T-907 Power Cable Fault Locator

User Manual

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This product complies with the design requirements for environmental protection and personal safety.

This product is a professional instrument specially designed for power cable faults. Please do not use it for any other purpose. The company assumes no responsibility or loss if it is used for other purposes.

The safety regulations in this user manual should be strictly adhered to.

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Data version	Revision date	Revision reason	Person
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Foreword

Thank you for purchasing the T-907 Power Cable Fault Locator (hereinafter referred to as T-907)

The T-907 is a high-performance portable fault locator for low, medium and high-voltage power cables. It can be applied for the pre-location of all kinds of faults, including open circuit, short circuit, low resistance, high-resistance and flashovers. It can be operated as a basic time domain reflectometer (TDR) or using the Arc reflection/Secondary/Multiple Impulse Method (SIM/MIM), Impulse flashover or Decay Method.

T-907 is a complementary product to Kehui’s High Voltage Surge Generators, Cable Fault Pinpointing Devices and Cable Fault Test Van and can also be used with appropriate equipment from other companies.

Kehui constantly improves its products, and the individual instruments provided may differ from the instructions in this manual without prior notice. We are always at your service if you have any queries or should you require further information.

Table of Contents

1. Safety Instructions

Safety Note: This user manual is the basic commissioning and on-site operation guide for the T-907 Cable Fault locator. All operators of the T-907 should read the contents of this manual in advance. The manufacturer of this product is not responsible for any loss caused by the operator's failure to comply with the operating procedures of this manual or for violation of the safe working practices 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 serious or fatal 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 may result in the test not functioning properly.
	Indicates that this is a useful guideline based on field practice.

Use of accessories: Please be sure to use Kehui’s spare parts to ensure the safe and reliable use of this instrument. Using accessories made by other companies will make any warranty null and void.

Repair and maintenance: This instrument must be repaired and maintained by Kehui or an agent authorised by Kehui. If you have any questions concerning maintenance, cable fault detection, on-site test consultation, etc., please contact the company at info@kehui.com.

2. Product overview

With the widespread use of power cables in power utilities, cable failures have correspondingly increased. A faulty cable causes interruption of supply to the consumers and increases “customer minutes lost”. It is important for the faults to be located quickly, accurately and safely, to shorten the repair time of faults. T-907 power cable fault locator, together with Kehui's high-voltage signal generators, provide sophisticated techniques for cable testing and fault location.

2.1 Description

The T-907 Power Cable Fault Locator uses modern microelectronics to produce a highly intelligent power cable fault location instrument. It has the advantages of simple and fast operation, high precision and strong noise immunity. It is a powerful tool for reducing labour and improving the efficiency of the maintenance crew in the electric power supply industry.

T-907 supports a number of working methods, including the time domain reflectometry (TDR) method, the secondary/multiple impulse method (SIM, MIM), an advanced impulse current method (ICM) and the decay method. The TDR injects a low voltage signal into the faulty cable and measures the pulse reflection from the fault. It is used to locate low resistance, short circuit and open circuit faults. The secondary/multiple impulse methods, using a HV generator and a signal coupler, are used to locate high impedance and flashover faults. The location is achieved by comparing two pulsed reflection waveforms, one during the fault ignition arc and the other during the arc extinguished state. The impulse current method, again in conjunction with a high voltage signal generator, provides more efficient fault break-down and fault location. An artificial intelligence technique is used to automatically measure the fault distance, without the operator having to manually interpret the waveforms. The decay method is used to locate flashover faults requiring high breakdown voltage, using either a VLF (very Low frequency) or a DC high voltage generator.

2.2 Product characteristics

- TDR, SIM/MIM, ICM, ICM-Decay and Decay test modes to cater for all types of power cable faults.
- Automatic TDR method is complemented with an intuitive and user-friendly design.
- SIM/MIM testing provides easily recognisable waveforms, using a waveform comparison feature for high precision fault location.
- ICM is automated by an artificial intelligence waveform recognition technique.
- The T-907 is controlled by an APP which can be run on a tablet PC connected to the device through wireless communication.

2.3 Technical Specifications

Technical Parameters	**Parameter Value**
Fault Location Methods	TDR, SIM/MIM, ICM, DC Flashover, Impulse flashover and Decay
Resolution	0.4m
Sampling Rate	400MHz
Cable length	250m to 64km
Blind spot	4m
Pulse width	40ns - 7µs
Pulse amplitude	30V
Velocity	90 - 300 m/µs
Output impedance	Adjustable from 5 - 87Ω
Power source	Polymer lithium-ion battery pack, 7.4V nominal
Input voltage	Maximum 60V
Battery Duration	Up to 8 hours
Battery Charger	AC 100-240V at 50/60Hz, output 8.4V, 3A DC (Main hardware only) 4 hours charging time
Display	Tablet PC
Size	330mm x 305mm x 152mm
Weight	2.8kg (Main hardware only)
Working temperature	-20^{o} to $+50^{o}$C
Storage temperature	-25^{o} to $+70^{o}$C
Relative humidity	20 to 90% at 50^{o}C
Atmospheric pressure	86 to 106kPa
Ingress protection	IP54 (lid closed)

3. Working Principles

The fault location methods of power cable can be broadly divided into four categories, based on the type of signal applied and the method of waveform acquisition. They are the TDR, arc reflection (also known as secondary/multiple impulse) method, impulse current method, and the decay method. The purpose and the working principles of these methods are explained below.

3.1 Time Domain Reflectometer (TDR) method

The time domain reflectometer method (also known as the low voltage impulse method) is used to locate low impedance, short-circuit or open circuit faults on the power cable. It can also be used to calibrate the cable length and to identify cable joints, T-joints and the end of the cable.

A schematic of the TDR method is shown in Figure 3.1.

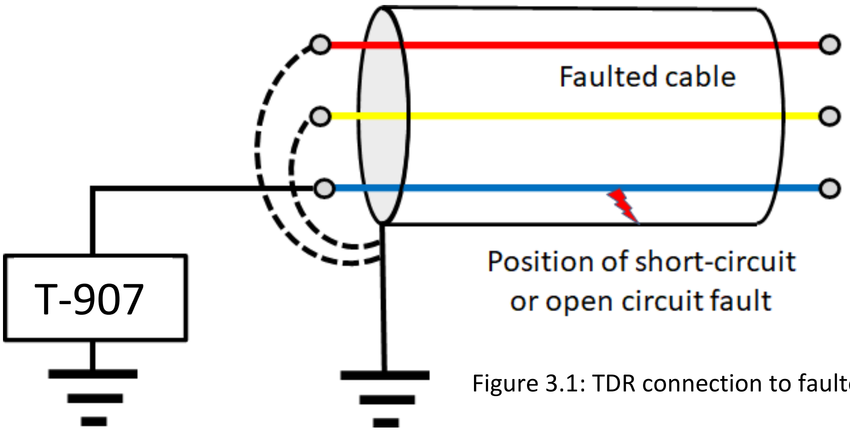


Figure 3.1: TDR connection to faulted cable

If a low voltage impulse is injected into one end of a cable of uniform impedance, it will travel to the far-end of the cable from where all, or part, of the signal will be reflected back to the source. However, if the impedance is not consistent due to a joint or a fault, then this will also result in a reflection, with a magnitude dependant on the impedance of the fault or discontinuity. For an open circuit fault, the reflected wave will have a negative polarity and for short circuit and low impedance faults, the reflected wave will have the same polarity. A comparison of these scenarios is shown in Figure 3.2.

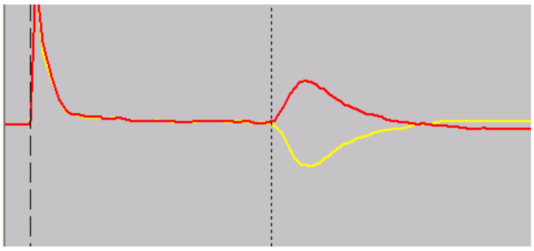


Figure 3.2: Comparison of TDR signals reflected from the far end of a healthy cable. The reflection from an open end is shown in red and from a short-circuited end is shown in yellow

In Figure 3.2 the dashed line on the left represents the start of the cable where the TDR instrument is connected and the dotted line (moveable cursor) represents the time it takes for the pulse to reach the far end of the cable. As the propagation velocity of the pulse in the cable is known, the cable length can be calculated. It should be noted that the measured time is for the pulse to reach the end of the cable and return to the instrument, therefore the distance measurement must be divided by 2.

Hence if L_x is the length of the cable, v is the propagation velocity of the pulse and Δt is the time measured by the cursor, the line length can be expressed as:

$$L_x = \frac{v\Delta t}{2}$$

The reflection from a fault will occur in a similar way, with the magnitude and polarity of the reflection depending on the impedance of the fault. Comparing the reflection from a faulted core with either a previously measured trace from the core before the fault, or with a healthy core in the same cable, will produce traces like those shown in Figures 3.3 and 3.4.

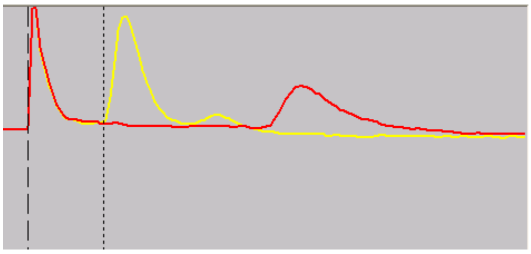


Figure 3.3: Comparison of TDR signals reflected from a faulted core with an open-circuit (yellow) and a healthy core of the same cable (red)

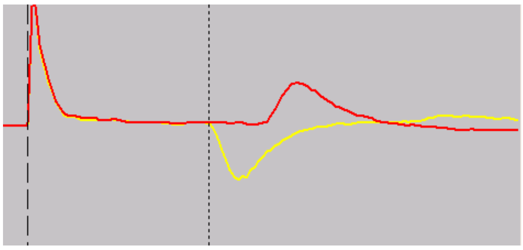


Figure 3.4: Comparison of TDR signals reflected from a faulted core with a short-circuit (yellow) and a healthy core of the same cable (red)

In Figures 3.3 and 3.4 the cursor can be moved to the point where the two traces deviate, which represents the position of the fault. The distance to the fault can be calculated using the same equation as before.

TDR is suitable for the pre-location of open and short circuits on the cable. However, for resistive or flashing faults, the TDR method is not applicable because the fault impedance is comparable to the insulation impedance of the cable, resulting in little or no reflection.

3.2 Arc reflection or Secondary/Multiple Impulse Method (SIM/MIM)

This method requires a high voltage surge generator, such as the Kehui T-305E. The surge generator injects a high voltage, high energy pulse in to the cable to break down the fault, such that it becomes a temporary short circuit. The system is represented, in simplified form, in Figure 3.5 as a storage capacitor which discharges through a contactor. A filter is required with this method, which consists of a coupling capacitor, which protects the TDR unit from the high voltage surge, and an inductor which blocks the TDR pulse from travelling in to the surge generator, such that it is directed in to the cable. Most surge generators include this filter as an integral feature, although it can also be a separate discrete device.

