Shielding Effect by a Buried Metallic Pipe against the Induced Voltage

Kang-In Lee, Sangmu Lee
Protocol Engineering Center
Electronics and Telecommunications Research Institute, Deajeon, South Korea

Abstract – **The communication line installed nearby the high-speed train railroad has induced voltage caused by high electric current which is supplied to electric car line. At this point, shielding effect can be expected in communication line, if structure which includes metals is placed around. In this paper, the screening effect was analyzed through experiments when a metallic pipe was buried near the communication line. The result of experiment conducted in high-speed railroad site shows induced voltage decreased to 75% level when a metallic pipe is buried in parallel with near the communication line rather than not the case. This result can be utilized to analyze screening effect by a structure including metal.**

Index Terms — **Induced voltage, Shielding effect, Metal pipe**

1. Introduction

A high speed railroad is the typical facility to generate big electrical power. At this moment, some of electric current leakage to ground through rail and ground connection component, it spreads everywhere in the ground according to characteristic of earth which is not a perfect conductor. If the earth resistivity is high, the electric current flows into underground more deeply. So the leaking current does less offset with current source and much electric induction is occurred[1]. This kind of induced voltage can cause not only deterioration of communication quality but machine malfunction. Besides inducing electric car line and induced object, if another facility which contains metal ingredient that can be induced is placed in the influence range, it reduces induced voltage of communication line. It is called shielding effect that can be a measures to induction phenomenon[2]. This paper will confirm for the shielding effect by underground utilities through measurement.

2. Environment of Measurement

For an empirical study of shielding effect of metallic pipe about phenomenon of induction, the induced voltage was measured on Daejeon in Korea, last May 19th, 2010. As buried metallic pipe does not exists near the measurement field at that time, induced voltage can be measured purely which communication received, without shielding effect from metallic pipe. Later, 300mm radius metallic water supply pipeline was buried 1.5m underground near the measurement site in 2011[3]. The following Fig. 2 shows the measurement site.

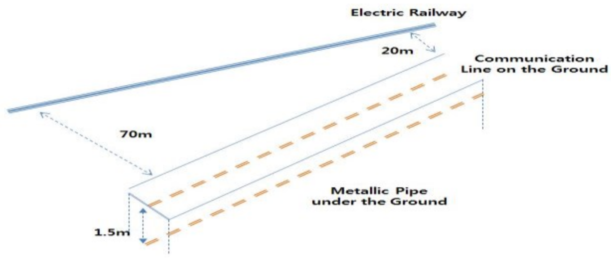

Fig. 2. Measurement Environment.

In the measurement conducted in 2013, communication line was installed on the road where metallic pipe has been buried. Thus we had made the measurement environment that the distance between shielding object and communication line maintains 1.5m and the average distance between the communication line and inducing object is 50m. Communication line was installed in parallel with the railroad and earthed at its both sides. Then induced voltage data was collected when train passed by normal voltage tester.

3. Forecasting calculation

Electromagnetic induction voltage's estimate calculation is based on basic formula of electromagnetic induction voltage, and the formula is as follows[4]:

$$V = j\omega MlIK \qquad (1)$$

M : Mutual inductance [H/m]
l : Distance of parallel with communication line and railroad [m]
I : Electric current leaked to ground [A]
K : Shielding factor
ω : $2\pi f$ (f = frequency)

Induced voltage is calculated as multiplying shielding factors when shielding object exists. Therefore, induced voltage gap by existence of shielding object can be checked after calculating shielding factor K's value. The decreasing proportion of induced voltage was predicted and compared with real data. The formula for shielding factor K is as follows.

$$K = \frac{1}{Z_{11}} \cdot \frac{Z_{1t} \cdot Z_{1e}}{Z_{et}} \qquad (2)$$

Z_{11} : Shielding object's earth return self impedance [Ω/km]
Z_{1t} : Mutual impedance between the shielding object and communication line [Ω/km]
Z_{1e} : Mutual impedance between the shielding object and electric car line [Ω/km]

Z_{et} : Mutual impedance between the communication line and electric car line [Ω/km]

First, shielding object's earth return self impedance(Z_{11}) can be calculated as follows[5].

$$Z_{11} = R_S + 0.99 \cdot 10^{-3} f + j\omega \cdot 2 \cdot 10^{-4} \ln \frac{D_e}{r'} \ [\Omega/\text{km}] \quad (3)$$

R_S :1 / shielding object's Conductivity (σ) × cross-section area(S)

