XCF-2100E Software User Manual

(XC-2100E Travelling Wave Fault Location System)

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Safety Instructions

Safety Note:

This user manual is the basic commissioning and on-site operation guide for the XCF-2100E software a component of the XC-2100E fault location system. All operators who use the XC-2100Esystem should read the entire contents of this manual, and the corresponding XC-100E hardware 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.

1. General

The XC-2100E Travelling Wave Analysis System software is designated XCF-2100E. The system uses the XC-100E data acquisition device (in the software, this is designated as TDU, short for transient data unit) to locate faults in power transmission lines. It is installed on a Master PC in a Microsoft Windows© environment. XCF-2100E collects transient data retrieved from the various TDU units installed in the substations, and automatically calculates the distance to the fault. It also allows the analysis of the recordings, saving the list of records and recorded waveforms. The system also makes use of Microsoft Excel©. Microsoft Windows© and Microsoft Excel© are registered trademarks of the Microsoft corporation and in subsequent sections they will be referred to as Windows and Excel respectively.

A second software, called XCF-2100E WEB Information System (referred to as XCF-WEB), allows remote PCs to monitor the Master PC information, save data and print results.

This manual, which includes an overview of the theory behind travelling wave fault location, should be used in conjunction with the operator manual of the XC-100E, to give a full overview of the operation of the XC-2100E system.

1.1 XCF-2100E Functions

The functions of XCF-2100E are listed in the table below. None of these will affect the normal operation of the TDU, which is always ready to record the waveform, independently of XCF-2100E operations.

Function	Description
System management	Password management
	Parameter management
	Consistency control
	Fault simulation
	Import/export parameters
	Connection
	TDU management
Communication	Communication with TDU
	Automatic upload of fault records from TDU
	TDU remote parameter configuration
	TDU remote reset
	System monitoring
Graphic	TDU alarms
	Real time network diagram
	Link real-time data to graphics
	Graphic display of network topology and devices

Function	Description
Alarm	Real time alarm
	Search and retrieve the alarm data history
Data management	Retrieval of fault records from the database
	Waveform quick view
	Non-volatile data storage
	Import/export data
	Database back-up, delete and store
Data analysis	Waveform analysis
	Fault type analysis
	Fault statistical analysis
Fault location	Wide area location
	Automatic double-end faults location
	Computer-aided single-end fault location
	Fault location in hybrid lines and T-junction lines
Google Maps	Display and modify tower locations
	Display fault location on Google Maps
Printing	Print fault location and analysis reports
	Print statistics
Web edition	Verify the latest fault location result
	Query and analyse travelling wave data
	Query location results
	Manage transient wave recordings
	TDU operation status verification
	Waveform analysis
	Download recordings
	Display real-time diagrams
External system interfaces	Edit system information using XML files
	Edit system information using the database
	Edit system information through the web

Data access and data operation are password protected. There are two levels of passwords: one for reading the data, the other for configurations, data modifications, and deletions.

1.2 XCF-2100E Operation

1.2.1 System management

- **Password management**
  - To ensure system security, there are two levels of authorisation for operators.
  - Password privileges are divided into: system manager and dispatcher.
  - Only the system manager level permits the operator to add, modify, and delete, as well as to authorise other users. The dispatcher level only allows data viewing.
- **Parameter management**

  Network parameters include:
  - Regional parameters. The system supports the surveillance of several regions. Each substation belongs only to one region.
  - Substation parameters: name, voltage level.
  - Line parameters: name, length, wave speed, T-branches - whether monitored or not.
  - Tower parameters: number, name, tower span, longitude and latitude coordinates. These parameters are used to display faults between two towers. Parameters can be modified manually or imported using Excel files.

  System parameters include:
  - Users;
  - Server parameters;
  - Database parameters.

  Communication parameters include:
  - Channel name;
  - Communication port;
  - Protocol type.
- **Consistency control**

  The system compares the input parameters and the configuration files acquired from the TDU, for the consistency verification of substation and line names. If there is a lack of consistency, the operator will be alerted to check the XCF-2100E data and system parameters.
- **Fault simulation**

  The simulation of a fault can be performed locally or remotely. XCF-2100E responds to a simulation command in the same way as to a real fault, and generates all reports, allowing the verification of the system operation correctness.

- **Import/export parameters**
  - Export and save the system and network parameters.
  - Import network parameters.
- **Connection**
  - System events;
  - Communication events;
  - Operation events.
- **XC-100E maintenance management**
  - The equipment maintenance feature allows installation, upgrade, change and repair of the devices to be manually logged into the database

No.	Substation	Equipment Name	Time	Type	Content
1	Wolford	Wfd1	January 10,2019 16:30:10	Change	Change·SD·Card

1.2.2 Communication

- **Communication with TDU**
  - TCP/IP communication, with the protocol IEC60870-5-104.
  - ICP/IP option with IEC61850-8-1 communications of Goose messages
  - RS232 serial communication, with the protocol IEC60870-5-103, DNP 3.0.
  - MODEM communication, with the protocol IEC60870-5-103, DNP 3.0.
- **Debugging communication protocol**
- **Manual retrieve transient wave records from TDU**
- **Remote configuration and reset of TDU**
- **Communication surveillance**
  - Transmission error detections, fault channel detection.
- **TDU alarm transmissions**
  - Equipment fault alarm, loss of GPS signal, trigger records.

1.2.3 Graphics

- **Graphic interpretations**
  - Single-line power network diagram.
  - Google Map display of fault location.
- **Link real-time data to graphics**

  Real-time data of substations and TDU installations are displayed on linked graphics.

- **Graphic displays**
  - Two cursors for zooming.
  - Visualisation of the time scale.
  - Visualisation of the triggering level.
  - Visualisation of saturation limits, for gain selection verification.
- **Network operation diagram**

  The software displays the single-line power network diagram. By clicking, the operator can verify the name of a substation or a line. The linked equipment can be examined by selecting the name.
- **System operation diagram**

  The software can also display the diagram of the location system, which shows the state of TDUs, and communication lines.

1.2.4 Alarms

- **Real-time alarms**

  Pop-up windows for: available records, watchdog faults, TDU faults, GPS signal loss and communication channel faults.
- **Retrieve and search the alarm history**

1.2.5 Data management

- **Data requests**

  It is possible to recover records, communication channel settings, users, using the following criteria: regions, substations, lines, date and time.
- **Quick view of waveforms**

  Quickly view waveforms after data selection.
- **Non-volatile data storage**
- **Data import/export**
  - Export data to a flash drive in a standard format, for off-line analysis.
  - Export or import the travelling wave records to a flash drive, in COMTRADE-99 format.
  - Export or import COMTRADE files to the system database.
- **Back-up, delete and restore of the database**
  - Provides a comprehensive back-up, delete and restore options for the user to manage the size of the database.

1.3 Waveform analysis

- Display and analyse double-end or single-end waveforms.
- Zoom in and out.
- High-pass or low-pass filtering of the waveform.
- Measuring the time delay from one cursor to another.
- Measuring waveform amplitudes.

1.4 Automatic event categorisation

The categorisation for trigger events was revised in the XC-2100E system from the following versions onwards.

- XC-100E firmware: V.2.0.4.
- XCF-2100E software: V1.9.7

Systems with earlier versions, put events in three categories, as follows:

a) Fault – For current inputs, if the fundamental current magnitude exceeds the 'setting' (default is 120% In), the event is categorised as 'Fault'. For voltage inputs, if the fundamental voltage magnitude is less than the 'setting' (default 70%Vn), the event is categorised as 'Fault'.

b) CB operation – If CB operation is detected within 200ms of the trigger instant and the event is not a fault, it is categorised as 'CB operation'.

c) Other disturbance – If an event cannot be categorised as a fault or a CB operation, it is categorised as 'Other disturbance'.

The revised categorisation has extended these into 11 types. Most of them are based on the characteristics of the waveforms in that category.

i) Manual Trigger – An event is categorised as such if it is caused by a manual trigger.

ii) CB operation – Same as the previous event categorisation.

iii) Back strike – Back strike refers to lightning strike on the earth wire or the tower creating overvoltage on the line. If a back strike does not cause a fault, it is categorised as such.

iv) Induced strike – Induced strike refers to lightning strike on the ground inducing surges on the lines. An induced strike is unlikely to cause a fault.

v) Direct strike – Direct strike refers to a lightning strike directly on the line, which does not cause a fault.

vi) Surge arrestor discharge – This refers to a lightning strike on the line which causes the surge arrestor to discharge. The surge arrestor discharge protects the line from a flashover.

vii) Back strike fault – This refers to a fault caused by a back strike.

viii) Direct strke fault - This refers to a fault caused by a direct strike.

ix) High Impedance fault – If the waveform matches the high impedance fault characteristic, it will be categorised as such.

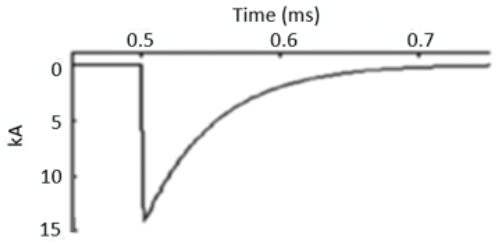
x) Non-lightning strike fault – This is for a fault cannot be categorised as a lightning strile fault or a high impedance fault.

xi) Disturbance – This is for an event which cannot be categoried into any of the above.

Details of the event categorisation are discussed in the following sections.

1.5 Lightning strike recognition

A typical lightning strike creates a current impulse of several kA, a pulse width of around 50us and a bandwidth of 20kHz, as shown:



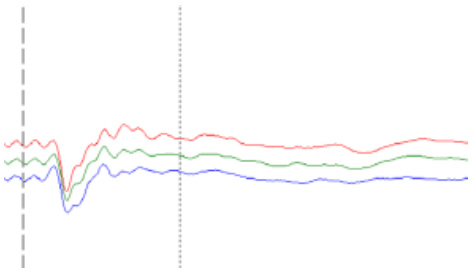
A lightning strike can strike on the ground, on the earth wire, on the tower, or on the line itself. The overvoltage caused by the lightning strike may create insulation breakdown of the line, resulting in a fault. All these events have certain distinct characteristics suitable for identification purposes.

1.5.1 Lightning strike without causing a fault

These are strikes on the ground, the earth wire, the tower or the line itself, but the high voltage created does not cause a fault on the line.

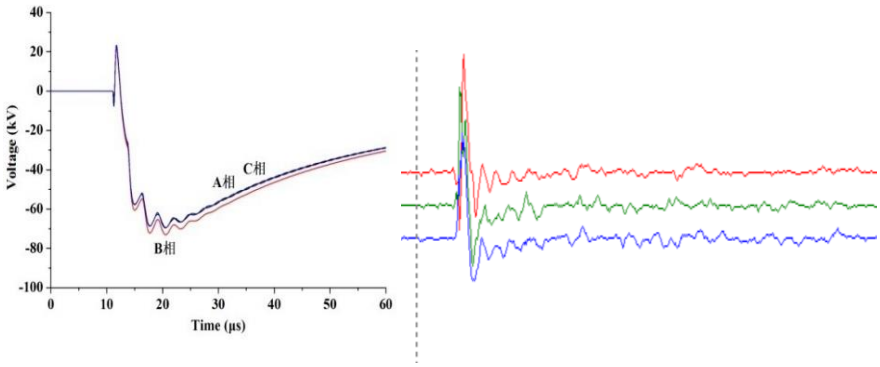
1.5.2 Strikes on the ground inducing surges onto the lines (induced strike)

Lightning strikes on the ground in the vicinity of an overhead line may induce impulse current signals onto the three phase conductors. The impulse period and the bandwidth are the same as the lightning current. All three phase currents have the same waveshape. Because of the weakness of the signal, the induced strike very seldom creates a fault. The diagram below shows a three-phase current waveform from an induced strike on the ground



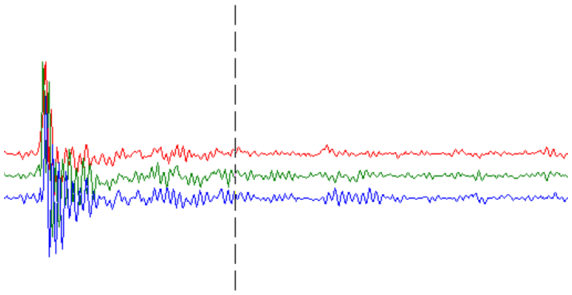
1.5.3 Strikes on the tower or the earth wire (back strike)

Strikes on the earth wire or the tower also create similar waveforms on all three phases. The overvoltage created on the line may cause insulation breakdown, therefore it is referred to as back strike. Because of the inductance of the line and the tower, the pulse width is narrower than the waveform induced from the ground. The diagram shows three-phase V and I waveforms for an induced strike on the tower or the earth wire:



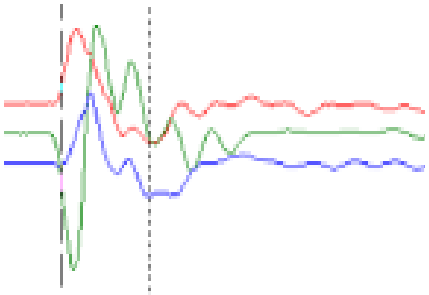
1.5.4 Strikes around the middle of the earth wire (back strike)

For a strike around the middle of the earth wire, the travelling wave oscillates between the two ends creating around 10% high frequency components. The three phase waveforms will have the same waveshape.



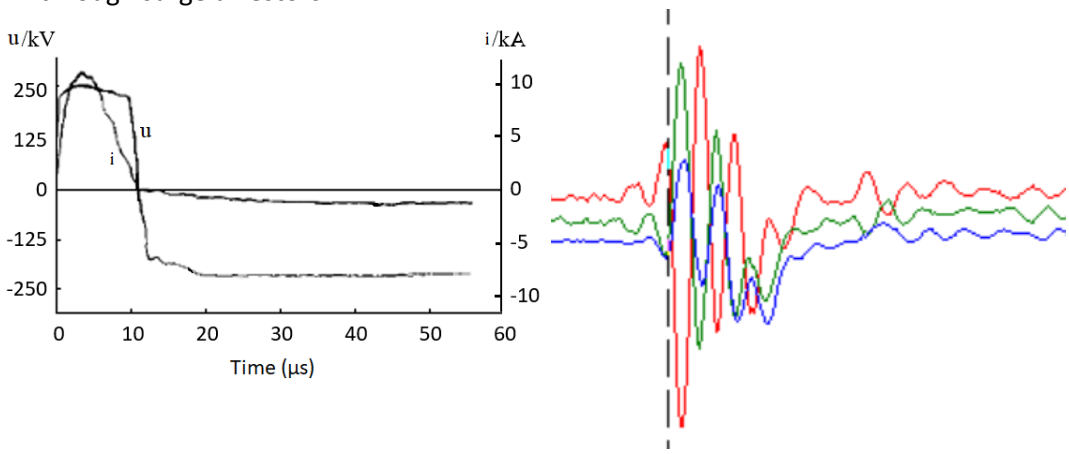
1.5.5 Strikes on the line without breakdown (direct strike)

The lightning bypasses the earth wire and strikes directly onto one of the phases. The initial polarity of the phase current is opposite to the other two phases. The three phase currents are no longer identical. In this case, the strike does not cause an insulation breakdown;



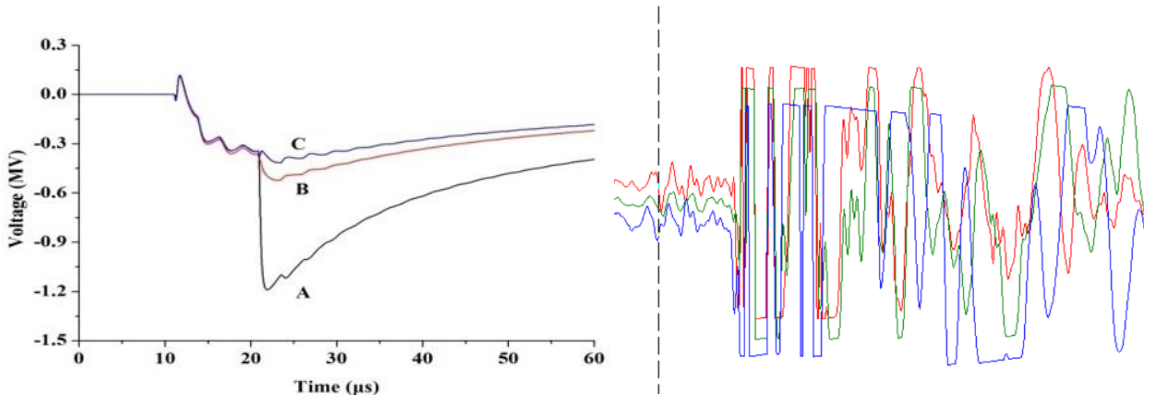
1.5.6 Strikes on the line causing discharge of surge arrestors (surge arrestor discharge)

Discharge by surge arrestors can cause cut-off at around 10us, resulting in more high frequency components. The effective bandwidth is around 100kHz and the three phases will have different waveshapes. The surge arrestors prevent a fault from occurring. The diagram shows voltage and current waveforms resulting from a strike on the line causing discharge through surge arrestors.



1.5.7 Back strike fault

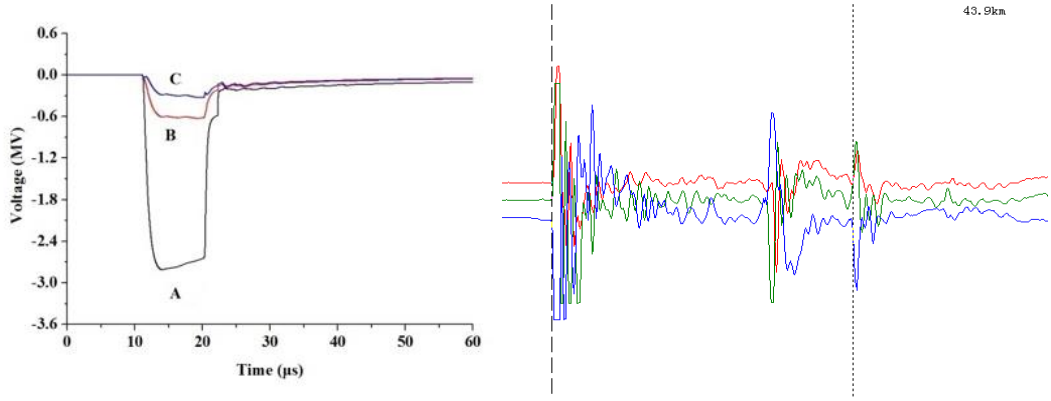
A back strike is caused by the lightning striking the earth wire or the tower. The strike creates an overvoltage on the line which discharges through a weak insulation along the line, or through the towers. The three phase waveforms are similar initially, but are no longer the same when the fault occurs. The diagram shows the voltage and current waveforms for a back strike fault showing the initial strike and the subsequent insulation breakdown.



1.5.8 Lightning strike directly onto the line (direct strike fault)

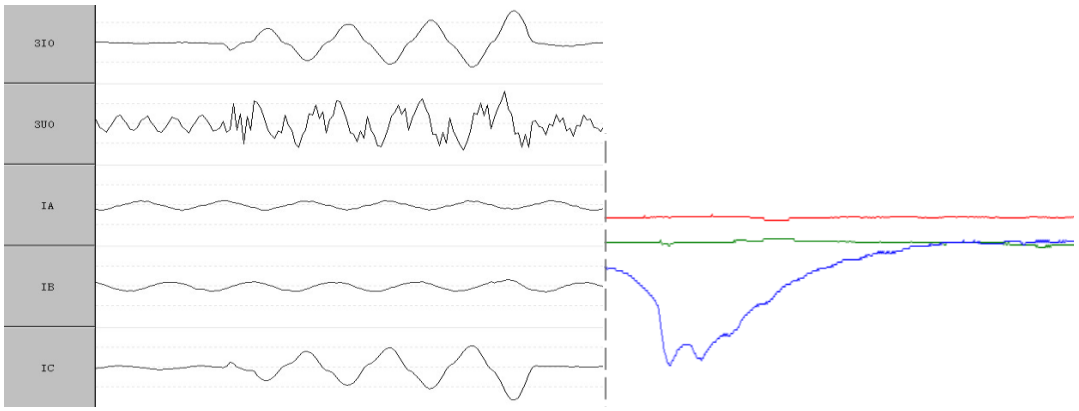
The lightning bypasses the earth wire and hits the line directly. The overvoltage creates an insulation breakdown. The sudden change in voltage creates the travelling wave signals. The travelling wave signal is strong, with the steep wave front.

The high frequency harmonics are significant. The waveshape of the three phase signals are not the same. Similar to the back strike, the location of the strike and the location of the fault (insulation breakdown) may not be the same. The diagram shows voltage and current waveforms for a direct strike on the line causing an insulation breakdown:



1.5.9 High impedance fault

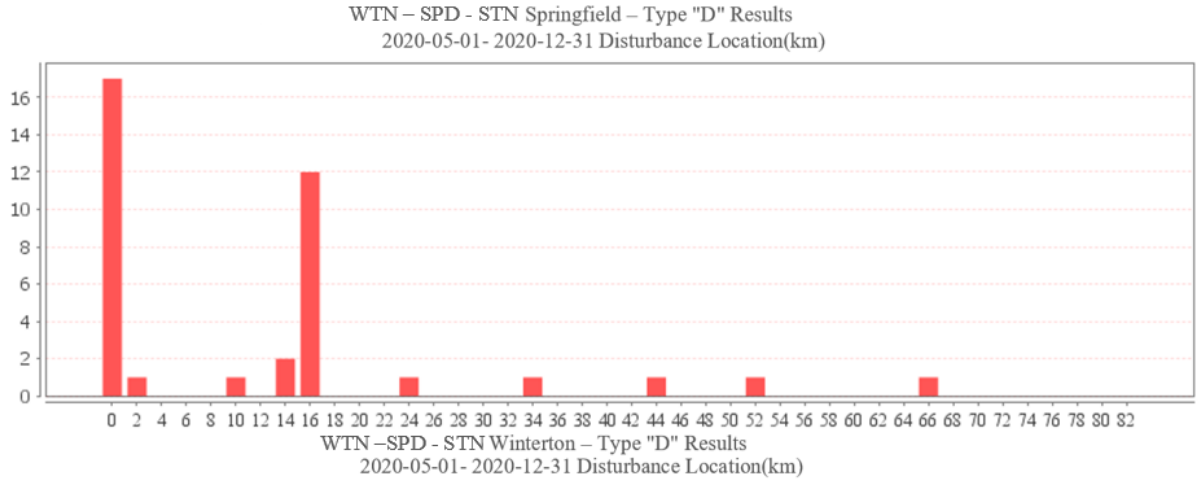
High impedance fault can be caused by bush fire or by tree contact. Bush fires in the vicinity of the line may cause phase-to-phase or phase-to-earth flash-over, creating an erratic change in fault current. For phase-to-earth flashover, the fault impedance is high resulting in weak travelling wave surges. The initial fault impedance of a tree fault is likely to be greater than 1kΩ, resulting in small fault current. The fault current gradually gets bigger as the tree branch is carbonised. The travelling wave signal produced is again weak. Typical high impedance waveforms are as follows:

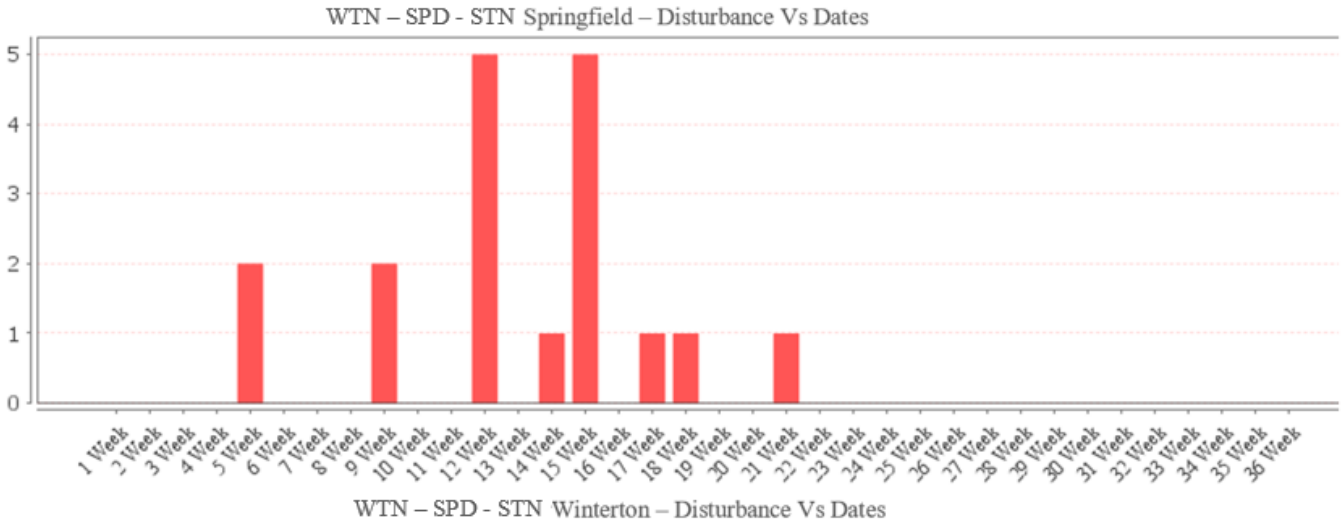


1.6 Equipment operation statistical analysis

Provides two statistical results for a line:

- Number of 2-ended results against the line distance
- Number of triggers (Single end records) against dates





1.7 Automatic double-end fault location

The calculation of the fault distance is based on the time of arrival of the travelling wave surge at both ends of the line. The calculated result is the distance of the fault to the substation in kilometer, together with the tower number if the tower locations are provided.

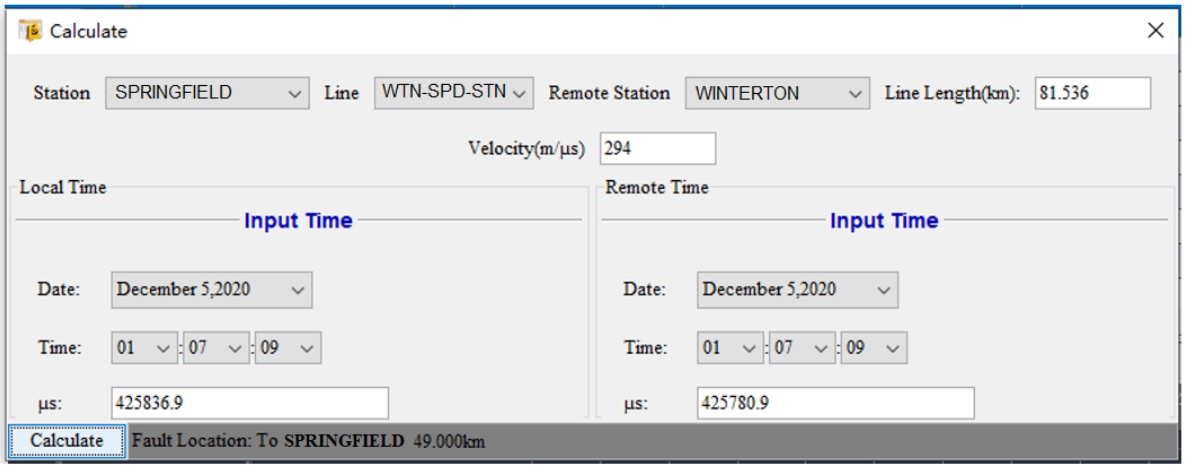
1.7.1 Wide-area fault location

The wide-area fault location feature allows a fault to be located using the arrival times of the travelling wave surges at different substations in the network.

If a number of TDU units have recorded the fault, the software can locate it even if one or both TDU units installed on the faulty line failed to react.

1.7.2 Calculation of the double-end fault location from manual input

The fault location can be calculated according to the manually entered arrival time of the surges at the line ends.



1.7.3 Computer-aided single-end fault location

The waveform recorded at one line end allows the user to perform manual analysis to identify the reflected wave. The software provides assistance to calculate the distance to fault once the reflected wave is identified.

1.7.4 Fault location in hybrid lines

The system can provide fault location to hybrid lines with a mixture of overhead and underground sections.

1.7.5 Indicating the faulty phase

The user can identify the faulty phase by reading the current values, and can check if the readings are greater than the threshold. In the following figure, it can be observed that there is a fault in Phase B.

1.8 Google Maps / Off-line maps overview

The user can select either on-line or off-line maps depending on the availability of the internet. In either case the following functions apply:

1.8.1 Tower placement and modifications

Google Maps offers an HMI system to import tower locations; the import can also be done with Excel files.

1.8.2 Locate the fault on the Google Maps

On the map the location of the tower on which the fault happened can be clearly observed.

1.9 Printing

1.9.1 Printing of fault location and analysis reports

- Fault location result.
- Single-end or double-end waveform.
- Substation names, line name.
- Date, time.
- Name of the TDUs.
- The characteristics and length of the line.

1.9.2 Printing Sequence of events

Printing sequence of events and faults including record name, fault location and alarms.

1.10 External system interfaces

- Allows the transfer of data to SCADA via the DNP3 protocol. (See Appendix 4).
- Allows the editing of system parameters through database files.

1.11 System limitations

- Maximum number allowed for substations: > 256.
- Maximum number allowed for lines: >1,000.
- Maximum number allowed for records: >1,000,000.

1.12 Local TDU interfaces

The TDU is provided with a USB connector which allows the following local features.

- Export: configuration, records summary, records data.
- Update: Configuration, Firmware.

1.13 XCF-2100E WEB performance

The Master Unit records and data can be accessed by other PCs. The access is operated by any INTERNET browser; **Note:** Java must be installed as explained in the following notes.

After entering, the following features are available.

- Real time diagram.
- Downloading of the travelling wave records; waveform analysis.
- Fault locations.
- System monitoring: status of the TDUs.
- System alarms.
- User management.

2. Software Setup

2.1 Connecting the system

Connections can be made to the TDU master unit in the following ways:

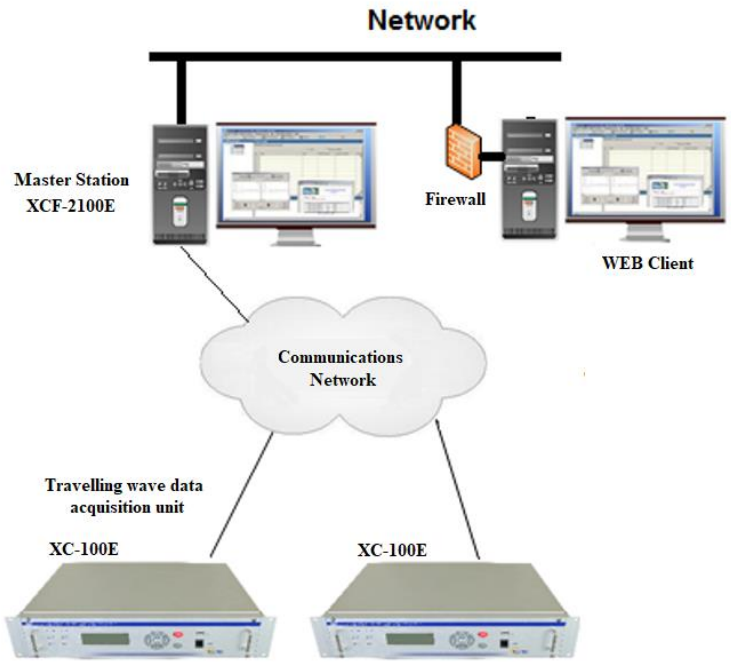
- TCP/IP: this is the fastest and best performing connection method. It should be used wherever possible.
- Point-to-point connection; this is also a fast method.
- Telephone (dial-up) line. To be used when no other means are available. This method is much slower than the others, and prone to a loss of communication.

2.2 System Configuration; TCP/IP network

The single-machine configuration is shown in the figure below. XCF-2100E and XCF-2100E WEB software are installed in the Master computer only. Other users, who want to access the system data, don't need to install any software (except Java, if it is not already installed - see later).

The Master unit operator can set up the system to view travelling wave records and fault location results, analyse fault waveforms and execute the computer-aided fault location. Other clients can view the fault data, fault waveforms and fault location results by using any browser.

The Master Unit can also communicate to SCADA (or equivalent) supervisors via the DNP3 protocol (see Appendix 4).

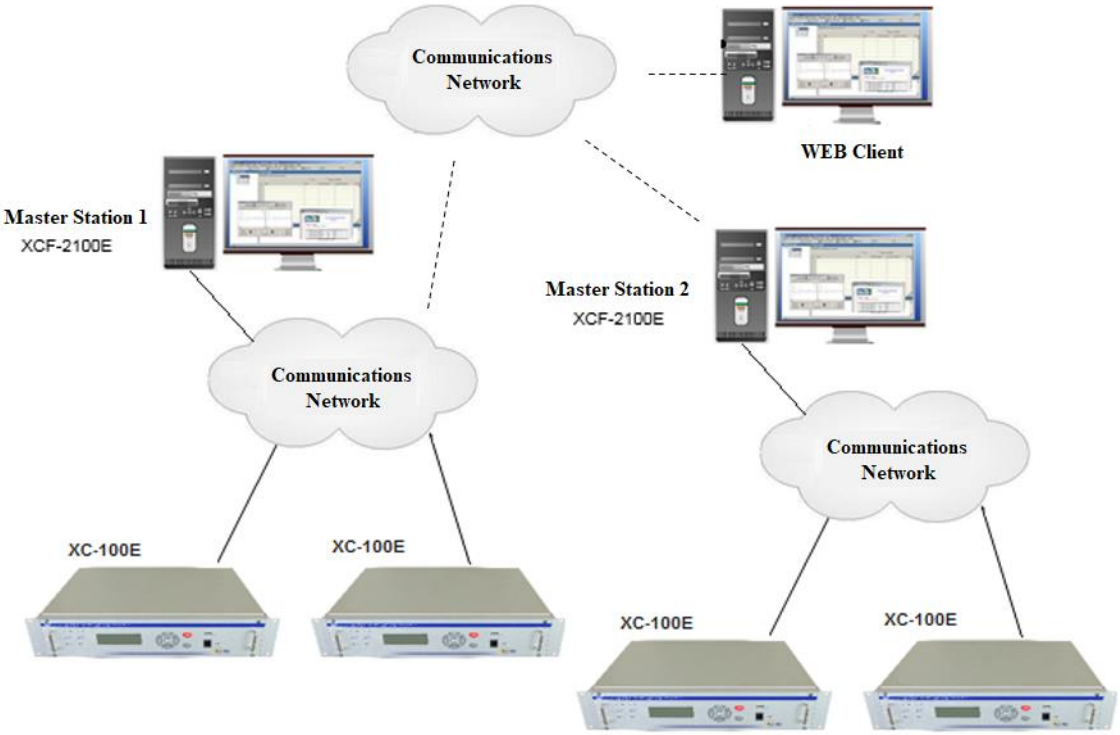


One machine configuration

Note: The only exception to the above is when **two** (**and not more**) Master units are required, communicating to all TDU units. This can be performed as follows:

- In the system, there are a number of TDU units: all of them have an address in the same area; they are connected by the connector FE1. For all TDU units, the port Programming for FE1 is 2404.
- There are two Master PC's: A and B.
- On PC A, the TDU unit is programmed, and, in the communication, the port number 2404 is set. This PC, is used to programme all the TDU units.
- On PC B, when programming the TDU units, they are given the same address, but the port number is 2405.
- Next, both PCs are connected to the network. As a fault is detected, the TDU units will send data to both of the PCs, A and B.
- **Note:** This is the only way to have more than one Master PC. If more are used data will be sent randomly and communication will no longer be ensured.

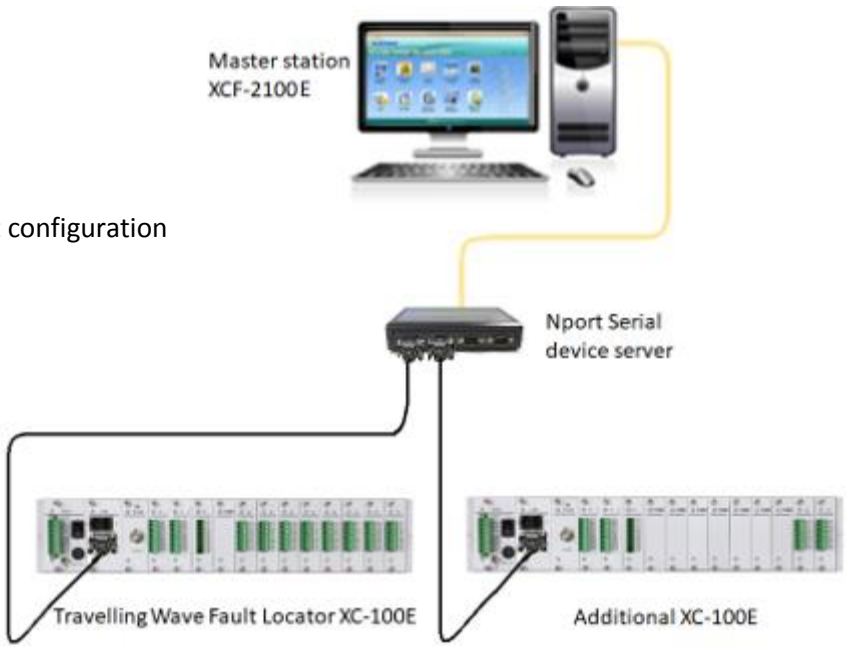
As an alternative, if a number of regions need to be connected, it is possible to set-up TDUs and Master Stations as follows.



- For each region, there could be a dedicated master, which follows the network operation;
- All clients could access these masters:
- The drawback is that there would be four databases, instead of a single one with all of the results.
- A single database can be created in any PC with XCF-2100E, importing data from the other Master Units.

2.3 Point-to-point serial communication

The TDU and the Master Unit are connected by a dedicated point-to-point data transmission channel, which may be fibre optic or microwave. The Master Unit has the XCF-2100E software installed, and also the XCF-2100E WEB, for the access of other Clients.

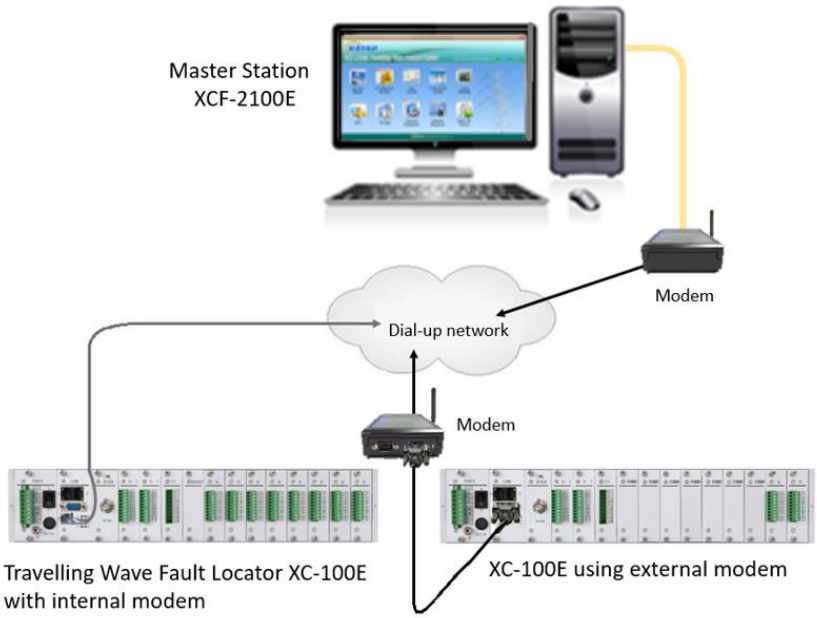


Point-to-point configuration

2.4 Dialling Communication

The TDU supports the dialling communication mode with the MODEM interface, or two RS232 ports (External Modem).

In this mode, there is no Master Unit: any unit can be equipped with XCF-2100E, and can access the TDU test results via the dialling communication. The only limitation is that the access to a TDU should be performed by one unit only.



Dial-up configuration

2.5 Hardware and Software Requirements

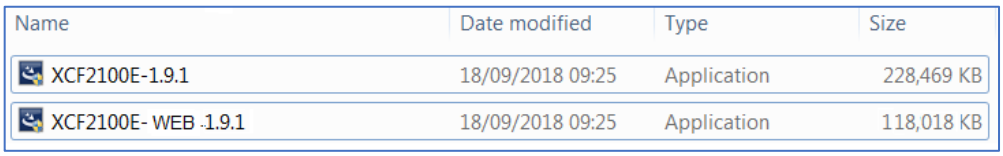
With both configurations, the requirements of XCF- 2100E are as follows.

- Minimum hardware requirements:
  - CPU: dual core 2.0GHz, or higher;
  - DRAM memory: at least 2 GB;
  - Hard Disk: 500 GB;
  - Monitor: 1024×768 pixels or 1600x900 pixels;
  - A mouse.
- Software:
  - Operating system: Microsoft Windows XP / 2008 / VISTA / Windows 7 / Windows 8, Professional Edition /Windows 10
  - Database:
    - MySql 5;
    - Microsoft SQL Server 2008;
    - Oracle 12c.

2.6 First Installation

The XCF-2100E software guides the operator through the installation process. Prior to the setup, all other software should be closed down, to avoid possible conflicts that may occur during the operation.

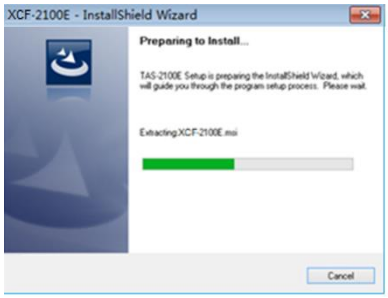
The software installation disc directory is shown in the figure below.



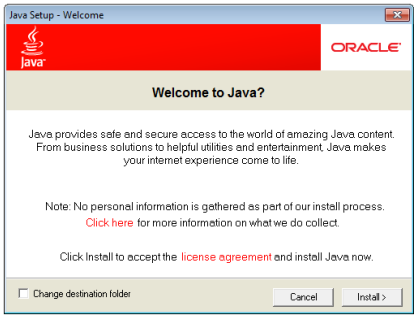
The detailed setup steps are as follows:

- Click XCF-2100E: the software starts installing.
- Before continuing, it is necessary to choose the language.

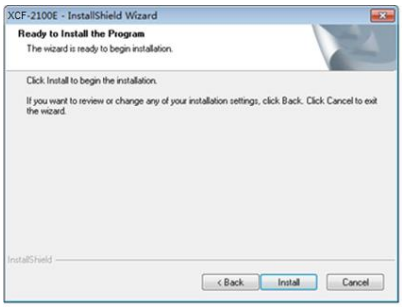
- Click ‘Next’ and enter the window of the installation software, as shown below. The default installation directory is under the system disk. If necessary, click the ‘Browse’ button to choose the installation directory.



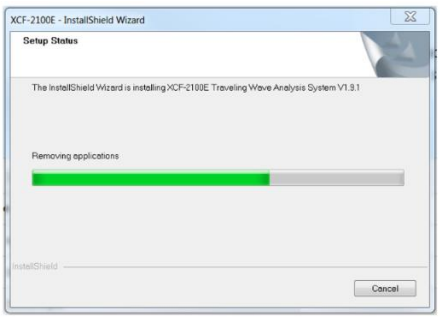
- Click ‘Next’: If it is not already available on the PC, the Java installation programme will automatically run. The installation window of Java is shown in the figure below.



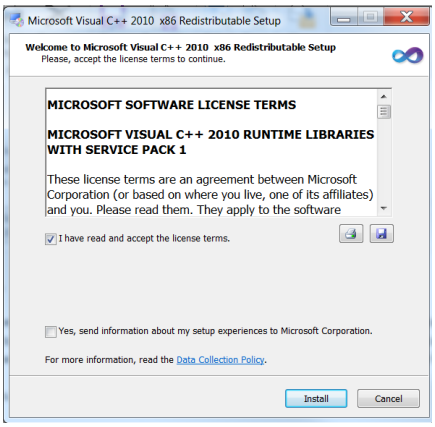
- After the installation of Java, if it was not already available, the following window will automatically be displayed.



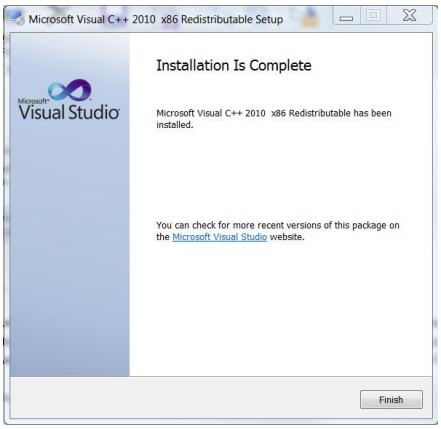
- After clicking ‘Install’, the installation will begin, as shown in the figure below.



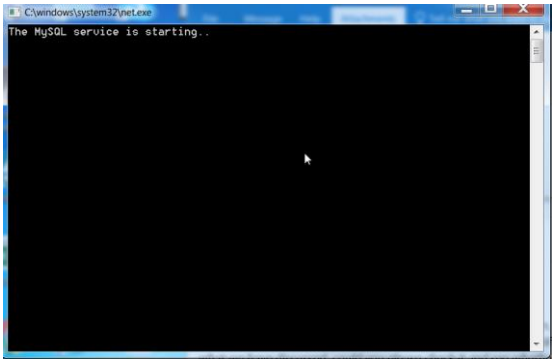
- Next, the programme displays the following window.



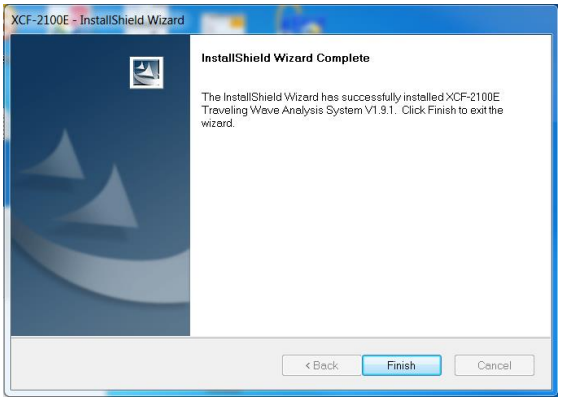
- Click Next: the completed installation window is shown in the figure below.



- Press Finish: The MySQL service starts.



- The installation is now complete.



- Press Finish: the XCF-2100E software is installed on your PC.

Note 1: XCF-2100E uses the software named ‘My SQL’ as a database.

Note 2: As the WEB server software uses the same database as XCF-2100E, it must be installed in the same directory.

After installation, the software is normally installed in the default directory:

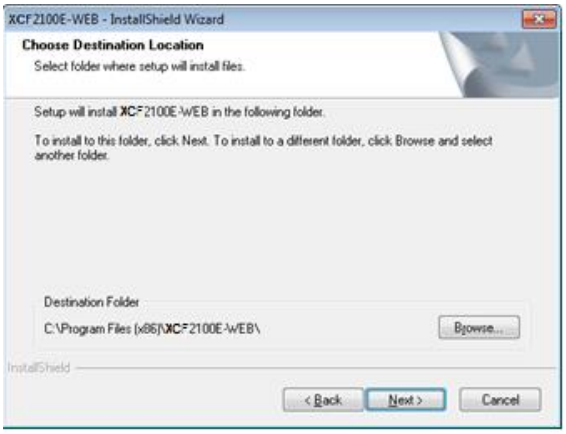
C:\Programme Files (x86)\XCF2100E,

The MySQL software is installed in:

C:\Programme Files (x86)\XCF2100E\MySQL Server 5.5.

Now, it is necessary to repeat the installation procedure for the XCF-2100E WEB software.

The first steps are the same as explained before. The directory selection window is as shown below. It must be in the same directory as XCF-2100E!

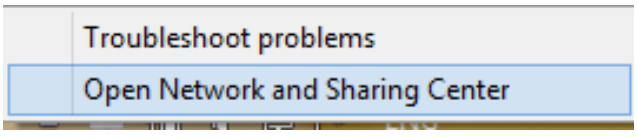


After selecting Next, the installation proceeds as usual. Once done two icons will be visible on the display as below.

2.7 Master PC IP Address

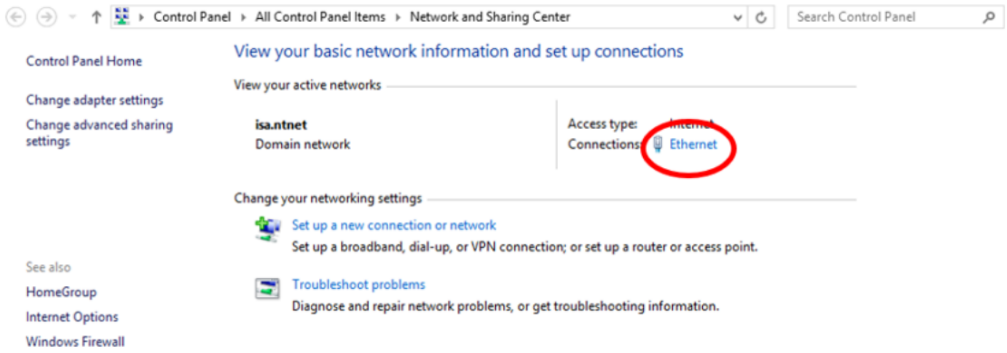
The Master PC must have a static IP address, so that it can be called by the Client browser (and, in case of Internet connection, it can connect to XCF-2100E). The procedure to set up the address is as follows.

- Right click on the Internet connection icon, at the bottom right of the screen: this provides the following selection.

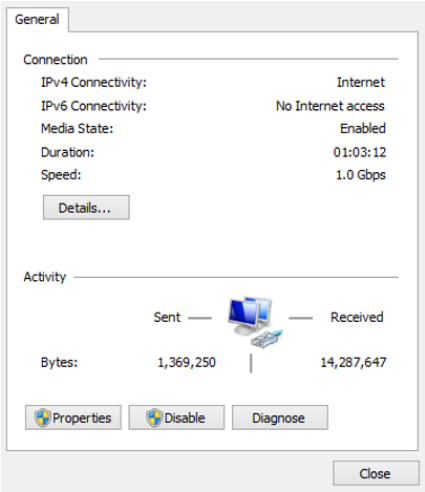


- Select ‘Open Network and Sharing Centre’: the following window is displayed

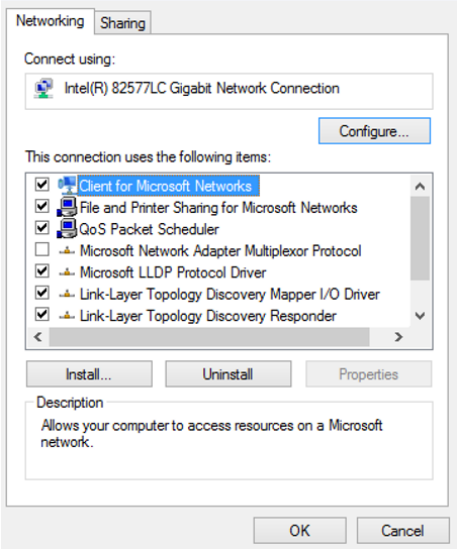
- **Note:** this is WINDOWS 1.8; other versions have similar selections).



Left click on Ethernet: the following window is opened.

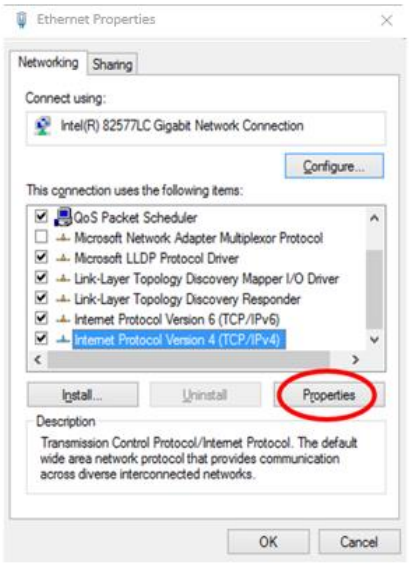


- Press ‘Properties’: the following window shown.



- Select ‘Internet Protocol version 4’, and then press ‘Properties’.

- The following window appears:



- Clicking Properties brings up the following:

- Now, select ‘Use the following IP address’, and input the address to be assigned to your PC.

- To conclude, select OK, and then Close: the IP address is programmed, and can be accessed from external Clients.

Note: If your company has an INTRANET service, it is likely that contact with the Master PC will be inhibited by Firewall software. In this case, the Firewall must be configured so that the Master PC address, can be accessed by external Clients; otherwise, the system will not work.

