686

AIM-D100-T series DC Insulation Monitor

User Manual V1.0

Acrel co.,Ltd

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The contents of this description will be updated and amended constantly, and it is inevitable that there will be a slight discrepancy between the physical product and the description in the product function upgrading. Please refer to the physical product purchased and obtain the latest version of the description through www.acrel-electric.com or sales channels.

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Modified Records

No.	Date	Version	Description
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AIM-D100-T series DC Insulation Monitor

1 Introduction



With the development of industry, many electrical equipment and plant equipment are powered by DC systems, which have ungrounded positive and negative terminals. For ungrounded (IT) distribution system, insulation resistance should be monitored to ensure the safe operation of the power supply system.

AIM-D100-T series DC insulation monitor can be applied in 10~1000V DC system for on-line monitoring of DC ungrounded system positive and negative pole to ground insulation resistance, and send out warning or alarm signal when insulation resistance is lower than the set value.

The product is based on the principle of unbalanced bridge, which avoids the problem that balanced bridge can not detect the insulation resistance when there are ground faults at both positive and negative poles.

The product can be applied to DC systems such as DC panels of power plants and substations, electric vehicle charging devices, UPS power supply systems, photovoltaic DC systems, energy storage systems and other DC power grids.

2 Model Description

AIM – D 100 – T H

- H: Extra Features: H - 100~1000V; L - 10~100V
- T: Model Code: T - General Model
- 100: Design Serial Number: 100 - Initial Serial Number
- D: Function Code: D - DC Monitoring
- AIM: Product Name: AIM - Acrel Insulation Monitor

3 Functional Characteristics

- Resistance monitoring. The product can monitor the insulation resistance of the positive and negative poles of the DC system to the ground. When the insulation resistance is lower than the set warning and alarm values, it can send out warning and alarm signals.
- Voltage monitoring. The product can monitor the voltage between the positive and negative poles of the DC system and the voltage between the positive and negative poles with respect to ground.
- Over- and under-voltage alarm function. The product can monitor the DC system voltage fluctuation, when there is over-voltage or under-voltage, it can issue an alarm signal in time.

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- Early warning alarm function. The product has two groups of independently adjustable set values, you can set the warning value and alarm value.
- LED indication function. The product panel has operation, communication and fault, over-voltage, under-voltage LED indicators, which can display the product status.
- LCD display function. The product adopts 128*32 dot matrix liquid crystal display, which can display parameter information.
- Relay output function. The product has 3-channel relay outputs, which can be selected as normally open or normally closed mode.
- Event record function. The product can record the time of the alarm and the type of fault, which is convenient for the staff to troubleshoot.
- Communication network function. The product has 1 RS485 interface and adopts Modbus-RTU protocol, which can be used for data interaction.
- Rail mounting. The product adopts the standard 35mm rail mounting.
- Plug-in terminals. The product adopts plug-in terminal wiring, which is convenient for wiring and installation.

4 Technical Parameters

Technical Parameter		Technical Specifications
Auxiliary power		DC 9~36V
Maximum power consumption		≤6W
Voltage monitor	Voltage range	AIM-D100-TH: DC 100~1000V； AIM-D100-TL: DC 10~100V
	Accuracy	0.5
	Overvoltage threshold	≥110% Rated Voltage
	Undervoltage threshold	≤90% Rated Voltage
Insulation monitoring	Insulation resistance range	1kΩ~10MΩ
	Warning and alarm range	10kΩ~10MΩ
	Accuracy	1~10kΩ: ±1k; 10k~500k: ≤3%
	System leakage capacitance	≤5μF
	Monitoring method	Cycle trigger: 5~500s delay can be set; Communication trigger: read on demand
	Insulation monitoring speed	500ms/cycle; 1000ms/cycle
	Internal DC impedance	＜1MΩ
Alarm method		LCD, LED indicator, relay output
Alarm output		3 relay outputs, N/O or N/C can be set
Contact capacity		5A 250V AC;

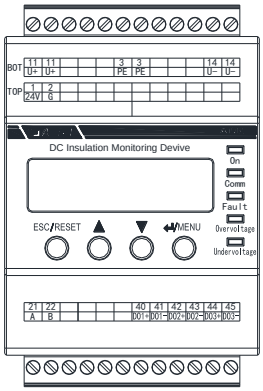
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		5A 30V DC
Fault Record		20 fault record
Communication		RS485 interface, Modbus-RTU protocol
Installation		DIN-rail installation
Protection level		IP30
Environment	Operating temperature	-40~+75℃
	Storage temperature	-40~+125℃
	Relative humidity	<95%, without condensation
	Altitude	<2000m

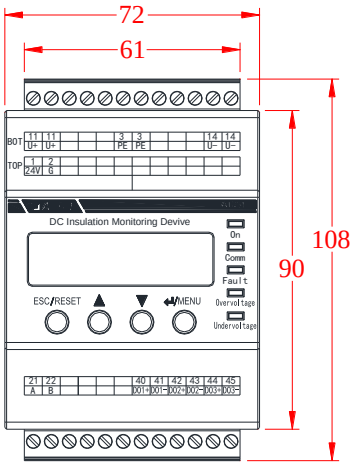
5 Installation and Connection

5.1 Shape and Size

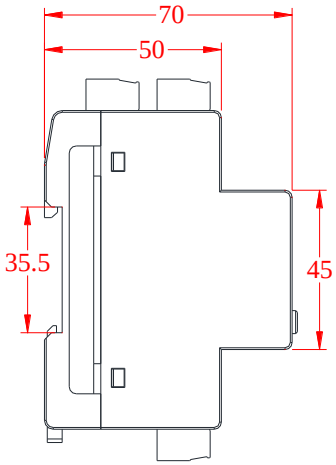
AIM-D100-T series DC Insulation Monitor adopts plastic casing, and its external dimensions are shown in the figure below. (Unit: mm)



