# Shirla Application Guide

## - All in one -

## Fully Automatic Cable Sheath Testing and Fault Location System

This new revolutionary and unique device is used for cable and cable sheath testing, fault prelocation as well as for sheath fault pin pointing according to the step voltage method.

The special measuring bridge performs measurements according to Murray and Glaser methods. With the integrated high voltage DC source, ***shirla*** can prelocate low as well as high resistive cable faults. The measuring principle enables the prelocation of earth related sheath faults and any kind of earth related cable faults in shielded as well as unshielded cables.


Analyses are done automatically and the results are displayed digitally.

For cable fault pin pointing according to the step voltage method, ***shirla*** applies a defined DC pulse pattern and the step voltage can be picked up by using the KMF1 or UL receiver set.

Ing. Tobias Neier
Version 1, 04-2010

# Content

# 1 Field of Application - Bridge Method


Fig. 1.1; shirla*, 10kV Cable and Cable Sheath Testing and Fault Location System

All faults having the characteristic to happen **between** two defined cores and therefore **two parallel wires** can be **prelocated** with any of the cable fault prelocation methods based on pulse **reflectometry**.

Certain cable structures enable cable faults to happen from a core to the outside and therefore the soil. Especially in unshielded cables that can either be high voltage DC cables used for railway supply, low voltage cables or also signal cables or so called pilot cables, faults mainly happen between a core and the surrounding soil.

As the related medium in that case can not be accessed like a grounded metal sheath, the theory of reflectometry is no more working. **An impulse only can travel, as long as the two parallel conductive paths are given.**

**Cable sheath faults** that are defects in the outer protective PVC insulation are showing the same electrical image like the above mentioned faults.

**Cable Sheath fault – negative side effect**

Cable sheath faults do not directly influence the electrical performance of a shielded cable, but do have a negative side effect in medium term operation of the cable. The **damages of the outer sheath enable water** from the surrounding soil **to penetrate** into cable. **Corrosion** of the cable sheath as well as **development of water trees** will lead to breakdowns sooner or later.

Therefore, according to IEC 60229 protective over sheaths have to be tested for commissioning and during maintenance. A DC voltage of 4kV/mm or maximum 10kV shall be applied for 1 minute. Faults need to be repaired to ensure the long term performance of the cable. These kinds of cable faults **can only be prelocated by using a measuring bridge**.

60229 © IEC:2007

**5 Electrical test after installation**

Where an after installation test of the oversheath is performed, a d.c. voltage of 4 kV per millimetre of specified thickness of extruded oversheath shall be applied with a maximum of 10 kV d.c. between the underlying metallic layers and the outer electrode, for a period of 1 min. All metallic layers under the oversheath shall be connected together.

This test requires that the oversheath has an outer “electrode” which may be moist backfill or a conductive layer.

Bridge methods are basically used for prelocation of low resistive faults. By using a high voltage source that is integrated in the latest generation of measuring bridge instruments “shirla*” **even high resistive faults** can be prelocated. All bridge measurement methods that work with direct current for locating faults in cables (Glaser and Murray) are based in principle on modified Wheatstone circuits.

***shirla** = **Sh**eath/ **I**nsulation/ **R**esistance/ **L**ocation/ **A**nalyser

# 2 Operation Principle

## 2.1 Principle of the Wheatstone circuit

The bridge is balanced when points a and b are subject to the same potential. In this situation, the galvanometer shows zero. Points a and b are at the same potential when the following condition is fulfilled:

$$\frac{R_1}{R_3} = \frac{R_2}{R_4} \text{ resp. } R_4 = \frac{R_2}{R_1} \times R_3$$

If $R_4$ is the resistance $R_x$ being sought then $R_x$ can be defined as:

$$R_x = \frac{R_2 * R_3}{R_1}$$

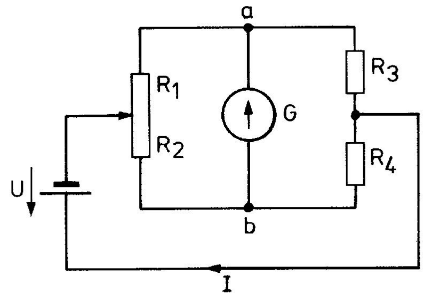



Fig. 2.1; Wheatstone circuit

## 2.2 Measuring circuit according to Murray

The measuring bridge circuit according to Murray is applied on arrangements, where beside the faulty core, **one healthy core with same diameter** and conductor material is present.

This circuit of the external loop comprises the back and forth wire as well as the resistance created via the linking bridge at the end. Therefore, the **linking bridge between the cores** is an essential part of the circuit and has to be close to zero ohms.

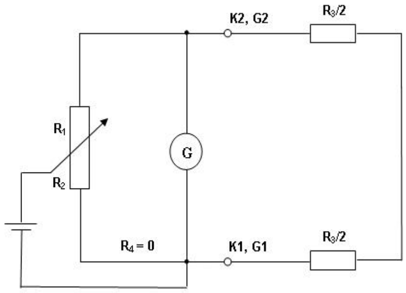



Fig. 2.2.1 Murray – Balancing Circuit

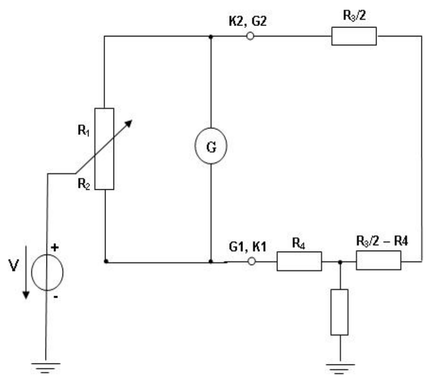



Fig. 2.2.2; Murray – Measuring Circuit

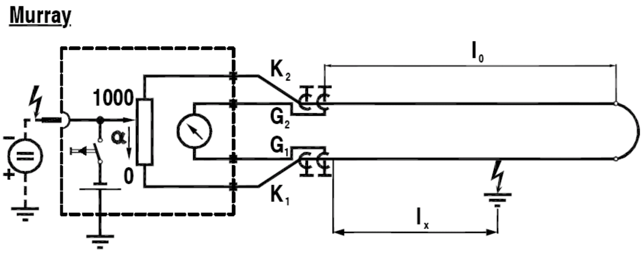



Fig. 2.2.3; measuring circuit according to Murray

## 2.3 Measuring circuit according to Glaser

Bridge measurement in accordance with Glaser can be used for cable sheath fault location in defective plastic cable sheaths and in **unshielded plastic low voltage cables**. This method requires to be operated via **two auxiliary lines** of equal cross section and material.

The difference compared to the Murray method is, that for this method the forward path defined via the two auxiliary lines is compensated. The remaining effective external circuit is the sheath only. As the sheath always is of different diameter compared to the core, this compensation is helpful. The two auxiliary cores do not necessarily need to be realized via two cores in one 3core cable, but also 2 cores of single core cables can be used. Like this, sheath faults can be located.

The distance to the fault can be determined in relation to the total cable length.

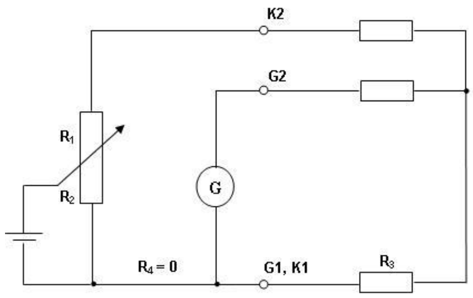



Fig. 2.3.1; Glaser – Balancing Circuit, insulated voltage source for balancing

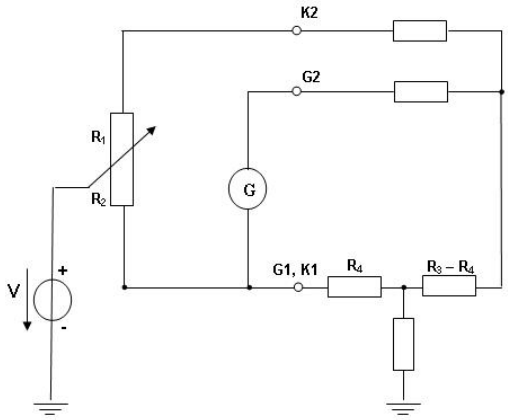



Fig. 2.3.2; Glaser – Measuring Circuit, ground related voltage source

*Connection according to* ***Glaser***

***with two auxiliary lines and constant line cross-section***

The distance between the end of the cable and the fault is:

$$l_x = \frac{\alpha}{100} * l$$

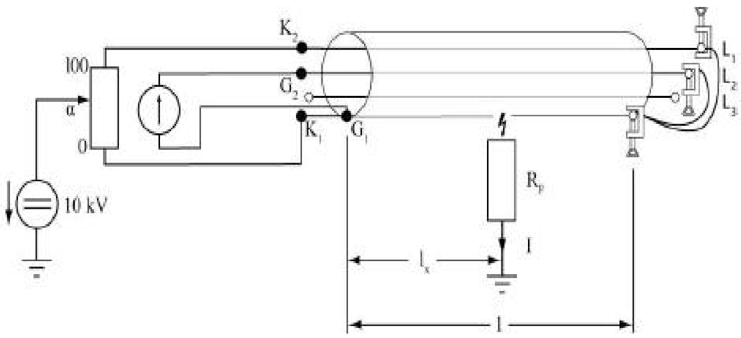



Fig. 2.3.3; Glaser, constant cross section of cable sheath, two cores used as auxiliary lines

# 3 Shirla Application in Pilot Cables

## 3.1 *Unshielded Pilot Cables*

**resistive fault**

*Core to Core Fault:*

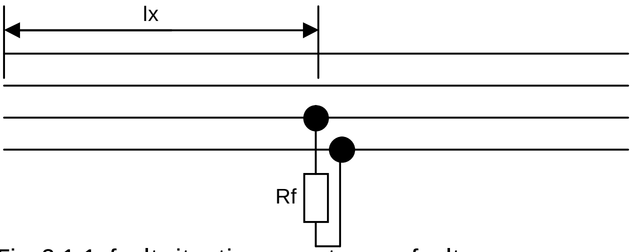



Fig. 3.1.1; fault situation, core to core fault

Connection according to **Murray**

=> **one healthy conductor required**
=> one of the faulty cores to be grounded at the near end

