T-NM1 Network Simulation Unit
User Manual
Version 1.3

Kehui International Ltd
9 Crane Mead Business Park
Viaduct Way, Ware, Hertfordshire
UK, SG12 9PZ
Phone: (44) 1920 358990
Fax: (44) 1920 358990
Website: http://kehui.com

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Revision history:

Version	Revision date	Revision reason	Person
1.0	2021.11.22	New document	AndWan/BilKib
1.1	2021.11.22	Changes to procedure	BilKib
1.2	2025.03.31	Addition of push-button	BilKib
1.3	2026.06.02	Address and general revision	

Document number: T-NM1_UM_EN

Table of Contents

1. Foreword

Thank you for purchasing Kehui's Network Simulator (hereinafter referred to as T-NM1).

The T-NM1 is used to simulate an LV cable network. Its main application is to provide a demonstration of how to use fault locator equipment, to train engineers on how to find faults on an LV cable.

The equipment consists of 200 m of cable, providing three phases, neutral and a metallic sheath. The cable is split into ten sections of varying length to allow faults to be applied in different places and to allow different configurations. In addition, six 10m lengths of cable can be configured as single-phase branches.

The network can be energised using the Kehui T-MNS1 isolating transformer, to simulate testing on a live system. This is particularly useful to allow the testing of the Kehui T-P22 or T-P23 fault locator, which monitors live systems. In conjunction with this, accessories are available to create transient faults on the system, to detect using the T-P23.

Throughout the manual the three phases are referred to as Red, Yellow and Blue. Alternative designations such as L1, L2, L3; A, B, C; Red, White, Blue etc. should be referred to this convention.

Similarly, the term Earth has been used throughout the manual in preference to Ground but the two terms can be considered synonymous.

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.

2. Safety Instructions

Safety Note: This user manual is the basic operating guide for the T-NM1. Any operator who will use the T-NM1 should read the entire contents of this manual in advance. The manufacturer of this product is not responsible for the loss caused by the operator's failure to comply with the operating procedures of this manual or for violation of the safe working procedures of the operator.

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

Symbol	Meaning
	Indicates a potential hazard that could result in fatal or serious injury
	Indicates a potential hazard which, if not avoided, may result in minor personal injury or property damage.
	Indicates that it contains important information and useful guidance for using this product. Failure to heed this information will result in the 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 such as maintenance, cable fault detection, on-site test consultation, etc., please contact info@kehui.com

3. Introduction

3.1 Product features

The Kehui low voltage (LV) cable network simulator provides a representation of a cable system for training and development applications. It is built from small cross-section four-core screened cable, which provides a realistic representation of a network. Using materials physical lengths of cable, it provides a simulation that is more accurate than one using discrete R, L & C component-based analogue models or computer software simulations. The flexible design allows branches to be added to the network at different positions and for various faults to be simulated.

3.2 Scope of application

Although the device can be used in a variety of ways, its principal application is to facilitate the use of fault location equipment for training and testing purposes. The network can be used un-energised, to demonstrate the use of fault locators using time domain reflectometry (TDR) instruments and other methods. When energised using the Kehui T-NMS1 Isolating Transformer 'on-line' network monitoring devices, such as the Kehui T-P23 can be demonstrated.

The T-NM1 LV Network Model consists of 10 sections of shielded 4-core cable in different lengths. Section 1 is 10 meters long and is connected between the left side of the network and socket 1 of the network model. Section 2 is 25m long and is connected between sockets 1 and 2 and so on. The Table below shows the length of each of the sections. The total length of cable, ignoring branches, is 200m.

To simulate an LV branched network, there are six, 2-core single-phase cables (each 10 meters in length), which can be used as single-phase branches. A selection of links with shrouded 4mm plugs, is included to facilitate this.

4. Key Features

- Accurate 3 phase representation of LV network of up to 200m in length
- Neutral and earth paths included
- Can be energised using an isolating transformer
- Simulation of permanent and transient phase and earth faults
- Standard 4mm shielded plug connections
- Flexible arrangement of line length and branch locations
- Neon indicators connected between the phases and the cable sheath, to show whether the cable is live

5. Internal Wiring

5.1 Overview

Figure 4.1 shows the front panel of the T-NM1 LV Network Model. On the top half of the panel, there are 5 different coloured lines representing the three phases (red, yellow, blue), the neutral (Black) and the cable screen (green). Each line has fourteen 4mm sockets divided into four groups, each connected to its neighbour by a link.

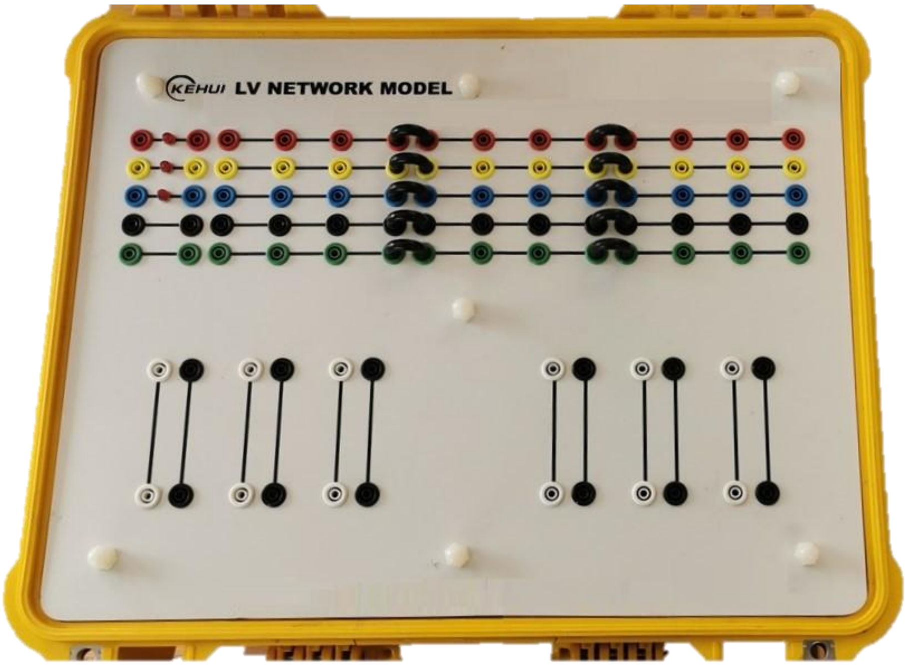


Figure 4.1 - Front panel of the LV Network Model

The six black and white sections at the bottom of the panel, each represent a 10m single-phase branch that can be connected to the main cable at the different nodes to give different phases and positions.

