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Clear Evidence of Lightning Strikes to a Building Installed with Multiple ESE Air Terminals

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***Abstract*—Studies on the failures of the early streamer emission air terminals in the form of lightning bypass observations in Malaysia have been recognized by CIGRE and NFPA for over two decades. In this case study, the subject building was periodically observed for new bypasses, from the time it was completed and installed with just one ESE air terminal to the time after two additional ESE air terminals and Franklin rods were added a few years later. The continued occurrences of bypasses provide clear evidence that the use of multiple ESE air terminals cannot protect a building from being struck by lightning. The incorrect positioning of Franklin rods according to the IEC62305 standard also contributes to the occurrence of bypasses.**

Keywords - lightning protection; air terminal; bypass; early streamer emission; Franklin rod

I. Introduction

The early streamer emission (ESE) air terminals (AT) were introduced in Malaysia in 1990 to replace the practice of installing radioactive AT that were banned by the government in 1988. The failure of the ESE-AT in the form of bypasses was first photographed in 1990 and later published in local/international conferences since 1995.

Although these failures have been acknowledged by the International Council on Large Electric Systems (CIGRE) and the National Fire Protection Association (NFPA) for over two decades, some local engineering academics/consultants (the proponents) still applied questionable methods to mislead the building owners/managers (the users) into using them. Some of these methods are presented in the following case study to highlight the deceptive methods applied by the proponents in persuading the users who are mainly unaware about lightning and lightning protection systems (LPS).

II. Types of LPS and Bypasses

A. Conventional AT

The conventional AT (C-AT) consists of vertical (e.g., Franklin rod) and horizontal (e.g., copper strip) conductors that neither attract nor repel a lightning bolt. They are positioned directly on the corners, edges and pointed parts of the roof according to the prevailing lightning protection standard such as the BS6651 and IEC62305. The Franklin rod is a passive device whose function is to intercept a lightning bolt and directs the lightning current to the grounding system via the down conductor and/or building rebar system.

B. Non-conventional AT

The non-conventional AT (NC-AT) are proprietary active devices of various shapes and sizes that claim to either attract or repel lightning bolts. Examples of NC-AT that claim to attract lightning bolts are the radioactive AT and the ESE-AT. Examples of NC-AT that claim to repel lightning bolts are the Dissipation Array System (DAS), the Charge Transfer System (CTS), the Bipolar (B-AT), the Semiconductor Lightning Extender (SLE-AT) and the Compound Plasma Lightning Rejection (CPLR-AT). None of the proponents of the NC-AT have provided indisputable scientific evidence that their devices can attract or repel lightning bolts [1][2].

C. Bypass

A lightning struck building would exhibit a *bypass* (i.e., physical damage) if the lightning interception occurred on non-metal surfaces such as wood, plastic, clay tiles, bricks, and concrete. These materials will exhibit bypasses of various sizes depending on their inherent physical strength and the magnitude of the current carried by the lightning bolts; and may cause a fire outbreak if the lightning interception point is combustible.

However, many modern buildings have been built with sheet metal roofs and facades or with ornamental metallic structures on the rooftops. Hence lightning strikes on these metallic features will not leave any significant bypasses that are easily detectable from a distance and will give the false perception that they have not been struck at all.

III. The ESE-AT

The ESE-AT accounts for more than 95% of all NC-AT installed in Malaysia. The proponents have claimed that the ESE-AT emit upward streamer discharges at the speed of 1×10^6 ms^{-1}. Since some of the proponents also claimed that the upward streamers are discharged up to 100 microseconds earlier than those from Franklin rods, they erroneously claimed that the ESE-AT can provide a protection radius (zone) of up to 100m. However, research suggests that this claimed speed is very much higher than actual streamer speeds observed in nature. [1][2].

Using the above defective argument, ESE proponents claimed that only one ESE-AT is sufficient to protect the whole high-rise building. However, when the building is repeatedly struck by lightning, the proponents will take one or more of the following action items to mislead the users on the problem:

A. Lightning event counter (LEC)

Normally, an LEC is installed on the down conductor to register the claimed number of lightning strikes to the ESE-AT. If the counter reading is high, the proponent will use it to convince the user that the ESE-AT have been struck repeatedly and is attracting the lightning bolts as claimed.

However, research suggests that the performance of the commercial LEC is very unreliable in registering the actual number of lightning strikes to the ESE-AT. In one case study, only 25% of the LEC used at a facility seemed to have registered the correct number of strikes [3].

B. Deficient mounting pole height

ESE-AT manufacturers and proponents claimed that the size of the protection radius of the AT depends on its height above the surface to be protected. If a bypass occurs within this radius, the proponent will usually claim that the height of the mounting pole is deficient and will then replace it with a taller pole to enlarge the claimed protection radius.