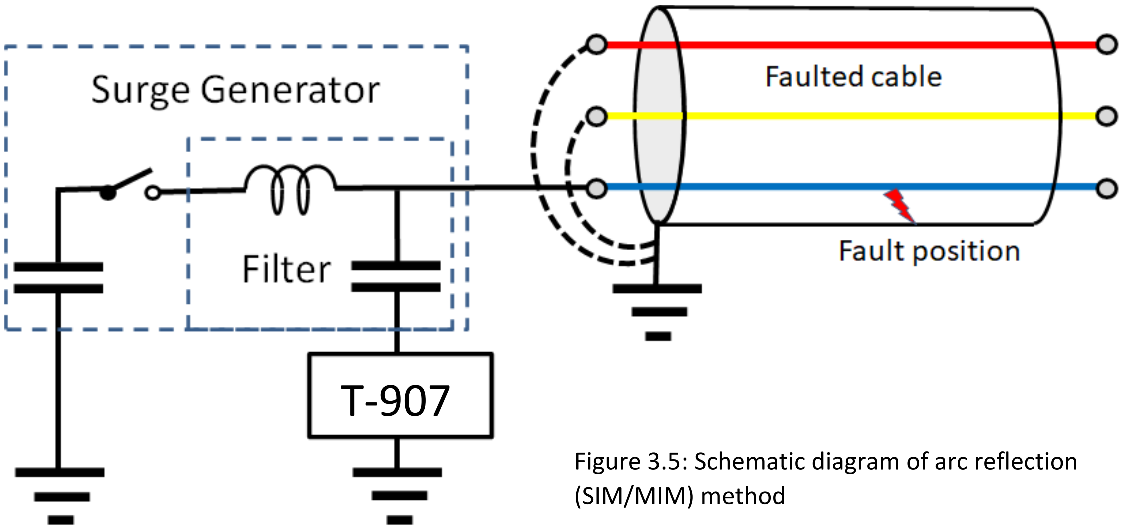


Figure 3.5: Schematic diagram of arc reflection (SIM/MIM) method

A TDR trace taken before or after, the surge is applied provides a reference signal (Figure 3.6). When the surge is applied and the fault is active, the TDR pulse is injected and its reflected impulse will have an opposite polarity to the reference. Comparing the two traces (Figure 3.6) allows the propagation time to the fault to be measured, allowing the distance to the fault to be determined.

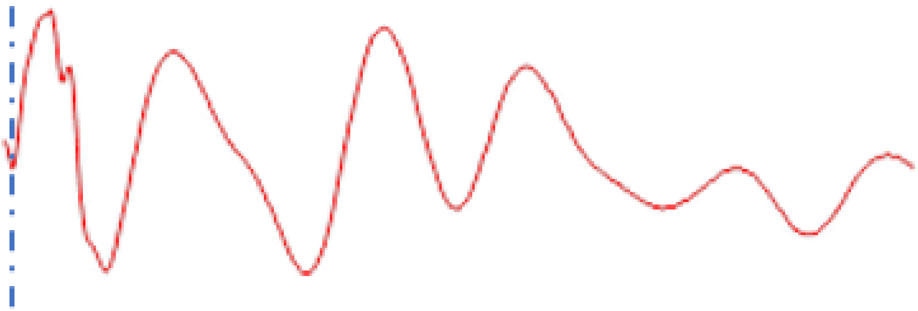


Figure 3.6 Arc reflection (SIM/MIM) trace on core prior to fault activation

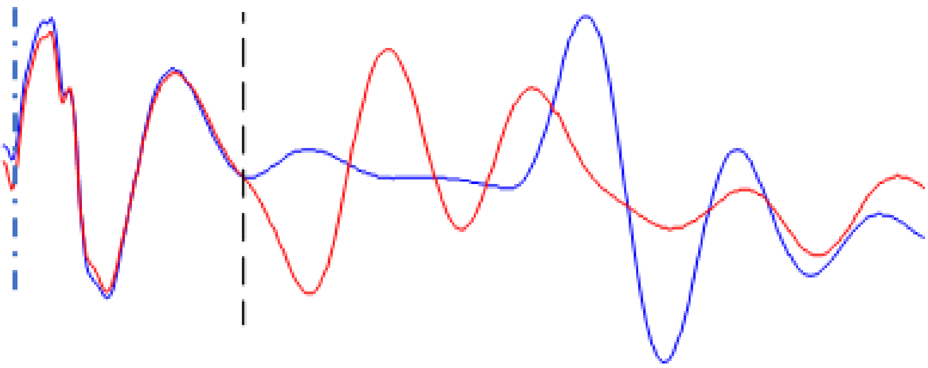


Figure 3.7 Comparison of traces, pre-fault and during fault activation

In Figure 3.6 the cursor has been moved to the point at which the traces diverge, this represents the fault position. The time represented by the cursor position is used to calculate the distance to the fault in the same way as with TDR.

The inclusion of the filter puts an inductive wave trap in series with the surge generator which may reduce its effectiveness in breaking down the fault.

3.3 Impulse Current Method (ICM) - Surge

ICM also requires the use of a surge generator, but the filter is not needed and will be switched out when this method is selected. A schematic diagram of the method can be seen in Figure 3.8, which shows that the full energy surge is injected in to the cable with no attenuation from the filter. This makes it more effective than the arc reflection method in breaking down the fault and, in most cases, eliminates any reason to use a fault burner to condition the fault.

The Impulse current equipment (ICE) functionality is usually incorporated in to the same device as the TDR used in Sections 3.1 and 3.2 (e.g., the Kehui T-907). The linear current coupler required to capture the signal from the fault, is often incorporated in to the surge generator (e.g., the Kehui T-305E). If this is not the case or the ICE does not have a compatible connection to the surge generator, an external current coupler can be used.

The linear current coupler is placed around the ground lead between the energy storage capacitor and the metallic shield of the cable. It picks up the magnetic field generated by the current in the earth lead to reproduce the current waveform.

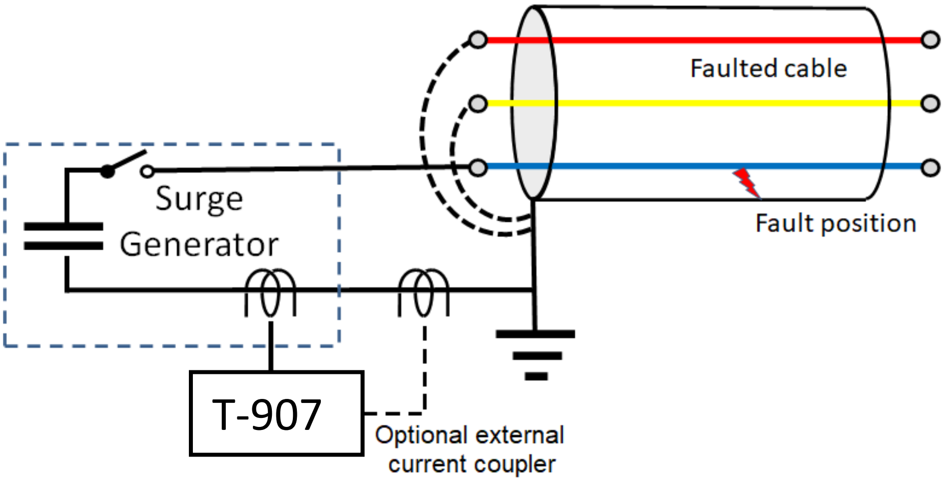


Figure 3.8 Set-up for Impulse Current Method

The fault in the cable is broken down by the high voltage, generating a current impulse which reflects multiple times between the Surge generator and the fault point. The waveform is captured at the current coupler and is analysed so the fault distance can be calculated.

The format of the waveforms detected by the impulse current method is illustrated in the following diagrams. The surge generator is represented in the top left and the cable runs from end A to end B with length L_{AB} ⊖ and ⊕ refer to the pulse polarity.

Figure 3.9 shows a healthy cable to which is applied a positive surge, which can be seen at T1A. It is reflected off the far end of the cable with the opposite polarity. This results in the current wave being cancelled out at T1B, it then returns to end A at time T2A. Although the current is cancelled at end B, the voltage is doubled increasing the probability of the fault breaking down, this being a major benefit of the ICM method, reducing the need for fault burning. The line length can be calculated from the time difference between T1A and T2A using the velocity of propagation divided by 2, as the time covers the propagation of the surge from one end of the line to the other and back again.

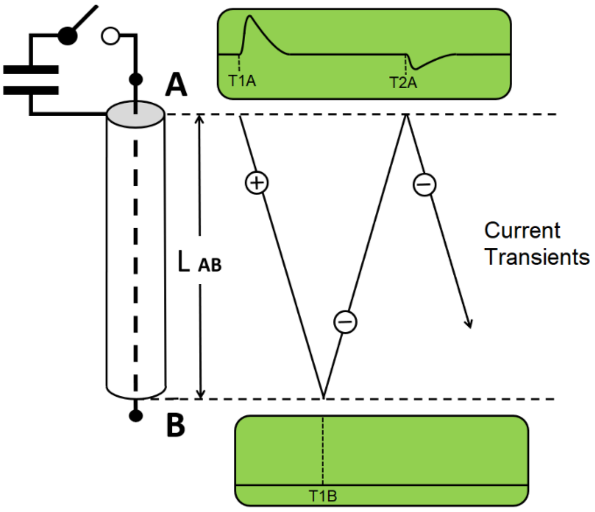


Figure 3.9: Impulse current method on a healthy cable

Figure 3.10 shows an open circuit fault. The surge no longer reaches the far end of the cable, but is reflected off the fault position with a negative orientation. The surge continues to reflect between the near end and the fault, changing its polarity each time it reaches the open circuit at the far end. The distance to the fault can again, be calculated from the time difference between T1A and T2A using the velocity of propagation divided by 2

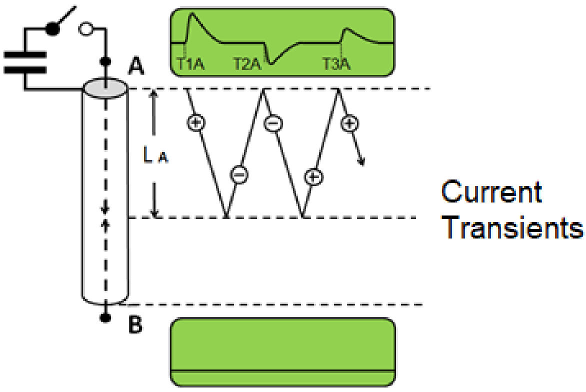


Figure 3.10: Impulse current method on an open circuit fault

Figure 3.11 shows a short circuit fault. In this case there is no change of polarity when the surge is reflected off the fault position

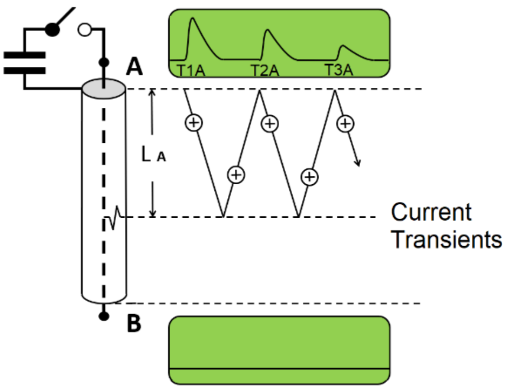


Figure 3.11: Impulse current method on a short circuit fault

Figure 3.12 shows a flashing fault. In this case the contactor of the surge generator is permanently closed and the surges originate at the fault point and travel in both directions. At the remote end they change polarity as they are reflected and are cancelled out. At the measured end, they will be seen as a succession of pulses with positive polarity.