5.2 Layout

The divisions (Groups) and sub-divisions (Sections) of the cables is shown in figure 4.2.

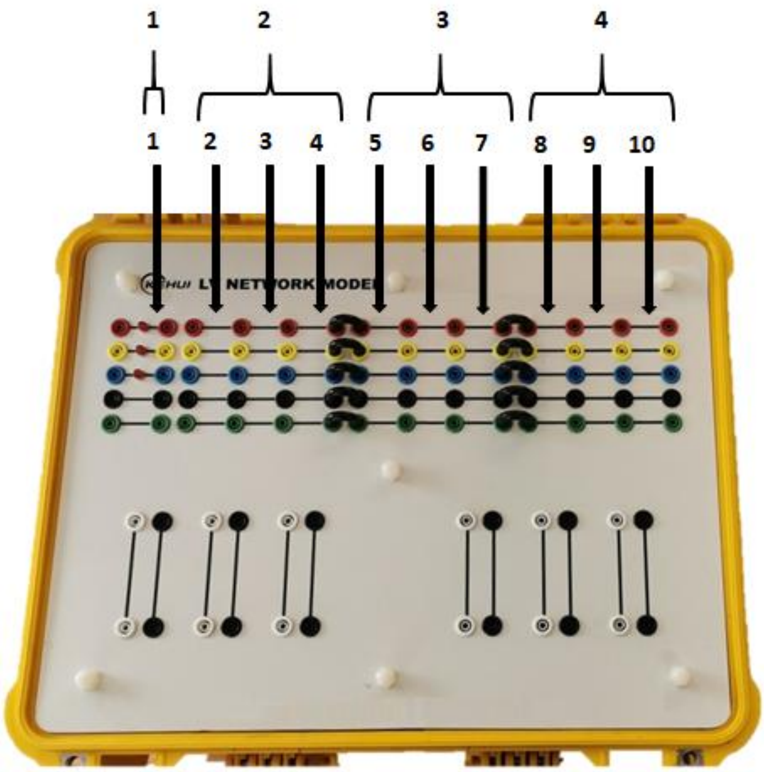


Table 4.2 - Length of each cable group and sub-section

Group	1	2			3			4		
Length (m)	10	55			75			60		
Section	1	2	3	4	5	6	7	8	9	10
Length (m)*	10	25	15	15	35	30	10	15	15	30

* Approximate lengths, each T-NM1 has a calibrated chart supplied in the lid

The 10 sections of cable are divided into four groups. The first section is 10 meters long and is designated as group 1. Group 2 consists of cable sections 2, 3 and 4 which sum to a total of 55 meters. Similarly, group 3 is made up of sections 5, 6 and 7, totalling 75 meters and finally, group 4, consists of sections 8, 9 and 10 containing 60 meters of cable.

There are three sets of links to connect these four groups allowing a long cable to be created, with a total length of 200 meters. As shown in figure 1, these are located at socket 1, 4 and 7 respectively. An open circuit can be made by selecting one of these locations and removing the link links on the required phase. To make a short circuit, on the unenergised network model, a piece of cable is connected between terminals on different phases, the neutral or the shield as required.

There are six branches, shown in black and white, each of which is 10m long.

5.3 Branched Network Connection

Figure 4.3 shows the network model in which a single-phase branch (white terminal) is connected in to the red-phase socket between sections 3 and 4. The branch neutral (black terminal) is also connected to the black terminal of the same group. If more branches are required on the simulated network, these can be made in the same way, with connections to the appropriate phase, up to a maximum of six.

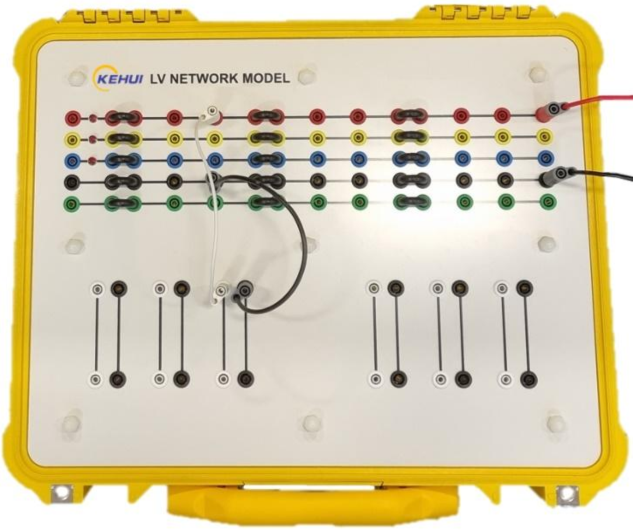


Figure 4.3 - LV cable network with a single-phase branch connected

6. Applying Faults to the Unenergised Network Model

6.1 Open Circuit fault

Figure 5.1 shows a network with an open circuit on the yellow phase, at the interface of the third and fourth groups (marked in red), whereby the yellow phase of the cable group 4 is disconnected from the rest of the network. This means that the yellow phase is broken 140 meters from one end and 60 meters from the other, while the other two phases retain their full cable length of 200 meters.

