METHOD STATEMENT
FOR
SITE TESTING AND COMMISSIONING
PROCEDURE FOR 110 kV XLPE CABLES.

METHOD STATEMENT FOR SITE TESTING AND COMMISSIONING PROCEDURE FOR 110 kV XLPE CABLE

The following are the list of tests proposed to be carried out at site on 110 kV cables.

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GENERAL

The aim of this procedure is to establish guidelines for site testing and commissioning of 110 kV XLPE Insulated Single-Core Underground Cables.

1. Phase Identification Test

Test Objective

This test is carried out to check the phase sequence of the 110 kV cable and to re-affirm whether they are marked correctly or not.

Test Instruments used

1kV / 5kV Megger MIT 520 or Equivalent

Test Set up Diagram

Please see below

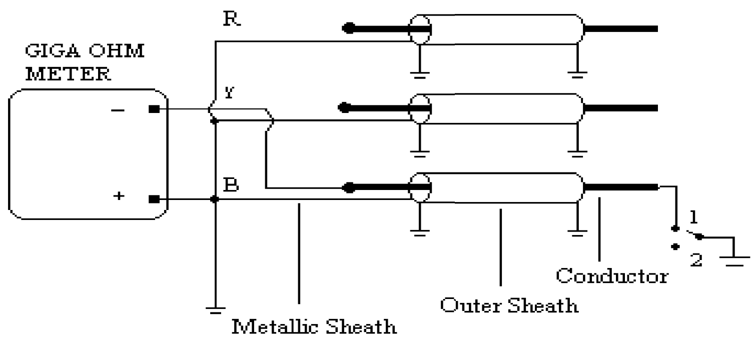
Test Procedure

a) To measure the phase of the cable, apply 500V/1kV DC voltage between the conductor and armor with the help of 5 kV Megger.
b) Ensure that other two phases are earthed during the test except the phase under test.
c) Instruct the operator at the other end to earth the same phase under test
d) Once the phase is earthed the Insulation resistance will become zero.
e) Hence it is confirmed as one phase, say Red.
f) Repeat the above steps for other 2 phases, Yellow & Blue

Test format

Please refer the attached format for ready reference.

Schematic diagram



2. Insulation Resistance Test

Test Objective

This test is carried out to check the insulation resistance of the 110 kV cable before and after the High voltage AC test.

Test Instruments used

5kV Megger MIT 520 or Equivalent

Test Sep up Diagram

None.

Test Procedure

a) To measure the insulation resistance of the cable, apply 5 kV DC voltage between the conductor and armour with the help of 5 kV Megger for a duration of 1 minute.
b) Ensure that other phases and circuits are earthed during the test.
c) Record the insulation resistance as indicated in the attached format.
d) Repeat the test after the high voltage test on the cable and note the IR value.

Test format

Please refer the attached format for ready reference.

Pass Criteria

The IR value measured shall be: >100 MΩ. (Mega Ohms)

3. Conductor DC Resistance Test

Test Objective

To measure and ascertain the DC resistance values for each 110 KV cable conductor for comparison with factory test and client specified values, and to check that cores are continuous throughout the circuit.

Instrument to be used

Megger DLRO 10/10X or equivalent device and Thermometer to measure the ambient temperature.

Test Set up Diagram

Refer the attached figure.

Test Procedure

This test should be performed after all terminations have been completed, and all shield grounds connected, either in grounding link boxes or at the cable terminations. The tests must be coordinated with the GIS specialist so that electrical access to the 110 kV terminations in the GIS cable boxes will be available – i.e the primary connections have not been made and the boxes are open to enable access within:

The three phase conductors at the GIS end of the circuit will be shorted and grounded via the GIS circuit ground switch or with a temporary copper cable of very short length. Measure the temporary copper cables resistance when it is connected for looping and record it.

At the GIS, a digital micro ohm meter will be connected to the termination top connectors of a pair of phases e.g. Red & Yellow phases. The micro ohmmeter will be DLRO 10/10X the loop resistance is calculated by the instrument from Measured Voltage (at the terminations) divided by measured loop current. Hence, the test lead resistances are eliminated from the obtained results.

The ambient shade temperature is measured using a digital thermometer and an estimate of the ground temperature made and recorded.