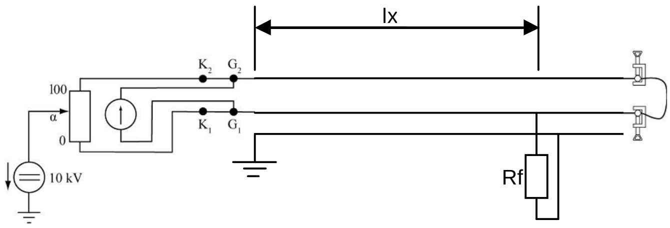
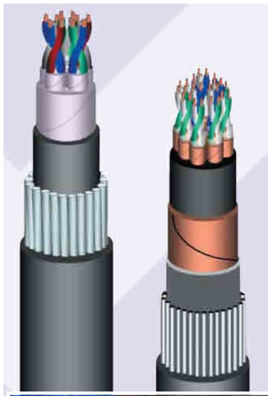



Fig. 3.1.2; connection acc. to Murray, core to core fault

## 3.2 *Shielded Pilot Cables*

**resistive fault**



*Core to Shielding Fault:*

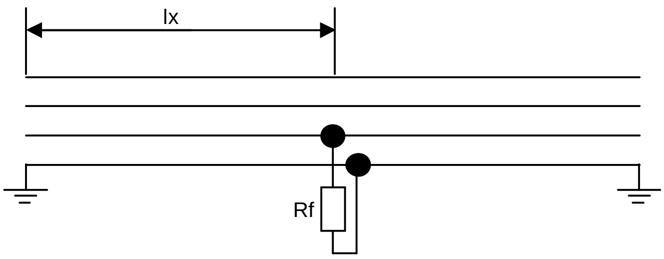



Fig. 3.2.1; Fault situation Core to Sheath Fault, shielded LV cable

=> **one** healthy conductor required
=> Faulty Core resistive Fault to Ground

Connection according to **Murray**

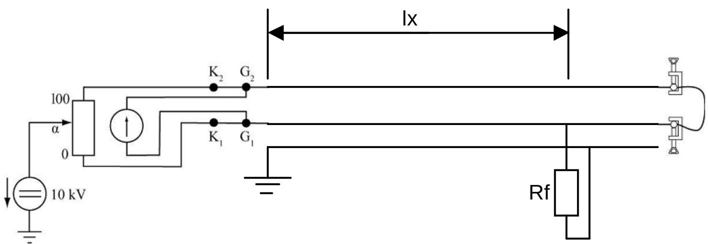



Fig. 3.2.2; Connection according to Murray, core to sheath fault

## 3.3 Fault Location on cable drums / cable factories - Pilot Cables

Fault prelocation on drums – both ends accessible

- ⇨ direct connection to both ends
- ⇨ forward path via one healthy core (Murray) / or two healthy cores (Glaser) can be **substituted by direct connection to the ends.**
- ⇨ **Connection arrangement equal to Glaser**
- ⇨ substitution of forward path
- ⇨ on demand, the connection leads for K2 and G2 can be extended. Glaser Methods is acting by compensation of test leads ( 2 healthy cores or extension of K2,G2)

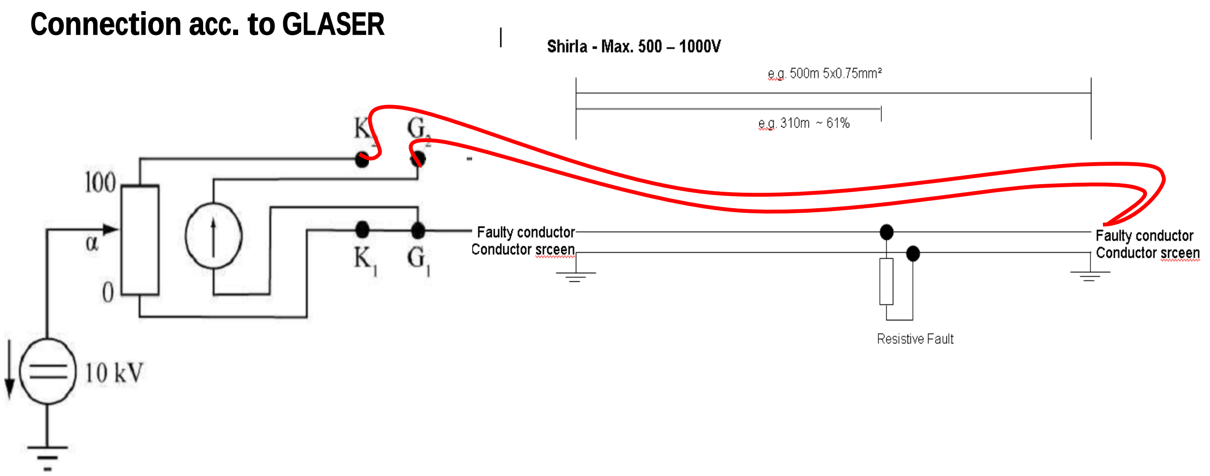



Fig. 3.3.1; Connection acc. to Glaser, extended test leads G2, K2

# 4 Shirla Application in LV cables

## 4.1 Unshielded PVC-insulated LV cables

**resistive fault**

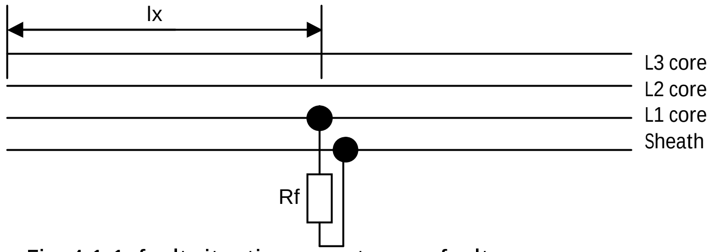



Fig. 4.1.1; fault situation, core to core fault

***Core to Core Fault:***

Connection according to **Murray**:

=> **one** healthy conductor required
=> one of the faulty cores to be grounded at the near end

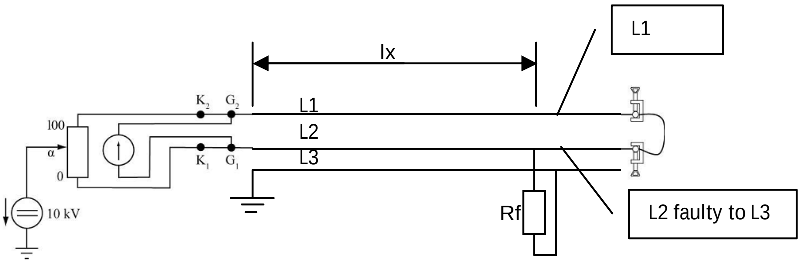



Fig. 4.1.2; Murray connection - core to core fault

***Core to Ground Fault:***

Connection according to **Murray**:

=> **one** healthy conductor required
=> Faulty Core resistive Fault to Ground

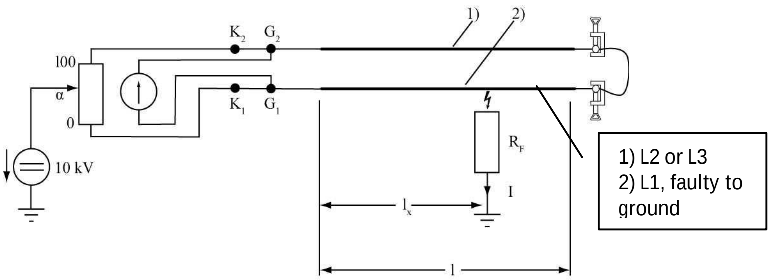



Fig. 4.1.3; Murray connection – core to ground fault

## 4.2 Shielded LV Cable

**resistive fault**

***Core to Core Fault*** => handle like unshielded LV cable

Connection according to **Murray**

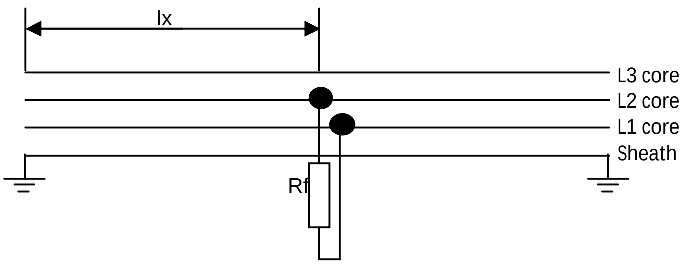



Fig. 4.2.1; fault situation – core to core fault

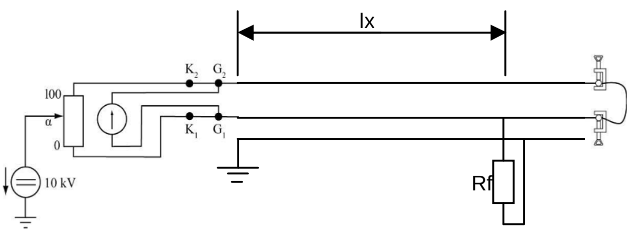



Fig. 4.2.2; Murray connection – core to ground fault

***Core to Sheath Fault:***
=> one healthy conductor required
=> cable sheath grounded on the near end

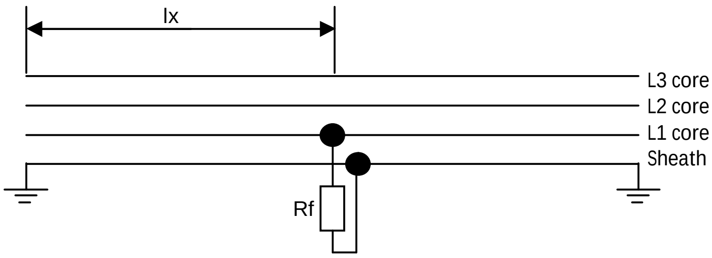


Fig. 4.2.3; fault situation – core to sheath fault

***Sheath to Ground Fault:***

=> **Two** healthy conductors required
=> Cable Sheath resistive Fault to Ground

Connection according to **Glaser**

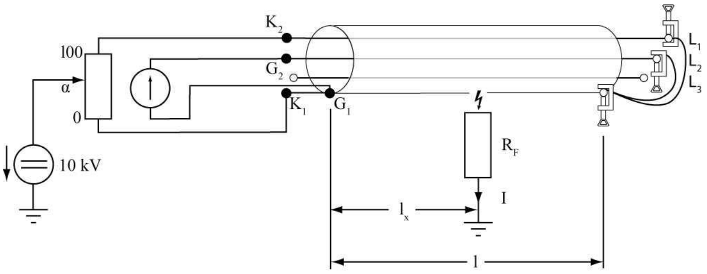


Fig. 4.2.4; Glaser connection – sheath to ground fault

## 4.3 Fault Location on cable drums / cable factories – LV cables

Fault prelocation on drums – both ends accessible

- ⇨ direct connection to both ends
- ⇨ forward path via one healthy core (Murray) / or two healthy cores (Glaser) can be **substituted by direct connection to the ends.**
- ⇨ **Connection arrangement equal to Glaser**
- ⇨ substitution of forward path
- ⇨ on demand, the connection leads for K2 and G2 can be extended. Glaser Methods is acting by compensation of test leads ( 2 healthy cores as extension for K2,G2)