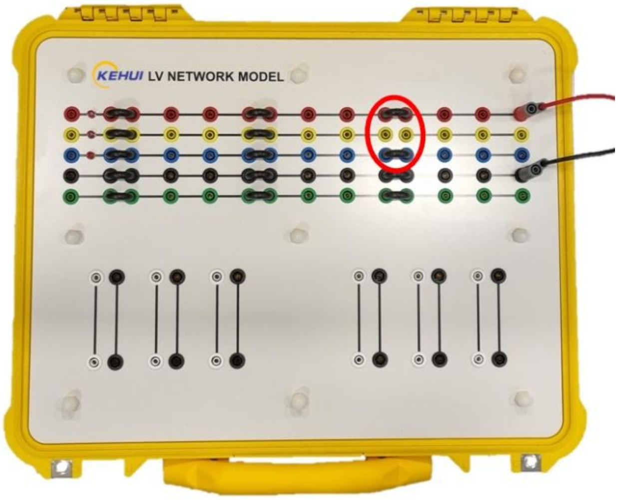


Figure 5.1 - LV cable network with an open circuit on the yellow phase

6.2 Short Circuit fault

There are two different ways of simulating a short circuit fault when using the T-NM1 unenergised.

The simplest method is to connect one or more of the phases to the neutral. Note this method is intended for use with a TDR unit. In this case the fault is on the red phase, 100m from one end.

This method must only be used when the T-NM1 is not energised as, if power is present, it will cause an actual short circuit, which will result in the operation of its protection circuits.

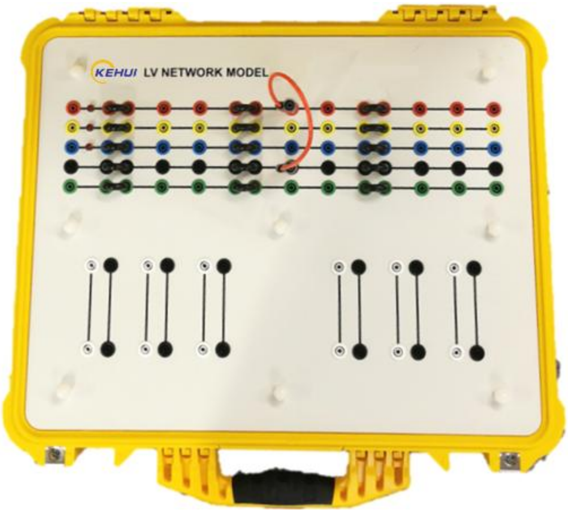


Figure 5.2 - LV cable network with a short circuit on the red phase

Alternatively, a T-PMU1 marker unit can be inserted into the required position on the T-NM1 to simulate the fault. When a TDR signal is applied to the network, the marker unit will appear as a short-circuit and cause the TDR pulse to be reflected.

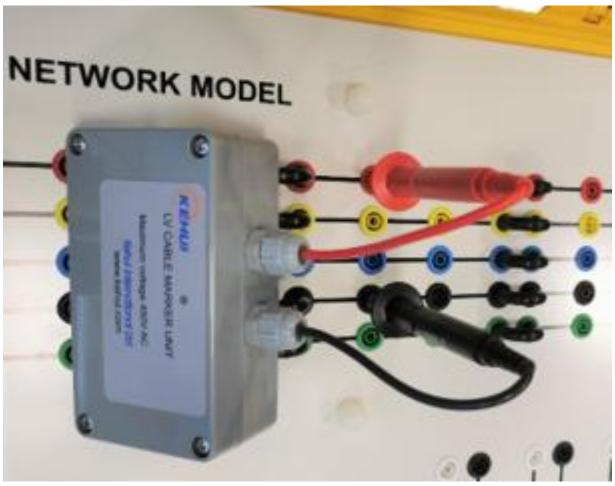


Figure 5.3 - LV cable network with a short circuit simulated by marker unit on the red phase

6.3 Resultant waveforms

For an open circuit fault, the reflected wave will have a positive polarity and for short circuit and low impedance faults, the reflected wave will have a negative polarity. A comparison of these scenarios is shown in Figure 5.4. The reflection from an open circuit is shown in red and from a short-circuit in yellow

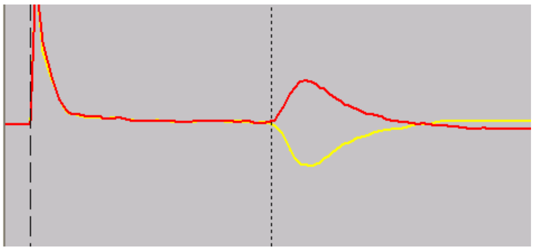


Figure 5.4: Comparison of TDR signals reflected from open and short-circuits

In Figure 3.1 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 fault point. 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 simulated fault point and return to the instrument, therefore the distance measurement must be divided by 2.

Hence if L_x is the distance to the simulated fault point, v is the propagation velocity of the pulse and Δt is the time measure by the cursor, the line length can be expressed as:

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

7. Powering the Network Model

If a live network is required, for applications such as the testing of the Kehui T-P22 or T-P23, the LV Network Model can be powered using the Kehui T-NMS1 isolating transformer (figure 6.1a). This will ensure the power supply is protected when faults are simulated. The unit is connected to the T-NM1 through a blocking coil (figure 6.1b). This serves the dual purpose of blocking the transmission of TDR pulses into the T-NMS1 and amplifying the current so that it can be used by the current input on a Kehui T-P22 unit.

When carrying out these tests, it is recommended that the operating manual for the device under test is at hand.

