THE APPLICATION
OF TECHNOLOGY

KEHUI

CABLE FAULT LOCATION

Kehui International

Kehui International, Hertford, UK

Kehui factory, Zibo, China

The word Kehui, literally means the Application of Technology in the Chinese language. This phrase perfectly defines the company's commitment to technological innovation, which it achieves whilst striving for the highest levels of quality.

The company was founded in 1991 as a joint venture with a major US organisation, before becoming independent in 2005. It has utilised the best of Asian, European and American expertise to develop a selection of cable and transmission line fault locators, as well as equipment for the automation of electrical distribution systems and its range of switched reluctance motors.

Cable Fault Location

Cables are a fundamental part of the electrical power system, delivering electricity discretely, whilst improving the environment by displacing unsightly overhead lines. However, their invisibility comes at the cost of making it more difficult to locate and repair the faults that they may incur. A faulted cable brings the inconvenience of a loss of supply, but where the load is particularly important, this inconvenience becomes far more critical.

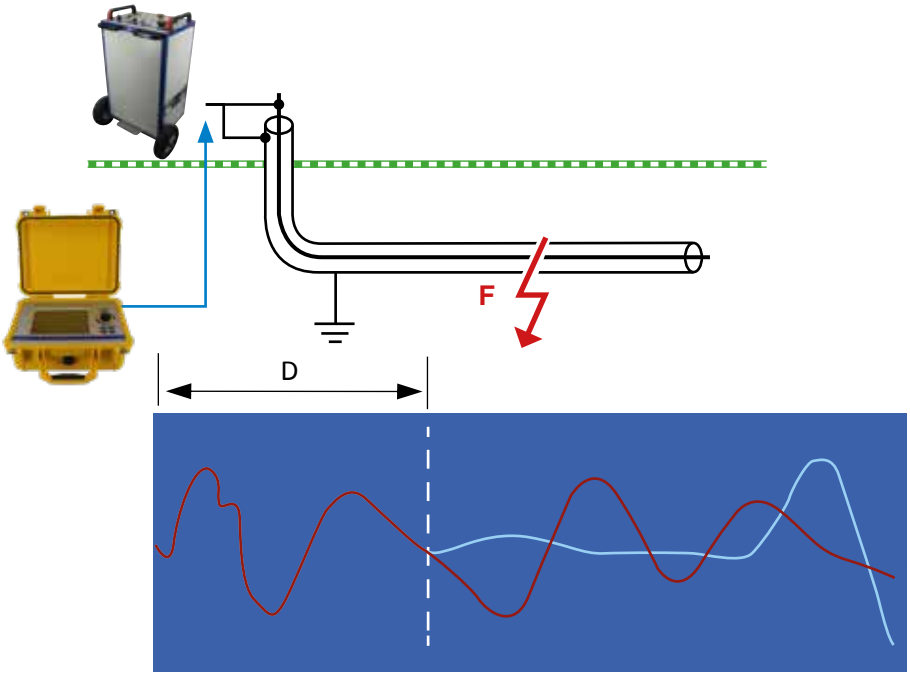
The primary objective of any cable fault location system is to provide quick, effective, accurate and safe fault location, thereby reducing system outages and “customer minutes lost”. Furthermore, the deregulated industry has led to the imposition of financial penalties on power companies in the event of a power failure. As a result, there is a lot of pressure to quickly find the fault and Kehui addresses this need for swift fault location through its range of products.

Principle of MV Cable Fault Location

Fault Pre-location

As the fault (F) is unlikely to exhibit a low resistance, it is usually necessary to modify it to create a situation where it becomes suitable for pre-location techniques to be applied. This is carried out using a surge generator to inject energy in to the cable. This energy converts the fault such that it becomes low-resistance, allowing the use of Time Domain Reflectometry (TDR) to measure the distance to the fault.

TDR injects an impulse on to the cable and compares the reflection from the fault position before and during the arcing. The deviation of the signals (D) represents the distance to the fault position, based on time and a known pulse propagation velocity. This technique allows the approximate position of the fault to be determined. The exact location will then be identified through pinpointing.



Pinpointing

As with the pre-location, the Surge generator is used to break down the fault. In this case it applies regular impulses to the cable which can then be detected at the fault point; both audibly, through a ground microphone, and electromagnetically. The signals are picked up remotely through Bluetooth© on a tablet, where an APP identifies the precise fault location.

