Customer Indoor Surge Phenomena due to Lightning Strike on the Joint Pole of Power Line and Telecommunication Line

M. Ikuta, A. Asakawa, S. Yokoyama, M. Soeda

Abstract--This paper describes an experimental study to examine how surge phenomena emerge when a lightning surge enters a customer's premises via a power line and a telecommunication line. In the test, the authors simulated various cases in which lightning strikes a pole on which a high-voltage distribution line, a low-voltage distribution line and a telecommunication line are jointly mounted. The variation of customer indoor surge phenomena resulting from differences in the installation conditions of a power drop wire and a telecommunication drop wire, and that of a surge protective device (SPD) and a bonding wire, was clarified. Further, it was found that the current passing through the telecommunication equipment was suppressed by connecting the grounding wire of the SPD, which is installed at the customer's incoming port of the power line, with the grounding wire of the surge arrester installed in the incoming port of the telecommunication line.

Keywords: Lightning, Lightning protection, Low-voltage line, Surge protective device, Telecommunication line.

I. Introduction

A variety of electronic and telecommunication equipment, which are vulnerable to lightning surges, has been extensively used by low voltage customers, following recent advances in the information-oriented and computerized society. These types of equipment are connected to both a power supply line and a telecommunication line. A surge current invading from either line passes through the equipment and then flows into the other line, bringing about increases in equipment damage arising from lightning surges [1] [2].

Therefore, the establishment of the total lightning protection of a system which consists of a low-voltage distribution line, a customer facility, and a telecommunication line is necessary. So various examinations have been executed [3] [4] [5] [6]. However, there is no examination of the case in which the lightning surge invades from both the power line and the telecommunication line when lightning strikes the pole where the distribution line and the telecommunication line are jointly mounted.

On the other hand, the introduction of the IEC standard into Japan is being advanced recently. A general customer facility in Japan has TT earthing system and a telecommunication arrester of the telecommunication company installed in the service entrance. It is necessary to confirm effectiveness of new code [7] to the customer facility with such features.

This paper describes an experimental study to examine how customer indoor surge phenomena emerge when lightning strikes the pole where the power distribution line and telecommunication line are jointly mounted. In the test, we simulated various cases with a different condition of the installation of the power drop wire and the telecommunication drop wire, and that of the surge protective device (SPD) and the bonding wire.

II. Experimental Methods

A. Experimental setup

An experiment was conducted using a 12 MV impulse voltage generator and an experimental distribution line at the Shiobara Testing Yard of the Central Research Institute of Electric Power Industry (CRIEPI).

A typical distribution system in Japan is as follows. The nominal voltage of the high-voltage distribution line is 6.6kV. The pole-mounted transformer steps down the voltage to 100/200V. Low-voltage customer facilities receive the electrical power at 100/200V via the low-voltage distribution line and the drop wire.

Fig.1 shows the layout of the experimental setup. The high-voltage distribution line and the telecommunication line were laid between the No.1 pole and the No. 11 pole, extending the circuit over a total distance of 430m. The overhead ground wire was not installed. To suppress surge reflection, the phase conductor of the high-voltage line, as well as the telecommunication core wire and a messenger wire, which comprises the telecommunication cable, were connected with 400Ω resistance and grounded at both line ends. Also, a telecommunication cable sheath conductor was connected to the messenger wire at both line ends. In this study, it is considered that the surge impedance of the telecommunication cable is of the same order as that of the distribution line because the surge propagates in both the cable core wire and the cable sheath conductor, and flows out to the ground.