The measurement is repeated for the remaining two pairs of phases. The individual phase resistance are calculated and corrected to 20^0C from the estimated ground temperature.

The measured values of conductor resistance compared with the resistances calculated by reference to the cable manufacturer's declared DC resistance of conductor per unit length of cable at 20^0C and the installed lengths of the cables.

Pass Criteria:

The Conductor Resistance value measured shall be: $\leq$ Ω

Please refer the attached format for ready reference.
Formula for temperature correction:

For Copper

$$R_{20} = \frac{R_t}{L\{1+0.00393 * (T-20)\}} \quad \Omega / Km$$

R_{20} = Conductor resistance at 20°C (Ohm/ Km)

R_t = Measured DC resistance per Phase (Ohms), $R_t = (R_m - R_{cl})$

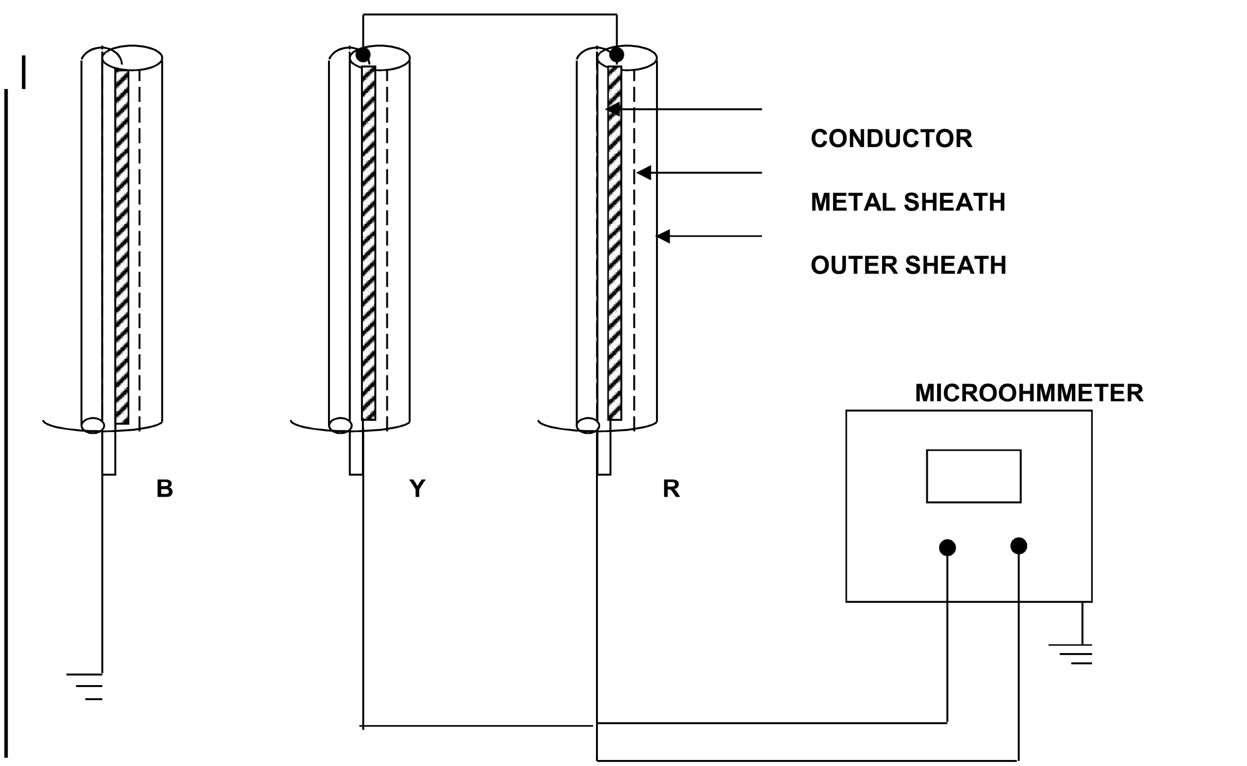
L = Exact Length (Km)

0.00393 = Temperature coefficient at 20°C for copper

T = Ambient temperature measured in °C

R_{cl} = measured test lead resistance at the remote end

R_m = resistance of 2 cable connect it in series by the connecting lead



4. Metallic Sheath Continuity Test

Test Objective

This test is carried out to check the phase sequence of the 110 kV cable and to re-affirm whether they are marked correctly or not.

