The 30th Annual Conference of the IEEE Industrial Electronics Society, November 2 - 6, 2004, Busan, Korea

DATA LOGGER APPARATUS FOR STRAY CURRENT MEASUREMENT OF SUBWAY AND POWER LINE

Jeong-Hyo Bae°, Yoon-Cheol Ha, Tae-Hyun Ha, Hyun-Goo Lee, Dae-Kyeong Kim, Jae-Duck Lee

Electric Power Research Laboratory
Korea Electrotechnology Research Institute
28-1, Sungju-dong, Changwon, Kyungnam 641-120, South Korea
Phone: +82-55-280-1362
Fax.: +82-55-280-1476
E-mail : jhbae@keri.re.kr

Abstract-
In present, most of metallic structures(gas pipeline, oil pipeline, water pipeline, etc) are running parallel with subway and power line in korea. Moreover subway system and power line make a stray current due to electrical corrosion on metallic structures. The owner of metallic structures has a burden of responsibility for the protection of corrosion and the prevention against big accident such as gas explosion or soil pollution and so on. So, they have to measure and analyze the data about P/S(Pipe to Soil) potential, amplitude of stray current, point of source of stray current and so.
In this paper, results of development about data logger apparatus for measurement stray current of subway and power line are presented.

Keywords : Interference, Stray Current, Subway, Power line, P/S Potential

I. INTRODUCTION

Underground metallic structures (gas, oil, and water pipelines, etc) are equipped with cathodic protection facilities to be protected from corrosion and to maintain longer life.
However, the steady maintenance and inspection of such structure is difficult due to the interference of stray current. The existence of stray current signifies the loss of energy. And the stray current originated from a subway system or a power line promotes corrosion of underground metallic structures and thus results in environmental pollution and large accidents. Currently, P/S(Pipe to Soil) potential due to stray current is manually measured in general.
We have developed an apparatus that can automatically measure this data. The data logger apparatus is capable of simultaneously measuring the stray current generated by a subway system or a power line and the P/S potential and analyzing the data. The apparatus is introduced in this paper.

II. The Mechanism of Stray Current Occurrence

A. The mechanism of DC stray current occurrence due to a subway system

In general, the load current of a subway system is designed to leave the substation, enter the train through the feeder, operate the train, and return to the substation through the rail. However, due to the resistance along the rail and imperfect insulation between the rail and the ground, the current strays from its intended path and escapes to the ground. It is called leakage current or stray current.
Stray current enters an underground metallic structures(gas, oil, and water pipelines) that work as a good conductor, flows through the structure, exits to the ground at a point where the soil resistivity is low or near the subway power substation area, and returns to the negative feeder of substation. And corrosion occurs most severely around the area where the current exits from ground metallic structures. This stray current induced corrosion in the subway system is called stray current corrosion or Electrolysis. [1]~[8]

B. The mechanism of AC stray current occurrence due to a power line

n general, 3 kinds of induced AC voltage occur on an underground metallic structure; capacitive induction, induction and resistive induction. In Korea, resistive induction accounts for the majority of induced AC voltage.[9]~[14]
The principle of resistive induction is as follows. Due to resistive coupling effect, energy in the form of AC or voltage can be transmitted between the grounding structure

0-7803-8730-9/04/$20.00 ©2004 IEEE

of a power system and an underground structure that share the same electrolyte(soil). In other words, on a power system with the grounded neutral conductor, unbalanced current flows to the neutral conductor due to system unbalance in 3 phase, or when the 3n(n=whole number) high frequency of the system flows to the neutral conductor, this energy is transmitted to a nearby underground metallic structure through the soil and if the underground structure is coated with an insulator, resistive induction voltage occurs between the structure and the ground.

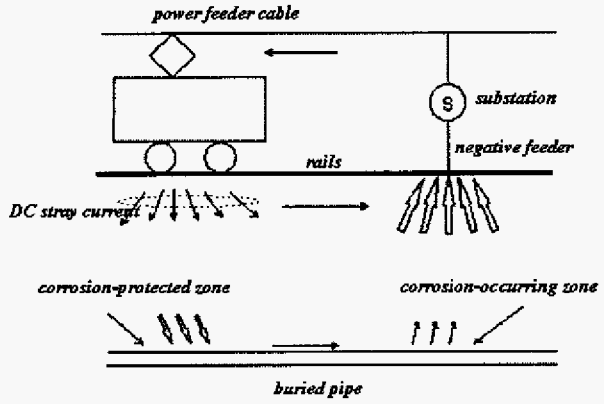

Figure 1. Diagram illustrating the occurrence of stray current due to a subway

As shown in Figure 2, suppose the grounding conductor of the power system is a hemisphere with the radius of r and current I flows into the ground with the uniform resistivity of ρ, then, the induced voltage v from the center of the hemisphere O to point x is as follows.

