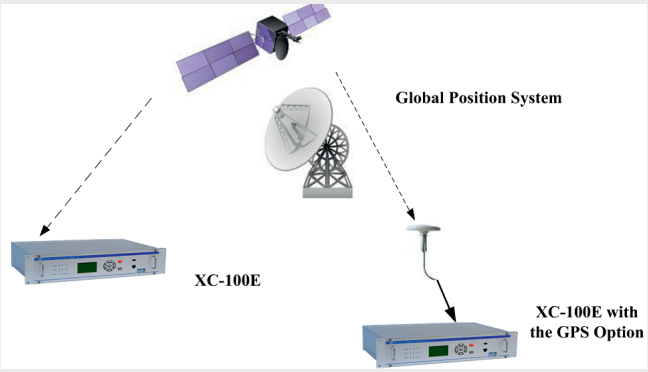
Traveling Wave Fault Location System

XC-2100E

TWFL - Travelling Wave Fault Location System

SCOPE is dedicated to the innovative use of electronics for Test & Measuring applications since 1988 for the Power Industry.
Our approach of seeking synergetic solutions to our customer's needs has enriched the quality of our ultimate goal – Customer Satisfaction. In fact, we owe our growth to the confidence with which our customers approach us for solutions. For achieving this SCOPE now has collaborated with some organisations which have done pioneering work in specific areas.
With the increased demand for uptime of power system and planned shutdowns even for testing purpose becoming scares, SCOPE is focussing more & more on on-line fault diagnostic systems. SCOPE is now offering On-Line Fault Location System for transmission lines of all types, based on travelling wave principle in association with KEHUI, one of the leading manufacturer of such system in world. KEHUI has installed more than 1000 systems across the world.

The Product



- **TWFL system** provides accurate fault location for Transmission Line which reduce the fault search time thus helps in quick recovery of the Power System after faults.
- The TWFL monitors Travelling Waves at both ends of Transmission Lines & provides accurate fault location parameters (like Fault Distance, Tower Number etc) for all kind of Power Lines including,
  - AC Transmission Lines
  - HVDC Transmission Line
  - Series Compensated Transmission line
  - Lines with T Branches
  - Lines containing cable section and Overhead Lines
- Measuring fault distance of single phase to ground fault in Non-effectively earthed Distribution System
- Travelling wave measurement technique is used for measurement of fault distance with best accuracy of ± 50 meter and maximum resolution of ± 5 meter and this depends on the accuracy of time synchronization (100 ns) as well as on the accuracy of input parameters like line-length and the velocity of travelling waves.
- TWFL system is free from influence of following factors which affect fault location accuracy of Impedance Measurement Method,
  - Resistance of line
  - Voltage & Current Transformer(CT,PT) errors
  - Insufficient accuracy of line parameters due to neglecting of line transposition, distributed capacitance etc.
  - Uncertainty of zero sequence impedance due to variation of earth resistance along the Line corridor
  - Load Flow
- The TWFL system includes following devices,
  - XC-100E – Travelling Wave Data Acquisition System with inbuilt GPS.
  - XCF-2100E – Master Station Software

TWFL System

1) XC-100 – Travelling Wave Data Acquisition System

LED Indications-

Power	Trigger
Run	Communication
Synchronisation	Data

- XC-100E is designed to acquire travelling waves in DC/AC transmission lines at faulty condition and transfer the data to the master station for fault distance location. It continuously samples the secondary output of CTs or PTs and stores the sampled data in a circular memory buffer.
- When the unit is triggered, i.e. the deviation of any input signals exceeded the pre-set threshold level, the embedded super-high speed Data Acquisition Unit (XC-100E) which is independent of the master station software, records and saves the transient travelling wave signal in real time.
- The pre-fault buffered data and the transient data, in a pre-set time frame, are transferred to the non-volatile memory. The acquired data are then sent to the master station software via the communication network for further processing.
- Our special interface control technique reduces the time interval between recording two subsequent travelling waves to less than 200 μs. With this approach, guaranteed seamless recordings of transient signals are done to avoid loss of fault waves.
- The configuration of XC-100E can be viewed and modified by the XCF-2100E software. This software can also be used to export travelling wave records from XC-100E, to display waveforms, and to upgrade the firmware of XC-100E.