Test Instruments used

1kV / 5kV Megger MIT 520 or Equivalent

Test Set up Diagram

Please see below

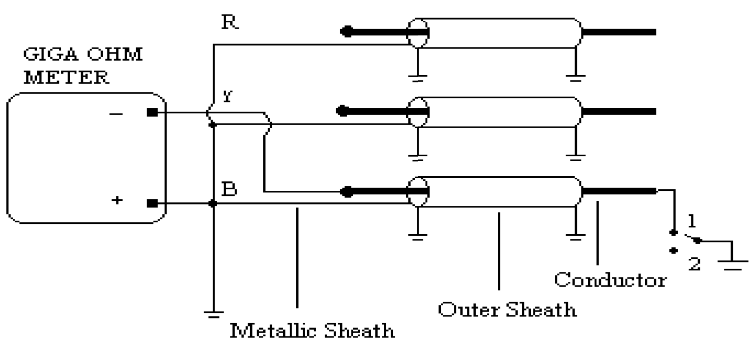
Test Procedure

a) Make sure that inner and outer metallic/ armor of the cable is connected in all link boxes by using solid wire.
b) To measure the phase of the cable, apply 500V/1kV DC voltage between the conductor and armor with the help of 5 kV Megger.
c) Ensure that other two phases are earthed during the test except the phase under test.
d) Instruct the operator at the other end to earth the same phase under test
e) Once the phase is earthed the Insulation resistance will become zero.
f) Hence it is confirmed as one phase, say Red.
g) Repeat the above steps for other 2 phases, Yellow & Blue

Test format

Please refer the attached format for ready reference.

Schematic diagram



5. Outer Sheath DC Voltage Withstand Test

Test Objective

The purpose of the 10 kV D.C. sheath test is to check the condition of the cable jacket, and to indicate any sheath damage during cable installation, back filling or compaction.

Test Instruments used

BAUR PGK 25/50/80 DC Tester or equivalent device

Test Set up Diagram

Please refer the attached.

Test Procedure

In all the sheath grounding or SVL link-boxes at the GIS 110 cable terminations, the links will be opened or SVL's removed to isolate the 380 kV cable shields from ground. The link box will then be locked or otherwise secured against unauthorized entry.

The GIS 110 kV terminations will be barricaded and warning notices posted to preventive approach by unauthorized persons to exposed cable shield and connections that will become energized during the tests.

At the GIS 110 kV cable terminations for the GIS circuits, the shield grounding links will be removed to isolate the cable shields from ground. Unauthorized persons will be kept away from the testing area. Due care will be taken by all persons to remain clear of exposed cable shields and connections at the GIS terminations that will become energized during the tests.

The D.C. output lead of a calibrated DC Hipot set (PGK 25/50/80 DC tester or similar), will be connected to alone of the cable shield terminals in the link box. The other two cable shields will be grounded via temporary clip-leads. The Hipot set will be grounded by connection to the substation ground grid.

D.C. voltage of 10kV is then applied to the 110 kV cable shield for one minute. The time will be measured by stopwatch.

The leakage current is monitored during the test and recorded at the start and end of the one-minute test duration.

The applied voltage will be reduced to zero and the charge retained by the cable shield discharged automatically to ground via a resistor when the test set HV source is switched off.

One of the temporary ground leads will then be connected to the cable shield just tested and the DC HV lead moved to the next phase shield to be tested. The foregoing will be repeated until all cable sheaths have been tested.

