21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org

**2016 CIGRE-IEC Colloquium**
May 9-11, 2016
Montréal, QC, Canada

# LIFE EXTENSION TECHNIQUE FOR EXTRA HIGH VOLTAGE POWER CABLES

**H C Sharma, D R Dharmadhikari, Kapil Kumar**
**Tata Power Delhi Distribution Limited (TPDDL)**
**INDIA**
**hc.sharma@tatapower-ddl.com**
**dr.dharmadhikari@tatapower-ddl.com**
**Kapil.kumar@tatapower-ddl.com**

## SUMMARY

Due to various requirements, the High Voltage cables (66kV and above) are large cross section area, single core cables. These single core cables are having inherent issue of development of voltage in the sheath while carrying alternating current and current in case it gets earthed intentionally or accidently.

Due to induction effect, voltage gets generated in the cable sheath. The sheath voltage depends on the current being carried in the cable, continuous length of the cable and the type of construction of the cable. The sheath voltage gets generated as per the Faraday's law of electromagnetic induction. These voltages are required to be limited to 65 volts as per Bureau of Indian Standards (BIS 3043).

As per current practice globally, the sheath current is not monitored and almost left unattended. Specially in the city environment, having low soil resistance and where water table is high, numerous failure of the cables have been reported due to high sheath current because of damage in outer sheath where many agencies are working in the same corridor. The multiple agencies working on the same corridor damage the outer PVC/HDPE sheath of the cable and the metallic sheath comes in contact with soil and gets earthed accidently. This results in voltage getting earthed in sheath and circulates high current .This is further more relevant in case of countries where there is high load growth like in India.

Due to circulation of undetected current in sheath because of above reasons, the sheath starts getting heated and insulation getting sandwiched between conductor and sheath started getting deteriorated and finally resulting in failure of the insulation. The life of the cable gets affected by frequent failures which is mainly as the voltage and the current of the sheath is not being monitored and reliability is hugely affected. Capital investments (CAPEX) of millions of Rupees is required for laying of EHV cables and they are expected to serve at least for a life span of around 20 to 25 years. The premature failure of the cable not only results in repeated capital expenditure and maintenance cost but also the interruptions in the power supply. Apart from this the cost of unserved energy due to circuit remaining out is huge in terms of financials and also affects brand image of company.

As the problem of damage of single core cables was increasing, Tata Power Delhi Distribution Ltd (TPDDL) started devising ways so that the problem can be addressed. The requirement was to avoid the damage of the link boxes used for cross bonding/earthing of the cable sheath and at the same time to monitor the voltage and current of the sheath. Immediately novel concept of bringing link boxes accessible & monitoring was implemented in a pilot project from RG-28 TO RG-6 circuit. By doing so we could avoid damage of the boxes, water ingress in the boxes and also if any agency damages the outer jacket/sheath of the cable , it disturbs the voltage and current data of the sheath on the both /one side of the damage. On its success the same were implemented in all the upcoming new projects. This was a major achievement in terms of technology and operational & maintenance ease.

The accessible link box has addressed the problem of bonding arrangement getting damaged & monitoring but again they need special effort to lay these cables in trefoil and the whole laying and jointing is very sophisticated process with losses due to sheath still persistent. Further frequent monitoring is required. The solution as above is a reactive/lag measure which is mainly for monitoring of the voltage and current in the sheath.

Keeping in view of the TPDDL circuit requirement in terms of voltage ,length, loop in loop out feasibility , laying ease , cost impact still it was felt that other options also needs to be explored.
The matter was discussed with the major cable manufacturers but no solution was found. After that we again deliberated it over the issues to be addressed and what actually shall be an ideal solution so that there no induction of the voltage in the sheath. This was possible only if three core cable can be used but manufacturing of three core cable of cable 1000 mm2 cross section was out of the question due very high per meter weight. Then came the idea of using 2 runs of 300 mm2 instead of single cable 1000 mm2. After determined and sustained efforts 3 core 300 mm2, 66kV cable was finally developed which is the ultimate solution for all the problems faced in single core cables.

**KEYWORDS**

Sheath Current
CAPEX
Single Core 66 KV Cable
Three Core, 66 KV Cable
Accessible Link box

## Problem Definition:
### (Reason for frequent failures of single core EHV cables)

In single core cables, due to induction effect, voltage gets generated in the cable sheath as per right hand grip rule. The sheath acts a secondary of the transformer while conductor acts as primary.

Fig-1, Single core cable.