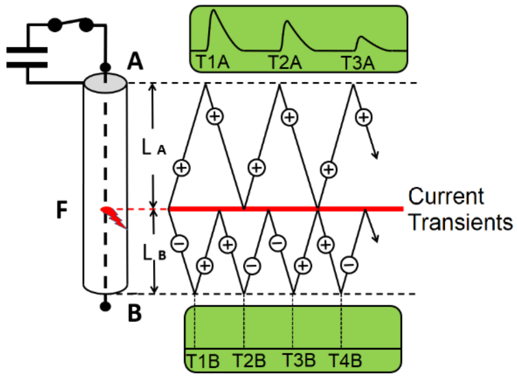


Figure 3.12: Impulse current method on a flashing fault

When the surge generator operates, it is normal for there to be a delay before the fault breaks down. During this period the surge will travel past the fault point to the far end of the line. When the fault breaks down, the resulting transients will behave in the same way as for the flashing fault in Figure 3.12. In this case the first pulse (T0A) should be discounted and the distance to fault calculated from the subsequent pulses (i.e., the time difference between T1A and T2A in Figure 3.13). T0A will initially reflect off the far end of the line and then off the other side of the fault, but the change in its polarity will cancel it out.

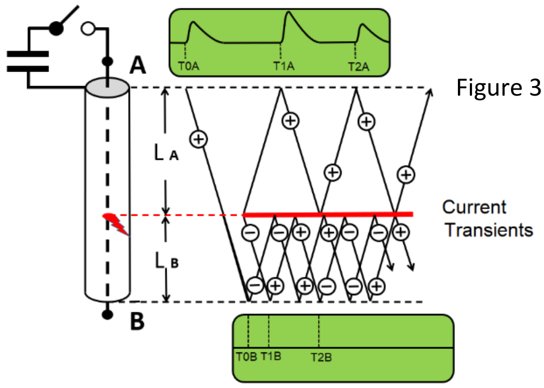


Figure 3.13: Impulse current method with a fault breakdown after a short ionisation time

If the ionisation time of the fault breakdown is longer, there may be sufficient time for the surge to reflect off the far end of the cable and return to the source before breakdown occurs. In this case the first two pulses should be discounted. As the pulse changes polarity at the far end, it is recorded as negative at the source and so can be readily identified (Figure 3.14). The initial surge will continue to reflect but all of the resulting pulses will be of negative polarity and can be ignored. The distance to the fault can be calculated from the time T1A to T2A.

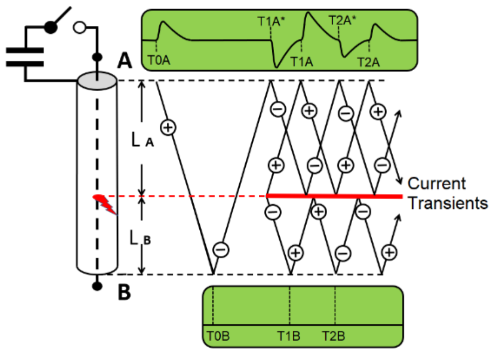


Figure 3.14: Impulse current method with a fault breakdown after a longer ionisation time

T-907 has an artificial intelligence technique which can usually interpret the waveforms to provide the fault location results automatically, but if it is unable to do this, manual measurement can be made from the time between the appropriate pulses. This is normally measured by moving the cursors on the instrument.

3.4 ICM – Decay (Also known as ICM – DC)

The ICM Decay method uses the variable DC output of the surge generator (which is its normal output but with the operating switch permanently closed), such that the output is increased until the fault on the cable breaks down. The resulting current waveform is then detected by a current coupler. The coupler may be internal to the voltage source (e.g. on the Kehui T-305E) or it can be a simple external device connected directly to the impulse current equipment (ICE), which in this case is the T-907 (see figure 3.15).

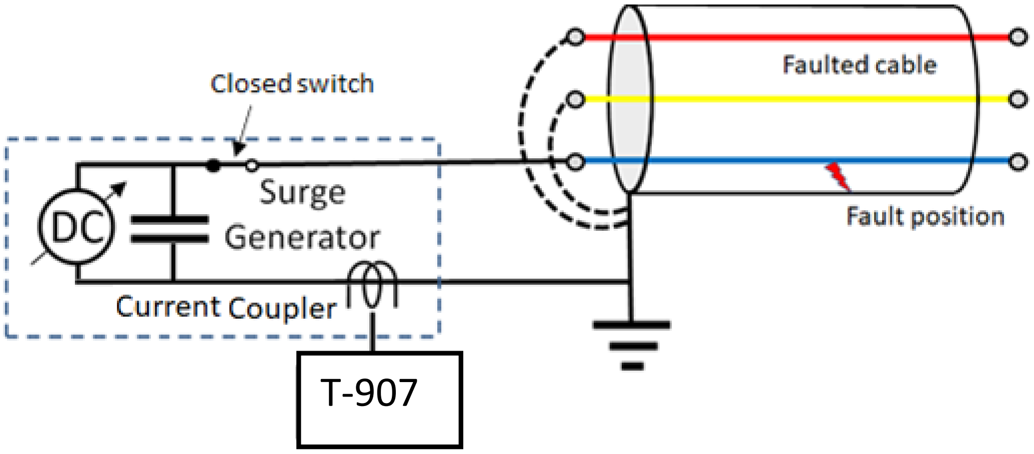


Figure 3.15 Set-up for Impulse Current Method

Initially, the DC signal is applied at a low level, below the breakdown value of the fault, and then gradually increased until the fault flashes over. This breakdown will produce a current travelling wave, detected by the current coupler in the earth loop, which reflects back and forth between the fault point and the HV source.

The distance to the fault can be calculated as before, using the time between two corresponding parts of subsequent peaks of the decaying waveform selected by the cursors on the instrument.

Figure 3.16 ICM Decay method waveform

3.5 Decay Method

The decay method uses either a DC or very low frequency (VLF) generator as the high voltage source. It needs to be used in conjunction with a capacitive voltage divider to supply the fault locator. It can be used as an alternative where the rating of the cable is too high to use a surge generator and a pressure test set has sufficient voltage to break down the fault.

The decay method's connection diagram is as shown in Figure 3.17. Its functionality may be incorporated into the same fault locator device as the TDR used in Sections 3.1 and 3.2 (e.g., the Kehui T-907).

If the available voltage is sufficient to break down the fault without using the surge facility, the DC supply can often be obtained from a surge generator with its contactor closed, the capacitor in the generator can be used as the capacitor divider (e.g., the Kehui T-305E).

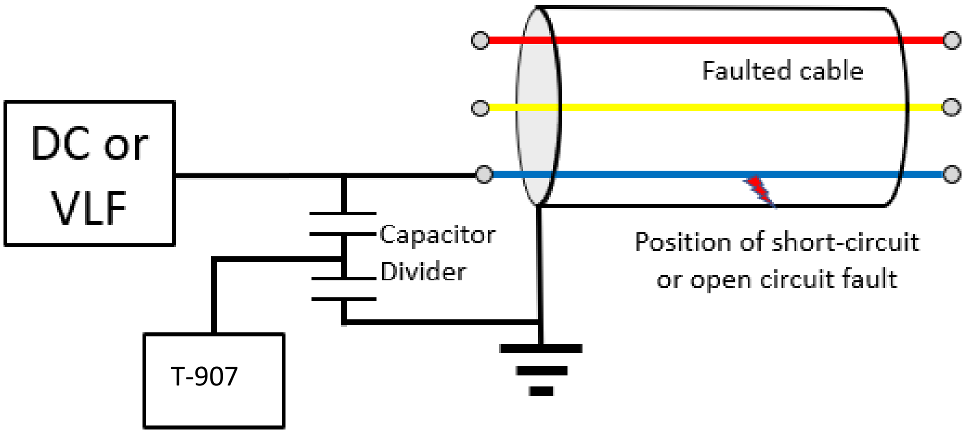


Figure 3.17 Set-up for the decay method

Initially, the DC or VLF signal is applied at a low level, below the breakdown value of the fault, and then gradually increased until the fault flashes over. This breakdown will produce a voltage travelling wave, which reflects back and forth between the fault point and the HV source.

The distance to the fault can be calculated as before, using the time between two corresponding parts of subsequent peaks of the decaying waveform selected by the cursors on the instrument.

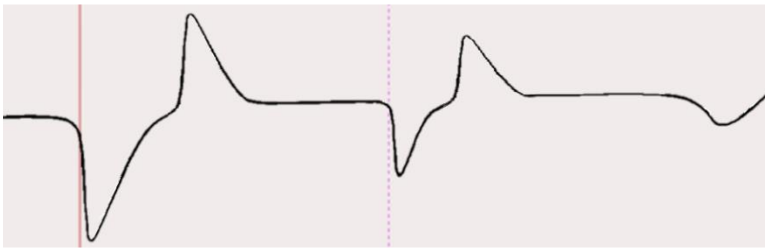


Figure 3.16 Decay method waveform

4. Using the fault locator T-907

4.1 Device layout

4.1.1 Accessories

The T-907 has a number of accessories, detailed in the Packing list featured in Section 12

4.1.2 Front panel composition

Figure 4.1 T-907 Front Panel

① <On/OFF> key: Switch instrument's power supply.

② <Power> indicator Shows whether the instrument is turned on. When the power light turns from green to red, it means that the battery is low.

③ <Trig> indicator: After triggering, the light will be on. Pressing the test button once turns it off.

④ <Run> indicator: This light comes on when the unit is powered on and then starts to flash when the T-907 is initialised and operational. It continues to flash indicating the device is working correctly.

⑤ Battery box

⑥ Charging port: For charging the instrument, using the charger supplied.

⑦ <GND>: For connecting the ground/earth wire during testing

⑧ <TRIG> (BNC socket): For connecting the appropriate trigger lead for the test mode used

⑨ <SIGNAL> (BNC socket): For connecting the appropriate signal lead for the test mode used

4.1.3 Charging the system

Initially the unit has to be charged using the battery charger supplied; plug the charger into a suitable power outlet and insert its plug in to the socket on the T-907 marked “charger” Figure 4.1.

If the device does not charge, when it is first used, it is likely that the batteries are not connected. Disconnecting the batteries is sometimes required as a condition of transit. If this is the case, follow the reconnection instructions in Appendix 1

[**Warning**] The batteries must be charged using the dedicated chargers provided. Using other chargers that do not meet the exact parameters, may cause damage to the instrument and the tablet.

4.1.4 Turning on the T-907

The detector power can be turned on or off by pressing the appropriate power on or off button on the front panel (② Figure 4.1). The detector power and run indicators light up when the detector is turned on, after a few moments the run indicator will start to flash.

If the unit does not turn on the first time it is used and it an attempt has been made to charge it, it is possible that the battery has been disconnected (see Appendix 1).

4.2 Using the tablet PC

The tablet PC is the controller for the T-907. It is connected to the main device through WiFi and controls it using a dedicated App pre-loaded in the factory and also available on the Kehui website.

4.2.1 Installing the APP

The APP can be downloaded from the Kehui website. Typical installation instructions are shown in appendix 2.

