T-P22 Low Voltage Cable Fault Locator

- Remotely controllable TDR & Disturbance Recorder designed specifically for low voltage power cable fault location
- Locates ***permanent***, ***intermittent*** & ***transitory*** faults
- Safe connection to energised cables via heavy duty fused test leads
- Internal GSM modem allows control and interrogation from anywhere in the world
- Stores last 20 events with 64 TDR traces (30 'pre-fault' and 34 'post-fault') PLUS 10 cycles of AC voltage/current waveforms
- Triggered from voltage distortion and/or over-current
- Used in conjunction with **T-V22 LV Cable Fault Monitor** to provide ***3 phase voltage gradient fault location system***
- 2, or more, **T-P22** units can be configured to operate as a quasi-synchronous **Travelling Wave Fault Location System**

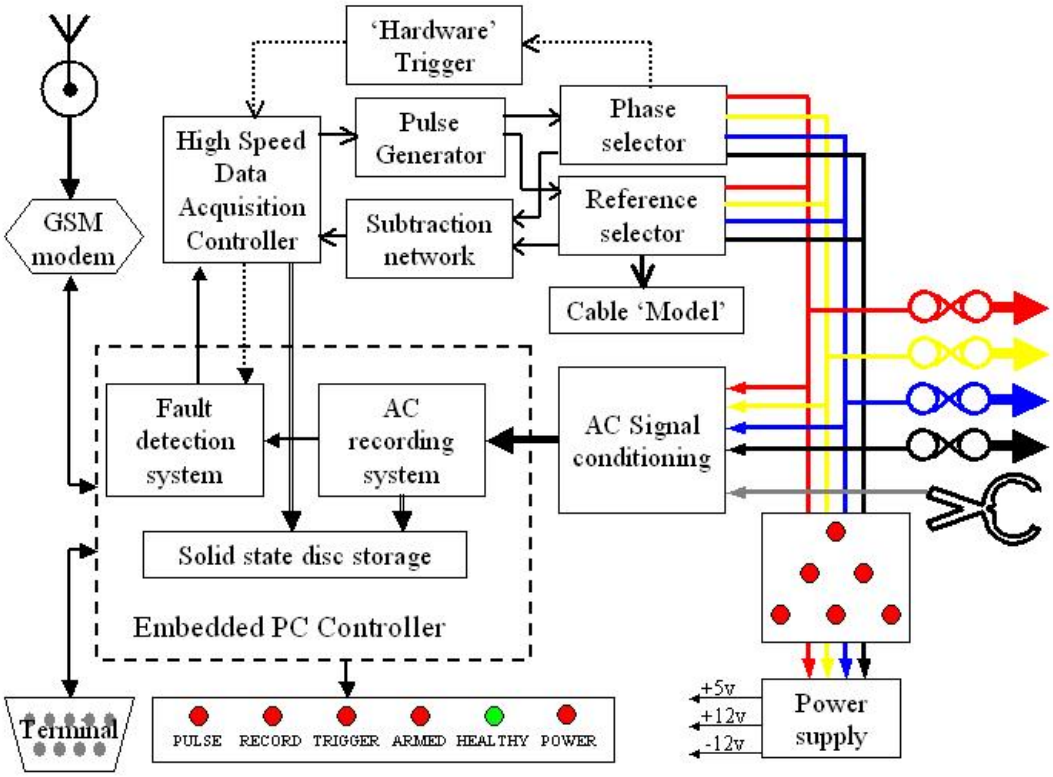
Description

The *Kehui* T-P22 has been designed for the location of all types of low voltage cable faults but especially the difficult and troublesome intermittent fault. It can be controlled locally from a portable PC or remotely over a telephone channel (either landline or GSM).

Unlike previously available TDR fault locators, the ***Kehui* T-P22** is connected simultaneously to all 3 phases of an LV cable to allow the local or remote operator to perform TDR testing on any combination of phases. Power for the ***Kehui* T-P22** is taken through the 3 phase test lead and the unit requires at least 1 phase to be energised.

The *Kehui* T-P22 includes a 4 channel transient recorder (3 voltages and 1 current) which is used to acquire information about the exact nature and behaviour of intermittent faults. The signals acquired by the transient recorder are also used to detect "trigger" conditions for the TDR system based on voltage distortion and/or over-current. Voltage recordings from several of ***Kehui* T-P22** units (and ***Kehui* T-V22 LV Cable Fault Monitors)** can be used for fault location by voltage gradient

By providing total control from a remote location the ***Kehui* T-P22** can be connected to a faulty cable by field staff who are not necessarily familiar with the analysis of TDR waveforms - the expertise in adjustment and interpretation being provided by a centrally located specialist. This becomes particularly beneficial when the equipment has to be left on-site awaiting the (re)-occurrence of an intermittent fault.