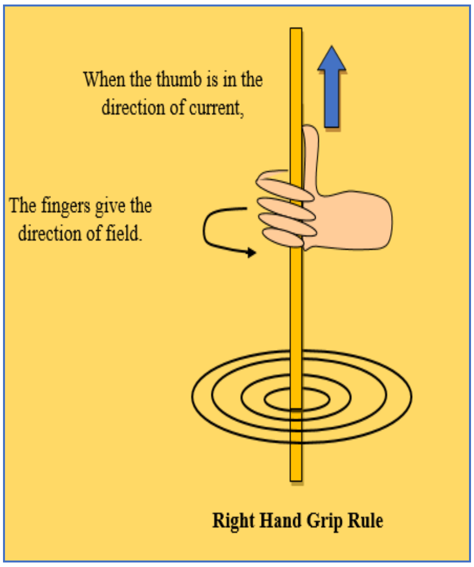


Fig-2, Right hand grip rule.

If the sheath is earthed at one end  as shown below the other end voltage would rise and the voltage rise would depend on the circuit length, current being carried by the cable and manufacturing of the cable.

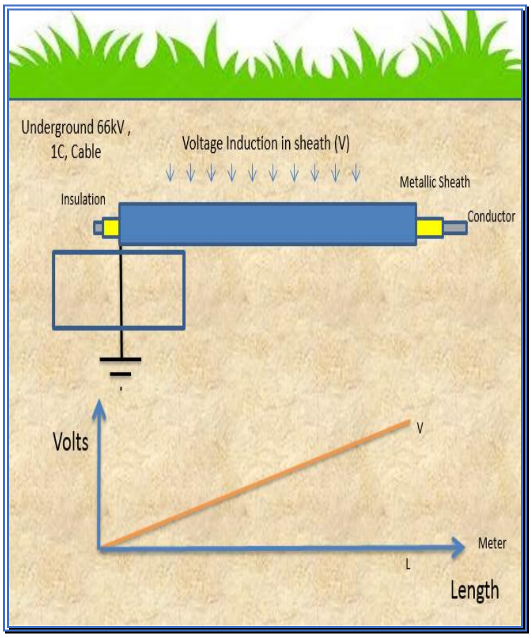


Fig-3, Un-bonded cable

The voltage rise needs to limited due to safety and other reasons, as per IEC/BIS 3043 the sheath voltage should not exceed 65 V. For short lengths of up to 1000 M, we can earth the sheath at one end and other end can be left open as shown above. The rise in voltage remains in safe limits. This is called single point bonding.

But in case of fault, the current in the cable rises to multiple times that of nominal current rating of the cable though for fraction of second, hence the voltage generated during that time in sheath also rises to very high values. To limit this voltage the other end can be connected to surge voltage limiter as shown below.

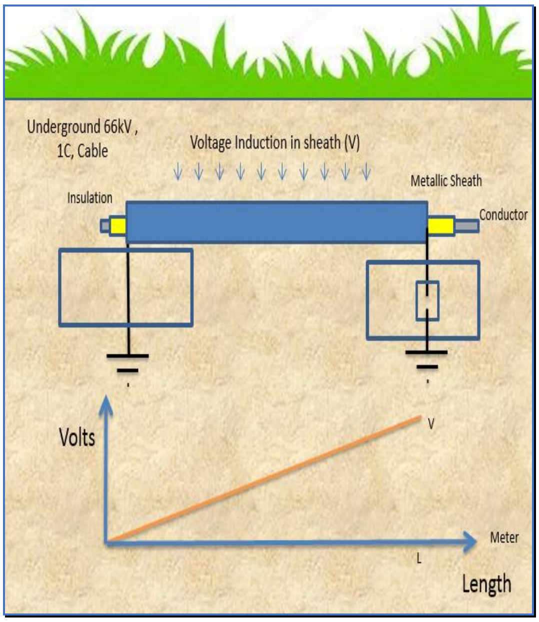


Fig-4, Single Point Bonding

There is no limit mentioned for the current but the same needs to be restricted to lowest value as it results in heating of the sheath, hence loss of energy and the same time damage the insulation and ultimate failure of the cable.

Broadly two methods are employed by industry based on the fact whether voltage is to be limited or the current.

## a) Voltage limiting:

The generation of the voltage largely cannot be controlled except there may be very minor variation based on construction of the cable however in long length of cable in the range of 2-3 KM. The sheath of different phases of the cable be cross bonded in such a way that each part is of equal length and voltage so generated in three different phases being 120 degree apart from each other finally makes a vector sum of almost zero voltage. The cable is finally earthed at both the ends. As the final residual voltage is almost zero the current flowing in sheath at this voltage is almost negligible. The entire arrangement of earthing and SVLs is enclosed in weatherproof boxes and buried along with the cables.