Appearance



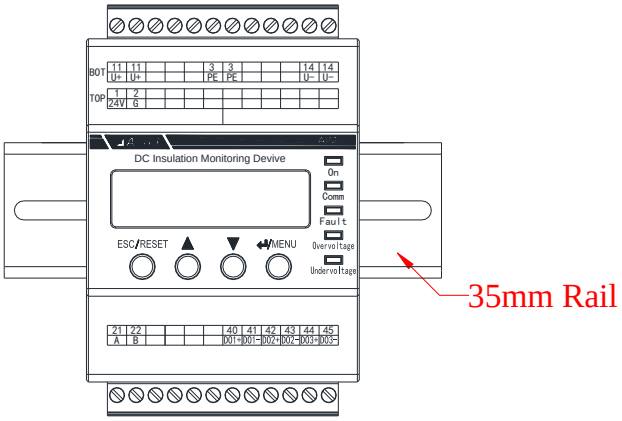
Front view



Side view

5.2 Installation

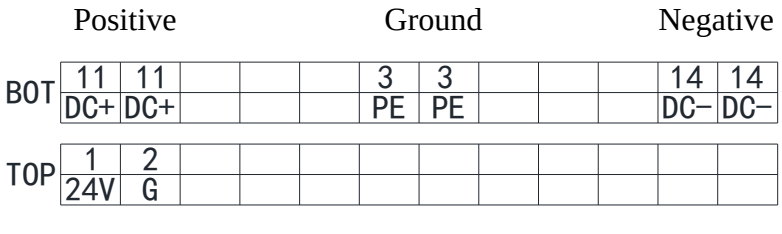
AIM-D100-T series insulation monitor adopts rail mounting method, the installation can be completed by mounting the meter on the standard 35mm rail and fixing it with snap fasteners. As shown in the figure below:



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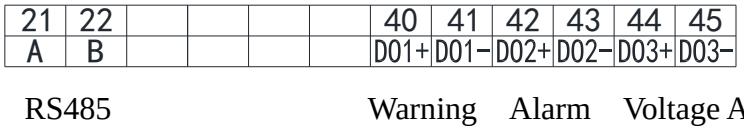
5.3 Wiring

AIM-D100-T series DC insulation monitor products have terminal blocks at the top and bottom, and the top terminal block is shown in the figure below:



The top of the instrument is divided into two rows of terminals: TOP row of terminals for the auxiliary power supply of the instrument, which needs to be connected to the DC 24V power supply, terminal 1 access to the positive pole of the power supply and terminal 2 access to the negative pole of the power supply; BOT row of terminals for access to the system wiring, terminal 11 access to the positive pole of the DC system, terminal 14 access to the negative pole of the DC system, and terminal 3 access to the PE grounding row on the site.

The lower wiring terminals are shown below:



The lower terminal 21, 22 for RS485 communication terminal, 21 access A, 22 access B, they can not be reversed. terminal 40 ~ 45 are for the relay output terminals, 40, 41 for DO1 output, indicating the warning, 42, 43 DO2 output, indicating the alarm, 44, 45 DO3 output, indicating the over-under-voltage alarm. The relay output can be set in normally open or normally closed mode, and can be connected to an external buzzer or audible/visual alarm, the relay is a passive output and requires an external power supply.

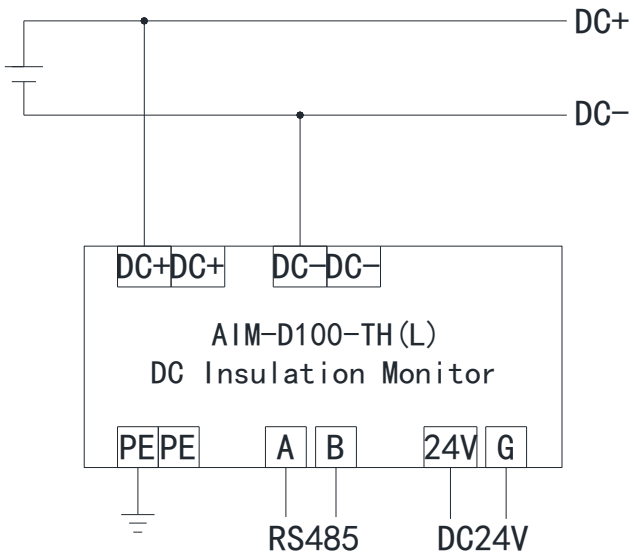
Wiring specification:

Auxiliary power supply, functional grounding, DC system positive and negative wiring, relay output wiring, you can choose 1.5mm2 multi-core copper wire.RS485 communication wiring can choose 0.75~1.5mm2 shielded twisted pair wire.

5.4 Wiring Diagram

AIM-D100-T Series DC Insulation Monitor is wired as shown in the following schematic when monitoring the DC system:

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5.5 Attention

1) When designing and installing insulation monitors, it should be noted that only one insulation monitor can be installed in a system. If multiple insulation monitors are installed in different locations of the same system, a control strategy should be used for insulation resistance monitoring.

2) The insulation monitor can be installed in the distribution box, and the installation location is free of dripping water, corrosive chemical gases, and sedimentation substances.