2) XCF-2100E – Master Station Software

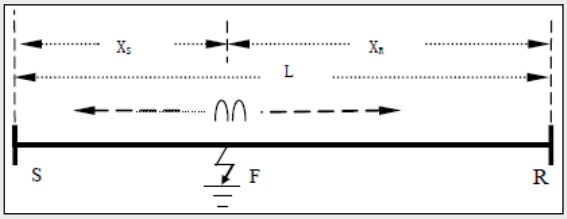
- Master Station PC is configured with the XCF-2100E software. It collects the transient data acquired by travelling wave data acquisition units installed at substations and calculates distance to fault automatically by using the double-ended method. It also allows user to view the transient waveforms and determine the distance of fault by identifying reflections from fault.
- It also provides the information about fault with the details of the two tower between which the fault has occurred.

The Measurement

Double End Method: The double-end method calculates the distance to fault based on time tags of travelling wave records acquired at both ends of the faulty line. Travelling Waves are produced by faults in the system and propagate along the Transmission Line to the both ends. These travelling waves in the system get replicated at secondary side of the substation CT which would be monitored by special designed split core CT.
Time Tags are done by GPS after arrival of transients at two time synchronised Data Acquisition Units usually at both ends of the Transmission Line. The exact fault distance is determined by using time difference of transient's arrival.

$$X_S=[(T_S-T_R).v+L]/2$$

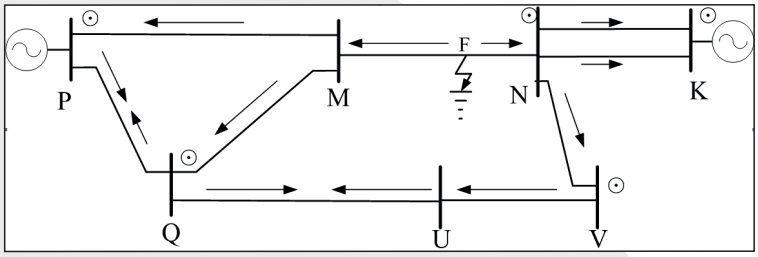
$$X_R=[(T_R-T_S).v+L]/2$$



X_S and X_R are the arrival times of fault generated transients at the two ends of the line. **V** is velocity of Travelling wave in overhead line, which is close to the velocity of light. L is total length of the line. For this double ended fault location method, it is necessary to use GPS in order to synchronise two transient records at both monitoring ends.

Type W (Wide Area) Method:

The wide area fault location can identify the fault point using time tags of travelling wave surges of multiple substations across the power network. Using this method we don't need to install Data acquisition unit at each substation even without compromising with the accuracy. Let us consider an example-

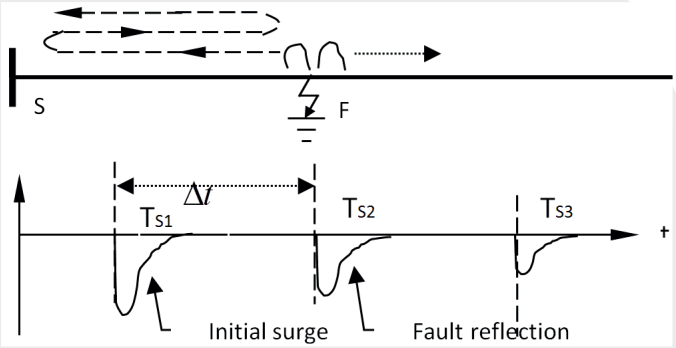


Take a fault on line MN at F, and assume that the XC-100E in substations N, K, V, P, Q (marked ⊙) have detected the fault surges. Substation N detected the surge first and it is selected as the reference substation. Substations K, V, P, Q detected the fault surge later, and are called subsequent substations.Using time tags of these four subsequent substations and of the reference substation the software can detect the fault point.

Type A (Single ended) Method

Type A Method determines fault distance by analyzing the fault generated travelling wave surge waveforms recorded at one end of the line. The distance is computed by measuring the time difference t between the first surge and the second one, which is the round trip time for the pulse from the line end to the fault.

$$X_L = \triangle t.v/2$$



Features of the product:

1. Features of XC-100E:

- It can monitor up to 8 lines.
- Various input modules like AI, AD, AV etc. to suit different substation and line conditions like HVDC or where only one line is connected to bus bar in generating stations etc.
- Maximum up to 36MHz sampling frequency.
- XC-100E is designed to trigger with high resistance faults. The typical fault resistance which is detected by the system is 1000 Ohm. Considering that a burden resistance ranges between 100 and 300 Ohm, this means that XC-100E triggers with fault values three times greater than the maximum burden.
- **Display**: Kit has LCD display through which shows Settings, Configurations, Records, Alarms etc. Through the display we can access and view-
  - Record Summary
  - Sequence of Events like loss of GPS connection, trigger etc.
  - Parameters
  - USB functions
  - Set Password
  - Version : 1.0.3
- Kit has in build Time Sync. module for high accuracy measurements.

