THE CHANGE OF LIGHTNING AIR TERMINAL AND TREND OF THE WORLD

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Abstract: Today, the system globally used as a lightning protection system can be classified into two types: 1) a general system which uses the conventional air terminal and 2) a functional system which uses the charge transfer system (CTS) or charge transfer air terminal and early streamer emission air terminal (ESE). There are many data which proves the effectiveness of the domestic and international conventional type of system which protects against the lightning according to the known standard. On the other hand, it is still difficult to confirm the performance of the functional system such as charge transfer system (CTS) and early streamer emission air terminal (ESE). This thesis has briefly reviewed the history of change of lightning air terminals from the lightning protection systems currently used in the market to those systems which can be applied in the future. Also, it reviewed the current situation of the domestic and international standardization organizations of the functional lightning air terminals such as CTS and ESE.

1 INTRODUCTION

It is fundamentally impossible to “perfectly protect” against lightning. The significance is in lowering the possibility of damages from the lightning strokes to the maximum. In case of developed countries, the idea of protection efficiency does not refer to the perfect protection against lightning within protection range or space to be protected, but to set up a protection probability and minimize the damages by lightning stroke within that protection efficiency. Environmental degradation has accelerated due to modern industrial development and destruction of the ozone layer has caused global warming and changes in climate worldwide. Plus, the frequency of lightning has actually risen in recent years. As the industrial technology has developed and the structure has become bigger, higher and modernized, the extent of the damage caused by lightning stroke is extended and people tend to realize the danger of lightning stroke. During 250 years, many unusual and alternative types of equipment had been introduced to minimize the damages by lightning stroke. Especially, during past 40 years, various methods have been used to enlarge the range that absorbs the charges of lightning air terminal and the equipment that does not provide any conditions of lightning stroke on the subject to be protected has been developed and commercialized Therefore, we need to review the lightning protection technology that is currently commercialized. In this paper, we examined the basic idea of each type of lightning air terminal, technical background with the history of lightning air terminal and the world's trend and also examined the current state of international organization for standardization.

2 STUDY ON PERFORMANCE PROPERTY AND FEATURES THROUGH THE HISTORY OF LIGHTNING AIR TERMINAL

The role of lightning air terminal is to protect the precious human lives and possessions from lightning stroke. Gentleman's Magazine published in March, 1750 first mentioned about the lightning air terminal. Its British version published 1751 covered the elecricity and in this book, Franklin said that the lightning air terminal is used to "protect the house and other possessions from the lightning stroke". In 1760, Franklin's point was proven to be true in Philadelphia and 400 lightning air terminals were used only in Philadelphia from 1753 to 1782. Afterward, many types of functional lightning air terminals were developed to protect the structure and human from lightning stroke. Such functional systems are divided into two main types. The first type of functional lightning air terminal was the protection system, which works as "lightning eliminator" aimed to change the atmospheric electricity of place above the subject to be protected and nearby area. This type of lightning air terminal was commercialized with the name of DAS (Dissipation Array System) and currently, it is consumed in the market under the name of CTS (Charge Transfer System). In contrast, another type of lightning air terminal does not apply the rolling sphere method as in conventional lightning air terminal. In fact, it is the equipment that causes Early Streamer Emission from the lightning protection system, where the lightning stroke may move forward to unprotected subject and therefore, significantly enlarges the space to be protected. Likewise, the lightning air terminal of modern days does not only create the path of lightning stroke, but also have functions

that are applicable to be designed and installed according to the purpose of the structure. In this paper, we tried to examine the validity of all kinds of lightning air terminal from conventional air terminal to current bipolar conventional air Terminal through the expected thoery analysis of functional systems and researches studied by international academia.