Block diagram of T-P22 Low Voltage Cable Fault Locator

T-P22 and accessories (3 phase fused test lead, CT clamp and cable & GSM antenna)

T-P22 Physical details:

Length	270 mm
Width	250 mm
Depth	120 mm
Weight	2.8 kg

Optional Accessories:

P-7 Blocking Coil

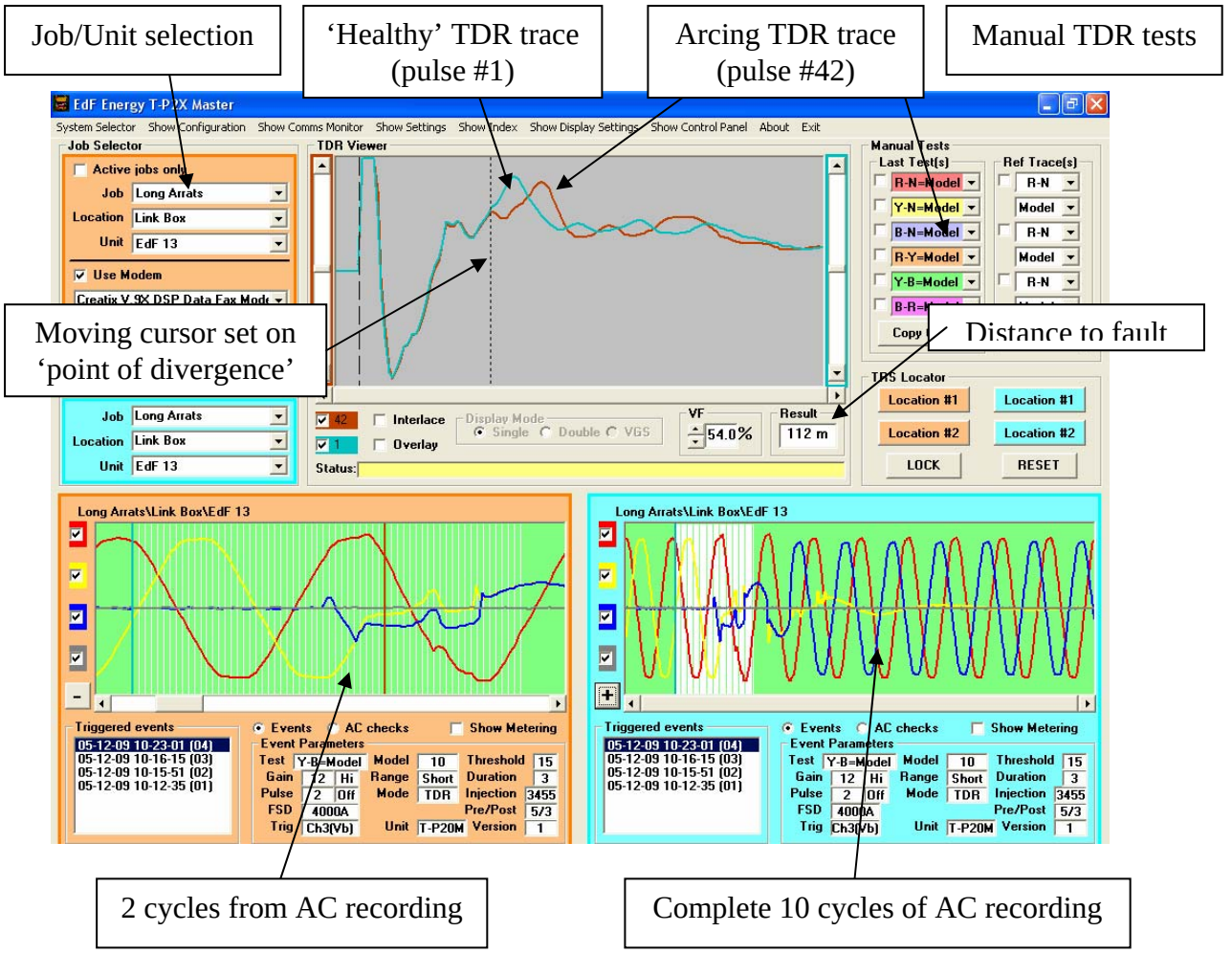
Fitted with 'Litton' connectors for insertion in series with REZAP feeder leads to 'isolate' the TDR pulse from the busbar.