**Connection acc. to GLASER**

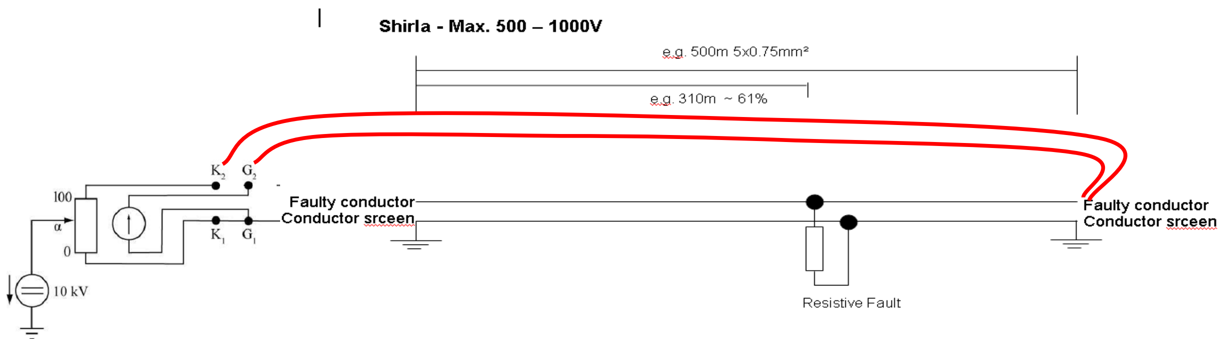


Fig. 4.3.1; connection acc. to Glaser, extended measuring leads K2, G2

## 4.4 Cable Fault Location in T-Branch Networks

Requirement: resistive Cable Fault
Murray:
1 healthy core
Glaser:
2 healthy cores

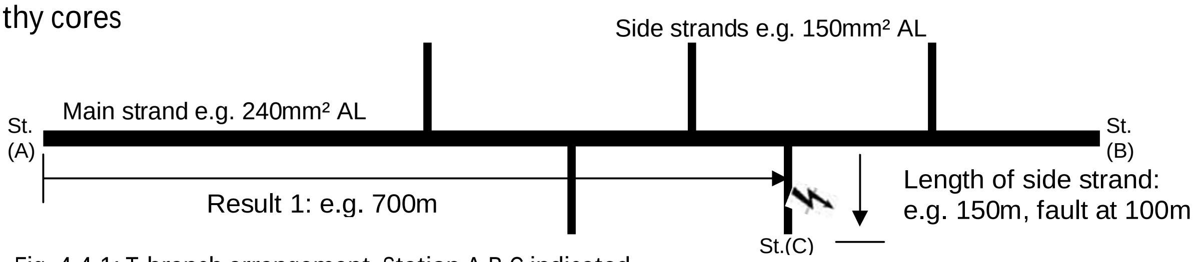



Fig. 4.4.1; T-branch arrangement, Station A,B,C indicated

***Measurement 1***

- connection at Station A
- short circuit bridges at Station B
- prelocation delivers the position of T-joint where leakage current leads away from main strand
- enter: e.g. 1000m,

- no details to be entered if main strand is continuous in diameter and cross section
- Result: l1, distance on main strand to faulty t-branch

**Connection according to Glaser**

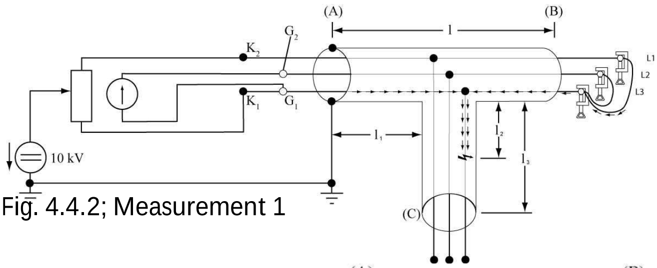



Fig. 4.4.2; Measurement 1

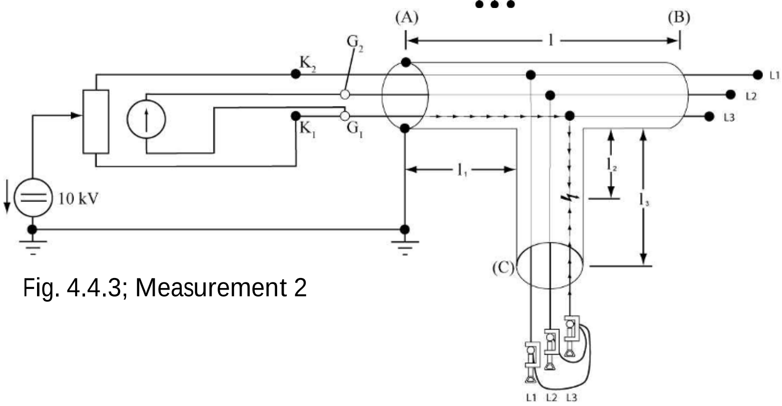



Fig. 4.4.3; Measurement 2

***Measurement 2***

- Change short circuit bridges to Station C (defined by result of Measurement 1)
- Define sections:
  Section 1: 700m 240mm² AL
  Section 2: 150m 150mm² AL
  => Result: total fault distance, 800m
  => section 1 [l1] + fault distance along side strand [l2]

FAULT LOCATION REPORT
SHIRLA V0.5.0
FILENAME: SH-L_002.TXT
2010-01-01 16:17
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Fault Location REPORT

Selected Method: GLASER

Applied Test Voltage: 0.03 kV
Measuring Current: 10.11 mA

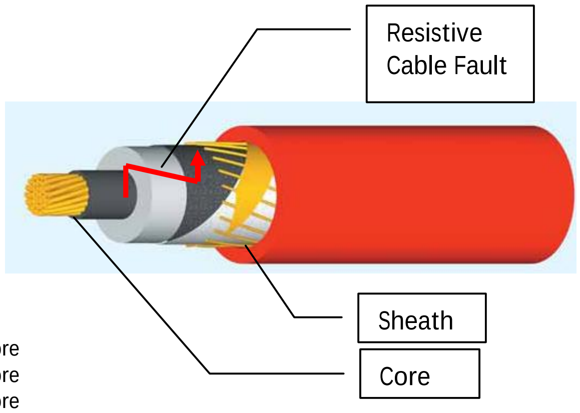
Fault Distance: 800m

Cable Sections:
1: 700 m 240 mm² Al ... **main strand**
2: 150 m 150 mm² AL ...**side strand**

Fig. 4.4.4; shirla Report

# 5 Shirla Application in MV cables

## 5.1 1-core MV XLPE cables




Resistive Cable Fault: ***Core - Sheath***

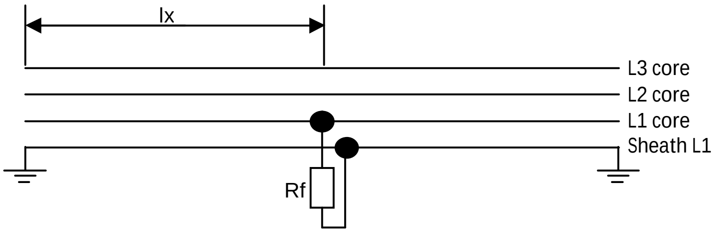



Fig. 5.1.1; Fault situation – core to sheath fault

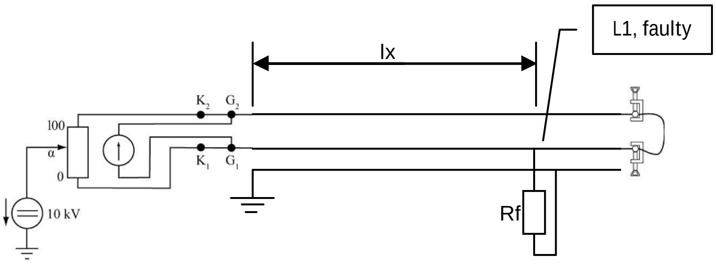
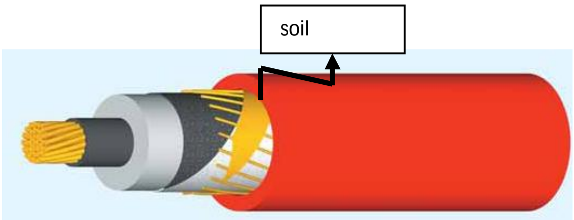



Fig. 5.1.2; Murray connection – core to sheath fault

Connection according to **Murray**:

- one healthy conductor required
- conductor of same cross section and material

Cable Sheath Fault: ***Sheath – Fault***
***Usually resistive, PVC insulation***




Connection according to **Murray**:

- one healthy sheath required
- sheath conductor of same cross section and material