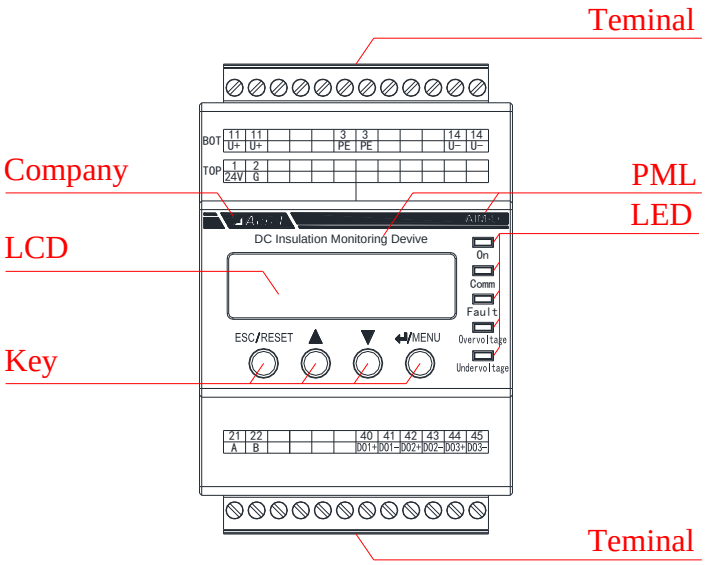
3) When wiring the insulation monitor, you should strictly follow the wiring diagram. It is best to use a pin socket connector for crimping, then insert the instrument terminal and tighten the screws to avoid abnormal operation of the instrument due to poor contact.

4) The insulation monitor should be reliably connected to the DC system being monitored to ensure the effectiveness of insulation monitoring.

5) Non-professionals are strictly prohibited from opening the product casing without authorization to avoid affecting product functions.

6 Programming and Usage

6.1 Panel Description



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6.2 LED Indicator Instructions

Indicator	Function Description
On	When the instrument is running normally, the indicator light flashes with a flashing frequency of approximately once per second.
Comm	When there is no data communication, the indicator light is off. When there is data communication, the indicator light flashes.
Fault	The indicator light flashes when an insulation fault occurs and is always on when an insulation fault occurs.
Overvoltage	Indicator light is always on when the system voltage exceeds the nominal voltage threshold
Undervoltage	Indicator lights up when the system voltage is below the nominal voltage threshold

6.3 Keys Operation

Keys Name	Keys Function
ESC / RESET	In non-programming mode, a short press is used to return to the main screen, In programming mode, a short press is used to return to the previous menu.
▲	In non-programming mode, a short press is used to switch to the previous screen, In programming mode, it is used for increasing or decreasing the value and selecting the setting item.
▼	In non-programming mode, a short press is used to switch to the next screen, In programming mode, it is used for increasing or decreasing the value and selecting the setting item.
↵ /MENU	In non-programming mode, short press to enter programming mode. In programming mode, it is used to confirm the operation.

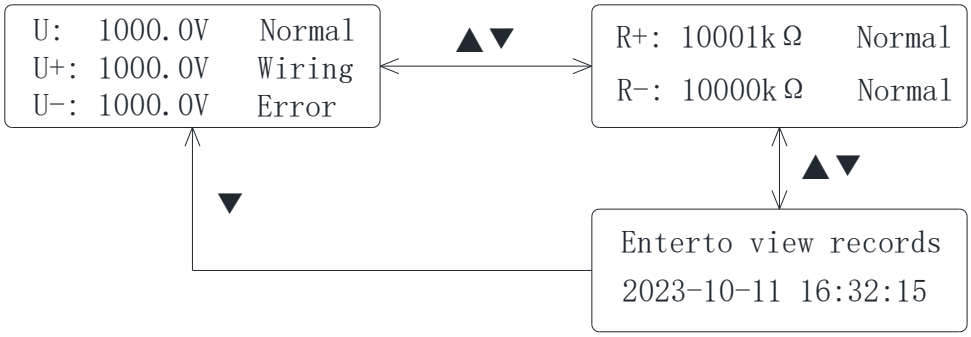
6.4 Description of key operation

6.4.1 Key operation under the main interface

1) Enter the running mode.

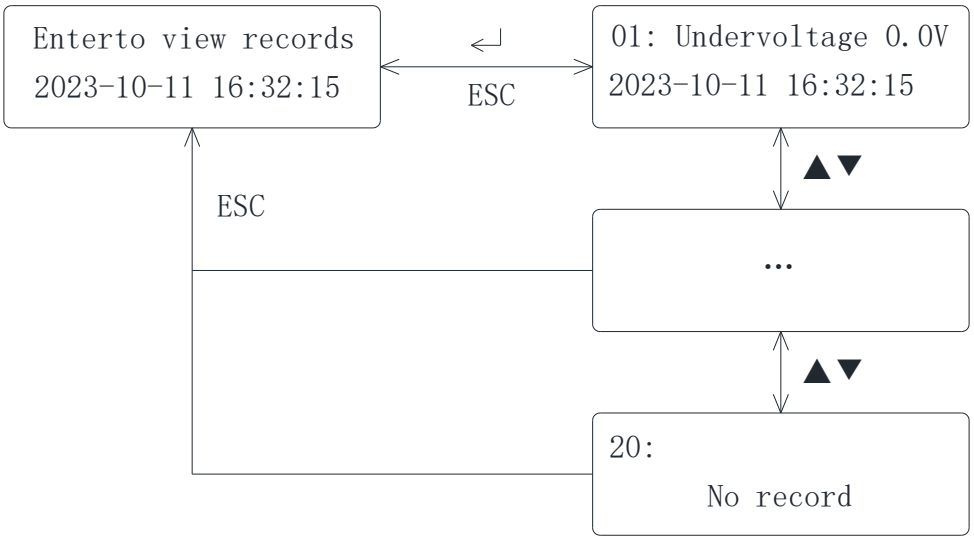
After power on, the software initialization and self-test are finished, the default mode entered is the running mode. The main interface displays system voltage, positive to ground voltage and negative to ground voltage. Press "▼" button, you can check the system insulation resistance, positive pole to ground insulation resistance, negative pole to ground insulation resistance, press "▼" button, you can switch to the fault record interface. Press "▼" again to return to system voltage interface.