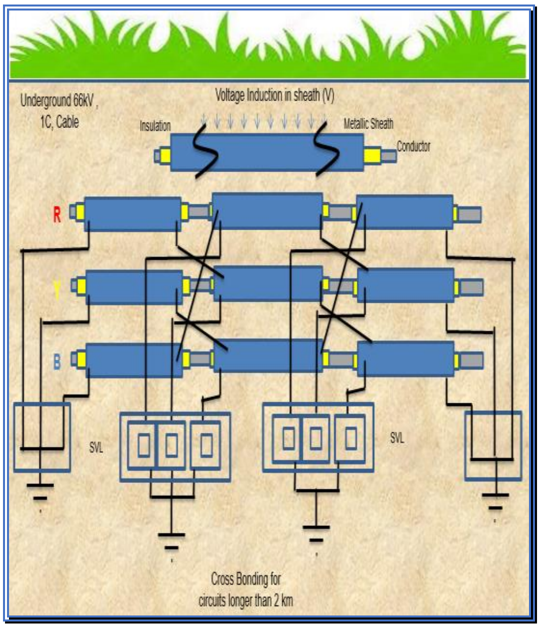


Fig-5, Cross Bonding

B) Current limiting:

In the other method where the length of the cable being small and cross bonding of the cable is not feasible and advisable. We can leave the small voltage generated in these cables but the sheath needs to be insulated in such a way that in normal circumstances the sheath is earthed at one end but insulated on the other end. No current is flowing in the sheath, however there is voltage of small magnitude on the sheath. However In case of the voltage of the sheath going above a threshold limit due to abnormal condition like short circuit of the cable , it gets earthed momentarily through Surge Voltage limiters and the voltage is brought back to normal limits.

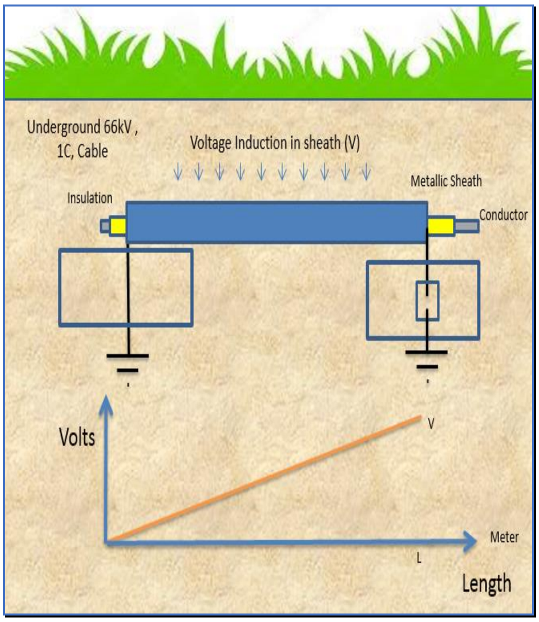


Fig-6, Single Point Bondin

There are few other combinations for limiting voltage and current based on the length of the circuit. The system run fine in ideal condition and as per current practice globally, the sheath current is not monitored very closely and almost left unattended. In the city environment and where water table is high and many agencies are working  in the same corridor, there are may be few reasons which disrupts this system quietly.

1) The damage to link box by agencies working or water ingress in the link boxes.
2) The damage to the outer sheath of the cable in between.

Fig-7, Damaged Cable

Fig-8, Damaged Link box

These can be said to be silent killers of the cable . The circuit gets disrupted  as shown below  and heavy current flows through sheath of the cable.