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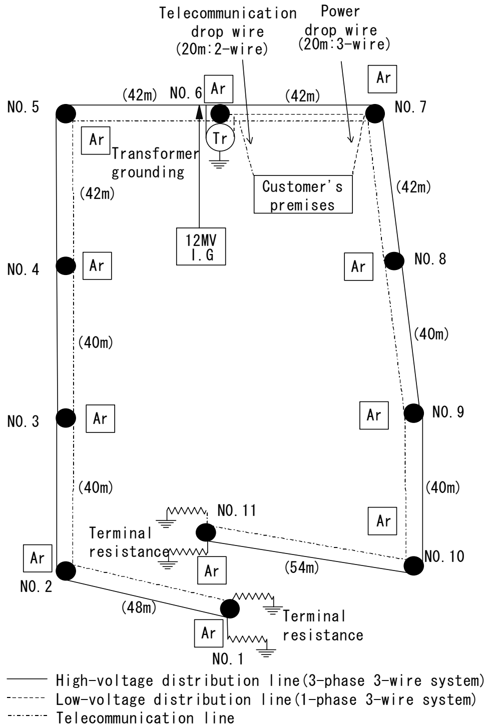


Fig. 1. Layout of the experimental setup.

Arresters, with resistances of about 100Ω, were installed on all poles. A transformer was installed on the No.6 pole where a lightning impulse current is injected. The transformer grounding wire was shared with the arrester grounding wire. Further, on the No. 6 pole, the telecommunication core wire was short-circuited with both a telecommunication cable sheath conductor and a messenger wire, and then connected to a transformer grounding wire. In the simulation, the potential of the grounding wire rose after lightning struck; and a spark-over occurred on the telecommunication line, resulting in the break-down of line insulation. A low-voltage line was laid between the No.6 and No. 7 poles; and, its remote end was open-circuited.

Fig. 2 shows the circuit configuration on a customer's premises. It consists of a watt-hour meter, a SPD, a grounding equipment (e.g. air conditioner), a telecommunication equipment (e.g. fax machine) connected to both the power line and the telecommunication line, and a telecommunication arrester installed at the telecommunication line's incoming port. The SPD, grounding equipment and telecommunication equipment were simulated using a varistor and a discharge tube, as shown in Fig. 3. This reproduced the setup in which both the power line and the telecommunication line were connected through the customer's telecommunication equipment. The SPD and grounding equipment were connected with 100Ω resistance and grounded. The telecommunication arrester was also connected with 100Ω resistance and grounded.

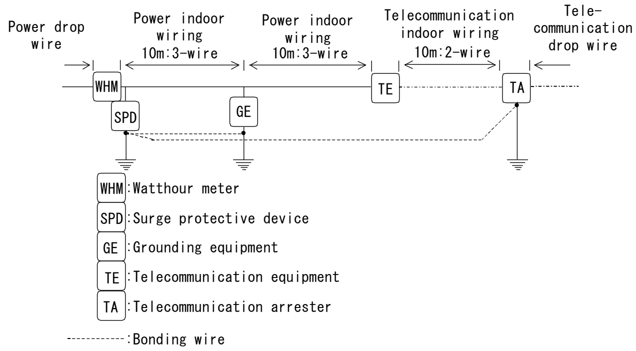
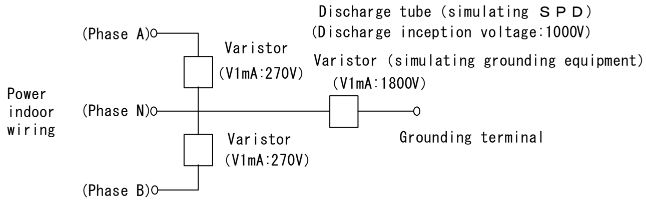
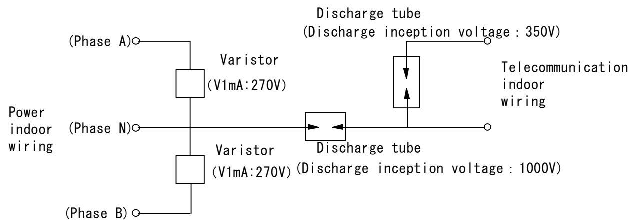


Fig. 2. Circuit configuration on a customer's premises.



