T-907L Power Cable Fault Locator
User Manual

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Legal Notices

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.

The storage, use and disposal of the product should be in accordance with the product manual, relevant contracts or relevant laws and regulations.

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Foreword

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

The T-907L 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-907L 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.

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1. Safety Instructions

Safety Note: This user manual is the basic commissioning and on-site operation guide for the T-907L Cable Fault locator. All operators of the T-907L 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-907L 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-907L 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-907L 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.

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
Signal Gain	<8km -40 to 50dB ≥8km 0 to 80dB
Pulse amplitude	30V
Velocity	90 - 300 m/µs
Output impedance	Adjustable from 5 - 87Ω
Internal memory	20MB
Power source	Polymer lithium-ion battery pack, 7.4V nominal
Input voltage	Maximum 60V
Output interface	USB
Battery Duration	Up to 8 hours
Battery Charger	AC 100-240V at 50/60Hz, output 8.4V, 3A DC. 4 hours charging time
Display	8” TFT with touch screen
Size	330mm x 305mm x 152mm
Weight	3 kg
Working temperature	-20° to $+50^{\circ}$C
Storage temperature	-25° to $+70^{\circ}$C
Relative humidity	20 to 90% at 50°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.

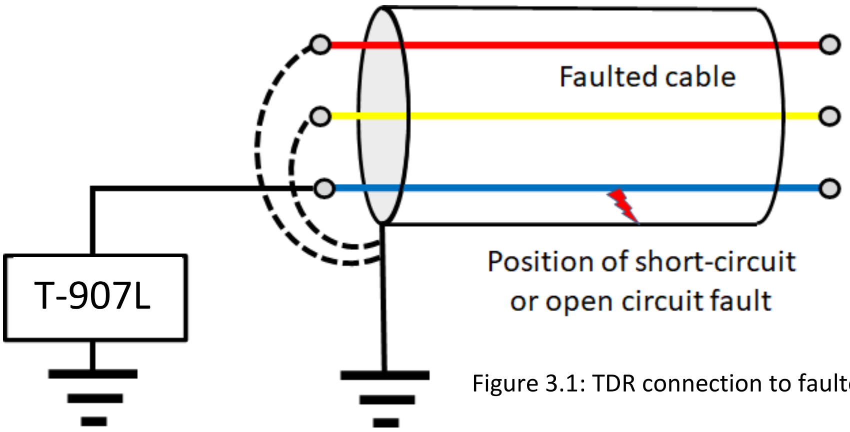

Figure 3.1: TDR connection to faulted cable

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.

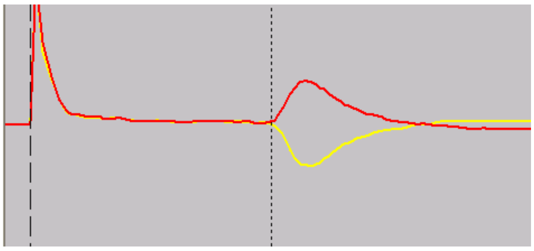

Figure 3.2: Comparison of TDR signals reflected from the far end of a healthy cable. The reflection from an open end is shown in red and from a short-circuited end is shown in yellow

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.

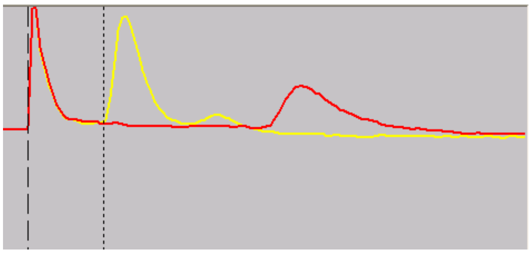

Figure 3.3: Comparison of TDR signals reflected from a faulted core with an open-circuit (yellow) and a healthy core of the same cable (red)

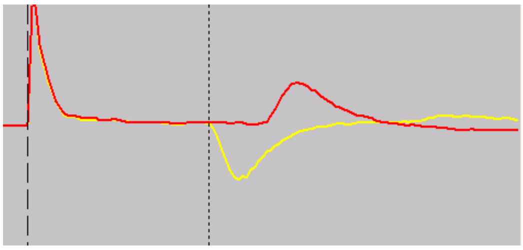

Figure 3.4: Comparison of TDR signals reflected from a faulted core with a short-circuit (yellow) and a healthy core of the same cable (red)

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 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 3.5, 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-907L). 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.

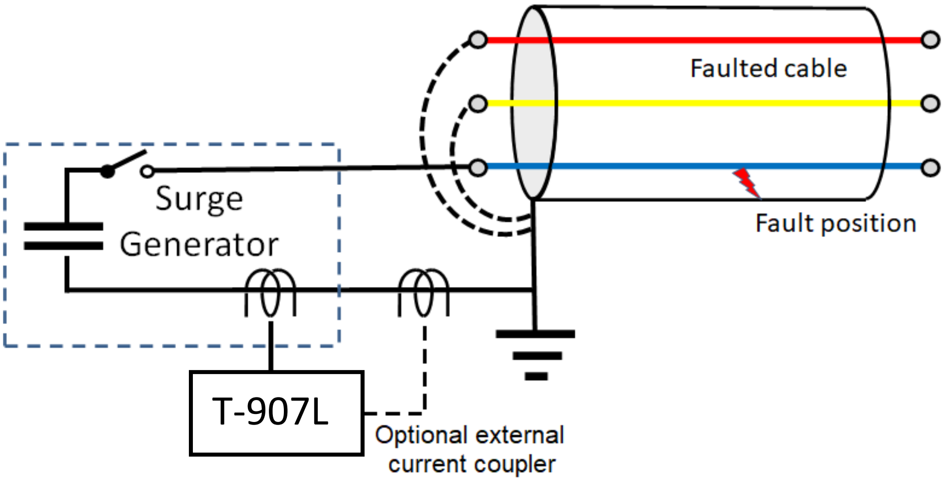

Figure 3.5 Set-up for Impulse Current Method

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 3.6 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.