T-305E High Voltage Surge Generator

The T-305E high voltage surge generator, is used for locating high impedance and flashing faults on distribution cables. It works in conjunction with a cable fault locator for pre-locating the fault position and then with a pinpointer to find the precise fault location.
It is applicable for different cable fault location techniques, such as the impulse current method (ICM) and the secondary/multiple impulse method (SIM/MIM).

The equipment consists of a capacitor bank, an in-built voltage transformer and a rectifier, switchable to achieve different capacitance and voltage levels. When the unit is switched off, its automatic and manual discharge facilities remove any residual capacitive charge. Additional Earth/Ground detection circuitry, blocks the operation of the unit if an effective Earth/Ground connection is not in place. These features, together with safety interlocking, ensure safe, reliable and easy-to-use operation. The T-305E also provides repetitive discharges to facilitate pinpointing, through the detection of the magnetic field and audio signals related to the fault discharging.

The T-305E owes its relatively low weight and manoeuvrability to its low current output. It is recommended to try to break down using ICM or MIM mode, however if burning current is necessary to treat the fault a separate burner T-ZGH60 is available.

Features

- **Surge energy up to 1024J (2048J optional)**
- **Supports the following impulse methods:**
  - **Secondary Impulse method (SIM)**
  - **Multiple Impulse Method (MIM)**
  - **Impulse Current Method (ICM)**
- **Manual and automatic capacitor discharge**
- **32kV DC output for hipot testing**

T-305E Technical Data	
Mains Supply	220V ± 10% (110V available through step-up transformer)
Mains Frequency	50/60Hz ± 20%
Maximum Power Consumption	1500W
Operating Modes	Single pulse, Cyclic pulse, DC
Surge Steps (1024J)	2µF (0 -32kV), 8µF (0 - 16kV), 16µF (0-8kV)
Surge Steps (2048J)	4µF (0 -32kV), 16µF (0 - 16kV), 32µF (0-8kV)
Surge Voltage	0 - 32kV; 0 - 16kV; 0 - 8 kV
DC Test (kV)/mA	0...32kV / 25mA Negative polarity
Pulse Ratio (Seconds)	4 - 30s
Mode Of Operation	DC / single impulse / multiple impulse
Discharge Period	4 – 15 s. Continuously adjustable
Testing Method	ICM, SIM/MIM
Dimensions	500 x 400 x 960mm (1024J) 500 x 400 x 110mm (2048J)
Weight	70kg (1024) 120kg (2048J)
Operating Temperature	-10 - +50°C
Ingress Protection	IP21

T-308 Compact High Voltage Surge Generator

The T-308 is a lightweight, compact high voltage surge generator ideal for transporting to site without the need for a specialist vehicle.

It is used for locating high impedance and flashing faults on lower voltage distribution cables. It works in conjunction with a compatible cable fault locator (such as the Kehui T-907L) for pre-locating the fault position and then with a pinpointer (such as the Kehui T-506) to find the precise fault location. It uses the impulse current method (ICM) of cable fault location.

It can also supply a 16kV DC supply, suitable for insulation testing.

T-308 Technical Data	
Output Voltage	0-16kV, Adjustable negative DC
DC Voltage	0-16kV/30mA negative polarity
Impulse energy	512J: (16kV/4μF)
Operating mode	DC / Pulse / Cyclic
Testing method	ICM
Discharge period	6s fixed
Working voltage	220/240Vac±10% (110V through step-up transformer)
Mains Frequency	50/60Hz ± 20%
Dimensions	500 x 305 x 454mm
Weight	25kg
Operating temperature	-10°C to +50°C
Ingress Protection	IP21 (IP54 with the lid closed)

Features

- **Lightweight, only 28kg**
- **Surge voltage ranges; 0-16kV**
- **Supports Impulse Current Method (ICM)**
- **High surge energy up to 500J**
- **Manual or automatic discharge**
- **Built in wheels and handle for ease of transportation**

T-907 Compact High Voltage Surge Generator

The T-907L and T-907 are lightweight, portable fault locators for low, medium and high-voltage power cables, which can be applied for the pre-location of all kinds of faults, including open circuit, short circuit, low resistance, high resistance and flashovers.

