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SVL's Damage Assessment and Improvement Method for Underground Cables

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1. Introduction

The protection of underground cables against transient overvoltages resulting from lightning and other causes is important in cable-line. So, The SVL(Sheath Voltage Limiter) is installed in not only transmission power cable system but also plant cable system.

This paper investigates the failure of SVL and presents improved configuration method of SVL in the underground cable system. EMTP(Electromagnetic Transient Program) is used in order to study the overvoltages and modeling of components of the system such as overhead lines, underground cables, SVLs and towers.

2. SVL's damgae

Sheath sectionalizing insulators in cross-bonded cable system and the insulators in a single-point bonded-cable system may flashover due to overvoltages generated by lightning, switching surges, or faults on the power system. It is necessary to provide some form of protection for these insulators under system transient conditions.[1] At present, SVLs(Sheath Voltage Limiters) are used for this purpose.

In the actual power system, a few SVLs were damaged in combined transmission line which is connected with overhead line and underground cable.

The Figure 1 shows the link box including SVLs installed on the underground transmission line. One of the SVL was completely short-circuited and exploded in the termination.

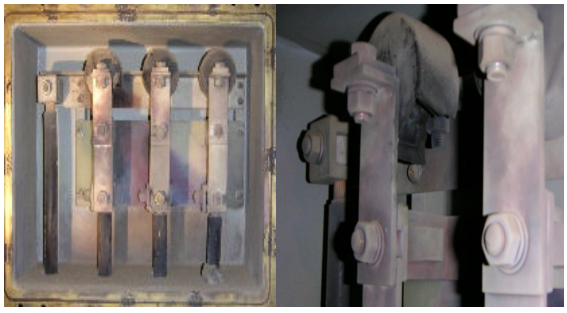

Fig. 1. Explusion accident of SVL in the link box

If surge current exceeds the rating of SVL flows to the line, its element is heated and finally broken down. As shown in Figure 1, SVL element has damaged by abnormal current and the screw has melted by arc.

Therefore, the resistance of SVL and earth were measured to find the cause of damage. The measured data are shown in Table 1.

Table 1. The measured data of SVL and earth resistance

Unit[Ω]

Jointing Bay	Resistance of SVL			Earthing Resistance
	R	Y	B	
A	0	3G	3G	-
# 1	Direct Earthing			46.8
# 2	7M	6M	1.5M	14.3
# 3	1M	1.5 M	0.7M	15.7
# 4	Direct Earthing			2.13
# 5	0.9G	0.9G	350 M	18
# 6	150 M	16M	100 M	3.82
# 7	Direct Earthing			15.4
B	7G	7G	6G	-

The most effective discharging way for protecting SVLs is to reduce earth resistance. Therefore, the ground resistance of all joint bays and substations should be kept less than 10 ohms. But, as seen in Table 1, the ground resistance at all joint bays and substations is higher than standard requirements.

Furthemore, SVL which was installed in R phase of A s/s, #2, and #3 was damaged.

In order to reveal cause of accident and take necessary countermeasure, an actual power system of underground cables was inverstigated and analyzed by a generalized circuit analysis program (EMTP) to compare with the measured values.

3. Systems Description

3.1 Power cable system

As seen the Figure 2, the power cable system consists of a 161kV source and an XLPE cable with the conductor size of 1200SQ. The length of overhead line is 9.98[km] and grounding resistance of tower is 10[Ω].

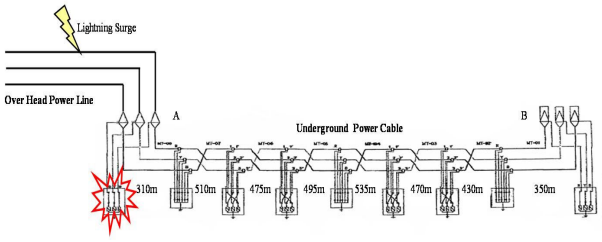

Fig. 2. Actual power cable system joined to overhead line

3.2. Lightning surge data

The magnitued of surge current is usually less than 40kA.

However, some reports have been presented that maximum value could be 141kA and 195kA in case of negative and positive surge[2].

In this paper, the lightning surge model for simulation is

1) Lightning current : 100[kA], 2/70[us]
2) Lightning strike point : Red phase of overhead line(600m distance from outdoor termaination)
3) Lightning strike type : Direct lightning

4. Simulation results

Figure 3. shows that the lightning overvoltage between the sheath and the ground plates of outdoor termaination exceeds prescribed standard requirement(can not be over 14kV). The overvoltage is intended to increase the problems of failure of sheath sectionalizing insulators, cable jackets, and SVLs.