2.8 Software Upgrade

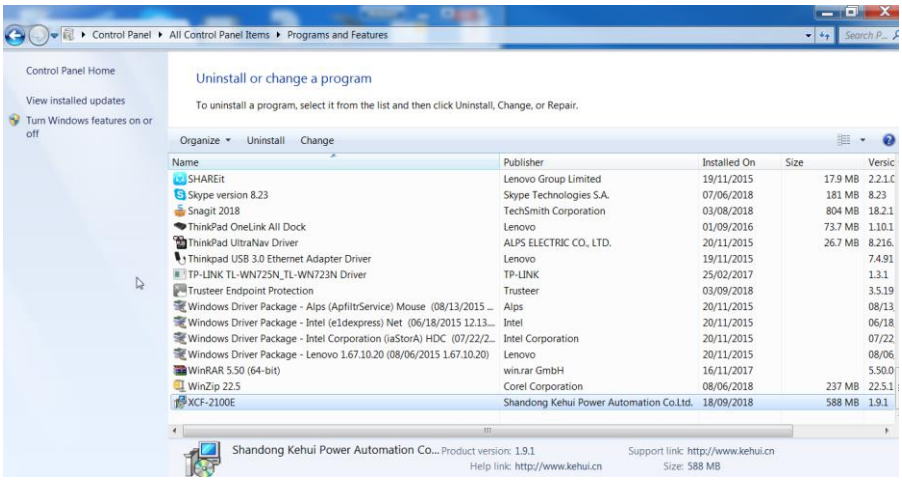
An upgrade to the software can be completed by double-clicking the 'XCF-2100E-XX' and 'XCF-2100E-WEB-XX' files and follow the procedure prompts.

2.9 Uninstall

The uninstall operation will delete the complete XCF-2100E software including all existing settings and results. Before uninstalling it, a database back-up should be made and files and diagrams should be exported. The operation is explained in the following sections. The back-up file is saved in the C: root, so it is not erased during uninstall. After the new install, the old data can be recovered.

To uninstall the programmes, use the Add/Delete command on the Windows Control Panel. The operation is as follows:

- Open the Windows Control Panel.
- Select Add/Delete and choose XCF-2100E (and then XCF-2100E WEB); then, follow the instructions to finish the uninstall operation.



2.10 XCF-WEB Client PC

Refer to Section 14.

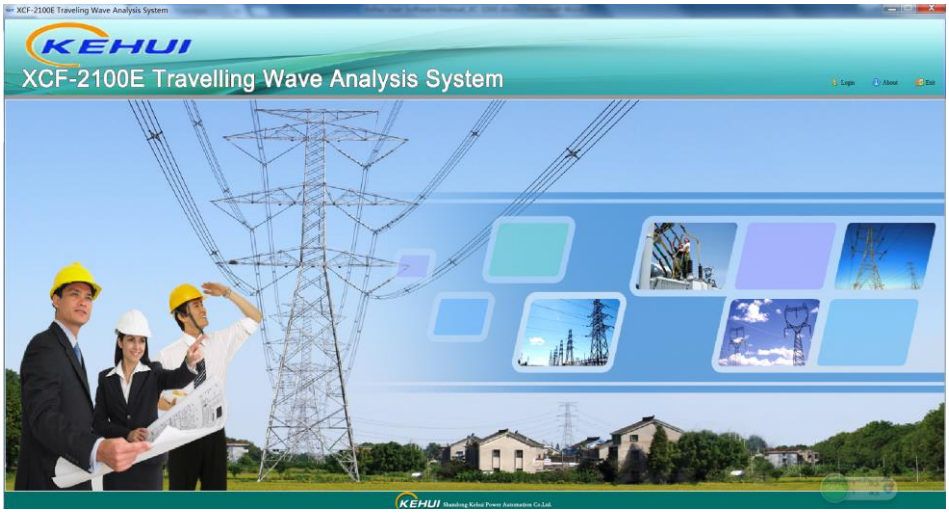
3. Software Introduction: XCF-2100E

This section provides an overview of the XCF-2100E software, including the start-up and menus. XCF-2100E Start up and Exit

3.1 Start-up

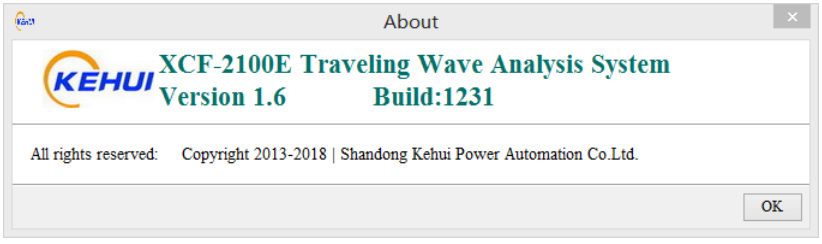
After installation, the following icon will can be added to the desktop, which can be used to launch the software.

Once it is launched, the Welcome window is opened.

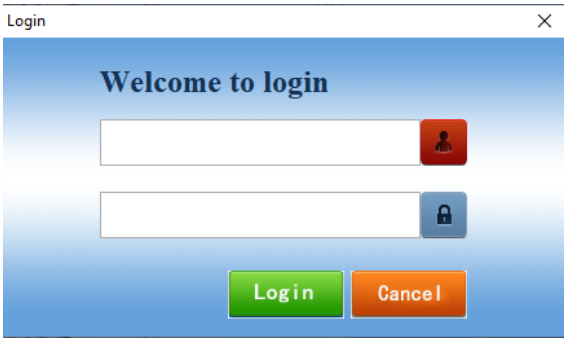


Three buttons appear at the top-right; Login, About and Exit.

Clicking on About will give information about the version number installed. This information is also available on the main Window.

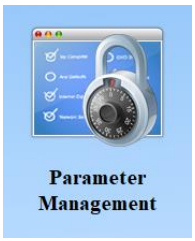


To access the software, click on Login (top right) and the following window will appear:

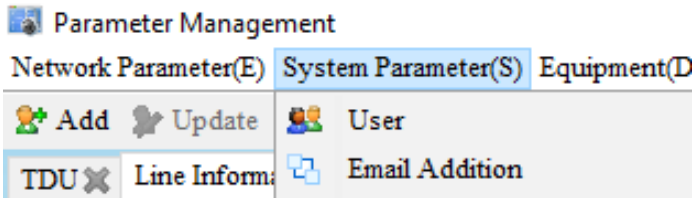


When using the software for the first time, enter '**admin**' as both the user name and the password (this is case sensitive). This takes the user to the main window Section 3.2. This window will allow the user list to be created providing user names and passwords for all appropriate personnel.

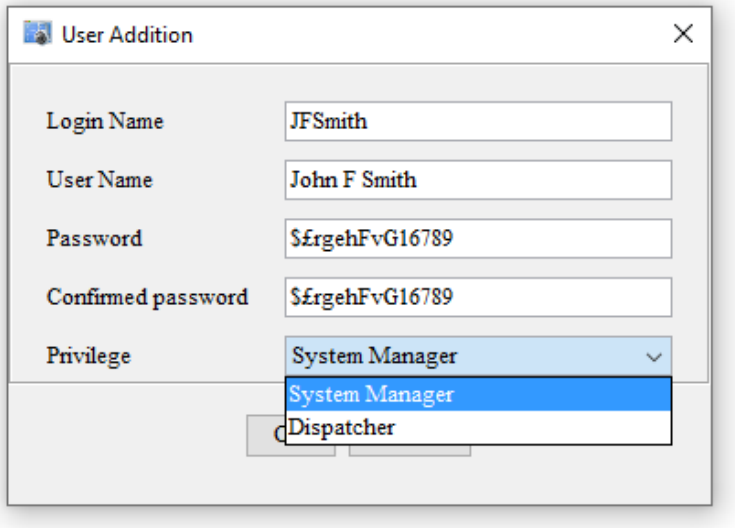
On the main window go to the Parameter Manager icon:



This opens the Parameter Management window where System Parameter(S) is selected from the ribbon, followed by User:

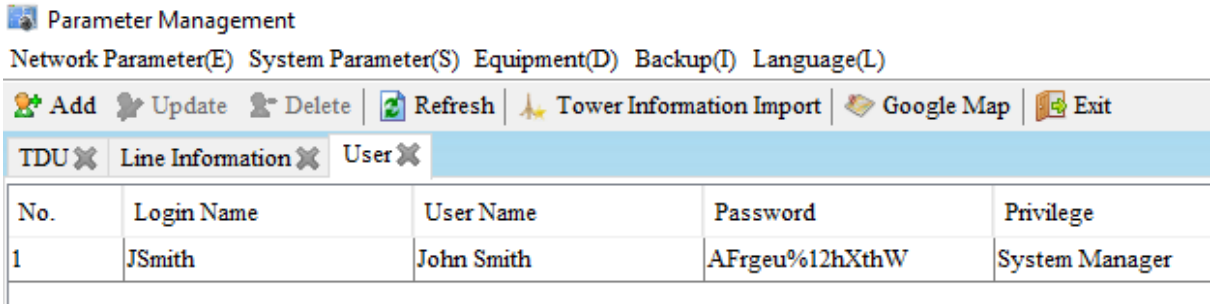


Clicking on Add will cause the User Addition window to appear:



- The Login Name is the name used to log in to the system, it is case sensitive and should only contain letters and numbers, there must be no special symbols or spaces. The system will reject the same name being entered twice.
- The User Name is the full name of the user
- The password can be set individually by each user, as this gives access to the system it should have an appropriate level of security.
- Privilege gives the user to different levels of access, either System Manager or Dispatcher, selected from a drop-down menu. The System manager is allowed to change settings in the system, the despatcher can only access data. Once this is selected pressing OK will add the user to the system. The user name 'admin' will always remain but should have its password changed as described later.

The new user appears in the list.



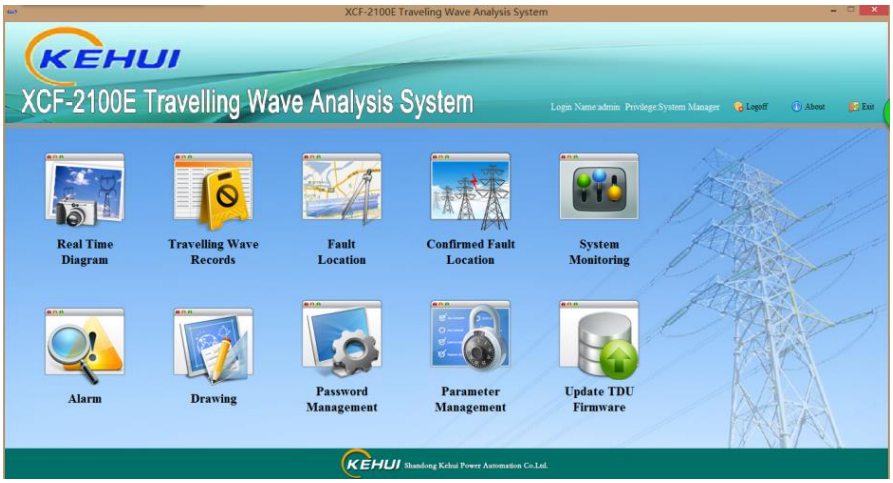
Note: this table is only accessible to system managers so it is not possible for Dispatchers to access the password details.

On the top of the Main menu is a Logoff command which returns the software to the Welcome window and allows the user to log in as themselves.

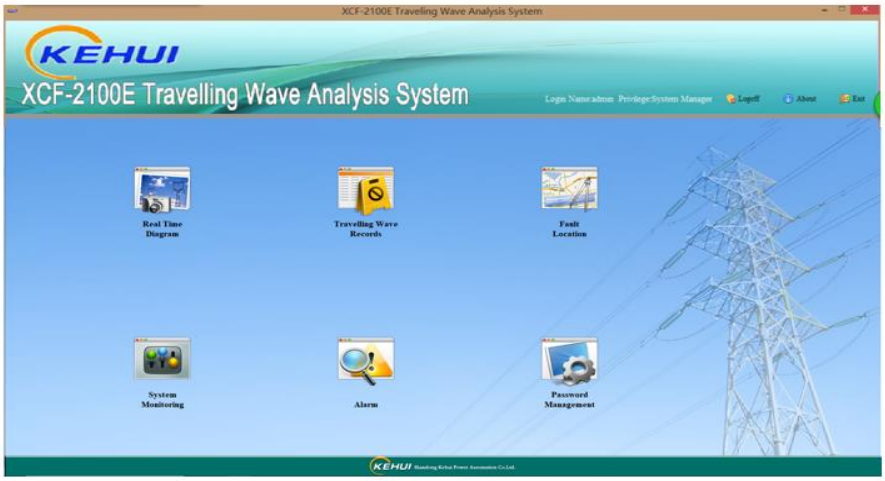
3.2 Main window

As already described, there are two access levels: administrator and dispatcher.

The difference between the two is that the administrator can access the 'Parameter Management', 'Update XCF Firmware' and 'Drawing' modules, the dispatcher cannot. The administrator window is shown below:

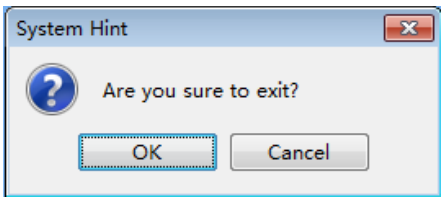


The dispatcher window is as below:



Dispatchers can watch the network and analyse faults, but cannot modify the XC-100E settings or update the XCF firmware and has no access to user details, although they can change their own passwords.

- Logoff returns the user to the Welcome page; from where, logging in will require the user name and password
- Exit will close down the programme after a pop-up for confirmation.



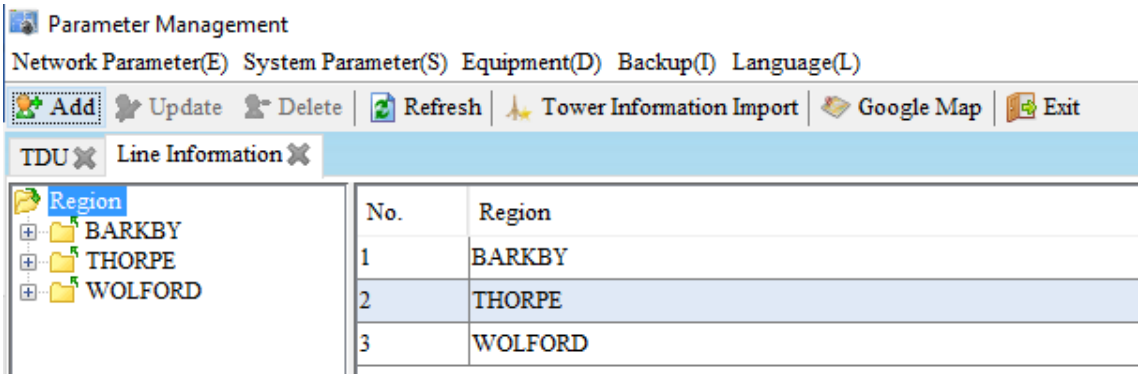
Clicking an icon on the main page will open a new window. When creating a new network, the system manager's first selection is Parameter management.

4. Parameter Management

The purpose is to create the network with all the necessary information. Programming steps are as follows:

- Set the power system voltage level.
- Create the network: region, substation, line, tower.
- Configure the XC-100E (TDU) equipment used in the substations.
- Send the configuration parameters to XCF-100E.
- Configure the circuit breakers.

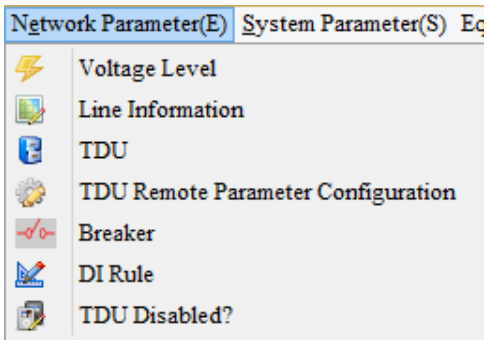
The window includes: title, menu bar, toolbar, table and status bar.



The toolbar includes the commands that are used during the setting operation.

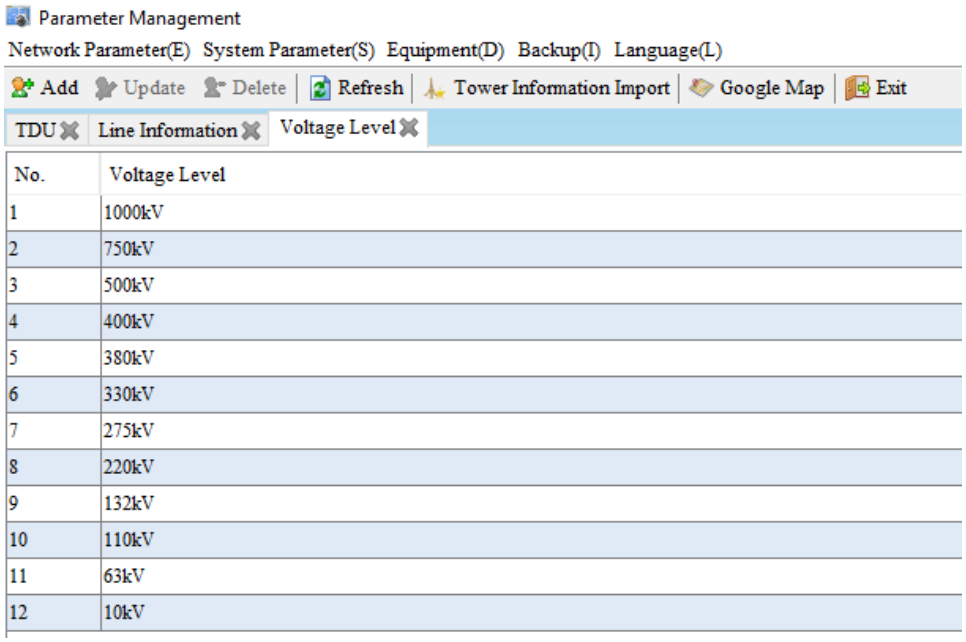
4.1 Network parameter

This can also be accessed by pressing 'Alt + e', providing the following pop-up menu.



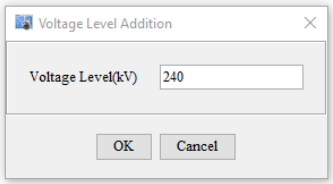
4.1.1 Voltage level

The selection allows the user to check if the substation voltages are available in the default list; if not, they can be added. The window lists the standard voltages.



No.	Voltage Level
1	1000kV
2	750kV
3	500kV
4	400kV
5	380kV
6	330kV
7	275kV
8	220kV
9	132kV
10	110kV
11	63kV
12	10kV

Pressing the ‘Add’ button opens the following pop-up window which allows new voltage level to be added.

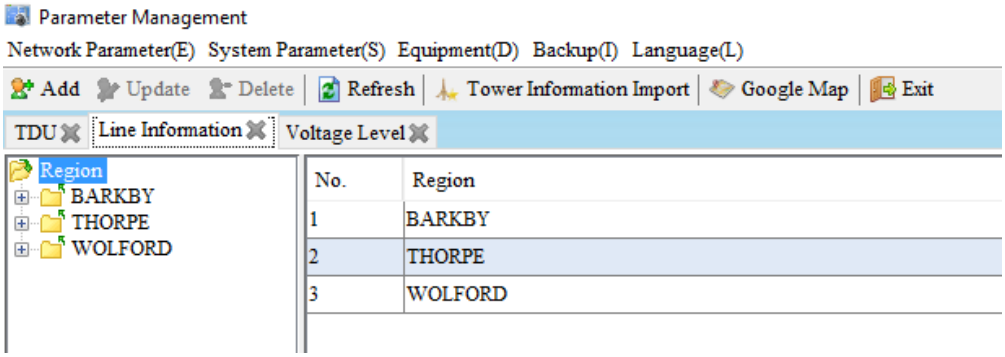


4.1.2 Line information

The selection

of the Network Parameters menu allows the creation of a region: including substations and lines, whether connected or unconnected.

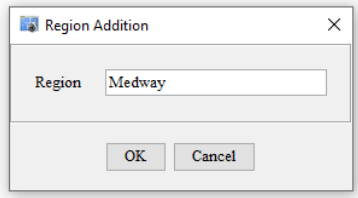
The Network selection window is divided into two parts: the regional summary is to the left and to the right, a table shows the data within the region.



4.1.2.1 Region selection

- Region addition

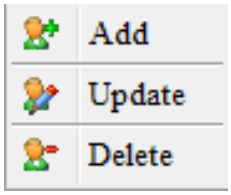
  Open the following window by pressing the ‘Add’ button on the tool bar, or right click on the right area.

  Keying in the region’s name and pressing ‘OK’, adds it to the system. Pressing Cancel exits the option without adding the region.

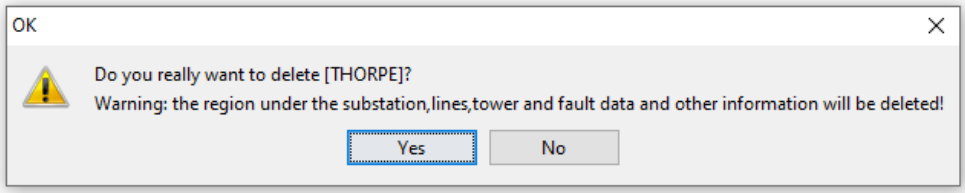
- Region update

  To change the name of the region, click the right mouse button on the region: giving the following choices.

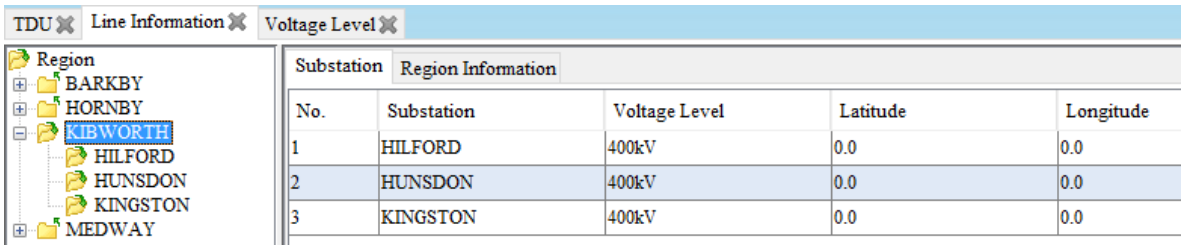
- Region deletion

  With the selection ‘Delete’ the following window opens.

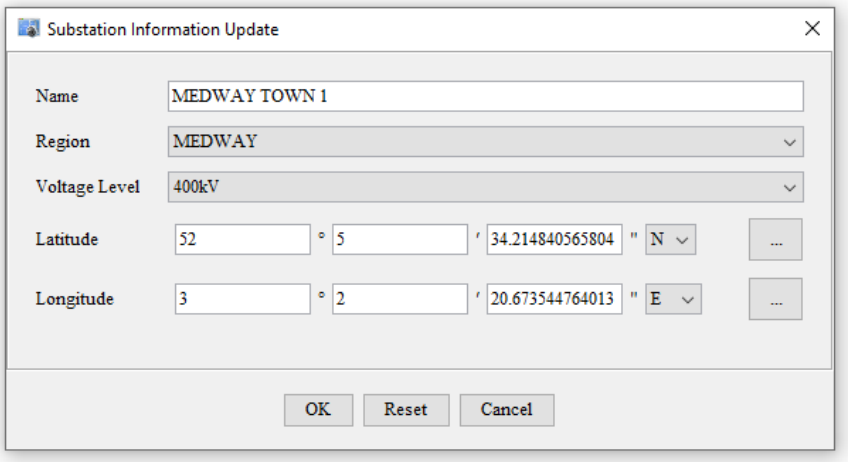


4.1.2.2 Substation selection

If a substation is selected, the window is as follows;



Press the ‘Add’ button of the toolbar, or click the right mouse button in the substation list: The following window opens. As an example, Mexico City 1 has been created.



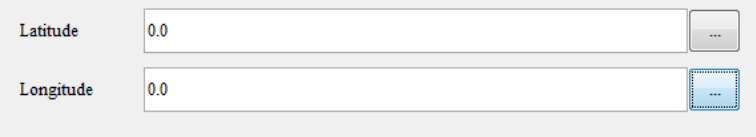
The ‘Voltage Level’ for the substation is just for information and usually corresponds to the highest voltage in the substation. The substation would normally have lines with different voltage levels.

The parameters of longitude and latitude are needed for the location on the Google Map.

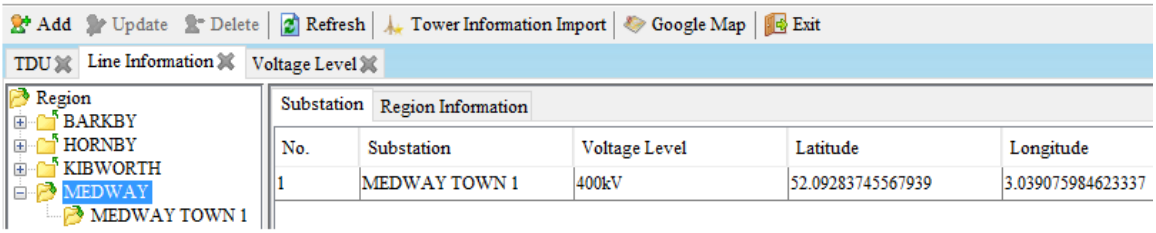
With the button .., the coordinate format can be chosen:

- Latitude, in degrees, minutes, seconds and decimals, up to 90 °, North, South;
- Longitude, in degrees, minutes, seconds and decimals, up to 180°, East, West;

- Degrees and decimals. For latitude, the North has a positive sign, and the South has a negative sign. For longitude, the east has a positive sign, and the West has a negative sign.



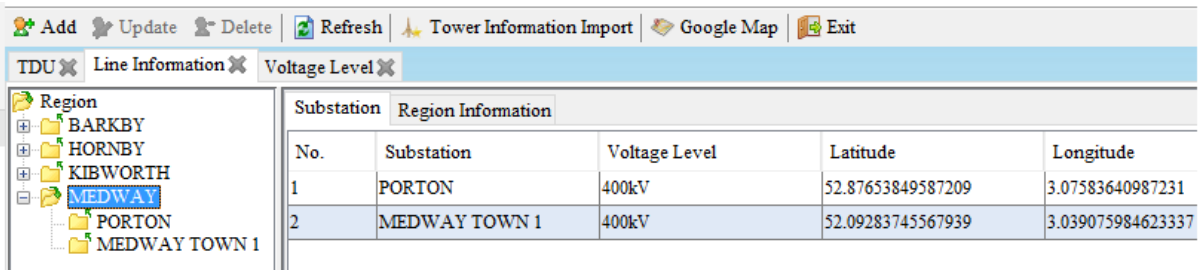
When 'OK' is selected, a new substation is added to the network. Now the window is as follows:



The window repeats the region information, and adds the substation information. The operations: Add, Update, Delete are available.

4.1.3 Line selection

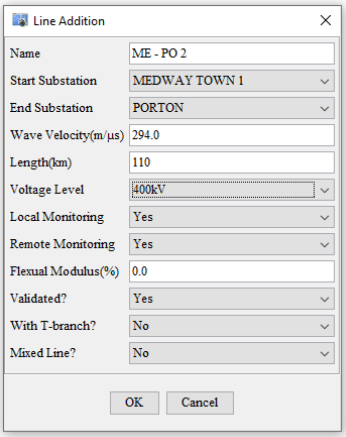
In this window, line information is programmed, including: length and transient wave velocity. It is also possible to programme whether the line has a 'T' branch, or if it has overhead sections and cable sections. Continuing with our example, we have added a substation named Porton. Now, the window is as follows:



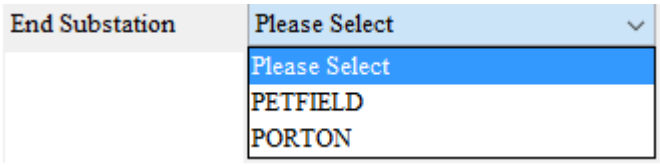
Two 400 kV lines are required to connect Porton to Medway Town 1, these will be designated ME - PO 1 and ME - PO 2.

- Line addition

  After selecting the substation, open the line addition window by clicking the 'Add' button on the tool bar, or right clicking the mouse on the line: the following window is shown:



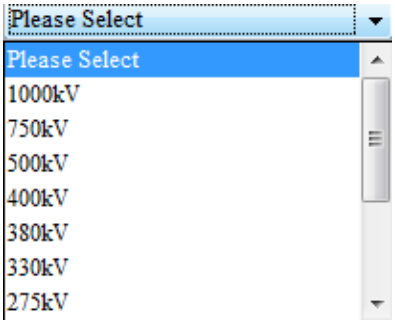
- Name of line: This must be written correctly
- Names of the local (start) and remote (end) substations. When these are entered, a pop-up menu appears, choose the one of the previously entered names.



- Wave velocity: This is the travelling wave speed, in m/μs. The default value is 294 m/μs: which can be used, or replaced with the measured value.
- Length of the line, in km.

  Note: For better accuracy, the line length should be taken from the CT at the first substation to the CT at the destination substation.

- Voltage level. This can be selected from the pop-up menu (from which the voltage can be selected).



The line voltage is a parameter used by the XCF-2100E software to calculate the peak current during the fault: see Appendix 1.

- Local and remote monitoring: ‘Yes’ means that the other end of the line is also monitored by a XC-100E.
- Flexual modulus. The line sags between towers and so the actual line length is longer than the sum of the tower distances. This modulus takes care of the difference. Since the system works on time differences, this difference is not problematic. If desired, one can measure the actual line length by closing the circuit breaker at one end. If ‘L’ is the nominal line length, and ‘x’ is the Flexual modulus, the time ‘T (L)’, measured in microseconds (µs), will be:

  T(L) = (L * (1+x))/291

  From this formula, we can calculate ‘x’. The software will continue to compute, considering the nominal length ‘L’, and the speed of 294 m/ µs. additional parameters are confirmed:

  - Validated?: Yes or no
  - With T branch?: Yes, if there is a branched line.
  - Mixed line? Yes, if the line is mixed, overhead and cable.

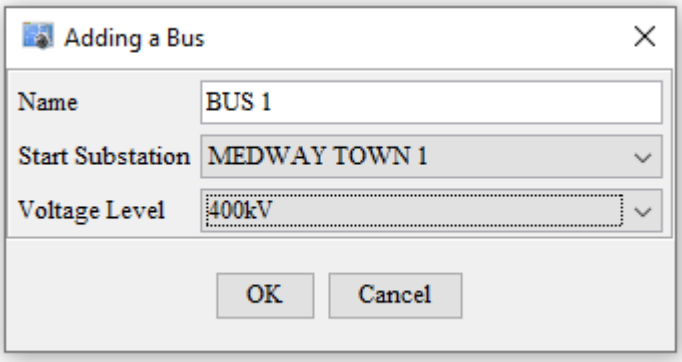
  When ‘OK’ is pressed, a new row is added to the network. Now the substation table looks as follows (line split in to two for clarity):

Line | Bus | Substation Information

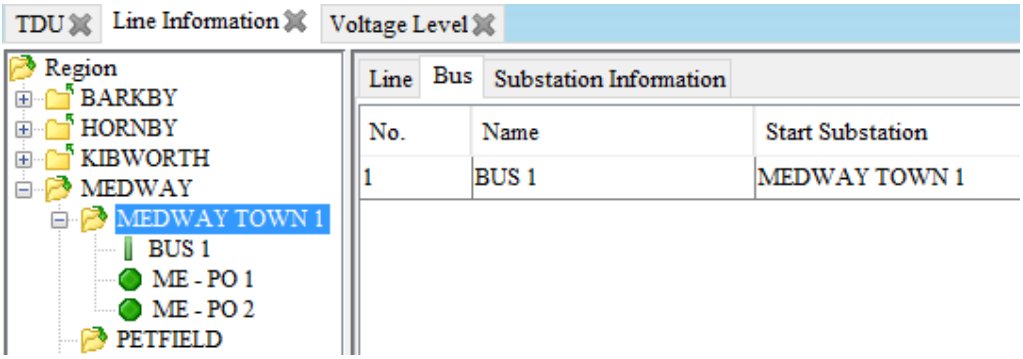
No.	Name	Start Substation	End Substation	Wave Velocity(m/µs)	Length(km)	Voltage Level
1	ME - PO 1	MEDWAY TOWN 1	PORTON	294.00	110.000	400kV
2	ME - PO 2	MEDWAY TOWN 1	PORTON	294.00	110.000	400kV

Local Monitoring	Remote Monitoring	Flexual Modulus(%)	Validated?	With T-branch?	Mixed Line?
Yes	Yes	0	Yes	No	No
Yes	Yes	0	Yes	No	No

The table summarises all parameters. In addition to the current measurement, the device can also measure the bus voltage. For this, the corresponding bus must be created. To the left, select the ‘bus’ tab, and then press ‘add’: the following window opens.



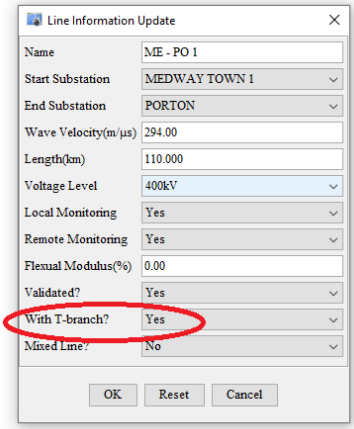
Enter the bus name and the voltage level. After pressing ‘OK’, the bus is added to the table.

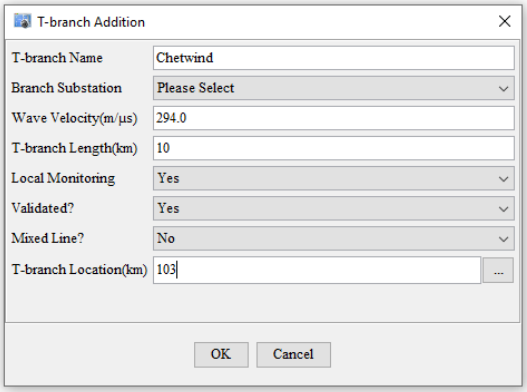


Note: If there is more than one bus in a substation, with different voltages, it is possible to create two buses at two different levels.

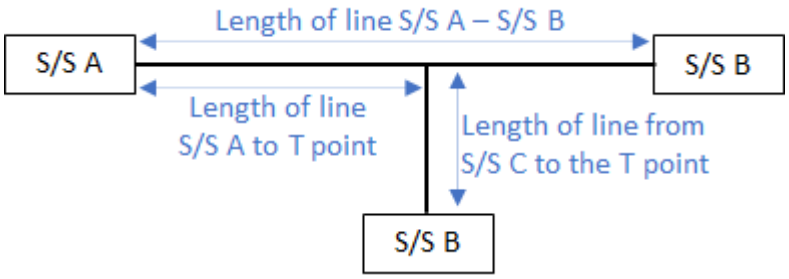
4.1.3.1 Line with T Branch

If the line has a T Branch, select ‘With T-branch’ as ‘Yes’ when creating the line. This can be done retrospectively by right-clicking the line and selecting adding a T-branch



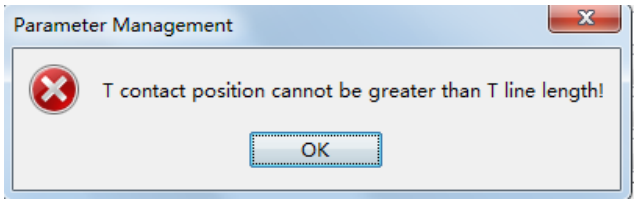


The parameters are explained in the following diagram.



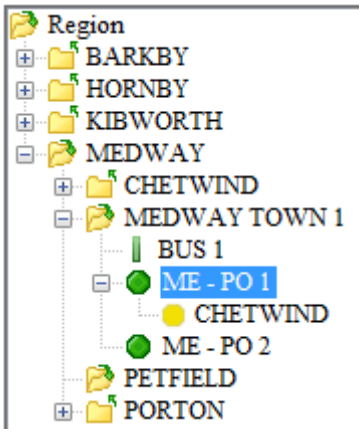
The line goes from A to B. At point T, there is a T branch which goes to substation C. **Note:** Substation C is already programmed.

- Name: The name of the T branch.
- Branch Substation: Substation C, at the end of the T branch.
- Wave Velocity: 294 km/µs.
- T branch length: Distance from Substation C to the T point
- Local Monitoring: Substation C.
- Validated?: Yes or No (validation is based on a confirmed measurement of the parameters
- Mixed Line?: Yes or No.
- T-branch Location: The distance from the substation A to the T point. The software checks that this distance is not greater than the length of the line. In case of error, it displays the following message:



In our example, we have added a branch to Chetwind. The branch is located 7 km before Porton, and is 10 km long.

In the window on the left, the software automatically adds the line information.



- The line is connected to three substations.
- The substation at the end of the T branch is shown in yellow.

In the window on the right, we find the following information:

T-branch | Tower | Line Information

No.	T-branch Name	Parent Line	Branch Substation	Wave Velocity(m/μs)
1	CHETWIND	ME - PO 1	CHETWIND	294.00

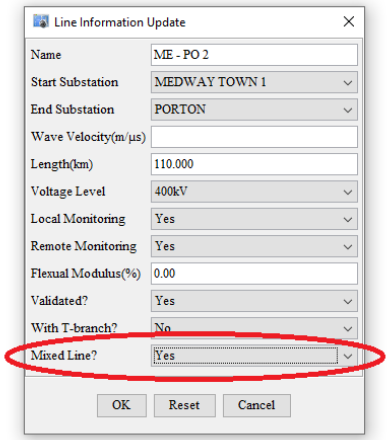
T-branch Length(k...	Local Monitoring	Validated?	Mixed Line?	T-branch Location(km)
10	Yes	Yes	No	103

This is a summary of the T-branched line. There are also two other tabs giving the Tower and Line information; which will be covered later.

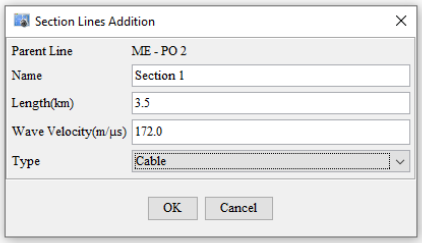
Note: The position of the connection point may be set by selecting a tower. If towers are not yet programmed, the position of the connection point can be changed afterwards.

4.1.3.2 Mixed Line

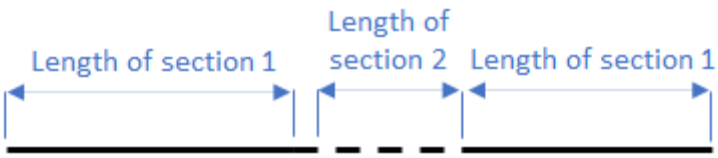
If the line is mixed, the programming window is as follows:



By selecting ‘Yes’ on the mixed line, the speed is removed as it will be calculated by the software. The pop-up window is as follows.

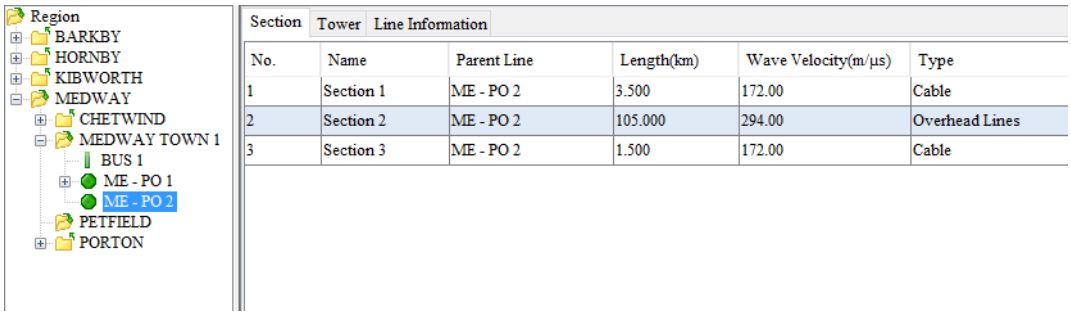


- Parent Line: This is the line to be defined.
- Name: the name of the line section, not the line name.
- Length: the length **of the section**.



- Wave Velocity: it is 294 m/µs for overhead lines and nearly 172 m/µs for power cables.
- Type: Select overhead line or cable.

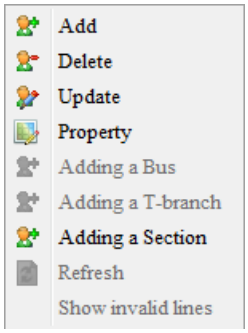
Press ‘OK’: after the confirmation, the pop-up window is still there. All sections of the line can be programmed. At the end, the window displays all the parameters.



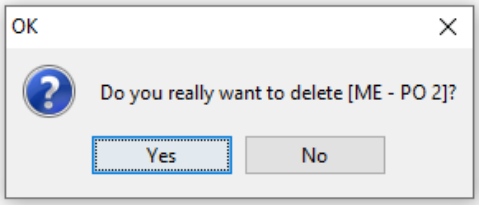
In our example, we have split the line ME-PO 2 into three sections. The first one, in Medway Town, is called Section 1; it is a cable 3.5 km long. The next section is the overhead line, 105 km long and the last section, in Porton, is a cable 1.5 km long. For more information, refer to Appendix 2.

4.1.3.3 Line Modification

To change the parameters of the line, click the right mouse button on the line name which will give the following choices.



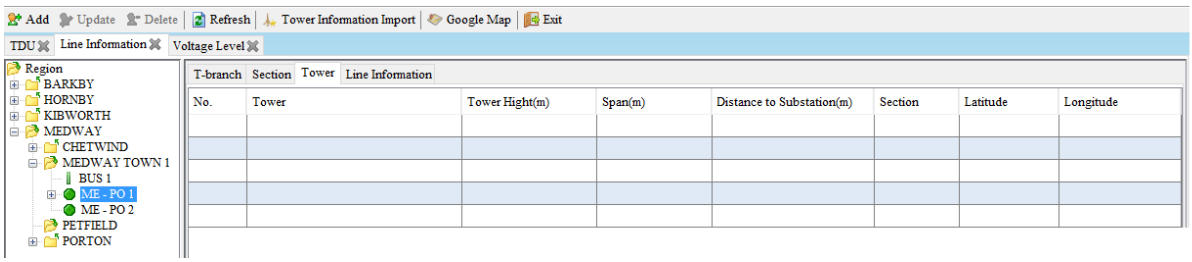
- Add: This opens a window to add parameters.
- Delete: This opens the following window opens.



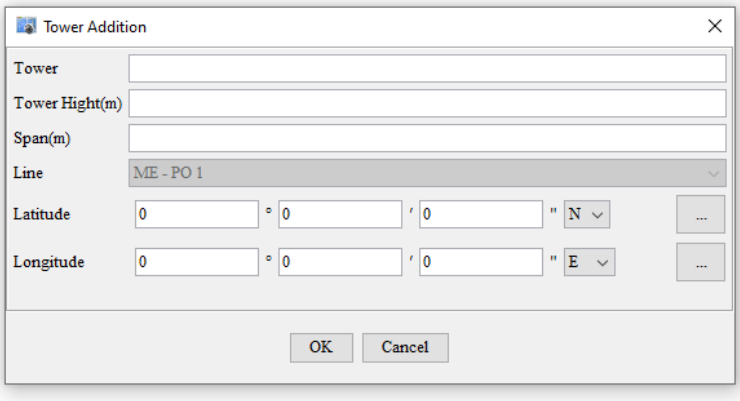
- After confirmation, the line section is deleted.
- Update: With this selection, the software opens the same window as for 'Add', allowing changes to the parameters and the ability to save them.
- Property: With this selection, the software opens the same window as 'Add', to allow the parameters to be viewed.
  - **Add T-branch:** If the line has a T-branch, the software opens a window to allow it to be added.
  - **Add a Section:** If the line is mixed, it allows a section to be added.
  - **Refresh:** This command updates the displayed lines.
  - **Show invalid lines:** This allows disabled lines to be viewed.

4.1.3.4 Tower Addition

Programming the tower locations allows the software to identify which tower is closest to the fault. Select the line where towers are to be added and select the Tower tab on the right.



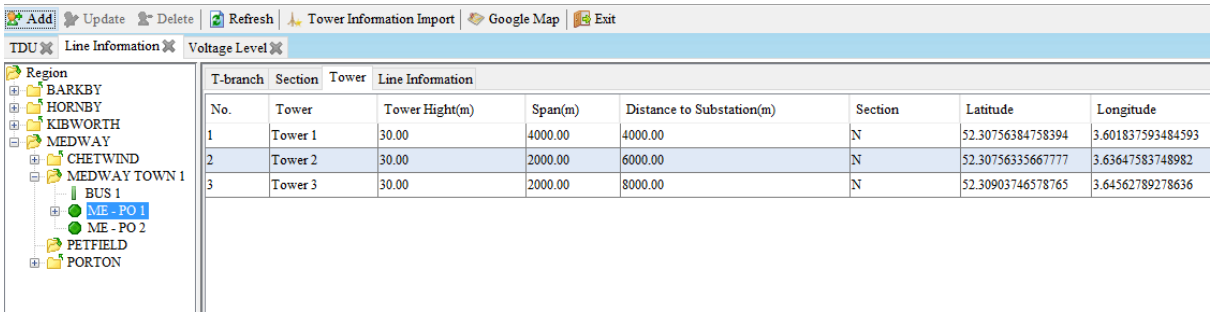
- **Add:** Press 'Add' and the following window opens.



Enter the parameters. Span is the distance (**in meters**) from the previous tower. For the first tower, the span is the distance from the substation (or, better, from the CT in the substation).

The latitude and longitude settings have been explained in the substation settings.

This is the window after adding some fully configured towers.



No.	Tower	Tower Hight(m)	Span(m)	Distance to Substation(m)	Section	Latitude	Longitude
1	Tower 1	30.00	4000.00	4000.00	N	52.30756384758394	3.601837593484593
2	Tower 2	30.00	2000.00	6000.00	N	52.30756335667777	3.63647583748982
3	Tower 3	30.00	2000.00	8000.00	N	52.30903746578765	3.64562789278636

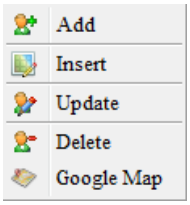
In the 'Distance to Substation' column, the software calculates and displays the distance of the tower from the substation. It gives an alert if the total length is more than the programmed line length.

The 'Section' displays information about the sections of a mixed line. In the case above, 'N' indicates that there are no additional sections in the line. Below is an example of a line with towers in section 2.

Section | Tower | Line Information

No.	Tower	Tower Hight(m)	Span(m)	Distance to Substation(m)	Section	Latitude	Longitude
1	TOWER 1001	30	5,000	5,000	SEC 2	59.383333333333333	1.0538333399
2	TOWER 1002	30	2,000	7,000	SEC 2	59.385833333333334	1.0425385839

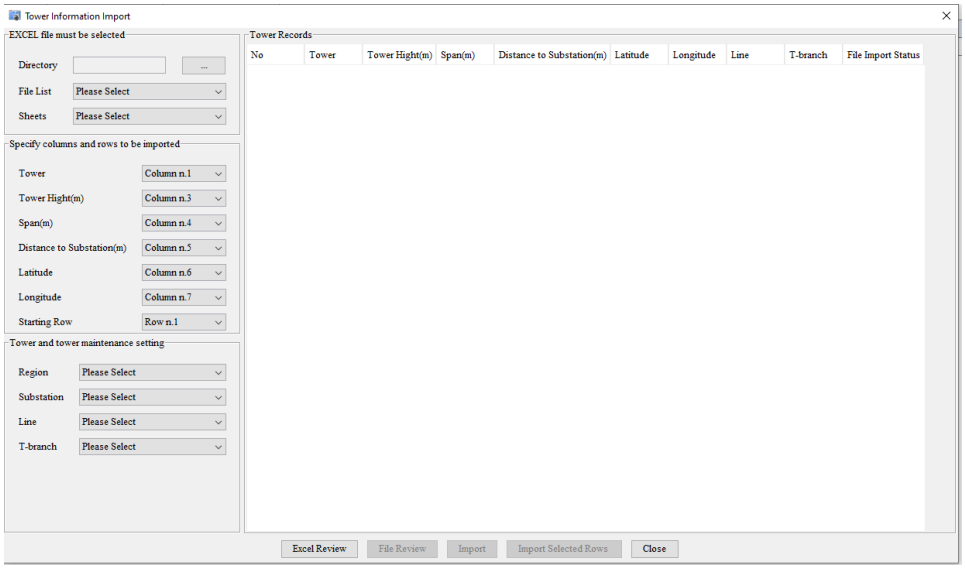
Select a tower with a left click: it is displayed in blue. Then, right click on it, the software opens the following pop-up window:



- **Insert**: This allows a tower to be inserted and is useful if a mistake is made during programming, a new tower can be inserted between two existing towers. The span before and after the newly inserted tower needs to be adjusted so that the overall line length remains the same.
- **Update**: The line configuration is updated, with all the towers.
- **Delete**: The selected tower is removed. Again, the spans may need to be modified.
- **Google map**: Refer to the dedicated Section 9.

4.1.3.5 Tower Information Import

This is accessed from the Tower Information Import button on the ribbon. This selection allows the import of data from an Excel file. The window is the following.



The tower parameters, which are the column headings, are as follows:

- Number: This is a consecutive number generated by the software.
- Tower name: This is the tower identification, e.g., T106. This field is mandatory.
- Tower height: in meters. This is optional.
- Span: The span is the distance (**in meters**) from the previous tower. For the first tower, the span is the distance from the substation. This is mandatory.
- Distance: This is the length of the line, computed from the sum of tower spans from one end of the line to the other end.
- Latitude and longitude: These can be omitted, but if available, they are input using either decimal, or degree-minute-second format. The latitude and longitude allow the towers to be positioned on the Google Map.

On the left of the screen, are the following selections:

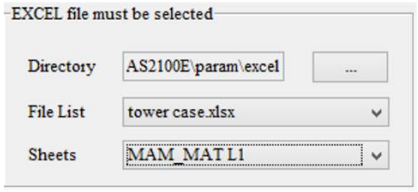
- Directory: Selected by pressing the icon .
- File List: Allows the selection of the file to import.
- Sheets: Selected from the 'File' tab.
- Specify the individual columns to be imported for each tower parameter. The columns in the Excel file may not be arranged in the same sequence as required by the software.

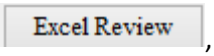
The column selection allows the selection of the correct column for each parameter. For example, if the Span (m) of the original spreadsheet is in Column 5, select Column 5 for the Span (m).

- The last selection, 'Starting Row', allows the selection of a row from the file where the first meaningful data are available.
- Finally, a selection of Region, Substation, Line and T-branch is made.

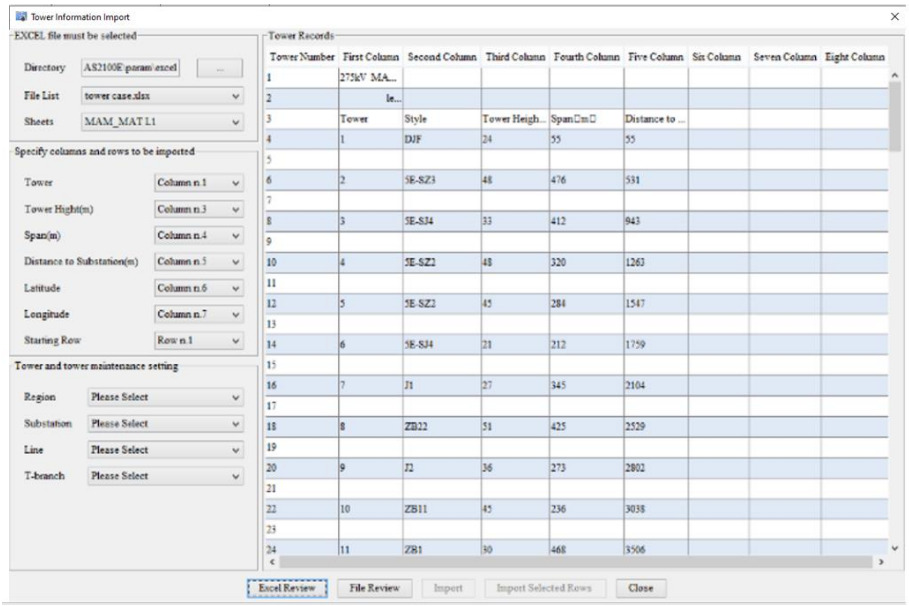
  As an illustration, go to Directory, and select: XCF2100E / param / excel

  Then, go to the File list selection, and select the file 'Tower case.xslx'. Lastly, in Sheets, select MAM_MAT L1.

