XC-100E Acquisition Unit User Manual

(XC-2100E Travelling Wave Fault Location System)

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Revision history:

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V2.0	9/6/2021	Reformat, new section numbering, edit & proof	BilKib / DiaKib/TonYip
V2.1	16/7/2021	DI module description amended	BilKib

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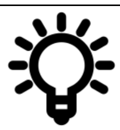
Safety Instructions

Safety Note: This user manual is the basic commissioning and on-site operation guide for the XC-100E acquisition unit, part of the XC-2100E travelling wave fault location system. All operators who will use the XC-2100E should read the entire contents of this manual in advance. The manufacturer of this product is not responsible for any loss caused by the operator's failure to comply with the operating procedures of this manual or for violation of the safe working procedures of the operator.

Meaning of the manual symbols Important instructions concerning personal safety, operating procedures, technical safety, etc., are marked with the following symbols:

Symbol	Meaning
	Indicates a potential hazard that could result in fatal or serious injury
	Indicates a potential hazard which, if not avoided, may result in minor personal injury or property damage.
	Indicates that it contains important information and useful guidance for using this product. Failure to heed this information will result in the equipment not functioning properly.
	Indicates that this is a useful guideline based on field practice.

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1. Introduction

The exposed nature of electrical transmission lines makes them susceptible to faults due to the environmental conditions in which they operate. Such faults can be cleared quickly by the system protection but the fault location must be found and inspected to ensure that the fault will not recur. In order to do this an accurate fault location technique is required. The need for accuracy is exacerbated where the line is extremely long or passes through difficult terrain.

Use is often made of impedance-based fault location techniques but these have a serious shortcoming for earth faults. The value of the impedance of the fault path through the ground can often only be estimated, which will lead to inaccuracies in the measurement of the distance to the fault.

Travelling Wave based fault location is inherently more accurate as it relies only on the speed of propagation of a wave through the conductors of the transmission line, which is inherently more predictable. Indeed, a travelling wave-based system can typically locate the fault position to within one tower span.

The XC-2100E system comprises XC-100E hardware used and the associated XCF-2100E software. It is suitable for a wide variety of line configurations including: DC lines; mixed overhead and cable lines; teed lines; series compensated lines and non-earthed distribution lines.

This manual concentrates on the XC-100E hardware, it should be used in conjunction with the XCF-2100E software manual for a comprehensive overview of the XC-2100E system.

1.1 What is a travelling wave?

Transient travelling waves are produced when a stable power system is disturbed, which can be under a short circuit fault, CB operation or lightning conditions. The disturbance can be represented as a voltage source at the point of disturbance which produces both voltage and current surges propagating in both directions (Figure 1.1).

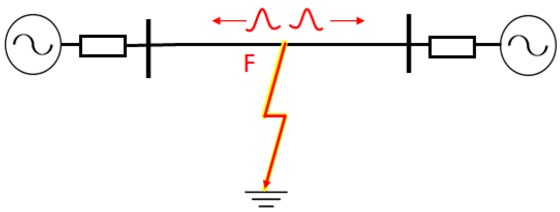


Figure 1.1 System fault producing travelling waves

The travelling wave (TW) signal propagates along the line through a continuous process of the TW voltage charging the line's distributed capacitance through the distributed inductance, creating the TW current along the way (Figure 1.2). Therefore, the travelling wave can be regarded as a single entity consisting of both voltage and current components.

The speed of propagation v is given by: $\nu = 1/\sqrt{L_0 C_0}$

The Line impedance Z_c is given by: $Z_c = \sqrt{\frac{L_0}{C_o}}$

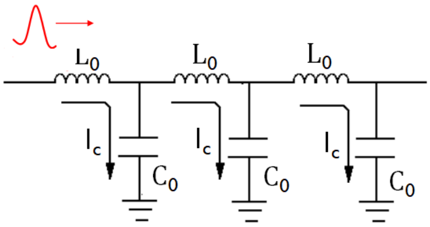


Figure 1.2 Propagation of travelling wave

Both the characteristic impedance Z_c and the propagation velocity v of the travelling wave are independent of the physical length and cross-sectional area of the line, but they are dependent on the construction, materials and insulation of the line, as seen in Table 1.1.

Medium	Typical propagation velocity (*v*)	Typical characteristic impedance (Z_c)
Overhead line	291 – 294 m/µs	300 – 500 Ω
Underground cable	156 - 174 m/µs	10 – 40 Ω

Table 1.1 Propagation velocity of travelling waves

The travelling wave will be affected by a discontinuity in the transmission line, which causes the characteristic impedance to change. As a result, a portion of the incident wave will be reflected back along the line, and the remainder will be transmitted through the discontinuity (Figure 1.3).

Typical discontinuities are:

- A busbar terminating with a transformer or with a number of incomers
- An open circuit breaker
- A short-circuit fault or an open conductor fault

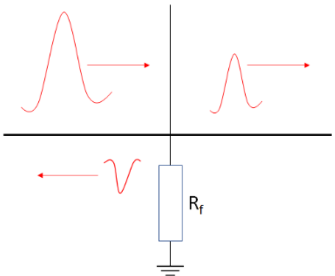


Figure 1.3 Reflection and onward transmission of travelling wave at line discontinuity

Total reflection takes place for open circuits and short circuits. For open circuits, the voltage will be reflected with the same polarity and current in opposite polarity, resulting in double voltage surge and zero current surge (Figure 1.4).

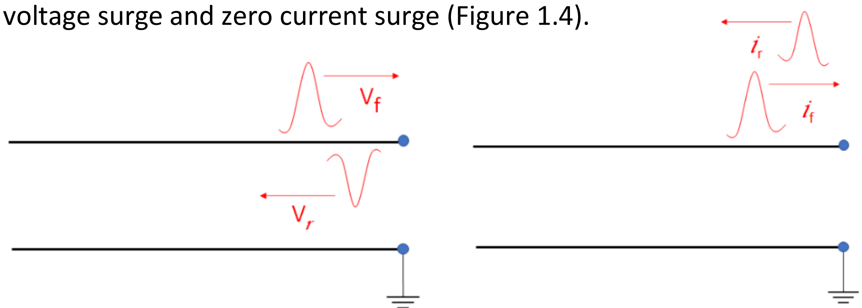


Figure 1.4 Travelling wave reflections at open circuit

For short circuits, the voltage will be reflected with opposite polarity and current in the same polarity, resulting in zero voltage surge and double current surge (as in Figure 1.5).

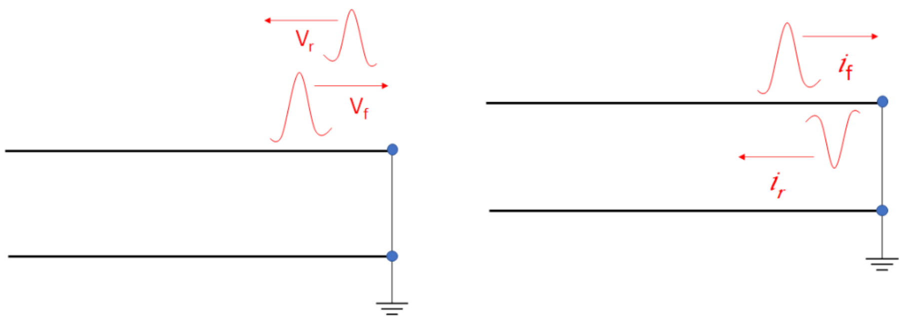


Figure 1.5 Travelling wave reflections at short circuit

1.2 Travelling wave fault location

As the velocity of the wave is known, the distance to the fault can be determined by measuring the time taken for a surge to travel from the fault to the substation busbar. The accuracy of the measurement is stable, as the velocity of the travelling wave is free from the influences such as fault resistance, instrument transformer errors and line configurations; all of which can adversely affect the accuracy of traditional fault location, based on measuring the impedance. The system is valid for all kinds of power lines including HVDC, double circuit, T-branch, series compensated, overhead and cable mixed lines. Importantly, the measurement does not involve current flowing through the earth path, which is a significant source of error, when using impedance methods on earth faults.

The travelling waves are detected by the XC-2100E acquisition unit (designated XC-100E), which is installed in the substation. When a fault occurs, the devices at each end of the line will measure the arrival time of the travelling waves. These units are time-synchronised by a GPS signal and so the arrival times of the waves resulting from the fault can be directly compared. The data from the XC-100E is transmitted to a master station running the associated XCF-2100E for analysis to derive the distance to the fault (Figure 1.6)

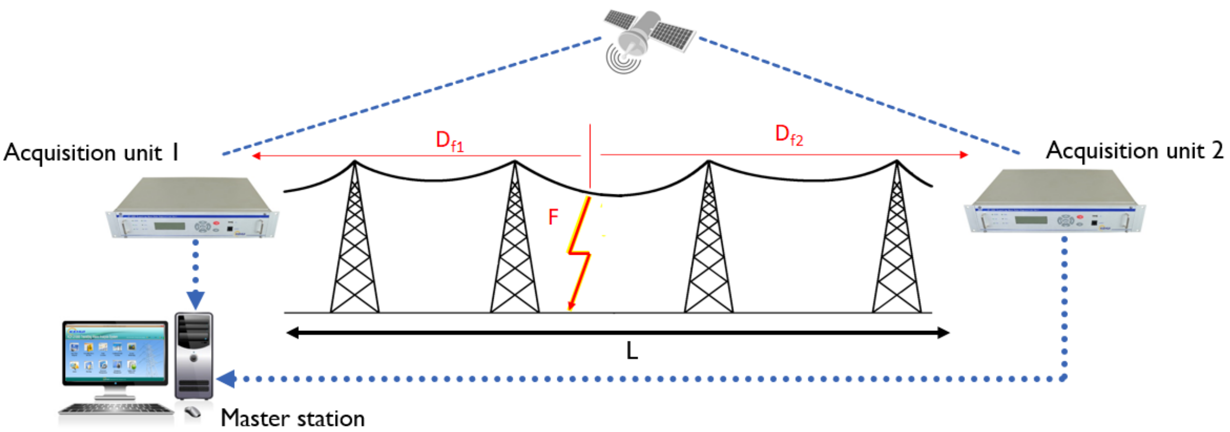


Figure 1.6 XC-2100 system

The distance to fault is calculated at the master station:

$$D_{fl} = L + v\,(T_l - T_2)$$
$$D_{f2} = L + v\,(T_2 - T_l)$$

Where:

- D_{fl} is the distance from the fault (F) to Acquisition unit 1
- D_{f2} is the distance from the fault to Acquisition unit 2
- v is the velocity of propagation of the travelling wave in the cable
- T_1 and T_2 are the arrival times at the respective Acquisition units
- L is the line length

The travelling waves will be transformed accurately through a conventional CT. They are detected by the acquisition units. These are generally connected to the system using a "clip-on" current transformer (CT) around the wiring between the protection core of the line CT and the protection system (other connection possibilities are discussed in Section 1.5).

1.3 Applications

The XC-2100E system is suitable for travelling wave fault location on the following systems:

i. AC overhead lnes: In this case the travelling waves are normally captured from the secondary of the protection cores of the line current transformers. This can either be a direct connection, with the secondary routed directly through the fault locator or, more commonly, indirect where clip on CTs are placed around the secondary wiring, so it does not need to be disturbed. If there is only one wire attached to the busbar, the current travelling wave will be cancelled and so the voltage wave needs to be measured. If capacitor voltage transformers (CVTs) are available, the wave is captured by putting a CT around their earthing circuits. Alternatively, it can be captured from a voltage connection to the metering core of an electromagnetic line voltage transformer.

ii. Series compensated transmission lines: Series compensation is the method of improving the system voltage by adding capacitance in series with the transmission line. This has no effect on the performance of fault location scheme as the high frequency travelling wave passes through it without significant attenuation. Alternative impedance-based fault location schemes will not perform accurately on series compensated lines.

iii. Overhead lines with "T" branches: there is no special hardware requirement for a T-branch line application. In addition to the fault locators located at the line ends of the "parent line", devices are also required at the ends of the T-branches. The master station software allows the T-branches to be defined in terms of their location and branch length. When a fault occurs, travelling wave signals will be captured at all the line ends. The software is then able to automatically calculate the location of the fault within the line.

iv. Hybrid lines comprising underground cables and overhead lines: The master station software allows each section of the hybrid line to be defined in terms of its section length and velocity of propagation. During the automatic two-ended fault location, these parameters will be taken into account to calculate the correct distance to the fault.

v. HVDC transmission lines, with a connection on the earth wire of the harmonic suppression filter: In this case the wave is captured by putting a CT around the earthing circuit of the line's surge suppression filter and is connected to the analogue current input of the fault locator.

1.4 Product Overview

The XC-2100E system comprises the acquisition units XC-100E and the master station software XCF-2100E. Figure 1.7 shows the front and rear views of acquisition units and screen-shots of the software. The configuration of the acquisition unit can be varied to meet particular applications (see Section 1.5). Also shown is one of the clip-on CTs and the GPS antenna, both of which are optional extras.

Figure 1.7 XC-2100E components

1.5 Connection to the system

The travelling wave can be captured in several ways:

1.5.1 Indirect current connection

This is the most commonly used connection as it allows the fault locator to be connected to the system retrospectively, without disturbing the existing wiring and allows up to eight lines to be monitored. The clip-on CTs are situated in the protection panel and are attached to the secondary wiring from the line CT to the protection devices (Figure 1.8). They are connected to the indirect current module (AI see Section 3.6.1). It is not recommended to use the metering cores of the CT as they are prone to saturating under fault conditions. The sensitivity of the arrangement can be increased by looping the cable from the line CT twice around the transformer, although this is not needed for most applications and may lead to spurious operation.

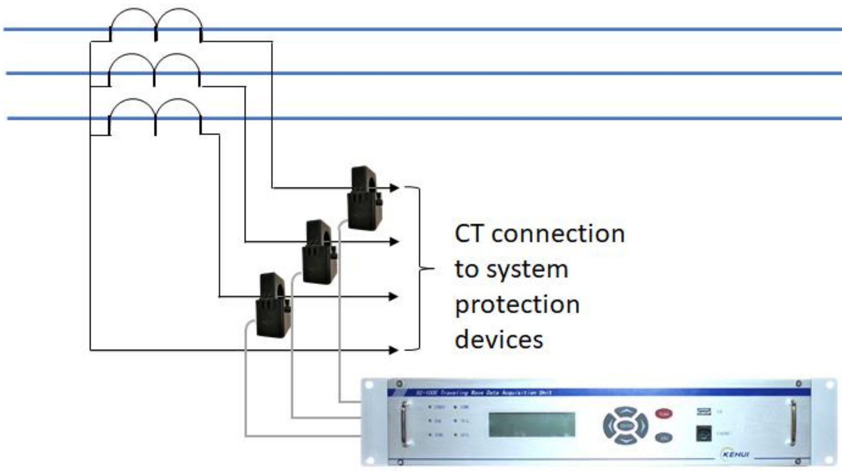


Figure 1.8 Indirect current connection

1.5.2 Direct current connection

In this connection method, the fault locator is connected in series with the protection wiring using the direct current module (AD see Section 3.6.2). To use this connection, the CT secondary wiring needs to be opened so it can only be fitted before commissioning of the substation, or when the protection is out of service.

Open-circuiting a current circuit from a live CT will produce dangerously high voltages. The output from the CT must be short-circuited before any wires are disconnected.

A maximum of four lines can be connected using this method. Direct current connection only allows four lines to be monitored, as AD modules are larger than the AI module used for indirect connection, allowing more to be fitted into the basic hardware.

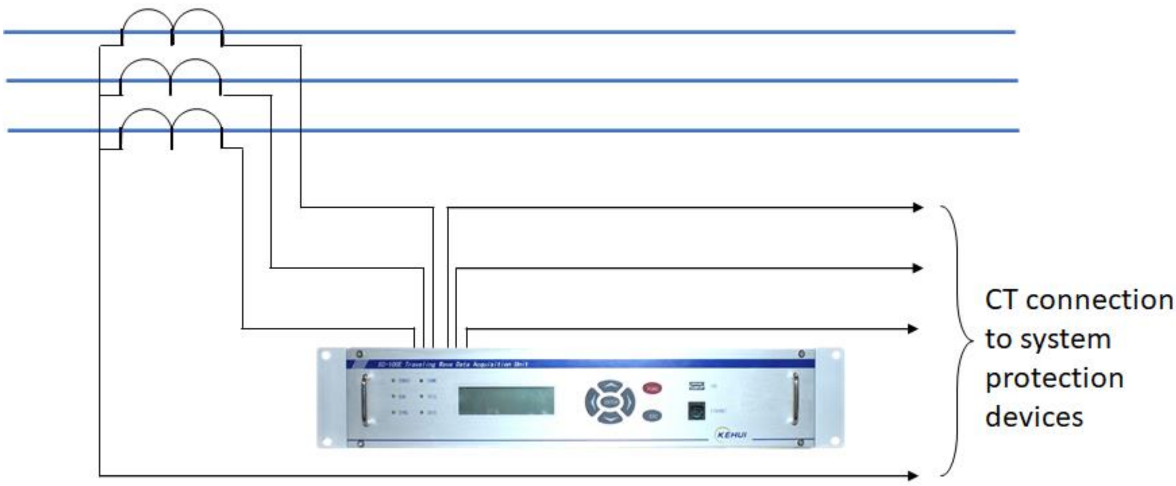


Figure 1.9 Direct current connection

1.5.3 Voltage connection

If there is only one line connected to the busbar, such as a generator connection, the amplitude of the transient current is limited. In this case, the voltage travelling wave can be used for the fault location measurement. The voltage transient is measured at the secondary of the (electromagnetic) potential transformer of the substation (Figure 1.10), which would normally be used for metering. In this case a voltage input module (AV see Section 3.6.3) is used in the fault locator.