- **Binary Inputs:** Upto 8 binary inputs to detect the CB position or relay trip command which will be used for types of Fault classification.
- **Alarm:**
  - Kit has alarm on two contacts on power supply module.
  - Pop-up window alarm for: triggered recordings, watchdog faults, XC-100E failures, GPS signals lost, and communication channel faults.
  - Optional DO module for more than two alarms.
- **Self- diagnostics:**
  - The kit performs continuous monitoring of conditions of all hardware modules including power supply module, comm. module, time sync. module, DI module, AI and AD module, DAU module, CPU module and flash disk.

2. Features of XCF-2100E:

- Up to 256 Nos. of Substation can be monitor by single XCF-2100E software.
- Up to 1000 maximum number of lines can be monitor.
- More than 1,00,000 number of travelling wave records can be stored.
- Master Software screen swapping time and Data retrieval response is less than 3 seconds.
- XCF-2100E Software performs automatic calculation of distance to fault using Double-End and Wide Area fault location methods and displays the result in Kilometer from both substations without needing further calculation.
- Email is sent automatically to concerned people indicating distance to faults.
- It can discriminate the nature of the recorded travelling wave disturbance by examining the magnitude of the power frequency current and status of Circuit Breakers (CBs).
- Lightings stroke on the line may also be able to trigger the XC-100E and TWFL can indicate the lighting striking location, based on time tags of lighting surges. However, the discrimination between lightings and faults can be made by examining the magnitude of the power frequency current.
- The faulty line and phase is identified by examining and comparing the three phase power frequency currents.
- XCF-2100E software automatically (can also manually) collects the remote substation fault data, and stores them in the local data base as soon as a fault is detected.
- The software can perform the complete simulation of a fault for easy diagnosis of the whole system.
- XCF-2100E software displays the single line diagram of power system networks. Users can view the travelling wave record index by clicking on a substation or a line element. The record can be viewed by selecting a corresponding record index. It can also display the diagram of a fault location system which shows the operation status of XC-100E and of the communication channels.
- XCF-2100E software can publish data to other systems using the table file/ XML file of the database, which provides the fault information, including name of the faulty line, fault occurrence time, fault distance. This allows these data to be written to another database, automatically after a fault.
- It allows to preview and export all past fault data and records for easy analysis.
- The software has unique feature to represent the fault in Google map.
- The software has feature to create graphical representation of the whole network through widgets. This allows easy viewing of whole network containing hundreds of lines.

Nature of the fault:

This is an unique feature of XC-2100E system.

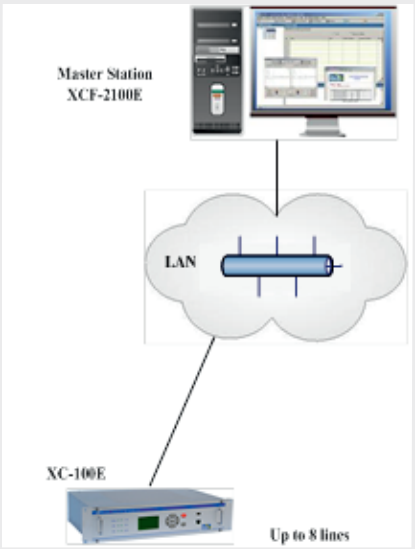
XC-100E calculates the 50Hz amplitude of the captured current signal using half-cycle or one cycle Fourier transform after it is triggered by a Travelling wave surge.