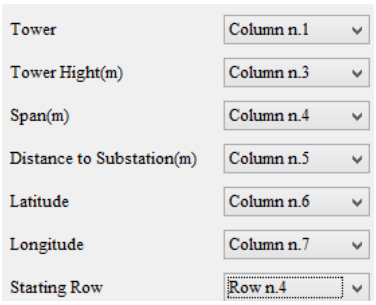


Now, on the bottom line, press Excel Review 

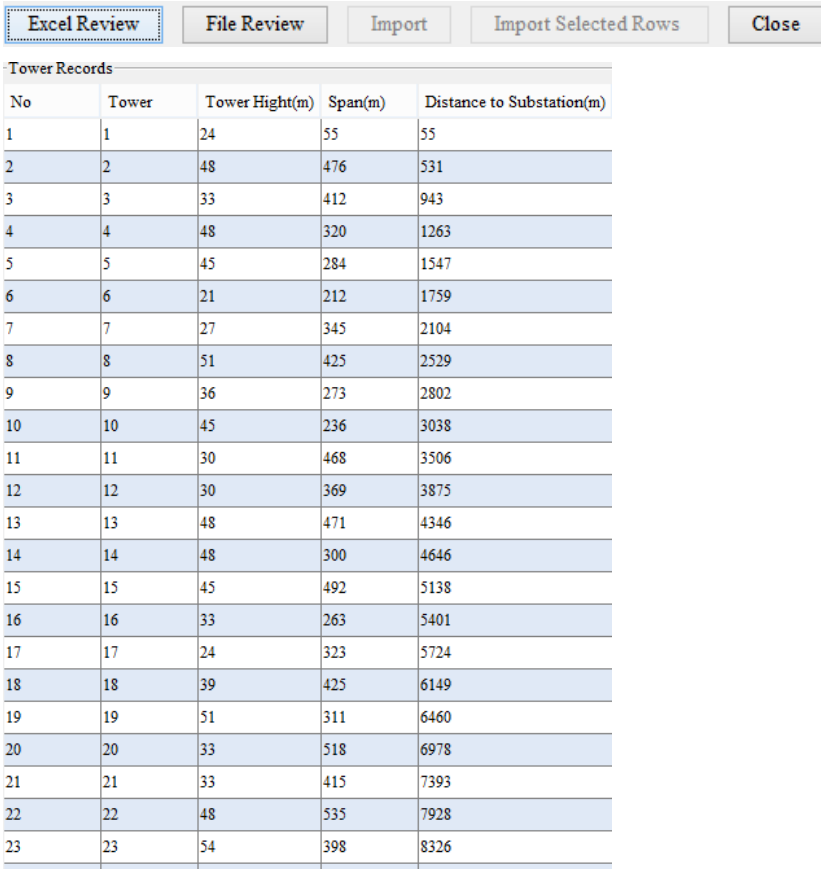
, to verify how the Excel data are organised, as follows:



As can be seen, the data in the Excel file are not the same as those expected by the software. For example, the tower name is in Column 1 on the Excel spreadsheet, the height is in Column 3; the span is in Column 4; the distance to the Substation is in Column 5. The first meaningful data starts from Row 4. The correct columns and the starting row selection can now be inputted as follows:

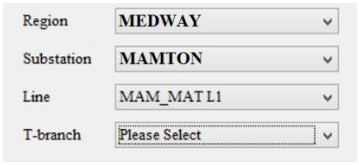


Press File Review, the tower information is now tidied up.



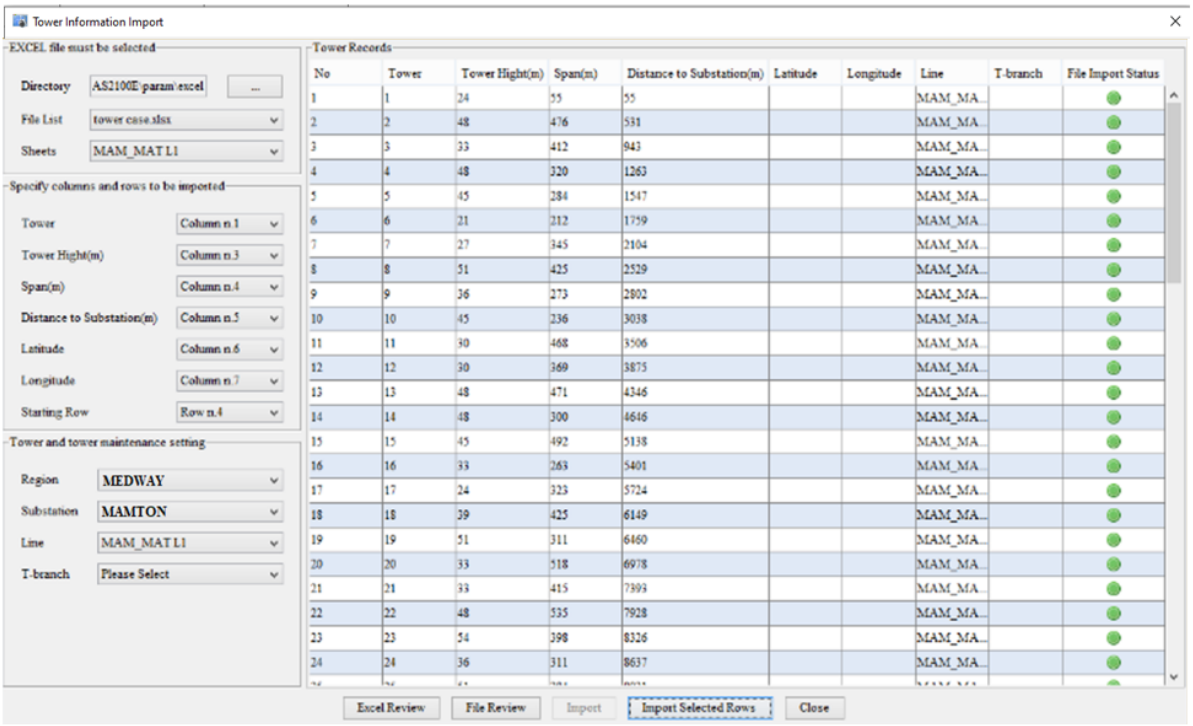
No	Tower	Tower Hight(m)	Span(m)	Distance to Substation(m)
1	1	24	55	55
2	2	48	476	531
3	3	33	412	943
4	4	48	320	1263
5	5	45	284	1547
6	6	21	212	1759
7	7	27	345	2104
8	8	51	425	2529
9	9	36	273	2802
10	10	45	236	3038
11	11	30	468	3506
12	12	30	369	3875
13	13	48	471	4346
14	14	48	300	4646
15	15	45	492	5138
16	16	33	263	5401
17	17	24	323	5724
18	18	39	425	6149
19	19	51	311	6460
20	20	33	518	6978
21	21	33	415	7393
22	22	48	535	7928
23	23	54	398	8326

The software now opens the ‘Import‘ button. On the left, select the region, substation and line of the towers.

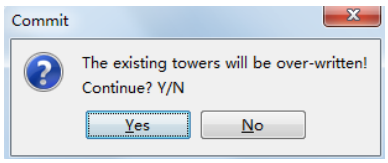


Press Import: the software imports the data and advises that the import is complete.

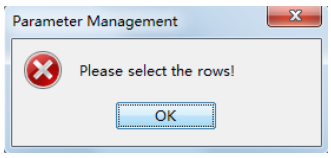
The table is now as follows:



If there are already programmed towers, they will be erased: before replacing data, the software gives an alarm.



With ‘Yes’, the Excel data is imported into the table. If required, a part of the file can be imported. In this instance, select the lines to be imported; then, press ‘Import selected rows’ and data are imported. If a row is not selected, the software displays the following warning.



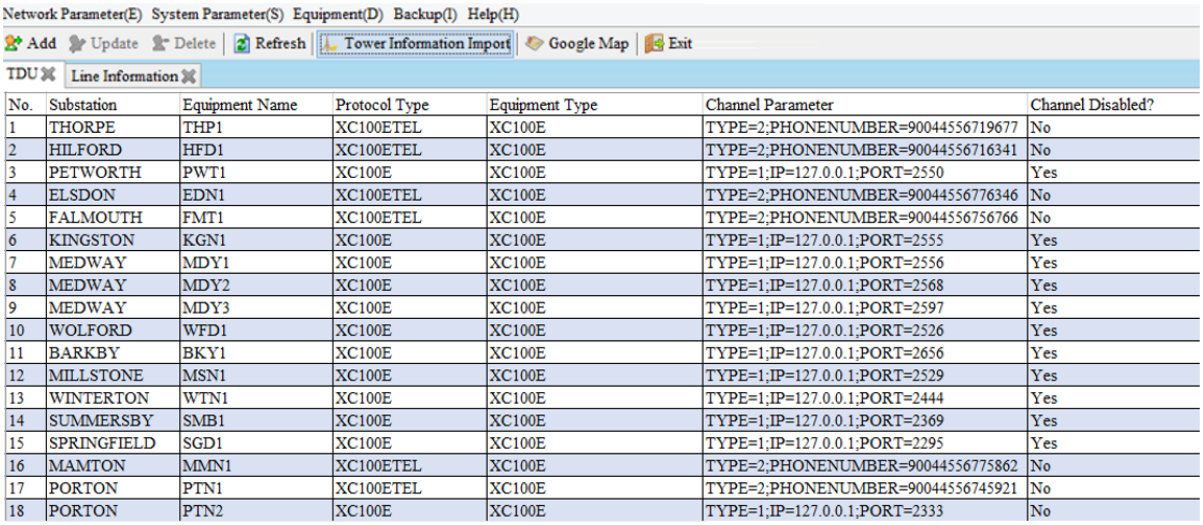
At the end, press ‘Close’ to exit the import section.

4.1.4 Importing the XC-100E

For simplicity and generality, the term TDU is used to represent the XC-100E. The

selection in the Network Parameter menu, allows the TDU window to be accessed, where a XC-100E can be added, edited and deleted.

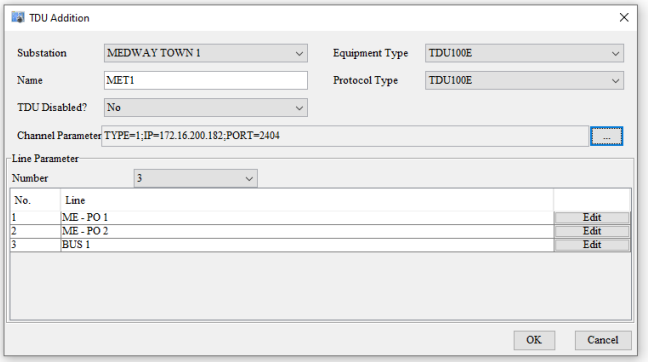
The window that opens is as follows: it lists all the programmed devices of all regions.



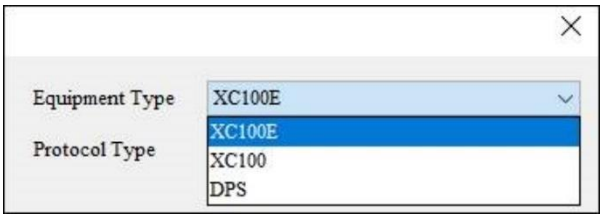
No.	Substation	Equipment Name	Protocol Type	Equipment Type	Channel Parameter	Channel Disabled?
1	THORPE	THP1	XC100ETEL	XC100E	TYPE=2;PHONENUMBER=90044556719677	No
2	HILFORD	HFD1	XC100ETEL	XC100E	TYPE=2;PHONENUMBER=90044556716341	No
3	PETWORTH	PWT1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2550	Yes
4	ELSDON	EDN1	XC100ETEL	XC100E	TYPE=2;PHONENUMBER=90044556776346	No
5	FALMOUTH	FMT1	XC100ETEL	XC100E	TYPE=2;PHONENUMBER=90044556756766	No
6	KINGSTON	KGN1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2555	Yes
7	MEDWAY	MDY1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2556	Yes
8	MEDWAY	MDY2	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2568	Yes
9	MEDWAY	MDY3	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2597	Yes
10	WOLFORD	WFD1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2526	Yes
11	BARKBY	BKY1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2656	Yes
12	MILLSTONE	MSN1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2529	Yes
13	WINTERTON	WTN1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2444	Yes
14	SUMMERSBY	SMB1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2369	Yes
15	SPRINGFIELD	SGD1	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2295	Yes
16	MAMTON	MMN1	XC100ETEL	XC100E	TYPE=2;PHONENUMBER=90044556775862	No
17	PORTON	PTN1	XC100ETEL	XC100E	TYPE=2;PHONENUMBER=90044556745921	No
18	PORTON	PTN2	XC100E	XC100E	TYPE=1;IP=127.0.0.1;PORT=2333	No

4.1.4.1 Add a device

In the TDU selection, press the ‘Add’ icon, the following window opens.



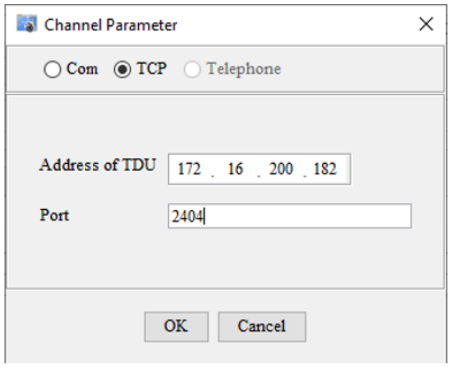
- Substation: Choose from the list.
- Equipment type: Choose from the list.
- Name: Name of the unit to be added.
- Protocol type. Clicking on this opens the following drop-down menu. It includes previous iterations of XC-100E and an earlier device.



  - If the communication mode is TCP / IP, select XC100E or XC100;
  - For a switched telephone line, select XC100ETEL;
  - For point-to-point, select XC100E or XC100;
  - The selection Trans-DNP (Distributed Network Protocol) is only supported by the XC100E unit. The function of the DNP protocol is to transfer the events and location information to other systems, such as SCADA.

- The selection Trans-103 is only supported by the XC100E; the connection can be TCP/IP or point-to-point. The selection applies for the IEC 60870 – 5 - 103 protocol, for connection to the SCADA system.

- Channel parameter. Here is the choice between the three types of communication. Click the three dots ... to the right of the Channel parameter section, provides access to the next window.



- The default is TCP: you must specify the IP address of XC-100E, XC100, or the receiver of the DNP protocol information, and the port number.

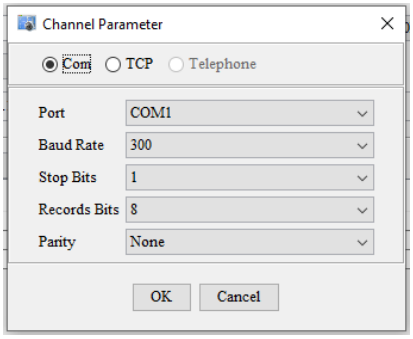
Note: If the address is 16, write 16, NOT 016.

Note: As the TCP communication is used for the local XC setting, it is necessary to input the TDU address even if TCP is not the communication mode.

Note: If the connection is based on the TCP/IP communication mode, the XC-2100 IP address and port number must match with the setting of XCF software. For instance, if the Master Unit address is:192.168.0.150, then all XC's will have the address: 192.168.0.xxx,

Where: Where xxx is any number except 150; also, XC numbers must be all different!

- The other selection is 'Com' and when selected, the below window opens. We can input the communication parameters.



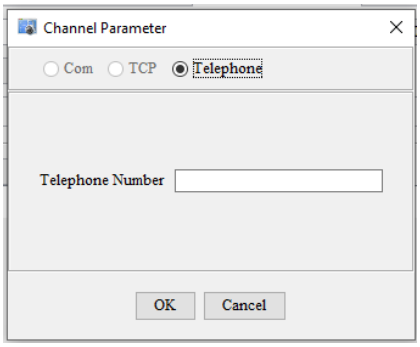
- The last selection is Telephone: it is accessible only if the protocol has been selected as type XCTEL. The telephone number can be programmed here.

Note: Sometimes there is a switched line. The telephone number is made of two parts: the telephone number plus the number of the internal line. In this instance, it is important to leave some time for the switchboard to make the connection. This is achieved by adding commas at the end of the number, before the internal line number. Each comma corresponds to a pause of 6 s.

Next, the internal line number can be repeated, which improves the ease of communication. It is programmed as follows:

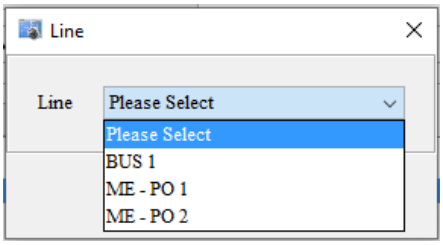
NNNNNNNNNN,,,,,XXXXX

Where: NNNNNNNN is the telephone number; commas are the pause before dialling the internal number; X is the single-digit internal line, repeated several times.



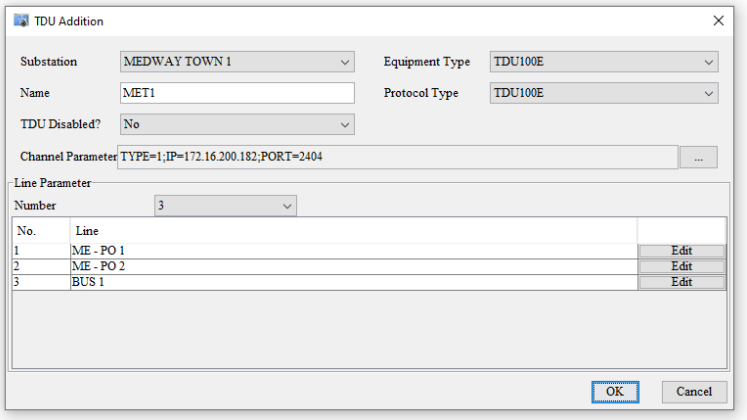
- **Channel disabled;** The term 'channel' refers to the communication line. This selection allows communication with the XC-100E to be disabled whilst leaving it connected. The normal selection is 'No'.
- **Line parameter**.

  First, select the number of substation lines, which are monitored by the same XC-100E: up to eight lines can be monitored with one equipment. The number includes the bus, if programmed. In our example, the selection is three. Then, press 'Edit ': the window will ask for the line to be selected.

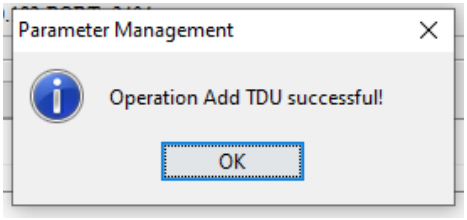


The window displays only the lines programmed for the selected substation. Once a line has been chosen it is no longer available for the next selection. Press OK for each selection made.

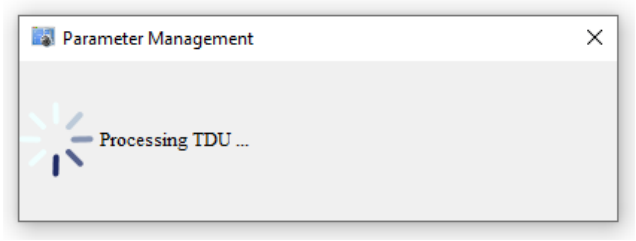
Note: the wiring of the XC-100E, must follow the same sequence of lines as are programmed. For instance, having programmed two lines and a bus on the XCF-2100E, after 'OK', the window is as follows.



Pressing ‘OK’, gives a confirmation message.



The software takes some time for the database upgrade; during this time, the following message is displayed.



The operation is repeated for all the substations equipped with the TDU. At the end, with three units, the window will look like this:

6	ELSDON	ELS1	TDU100E	TDU100E	TYPE=1;IP=172.16.200.186;PORT=2404	No
20	HILFORD	HIL1	TDU100ETEL	TDU100E	TYPE=2;PHONENUMBER=90033557464723,,,,,,,33333...	No
14	SPRINGFIELD	SGD1	TDU100E	TDU100E	TYPE=1:IP=172.16.200.182:PORT=2404	No
19	SUMMERSBY	SBY1	TDU100ETEL	TDU100E	TYPE=2;PHONENUMBER=90033557471861,,,,,,,555	No
16	WINTERTON	WTN1	TDU100E	TDU100E	TYPE=1;IP=172.16.200.184;PORT=2404	No

The three communication modes have very different transmission times and operating modes. For ETHERNET, the transmission time is almost negligible, such that there is a real time alarm after a fault. Also point-to-point can be fast, depending on the network. For the telephone connection, however, the operation is very much slowed down and depends on the reporting cycle chosen. If hourly calls are selected, there will be up to an hour’s delay with respect to the fault; however, the telephone bill will increase with the regularity of the reporting. If calls are made only when alerted to a problem, the bill will be minimised, but the fault information will be delayed.

There are two types of results which can be requested:

- Summary: This allows the software to calculate the distance of the fault, and to record it. The summary has few data, and is also fast with the telephone communication.
- Records: These take much more time. Here is the formula to calculate the recording time of transmissions for the point-to point and for the telephone selections.

  T=R*F*N*P*B/S

  T = (Data time in secs.)
  R = (Recording time seconds)
  F = (Sampling frequency, in Hz)
  N = (Number of channels, including those not used)
  P = (Number of phases per line = 3)
  B = (Number of bits per word = 12)
  S = (Speed of serial transmission, baud)

Example:

Recording Time = 1ms;

Sampling frequency = 1 MHz;

Number of channels: 4;

3 phases;

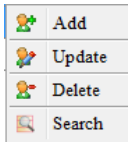
12 bits;

Transmission rate: 1200 baud.

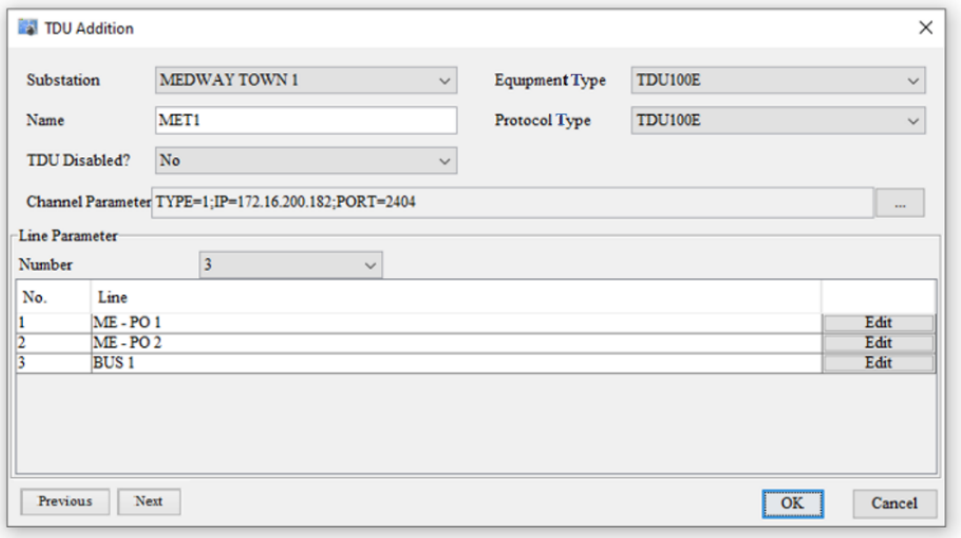
The time is: 600s, or 10 minutes.

4.1.4.2 Update the parameters of a TDU

To change the XC-100E settings, click the right mouse on the record that needs to be changed: it provides the following choices.



As an alternative, double clicking the selected substation of the TDU table allows the following window to be opened:



It is the same as the one which opens with 'Add', apart from the additional selections 'Previous' and 'Next', on the bottom left.

'Previous', saves the current setting, and displays the former one.

'Next', saves the current setting, and displays the next one.

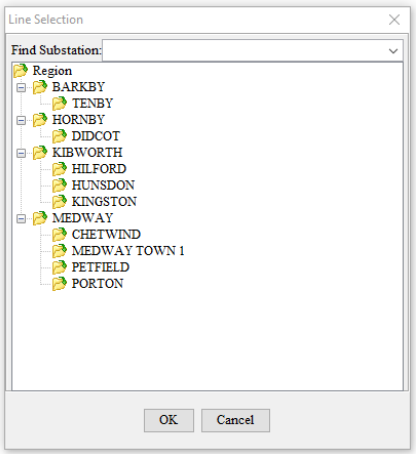
After modification, press OK.

4.1.4.3 Delete a TDU

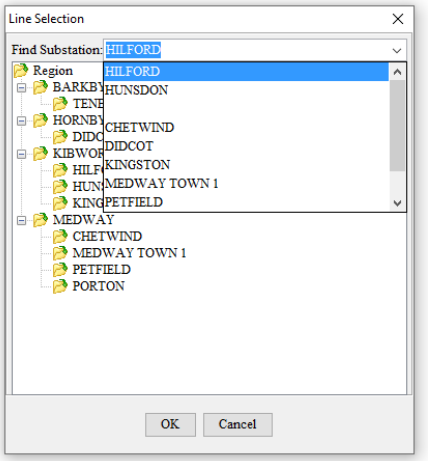
Choose the record to be removed and delete it by pressing the 'Delete' button on the tool bar, or right click the mouse, and select 'Delete'.

4.1.4.4 Search

This selection can be made by right-clicking the mouse on a selected substation, and allows a substation and its characteristics to be found amongst all programmed substations. The following window opens.



Enter the first letter of the substation name: the window displays the substations with the same initial letter.



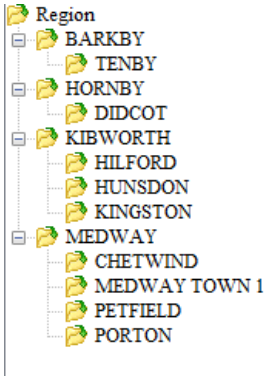
With this operation, the substation can be found rapidly; once selected, the data can be seen.

4.1.4.5 Remote parameter configuration

With the selection of TDU Remote Parameter Configuration ,from the Network Parameter menu, the XC-100E can be configured locally or remotely, via the TCP/IP connection. This is done during the commissioning of the XC-2100E system.

Note: Remote configuration is available only for the Ethernet connection.

In this example, regions Hornby and Barkby only have a telephone communication.



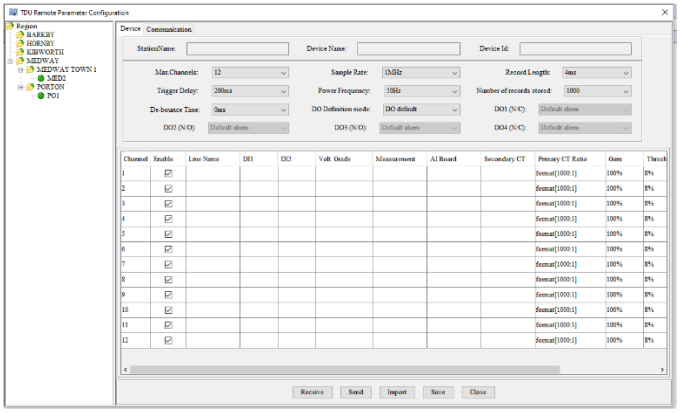
If there is a telephone connection and the parameters are to be changed, follow the following procedure:

- Select the substation;
- Read the IP address of the device using the local display;
- Select the unit in the software, and modify the connection from telephone to TCP-IP;
- Connect a PC to the XC-100E: to change the parameters.
- To finish, the telephone connection must be re-selected.

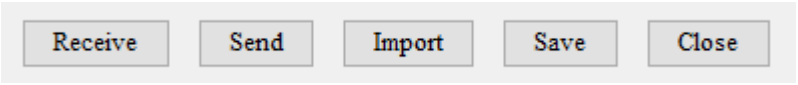
Note: If the XC-100E has already been programmed, simply select ‘Receive’ and all parameters will be acquired from the equipment

4.1.4.6 Programming window

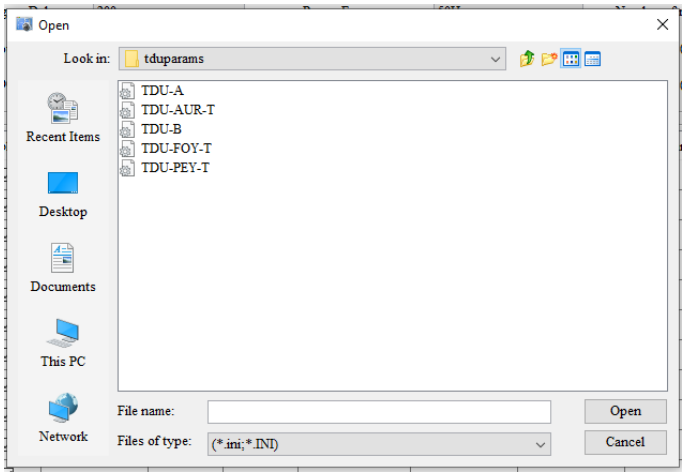
The programme window appears with the selection of TDU Remote Parameter Configuration from the Network Parameter menu.



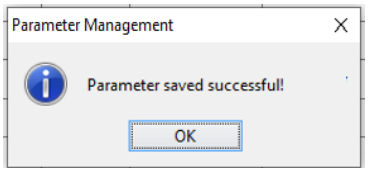
The window has two tabs: Device and Communication. For both options, the controls on the bottom line are the followings.



- **Receive:** Gets the parameters of the selected XC-100E.
- **Send:** Sends parameters to the selected XC-100E.
- **Import:** With this command, the programme opens the standard dialogue window.



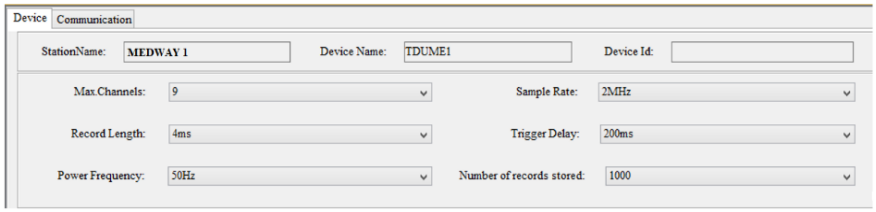
The saved settings can be searched and loaded. The setting files have the extension '.ini'. These are displayed after confirmation.



- **Save:** With this command, the programme saves the file in the directory XC2100E\param\XCparams. The file name is the same as the equipment. The software gives confirmation of registration.
- **Close:** the operation is stopped

4.1.4.7 Programming the device

Coming back to the settings window, parameters to be set are as follows:



- **Station name:** Select, on the left, the XC to be programmed: the name of the substation and of the device are shown above in the table.
- **Device name:** It shows the name of XC-100E already assigned.
- **Device ID:** Not accessible, leave it blank. It is filled by the XC device, after the connection.
- **Max. Channels:** This is the total number of analogue XC-100E inputs: it is 3 * (total number of analogue modules); it is **3** for each monitored line.
- **Sample rate:** The maximum programmable frequency depends on the number of inputs; see the following table.

INPUTS	**3**	**6**	**9**	**12**	**15**	**18**	**>18**
MAX FREQ, MHz	12	6	4	3	2,4	2	1.5

Note: Selecting a high frequency means creating bigger fault record files. Unless there is a specific reason, 1MHz should be selected.

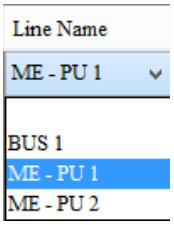
This is particularly advisable in case of telephone or point-to-point communications.

- **Record length:** 1ms is enough for a line 300 km long. Selecting a longer duration means creating bigger fault record files. This is particularly advisable in the case of telephone or point-to-point communications.
- **Trigger delay:** During this time the equipment ignores all triggers. With the default value of 200ms, CB opening transients are ignored following the fault, but it is ready to trigger on the CB close transients, that serve to calibrate the line length.
- **Power frequency:** 50 or 60Hz.
- **Number of records stored:** Select 5000, which ensures that there are a lot of records available before they are overwritten.

The following parameters can be programmed in the window. First, select the line; then, enter the desired field.

Channel	Enable	Line Name	DI1	DI2	Volt. Grade	Measurement	AI Board	Secondary CT	Primary CT Ratio	Gain	Threshold	Setting	Invert
1	☑								format[1000:1]	100%	8%		No
2	☑								format[1000:1]	100%	8%		No
3	☑								format[1000:1]	100%	8%		No
4	☑								format[1000:1]	100%	8%		No
5	☑								format[1000:1]	100%	8%		No
6	☑								format[1000:1]	100%	8%		No
7	☑								format[1000:1]	100%	8%		No
8	☑								format[1000:1]	100%	8%		No
9	☑								format[1000:1]	100%	8%		No

- **Channel.** One analogue channel can only be assigned to one phase of a line.
- **Enable**. Allows a selected input to be monitored.
- **Line name**. Repeat the same name for the three phases. For the selection, click with the mouse: the drop-down menu gives the choice of names. Select lines in the same sequence as they were selected when programming the TDU. The corresponding line voltage is displayed.

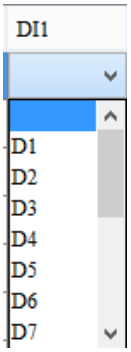


- **DI1 and DI2.** In these fields it is possible to select the logic signals, connected to the DI module(s), which give the CB position for the different lines.
- The unit has two slots available. As there are some different types of modules available, also the input numbering changes accordingly.

- The following table summarises the input names.

MODULE TYPE	No. OF INPUTS PER MODULE	FIRST MODULE INPUTS IDENTIFICATION	SECOND MODULE INPUTS IDENTIFICATION
STANDARD, OPTION 1	5	D1, D2, D3, D4, D5	D6, D7, D8, D9, D10
OPTION 2 OPTION 3	8	D1, D2, D3, D4, D5, D6, D7, D8	D9, D10, D11, D12, D13, D14, D15, D16

For the input selection, left click on DI1 or DI2: the drop-down menu opens, providing up to 16 inputs available.



The two fields, DI1 and DI2, allow selecting **two** logic signals for the **same** line. The user can decide to configure 1 DI field only or both. If the line needs only to configure 1 input, the other input should be left blank: the software will display the CB status according to that DI input only.

If two DI signals have been associated to one line, the software will display the CB status according to the two DI inputs, after having set their logic combination. Please refer to Section 4.1.4.7.

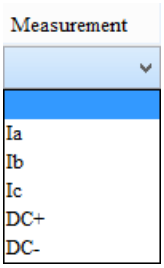
The software monitors the change in position of the CB, during ± 100ms with respect to the fault recording: if the position has changed, the fault is reported as CB operation.

As DI1 or DI2 input for one phase are selected, all phases of the same line are programmed with the same input. All inputs have to be programmed, otherwise the software will not complete the Programming.

This Programming must match with the one performed in the Circuit Breaker Programming.

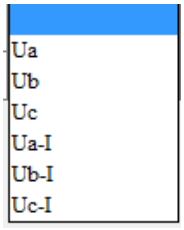
- **Volt. grade.** This displays the voltage of the selected line.

- **Measurement.** This parameter defines the type of measurement to be performed on that input. In case of a line, available selections are as follows.



  - Ia, Ib, Ic: phase currents;
  - DC+: DC voltage.

  In case of a bus or of an external CT, available selections are;.



  - Ua, Ub, Uc: phase voltages.
  - Ua-I, Ub-I, Uc-I: currents through the ground connection of the voltage phases, in case of external CT.

- **Module.** The type of module used on a phase can be selected. For lines, there are two modules: AD for the direct connection to the substation CT secondary current; **AI** for the connection via the split-core CT. If the selection is measuring a bus voltage, the AV module is automatically selected.
- **Measurement CT**. For the AI module, the programme automatically selects Split-core CT; for AD and AV modules, no selection.
- **CT ratio**. Sets the ratio of the substation current transformer. With this setting, the software calculates the gain of the module. The parameter must have the form 2000:5. If the measurement is voltage, this option cannot be selected.
- **Gain**. Here we can set the gain factor of the input, which multiplies the gain calculated on the basis of the other parameters. This factor can be set between 50% and 150%, depending on the first recordings: reduce the gain if XC triggers too much; increase it if it triggers too seldom. The default value is 100%.
- **Threshold**. It is the percentage of the maximum transient signal peak on which the recording is started (see Appendix 1). If the peak exceeds this value, XC-100E will trigger and record the event. The adjustment range is from 4% to 20% of the peak. The default value is 8%.
- **Setting**. Setting refers to the magnitude of the fundamental frequency component of the input signal, and serves to determine whether an event is a fault or not. The setting can refer to current (AI or AD modules) or voltage (AV module).

For the current, the setting is the current threshold value in percentage of the nominal current. If the current magnitude exceeds this threshold, the event is classified as a fault. The current setting's default value is 140%; the range is 120% to 240%.

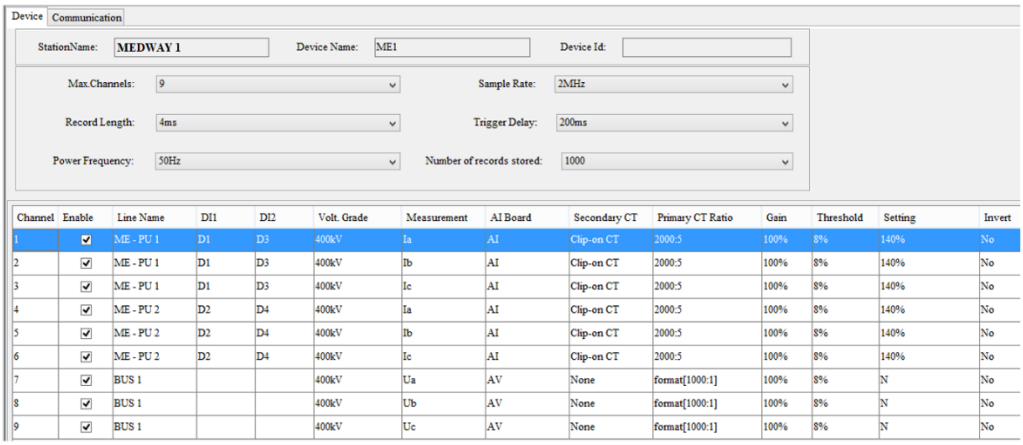
For the voltage, the setting is the voltage reduction in percentage of the nominal voltage. If the voltage magnitude drops below the setting, the event is classified as a fault. The voltage setting's default value is 20%; the range is 10% to 80%.

Note: the rated voltage (phase-phase) of the AV module is 100V. If the voltage is different, such as 110 V, set the gain at 90%.

The software measures the current or the voltage during 20ms after the fault, independently from the duration of the recording.

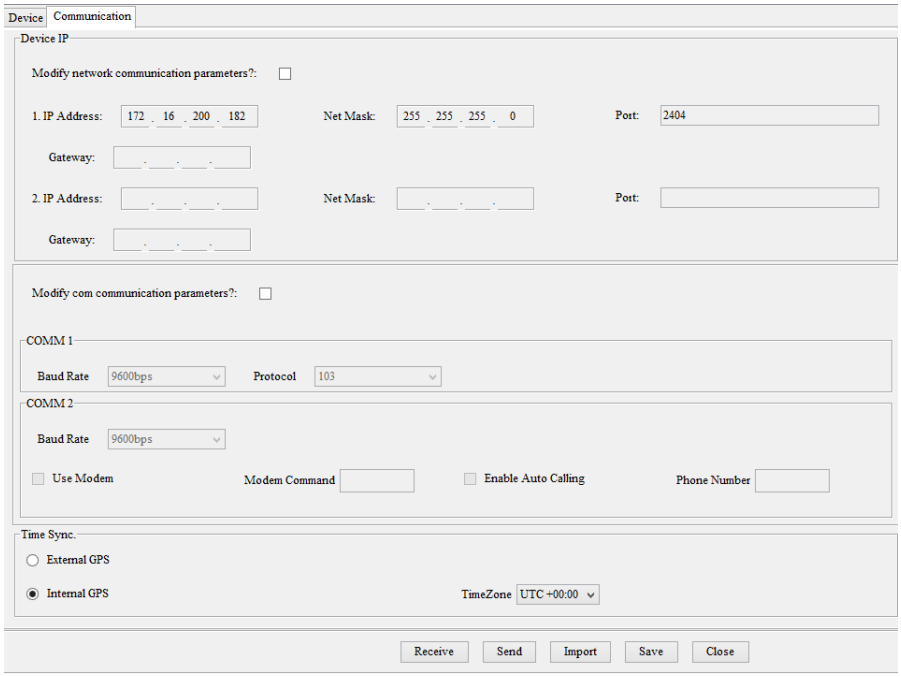
- **Inverse**. If the polarity of the connection is reversed, this setting allows the error to be fixed, without changing the connection.

This is the window after Programming:



Channel	Enable	Line Name	DI1	DI2	Volt. Grade	Measurement	AI Board	Secondary CT	Primary CT Ratio	Gain	Threshold	Setting	Invert
1	☑	ME - PU 1	D1	D3	400kV	Ia	AI	Clip-on CT	2000:5	100%	8%	140%	No
2	☑	ME - PU 1	D1	D3	400kV	Ib	AI	Clip-on CT	2000:5	100%	8%	140%	No
3	☑	ME - PU 1	D1	D3	400kV	Ic	AI	Clip-on CT	2000:5	100%	8%	140%	No
4	☑	ME - PU 2	D2	D4	400kV	Ia	AI	Clip-on CT	2000:5	100%	8%	140%	No
5	☑	ME - PU 2	D2	D4	400kV	Ib	AI	Clip-on CT	2000:5	100%	8%	140%	No
6	☑	ME - PU 2	D2	D4	400kV	Ic	AI	Clip-on CT	2000:5	100%	8%	140%	No
7	☑	BUS 1			400kV	Ua	AV	None	format[1000:1]	100%	8%	N	No
8	☑	BUS 1			400kV	Ub	AV	None	format[1000:1]	100%	8%	N	No
9	☑	BUS 1			400kV	Uc	AV	None	format[1000:1]	100%	8%	N	No

4.1.4.8 Programming the communication

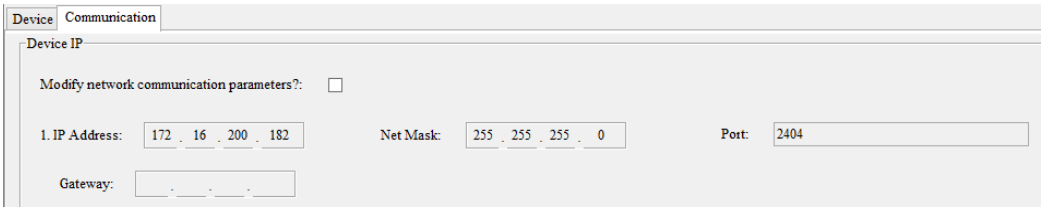


The window allows programming of all communication parameters. To change the parameters, select the check box 'Modify network communication parameters?': pressing Save, parameters will be modified.

The first selection refers to the Ethernet connection. XC-100E has two Ethernet ports at the back; the first is designated as FE1, which is also physically connected to the Ethernet port situated on the front panel of the device.

Note: As these connectors are physically joined together; there must only be one connection.

- The address is made up of three parts: IP Address, Subnet Mask, Default Gateway, Port number. The software that controls that the port number is in the range 1024 to 65535; otherwise, it gives an alarm.



The network manager must plan the address to give to all TDUs, in order to avoid having the same address on two different devices. The default port number is 2404.

The IP address of the FE1 port must match the address programmed in the TDU selection! If it is necessary to change the address, change it in the TDU selection, and repeat it here.

Note: The PC must have an address in the same segment of the TDU which is to be programmed: the first three digits must be same. The TDU comes from the factory with the address 192.168. 0.XXX: the user can change it, as desired. For the initial connection, the address of the computer must be 192.168.0.XXX, where XXX cannot be the same as the one programmed in the device.

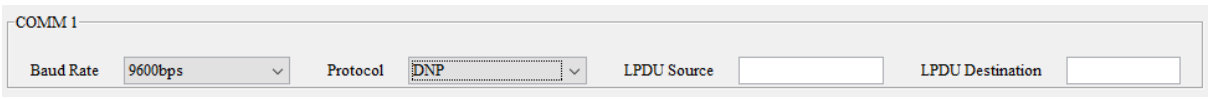
Most communication errors are address errors. It must be considered that, when a device is selected, the type of communication and address of the TDU is programmed: in case of communication problems, always check the settings.

- Second IP address, gateway FE2: the second port can be given a different address with respect to FE1.

Note: Bot the rear Ethernet ports on the TDU support the IEC61870-5-103 standard for communication with the XCF-2100E.

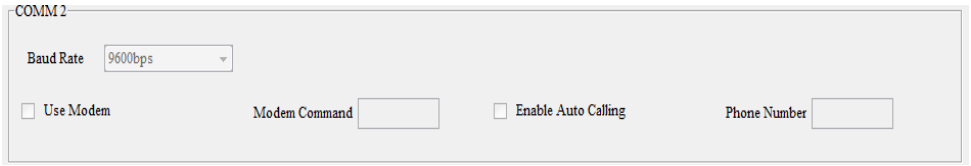
- If the communication is Ethernet, the Programming is complete. If not, check the 'Modify com.' box: the corresponding setting windows are enabled, which allows COMM1 and COMM2 serial ports to be configured.

- COMM1 protocol: choosing 103 (representing IEC61870-5-103) or DNP (for DNP3) from the drop-down menu selects the point-to-point communication. 103 provides another communications channel to XCF-2100E. DNP3 is for communications to SCADA.
- The selection DNP gives the following window.



- This allows the Link Protocol Data Unit (LPDU) to be entered, both for the source and for the destination.

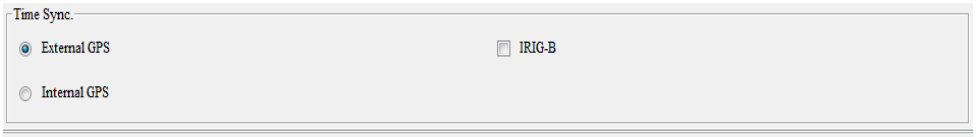
- COMM2 provides a Modem connection to XCF-2100E, using IEC70870-5-103. The selection can be programmed as follows:
  - Check the 'Use Modem' box.
  - MODEM Command: it must be programmed; the default is ATS0 = 1.



  - Enable auto calling: with this selection, the XCF-2100E master station software calls the XC-100E at a fixed time interval for which the phone number needs to be added.

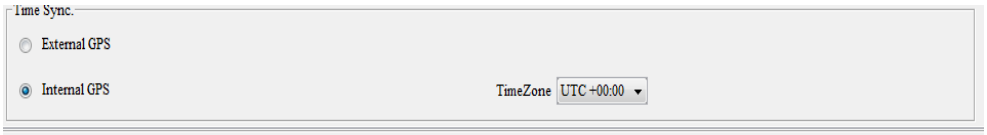
Note: this will affect the telephone bill.

  - Time synchronisation. Five modules are available; the selection should match the type of module which has been installed in the XC-100E. There are three selections:
  - External GPS. Select this choice when the module is 1 PPS input, 5 V, or 1 PPS input, optical fibre.



    - IRIG-B. Check the box when the module is IRIG-B DC, or IRIG-B, optical fibre. With this selection, the software provides the prompt of the year seen by IRIG-B

    - Internal GPS



This selection allows the time zone to be set for the location where the XC-100E will be installed. The software tracks time changes due to daylight-saving time.

4.1.5 Circuit Breaker

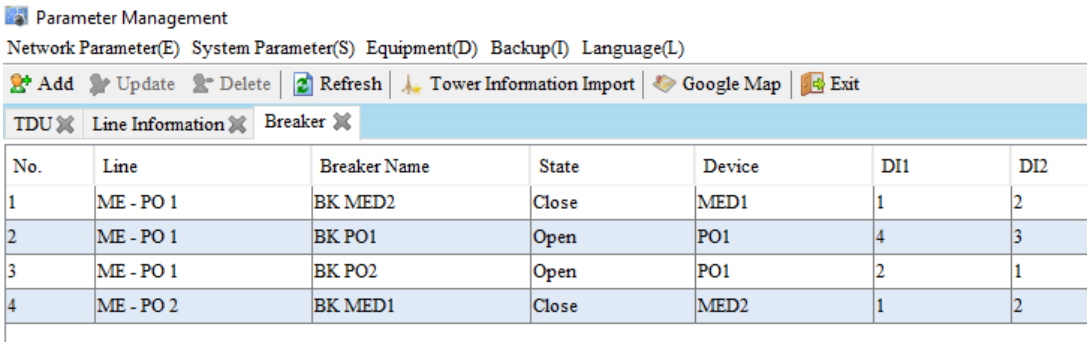
The selection

, in the Network Parameters menu, allows the user to programme the information of the breakers at both ends of the line, and to specify the corresponding digital input.

Note: This feature does allow measurement of the CB operation times. The recording is initiated by the trigger; the TDU monitors the CB position only 100ms before and after operation. If a CB operation does not cause a trigger, it is not recorded.

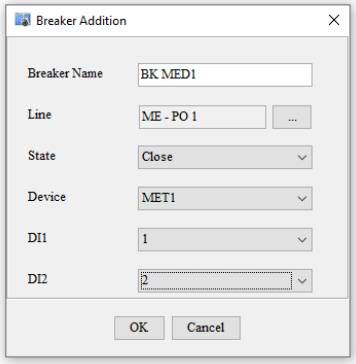
4.1.5.1 Adding a circuit breaker

The software opens the following window, showing all the circuit breakers in all networks.

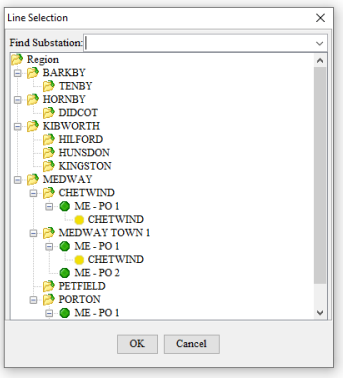


No.	Line	Breaker Name	State	Device	DI1	DI2
1	ME - PO 1	BK MED2	Close	MED1	1	2
2	ME - PO 1	BK PO1	Open	PO1	4	3
3	ME - PO 1	BK PO2	Open	PO1	2	1
4	ME - PO 2	BK MED1	Close	MED2	1	2

In the breaker selection, under network parameters, press the 'Add' icon: The following pop-up window opens.



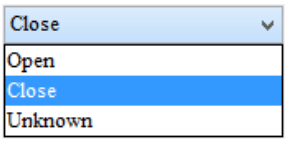
Add the name of the circuit breaker in the appropriate section. Then choose the line it is associated with by clicking on the button with three dots ... : the following pop-up window appears; it represents the network.



In the 'Find Substation' area, select the substation name on the scroll-down window and use the mouse to choose the line.

The remaining boxes are populated as follows:

- State: Allows the CB position to be inputted, when the signal is HIGH.



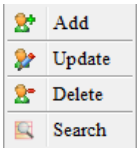
  The pop-up window gives three choices: Open, Closed or Unknown, where the latter means that any level is alright.

- Device. Choose the equipment that is connected to the CB position logic signal.
- DI1, DI2. XC can monitor two inputs per CB. For instance, the CB Closed and the CB Open signals. This selection must be the same programmed in the TDU parameters! The software can be programmed on the logic combination of the two inputs: see next Section.

Note: clicking on the window columns allows the arrangement of the table in ascending or descending order of: number, line name, breaker name, DI state, device name, DI pin number. This facilitates the search.

4.1.5.2 Breaker update

Choose the breaker record to be changed and change the record by clicking the 'Update' button on the tool bar, or by right clicking the mouse. The right click menu is the following.



4.1.5.3 Breaker deletion

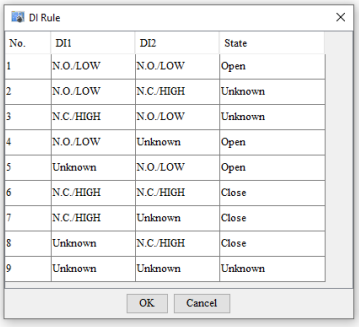
This is the same operation as with the other selections.

4.1.6 DI Rule

The selection

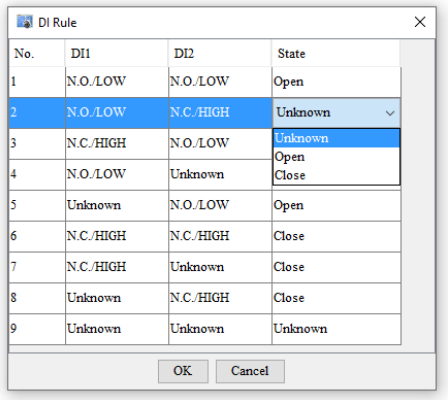
, in the Network Parameters menu, allows the combination logic of the two DI1, DI2 logic inputs to be programmed. This allows the TDU to monitor if the recording has originated from a CB operation. The DI rule is used when there are two digital inputs for one line, and it is necessary to use their logical combination to confirm the CB status.

After the selection, the programme displays the following window:



Note: In the table, Open and Close refer to dry (no voltage) logic inputs, **NOT** to the CB position. When inputs are wet (with voltage), Open corresponds to low voltage, Close corresponds to high voltage.

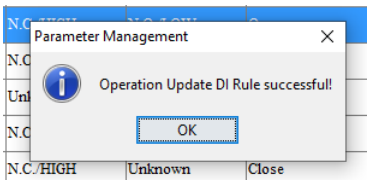
The previous table displays all nine possible combinations of DI1 and DI2, and of the resulting State. In the inputs, Unknown means that the input is not considered. The State can be programmed for each combination, as follows.



As shown in the above window, for the second rule, when DI1 is 'N.O./LOW' and DI2 is 'NC/HIGH', the CB State can be set to 'Unknown'. After modification, press 'OK' to confirm it. The XCF software will decide the CB state by the DI rule. For example, if DI1 is 'N.O./LOW', DI2 is ' N.O./LOW ', the software will decide that the CB is 'Open' according to DI rule No.1; if DI1 is 'N.C./HIGH', DI2 is ' N.C./HIGH ', the software will decide that the CB is 'Closed' according to DI rule No. 6.

The rule works where there is only one input. For example, if only DI1 is connected to the digital input, DI2 is set as 'Unknown' in the DI rule and the CB state only depends on DI1.

Once the selection has been made, press OK: which gives the following message:

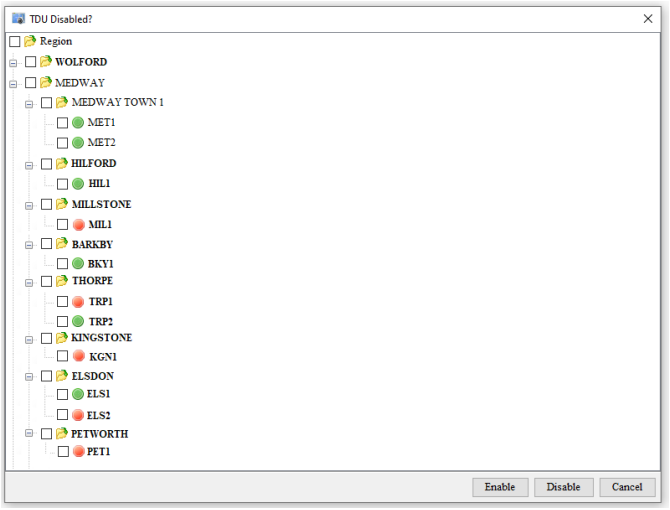


4.1.7 TDU disabled?

The selection

is available in Network Parameters. It allows the device to be disabled or enabled. The selection is useful when one device has a problem, but it is still necessary to monitor the other units in the region.