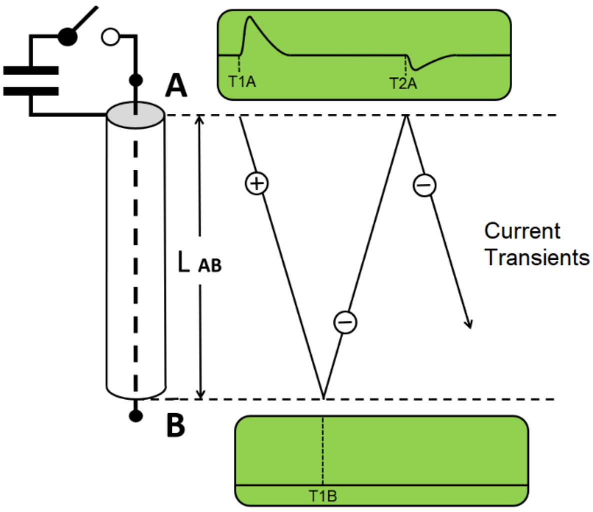

Figure 3.6: Impulse current method on a healthy cable

Figure 3.7 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

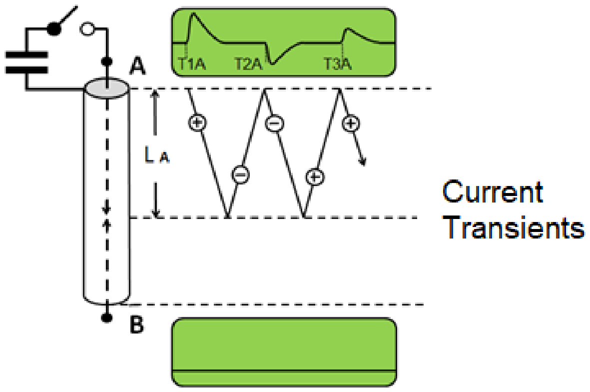

Figure 3.7: Impulse current method on an open circuit fault

Figure 3.8 shows a short circuit fault. In this case there is no change of polarity when the surge is reflected off the fault position

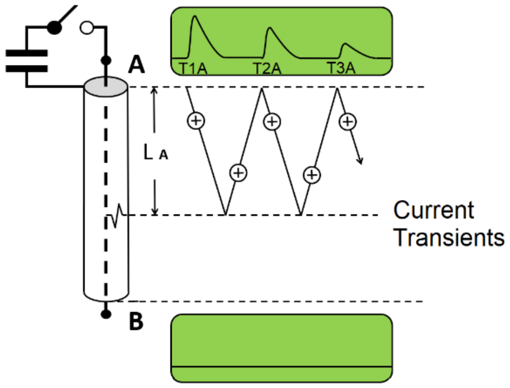

Figure 3.8: Impulse current method on a short circuit fault

Figure 3.9 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.

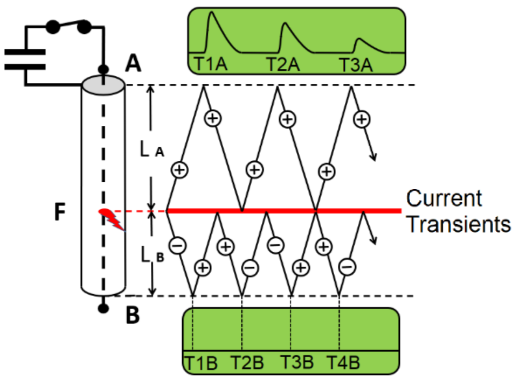

Figure 3.9: Impulse current method on a flashing fault

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 3.9. 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 3.10). 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.

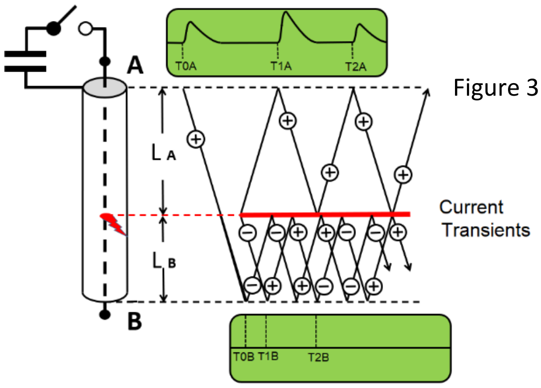

Figure 3.10: Impulse current method with a fault breakdown after a short ionisation time

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 3.11). 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.

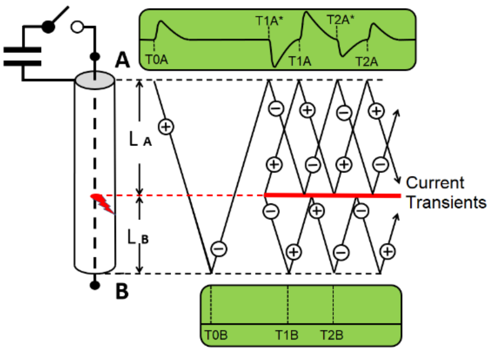

Figure 3.11: Impulse current method with a fault breakdown after a longer ionisation time

T-907L 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.

3.3 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 3.12 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.

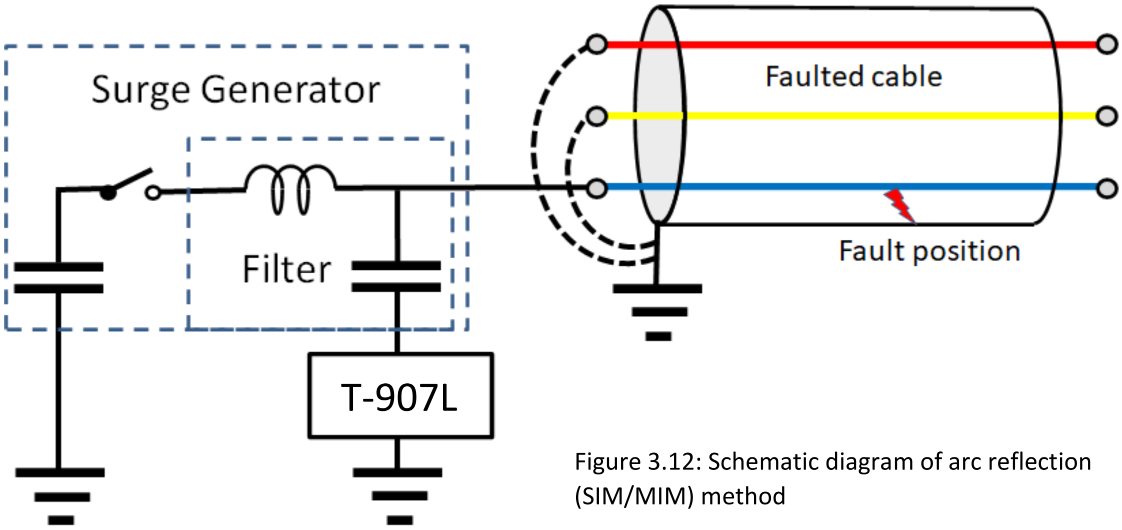

Figure 3.12: Schematic diagram of arc reflection (SIM/MIM) method

A TDR trace taken before or after, the surge is applied provides a reference signal (Figure 3.13). 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 3.14) allows the propagation time to the fault to be measured, allowing the distance to the fault to be determined.