2.1 Conventional air terminal

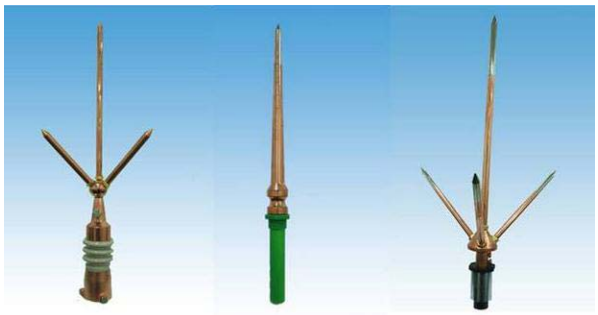

Figure 1: Conventional air terminal

In 1752, when nobody knew what the lightning stroke actually is, famed American Franklin proved that lightning stroke is in fact the electricity through the scientific experiment using a kite and proposed that using the lightning air terminal, the electricity in the storm can be safely discharged in the ground and it also prevents the falling of lightning stroke right at the structure. When a hot and humid unstable air mass becomes cumulonimbus clouds, the upper part of cloud has positive (+) charge and the lower part has negative (-) chare. At this moment, the ground is positively (+) charged in opposition to lower part of clouds due to electrostatic induction and capacitance is formed between the ground and the cloud. On a sunny day, the electric field between the ground and the cloud is about 100[V/m], but at the place where a thundercloud is approaching, more than hundreds [kV/m] of electric field is generated. At this moment, if a tip (sharp point) has higher electric field than surrounding electric field, positive and the electric field around the tip is high enough, the positive (+) ion is moved from the ground and released through the tip and such phenomenon is called the ionizing event. Also, the current is flowing due to movement of positive (+) ion and this current is called the point-discharge current. Ion around the tip tends to move upward with higher electric field. This is called the upward leader or the upward streamer. Like so, the conventional air terminal creates the upward streamer and absorbs the lightning stroke.

2.2 Mechanical air terminal

Figure 2: Mechanical air terminal

As shown in the performance property of conventional air terminal, the lightning air terminal is positively (+) charged with electricity and on the contrary to this, the lighting stroke is negatively (-) polarized. Using such condition with the electrostatic induction, the mechanical air terminal is designed to arrange a huge energy source, the (-) lightning stroke, which is a negative (-) polarity, nearby the lightning air terminal and to be discharged at low electric field. Also, as shown in the figure, when a sharp tip (electric field concentration) is attached to the end of lightning air terminal insulated with insulator, the surrounding electric field increases as if the lightning stroke is moved nearby the lightning air terminal and the electric field energy gathers around the sharp tip and the dielectric breakdown of air between the lightning air terminal occurs and such phenomena is known as the corona discharge. Consequently, mechanical air terminal faster than conventional air terminal upward streamer is generated.

2.3 Radioactive air terminal

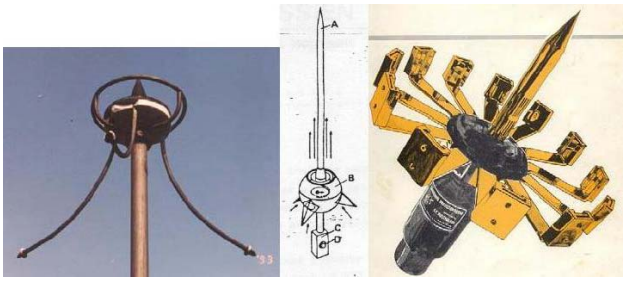

Figure 3: Radioactive air terminal

Since, the mechanical air terminal works mechanically, the upward streamer is not actively generated. Meaning that, the streamer is not generated at an even pace as it is generated according to the changes of surrounding's electric field. To solve such problem, a new method has been proposed and that proposal was to seal a radioactive isotope of radium or thorium, pass the ion around this, increase the ionization of surrounding air, generate the high-voltage and eventually cause discharge and generate the streamer. Ionization method for protection against the lighting was inspired by J.B.Szillard, who had proposed an idea through the paper submitted to

Paris Science Academy in 9th of March, 1914. Gustav P. Carpart, co-worker of Madame Curie got a patent on the first ionization lighting method in 1931 and his son, Alphonse Capart commercialized this method in 1953. However, Muller-Hillbrand in 1962 and Gillespie in 1965 argued that the radioactive isotope cannot cause the lightning stroke based on their researches. In 1987, IEC TC81 technical committee prohibited the use of radioactive isotope in IEC 62305 standard because of its danger. In 1990, ESE (Early Streamer Emission) air terminal has introduced, replacing the radioactive air terminal.

2.4 ESE using Electronic Element

Figure 4: Early Streamer Emission (ESE)

When the lighting moves forward to the subject that is not protected, ESE air terminal generates Early Streamer Emission beforehand, so that the downward leader can contact the lightning air terminal. According to producers of ESE lighting rod, ESE air terminal based on its specially designed electrical structure and features generates faster upward streamer compare to the conventional air terminal and has following advantages in terms of path of upward leader. Meaning that, ESE air terminal is designed to enlarge the space to be protected. Most of ESE air terminal is based on electronic form. Internal structure of electronic lightning air terminal is divided into three major parts and they are Capacitor, Detector and Transformer. In other words, since the surrounding's electric field energy density, which is the energy source is low on a sunny day (about 100[kV/m]), there is not much of energy source to be stored [1]. However, when lightning stroke is about to fall, the electric field of surrounding is increased to be hundreds [kV/m], the energy is absorbed from surrounding electric field and stored in Capacitor. Plus, when the lightning stroke is falling, the electric field of surrounding is increased and the detector inside the lightning air terminal detects the lightning stroke, discharges the stored energy from the circuit, generates the high-voltage through the transformer and the lightning air terminal eventually emits the streamer.

