TECHNICAL BULLETIN
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Impedance Measurements on Short Lengths

Positive and zero sequence impedance testing on short length (≤≈400m) cable circuits (usually single point bonded) is discouraged. Various reasons are discussed in this bulletin. Although the tests can be undertaken, we share this information so that informed decisions can be taken on the usefulness of the measurements and final decision on the undertaking of the tests.

The main contents of the technical bulletin follow….

To measure the positive and zero sequence impedances, a three-phase and single-phase current injection test is necessary, preferably in the range of 25-100A, together with measurements of current, voltage and phase angle. CBI-electric: African cables has custom made injection transformers which facilitates the generation of appropriate voltages and currents to ensure accurate measurement of the positive and zero sequence impedances according to ESI 09-4.

This document aims to discuss the tests fundamental pitfalls of the testing when tests are undertaken on single point bonded ("SPB") cable systems.

SPB cable systems are usually shorter length cable system when compared to cross-bonded systems. This is due to sheath standing voltages being a function of length, thus limiting the maximum practical cable system length possible using SPB. Secondly, SPB is often used to link an overhead line to indoor switchgear or GIS and hence is usually short in length.

With reference to positive and zero sequence impedance, the addition of the ECC provides and alternate earth path for some zero sequence currents depending on the origin of the fault. This is especially relevant to SPB cable systems linking overhead lines to switchgear where a through fault from the overhead line would be routed through the ECC and not the cable metallic sheath. The flow of zero sequence current from a cable fault would depend on the position of the fault and the direction of current flow toward the source and hence which end is solid bonded and which end is protected with an SVL.

With relevance to the testing methodology, SPB circuits are tested in the normal operating state with SVLs in place and the ECC connected. Other permutations possible are bridged SVLs (simulating a TOV condition under which the SVLs are designed to conduct and clamp the sheath voltage) and disconnected ECC with bridged SVLs (basically mimicking the datasheet calculation of all zero sequence current through the sheath. The value of each permutation will depend on client requirements for input into protection relay impedance models but for the vast majority that normal operating state of the circuit is sufficient**.**

Furthermore theoretical calculation accuracy invariably decreases with decreasing cable length due to the following effects:

1. Star point / earth lead resistance.
2. Reactance of the star point / earth lead and supply connections.
3. The spacing of outdoor terminations and theoretical reactance.
4. Return of 3 single phase currents through the ECC.

CBi-electric: african cables | a division of ATC (Pty) Ltd | Registration No. 1955/003773/07
PO Box 172, Vereeniging 1930 | Steel Road, Peacehaven, Vereeniging, 1939, South Africa
Tel: +27 16 430 6000 | www.cbi-electric.com | Member of the REUNERT Group | B-BBEE Level 1
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1 Star Point / Earth Lead Resistance

The CBI-electric: African cables test equipment uses “appropriate” earth leads to form the star point or earth on the far end of the cable circuit under test – usually 5m of 95mm² Cu leads. These earth leads are a series resistance to zero sequence measurement current and so should be included in the theoretical calculations. What is important to note here in the magnitude of their influence when compared to the HV cable under test – the 5m of Cu earth leads are effectively equivalent to 25m of 132kV 1000mm² Al XLPE cable. Thus as the cable circuit length decreases the influence of the earth leads, and theoretical calculations, increase.

2 Reactance of the Star Point / Earth Lead and Supply Connections

The placement / routing of supply leads and star point / earth leads connections is limited and while some loop reactance can be minimised, the effect cannot be eliminated. Whereas the series resistance component discussed above are easily added to the theoretical calculations, this reactive component are must harder to estimate and quantify and once again the effects on shorter cable circuits is more pronounced than longer circuits where the cable dominates the measurement.

3 Outdoor Spacing of Terminations

Outdoor terminations of cables linking overhead lines are often separated by at least 3m and result in a large enclosed loop (area). While cables are often buried in a Close Trefoil formation, this area formed by the outdoor terminations can result in the equivalent circuit reactance of cables buried in Flat formation with a 2-D phase spacing depending on the circuit length. The cable trench geometry in relation to the orientation of the terminations and if any phase transposition occurs at the terminations, will affect the resulting reactance. While this is often difficult to quantity, on longer cable routes the effects become negligible.

4 Single Phase Current Return on ECC

Testing under the normal operating condition of a SPB cable system, the three single phase currents conducted down the conductor return via the ECC (as the sheath is not connected to earth due to the SVLs). The result of this is the equivalent of 3 x ECC resistances and 3 x ECC reactance. The reactance of the ECC is also not easily determined due to the unknown geometrical relationship of the ECC to the cable circuits near to terminations and link boxes. Once again a phenomenon which only becomes relevant to short cable circuits and negligible to longer circuits.

5 Flat Formation Large Conductors

Outer cables of cables laid in Flat formation have different impedances due to different mutual inductances. The effect becomes more pronounced as the cross sectional areas of the conductors are increased. The phenomenon is described in Technical Bulletin number 29.

6 Conclusions

The recommendation of ESI Standard 09-4 that cables longer than 400m should be measured should now be better understood.

It is hence a recommendation of CBi-electric: african cables that short length cables, which are usually single point bonded, not undergo positive and zero sequence testing but instead dc Ducter measurements confirming the conductors, ECC and sheath resistances and of course not neglecting other standard after installation tests which are undertaken as standard tests.