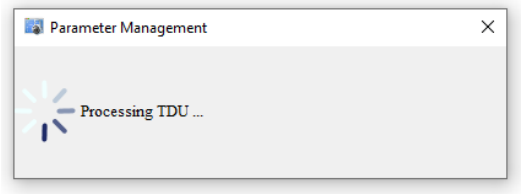
After selection, the following window is opened.



In the window, a green dot means the corresponding unit is enabled, while the red mark means that it is disabled.

In the list, select the device requiring a change of state (the software supports a multiple selection). If the selected device should be available, press the ‘Enable’ button and conversely to disable press the ‘Disable’ button.

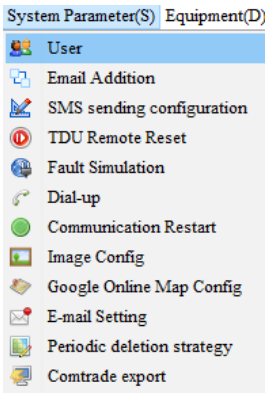
After the command, the following message is displayed.



When this disappears, the operation is completed, and the window is closed.

4.2 System Parameters

This is selected from the ribbon or with ‘Alt + s’ and provides this pop-up window:



The following sections explain the options:

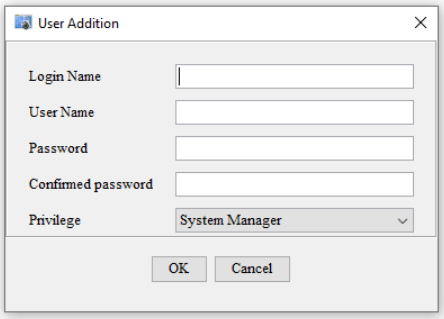
4.2.1 User

This selection allows users to be added or deleted from the list of people who can access the programme, and to set their privileges.

The icon is : This gives a list of existing users.

No.	Login Name	User Name	Password	Privilege
1	DJones	David Jones	dgJ45df	Dispatcher
2	JSmith	John Smith	AFrgeu%12hXthW	System Manager

Press Add: the following window is displayed.



- The ‘Login Name’ is the name used to login the software. It can be any name.
- The ‘User Name’ is the actual name of the operator using the software.
- Password. Relating to a particular the user.
- Confirmed password: repeat the password.
- Privilege: with the slide-down window, ‘System Manager’ or ‘Dispatcher’ can be selected.

After the confirmation, the new user is added to the table, which can then be updated or deleted as required.

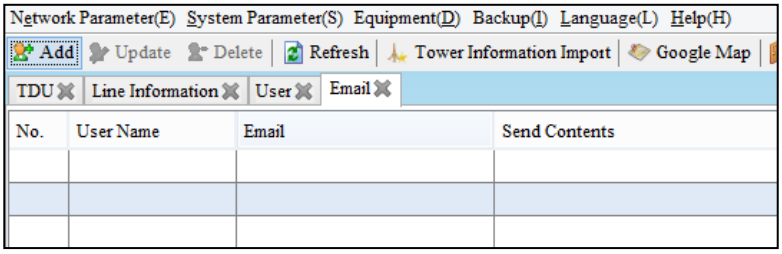
4.2.2 Email addition

When a fault occurs, the equipment can send an email to the address programmed here. The programming is performed in two steps:

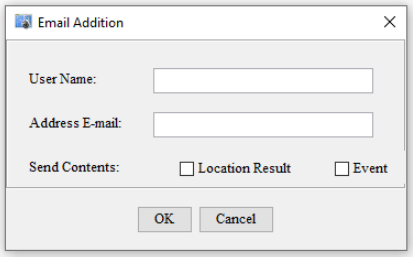
- First, programme the E-mail setting, as explained in Section 4.5. With this operation, the data of the calling PC is provided;
- Next, with this selection, programme all the addresses to which the information should be sent.

The icon is

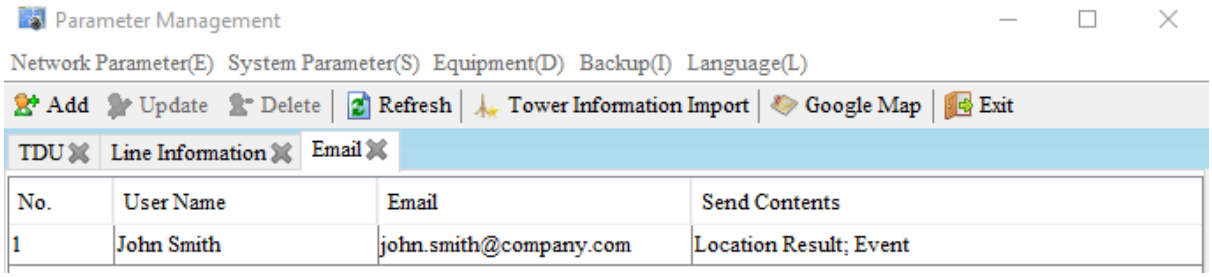
: pressing it provides the list of the existing mail address.



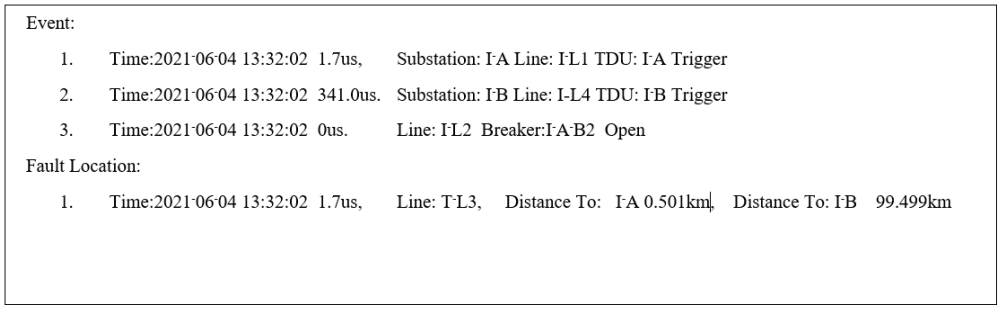
Pressing the 'Add' icon, opens the following window.



After entering the name and address, the type of message that will be sent automatically can be chosen: e.g., the fault location result or all events. Pressing 'OK', confirms the selection. On the main page, the programmed address appears.

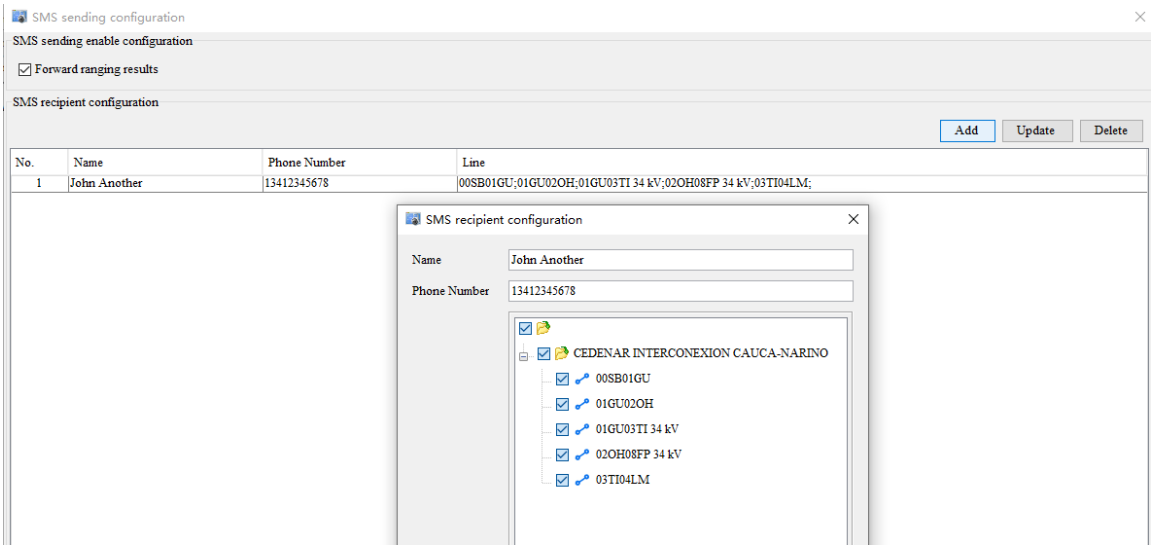


Selecting the address, allows it to be Updated or Deleted. An example of the received information is as follows:



4.2.3 SMS sending configuration

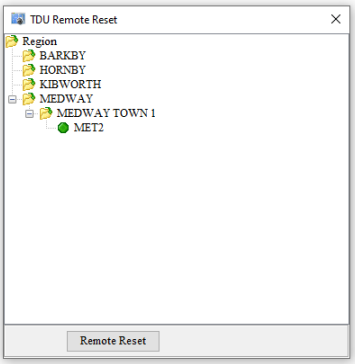
This feature is used to send SMS messages of 2-ended fault location results to the user's mobile phone. The configuration requires the name of the user, the mobile phone number and the line (or lines) of which the fault location result is to be sent. In the example below, the network under monitoring consisting of 5 lines are selected. The result of any 2-ended fault location on those lines will be sent to the recipient.



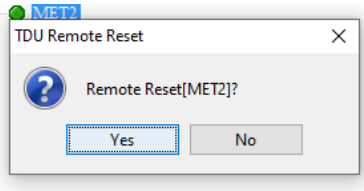
4.2.4 TDU remote reset

With this selection, an XC-100E unit which does not respond correctly, can be reset; this operation is available when the master unit is connected to the network. The icon is

The window is as follows:



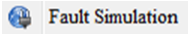
Select the TDU to be reset, and press ‘Remote Reset’: the software asks for a confirmation.



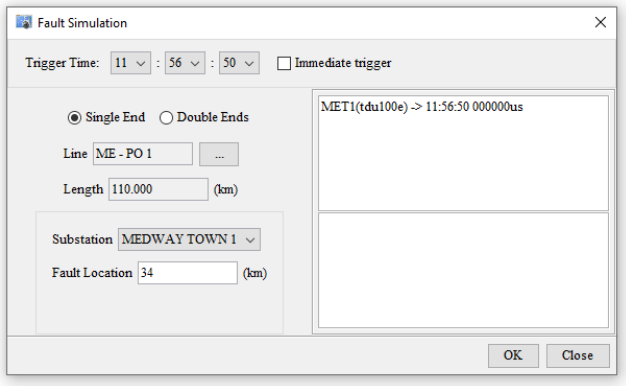
Answer ‘Yes’ to perform the operation

4.2.5 Fault simulation

This selection allows the simulation of a fault trigger in the TDU, in single end or double end modes. The operation serves to check the software performance: transmission of fault record, fault location, alarms etc.

The function is available only when the master unit is connected to the network. The icon is as follows 

: once pressed, the following window is opened.

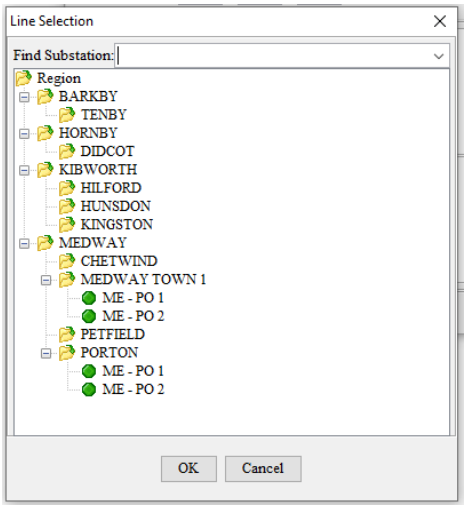


With the selection ‘Single End’, the programme displays the above window. Choose:

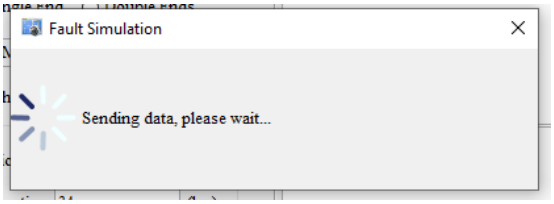
- Trigger time: the software will wait until the programmed time, and then send the simulation command. Checking ‘Immediate’ trigger results in the trigger being sent as soon as OK is pressed.

- Line: Press the icon

to select the line which the simulated fault will be applied to.

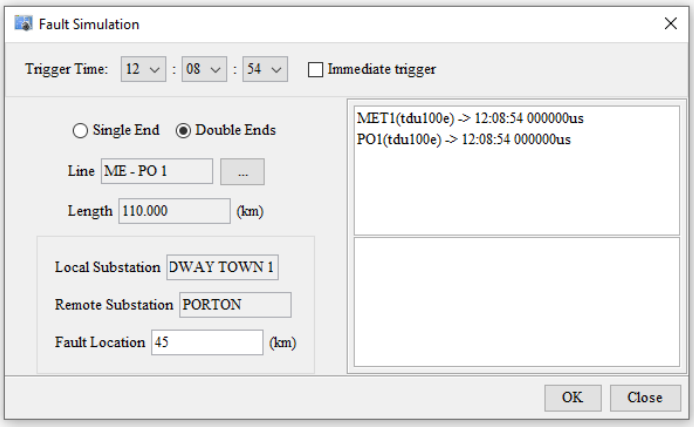


- Length: the software displays the line length which has been set during configuration.
- Substation: select the substation from which the simulated fault distance is to be applied.
- Fault location: Enter the distance from the substation to the simulated fault.
- Press ‘OK’, the following window opens:



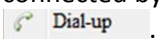
At the end, the fault is recorded on the selected XC-100E. When the fault data is received, the trigger times will match those displayed before the start of the test.

- With the selection ‘Double Ends’ the programme displays the following window.



In this case the line is selected as above; then, the software displays the two substations at the ends of the line. The fault location distance is from the Local Substation. The right-hand pane shows the expected time of the triggers at either end.

4.2.6 Dial-up

This instigates the download of fault information when a TDU on the system is connected by a telephone line. The selection is active only if TDUs are connected. The icon is 

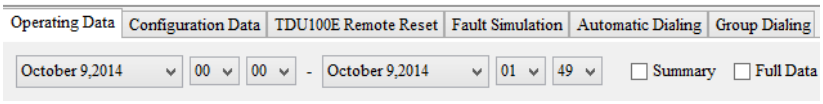
. The following window is opened.

Listed substations and TDUs are those which have been selected on the Telephone communication.

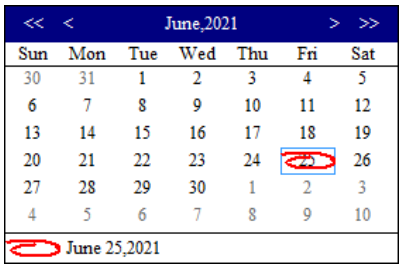
At the top, there is the selection ‘MODEM Config’ which allows the selection of the type of MODEM being used by the PC, from the drop-down menu. From the ribbon, select Operating Data to configure the dial-up mode.

4.2.7 Operating data

This allows the selection of data for download, by defining the recording time and data type. The following can be selected:



- Time Selection: It is used to select the time range of the TDU records: to the left the first record, to the right the last one. When the window is opened, the software displays the current date on both sides. Pressing the selection window, the following is displayed.

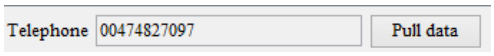


  The circle highlights the current day. Any other day can be selected if necessary, a single left arrow < selects the previous month; two left arrows << select the previous year. Select the desired day and time for the beginning and the end of the period which includes the recording required for download: the transmission will take some time.

- Summary: The download of the summary of recordings can be selected to have the list of faults. The summary includes: fault distance, if the same fault has been recorded at both ends of the line, fault time, fault phase, but it does not include the waveform. The fault distance will be computed only after the summary of TDU recordings at both ends of the line has been downloaded.

- Full data: This is used to obtain both the summary and the associated waveforms. **Note:** this operation will take several minutes, whilst the summary alone, takes just a few seconds.

  After the selection of the substation, select the TDU from which to download the data: the corresponding telephone number is shown.



  Then, press 'Pull data': the selected phone number will be called; the call is confirmed in the bottom portion of the window. TDU will send the data to the software; for the data analysis, see the Section 7 'Travelling Wave Records'.

  At any moment, or at the end of data transfer, press 'Ring off' to close the communication.

4.2.7.1 Dial up Configuration data

The operations are explained in Section 4.1.4.5; the only difference is that here, the composition of the phone number is provided.

4.2.7.2 Dial up Remote reset

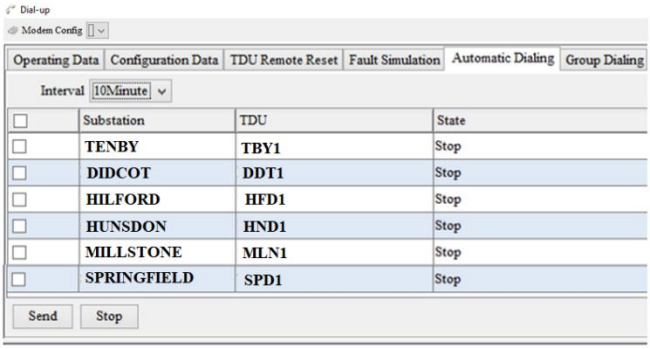
The operations are explained in Section 4.2.4; the only difference is that here the composition of the phone number is provided.

4.2.7.3 Dial up Fault simulation

The operations are explained in Section 4.2.5; the only difference is that here, the composition of the phone number is provided.

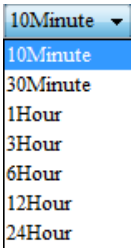
4.2.7.4 Automatic dialling

The following window is displayed:



This selection allows the downloading TDU data to be carried out automatically. This allows the user to be alerted about events with a short delay; the limitation is the cost of the calls.

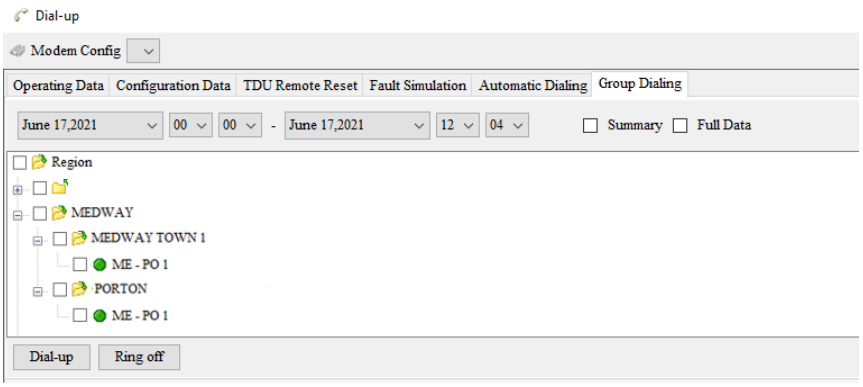
The window lists all TDUs which are connected by telephone. The required TDU can be selected by checking the box. The interval between calls can be set from 10 minutes to 24 hours.



After these selections, press ‘Send’: the automatic call instruction is sent to all selected TDUs.

4.2.7.5 Group dialling

The following window is displayed:

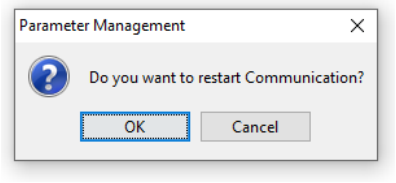


The purpose of this selection is to consecutively call more than one TDU, to see if there is a fault record: The received data summaries will include fault locations where appropriate.

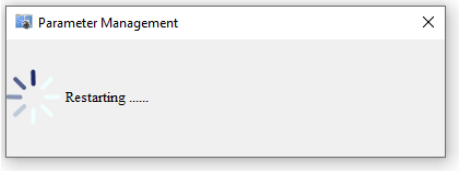
4.2.7.6 Communications restart

The selection

allows the software to restart communication system between the master station software and the equipment. The following confirmation window is opened:



Next, the software displays the time it takes to complete the operation.

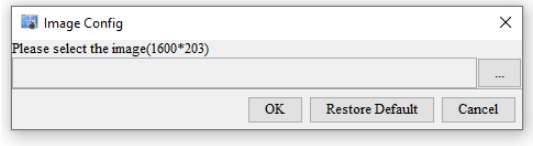


4.3 Image configuration

This selection

allows a company logo to be displayed on the software front page, instead of KEHUI.

The following window is opened.



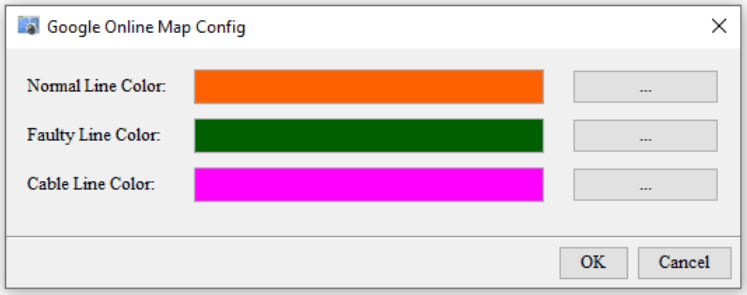
Select the directory and the file with the required logo, and then press OK. The logo can have a .jpg or .bmp extension; the dimension should be 1600*203 pixels. Press OK, then exit and re-start the XC-2100E software: the new logo is displayed.

Pressing ‘Restore default’, will restore the original KEHUI logo to the welcome page.

4.4 Google Online map configuration

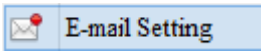
The selection

allows the colour of the healthy and the faulty line to be chosen for the Google map. The following window is opened.

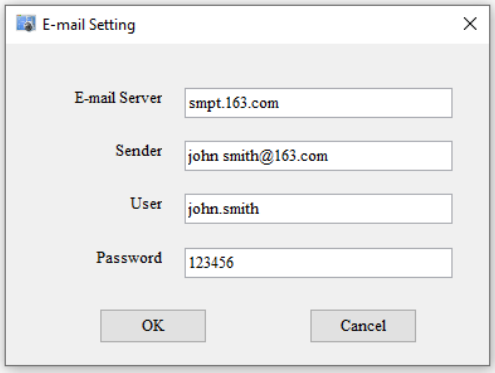


Alternative colours can be selected from the colour table accessed by the three dots adjacent to each line.

4.5 Email setting

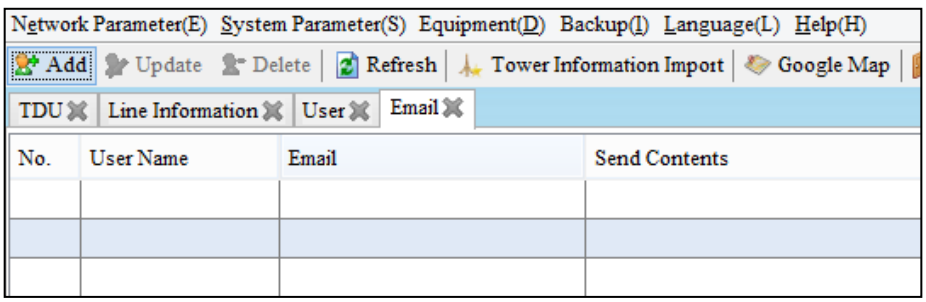
The selection 

allows for Programming of the Sender data. The following sender information should be inputted.



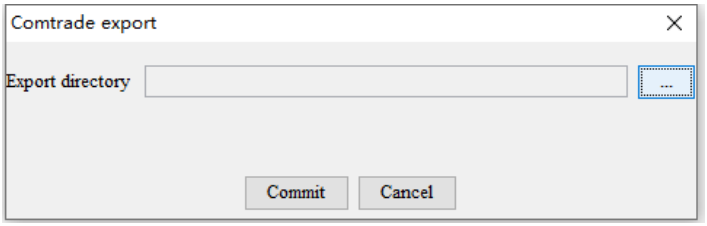
- E-mail Server: Sender E-mail server;
- Sender： Sender E-mail address;
- User： Sender E-mail user name;
- Password： Sender E-mail password.

After configuration, the XCF software will send the information to the E-mail address configured in the ‘Email addition’ menu, as explained in Section 4.2.2. The ‘Email addition’ configuration is as follows.



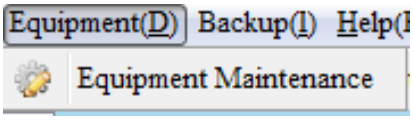
4.6 Comtrade Export

The Comtrade files in primary and secondary quantities will be exported into a user-defined directory if configured. The set-up of this directory is done through the 'Comtrade Export' facility as shown.



4.7 Equipment maintenance

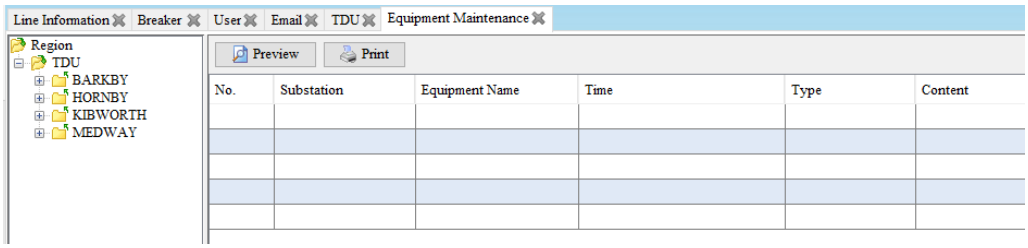
This feature is used to manually record a maintenance operation to a TDU. The selection is accessed as follows:



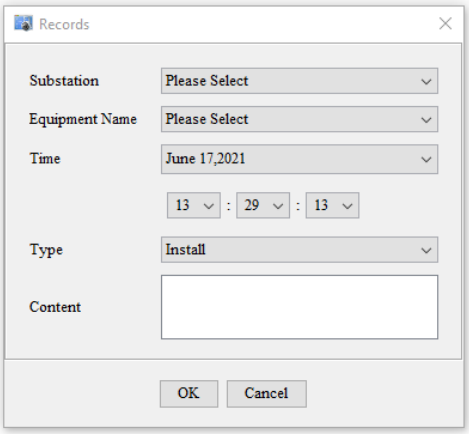
It is also accessed with Alt + d.

This selection allows the user to add, modify and delete all information about any maintenance, repair, replacement etc., performed on any TDU throughout the selected region.

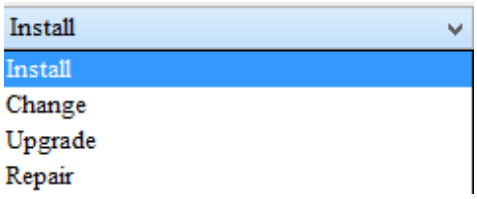
The window is divided into two parts: the equipment tree on the left, and the list of information on the right.



Open the maintenance window by clicking the 'Add' button on the tool bar, which gives the following window. Select the substation, equipment name and time related to the required maintenance session.



There are four possible maintenance types which can be selected. It is also possible to enter comments in the Contents box.

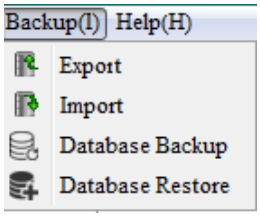


Press OK, and the maintenance information is saved for future reference.

4.8 Database back-up, delete and restore

The XCF-2100E provides a database back-up facility (to aid in the event of PC crash or hard disk failure), which contains the setting parameters, fault and alarm records. This back-up can also be used when engineering support is required such that the database can be provided to assist in the analysis of fault incidents.

This function is also accessed with Alt + i. Here is the window that is opened:



The software provides the import and export operation on two types of data: current data, and the entire database. The difference between the two is as follows.

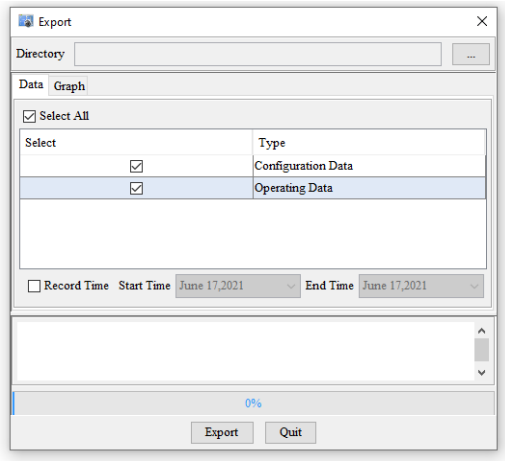
- When data are imported (or exported), they are added to (or saved from) the lines and networks that are currently used by the software. In particular:
  - New lines are added to the existing ones;
  - New data of the existing lines are added;
  - Data already available in existing files are ignored.
  - When the database is restored, all current information is cleared. Data can be retrieved as they were at the time of the last back-up.

In conclusion, the normal operation is data import or export. Database restore is used when data are damaged, or during the first installation. The following is an explanation of the operation:

4.8.1 Data Export

This command allows the current data to be saved to files in Excel format, allowing them to be sent to other users. This performance is particularly important when the TDUs are connected by phone, as it allows all interested people to get data without being obliged to connect to the TDU.

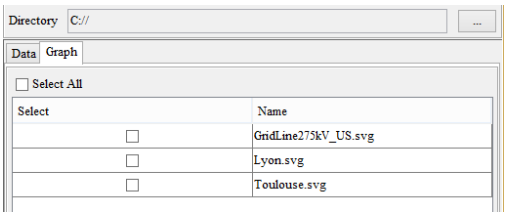
The window is as follows:



Select the back-up directory, pressing the button ... . The software opens the standard selection window; the default is C:

This selection is the one to be used when results are to be sent to someone.

- In the Graph tab, shown below, the window shows the diagrams that are available.



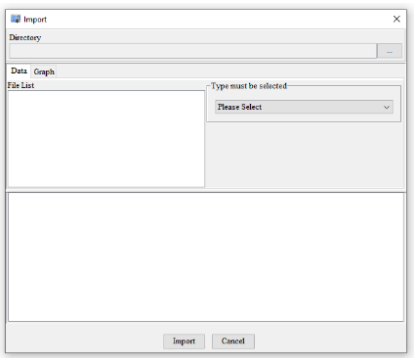
Select the diagrams to save.

Based on the selections, the software stores the selected data in different files; they are:

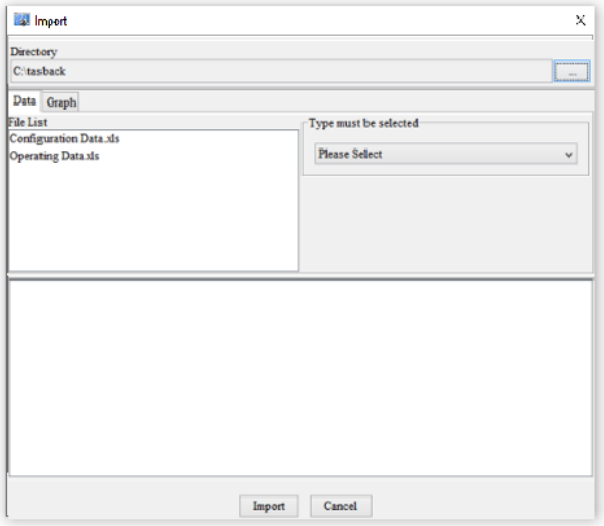
- Configuration data.XLS, for all settings. Data saved with this selection are: Voltage level, Region, Substation, line, XC, Channel, XC line, Equipment, Equipment State, Breaker, T-branch, Tower number, Email, Section, DIRule.
- Operating Data.XLS, for test results. Data saved with this selection are: Fault Analysis, Fault Data, Measure span, Fault data result, WAN measure, Wave data queue, Wave data queue history, SOE, Event.
- File Name.SVG, for the network graph. This file can be opened by the XCF software.

4.8.2 Data Import

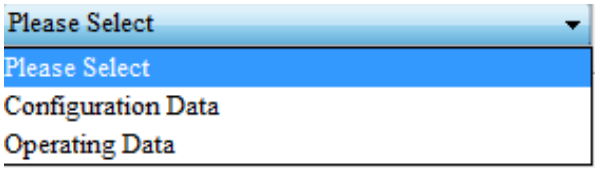
This command allows the retrieval of data that has been saved, or has been received. The window is as follows:



- Select the directory to look for the file, pressing the button ... : the software opens the standard selection window. The software displays the files with extensions '*.xls' or '*.xlsx' that exist in the selected directory. They are designated; 'Configuration data.xls', and 'Operating data.xls'.



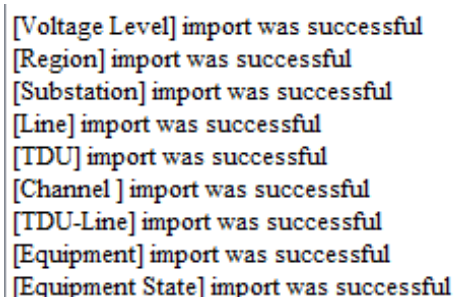
- Choose the type of data to import. There are two choices:



The selection refers to the type of data to be imported, see the characteristics in the section before. After the selection, the software highlights the files with the selected name.

- Press 'Import ': the software loads data from the Excel file. Before proceeding, the software checks the consistency of the data format and imports, if the values already exist, the software ignores the new data and continues.

The result of the operation is displayed below: if all went well, the message displayed is 'import was successful'; otherwise, the message says that it was wrong.

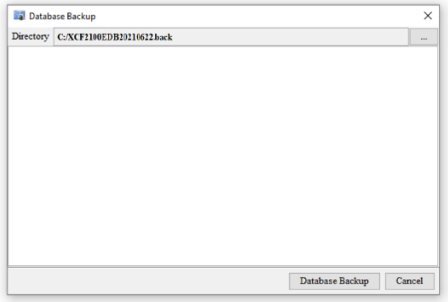


The last messages are 'Configuration data input is completed' or 'Operation data input is completed'.

- For the graph import, as above, select the directory: the software displays all files with the extension .svg. Select the desired one, and press 'Import'.

4.8.3 Database back-up

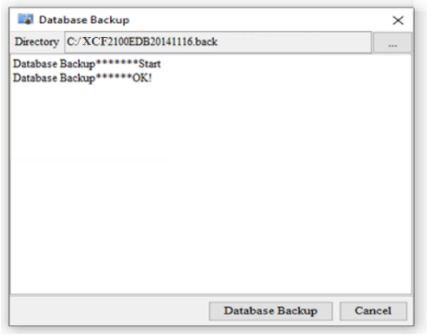
This command backs up the database. The window is as follows:



The software, by default, displays the C: directory, and the file name, which is XCF2100E followed by the date: the directory can be accepted or changed.

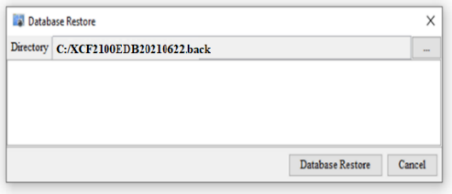
Press ‘Database back-up’: if data is saved on the root of the C drive, this file will not be deleted if the XCF software is uninstalled.

After saving, the window is as follows.

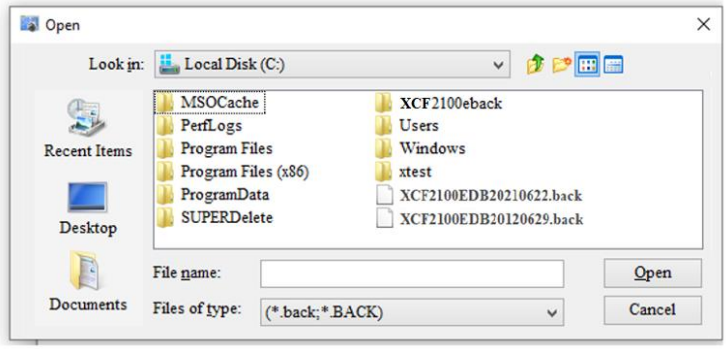


4.8.4 Database restore

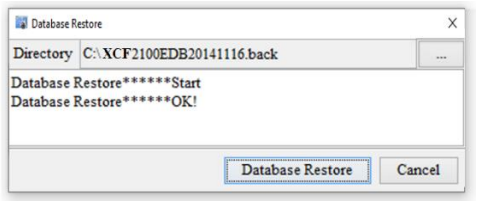
This command allows the retrieval the database that has been saved. The window is as follows:



Choose the C: directory, pressing the icon ... : the standard selection window is opened.



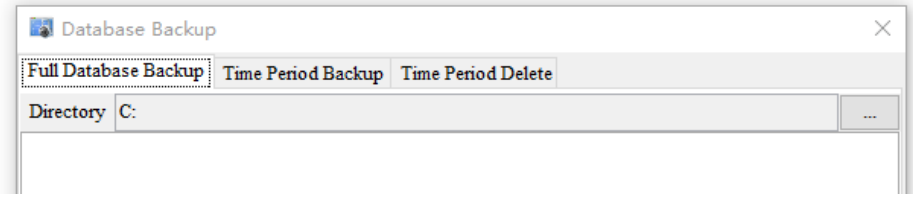
After this selection, the software will display the names of 'bak' files that exist in the selected directory. Choose the required one, and press 'Database Restore'. **Note:** the name of the .bak file includes the date when it was saved. The following window is shown;



Additional back-up, delete and restore facility

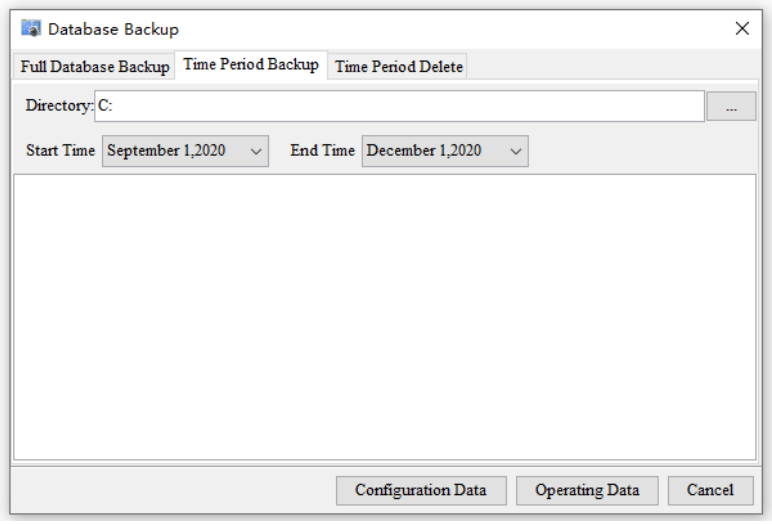
In addition to the existing back-up facility which backs up the entire database, additional database back-up, delete and restore facilities are now added to manage the size of the database.

In the Database Back-up window, apart from the existing full back-up for the whole database (i.e., 'Full Database Back-up'), two additional features are added: 'Time Period Back-up' and 'Time Period Delete'.



Time Period Back-up allows the user to enter a time period (i.e., the 'start time' and the 'end time') within which the data will be backed up. The user can also select to back up the 'Operating data' or the 'Configuration data'.

The 'Operation Data' refers to the event and fault records within the user defined time period. The configuration data refers to the setting parameters at the instance of the back-up process.



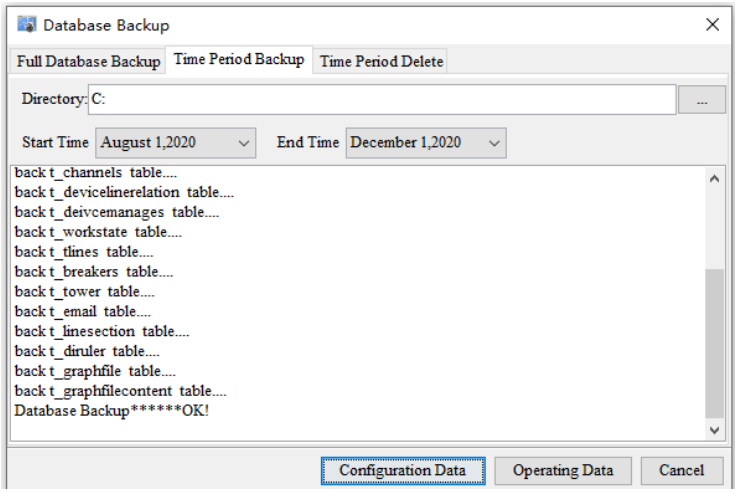
The back-up files will have the following name tags added at the end of the file names as follows:

Full Database Back-up： XCF2100EDBxxxxxxxx_full.back where xxxxxxxx is the back-up date.

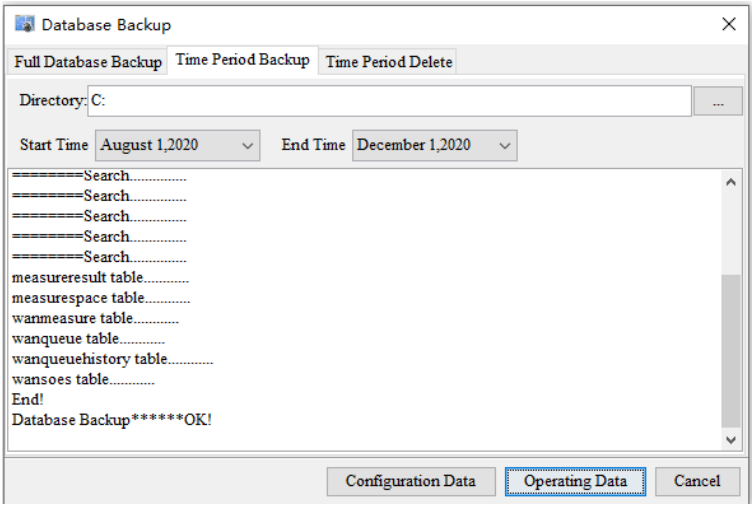
Time Period Back-up (Operating data): XCF2100EDBssssssss_eeeeeeee.back where ssssssss is the start date and eeeeeeee is the end date.

Time Period Back-up (configuration data): XCF2100EDBxxxxxx_config.back where xxxxxxxx is the back-up date.

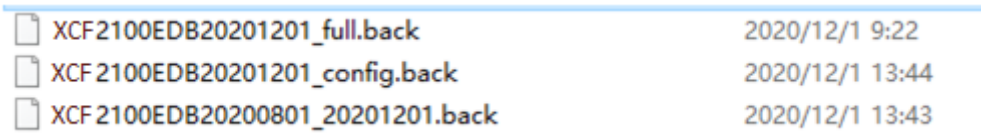
An example of the Configuration Data back-up is as follows:



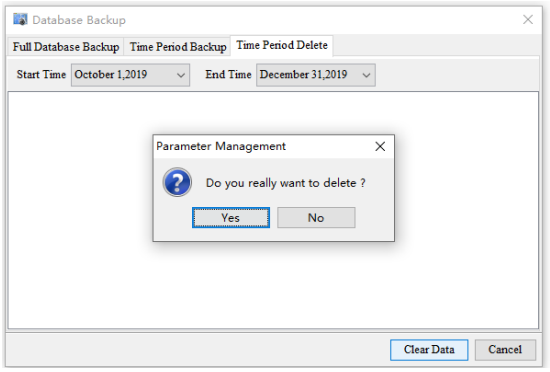
An example of the Operating Data back-up from August 1 2020 to Dec 1 2020 is as follows:



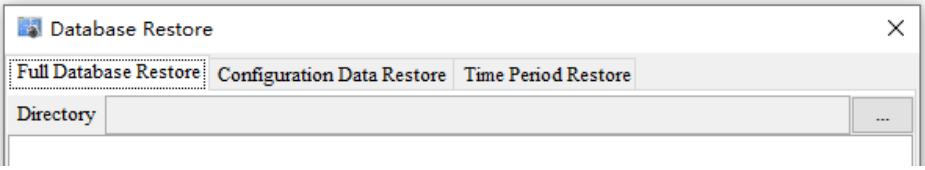
The back-up files are as follows:



Time Period Delete allows the user to select the time period within which the data in the database will be deleted. A window will appear asking for confirmation.



The 'database restore' window now consists of 'Full Database Restore', 'Configuration Data Restore', 'Time period Restore'. They correspond to the different back-up process.



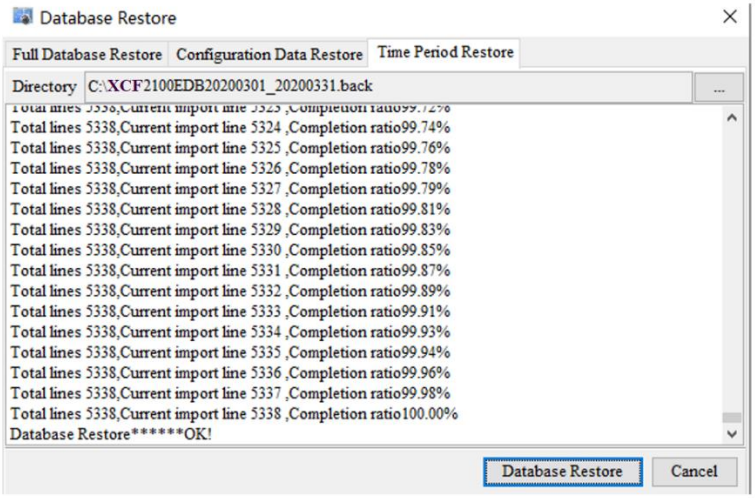
Full Database Restore can only restore the full back-up files XCF2100EDBxxxxxxx_full.back. To be backward compatible, it can also restore the existing XCF2100EDBxxxxxxx.back files.

Configuration Data Restore can only restore XCF2100Exxxxxxxx_config.back files.

Time period Restore can only restore the back-up files with a time period e.g., XCF2100EDBssssss_eeeeee.back. The data is inserted in the existing database rather than replacing the database.

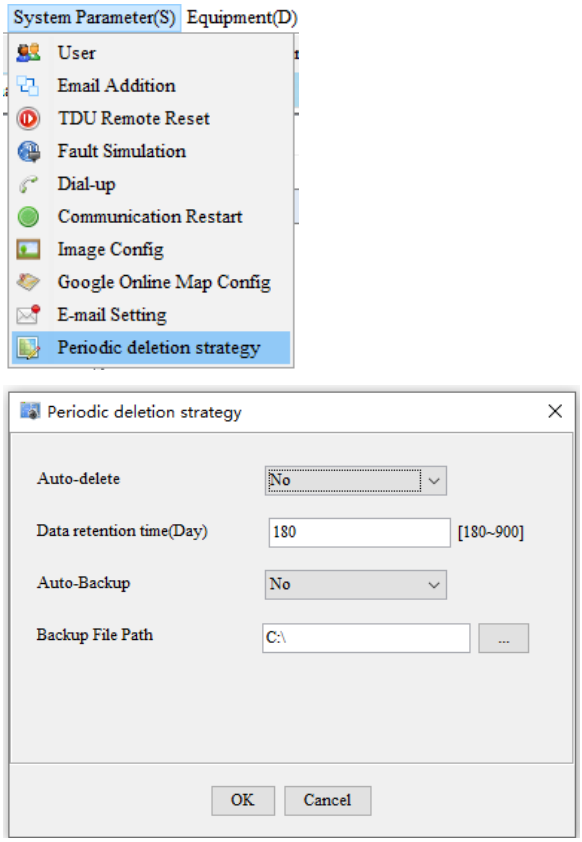
Typically, the user will back-up the fault data for a selected period, for example, from 1 March 2020 to 31 March 2020. The user will then perform a 'time period delete' for the same time period to reduce the size of the database. When it is necessary to retrieve the back-up data, the user will then perform a 'time period restore' by assessing the back-up file with dates from 20200301 to 20200331.

The restore process is shown on the screen entry window until the process is 100% complete, as shown in the screenshot below.



4.8.5 Automatic back-up and delete facility

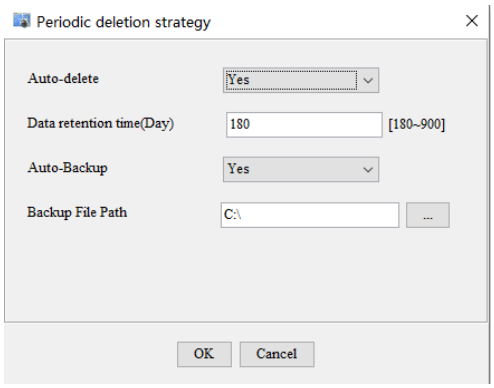
There is also a 'Periodic deletion strategy' which allows the user to automatically back-up and delete old data, whilst retaining a period of the latest data, as shown.



This automatic feature is disabled by default, with the 'Auto-delete' and the 'Auto-backup' set to 'no'. This feature should only be used if the user understands clearly how it works and is comfortable with the process.

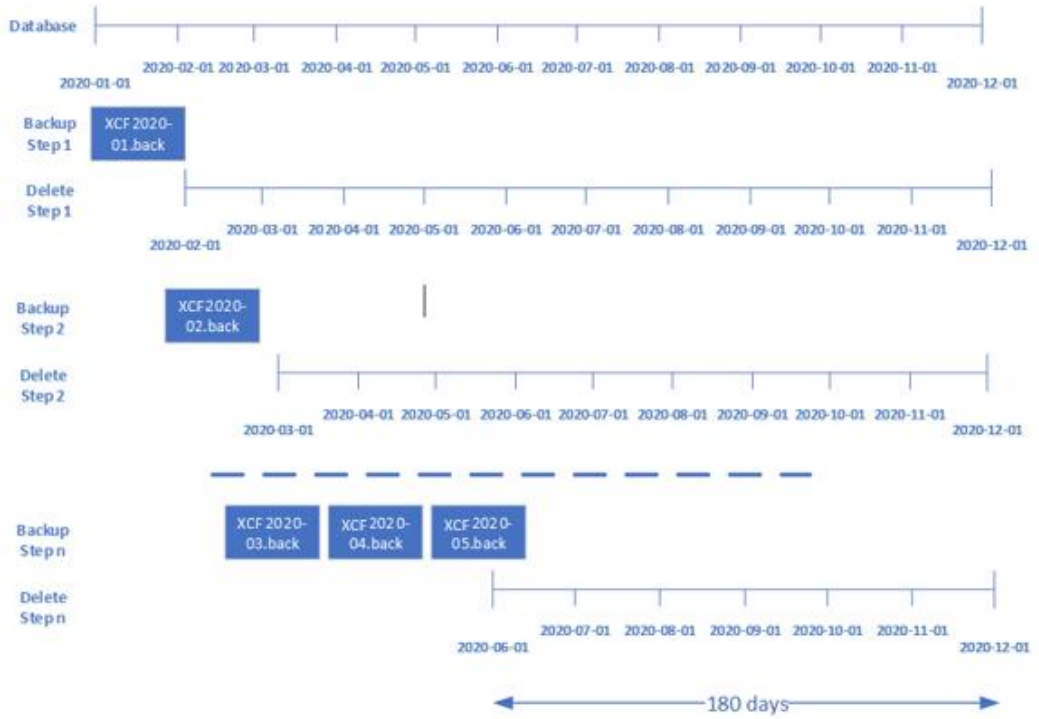
Changing the above settings does not initiate the automatic process immediately. The automatic process is started only after the XCF-2100E software is re-initialised. This avoids the possibility of accidental change of settings causing unintentional deletion of the records.

To perform automatic back-up and restore, select Auto-backup and Auto-delete to 'Yes' as in the screen shot below and click 'OK'. The settings are confirmed but will only be executed after the XCF-2100E is re-initialised.



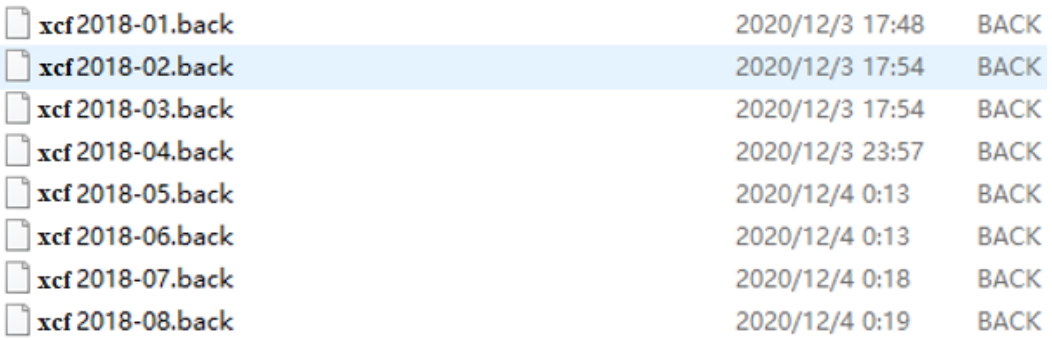
The automatic process starts by backing up the records of the 'oldest' month in the database, with the year and month clearly labelled in the back-up filename (e.g., XCF2020-02.back). It then deletes the records from that month. It subsequently proceeds to back-up and delete the 'next oldest' month's record.

This process will carry on until the last 180 days is reached, as shown in the following diagram:



Warning: If this process is performed on an existing large database which has never been backed up before, this process can take a long time. However, the process is done in the background and will not affect the software's real-time operation. The back-up process can be checked by looking at the back-up files generated. The number of files will gradually increase, with the year and month getting closer and closer to the 180 days' mark.