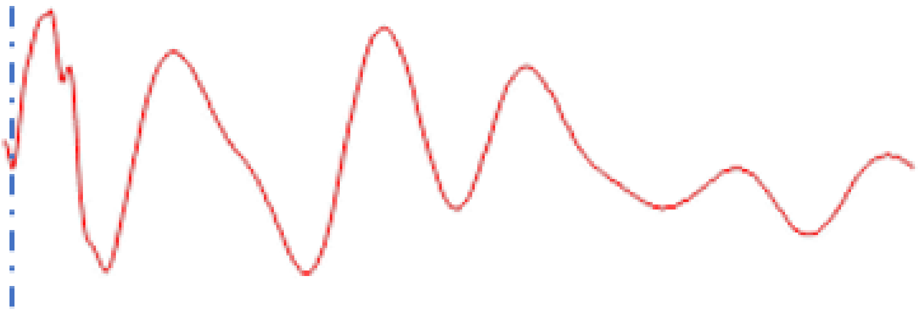

Figure 3.13 Arc reflection (SIM/MIM) trace on core prior to fault activation

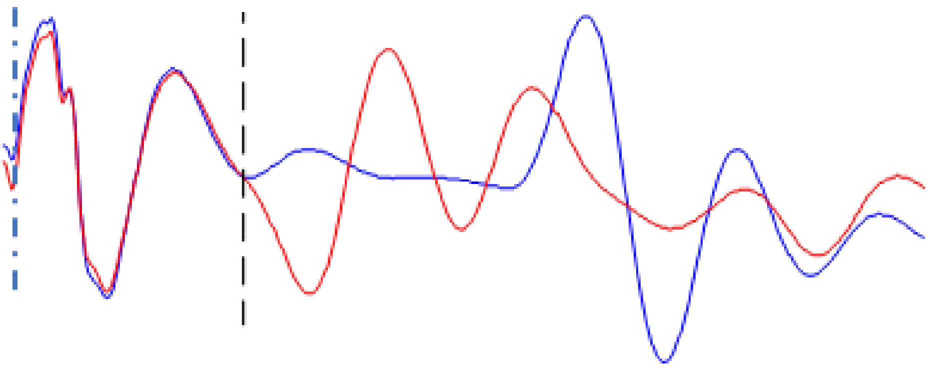

Figure 3.14 Comparison of traces, pre-fault and during fault activation

In Figure 3.14 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.

4. Using the fault locator T-907L

4.1 Device layout

4.1.1 Accessories

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

4.1.2 Front panel composition

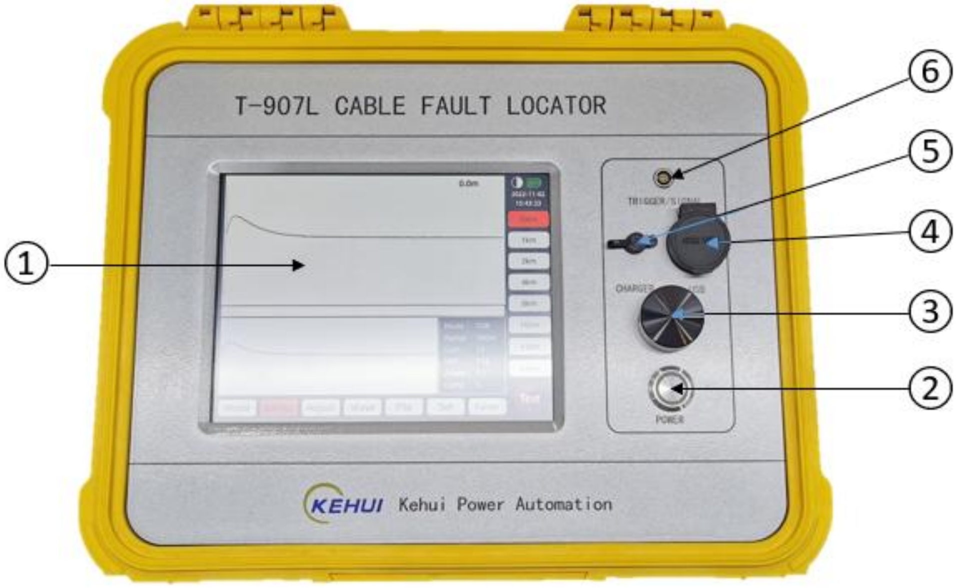

Figure 4.1 T-907L Front Panel

① LCD display 8” TFT touch screen.

② <On/OFF> key: Switch instrument’s power supply.

③ Cursor control, to move the cursor on the screen

④ USB port, for exporting waveform data on a memory stick

⑤ Charging port, for attaching the battery charger

⑥ Trigger/signal port for connecting the test leads. Different test methods require different leads.

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-907L 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 charger provided. Using other chargers that do not meet the exact parameters, may cause damage to the instrument.

4.1.4 Turning on the T-907L

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).

4.1.5 T-907L Display

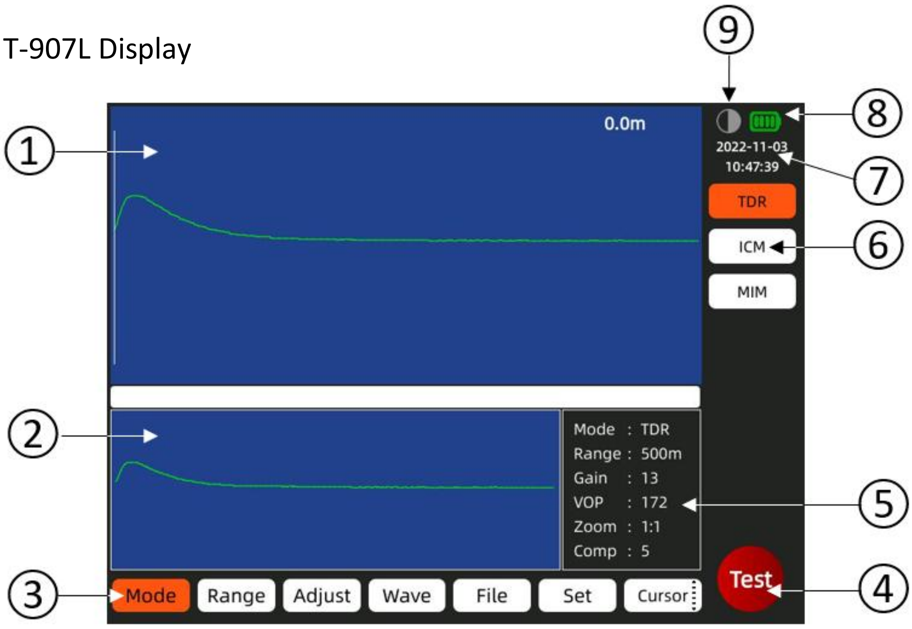

Figure 4.2 T-907 display

① main display area: display waveform details

② Thumbnail area: display the entire test waveform

③ Main menu area: function menu

④ Test button: Short-press for test, long press for automatic test in low voltage pulse mode

⑤ Test information area: Displays the parameter settings of the current test

⑥ Sub-menu area: Menu options to realise specific operations

⑦ Date and time

⑧ Battery monitor

⑨ Night/day mode (Pressing changes the background colour for improved sunlight visibility)

4.2 Operation instructions of the menu

After the instrument is turned on, the instrument screen displays the "Kehui icon", and the current test waveform is displayed in the centre of the screen ①; the thumbnail is displayed at the bottom ②; with other information distributed around the screen as previously indicated.