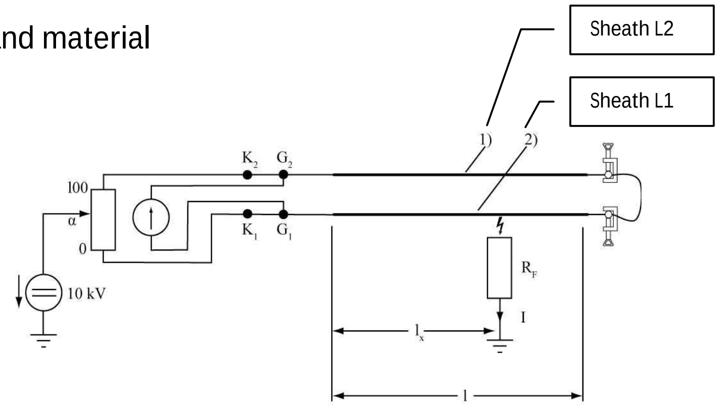



Fig. 5.1.3; Murray connection – core to sheath fault

***if healthy sheath not available**: (all 3 single cores with sheath fault)*

- use 1 healthy core (with same length)
- use multi sector – mode

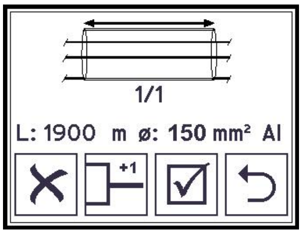



Fig. 5.1.3; Shirla display, multi-sector mode

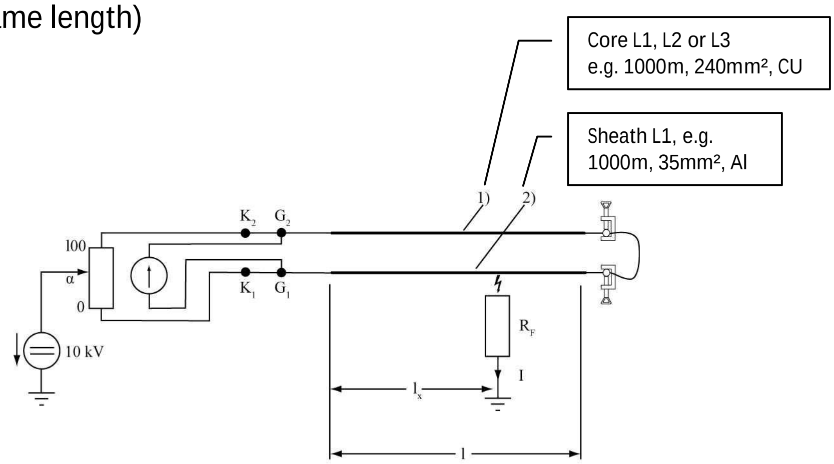



Fig. 5.1.4; Murray connection, multi sector - mode

E.g. total length 1000m,
240/35mm², Al,Cu

1. define sectors
   Sector 1 … 1000m, 35mm² Cu … sheath
   Sector 2 … 1000m, 240mm² Al … core
2. result < 50% (50% = 1000m)
3. correct indication in meter, %-value = 1/2

FAULT LOCATION REPORT
SHIRLA V0.5.0
FILENAME: SH-L_001.TXT
2010-01-01 15:06
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Fault Location REPORT

Selected Method: MURRAY

Applied Test Voltage: 0.03 kV
Measuring Current: 10.11 mA

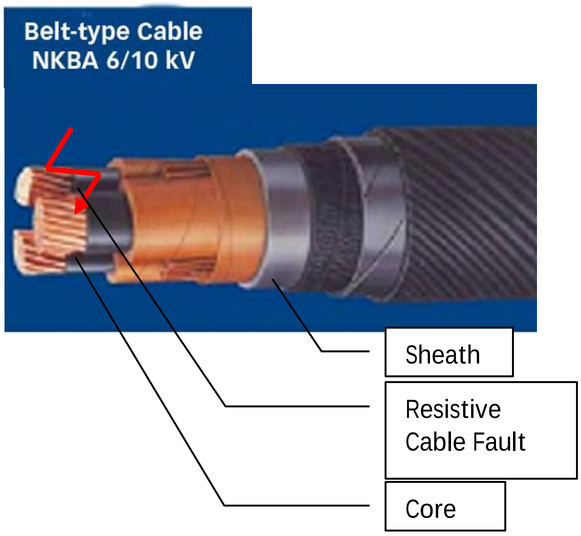
Fault Distance: 250m (12,5%)

Cable Sections:
1: 1000 m 35 mm² Cu ... **Sheath**
2: 1000 m 240 mm² AL ….**Core**

Fig. 5.1.5; Shirla Report

## 5.2 3-core MV XLPE / PILC cables

*Unshielded 3-core cables PILC (belt-type)*




*Resistive Cable Fault:* ***Core to Core***

- ⇨ handle like unshielded LV cable
- ⇨ see Fig. 4.1.2; Murray connection
  - core to core fault

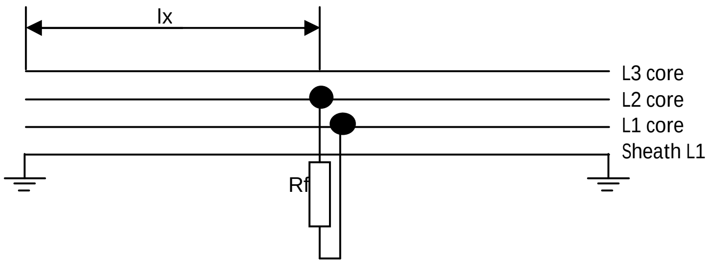
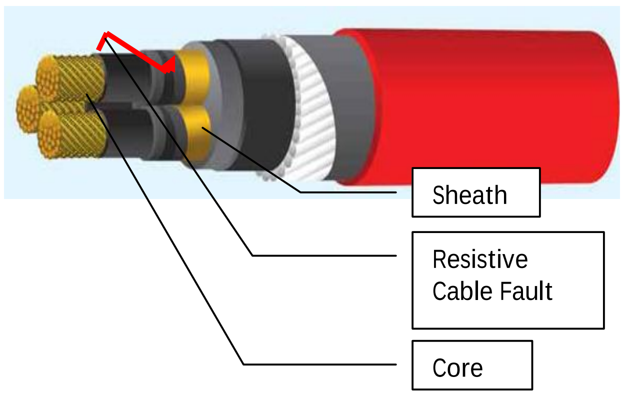



Fig. 5.2.1; Fault situation: resistive Fault - Core to Sheath

*Shielded 3-core cables XLPE / PILC*




*Resistive Cable Fault:* ***Core to Sheath***

*Prelocation according to* ***Murray***

=> **one healthy conductor required**

=> cable sheath grounded on the ends

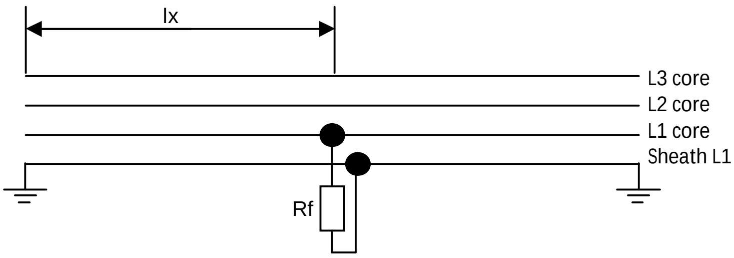



Fig. 5.2.2; Fault situation: resistive Fault - Core to Sheath

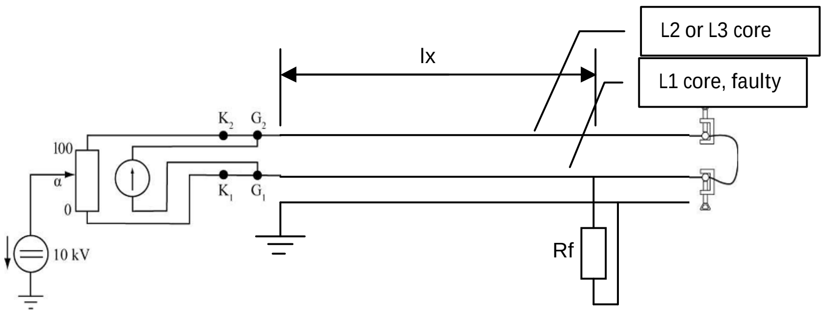



Fig. 5.2.3; Connection according to Murray

*Prelocation according to* ***Glaser***

=> **Two healthy conductors required**
=> Cable sheath grounded on the ends

**Similar result compared to Murray**

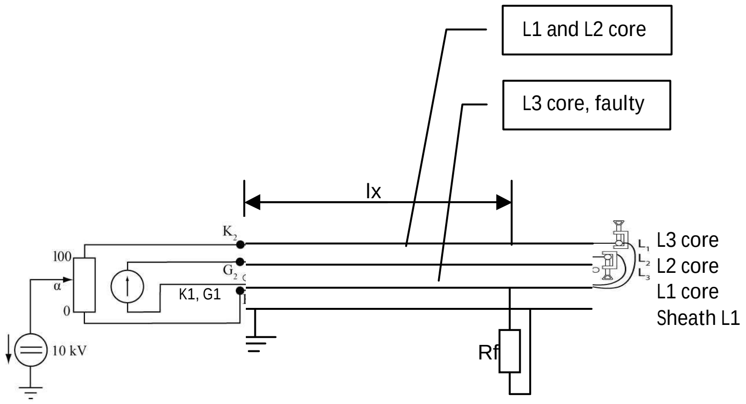
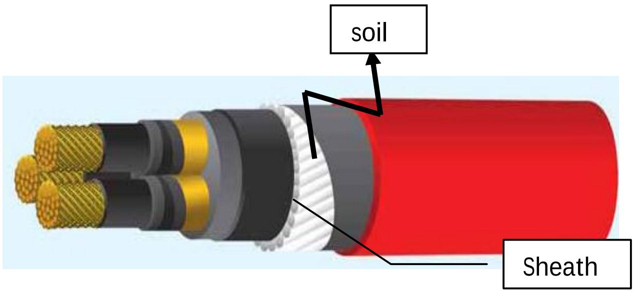



Fig. 5.2.4; Glaser connection – core to sheath fault

Cable Sheath Fault: ***Sheath – Fault Resistive Fault, PVC insulation***




=> **Two** healthy conductors required
=> Cable Sheath resistive Fault to Ground

Connection according to **Glaser**

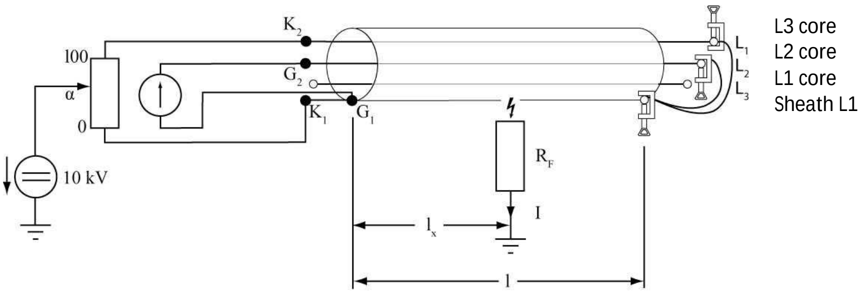



Fig. 5.2.5; Glaser connection – sheath to ground

=> If only one healthy core available,
Use Murray with section-mode see application in 1-core MV cable