The typical back-up files produced are as shown below (this is an example only):



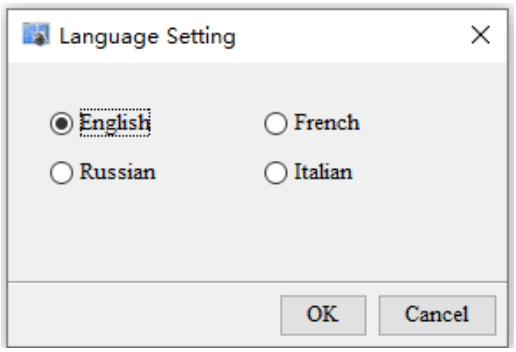
The back-up and delete actions for different combinations of auto-backup and auto-delete settings are as follows.

As can be seen, if auto-delete is set to 'no', no action will be taken as a periodic back-up will produce multiple duplicate back-up data which will eventually fill up the PC's disk space. The 'auto-delete=Yes' and 'auto-back-up=No' combination is used when reloading an existing database which already has a back-up. Disabling the auto-back-up in this case will prevent duplicate back-ups in the PC which are not necessary.

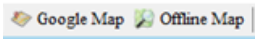
Configuration	Auto-delete	NO	NO	YES	YES
	Auto-backup	YES	NO	NO	YES
Actions after system re-start	Auto-delete	NO	NO	YES	YES
	Auto-backup	NO	NO	NO	YES

4.9 Language setting

The language selection window is as follows. The language selected will only be applied after the software has re-started.



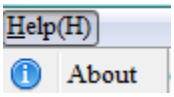
4.10 Google Maps / Off-line maps selection

The purpose of selection 

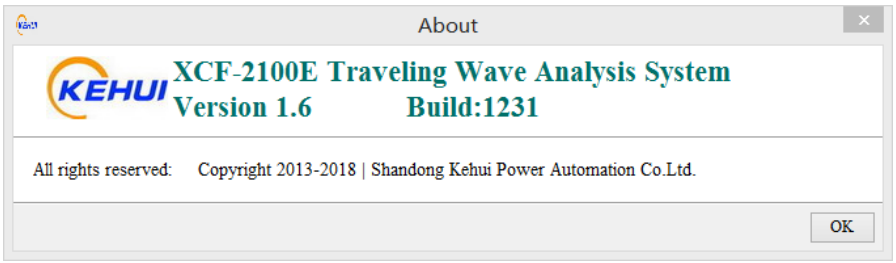
is to add or to change the position of the towers in the region. For more information about Google Maps and off-line maps, refer to the corresponding Section 9.

4.11 Help

The Help facility can also be accessed using the shortcut Alt + h. Here is the window that opens.



The software version is shown:



5. Graph drawing

The icon giving access to the drawing section, which allows the user to create the network diagram. The diagram will display, in real time, everything happening in the network. Before selecting, it is worth preparing a basic paper drawing of the desired schematic as a template. To access the feature, the drawing icon is used:

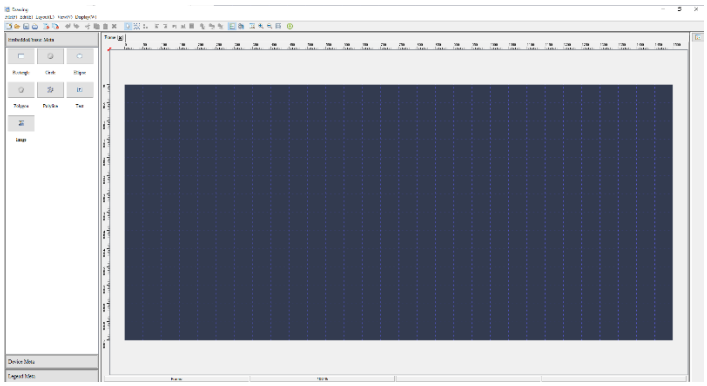
5.1 Basic Terminology

- **Graph:** is the single-line network schematic.
- **Sub-graph:** When a section of a graph can be used by other graphs, it is defined and then saved as a sub-graph, so as to increase the flexibility and the speed of drawing.
- **Meta:** In an electric power system, there are many common devices, such as: substations, breakers, lines and so on. These devices are represented as an icon in the diagram, but some of them are not just a drawing, as, during operation, the software displays their status; so, they are called device meta, while the others are called embedded basic meta and legend meta. The use of the Meta has the following benefits:
  - Consistency of the graphs;
  - Convenient alterations. If a Meta needs to be modified, it is sufficient to change the Meta icon.
- **Base colour of the graph:** Before a graph is generated, its base colour can be chosen. The default base colour is black.
- **Graph background:** In a graph, objects which are just a drawing and don't need to be changed, are called the background. For example: the title of the graph, geographic names, names of devices, numbers of devices, names of lines, names of users etc.

- **Foreground of graph:** In a graph, objects, which not only represent their presence but also note pertinent information and states, are called the foreground. Examples of foreground objects include; substations, circuit breakers, lines, working conditions, channels etc.
- **Border colour and fill colour of the Meta:** The Meta is a name for closed figures, such as: rectangles, circles, ellipses, sectors and polygons, are classified as either hollow figures or solid figures. The hollow closed figures have only borders, and their colour is the colour of the borders. For solid figures, the colour of the part within the borders is the fill colour. As can be seen, the colours of the solid figures consist of the border colour and the fill colour.

5.2 Drawing programme window

The window is below:



At the top is the title bar; below this are the menu and toolbars.

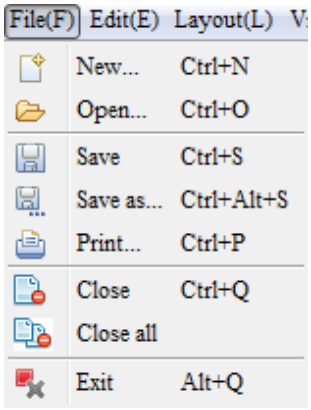
At the left of the window are three toolboxes: embedded basic meta, device meta, legend meta.

In the middle of the window is the drawing region.

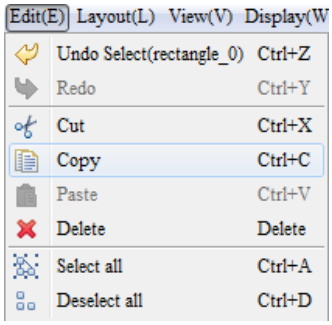
At the rightmost of the window is the attribute window. Below the attribute window is the navigation window (now they are closed).

In the toolbar there are all necessary standard tools for drawing. Tools are separated into six groups; for each group there is an arrow that opens a drop-down menu which the choice of tools can be made.

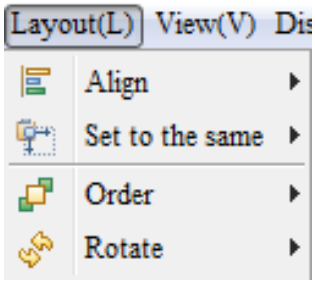
The ‘File’ selection includes:



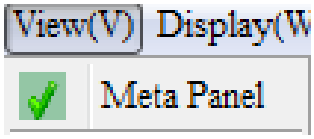
The ‘Edit’ selection includes:



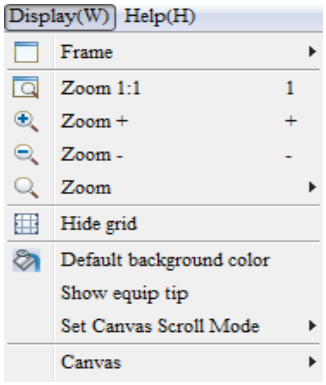
The ‘Layout’ selection includes:



The ‘View’ selection includes:

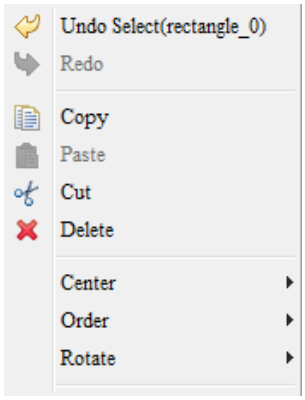


The ‘Display’ selection includes:



Here is the toolbar containing the operational commands, it is cut in half for clarity;

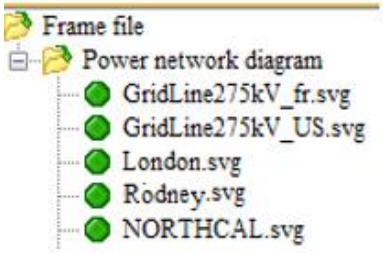
Finally, after drawing some meta, clicking the right button on the meta gives the following window.



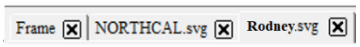
These commands are explained in the follow sections.

5.3 File

- **New**: resets the existing graph.
- **Open**: the software opens the following window:

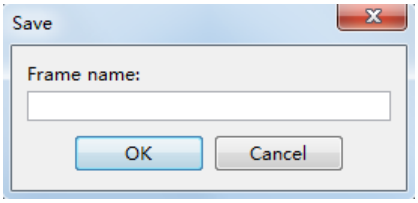


The file that was saved can be opened with the 'Save' command. Selection 'Gridline 220kV_fr' refers to a particular network.

More than one graph can be opened, 

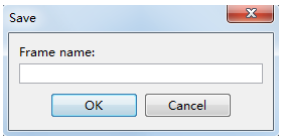
and you can move from one graph to another.

- **Save** : if it is a new graph, the software opens this window:



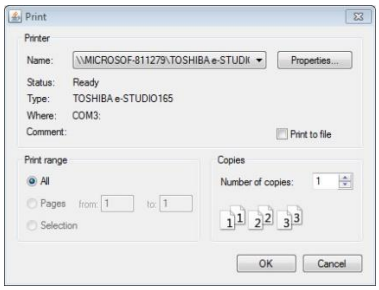
You can enter the file name. With this command the file is saved as a 'Power system diagram', with the extension .svg. **Note:** Do not insert a space in the file name! If the scheme had already been saved, with this command, the software registers it with the same name without asking.

- **Save as**. With this command, the software always opens the following window.



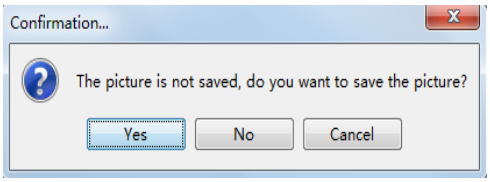
Note: the file name **must not include spaces**.

- **Print** **.** With this command, the software will open the standard selection window.



With 'OK', the graph is printed on an A4 sheet.

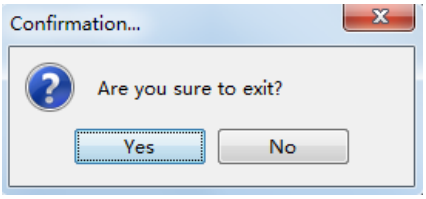
- **Close** . If the graph has not been saved, the software displays the following warning:



- With 'Yes', the software saves the drawing and exits;
- With 'No', the software leaves and does not save the drawing;
- With 'Cancel', the programme cancels the command.

- **Close all** : all graphs are closed.

- **Exit**: If there are changes that have not been saved, the software displays the following message.



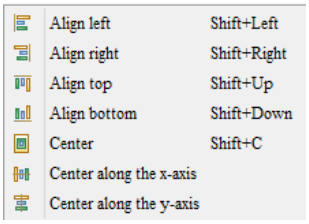
5.3.1 Edit

- With **Cancel** : the last operation is canceled.
- **Redo** : repeat the last operation.
- **Copy, cut, paste, delete** : they are the standard drawings selections.
- **Select all** : the software selects all the drawing.
- **Deselect all** : unselects all the selected meta.

5.3.2 Layout

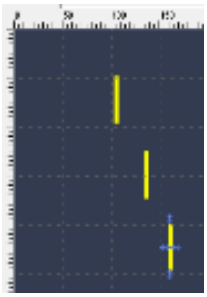
In the diagram all meta can be selected with the 'select all' command, or they can be selected individually using the mouse. The position of the selected components can be changed with the mouse pointer. The commands are as follows.

- **Align**. As selected, the following window is opened.



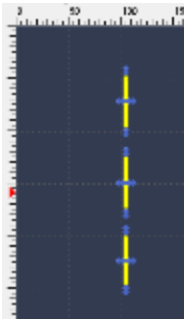
The first four commands are also available on the toolbar: .

Considering the following diagram:

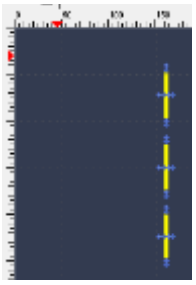


The following commands are available:

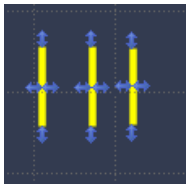
'Align left':



'Align Right':



'Centre':

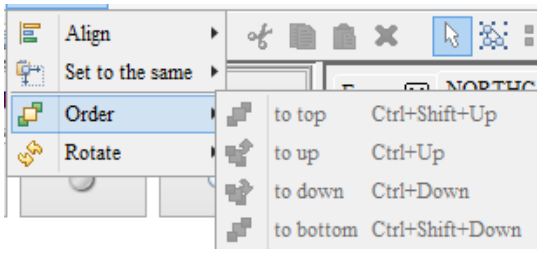


And so on.

- **Set to the same…** On the control bar, the software opens the following window.

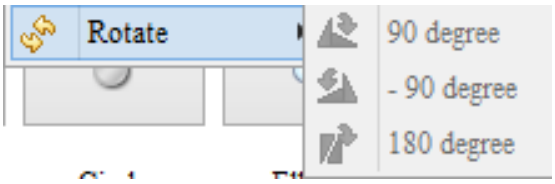
On the toolbar, the same commands are available:

- Width: all components have the same width;
- Height: all components have the same height;
- Size: all components have the same width and height.
- Order. With this selection, the software opens the following window:



With these commands, the order of the elements can be set.

- **Rotate**. With this selection, the software opens the following window.



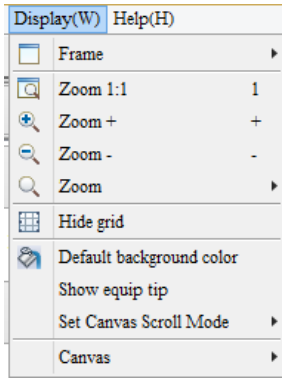
The drawing or the selected text can be rotated

5.3.3 View

The selection will close or open the left part of the window, with meta: it helps in the case of a big diagram.

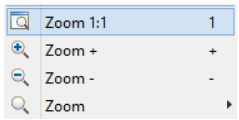
5.3.4 Display

Display opens the following selection window.



- **Frame**. Pressing the right button, displays the list of open drawings.

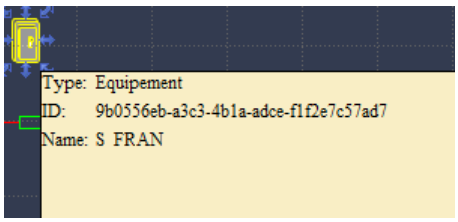
- **Zoom**. On the toolbar, these commands are available: ; on the control bar, the software displays the following selections.



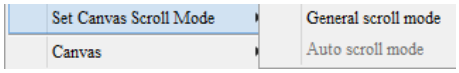
Zoom ranges from 5% to 1000%.

- **Hide or display the grid** **.**
- **Default background colour**. This selection returns the background colour default black, if it was changed.

- **Show equipment tip.** Once selected, when adding a meta, such as a TDU, breaker or line, the software displays the meta settings summary, as follows.

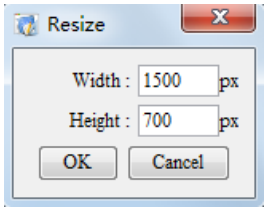


- **Set canvas scroll mode**. Two selections are available.



When the size of the meta is larger than the screen, selecting Auto scroll mode, automatically locates the meta.

- **Canvas.** With this selection, the following window opens.

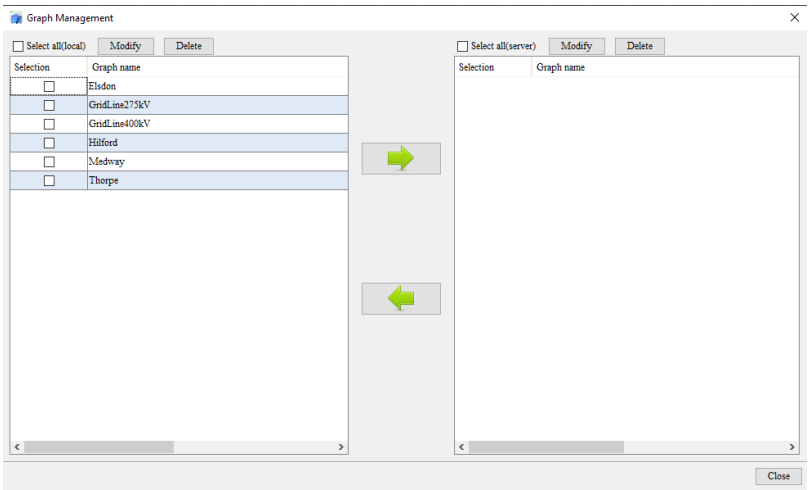


The size of the canvas, in width and height, can be changed to add other meta.

5.4 Graph Manager

The purpose of this selection situated on the right-hand end of the ribbon, is to save a drawing in the general Database, so that it can be seen also by other users, such as those using XCF-WEB. This operation is important when using an XCF software revisions before 1.6: as later versions allow new diagrams are automatically added to both local and Database files.

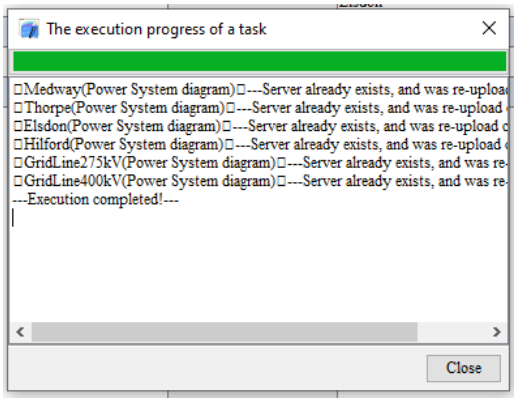
With this selection the following window is opened.



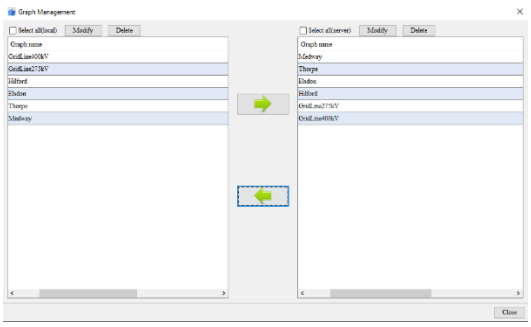
In the window, there are two parts: left and right. The left part shows the local graphs list and cannot be seen by other users; the right part shows the graphs that were saved in the database, and can be seen by other users. At the top of each part, there are two buttons: ‘Modify’ and ‘Delete’.

- Files copy; left to right.

  Via this icon the user can copy the selected files to the Database (moved from the left to the right). The user can select one or more files, or check all files. Pressing OK, the following window is displayed.



  Now the window looks like the following.



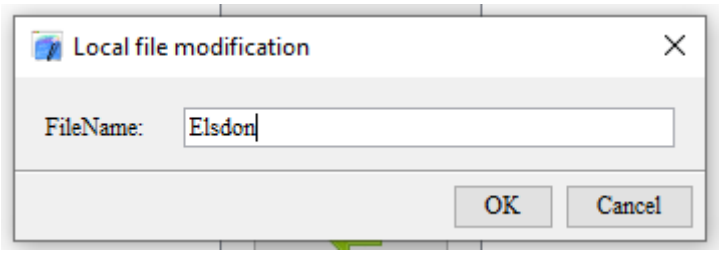
- Files copy, right to left.

  By clicking this icon the user can copy the selected files to the local directory (from right to left). The user can select one or more files, or check all files.

  Note: Only the downloaded files can be viewed by the local user.

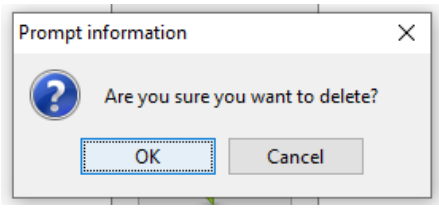
- Modify

  The user can modify the local or Database graph file name. Select the file, and click 'Modify' to enter the edition window, as shown in the figure below.



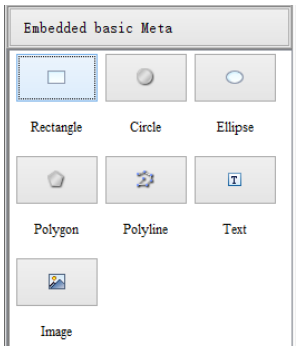
- Delete

  The user can delete the local or Database graph file. Select the file, and click ‘Delete’ to enter the confirmation window, as shown in the figure below:



5.4.1 Embedded basic meta

The first toolbox to the left, has the following meta.



These allow explanations to be added to complete the drawings; unlike the device meta, they are not dynamically linked to what is happening in the network. There are two ways to operate with these meta.

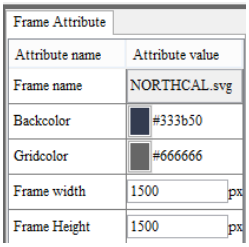
- To select the meta: Rectangle, Circle, Ellipse, Text, Image, press the left mouse button, keep it pressed, and drag the icon to the drawing area. By releasing the key, the meta is placed.
- For meta: Polygon, Polyline, click on the icon (do not drag them) and move to the drawing area: use the cross to draw.

Then, as with other drawing elements, the following can be performed:

- Drag the meta in the drawing, with the four arrows icon ;
- Increase or reduce the drawing, with the double arrows, horizontal or vertical ;
- Increase or reduce, with double diagonal arrows or .
- Selecting the meta and pressing the ‘Delete’ key on the keyboard, removes it.
- The right side gives access to the attributes of the basic drawing or meta that has been selected.

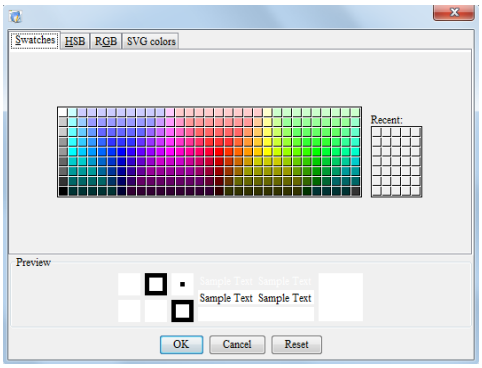
5.4.1.1 Drawing and meta-attributes

The attributes can be opened and closed by pressing the small icon in the window top right. If this is done without selecting any meta, the following selections.



The attributes are in the frame, if a component is selected, the attributes of that component. The frame provides the following choices:

- **Frame Name**: This is the name of the drawing. To change it, the drawing must be saved, the file name is the name of the frame.
- **Back colour**. Clicking the coloured square in the attribute column opens the colour pallet; the default is black.

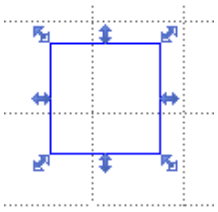


The software allows the colour to be selected as pre-designed swatches, HSB (hue, saturation, brightness), RGB (Red, green, blue; each set from 0 -255) or SVG (scalable vector graphics).

- **Grid Colour:** This works in the same way as the background colour, the default is grey.
- **Width and height of the frame:** Measured, in pixels.

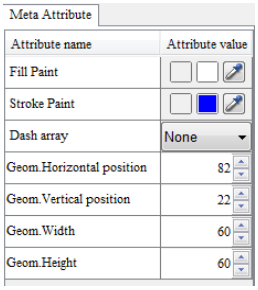
5.4.1.2 Meta: rectangle, circle, ellipse etc.

To add a shape to the frame, drag the icon to the drawing area:

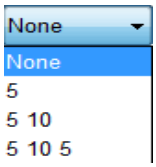


It can be placed by selecting the centre and moving it to the required position. By selecting the edges, it can be enlarged, reduced or the shape can be changed. This is the same for the other shapes.

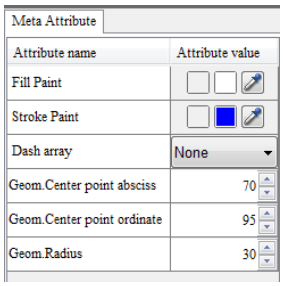
- With the rectangle meta, attributes are as follows.



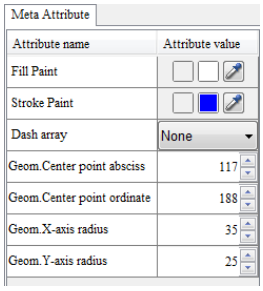
  - **Fill paint**: This is the fill colour.
  - **Stroke paint**: This is the line colour.
  - **Dash array**: This allows the line to be changed to a dotted line.



    Where:
    - None: the line is continuous.
    - 5: the dash and space length are the same.
    - 5 10: the spaces are twice the length of the dashes.
    - 5 10 5: the line has a pattern of one long then two small dashes.
  - **Horizontal and vertical positions**: allows the shape to be positioned based on the coordinates of the top left corner.
  - **Width and height**: measured in pixels.
- The circle meta has the same attributes but is defined as the horizontal and vertical coordinates of its centre and the radius.



- The ellipse meta, is defined by the coordinates of the ellipse centre, plus its X and Y axes.

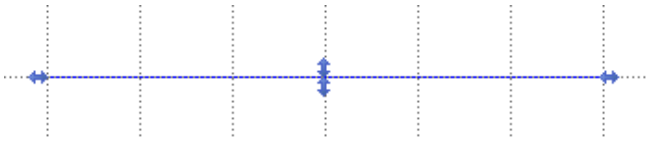


- For the **polygon** meta, click on the icon (do not drag it), the cursor appears as a cross on the frame. Position the cross on the first part of the polygon and click, move to the second point and click, continue until all the corners are in place and click with the right mouse button: the software automatically draws the last side. The polygon. Can be adjusted using the arrows as with the other shapes.

5.4.1.3 Polyline meta

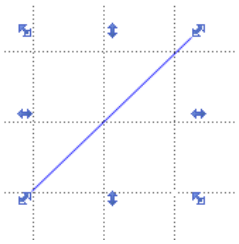
Click on the icon (not drag) and go over the drawing area: the cross is the starting point. Clicking the left button of the mouse positions the cross as the first point. Then move to the second point and draw a line. If the 'CTRL' key is pressed the line is straight; otherwise, any shape is possible. When the button is released, the first line is drawn. To finish, press the left and then the right mouse button.

For horizontal line, the result is as follows.

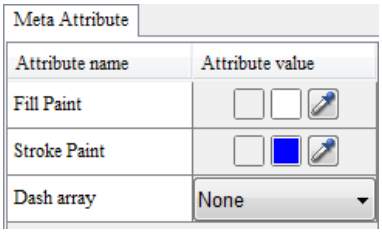


Using the arrows to the right or left, extend or reduce the line. Use the arrows , the line thickness can be changed. If any other point is pressed the line in the drawing can be dragged.

If the line is diagonal, the following picture is obtained.

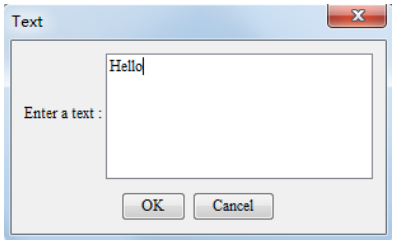


The slope can be extended, reduced, moved or changed. With this metadata, the attributes are as follows:



5.4.1.4 Text meta

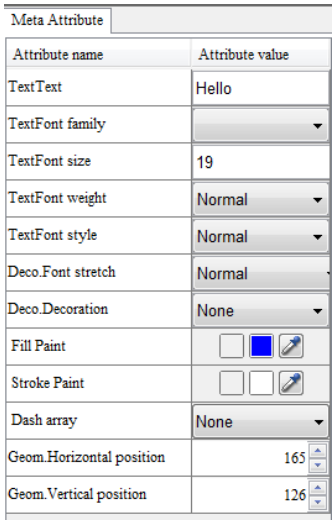
For this selection, the icon must be clicked, then dragged onto the drawing area into the desired position. When the mouse button is released, the following window opens.



Enter the text, and confirm with ‘OK’: the text is displayed in the drawing.

Using the arrows, enlarge or reduce the text - it can be positioned as desired.

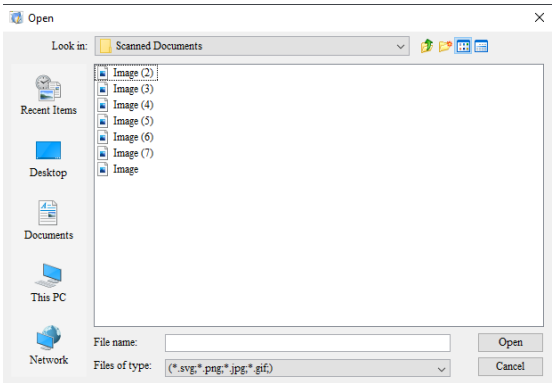
With this meta, attributes are as follows.



The image can be can enlarged or reduced, the direction changed, or the colour amended.

5.4.1.5 Image Meta

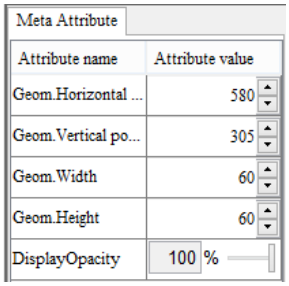
For this selection, click on the icon and drag it onto the drawing area, in the desired position. When the mouse button is released, the following window opens:



The desired image file, can be searched, it can have extensions: svg, png, jpg, gif. The image is placed in the drawing by confirming with ‘OK’.

Using the arrows, the image can be enlarged or reduced; or it can be moved by dragging it as desired.

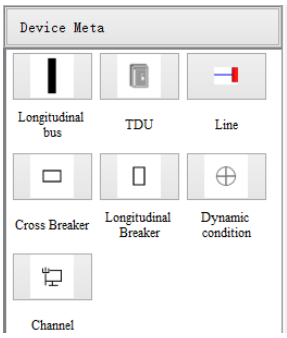
With this meta, the attributes are as follows.



With the last selection the image can be darkened.

5.5 Device meta

These meta are used for the network diagram. The window is as follows;

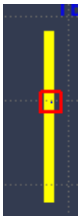


Use these meta to create the network diagram. During the operation, they change colour to highlight where the fault occurred, or if the connection is correct.

The drawing is performed as follows:

- For all meta except the line, draw the meta on the drawing area;
- For the line, click on it. Then, move onto the drawing: a cross selects where the line is started. Click on the starting point, and then move the mouse. Pressing Ctrl, the line is horizontal, at 45°, or vertical. At the end of the line, double click: the line is drawn.

Note: usually, lines connect buses. It is important that the line actually starts from the bus. When you are on the bus, a red square confirms it.

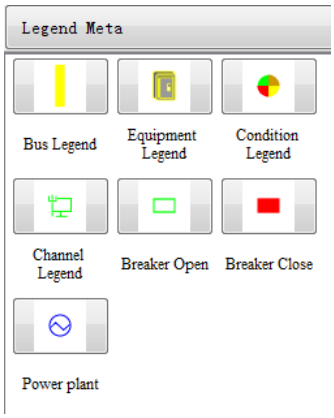


Now left click and draw the line until it reaches the other bus, and double click when the red square is displayed.

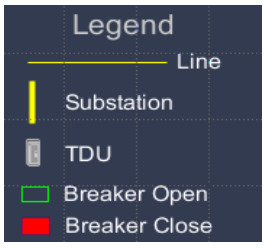
The meta-assignment is explained in the following sections.

5.6 Legend meta

The selection allows the user to add some icons on the drawing, for clarity. The window is as follows;

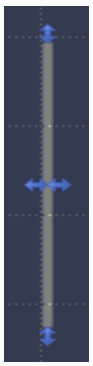


The purpose of these meta is to draw the diagram legend scheme, as in the following example.

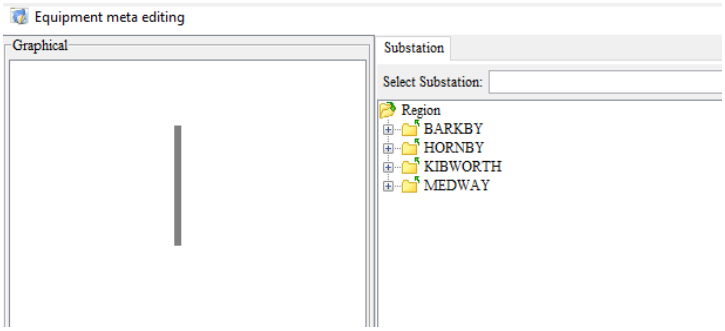


5.6.1 Substation definition

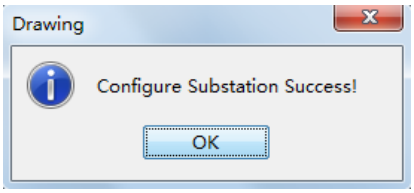
The substation is defined by the grey Bus meta, which is dragged on to the drawing page from the Device Meta selection:



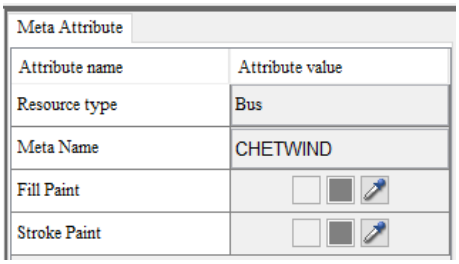
Double-click the busbars: The following window is opened:



Select the substation bus by double clicking the substation, or look for it under 'Select substation'. Press 'Save' and the following message appears.



Press 'OK' and exit - the busbar is displayed in yellow. The following attributes on the right of the screen.

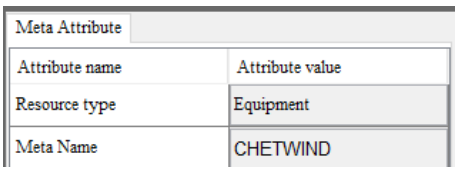


Continue with all substations.

5.6.1.1 TDU configuration

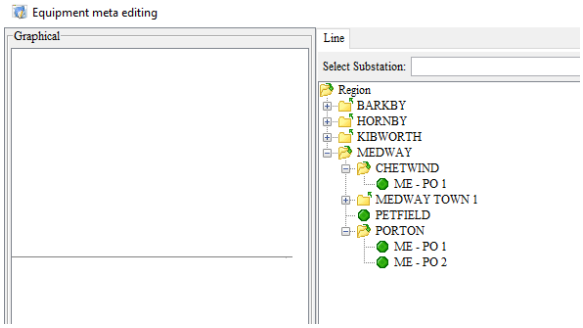
After placing the substations, place the grey TDU icon by their side. Then, double-click the icon. The software opens the window with a list of substations. **Note**: the name of the TDU must be the same name of the substation.

As for busbars, when the name is assignment, the icon becomes yellow. On the right the attributes of the equipment are listed.

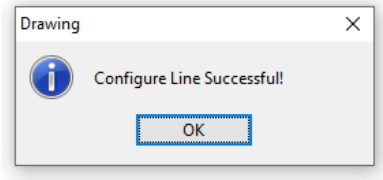


5.6.1.2 Line configuration

Click the ‘Line’ meta, and draw a line as explained. Then double click on it: the window on the left opens the list of lines.

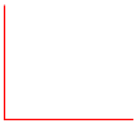


Select the line: It can be double clicked it, or found under ‘Select substation’. Press ‘Save’: the following message appears.

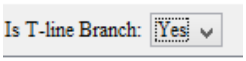


When the choice is made, in ‘Selected line’, the window shows the chosen name.

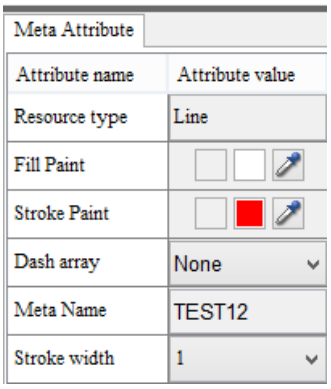
If the line has a T-branch, it is referred to as follows.



In this instance, select the following.

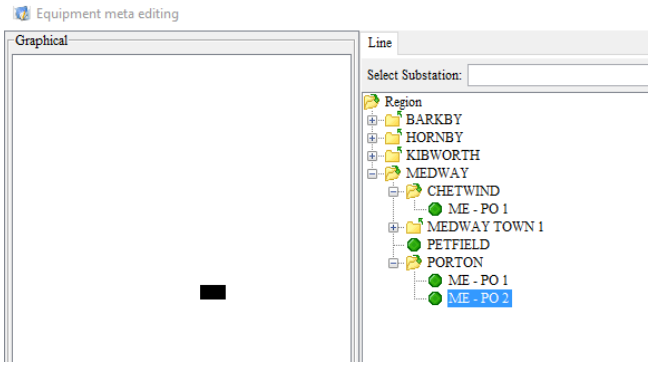


Finally, press ‘Save’, the name of the line is assigned to the meta; the colour of the line becomes red. On the right, the attributes of the line are listed.

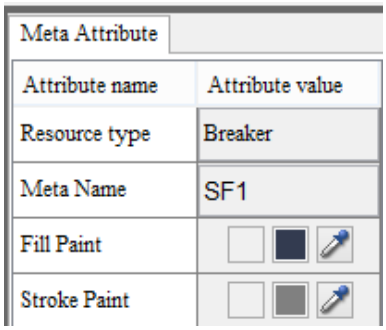


5.6.1.3 CB configuration

Drag the Circuit Breaker Meta on the desired line: it is blue. Then, double-click it to open the CB Meta configuration window.



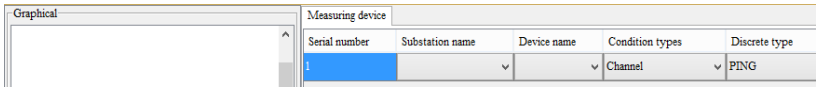
Select the breaker from the list and press Save: the operation is confirmed. The CB attributes are listed on the right.



5.6.1.4 Channel configuration

This meta allows to monitor the TDU network. The Channel tells us whether there is a connection problem.

Drag the Channel Meta, which is grey, and then double-click on it, to open the channel Meta configuration window.



On the right, choose:

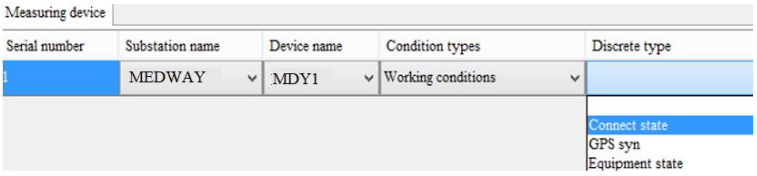
- The name of the substation;
- The name of the equipment (which must already be assigned);
- The condition type (Default: input);
- The type of set (Default: PING).

Finally, press ‘Save’: the CB name is assigned to the meta. In the diagram, the icon is green.

If the system recognises a communication problem, the icon will turn to red.

5.6.1.5 Dynamic connection condition

This selection monitors the connection of XC-100E network, and adds to the former one a living icon. Drag the 'Dynamic condition' meta on the drawing page: it is grey. Double-click it: The following window opens.



On the right, choose:

- The name of the substation;
- The name of TDU (which must already be assigned);
- The type of condition (working condition);
- The type of discrete indication, that selected from a drop-down menu:
  - Connection Status: connected or not;
  - GPS Syn.: GPS synchronised or non;
  - Equipment state: OK, default.

More than one condition can be selected, with the command 'Add'.

Serial number	Substation name	Device name	Condition types	Discrete type
1	MEDWAY	MDY1	Working conditions	Equipment state
2	MEDWAY	MDY1	Working conditions	Connect state
3	MEDWAY	MDY1	Working conditions	GPS syn

Finally, press 'Save': the name of the line is assigned to the meta. In the diagram displays the following icon, which rotates when everything is normal.

If the system recognises a problem on a TDU, the icon will turn to red.

5.7 Real-time Diagram

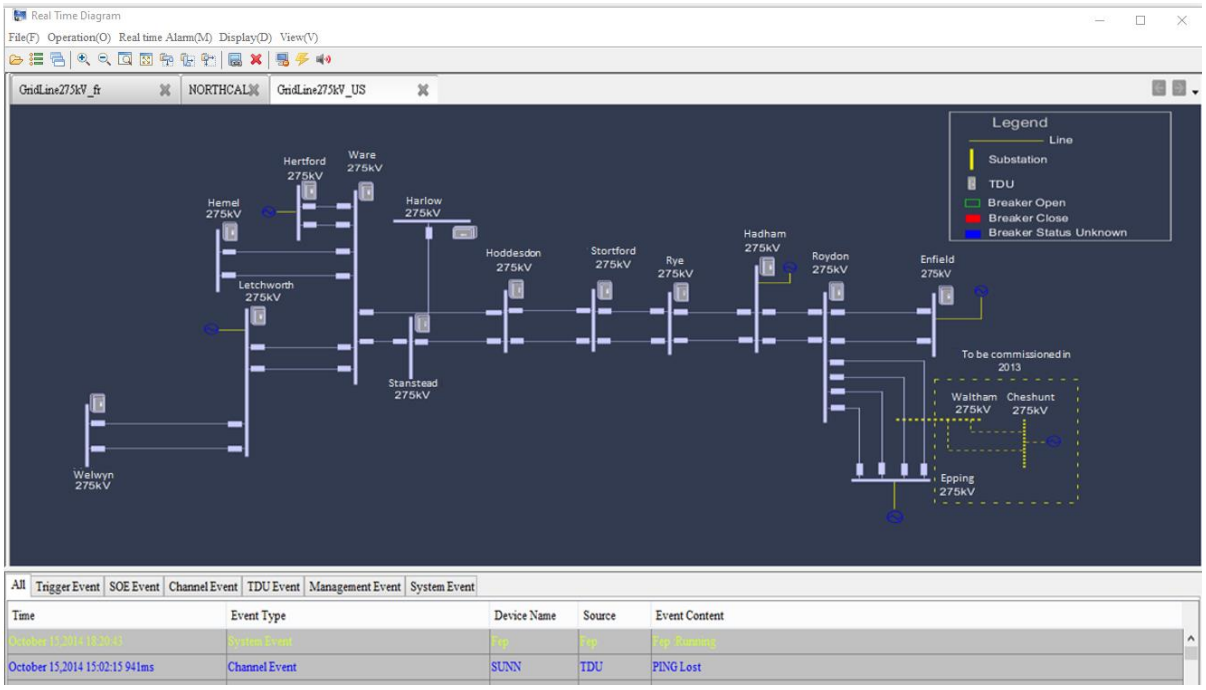
This module has the following icon.

The real-time diagram module is **the primary operation interface** of the travelling wave system, and is used to view information such as: operation diagram, single-line diagram and real-time condition of equipment. Moreover, this interface allows the user to search the fault information and access the waveform analysis window.

The software monitors the TDU units continuously. Every second it checks if they have messages. If they do, the message will be received by the software: the summary first, then the recordings. The summary is sufficient for the software to display the diagram of the fault line and to locate the fault.

5.7.1 Main window

The main window shows the network schematic diagram, and the list of events related to the line. The following is an example of what is displayed.

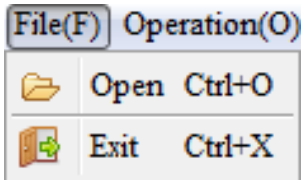


- Toolbar

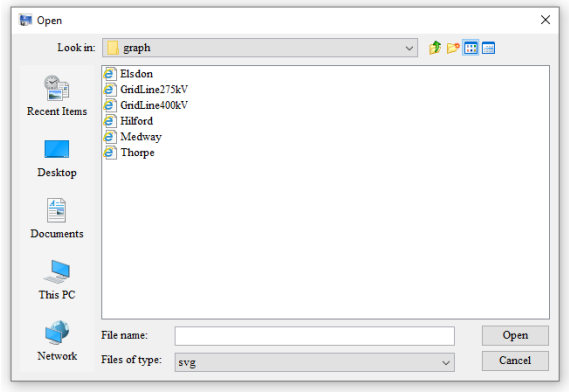
All the buttons in the toolbar are in one-to-one correspondence with the menu items. When the user moves the mouse to a button, the tip is displayed.

5.7.2 Menu

- With File menu

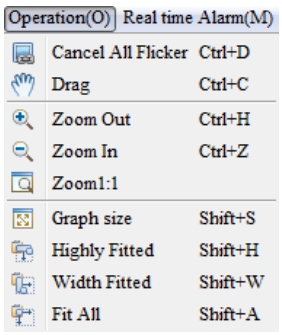


- Open: open the graph database.

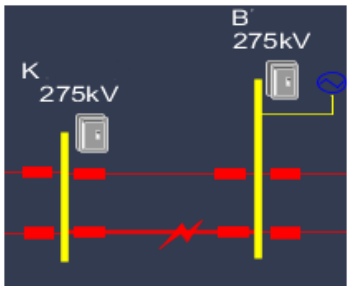


Files have the extension .svg.

- **Operation menu**



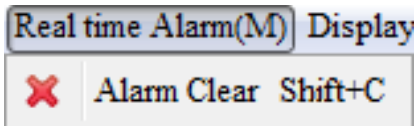
- Cancel All Flicker: after a fault, the alarm icon flashes in the current active graph; this command cancels this feature.
- When there is a fault on a line, it appears as follows: that the lightning symbol flashes.



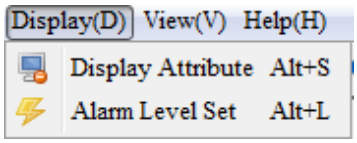
On selecting the line with the right button, the following menu appears.

  - Cancel flicker: it stops the flickering on the selected line.
  - Cancel all flicker: it stops all flickers.
- Drag: when the size of the displayed graph is larger than the display area, the mouse pointer changes into a hand allowing it to be dragged.
- Zoom Out: zooms out the current graph.

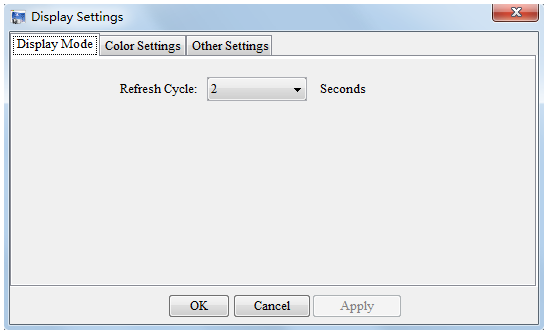
- Zoom In: zooms in the current graph.
- Zoom1:1: use the original size of the graph.
- Graph size: use the original size of the graph for displaying.
- Highly Fitted: use the height of the display area of the current graph for graph zooming and displaying.
- Width Fitted: use the width of the display area of the current graph for graph zooming and displaying.
- Fit All: use the display area of the current graph to the actual area of the graph for graph zooming and displaying.
- Real-time alarm menu



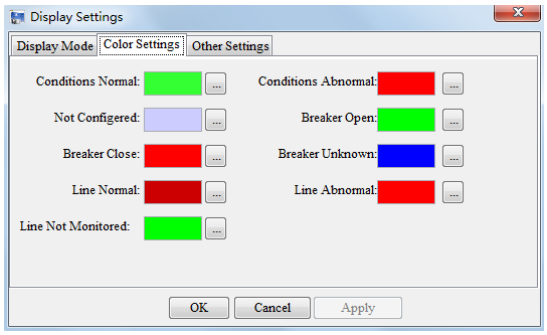
- **Alarm Clear:** clears the currently displayed alarm information. The corresponding alarm information is cleared automatically after the user clicks Yes.
- **Display menu**



- Display Attribute: when selected, the following window opens.

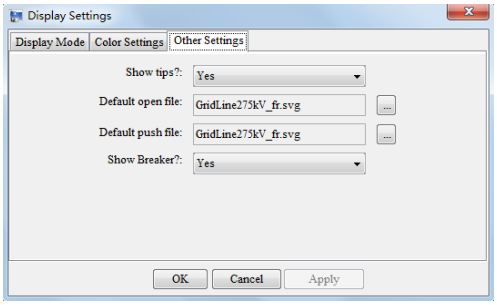


- Display mode: allows the period of screen updating to be selected.
- Colour Settings: when selected, the following window opens.

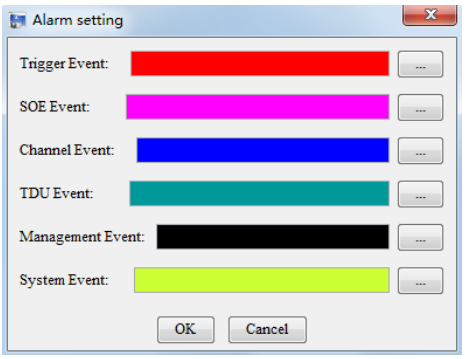


This choice allows for the visualisation in different colours of the normal and the fault situation.

- Other Settings: when selected, the following window opens.

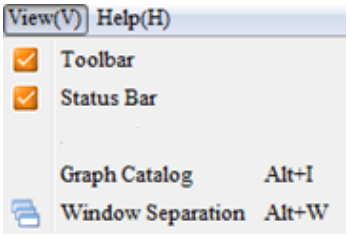


- Show tips. With 'Yes', able to go to a line and can read its settings; with 'No', the settings are not displayed.
- Default open file: Selectable by the user.
- Default push file: Select the graph that opens during a fault.
- Show breaker: with 'No', circuit breakers are hidden.
- Alarm setting: allows different colours to be selected for different types of alarms.

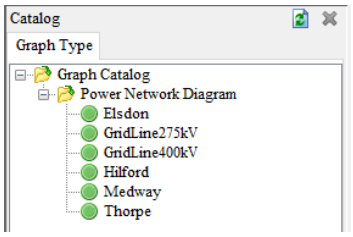


- Trigger Event: Operates in case of a recognised and localised fault. It does not appear after a lightning or circuit breaker event.
- Breaker (SOE) Event: Operates in case of the operation of a circuit breaker.
- Channel Event: Loss of communication.
- TDU Event: Operates in case of a faulty TDU, including: loss of GPS, loss of GPS synchronisation.
- System Event: For example, loading parameters locally.

  Press the icon : the colour palette opens.
- Select: or deselect an audible warning.
- View menu

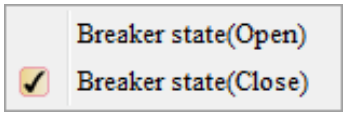


- Toolbar: Display or hide the toolbar.
- Status Bar: Display or hide the working log.
- Graph catalogue: Display or hide the local graph catalogue. The graph catalogue is displayed in a tree form, and is located on the left side of the window. When the name is double-clicked, the corresponding image will be displayed in the graph panel. The user may click the refresh button at the upper right corner of the graph catalogue panel to refresh the local graph information.



- Window separation: Two window views are possible: one for the diagram, and the other one for the real-time alarm.
- Help menu
- About: Displays version information.
- Breaker menu

  Right-click on a circuit breaker to open the menu;



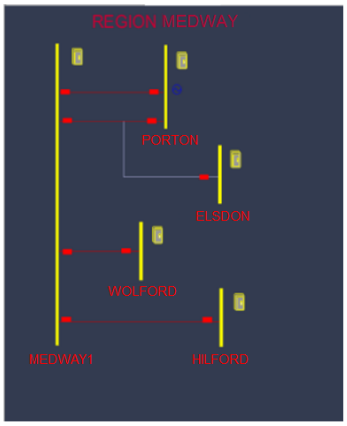
- Breaker open: select the breaker as Open.
- Breaker close: select the breaker as Closed.

This allows the selection of the correct position of the circuit breaker, if the corresponding logic signal has not been connected to a TDU.

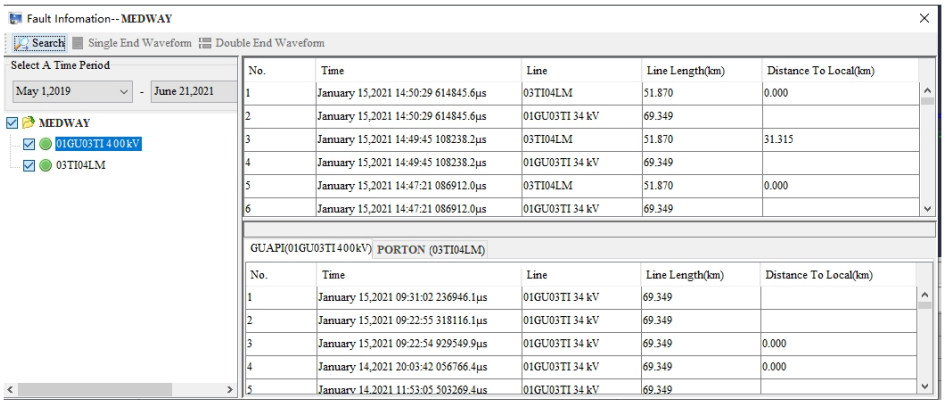
5.7.3 Diagram operations

When a graph is opened, the substation completes a graph-refresh based on the device information.

When a fault occurs, the corresponding line flickers, and the fault location is marked with the lightning icon until the flicker is cancelled manually (by right-clicking the fault line to select the menu ‘Cancel Flicker’ or ‘Cancel All Flicker’). It will automatically reset according to the pre-set automatic flicker time.