4.2.1 Choice of working mode

Click the <Mode> button at the bottom of the screen, and the terminal menu on the right side of the screen will display three working modes: "low voltage pulse", "pulse current" and "multiple pulse". Press the key, and the corresponding working mode will be displayed in the screen test information bar. At start-up, the instrument is automatically set to "low voltage pulse" mode.

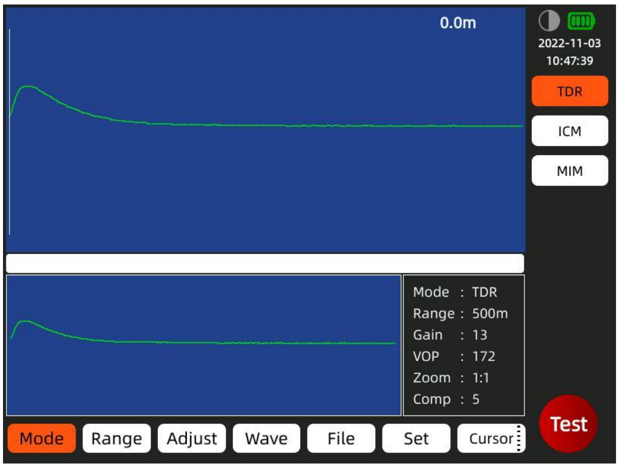

Figure 4.3 Operating mode selection

4.2.2 Choice of Range

Click the <Range> button at the bottom of the screen, and the terminal menu on the right of the screen will display eight ranges: "500m", "1km", "2km", "4km", "8km", "16km", "32km" and "64km". Depending on the length of the cable being measured, determine the required range. Click the corresponding range button, and the corresponding range information will be displayed in the test information section of the screen. At start-up, the range of the instrument is automatically set to "500m".

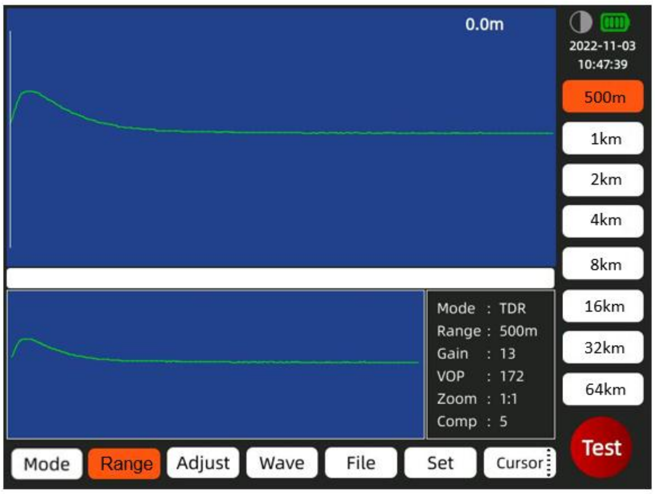

Figure 4.4 Range settings

4.2.3 Instrument adjustment

Click the <Adjustment> button at the bottom of the screen, and the terminal menu on the right of the screen will display "Gain +", "Gain -", "Comp +", "Comp -" (in low-voltage pulse and multiple pulse mode, it will display "Balance +", "Balance -", in the pulse current mode, six key names including "delay +" and "delay -"), "wave speed +" and "wave speed -" are displayed.

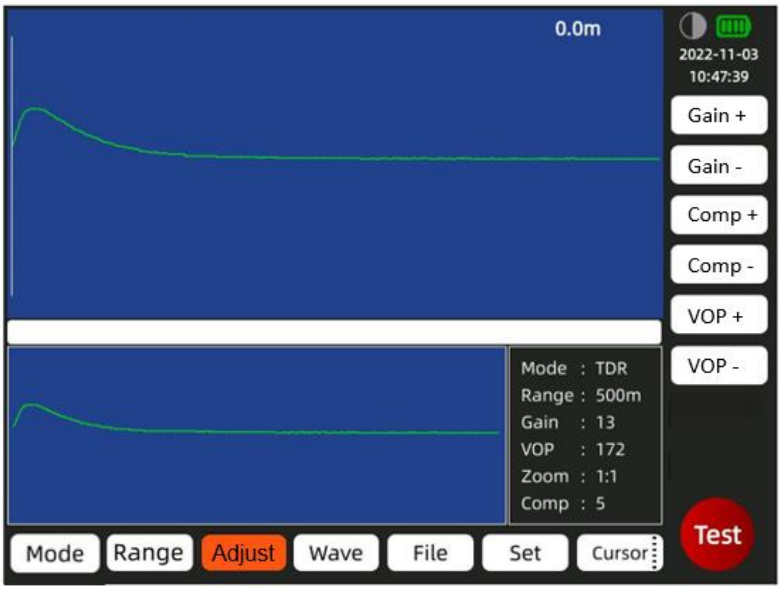

Figure 4.5 Adjustments

Click the <Test> button, and the test waveform will change when the low-voltage pulse occurs. Under the pulse current and multiple pulses, the screen displays the message "waiting for triggering" (in the state of "waiting for triggering", only the operation of the "cancel" button is valid. The test waveform is displayed after the high-voltage discharge at the fault point is triggered.

i. Gain adjustment

Click the "Gain+" and "Gain-" buttons, and the gain information "Gain: XXX" in in the test information section of the screen will change. In the low-voltage pulse working mode, the waveform displayed on the screen also changes accordingly.

ii. Balance adjustment

In the low-voltage pulse working mode, click "Comp+" and "Comp -", and the balance information "Comp: XXX" in the in the test information section of the screen will change. The instrument will adjust the resistance of the balance network, and the waveform displayed on the screen will change accordingly; at the same time, a "click" sound of the relay will be heard.

iii. Adjustment of wave speed

Click the "VOP +" and "VOP -" buttons, and the "VOP=XXX" wave velocity value displayed in the test information section of the screen will change accordingly, and the distance value at the upper right of the screen will also change.

[Note] The reference wave velocity values of several cables are shown in the table below:

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

iv. Adjustment of trigger delay

In the pulse current or multiple pulse mode, click the "delay +" and "delay -" buttons, and the delay information "delay XXX" in the test information section of the screen will change.

After the delay is adjusted, the T-907L power cable fault distance meter will start to collect waveform signals after a delay of XXXus from detecting the trigger signal during the test.

4.2.4 Waveform operation

Click the <Operation> button at the bottom of the screen, and the function keys including; "Zoom in", "Zoom out", "Restore", "Memory" and "Compare" will be displayed on the terminal menu on the right of the screen.

