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# 활선 상태에서의 OPGW 가선 시 전기적인 현상 고찰

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# Electrical Consideration in OPGW Live-Line Installation

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**Abstract** OPGW(Optical Ground Wire) whose demand is increasing worldwide have composite function as optical communication and grounding for preventing transmission line from lightning. While continuous efforts have been made to increase the transmission capacity and speed, the working method to replace the existing ground wire with OPGW under live-line condition is coming to force newly as installation aspects. Particularly, this requirement became more serious in developing country that the electric power supply is not sufficient and power outage is impossible for supply and dead of electric power. LS cable Ltd. has developed the new installation method in full live-line condition to solve the confronted problem and to meet the market demand. In this paper, Electric Problems in live-line installation is considered to predict dry-band arcing. This can be used by Makers to predict dry-band arcing in insulating ropes installed on earth wire of power transmission system.

## 1. INTRODUCTION

OPGW stringing work is to replace the existing earth wire on over head transmission line system of OPGW.

Even though it shall be done with power outage of power line, the necessity of more economic installation method is coming to the force due to the difficulty of weak electric power supply in developing country and difficult site situation such as acquisition of right-of-way, passing the obstacle.

Positively copying with such these circumstances new installation method is required to perform the stringing work under live-line condition with the reliability and safety to minimize the influence on overhead transmission system when unseen accident is occur according to operating voltage increasing high.

We intend to introduce generally the new installation method under live-line condition in this paper with a point of reliability and safety view.

The Objective of this paper is to present a simulation technique that can be used to predict dry-band arcing failure in insulating rope for live-line installation.

## 2. OPGW LIVE-LINE INSTALLATION

### 2.1 Equipments

We have developed compact equipments for OPGW live-line installation, which make the installation quicker. And we simulated the stringing method with an unmaned helicopter, which make the installation enable even in the case that there is no existing ground wire. The features of the equipments were represented in table 1 and every equipment were evaluated by the field test. The pictures of equipments and testing were shown in fig 1.

Table 1. The features of equipments for OPGW live-line installation

| Mobile unit | Recovery machine | Supporting roller |
|---|---|---|
| • weight : 22kg<br>• pulling force : 60kgf<br>• rising deg. : 31deg<br>• speed : 0~50mpm<br>• R/C : Radius 0.5m | • weight : 9kg<br>• breaking force : 0~70kgf<br>• diameter : Max.70mm | • weight :1 kg<br>• No. of steps : 3<br>• tensile strength : 550kgf |

Fig1. Picture of testing

### 2.2 Procedure

Figure 2 shows equipments for live-line installation - Mobile unit, supporting rollers, guide rope, pulling rope and etc. Installation process involves retrofitting of existing earth wire with OPGW without shutting down the line as following

(1) The existing earth wire is used as a pathway on which the retrofitting activity is carried out.

(2) A "Mobile unit" is used to pull a system of supporting rollers along the existing earth wire using a "Guide rope"

(3) The Mobile unit also carries a "Pulling rope", which is then used as a pilot to pull the OPGW.

(4) Existing earth wire is released and the OPGW is simultaneously tensioned and replaces the earth on the cross-arm.

(5) Earth wire is then recovered back by "Recovery machine",followed by the rollers and the rope.