## 5.3 *Fault Location on cable drums / cable factories – MV cables*

Fault prelocation on drums – both ends accessible

Resistive Cable Faults – Core to Sheath

- ⇨ direct connection to both ends
- ⇨ forward path via one healthy core (Murray) / or two healthy cores (Glaser) can be **substituted by direct connection to the ends** as shown below**.**
- ⇨ **Connection arrangement equal to Glaser**
- ⇨ substitution of forward path
- ⇨ on demand, the connection leads for K2 and G2 can be extended. Glaser Methods is acting by compensation of test leads ( 2 healthy cores as extension for K2,G2)

**Connection acc. to GLASER**

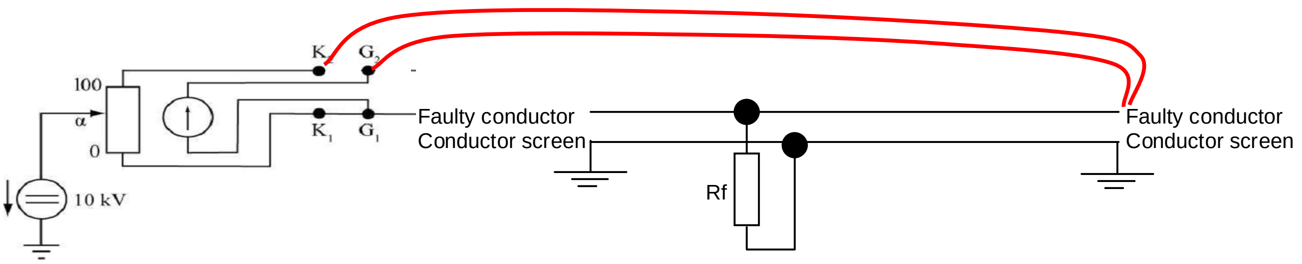



Fig. 5.3.1; connection acc. to Glaser, extended measuring leads K2, G2

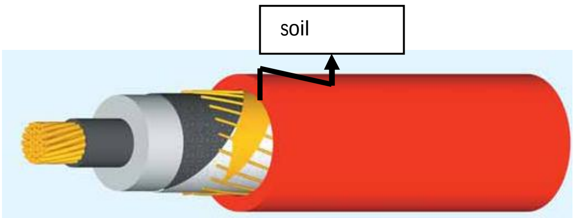
# 6 Shirla Application in HV cables

## 6.1 1-core HV XLPE cables


### 6.1.1 Non – Crossbonding arrangement

⇨ ***no grounded link - boxes***

Cable Fault Type: ***Sheath Fault***




Connection according to **Murray**:

- one healthy sheath required
- sheath conductor of same cross section and material

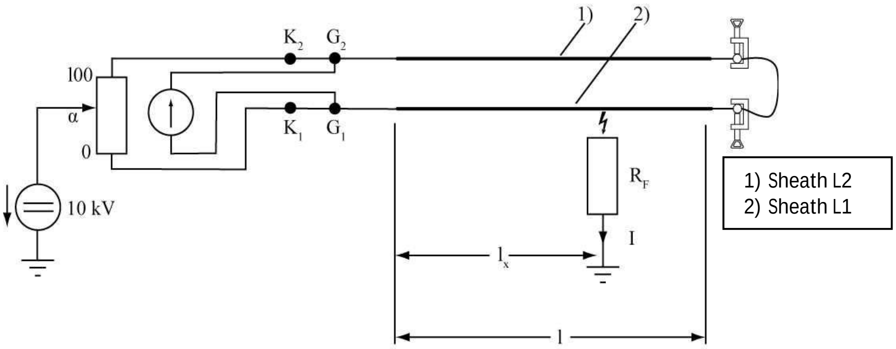



Fig. 6.1.1; connection acc. to Murray, sheath to ground fault

***if healthy sheath not available:*** *(all 3 single cores with sheath fault)*

- use 1 healthy core (with same length)
- use sector – mode

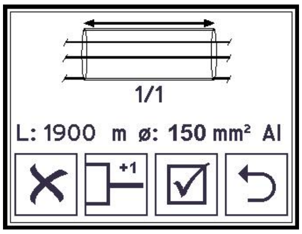



Fig. 6.1.2; Shirla display, multi-sector mode

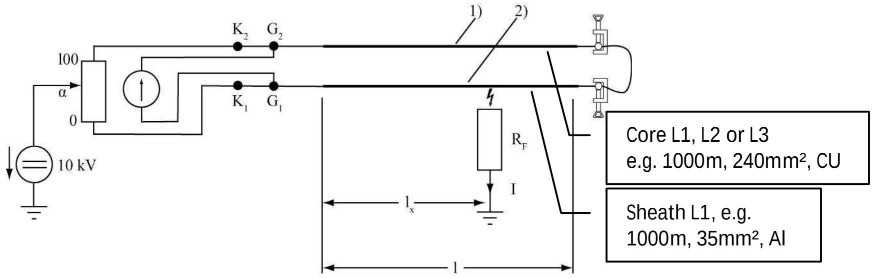



Fig. 6.1.3; connection acc. to Glaser, extended measuring leads K2, G2

**E.g.** total length 1000m, 240/35mm², Al,Cu

1. define sectors
   Sector 1 ... 1000m, 35mm² Cu ... sheath
   Sector 2 ... 1000m, 240mm² Al ... core
2. result < 50% (50% = 1000m)
3. correct indication in meter, %-value = 1/2

FAULT LOCATION REPORT
SHIRLA V0.5.0
FILENAME: SH-L_001.TXT
2010-01-01 15:06
-----------------------------

Fault Location REPORT

Selected Method: MURRAY

Applied Test Voltage: 0.03 kV
Measuring Current: 10.11 mA

Fault Distance: 250m (12,5%)

Cable Sections:
1: 1000 m 35 mm² Cu ... **Sheath**
2: 1000 m 240 mm² AL ….**Core**

Fig. 6.1.4; Shirla Report

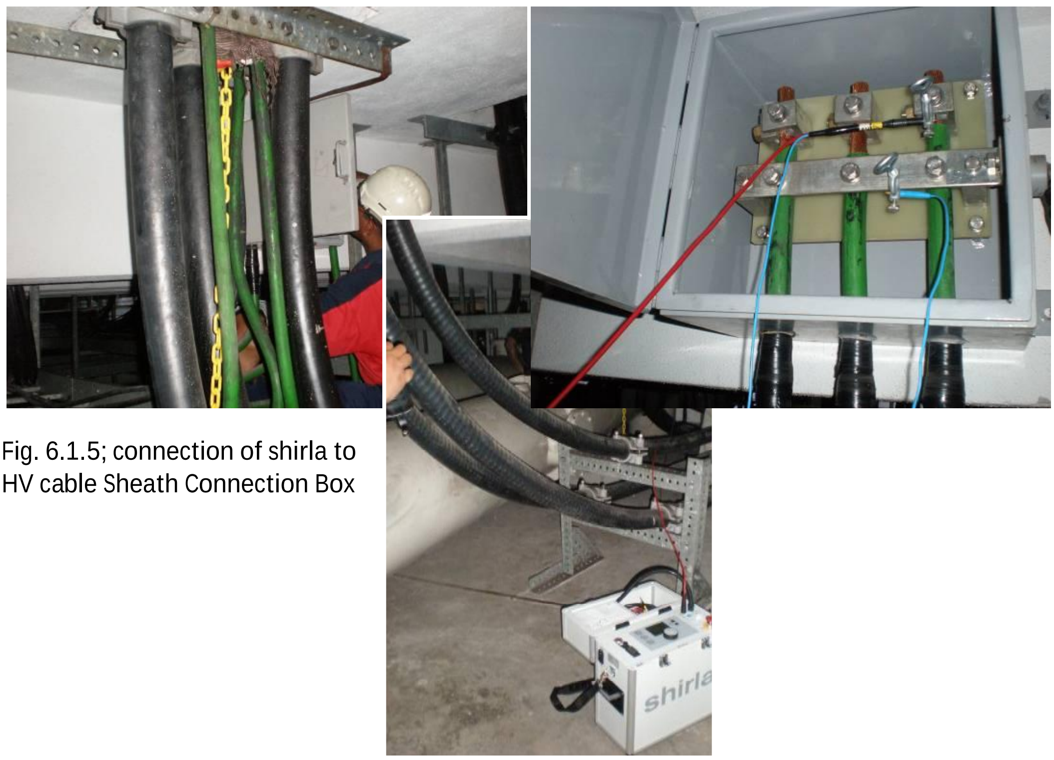



Fig. 6.1.5; connection of shirla to HV cable Sheath Connection Box

## 6.1.2 Crossbonding arrangement

Measuring Bridge is **not influenced** by Cross Bonding Arrangements

- ⇨ ***grounded joints need to be disconnected from ground***
- ⇨ ***surge arrestors need to be disconnected (to apply high voltage)***

Cable Fault Type: ***Sheath Fault***

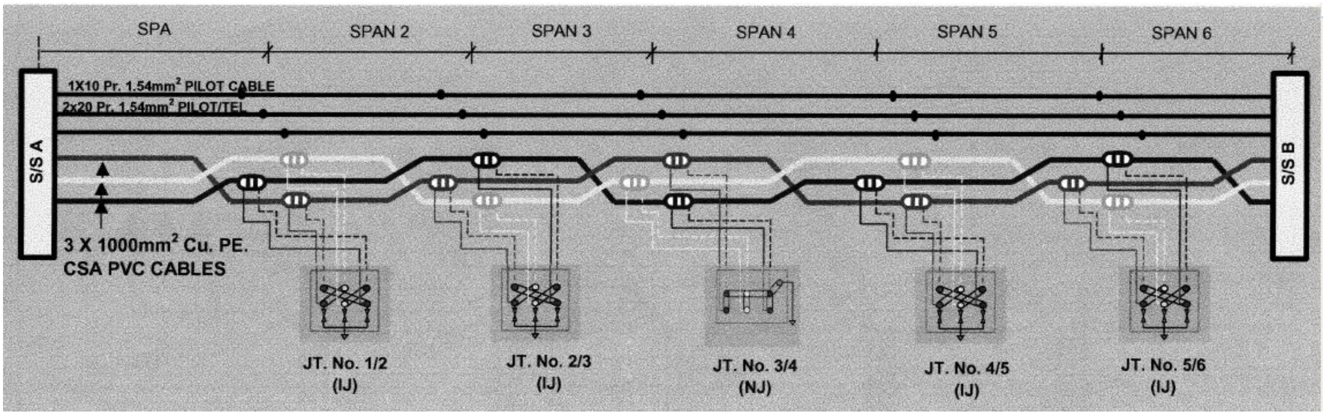
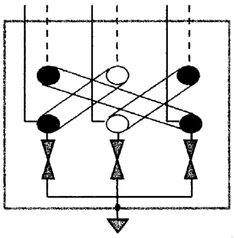
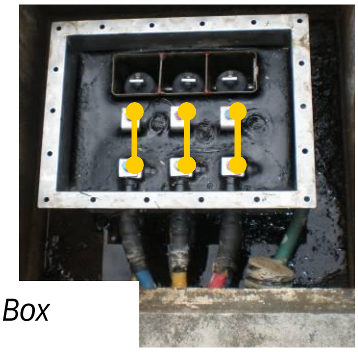
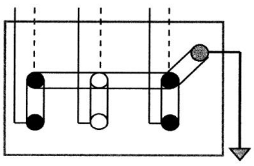