They can operate in five modes: Time Domain Reflectometry (TDR), Secondary/Multiple Impulse Method, (SIM/MIM), Impulse Current Method (ICM), ICM (current) Decay and the Voltage Decay Method.

Most power cable faults exhibit a high resistance, which requires the application of a high voltage surge to break it down for the purpose of pre-location. Of the operating modes available, ICM is the most effective method of producing a flashover at the fault point using a standard surge generator. In the T-907L and T-907, the ICM is augmented by an Automatic Impulse Current (AIC) method, in which waveform recognition techniques are applied to calculate the fault location automatically, without the need for the operator to manually interpret the waveforms. For flashover faults requiring a high breakdown voltage, the Decay Method can be applied in conjunction with a HV DC source. The cable is charged by the DC source until it breaks down, creating a transient voltage signal which is captured through a capacitive voltage divider and used for fault location analysis.

T-907 and T-907L Technical Data	
Measuring range	64km
Fault location methods	TDR, ICM, SIM/MIM and Decay
Voltage of transmitting pulse	30V
Pulse width	40ns-7µs
Voltage withstand	400V AC (50/60Hz)
Output impedance	5-87Ω
Sampling rate	400MHz (2.5ns)
Display T-907L	8 inch, TFT, Touch screen, colour LCD
Display T-907	Independent wirelessly connected 8" tablet
Charger	Input: 110V – 240V AC; Output 3A, 8.4V DC
Charger (T-907 Tablet)	Input: 110V – 240V AC; Output 3A, 5V DC
Dimensions	270 x 250 x 120mm
Dimensions tablet (T-907)	2270 x 140 x 18mm
Weight	3kg
Weight tablet (T-907)	<1kg
Operating temperature	-10°C to +50°C
Ingress protection	IP54: Splash proof and dust protected (when closed)
Storage temperature	-20°C to +50°C

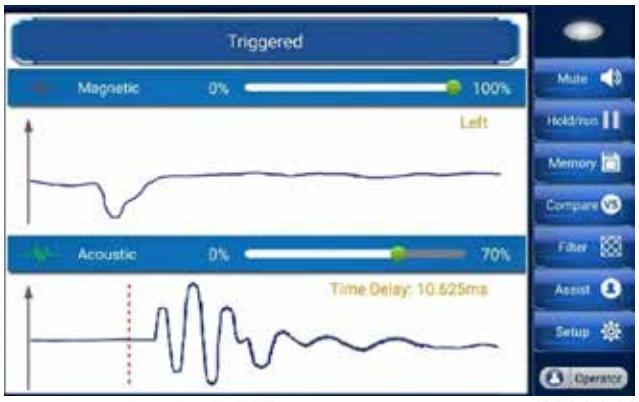
Features

- **5 operating modes**
- **Measuring range to 64 km**
- **Automated ICM mode**
- **400MHz sampling rate**
- **Integral back-lit colour touchscreen display with alternative screen colours for different ambient conditions**
- **Versions with integral (T-907L) and external user interfaces (T-907)**

T-506 Smart Pinpointer for Power Cable Faults

The T-506 is used together with a high voltage surge generator, to pinpoint high resistance and flashover faults on power cables. It utilises an Application (App) running on an Android device, connected wirelessly to a hand-held sensor. The HV surge generator injects periodic high voltage surges down the cable which causes flashover at the fault point. The sensor detects magnetic and audio signals emanating from the faulted cable during this process. Although most Android tablets can be used, a pre-programmed, ruggedised device, with a hands-free neck strap, is available from Kehui. The tablet has two modes; the Operator mode provides an intuitive indication of the position of the cable and the position of the fault relative to the user's location. The Waveform Analysis mode allows the user to diagnose the fault position from the magnetic field and audio waveforms. The tablet also has a waveform recognition technique which recognises the audio signal from the flashover and rejects other spurious noise signals.

The equipment features waveform recognition to identify the 'thumping' signal and differentiate it from other environmental noise. It does this through a 'learning' process based on a large number of previously recorded signals using artificial intelligence. It is complemented by the use of noise-cancelling earphones to assist the user in hearing the sound of the discharge at the fault position.