Figure 4.6 Waveform operation

Click the "Zoom in" button and the screen waveform will be partially enlarged horizontally, providing more detail; click the "Zoom out" button, the screen waveform will be partially zoomed-out horizontally; In the test information section of the screen, the ratio information "XX:1" changes accordingly.

Click the "Memory" button to temporarily store the current screen waveform in the instrument, and click "Compare" to simultaneously display the current waveform and the temporarily stored waveform on the instrument screen for comparison.

The T-907L has 20MB of internal memory. This cannot be readily translated into the number of records that can be saved as records can vary significantly in size:

Measurement type	File size at 500m range	File size at 64km range
TDR	2kB	256kB
ICM	8kB	256kB
SIM	4kB	512kB

4.2.5 Document management

Click the <Document> button at the bottom of the screen, and the terminal menu on the right side of the screen will display function keys such as “Local Record”, “Local Storage”, “Data to USB Disk”, and “Screenshot to USB Disk”.

i. Waveform storage

Click the "Save" button, and the screen will display the prompt message asking whether to save the waveform data to the local disk, click "Yes", and the current waveform will be stored in the local database of the instrument.

[Note] When saving the waveform, do not cut off the power until the save is successful.

Figure 4.7 Waveform storage

ii. Waveform browsing

Click the "Local Record" button to open the local database and drag the right slider to browse the waveform records; the time stamp of the waveform test is displayed under the file column. Click on a particular record and the thumbnail area will display the waveform.

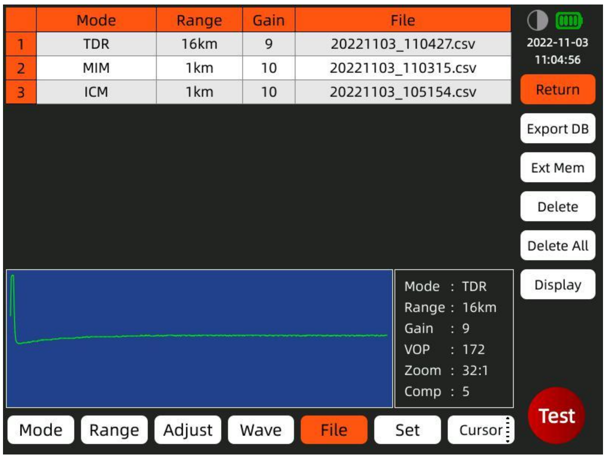

Figure 4.8 Local records

iii. Save data to a memory stick

Insert the memory stick into the USB port; click the "Records" button, select the waveform to be exported, click "Ext Mem" and the instrument will export the waveform of the current row of the database to the memory stick.

[Note] When the data is saved to the memory stick, wait for the prompt "saved successfully" before removing it.

iv. Export database file to a memory stick

Insert the memory stick into the USB port, click the "Records" button, click "Export DB", and the instrument will export the entire database file to the memory stick.

4.2.6 Instrument settings

Clicking the <Set> button at the bottom of the screen, and the function keys including "time setting", "software upgrade" and "cursor zero point" will be displayed on the right of the screen.

Figure 4.9 Settings

Time settingClick the "Set Time " button, the screen will display the data shown in Figure 4.5, click the "OK" button after any adjustments.

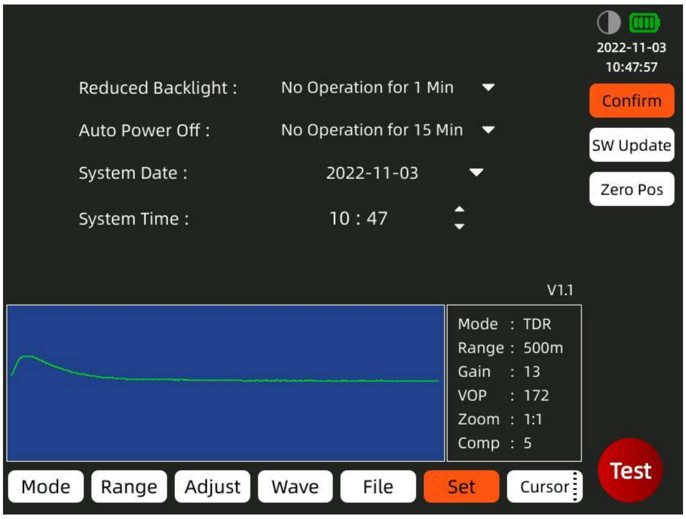

Figure 4.10 Time Settings

i. Software upgrade

The software may be updated on request.

Copy the file named "T-907L" to the root directory of a memory stick, and insert the stick into the USB port of the instrument. After it is recognised successfully, it will prompt "USB disk insertion", click the "software upgrade" button. Clicking the <settings> button at the bottom of the screen, causes function keys such as "time setting", "software upgrade" and "cursor zero point" to be displayed on the right of the screen.

ii. Cursor Zero Setting

Cursor zero works only in the multi-pulse mode and is used to set the initial position of the real cursor. After moving the real cursor to the desired position, press the "Cursor Zero" key, and the software will automatically position it at this position when performing multiple pulse tests.

4.3 Cursor movement

Turning the cursor knob on the panel (Figure 4.1③), causes the virtual cursor of the instrument to move left or right on the screen; the distance displayed on the upper right of the screen will increase or decrease accordingly. Click the <cursor> button, the real cursor will move to the position of the virtual cursor, and use this as the starting point to calculate the distance between the virtual and real cursors.

4.4 Waveform management background software

The instrument provides an MS Windows version of its waveform management software. This software can open a single waveform file or a database file exported from a memory stick and perform analysis on it.

4.5 Instrument power management and charging

4.5.1 Power management

i. Automatic brightness adjustment: After the instrument is turned on, it consumes a lot of power at high brightness. If there is no key operation within 1 minute (this time can be adjusted in the time setting), the instrument will automatically reduce the brightness to save battery power.
ii. Battery capacity indication: The battery symbol on the upper right of the LCD screen represents the remaining power of the battery.
iii. Automatic shutdown: When the instrument is working, if there is no key operation within 15 minutes (this time can be adjusted in the time setting), the instrument will be automatically turned- off.
iv. Under-voltage shutdown: When the lithium battery voltage is lower than 7V, the instrument will automatically shut down to protect it.

4.5.2 Charging

When the battery symbol displayed on the screen turns red, it indicates that the battery is low. The instrument uses a rechargeable lithium battery, which should then be recharged.

When charging, connect the power plug of the battery charger in to the mains socket and connect the output plug to the "charging" jack on the front panel of the instrument. The "charging indicator" light of the charger indicates the charging status: when the red light is on, it indicates fast charging; while the green light Indicates it is fully charged.

Only use the battery and charger that come with this product. Using other manufacturers' products will could damage the battery leakage and may be dangerous.