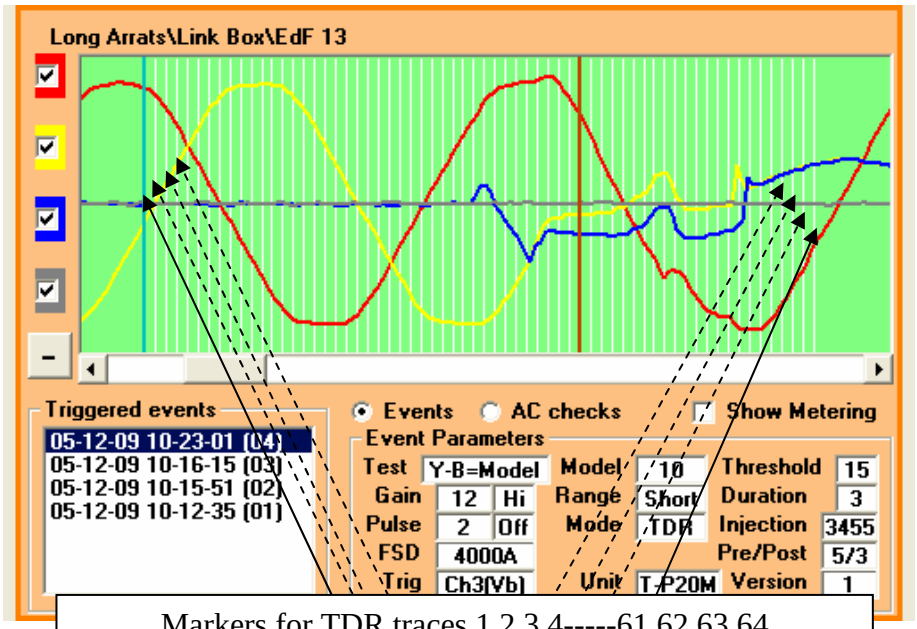
T-V22 LV Cable Fault Monitor

This unit is similar to the **T-P22,** but excludes the current transient recording channel and all TDR functions. It can be used for voltage complaint monitoring and, together with other **T-V22** and/or **T-P22** units, for voltage gradient fault location.

Length	210 mm
Width	165 mm
Depth	90 mm
Weight	1.5 kg

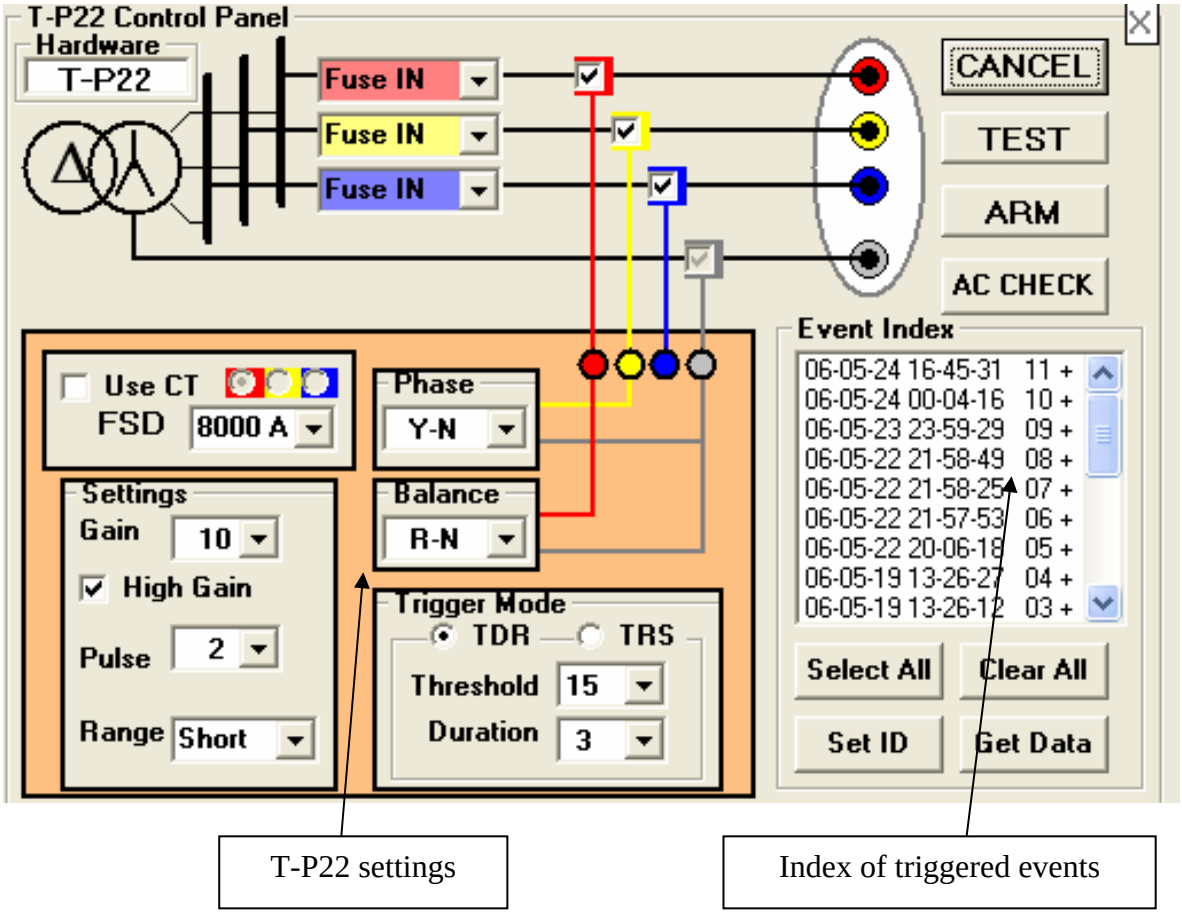
T-P2X Master - remote control, communication and analysis software





