Climate Change and its Impact on Lightning Protection Practices

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Abstract—Climate change has resulted in more frequent thunderstorm occurrences in the temperate zones and in desert regions where lightning activity is lower compared to the equatorial regions. Buildings and structures that do not have effective lightning protection systems will be more impacted by lightning strikes than in the recent past. The IEC 62305 standard provides an effective lightning air terminal (i.e. lightning rod) placement method that can be applied on buildings with either simple or complex geometries. However, buildings that have been installed with non-conventional lightning protection systems, such as the Early Streamer Emission (ESE) air terminals, will experience more damages as these systems have already been proven as not effective for over 25 years.

Keywords – lightning protection; Collection Surface Method; lightning interception; air terminal; bypass; Early Streamer Emission.

I. INTRODUCTION

Climate change has resulted in more thunderstorms occurring in the temperate zones and even in desert regions. This has resulted in an increase in the occurrences of catastrophic flash floods, tornadoes, lightning, and wildfires in some countries.

Consequently, buildings and open spaces in those areas are now at higher risk of being struck by lightning if they are inadequately protected against this dangerous phenomenon. Fortunately, our understanding of lightning protection practices has been significantly improved by scientific research conducted around the world, particularly in areas with high lightning activity such as the tropical and equatorial regions.

Some of the results of these research activities have been incorporated into lightning protection standards such as the IEC 62305 which was published in 2006 by the International Electrotechnical Commission (IEC). The application of this standard in full can significantly improve the protection of buildings, structures and open spaces from lightning strikes.

II. THE IEC 62305 STANDARD

The IEC 62305 standard provides simple yet effective air terminal (i.e. lightning rod) placement methods that can be applied on any building or structure that are exposed to lightning. These methods have earlier been applied in some national lightning protection standards that have now been replaced by the IEC 62305, and in the current American standard NFPA780.

A. *Air Terminal Placement Methods*

The IEC 62305 mentioned three well established methods for designing air termination networks. They are:
(a) Protection Angle Method (G. Lussac, 19th century),
(b) Mesh Method (J. C. Maxwell, 19th century) and
(c) Rolling Sphere Method (T. Horvath, 1960).

The Rolling Sphere Method is suitable for identifying all the exposed building surfaces that are at risk of being struck by lightning. However, this method is unable to detect the high-risk locations where lightning has been frequently intercepted which resulted in *bypasses* (i.e. damages due to lightning strikes).

To overcome this detection problem, the IEC 62305 standard also provides a basic guide for the placement of air terminals to effectively intercept the lightning bolt. This guide is based on the latest air terminal placement method known as the Collection Surface Method (Hartono & Robiah, 1995, 2000) [1, 2].

B. *The Collection Surface Method*

This method was developed based on statistical analysis of observed bypasses on high-rise buildings in the very high lightning activity zone found in Kuala Lumpur and Singapore. It is based on the Rolling Sphere Method but instead of focusing on the surface of the imaginary sphere, the Collection Surface Method focused on the center of the sphere as it is rolled over the surface of the building.

The center of the sphere will generate an imaginary surface for every point on the physical surface of the building and the size of the imaginary surface correspond to the risk of that point being struck by lightning. It was found that corners, exposed points and edges have higher collection surfaces than flat surfaces. This method was proved to be able to predict the effective positions of the air terminals by lightning experts from Australia. [3]

The method was first applied in the revised Australian standard, AS1768, in 2003 [4]:

Field data of damage caused by lightning flashes terminating on structures identify the parts that are vulnerable to strikes. The most vulnerable, associated with over 90% of observed lightning damage, are nearly always located on upper parts of structure, such as—
(a) pointed apex roofs, spires and protrusions;
(b) gable roof ridge ends; and
(c) outer roof corners.