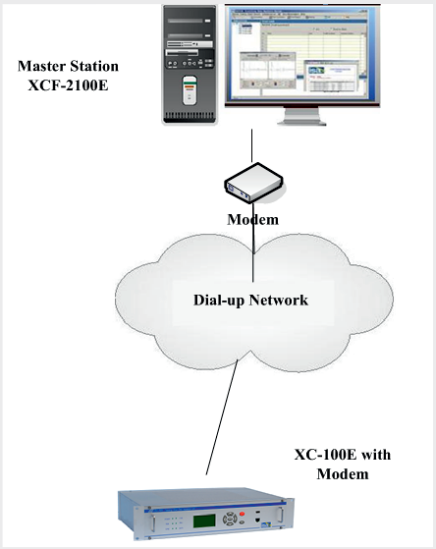
The software can discriminate the fault from normal CB (circuit breaker) operations and disturbance by examining if the 50Hz fault current is larger than the setting.

Nature of event	Criterion	
	50 Hz current exceeded setting (AI/AD/AV)	Change of CB status detected(DI)
Fault	Yes	Not applied
CB operation	No	Yes
Disturbance	No	No

Communication Network:

Master Station Software XCF-2100E collects transient data from Data Acquisition Unit XC-100E by Communication Network. The whole TWFL unit communicates with each other through Communication Network as follows.





1) Dial Up

The data transfer by using telephonic network is possible by using Dial Up modem. The XC-100E unit & Master Station are connected to the telephonic network by using RS-232 port. The transient data acquired by XC-100E are sent to Master Station by Dial Up communication.

2) Ethernet

The XC-100E and the master station are connected to a TCP/IP network via their Ethernet ports. The TCP/IP communication method can support the different field applications. All the XC-100Es installed in the substation are directly connected to the master station by multiple dedicated IP addresses in the substation.

3) Point to Point

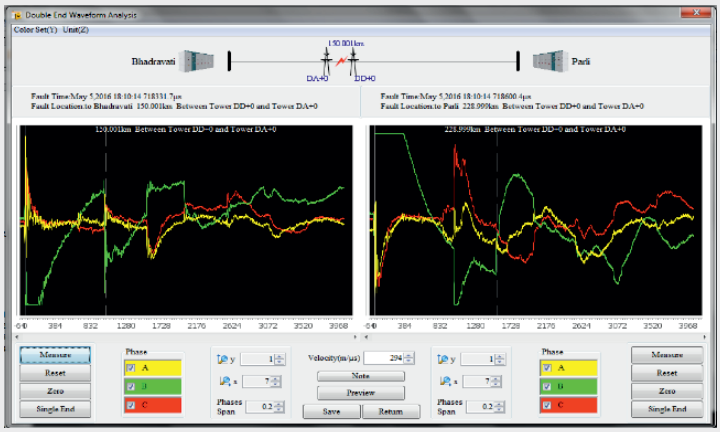
The XC-100E and the master station are linked together through a dedicated point to point data transmission channel provided by Optical Fiber or Microwave Communication Network. Both of them are interfaced to the communication channel via RS-232 port.

Time synchronization

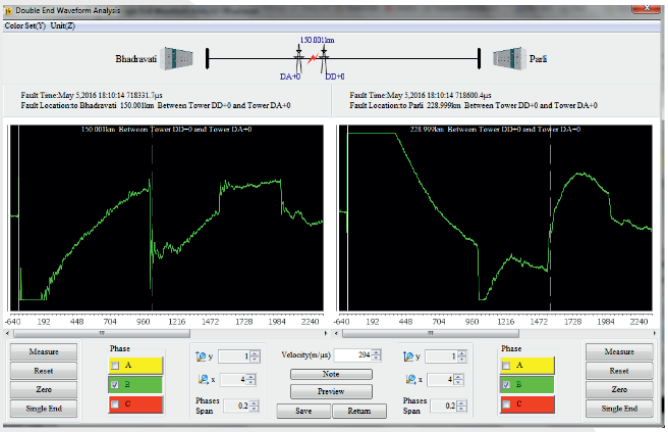
There are five different types of time synchronization modules available-
Default: Internal GPS module

Double End Result / Waveform of XCF-2100E

Following is the result from one installed TWFL system. The fault distance can be clearly viewed from each substation above the waveforms along with tower information.



Screenshot 1 – Waveforms for all phases.