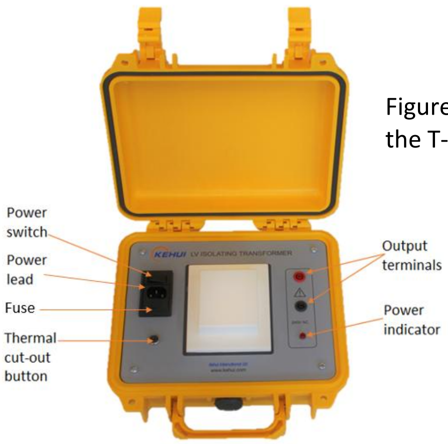


Figure 6.1a T-NMS1 providing power for the T-NM1 LV Network Model

Figure 6.1b Blocking coil

Figure 6.2 shows the connection between the two units; it is recommended to connect the power supply through the blocking coil. In the diagram the coloured wires on the right of the T-NM1 unit (connected in this example, on the last terminal of Group 4) are the connections to a Kehui T-P23 unit and the cable on the left of the T-NMS1 is its mains lead.

To energise the unit, operate the power switch, the power indicator will light and the corresponding indicator on the live phase of the T-NM1 will also illuminate.

Figure 6.2 – T-NMS1 providing power for the T-NM1 LV Network Model

Some network monitors, such as the Kehui T-P22, require a current input in addition to the voltage inputs.

When used in the field, the T-P22 unit receives its current input through a clamp CT, connected around the cable being monitored. In the model, the current can only be accessed between the T-NMS1 and the T-NM1. Figure 5.3 shows the clamp CT attached around the connection wire from the isolating transformer output to the phase A of the network model. It shows the blocking coil (supplied with the T-NMS1) attached around the CT in order to increase the current. This is necessary because the current used in the network model is very small.

Figure 6.3 –T-NM1 with current connection for T-P22

8. Applying Faults to the Energised Network Model

This section will only make reference to the T-P23 for clarity. All of the tests are equally applicable to the T-P22 except for the additional current connection shown in figure 6.3.

Only earth faults can be simulated on the energised T-NM1 as the supply is single phase.

8.1 Open Circuit fault

Open circuits on a live network model are created in exactly the same way as for unenergised systems (Figure 7.1), by removing a link on the phase with the fault. When performing this test, make sure that the T-P23 remains energised by either, ensuring the power supply is not connected to the line with the open circuit, or connecting the T-P23 and the power supply at the same end of the network. For this, it is important that the blocking coil is used to connect the power supply, as this has the effect of making the connection at an “open end”, otherwise a portion of the TDR pulse will travel back in to the power supply from where it will be reflected, producing a less distinct trace.

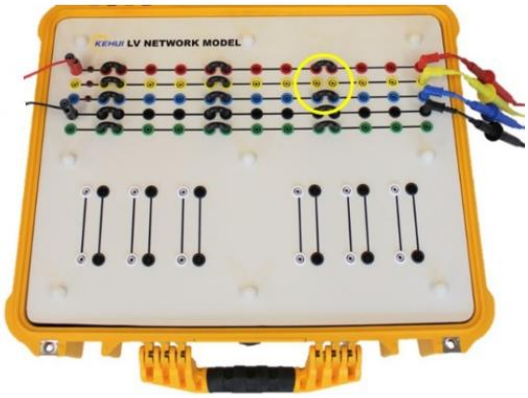


Figure 7.1 - LV cable network with an open circuit on the yellow phase

The open circuit can be examined using the T-P23 attached at the right-hand end of the network model. To do this, Test TDR pulses are injected into the three phases in turn. The resulting traces can then be displayed together as shown in Figure 7.2a and b. The yellow phase shows the reflection of the open circuit. Moving the cursor to the point at which the yellow trace deviates, shows it to be at 60m from the measuring point (figure 7.2a) which corresponds to the length of cable group 4 on the T-NM1. The reflections on the red and blue phases are from the line end, which is confirmed by the measurement showing the distance to be 200m (figure 7.2b) which is the length of cable in the T-NM1.

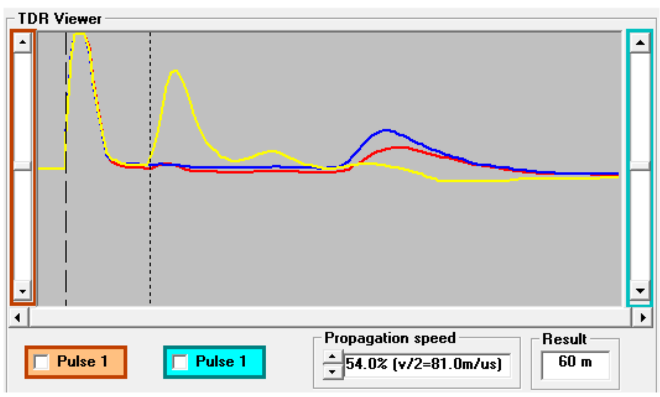


Figure 7.2a Distance to TDR reflection from a yellow phase open circuit

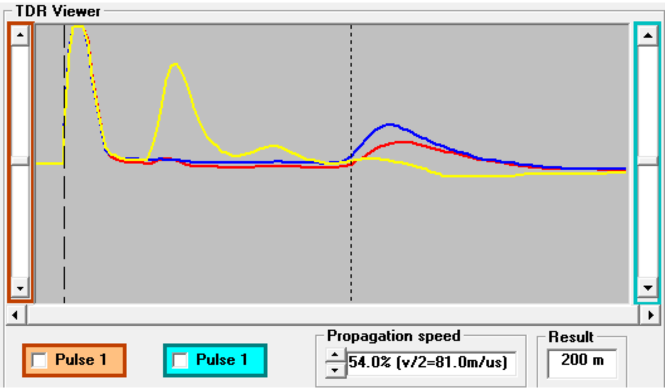


Figure 7.2a Distance to TDR reflection from the end of the cable

8.2 Short Circuit fault

A simple short circuit including the live phase must not be used when the T-NM1 is energised with the T-NMS1, as it will cause an actual short circuit which will result in the operation of its protection circuits. However, it is permissible to apply simple short circuits to the other two phases, which can be detected by the fault locator

Alternatively, if an earth fault is required on the live phase the fault switch can be inserted into the required position on the T-NM1 to simulate a short-circuit fault (figure 7.3). Care must be taken to press the button for a very short period, preferably a short jab. If the fault is applied for too long, it may initiate the protection on the power supply.