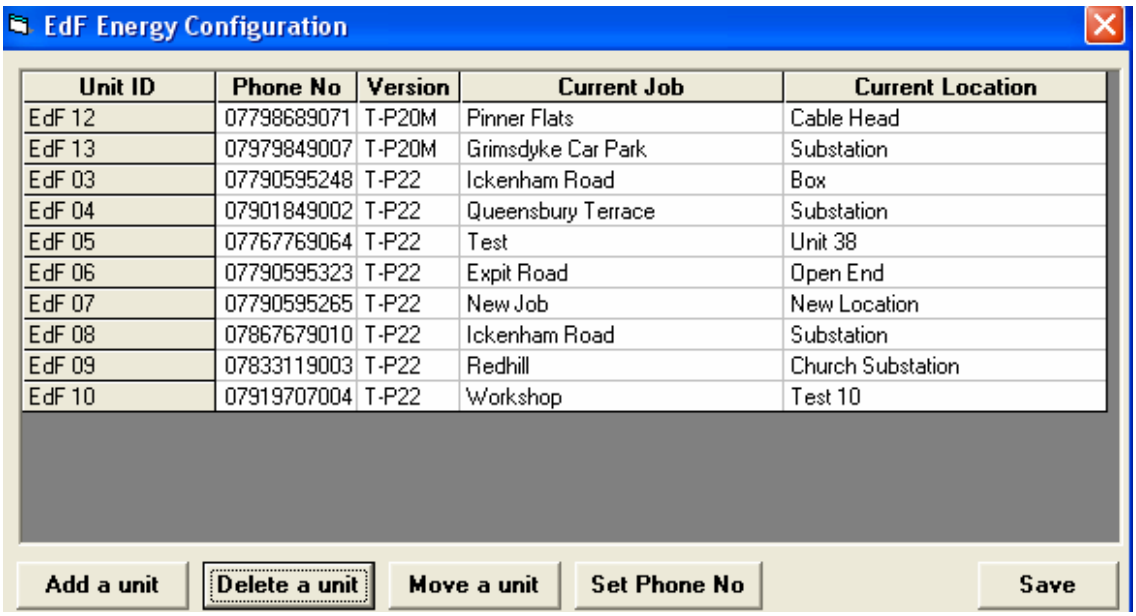
Markers for TDR traces 1,2,3,4-----61,62,63,64

Control Panel Window (appears when connected to a T-P22)