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2) Viewing Alarm Records

In the main interface, press "▼" twice to switch to the fault record interface, and press "↵/MENU" to view specific fault records. Press "▲" and "▼" buttons to switch to page flip, query up to 20 fault records in turn, including fault type, fault value and fault time. The first fault record is the latest record, and the 20th fault record is the earliest fault record. Press "ESC/RESET" button to return to the fault record interface.



3) Entering Programming Mode

In the main interface, press "↵/MENU" key to enter the password input page of programming mode. Press "▲" and "▼" to enter the correct password, then press "↵/MENU" to enter the programming mode. The default initial password of the unit is 0001.

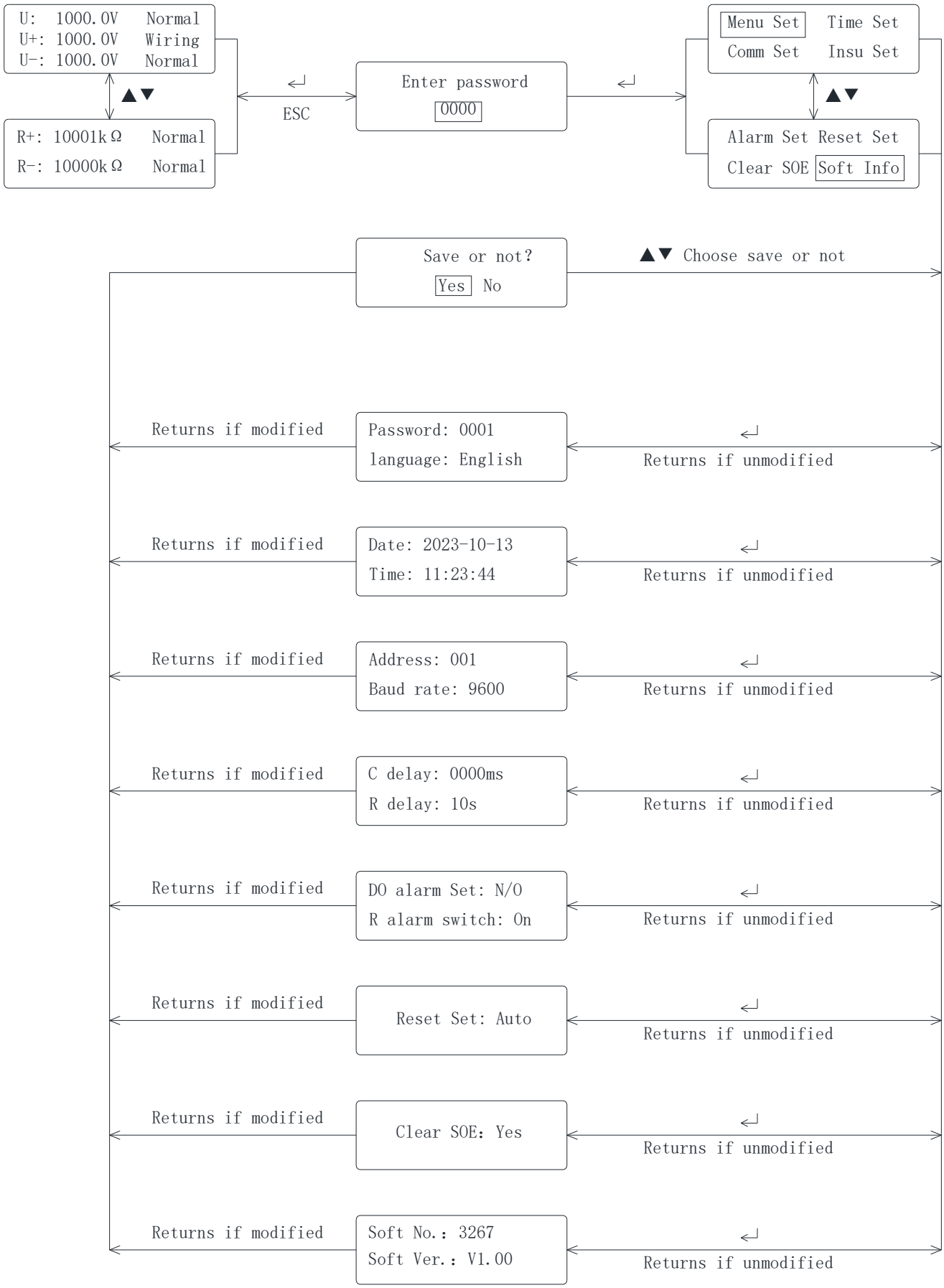
4) Exit Programming Mode

In programming mode, press the "ESC/RESET" key and confirm whether the set parameters are saved before exiting, then the device can exit the programming mode and enter the operation mode.

6.4.2 Related parameter settings

The details are shown in the following figure:

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Notes: Default capacitance delay is 0000ms, monitor time is 1000ms, R delay is 5s, R+, R- warning threshold is 100kΩ, R+, R- alarm threshold is 50kΩ, Voltage alarm switch is off by default, and open after setting the rated voltage; overvoltage threshold 120%, undervoltage threshold 80%.

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7 Communication Instruction

7.1 Communication Protocol

The RS485 interface of the instrument adopts the Modbus-RTU communication protocol. The protocol defines the address, function code, data, check code, etc. in detail, which is a necessary content to complete the data exchange between the host and the slave.

7.1.1 Transmission method

Information transmission is asynchronous and in bytes. The communication information transmitted between the host and the slave is in an 11-bit format, including 1 start bit, 8 data bits (the smallest significant bit is sent first), and no Parity bit, 1 stop bit (N-8-1).