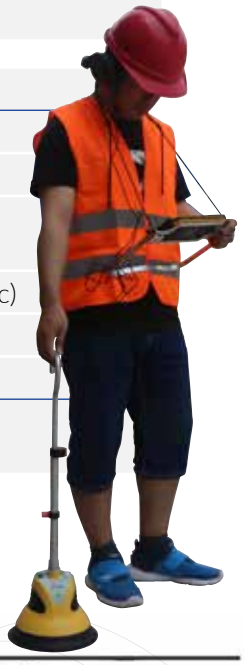


Features

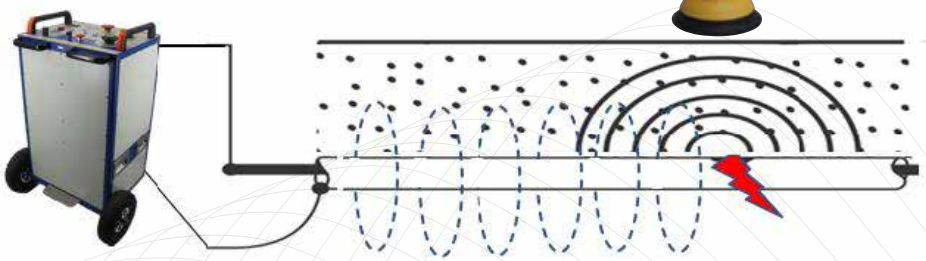
- **Display APP available for use on Android devices**
- **Option of pre-programmed, ruggedised hands-free Tablet**
- **Two level display with switchable Expert and intuitive Standard modes**
- **Intuitive display (right) indicates the user's position relative to the cable and the relative distance to the fault**
- **Hands-free Bluetooth connection from the receiver to the tablet PC**

T-506 Technical Data	
Sensor	
Accuracy	≤0.2m
Detector dynamic range	Sound/magnetic channels >110dB
Magnetic field frequency Range	160Hz – 50kHz
Audio Frequency range	100 – 1500Hz
Audio Filter stages	• No filter 100-1500Hz
	• Low pass filter 100 – 400Hz
	• Band pass filter 150 – 600Hz
	• High Pass filter 200 – 1500Hz
Ingress Protection	IP65
Dimensions	Diameter 23cm (outer rim)
Height	Adjustable 54cm-77cm
Weight	2kg

Receiver; (Details of Kehui supplied Android tablet)	
Dimensions	21 x 13.5 x 2 cm
Weight	0.61kg
Display	8-inch, 800 x 1280 IPS LCD Brightness 450 Nit
Gain	120dB (acoustic and magnetic)
Weight	1kg including harness
Ingress Protection	IP65
Working temperature (Sensor and Receiver)	-10 °C to 50 °C



The tablet for the T-506 can also be used to operate the T-907 fault locator.



When the fault breaks down the current flow along the cable creates a magnetic field, whilst the sound of the breakdown produces an acoustic signal. These are both detected by the T-506.

T-1200 Cable Test Van

The T-1200 test van brings together Kehui's cable fault location solutions in a vehicle. Providing ease of transportation, convenient connections to 50m cables housed on integral drums and a comfortable air-conditioned working environment. A back-up generator or battery can be installed to provide a local power supply if required. The van's industrial PC provides a large clear LCD display and runs analysis software to facilitate the fault location.