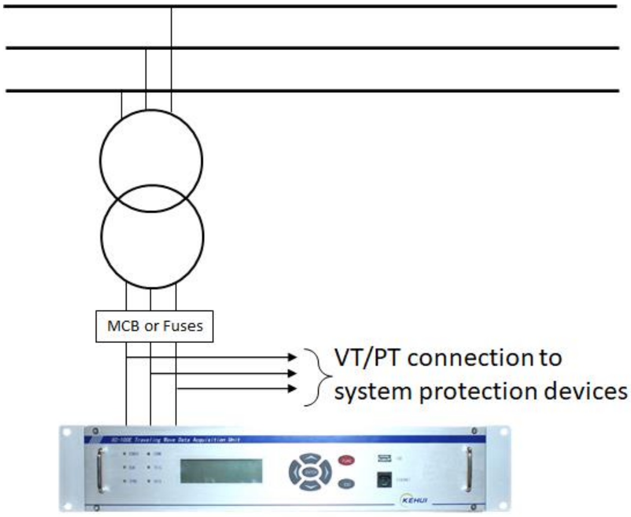


Figure 1.10 Voltage connection

1.5.4 Remote connection to capacitor voltage transformer (CVT)

If there is only one line connected to the busbar and the voltage transformer is a CVT, it presents a short circuit to the travelling wave current. In this case, the current pulse is captured using a CT on the CVT cable earth. The CT is normally mounted in a small cubicle adjacent to the transformer, and the signal is connected directly to an AD module (figure 1.11).

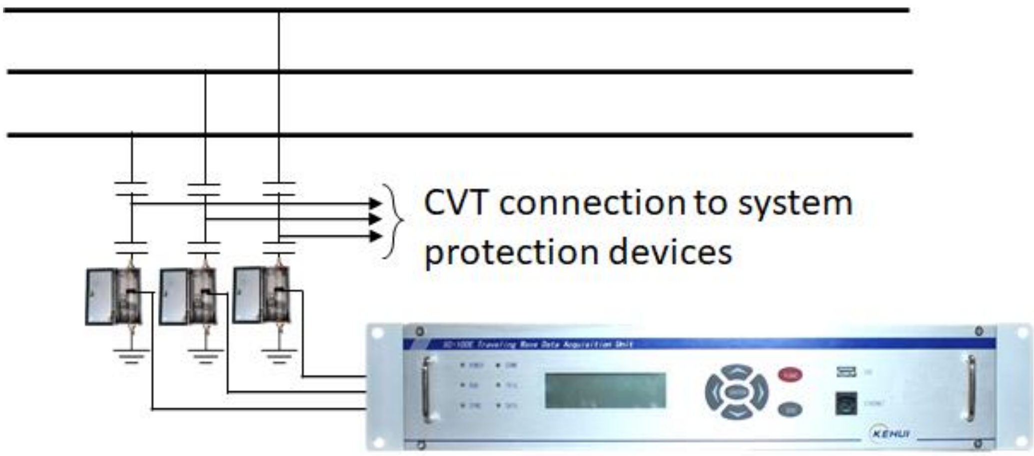


Figure 1.11 CVT connection

1.5.5 Connection to an HVDC system

On an HVDC system the most effective way of capturing the travelling wave is at the earthing point of a surge suppression capacitor (figure 1.12). The capacitor will present a low impedance to the high-frequency travelling wave, which will pass through it to earth. A CT is put on to the earth connection of the capacitor, which would normally be situated in the substation switchyard. The CT and protective cubicle used are the same as those in the CVT example in Section 1.5.4. with the CT connected to an AD module.

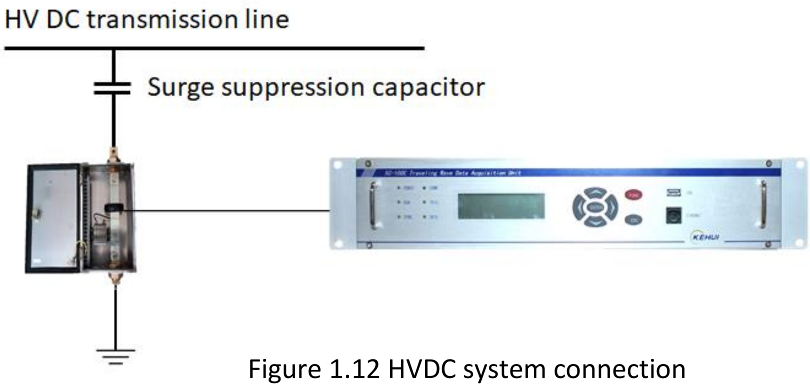


Figure 1.12 HVDC system connection

1.6 Technical Specification

1.6.1 General information XC-100E Acquisition units

Item	Description	Notes
Mounting	Dimensions: 483mm × 323mm × 83mm	2U, 19” rack
Mechanical	Conforms to IEC standards for EMI-EMC compatibility	
Weight	< 4kg without modules: < 6 kg with modules	
Power Supply	Basic module: 85 to 264V, 50/60 Hz AC or 90 to 260V DC Power Consumption: <10 W	Option 1: 35 to 65V DC Option 2: 35 to 140 V DC Option 3: 100 to 300 V DC
Sampling Frequency	36 MHz (one channel), 12 MHz, 8 MHz, 6 MHz, 4.8 MHz, 4 MHz, 3 MHz, 2.4 MHz, 1.5 MHz and 1 MHz	All are user selectable; default 2 MHz
Internal Memory	8 GB	Secure Digital (SD) non-volatile memory
Transient record length	1 to 20ms	Configurable, default 2ms

1.6.2 Interface and communications

Item	Description	Notes
Front Panel LED Indicators	6 LEDs	Power, Run, Synchronisation, Trigger, Communication, Data
Front User Interfaces	USB port and 100BASE-T Ethernet Port	
Rear User Interfaces	Communication Module #1: 1 x Internal Modem, 1 x RS232; 2 x Ethernet Ports Communication Module #2: 2 x RS232, 2 x Ethernet Communication Module #3: 1 x RS232, 2 x Ethernet, for IEC61850 Goose protocol	
GPS Antenna	Cover diameter: 100 mm; total height: 180 mm. Cable length: 30 m (Optional lengths: 40 m, 50 m, 60 m, 100 m) Connector: BNC type	
Internal Time Synchronisation	Time Accuracy: 100 ns available for inbuilt GPS module.	

1.6.3 Inputs and outputs

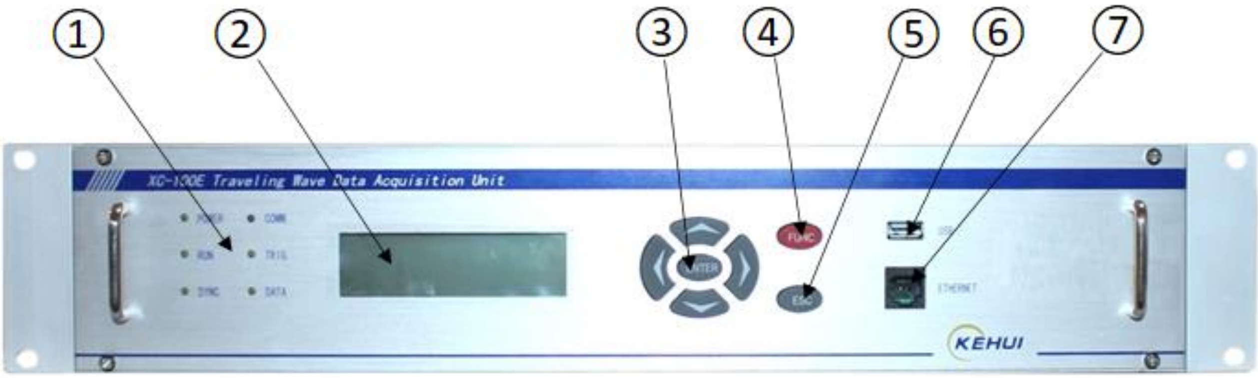
Item	Description	Notes
Analogue Inputs	**AD** Module: Direct current input from substation protection CT	Nominal current: 5A or 1A Burden: < 0.4 VA (In= 5A); < 0.1 VA (In = 1A). Overload withstanding: 400% In, continuous. 4000% In, 1s
	AI Module with split core CT: Current input through a split core CT	Nominal: 5A / 1A Burden: <0.4 VA (In - 5A), <0.2VA (In - 1A) Overload withstanding: 400% In for continuous. 4000% In for 1s CT Cable length up to 20 m maximum
	AI Module with external CT: Current input through an external CT	Nominal secondary current: 5A or 1A Burden: close to 0 Overload withstanding: 400%In, continuous. 4000% In, 1s External CT ratio: 200:1 Cable length: up to 2 km
	AV Module: Input from substation VT.	Nominal primary: 57V/63.5V/69V (phase voltage) Maximum permanent voltage: 120 V. Burden: < 0.4VA Overload withstanding: 200% Un, continuous. 250% Un, 10 s
Digital Inputs	DI module with 5 inputs, Versions are available for the following nominal DC voltages: 24V ± 10%, 48V ± 20%, 110V ± 20%, 220V ± 20%	Specify the voltage level: Option #1: 8 dry inputs with common reference Option #2: 5 isolated dry inputs
Alarm Contacts	Contact rating: 28V DC/2A, 250V AC/0.5A	2 dry contacts Contact #1 (N/C): Abnormal alarm (power loss or GPS sync loss) Contact #2 (N/O): Equipment triggered
Configurable Output Contacts (Optional)	Contact rating: 28V DC/2A, 250V AC/0.5A	4 dry contacts, 2 N/O, 2 N/C. Configurable alarms (GPS sync loss, Triggered, SD fail, Unhealthy)

1.6.4 Environmental

Item	Description	Notes
Operating Temperature	- 10°C - 55°C; storage: -40°C to 85°C.	
Relative Humidity	0 - 90%, not condensing.	
	Tested for Shock, Vibration, Safety etc. as per relevant IEC	
Equipment safety	IEC 60950 - 1:2005 - A1:2009 - A2:2013	Information technology equipment -safety: Part 1 General requirements
Equipment safety	IEC 61010-1: 2010	Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements
Electromagnetic compatibility (EMC) – Part 1	EN61326-1: 2013 - CISPR 11: 2009 - A1: 2010	General requirements
Electromagnetic compatibility (EMC) – Part 3-2	EN61000-3-2: 2014	Limits for harmonic current emissions
Electromagnetic compatibility (EMC) – Part 3-3	EN61000-3-3: 2013	Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems
Electrostatic Discharge	EN61000-4-2: 2009	Electrostatic discharge immunity test
Electromagnetic compatibility (EMC) – Part 4-3	EN61000-4-3: 2006 - A2:2010	Radiated, radio-frequency, electromagnetic field immunity test
Electromagnetic compatibility (EMC) – Part 4-4	EN61000-4-4: 2012	Electrical fast transient/burst immunity test
Electromagnetic compatibility (EMC) – Part 4-5	EN61000-4-5: 2014	Surge immunity test
Electromagnetic compatibility (EMC) – Part 4-8	EN61000-4-8: 2010	Power frequency magnetic field immunity test
Electromagnetic compatibility (EMC) - Part 4-11	EN61000-4-11: 2004	Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase
CE Mark	The XC-100E unit is CE Marked	CE

2. XC-100E Hardware

2.1 Front panel



Element	Description
①	LED Array (see Section 2.2)
②	LCD display for settings and configurations, alarms and travelling wave record information. Pressing any button turns on the backlight.
③	Function buttons: Enter = to move to selected menu item or confirm setting Left/right = navigation in menu Up/down = increase or decrease setting
④	Func. Button: Illuminates the screen, Acts in conjunction with arrow keys, as a menu shortcut Acts in conjunction with ENTER key to reboot the device
⑤	ESC: Return to the previous menu item
⑥	USB Port: Export or import records and configuration files to/from a USB memory. Update the firmware from a USB memory.
⑦	RJ 45 Maintenance port*: Configuration and set-up, Downloading records, Application programme upgrading and maintenance. These operations are implemented using the XCF-2100E software

*NOTE: The RJ-45 front-panel connection is made in parallel to the rear panel connector FE1. FE1 must be disconnected when this port used.

Figure 2.1 Fault locator front panel

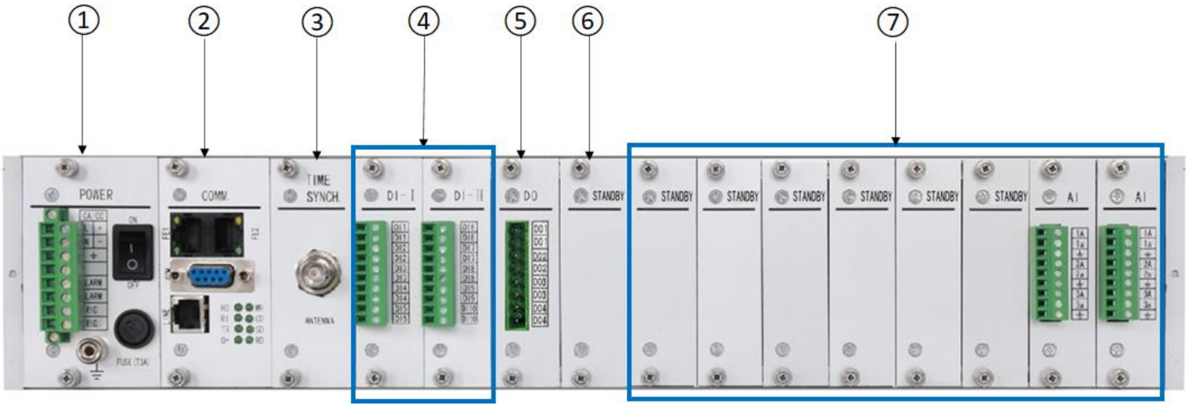
2.2 LED Array

LED	Description
POWER	Indicates that the unit is operating
RUN	The RUN LED blinks once per second when the unit is operating correctly
SYNC.	The synchronisation SYNC indicator blinks once per second when the device is receiving a synchronisation signal. It stops blinking if the GPS signal is lost.
COMM.	The communication COMM indicator blinks when any port transmits or receives data.
TRIG.	The trigger TRIG indicator comes on when the device is triggered. It stays on for a short time and then goes out again.
DATA	The DATA indicator illuminates when a new travelling wave record is downloaded to the Master Station, it turns off when the data transfer is complete.

Figure 2.2 LED array

2.3 Hardware modules

A number of hardware configurations are possible. The minimum arrangement will include a power supply, a communications module, a time synchronisation module, one digital input module and one analogue input module.



Element	Description
①	Power supply
②	Communications module
③	Synchronisation module
④	One or two digital input modules
⑤	Digital output module
⑥	Available for digital output expansion
⑦	Analogue input modules – up to eight can be incorporated (two AI modules are shown in the illustration). The Direct input module (DI) and analogue voltage module (AV) are twice the width of the AI module and so the maximum that can be accommodated is four.

Figure 2.3 Module layout

2.4 Architecture of the equipment

The XC-100E consists of: the central processing unit (CPU) and the peripheral elements shown in the block schematic (Figure 2.4).

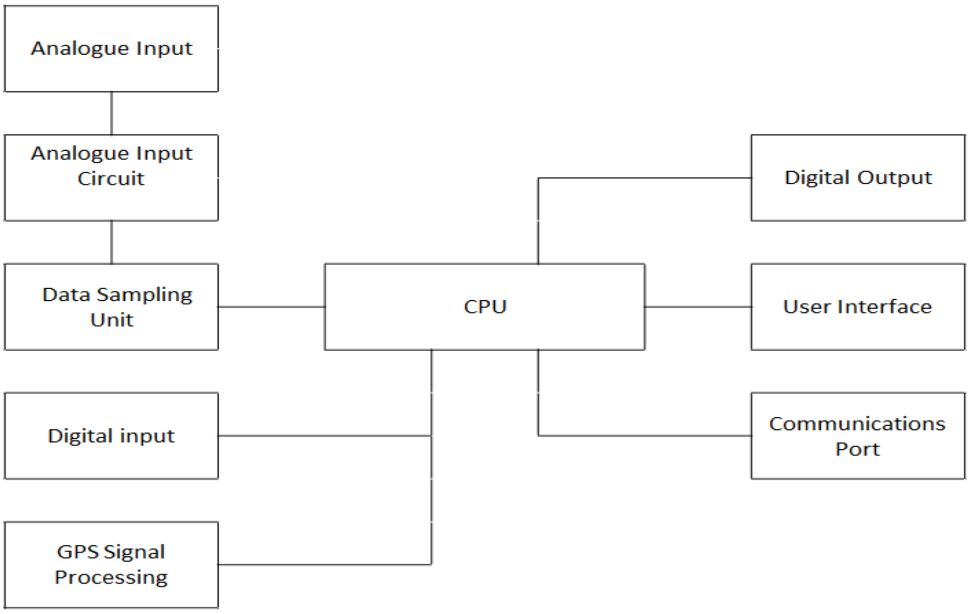


Figure 2.4 XC-100E Block diagram

2.4.1 CPU

The CPU is the core of XC-100E. It reads and processes travelling wave data from the data acquisition unit (DAU, Section 2.4.3), saves records temporarily and transmits the records, using the communication protocol, to the external master station. The CPU also controls time synchronisation, setting and configuration, while monitoring the operation state, the triggers and the alarms.