7.1.2 Information frame format

Address Code	Function Code	Data Zone	CRC check code
1Byte	1 Byte	n Byte	2 Byte

Address code: The device address code is at the beginning of the data frame and consists of one byte (8-bit binary code), ranging from 0 to 255 in decimal. The device can set the address to 1 to 247. These bits identify the address of the user-specified end device that will receive data from the connected host. The address of each terminal device must be unique, and only the addressed terminal will respond to a query containing this address. When the terminal sends back a response, the slave address data in the response tells the host which terminal it is communicating with.

Function code: The function code indicates what function the addressed terminal performs.

Function Code	Definition	Explanation
03H/04H	Read data register	Get the current binary value of one or more registers
06H/	Preset single registers	Set binary values to single registers
10H	Preset multiple registers	Set binary values to a series of multiple registers

Data zone: The data area contains the data required by the terminal to perform specific functions or the data collected when the terminal responds to queries. The content of these data may be numerical values, reference addresses or setting values. For example: the function code tells the terminal to read a register, and the data zone needs to indicate which register to start from and how much data to read. The embedded address and data vary according to the type and content between slaves.。

CRC check code: The error check (CRC) field occupies two bytes and contains a 16-bit binary value. The CRC value is calculated by the transmitting device and then appended to the data frame. The receiving device recalculates the CRC value when receiving the data and then compares it with the value in the received CRC field. If the two values are not equal, it occurs. mistake.

7.2 Function Code Introduction

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7.2.1 Function code 03H or 04H: read register

This function allows users to obtain data and system parameters collected and recorded by the device. There is no limit to the number of data requested by the host at one time, but it cannot exceed the defined address range.

The following example reads a measurement value of 00 08H from the slave machine with address 01.

Host send		Sent information
Address code		01H
Function code		03H
Starting address	High byte	00H
	Low byte	08H
Register count	High byte	00H
	Low byte	01H
CRC check code	Low byte	05H
	High byte	C8H

Slave return		Returned information
Address code		01H
Function code		03H
Byte count		02H
Register data	High byte	00H
	Low byte	50H
CRC check code	Low byte	B8H
	High byte	78H

7.2.2 Function code 06 or 10H: write register

Function code 10H allows the user to change the contents of multiple registers. The time and date in the instrument can be written with this function code. The host can write up to multiple data at a time (not exceeding the length defined by the instrument itself).

The following example is to set the date and time of the slave machine with address 01 to Friday, December 01, 2009, 12:00.

Host send		Sent information
Address Code		01H
Function Code		10H
Starting address	High byte	00H
	Low byte	04H
Register count	High byte	00H
	Low byte	03H
Register count		06H
0004H Data to be written	High byte	09H
	Low byte	0CH
0005H Data to be written	High byte	01H
	Low byte	05H

Slave return		Returned information
Address Code		01H
Function code		10H
Starting address	High byte	00H
	Low byte	04H
Register count	High byte	00H
	Low byte	03H
CRC check code	Low byte	C1H
	High byte	C9H

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0006H Data to be written	High byte	0CH
	Low byte	00H
CRC check code	Low byte	A3H
	High byte	30H

Note: The above data is for reference only. Please refer to the address table for register definitions.

7.3 Register Address Table

No.	Address	Parameter	Read /Write	Value range	Data Types
0	00H	Password	R/W	0000~9999 (default 0001)	UINT16
1	01H	Address	R/W	1~247 (default 1)	UINT16
2	02H	Baud rate	R/W	0~3: 4800, 9600, 19200, 38400 (Unit: bps) (default 1)	UINT16
3	03H	Language	R/W	0: Chinese; 1: English (default 0)	UINT16
4	04H	LCD Contrast	R/W	10~60 (default 20)	UINT16
5	05H	LCD backlight time	R/W	0~600**s** 0 for constant light (default 60)	UINT16
6	06H	Year	R/W	0~99, year needs +2000	UINT16
7	07H	Mont	R/W	1~12	UINT16
8	08H	Day	R/W	1~31	UINT16
9	09H	Hour	R/W	0~23	UINT16
10	0AH	Minute	R/W	0~59	UINT16
11	0BH	Second	R/W	0~59	UINT16
12	0CH	Software number	R		UINT16
13	0DH	Software version	R		UINT16
14~31	0EH~1FH	Reserved	R		UINT16*18
32	20H	Fault type	R	bit15: 1 DC+ and DC- connected error; 0 is normal bit14~bit6: Reserved bit5: 1 negative pole insulation fault warning; 0 is normal bit4: 1 negative pole insulation fault alarm; 0 is normal bit3: 1 positive pole insulation fault warning; 0 is normal bit2: 1 positive pole insulation fault alarm; 0 is normal bit1: 1 undervoltage; 0 is normal bit0: 1 overvoltage; 0 is normal	UINT16

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				00 18 means 0000 0000 0001 1000	
33	21H	Positive pole insulation resistance	R	Unit: kΩ; Ratio is 1 For example, 10000, the resistance is 10000kΩ	UINT16
34	22H	Negative pole insulation resistance	R		UINT16
35	23H	Positive pole voltage to ground	R	Unit: V; Ratio is 0.1 For example, 4567, the voltage is 4567*0.1=456.7V	UINT16
36	24H	Negative pole voltage to ground	R		UINT16
37	25H	System voltage	R		UINT16
38~47	26H~2FH	Reserved	R		UINT16*10
48	30H	Voltage alarm switch	R/W	0xFEFE on 0xEFEF off (default is off)	UINT16
49	31H	Voltage rated value	R/W	0~1000V (default 1000)	UINT16
50	32H	Overvoltage value	R/W	100~120% (default 120)	UINT16
51	33H	Undervoltage value	R/W	80~100% (default80)	UINT16
52	34H	Insulation alarm switch	R/W	0xFEFE is on (default is on) 0xEFEF is off	UINT16
53	35H	Positive pole insulation resistance fault warning value	R/W	10~10000kΩ (default 100)	UINT16
54	36H	Positive pole insulation resistance fault alarm value	R/W	10~10000kΩ (default 50)	UINT16
55	37H	Negative pole insulation resistance fault warning value	R/W	10~10000kΩ (default 100)	UINT16
56	38H	Negative pole insulation resistance fault	R/W	10~10000kΩ (default 50)	UINT16