Fig. 6.1.6; Cross – Bonding System Diagram





*Cross-Bonding Link Box*



*Solid-Bonding Link Box*

Fig. 6.1.7; Cross-Bonding Link Box, surge arrestors disconnected

Fig. 6.1.8; Solid-Bonding Link Box, grounding disconnected

<u>Requirement:</u>

- min. 1 healthy core or healthy sheath

Connection according to **Murray**

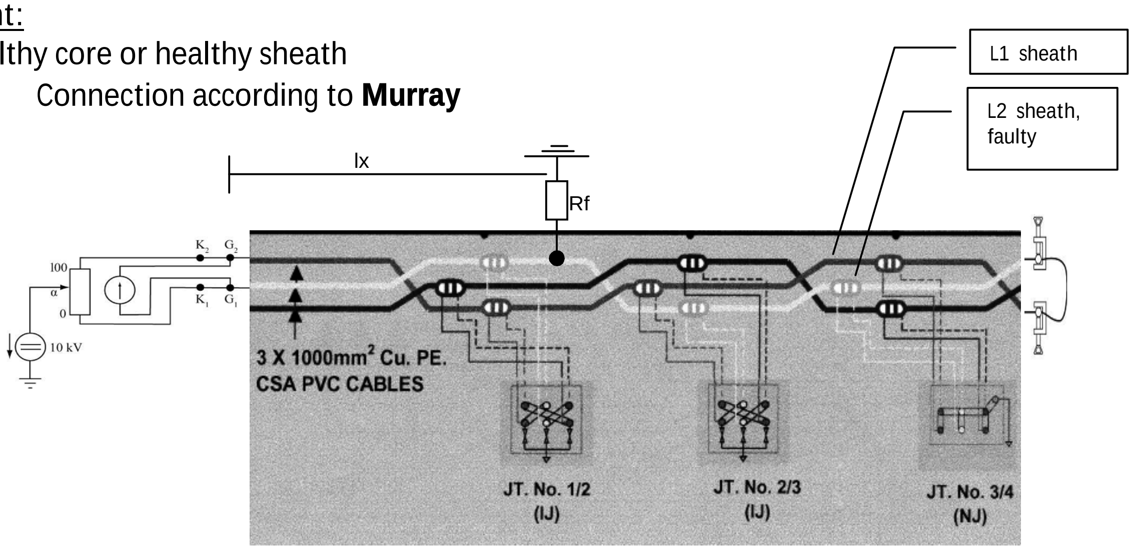



Fig. 6.1.9; Connection acc. to Murray, no influence of cross-bonding arrangement

### 6.1.3 Multiple – Sheath Fault

Multiple sheath faults will lead to an average result.
**The average is considering the position and the fault resistances´ ratio.**
**Multiple – sheath faults can not be prelocated!**
=> reduce length of cable under test
=> reduce probability of Multiple – sheath faults

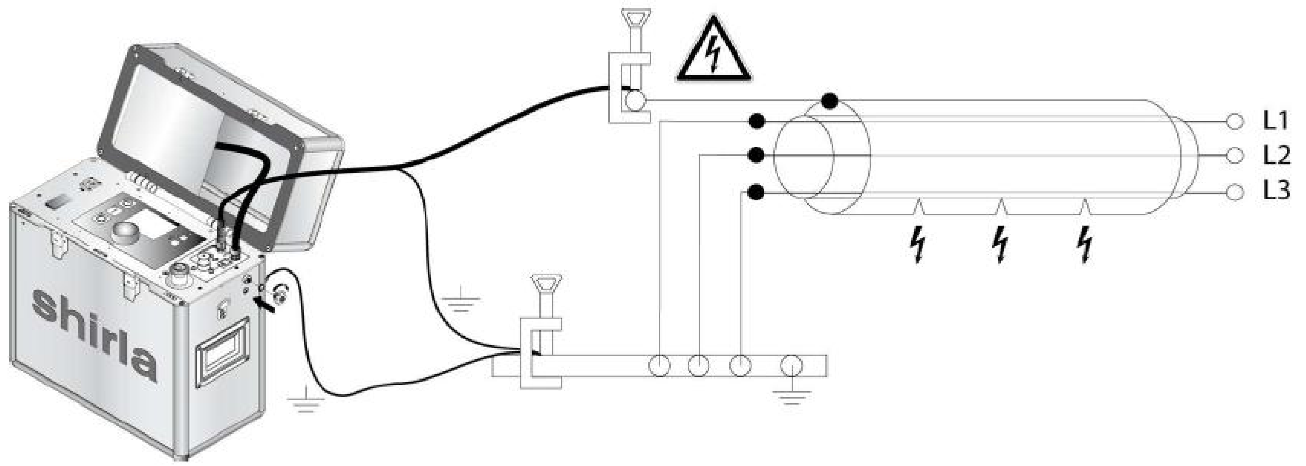



Fig. 6.1.10; Shirla connected for testing & pin-pointing; cable with multiple sheath fault

To reduce the probability of a Multiple – Sheath Fault

⇨ **measurement from link-box to link-box**

Fig. 6.1.11; connection at link-box, battery operation

**Effect of Multiple Sheath Fault**

The effect to the measuring result is that the measuring bridge is balanced on the average fault ratio. Depending on the fault resistances of the individual faults the ratio can be very unbalanced. The measuring result therefore may not let conclude on the real faulty position.

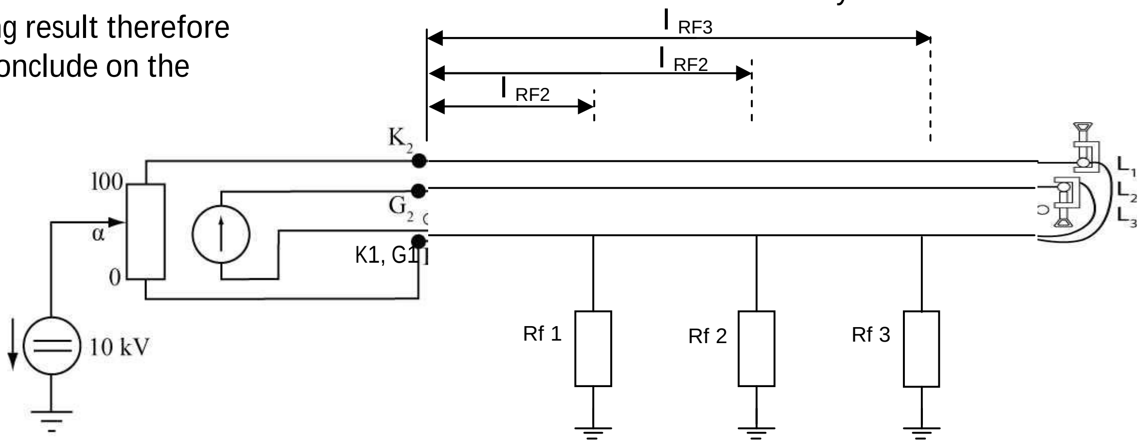



Fig. 6.1.12; Multipe Sheath Fault with Fault Rf1, Rf2, Rf3

Table with examples of fault indication – multiple faults

| **Total length 1000m, U= 10kV I set = 3mA** | **Fault No. 1 Rf 1** | **Fault No. 2 Rf 2** | **Fault No. 3 Rf 3** | **Indicated average Fault Distance** |
|---|---|---|---|---|
| Equal resistance ratio R total = 3,3kOhm | 10kOhm, 1mA 250m | 10kOhm, 1mA 500m | 10kOhm, 1mA 750m | **Approx. 500m** |
| R total = 476Ohm | 1kOhm, 1,43mA 250m | 1kOhm, 1,43mA 500m | 10kOhm, 0,14mA 750m | **Approx. 386m** |
| R total = 476Ohm Symmetrical ratio | 1kOhm, 1,43mA 250m | 10kOhm, 0,14mA 500m | 1kOhm, 1,43mA 750m | **Approx. 500m symmetric** |
| R total = 667Ohm | 1kOhm, 2mA 250m | 2kOhm, 1mA 500m | - | **Approx. 333m (250m +1/3 of 250m)** |
| R total = 667Ohm | - | 1kOhm, 2mA 500m | 2kOhm, 1mA 750m | **Approx. 583m (500m +1/3 of 250m)** |
| R total = 667Ohm | 1kOhm, 2mA 250m | - | 2kOhm, 1mA 750m | **Approx. 416m (250m + 1/3 of 500m)** |

Fig. 6.1.13; Table of examples, ration of fault resistance and location – calculated average distance

## 6.2 *Fault Location on cable drums / cable factories – HV cables*

Fault prelocation on drums – both ends accessible

Resistive Cable Sheath Fault

- ⇨ direct connection to both ends
- ⇨ forward path via one healthy core (Murray) / or two healthy cores (Glaser) can be **substituted by direct connection to the ends** as shown below**.**
- ⇨ **Connection arrangement equal to Glaser**
- ⇨ substitution of forward path, eliminate any connection resistances
- ⇨ on demand, the connection leads for K2 and G2 can be extended. Glaser Methods is acting by compensation of test leads ( 2 healthy cores as extension for K2,G2)

### 6.2.1 Double Shielded HV cables

Double shielded HV cables are designed with two cable sheath layers that are insulated via a PVC layer to each other. Faults of between these two sheath layers can be prelocated with the measuring bridge only.