The Collection Surface Method was later applied in the IEC 62305 [5] after it was examined by the IEC Technical Committee No. 81:

Air-termination components installed on a structure shall be located at corners, exposed points and edges (especially on the upper level of any facades) …

Following the publication of the IEC 62305, Czech [6] and German [7] lightning experts developed software based on the Collection Surface Method that can predict the lightning strike location on any complex shaped building. They also suggest that applying the method in full compliance with the standard can provide up to 98% lightning interception efficiency.

III. COMMON ERRORS IN AIR TERMINAL PLACEMENTS

Air terminals that have been positioned not in full compliance with the IEC 62305 standard have repeatedly failed to intercept the lightning stroke, and this led to the occurrences of bypasses [8]. More than 90% of buildings in Malaysia have been installed with conventional air terminals that were not positioned according to the standard.

The reasons given for these failures are that the engineers who designed the air termination systems falsely believed that air terminals, conventional or non-conventional, can attract lightning and so the air terminals can be positioned anywhere on the exposed surface. This is partly due to the false belief being published in a book and taught in various local universities [9]. Consequently, some of them failed to understand the basis for air terminal placement according to the standard. Furthermore, most of them do not have any access to the past and/or present lightning protection standards for their study and reference.

Figure 1. Example of an air terminal (arrowed) incorrectly positioned away from the ridge end of the roof where a bypass (circled) had occurred.

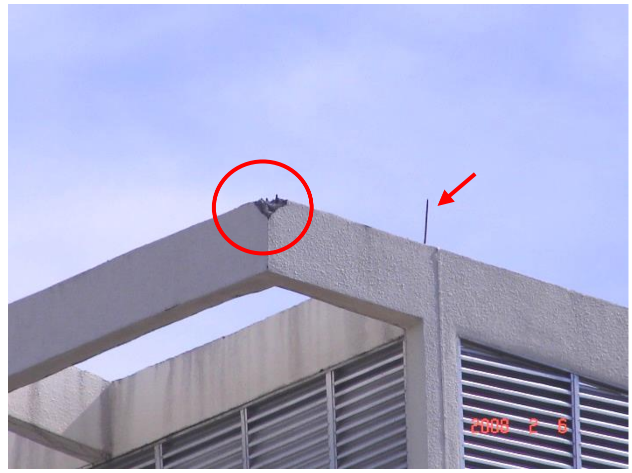

Figure 2. Example of an air terminal incorrectly positioned away from the outer corner of the roof where a bypass had occurred.

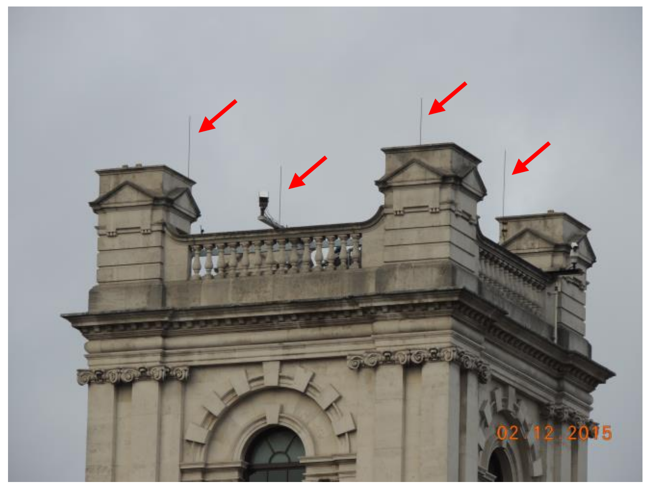

Figure 3. Example of air terminals incorrectly positioned at the inner corners instead of the outer corners of the roof.

Figure 4. Example of a major bypass on an unprotected part of a roof firewall.

Figure 5. Example of a minor bypass on a roof firewall installed with an air terminal positioned not in accordance with the IEC 62305 standard. If the air terminal had been positioned at the end of the firewall, the bypass could have been prevented.