2.4.2 Analogue input circuit

The analogue input circuit transforms, filters and amplifies the current or voltage travelling waves from the line instrument transformers, converting them to low-level signals suitable for the A/D converter.

2.4.3 Data acquisition unit (DAU)

The DAU comprises the analogue input and its associated circuitry and the data sampling unit. To achieve 50m resolution in the distance to fault measurement, the travelling wave sampling frequency should not be less than 6MHz, which is beyond the capability of most A/D converters and data acquisition techniques. Hence, dedicated data acquisition hardware is employed in the XC-100E to facilitate travelling wave recording.

In normal operation with no fault present, the analogue signal is measured continually and saved to a temporary memory. When a fault occurs on the line, the CPU is alerted and stores the event data. The measured travelling wave arrival time is then transmitted to the substation master station for analysis. When the travelling wave is received, the trigger will be disabled for a settable period between 10 and 1000ms to ensure that it does not react to the operation of the circuit breaker resulting from the initial fault. The unit will not respond to any actual faults occurring in this period.

2.4.4 High precision clock and synchronous signal receiving circuit

The clock used in XC-100E has a high accuracy with an error less than 100ns. It sends the timing signal to the DAU for time synchronisation. The clock signal is created in the internal GPS module, connected directly to an external antenna, or is received directly from an external device.

2.4.5 Communication interface

The communications interface sends the data resulting from the event to the master station software. The data are saved so that in the event of a transmission failure, they are available for retransmission.

2.4.6 Digital inputs and outputs

All digital signal inputs to the device are optically isolated and all digital outputs are relay contacts to maintain electrical isolation for the device.

3. Module Descriptions

3.1 Power supply module

There are three variants of the power supply modules available to allow the equipment to be used with different battery voltages. In each case the power consumption is <10W

- 85V to 264V, 50/60Hz AC or 90 to 260VDC
- 35 to 140V DC
- 100 to 300V DC

Figure 3.1 Power supply module

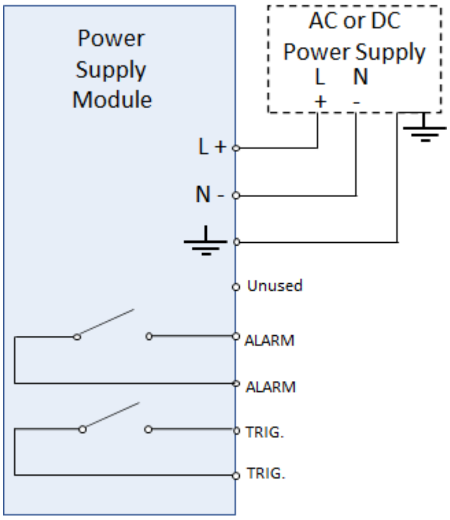


Figure 3.2 Power supply schematic diagram

The module features a switch to energise the fault locator and a fuse to protect the power supply. The earth terminal should be connected to the copper bar in the cubicle. The power supply is designed to tolerate a maximum supply interruption duration of 200ms without the fault locator losing power.

The module includes two relay output contacts which are available to provide alarms to the substation monitoring system.

The first of these is normally a closed contact labelled “ALARM” which will be closed when the device is not powered-on and when the equipment is not synchronised. After synchronisation, the contact opens and will close again if the supply voltage drops below a threshold, the watchdog* intervenes or the synchronisation signal is lost.

The second contact marked " TRIGGER " is normally open, but when the equipment triggers, it closes for 3s and alerts the system to retrieve the travelling wave data. In the case where there are multiple triggers, the contact only closes once.

**The watchdog is an integral element of the device which monitors its healthy functioning. If any unusual activity occurs the watchdog triggers a mini-reset to ensure continued healthy functioning of the device. If this fails, the user will be alerted by the alarm.*

3.2 Communications module

The communication module allows travelling wave data to be sent to the master station for the distance to fault calculations to be made.

3.2.1 Standard communications module

The standard module includes four 100 Mbit Ethernet ports, type RJ45. Two ports are used for communication with the master computer, SCADA system and the communication server for the substation or system protection. The third provides an output from the internal modem to the telephone system using a standard RJ11 connector.

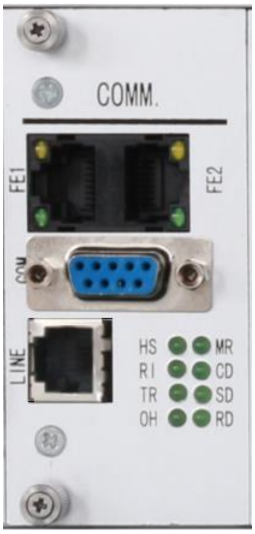


Figure 3.2 Standard Communication module

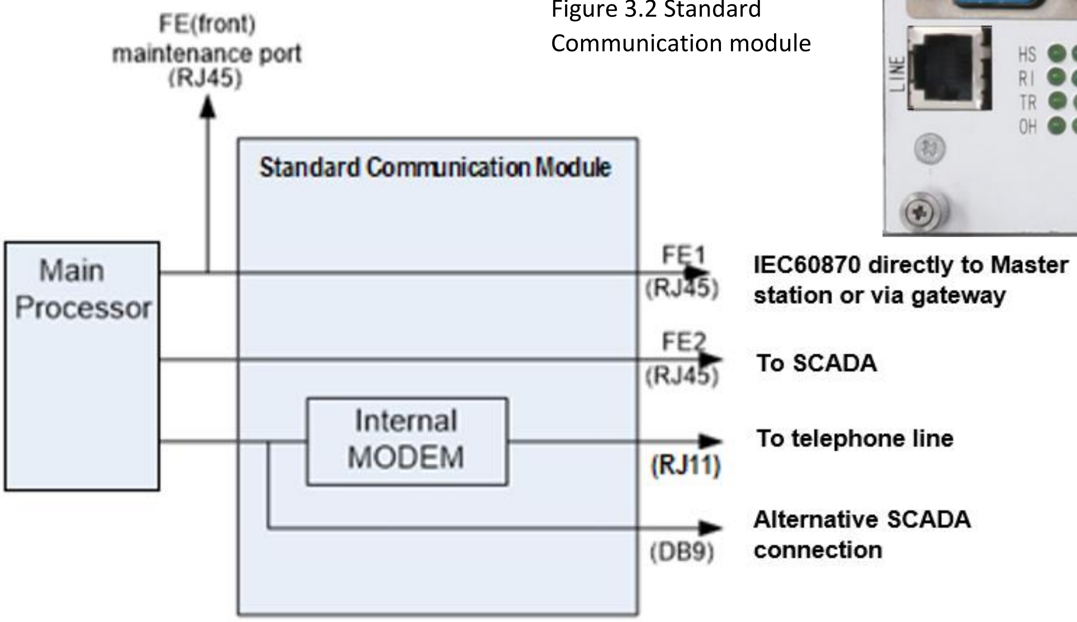


Figure 3.3 Standard communication module schematic diagram

An additional Ethernet connector is located on the XC-100E's front panel (Figure 3.4) which allows temporary local access by a laptop PC during commissioning and maintenance.

Figure 3.4 XC-100E front panel showing maintenance Ethernet port

A DB9, RS232 port is also provided for point-to-point communication to the Master Station, SCADA local substation RTU or protection system, which has a Baud rate: 1.2 to 38.4 kbps and supports the IEC60870-5-103, DNP3.0 protocol.

The module has eight indicator LEDs for the MODEM operation. Their meaning is explained in the table below.

No.	Code	Note
1	**MR**	Ready/Testing: When the modem is powered, the indicator is lit. When the modem is in self-checking or diagnosing modes, the indicator flashes.
2	**HS**	High speed: When the modem is working in high-speed mode whilst uploading and downloading, this indicator is lit.
3	**CD**	Carrier Detection: When the local modem receives a carrier data signal from the remote modem, the CD indicator is lit.
4	**RI**	The RI will be lit when either the modem is set to Auto answer mode or, if when the modem is ringing (if set to Ring).
5	**SD**	Send data: When the data is transferred from the local modem to the remote modem, the SD indicator flashes.
6	**TR**	Terminal ready: When the DTR signal is received, the TR indicator is lit.
7	**RD**	Receive ready: When the local modem is transforming the data to the connected device, the RD indicator flashes.
8	**OH**	Off-Hook: When the modem is working, the OH indicator is lit. When the modem stops working, the indicator of OH is not lit.

Figure 3.5 Definition of LED Indicators

3.2.2 Basic communications module

The basic communications module has no internal modem. It provides two rear 100 Mbit Ethernet ports, type RJ45. These support the IEC60870-5-104 protocol for network communication to the Master Station or SCADA. The network layer is IPv4. The front port is supported as before. There are also two DB9 RS232 ports for the point-to-point communication to the Master Station, SCADA local substation RTU or protection system. These have a baud rate: 1.2 to 38.4 kbps and can support the IEC60870-5-103, DNP3.0 protocol.

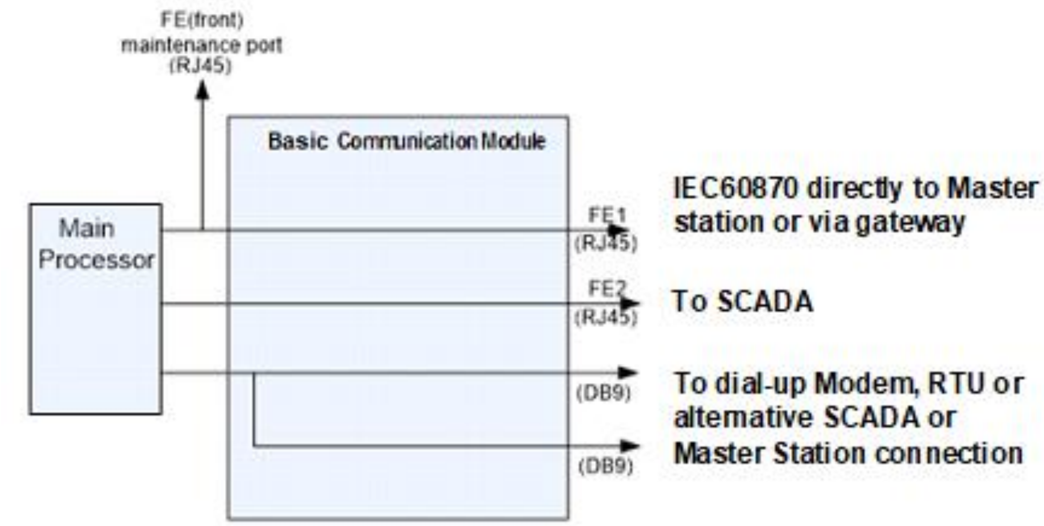


Figure 3.7 Basic Communication module, functional layout

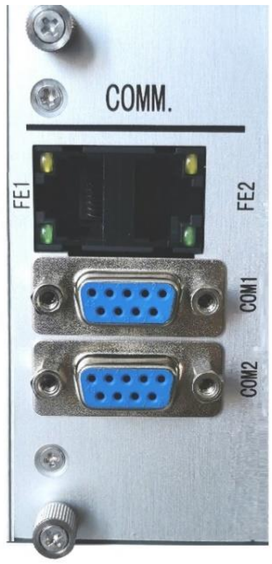


Figure 3.6 Basic Communication module

3.2.3 IEC61850 Communications module

The optional IEC61850 module has a dedicated microprocessor inside to run the IEC61850 protocol. In this version, the output FE1 is dedicated to IEC61850 communication and the front port is connected to FE2. Travelling wave data for the fault location process is sent to the master station using IEC60870-5-103.

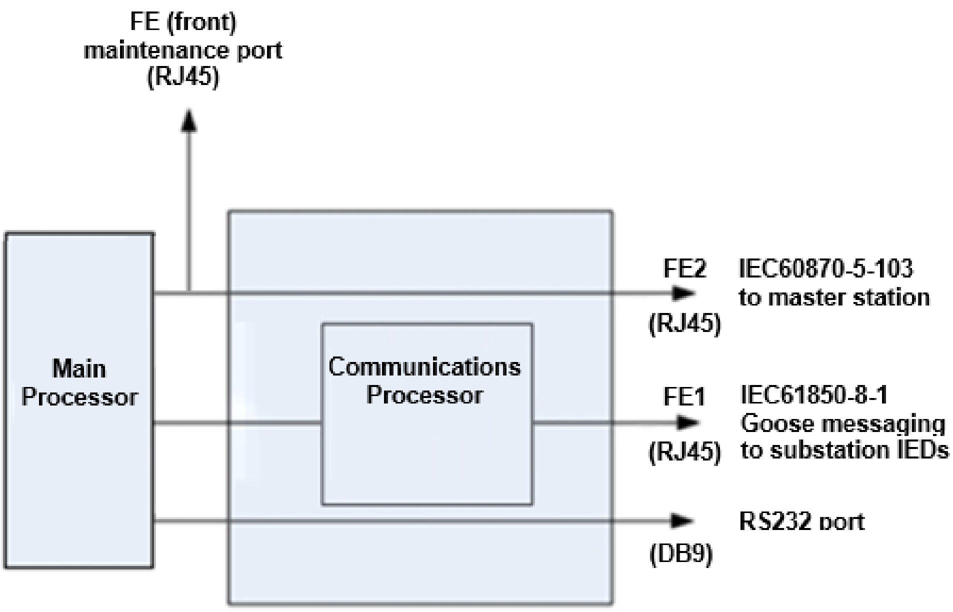


Figure 3.9 IEC61850 Communication module, functional layout

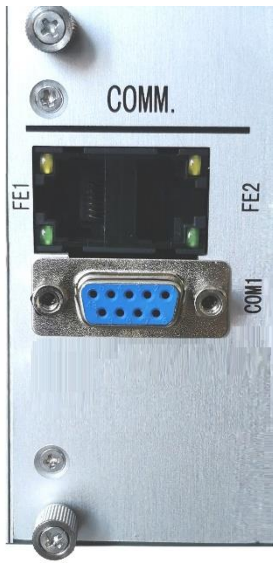


Figure 3.8 IEC61850 Communication module

3.3 Time synchronisation module

Accurate time synchronisation of the devices at either end of the line is vital in order to get a two-ended measurement of the fault location. Depending on the application, the XC-100E can be placed in one of five different synchronisation modes, internal synchronisation or one of four external synchronisation modes. The external modes are for use with different timing protocols available from suitable time synchronising equipment such as the Kehui T-GPS.

3.3.1 Internal GPS module

The internal synchronisation module has a BNC connector for the antenna.
The synchronisation status is visible on the frontplate.

Figure 3.10 GPS (Antenna)time synchronisation module

3.3.2 External IRIG-B (DC) synchronisation signal module

The external synchronisation module is used with an external source providing an IRIG-B (DC) synchronising output at 5V TTL level, connected through its BNC connector. This module can be used with a cable of maximum length 90m, and for greater distances optical fibres should be used.

Figure 3.11 External IRIG-B signal, synchronisation

3.3.3 External IRIG-B synchronisation using signal over optic fibre module

The external synchronisation module has a type ST optical fibre input for connection to a source with a suitable IRIG-B synchronising output such as the Kehui T-GPS unit. This module does not impose a practical distance limit to the synchronising signal source.

Figure 3.12 External optical IRIG-B signal, synchronisation unit

3.3.4 External GPS with RS485 and one pulse per second (1PPS) input module, 5V TTL

The RS485 serial message from the external GPS clock source through the DB9 connector, provides the time and date information to the XC-100E. This is augmented by the 1PPS signal from the GPS clock, connected to the BNC connector, to provide the 1µs resolution for the travelling wave fault location. This module can be used with a cable of maximum length 90m, for greater distances optical fibres should be used.

Figure 3.13 External RS485 and 1PPS synchronisation unit

3.3.5 External 1PPS synchronisation signal module

The module receives an RS485 serial message through an optical fibre from the external GPS clock source through the ST optical connector. It provides the time and date information to the XC-100E and is augmented by the optical 1PPS signal from the GPS clock, to provide the 1µs resolution for the travelling wave fault location.

This module does not impose a practical distance limit to the synchronising signal source.

Figure 3.14 External optical RS485 and 1PPS synchronisation unit

3.4 Digital Input (DI) module

The XC-2100E system needs to differentiate between fault-induced travelling waves and those which result from system switching. To allow this the system requires digital inputs to monitor the circuit breaker auxiliary contacts. The XC-100E can accommodate a maximum of two digital input (DI) modules, depending upon the number of digital inputs required.