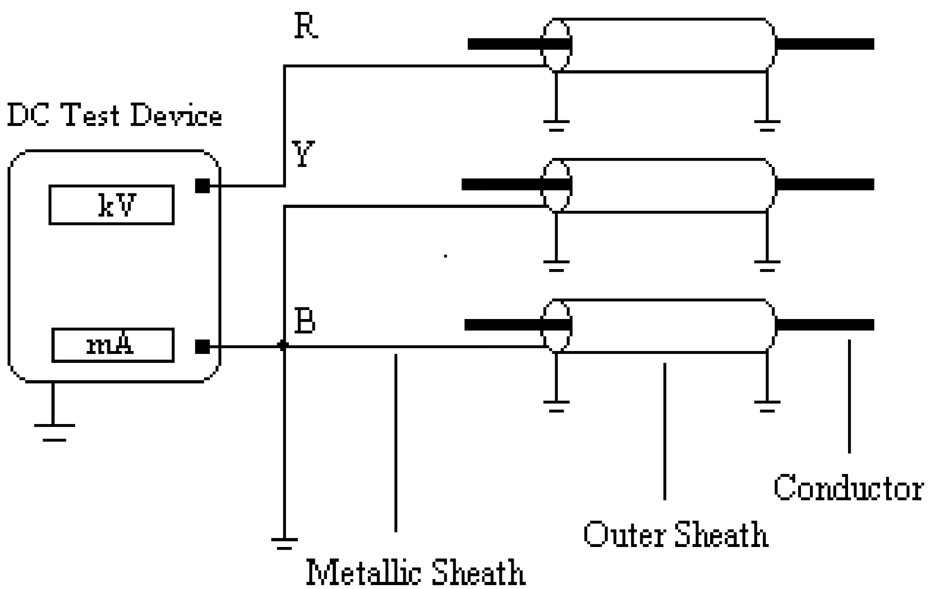
Test Format

Please refer the attached Format.

Pass Criteria

The jacket should not breakdown within the minute at 10 kV. Breakdown is indicated by a failure to reach the 10kV test voltage, high leakage current and probable tripping of the DC HV set.

Diagram for over sheath D.C. Voltage Withstand Test



6. **Capacitance Test**

Test Objective

The purpose of this test is to compare the measured value of capacitance of each 110 kV cable with the capacitance calculated by reference to the manufacturer's declared capacitance per unit length of cable and the installed length of each cable.

Instrument to be used

Fluke 189 (True RMS Multimeter)/ MEGGER MIT520/10 or Equivalent

Test Set up Diagram

As per below diagram.

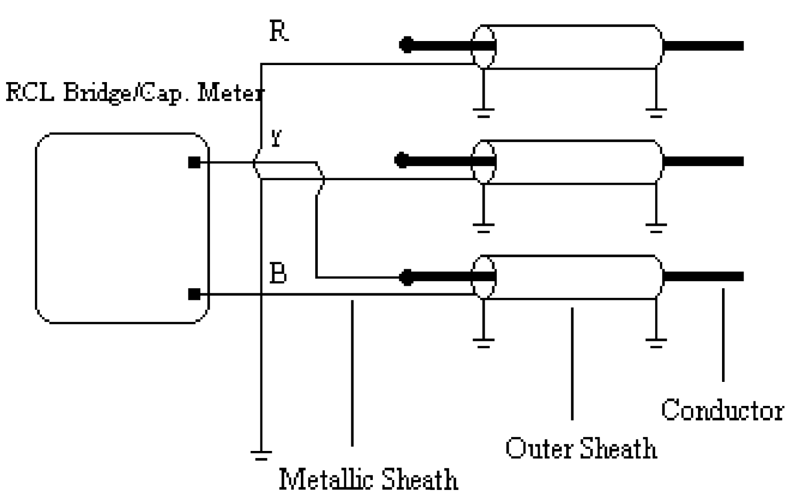
Test Procedure

Connect the test lead between conductors & metallic screen and record the measurements for all the three phases. Then the test leads are connected between the conductors of any two phases and repeated for all the three phase (i.e. R- Y, Y-B & B-R)

The readings are recorded in the test format as per the attached Test Format

Test format

Please refer the attached format.



Test setup Diagram

7. Measuement of Leakage Current and Insulation Resistance of SVL Test

Test Objective

The purpose of this test is to verify that the SVL's are not damaged during installation and to verify their characteristics. The insulation resistance of SVL's is done after the characteristic test.

Instrument to be used

BAUR PGK 25/50/80 DC Tester or equivalent device, Megger MIT 520 or Equivalent

Test Set up Diagram

Please refer the attached drawings.

Test Procedure

Leakage current is recorded when a certain kV (depends on rated voltage of the SVL) DC is applied across SVL brackets.
The readings are recorded in the test format as per the attached Test Format.

The internal insulation resistance shall be measured between the base of SVL's and support frame. This test will be done after the SVL characteristics test and before the HV AC test.

Test format

Please refer the attached format.