(a) SPD and grounding equipment



(b) Telecommunication equipment

Fig. 3. Circuit of simulated equipments.

B. Test method

We injected about 13 kA lightning impulse current into the top of the No.6 pole and measured the surge waveform of: the injected current, the power drop wire current, the telecommunication drop wire current, and the current passing through the telecommunication equipment (to be referred to as "telecommunication equipment current"). Fig. 4 shows a injected current waveform.

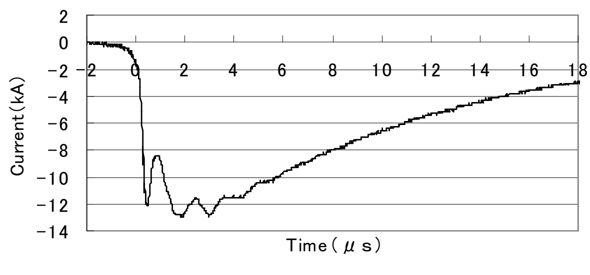


Fig. 4. Injected current waveform.

III. Experimental Results

A. Variation of surge phenomena resulting from differences in the installation conditions of the power drop wire and the telecommunication drop wire

To examine the variation of surge phenomena resulting from differences in the installation conditions of the power drop wire and the telecommunication drop wire, we tested four different cases in which the power drop wire and the telecommunication drop wire were laid from pole No.6 where a lightning impulse current was injected or from the adjacent pole No.7. In addition, in the case in which only the telecommunication line was mounted on a pole, only the telecommunication drop wire was laid from the No.6 pole. The different cases are described in Table I. In the case in which the telecommunication line was installed alone, the power drop wire side on the customer's premises was connected with a 100Ω resistance, thereby simulating the pole transformer grounding; and, it was grounded. In addition, the SPD was not installed on the customer's premises in order to simulate the conventional indoor facility.

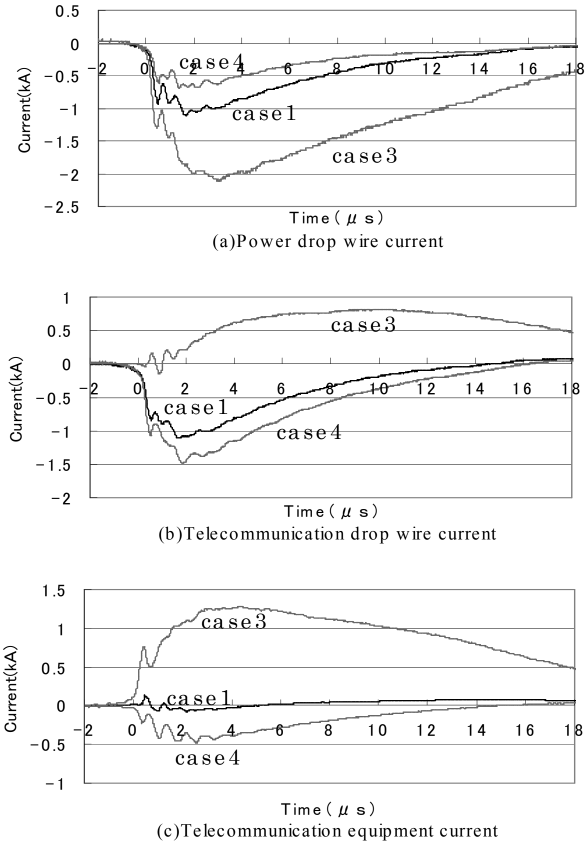
TABLE I
INSTALLATION CONDITIONS OF POWER DROP WIRE AND TELECOMMUNICATION DROP WIRE

	case1	case2	case3	case4	case5
Power wire	NO.6	NO.7	NO.6	NO.7	—
Telecommunication wire	NO.6	NO.7	NO.7	NO.6	NO.6