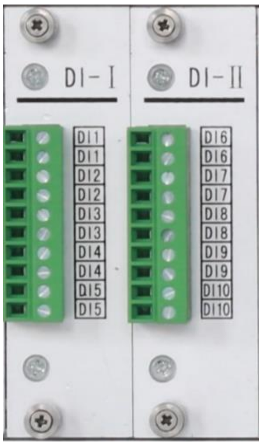


Figure 3.15 Two 5 input DI modules

3.4.1 The Standard DI module (8 inputs and common return)

The standard DI module has 8 inputs and a common return, Versions are available for the following nominal DC voltages:

- 24V±10%: Suitable for voltages in the range 21.6 – 26.4V
- 48V±20%:: Suitable for voltages in the range 38.4 – 57.6V
- 110V±20%: Suitable for voltages in the range 100 – 132V
- 220V±20%: Suitable for voltages in the range 176 – 264V

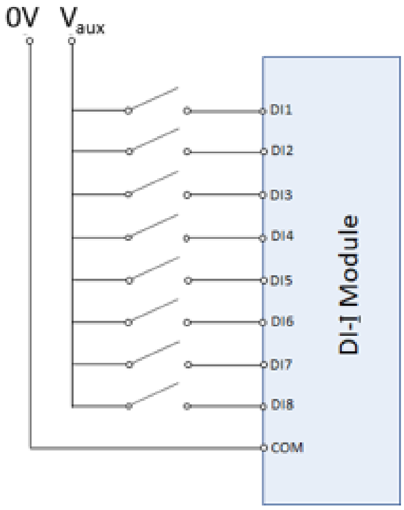


Figure 3.16 DI module schematic diagram with 8 inputs and a common return

Figure 3.17 DI module with 8 inputs and a common return

3.4.2 5 input DI module

DI module with inputs grouped in to 5 pairs, versions are available for the following nominal DC voltages:

- 24V±10%: Suitable for voltages in the range 21.6 – 26.4V
- 48V±20%:: Suitable for voltages in the range 38.4 – 57.6V
- 110V±20%: Suitable for voltages in the range 100 – 132V
- 220V±20%: Suitable for voltages in the range 176 – 264V

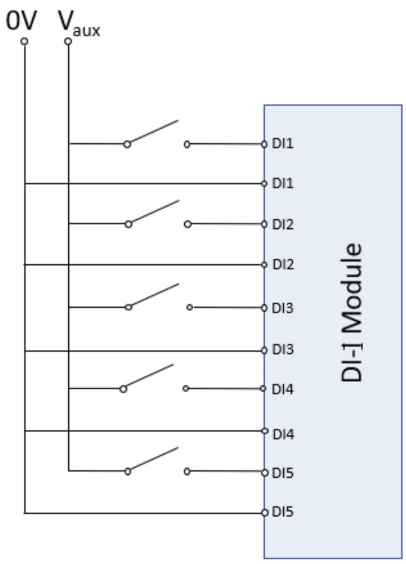


Figure 3.18 5-input DI module schematic diagram with 5 input pairs

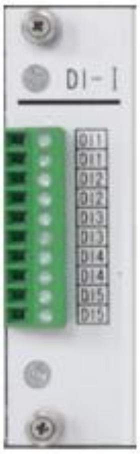


Figure 3.19 DI module with 5 input pairs

3.5 Digital Output (DO) module

As an option, the device can be provided with a digital-out (DO) module which provides four additional relay contacts. The function of these contacts can be set by the XCF-2100E software.

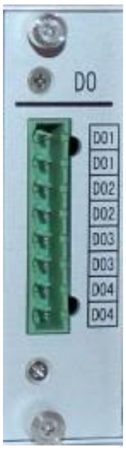


Figure 3.20 DO module

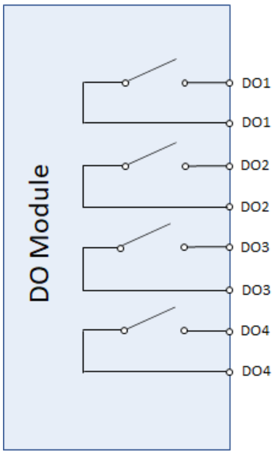


Figure 3.21 DO module schematic with 4 output contacts

3.6 Analogue input module

To fulfil its function, the fault locator must capture travelling waves from the line being monitored. This is achieved by coupling the fault locator to the line instrument transformers or, in the case of DC transmission lines, the line filter. The Analogue input modules allow this capture, with different configurations available to meet the needs of the application and user preference.

3.6.1 AC line, indirect current connection AI module

This is the most commonly used connection method as it allows the fault locator to be introduced to a system without disturbing the existing wiring. It allows up to eight lines to be monitored, with one AI module having connections for three phases. Each set of inputs will be connected to a clip-on CT.

Figure 3.22 AI module

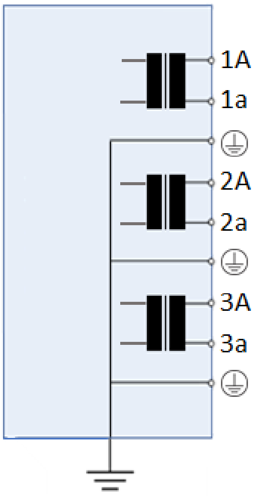


Figure 3.23 AI module schematic

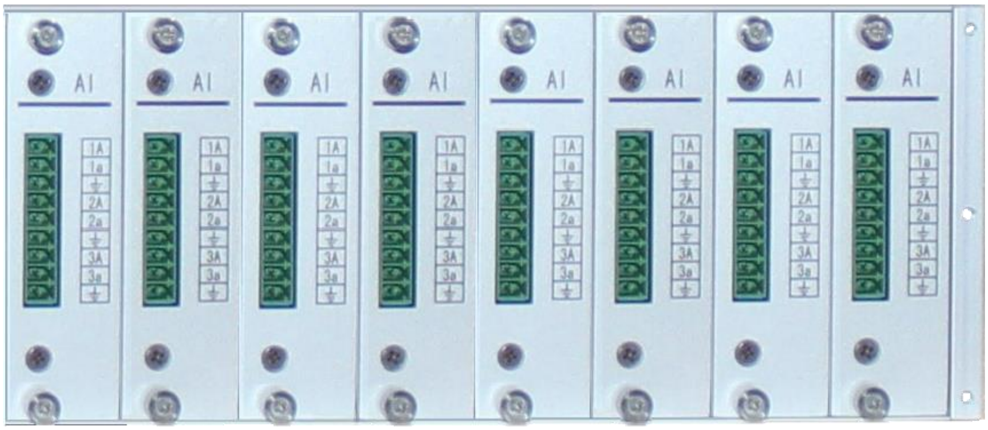


Figure 3.24 XC-100E device, fully populated with 8 AI Modules

3.6.2 Direct current connection AD module (AC or DC lines)

This method puts the fault locator in series with the protection devices and may be preferred where the device is being fitted to a new protection panel. It allows up to four lines to be monitored, with one AD module per line. Figure 3.25 shows a full complement of four modules. The method of connection is illustrated in Section 1.5.2, Figure 1.9. This module would also be used when connecting the fault locator to the earth point of a CVT or capacitor.

The module is suitable for 1A and 5A rated systems with the required value selected with an internal link shown in Figure 3.24. A test port is included to allow the injection of simulated travelling waves in to the input circuitry without disturbing the wiring. This is required during the commissioning procedure.

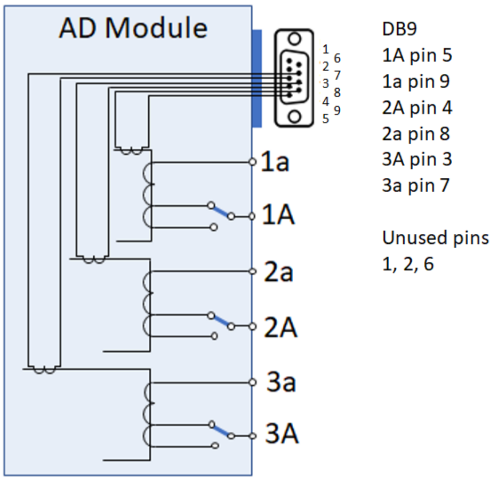


Figure 3.25 AD module input circuitry

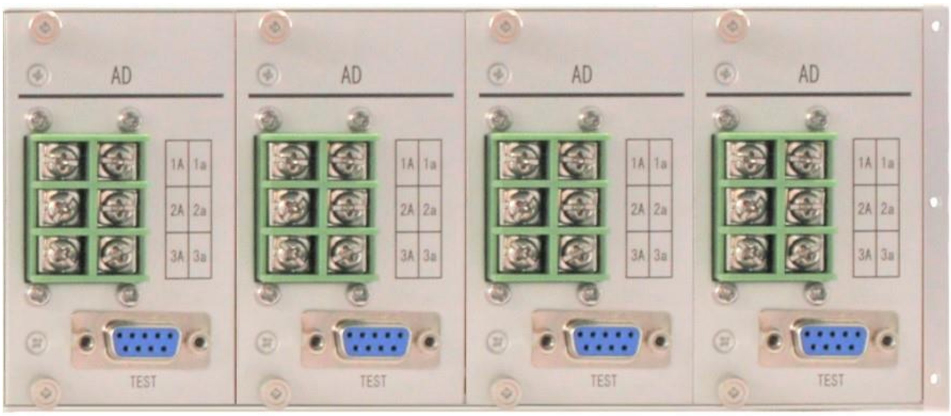


Figure 3.26 XC-100E device, fully populated with four direct current input modules

3.6.3 Voltage connection AV module

This connection method is used if there is only one line connected to the busbar, limiting the amplitude of the transient current. The voltage transient is measured at the secondary of an (electromagnetic) potential transformer of the substation (Figure 1.10), which would normally be used for metering. The module has a nominal voltage: of 57 - 69V (phase voltage) and presents a burden < 0.4 VA. Its rating allows an overload withstand of 200% U_n continuously or 250% U_n for 10 s.

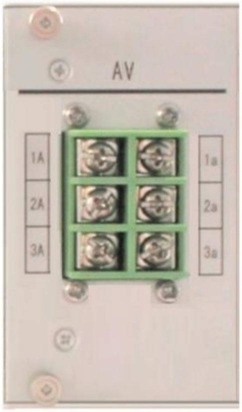


Figure 3.27 AV module

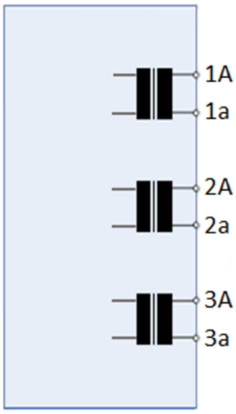


Figure 3.28 AV module schematic

3.7 Blanking plate

It is usual that the XC-100E hardware is not fully populated with modules. In this instance the spaces are occupied with a blanking plate as illustrated in Figure 3.28.

Figure 3.29 Blanking plate

4. Installation

4.1 Receiving

Remove the device from its packaging and check to ensure that it has not suffered any damage during transit. If any damage is identified this should be photographed and Kehui or its representative should be immediately informed, with copies of the photographic evidence.

The device in its case is very robust and no special precautions need to be taken. However, to prevent the ingress of dust or dirt, it is recommended that modules are not removed from the case.

Ensure that the contents match the items in the order. The Packing List with photographs can assist this process (refer to Section 8).

4.2 Storage

If the equipment is not required for immediate use, return it to its carton and store in a clean dry place within the temperature range -40^{o} to 50 ^{o}C.

4.3 Fitting

The device should be installed inside the substation subject to a temperature not exceeding the range 0^{o} to 50^{o} C and free from excess vibration. The rack or panel in which the device is mounted should be vertical to within 5^{o}.

4.3.1 Rack Mounting

In accordance with IEC 60297, the device will fit in to a standard 19” (483mm) rack and is 2U (88mm) high. Other dimensions are given in Figure 4.1.

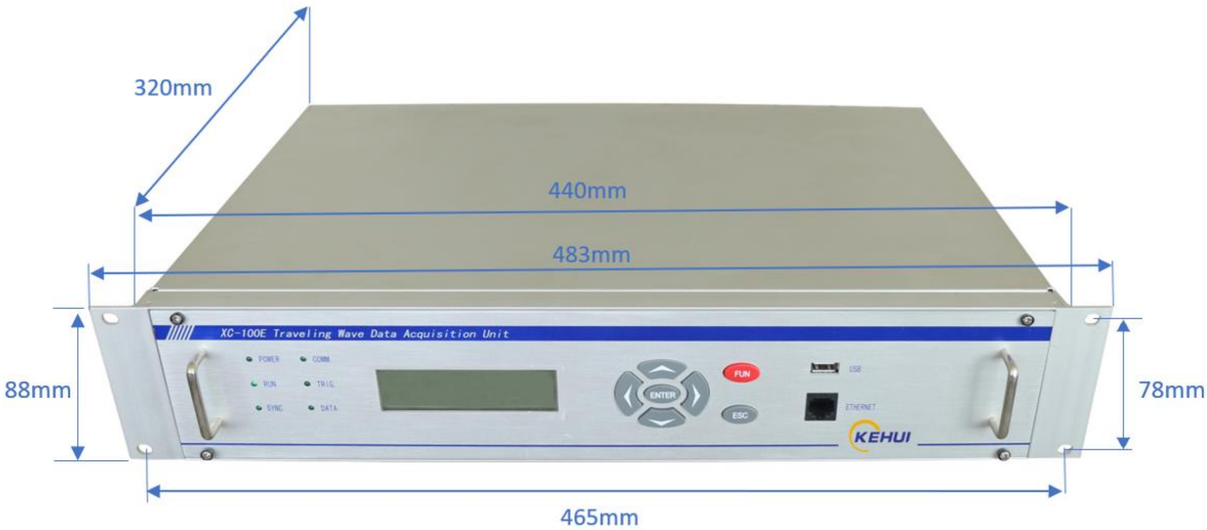


Figure 4.1 device dimensions

4.3.2 Panel Mounting

The device is also suitable for panel mounting into a cut-out in accordance with the dimensions shown in Figure 4.1, at least 5cm should be free above and below the unit to allow for heat dissipation.

4.4 Earthing/Grounding

The case earthing terminal situated on the rear of the power supply module (Figure 4.2) should be used to connect to the earth of the cubicle using a 10 to 14AWG copper conductor or a 4 mm^2 split copper conductor. The conductor should be as short as possible, to provide a reliable earth connection. The cubicle earth should be connected to the earth grid of the substation.

Figure 4.2 Device earth stud, circled in red

4.5 Power supply

The connections to the power supply are made using the 8-way terminal block shown in Figure 4.3. Crimped connectors are secured using the screws adjacent to the terminals. The wired terminal block is a push-fit into the terminals built-in to the power supply module (Figure 4.4). For a DC supply, the positive and negative connections from the battery, plus an earth are connected to the + and – terminals. For AC operation the same terminals are used (labelled L and N. For clarity the alarm and trigger connections are omitted.

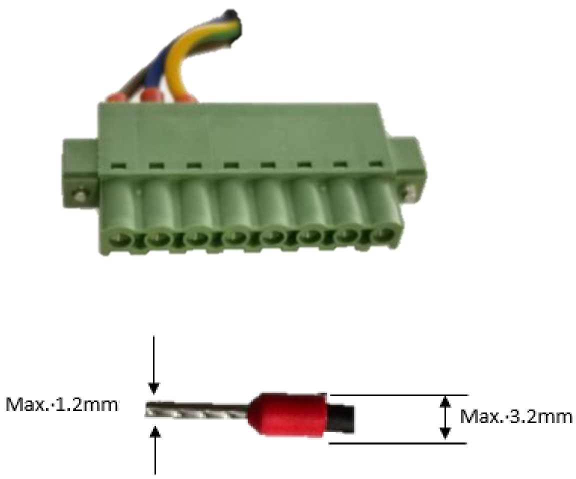


Figure 4.4 Power supply terminal block and crimp termination

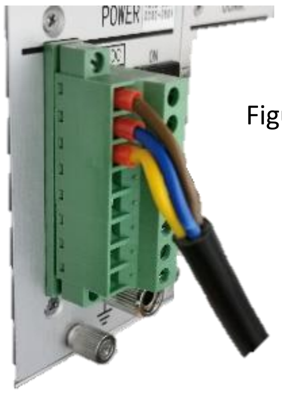
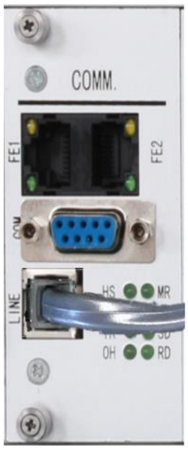


Figure 4.3 Terminal block

4.6 Communication

There are three versions of the communications module each allowing different forms of communication. Note that it is usual for some connections to remain unused.

a) Serial connection using DB9 connector: May be used for connection to some SCADA systems or dial-up modem



b) RJ11 connector: Where an internal modem is used, this will connect to the telephone line

c) RJ45 cable for connection to the master station, a gateway to the master station or a SCADA system

Figure 4.5 Connections to the Communication module

4.6.1 Point to point serial communication

XC-100E and the master computer can be connected by a dedicated point-to-point data transmission channel, which can be fibre optic or microwave (Figure 4.6). Both are interfaced via a serial RS-232 channel. The communication frequency is 1200-56000 bauds, which is selectable with the value dependent upon the line quality. Again, the number of XC-100E units depends on the application.