**resistive Fault between Inner and Outer Sheath**

**Connection acc. to GLASER**

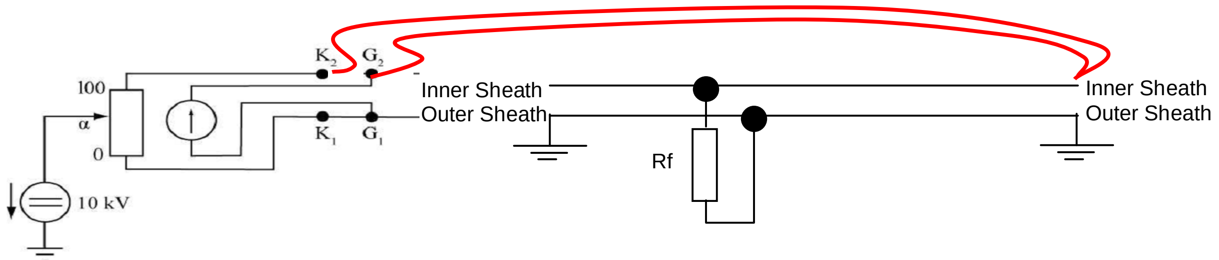
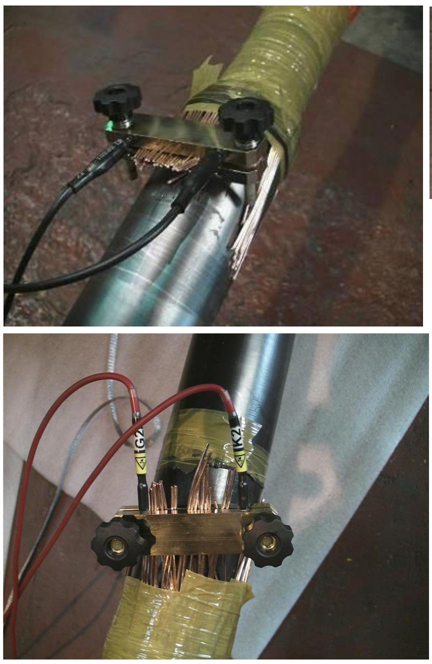



Fig. 6.2.1; Connection acc. to Glaser; extended measuring leads G2, K2



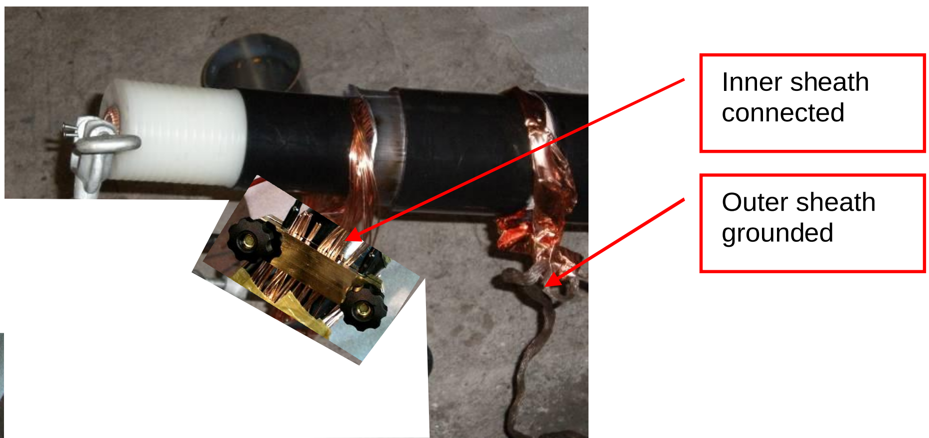




Fig. 6.2.2; Special connection clamps to eliminate connection resistances

## 6.2.2 Normal Shielded HV cables

**resistive Sheath Fault**

To detect sheath faults in cable factories, the whole cable drum usually is **put into a water bath completely**.
Leakage current will flow from the sheath fault to the surrounding water.

**Connection acc. to GLASER**

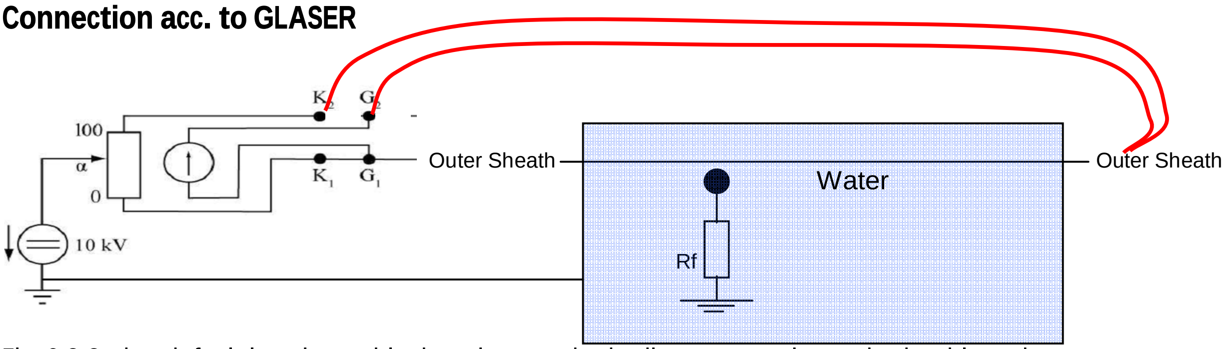



Fig. 6.2.3; sheath fault location, cable drum in water bath; direct connection on both cable ends

## 6.2.3 Graphite Coated HV cables

Resistive Fault between Outer Sheath and Graphite Coating

Graphite Coating can be considered as conductor.

- ⇨ remove graphite Coating on both ends
- ⇨ tapping of graphite coating via copper wire
- ⇨ Graphite Coating representing conductor

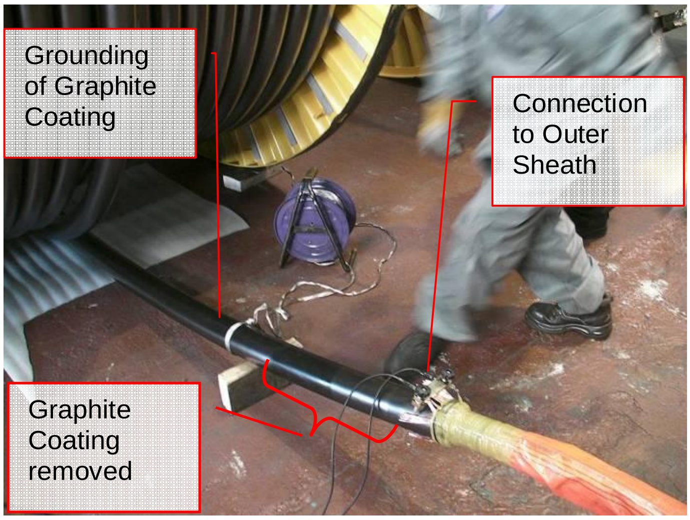



Fig. 6.2.4; connection to cable sheath, graphite coated cable

**Connection acc. to GLASER**

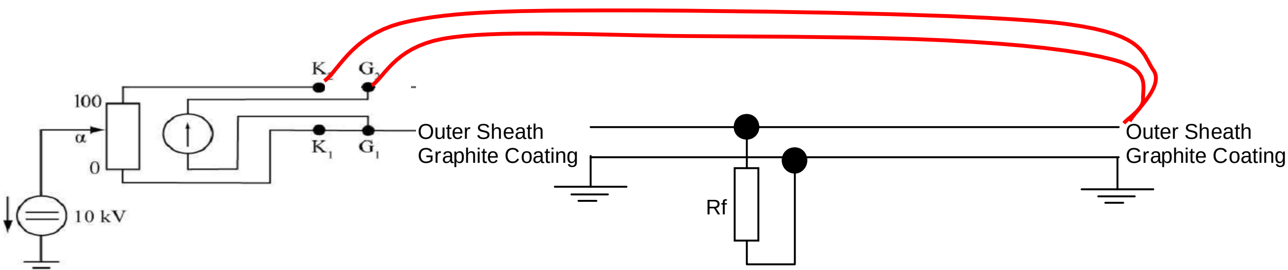



Fig. 6.2.5; Connection acc. to Glaser; special connection clamps; extended connection lead G2, K2

# 7 Cable Fault / Cable Sheath Fault Pinpointing – Step Voltage Method

## *7.1 General Explanation – Application of Step Voltage Method*

Cable faults that are showing up in a **solid grounded** condition do not enable to create a flashover at the faulty point by means of a surge generator. Therefore **no acoustic signal** is audible and the cable fault pinpointing according to the acoustic fault location is not possible. This condition is mainly resulting from a **completely burnt cable fault** that is furthermore **resistive to the surrounding soil**. These kinds of cable faults can be pinpointed by means of the step voltage method explained below.

Fig. 7.1.1; Earth fault in LV cable, solid short circuit between all cores

Faults in **low voltage cables as well as pilot cables** (signal lines) are often difficult to be pin-pointed, because the **maximum voltage** that may be applied to these cables does **not** enable to force **sufficient surge energy** to create a strong flashover that can be pinpointed by means of the acoustic method. As these cables are mainly unshielded, the fault in most cases also appears towards the surrounding soil. Also here, the **step voltage method** is the suitable pin-pointing method.

Fig. 7.1.2; Detection of mechanically damage joint via step voltage method

The 3rd fault type showing similar conditions is the **cable sheath fault**. A fault in the outer protective PVC insulation of a XLPE cable can not be located via the acoustic method, **as no defined potential** point, where the flashover can take place, is given.

Here, also the step voltage method enables the localisation. This method also enables to locate **several sheath fault locations** along a cable.