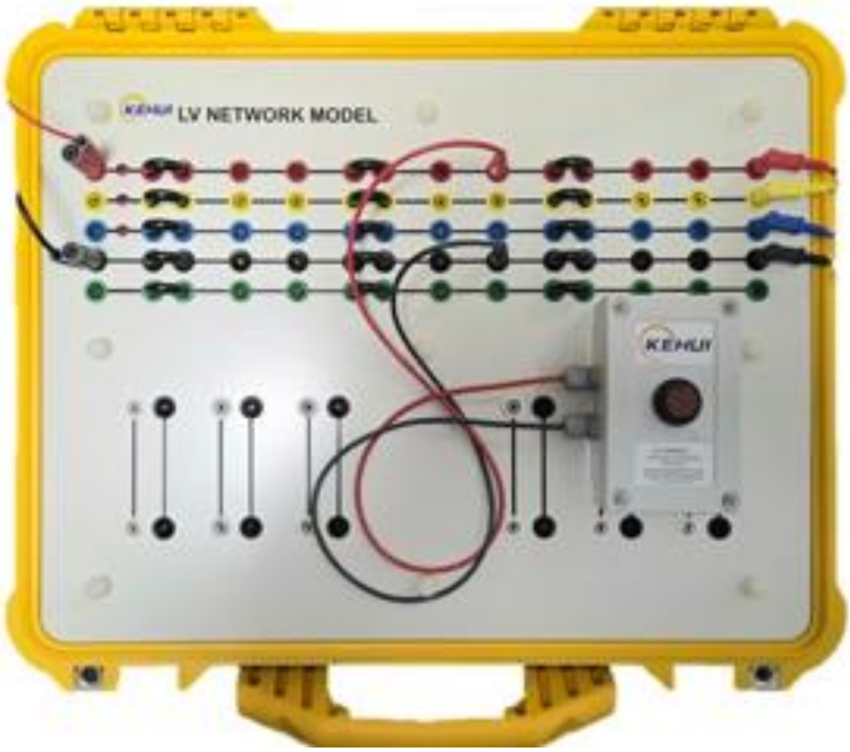


Figure 7.3 Energised LV cable network with a short circuit simulated by the push-button

Figure 7.4 Fault simulation push-button

Using the manual trigger facility and ensuring that the correct phase is selected in the T-P2X Master software, triggering the T-P23 will result in the waveform shown in Figure 7.4, where the blue trace is the pre-trigger reflection from the line end and the brown trace is the reflection caused by the short-circuit.

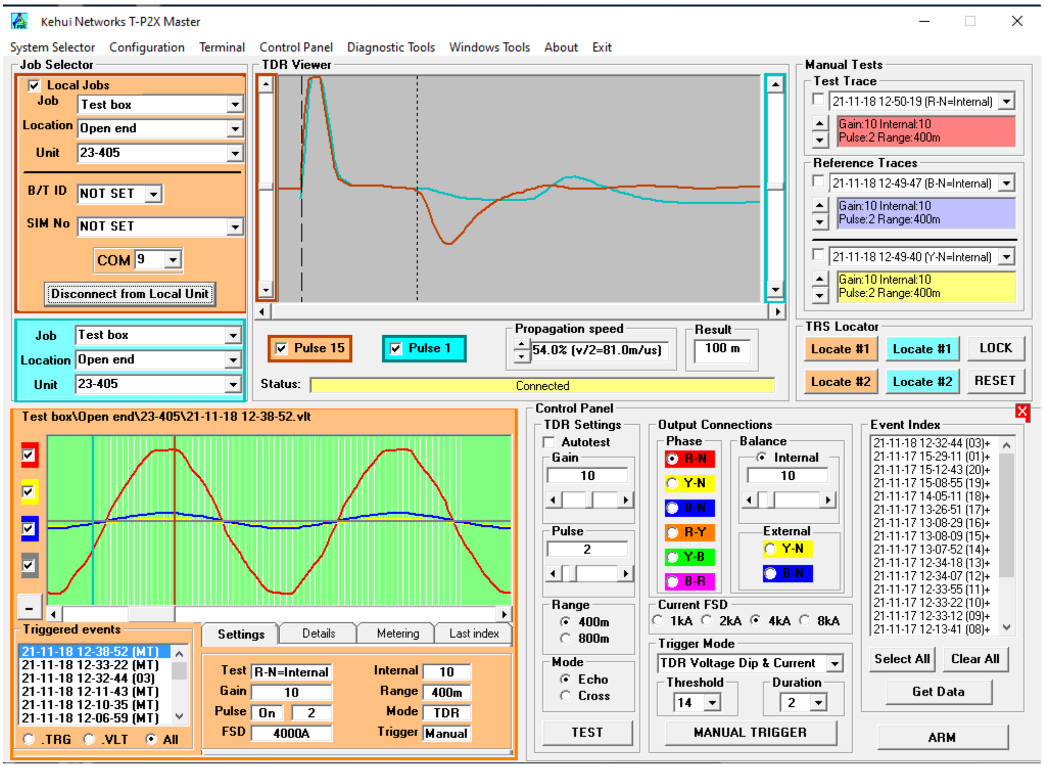


Figure 7.5 T-P2X Master software showing a trace from a short-circuit created with the T-MU240

Single TDR pulses can now be launched from the T-P23 using the TEST function in the T-P2X Master software. These should be sent on all three phases and displayed together in the Test Trace section of the T-P2X Master by ticking the three traces (figure 7.6).