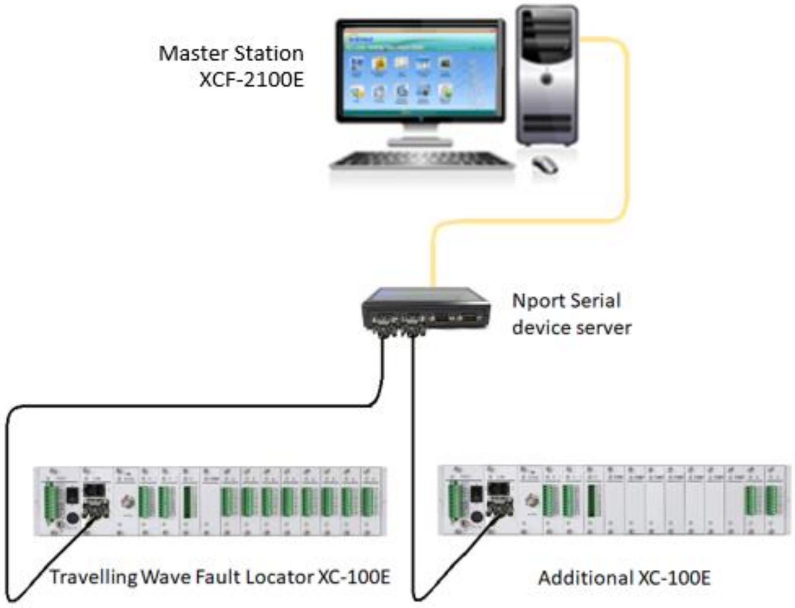


Figure 4.6 Master station point to point connection

4.6.2 Connection to a TCP/IP network

XC-100E and the master computer are connected to a TCP/IP network via either of the Ethernet ports FE1 or FE2 on the rear of the COMM. Module (Figure 4.5). The connection scheme for two devices is shown in Figure 4.7. That the maximum number of lines that can be monitored by one XC-100E unit is 8 using the AI module or 4 with the AD module. Figure 4.7 shows two devices, if only one is needed a direct connection to the Master Station can be made. If more lines are present, or there are other configurations required, additional devices may be required. Each can be programmed to replace the default IP address with a unique one to allow it to be identified in the network.

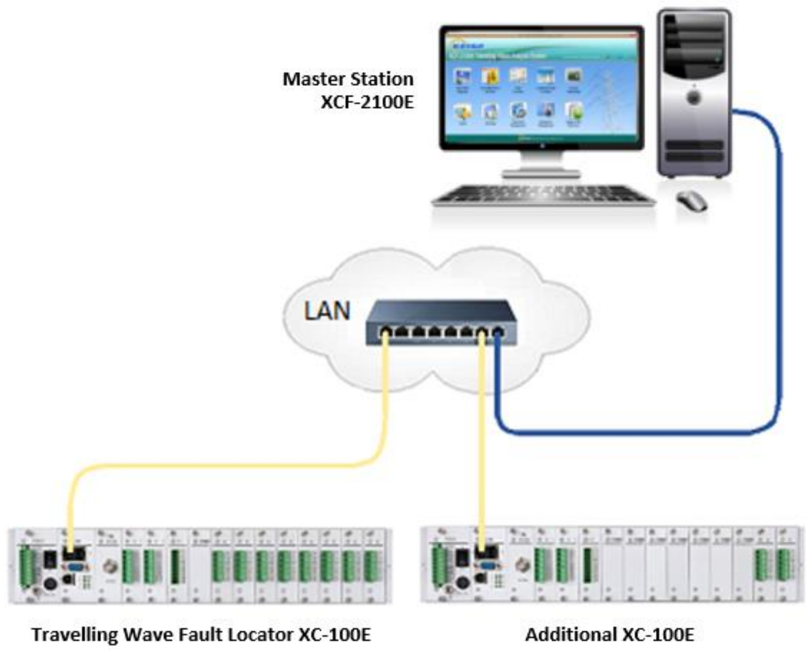


Figure 4.7 Master station connection

4.6.3 Dial-up communications

The XC-100E also supports communication mode using the telephone system. This can be achieved with the internal Modem interface connected with the RJ11 connection or by using an external Modem connected through the RS232 (DB9) or ethernet (RJ45). This connection is shown in Figure 4.8.

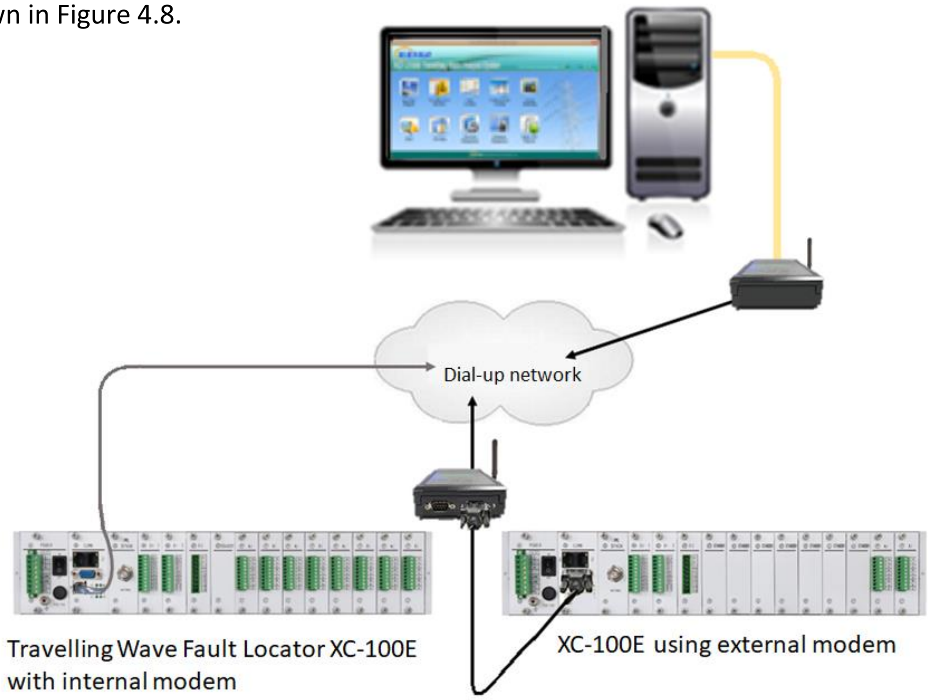


Figure 4.8 Master station dial-up connection

4.7 Time synchronisation

Depending on the Time synchronisation module selected, the XC-100E can either be arranged to utilise an internal GPS receiver or a synchronisation signal from external equipment.

4.7.1 Internal synchronisation

For internal synchronisation the XC-100E is connected directly to an antenna (Figure 4.9). The antenna must have direct access to the satellite system and hence should be in the open air away from obstructions, the angle at which the signal can be received should be in excess of 160°. Different cable lengths from 40m to 100m are available to allow this to be achieved. A lightning protection device (lightning arrester should be mounted in close proximity to, and above, the antenna. This is to ensure that in the event of lightning it will not strike the antenna which would damage the XC-100E. (Figure 4.10)

Figure 4.9 Antenna and lead

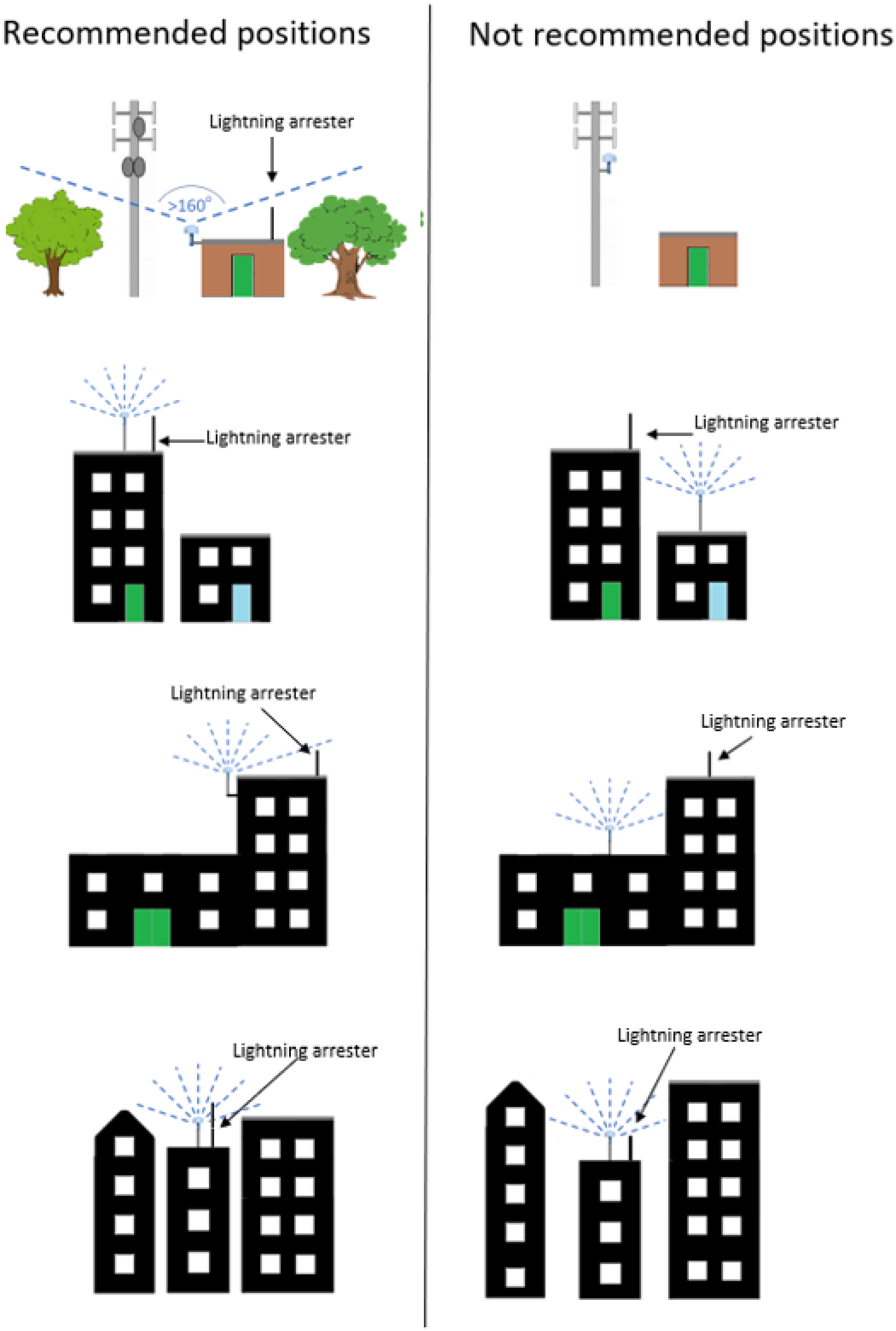


Figure 4.10 Antenna siting guidance

The antenna is supplied with a mounting kit to allow it to be fixed in position (Figure 4.11).

Figure 4.11 Antenna and mounting kit (complete assembly on the right)

For safety, the antenna should be connected in series with the surge protective device (SPD) provided (Figures 4.12 and 4.13). If possible, this should be mounted directly on to the copper earthing bar in the cabinet, if this is not possible the short earthing cable provided, should be used.

Figure 4.12 Surge protective device (SPD)

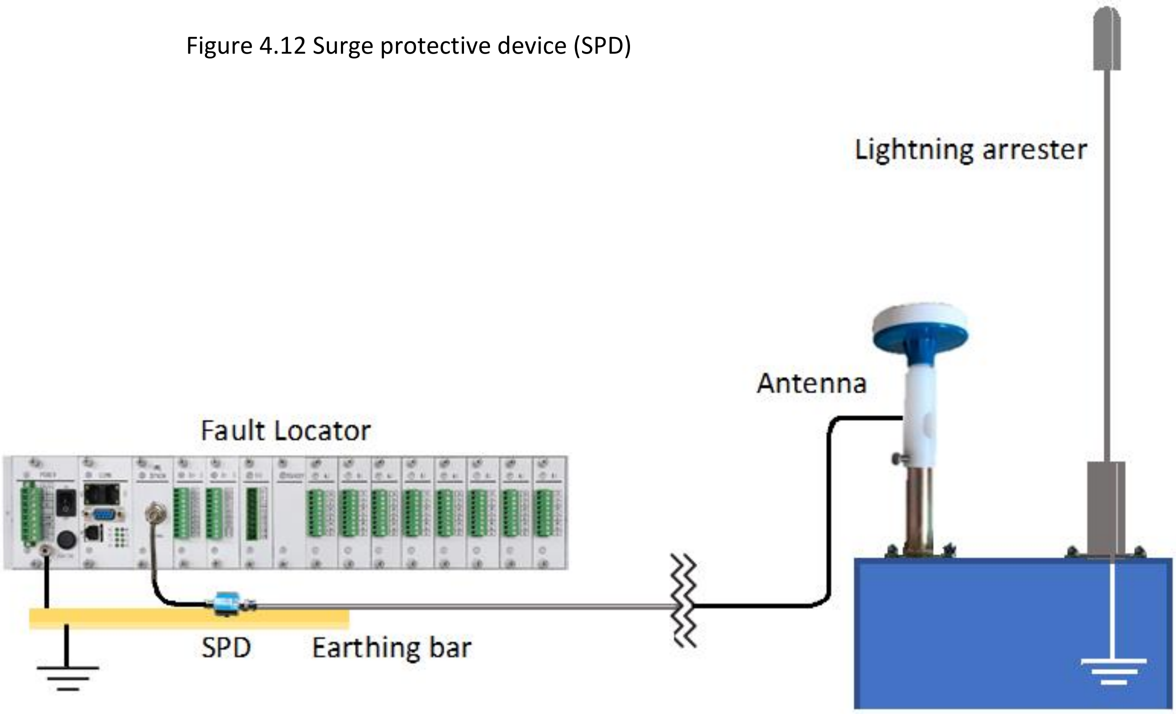


Figure 4.13 Time synchronisation with internal receiver

4.7.2 External synchronisation

Often, a master clock is available in the substation which provides a synchronising signal to all of the relevant equipment situated there. An example of such a clock is the Kehui T-GPS device, although the XC-100E can be used with most time synchronising systems. As highlighted in Section 3.3, there are a number of options depending on the time code preferred and the means of connection (electrical or optical).

4.8 Digital inputs and outputs

4.8.1 Output contacts

In addition to the alarms provided on the power supply module (Section 3.1), the device can be provided with an optional digital-out (DO) module (Section 3.5) which includes four additional relay contacts. The function of these contacts can be set by the XCF-2100E software. Connections are the same as for the power supply module as shown in Figure 4.14.

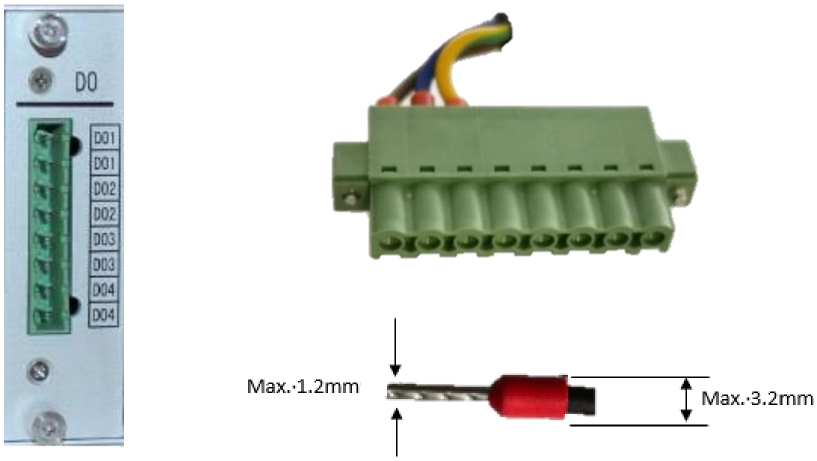


Figure 4.14 DO module connections

4.8.2 Input contacts

As described in Section 3.4, there are two types of input modules depending on whether the input is a dry contact or involves the application of voltage

The connection diagrams are shown in Section 3.4 and the method of connection is as with the DO module (Figure 4.14).

4.9 Analogue inputs

4.9.1 Indirect current connection

The indirect current connection uses the AI module. In this format, the travelling wave is captured at the secondary of the protection CT. Small clip-on CTs are provided which are fastened around the wiring from the protection CT to the protection relays. Note, do not use wiring from the metering cores on the line CT, as these may saturate under fault conditions, preventing the capture of the travelling wave.

The method of connection is illustrated in Figure 4.15. Each module is connected to three clip-on current transformers, one per phase, clipped around the corresponding wire from the protection core of the line CT to the protection equipment. The user must select whether the CT is rated at 1A or 5A when ordering the device.