4.2.2 Connecting the tablet

With the tablet turned on, tap on the settings icon

Go to “Wireless and Networks” and select WiFi, ensure that it is turned on. If the T-907 is switched on, it will appear in the list of available networks. Note that it will correctly state that there is no internet access detected. Tapping on the name will connect the unit,

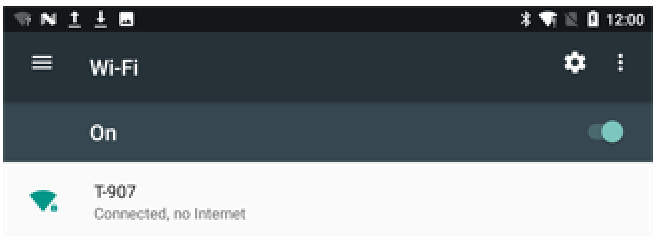


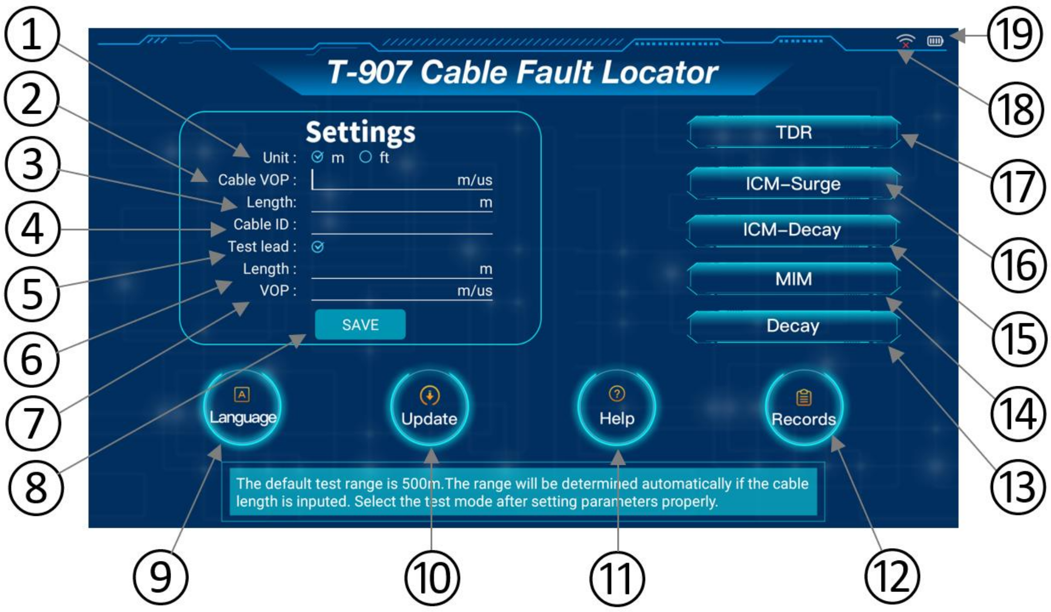
Figure 4.2 Typical Tablet WiFi setting page

Returning to the home page the T-907 APP symbol should be tapped.

This will bring up the APP home page as seen in figure 4.3.

4.2.2 T-907 Home display

The T-907 is controlled from an APP run on a tablet PC. The main interface is shown below:



① Unit: Choose the unit of measurement between metres and feet

② Velocity of propagation (VOP): Set the VOP for the cable under test

③ Cable length: Sets the length of the cable under test (default 500m)

④ Cable ID: A keypad will allow a suitable cable identification to be entered

⑤ Test lead: The test lead connects the device and the cable under test This setting gives the user the option of whether to take this in to account in the measurement

⑥ Lead length: Sets the length of the test lead, if “Test lead” is selected

⑦ VOP: Sets the VOP of the test lead, if “Test lead” is selected

⑧ SAVE: Saves the settings for the test

⑨ Language: Allows available languages to be selected

⑩ Update: Checks for and downloads updates to the APP, when connected to the internet

⑪ Help: Provides an overview of the available settings

⑫ Records: Access the saved records

⑬ Decay: Select the Decay mode

⑭ MIM: Select the Multiple Impulse Method

⑮ ICM Decay: Select the ICM Decay Method

⑯ ICM Surge: Select the Multiple Impulse Method

⑰ TDR: Select the TDR Method

⑱ WiFi indicator: Shows if the table WiFi is connected

⑲ Battery Indicator: Shows charge level on the tablet battery

Figure 4.3 T-907 tablet home display

4.3 General settings

4.3.1 Settings

In order to obtain an accurate fault location measurement, the range should be set to apply suitable scaling to the x axis of the trace. This is set with a button on the left side of each of the APP screens relating to the mode of operation to be used. These produce the sub-menu shown in figure 4.4 on which the range should be set twice the length of the cable under test.

Figure 4.4 Range selection

If required, waveforms can be enhanced by adjusting the gain using the Gain+ and Gain- buttons on the right-hand side of the test mode APP. For ranges greater than 1km, the zoom feature can also be used by pressing the Zoom+ and Zoom- buttons at the bottom of the display.

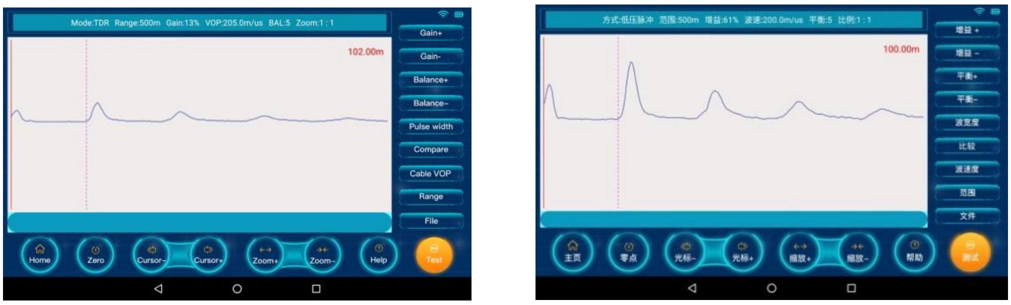


Figure 4.5 Gain adjustment in the TDR mode

4.3.2 VOP velocity of propagation

The VOP is the velocity of propagation of waves in the cable. The default value is 195m/µS but if the actual value is known, this can be adjusted using the Cable VOP button on the right of the screen, which brings up the sub-menu in figure 4.6 allowing the VOP figure to be adjusted in steps of 1m/µs (default 195m/µs).

Typical values for VOP are as follows:

Cable Insulation Dielectric	VOP (m/µs)
Oil paper	160
XLPE	170
PE	201

Figure 4.6 VOP adjustment

4.3.3 Storing results

Once the waveform is created, it can be stored by pressing the File button on the mode display in use. This brings up the menu in figure 4.7. Pressing Save will bring up the screen in figure 4.8. which allows the user to label the trace for future use. A keyboard appears, which allows the description to be entered and pressing SAVE will then store the file.

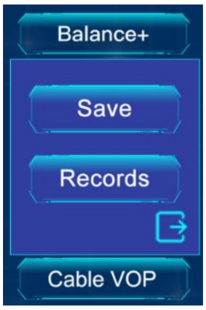


Figure 4.7 File menu

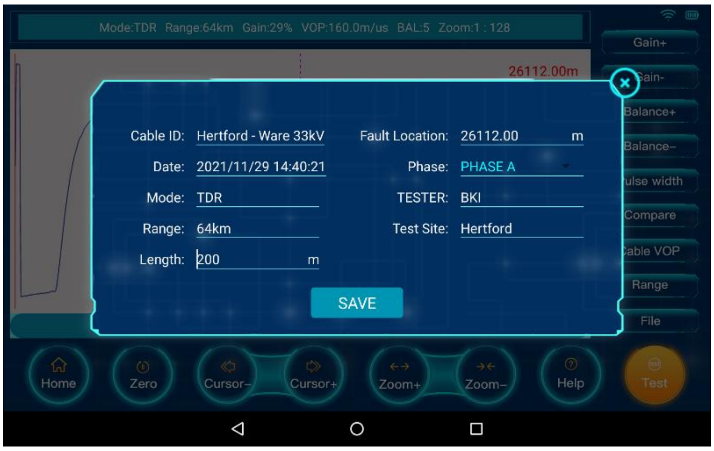


Figure 4.8 File saving data

4.3.4 Comparing results

Effective use of the TDR mode is often based upon comparing records of the faulty line with healthy traces from before the fault occurred or from similar lines such as the other phases of the cable.

To compare two traces, one of them should be displayed and Compare is pressed. This gives two options as shown in figure 4.9

Pressing Memory saves the current trace. A new trace can then be made or an existing one extracted from the memory by pressing File and selecting Records from figure 4.7. The resulting screen is shown in figure 4.10

Figure 4.9
Comparison menu

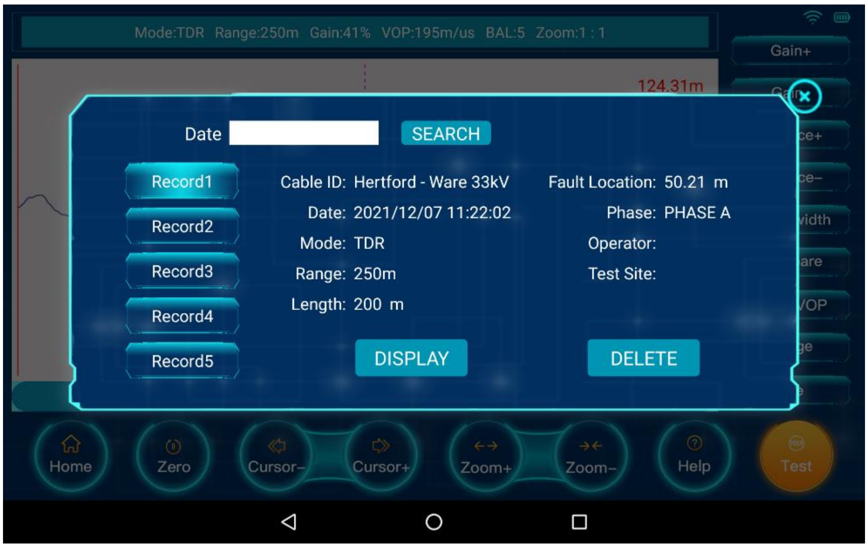


Figure 4.10 File structure

Selecting the record provides the trace data in the main screen, which can then be displayed or deleted or another record selected.

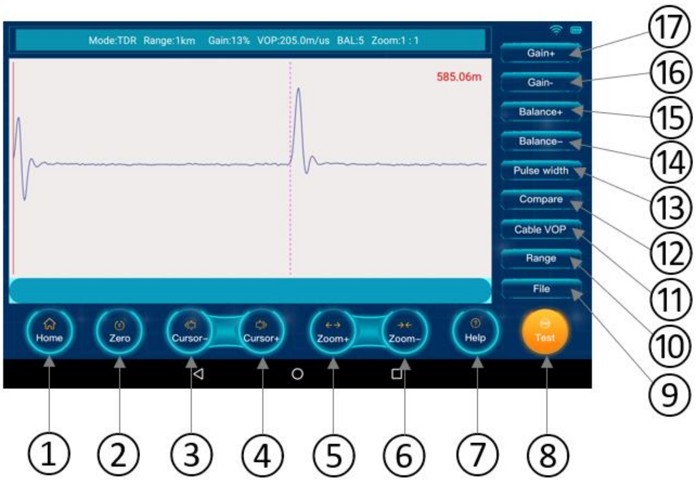
Access to later records is achieved by scrolling the list. Records taken on other dates can be accessed by pressing on the date field and selecting the required date from the resulting menu.

Once the required trace has been displayed, pressing on Both (figure 4.9) will display both it and the trace stored in the temporary memory as shown in figure 4.11.

Figure 4.11 Comparison of traces

4.4 TDR Mode

Pressing TDR (Figure 4.3 ⑰) brings up the TDR mode display.



① Home: Returns the user to the main interface figure 4.2

② Zero: Sets the base cursor at the present position of the moveable, dotted cursor

③ Cursor-: Moves the dotted cursor to the left

④ Cursor+: Moves the dotted cursor to the right

⑤ Zoom+: Zooms in to the waveform (only operates at Range > 1km)

⑥ Zoom-: Zooms out from the waveform (only operates at Range > 1km)

⑦ Help: Provides explanation of the functions of each button

⑧ Test: Injects a TDR pulse into the network

⑨ File: After pressing, there are two options of save or records. Press the save button and the save interface appears (figure 4.3). This allows the present trace and its parameters to be saved. Pressing the Records button allows previously saved records to be accessed.

