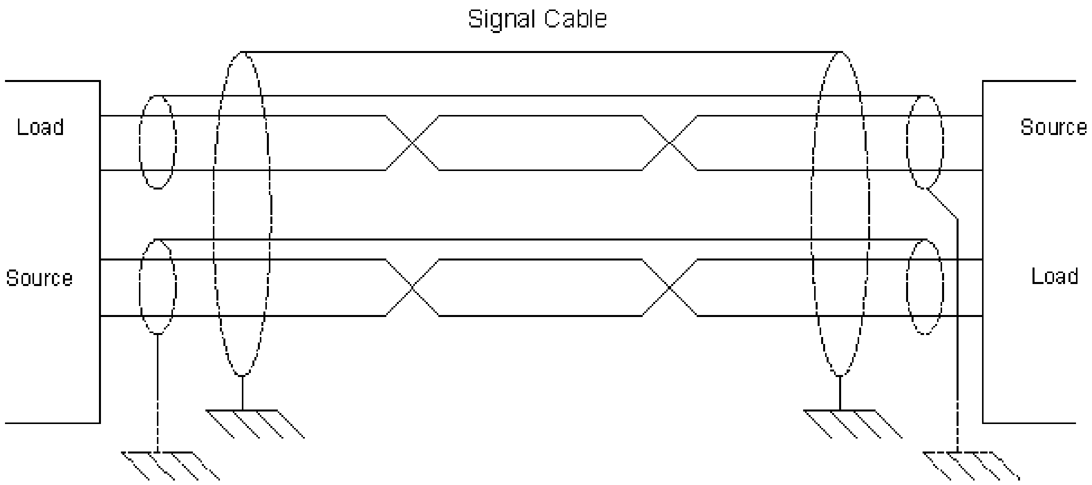
Attention! Never allow the current transformer (CT) secondary circuit connected to this equipment to be opened while the primary system is live. Opening the CT circuit will produce a dangerously high voltage.

### 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 cubicleshouldreliably 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 cubicleand the grounding point near the measurement source. Ensure a single shield connection a suitable short cross-sectional wire (maximum 10CM) for ground connection.




### 11.7.5 Install the optical cable

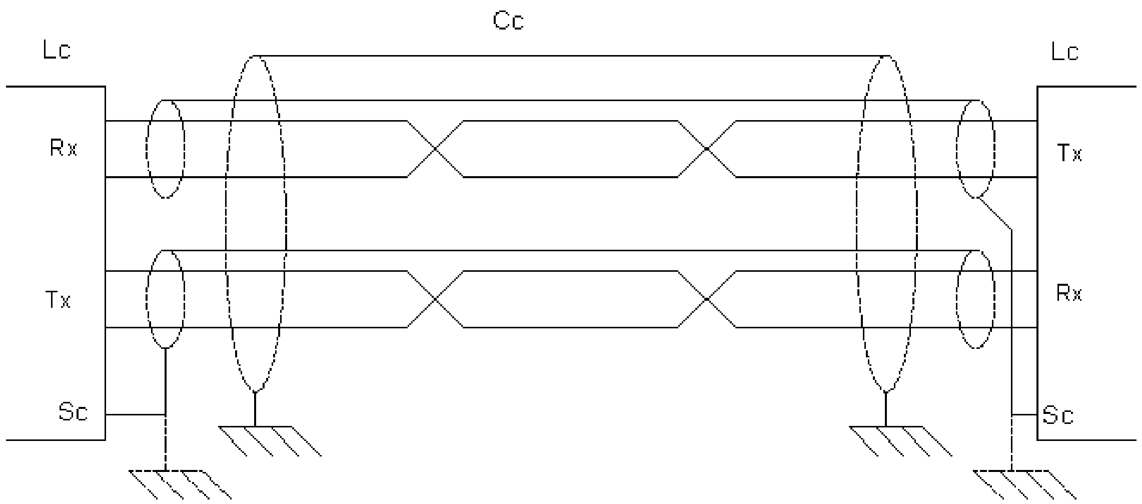
Care should be taken to handle the cable without substantial bending. The minimum curvature radius of the plastic optical fiber is 15 cm and the glass optical fiber is 25 cm. To use the cable clamp, a loose buffer sleeve should be used.

When connecting or removing the optical fiber,pleasetake 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 toinstall 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.




Cc: communication cable

Lc: lineconnector

Rx: receive signal input

Tx: transmitsignaloutput

Sc: shielded (grounding) connection

## 11.8 Installationcheck

### 11.8.1 Checktheinstallation

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 thedevice label. After the device is powered on, the software version can also be checkedthrough the LCD interface.

### 11.8.3 Devicestart

ifconfirm that the wiring is correct duringthe installation check, you can supplydevicewith power andstartit.

Configuration file needs to read during device startup process.Itneeds a certain period of timefor the startup process.The startup time is relatedtothe size ofconfiguration 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 modulesto 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 theremoved 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 switchgear taking place or of relay device not runningcorrectly. 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 possibilityofelectricalshock, allcurrent 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 thedeviceisfixedto 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 Manual Version History

In the current version of the instruction manual, several descriptions on existing features have been modified.

**Table 14-1Manual 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..<br>Add the binary input hardware demo diagrams in the binary input tables.<br>Update the description of IEC61850 dual-MMS Ethernet. |
| 1.01 | 1.02 | 1.02 | 2016-01-24 | Add parameters of fault location function.<br>Output TEMP_RL is added Internal improvements.<br>Update the configurable signals. |
| 1.02 | 1.03 | 1.10 | 2016-08-16 | Update the communication description.<br>Update the mechanical specifications.<br>Update the main CPU module picture.<br>Update the setting list. |
| 1.03 | 2.01 | 1.20 | 2017-12-16 | Update all the protection functions.<br>Add the “4.2 Supervision Alarm and Block” chapter<br>Increase the amount of the terminal of BI module.<br>Update the logic diagram of the Three-phase thermal overload protection.<br>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.<br>Update the IDMT curves. |
| 2.03 | 2.03 | 2.03 | 2018-08-21 | Modify thedrop-off to pickup ratio to 97%<br>Add GPS time synchronization IEEE 1588 |
| 2.03 | 2.03 | 2.03 | 2018-09-21 | Add chapter 9.6 |