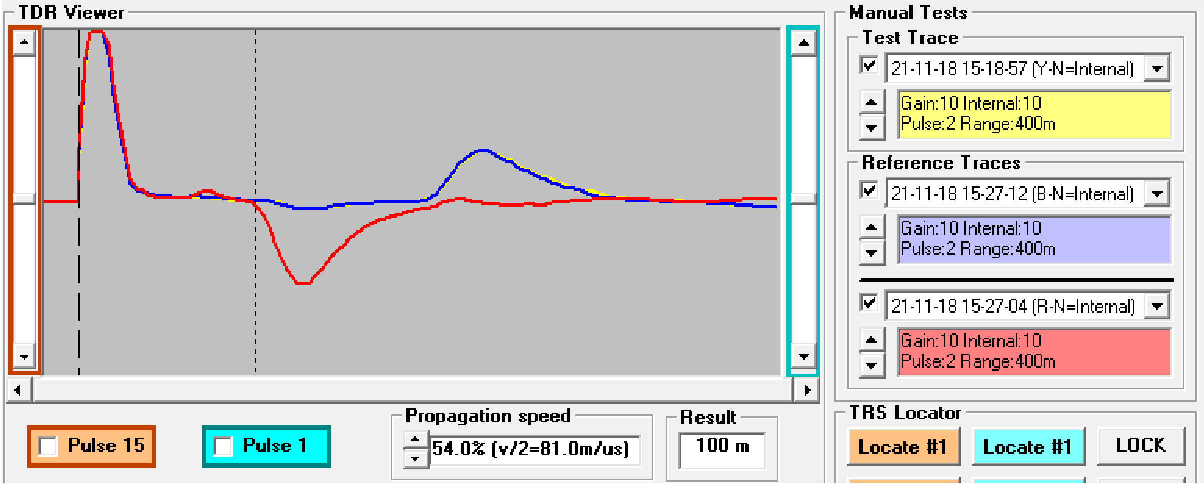


Figure 7.6 T-P2X Master software showing a short-circuit on the red phase

The negative reflection is on the red phase at 100m, with the other two phases reflected from the open-circuit at the end of the cable. As the blue and yellow phase cables are identical, the yellow trace is hidden behind the blue.

Introducing an open circuit on the yellow phase at 130m, by removing one of the links, shows the resulting positive reflection (figure 7.7).

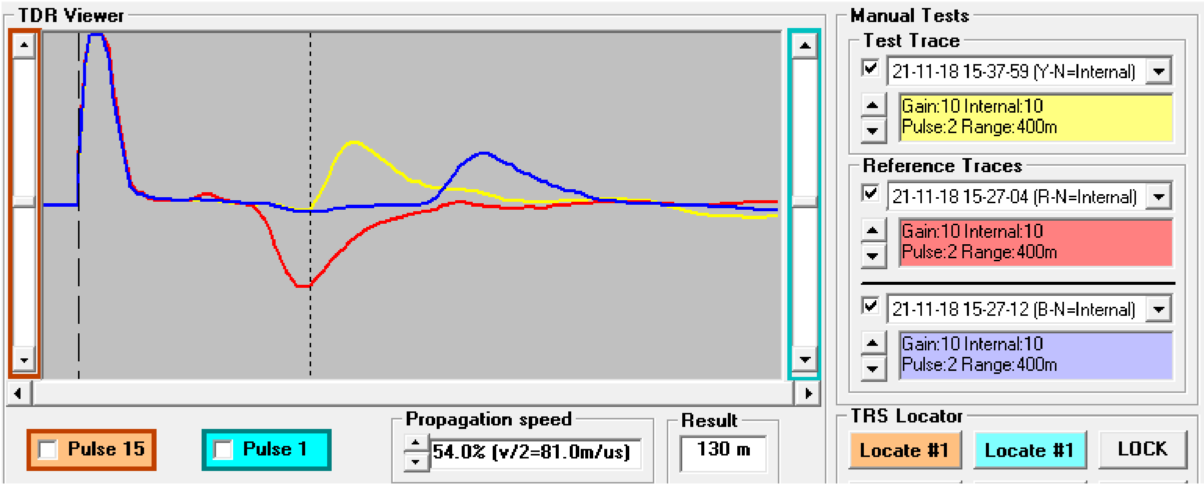


Figure 7.7 T-P2X Master software showing a short-circuit on the red phase and open circuit on the yellow phase

9. TRS Mode and the Network Model

The TRS mode is an enhanced fault location method. It requires two T-P23 devices which use a quasi-synchronous Travelling Wave Fault Location system. The units are connected at either end of a suspect cable such that when the cable fault ignites, they can detect the resultant travelling waves and calculate the distance to fault based on their arrival times.

To demonstrate the TRS mode, the network is energised as before, with the output from the T-NMS1 power supply unit connected to the lines for which the measurement is to be taken. The two T-P23 units are connected at each end of the cable in the network model (figure 8.1) with the relevant inputs connected via the T-NMS1 4mm plugs as shown in figure 8.2. The positive terminal of the TMNS-1 is connected via the blocking coil to whichever of the phases the user wants to energise.