The cable from the clip-on CT to the fault locator has three cores, colour-coded as brown, blue and yellow/green. The brown wires for each phase are connected to the "A" terminals (1A, 2A and 3A), the blue wires are connected to the "a" terminals (1a, 2a and 3a) and the green/yellow wires are connected to the terminals with the earth/ground symbol ⏚

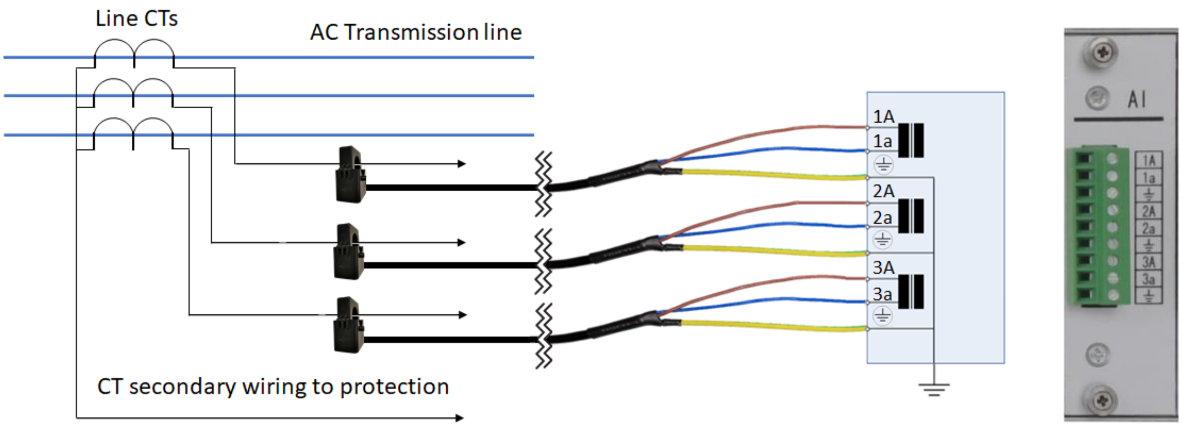


Figure 4.15 Wiring for the AI module

Figure 4.16 shows the clip-on CT provided with the AI module. The CT is clipped around the secondary wiring connecting the line CT to the system protection. The direction of the current in the secondary wiring must match the direction of the moulded arrow on the CT.

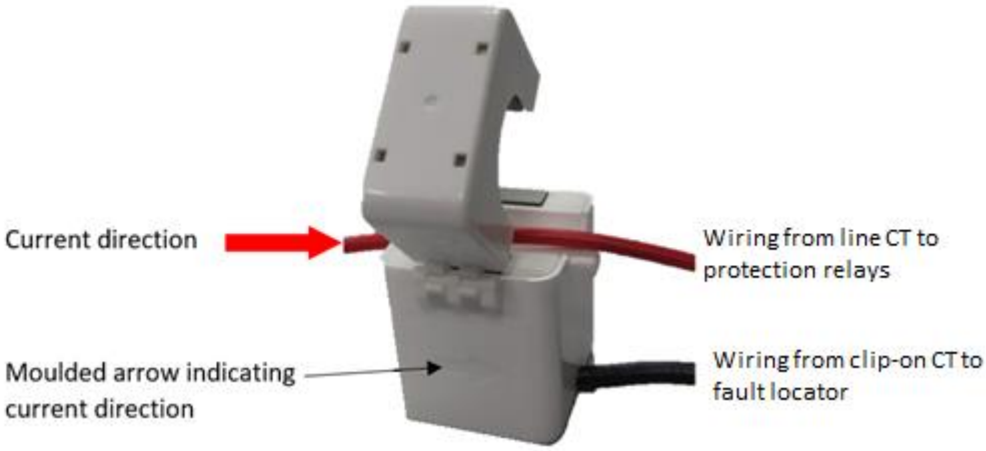


Figure 4.16 Clip-on CT

Normally, three clip-on CTs are required, one per phase, for convenience, these can be mounted on the plate shown in Figure 4.17.

Figure 4.17 CT mounting plate

The standard lead on the CT is 5m, it can be extended with additional cable of the same characteristic up to 20m. For longer distances, up to 40m, an additional primary turn is required on the CT to increase its sensitivity.

4.9.2 Direct current connection

The direct current connection uses the AD module. Its use is similar to the AI module but instead of the interposing CT, the device is connected in series between the secondary of the line CT and the system protection devices connected to it (Figure 4.18).

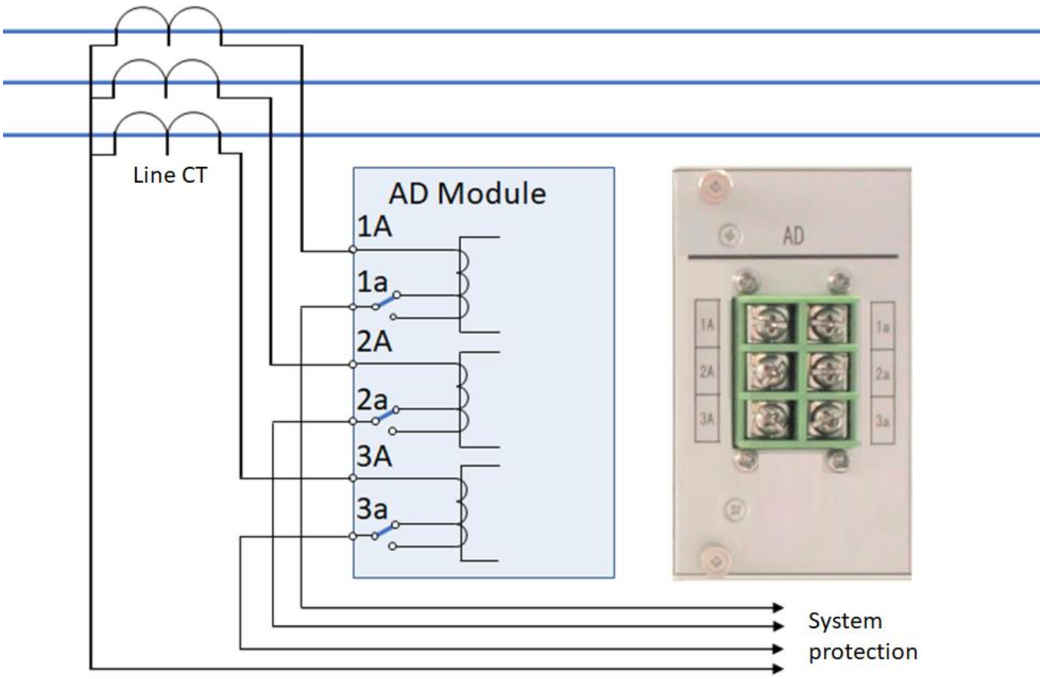


Figure 4.18 Wiring for the AD module

The module has a screw-clamp connector, the pitch between the channels is 10mm and wire diameter up to 6mm can be accepted.

The wiring should be connected using ring-type crimps (Figure 4.19). The size of the plastic insulation on the crimp must be less than 7.5mm, the maximum external diameter of the ring should be 6.4mm, with an internal diameter of 4.2mm.

Figure 4.19 CT wire crimp connector

The module contains three small CTs: CT1, CT2, CT3, one for each phase, with the following characteristics:

Nominal current	5A/1A
Burden	< 0.4VA (I_n = 5A) < 0.2VA (I_n = 1A)
Overload	4000% I_n, 1s

The links shown in Figure 4.20 allow the device to be configured for use with CT secondary outputs of 1A or 5A. Figure 4.20 shows the position of the link on the circuit board.

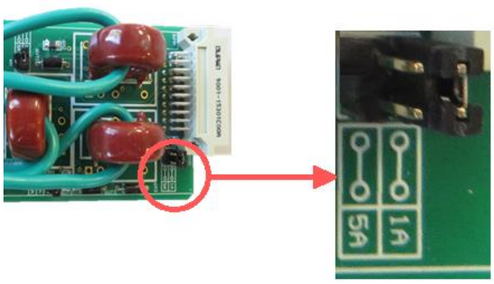


Figure 4.20 Secondary current selection link

To fit the XC-100E with the AD module, it is necessary to open the CT secondary wiring in the substation. If the substation is in service, it is important to short-circuit the output of the CT, otherwise, a dangerous voltage may be generated.

4.9.3 CVT connection

This application is explained in Section 1.5.4 and requires CTs to be positioned around the earth connections of the CVT. These are situated in cabinets in the substation yard and are connected to the XC-100E through cables connected to the AD module (Figure 4.21). These cables can be up to 2km long and must be considered as part of the measured distance to fault. The cable cabinet is shown in figure 4.22.

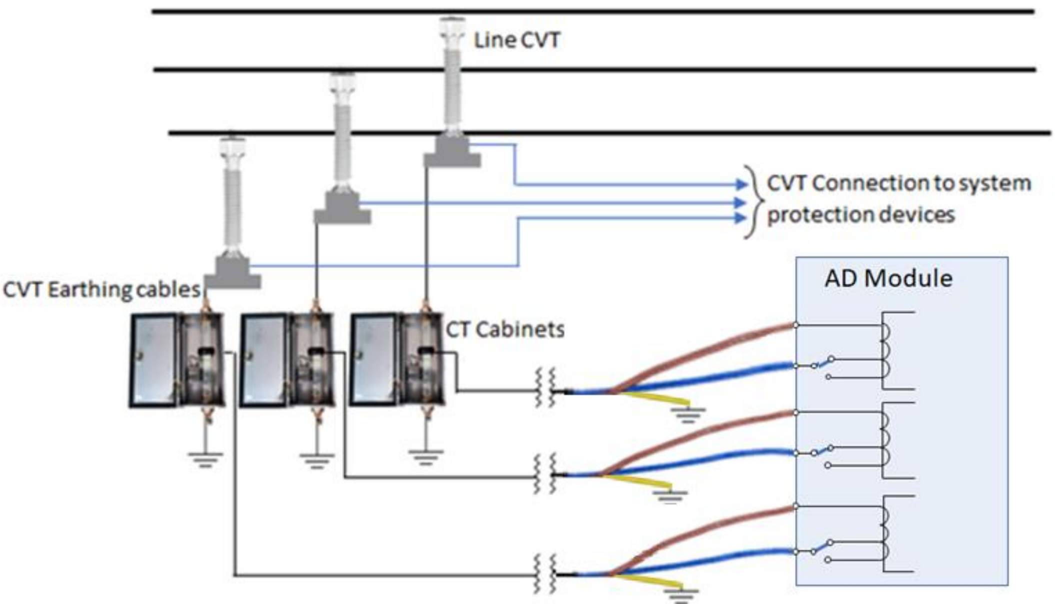
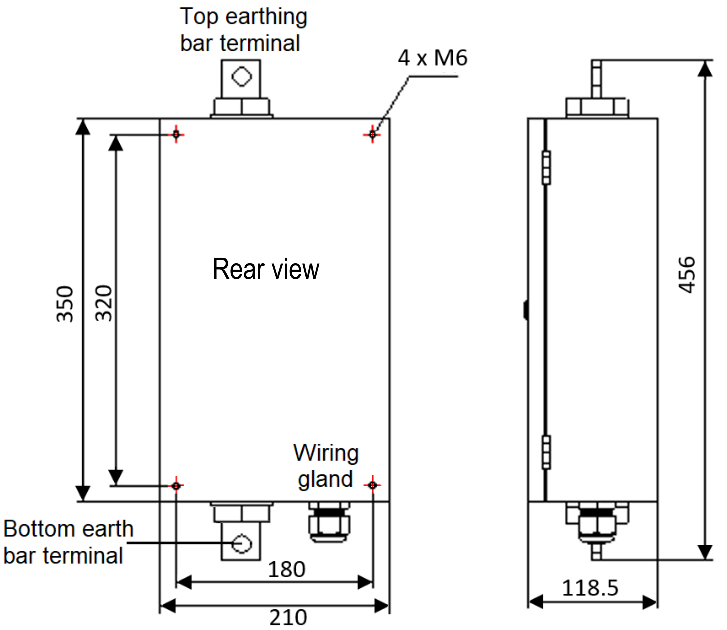


Figure 4.21 Wiring for connection to CVTs

The external toroidal CT has the following characteristics:

Nominal secondary current	1A or 5A
Overload withstand	400%I_n, continuous 4000% I_n, 1s.
Ratio	200:1.
Dimensions	103mm (H) x 80mm (L) x 26.5mm (W)
Hole diameter	44mm.
Connection cable	Up to 2km (not supplied).
Cabinet dimension	250mm (H) x 150mm (L) x 120mm (W).



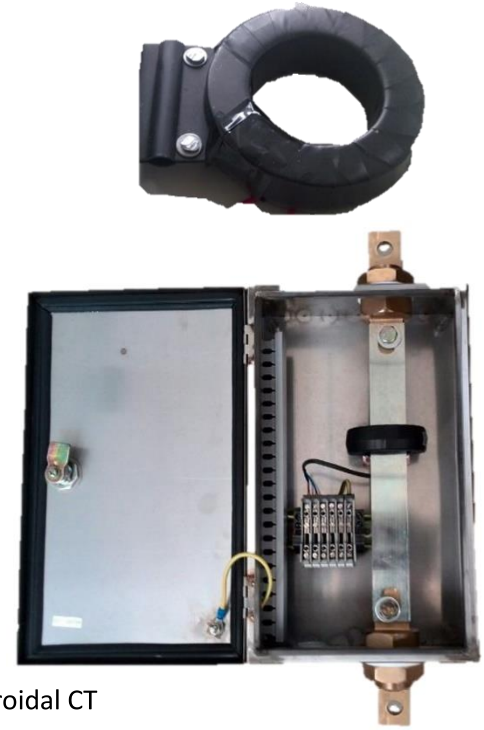


Figure 4.22 External CT mounting box and toroidal CT

The line to which the CVT is attached should be de-energised before the installation is attempted.

Three CT mounting boxes should be installed as close as possible to the CVTs. Mounting the boxes requires four M6 screws at the rear.

The earth connections on the three phases should then be opened. If necessary, cut the earth cable, and attach it to the 16mm holes on the bar through the CT mounting box.

The cable to the XC-100E is fed through the gland in the bottom of the cabinet. The connection to the CT secondary can be found inside the box adjacent to the earth bar. The cable has two 1mm^2 conductors plus a shield. The brown wire is connected to the terminal on the left and the blue wire on the adjacent terminal.

Do not connect the shield to this terminal, it must only be earthed at the far end, on the cubicle where the XC-100E is installed, otherwise a very dangerous loop will be created.

If an AI module is used in place of the AD, clip-on CTs are also required. The brown and blue wires are connected together at the cubicle and looped through the clip-on CT in the same manner as in Figure 4.16.

4.9.4 Inductive voltage transformer connection

This application for which this connection is used, is explained in Section 1.5.3. An AV module is fitted, which is connected to the secondary of a potential transformer of a substation as an input.

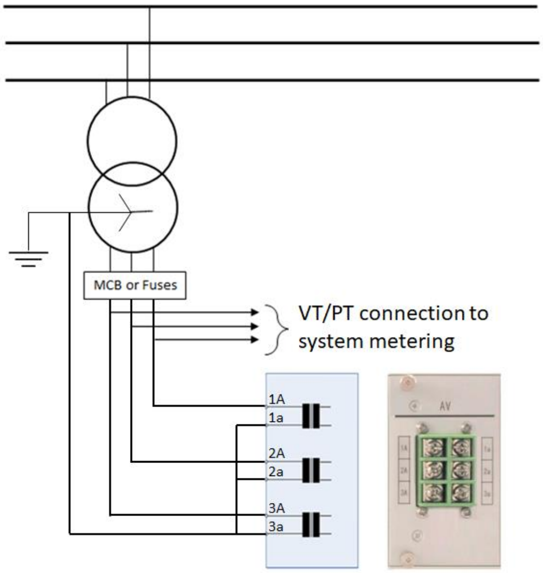


Figure 4.23 Wiring for connection for the AV module

The circuit breaker (MCB) should be opened, or the fuses removed before installing the device due to the presence of high voltages.

The AV module has similar terminals to the AD module and wiring termination uses the same ring type crimps shown in Figure 4.19, Section 4.9.2.

4.9.5 DC Systems

The application for DC Systems is explained in Section 1.5.5 and requires a CT to be positioned around the earth connections of the filter capacitor. This is situated in a cabinet in the substation yard and is connected to the XC-100E through cables connected to the AD module (Figure 4.24). These cables can be up to 2km long and must be considered as part of the measured distance to fault. The cabinet and CT are identical to those in Section 4.9.3 Figure 4.22.

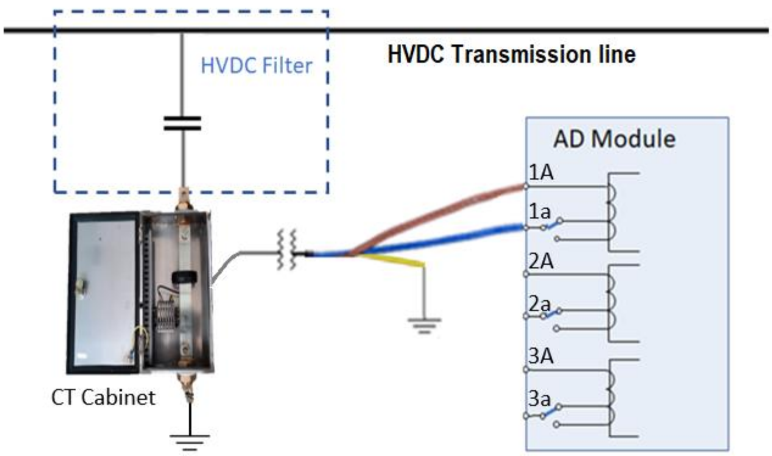


Figure 4.24 Wiring for connection for HVDC systems

The line to which the CVT is attached should be de-energised before the installation is attempted.

The CT mounting box should be installed as close as possible to the filter capacitor. Mounting the box requires four M6 screws at the rear.

The earth connections on the three phases should then be opened. If necessary, cut the earth cable, and attach it to the 16mm holes on the bar through the CT mounting box.

The cable to the XC-100E is fed through the grommet in the bottom of the cabinet. The connection to the CT secondary can be found inside the box adjacent to the earth bar. The cable has two 1mm^2 conductors plus a shield. The brown wire is connected to the terminal on the left and the blue wire on the adjacent terminal.