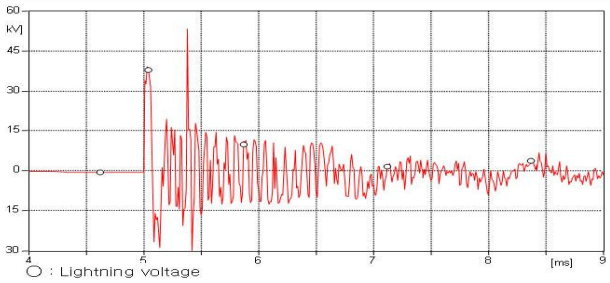

Fig. 3. Lightnig overvoltagee between the sheath and the ground plate of outdoor termaination(A)

Figure 4. shows the lighting current flow into the SVLs of both terminations exceeds the rating of SVL. As a general, the current flow to the SVL can not be over 23kA.

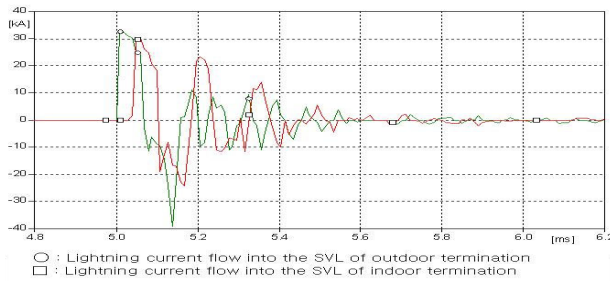

Fig. 4. Lightnig current flow into the SVL of bothterminations

According to simulation results by EMTP, all SVLs of outdoor termination(A) and indoor termination(B) must be influenced by the penetration of abnormal lightning surge.

It is recommend for customer that 2sets of link boxes are required to be connected, in parallel, to the line at outdoor termination as well as indoor termination, which enables to reduce abnomal lightning current by 50%.

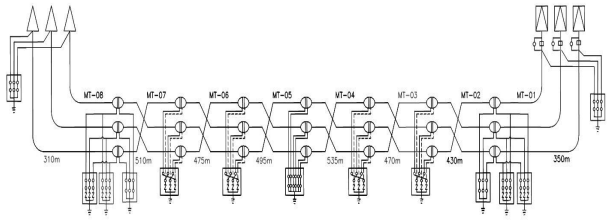

Fig 5. Proposed systm to prevent SVL's accident

The recommended system is shown in Figure 5. The lightning curret flowing into SVL is decreased dramatically as shown in Figure 6.

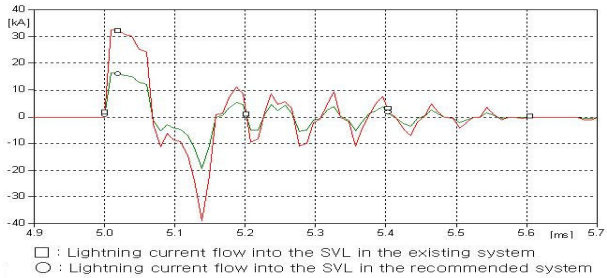

Fig. 6. Comparison of lightening current between existing and recommended system

5. Conclusion

Lightning voltage and surge current, described in this paper, in a practical underground cable have beeen studied by means of EMTP simulation. The abnormally high surge voltage at the underground cable which installed in power system may damage SVL and eventually lead to a explosion accident of SVL.

Therefore, below is our proposal for improving the current phenomenon.

1) Partial supplement of Earthing System : 2sets of link box is required to be connected, in parallel, to the line at outdoor termination as well as indoor termination to enable the excessive value by abnormal lightning current to be reduced to half of that value.

2) Resistance of ground : The ground resistance of all joint bays and substations should be kept at 10 ohm or less.

References

(1) ANSI/IEEE STd 575-1988, "IEEE Guide for the Application of Sheath-Bonding Methods for Single-Conductor Cables and the Calculation of Induced Voltage and Currents in Cable Sheaths"
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(3) Yasunobu Yoshino, Toshio Shimizuu, Hiroto Ueno, Chen Min, "Computer Calculation of Lighting Voltage in Overhead Transmission Line Joined to Underground Cable", ICEE'99
(4) Mustafa Kizilcay, "Surge Propagation in a 400kV Cable System", 2004 International Workshop on ATP_EMTP, pp.52-53, Februarry 2004