Fig. 5 shows measured waveforms for case 1 (in which both the power drop wire and the telecommunication drop wire were placed on the No. 6 pole), case 3 (in which the power drop wire was laid from the No.6 pole and the telecommunication drop wire was laid from the No.7 pole), and case 4 (in which the power drop wire was laid from the No.7 pole and the telecommunication drop wire was laid from the No.6 pole). In the power drop wire current, the peak values were different; however, a negative surge current flowed into the customer's premises in any case. In case 1 and 4, the telecommunication drop wire current flowed into the customer's premises; however, in case 3, the current, which flowed from the side of the power drop wire, was reversed to the pole via the telecommunication drop wire. In case 1, the telecommunication equipment current was minor. And, in case 3, the current flowed in the direction of the telecommunication drop wire from the side of the power drop wire. In case 4, it flowed to the reverse direction.

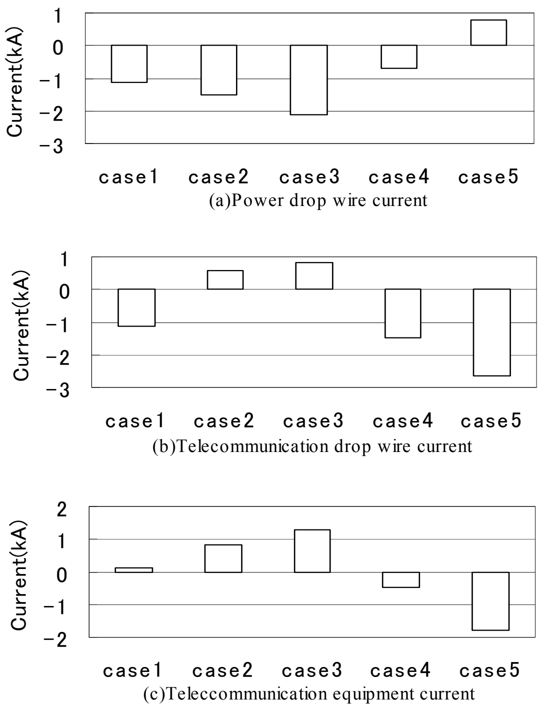
Fig. 6 shows variations in the peak value for each measured waveform of the power drop wire current, the telecommunication drop wire current, and the telecommunication equipment current resulting from differences in the installation conditions of the power drop wire and the telecommunication drop wire. The power drop wire current obtained in case 5 shows the current flowing into the resistance, thereby simulating the pole transformer grounding. The following findings were obtained from Fig. 6.

-In case 1, the surge current, which had almost the same peak value flowing from both the power drop wire and the telecommunication drop wire, invaded the customer's premises. Because the current passing through the telecommunication equipment is minor, the power drop wire current as well as the telecommunication drop wire current



(a)Power drop wire current
(b)Telecommunication drop wire current
(c)Telecommunication equipment current

Fig. 5. Examples of measured waveforms.



(a)Power drop wire current
(b)Telecommunication drop wire current
(c)Teleccommunication equipment current

Fig. 6. Variations in waveforms resulting from differences in installation conditions of power drop wire and telecommunication drop wire.

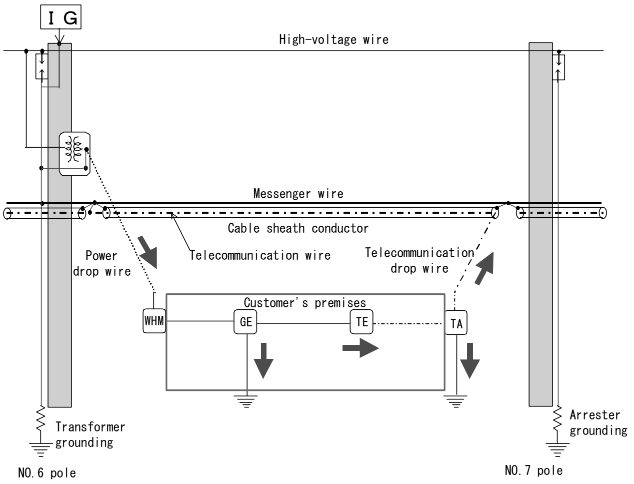
almost flowed into the grounding electrodes of the grounding equipment and the telecommunication arrester.