Do not connect the shield to this terminal, it must only be earthed at the far end, on the cubicle where the XC-100E is installed, otherwise a very dangerous loop will be created.

If an AI module is used in place of the AD, a clip-on CT is also required. The brown and blue wires are connected together at the cubicle and looped through the clip-on CT in the same manner as in Figure 4.16.

4.9.6 System overview

Figure 4.25 shows a single line diagram of a hypothetical network. Substation A has eight lines connected to the busbar and all of these can be monitored with a single XC-100E with eight AI modules connected to the protection cores of the line CTs. Ideally all of the lines should have a fault locator at both ends in order to give the most accurate automatic results.

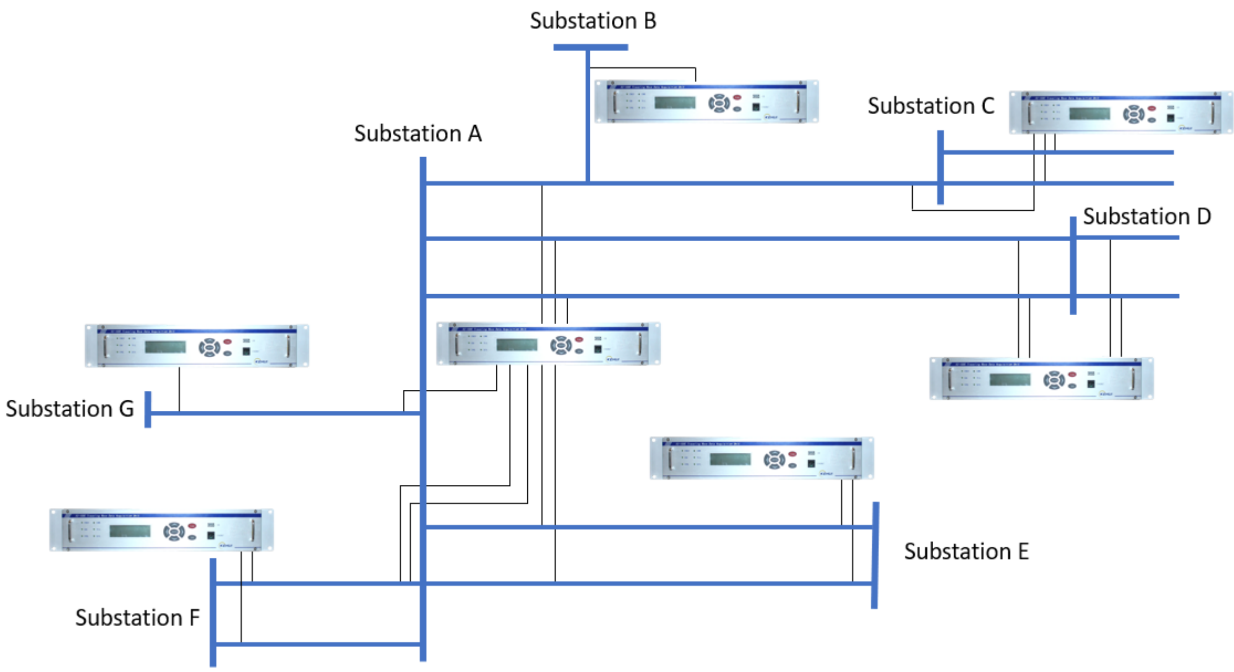


Figure 4.25 Network with XC-100E Travelling Wave Fault Locators

At Substation B there is only one line connected to the busbar and so it is necessary to detect the voltage travelling wave. In this case, the only voltage connection available is an inductive VT (PT) used for the metering in the substation, hence, the XC-100E is fitted with a single AV module. At Substation C three lines are connected to the busbar and either three AI modules or three AD modules can be used. If the fault locator is being fitted to a live substation, the AI modules are generally preferred, as they can be fitted without disturbing the existing CT wiring.

Substation D has four lines to be monitored and hence, four AI or AD modules are used. Substations E and F both have two lines to be monitored and correspondingly each unit has two AI or AD modules. Finally, substation G has a single line, but has a CVT feeding the local protection system. In this case a cabinet containing a CT is inserted between the CVT earthing connection and the earth. The CT is connected by a lead across the switchyard which is connected to the fault locator in an indoor cubicle. In this case, the XC-100E is fitted with an AD module, although an AI module could also be used.

5. Menu

The local user interface consists of the LCD and the menu buttons (Figure 5.1).

Figure 5.1 User interface

The screen can be illuminated by pressing the red FUNC. Button.

5.1 Main Menu

The local user interface allows the status of the equipment to be checked, including settings, recordings and connections via the front panel buttons.

When the equipment is turned on, the LCD will light-up and go through a start-up check and, after a few seconds, the following message will be displayed.

KEHUI

XC - 1ØØE

- - - - - - - - - - - - -

26–05-2021 14: 15 :50

The date and time appear at the bottom of the display in the format:

DD-MM-YYYY; HH: MM: SS.

After 30 seconds, the backlight turns off and will illuminate again when any button is pressed. The main menu can be accessed by pressing ENTER for more than 2 seconds, providing the following screen:

```
Record  Summary
SOE
Parameter
USB
OPtion
Device information
```

The ▼▲ arrows are used to move up or down, and the ENTER button to select the relevant option. Pressing the ESC will return the user to the previous screen.

5.2 Record Summary

With this selection, access is gained to the following screen.

```
View Record Summary
Clear record Summary
```

Selecting View Record Summary provides a list of fault records for the device.

```
01      26-05-2021  08:04:01. 483807.8
02      26-05-2021  09:13:41. 425031.4
03      25-05-2021  10:09:57. 214303.5
04      23-05-2021  15:55:27. 742333.0
05      20-05-2021  23:14:52  564499.6
06      16-05-2021  14:39:16. 303776.1
```

The time of the event is measured at a fraction of a microsecond. The list can be viewed with the ▲ arrows. The last 30 records can be viewed.

Once a record is selected, press ENTER to retrieve the fault information.

```
01    26-05-2021  08:04:01. 483807.8

  Trigger Channel :               01
```

The second selection is to delete records; the command is followed by the message:

```
        Clear Record Summary
Password :

            ØØØØ
```

To ensure data security it is necessary to enter the password. The default password appears as four zeros with a cursor under the first digit, this can be changed in Option (see Section 5.1.8). The number is entered using the ▼▲ arrows until the correct digit is selected. The ▶ arrow moves the cursor to the next digit, similarly ◀ will move the cursor to the left. Pressing ENTER will delete the records.

A warning will be given not to turn the device off then a message will indicate that the SD card (the storage medium) has been cleared. The records have now been erased and a message will appear when View Record Summary is selected stating "No Record Summary".

5.3 Sequence Of Events (SOE):

Selecting SOE will give access to the event records, these differ from the fault records in the previous selection, as they include loss of the GPS connection and triggering.

01	26-05-2021	08:04:01. 483
02	26-05-2021	09:13:41. 425
03	26-05-2021	09:12:33. 315
04	25-05-2021	18:33:54. 119
05	25-05-2021	10:09:57. 214
06	25-05-2021	08:03:22. 864

Information about the nature of the event can be obtained by selecting it with the ▼▲ arrows and pressing ENTER.

```
01.     26-05-2021     08:04:01. 483

   Device triggered
```

Note: this information will be lost if the XC-100E is a) switched off or b) after a software reset.

5.4 Parameter

This selection allows equipment settings to be read and modified. It is commonly used to change the IP addresses of FE1 and FE2 as required by the utility's communication network department. For other settings, it is normally better to make changes using the XCF-2100E software, particularly if the changes are complex. Selecting Parameter and pressing ENTER results in the following screen:

```
Line Parameter
FE1
FE2
Time zone setting
Save
```

Selecting Line Parameter gives the following screen.

Items : ■ ■ ■	Channel: Ø1	Line : Ø1 AI
Gain	Threshold	Setting
1ØØ %	Ø8 . %	14Ø %

The black marks correspond to each of the analogue input modules included in the device. Individual modules can be selected using the ▶ ◀ arrows, the channel number refers to input module selected.

The display shows the line number and the type of module (in this case AI). The settings shown are:

- The Gain setting allows the sensitivity of the system to be changed by amplifying the received signal. This allows the system to be sensitised to allow smaller signals to be identified or desensitised to prevent spurious operation. It has a default value of 100%.
- The Threshold (trigger) setting for which the default is 8% of the maximum current peak, which is defined as follows:

$$\text{maximum current peak} = \frac{1.41 \text{ x Line voltage}}{300\sqrt{3}}$$

Where 300 Ohm is the typical high frequency line impedance.

- The Setting value is an overcurrent value and is a percentage of the power frequency (50 or 60Hz) nominal current (1 or 5A). It helps prevent spurious operation by checking for the presence of fault current and helps reject operation for high frequency phenomena, such as lightning.

To change the setting, press ENTER and the cursor will appear under the first digit of the gain value, using the ▶ ◀ arrows, it can be moved to the Threshold or Setting values. Once the value to be changed is selected, the ▼▲ arrows can be used to change it. When all the settings have been changed, the Enter key is pressed, followed by ESC. This returns the user to the main parameter screen, where the ▼ arrow is used to select Save

```
   Line Parameter
   FE1
   FE2
   Time zone setting
■  Save
```

Pressing ENTER displays the Password screen with the cursor under the first digit of security number which is set using the ▼▲ arrows. The ▶ ◀ arrows can be used to select different digits.

```
                  Save
Password :

                  ØØØØ
```

When the security number has been entered, press ENTER. If the security number is wrong, a message stating Password Error! will appear and the system returns to the previous screen. If the number is correctly entered a final prompt is given to allow the setting to be made.

```
Do You want to save?
          YES          NO
```

There will then be a delay as the system reboots and goes through some internal checks, it then returns to the main menu page with the new settings saved.

5.5 FE1 and FE2

FE1 and FE2 are the "Fast Ethernet" ports on the communications module, accessible at the rear of the device. The settings to allow external equipment to communicate with them are accessed on the main parameter screen. The settings for FE1 and FE2 are done in the same way. The required port is selected using the ▼▲ arrows and then the ENTER button is pressed to access the address page.

```
Line Parameter
FE1
FE2
Time zone setting
Save
```

The address page provides the parameters to allow the port to be accessed from external equipment such as the master station computer.

```
IP Address          : 172.168.001.100
Gateway             : 172.168.001.254
Net Mask            : 255.255.  0.  0
Port                : 2404
```

To select the parameter to be modified (IP address, Gateway etc.) the ▼▲ arrows are used and then the ENTER button is pressed. The cursor will move to the first digit of the address value. This can now be changed using the ▼▲ arrows. The ▶◀ arrows will move the cursor to other parts of the address. Settings are saved by pressing ENTER, then ESC then selecting Save, in the same way as Section 5.1.3.

5.6 Set time zone

Select time zone setting from the Parameter menu and press ENTER;

```
Line Parameter
FE1
FE2
Time zone setting
Save
```

The screen will show the time zone in terms of UTC. Initially the cursor will appear below the plus or minus sign, pressing the ▼▲ arrows, will toggle between them. The other numbers can be changed in the usual way and saved as with the other parameters.

```
UTC + Ø1 : ØØ
```

5.7 USB memory

The XC-100E configuration, record summary and record data can be exported to a USB memory inserted into the device front panel. USB can then be selected on the main menu.

```
   Record Summary
   SOE
   Parameter
■  USB
   OPtion
   Device information
```

When the ENTER key is pressed, If the memory cannot be read, the following message will appear:

```
U disk mount fails!
```

If the memory is accessible the following menu appears:

```
■  ExPort
   UPdate
   Remove
```

Selecting Export gives the following window:

```
▄▀     Configuration
       Record Summary
       Record data              ( Total : 0000  )
         Number  Of  Latest  Records :
          1 0 0    2 0 0   5 0 0   ALL
     Done
```

Select either or both of these files for export:

- **Export configuration:** to export the device configuration
- **Export record summary:** to export the records list

Once the files are selected, also select Record data, which allows the amount of data to be exported to be selected. Using the ▶ ◀ arrows either 100, 200, 500 or all the files can be selected. Finally, with the vertical arrows, select Done, and press Enter to confirm the export. The display prompts for the password (default: 0000), and then displays the following messages:

```
CoPy   TDU100E.CFG comPleted!

CoPy   INDEX.DAT comPleted !
```

When finished, press the ESC button; then, in the main page, select Remove and press Enter: the message is as follows:

```
   ExPort
   UPdate
▄▀ Remove

          Safe remove!
```

The memory can then be safely removed.

5.8 Update

It is possible to update configuration file or the firmware.

- The configuration file will be prepared in a USB memory with a directory named UPCFG. In this directory, the firmware configuration file named TDU100E.CFG is copied. **Note**: CAPITAL letters are used in the configuration file.
- New firmware releases will be prepared in a USB memory with a directory named UPPRO. This directory contains all the firmware upgrade files for uploading into the XC-100E. **Note**: CAPITAL letters are used.

To Update, first select Update in the main page, and press ENTER.

```
   ExPort
 ▬ UPdate
   Remove
```

The resultant window offers two choices.

```
   Update Configuration
 ▬ Update firmware

   Done
```

One or both of the options can be selected. To carry out the update, the cursor is moved to Done, and the ENTER key is pressed. Where both updates are selected, after the password introduction, the display will be:

```
Update OK :        xc.cfg
USB
Update OK :
   UPdating…, do not Power off !
```

The first line confirms that the XC-100E has been configured. The second line identifies whether the firmware upgrade is in progress or finished.

Do not power the unit off during the firmware upgrade.

When the upgrade is complete the display advises that the USB memory should be removed:

```
Unplug the U disk, Please!
The update is complete, reboot!
```

After this message above XC-100E will reboot and the new firmware is installed.

5.9 Option

Selecting Option on the main menu allows the language and the password to be changed.

```
   Record Summary
   SOE
   Parameter
   USB
 ▬ OPtion
   Device information
```

Select Option and press ENTER

Languauge Setting Set Password

There is a choice between setting the menu language and setting the password. If a different language is required, select Language Setting and press ENTER;

■ English French Russian Done

Select the required language, move the cursor to Done and press ENTER, the device will reboot and the menu will appear in the language selected.

If it is required to change the password, select Option as before, then select Set Password.

Language Setting Set Password

This reveals the password setting page

Old Password :	0000
New Password :	1234
Re-enter :	1234
Save	

Select Old Password and press ENTER and a cursor will appear below the first digit. This can be changed using the ▼▲ arrows. Then use the ▶ ◀ arrows to move to the other digits and change these in the same way. When the password is complete press ENTER. Then select New Password and repeat the process to enter the new password and finally, select Re-enter and put in the new password again. Once this is complete, select Save, a prompt appears to confirm that the change should take place.

Do You want to save?	
YES	NO

Select YES to change the password and press ENTER. The screen will refresh, then press ESC. A message will advise that the password has been reset successfully.

If the Password is forgotten, contact info@kehui.com for assistance.

5.10 Device information

The final section of the main menu includes various device data

```
    Record Summary
    SOE
    Parameter
    USB
    OPtion
▀▀  Device information
```

Selecting Device information and pressing ENTER produces the following screen:

```
ID :    20200704914        V 2. 0. 2. B
FE1 :  172.   16. 200. 179
FE2 :  172.   16. 200. 171
SYNC. :  GPS                UTC+01 :00
Channel :   03             2   MHz     1ms
```

The elements of the screen are as follows:

- ID: Device firmware number, followed by the version number.
- FE1: The IP address of the FE1 ethernet port at the rear of the unit and the front port.
- FE2: The IP address of the FE2.
- SYNC: The synchronisation method, in this case GPS.
- UTC: The selected time zone.
- Channel: The number of channel in the device, each module has three channels, one per phase.
- The sampling rate is 2MHz/1ms.

5.11 FUNC. button

In the unlikely event that there is a need to reboot the device, this can be achieved by pressing the ENTER button and, without releasing it, quickly pressing the red FUNC. button

```
                 Reboot
     Password :

                ØØØØ
```

Submitting the password and pressing ENTER will cause the device to reboot.

The FUNC. button has some additional functions associated with it, acting as a menu shortcut;

- Press FUNC and then ◀ : the screen displays the list of records;
- Press FUNC and then ▶: the screen displays the list of events;
- Press FUNC and then ▲: the display shows the last record;
- Press FUNC and then ▼: the display shows the last event.

6. Commissioning

6.1 Introduction

These instructions allow the user to test the XC-100E hardware, they include testing the communications with the master station. The initial test is to check the time synchronisation, followed by the triggering circuit to show that the unit will react to the receipt of a travelling wave. (This can be done either with a battery or a dedicated test unit, available as an accessory). Finally, the communication between the device and the master station is proved.

6.2 Synchronisation

Synchronisation is achieved either internally, with a direct connection to an antenna, or externally from a substation clock (with a number of different formats available). In either case, a proper synchronisation signal will result in the SYNC. LED illuminating. If a synchronisation alarm has been allocated in the optional DO module, this should be monitored to make sure the it is open. Lack of synchronisation will also cause the alarm contact in the Power module to close. Removing the synchronising signal from the Time SYNC. module should cause it to close and the SYNC. LED to extinguish.

If the synchronisation is internal and the SYNC. LED does not light-up, it could indicate that the antenna requires repositioning.

6.3 Battery induced signal test

The simplest method of testing the triggering of the XC-100E is to pass a connection from a 9V battery through the current transformer attached to the AI or AD module in the device (Figure 6.1).

