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Performance Evaluation of Early Streamer Emission Lightning Air Terminal

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Abstract: Studies have claimed that ESE (Early Streamer Emission) air terminals offer a vastly increased zone of protection over that of traditional lightning rods (Franklin rods) by causing the emission of an upward streamer/ leader: The upward streamer/leader will propagate towards the tip of the downward leader at an early stage in the attachment process.. This paper shows the results of a performance evaluation test of a particular type of the ESE air terminal (called "ElecHippo") with a simple rod tested at the Korea Electrotechnology Research Institute (KERI). The corona emission current of the ElecHippo made by Yong-Jin Enterprise Corp. has also been measured at the Occupational Safety & Health Research Institute (OSHRI). The results show that the ElecHippo meets the French standard of NFC 17-102-1995. The results also verify the ESE performance by measuring the ion emission current generated in the discharge electrode gap as a function of the capacitance and inductance of the equipped devices. Finally, we propose a new method for grounding the system to reduce the lightning damage by combining the ESE air terminal, the early discharge earth plate, the lightning strike recorder and the surge protection device.

Keywords: early discharge earth plate, early streamer emission, lightning air terminal, lightning strike recorder

1. Introduction

There are many cases of installing lightning air terminals in order to protect human lives and facilities from the lightning strike. Especially these days, the Early Streamer Emission (ESE) lightning air terminal is on the trend of wide usage because of its economic benefits and the advantage of protective radius of lightning strike covering a wide area.

The ESE lightning air terminals had been materialized in France about 15 years ago and selected as the lightning protection standard (French Standard NFC 17-102) of France in 1995 [1].

Other than France, it is being used at various regions where the lightning strike occurs frequently such as Southeast Asia, etc. and its installed number in the world is reaching up to tens of thousand units. But this ESE lightning air terminals also have systematic and technological problems such as limited test standard and demonstration of performance [2, 3].

In this paper, we attempted the characteristics of the ESE to demonstrated through the discharge property experiment on a laboratory standard followed by variation in electrical parameter at the electronic circuit inside the ESE lightning terminal and the evaluation by the Korea Electrotechnology Research Institute (KERI), a national official testing body, for the usage as systematic and technical data on early discharge for protective area as well as the practical usage of the ESE lightning air terminal with joint efforts by the Occupational Safety & Health Research Institute (OSHRI) of the Korea Occupational Safety & Health Agency (KOSHA) and the Yong-Jin Enterprise Corp..

Finally, we would like to propose the new lightning strike protection and grounding system using the ESE lightning air terminal, the lightning strike recorder and the Early Discharge Earth Plate (EDEP).

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2. Experimental Set-up of the ESE Air Terminal

2.1 Principle and Property of the ESE

The ESE lightning air terminal emits the streamer

several tens microsecond faster than other projected objects nearby metallic structures because of using an electronic circuit. Thus, if the ESE lightning air terminal installed several meters higher than the subject for protection, the protective radius from the lightning strike becomes about the area of 100 m.

Because the power supply of an electronic circuit uses the rise of electric strength of ground by the contact of a thundercloud, the wiring and battery to charge the power capacitor within the capsule are unnecessary and have the characteristics of simple installation work and maintenance.

The ESE lightning air terminal emits large quantity of ions into atmosphere due to the interior early discharge circuit. If the electron conditions of electric field are satisfied in the middle of thundercloud, the inner device first generates upward leader by ionizing the surrounding air and this gets contacted with the front of down leader. It is shorting the contact time of down leader from thundercloud and the upward leader, which had been emitted at the early stage. Fig. 1 shows the configuration of the ESE lightning air terminal.

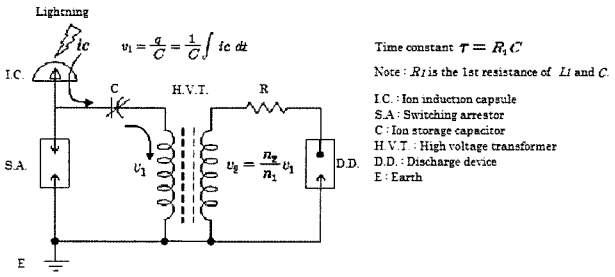

Fig. 2. Electronic circuit of the ESE.