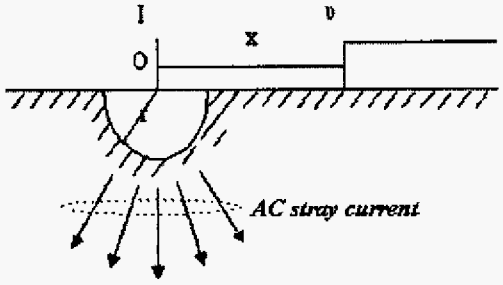

Figure 2. Induced AC voltage due to resistive induction

According to the Ohm's law,

$$v = IR \quad \cdots\cdots (1)$$

Where, $R = \int dR = \int \rho (dr/2\pi r2)$,

Therefore,

$$v = \rho I/2\pi x \quad \cdots\cdots (2)$$

In other words, on the pipeline that is separated by x from the grounding conductor that generates current I into the ground, the amplitude of voltage calculated by formula (2) is induced.

As can be seen in formula (2), when the current discharged to the ground is constant, the magnitude of resistive induction voltage induced to the pipeline depends on the soil resistivity and the distance between the grounding conductor and the pipeline.

Currently in Korea the most problematic AC stray current occurs due to multiple grounding wire of the neutral wire in 22.9kV D/L(distribution line) system. As shown in Figure 3, the primary voltage of power transmission system used in Korea is 22,900[V], 3 phase 4 wire system and multiple grounding wire of the neutral wire is used. This neutral conductor(4th wire) is grounded at certain intervals, and it is designed that normally the current of 60[Hz] can not flow through it. However, if a third high frequency occurs due to different load on 3 phase conductor, it flows through the neutral conductor and part of it enters the ground through the grounding. As the underground pipeline is a good grounding conductor, the 3rd high frequency that flowed into the ground enters the pipeline easily due to resistive coupling effect. The 3rd high frequency thus entered the pipeline depolarizes the polarization of pipeline surface or increase the consumption rate of Mg anode. Also it could give electric shock to operators or cause a huge explosion due to arc during a leakage accident.

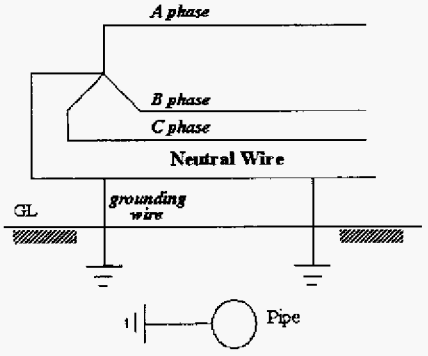

Fig. 3. Diagram of 22.9kV power transmission system of KEPCO(3phase 4 wire system)

III. Development Background

To prevent big accidents caused by stray current, the pipe-to-soil voltage of a buried metallic structure is measured on a regular basis using a portable measuring instrument or a corrosion inspection system developed by the inventor of the present invention to inspect whether the metallic structure is protected from corrosion.

Unfortunately, however, the apparatuses used for corrosion inspection were not capable of directly measuring the stray current and thus it was impossible to analyze the stray

current.
The existing oscilloscope can be used to measure stray current. But, to measure the current flowing on the rail, the oscilloscope has to be installed when the subway system is not in operation and the data needs to be collected the next day.
As the oscilloscope is expensive and big, it is not easy to install it around the rail, and several oscilloscopes have to be installed simultaneously but the cost is prohibitive.
As the analog meter and corrosion monitoring device installed in the corrosion protection measurement terminal analyze only the pipe to soil potential, it is not possible to find the location and magnitude of current leakage and therefore it is very difficult to mitigate the effect.
As a result, it is imperative to develop a small, low cost, stand alone, data logger measurement device that can measure the stray current originated from a subway system at rail impedance bonds and analyze the stray current by measuring the current at each point of the rail.

IV. Research content

1). System operation principle

As can be seen in Figure 4, this system is a multiple function system that is capable of the following. It can measure the stray current on the negative feeder of subway by using the shunt, measure the current flowing through the grounding conductor, and measure the pipe to soil potential of an underground metallic structure at the measurement terminal. It receives an input from the measurement device(SCMS2, Stray Current Measurement System Version 2) and stores the data in the analysis computer through the communication box. The stored data is processed for desired outputs using programs. In the measurement device, each input signal enters into the A/D converter that is the signal input area, and the input data is converted into digital data and stored in the memory.

2) System configuration

Internal and external system configurations are as follows.

2.1 Internal system
- MPU(Main Processing Unit)
- A/D converter(Analog to Digital)
- Memory(For Data storage)
- Recharge battery(Li-ion secondary battery)
- RTC(Real Time Clock)
- Communication(USB communication)
- DC/DC converter(For power supply)
- Case(For SCMS2 and battery)

2.2 External system
- Communication and recharge Box(For SCMS2 communication and recharge)
- Recharge Box(For battery pack recharge)
- Current sensor storage Box(Current sensor transportation and storage Box)
- Transportation Box(SCMS2 and current sensor transportation Box)
- Current sensor(For current measurement)
- Current measurement Cable
- Shunt measurement Cable
- DC measurement Cable

3) System specifications

The system specifications are as follows.