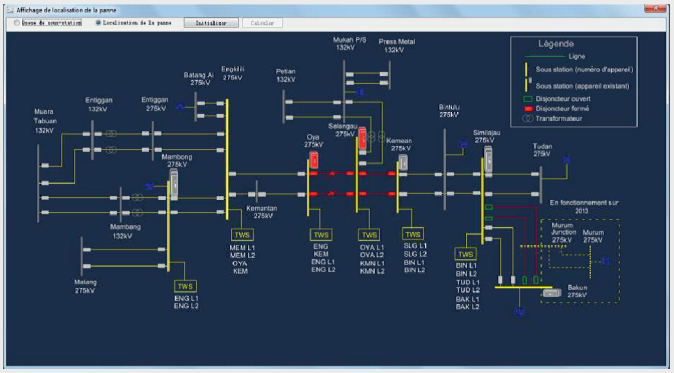
Screenshot 2 – Waveforms for faulty B phase.

Fault location:

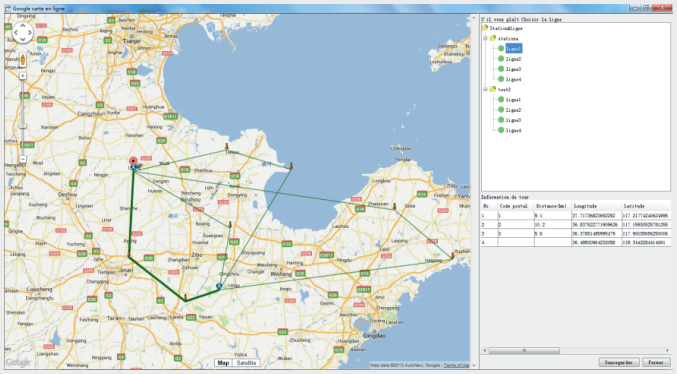
- **Double end computer aided fault location.**
  The fault location is achieved by manually selecting the faulty line with time tags of fault record at both ends of the line.
- **Double end fault location manual calculator.**
  The distance to fault is calculated based on the manually inputted time tags of travelling wave records at the both ends of the faulty line.
- **Single end computer aided fault location.**
  The user analyzes the single end travelling wave waveform using the tools provided and determines the distance to fault.
- **Support the fault location of mixed cable and overhead line.**
  In this case, is possible to input the different lengths and speed of light in the cable and overhead lines.

Result/View:

Fault Area View: The whole network in one screen



Locate the fault on the Google map



On the map the location of the towers between which fault occurred can be clearly viewed.

SYSTEM CONFIGURATION

Basic Configuration-One Master Station

The configuration of a system with one master station is shown in Fig. 1. All software modules are installed in one PC. The operator can set up the system to view travelling wave records and fault location results, analyze fault waveforms and execute the computer-aided fault location. Other clients can view fault data, fault waveforms and fault location results by accessing the WEB publishing page of XCF-2100E.

Extended configuration-Two-Master Station

The configuration of a system with one master station is shown in Fig. 2. The system consists of a server and a workstation. HMI modules are installed in the workstation, and in the communication module. Database service modules and WEB service modules are installed in the server.