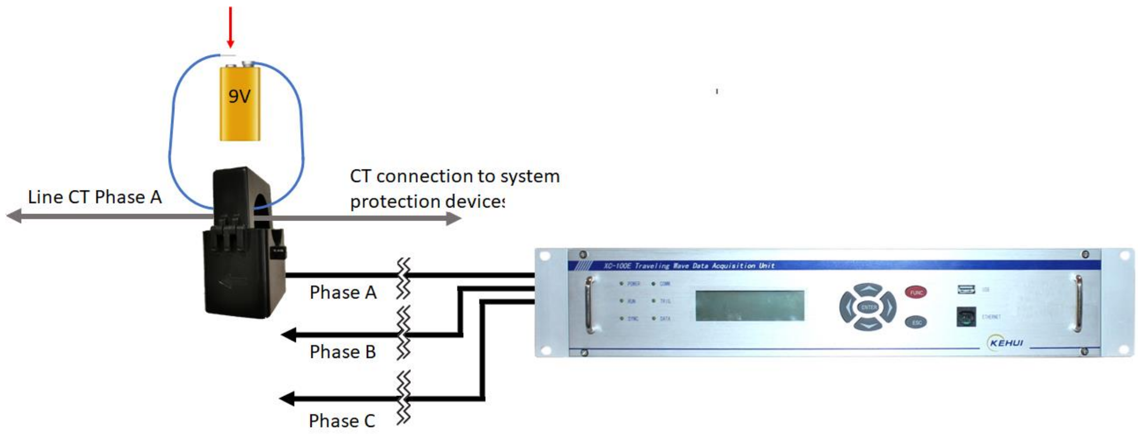


Figure 6.1 Battery circuit with AI module to induce signal in trigger circuit

Momentarily completing the circuit will induce a signal on the current circuit which will simulate the travelling wave, leading to the triggering of the XC-100E, this will operate the TRIG. LED on the device frontplate and provide a record which can be accessed from the front panel (Section 5.2).

If the AD module is used, the input circuitry must be accessed through the test plug. Figure 6.2 shows a test cable with male DB9 plugs on each end (not supplied); this is shown for clarity, any appropriate means of accessing the correct terminals of the AD test socket may be used. The travelling wave can be simulated by momentarily touching the appropriate terminals with leads connected to the battery.

Phase A: pins 5 and 9
Phase B: pins 4 and 8
Phase C: pins 3 and 7

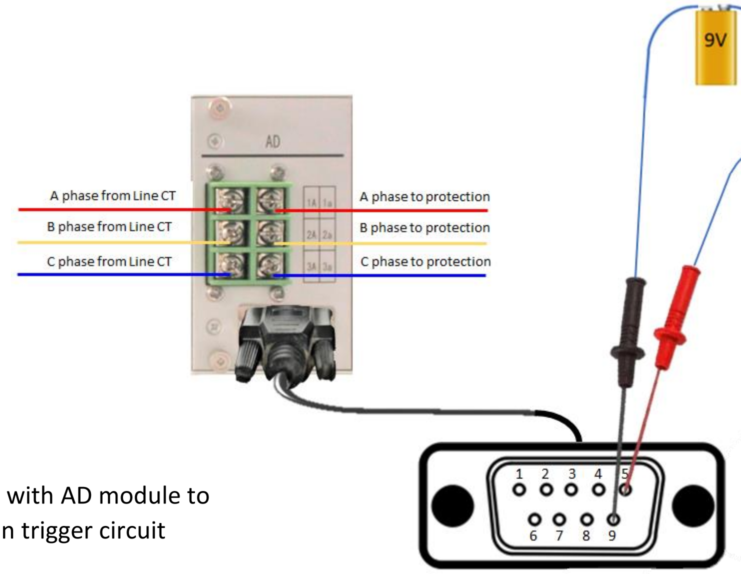


Figure 6.2 Battery circuit with AD module to induce signal in trigger circuit

Contact must always be momentary, a prolonged short-circuit of the battery could be dangerous.

6.4 TSG-10 Impulse generator

The TSG-10 (figure 6.3) is an optional accessory which will induce a closely defined transient on to the XC-100E input circuitry, in order to simulate a travelling wave and trigger the device. The unit is provided with a charger for use with 220V, 50/60Hz supplies.

Figure 6.3 TSG-10 showing dimensions

Element	Description
①	Charger input
②	Trigger output, for injecting the pulse (BNC)
③	DI (Digital input): to receive confirmation of trigger from the TRIG. output contact on the XC-100E power supply module (BNC)
④	On/off switch
⑤	Six position switch 0.1 A (6) to 2.0A (1) see label
⑥	Trigger button:
⑦	Trigger indication
⑧	Power on indication
⑨	DI (Digital input): to receive confirmation of trigger from the TRIG. output contact on the XC-100E power supply module

Figure 6.4 TSG10 Description

6.4.1 Test set-up

A) AI Module: Connect the system as shown in Figure 6.5. Connect the two crocodile clips on the Trigger cable together, having passed the cable through the interposing CT connected to the AI module. The DI lead is connected to the TRIG. output on the Power module.

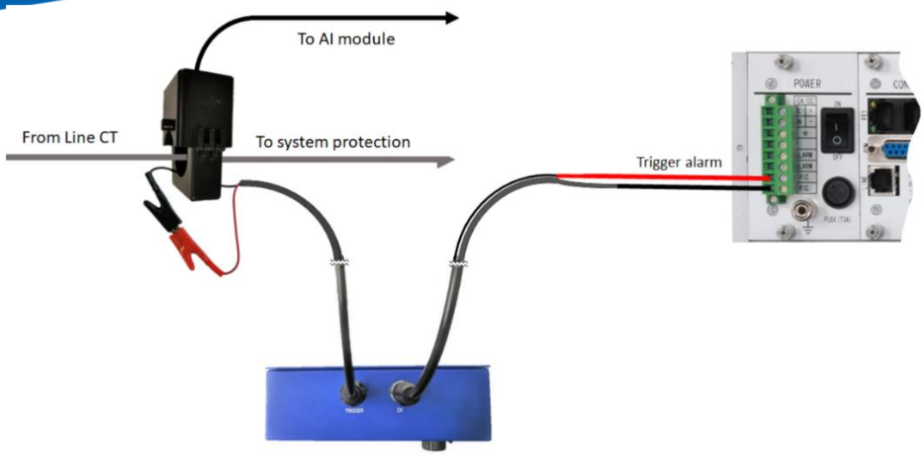


Figure 6.5 TSG-10 connections

B) AD Module: The AD module is fitted with a DB9 female test plug which allows a simulated travelling wave to be injected on to the current circuit. A DB9 connector with a standard serial cable pigtail will give access to this. The pins can be identified as follows:

Phase	AD Module Connection	Equivalent DB9 terminal	Wire colour on pigtail
A	1A	3	Red
A	1a	7	Blue
B	2A	4	Orange
B	2a	8	Purple
C	3A	5	Yellow
C	3a	9	Grey
	Unused	1	White
	Unused	2	Brown
	Unused	6	Green

The connection to the TSG-10 is shown in Figure 6.6 (wired for the A phase). Connection is made to the pigtail with crocodile clips on a cable from the device's Trigger BNC cable. The DI BNC connector is connected to the TRIG. output of the Power module on the XC-100E device.

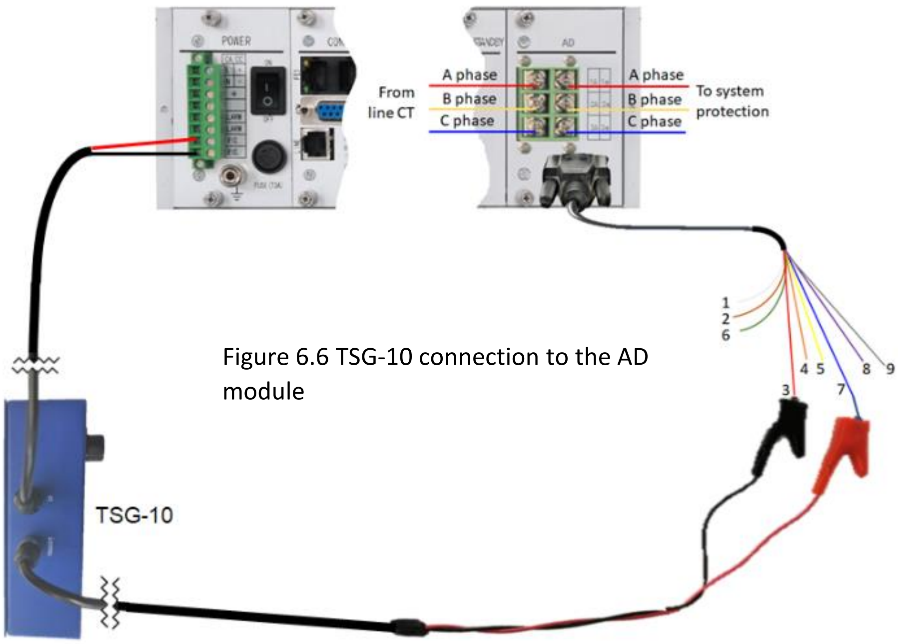


Figure 6.6 TSG-10 connection to the AD module

6.4.2 Test procedure

Pressing the TRIGGER button on the TSG-10 (see diagram in Figure 6.4 item ⑥), will cause a signal to be induced on the current input which will trigger the XC-100E. The trigger contact on the Power module will close, causing the DI light on the TSG-10 to illuminate.

The XC-100E will record the pulse. Check the record summary from the front panel (Section 5.2) or by using with the XCF-2100E software. The recorded phase should be the one that is connected; otherwise, correct the connection. This should be repeated for each of the phases. If the pulse is not recorded its magnitude can be adjusted on the TSG-10 using the six-position switch.

If the XCF-2100E software is connected, the polarity of the connection can be checked in the recorded waveform. If it is positive (Figure 6.7a), the connection is correct; if it is reversed (Figure 6.7b) check that the wiring is correct. If this cannot easily be corrected the polarity can be reversed in the software.

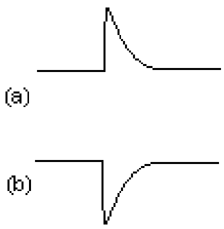


Figure 6.7 Wave polarity

6.5 Communication test with the master station software

After confirming that XC-100E triggers and records normally, the communication between XC-100E and the master station should be tested. The XCF-2100E software must be installed in the master station (see the XCF-2100E software manual for full details). The process will differ depending on the communication medium used.

6.5.1 Point to point communication

In this case, the master station continuously accesses the XC-100E, which transmits data after triggering and recording (Section 4.6.1). To test this, a fault can be simulated, as shown in Sections 6.2 or 6.3 and the master station must be checked to confirm that it has received the data. A software-initiated trigger as described in the XCF-2100E manual, can also be used for this test, this has the advantage that the entire system, involving multiple units is tested.

Once the fault has been initiated the following data should be checked. The XCF software in the master station should record the trigger time, the substation name and line designation allocated to the device. Usually, real-time communication is used between the XC-100E and the master station. In this case, records are received in a matter of seconds.

Note that the master station name and the line name in the TDU unit and the TAS software must match. If the they are not the same, the record will not be recorded as it cannot be put in the correct place in the database.

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6.5.2 TCP/IP Ethernet communication

The Ethernet communication is also real time communication; hence the test is similar to the point-to-point communication in the previous section.

6.5.3 Dial-up communication

In this case, the dialling communication is used for the data exchange between XC-100E and the master station with XCF-2100E. The test is similar to the previous sections, except that the dialling communication is tested by checking the records in the Master Station. The process is not automatic and takes more time than the other methods. For details, reference should be made to the dialling communication section in the XCF-2100E User Manual.

7. Maintenance and trouble shooting

7.1 Maintenance

7.1.1 Regular inspection

The device should be inspected periodically. If a problem is identified and cannot be solved by the user, contact info@kehui.com or the nearest Kehui representative.

Regular inspection should include the following checks:

- the environment is clean and well-ventilated and the XC-100E is free of dust.
- the temperature of the cabinet is normal, it must not approach 50°C, which is the withstand temperature of the device.
- the Power LED is on and the SYNC and COM LEDs are flashing normally.
- the connections on the rear panel fit firmly.

7.1.2 Maintenance test

Every three years it is advisable to perform a thorough commissioning test to verify that the device is working correctly.

First check whether the device signals an internal failure. Power-on the device, check the abnormal operation alarm contact (marked ALARM) on the back panel with a multi-meter. If the contact is open, the device is working normally. If it is not open, it is faulty.

Check whether the device can start, record and transmit data normally. The test is similar to the commissioning test explained earlier.

7.2 Troubleshooting

If problems arise with the equipment, firstly check all of the connections and ensure the modules are inserted correctly. If problems persist, the below trouble-shooting procedures should be followed.

7.2.1 The power LED is off

This may be due to one of the following:

- Check the power switch is on.
- The fuse has blown. To confirm this, switch off the device, remove the fuse from the rear of the power module and check it presents a short circuit by using a multi-meter or continuity checker. If it is open-circuit, replace it with a type F3A fuse.
- Measure the voltage of the external power source to ensure the voltage is sufficient.

7.2.2 The RUN LED does not flash

Restart the XC-100E by turning the power switch off and on again.

7.2.3 The time synchronisation LED does not flash

This indicates that the device is not receiving the synchronisation signal. The procedure depends on the synchronisation method employed

A) Internal GPS: Check all the connections on the connecting cable and measure the integrity of the surge protective device (SPD) to ensure that it is still intact. If these are correct, check the placement of the antenna to ensure that it is in line with the requirements shown in Figure 4.10.

B) IRIG-B: Check the connection from the master clock to the Sync. module, particularly its polarity. Confirm that the clock, noting whether it matches the satellite signal (using an independent synchronised device such as a mobile phone). Confirm that the time on the XC-100E is consistent with other substation equipment fed from the same IRIG-B signal. These tests will help to identify if the problem is in the fault locator or there is an issue with the substation master clock.

C) If the module is connected using optical fibres, the integrity of the optical interfaces needs to be confirmed.

D) IPPS: Check the connection from the master clock to the SYNC. Module, in particular that the RS-485 connector fits firmly. Confirm that the clock is correct, noting whether it matches the satellite signal (using an independent synchronised device such as a mobile phone). Confirm that the time on the XC-100E is consistent with other substation equipment fed from the same 1PPS signal. These tests will help to identify if the problem is in the fault locator or there is an issue with the substation master clock.

If the module is connected using optical fibres, the integrity of the optical interfaces needs to be confirmed.

7.2.4 Internal alarm

If the equipment appears to be working, a possible cause of the alarm is that the equipment is not receive the synchronisation signal; see Section 7.2.3.

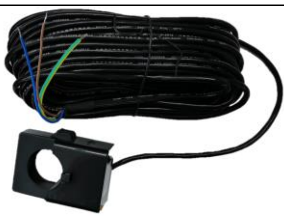
7.2.5 No data transmission

Confirm that the communication indicator on the front panel is flashing normally; if so, the data sending and receiving should also be working properly. If not, check all the connections, and the parameters to ensure the configuration is correct.

After confirming that the data sending and receiving is normal, check that the substation and line definitions of the TDU-100E unit and the Master Station are matching.

A possible cause of data not being transmitted is that a fault has occurred and one unit does not receive a fault record. In this case, a fault simulation should be performed at both ends (sections 6.3 and 6.4) to establish whether there is a communication problem.

8. APPENDIX A: XC-100E Packing list

Item	Description	Photograph	Quantity
1	XC-100E main unit. n.b. the module complement will vary. The modules provided should be checked against the order acknowledgement		1
2	Spare Fuses		2
3	10-way terminal Block (Quantity depends on the number of DI modules supplied, for 5 input DI module use)		0, 1 or 2
4	8-way terminal Block (Quantity depends on the number of DO module supplied)		0 or 1
5	Power Cable and Terminal Block		1
6	9-way terminal Block (Quantity depends on the number of DI modules supplied, for 8 inputs with 1 common point use)		0, 1 or 2
7	9-way AI module connector (one per AI module). They are not required for other AC input modules		1 for each AI module provided
8	Clip-on CT and lead, 3 CTs are used with each AI module. They are not required for other AC input modules		3 for each AI module provided

Item	Description	Photograph	Quantity
10	RJ11 Cable (for use with standard Comm. Module)		0 or 1
11	2 Ethernet cables for use with all Comm. Modules (includes 1 straight and 1 crossed lead)		1 set
12	GPS Antenna kit (for use with internal GPS time synch. Module)		0 or 1
13	Antenna Cable (for use with internal GPS time synch. Module)		0 or 1
14	Surge Arrester (for use with internal GPS time synch. Module)		0 or 1
15	Surge Arrester Earthing Lead (for use with internal GPS time synch. Module)		0 or 1
16	BNC Connector (for use with internal GPS time synch. Module)		0 or 1
17	BNC Extension Cable for Surge Arrester		0 or 1

9. Appendix B: XC-100E Optional accessories

Description	Photograph
CT mounting plate for three clip-on CTs (CTs and cables not included)	
External toroidal CT (for use in CVT and HVDC applications)	
External CT mounting box and toroidal CT (for use in CVT and HVDC applications)	
TSG-10 impulse simulator (includes BNC cable with crocodile clip, BNC cable with bare ends and charger).	
XC-100E Carry case (XC-100E unit not included)