IV. ALTERNATIVE FORMS OF CONVENTIONAL AIR TERMINALS

In some countries, the conventional lightning rod is synonymous with the cylindrical shaped metallic conductor with a pointed or blunt tip which is screwed onto a metallic base plate which is then affixed to the roof tile or surface. The lightning rod is connected to adjacent rods by installing a metallic tape through the base plate.

However, there are alternative forms of air terminals where the rod and tape are replaced by a cylindrical metallic conductor which can be cut and bend into the required length and shape according to the usage. They can be fixed to the horizontal or vertical surface of the building using simple brackets. Hence these alternative air terminals are more economical to manufacture, store and easier to install.

Figure 6. An example of a continuous solid cylindrical conductor applied as an air terminal on the ridge end of the roof.

Figure 7. Another example of a continuous solid cylindrical conductor applied as an air terminal on the ridge end of the roof.

Figure 8. An example of a continuous solid cylindrical conductor applied at the outer corner of the roof.

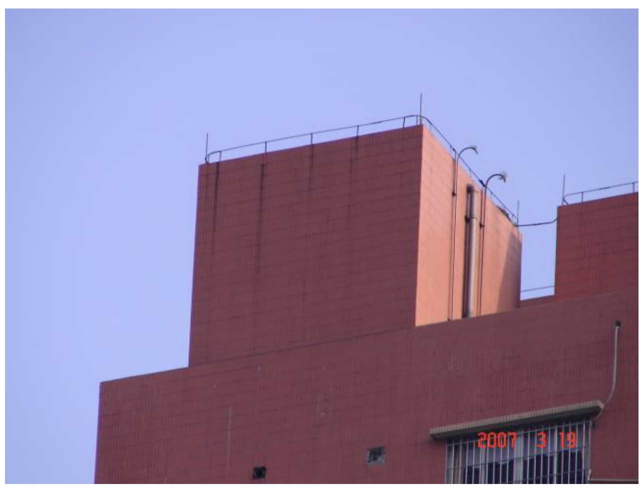

Figure 9. An example of a continuous solid cylindrical conductor suspended horizontally above the roof to better intercept the lightning bolt.

Figure 10. An example of a continuous solid cylindrical conductor suspended high above the roof on masts to protect vulnerable rooftop equipment.

V. NON-CONVENTIONAL AIR TERMINALS

These are air terminals that are claimed to have extra-ordinary large protection zones by their proponents (i.e. inventors, manufacturers, vendors, dubious academics). They claimed that these air terminals can either attract or repel the lightning bolts, but their claims have never been proven scientifically since their invention. As such, the proponents claimed that only one air terminal is generally sufficient to protect the whole high-rise building or a group of closely built smaller buildings and structures.

The use of these air terminals has already been rejected by the scientific community since the 1980s but generic versions of them have repeatedly been invented since then by opportunistic inventors. For example, the radioactive air terminals were initially invented in the early 1970s, but their claims have been scientifically disproved a few years later. However, the non-radioactive versions of the air terminals were re-invented by the same inventors and renamed the early streamer emission (ESE) air terminals in the late 1980s. Like the radioactive air terminals, the ESE air terminals were claimed to provide a protection radius of between 50 to 100 m. However, studies show that such claims were baseless and can endanger the buildings and people who use them. [10 - 26]

The ESE air terminals seemed to have become the dominant non-conventional air terminals sold in the world market. However, many high-rise buildings in lightning prone countries that use the ESE air terminals have been struck by lightning, some repeatedly, resulting in numerous bypasses.

In Malaysia, many high-rise buildings displayed multiple bypasses after being installed with one or more ESE air terminals. While most bypasses occurred at the perimeter of the roof within the claimed protection zone, more and more bypasses were seen to have occurred very close to the ESE air terminals themselves, some within ten meters.

A. Close Proximity Bypasses

The incidences of bypasses well within the claimed protection zone of the ESE air terminals have risen in tandem with the increase in the number of high-rise buildings using them.