Figure 8.1: Connection of T-NM1 Network Model connected to test TRS scheme

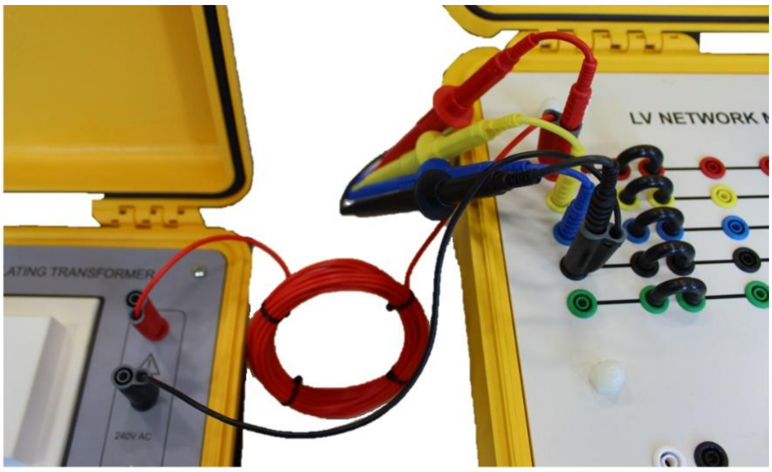


Figure 8.2: T-P23 connection for B-N fault with T-NMS1 power supply also connected

9.1 Synchronising pulses

To simulate the use of the T-P23 in the field, the first task is to check that the synchronising pulses are passing from one end to the other. To do this, the two T-P23 units are put in to TRS mode, one as a Master and the other as a Slave. Applying a TEST on the control panel to the Master unit will produce the trace shown in figure 8.3 with two spikes representing the synchronising pulses from the device to which the test was applied (the pulse from the local unit is on the extreme left of the display).

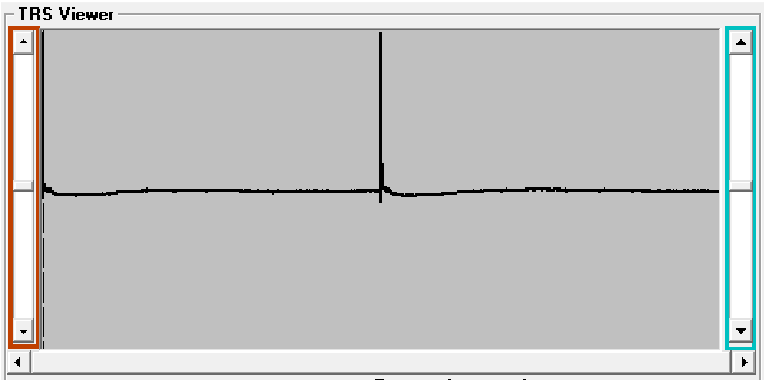


Figure 8.3 TRS synchronising pulses from a local unit

Putting both units in to Master mode and repeating the Test shows the additional synchronising pulses from the far end (Figure 8.4).

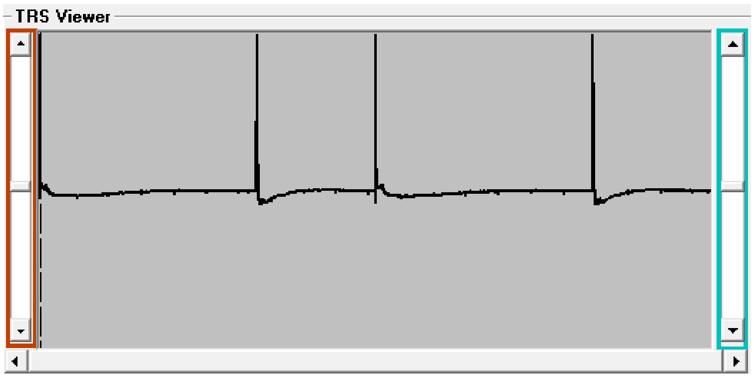


Figure 8.4 TRS synchronising pulses from the local and remote units

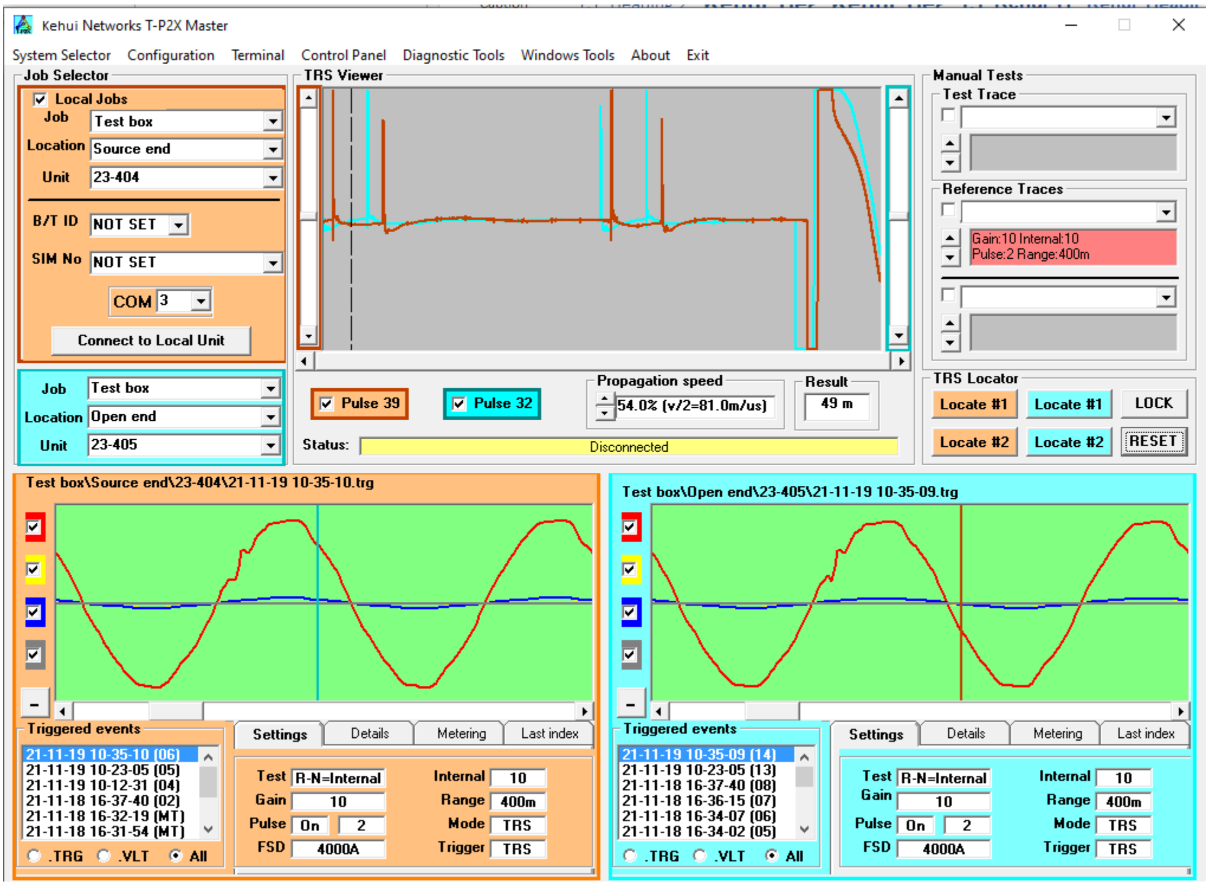
If this approach is used in the field, it is possible that the attenuation of the cable is too severe for the pulses to traverse it. In this situation a T-SU1 signal booster will be required.