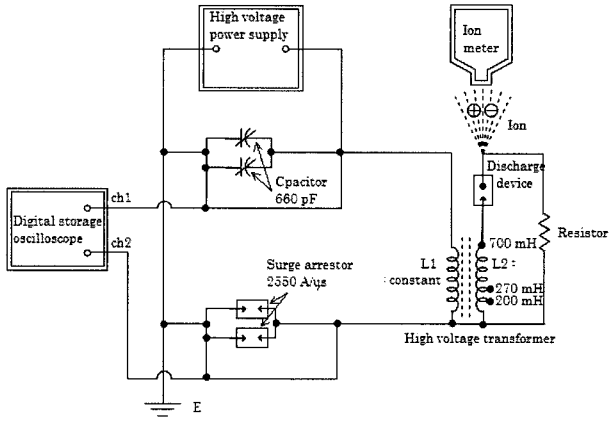

Fig. 3. Measurement circuit diagram of ion current.

2.2 Measurement of Ion Emission Current

In order to check the discharge property through the experiment by laboratory standards following the variation of electrical parameter at the electronic circuit of the ESE lightning air terminal, the experimental circuit has been established like Fig. 2.

In order to confirm the discharge at the discharge device, the measurements have been made like Fig. 3 using Ion Meter (Maker; SIMCO ARANSBURG Co., Model; ICM-1, Range; 1~1000 nA).

2.3 Experimental Results and Discussions

From Fig. 4 to Fig. 7 are graphs showing the measured results of switching frequency, ion current and switching voltage as a function of input voltage of electronic circuit in the ESE lightning air terminal. The detailed experimental conditions of symbols indicated at the graphs are measured values made by the conditions of Table 1.

In the relation between input voltage and switching frequency of Fig. 4, the frequency increased in the overall experimental conditions as the input voltage increased. The reason is that caused by spark over voltage of time constant of S.A and resistance of H.V.T and capacitance of C.

Table 1. Detailed experimental conditions of the symbols

Symbols	Test conditions			
	Capacitance (pF)	Surge arrester	Inductance of high voltage transformer	
			1st (mH)	2nd (mH)
T1	660	2 ea, parallel	Fixed	700
T2	660	1 ea	"	700
T3	1,320	1 ea	"	700
T4	660	1 ea	"	270
T5	1,320	1 ea	"	270
T6	660	1 ea	"	200
T7	1,320	1 ea	"	200

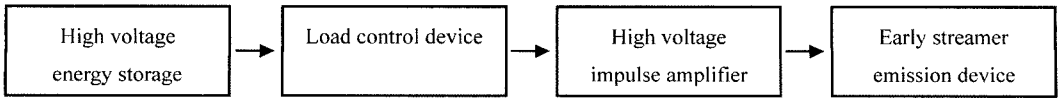

Fig. 1. Configuration of the ESE lightning air terminal.

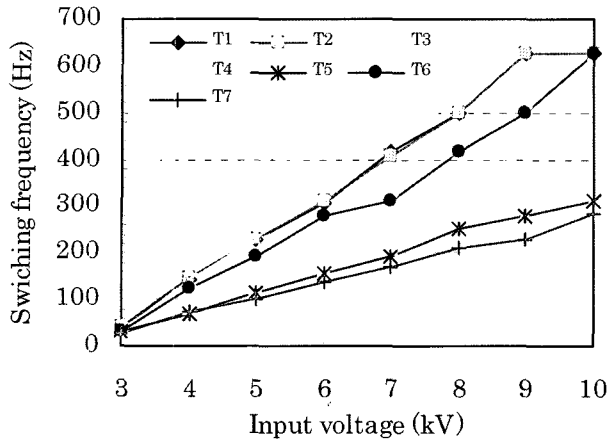

Fig. 4. Switching frequency as a function of input voltage.