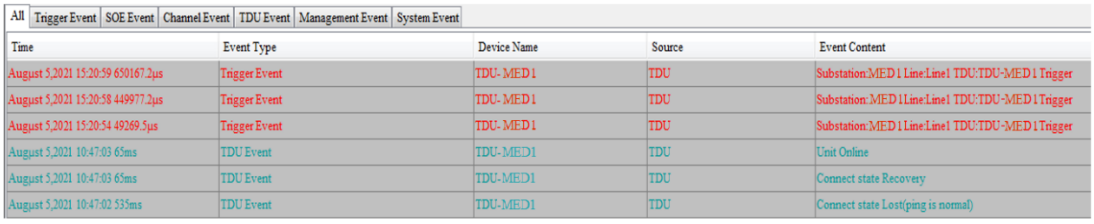
Left click on a substation or a line: the software opens a window with the fault record information, as follows:



Select a fault on the board, and then press the selections below:

This accesses the record analysis window discussed in Section 7.3.

5.7.4 Real-time alarms



The lower part of the window lists the event information acquired by the TDU network. We recognise the different types of alarms depending upon the selected colours. The last alarm information is at the top of the list. The following selections are available.

Select the ‘All’ tab to read all types of alarms. On other tabs, only the alarm of the selected type can be viewed. For each fault, the information in the table is as follows.

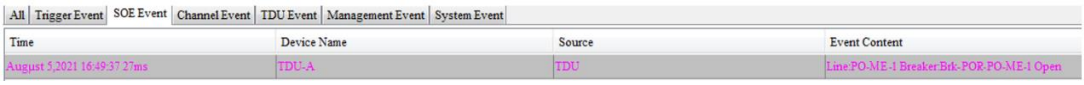
Time	Event Type	Device Name	Source	Event Content

The contents of the warning are:

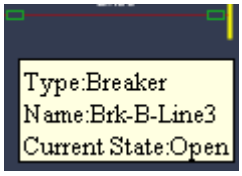
- GPS Signal Recovered/Lost
- Connection Status Recovered/Lost
- Equipment status Normal/Abnormal
- (Name of XC) Online/Lost
- PING Lost/Recovered
- XC Processor Online/Offline

Sequence Of Events

When the state of a circuit breaker changes, it produces a SOE alarm, which is displayed as follows.

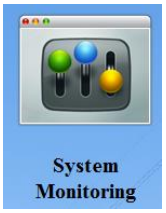


The figure corresponding to the circuit breaker changes, as shown below.



6. System Monitoring

The module is accessed via the following icon:



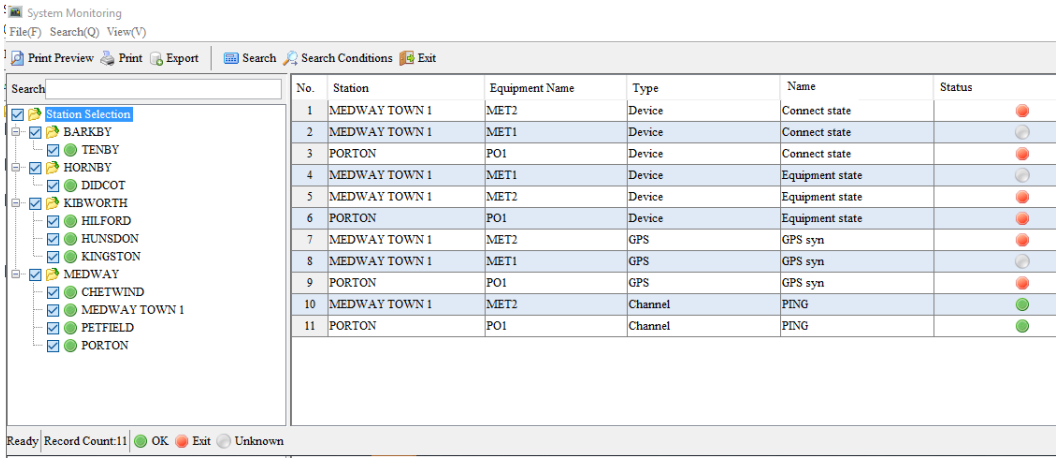
It is mainly for viewing in real-time the condition of the TDUs of all substations. The summary information includes channels, equipment and GPS, and the corresponding detailed information includes equipment state, response state, connection state, GPS pulse, GPS time and so on.

The module can list all substations, which the user can select to observe the real-time condition information.

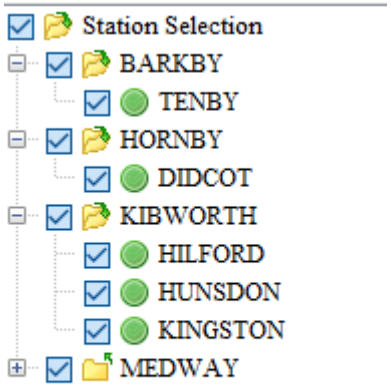
Note: This function is not available with the dial-up communication unless there is already a connection to the TDU.

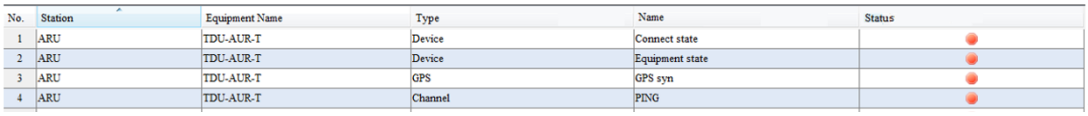
6.1 Main window

The main window is as follows.



When a TDU is added, the software automatically adds the four lines that verify its proper operation. The information is available when the master unit is connected to the network. The window is as follows. The red dot indicates a problem; the green dot is for OK.





The information in response to the survey is as follows.

- PING: indicates that the communication between the master station software and the TDU is OK. If the master station cannot call the TDU, the alarm appears.
- Equipment state: The TDU works properly, or it has a fault.
- Connect state: This alarm means that the master station software and TDU are working properly, but there are connection problems.
- GPS syn: this alarm means that the GPS is not synchronised.

The left side of the window displays the substation tree; on the right, the equipment status in the selected substation can be read. The toolbar is on the top, below is the status bar.

The table includes the following information.

- Substation;

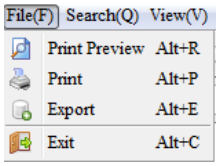
- Equipment Name; This monitors information for each device, hence the substations and equipment are repeated.
- Type; including the GPS system, the equipment and the communication channel.
- Name;.
  - For GPS, the communication is ‘GPS Syn’.
  - For the equipment, it is ‘Equipment state’.
  - For the channel, it is ‘PING’;
- Status. It may be operating correctly (shown as a green light) or incorrectly (indicated by a red light).

Note: This value is only available with Ethernet and serial connections. It is not possible with a telephone connection except whilst the equipment is connected.

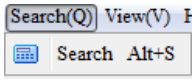
Each column in the table can be organised alphabetically ascending or descending: by clicking at the top.

The control bar selections are as follows.

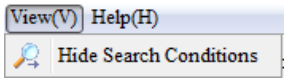
- File.



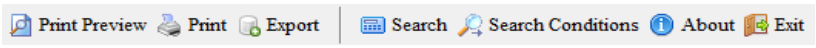
- Search.



- View.

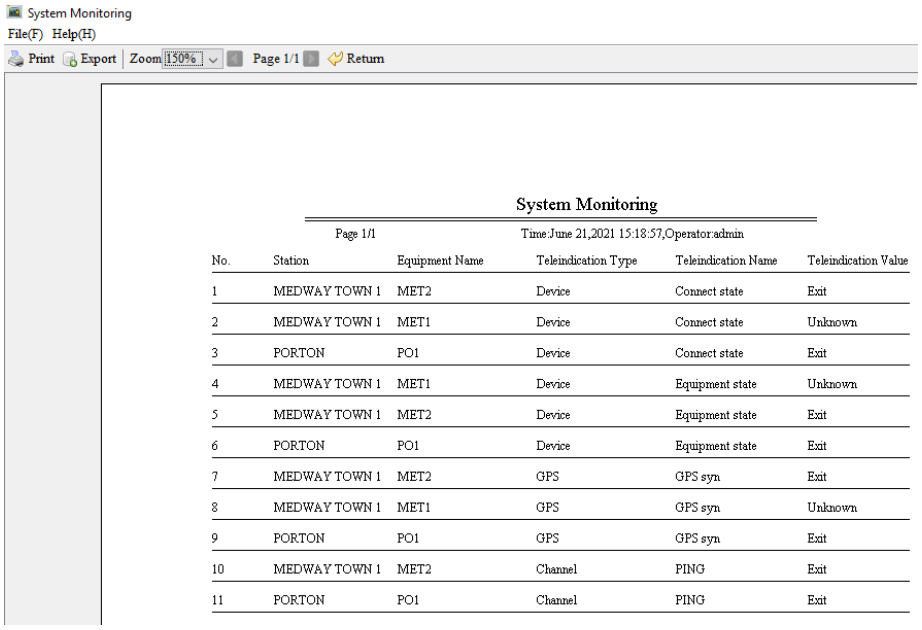


The toolbar has the same commands as the control bar;



6.2 Print preview and print

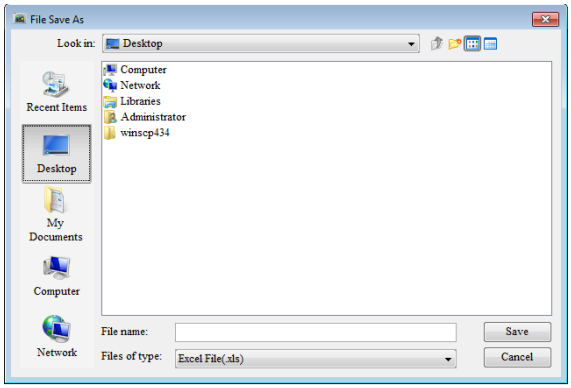
When ‘Print Preview’ is selected, the software selects the data to be displayed, which can be previewed in the window.



Data is organised as in the database. If there is no data in the list, a message alerts the operator.

6.3 Export

The software provides the ability to export the table to an Excel file. By pressing the ‘Export’ button, the software opens the standard dialogue window.



Select the directory, choose a file name and press ‘Save’. The saved Excel file has the same structure of the database.

6.4 Search

If the name of the substation is introduced into the ‘Search for the substation’ window, the substation (or region) is shown in blue.

Note: The software is case sensitive.

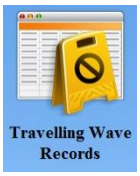
One or more substations can be selected on the left; pressing the search button, on the right, the software displays the information of the selected substations.

The toolbar changes according to the actions. During the search, the signal ‘Searching’ is displayed on the status bar. At the end of the search, it displays the number of records that match the search criteria.

6.5 Tree Network

The ‘Tree Network’ button allows the hiding or viewing of the tree structure on the left.

7. Travelling Wave Records



This module allows accessing the following information;

- List of recorded events, classified as Fault, CB operation or Lightning.
- Automatic fault location result, based upon the Wide Location Area technique.
- Dual end fault location technique is included.
- Compressed view of the fault waveforms.

The above information is automatically added to the module when a TDU is connected via Ethernet or point-to-point. When the network is connected for the first time, the software automatically downloads all recordings saved in the TDU.

The software then continuously monitors the network, and verifies if there are messages. In case of new records, they are automatically downloaded by the TDU: the summary first, and after the recording. The summary allows the software to compute the distance to fault and the recording follows in a time which depends upon the recording frequency and duration.

For the telephone communication, data are added when records are discharged. For fault location, data are valid only after the last TDU of the region has sent its data.

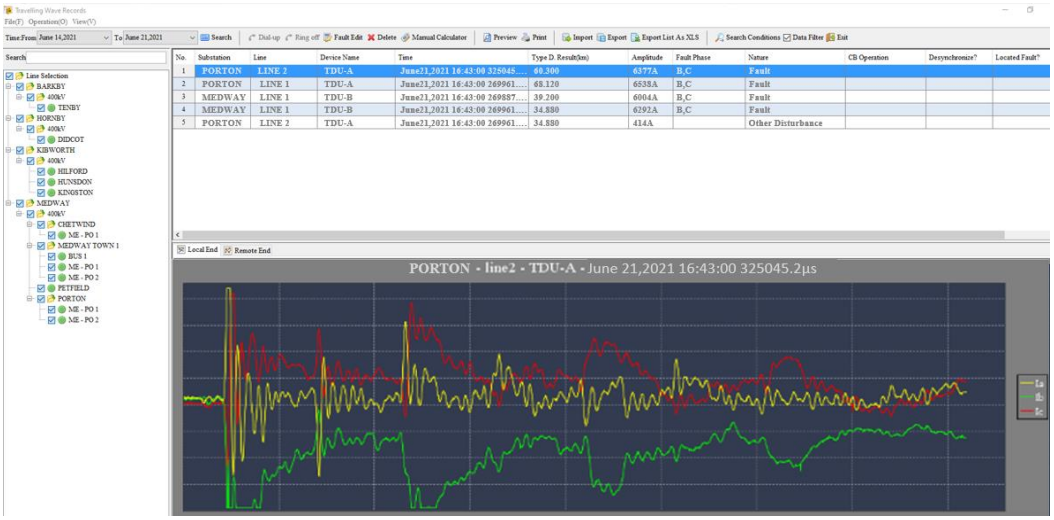
In addition to the analysis, it is possible to decide if a recording is relevant, and in particular, if it is a real fault. In the first instance it is possible to add the fault to the Fault Location module, and to the Confirmed faults module.

It is also possible to export and import the travelling wave data, to print the data and to manually measure the distance.

Usually, among all monitored lines of the region, only one will be faulty at a given time.

7.1 Fault information window

The fault information window is shown here below.



The window displays the travelling wave records, the automatic fault location results and the recorded waveforms.

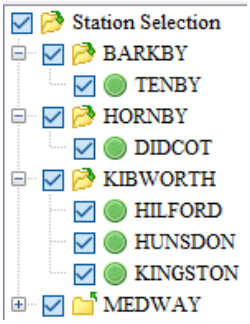
The window includes five parts. To the left side is a tree for line selection; the central area includes fault data browsing area and waveform fast-displaying area. The top includes the menu and the tool bar; and the bottom is the status bar.

The tree selection area includes region, substation and the lines connected to the substation. The tree structure can be reduced to the region level.

In the main page the travelling wave records can be viewed, providing the automatic fault location results and fault waveforms.

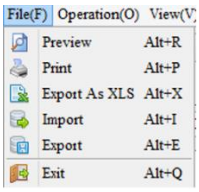
The waveform fast-display is to fast browse and check the relevant data of the fault. It is divided into two pages, local TDU waveform and remote TDU waveform.

This module also includes the printing function and export in Excel format.

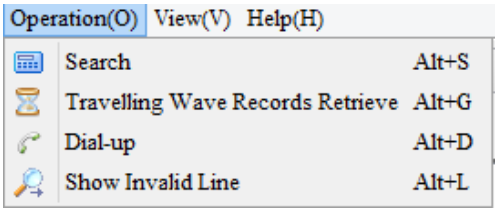


For instance, here we select the Herts region. The first line of the window is the command bar.

Select File to access the following sliding window.

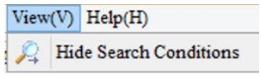


Select Operation to access the following sliding window.



The Operation Search and Dial-up are also available in the toolbar; these will be explained later.

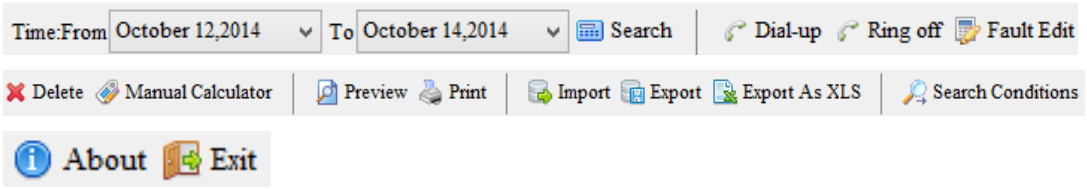
Selecting View, accesses the following drop-down menu.



The network tree can be closed or opened on the left. The operation is also available from the toolbar

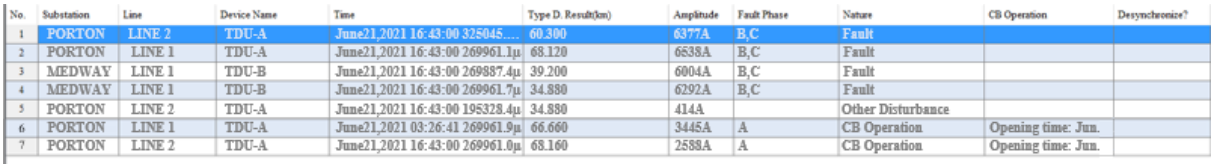
.

Select Help & About to view the software revision number. The toolbar is as follows:



7.2 Fault Records View

One or smore lines can be selected from the tree on the left, the records' beginning and end time can be selected in the toolbar. If results are only required from one line, select it in the tree, or use 'Substation search'. Using the <Search> button will produce the fault record list, displayed in the main area. Here is an example;

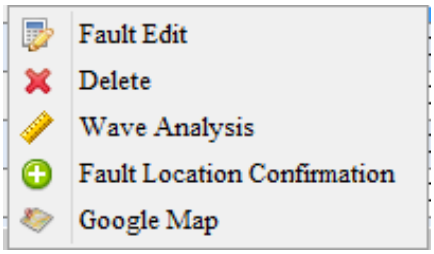


No.	Substation	Line	Device Name	Time	Type D. Result(km)	Amplitude	Fault Phase	Nature	CB Operation	Desynchronize?
1	PORTON	LINE 2	TDU-A	June21,2021 16:43:00 325045....	60.300	6377A	B,C	Fault		
2	PORTON	LINE 1	TDU-A	June21,2021 16:43:00 269961.1μ	68.120	6538A	B,C	Fault		
3	MEDWAY	LINE 1	TDU-B	June21,2021 16:43:00 269887.4μ	39.200	6004A	B,C	Fault		
4	MEDWAY	LINE 1	TDU-B	June21,2021 16:43:00 269961.7μ	34.880	6292A	B,C	Fault		
5	PORTON	LINE 2	TDU-A	June21,2021 16:43:00 195328.4μ	34.880	414A		Other Disturbance		
6	PORTON	LINE 1	TDU-A	June21,2021 03:26:41 269961.9μ	66.660	3445A	A	CB Operation	Opening time: Jun.	
7	PORTON	LINE 2	TDU-A	June21,2021 16:43:00 269961.0μ	68.160	2588A	A	CB Operation	Opening time: Jun.	

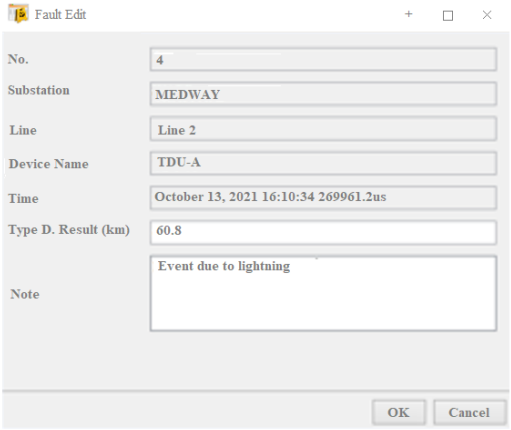
Record results include the following information.

- Record number;
- Substation;
- Line;
- Device name;
- Fault time;
- Type D result; that is, distance to fault, when it can be computed with the double recording system;
- Amplitude; that is, the RMS mains frequency current value at the time of trigger
- Fault phase(s);
- Nature of fault: Refer to the section on event categorisation (Section 1.4).
- For Breaker operation, the time it occurred, which is not the time of fault;
- De-synchronised? If yes, this means that the TDU was not GPS synchronised at the moment of fault. In this instance, type D (double end) fault location is impossible, but type A (one end) fault location can be performed on both ends of the line so accurate fault location is possible.

- **Note:** To add notes right-click on a recording to access this window, then select Fault Edit.

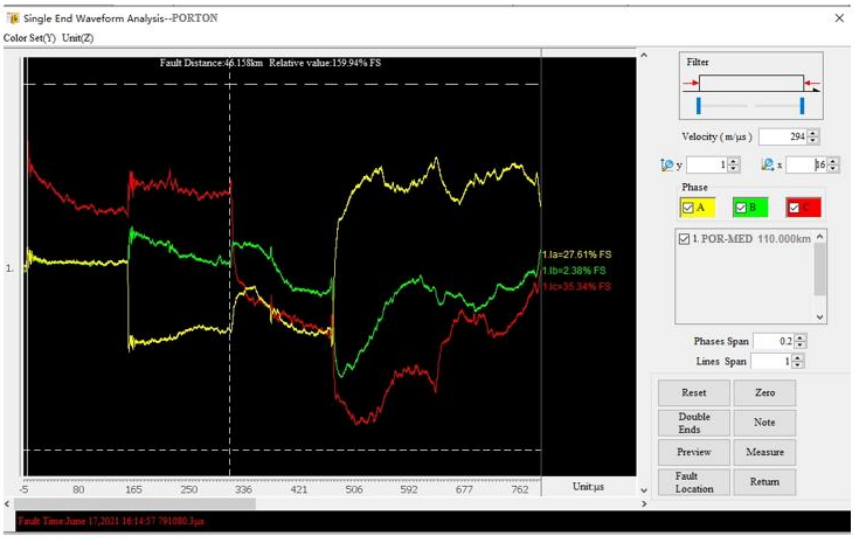


The automatic fault location can be corrected and relevant notes entered as shown below;



The operation is also accessed from the appropriate command of the toolbar.

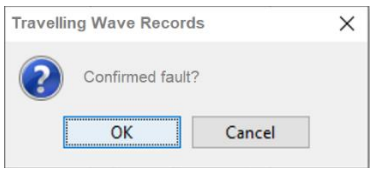
- **Wave analysis**. This selection accesses the following window:



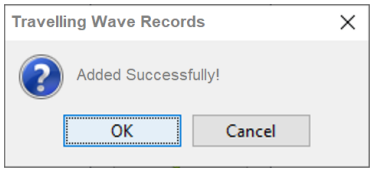
The operation on this window is explained in the following Section.

- **Fault location confirmation**.

The fault confirmation asks for confirmation that the fault is real.



Your action is confirmed:



- **Google map**. This opens the map to show the fault location (provided the substation and tower coordinates have been programmed). This is covered in Section 9.

7.3 Fast Display Waveform

The fast-display waveform is under the records list. After clicking a record, the corresponding fault waveform is displayed. If a record only has the local travelling wave data, it advises that no waveform record is available. If a record has both the local and the remote travelling wave data, the fast-display area will have two pages, one for the local travelling waveform and one for the remote travelling waveform.

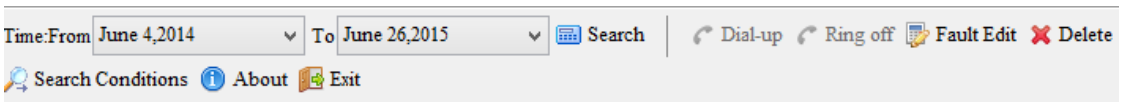
Following the above selection, in Ware, line 2, date Oct. 18th, time 16:10:34, the following record of a fault can be displayed.

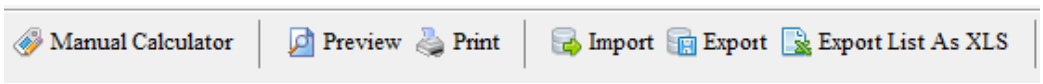
This is the waveform at one end; pressing Remote End displays the matching recording from the other end.

Double clicking on the selected line, will access the same window as the wave analysis.

7.4 Commands Explanation

The toolbar is as follows (cut in two for clarity):

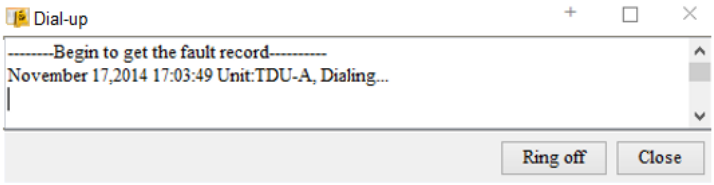




7.4.1 Dial-up and ring off

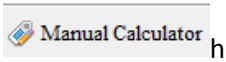
We have already seen these commands in Section 4.2.6.

The difference here is that a recording in the list, from which to collect the complete data, is already selected. As Dial-up is selected and the software starts the communication.

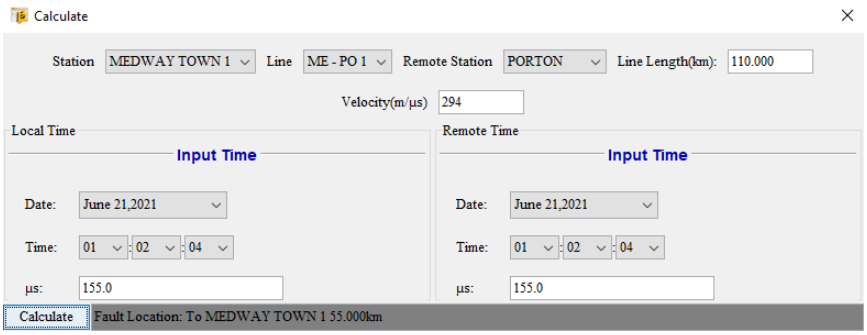


When the termination message arrives, press Ring off. After calling, you can Ring off at any time.

7.4.2 Manual calculator

The manual calculator 

helps to compute the distance to the fault, given the times at the two substations. When selected, the following window is displayed.

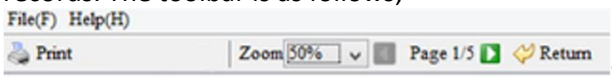


Times can be entered at the two ends of the line. As the values are entered, the software computes and displays the fault distance from one end. In this case, with equal times, the result is 55km, which is half the line length.

7.4.3 Preview

Prior to printing, this selection

is available also under File to display the list of records. The toolbar is as follows;



- Return

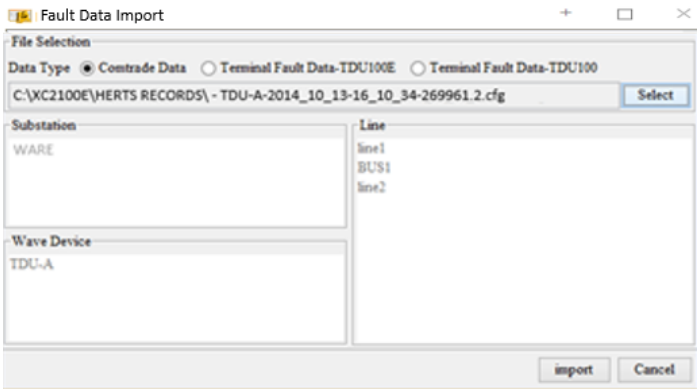
: allows the preview to be exited.

7.4.4 Import file

The selection

is available under File. Fault information obtained from other places can be directly imported into the software for analysis.

The information comes from an Excel file for the summary, and from a COMTRADE (Common format for Transient Data Exchange for power systems) file for the recording. COMTRADE is a file format for storing oscillography and status data related to transient power system disturbances. It is defined in IEEE standard C37.111-1999. This is the selection window;

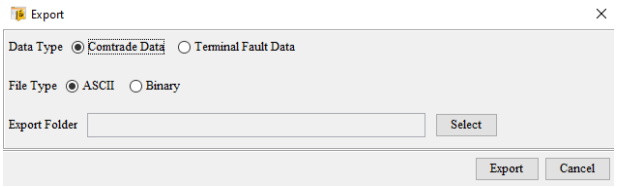


Select the directory and the file to be imported: the standard communication window is opened. Once selected, press Import: the operation is confirmed.

7.4.5 Export

This selection

is available under File. The purpose is to save and send a recording(s) to another user. Fault waveforms can be exported in the standard COMTRADE format. The following window is opened.



The standard foresees a number of files of different types, designated by the following file extensions: *.CFG, *.INF, and *.DAT.

The *.DAT file contains the digitised sample data in an ASCII text format or binary format. The *.CFG file contains configuration data about what is in the *.DAT file, including information such as signal names, start time of the samples, number of samples, min/max values, and more. The .INF file adds other information.

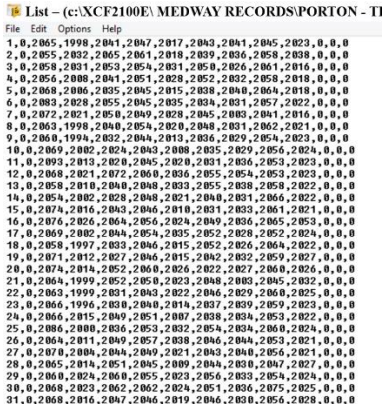
The following is the example of a .cfg file.

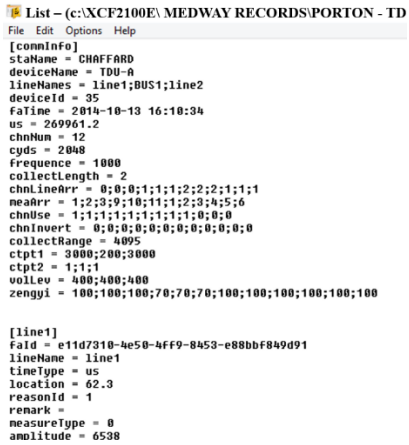
List – (c:\XC2100E\HERTS\RECORDS\WARE

File Edit Options Help

```
WARE, 35.1999
12,12A,0D
1,Ia,A,,A,1,0,0,-2048,2047
2,Ib,B,,A,1,0,0,-2048,2047
3,Ic,C,,A,1,0,0,-2048,2047
4,Ua-I,A,,A,1,0,0,-2048,2047
5,Ub-I,B,,A,1,0,0,-2048,2047
6,Uc-I,C,,A,1,0,0,-2048,2047
7,Ia,A,,A,1,0,0,-2048,2047
8,Ib,B,,A,1,0,0,-2048,2047
9,Ic,C,,A,1,0,0,-2048,2047
10,Ua,A,,A,1,0,0,-2048,2047
11,Ub,B,,A,1,0,0,-2048,2047
12,Uc,C,,A,1,0,0,-2048,2047
50
1
1000,2048
10/13/14,16:10:34.269961.2
10/13/14,16:10:34.269961.2
ASCII
```

This is an example of a .dat file.





And the following is the example of an .inf file.

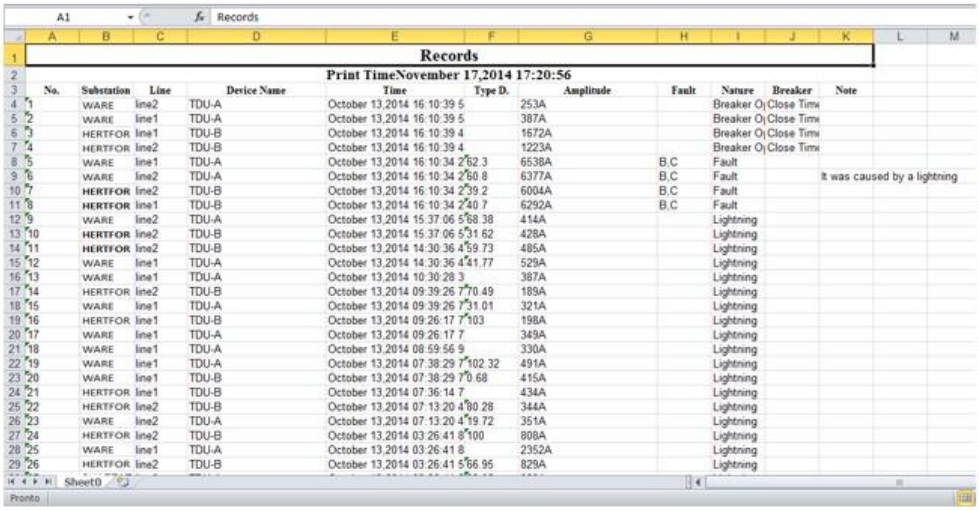
CFG and DATA files are mandatory for the re-import of data. Although the values of the digitised samples in the *.DAT file are viewable without the *.CFG file, the value of the data is greatly diminished as it would be very difficult to fully reconstruct the meaning of the data without the *.CFG file.

Note: The *.DAT file can be ASCII text format or binary format, allowing the corresponding selection button to be found.

7.4.6 Export as .XLS

The selection

is available also under File**.** The results table can be exported as an Excel file. The software opens the standard page: input the name and press Save; Click OK to open the Excel file.



Records

Print TimeNovember 17,2014 17:20:56

No.	Substation	Line	Device Name	Time	Type D.	Amplitude	Fault	Nature	Breaker	Note
1	WARE	line2	TDU-A	October 13,2014 16:10:39 5		253A		Breaker O	Close Tim	
2	WARE	line1	TDU-A	October 13,2014 16:10:39 5		387A		Breaker O	Close Tim	
3	HERTFOR	line1	TDU-B	October 13,2014 16:10:39 4		1672A		Breaker O	Close Tim	
4	HERTFOR	line2	TDU-B	October 13,2014 16:10:39 4		1223A		Breaker O	Close Tim	
5	WARE	line1	TDU-A	October 13,2014 16:10:34 2	62.3	6538A	B,C	Fault		
6	WARE	line2	TDU-A	October 13,2014 16:10:34 2	60.8	6377A	B,C	Fault		It was caused by a lightning
7	HERTFOR	line2	TDU-B	October 13,2014 16:10:34 2	39.2	6004A	B,C	Fault		
8	HERTFOR	line1	TDU-B	October 13,2014 16:10:34 2	40.7	6292A	B,C	Fault		
9	WARE	line2	TDU-A	October 13,2014 15:37:06 5	68.38	414A		Lightning		
10	HERTFOR	line2	TDU-B	October 13,2014 15:37:06 5	31.62	428A		Lightning		
11	HERTFOR	line2	TDU-B	October 13,2014 14:30:36 4	59.73	485A		Lightning		
12	WARE	line1	TDU-A	October 13,2014 14:30:36 4	41.77	529A		Lightning		
13	WARE	line1	TDU-A	October 13,2014 10:30:28 3		387A		Lightning		
14	HERTFOR	line2	TDU-B	October 13,2014 09:39:26 7	70.49	189A		Lightning		
15	WARE	line1	TDU-A	October 13,2014 09:39:26 7	31.01	321A		Lightning		
16	HERTFOR	line1	TDU-B	October 13,2014 09:26:17 7	103	198A		Lightning		
17	WARE	line1	TDU-A	October 13,2014 09:26:17 7		349A		Lightning		
18	WARE	line1	TDU-A	October 13,2014 08:59:56 9		330A		Lightning		
19	WARE	line1	TDU-A	October 13,2014 07:38:29 7	102.32	491A		Lightning		
20	WARE	line1	TDU-B	October 13,2014 07:38:29 7	0.68	415A		Lightning		
21	HERTFOR	line1	TDU-B	October 13,2014 07:36:14 7		434A		Lightning		
22	HERTFOR	line2	TDU-B	October 13,2014 07:13:20 4	80.28	344A		Lightning		
23	WARE	line2	TDU-A	October 13,2014 07:13:20 4	19.72	351A		Lightning		
24	HERTFOR	line2	TDU-B	October 13,2014 03:26:41 8	100	808A		Lightning		
25	WARE	line1	TDU-A	October 13,2014 03:26:41 8		2352A		Lightning		
26	HERTFOR	line2	TDU-B	October 13,2014 03:26:41 5	66.95	829A		Lightning		

Sheet0

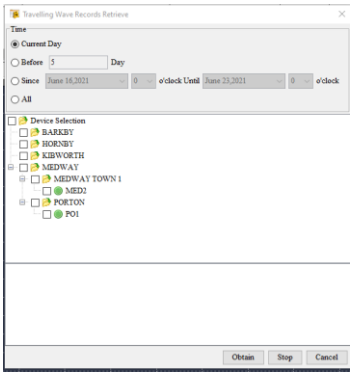
Pronto

7.4.7 Travelling wave records retrieve

With the above selection we have completed the commands on the toolbar. There are two more under Operation; the first one is

.

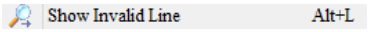
The selection enables the retrieving of data which were not downloaded automatically, because of communication problems.

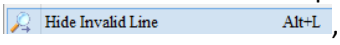


The selection refers to Ethernet connection problems so regions which have telephone links are not considered.

Press Obtain: the operation continues until data are retrieved.

7.4.8 Show invalid line

Select Operation, and then 

: all recorded lines are displayed, even if they have been disabled. The opposite operation, 

, is now accessible.

7.5 Google Map/Off-line map usage

With the Google map selection, the location of the substations, lines, towers and fault location can be displayed on the Google map. The PC has to be able to access the internet to realise this function.

For utilities which do not allow internet access, an off-line map feature is also provided. A user-defined map area is pre-installed in the software, and all the above map operations (such as fault location on the map) can be realised.

Both the on-line Google map and the off-line map features are explained in Section 9.

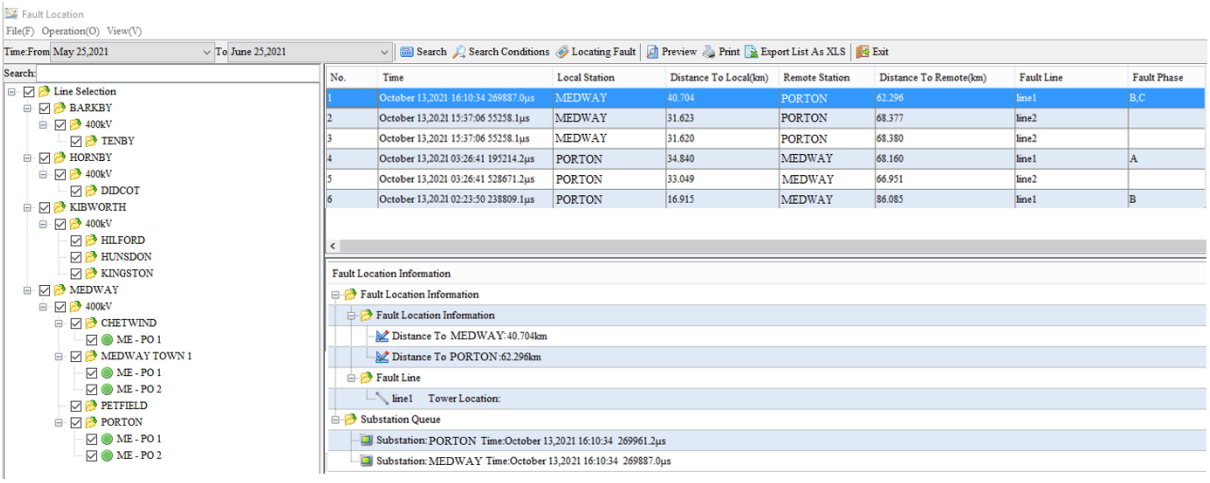
8. Fault Location

To access click on the following icon;

The purpose of the module is to collect all events which have been located in the Travelling wave records module, and to inform about the tower where the fault has occurred.

The information is automatically added to the module when the TDU is connected via Ethernet or point-to-point, after the Travelling wave records module has located the fault (using the Wide location area algorithm).

Note: This refers to events, and not of faults; therefore, whenever an event has been located, regardless of the type of fault (lightning or a CB operation), it is automatically added to the module. In case of telephone communication, the user can select the events which are to be copied into this module; the procedure is explained as follows. The Fault location window is shown below.



This window includes five parts: The left side provides a tree for line selection and the central area includes fault data table and fault information, with the menu and tool bar above.

The tree selection area includes the region, voltage level grade, substation and the lines connected to the substation.

8.1 The results table

The results table provides the following data.

- Fault time;
- Local station;
- Distance to the Local station;
- Remote station;
- Distance to the remote station;
- Fault line;
- Fault phase.

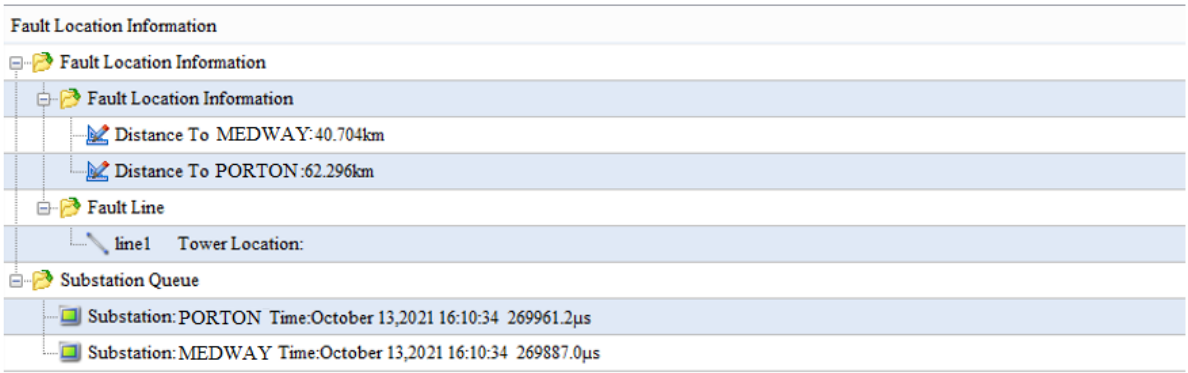
No.	Time	Local Station	Distance To Local(km)	Remote Station	Distance To Remote(km)	Fault Line	Fault Phase
1	October 13,2021 16:10:34 269887.0μs	MEDWAY	40.704	PORTON	62.296	line1	B,C
2	October 13,2021 15:37:06 55258.1μs	MEDWAY	31.623	PORTON	68.377	line2	
3	October 13,2021 15:37:06 55258.1μs	MEDWAY	31.620	PORTON	68.380	line2	
4	October 13,2021 03:26:41 195214.2μs	PORTON	34.840	MEDWAY	68.160	line1	A
5	October 13,2021 03:26:41 528671.2μs	PORTON	33.049	MEDWAY	66.951	line2	
6	October 13,2021 02:23:50 238809.1μs	PORTON	16.915	MEDWAY	86.085	line1	B

The XCF software, based upon the data recorded in the Travelling wave records module, has performed the fault location, and organised the table matching the two substations at the end of the line which have recorded the same fault.

As for the other module, the date of recorded faults can be selected, so that the table displays only the events of interest.

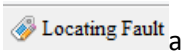
8.2 Fault location information

After selecting a recording, the fault location information is displayed as follows (it can also be viewed in graphical form.



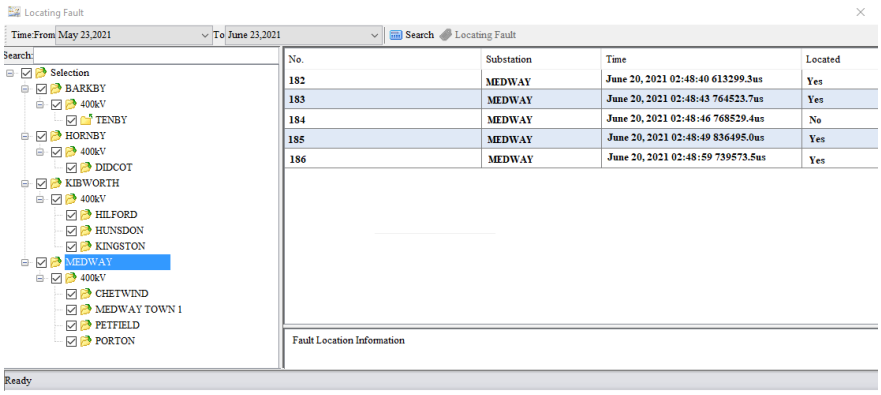
It provides information about the faulty tower.

8.3 Locating the fault

This locating fault icon 

allows the located faults to be imported when they have been downloaded **by the telephone line**.

Pressing the icon displays the following window:

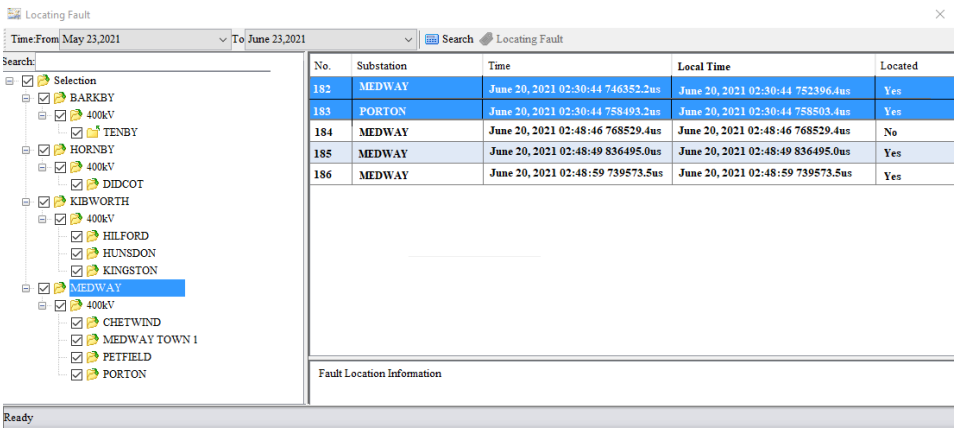


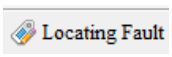
The table lists the following columns:

- Fault number;
- Substation;
- Time when the fault occurred;
- Located – yes or no;

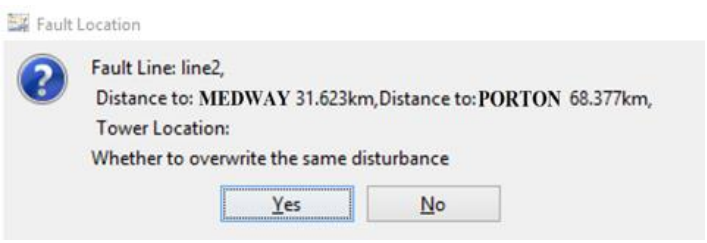
The import operation is performed as follows;

- First, open the Travelling Wave records module, and note the required date and time of the records;
- Next, in the Locating fault window above, select the time frame when the faults occurred;
- Now select the relevant event. As the substation is clicked, the window magnifies also the line of the substation at the other end of the same fault. In the following example, the selected events occurred on October 13th, at 15:37:06;

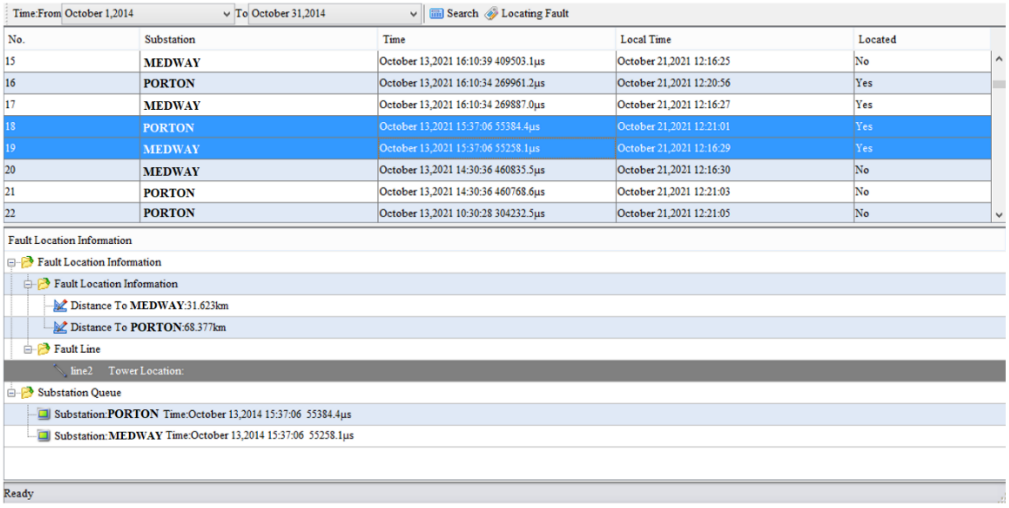


- Press the 

icon again: the following confirmation window is displayed.



- Select Yes to observe the following;



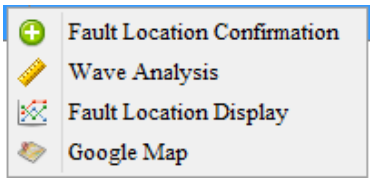
On the two selected lines, the location column to the right states ‘yes’, meaning the fault is located; below, the ‘Fault location information’ states the characteristics of the fault.

No.	Time	Local Station	Distance To Local(km)	Remote Station	Distance To Remote(km)	Fault Line	Fault Phase	Tower
1	October 13,2014 16:10:34 269887.0µs	MEDWAY	40.704	PORTON	62.296	line1	B,C	
2	October 13,2014 15:37:06 55258.1µs	MEDWAY	31.623	PORTON	68.377	line2		
3	October 13,2014 03:26:41 528671.2µs	PORTON	33.049	MEDWAY	66.951	line2		
4	October 13,2014 03:26:41 195214.2µs	PORTON	34.840	MEDWAY	68.160	line1	A	
5	October 13,2014 02:23:50 238809.1µs	PORTON	16.915	MEDWAY	86.085	line1	B	

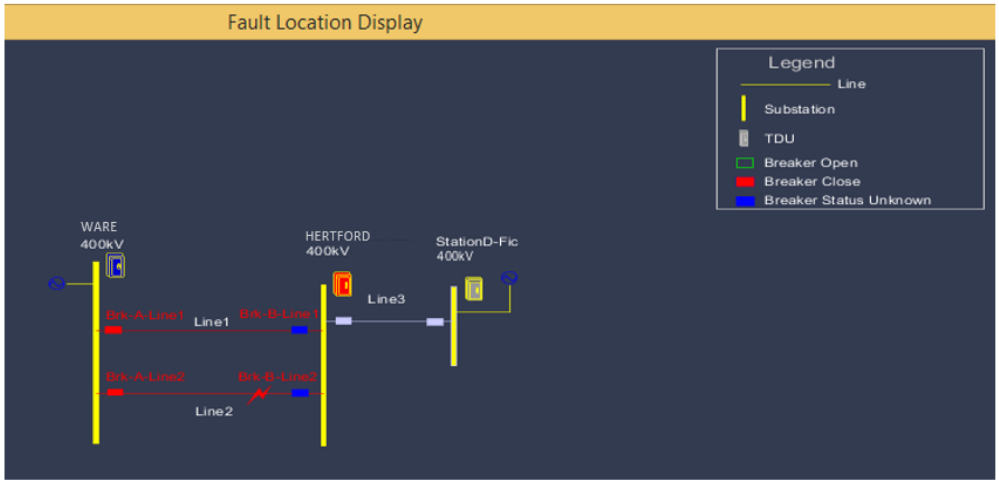
- By closing the Locating fault window, and returning to the Fault location, this adds the selected event to the list.

8.4 Further operations

Right click on an event to generate these four options.



- **Fault location confirmation:** XCF opens the confirmation window. Click OK: the fault is confirmed.
- **Wave analysis:** XCF opens the two wave records: See next Section.
- **Fault location display:** Double click on the desired event: XCF opens the fault area window, as shown in the figure below.



When this window is opened, the fault position display flickers.

- **Description of the graph:**

  The substation is equipped with the travelling wave device.

  The CB is closed.

  The CB is open.

  Line1 This is the line.

  Fault location.

- **Fault Location**

  The fault point is displayed by the flashing icon, and the TDU and line are usually displayed in yellow. The flashing interval is 500ms, and can be modified.

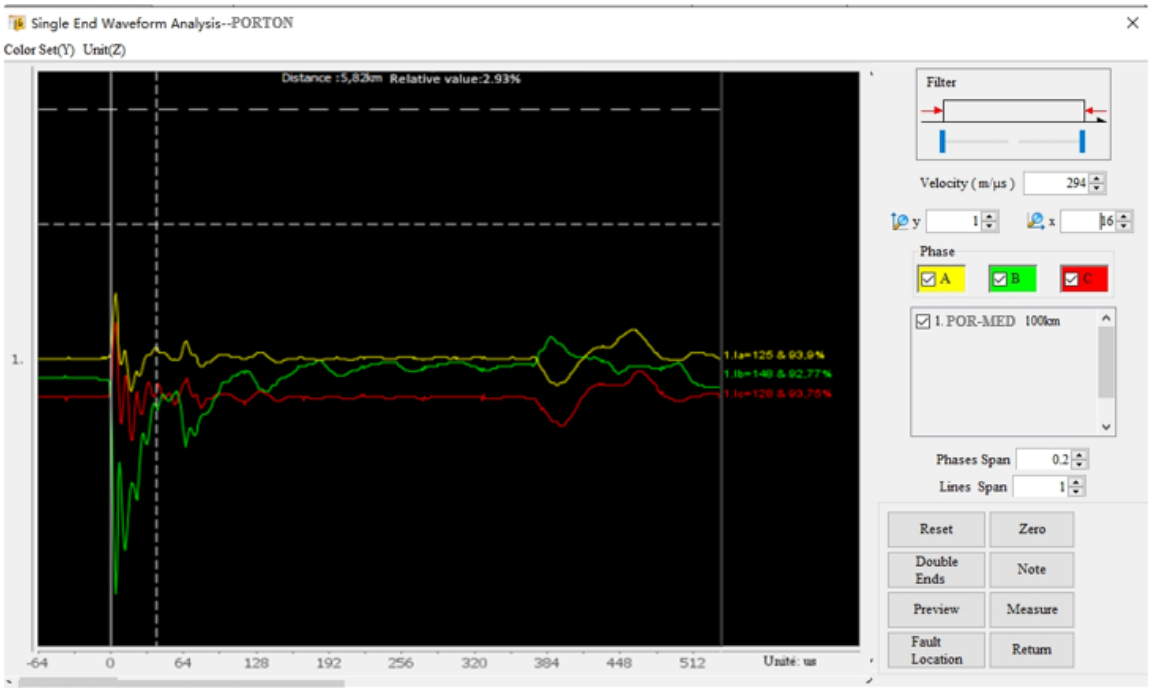
8.5 Travelling Wave Analysis

Travelling wave analysis consists of single end analysis and double end analysis. The single end analysis is used to determine the fault location by manually analysing the waveform recorded at one substation. The double ends analysis provides the automatic fault location result, which can be further verified by analysing the local and remote substation waveforms.