Fig. 7.1.3; sheath faults, termite damage on outer sheath, mechanical damage at joint

## *7.2 Step Voltage Method in direct buried cables*

### 7.2.1 Pin-pointing of single ground faults

- cables with **no outer graphite coating**

Output Voltage , Current defines the size and intensity of the voltage funnel.
**High Voltage and max. current => most successful**

Fig. 7.2.1; step voltage method, two earth probes connected to UL30 receiver

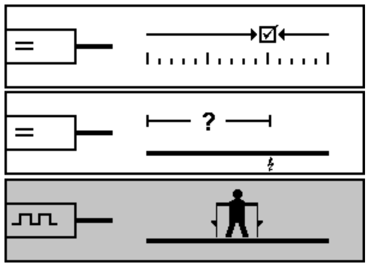


Fig. 7.2.2; Shirla display, pin-pointing mode

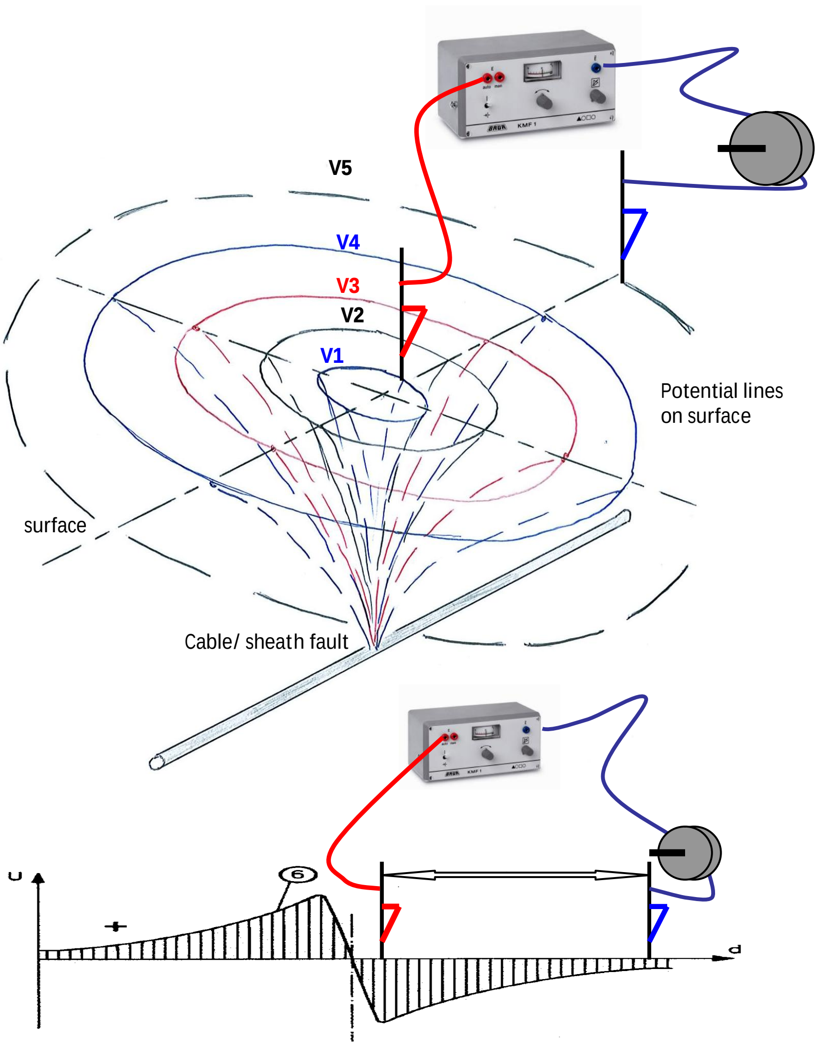



Fig. 7.2.3; voltage funnel detected via potential lines on the surface

As soon as the earth sticks are **placed symmetrical above the fault**, the resulting voltage is zero and **the fault position is determined**.

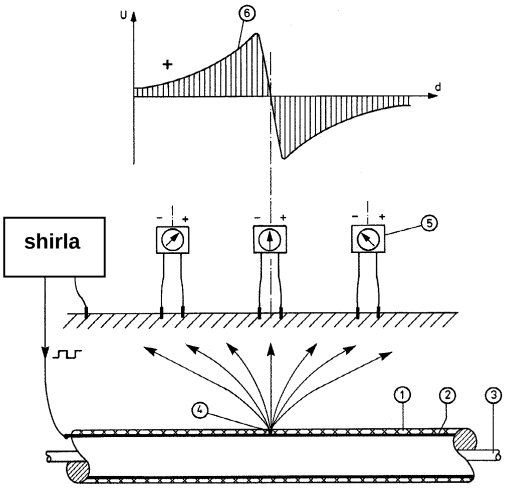



Fig.7.2.4; discharge of HV pulse; voltage drop in shape of a voltage funnel, zero position above the fault, step voltage can be measured at the surface

## 7.2.2 Pin-pointing of multiple ground faults

In case of multiple sheath faults, e.g. 3 faults, all faults can be located as explained below during one passage over the cable route. This requires appropriate practice and one should know that the **step voltage shows several passing through zero position** that might irritate (5 passing through zero / 3 faults).

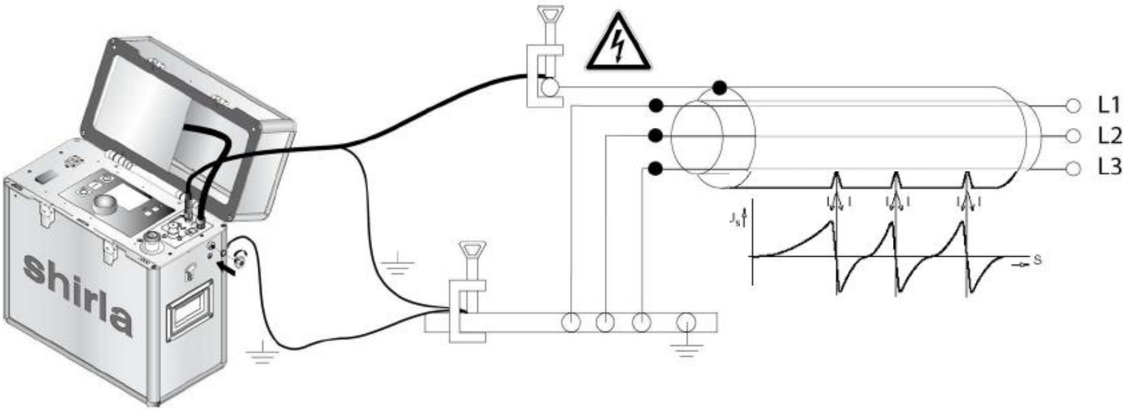
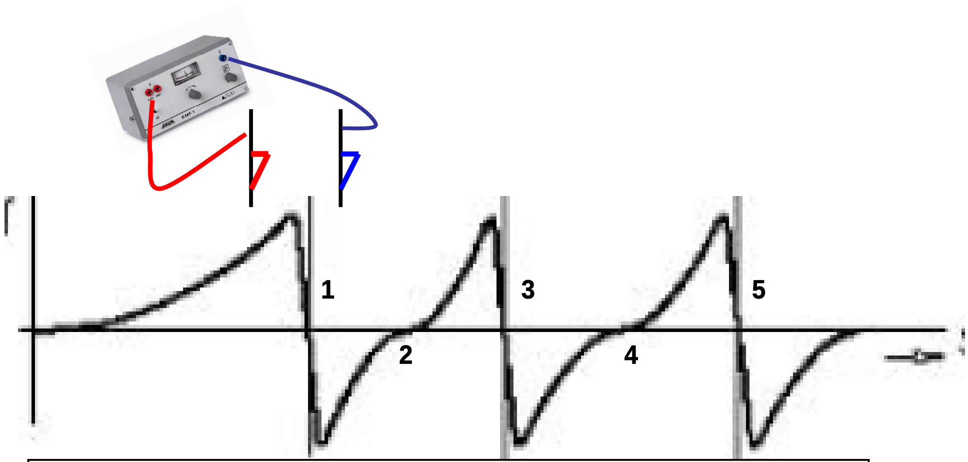



Fig. 7.2.5; Shirla connected for fault pin-pointing, multiple fault indication




1... sharp change of polarity / clear zero position, faulty point
2... wide, soft change of polarity / soft zero position
3... sharp change of polarity / clear zero position, faulty point
4... wide, soft change of polarity / soft zero position
5... sharp change of polarity / clear zero position, faulty point

Fig. 7.2.6; multiple zero indications at multiple faults

### 7.2.3 Pin-pointing of ground faults in HV cables w/ graphite coating

The applied voltage shall be kept as low as **approx. 1kV**. Too high voltage applied effects that the leakage current jumps onto the graphite layer and not voltage funnel can be detected.
By limiting the voltage, this effect can be prevented widely.

### 7.2.4 Pin-pointing of ground faults in cables layed in PVC conduit

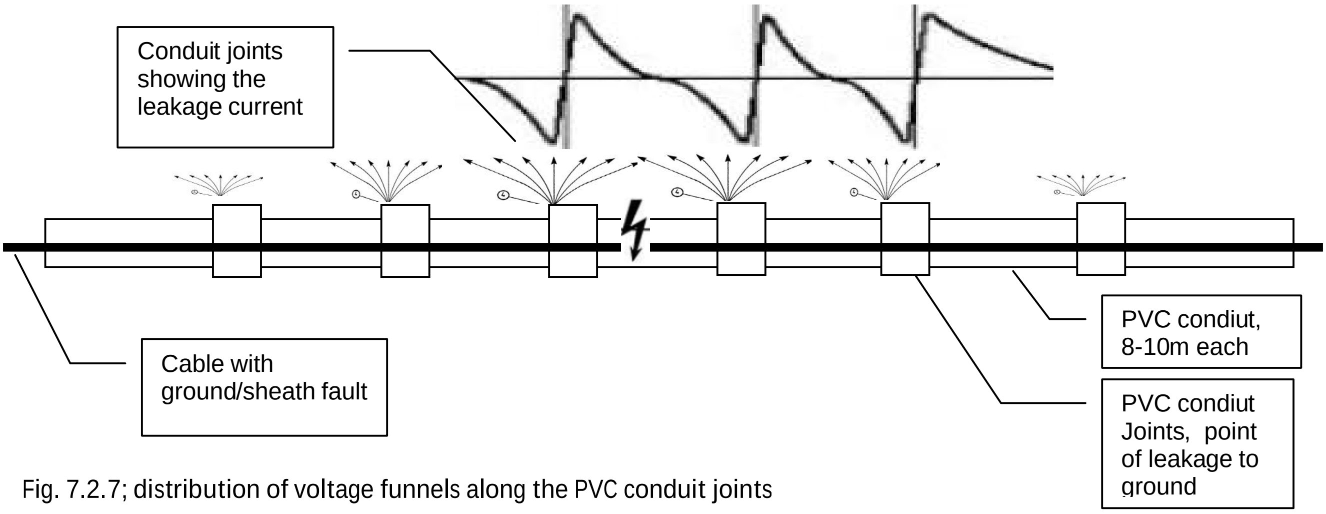



Fig. 7.2.7; distribution of voltage funnels along the PVC conduit joints

Cable conduits are usually containing water or humidity inside. Therefore sheath faults can be prelocated and pin-pointed.
The leakage current exits the nearby conduit joints and creates voltage funnels that can be located.

For pin-pointing it is important **to use low current setting of. max. 30mA** of pulsing current. This enables to keep the signal only in the close area of the fault.

**Too high current** effects that the leakage current exits the conduit joints and creates **voltage funnels at every conduit joint over a long distance.**