-In case 2, the current flowing into the customer's premises via the power drop wire split into the grounding electrode of the grounding equipment and the telecommunication equipment. After passing through the telecommunication equipment, some of the current flowed into the grounding electrode of the telecommunication arrester, while the rest flowed to the pole via the telecommunication drop wire.

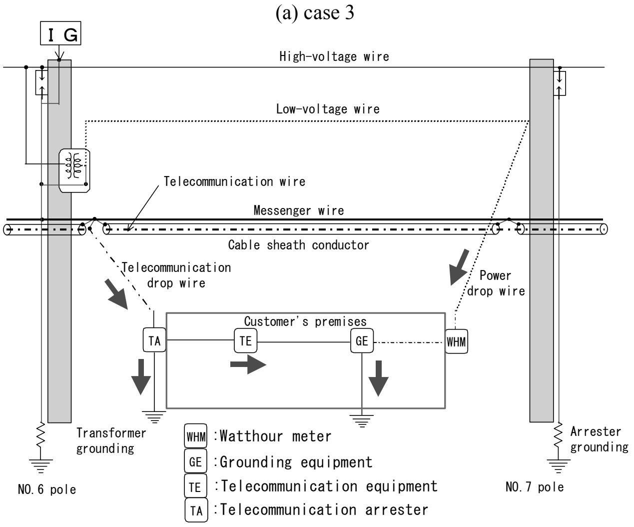
-The state of the current flow obtained in case 3 is similar to that obtained in case 2, as shown in Fig. 7(a).

-The state of the current flow in case 4 is shown in Fig. 7(b). The current flowed into the customer's premises from both the power drop wire and the telecommunication drop wire.

Because the telecommunication equipment current flowed in the direction of the power drop wire from the telecommunication drop wire, or in the reverse, in cases 1, 2, and 3, the current entering from the telecommunication drop wire split into the grounding electrode of the telecommunication arrester and the telecommunication equipment, resulting in its flowing into the grounding electrode of the grounding equipment.



(a) case 3



(b) case 4

Fig. 7. State of the current flow.

-In case 5, since only the telecommunication line is installed on a pole, the current flowed into the customer's premises from the pole via the telecommunication drop wire and then flowed to the power drop wire. As evidenced by the results of cases 1-4, the telecommunication equipment current of the case in which a lightning impulse current is injected into the pole where the power line and the telecommunication line are jointly mounted is smaller than that of the case in which the lightning impulse current is injected into the pole where only the telecommunication line is mounted.

The directions of current in the telecommunication drop wire and the telecommunication equipment vary depending on the installation conditions of the power drop wire and the telecommunication drop wire. Although the lightning strikes the pole, the surge current flowing into the customer's premises via the power drop wire occasionally flows back to the pole via the telecommunication drop wire. This may be attributed to the potential difference generated by the impedance of the ground wire between the connecting point of the transformer's grounding and the connecting point of the telecommunication wire and ground wire; and the change in the circuit length of the power line and the telecommunication line resulting from a change of the pole where drop wires are installed. In addition, because the messenger wire was connected directly to the pole, the backflow may be caused by impedance at the side of the telecommunication line, which is extremely small in comparison with that found at the side of the power line.

The current in the telecommunication equipment causing damage was the smallest in case 1. By contrast, in case 3, the current in the telecommunication equipment was the largest, except in case 5 in which the telecommunication line was installed alone. Because the length of the power line from the No.6 pole to the customer was short, the power drop wire current increased. Further because the circuit length of the telecommunication line laid from the No.7 pole was long, the inflow of the surge current was suppressed.