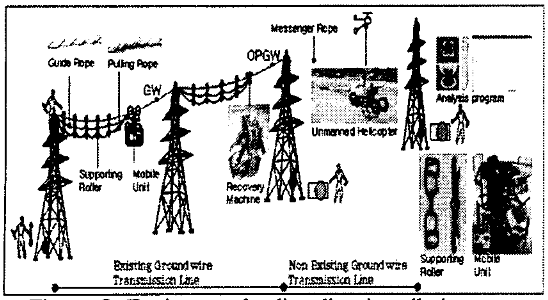

Figure 2. Equipment for live-line installation

### 2.3 Dry-band Arcing

Dry-band Arcing When the local dry zone is formed on wet rope, the arc is occurred near the grounded points due to the potential difference along the rope. Dry-band arcing of ropes in live-line installation is normally occurred when the surface resistance of the rope becomes lower due to the rain or surrounding moisture at night. Generally, the rope itself has high insulation resistance of $10^{12}\Omega$ to endure the electrical stress along the rope but the insulation resistance can be dramatically decreased to $10^{5}\Omega$ in a rainy day. At this low resistance, the surface of rope is locally dried due to the leakage current so that the tracking can be occurred. If this situation is continued, the insulation rope can be burnt out and be disconnected. This can result in trip of power line. Therefore, it is advised not to perform the installation work in the raining condition and all equipment including insulation rope should be withdrawn from existing grounding wire.

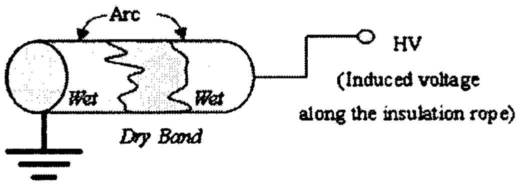

Figure 3. Dry-band arc in insulating rope

## 3. FORMULATION

Dry-band arc occurs on ropes when fog or drizzle wets rope, The power lines induce a space potential on rope. The space potential difference on grounded point drives a current through the wet rope along the rope and produce small dry-band. This high voltage produce arc on the rope. Long time exposure to this arc damaged the rope and result in tripping the power line. Next paragraph describes a numerical algorithm to analyze the circuit and predict dry-band arcing in insulating rope with different sag conditions. A Thevenin equivalent circuit is used to represent the insulating rope by capacitive coupling and Kirchoff's current law(KCL) is then used to derive the node equations of the circuit. This method is useful to calculate the voltage and current distribution along the ropes.

### 3.1 Thevenin Equivalent Circuit of Insulating Rope

A finite number of sections in series approximate the distributed nature of the circuit for numerical analysis. The equivalent circuit at given point along the span is shown in Figure 4. The rain and drizzling caused induction of potential of rope. This space potential is induced by capacitive coupling with power line and conductive rope At the point of rope position, induced potential of rope is calculated by equation 1~6.

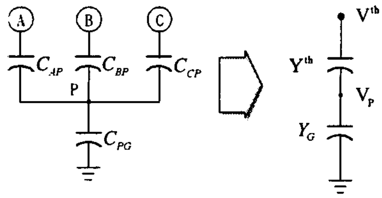

Figure 4. Calculation of space potential

$$V_{th}^{P}=\frac{C_{AP}+a^{2}C_{BP}+aC_{CP}}{C_{AP}+C_{BP}+C_{CP}+C_{GP}}V,\quad a=0.5+j0.866$$
---------------(1)

$$Y^{th}=\omega C^{th}$$
---------------------------------------------(2).

$$C_{th}=C_{AP}+C_{BP}+C_{CP}$$
---------------------------------------------(3)

$$Y_{G}=\omega C_{G}$$
---------------------------------------------(4)

$$I^{th}=Y^{th}V^{th}$$
---------------------------------------------(5)

Using above equations, node voltage of point P can be calculated by equation 6.

$$V_{P}=\frac{I^{th}}{Y^{th}+Y^{G}}$$
---------------------------------------------(6)

### 3.2 Equivalent Circuit of Insulating Ropes

Figure 5 shows a distributed characteristics of rope divide into m sections. The first and the last sections are grounded to represented tower or aluminum rollers. A circuit is consisted of connecting of points by surface resistance of rope.