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		alarm value			
57~62	39H~3EH	Reserved	R		UINT16*6
63	3FH	Insulation monitoring time	R/W	0:500ms/cycle; 1:1000ms/cycle	UINT16
64	40H	Insulation monitoring trigger mode	R/W	0x01: Cycle (default is cycle) 0x10: Communication 0x11: Cycle and Communication	UINT16
65	41H	Capacitor delay time	R/W	0~60000ms (default 0)	UINT16
66	42H	Resistances monitoring delay time	R/W	5~500s (default 5s)	UINT16
67	43H	Reset mode	R/W	0: Auto; 1: Manual (default 0)	UINT16
68	44H	DO relay mode	R/W	0: N/O; 1: N/C (default 0)	UINT16
69	45H	Reserved	R		UINT16
70	46H	Reset meter	R/W	Write 1 reset meter, invalid read	UINT16
71	47H	Clear SOE	R/W	Write 1 clear SOE, invalid read	UINT16
72~79	48H~4FH	Reserved	R		UINT16*8
80	50H	SOE 1 Fault type	R	1: overvoltage 2: undervoltage 3: positive pole insulation fault alarm 4: positive pole insulation fault warning 5: negative pole insulation fault alarm 6: negative pole insulation fault warning	UINT16
81	51H	SOE 1 Fault value	R	Fault insulation resistance: unit kΩ, ratio 1; Fault voltage: unit V, ratio 0.1	UINT16
82	52H high	SOE 1 time-year	R	Fault time-year	UINT16
	52H low	SOE 1 time-month	R	Fault time-month	
83	53H high	SOE 1 time-day	R	Fault time-day	UINT16
	53H low	SOE 1 time-hour	R	Fault time-hour	
84	54H high	SOE 1 time-minute	R	Fault time-minute	UINT16
	54H low	SOE 1 time-second	R	Fault time-second	
85~179	55H~B3H	SOE 2~20 element	R	Format of the SOE is the same as SOE 1	UINT16*95

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7.4 Register Operation Description

7.4.1 Insulation Monitoring Trigger Mode

0x40H is the insulation monitoring trigger form, there are three main types: cycle trigger, communication trigger, cycle and communication trigger, default cycle trigger.

Cycle trigger form, timed monitoring, monitoring time 500ms or 1000ms once, after monitoring update register data, after a polling delay (0x42H), continue to trigger monitoring. After a polling delay (0x42H), the monitoring will continue to be triggered. The host communication reads 0x20H~0x24H register data, and the instrument returns the latest data in the register.

Communication trigger form, polling delay (0x42H) is invalid, insulation monitoring in standby mode. Host communication read 0x20H~0x24H register data, the instrument triggers a monitoring, monitoring time 500ms or 1000ms once, monitoring register data refresh and return data, monitoring time repeated reading data is invalid, not monitoring can not return data. It is recommended that the interval between two readings when communication is triggered is more than 2500ms, and the timeout time is more than 1500ms.

Cycle and communication trigger form, the first instrument timed monitoring, monitoring process communication read 0x20H ~ 0x24H register data, the instrument triggered an insulation monitoring, monitoring time 500ms or 1000ms once, monitoring register data refresh and return data. When the next cycle is triggered, the meter automatically triggers the monitoring and refreshes the register data. This mode is used for debugging.

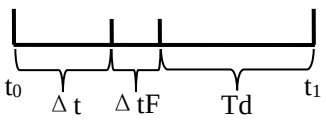
7.4.2 Insulation Monitoring Time

0x3FH is the insulation monitoring resistance time, and the insulation monitoring period can be set to 500ms or 1000ms. The accuracy of 500ms is slightly worse.

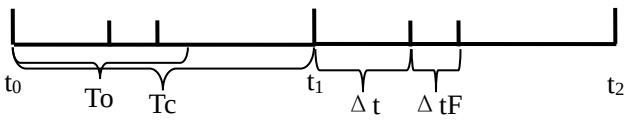
7.4.3 Insulation Monitoring Capacitor Delay Time

0x41H is the insulation monitoring capacitance time. When the system capacitance is >5μF, the insulation resistance monitoring has a long response time and the insulation monitoring accuracy deteriorates. You can set the insulation monitoring capacitance time to 1000ms/10μF and increase the monitoring time to stabilize the insulation measurement and eliminate the influence of capacitance. Monitoring time description:

The cycle trigger defines polling delay as Td, insulation monitoring resistance time as Δt, insulation monitoring capacitance time as ΔtF; the communication trigger defines reading interval time as Tc, and timeout as To. The time correspondence is shown in the following figure:



Cycle trigger



Communication trigger

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7.4.4 Alarm Setting

0x30H~0x33H are voltage alarm related registers, which can set the rated voltage and issue alarm when overvoltage or undervoltage occurs in the system voltage.

0x34H~0x38H are insulation resistance related registers, which can set warning and alarm thresholds, and issue warning or alarm when insulation resistance exceeds the limit.