The travelling wave analysis is launched by double-clicking a fault record. A single end waveform analysis window appears. Within this window, there is a ‘Double Ends’ button. If there is a corresponding record which is able to form a double end result, clicking this button will launch a double ends analysis, showing both the ‘local’ and the ‘remote’ waveforms.

8.5.1 Single end waveform analysis

The window of single end waveform analysis is as shown below.



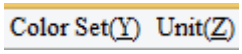
The waveform area displays all the disturbance waveforms that have been recorded by the TDU.

This window consists of four parts: The left side is the waveform display panel. The panel has 4 cursors: two vertical ones and two horizontal ones. The vertical ones consist of a solid cursor and a dotted cursor, used to measure the time difference between the two. The horizonal ones consist of a coarse dotted cursor and a fine dotted cursor, used to show the full magnitude range of the waveforms.

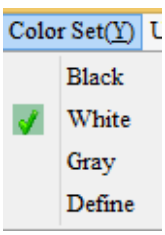
The right side is the control panel, used for changing the visual display of the waveforms (e.g., band-pass filter to remove noise, zoom etc.) to assist of the analysis.

The single end analysis is performed by manually moving the dotted cursor to the reflected wave. The software measures the time difference between the incident wave and the reflected wave, and calculate the distance to the fault. This result is shown in the top of the screen.

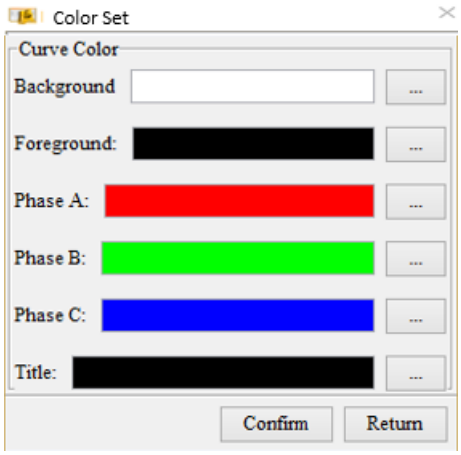
There are other controls as follows: On the top left there are colour and unit selection settings.



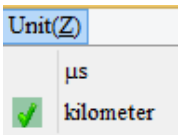
- **Colour set**: provides the following colour selection:



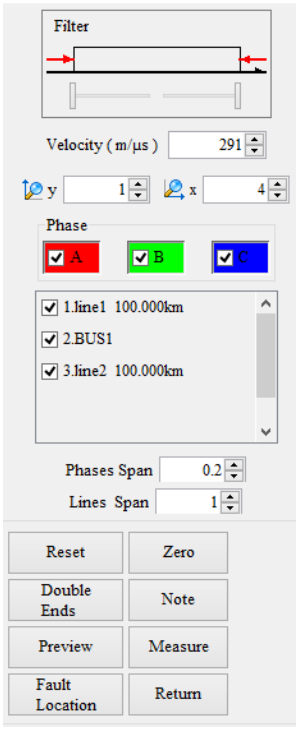
The first three selections provide alternative background colour. The fourth selection 'Define' produces the following menu, which allows other colours (such as Phase A, B and C) to be selected.



- **Unit:** this allows the selection of the fault distance in microseconds or kilometers



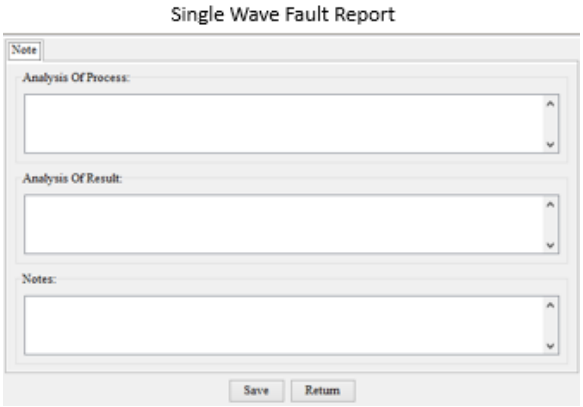
On the right, there is access to the following selections.



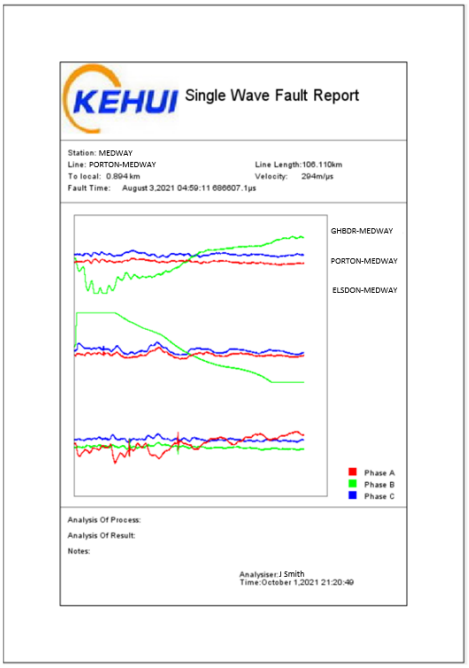
- **Filter**. The waveform can be filtered by a user-defined band-pass filter, which removes the low frequency and the high frequency components. The filter is defined by moving the two cursors.
- **Speed**. This can be modified to allow the measured line length to match the actual line length. The unit of measurement is m/μs.
- **Zoom**. The width of both the Y and the X axes can be increased or reduced.

- **Phase**. The phase to be displayed can be selected.
- **List of records**. The waveforms from the lines monitored can be selected.
- **Phases span**. The three phase waveforms are displayed on the same horizontal axis by default. It is possible to separate out using this function to give a clearer indication.
- **Lines span**. If the device monitors more than one line, their waveforms can be further separated to aid clarity.
- **Reset:** The distance measuring cursor returns to the initial position.
- **Zero**: The two cursors return to the initial position, the dotted one is superimposed on to the continuous line, and the fault distance displays zero. The dotted line can be moved by the cursor.
- **Double ends**: Switch to the double-ended waveform analysis window.

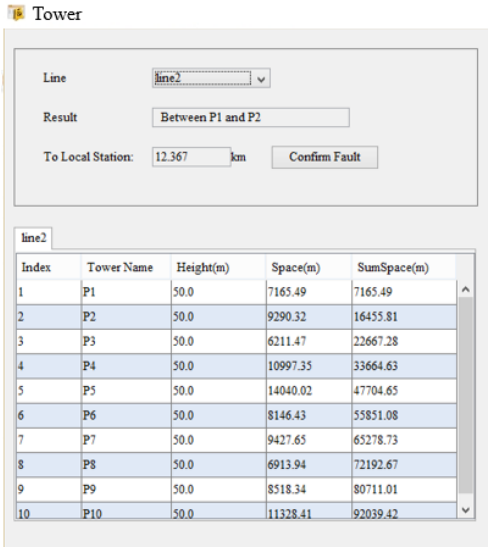
Note: It is possible to edit and record the analysis process and add remarks. The Note window is as follows:



- **Preview**: Preview the printing result of the waveform analysis report.



- **Measure**: Show the current measurement type (current or voltage).
- **Tower**: Switch to the tower position analysis window.

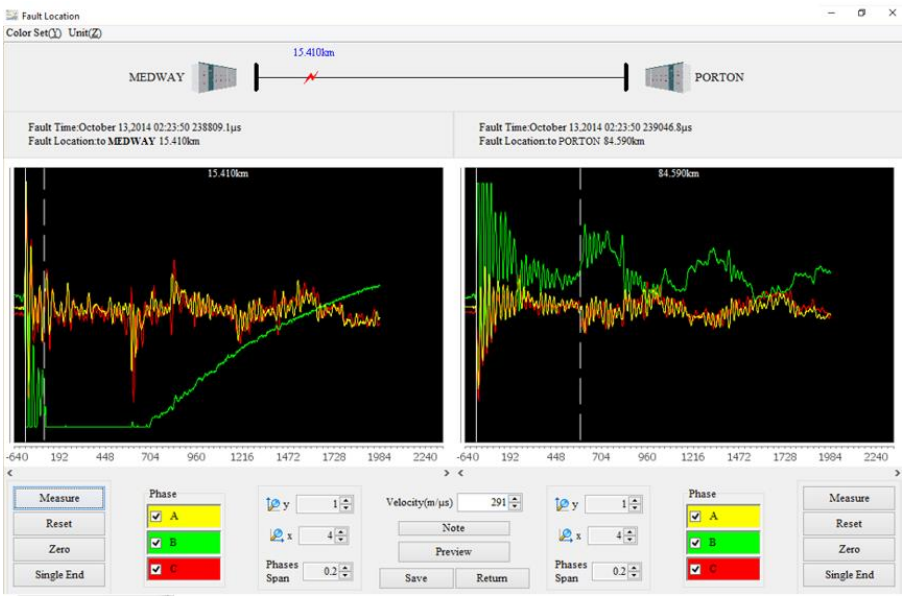


Index	Tower Name	Height(m)	Space(m)	SumSpace(m)
1	P1	50.0	7165.49	7165.49
2	P2	50.0	9290.32	16455.81
3	P3	50.0	6211.47	22667.28
4	P4	50.0	10997.35	33664.63
5	P5	50.0	14040.02	47704.65
6	P6	50.0	8146.43	55851.08
7	P7	50.0	9427.65	65278.73
8	P8	50.0	6913.94	72192.67
9	P9	50.0	8518.34	80711.01
10	P10	50.0	11328.41	92039.42

- **Return**: Closes the current window.

8.5.2 Double end waveform analysis

The double end waveform window for the travelling wave analysis is as shown in the figure below.



The double end waveform analysis window displays the waveform of local and remote substation and the automatic location result. The panel above displays the names of local and remote substations, fault distance and tower location results.

The fault waveform at the local and remote substation is displayed in the middle area, on the left side is the waveform of the local substation and the right side is the remote substation. The lower part is the control panel explained earlier.

As the fault distance is known, it is useful to see it on the single end diagram which is the corresponding waveform.

8.5.3 Line length calibration

The length of the line is typically calculated by adding the geographical line span between the tower locations on the map, but this does not represent the true line length, as the line sag and the elevation are not taken into account. Without line length calibration, the two-ended result will produce an error as shown below.

Consider the formula for the fault location:

D = (L - ((T1)B – (T1)A) * v)/2

Where (T1)B and (T1)A are the times of arrival of the first impulse at the two substations, B and A. If:

(T1)B – (T1)A = 0, D = L/2

In this instance, the error is zero. But if:

(T1)B – (T1)A * v = L1, where L1 is the actual line length, then:

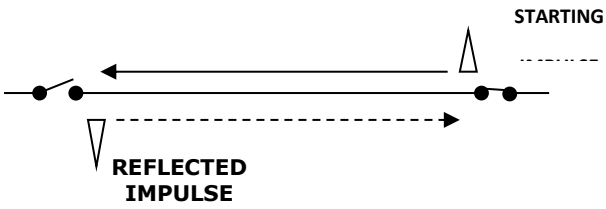
D = (L – L1) / 2

As a consequence, the result could be a negative figure; the error is maximised. The best way to avoid this error is to correct the wave speed, so that L1 = L, and D = 0. The corrected speed is:

V1 = L1 / ((T1)B – (T1)A)max

Where ((T1)B – (T1)A)max is the maximum time difference between the impulses, which occurs when the fault has occurred in the substation. This process of establishing the correct wave speed is called line length calibration.

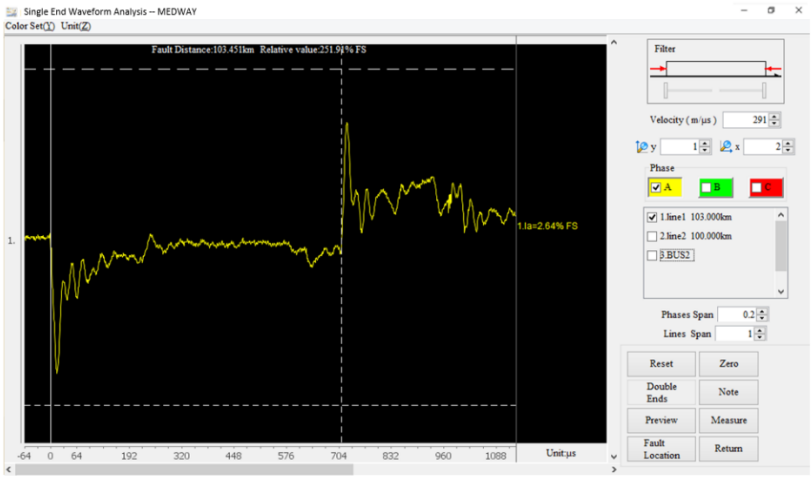
Line length calibration can be performed when there is an opportunity of a line outage, with the circuit breakers (CBs) at both line ends are open. By closing the CB onto an unloaded line (i.e., remote end open-circuited), both the wave generated by the CB closing and the wave reflected from the remote end can be captured. The wave speed can then be adjusted manually to calibrate the lien. Alternatively, a successful auto-reclose after a fault with the remote end still open-circuited will provide the same opportunity for line calibration. Both scenarios are represented in the following diagram.



Let us consider the following case.

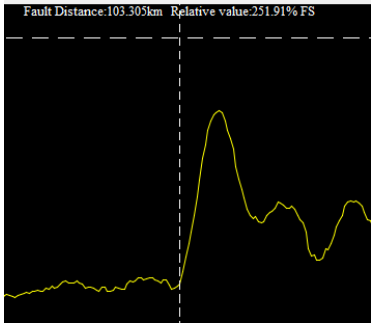
Substation	Line	Device N...	Time	Type D. Result(km)	Amplitude	Fault Phase	Nature
MEDWAY	line2	TDU-B	October 13,2021 16:10:39 409503.1 µs		1672A		CB Operation

The following picture shows the CB close after a fault.



When the dotted cursor is located, the message at the top of the window states the distance of the reflected line.

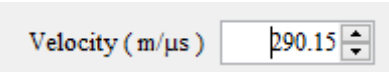
The image can be zoomed for a more accurate cursor location. It is positioned at the point when the waveform starts its transient.



Based on the default wave speed of 291 m/μs, the measured length is 103.305 km. This value appears at the top right of the window. If the actual line length is 103 km. Then, the wave speed can be corrected:

V1 = 291 * 103/103.3 = 290.15 m/μs.

Instead of doing this calculation, the simpler way is to adjust the velocity until the line length reaches 103 km. The new wave speed (in this case 290.15m/us) can then be applied for future fault locations by entering into the Line setting table.



Line | Bus | Substation Information

No.	Name	Start Substation	End Substation	Wave Velocity(m/μs)
1	line1	MEDWAY	PORTON	290.00
2	line2	MEDWAY	PORTON	290.00

8.6 Mixed lines

Where mixed lines are involved the transient wave speed changes from the cable to the line so we cannot use the normal computation formulas, which are based upon a constant speed. The XCF-2100E software handles mixed lines in the following way.

The solution is to convert the mixed line into a fictitious line, where the wave speed is constant, and equal to 300 m/µs. The conversion is performed as follows.

Let us consider a sector of the line: the time t the wave takes to travel it is:

$$t = \frac{l_{set}}{v_{set}}$$

Where l_{set}, v_{set} are respectively the sector length and the sector wave speed.

Now, let us call l_b the equivalent sector length. When the wave speed is v_b : the length is computed as follows.

$$l_b = \frac{l_{set}}{v_{set}} \times v_b$$

Adding up all equivalent line lengths we get the equivalent line length.

$$L_b = \sum_{1}^{i=n} \frac{v_b}{v_i} \times l_i$$

Now we are ready to compute the fault distance.

After the fault, using the standard computing formulae for a constant speed, we can compute the equivalent fault distance, starting from a substation: we call it l_{bF}. Now we can compute the actual distance with the following algorithm.

- Subtract the equivalent length of the first sector, l_{b1}, from l_{bF}.
  - If the result is negative, then the fault is located in the **first** sector; otherwise, we proceed.
- Subtract the equivalent length of the first two sectors, $(l_{b1} + l_{b2})$, from l_{bF}.
  - If the result is negative, then the fault is located in the **second** sector; otherwise, we proceed.

We continue this way, until we locate the faulty section. Now, we locate the fault as follows.

Let us call the 'residual' cable length the difference of l_{bF} and the total equivalent length of the non-faulty sectors:

$$l_r = l_{bF} - \sum_{1}^{i=m} \frac{v_b}{v_i} \times l_i$$

Where m is the number of the non-faulty sector.

We can eventually compute the real distance to fault, as follows. First, we compute the distance to fault in the faulty sector.

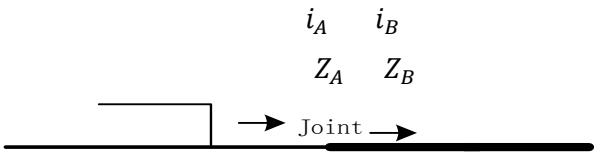
$$l_{sF} = \frac{l_r}{v_b} \times v_{sF}$$

Where V_{sF} is the real wave speed in the faulty section. The distance to fault is:

$$l_F = l_{SF} + \sum_{i=1}^{m} l_{si}$$

Where l_{si} is the length of sectors before the fault.

Another problem to be considered is that, when the line is mixed, at the joints the wave finds an impedance mismatch, and is partly reflected. Let us consider the following figure.



Let us call i_A the current before the joint, and i_B the current after it they are related by the following formula.

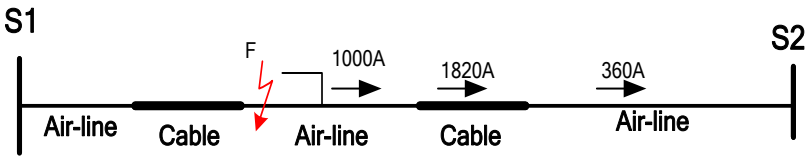
$$i_B = \frac{2Z_A}{Z_A + Z_B} i_A = \rho i_A$$

Where Z_A is the characteristic impedance of section A, and Z_B is the characteristic impedance of section B. The coefficient;

$$\rho = \frac{2Z_A}{Z_A + Z_B}$$

is the joint reflection parameter.

When section A is an overhead line, and section B is a cable, ρ ≈ 1,82. This means that current i_B is bigger than i_A : if i_A is 1000A, then i_B is 1820 A. If the line goes from the cable to the overhead line, the current i_B is smaller than i_A : the coefficient ρ ≈ 0,198. Considering the following example:



It is clear that the original current peak, 1000 A, is very much attenuated as it reaches the substations S1 and S2. It is therefore apparent that the more the joints, the more attenuated is the current.

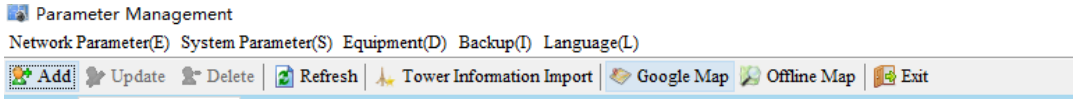
In practice, there are rarely more than three sectors and more than five is almost unknown, hence the fault can normally be detected without difficulty.

9. On-line Google Map/Off-line Map

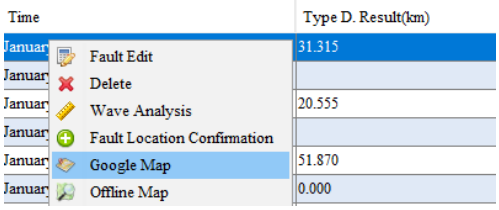
9.1 On-line Google Map

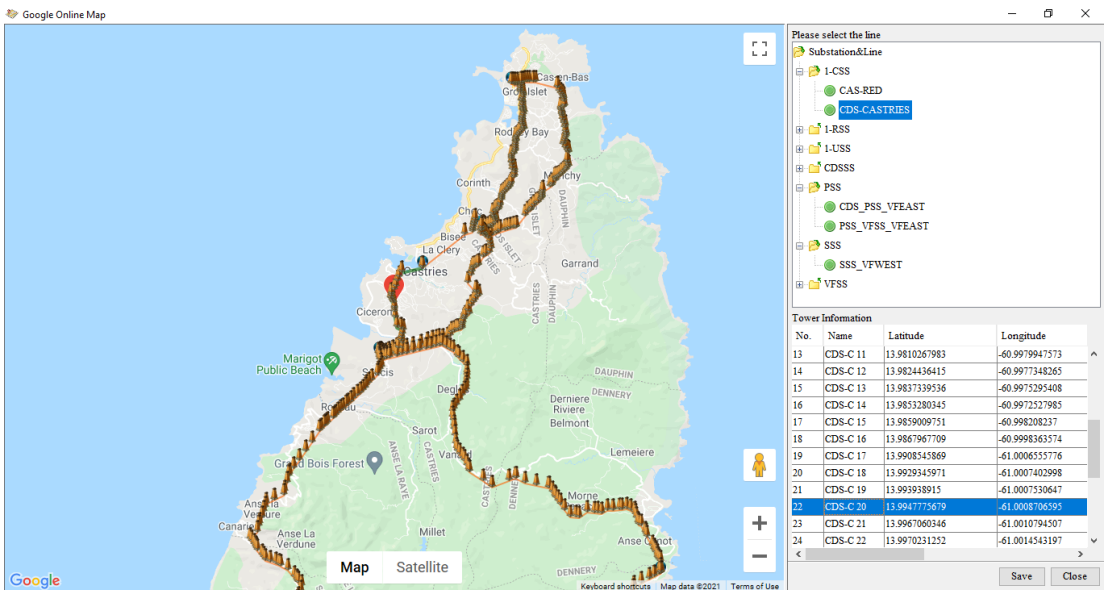
The Google Map function allows the location of the substations, lines, towers and fault location to be shown on an on-line Google Map. The longitude and latitude information allow these items to be positioned accurately on the map. The PC needs to access the Internet for this function to be available.

The Google map is launched by selecting the 'Google Map' icon of the task bar from 'Parameter management' as shown. Only the substations, lines and towers information will be shown as the fault location is not available in the 'Parameter Management' module.



The Google Map is also launched in the 'Travelling wave records' and the 'Fault location' module, by right-clicking on a selected fault record. A pull-down menu appears and the 'Google Map' can be selected.





On the left, the window shows the map and the lines. On the right, the window shows network topology of the substations and the lines. Selecting a particular line allows the tower information to be displayed.

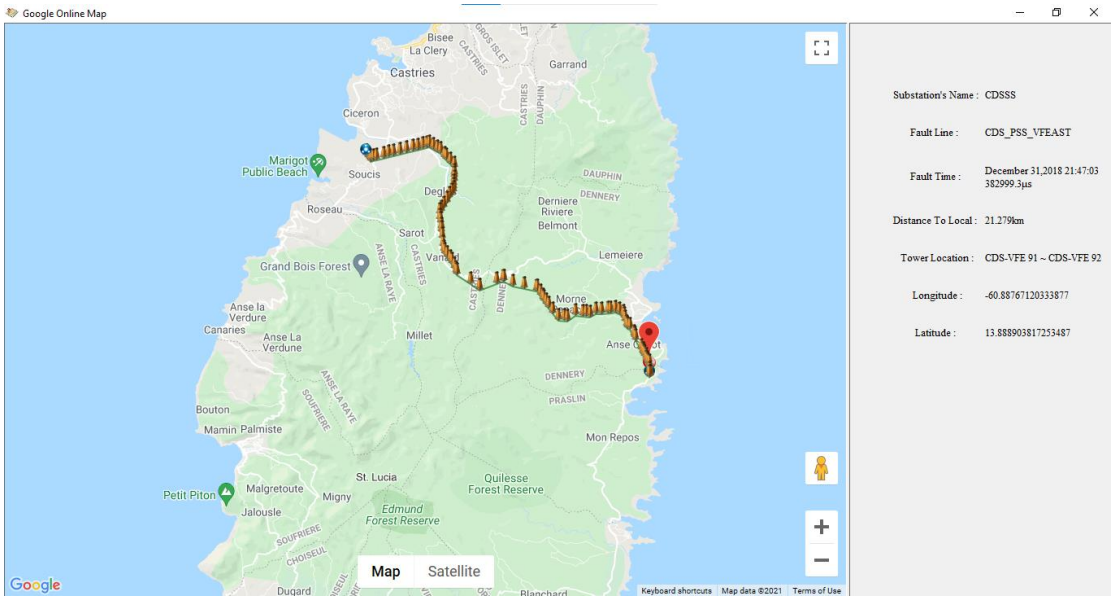
The icons on the map are explained below.

No.	Icon	Note
1		The first and last substations
2		Tower position
3		A static icon shows the position of the selected tower. A flashing icon shows the position of the fault.

The satellite map can also be shown if the <Satellite> button at the bottom of map, is pressed.

The map can be zoomed and towers moved using the mouse. Press the <Save> button to save the tower setting.

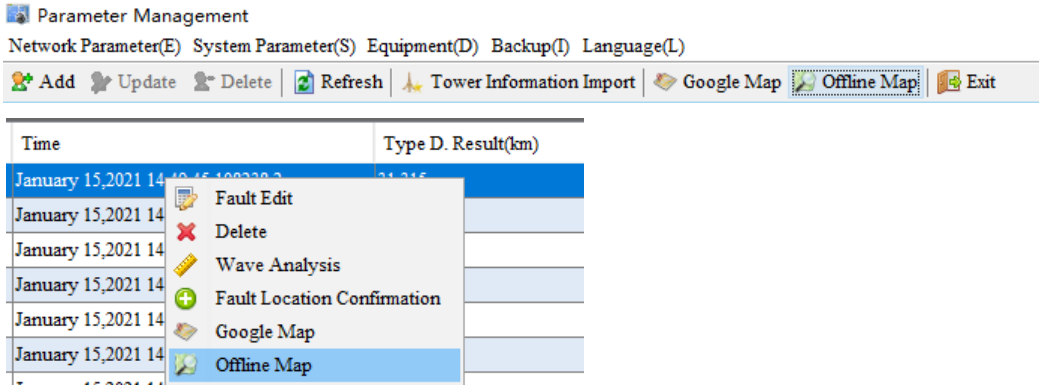
An example of the map with fault locations is shown in the following figure. Related information such as the faulty line, time of fault, fault distance, longitude and latitude of the fault location are shown on the right-hand pane.



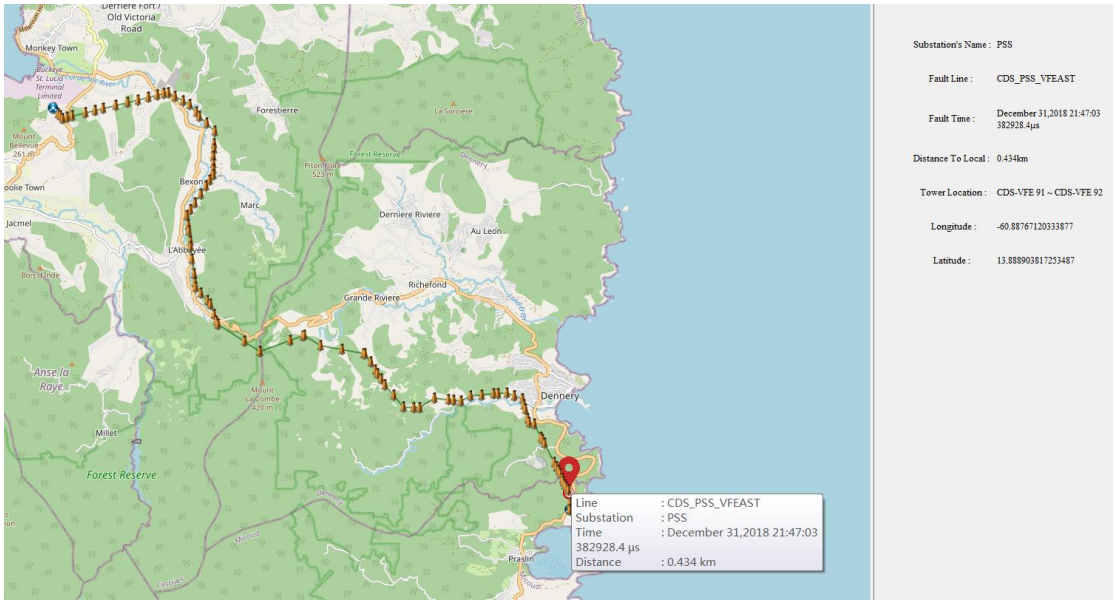
9.2 Off-line Map

For utilities which do not allow internet access on their local area network, an off-line map feature is provided. The off-line map feature allows a map of a pre-determined area to be downloaded and stored in the XCF-2100E database. Afterwards, all the on-line Google map features are available with the off-line map.

The off-line map feature is launched in a similar way as for the on-line Google map feature as shown below. Instead of selecting Google Map, the user should select Offline Map.



An example of the offline map showing a fault location is as shown below;



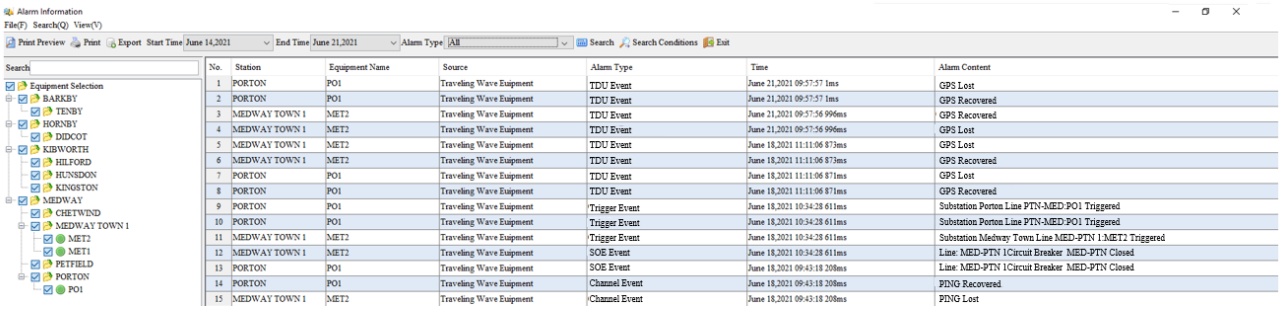
The off-line map feature is provided from XCF-2100E V1.9.7 onwards. After the user has defined an area on the map where the network locations are required, the offline map needs to be downloaded by Kehui's support team and loaded into XCF-2100E.

10. Alarm Information

This module allows the user to view the alarm information produced by all devices.

The alarm information comes from the TDUs, and a part is also from the communication module. For the alarm view, choose the equipment, set the search date range and the alarm type. The alarm type includes; system, channel, working condition, operation and other alarm.

The main window is shown in the figure below.



This window comprises three parts; the left side is the tree for line selection, the table on the right lists all the alarms of the selected region or substation in the selected time period, and the top contains the function keys.

The table lists: substation, device name, alarm source, alarm type, time and alarm content. There are two alarm sources: the TDU itself, and the communication module.

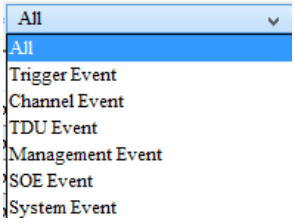
The alarm from the communication module is the system alarm. Because the communication module does not belong to any substation, in case of such event, the substation column would report an asterisk.

10.1 List of alarms

One or more devices can be chosen from the condition tree on the left, the time window can be set in the toolbar.

10.2 Alarm type

A specific alarm type, or all alarms, can be selected in the drop-down list;

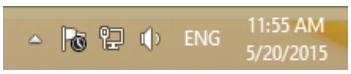


- Trigger event: the TDU has triggered for any type of triggered event (see Appendix 6).
- Channel event: problem on the communication channel, such as PING lost.
- TDU event: any situation occurring on the TDU, including the loss of synchronisation, power-off and on.
- Management event: TDU was reset, or settings were changed.
- SOE event: whenever there is a CB operation, the event is recorded, regardless to the triggering.
- System event: operations on the TDU front panel.

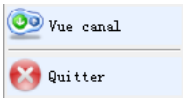
When searching the alarm information, the status bar on the bottom right will display the current status of the searching process. When the searching process is running, the tip 'data searching' will be presented on the status bar. After the searching is finished, it will present the total records count.

10.3 Communication Module

When the programme is communicating with the TDU, the icon of the communication module will be displayed at the right corner below, in the WINDOWS system tray area.

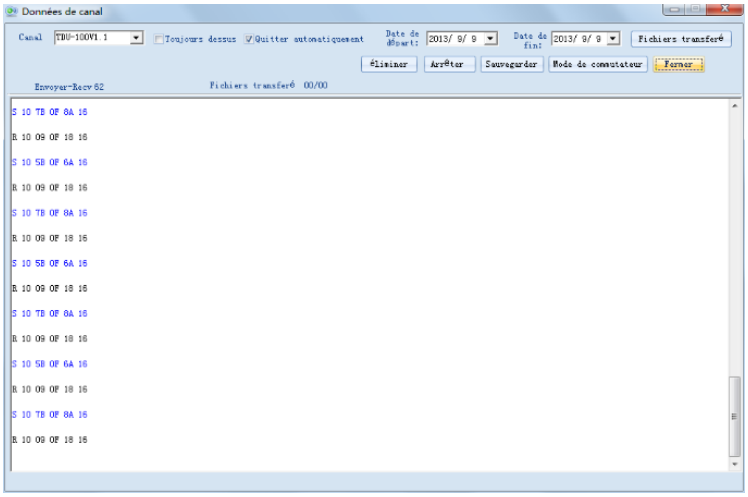


Click the icon with the right key: the following menu will pop up.



10.4 Channel data view

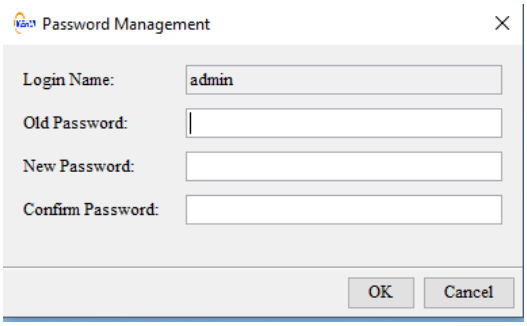
The main function of the channel data view is to view and store the communication message content of each equipment and communication module. The window of channel data view is as shown in the figure below:



11. Password Management

This selection allows the user to set the User ID and Password. The ID is created in the selection ‘Parameter management’, ‘System parameters’, ‘User’, which can be accessed only by an Administrator.

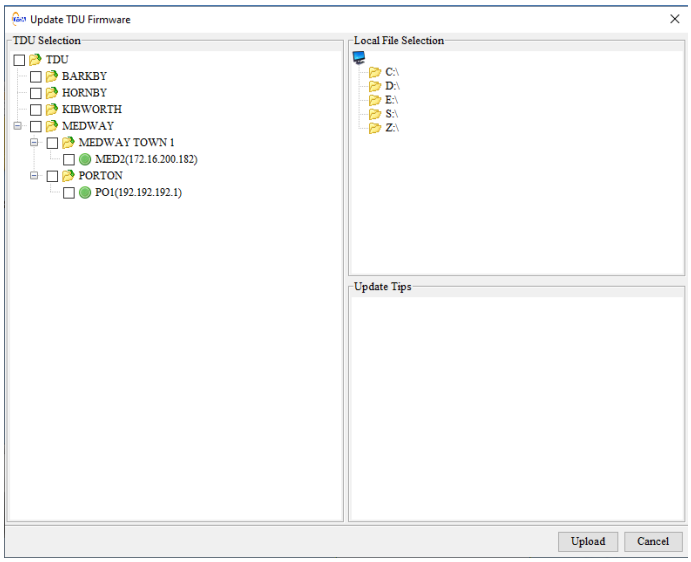
The software opens the following window.



This window displays the name which has been entered in the software and can only be changed by a system administrator in the Parameter Management section of the software. To change the password, enter the old password on the appropriate line and then add a new password, confirming it on the next line. Clicking OK, gives a confirmation message.

12. Update TDU Firmware

This allows the user to update the firmware resident in the TDU. The software opens the following window.



To update the firmware, select the TDU to be updated and, on the right, select the new firmware file.

To update the firmware, select the TDU to be updated and, on the right, select the new firmware file. After the selection of the file, click Upload. The software will provide an alert when the operation is concluded.

The firmware update operation is risky, because it is important to use the correct update file. It is vital that the TDU remains powered on whilst the firmware update is being performed. If the power is lost, the TDU will be disabled at the next power-on. However, it can be recovered with a further firmware update.

13. Database Structure

The Database structure is explained in Appendix 3.

14. Software Description: XCF-2100E WEB

14.1 XCF-2100E-WEB

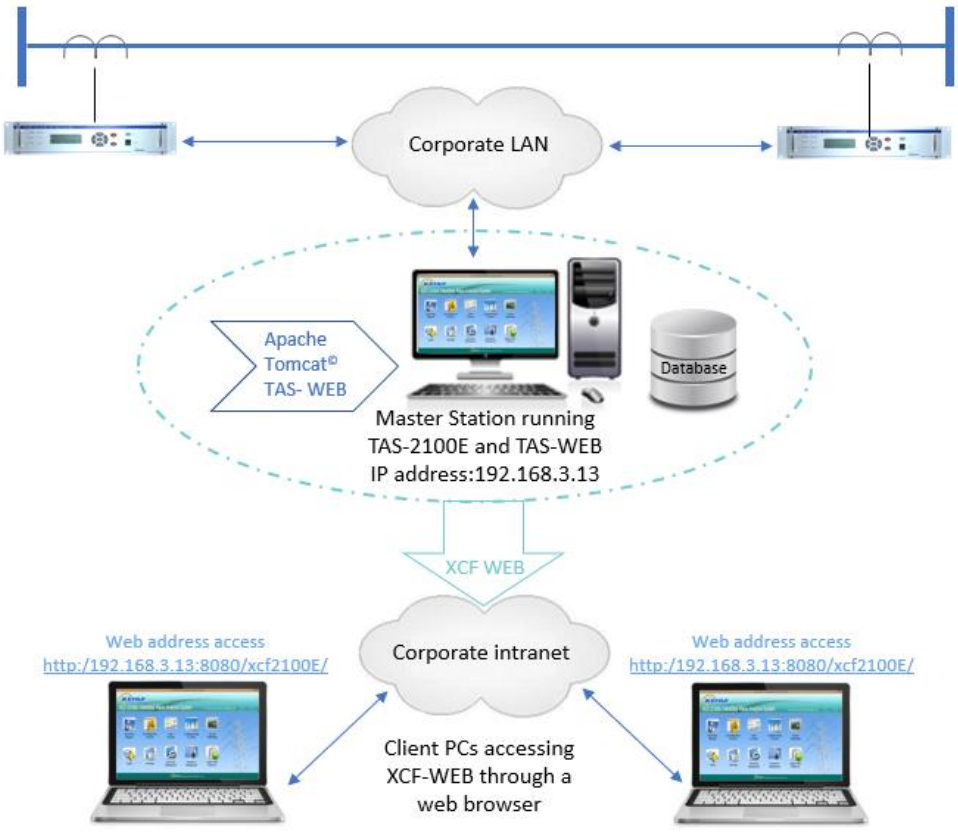
XCF-2100E-WEB (referred to as XCF-WEB for short) is a software extension to the master station software XCF-2100E. Its purpose is to provide remote access by another PC to the master station. Both the XCF-WEB and the XCF-2100E software are installed in the same PC, referred to as the Master Station PC. The XCF-WEB allows a remote PC, referred to as the Client PC, to access in real-time the XCF-2100E's database in the Master Station PC, which contains all the fault and alarm records acquired from the XC-100E devices on the network.

The XCF-WEB is developed using the public domain software Apache Tomcat which converts the Master Station PC into a web server. The master Station PC will need to have a static IP address to allow the Client PCs to connect to XCF-WEB. The Client PCs, typically connected through the intranet of the corporate communications network, will need to make a Uniform Resource Locator (URL) request (commonly known as web request) through its web browser to establish the connection.

For example, if the IP address of the master station PC is 192.168.3.13, the Client PC will need to enter the following address in the URL address bar of its web browser. If the connection is successful, the first page of XCF-2100E will appear in the browser, prompting for the user's name and password.

http://192.168.3.13:8080/XCF2100E/

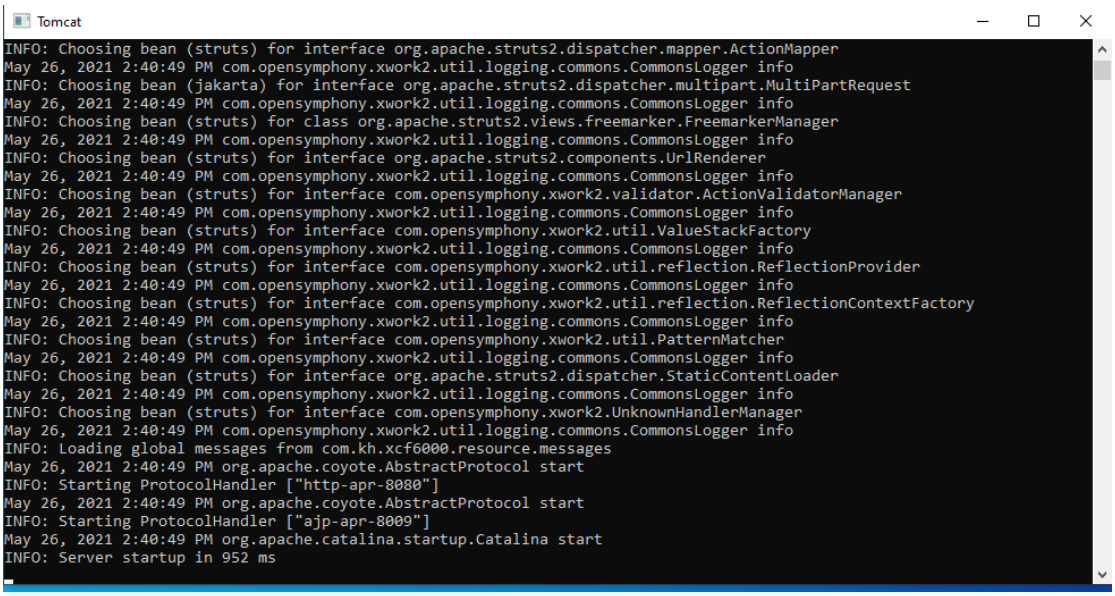
The arrangement can be seen in the following diagram:



14.2 Running XCF-WEB in the Master Station PC

The pre-requisite for running XCF-WEB is to have the Master Station PC configured with a static IP address. This is invariably the case during commissioning, when it is necessary for the master station PC to be in the same subnet address group as the TDUs. This has been explained in the communications section of this manual.

XCF-WEB needs to be installed in the master station PC running the XCF-2100E, using the XCF-WEB installation package provided. After the XCF-2100E-WEB has been installed, double-click the newly created icon and the software will start. A DOS window appears (see below). The last line of the text indicates that the 'Server starting up in xxx ms'. This time is normally less than 1s, the server should have been up and running by the time the last message appears.



The XCF-WEB can now be left running in the master station PC to allow continuous remote access by the Client PCs. If this program is terminated, the remote access feature will immediately stop.

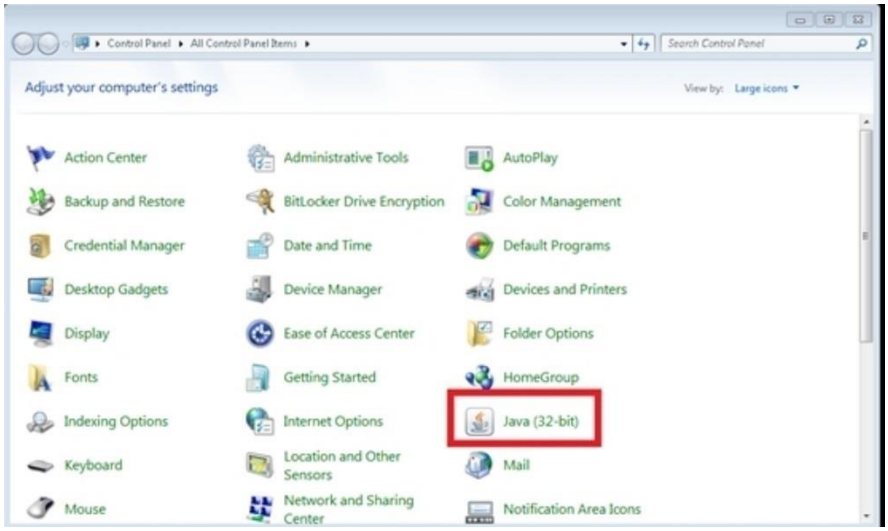
14.3 Configuring the Client PC for accessing XCF-WEB by a Client PC

The Client PC needs to have the Java Runtime Environment installed. This is essential as XCF-WEB is written in Java language. When a Client PC is connected to the XCF-WEB, XCF-WEB will download Java plug-ins (i.e., software components) to the Client PC. Without Java installed and without allowing the plug-ins to be downloaded, a lot of the remote operations cannot be realised.

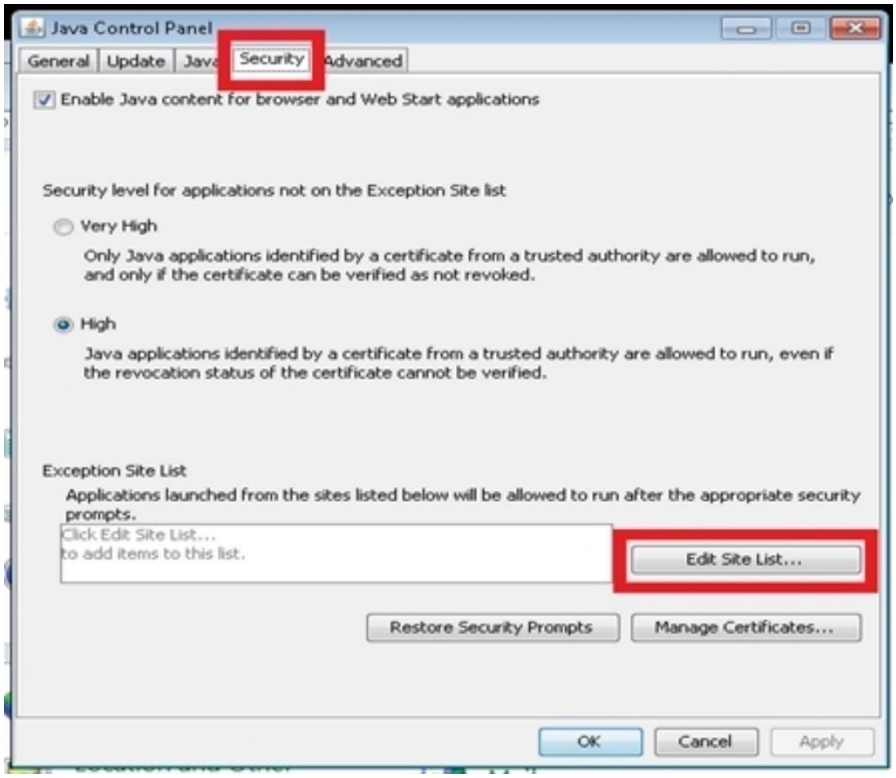
Java is a public domain software and can be downloaded from the following web site:

www.java.com

After download, a Java icon will appear in the Client PC's control panel as follows:



It is necessary to configure Java to allow access to the XCF-WEB's URL address. Open the Java Control Panel and locate the Security tab. Select <Edit Site List>. Add the URL address (e.g., http://192.168.3.13:8080/XCF2100E/) into <Edit Site List> box. Click 'Add' and 'OK' to complete the operation.



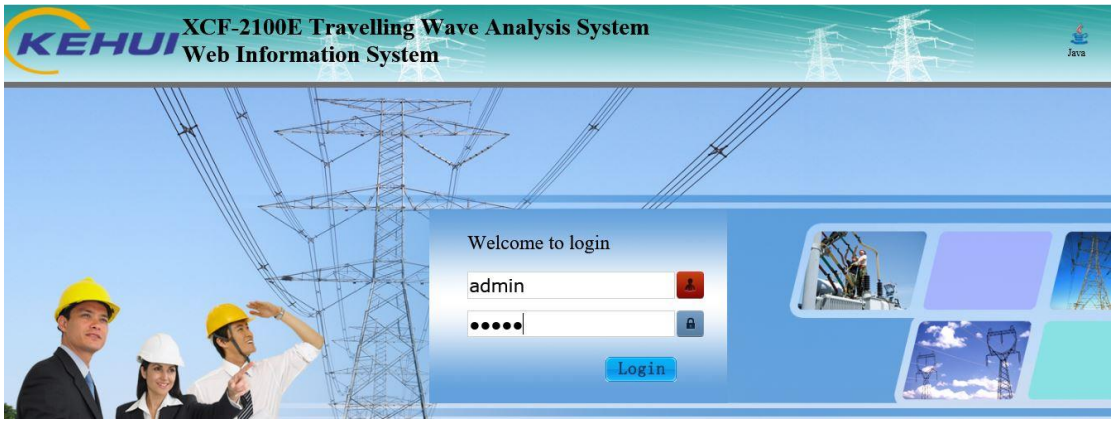
14.4 Accessing the XCF-WEB

To access the XCF-WEB by the Client PC, the user needs to launch an internet browser. The recommended browser is the Internet Explorer as it has no restriction in accepting Java plug-ins.

After the internet browser has been launched, the user can enter the URL address of the XCF-WEB into the URL address bar of the internet browser, as follows:

http://192.168.3.13:8080/XCF2100E/

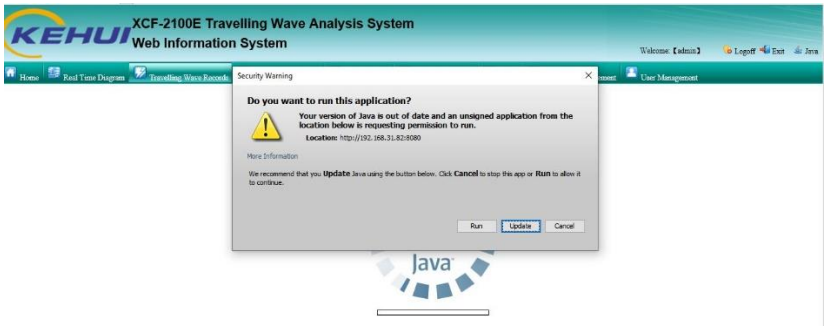
The front page of the XCF-WEB will start, prompting for the user name and password, which are the same as those set up for XCF-2100E.



After log-in, the large icons in the XCF-2100E user interface page are now available as smaller icons in the menu bar. Single-click the icon to open up the relevant software module. The user is now able to operate the XCF-2100E remotely in the same way as operating directly with the Master Station PC, but with some restrictions.

The major restriction of XCF-WEB is that the Client PC is not allowed to change the contents of the database, including most settings. Effectively this is a 'read only' operation and not a 'read-write' operation (but with exceptions as explained in later sections).

For example, single-clicking <Travelling wave records> will open up the Records page as shown. If the Java plug-in has not been downloaded for this particular operation, a Java symbol appears together with a pop-up window requesting permission to run the Java plug-in. After accepting this request by pressing 'Run', the records will appear.

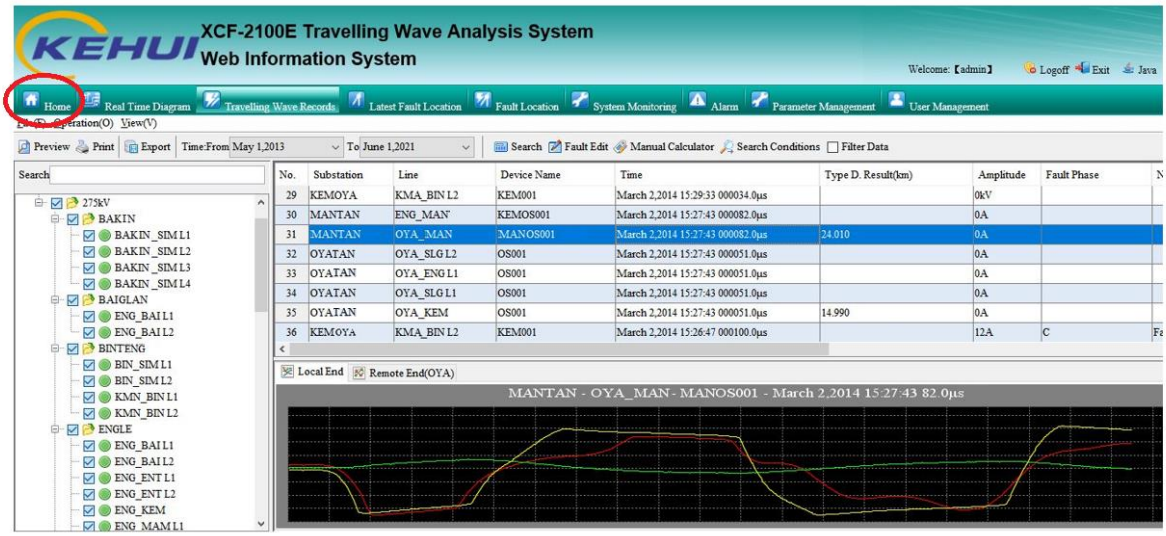


The user can now select any record and perform singe-ended or double-ended analysis in exactly the same way as is done locally. Individual waveforms can be selected, allowing zooming and movement of the cursor etc. There are no restrictions on the operations which can be performed on the fault records for analysis purposes, as these operations do not change the contents of the records in any way.