⑩ Range: The range should be set at least twice the actual cable length. Completing the cable length section on the home page will set this automatically

⑪ Cable VoP: This button allows the velocity of propagation of the cable to be set. A submenu appears with VOP+, VOP- and Save, which are used to adjust the default VOP value.

⑫ Compare: A submenu is produced with buttons marked Memory and Both. Memory temporarily saves the present trace. It can then be compared to a subsequently displayed waveform by pressing on Both.

⑬ Pulse width: allows the pulse width to be adjusted

⑭ Balance -: Allows the balance value to be reduced

⑮ Balance +: Allows the balance value to be increased

⑯ Gain-: Allows the gain value to be reduced

⑰ Gain+: Allows the gain value to be increased

Figure 4.12 TDR screen

4.4.1 Connecting the TDR system

Before any testing is carried out, ensure that the cable is switched off and thoroughly discharged. Isolate it from other equipment and connect its metal protective sheath to ground.

Switch on the T-907 and connect it to the Tablet APP by WiFi.

The red clip on the signal output cable is connected to the cable core under test and the black clip is connected to the earth.

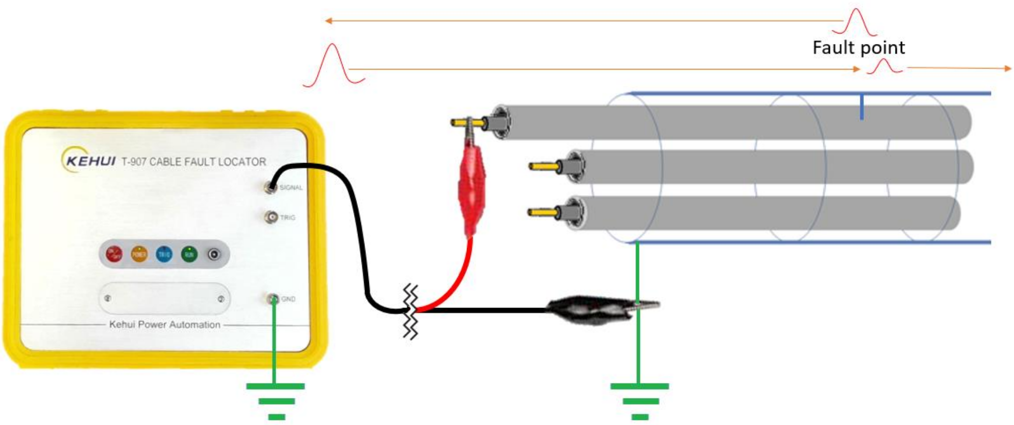


Figure 4.13 T-907 TDR connection

4.4.2 Performing the TDR test

The Range, Gain VoP and Zoom settings shown in section 4.3 should be made. In addition, the balance and pulse width can be set using the controls shown in figure 4.12. The objective of the balance setting is to try and match the unit to the characteristic impedance of the cable and, as far as possible, to minimise the injected pulse at the start of the trace. The balance control adjusts an internal resistor network, by changing the position of internal relays which can be heard when the setting is made.

This setting determines the pulse width which can be increased to inject more energy into the cable. A wider pulse width will travel further but may obscure detail of the fault if it has occurred close to the terminal. Additionally, its leading edge will be less well defined, affecting the accuracy of the measurement

The TDR pulse can be launched by pressing the Test button (figure 4.12 ⑧). The corresponding TDR trace will then appear on the screen

The waveform can be adjusted by changing the gain, zoom (section 4.3), balance and pulse width. Each time an adjustment is made the test is repeated to implement the change on the waveform.

4.4.3 Distance to the fault

The cursor (the dotted line shown in the centre of figure 4.14) can be moved left and right using the appropriate buttons, until it coincides with the beginning of the reflected wave, this represents the distance to the fault which is displayed in the top right.

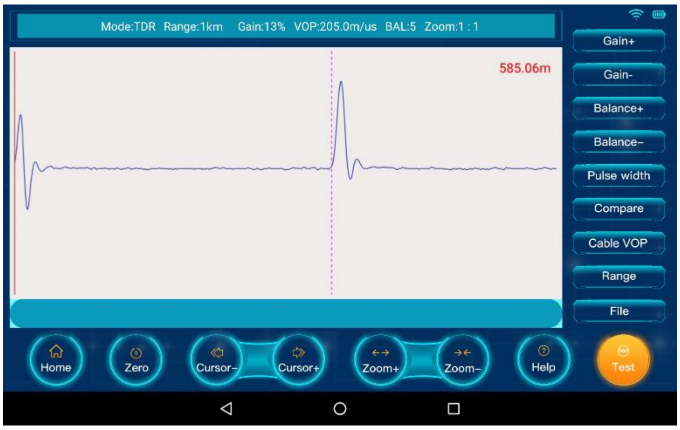


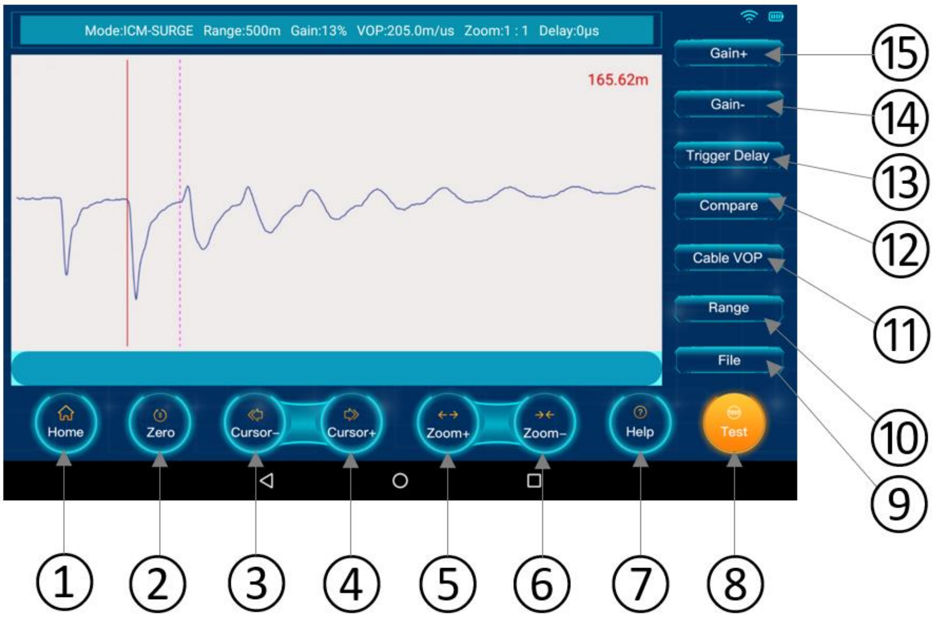
Figure 4.14 Distance to the fault

Once the result has been obtained the trace can be saved as described in section 4.3.3 and compared with previously recorded traces following the procedure in section 4.3.4.

If the actual length of the line being measured is known, but does not match the measured length, the VOP can be amended until the figure is correct (section 4.3.2). This figure can then be used for subsequent tests on this cable.

4.5 ICM-Surge Mode

Pressing on ICM-Surge (Figure 4.3 ⑯) brings up the ICM-Surge mode display (figure 4.14).



① Home: Returns the user to the main interface figure 4.2

② Zero: Sets the base cursor at the present position of the moveable, dotted cursor

③ Cursor-: Moves the dotted cursor to the left

④ Cursor+: Moves the dotted cursor to the right

⑤ Zoom+: Zooms in to the waveform (only operates at Range > 1km)

⑥ Zoom-: Zooms out from the waveform (only operates at Range > 1km)

⑦ Help: Provides explanation of the functions of each button

⑧ Test: Arms the T-907 in preparation for the test surge

⑨ File: After pressing, there are two options of save or records. Press the save button and the save interface appears (figure 4.3). This allows the present trace and its parameters to be saved. Pressing the Records button allows previously saved records to be accessed.

⑩ Range: The range should be set at least twice the actual cable length. Completing the cable length section on the home page will set this automatically

⑪ Cable VoP: This button allows the velocity of propagation of the cable to be set. A submenu appears with VOP+, VOP- and Save, which are used to adjust the default VOP value.

⑫ Compare: A submenu is produced with buttons marked Memory and Both. Memory temporarily saves the present trace. It can then be compared to a subsequently displayed waveform by pressing on Both.

⑬ Trigger Delay: Allows the trigger to be delayed, allowing time for the fault to break down

⑭ Gain-: Allows the gain value to be reduced

⑮ Gain+: Allows the gain value to be increased

Figure 4.15 ICM-Surge display

4.5.1 Connecting the ICM Surge system

Before any testing is carried out, ensure that the cable is switched off and thoroughly discharged. Isolate it from other equipment and connect its metal protective sheath to ground.

This initial description assumes the use of the Kehui T-305E surge generator, although other devices can be used if suitable signal outputs to the T-907 are available. The test should only be carried out after the user has thoroughly read the associated instruction manual.

Note: This ground connection is the working ground. This has the ground potential and acts as the reference during discharge.

Position the T-305E close to the cable and place the T-907 on the T-305E tray for ease of operation.

Connect the output of the T-305E to the trigger input of the T-907 (Figure 4.16).

Select the ICM setting is selected on the top of the T-305E.

As the T-907 is provided with an external linear current coupler, it can be used with any suitable surge generator. The user should thoroughly read the associated instruction manual before using the chosen surge generator.

Refer to Figure 4.17 for the connection of the surge generator. The linear current coupler required for ICM is provided with the T-907. Switch on the surge generator and select the pulse mode and the ICM test method.