T-P22 settings

Index of triggered events

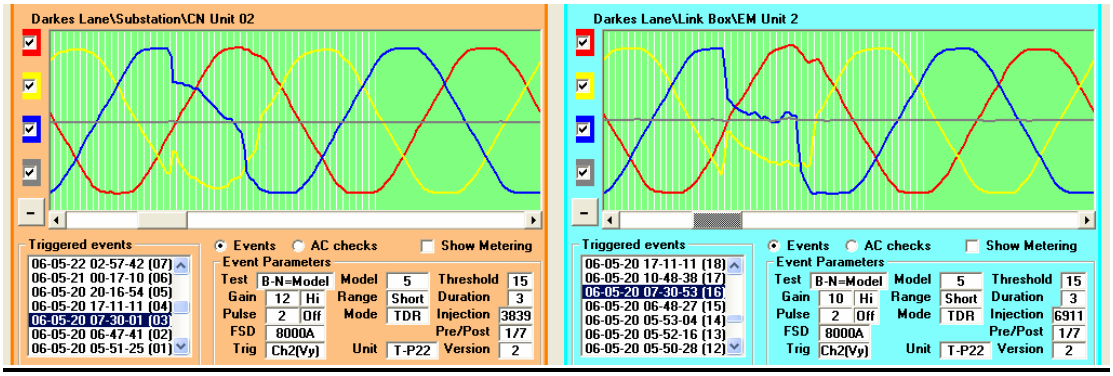


Unit ID	Phone No	Version	Current Job	Current Location
EdF 12	07798689071	T-P20M	Pinner Flats	Cable Head
EdF 13	07979849007	T-P20M	Grimsdyke Car Park	Substation
EdF 03	07790595248	T-P22	Ickenham Road	Box
EdF 04	07901849002	T-P22	Queensbury Terrace	Substation
EdF 05	07767769064	T-P22	Test	Unit 38
EdF 06	07790595323	T-P22	Expit Road	Open End
EdF 07	07790595265	T-P22	New Job	New Location
EdF 08	07867679010	T-P22	Ickenham Road	Substation
EdF 09	07833119003	T-P22	Redhill	Church Substation
EdF 10	07919707004	T-P22	Workshop	Test 10

Example of System Configuration Table

Examples of simultaneous voltage recordings

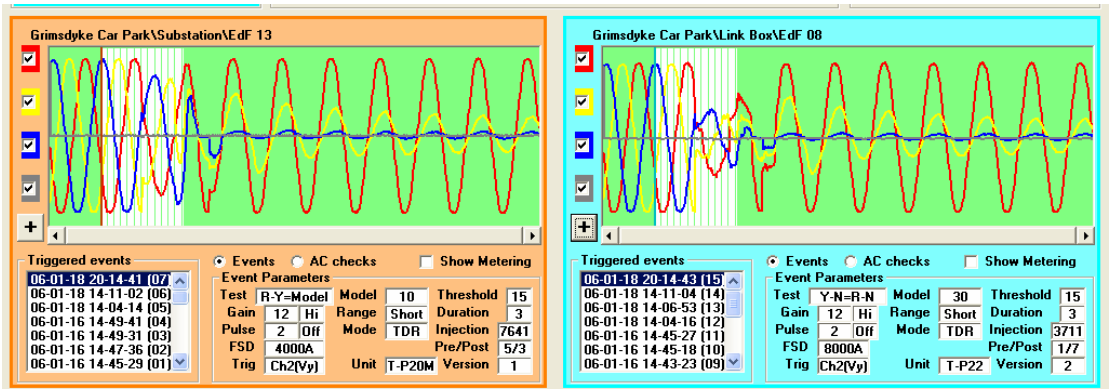
Transitory Fault on Main (less than half cycle duration