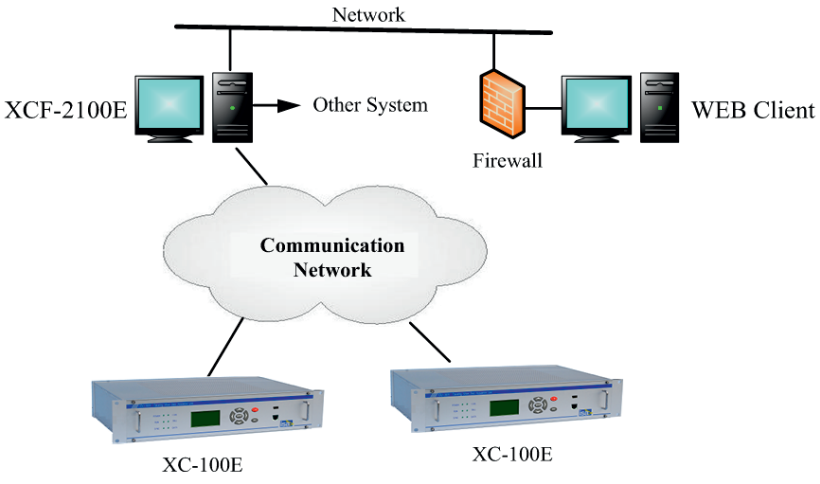


Fig.1 System configure with one master station

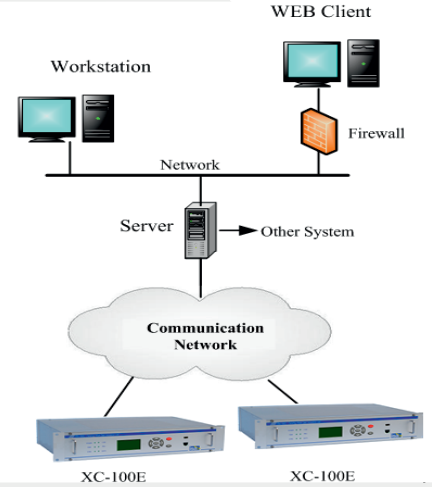


Fig. 2 Two Master Stations Configuration

Specifications

Data Acquisition System:-

Analog Input:

- Channels: 3-24 configurable for 1-8 line application

Input Module:

- **AD** Module **:** Direct current input from substation protection CT.
  - Nominal current: 5A or 1A.
  - Burden: < 0.4 VA (I_n= 5A); < 0.1 VA (I_n = 1A).
  - Overload withstanding: 400%I_n, continuous. 4000% I_n, 1s
- **AI** Module with split core CT**:** Current input through a split core CT
  - Nominal: 5A / 1A
  - Burden : <0.4 VA (In - 5A), <0.2VA (In - 1A)
  - Overload withstanding: 400% In for continuous. 4000% In for 1s
  - CT Cable length up to 20 m maximum,
- **AI** Module with external CT : Current input through an external CT.
  - Nominal secondary current: 5A or 1A.
  - Burden: close to 0.
  - Overload withstanding: 400%I_n, continuous. 4000% I_n, 1s.
  - External CT ratio: 200:1.
  - Cable length: up to 2 km.
- **AV module**: Input from substation VT.
  - Nominal primary: 57V/63.5V/69V (phase voltage).
  - Maximum permanent voltage: 120 V.
  - Burden: < 0.4VA.
  - Overload withstanding: 200% U_n, continuous. 250% U_n, 10 s.

Length of Transient Record:

- 1 to20ms programmable, standard 2ms.

Sampling frequency:

- 36 MHz (one phase), 12 MHz, 8 MHz, 6 MHz, 4.8 MHz, 4 MHz, 3 MHz, 2.4 MHz, 1.5 MHz, 1 MHz & 500 kHz all are user selectable; default 2 MHZ

Internal Time Synchronization:

- Time Accuracy: 100 ns available for Inbuilt GPS module

Non-volatile memory:

- Standard: 8 GB

Contact outputs:

- 2 Dry contacts (normally open). 1 for power failure or power failure alarm and 1 for "GPS sync. Lost" alarm
- Contact rating: 28V DC/2A, 250V AC/0.5A

Communication port:

- **2 Ethernet** ports : Supports IEC60870-5-104
  For network communications to the master station, SCADA, local communications to the substation RTU
- **2 DB9 RS232** ports:
  Two DB9 RS232 ports for communications to the master station, SCADA, local substation RTU
- **USB**: For firmware update and local download of data
  Other Options are available.

GPS Antenna:

- Cover diameter: 100 mm; total height: 180 mm.
- Cable length: 30 m (Optional lengths: 40 m, 50 m, 60 m, 100 m)
- Connector: BNC type.

Power supply:

- Voltage: 85 to 264V, 50/60 Hz AC or 90 to 260V DC.
  - Option 1: 35 to 65V DC.
  - Option 2: 35 to 140 V DC.
  - Option 3: 100 to 300 V DC.
  - Power consumption: <10W

Mechanical:

- Physical dimension: 2U, 19"
- Weight: <4kg without modules, with modules< 6 Kg

Environmental:

- Operating temperature: - 10°C - 55°C; storage: -40°C to 85°C.
- Relative humidity: 0 - 90%, not condensing.
- Tested for Shock, Vibration, Safety etc. as per relevant IEC

Immunity: Conforms to IEC standards for EMI-EMC compatibility.

Benefits:

- Directly get distance of fault point from both substations.
- Emails are sent to maintenance crew automatically (Internet is required).
- Free from inherent shortcomings of impedance method, hence provide very accurate result.
- Prevents revenue loss by reducing downtime by getting to faults' site faster and saving in search time.
- Helps improve availability for Utilities.
- Tracks intermittent self-clearing fault and trouble areas.

Simple solutions for difficult measurements®

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