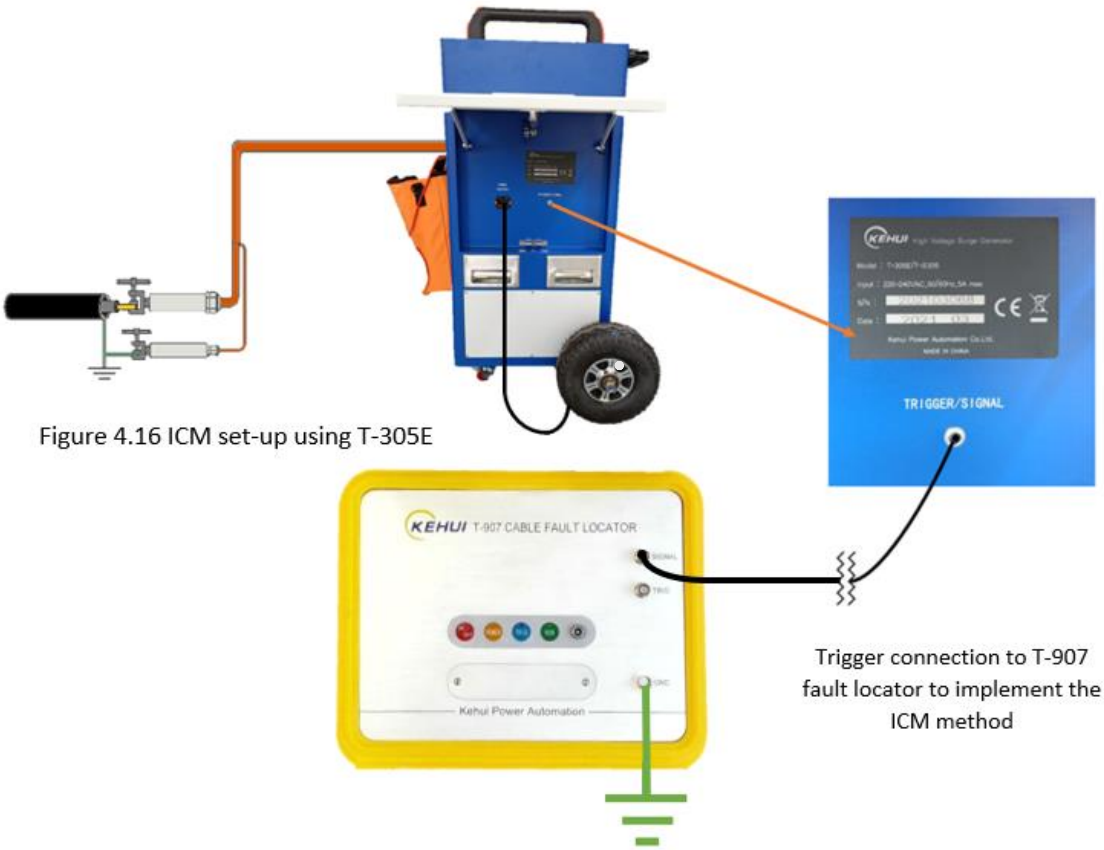


Figure 4.16 ICM set-up using T-305E

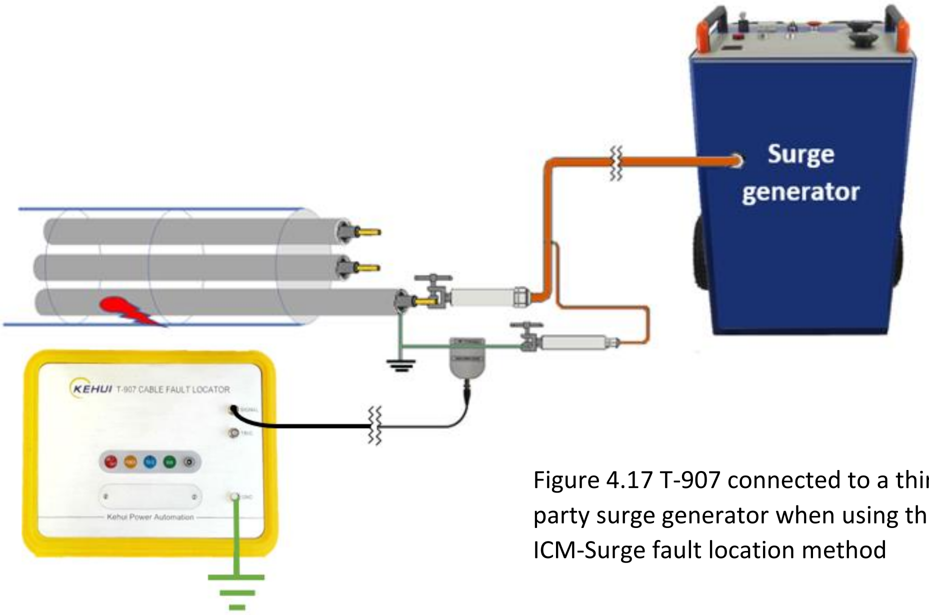


Figure 4.17 T-907 connected to a third-party surge generator when using the ICM-Surge fault location method

4.5.2 Performing the ICM Surge test

Switch on the T-907 and connect it to the Tablet APP by WiFi.

The Range, Gain VoP and Zoom settings shown in section 4.3 should be made.

Pressing the Test button (figure 4.15⑧) leads to the “Armed” prompt (figure 4.18) which means that the device is ready to trigger, when the surge generator operates.

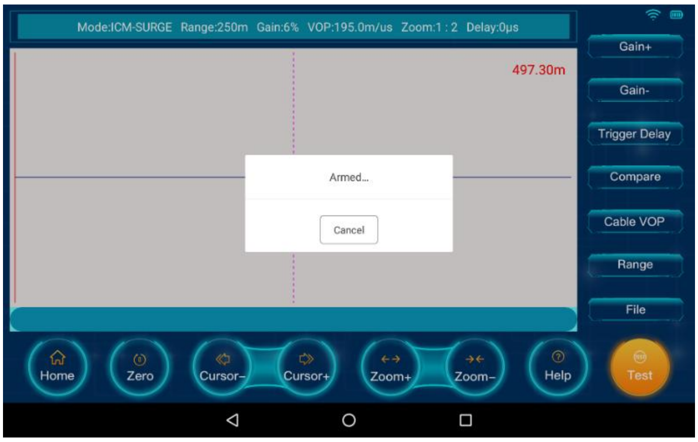


Figure 4.18 Armed prompt

On discharging the surge generator, the T907 will automatically locate the fault distance and position the curser at the fault position on the waveform (Figure 4.19). If the gain is not suitable, the display will indicate that the gain is too big or too small. Adjust the gain accordingly until a desirable waveform is displayed

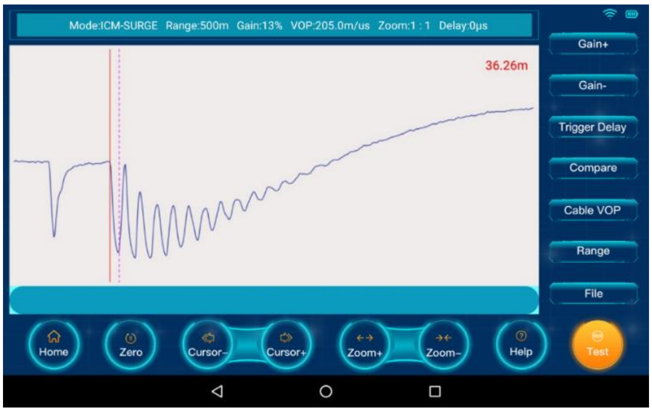


Figure 4.19 Automatic fault location for the ICM method

4.5.3 Delay Trigger

When the surge is applied, the normal burn-down duration of the fault will only be a few microseconds. However, sometimes, when the cable sheath is broken, the fault is associated with the ingress of moisture. In this situation, the discharge delay at the fault point can be hundreds of microseconds, or sometimes even milliseconds.

A typical cable fault locator starts to record the signal when the surge generator contactor closes, and the time recorded is limited by the instrument. If the discharge delay is prolonged, the instrument may already have completed recording when the fault point discharges.

As shown in Figure 14.20, the instrument record time is t_0. The fault burn-down time is at A, which exceeds the recording time t_0.

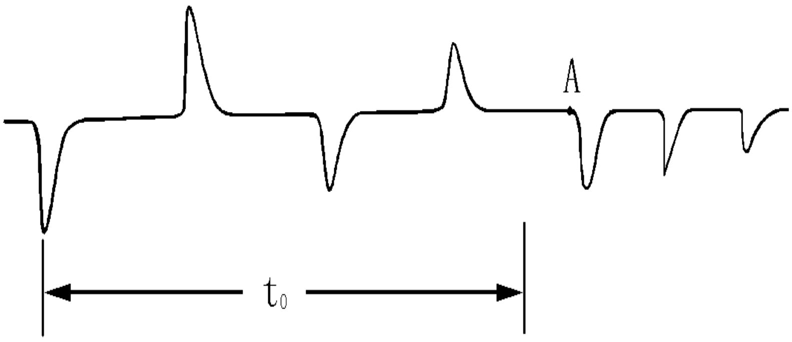


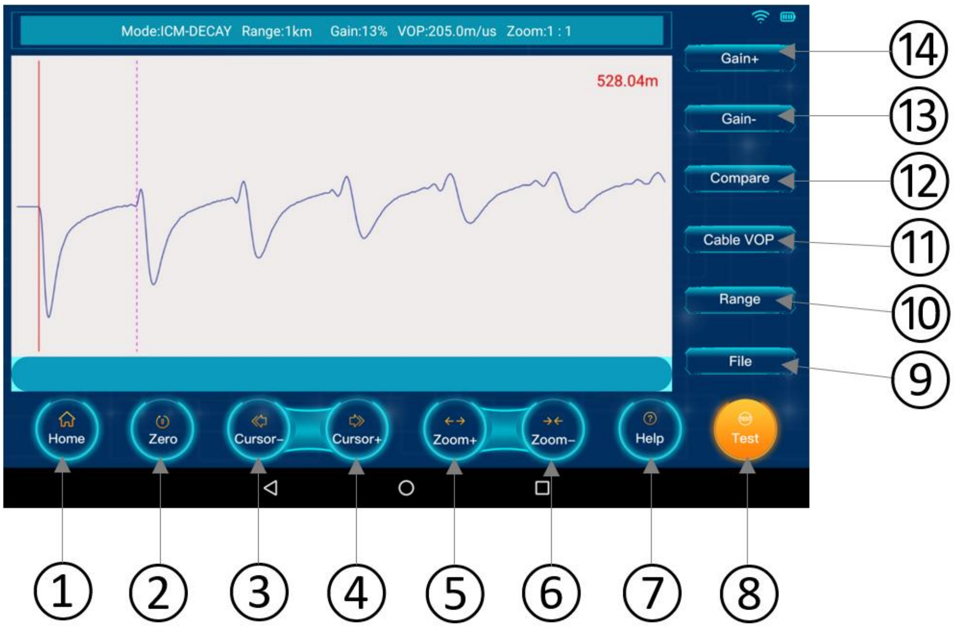
Figure 14.20 Long discharge delay

The Delay Triggering function of T-907 can solve this problem. It will initiate a time delay when the contactor closes. After the pre-set time delay, the instrument will begin to record the waveform.

As a default the delay is set to 0. By pressing on Trigger delay (Figure 4.15 ⑬). This allows the delay to be increased or decreased in 5μs steps.

4.6 ICM-Decay Mode

Pressing on ICM-Decay (Figure 4.3 ⑮) brings up the ICM-Decay mode display (figure 4.21).



① Home: Returns the user to the main interface figure 4.2

② Zero: Sets the base cursor at the present position of the moveable, dotted cursor

③ Cursor-: Moves the dotted cursor to the left

④ Cursor+: Moves the dotted cursor to the right

⑤ Zoom+: Zooms in to the waveform (only operates at Range > 1km)

⑥ Zoom-: Zooms out from the waveform (only operates at Range > 1km)

⑦ Help: Provides explanation of the functions of each button

⑧ Test: Arms the T-907 in preparation for the test surge

⑨ File: After pressing, there are two options of save or records. Press the save button and the save interface appears (figure 4.3). This allows the present trace and its parameters to be saved. Pressing the Records button allows previously saved records to be accessed.

⑩ Range: The range should be set at least twice the actual cable length. Completing the cable length section on the home page will set this automatically

⑪ Cable VoP: This button allows the velocity of propagation of the cable to be set. A submenu appears with VOP+, VOP- and Save, which are used to adjust the default VOP value.

⑫ Compare: A submenu is produced with buttons marked Memory and Both. Memory temporarily saves the present trace. It can then be compared to a subsequently displayed waveform by pressing on Both.

⑬ Gain-: Allows the gain value to be reduced

⑭ Gain+: Allows the gain value to be increased

Figure 14.21 ICM- Decay display

4.6.1 Connecting the ICM-Decay system

Before any testing is carried out, ensure that the cable is switched off and thoroughly discharged. Isolate it from other equipment and connect its metal protective sheath to ground.

This description shows the use of the Kehui T-305E surge generator, although other devices can be used if suitable signal outputs to the T-907 are available. The test should only be carried out after the user has thoroughly read the associated instruction manual.

Note: This ground connection is the working ground. This has the ground potential and acts as the reference during discharge.

Position the T-305E close to the cable and place the T-907 on the T-305E tray for ease of operation.

Connect the output of the T-305E to the trigger input of the T-907, Figure 4.22.

The Pulse setting and the is selected on the top of the T-305E.

Select the DC Mode and ICM on the controls at the top of the T-305E.