0x43H is alarm reset mode, which can be set automatically or manually. In manual mode, the meter needs to be reset manually after the fault is lifted.

0x44H is the relay output setting, it can be set as normally open or normally closed, and the relay status will be flipped when the alarm occurs.

7.5 Message Example

7.5.1 Read the insulation monitoring status

Host Send: 01 03 00 20 00 05 84 03

Slave Response: 01 03 0A 00 18 00 64 00 0A 11 94 01 C2 F7 A0

Data Analysis: 00 18 represents the fault type, the binary system is 0000 0000 0001 1000, the fault is positive insulation fault warning, negative insulation fault alarm; 00 64 represents the positive pole to ground insulation resistance, 100kΩ; 00 0A represents the negative pole to ground insulation resistance, 10kΩ; 11 94 represents the positive electrode to ground voltage, 4540/10 =454.0V; 01 C2 represents the negative electrode to ground voltage, 450/10=45.0V.

7.5.2 Read the system voltage status

Host Send: 01 03 00 25 00 01 95 C1

Slave Response: 01 03 02 00 9A 38 2F

Data Analysis: 00 9A represents the system voltage, 154/10=15.4V.

7.5.3 Set Alarm Parameters

The alarm switch is turned on by default, the positive and negative insulation fault warning values default to 100kΩ, and the positive and negative insulation fault alarm values default to 50kΩ. No changes are required without special requirements. If you need to change, please refer to the following example.

1) Turn on the alarm switch

Host Send: 01 06 00 34 FE FE 09 E4

Slave Response: 01 06 00 34 FE FE 09 E4

2) Turn off the alarm switch

Host Send: 01 06 00 34 EF EF C5 B8

Slave Response: 01 06 00 34 EF EF C5 B8

3) Alarm threshold setting

Host send: 01 10 00 35 00 04 08 00 64 00 32 00 64 00 32 26 3E

Slave response: 01 10 00 35 00 04 D1 C4

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Data analysis: 00 64 means setting the positive insulation fault alarm value to 100kΩ; 00 32 means setting the positive insulation fault alarm value to 50kΩ; 00 64 means setting the negative insulation fault alarm value to 100kΩ; 00 32 means setting the negative insulation fault alarm value to 50kΩ.

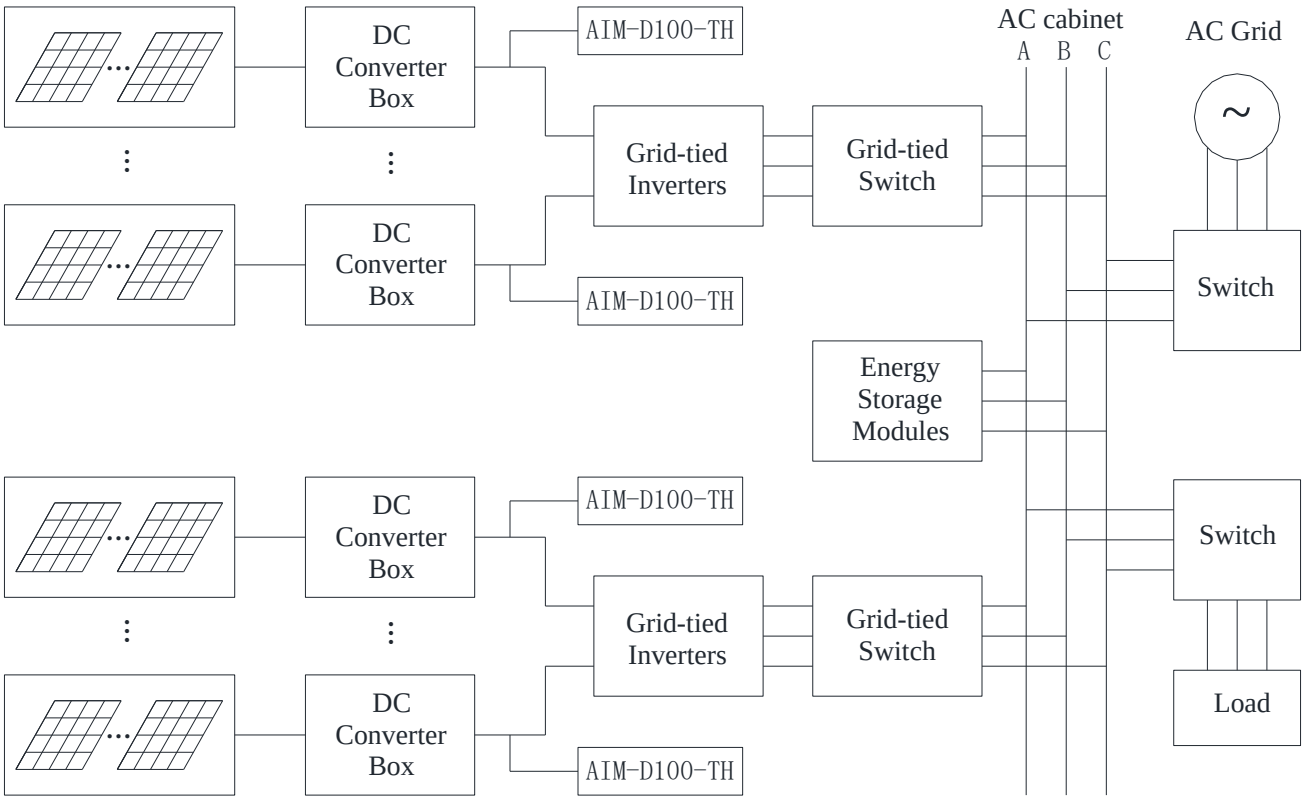
8 Application

AIM-D100-T series DC insulation monitors can be applied in PV, energy storage, DC screen, UPS and other DC systems. The following is a brief introduction to the PV DC system and DC screen system as an example.