Figure 12. A high-rise building photographed with a bypass about 25 m from an ESE air terminal.

Figure 13. Close-up photograph of the bypass and the ESE air terminal.

Figure 14. Photograph of the same building with a new bypass taken 5 years later. The old bypass has been repaired.

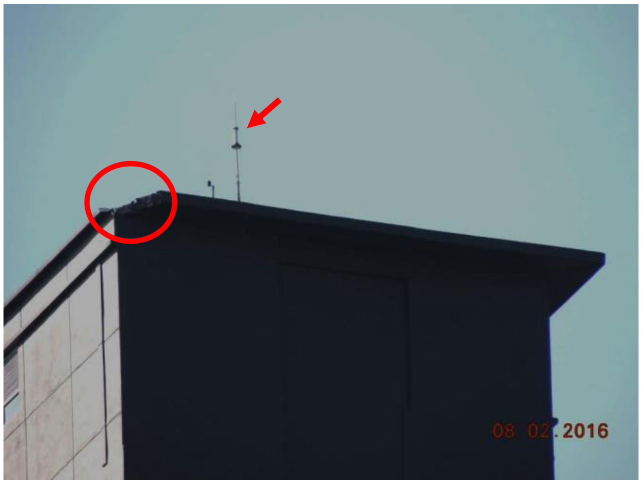

Figure 15. Close-up photograph of the new bypass which is located less than 10 m from the ESE air terminal.

Figure 16. Close-up photograph of an ESE air terminal surrounded by 3 nearby bypasses.

B. Bypasses to more than one ESE Air Terminals

Some buildings were installed with additional ESE air terminals after they have been struck by lightning repeatedly. However, these actions were a failure because the bypasses continued to occur even after the additional air terminals have been installed.

Figure 17. A building photographed with two ESE air terminals.

Figure 18. The same building photographed with a bypass about 5 years later.

In one case study that spanned several years, a high-rise apartment building was installed with an ESE air terminal was repeatedly struck by lightning. This continued even after the height of the air terminal was increased. After two additional ESE air terminals were added, more bypasses still occurred as the building continued to be struck by lightning [27].

C. Close Proximity Bypass in France

In 2009, the stone cross on a 25 m high bell tower in the town of Sigolsheim was damaged by a direct lightning strike [28]. The stone cross was situated on a ridge end of the roof and a mere 7 m from an ESE air terminal which was installed on the opposite end. This is clear evidence that the ESE air terminal cannot attract lightning better than a stone cross and that its claimed protection zone is false.

Figure 19. The bell tower showing the remnants of the damaged stone cross (left) and the ESE air terminal (right) about 7 m away. (Picture courtesy of Dernières Nouvelles d'Alsace)

VI. CONCLUSION

Climate change is expected to bring more violent thunderstorms to many parts of the world and with them more lightning flashes. Buildings and structures that have already been installed with conventional lightning protection systems that fully complied with the IEC 62305 standard are well protected from the deleterious effects of lightning. However, those that have been installed with non-compliant conventional systems or with the non-conventional systems are potentially at much higher risk of being struck and damaged by multiple lightning bolts. This is evidenced from the hundreds of ESE installed buildings that have been struck by lightning repeatedly in Malaysia.

To mitigate this impending problem, the relevant authorities should enforce the IEC 62305 standard on all existing and future buildings and structures. Non-compliant conventional lightning protection systems should be improved until they fully comply with the provisions of the standard while non-conventional systems should be completely replaced with conventional ones.

Engineers tasked with designing lightning air termination systems must ensure that they are fully competent to understand the physics of lightning as well as the provisions of the IEC 62305 standard to ensure the safety of the buildings and the people who use them. Universities that offer lightning protection courses must ensure that their lecturers are well qualified to do so and that their curriculum and research activities are not detrimental to public safety.

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