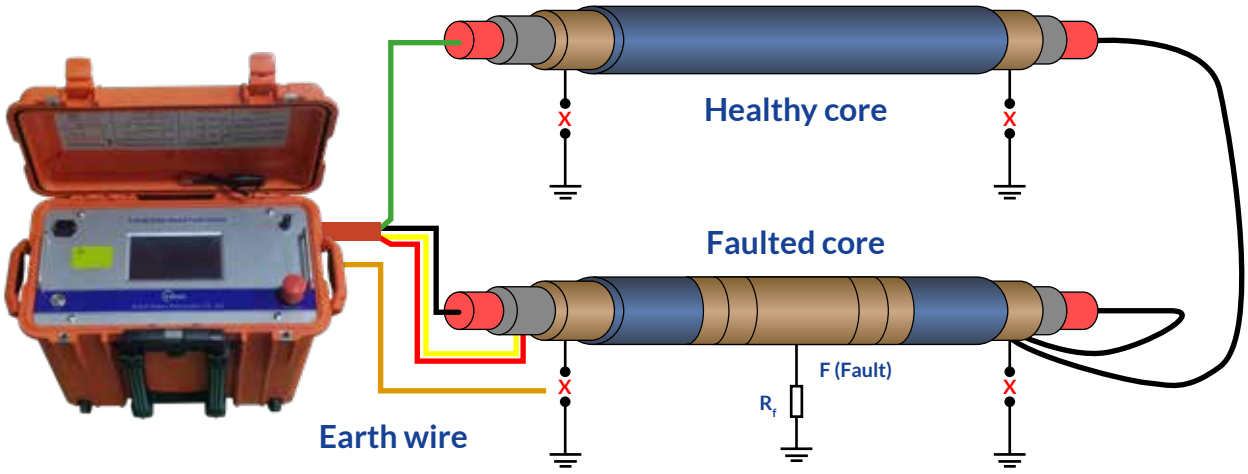
Cable Sheath Fault Location

Cable sheath faults occur when the outer insulation of a buried cable is damaged, exposing the metallic sheath to the earth. This cannot be detected by using a surge generator, as with core faults, as there will not be a flashover. Therefore, the TDR pre-location will not identify the fault and there is no acoustic signal to use for pinpointing. Under these circumstances, alternative methods of fault detection and pinpointing are required.

Sheath Fault Pre-location using T-H300

The suspect cable sheath is connected to a healthy core or to another healthy sheath at the remote end. Current is injected into the cable sheath from the T-H300, and the DC voltage is measured between the sheath and the core. There is no current flow from the fault point to the near end of the sheath where the voltage is measured, therefore they are of equal potential and so the measured voltage is effectively the voltage drop across the faulty section of the sheath. The DC resistance (R) between the measured point and the fault can thus be calculated as: R = V/i (where V is the measured voltage and i is the measured current).

Alternatively, the bridge feature of the T-H300 can calculate the distance to the fault using the Murray Loop technique, in which the faulty core is short-circuited with a healthy one and connected to the test set. A variable impedance in the test set is adjusted until the system is balanced, indicated by the measured voltage across the terminals of the cables equalling zero. At this point, the ratio of the direct impedance to the fault and that through the healthy core is equal to the ratio of the impedances in the test set. From this, the distance to fault can be calculated.



T-H300 Sheath Fault Locator

The T-H300 provides an accurate automatic or manual fault location for cable sheath faults. It utilises either a bridge, working on the Murray Loop principle or the DC resistance method, both in conjunction with an internal high voltage DC source. The device can be used in automatic mode, providing accurate fault location based on only entering the cable length, or manual mode can be used. The equipment also allows the measurement of insulation impedance.

Features

- **Automatic or manual sheath fault location**
- **Insulation resistance testing and measurement**
- **Integral high voltage source**
- **7-inch touch screen interface with menu-guided test procedures**
- **Independent of the internal resistance and contact resistance of the test leads, resulting in high measurement accuracy**
- **Unaffected by measurement current fluctuations and highly resistant to interference**

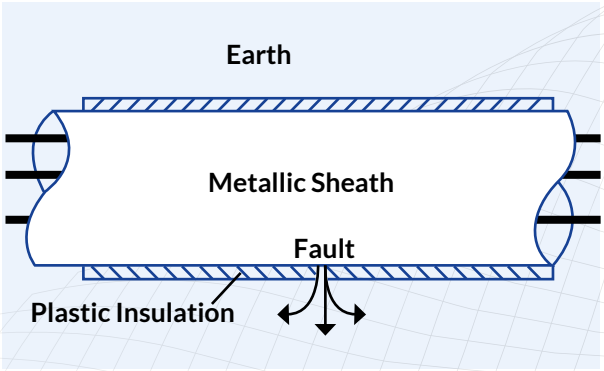
T-H300 Technical Data	
Output voltage	0 – 12kV
Output current	0 – 50mA
Current measurement range	0-50mA; resolution: 10μA
Voltage test range	0 - 50mV; resolution 10μV
Measurement distance error	1%
Power supply	AC220V 50/60Hz
Dimensions	500mm x 457mm x 305mm
Weight	20kg
Storage temperature	-20°C to +60°C
Working temperature	-10°C to +50°C
Relative humidity	25°C (20~90)%RH
Atmospheric pressure	86 – 106 kPa

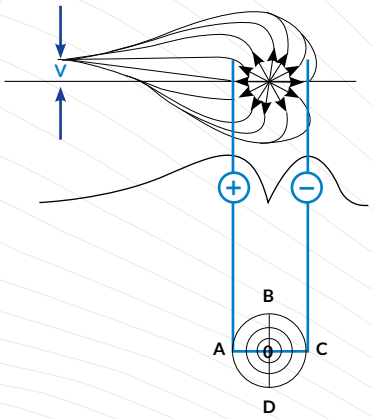
Cable Sheath Fault Pinpointing

When a cable is buried, it can be considered to be surrounded by the earth at all points along its length but due to its insulation, the fault is the one point of galvanic contact between the sheath and the earth.