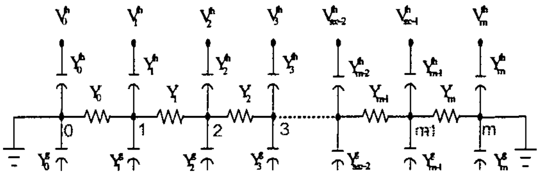
Figure 5. Distributed model of rope

### 3.3 Calculation of Sag

To calculate the capacitance values along the length of the span, the sag of the power lines and the earth wire must be known. The sag at mid span is specified as a percentage of span length. To simplify calculation, the height of the conductor and earth wire is assumed to be a hyperbolic function along the span. The origin is assumed to be at mid-span like figure 6

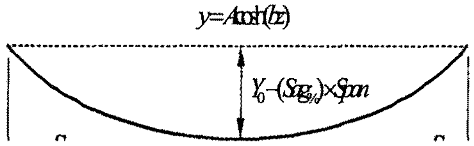

Figure 6. Sag calculation

$$y = A\cosh(bz) \qquad \text{------------------------------------(7)}$$

$$A = Y_0 - (Sag_{\%}) \times Span \qquad \text{--------------------------------(8)}$$

$$b = \frac{2}{Span}\cos^{-1}\left(\frac{Y_0}{A}\right) \qquad \text{------------------------------------(9)}$$

where, y : height of conductor
z : distance from tower
A , b: constants

## 4. SIMULATION AND RESULTS

Table 2 shows simulation conditions to evaluate the effect the rain and sag conditions.

Table 2. Simulation Condition

| | |
|---|---|
| System voltage [kV] | 275 |
| No. of circuits | 2 |
| No. of ground wire | 2 |
| Span Length [m] | 500 |
| Radius of conductor [mm] | 28.62 |
| Radius of ground wire [mm] | 12.95 |
| Earthing distance of roller[m] | 50 |
| Resistance of Rope [MΩ] | 0.1 |

When it rains, Insulating rope accumulate water on rope surface and lose the insulating characteristics. Capacitive coupling between the transmission line and rope drives a leakage current through the conductive layer along the rope. Figure 7 to 8 show the potential and current distribution along the rope for two different sag conditions. The maximum current is near the grounded rollers at rope. This leakage current dries the wet conductive layer and forms small dry-band near the grounded points. So, the high open circuit voltage appears across the dry-band, This can be burn the rope locally and lead to trip incidents of power line. Therefore, it is advised not to perform the installation work in the raining condition and all equipment including insulation rope should be withdrawn from existing grounding wire.

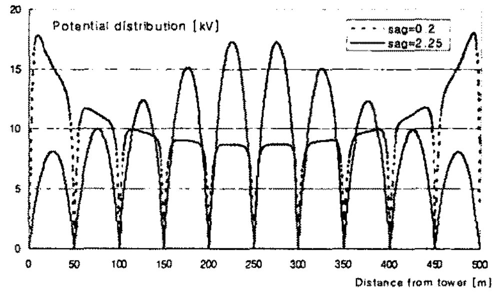


Figure 7. Potential distribution along the rope

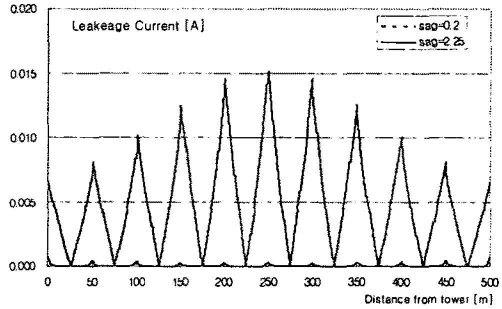


Figure 8. Current distribution along the rope

## 5. CONCLUSIONS

This paper describes a numerical simulation to analyze electrical phenomenon in live-line installation. The sag of the phase conductor and Ground wire is considered in this algorithm.

Conclusions are as follows.

1) Analysis program for live-line installation is developed to simulate the electrical phenomenon distribution of space potential, induced voltage and current of rope etc.

2) When it rains, sag of earth wire is increased by water absorption of rope and surface resistance of rope is decreased. Therefore induced current of along the rope is increased rapidly. At that time. Dry-band arc can occur at the near grounded points.

3) It is advised not to perform the installation work in the raining condition and all equipment including insulation rope should be withdrawn from existing grounding wire.

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