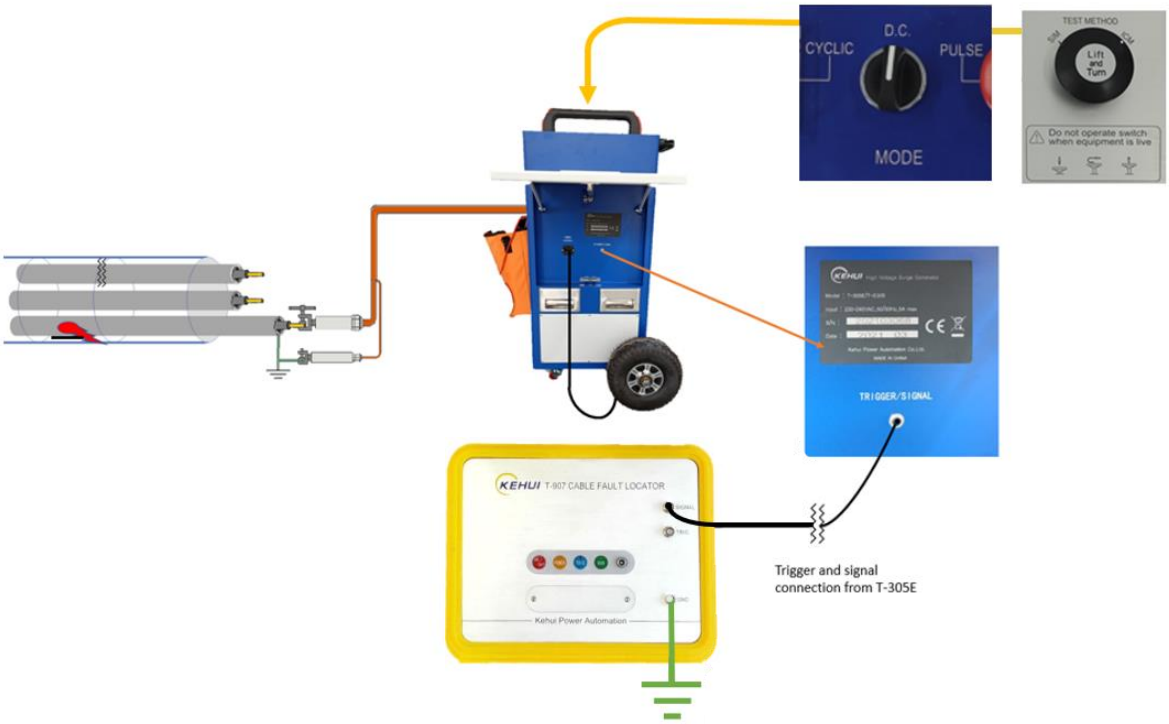


Figure 4.22 connection of T-907 to T-305E in ICM decay mode

Alternatively, a suitable third-party surge generator can be used, with the T-907 connected with the current coupler supplied, connected to the Signal input on the T-907.

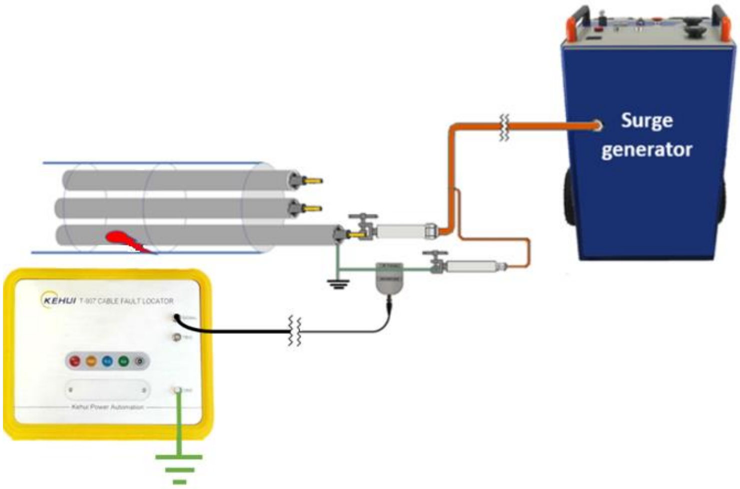


Figure 4.23 T-907 connected to a third-party surge generator when using the ICM Decay method

4.6.2 Performing the ICM Decay test

Switch on the T-907 and connect it to the Tablet APP by WiFi.

The Range, Gain VoP and Zoom settings shown in section 4.3 should be made.

Pressing the Test button (figure 4.14⑧) leads to the “Armed” prompt (figure 4.17) which means that the device is ready to trigger, when the surge generator operates.

With the system connected, the voltage is steadily increased until the fault breaks down and a flashover occurs. The capacitor energy is released, recharged, re-discharged, and so on The resulting waveform is shown in figure 4.24.

Figure 4.24 ICM Decay waveform

If the waveform amplitude is too small or too large, the gain can be adjusted, pressing <Test> (Figure 4.21 ⑧) continues the testing process. This can be repeated until a waveform with a suitable gain is obtained. The distance to the fault is measured between similar points on consecutive cycles using the cursors.

4.7 Arc reflection Secondary or Multiple Impulse Method (MIM) Mode

Pressing on MIM (Figure 4.3 ⑭) brings up the MIM mode display (figure 4.23).

① Home: Returns the user to the main interface figure 4.2

② Zero: Sets the base cursor at the present position of the moveable, dotted cursor

③ Cursor-: Moves the dotted cursor to the left

④ Cursor+: Moves the dotted cursor to the right

⑤ Zoom+: Zooms in to the waveform (only operates at Range > 1km)

⑥ Zoom-: Zooms out from the waveform (only operates at Range > 1km)

⑦ Help: Provides explanation of the functions of each button

⑧ Test: Arms the T-907 in preparation for the test surge

⑨ File: After pressing, there are two options of save or records. Press the save button and the save interface appears (figure 4.3). This allows the present trace and its parameters to be saved. Pressing the Records button allows previously saved records to be accessed.

⑩ Next: View the next waveform from the MIM operation

⑪ PRE: View the previous waveform from the MIM operation

⑫ Range: The range should be set at least twice the actual cable length. Completing the cable length section on the home page will set this automatically

⑬ Cable VoP: This button allows the velocity of propagation of the cable to be set. A submenu appears with VOP+, VOP- and Save, which are used to adjust the default VOP value.

⑭ Trigger Delay

⑮ Origin: This sets the present position of the real cursor as the zero point. This new position will be remembered the next time the APP is opened.

⑯ Gain-: Allows the gain value to be reduced

⑰ Gain+: Allows the gain value to be increased⑮

Figure 4.25 MIM display

4.7.1 Connecting the MIM system

Before any testing is carried out, ensure that the cable is switched off and thoroughly discharged. Isolate it from other equipment and connect its metal protective sheath to ground.

This description assumes the use of the Kehui T-305E surge generator, although other devices can be used if a suitable trigger signal and input from the T-907 is available. The test should only be carried out after the user has thoroughly read the associated instruction manual.

Note: This ground connection is the working ground. This has the ground potential and acts as the reference during discharge.

Position the T-305E close to the cable and place the T-907 on the T-305E tray for ease of operation.

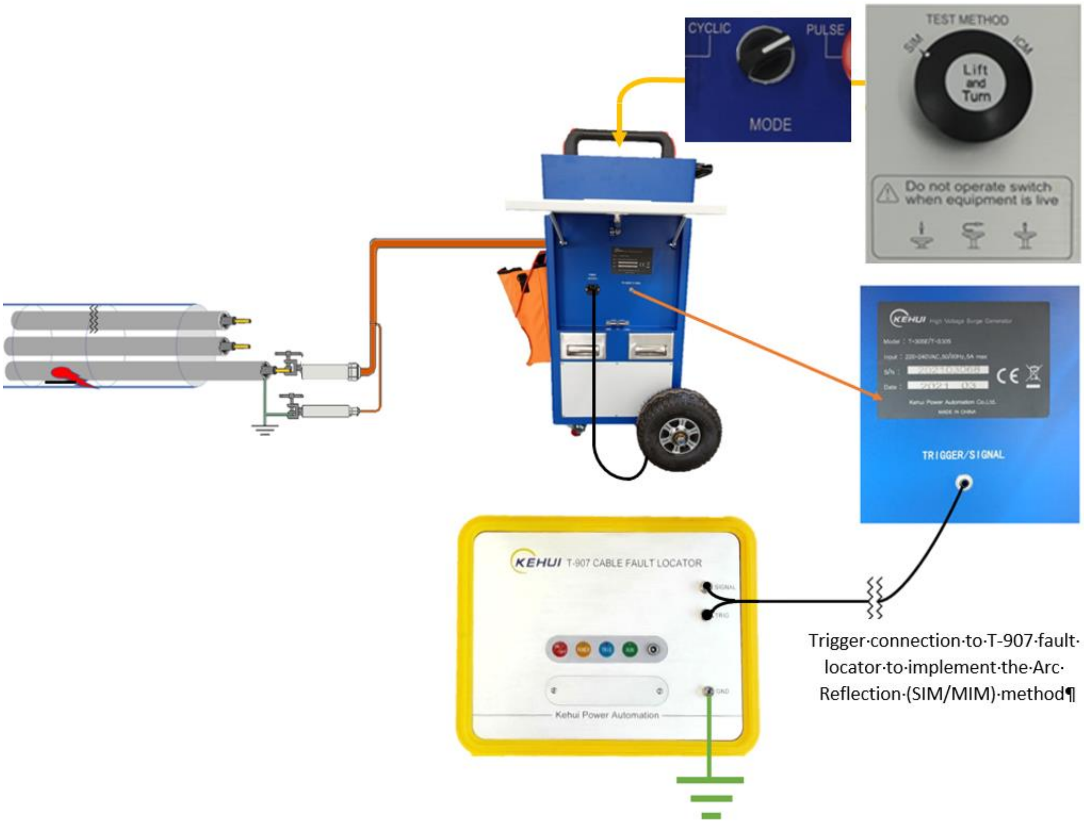


Figure 4.26 MIM mode connection

Connect the working ground, protective ground and the auxiliary ground. The protective ground and the auxiliary ground must be connected separately. Connect the T-305E Trigger/Signal connection with the T-907's Trigger/Signal connections using the lead supplied (Figure 14.26). The socket on the T-305E is beneath the tray as shown. Switch on the T-305E, select <Pulse> mode, and select <SIM > test method. The cable under test is connected as shown (refer to the T-305E manual for instructions).

4.7.2 Performing the MIM test

Switch on the T-907 and connect it to the Tablet APP by WiFi.

The Range, Gain VoP and Zoom settings shown in section 4.3 should be made.

Pressing the Test button (figure 4.14⑧) leads to the “Armed” prompt (figure 4.17) which means that the device is ready to trigger, when the surge generator operates.

Turn on the T-907, set the work mode as MIM. Press the <Test> key, and the instrument will display the prompt message "Armed…".

After the surge generator is discharged, the T-907 APP will display a test waveform (figure 4.27), and will automatically select an overlapped one for display. Move the cursor to where the two traces deviate to determine the distance to the fault point.