B. Variation of surge phenomena resulting from differences in the installation conditions of the SPD and the bonding wire

To examine the variation of surge phenomena resulting from differences in the installation conditions of the SPD and the bonding wire on a customer's premises, we studied three different cases, from A to C, as shown in table II, focusing on case 1 (in which the telecommunication equipment current was at a minimum), case 3 (in which the current was at a maximum), and case 4 (in which the current flowed to the reverse direction).

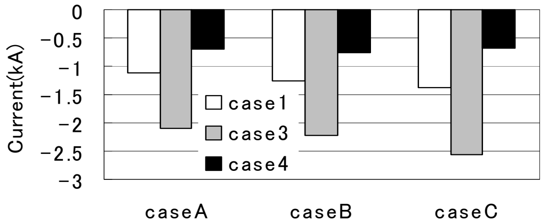
TABLE II
INSTALLATION CONDITIONS OF SPD AND BONDING WIRE

		caseA	caseB	caseC
SPD		×	○	○
Bonding wire	SPD-Grounding Equipment	×	○	○
	SPD-Telecommunication arrester	×	×	○

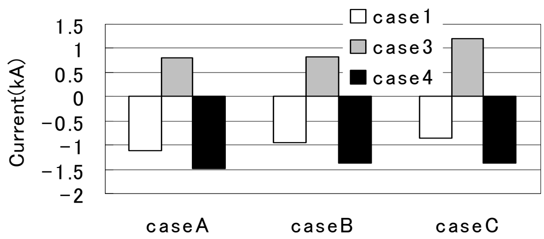
Fig. 8 shows measured waveforms for case A, case B, and case C, in case 3. In these three cases, similar waveforms were found in the power drop wire current, the telecommunication drop wire current, and telecommunication equipment current, though each peak value was different.

Fig.9 shows variations of the power drop wire current, the telecommunication drop wire current, and the telecommunication equipment current resulting from differences in the installation conditions of the SPD and the bonding wire on the customer's premises. The figure illustrates the peak value of each measured waveform. The power drop wire current and the telecommunication drop wire current did not vary much according to changing cases.

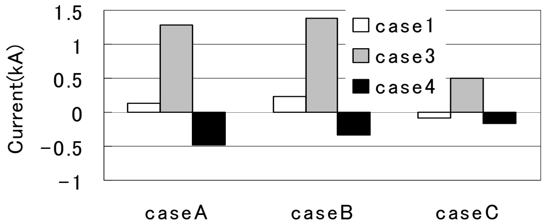
As for the telecommunication equipment current, compared with case A, it did not vary much in case B. Because the current route did not change in case B even if SPD was newly established as shown in Figure 10(a), as compared with case A which simulated the conventional customer's premises shown in Fig. 7(a). However, in case C, the telecommunication equipment current reduced, because the bypass current flowed into the bonding wire as shown in Fig. 10(b). Such an effect appeared regardless of differences in the installation conditions of the power drop wire and the telecommunication drop wire. The telecommunication equipment current was suppressed to 30% at a minimum.