14.5 Functions available with XCF-WEB

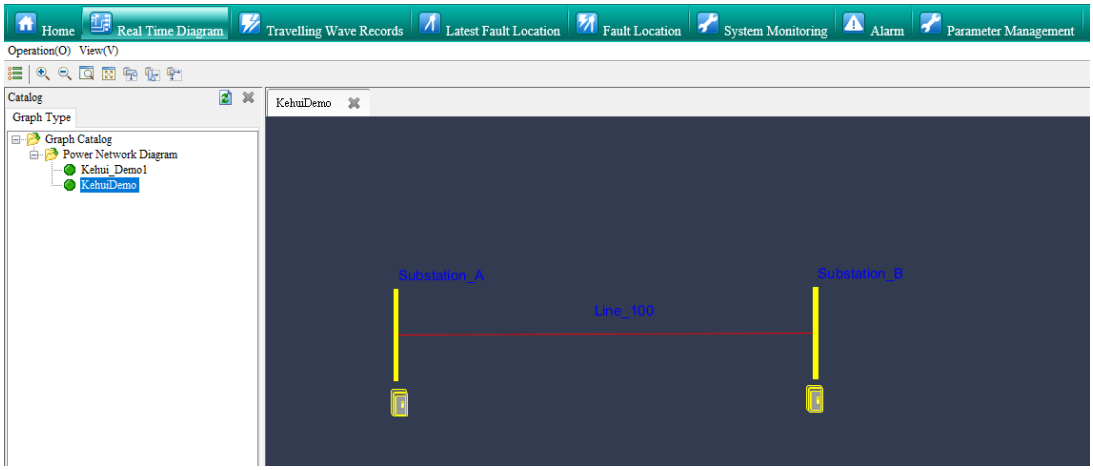
a) Home

'Home' is a blank page with only the menu bar at the top allowing the user to access other software modules. If the user is already accessing another software module, selecting the home icon will cause an exit from that module.



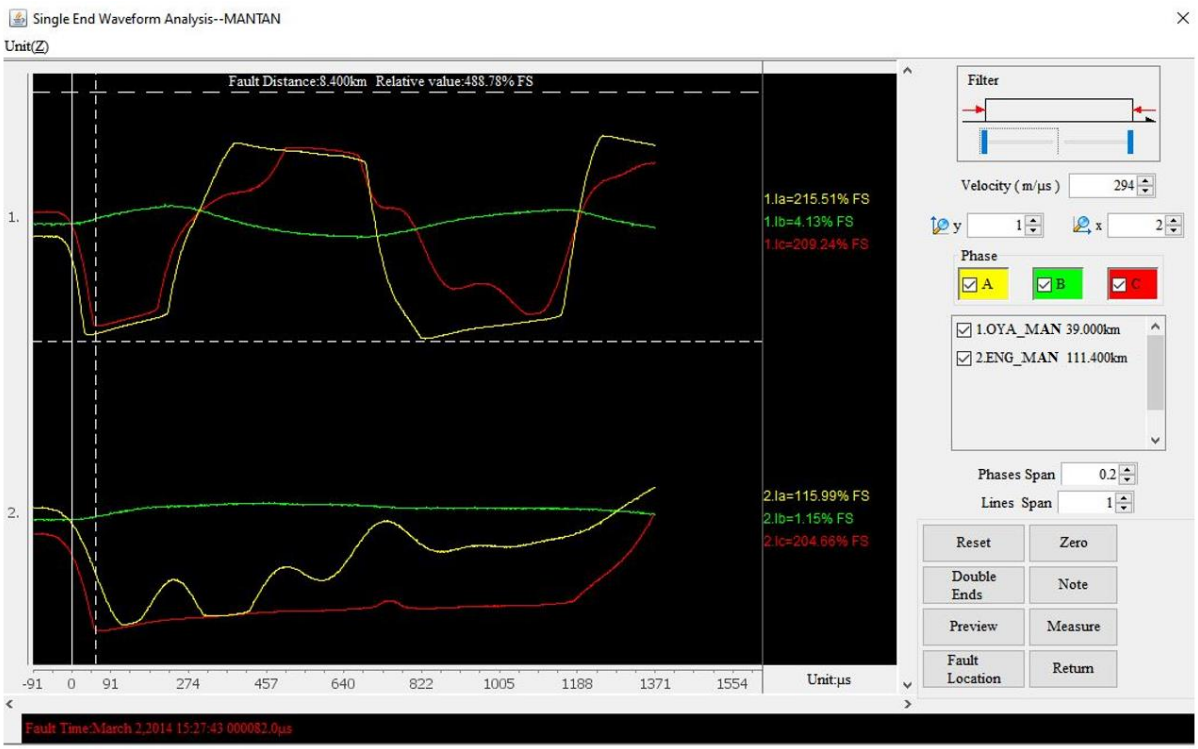
b) Real Time diagram

Selecting the ‘Real Time Diagram’ icon allows the user to access the real time diagram software module of XCF-2100E. The single-line diagram of the network created by the user will be available.



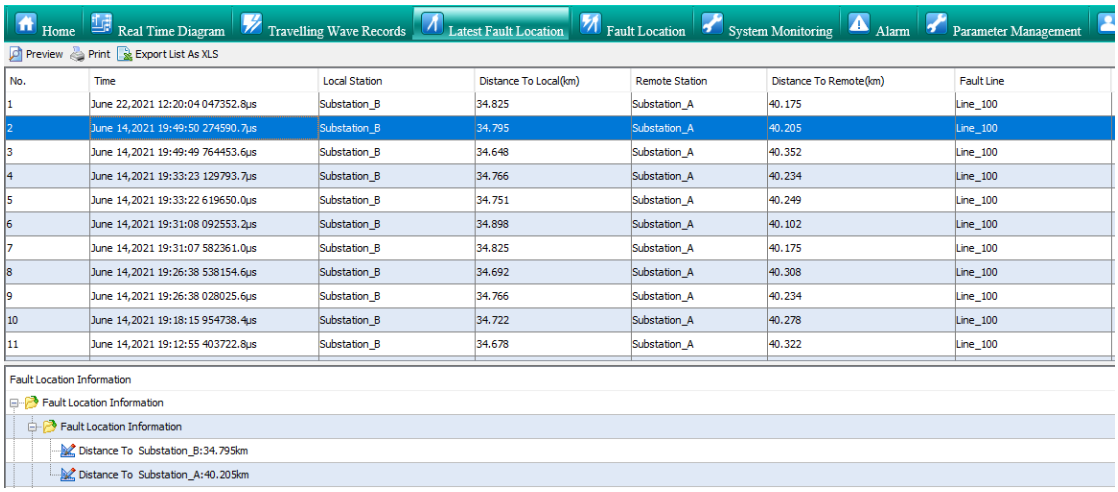
c) Travelling wave records

Selecting the travelling wave records icon allows the user to access the ‘travelling wave records’ module of XCF-2100E. All the fault records are available for access. The user can perform search operations and select a particular record for analysis in the same way as the XCF-2100E.



d) Latest fault location

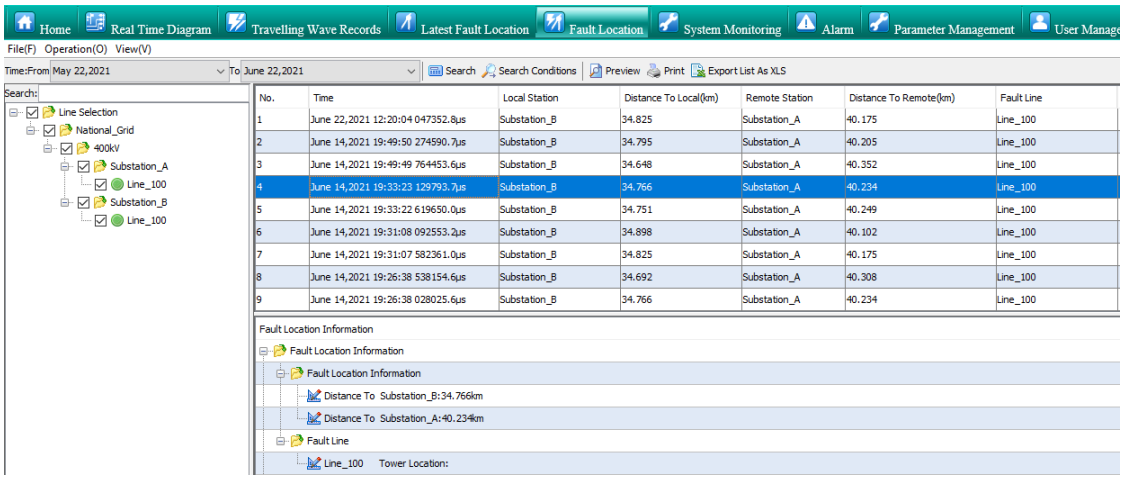
Selecting this icon shows the two-ended results arranged in the order of date and time of occurrence, starting with the most recent result. This is the quickest way to look at the latest fault location results without any search operation. The source substation, line, destination substation, fault location and types of faults are shown for each result. Selecting a result shows the location of the fault in the real-time diagram.



No.	Time	Local Station	Distance To Local(km)	Remote Station	Distance To Remote(km)	Fault Line
1	June 22,2021 12:20:04 047352.8μs	Substation_B	34.825	Substation_A	40.175	Line_100
2	June 14,2021 19:49:50 274590.7μs	Substation_B	34.795	Substation_A	40.205	Line_100
3	June 14,2021 19:49:49 764453.6μs	Substation_B	34.648	Substation_A	40.352	Line_100
4	June 14,2021 19:33:23 129793.7μs	Substation_B	34.766	Substation_A	40.234	Line_100
5	June 14,2021 19:33:22 619650.0μs	Substation_B	34.751	Substation_A	40.249	Line_100
6	June 14,2021 19:31:08 092553.2μs	Substation_B	34.898	Substation_A	40.102	Line_100
7	June 14,2021 19:31:07 582361.0μs	Substation_B	34.825	Substation_A	40.175	Line_100
8	June 14,2021 19:26:38 538154.6μs	Substation_B	34.692	Substation_A	40.308	Line_100
9	June 14,2021 19:26:38 028025.6μs	Substation_B	34.766	Substation_A	40.234	Line_100
10	June 14,2021 19:18:15 954738.4μs	Substation_B	34.722	Substation_A	40.278	Line_100
11	June 14,2021 19:12:55 403722.8μs	Substation_B	34.678	Substation_A	40.322	Line_100

e) Fault location

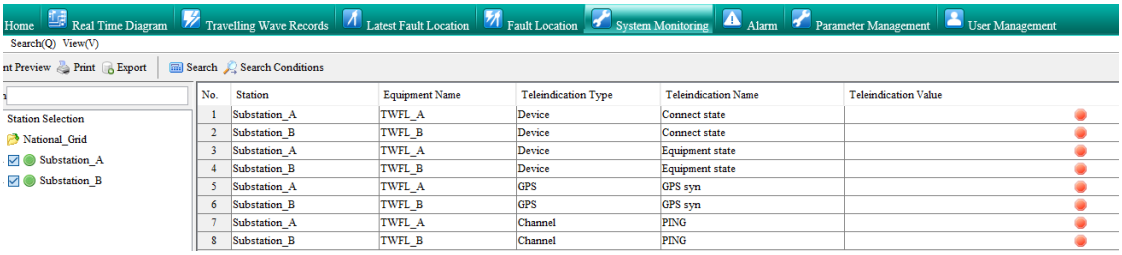
This is similar to the Latest Fault Location, except that there is search bar to search for historical results. There is also a line selection from the network topology in the left-hand pane, allowing a sub-set of the results to be shown.



No.	Time	Local Station	Distance To Local(km)	Remote Station	Distance To Remote(km)	Fault Line
1	June 22,2021 12:20:04 047352.8μs	Substation_B	34.825	Substation_A	40.175	Line_100
2	June 14,2021 19:49:50 274590.7μs	Substation_B	34.795	Substation_A	40.205	Line_100
3	June 14,2021 19:49:49 764453.6μs	Substation_B	34.648	Substation_A	40.352	Line_100
4	June 14,2021 19:33:23 129793.7μs	Substation_B	34.766	Substation_A	40.234	Line_100
5	June 14,2021 19:33:22 619650.0μs	Substation_B	34.751	Substation_A	40.249	Line_100
6	June 14,2021 19:31:08 092553.2μs	Substation_B	34.898	Substation_A	40.102	Line_100
7	June 14,2021 19:31:07 582361.0μs	Substation_B	34.825	Substation_A	40.175	Line_100
8	June 14,2021 19:26:38 538154.6μs	Substation_B	34.692	Substation_A	40.308	Line_100
9	June 14,2021 19:26:38 028025.6μs	Substation_B	34.766	Substation_A	40.234	Line_100

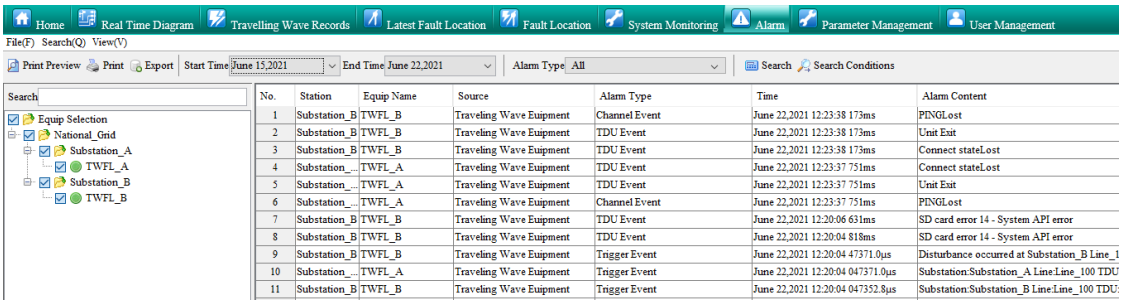
f) System Monitoring

This icon accesses the System Monitoring Module of XCF-2100E. All the information from this module is available for viewing.



g) Alarm

This icon accesses the Alarm Module of XCF-2100E. All the information from this module is available for viewing.



h) Parameter management

The parameter management allows the Client PC to examine the settings and network configuration. Settings change are in general not allowed, but with the following exceptions.

When the user is logged in as System Manager in the XCF-WEB, he/she is able to change some of the settings and execute commands for analysis and testing purpose. This allows remote analysis and maintenance to be done through the XCF-WEB without compromising the security of the system.

The settings and commands to be changed by XCF-WEB by a Systems Manager are as follows:

Line parameter

Only the wave velocity and the line length are allowed to be changed for analysis purpose.

TDU Remote Reset

Able to perform remote reset of the TDU.

Fault simulation

Able to perform fault simulation of the system.

Communication Restart

Able to restart communications.

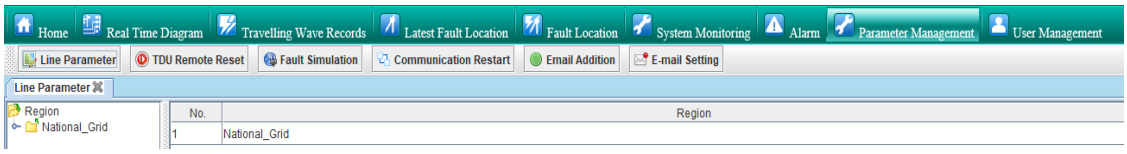
Email addition

Able to create an additional email account for a new recipient of email notifications.

E-mail setting

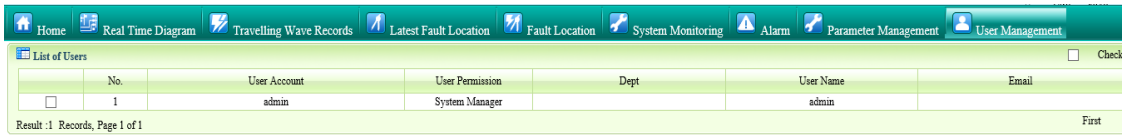
Able to change the email settings of an existing recipient, so that the email notification can be sent to a different mail box.

These functions appear in a special menu bar below the main menu bar, as shown.



i) User Management

The user can only remotely view information in the user management module but not to do any changes.



15. Troubleshooting

15.1 Dial-up

■ No response to pressing of <Request> button.

✓ Solution: check whether the MODEM is installed, and that the correct Dial Device is programmed.

■ The software displays the message ‘Communication Terminated Strangely’.

✓ Solution:

a) Check if the drive programme and the connection of the MODEM are correct, especially if there is more than one MODEM.

b) If the MODEM can dial and you can hear the dial sound, but this message appears, check if the telephone number is correct.

c) If the message is displayed during data transmission, wait for a few minutes and then dial again (To allow the remote MODEM to restart).

d) If the message is frequently displayed during data transmission, usually it is because the bandwidth is insufficient or because of strong interference and in this case the telephone line must be replaced.

■ The communication is not successful.

✓ Solution: Contact the substation and request the exact fault start time. Then use the following formula to compute the fault distance manually.

15.2 Printing problem

The printer fails to print when < Print> is pressed.

✓ Solution:

a) Check whether the printer is installed and can be used normally.

b) Check whether there is paper in the printer

APPENDIX 1: COMPUTING THE SURGE CURRENT

The TDU triggers when the peak of the travelling wave is higher than the programmed threshold. The setting is referred to the maximum peak. Here we explain how the maximum current is computed from the other parameters.

i. The maximum voltage applied to the fault is the nominal voltage divided by the square root of three, which gives the phase voltage, and multiplied by the square root of two, which gives the peak of the sinusoid.

$$V_{fp} = \frac{\sqrt{2}.V_L}{\sqrt{3}} = 0.816V_L$$

ii. The nominal current is the voltage peak divided by the line (or cable) impedance. This is not to be confused with the low frequency line impedance: at these frequencies. The line impedance depends upon the dielectric and magnetic parameters of the isolating mean. The impedance is nominally 300 Ohm for overhead lines, and 20 to 40 Ohm for cables.

$$i_{fm} = \frac{V_{fp}}{Z_w} = \frac{0.816.V_L}{Z_w}$$

iii. When the impulse reaches the busbars, it is reflected by an amount which depends upon the impedance mismatch.

If there is no line leaving the busbars, the impedance becomes infinite, and there is a total reflection of the opposite sign, which nulls the current impulse.

If many lines leave the busbar, the impedance is very low, and the current peak is reinforced. The maximum amount of reinforcement is 100%; so, the detected current peak can be twice the value computed above.

$$i_{bm} = 2.\ i_{fm} = 1.63\frac{V_L}{Z_w}$$

The actual current entering our sensor depends upon the CT ratio.

$$i_{2m} = \frac{i_{bm}}{n_{CT}} = 1.63\frac{V_L}{n_{CT}.Z_w}$$

Where n_{CT} is the CT ratio

iv. For example, let us compute the current i_{2m} on the overhead line, with the following data.

Nominal voltage: 420 kV

CT ratio: 3000:5.

We have:

i_{bm} = 2282 A;

i_{2m} = 3.8 A.

With the threshold set at 5%, the minimum current peak causing the trigger is 190 mA.

APPENDIX 2: SETTING PARAMETERS

SELECTION 1	SELECTION 2	PARAMETER	U.M.	EXAMPLE
PARAMETER MANAGEMENT	VOLTAGE LEVEL	NOMINAL VOLTAGE	kV	420
PARAMETER MANAGEMENT	LINE PARAMETERS	REGION NAME	REGION	North Cal
PARAMETER MANAGEMENT	LINE PARAMETERS	SUBSTATION NAME	S/S	S FRAN
PARAMETER MANAGEMENT	LINE PARAMETERS	NOMINAL VOLTAGE	kV	420
PARAMETER MANAGEMENT	LINE PARAMETERS	S/S LATITUDE	DEGREES	38°34'17'' N
PARAMETER MANAGEMENT	LINE PARAMETERS	S/S LONGITUDE	DEGREES	122°25'24'' W
PARAMETER MANAGEMENT	LINE PARAMETERS	LINE NAME	N.A.	FRA-JO-SUN
PARAMETER MANAGEMENT	LINE PARAMETERS	WAVE SPEED	m/µs	291
PARAMETER MANAGEMENT	LINE PARAMETERS	LINE LENGTH	km	100
PARAMETER MANAGEMENT	LINE PARAMETERS	BUS NAME	N.A.	FRA1
PARAMETER MANAGEMENT	LINE PARAMETERS	MIXED LINE : SECTOR NAME	N.A.	SECTOR 1
PARAMETER MANAGEMENT	LINE PARAMETERS	MIXED LINE : SECTOR LENGTH	km	5
PARAMETER MANAGEMENT	LINE PARAMETERS	MIXED LINE : SECTOR WAVE SPEED	m/µs	172
PARAMETER MANAGEMENT	LINE PARAMETERS	T-LINE : NAME	N.A.	SUNNY BRANCH
PARAMETER MANAGEMENT	LINE PARAMETERS	T-LINE : LENGTH	km	20
PARAMETER MANAGEMENT	LINE PARAMETERS	T-LINE : LOCATION	km	85
PARAMETER MANAGEMENT	TDU PARAMETERS	NAME	N.A.	SFRA
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS	N.A.	172.16.200.102
PARAMETER MANAGEMENT	TDU PARAMETERS	TELEPHONE NUMBER	N.A.	N.A.
PARAMETER MANAGEMENT	CB PARAMETERS	NAME	N.A.	SF1
PARAMETER MANAGEMENT	CB PARAMETERS	STATE	N.A.	CLOSED
PARAMETER MANAGEMENT	TOWER PARAMETERS	NAME	N.A.	FRAT1
PARAMETER MANAGEMENT	TOWER PARAMETERS	HEIGHT	m	25
PARAMETER MANAGEMENT	TOWER PARAMETERS	SPAN	m	500

SELECTION 1	SELECTION 2	PARAMETER	U.M.	EXAMPLE
PARAMETER MANAGEMENT	TOWER PARAMETERS	PYLON LATITUDE	DEGREES	
PARAMETER MANAGEMENT	TOWER PARAMETERS	PYLON LONGITUDE	DEGREES	
PARAMETER MANAGEMENT	TDU PARAMETERS	MAX CHANNELS	N.A.	6
PARAMETER MANAGEMENT	TDU PARAMETERS	SAMPLE FREQUENCY	MHz	1
PARAMETER MANAGEMENT	TDU PARAMETERS	RECORD LENGTH	ms	1
PARAMETER MANAGEMENT	TDU PARAMETERS	TRIGGER DELAY	ms	200
PARAMETER MANAGEMENT	TDU PARAMETERS	POWER FREQUENCY	Hz	50
PARAMETER MANAGEMENT	TDU PARAMETERS	NUMBER OF RECORDS	N.A.	1000
PARAMETER MANAGEMENT	TDU PARAMETERS	ENABLE	N.A.	YES
PARAMETER MANAGEMENT	TDU PARAMETERS	DI INPUT	N.A.	D1
PARAMETER MANAGEMENT	TDU PARAMETERS	MEASUREMENT	N.A.	Ia, Ib, Ic, Ua, Ub, Uc
PARAMETER MANAGEMENT	TDU PARAMETERS	AI BOARD	N.A.	AI, AV
PARAMETER MANAGEMENT	TDU PARAMETERS	SECONDARY CT	N.A.	CLIP-ON CT
PARAMETER MANAGEMENT	TDU PARAMETERS	PRIMARY CT RATIO	N.A.	3000:5
PARAMETER MANAGEMENT	TDU PARAMETERS	GAIN	%	100
PARAMETER MANAGEMENT	TDU PARAMETERS	THRESHOLD	%	5
PARAMETER MANAGEMENT	TDU PARAMETERS	SETTING	%	120
PARAMETER MANAGEMENT	TDU PARAMETERS	INVERT	N.A.	NO
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS PE1	N.A.	192.16.200.102
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS PE1 ; MASK	N.A.	255.255.255.0
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS PE1; GATEWAY	N.A.	
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS PE1; PORT	N.A.	2404
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS PE2	N.A.	172.16.200.103
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS PE2 ; MASK	N.A.	255.255.255.0
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS PE2; GATEWAY	N.A.	

SELECTION 1	SELECTION 2	PARAMETER	U.M.	EXAMPLE
PARAMETER MANAGEMENT	TDU PARAMETERS	ETHERNET ADDRESS PE2; PORT	N.A.	2405
PARAMETER MANAGEMENT	TDU PARAMETERS	COMM1; SPEED	Baud/s	(9600)
PARAMETER MANAGEMENT	TDU PARAMETERS	COMM2; SPEED	Baud/s	(9600)
PARAMETER MANAGEMENT	TDU PARAMETERS	COMM1; PROTOCOL	N.A.	(103)
PARAMETER MANAGEMENT	TDU PARAMETERS	COMM2; PROTOCOL	N.A.	(103)
PARAMETER MANAGEMENT	TDU PARAMETERS	MODEM; CODE INITIALKEHUITION	N.A.	(ATS0=1)
PARAMETER MANAGEMENT	TDU PARAMETERS	MODEM; TELEPHONE NUMBER	N.A.	
PARAMETER MANAGEMENT	TDU PARAMETERS	INTERNAL GPS: TIME ZONE	N.A.	UTC - 8
SYSTEM PARAMETERS	USER	PRIVILEGE	N.A.	ADMIN
SYSTEM PARAMETERS	USER	NAME ID	N.A.	
SYSTEM PARAMETERS	USER	COMPLETE NAME	N.A.	
SYSTEM PARAMETERS	USER	PASSWORD	N.A.	

APPENDIX 3: DATABASE STRUCTURE

A3.1: Event table（t_events）

When the TDU triggers, the event is sent to the XCF2100E database. To access the Sequence of Events (SOE), the query condition is 'type', the value is '6'. To access a fault event, the query condition is 'type', the value is '5'.

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
Id	ID	Varchar(36)	Yes		No	
time	Time	Varchar(30)				Format： 2012-06-08 12:00:00
type	Type	Varchar(1)			1 2 3 4 5 6	0: System 1: Channel 2: Operation 3: Action 5: Fault Event 6: SOE
deviceId	Device ID	Int		Associated the table of 't_devices'		
Device Type	Device type	Varchar(1)			No	0: XC 1： gps
content	Content	Varchar(255)				

The table of 't_events' is associated to the table of 't_devices'. The 'deviceId' in 't_events' corresponds to 'deviceId' in 't_device'.

A3.2 Fault data table（t_faultDatas）

When the TDU is triggered by a fault, it generates fault data, including: fault time, fault waveform etc. You can extract these data in the following table.

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
Id	ID	Varchar(36)	Yes		No	
faultTime	Fault time	Varchar(20)			No	Format: 2012-06-11 12:00:00
us	Microsecond	int			No	
deviceId	Device ID	int		T_devices		
data	Data	Image			No	
deviation	Fault record deviation	Int				
procTime	Processing time	Varchar(20)				Format: 2012-06-11 12:00:00
lineId	Line ID	Varchar(36)		T_lines		
isfault	Line fault?	Varchar(1)				0: No 1: Yes
validData	Data available?.	Varchar(1)				1: No 2: Available
location	Manually analysis results	double				
reason	Trigger nature	Varchar(1)				1: Fault 2: CB Action 3: Lightning
collectFrequency	Sampling frequency	Varchar(10)				
collectLength	Sampling duration	Varchar(10)				

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
collectRange	Range	Varchar(10)				
remark	Remark	Varchar(255)				
measureType	Measuring type	Int			Yes	0: Current 1: Voltage
timeType	Time type	Varchar(2)				Us/ms
amplitude	Amplitude	Int				A/V
phase	Fault phase	Varchar(5)				A/B/C
breakerdesc	CB description	Varchar(30)				
triggerType	Trigger type	Varchar(0)				0: Line trigger 1: Manual trigger

Amplitude: the unit for current is ampere (A), for voltage is volt (V).

A3.3 Wide area location result table (t_wanmeasure)

The information in the table of 't_faultDatas' is simple fault information. If you want to inquiry more information, you can inquiry in the following table.

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
id	ID	Varchar(36)	Yes			
measureTime	Time	Varchar(20)				2012-11-05 12:00:00
us	Microsecond	int				
startsubstationid	Starting substation(T0)	Varchar(36)		T_substations		
substationA	Head-end substation	Varchar(36)		T_substations		
locationA	Location to head-end substation	Double				
substationB	End substation	Varchar(36)		T_substations	Yes	
locationB	Location to end substation	double			Yes	
faultlineId	Fault line id	Varchar(36)		T_lines	Yes	
details	Detailed information	text			Yes	Location result file with xml format
towerlocation	Tower location	Varchar(36)		t_tower		
faultId1	Fault record 1	Varchar(36)		t_faultdatas		
faultId2	Fault record 2	Varchar(36)		t_faultdatas		
phase	Fault phase	Varchar(5)				A/B/C

The above three tables are associated with the following tables.

A3.4 Device table（t_devices）

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
Id	ID	Varchar(36)	Yes		No	
deviceId	Device ID	int			No	
name	Device name	Varchar(50)			No	
protocoltype	Protocol type	Varchar(2)				0:XC100， 3:XC100E 4:XC100ETEL 5:Trans-DNP, 6:Trans-103
channelNum	Channel number	int				1、2
used	Disable/Enable	Varchar(1)				1: Enable 0: Disable
noResponTime	No response time	Int				
extParam	Extended Parameters	Varchar(100)				
faultNum	Determine number of fault	Int				
deviceType	Device type	Varchar(2)			No	1: XC100E 2:XC100
CollectFrequency	Sampling frequency	Varchar(10)				
CollectLength	Sampling duration	Varchar(10)				

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
substationId	Substation	Varchar(36)		t_substations		
gpsId	GPS ID	Varchar(36)				
measureType	Measuring type	Int			Yes	0: Current 1: Voltage

The 'substationId' in 't_device' corresponds to the 'Id' in 't_substations'.

A3.5 Substation table（t_substations）

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
Id	ID	Varchar(36)	Yes		No	
name	Substn. name	Varchar(30)			No	
voltageLevelId	Voltage level	Varchar(36)		T_voltagelevels	No	
districtId	District	Varchar(36)		t_districts	No	
longitude	Longitude	Varchar(20)			Yes	
latitude	Latitude	Varchar(20)			Yes	

A3.6 Voltage level table（t_ Voltagelevels）

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
Id	ID	Varchar(36)	Yes		No	
name	Volt level name	int			No	

A3.7 District table（t_districts）

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
Id	ID	Varchar(36)	Yes		No	
name	District name	Varchar(50)			No	

A3.8 Line table（t_lines）

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
Id	ID	Varchar(36)	Yes		No	
name	Line name	Varchar(30)			No	
substationAID	Local line end	Varchar(36)		T_substations		
substationBID	Remote line end	Varchar(36)		T_substations		
speed	Velocity	Double				Unit： m/us
length	Line length	Double				Unit： km
voltagelevelId	Voltage level	Varchar(36)		T_voltagelevels		
substationABackup	Back-up for local end	Varchar(36)		T_substations		
substationBBackup	Back-up for remote end	Varchar(36)		T_substations		
monitorA	Local end monitored?	Varchar(1)			No	0: No 1: Yes
monitorB	Remote end monitored?	Varchar(1)			No	0: No 1: Yes
modulus	Sag parameter	Numeric(18,2)			No	Default is1

Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
isUse	Using or not	Varchar(1)			No	0: No 1: Yes
IsTline	T branch Included?	Varchar(1)			No	0: No 1: Yes
hasSection	Sections included?	Varchar(1)				0: No 1: Yes

A3.9 Tower table（t_towers）

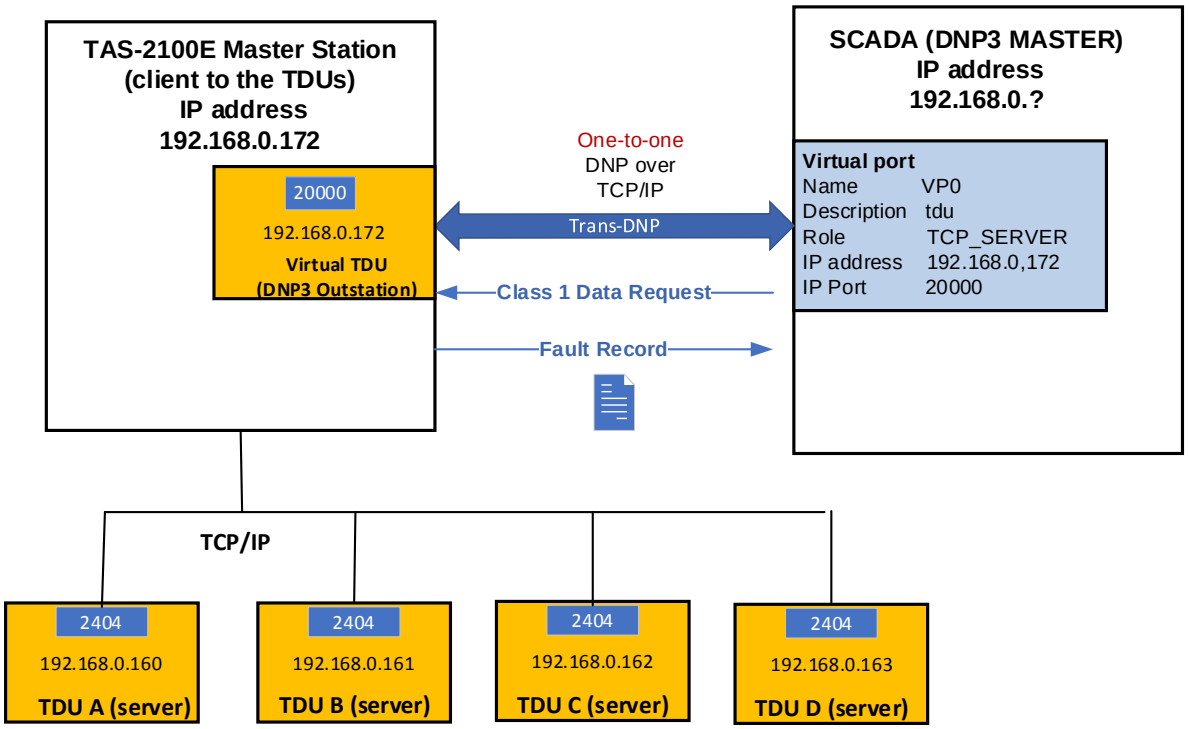
Row	Description	Data type	Primary Key	Foreign key associated table	Empty?	Remark
Id	ID	Varchar(36)	Yes		No	
towerId	Tower ID	Varchar(10)			No	number
name	Tower name	Varchar(50)			No	
towerHigh	Tower height	Double			No	Unit： m
space	Tower span	Double			No	Unit： m
sumSpace	Total span	Double			No	Unit： m
lineId	Line	Varchar(36)		T_lines	No	
towerServiceId	Tower server	Varchar(36)			Yes	
tLineId	T branch ID	Varchar(36)			Yes	
longitude	Longitude	Varchar(20)			Yes	
latitude	Latitude	Varchar(20)			Yes	

APPENDIX 4 DNP3 COMMUNICATIONS TO SCADA

A.4.1 Introduction

The purpose of the Trans-DNP3 communications between the XCF-2100E master station and the Scada is to transmit the travelling wave fault records to the Scada. A virtual TDU is created at the virtual substation under a virtual region. The virtual TDU represents all the TDUs connected to the master station. When a fault occurs and two-ended results have been obtained from the other TDUs, a fault record is created at the virtual TDU, which will then be transmitted to the Scada on request. The communications are represented in the following diagram.

This Feature with the new fault record format is provided in XCF-2100E from V.1.9.6 onwards.



The fault record contains the following information.

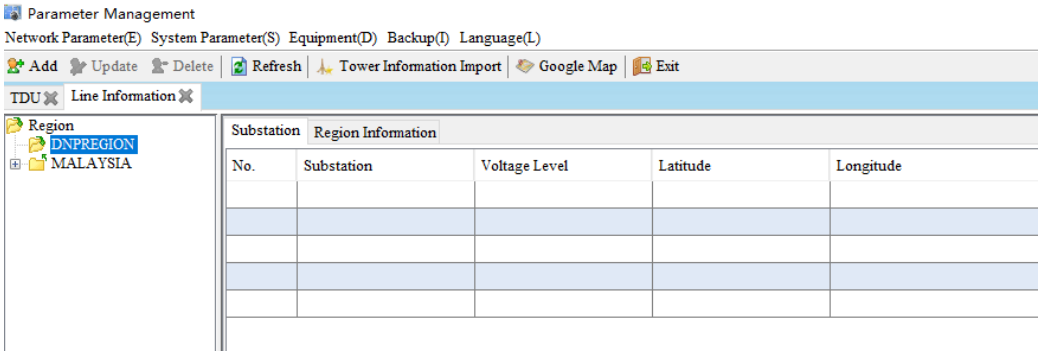
a) Distance to fault from Substation A
b) Distance to fault from Substation B
c) Binary input event with time indicating faulted phase(s)
d) Longitude and latitude of the fault

The fault record information is grouped together as a message to respond to a Class 1 Data Request from Scada. Contents of the fault record are valid DNP3 points. The Scada needs to make a periodic request for Class 1 data to XCF-2100E. If a 2-ended fault record is available for a particular line, the fault record will then be transmitted to Scada.

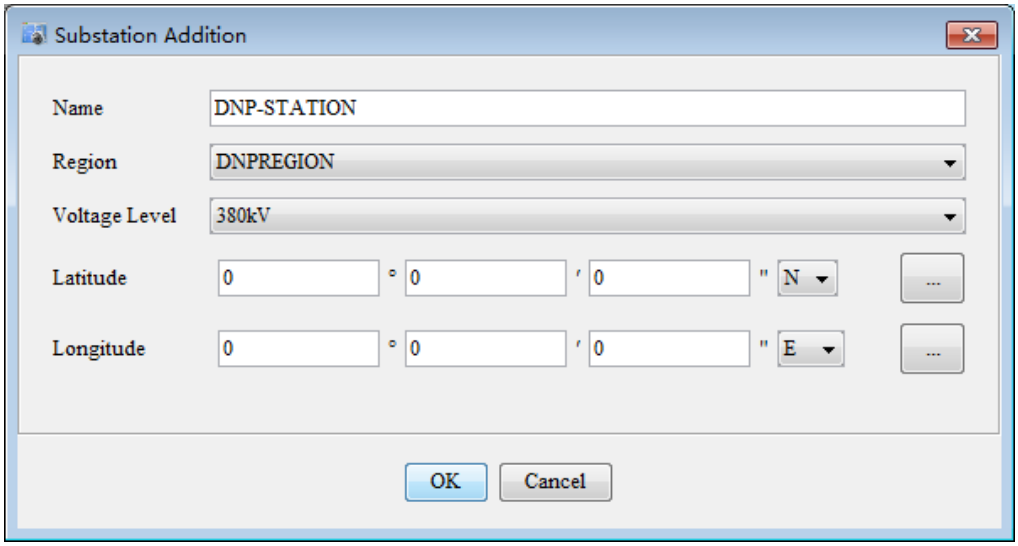
A.4.2 Configuration of XCF-2100E

A Virtual TDU-100E needs to be set up in XCF-2100E at the 'region' of the network under monitoring. The steps are as follows:

a) Open <Parameter Management>, in the <Line Information> page, create a virtual Region. The example below shows a DNPREGION being created.

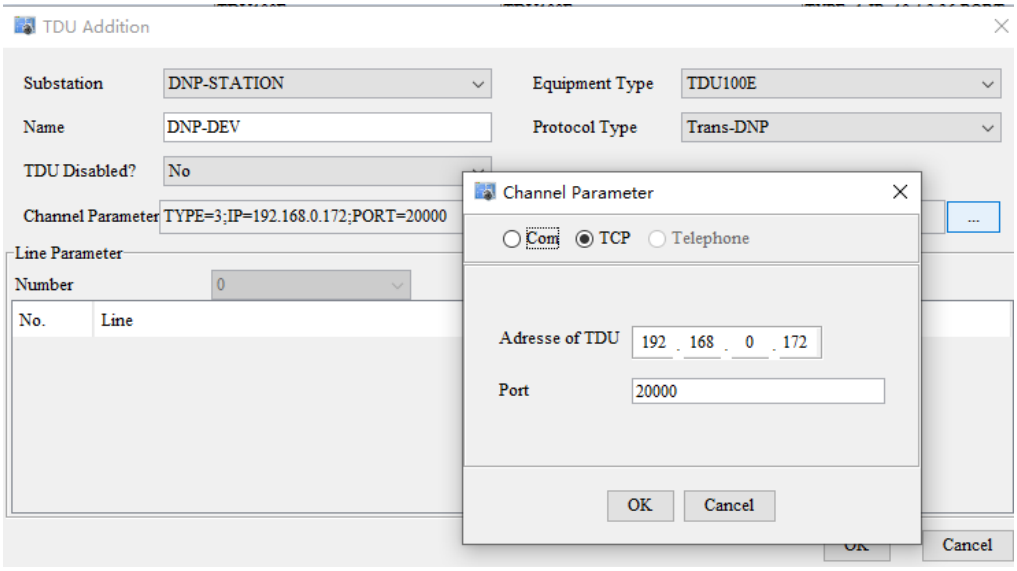


b) Under the Virtual Region, create a Virtual Substation. In this example, a DNP-STATION is created.



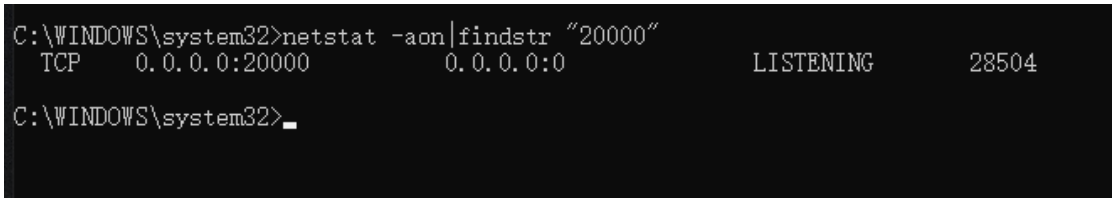
c) You can now create the virtual TDU. Under the <TDU> page, select <ADD> in the menu bar. A pop-up window appears. Select the Virtual Region and the Virtual Substation which you have created, and give the TDU a name (e.g., DNP-DEV).

d) In the <Protocol Type>, select <Trans-DNP>. Open <Channel Parameter>, enter the IP address of the master station running the XCF-2100E, and set the port number to 20000.

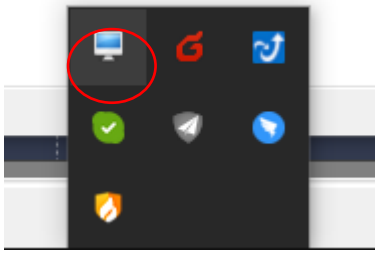


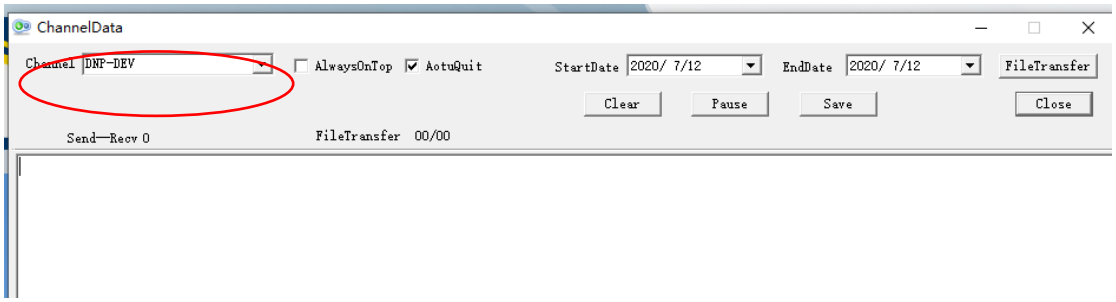
The virtual TDU is now created and the XCF-2100E is now ready for request from the Scada system.

To ensure that the port 20000 is open and is listening to incoming communications traffic, open the Command Line Monitor (CMD) as an administrator, then use the netstat (Network Statistics) command to check.



The incoming traffic can also be monitored by the View Channel facility of XCF-2100E. Right-click a small VDU icon on the right-hand side of the Windows Toolbar to open View Channel, select the virtual TDU <DNP-DEV> to monitor the incoming data traffic.





A.4.3 Commands from Scada system

The DNP3 commands accepted by XCF-2100E from Scada are as follows. The messages shown are typical only.

a) Reset Remote Link

The request from Scada (i.e., the Master) to reset the remote link of the Outstation (i.e., XCF-2100E) is as shown. The response from XCF-2100E is also shown. The green highlighted data are the Start field and the checksums.

```
MASTER:        05 64 05 C0 00 00 00 00 79 3A

OUTSTATION:    05 64 05 00 00 00 00 00 B7 6B
```

b) Request for Class 1 Data (Request for fault record)

Scada needs to make periodic Class 1 Data request to XCF-2100E to obtain the fault location results. The typical request from the Master is as follows, consisting of the data link header block, the transport layer (only 1 byte) and the application data. The green highlighted data are the Start field and checksums.

```
MASTER: 05 64  05 64 0B C4 00 00 00 00 64 47 C2 C3 01 3C 02 06 E9 A3

    | Data link header block        | Transport &Application|
```

The response from XCF-2100E when there is no fault record is as shown.

```
OUTSTATION: 05 64 0A 44 00 00 00 00 F7 93 C2 C3 81 00 00 D1 A4  (No fault record)
```

If there is a fault record, the response is explained in the fault record section later.

c) Results Confirmation

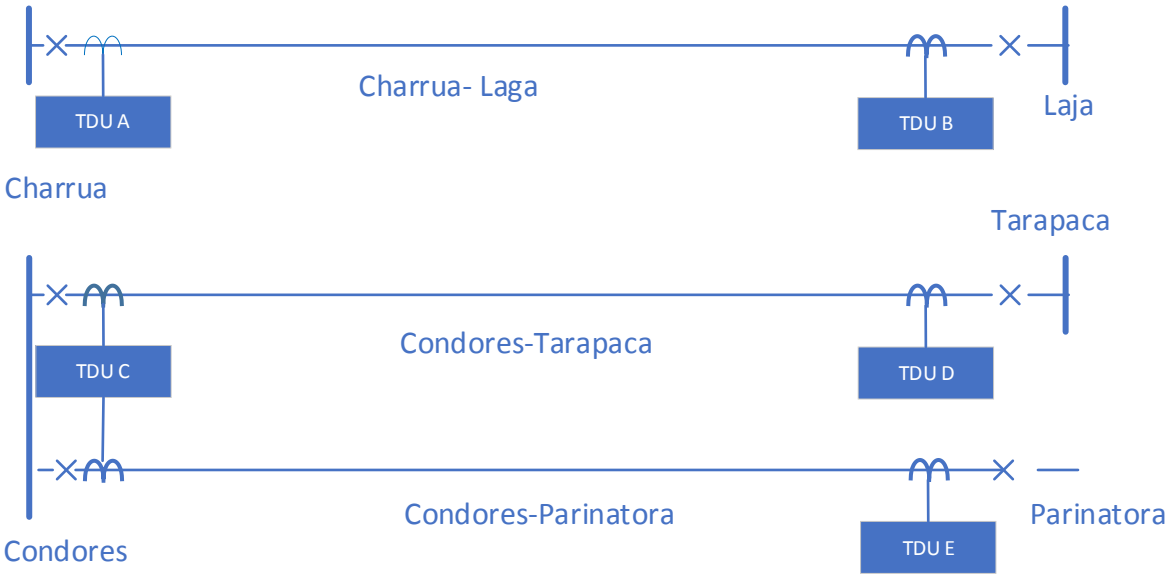
```
MASTER: 05 64 08 D3 00 00 00 00 B4 97 C2 C2 00 A6 BE  (Scada confirms receipt of result)

OUTSTATION: 05 64 05 00 00 00 00 00 B7 6B  (XCF-2100E acknowledges the confirmation)
```

A.4.4 The fault record in DNP3

The format of the fault record uses valid DNP3 points and therefore complies with DNP3 protocol. The format can potentially be expanded in the future to cater for different network configurations and different user requirements.

The fault record reflects the fault based on the following network topology.



The fault record needs to inform the Scada which line is at fault, the fault distances from the substations at two ends and the fault location in terms of longitude and latitude. Indexing is used to indicate which line and which substation the data (e.g., fault distance) belong to.

A.4.5 Fault record format

A fault record containing fault location data is not defined by DNP3. The example below shows a fault record composing of valid DNP3 points, using the above network typology.

- Fault distance, longitude and latitude – DNP3 object 30 variation 5 (32-bit analogue floating point)
- Fault flags (trigger flags) – DNP3 object 2 variation 2 (binary input status with time)

The composition of the fault record is as follows:

Line Name	Data	DNP object	Index
Charrua-Laja (Charrua-Laja)	Distance to fault from substation **Charrua**	30 variation 5 (32 bit analog/float point)	0
	Longitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	1
	Latitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	2
	A phase Trigger	2 variation 2 (Binary input status with time)	0
	B phase Trigger	2 variation 2 (Binary input status with time)	1
	C phase Trigger	2 variation 2 (Binary input status with time)	2
	Distance to fault from substation **Laja**	30 variation 5 (32 bit analog/float point)	3
	Longitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	4
	Latitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	5
Condores-Tarapaca (Condores-Tara)	Distance to fault from substation **Condores**	30 variation 5 (32 bit analog/float point)	6
	Longitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	7
	Latitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	8
	A phase Trigger	2 variation 2 (Binary input status with time)	3
	B phase Trigger	2 variation 2 (Binary input status with time)	4
	C phase Trigger	2 variation 2 (Binary input status with time)	5
	Distance to fault from substation **Tarapaca**	30 variation 5 (32 bit analog/float point)	9
	Longitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	10
	Latitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	11
Condores-Parinacota (Condores-Pari)	Distance to fault from substation **Condores**	30 variation 5 (32 bit analog/float point)	12
	Longitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	13
	Latitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	14
	A phase Trigger	2 variation 2 (Binary input status with time)	6
	B phase Trigger	2 variation 2 (Binary input status with time)	7
	C phase Trigger	2 variation 2 (Binary input status with time)	8
	Distance to fault from substation **Parinacota**	30 variation 5 (32 bit analog/float point)	15
	Longitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	16
	Latitude coordinates of fault point	30 variation 5 (32 bit analog/float point)	17
Device Name	**Data**	**DNP object**	**Index**
TDU-CHA	CHARARUA TDU	1 variation 2 (Binary input with status: 0 - disconnected, 1 - connected	0
TDU-LAJ	LAJA TDU	1 variation 2 (Binary input with status: 0 - disconnected, 1 - connected	1
TDU-CND	CONDORES TDU	1 variation 2 (Binary input with status: 0 - disconnected, 1 - connected	2
TDU-TAR	TARAPACA TDU	1 variation 2 (Binary input with status: 0 - disconnected, 1 - connected	3
TDU-PAR	PARINACOTA TDU	1 variation 2 (Binary input with status: 0 - disconnected, 1 - connected	4

Important Note: *The line name convention of XCF-2100E allows only 16 characters. It is therefore necessary to abbreviate the line names as can be seen in the brackets in column 1 (Line name). The line names and the substation names set up during XCF-2100E configuration need to be consistent with the names in the DNP3 configuration file <dnp3conf.json>, so that the correct data can be put into the fault record.*

A.4.6 Configuration of the fault record for different network topology

The configuration of the fault record is done in the <dnp3conf.json> configuration file. 'LineMap' data structure is constructed based on the three lines provided by Chile. New lines can be added by created a new block of settings with the same data structure consisting of 'lineName', 'stationA', 'stationB' etc. A new network topology can also be created as on the same data structure.

```
'lineMap':
	[
		{
			'lineName':'Charrua-Laja',
			'stationA':'Charrua',
			'stationB':'Laja',
			'DistanceA_addr':0,
			'GPSLongitude1_addr':1,
			'GPSLatitude1_addr':2,
			'Adata_addr':0,
			'Bdata_addr':1,
			'Cdata_addr':2,
			'DistanceB_addr':3,
			'GPSLongitude2_addr':4,
			'GPSLatitude2_addr':5
		},
		{
			'lineName':'Condores-Tara',
			'stationA':'Condores',
			'stationB':'Tarapaca',
			'DistanceA_addr':6,
			'GPSLongitude1_addr':7,
			'GPSLatitude1_addr':8,
			'Adata_addr':3,
			'Bdata_addr':4,
			'Cdata_addr':5,
			'DistanceB_addr':9,
			'GPSLongitude2_addr':10,
			'GPSLatitude2_addr':11
		},
		{
			'lineName':'Condores-Pari',
			'stationA':'Condores',
			'stationB':'Parinacota',
			'DistanceA_addr':12,
			'GPSLongitude1_addr':13,
			'GPSLatitude1_addr':14,
			'Adata_addr':6,
			'Bdata_addr':7,
			'Cdata_addr':8,
			'DistanceB_addr':15,
			'GPSLongitude2_addr':16,
			'GPSLatitude2_addr':17
		}
	]
}
```