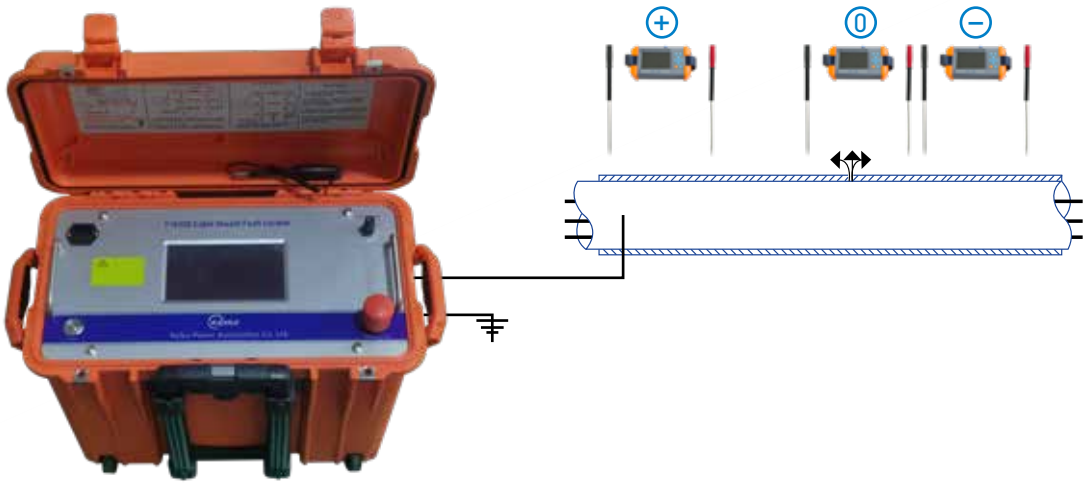
If a voltage is applied between the metallic sheath and the earth it produces currents which expand in to the ground.

An idealised plan view of the fault (diagram below right, where the centre of the circle is 0) indicates the concentric points of equipotential (the pool of potential), such that the voltages at A, B, C and D are equal but A -0 is positive, whereas 0 - C is negative. It should be noted that in a real situation the voltage rise on the source side is more gradual and so the equipotential lines will not be circular.





The T-KF200 uses this phenomenon to pinpoint the sheath fault. The faulty cable is disconnected from the supply and the earth, the T-100C is connected to its metallic sheath and a voltage applied. The spikes are inserted in the ground as far apart as possible and the polarity of the reading on the T-KF200 is noted. The test is repeated at regular intervals along the cable path, until a change in the polarity is noted. The null point between the peaks of polarity will represent the position of the fault.



T-KF200 Cable Sheath Fault Pinpointer

The T-KF200 can pinpoint the location of a fault on a buried power cable sheath using the Pool of Potential method. The unit can receive a signal generated by the T-KF200 voltage source.

If a cable is not buried in the ground, the T-KF200 can also determine the direction of the fault using its current sensing accessory, then find its exact position through sectionalising (i.e. determining the current direction at different access points on the cable, until the faulty section is identified).

For applications where a cable is laid on cable supports (cleats), such as in dedicated cable tunnels or pipe trenches, faults can be pinpointed using a high voltage probe.