Voltage recording in substation

Voltage recording at far end

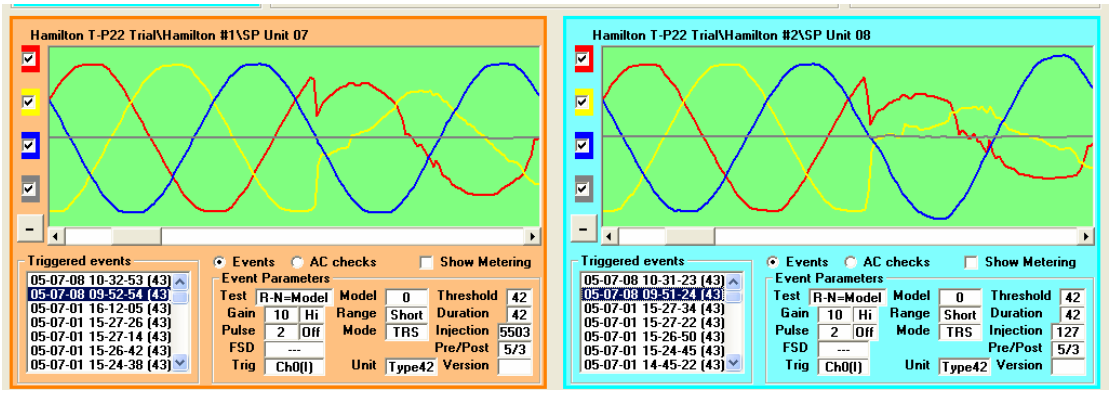
Intermittent Fault on Main



Voltage recording in substation

Voltage recording at far end

Intermittent Fault on branch off Main

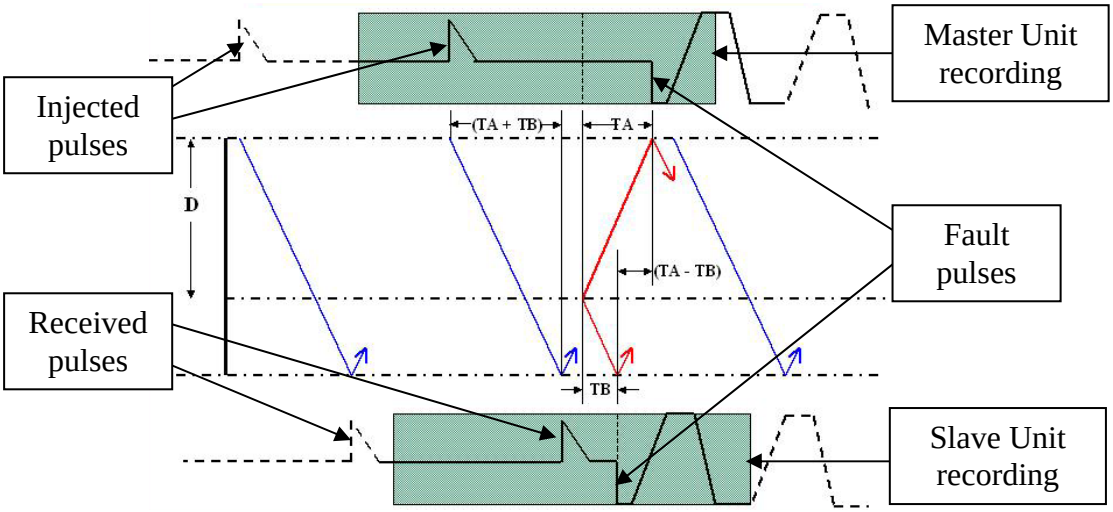


Voltage recording in substation

Voltage recording at far end

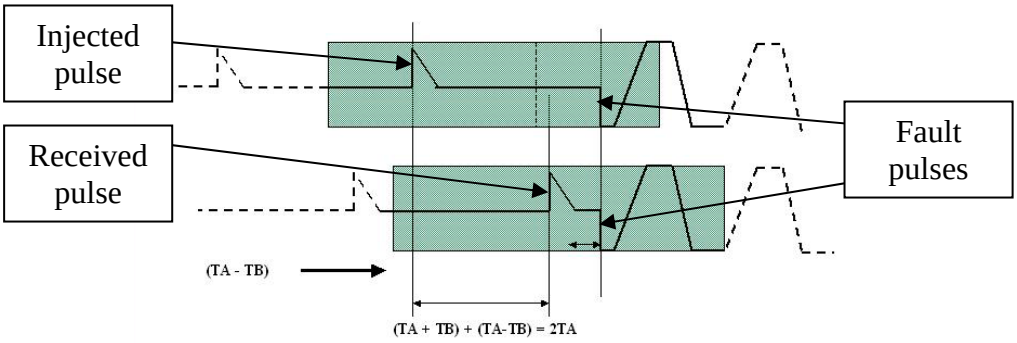
TRS Fault Location Method

The high frequency acquisition section of the *Kehui* **T-P22** can be remotely configured to operate as either a multi-pulse **TDR** or as a transient recorder (**TRS** mode). In the **TRS** mode, the pulse generator is enabled or disabled to make the **T-P22** a Master or Slave unit respectively. Two **T-P22** units are required for a Travelling Wave Fault Location System – located on either side of the fault position (generally in the substation and at the remote end).The diagrams below give a basic explanation of the method).



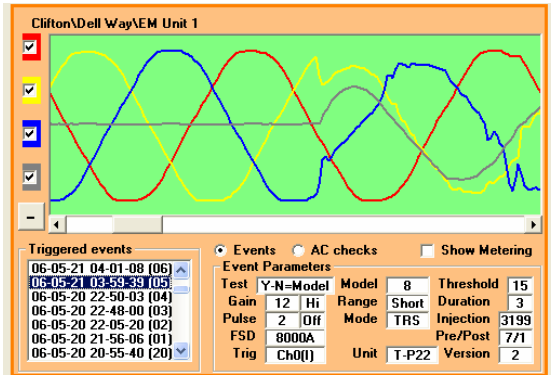
The lattice diagram above shows the transient recordings (green areas) of the Master and Slave units when triggered by the large high frequency signal generated by the fault (red line). The Master unit generates a continuous train of synchronising pulses (blue lines) which are too small to trigger either the Master or the Slave units.