Do not store and charge in high temperatures, high humidity or in a dusty environment to avoid malfunction.

If the power cord is damaged do not use the charger, the cord must be replaced.

In order to protect the lithium battery, it is best to charge the battery when it indicates an undervoltage and only use it after it is fully charged.

5. Test Instructions

5.1 Diagnosis of Power Cable Fault Properties and Selection of Test Methods

Before measuring the distance to the cable fault point, the tester must determine the insulation condition of the cable and the nature of the fault, an appropriate distance measurement method can then be chosen to quickly and accurately measure the fault distance.

First, use a megohmmeter to measure the insulation resistance of each phase to ground and phase to phase at one end of the cable. If the insulation resistance is very high, a conductor continuity test should be done, short-circuit the three-phase conductor to the ground at one end of the cable, and repeat the measurement at the other end to determine whether the cable is broken.

According to the test results, faults can be divided into the following categories:

i. Low resistance and short circuit fault:

The insulation resistance between the cable core wires and the ground or between the core wires is measured with a multimeter. If the resistance value is less than 200Ω, it is a low-resistance fault and can be measured by the low-voltage pulse method.

ii. Open circuit fault:

Cable core wire disconnection fault, usually accompanied by grounding phenomenon. It can be measured by low pressure pulse method.

iii. High resistance and flashover faults:

The insulation resistance between the cable core wire and the ground or between the core wires is high, which can be measured by the multiple pulse method or pulse current method.

Based on the nature of the cable fault, choose the appropriate test method.

5.2 TDR test

5.2.1 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.

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.

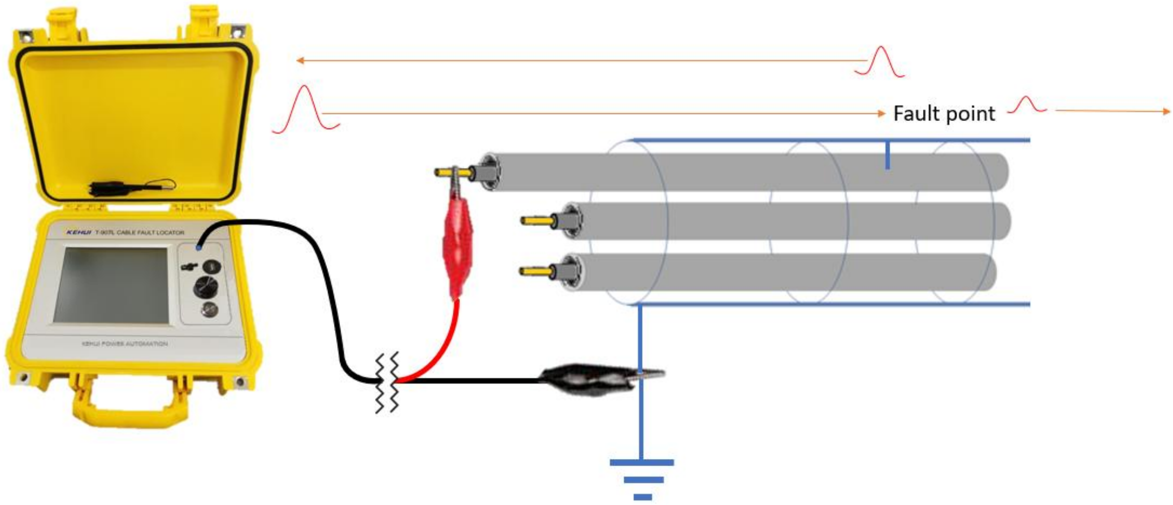

Figure 5.1 T-907L TDR connection

5.2.2 Performing the TDR test

The Range, Gain, VoP and Zoom settings shown in section 4.2.3 should be made. In addition, the balance and pulse width can be set. 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 4.3 ④). The corresponding TDR trace will then appear on the screen

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

5.2.3 Distance to the fault

The cursor (the dotted line shown in the centre of figure 5.2) 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.

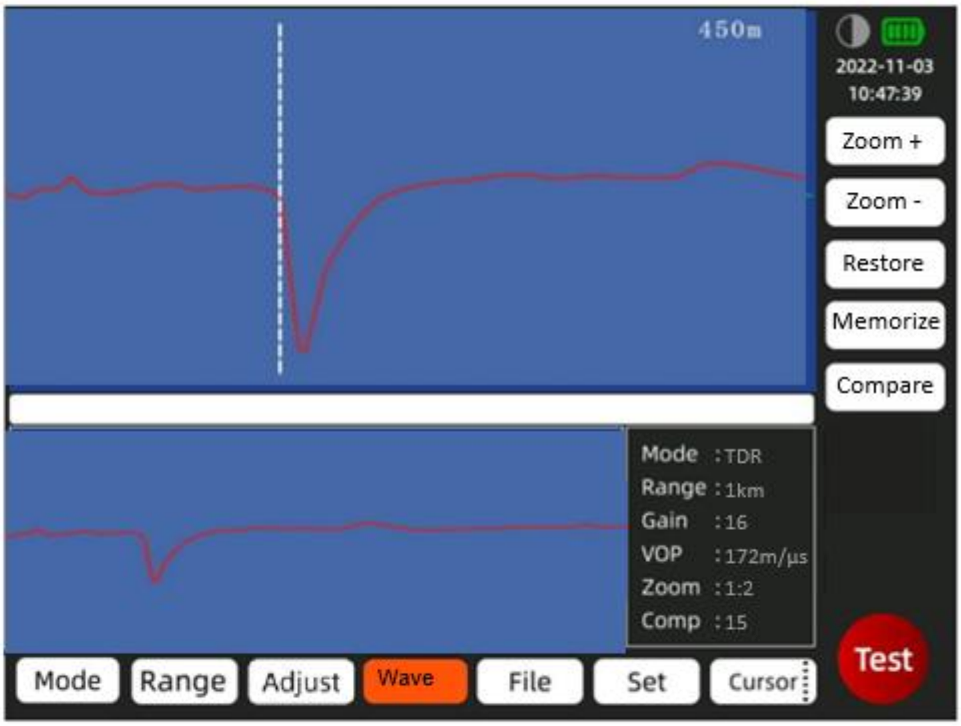

Figure 5.2 Test waveform

Under the operation menu, the waveform can be zoomed in on the point where the virtual cursor is located to obtain a more detailed waveform. At the same time, the virtual frame in the thumbnail will mark the position of the partial enlarged image in the full image.

Once the result has been obtained the trace can be saved and compared with previously recorded traces.

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. This figure can then be used for subsequent tests on this cable.

5.2.4 Waveform comparison method

When the range mode gain is constant, the fault point of the cable can be identified more easily by comparing the pulse reflection waveforms of the faulted phase and a healthy one.

First measure the TDR waveform of the faulty phase and store it; then measure the TDR trace of a healthy phase, press the <Comparison> key to display the two waveforms on the screen at the same time and move the cursor to where the waveforms separate, this is the fault point.