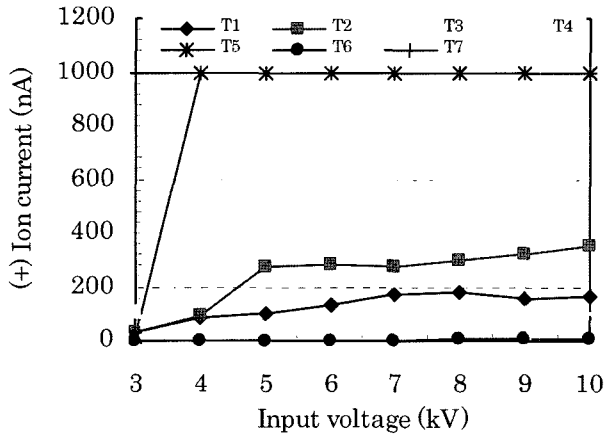

Fig. 5. Positive ion current as a function of input voltage.

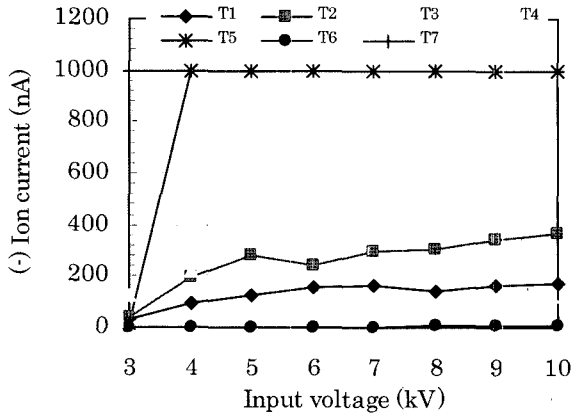

Fig. 6. Negative ion current as a function of input voltage.

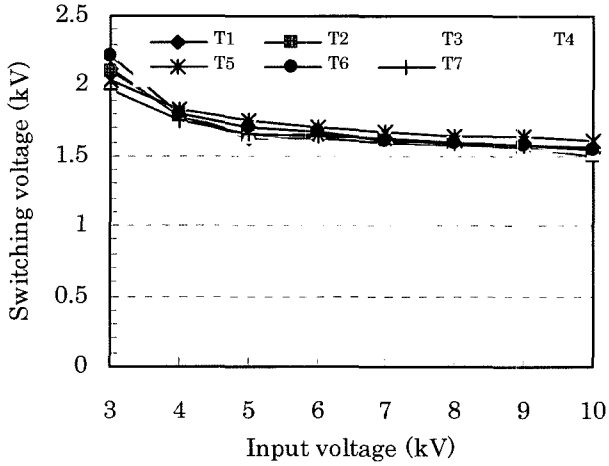

Fig. 7. Switching voltage as a function of input voltage.

In the relation between input voltage and positive ion current and negative ion current, the increase in positive ion current and negative ion current followed by input voltage is caused by increase of switching frequency and the increasing gap of positive ion current and negative ion current gets much high as C becomes high.

But the amplitude of positive ion current and negative ion current is almost the same. The reason for the graphs of symbols T5 and T7 showing as straight line in Fig. 5 and Fig. 6 are because the value of ion current exceeds the maximum value of measuring instrument (Max. range; 1000 nA).

In the case of the relation between input voltage and switching voltage in Fig. 7, the switching voltage is sustained constantly as each condition although input voltage is increased.

From the results of the experiment, the generating capacity of positive ion and negative ion increased that the input voltage, switching frequency, capacitance and inductance get high.

3. Performance Evaluation of the ESE Air Terminal (ElecHippo)

3.1 Outer Shape of the 「ElecHippo」 ESE lightning Air Terminal

The outer shape of the 「ElecHippo」 ESE lightning air terminal is in a form of round dish. In other words, its distinctive trait is that it fits well in any buildings with a silly design of U.F.O image. Fig. 8 shows the outer shape of the 「ElecHippo」.

3.2 Results and Discussions of Performance Test

The products made based on basic experiment of chapter 2 (2 types; YJ-ESEL-S800, YJ-ESEL-S1200) have been evaluated at the KERI. Table 2 shows the test results of comparison of difference in triggering time between the 「ElecHippo」 ESE lightning air terminal and Franklin rod. The lightning protection standard (French Standard NFC 17-102) has been used for the test stan-

Table 2. Test results of average upward leader trigging time

Model	Average upward leader triggering time		Time difference
	ElecHippo	Franklin rod	
YJ-ESEL-S800	135.5 μs	160.9 μs	25.4 μs
YJ-ESEL-S1200	111.2 μs		49.7 μs