(a)Power drop wire current

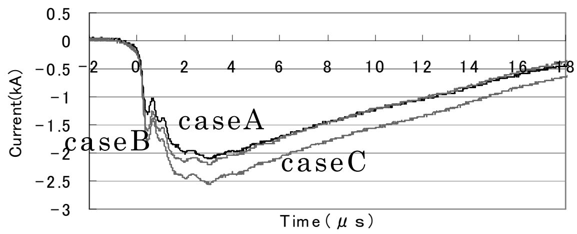


(b)Telecommunication drop wire current

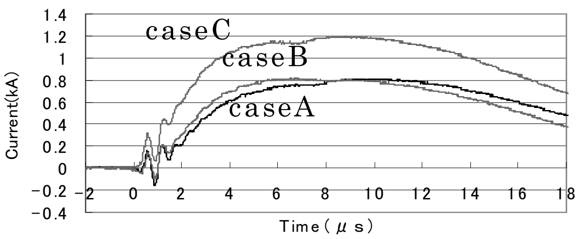


(c)Teleccommunication equipment current

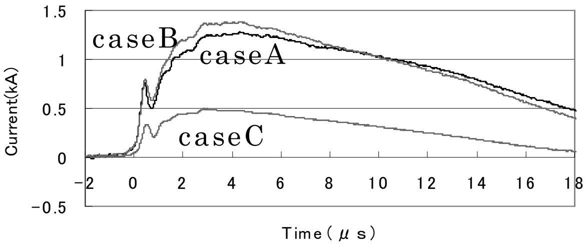
Fig. 9. Variations in waveforms resulting from differences in installation conditions of SPD and bonding wire.



(a)Power drop wire current

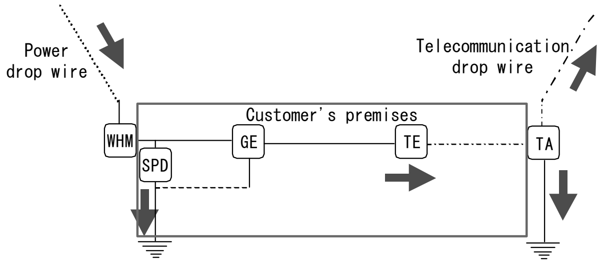


(b)Telecommunication drop wire current

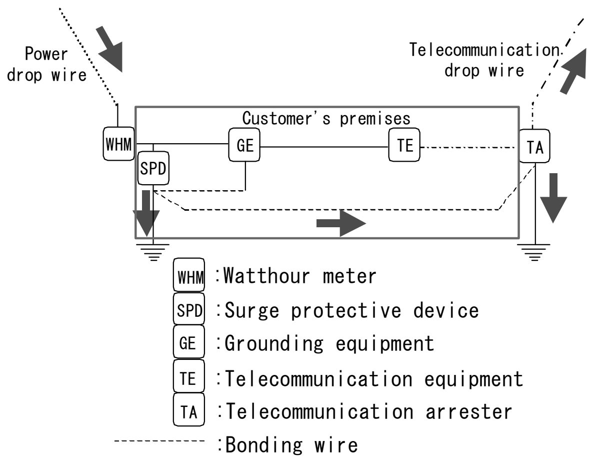


(c)Telecommunication equipment current

Fig. 8. Examples of measured waveforms in case 3.



(a) case B



(b) case C

Fig. 10. State of the current flow in case 3.

IV. CONCLUSIONS

We studied experimentally the variation of indoor surge phenomena resulting from differences in the installation conditions of the power drop wire and the telecommunication drop wire, and occurring when lightning strikes a joint pole on which the power line and the telecommunication line are jointly mounted and when a lightning surge invades via both the lines. Further, focus was also placed on such variation resulting from differences in the installation conditions of the SPD and the bonding wire on the customer's premises. The following results were found.

- The current in the telecommunication equipment was small in the case in which a lightning surge current was injected to a pole on which the power line and the telecommunication line were jointly installed, as compared to the case in which only the telecommunication line is installed.
- When injecting a lightning surge current into a pole on which the power line and the telecommunication line are jointly installed, the directions of the currents in both the telecommunication drop wire and the telecommunication equipment vary according to the installation conditions of the power line and the telecommunication line. The current of the telecommunication equipment was the largest when the power drop wire was laid from the lightning struck pole and the telecommunication drop wire was laid from the neighbor pole.
- By connecting the groundings of both the SPD and telecommunication arrester, the current of the telecommunication equipment can be reduced effectively.

In this study, we understood the overall branching manner of the surge current. Future study will be conducted to examine the detailed state of surge current flowing into each appliance on a customer's premises. The studies will contribute to clarifying the performance required for a built-in surge protective element.

V. REFERENCES

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VI. BIOGRAPHIES

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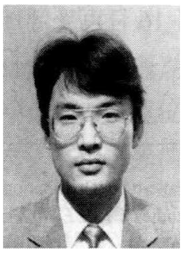

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