Diagram for SVL Operating Voltage Test

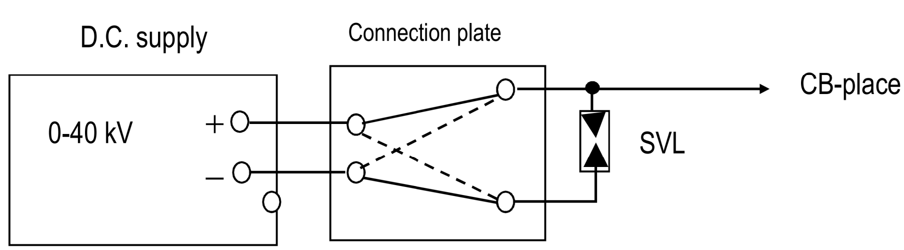
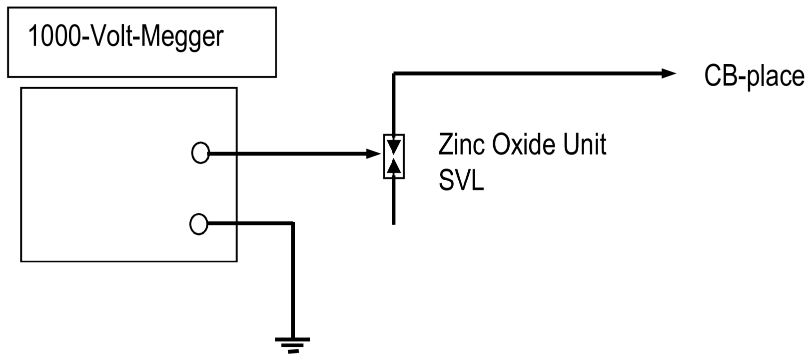


Diagram for SVL operating voltage test

SVL Visual Inspection and Insulation Resistance Test



8. Link Box Contact Resistance Test

Test Objective

The purpose of this test is to verify that the contact resistance of the sheath and SVL's.

Instrument to be used

Megger DLRO 10/10X or equivalent device or Equivalent

Test Set Up Diagram

Please refer the attached drawing

Test Procedure

Using the digital micro ohmmeter measure the contact resistance between joint lug to Bonding leads and records the values. Similar technique is used to measure contact resistance between SVL lead to terminals
This test should be done after the HV AC test as the connections will be remade after the test.

Pass Criteria: Contact resistance must be less than 20 microΩ

Test format
Please refer the attached format.

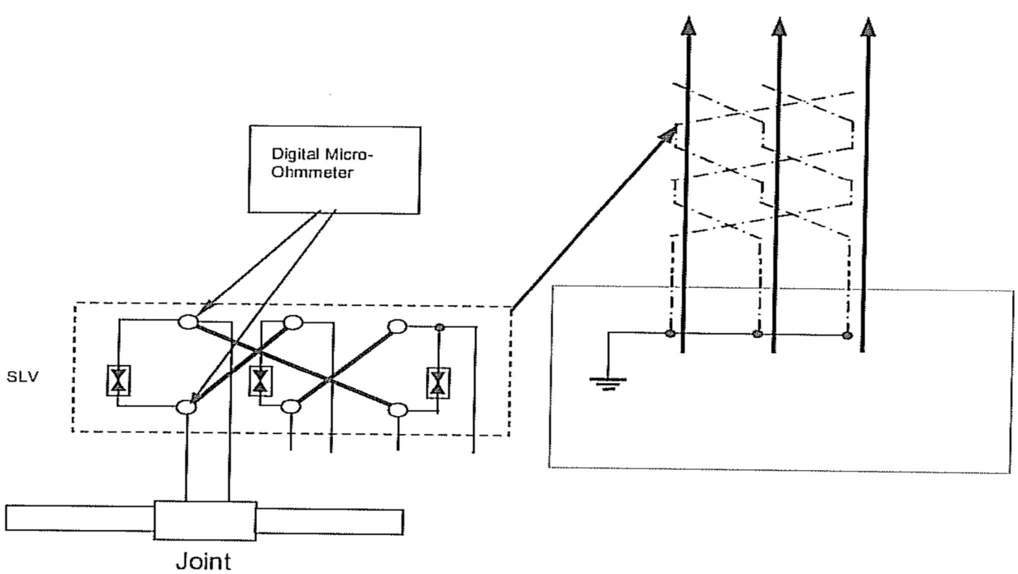


Diagram of measuring sheath system contact resistance

9. **<u>Earth Resistance Test</u>**

<u>Test Objective</u>

The measurement of earth resistance is mainly intended for the purpose of grounding the links of bonding system of High Voltage cables.