Fig. 8. Out shape of the 「ElecHippo」

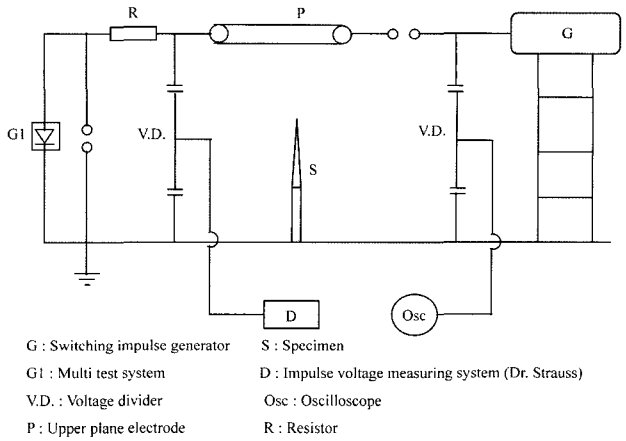

Fig. 9. Configuration of test circuit.

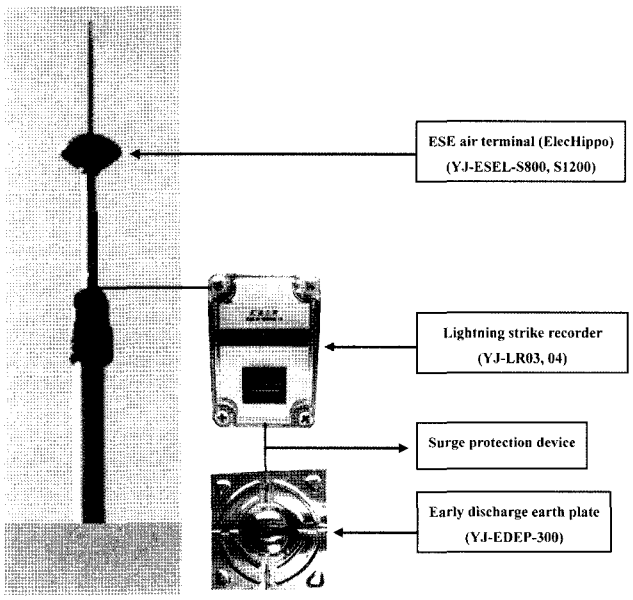

Fig. 10. New systematic grounding system.

dard. Fig. 9 shows the configuration of the test circuit.

It was confirmed that the YJ-ESEL-S800 has the performance of 81 m of protective radius by discharging 25.4 μs faster than the average triggering time of Franklin rod. It was also confirmed that the YJ-ESEL-S1200 has the performance of 118 m of protective radius by discharging 49.7 μs faster than the average triggering time of Franklin rod.

4. A New Method of Grounding System

We propose the new lightning strike protection and grounding system using the ESE lightning air terminal as shown in Fig. 10. The new grounding system is combined of the ESE lightning air terminal, the lightning strike recorder, the surge protection device and the EDEP in order to protect human lives and properties from lightning strike more safely.

4.1 ESE Air Terminal (ElecHippo)

The features of the 「ElecHippo」 ESE lightning air terminal are as follows;

· needs not a power supply.
· operates only at the time of lightning strike and does not operate at usual times.
· the protection area is wider than traditional lightning air terminals.
· all materials are stainless-steel so that there is no harmful of corrosion or rusting.
· reacts continuously even during continued lightning strikes.
· matches well with building than other lightning air terminals because of its good design.

4.2 Lightning Strike Recorder

The performance of the lightning strike recorder according to the evaluation of the KERI is shown in Table 3. Fig. 11 shows the outer shape of the lightning

Table 3. Specifications of lightning strike recorder

Type	YJ-LR03, YJ-LR04
Current sensitivity	1500 A, 8/20 μs impulse
Operating range	Min. 1500 A, Max. >220 kA, 8/20 μs
Display	Mechanical 6 digits (not re-settable)
Dimensions	75 mm(W) × 110 mm(D) × 70 mm(H)
Construction	Polycarbonate enclosure, IP 67
Weight	340 g
Operating temperature	- 15 °C ~ + 65 °C

strike recorder.