8.1 Photovoltaic DC System

Photovoltaic power supply system converts light energy into electricity, which generally includes PV panel arrays, convergence boxes, grid-connected inverters, monitoring instruments and grid-connected switches, etc. It can be connected to the AC grid, or provided for use by power-using equipment, or charged by energy storage modules.

The following figure in the photovoltaic system, photovoltaic module power convergence through the inverter and into the grid, the inverter with its own isolation transformer, each convergence box front-end is divided into an independent system, for the independent ungrounded DC system, should be equipped with an insulation monitor to detect the insulation of the DC bus and the branch circuit to the ground, when the occurrence of insulation damage or single-pole grounding, the instrument can be a timely alarm to alert the staff of the circuit to carry out maintenance Troubleshooting, to prevent the expansion of faults caused by short circuit. Insulation monitor on the photovoltaic DC system online monitoring, can guarantee the safety, stability, and reliability of the system.

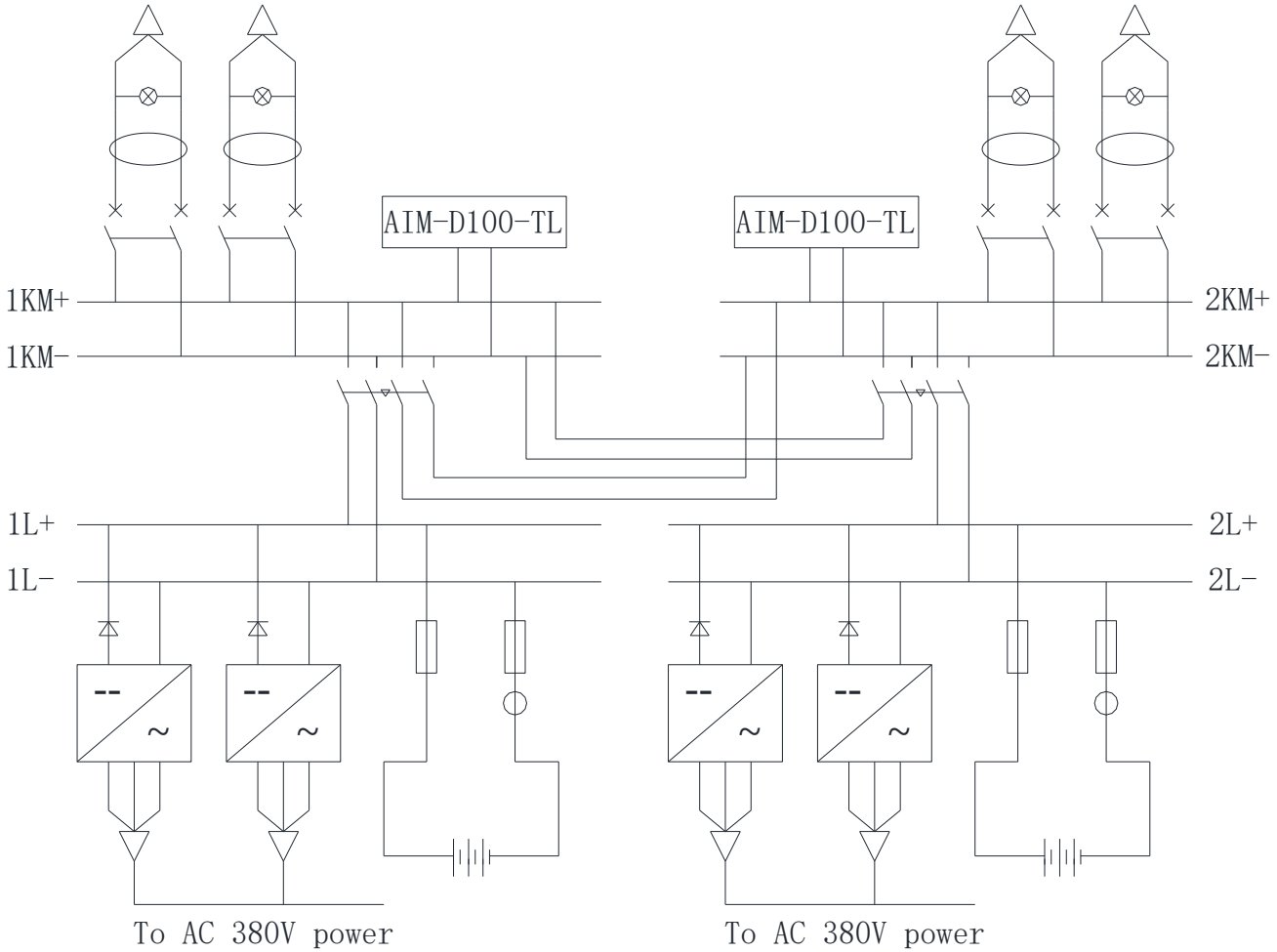


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8.2 DC panel system

The monitoring and control equipment in the substation is independently powered using either DC or AC panels. For the AC screen, DC screen, the general use of ungrounded (IT) power distribution system.

The following figure DC screen distribution box system, DC screen access to AC 380V power supply, the battery module is usually in the charging state, DC screen through the 1KM +, 1KM - DC bus to provide power to the monitoring equipment, when the AC380V power supply is lost, the DC bus to continue to use the backup battery power supply, to ensure that the monitoring equipment for normal use. The instrument can monitor the insulation of DC bus and branch circuit, when any position in the DC system insulation damage or single-phase grounding occurs, the instrument sends out an alarm signal, prompting the staff to troubleshoot. The online monitoring of the DC screen system by the insulation monitor can guarantee the safety, stability, and reliability of the system.



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