<u>Instrument to be used</u>

Kyoritsu Digital Earth Resistance Meter or Equivalent

<u>Test Set Up Diagram</u>

Please refer the attached drawing

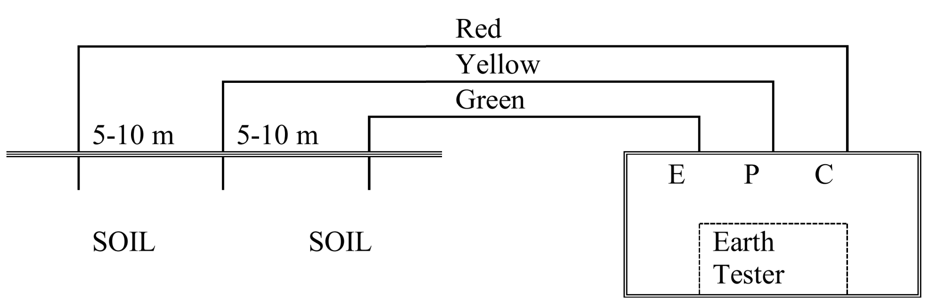
<u>Test Procedure</u>

Check the battery voltage. Depress the push button. Switch ON and slide the switch to position 20 ohms and hold down the push button and take a reading.
The electrode under test should be connected to the Position E using a green lead. Red lead should be connected to the P position and Yellow should be connected to the C position.
The red lead should be connected to the middle of Green and yellow lead about 5-10 meters apart.

<u>Pass Criteria</u>: Earth resistance must be less than 2Ω inside GIS Perimeter and less than 10Ω at the joint pits.

Test format
Please refer the attached format.

Schematic Diagram:



10. Cross Bonding Verification Test

Test Objective

With the cross bonding checks, the right connection of the bonding cables can be checked and when correctly bonded, no current may flow in the lead alloy sheaths of the cable in case of an ideal situation.

This is only the case when all cable sections have the same length and the spacing between the cables is constant along the cable route. Practically speaking, some induction current will always flow as the configuration of the cable system is never ideal. The actual site requirements and situation dictate what the actual cable section lengths that may differ from section to section.

Instrument to be used

3-Phase isolation transformer, Multi meter, Clamp meter, Digital Power Meter or Equivalent

Test Set Up Diagram

Please refer the attached drawing fig 6.

Test Procedure

The measurement will only take place when the circuit is completely installed in all respects. The terminations however should be inserted into termination boxes but links should be removed in order to have electrical access to the cable core whereupon the equipment will be connected. If the cable termination is already connected with the GIS then it is also possible to use the motorized grounding in the GIS to have an access to the conductor.

After having checked the cross bonding visually in each link box along the route measuring equipment can be connected.

Connect the 3-phase transformer to the 3-cables according to attached figure below. With all bonding links in their normal position, the 3 cables are fed through a 3 phase transformer to inject the current of 40-80 amperes in each cable.

Sheath current and sheath to ground voltages are measured at the nearest cross bonding link box, by using the clamp meter.