T-KF200 Technical Data	
Modes of operation	Step-voltage pinpointing Fault current pinpointing High voltage probe pinpointing Current signal, sensor input
Step voltage (Ground spikes)	Accuracy 1% (±0.1mV) Maximum sensitivity 0.1mV Maximum input range ±300V
Fault current pinpointing (Current sensor)	Accuracy 1% (±1mA) Maximum sensitivity 1mA Maximum input range ±1mA
High voltage probe pinpointing (High voltage probe)	Accuracy <1% (10V – 10kV) Maximum sensitivity 1V (10V – 1kV); 10V (1kV – 10kV) Maximum input range ±10kV
Built-in battery	18650 lithium Battery, nominal 3.7V, 6.8Ah
Operating temperature	-10°C to 50°C
Dimensions	220mm×125mm×55mm
Weight	0.9kg

Features

- **High sensitivity and large response range.**
- **The fault point can be segmented by measuring the resistive current in the faulty cable with a current sensor.**
- **Fault location on cleat mounted cables using a high voltage sensor**
- **High-performance rechargeable lithium battery, continuous operation for more than 8 hours.**
- **Rugged housing, lightweight and portable.**

T-P23 Online Low Voltage Transient Fault Location

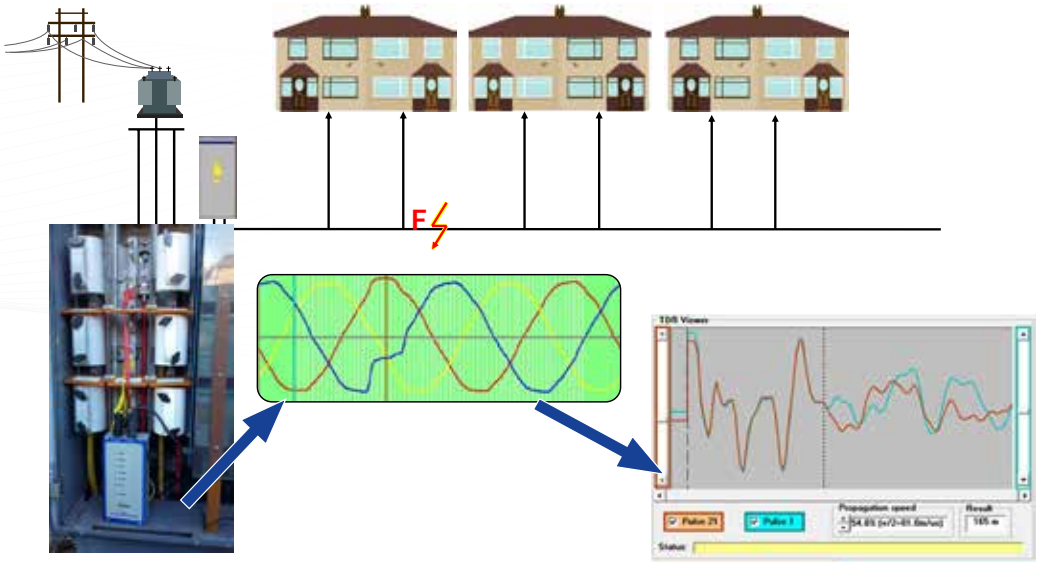
The Kehui T-P23 has been designed for the location of all types of low voltage cable fault, without the need to disconnect consumers. If a fault is suspected on an LV cable, due to a blown fuse or customer complaints, the device is connected to the cable at the substation or at an intermediate location, such as a fuse or link box. When a fault triggers the device a Time-Domain Reflectometry (TDR) test is performed on a pre-set combination of phases. A transient recorder is included to display the 3-phase voltages of the faulty cable, so that the exact nature and behaviour of intermittent faults can be identified.

In addition to its use as a TDR, quasi-synchronous Travelling Wave Fault Location can be performed using two, Kehui T-P23 units, providing two sets of results which can enhance the accuracy. The 3 phase voltage recordings from any two, or more, Kehui T-P23 units can also be used for Fault Location using the Voltage Gradient method.

The T-P23 can be controlled locally using a wirelessly connected PC or tablet. However, the device can also be remotely controlled over the GPRS network. This allows connection to a faulty cable by field staff, with the interpretation of the results provided by a centrally located specialist. This becomes particularly beneficial when the equipment has to be left on-site awaiting the recurrence of an intermittent fault.

Features

- **Locates all LV cable faults including transient and intermittent faults**
- **Monitors all three voltage phases simultaneously**
- **Remote control using integral GSM/GPRS modem**
- **Automatic remote notification of trigger and access to records**
- **Self-powered from the supervised cable, through the test leads**



Kehui International Ltd.
2 Centrus, Mead Lane
Hertford SG13 7GX
United Kingdom
Tel: +44 (0) 1920 358990 | Email: info@kehui.com | www.kehui.com

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