This method can be used to determine the wave velocity of similar cables when the length of the healthy cable is known. Measure the open-circuit and short-circuit waveforms of the opposite ends of the cable respectively, and adjust the wave velocity so that the distance between the waveform difference point is equal to the length of the cable. The wave velocity value displayed by the instrument at this time is correct for this type of cable. It is worth noting that the wave velocity in the cable is related to the properties of the insulating medium of the cable, but not to the material and cross-sectional area of the conductor, as shown in Figure 5.3.

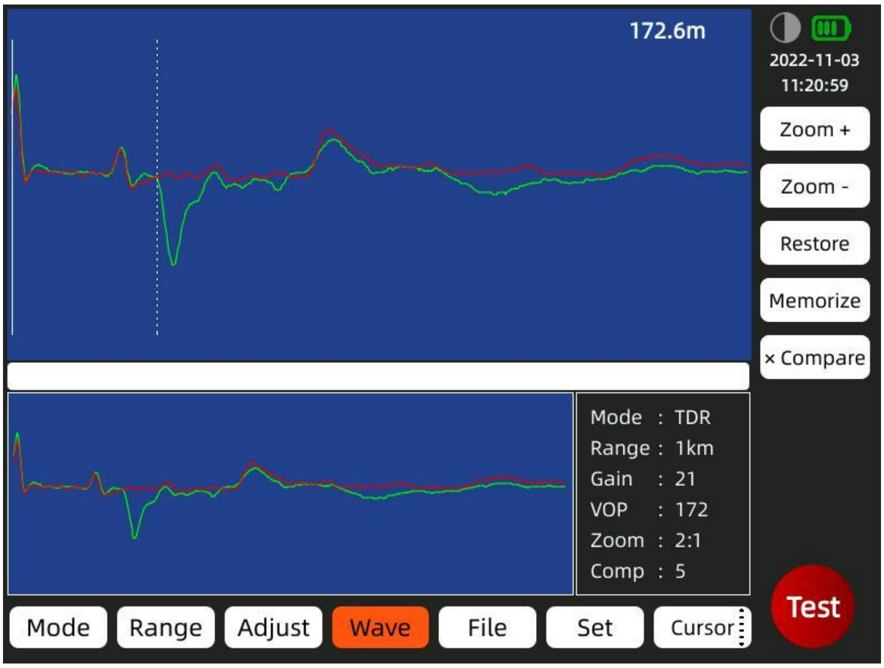

Figure 5.3 Waveform comparison

5.2.5 Automatic testing

In the TDR mode, pressing the <test> key for more than one second, will cause the instrument to automatically adjust the range, gain, and balance, and position the cursor on the fault point to display the distance to the fault point.

5.3 ICM-Surge Mode

5.3.1 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-907L 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-907L on the T-305E tray for ease of operation.

Connect the output of the T-305E to the trigger input of the T-907L (Figure 5.4).

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

As the T-907L 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 5.5 for the connection of the surge generator. The linear current coupler required for ICM is provided with the T-907L. Switch on the surge generator and select the pulse mode and the ICM test method.

Figure 5.4 ICM set-up using T-305E

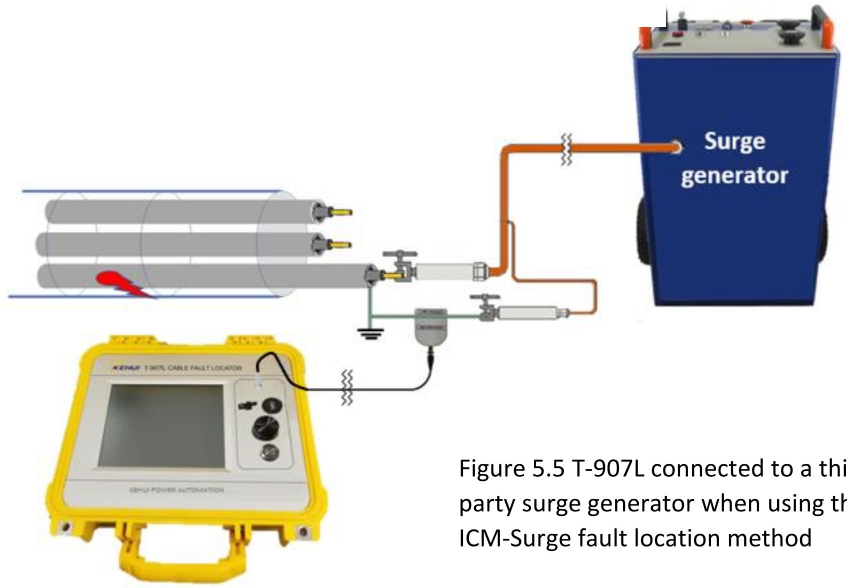

Figure 5.5 T-907L connected to a third-party surge generator when using the ICM-Surge fault location method

5.3.2 Performing the ICM Surge test

After connecting the test, press the T-907L <Switch> key to turn on the instrument, use the “ICM” menu under the <Mode> menu to set the working mode, and use the “VOP + “, “VOP –“ to set the appropriate velocity of propagation and use the <Range> menu to select the appropriate range (generally 2 to 4 times the total length of the cable). Press the <TEST> key, and the instrument will display the prompt message of “waiting for trigger”. After the surge is discharged, T-907L will display the pulse current waveform on the screen, and the cursor knob can be rotated to determine the distance to the fault point. If the gain is not suitable, adjust it and repeat the test until a satisfactory pulse current waveform is obtained, as shown in Figure 5-6.

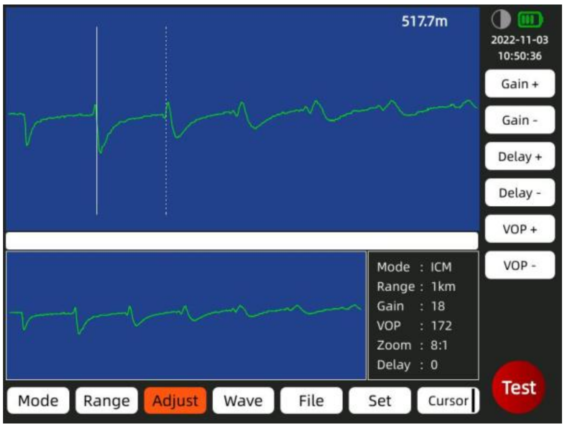

Figure 5.6 ICM waveforms

5.3.3 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 5.7, the instrument record time is t_0. The fault burn-down time is at A, which exceeds the recording time t_0.