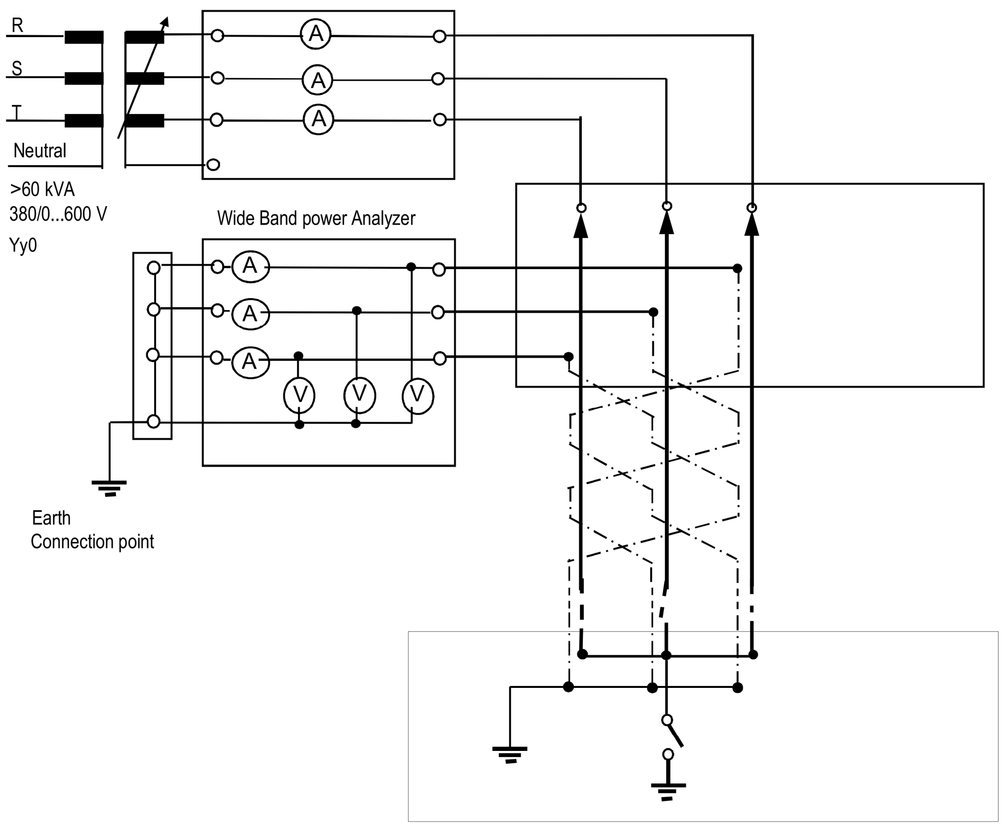
The test current is then reduced and wrong connection is deliberately made at the cross bonding box.

The current is then raised and the sheath currents and sheath to ground voltages measured again at the same link box. It is noted high current and voltage.
After recording the above values, normal connections are restored and current and voltages are measured at each cross bonding link box. The noted current/voltage should be always very less compare to the current/voltage measured when wrongs connection was done.
The power source is a 3-phase current supply that should be available in the substation.

Test format

Please refer the attached format.

Diagram for Verification of Cross-Bonded Sheath System



11. Positive/ Negative and Zero Sequence Impedance Tests

Test Objective

To measure the positive/Negative sequence and zero sequence impedance of the cable circuits

Instrument to be used

3 Phase and 1 phase isolation transformer, Power meter, Voltmeter, Ammeter, Clamp meter.

Test Set Up Diagram

Please refer the attached drawing Fig 7 and Fig 8.

Test Procedure

Positive sequence impedance have been calculated assuring that there is no other metals that are placed with an influential distances of the cable (Railway lines, pipe lines or buried equipment etc.). The presence of the other metals will influence the sequence impedance. Because of the influence of other unknown factors, it is recommended that the impedance should be measured in the field after the circuits are installed.

Zero sequence impedance of the cable is not a fixed quantity and depends on the environment. Measurements on installed cables have to be carried out, in order to obtain the exact values.

All cable shields, link box connections and ground wires for the circuit under test, and any parallel circuits must be configured in the normal in-service state. Any CT's through which the primary circuit passes (as configured for this procedure) must have their secondary either short circuited or connected to their normal burden, so that CT secondary currents can flow. The tests must be coordinated with the GIS specialist, so that electrical access to the 110 kV terminations in the GIS cable boxes will be available – i.e. when the boxes are empty of SF6, the primary connections have not been made and the boxes are open to enable access within:

The three phase conductors at the GIS end of the circuit will be shorted and grounded via the GIS circuit ground switch or through temporary shorting cables of short lengths.

At the test end a double wound transformer with an ungrounded secondary winding is used to inject current into the circuit either injecting into pairs of phases (one phase and returning through another) (positive sequence impedance Z_1 measurement) or injecting into all three phases and returning through the shields and/or ground (zero sequence impedance Z_o measurement). Circuit diagrams are shown below. Separate current and voltage connections will be made to the 110 kV termination top connections so that test lead impedance is excluded from the measurements.