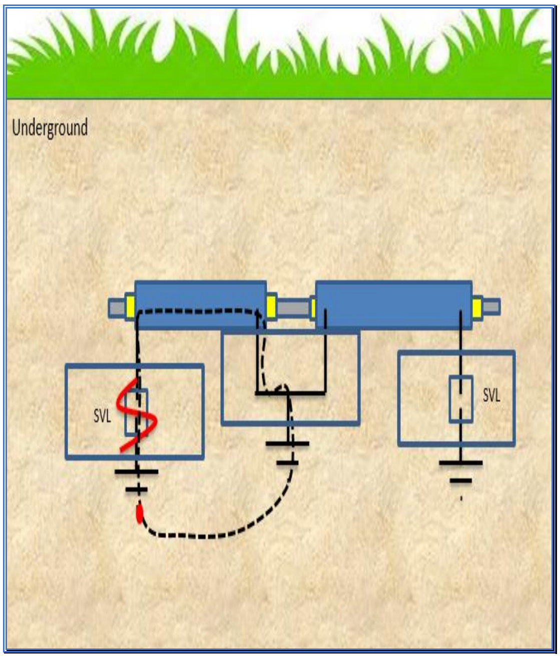


Fig-9, Fault current in Single Point Bonding

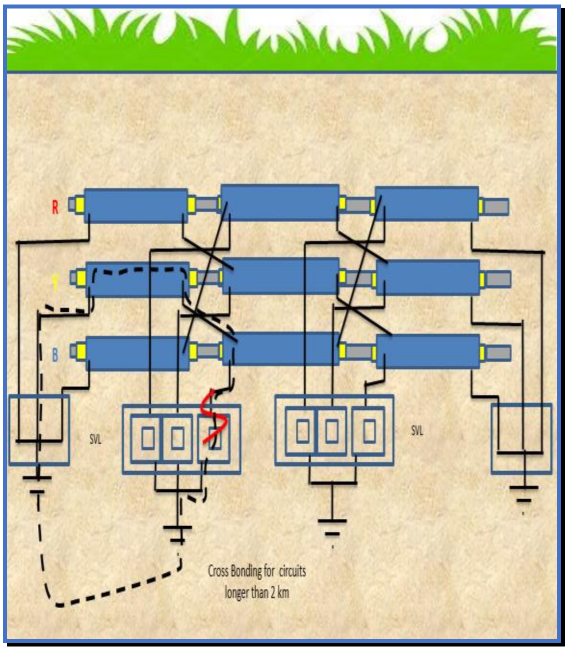


Fig-10, Fault Current in Cross Bonding

The life of the cable gets affected and due to fréquent failure occur due to non-monitoring of the sheath current . Very heavy Capital investments (CAPEX)  is required for laying of 66 KV  cables and they are expected to serve at least for a life span of around 20 to 25 years. This inherent problem results in repeated CAPEX investment in addition to frequent repair (maintenance) cost. Apart from above there is also cost associated to unserved energy due to circuit remaining out. It also affects the brand image of company.

In the modern era where we are talking of un-interrupted supplies to our end consumer, any EHV cable failure results in huge power deficit to the area it is feeding. Increasingly these circuits are becoming problem to maintain as more and more utilities are expanding underground and the bonding arrangements are getting damaged unnoticed.

## Solutions for the above Problems:

### A) Arrangement for continuos monitoring- accessible link boxes :

The proposed solution is to monitor the cable sheath voltage and current. For this purpose all the boxes containing earthing link , surge voltage limiters are made accessible. The sheath voltage and current can be monitored manually or though sensors continuosly. At every joint health of that particular cable section can be ascertained. The analysis of the data so collected can be used for outer sheath integrity. In case high sheath current is flowing, it means external damage has been done to the cable or bonding arrangement has gone faulty in that particular section of cable length. So, the solution lies in making the monitoring possible by bringing the bonding arrangement accessible and visible. The corrective action should follow based on analysis of the data of voltage and current.

**Implementation:**

To practically implement this the Bonding arrangement were made accessible by placing them above the ground in line with the available standards & specifications as shown below. The bonding arrangement consisting of link box, bonding cables, surge voltage limiters were placed outside in a cover box specially designed for above ground applications.


Fig-11 Above the Ground Link Box

Accessible link box were provided on every joint depending on the length of the circuit.

The system also provides an additional benefit of making it easy for  future Line-In Line –Out (LILO) requirement to avoid re-digging  work.

**Results:**

The accessible bonding arrangement has been implemented in around 7 different circuits of TATA POWER Delhi Distribution limited in last 2 years and are under service from last 1-2 years. These are now easily monitored.

There is no single incident of cable fault due to high sheath current in last 2 years as sheath current of different sections of various cable systems are monitored regularly and if high sheath current is noticed same is checked and rectified.

A comparative consisting of various parameters is shown below to summarize the change this arrangement has brought above the buried one:

| Parameters | Unaccessible link box | Accessible link box |
|---|---|---|
| LILO | Difficult & Costly | Easy & no extra cost |
| Reliability | highly un-reliable | high |
| flexibility | Difficult & Costly | Easy & no extra cost |
| Preventive maintenance | not possible | possible |
| Monitoring | not possible | possible |
| Faults | high | low |
| Cost effect | high OPEX & unnecessary burden on CAPEX | Negligible |

The same arrangement is Implementable across the power industry for single core cables of rating of 66KV & above

Conclusion :

The solutions proposed above will result in improved reliability, enhanced life of cable at EHV level and making it easy to carry out LILO while reducing the O&M cost considerabally.

## BIBLIOGRAPHY

[1] BIS 7098 PART III
[2] BIS 3043
[3] IEC60840