9.2 Short Circuit fault

A disturbance can now be applied using the push-button. Ensure that the two units are set as Masters with the filter off. The black probe of the T-MU1 should be inserted into one of the lines on which the fault is to be applied and the red probe should momentarily be pushed into the relevant phase in the same group of terminals (figure 8.3). This will cause the two T-P23 units to trigger, saving a record in each of them. The record can be accessed from each unit and displayed in the T-P2X Master software (figure 8.4).

Figure 8.5 Applying a fault to the TRS scheme using the push-button

Figure 8.6 T-P2X Master screen after applying a fault to the TRS scheme using the push-button



The fault-finding process described in the appropriate manual is now followed and the results are displayed on the T-P2X master as shown in Figures 8.7a and b representing the fault location as seen from each end. The cable in the T-NM1 is 200m long, which is the sum of the two lengths. The resolution of the measurements is such, that such exact results are not always possible and small variations in length may be seen.

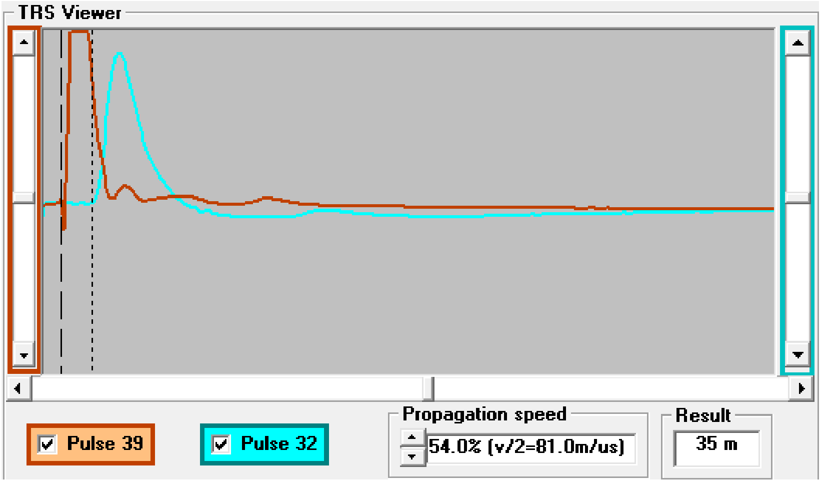


Figure 8.7a Fault location from the source end

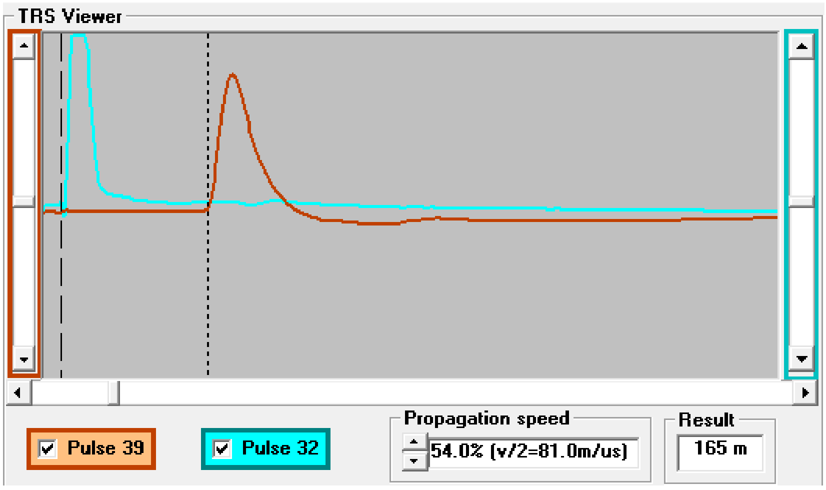


Figure 8.7b Fault location from the open end

Simulated faults can be applied in this way, on different phases and at different positions on the cable as required.

10. Packing List and Accessories

10.1 T-NM1 standard packing list

No.	Materials	Picture	Quantity
1	T-NM1 Units including leads and links		1
2	Fault push-button		1
3	Set of 5 Links		3 sets of 5 links
4	Cables (white and black)		6 pairs
	User Manual (free website download)		1

10.2 Accessories

10.2.1 T-NMS1 Isolating Transformer (ordered separately)

No.	Materials	Picture	Quantity
1	T-NMS1 Isolating transformer		1
2	Power cable (Type G plug is supplied as standard, alternative plug types must be stated with the order).		1
3	Blocking coil		1
4	Black connecting cables		1

10.2.2 T-MU1 Marker unit (ordered separately)

No.	Materials	Picture	Quantity
1	T-MU1 Marker unit with fused leads and crocodile clips		1
2	Probes for use with fused leads		1 pair