3.1 DC Current Sensor
1) Product type : Capable of measuring up to 2,000[A]
2) Dimension : 82 × 69 × 42
3) Range : 0 ~ 800A, Maximum: 2,000A
4) Output : ±4V/rated current, ±10V/maximum current

3.2 Shunts Sensor
1) Size : 50 × 200
2) Range : 0 ~ 3,000A
3) Output : 0 ~ 3V

3.3 A/D Converter
1) Resolution : 12-Bit
2) Conversion Time(Conversion speed) : 35 us
3) A/D method(Conversion type) : 12-Bit analog-to-digital converters

4) Program function

The system program functions are as follows.

4.1 Application S/W function
- Setting the year, month, date, time and measurement interval
- Store measured data and incorporate it into the database(USB communication)
- GUI type menu and graphic processing of data
- Print reports

V. Conclusions

With the development of this device, it is possible to analyze the relationship between the stray current and the pipe to soil potential of an underground metallic structure by measuring them simultaneously. It is also possible to measure the stray current generated by a subway system or a pipeline and pipe to soil potential of an underground metallic structure at multiple points at low cost, and to analyze the relationship between these. This system will be commercialized after it is applied in the field and the program is adjusted.

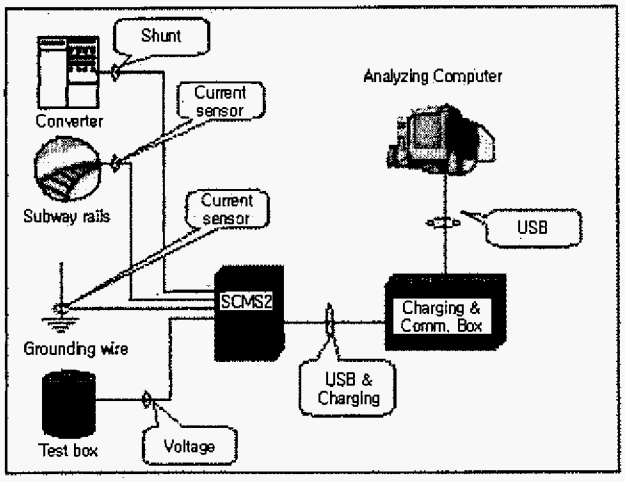

Fig. 4. System configuration

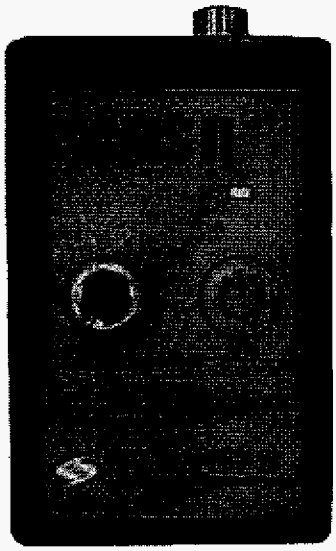

Fig. 5. External view of the measuring device

REFERENCES

[1] J.H. Bae and 2 el" A Study on the Mitigation Method for Stray Current on Underground Metallic Structures" , KIEE summer conference, 1998.

[2] " A Study on the Current and Potential Distribution of Cathodic Protection" KOGAS Report, 1995. 5

[3] " A Study on the Corrosion Control for Underground POF Cables" KEPCO Report, 1989.12

[4] Michael J.Szeliga, et al., "Stray Current Control Washington Metropolitan Area Transit Authority's A-Route" CCI, 1990.

[5] H.E. Bomar et al.,"Bay Area Rapid Transit System(BART)" Stray Current Corrosion, pp45-174, NACE, 1994.

[6] Robert J. Wilson et al., "Soild State Solutions to Stray Current Control - Toronto Transit Commission" Stray Current Corrosion, pp231-304, NACE, 1994.

[7] John Morgan, "Cathodic Protection" NACE, January 1993.

[8] " Cathodic Protection Interference Training Guide" , The Gas Company Bill Graves Local Distribution Services Technical Consultant. Februray 1996.

[9]DIN 30676: Planung und Anwending des Kathodischen Korrosionsschutzes fur den Aubenschutz, Ausg. Okt. 1985.

[10]Stalder, F., "Pipeline Failures, Materials Science Forum", Vol. 247 (1997) pp. 139-146.

[11]Ragault, I., "AC Corrosion Induced by VHV Electrical Lines on Polyethylene Coated Steel Gas Pipelines", NACE International, Corrosion '98, Paper No. 557, 1998.

[12] IEEE Guide for Satety in AC Substation Grounding, ANSI/IEEE Std 80-1986

[13]"Principles and Practices of Electrical Coordination Between Pipelines and Electric Supply Lines", CAN/CSA-C22.3 No. 6-M91

[14]"Cathodic Protection considerations for Pipelines with AC Mitigation Facilities" PRC International Corrosion Supervisory Committee. Jan. 1999.