The transformer is set to inject about 40-80 Amps the exact value will be to be set at the site based on the respective secondary tapping.

Current is injected into the circuit as per the circuit diagrams and voltage, current and phase angle are measured and recorded.

A check value is measured by injecting into one phase and returning through the shields/ground and voltage and current are recorded giving an absolute value of the impedance.

The sequence impedance is calculated using simultaneous equations.

Zave = Uave / Iave Ω

R = |Zave| cosØ Ω => Real component

X = j|Zave| sinØ Ω => Imaginary component

Z+/-’ = R + jX Ω => Rectangular Form

Z+/- = R + jX / total cable length (in kinometer) Ω/km => Rectangular Form

Convert to Polar form

Z+/-’ = $\sqrt{R2+X2}$ Ω => Polar magnitude

Z+/-’ = arctan $\frac{jX}{R}$ Ω => Polar angle

<u>Pass Criteria:</u>

The Positive/Negative Sequence value measured shall be: Ω/Km in Rectangular Form.
The Zero Sequence value measured shall be: Ω/Km in Rectangular Form.

Test Diagram

Please refer below for the test diagram.

POSITIVE / NEGATIVE SEQUENCE IMPEDANCE TEST

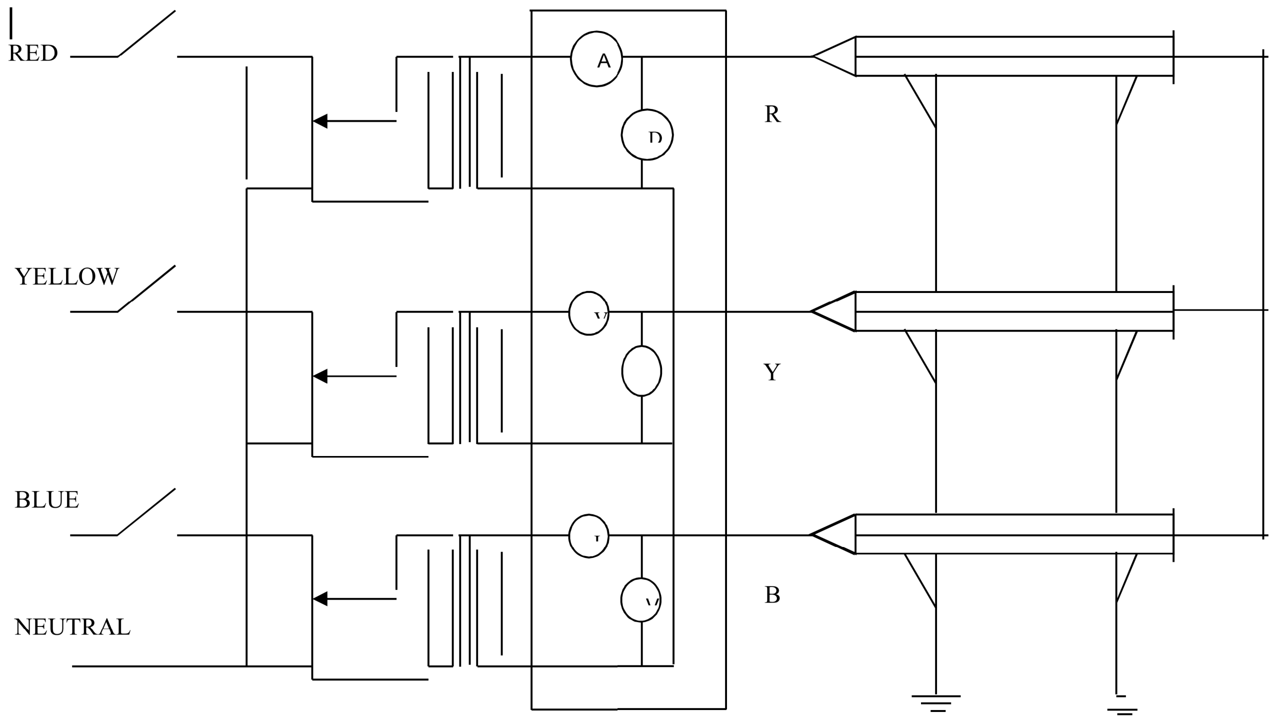


Figure 7

ZERO SEQUENCE IMPEDANCE TEST