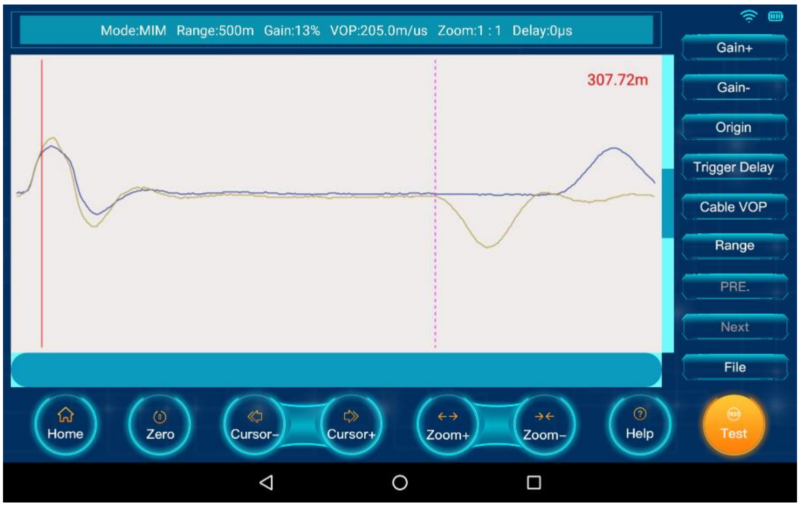


Figure 4.27 trace in MIM Mode

If the waveforms have poor coincidence, the slider on the right side of the screen will allow one to be moved vertically (figure 4.28).

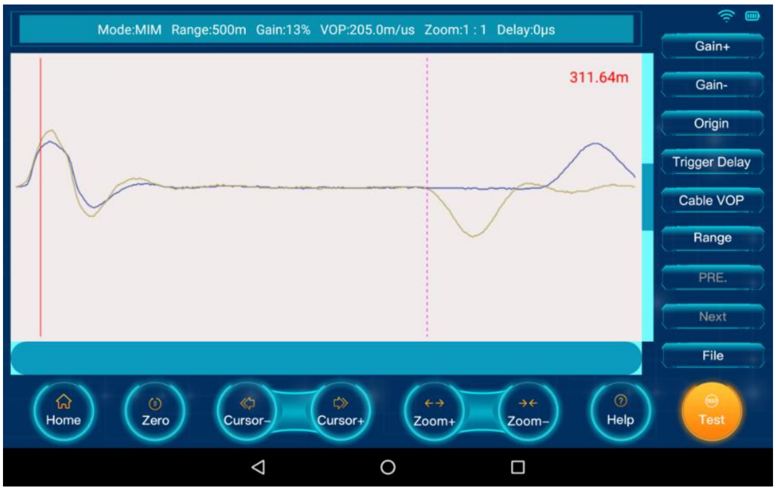
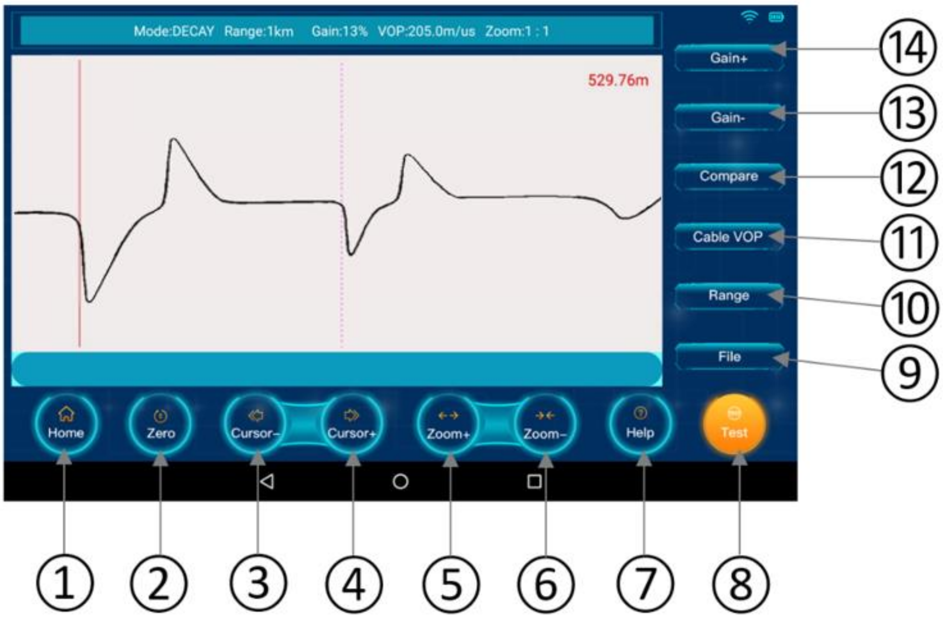


Figure 4.28 MIM with improved alignment

If the trace is unsuitable, other traces from the same test can be selected by using the PRE and Next buttons. There are a maximum of 8 traces to choose from.

4.8 Decay Mode

Pressing on MIM (Figure 4.3 ⑬) brings up the Decay mode display (figure 4.29).



① Home: Returns the user to the main interface figure 4.2

② Zero: Sets the base cursor at the present position of the moveable, dotted cursor

③ Cursor-: Moves the dotted cursor to the left

④ Cursor+: Moves the dotted cursor to the right

⑤ Zoom+: Zooms in to the waveform (only operates at Range > 1km)

⑥ Zoom-: Zooms out from the waveform (only operates at Range > 1km)

⑦ Help: Provides explanation of the functions of each button

⑧ Test: Arms the T-907

⑨ File: After pressing, there are two options of save or records. Press the save button and the save interface appears (figure 4.3). This allows the present trace and its parameters to be saved. Pressing the Records button allows previously saved records to be accessed.

⑩ Range: The range should be set at least twice the actual cable length. Completing the cable length section on the home page will set this automatically

⑪ Cable VoP: This button allows the velocity of propagation of the cable to be set. A submenu appears with VOP+, VOP- and Save, which are used to adjust the default VOP value.

⑫ Compare: A submenu is produced with buttons marked Memory and Both. Memory temporarily saves the present trace. It can then be compared to a subsequently displayed waveform by pressing on Both.

⑬ Gain-: Allows the gain value to be reduced

⑭ Gain+: Allows the gain value to be increased

Figure 14.29 Decay display

4.8.1 Connecting the Decay mode system

Before any testing is carried out, ensure that the cable is switched off and thoroughly discharged. Isolate it from other equipment and connect its metal protective sheath to ground.

The test should only be carried out after the user has thoroughly read the instruction manuals of the equipment used.

Note: This ground connection is the working ground. This has the ground potential and acts as the reference during discharge.

The decay method will normally use a VLF or DC supply which has sufficient capacity to breakdown the fault on the cable, in conjunction with an external capacitor. to the cable under test. Connect a capacitor as shown in Figure 14.30. The current coupler is connected around the capacitor’s earth connection. The signal from the coupler is fed into the T-907’s trigger input.

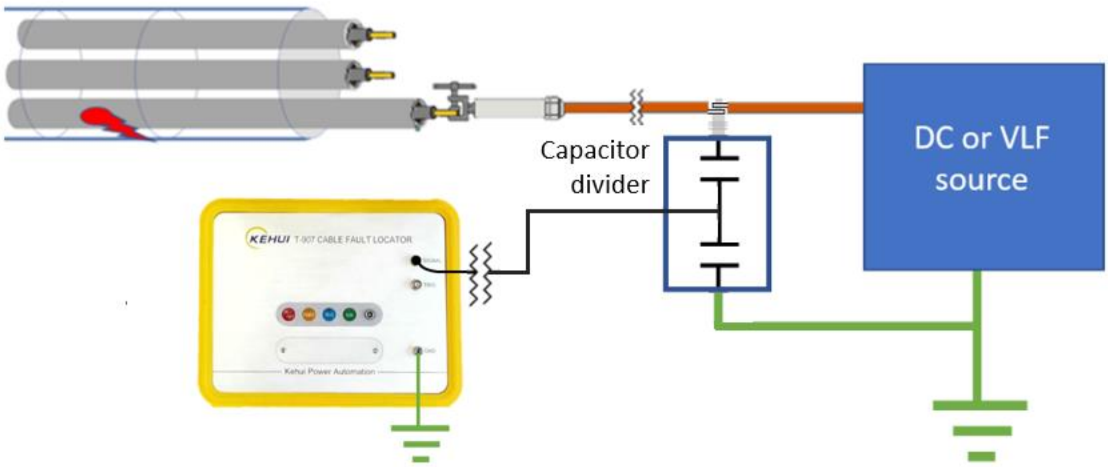


Figure 4.30 Connection for Decay method using DC or VLF source

4.8.2 Performing the Decay test

Switch on the T-907 and connect it to the Tablet APP by WiFi.

The Range, Gain VoP and Zoom settings shown in section 4.3 should be made.

The system is armed by pressing on the Test button.

With the system connected, the voltage is steadily increased until the fault breaks down and a flashover occurs. The resulting waveform is shown in figure 4.31.

If the waveform amplitude is too small or too large, the gain can be adjusted, pressing <Test> (Figure 4.29 ⑧) continues the testing process. This can be repeated until a waveform with a suitable gain is obtained. The distance to the fault is measured between similar points on consecutive cycles using the cursors.

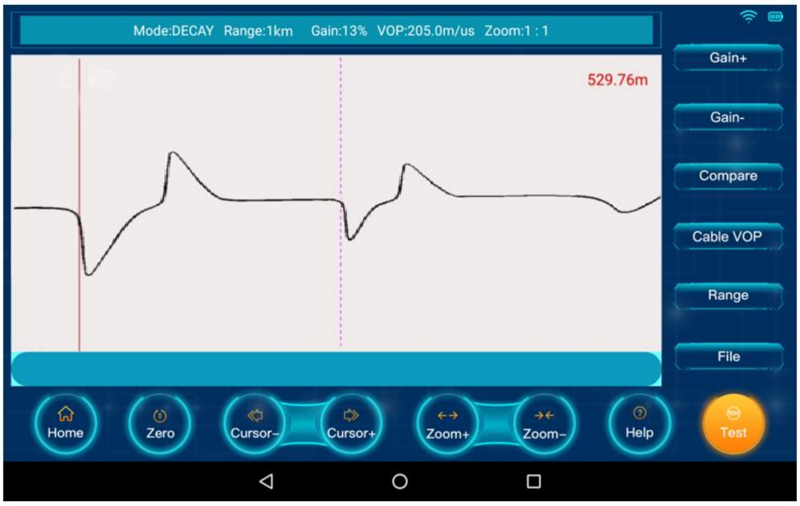


Figure 4.29 Decay waveform

5. Transport and Storage

5.1 Transport Note

The instrument has undergone temperature, humidity, vibration and impact tests before shipment. However, it is still prudent to take care when transporting it and to avoid long term exposure to sun and humidity.

5.2 Storage Requirements

The storage requirements are as follows:

1) Temperature range -40°C to +50°C
2) Relative humidity 40°C (20 to 90) %RH
3) Atmospheric pressure (86 to 106) kPa

6. Packing list – T-907

No.	Description		Quantity
1	Power Cable Fault Locator		1
2	Tablet with T-907 App		1
3	Carrying Bag		
4	Current Coupler (including BNC to Lemo plug connector)		1
5	Coupler Cable (BNC to BNC)		2
6	Testing Cable		1
7	T-907 Charger		1
8	Tablet Charger		1
9	Manual and Certificate		1

Appendix 1 Battery connection

Due to airline regulations, the T-907 unit is often shipped with the battery disconnected or removed (in which case it will be in the packaging). When the unit is first unpacked, plug the charger into a suitable power outlet and insert it in to the charger socket on the T-907 (Section 4.2.2). Press the on/off button. If the unit's Power light does not illuminate, it is probable that the battery is disconnected. The following instruction should be followed if this is the case.

i. Opening the box

Use an appropriate Allen key to remove the battery cover, as shown in Figure A1.

Figure A1.1 Opening the battery box

ii. Reconnecting the battery

The battery is connected to the instrument via a small plug which can be located by removing the battery pack from its holder. Reconnect the plug to the socket and check that it is secure, then return the battery to location. Finally replace the battery holder.