2.5 DAS-CTS air terminal

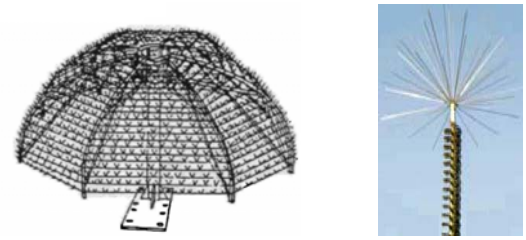

Figure 5: DAS-CTS air terminal

J.M.Cage lived in California in 1930 obtained the patent on multi-point discharge system for protection against the lightning stroke for the very first time. After that, Roy B.Carpenter jr commercialized this idea in 1971 and developed the lightning air terminal under the name of DAS in 1973. However, the research of DAS was not proved at that time. So, new concept of CTS was introduced and used to develop the lightning air terminal. The purpose of using such devices is to change the charges of air above and around of the subject to be protected to avoid the lightning stroke or decrease the possibility for the lightning stroke to be formed. In early 1990, the lightning air terminal developed in America was to prevent the direct struck by the lightning stroke using this lighting rod. On the domestic side, the lighting rod was first introduced in the late 1990 and recognized from early to mid 2000. This lighting rod looks like a chestnut bur with lots of thorns. In contrast to ESE, DAS discharges ion to the air through electrodes composed of several thorns, preliminary dispersion the space charge and therefore, protect the structures by controlling induction of lightning stroke. However, its effect and economic feasibility has not clearly proved yet.

2.6 Bipolar conventional air terminal

Figure 6: Bipolar conventional air terminal (BCT)

Bipolar conventional air terminal was developed, commercialized in Korea, in 2002 for the very first time in the world and the purpose of this air terminal was to prevent the direct stroke by the lightning stroke to the structures. Not like DAS or CTS, it significantly increases the amount of corona discharge, removes the concentrated electric field caught by the lightning air terminal in advance and it ultimately does not create the condition for lightning stroke. Details regarding the experiment and theory for this device was published and introduced in IEEE paper with the title of "Local Electric Field Analysis for Evaluation

of Charge Transfer System Using Sequential Subwindow Technique", in March 2004. Bipolar Conventional Air Terminal was developed to prevent the lightning stroke toward the structures [10]. In other word, it generates the corona beforehand to not induce the pre-emission of thundercloud and discharges the charges to the air. It connects and installs the circular electrode to the supporting part of air terminal on the upper part in order to increase the flashover voltage, so that the electric field of thundercloud is charged with electricity in accordance of bipolar theory. When charged thundercloud approaches, the positive(+) charge is concentrated on the tip of air terminal installed on the top of the structure and the circular-shaped conductor that has been electrically induced transfers the charges to the air as the corona discharges is actively generated among the negative(-) electro-puncture, the induced bipolar circular-shaped conductor and brush on side of air terminal. Meaning that, the positive charge transferred to the whole building is distributed in the air. The basic theory of this "bipolar conventional air terminal" is to remove the concentrated electric field from the top of the building, prevent the beforehand discharge of lightning stroke and therefore, to protect the structure or the subject to be protected against the lightning stroke by equalizing the electric field between the ground and the air. This method follows the current IEC 62305 standard and this bipolar conventional air terminal is mainly designed and installed on the spot where the Conventional lightning air terminal is installed, to lower the possibility of direct lightning stroke.