4.3 Early Discharge Earth Plate (EDEP)

The EDEP has lowered resistance by increasing the surface area using cutting and bending process where saw shape is applied to traditional flat earth plate which absorbs and discharges the lightning strike current to the ground and maximized the grounding discharge effect by making many sharp corners. Fig. 12 shows the image of the EDEP.

The KERI has measured DC flashover voltage and

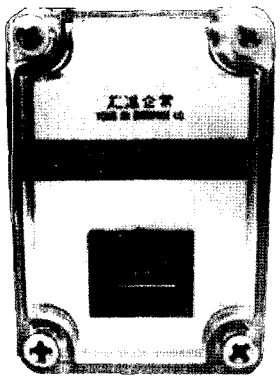

Fig. 11. Outer shape of lightning strike recorder.

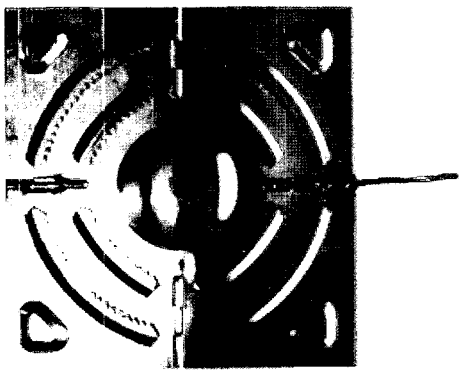

Fig. 12. Outer shape of the EDEP.

Table 4. Test results of the EDEP

Specimen	DC flashover voltage (kV)	DC applied voltage (kV)	Corona emission current (μA)
Traditional earth plate	315	100	30
		200	150
		300	450
EDEP	320	100	50
		200	400
		300	900

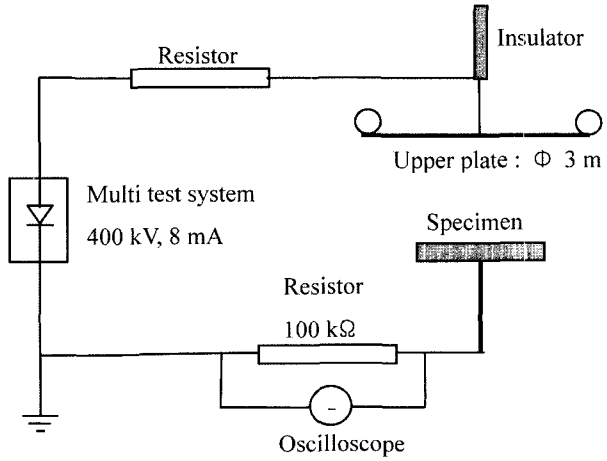

Fig. 13. Configuration of test circuit.

corona emission current to compare the EDEP with traditional earth plate and the results are shown in Table 4. Fig. 13 shows the configuration of test circuit.

The performance of the EDEP is shown in table 4. The corona emission current is generated more 2 times higher than the traditional earth plate. It will be considered that a number of saw-shaped sections formed in the EDEP discharge fast the lightning strike current to the ground.

5. Conclusions

In this paper, the discharge properties have been tested by the laboratory standard experiment followed by the variation of the parameters within the electronic circuit of the ESE lightning air terminal. The purpose is to use them as systematic and technical data on early discharge as well as the wide area property of the ESE lightning air terminal.

The ability to emit positive ions and negative ions in the ESE lightning air terminal increased;

- as the input voltage and switching frequency increased

· as the capacitance increased.
· as the inductance increased.

Therefore, while there are many types of parameters that influence the wide area property of the absorption of lightning strike of the ESE lightning air terminal, it is confirmed from the results of the experiment that the radius for absorbing the lightning strike becomes wide in proportion to the amount of ion generated at the inner electronic circuit if the circumstance influences (e.g., convection current, humidity, etc.) of the ESE lightning air terminal are held constant.

The protective radius of the ElecHippo, an ESE lightning air terminal, has the maximum value of 118 m.

The lightning strike recorder was confirmed as safely operable at 1500 A, 8/20 μs impulse.

Although the DC flashover voltage of the EDEP is found to be 5 kV higher than the traditional earth plate, the corona emission current generated is more than 2 times that of the traditional earth plate. It is found that a number of saw-shaped sections formed in the EDEP can quickly discharge the lightning strike current to the ground.

References

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