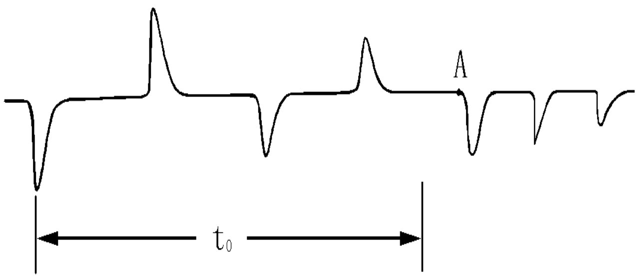

Figure 5.7 Long discharge delay

The Delay Triggering function of T-907L 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. Using the Trigger delay allows the delay to be increased or decreased in 5µs steps.

5.4 Impulse Method (MIM) Mode

5.4.1 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-907L 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-907L on the T-305E tray for ease of operation.

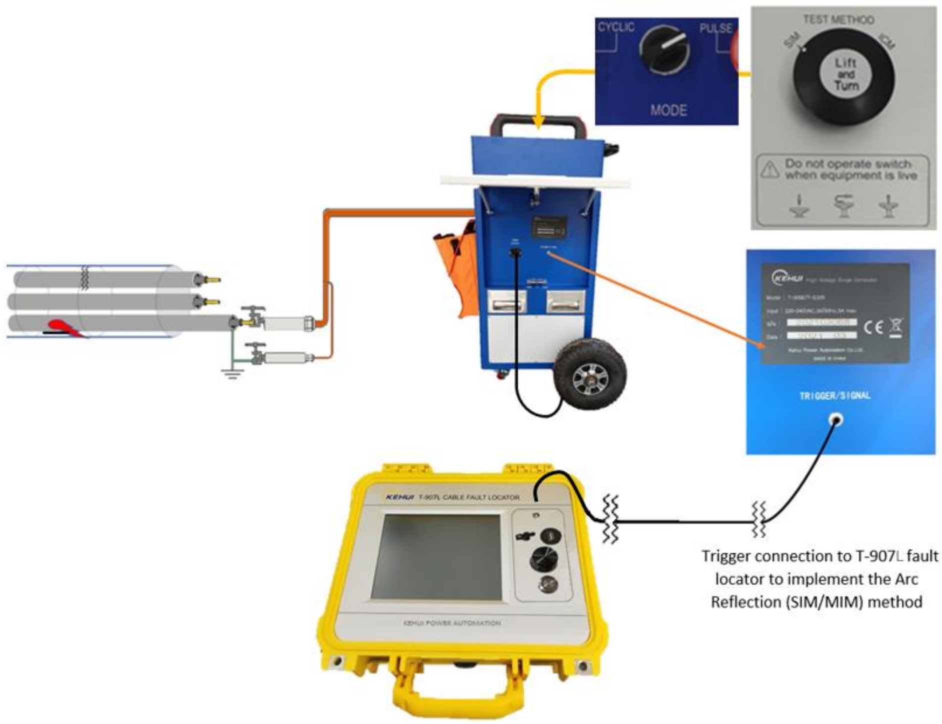

Figure 5.8 MIM mode connection

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-907L's Trigger/Signal connections using the lead supplied. 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).

5.4.2 Performing the MIM test

Switch on the T-907L.

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-907L, 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-907L 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.

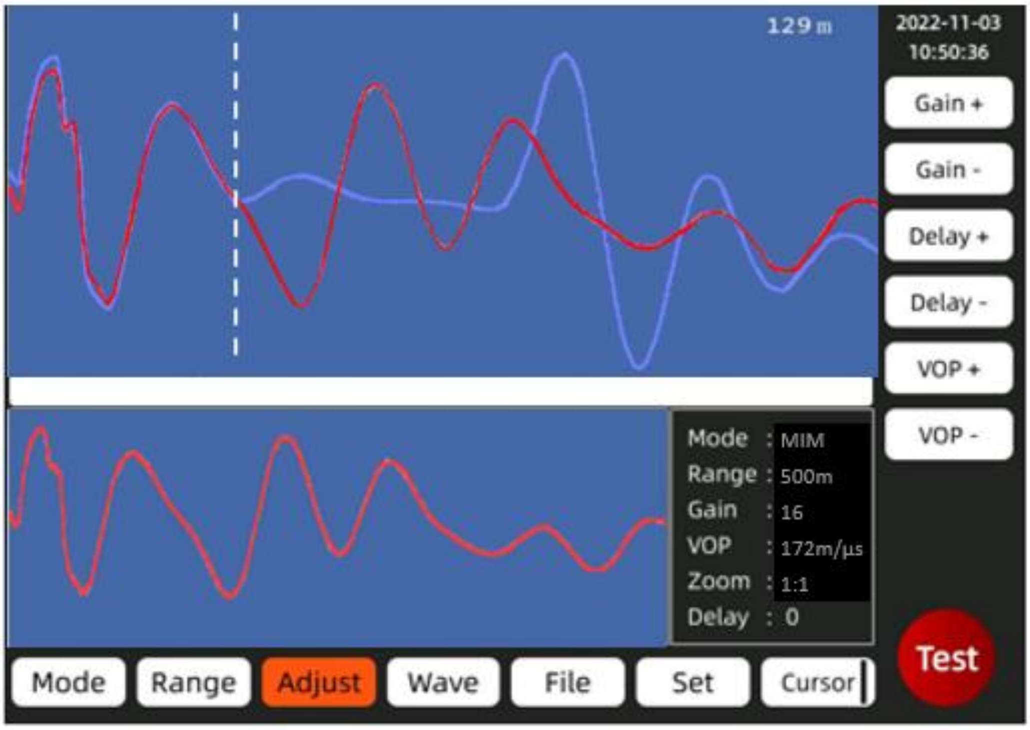

Figure 5.9 trace in MIM Mode

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.

6. Transport and Storage

6.1 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.

6.2 Storage Requirements

The storage requirements are as follows:

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

7. Packing list – T-907L

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

Appendix 1 Battery connection

Due to airline regulations, the T-907L 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-907L (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.

Opening the box

Disconnect the charger and open the box of the T-906 by removing the 4 screws on the bottom part of the box (Figure 4.7). Take care to put the screws in a safe place for re-assembly.

Figure A1-1

Figure A1-2

Figure A1-3

4.3.2 Removing the instrument

Take out the inside part as shown in Figure 4.8, being very careful as there are some connection wires inside

Then remove the 2 screws marked above with the red circles in figure 4.9, this allows the complete metal box inside to be removed. This can be opened by removing the 4 screws on the metal box, (Figure 4.10). Again, keep the screws safe.

Figure A1-4

Figure A1-5

This will expose the inner part of the instrument, including the battery pack and the connection wire, plug it back to the terminal as marked in Figure A1-5, above.

Plug the charger into the socket on the T-906 and ensure that it is working correctly by pressing the power on/off button on the front panel. Take care not to touch any of the circuitry.

If it is working correctly reverse the disassembly instructions and put the device back together. Ensure that all of the screws are properly tightened. The device can now be used.