D_e : $659\sqrt{\rho / f}$, ρ = earth resistivity

r' : $r \cdot m$

r = shielding object's radius

$m = (0.4625/3)x^2 + (0.505/6)x + 0.774$

$x = 1 - (t/r)$, $t = 1/\sqrt{\pi f \mu \sigma}$

In this point, t is skin depth when electric current flows on the surface of metal shielding object. Other factors (Z_{1t}, Z_{1e}, Z_{et})in formula (2) for calculating shielding factor, mutual impedance can be calculated by multiplying the $j\omega$ by mutual inductance. The formula for mutual inductance as follows[4]:

$$M = \left(4.6 \log_{10} \frac{2}{kd} - j\frac{\pi}{2} \right) \times 10^{-7} \ [\text{H/m}] \quad (4)$$

k : $4\pi\sqrt{3/\rho} \times 10^{-3}$

d : distance between objects [m]

Shielding object is buried 1.5m below the installed communication line. As the road where communication line was installed is gradually away from inducing object, from 20m to 70m, the distance's range from communication line and shielding object to inducing object is determined to 20~70m, and then apply for corresponding values of measurement environment to each formula. The values which need to know to apply the calculation are conductivity and magnetic permeability of steel which is a main component of shielding object, buried shielding object's radius(0.15m), frequency(60Hz), earth resistivity in measurement field(153 $\Omega \cdot \text{m}$) and distance between objects. As a result, the shielding factor is obtained as following fig.1.

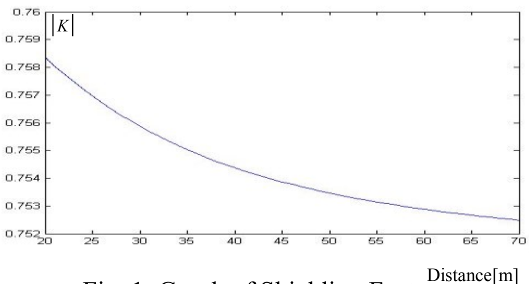

Fig. 1. Graph of Shielding Factor.

The calculation result shows that the shielding factor was confirmed as average 0.754.

4. Data Analysis

Measured induced voltage values in 2010 when the shielding object was not buried yet and in 2013 when the shielding object is buried are written in Table 1. In 2010, the average value was 6.2Vrms, in 2013, the average value was 4.7Vrms. Therefore induced voltage value in 2013 decreased to 75.33% after shielding object is buried comparing to absence of shielding object. In conclusion, shielding factor is verified about 0.7533. This conclusion was not different from predicted shielding factor's calculation result through formula of electromagnetic induction voltage, a little difference was judged by natural environment factor which was not controlled when composing measurement environment.

TABLE I

Data for Induced voltage

Peak Voltage (Vms)											
2010						2013					
6.9	4.1	5.5	6.8	6.7	7.3	4.1	4.0	4.6	5.2	6.1	4.2
7.1	4.9	10.0	7.4	4.7	5.1	4.0	3.3	3.9	5.6	3.5	4.5
5.2	4.8	7.0	6.6	4.6	7.2	6.0	5.8	5.7	3.6	5.9	4.3
Avg			6.217			Avg			4.683		
Shielding Factor						0.7533 (4.683/6.217)					

5. Conclusion

The communication line installed nearby the high-speed train railroad has induced voltage caused by magnetic coupling with electric car line, and the shielding effect was confirmed when a metallic pipe is buried nearby the communication line. Experiment was implemented twice. In order to have only the variable as existence of underground steel pipe, other parameters are maintained at the most same condition in the two experiments. Finally, we compares and analyzes about data of two cases. As a result, when a metallic pipe is buried parallel with communication line and electric car line within effective range, the shielding effect of metallic pipe is verified that reduce induced voltage as 75% level. This result could be used to analyze the shielding effect of metallic pipe such as a water pipe, gas pipe at predicted calculation of induced voltage in communication environment.

Acknowledgment

This work was supported by Institute for Information & communications Technology Promotion(IITP) grant funded by the Korea government(MSIP) (No.R0166–16–1020, The Study on the Technical Regulation of Broadcasting and Telecommunication Facilities)

References

[1] Sangmu Lee, Pyung-Dong Cho, "Shielding Effect by a Metallic Pipe against Electromagnetic Interference with ELF from High Speed Railway System", in *ICMTCE2011,* 2011, Bejing, China, pp.5-8.

[2] Sangmu Lee, Changsoo Eun, Pyung-Dong Cho, "Analysis on the Shielding Effect by a Metallic Pipe against Electromagnetic Induced Voltage", in *ICMMT2010,* 2010, Chengdu, China, pp.1837-1840

[3] Kang-In Lee, and SangMu Lee, "Measurement Data Analysis on the Screening Effect Given to Communication Line by the Metallic Pipe against Induced Voltage" in *2015 KICS*, 2015, Siem reap, Cambodia

[4] Telecommunications Association, "Induction ", December 1978.

[5] ITU-T Directives, "Concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines" Volume 2. Calculating induced voltages and currents in practical cases, 1999.