The large fault pulses of the Master and Slave recordings are aligned and the fault is located by measuring the time interval between the injected and received synchronising pulses in the pre-trigger period of the Master and Slave unit recordings, as shown below.

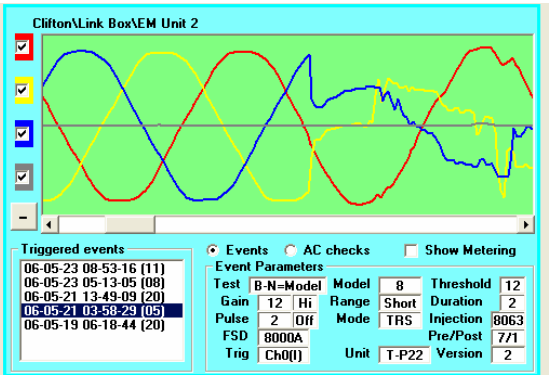


D = 2TA x v/2

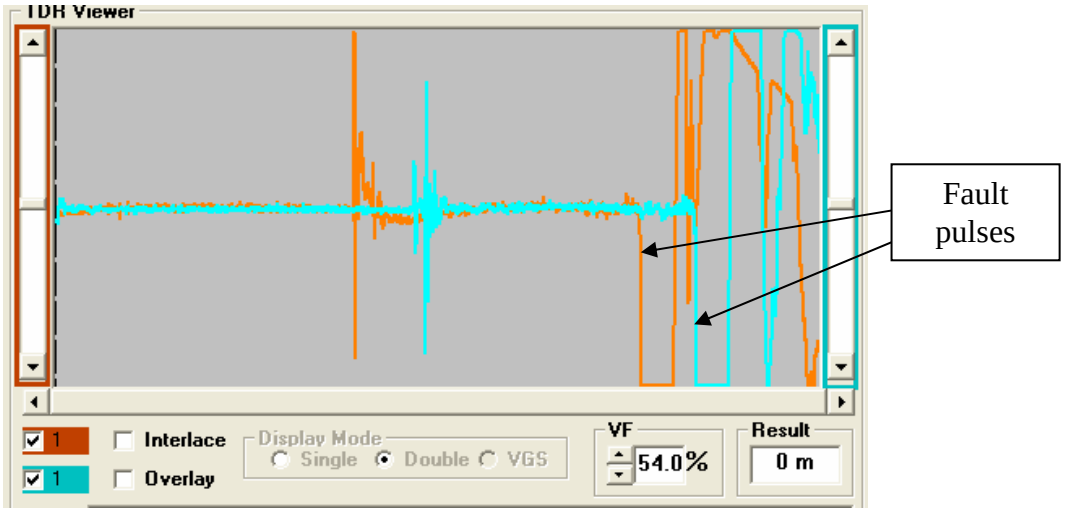
Example of TRS fault location



Voltage recording in substation



Voltage recording at far end



Transient recordings at substation and far end before alignment

Aligned and expanded transient recordings at substation and far end

Notes on LV Cable Fault Location

Classification of LV Cable Faults

Transitory	-	irregular voltage dips
Intermittent	-	irregular fuse operations
Persistent	-	repetitive fuse operations
Permanent	-	opens and welded shorts

Problems specific to LV Cable Fault Location

Multiple branches
Single phase services
Access to terminals
Connected loads
Fault behaviour

Behaviour of LV Cable Faults

Many LV cable faults 'progress' from the *Transistory* condition to the *Non-Persistent* and then to the *Persistent* condition. (Complaints of 'flickering lights' are an indication of the probable existence of a *Transitory* cable fault)

During this 'progression' LV cable faults are *unstable/non-linear* and are only apparent, and therefore pre-locatable, when the cable is energised at normal working voltage.

Only when a fault has 'progressed' to a *Permanent* condition, where it exhibits a *stable/linear* characteristic, will there be the possibility of pre-location with the cable in a de-energised state.

All *unstable* LV cable faults require *pre-conditioning* in order to make them locatable. The only acceptable method of *pre-conditioning* for cables with consumers still connected is to re-energise at normal working voltage.