3 ESE AND DAS-CTS RESEARCHES AND THEIR TRENDS

3.1 ESE (Early Streamer Emission)

Controversy over the effect of ESE has been discussed in many academic and research institutions since 1980. IEC has requested the famed French CIGRE and TC81, the technical committee that is in charge of the lightning protection standardization to investigate Lightning Interception Process and technical controversy over ESE technique in 1992. CIGRE working group SC33.01.03 concluded that "there are not enough theoretical analysis result or practical data to prove that ESE is much efficient in protection against the lightning stroke compare to conventional air terminal." through several discussions from 1994 to 1995. After meetings in 1995 and 1997, TC81 decided not to make IEC standard for ESE technology. Currently, even EC, which has very close relationship with IEC and CENELEC (European Committee for Electro Technology Standardization), the standardization organization of EFTA do not have any standard for ESE technology. In America, NFPA discussed the standardization of ESE as a draft of ESE standard (NFPA 781 Draft) has brought in. The committee that evaluates the draft was composed of authorized representatives of French, Australian and American manufacturers. Though the proposed NFPA 781 was submitted to NFPA Council in January, 1993, the proposal was handed over to the technical committee as more researches were requested. Afterward, the technical committee posed a problem because this draft was proposed and lobbied by the manufacturers. The Council requested the third part to evaluate the proposal and delayed the standardization. NIST (National Institute of Standard and Technology) evaluated their proposal and based on the evaluation, the Council held a public hearing on the standardization of ESE in July, 1995 [11]. As a result, the Council passed a vote of rejecting NFPA 781 proposal. Likewise, the controversy in connection with the efficiency of ESE was over. Recently, CENELEC agreed to eliminate the past standard with respect to ESE.

3.2 DAS(Dissipation Array System)-CTS(Charge Transfer System)

Meanwhile, the feedback on DAS-CTS from various countries is similar to ESE. DAS was developed by Roy B. Carpenter Jr in 1971, as he rushed into the lightning protection field through multi-point discharge system. He insisted that the structure that installed this system might avoid direct lightning stroke by the lightning stroke. To prove and evaluate the validity of his and his company's proposal, J. Hughes held a meeting "Evaluation on the lightning protection technology for high-rise building" at Lyndon B. Johnson Space Flight Centre of Clear Lake City (Houston), Texas on 6th of November, 1976. The final report was presented on 31st of January, 1977. However, his proposal did not go last long because a researcher, who was requested to prove this proposal by American Government, took several pictures of lightning stroke falling on DAS. As the fact that DAS could not work best, had become widely known, the manufacturer introduced new concept of CTS. However, another research proved that neither DAS nor CTS can prevent the lightning stroke. Though the manufacturer of CTS proposed the standard for CTS to IEEE, the proposal was deferred because there was no scientific theory for development of CTS. Nevertheless, the developers sell CTS all around the world, arguing that IEEE standard for CTS is on progress.

4 REPEATED PROPOSAL OF ZIPSE

According to the research of Abdual M. Mousa and Donald W. Zipse in 1994, DAS cannot control or prevent the generation of lightning stroke and it works no better than the Conventional air terminal [3]. They especially pointed out that when the

building is less than 300m, DAS has no effect on reducing the frequency of lightning stroke at all. However, Zipse said "the Charge Transfer System of preventing lightning strikes to protected areas is a valid concept and will replace the Franklin rod method in many applications" in his paper, "the lightning protection method: an update and a discredited system vindicated" published in 2000 [4]. Based on his proposal and paper, Zipse submitted CTS standard application to IEEE and IEEE standard committee accepted "Draft standard for the lightning protection system using the CTS for commercial and industrial installations(Draft IEEE P1576/02.012001)", also known as Zipse PAR (Project Approval Request) 1576 project on 7th of December, 2000. However, IEEE committee rejected Zipse's draft standard application in 2004 due to lacks of scientific basis.

5 CONCLUSION

It has been 250 years, since Franklin studied and developed the lightning air terminal to protect precious human lives and possessions of local community. During past few years, great efforts were exerted and many possible proposals were presented to improve the efficiency of lightning protection. For several years, many functional systems including ESE and DAS were introduced, but they could not show any advantages compare to the conventional air terminal. Plus, the damage case has presented recently through many papers. The lightning air terminal should be designed and installed based on reasonable and scientific basis to protect not only human lives, but also structures against the lightning stroke. Recently, a high-rise building has appeared and the society has become advanced information-oriented society. This is why the present days require new lightning technology more than ever. In this paper, we presented the whole changes, history of lightning air terminal, the development of technology, the types of functional systems and the trend of world's lightning air terminal market. Though it is impossible to perfectly protect against the lighting, we believe that the damages caused by the lightning stroke can be minimized using newly developed lightning air terminals and presented papers. The lightning air terminal that would be developed in near future should be presented based on the papers and practical experiments that can approve the technology. We also believe that the damages or accident caused by direct lightning stroke of lightning stroke can be reduced and diminished, if the lightning protection system is designed in consideration of the protection probability considering diverse variables including the importance of structures, the frequency of lightning stroke, and the size of lightning current and together with IEC regulations.

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