When time intervals between re-energisation and the next burst of fault activity are long the most economic and convenient method of maintaining supply will be a fuse. For frequently recurring intermittent faults, and where space is available, REZAP units allow supplies to be restored quickly and may 'assist' in *pre*-conditioning the fault into a *persistent* or *permanent* condition.

Methods of locating LV cable faults

Unstable/non-linear faults:

Power Frequency Methods

TDR Methods

Stable/linear faults:

TDR Methods

Power Frequency methods can be based on voltage or current.
Both methods require access to multiple locations
Voltage sensors can be connected at convenient points such as consumer terminals, link boxes, street light columns etc…
Current sensors must be placed around the faulty cable at points such as link boxes, feeder pillars or exposed cores
Voltage sensing allows fault location
Current sensing only allows fault sectionalisation

TDR methods require that the fault produces a reflection (echo) which can be identified amongst the reflections from joints and other impedance discontinuities.
The reflection magnitude is a function of the fault resistance
Fault reflection recognition is simplified if *comparison* techniques can be used such as:

Before and After (permanent faults after *pre-conditioning*)

Before and During Arcing (all types of unstable fault)

NOTE: Comparison is not normally possible between the faulty and a healthy phase due to single phase connections

The *Kehui* **T-P22/T-V22** units can be used in either mode thereby allowing the most appropriate method to be used for each specific case. However the over-riding advantages of **TDR** methods are that they are less dependent on cable records and faults can often be located from a single measurement point. **Power Frequency** methods, by comparison, do not suffer from problems of pulse attenuation nor do they require high frequency 'isolation' from busbars with multiple cables connected.

When *Kehui* **T-P22** units are operated in the **TRS** mode (i.e. as Travelling Wave Fault Locators) the problems of attenuation are significantly reduced and the need for high frequency 'isolation' at busbar connections avoided. Combining **TDR** and **TRS** results can often identify whether a fault is on the main cable or along a branch.

Conclusions

LV cable faults present a greater technical challenge to a DNO than HV cable faults

Re-organisations within DNOs have created a need for simple equipment and procedures which can be installed by jointers

Incentives imposed by the Regulator have increased the urgency to restore supplies after permanent faults and to maintain supplies by reducing the number of intermittent faults

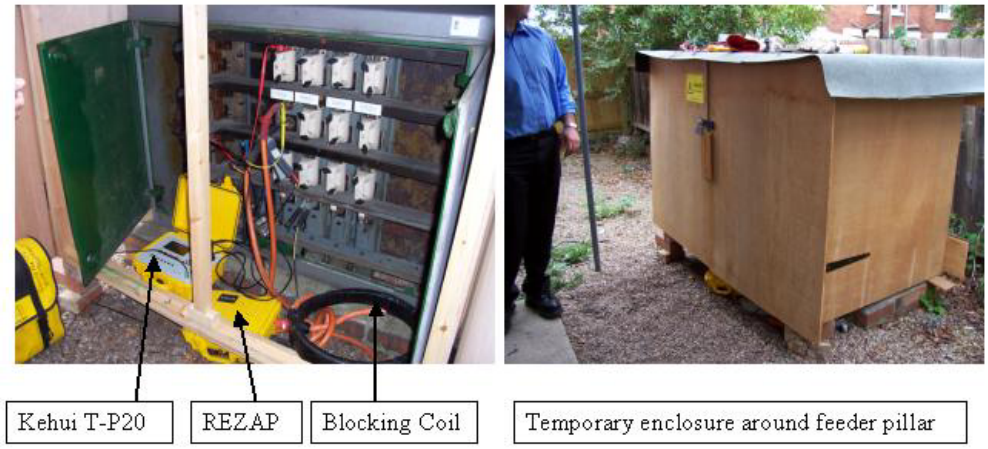
Transitory faults degrade PQ and can affect electronic equipment

Observing the power frequency transients caused by LV cable faults is essential to understanding their character

Fault location devices with remote control, such as the *Kehui* **T-P22/T-V22** allow *diagnosis* and *pre-location* to be performed by centrally located specialists

Pinpointing with the *Fault Sniffer* can be used to confirm the *pre-location* before commencing excavations

Transitory fault phenomena can be used for condition monitoring to provide *early warning* of pending problems to prevent consumer interruptions and power quality complaints



Location of an intermittent fault at an outdoor substation using an early prototype of the *Kehui* T-P22. This fault had existed for over 6 months and was located within 24 hours of installing the T-P20.