C. Using a different ESE-AT

The proponent may recommend that the existing ESE-AT be replaced by another ESE-AT of a different model/brand. Alternatively, he may recommend that another ESE-AT mounted on a taller pole be installed next to the existing one so that the combined protection radii will protect the whole building. However, research suggests that this method also failed to protect a building from being struck by lightning and provided clear evidence that the claimed protection radii of the ESE-AT are false and unproven [4].

D. Adding more ESE-AT

The proponent may recommend adding one or more ESE-AT of the same brand or of a different brand at several evenly spaced locations on the roof. This suggests that the protection radius of the initial ESE-AT is smaller than originally claimed. Again, research have shown that this method also failed to protect the building from being struck by lightning and provided more evidence that the claimed protection radii of the ESE-AT are much smaller than claimed [4].

E. Adding a C-AT system

The proponent may finally recommend that a C-AT be installed to comply with the lightning protection standard. This again suggests that the use of multiple ESE-AT is not effective in protecting the building from lightning strikes.

However, in many cases, the bypasses will continue to occur if the C-AT have been installed without full compliance with the recommended air terminal placement method.

IV. Long Term Case Study

The UNIV360 Place condominium was completed in early 2015 and is located next to a major highway; hence it is possible to monitor the building on a regular basis and photograph the appearances of new bypasses (Fig. 1 and 3).

This case study is divided into two phases:

1) Phase 1 is the period from the time when the building was photographed with the first ESE-AT (ESE#1) installed.

2) Phase 2 is the period from the time when ESE#1 had been remounted on a taller pole, ESE#2 and ESE#3 had just been installed while a C-AT system was under installation.

A. Phase 1: From April 2015 to May 2016

The building was initially photographed with ESE#1 (Fig. 2) installed in April 2015. In the 8-month period from October 2015, a total of five bypasses were photographed.

TABLE I. PHASE 1 INFORMATION

Photograph date	Item photographed
April 2015	ESE#1 (Fig. 2)
October 2015	Bypass #1 i.e., B#1 (Fig. 4)
December 2015	B#2 (Fig. 5)
May 2016	B#3 (Fig. 6), B#4 (Fig. 7) and B#5 (Fig. 8)

B. Phase 2: From July 2016 to December 2019

In July 2016, ESE#1 have been reinstalled on a taller mounting pole while ESE#2 and ESE#3 have recently been installed. A C-AT system was under installation which was completed a few weeks later. The unusually high number of lightning strikes to the building was believed to be behind this major modification to the lightning protection system.

However, another four new bypasses were photographed after the above modifications were completed with three of them detected within a calendar year. No new bypasses were observed from January 2020 until March 2021.

TABLE II. PHASE 2 INFORMATION

Photograph date	Item photographed
July 2016	ESE#1 remounted on a taller pole (Fig. 9 and 10); ESE#2 (Fig. 11) and ESE#3 installed
November 2017	B#6 (Fig. 12)
May 2018	B#7 (Fig. 13)
November 2018	B#8 (Fig. 14)
December 2019	B#9 (Fig. 15)

V. Discussions

A. Bypass frequency and size

The number of bypasses that occurred at the Univ360 Place provides clear evidence that high-rise buildings in Malaysia installed with multiple ESE-AT can still be struck by lightning several times a year. This suggests that the ground flash density in some areas can be very high and that tall and large buildings installed with just one ESE-AT are also at high risk of being struck by lightning.

After the C-AT was installed, the frequency and size of the bypasses that occurred were smaller than those which had occurred previously. This suggests that the Franklin rods may have intercepted some of the lightning bolts or reduced the damaging impact of the lightning strikes to the building.

B. ESE#1 installation

The above AT was installed at the centre of the roof which is approximately 140 m long. The claimed protection radius of the AT must be much bigger than 70 m for it to protect the whole building from lightning strikes. Since the lateral distance between B#4 and ESE#1 is approximately 60 m, this is clear evidence that the protection radius of ESE#1 is smaller than 60 m. Furthermore, since more bypasses continued to occur after ESE#1 has been remounted on a taller pole, this is clear evidence that this practice is impractical.

C. *ESE#2 and ESE#3 installation*

The above two AT were installed in response to the failure of ESE#1 to protect the building from being struck by lightning repeatedly. Since they were installed at approximately midway between ESE#1 and the far ends of the building, the horizontal distance between them and the far ends of the building is approximately 40 m.

However, the building was still repeatedly struck by lightning after ESE#2 and ESE#3 were installed. The horizontal distance between B#7 and ESE#2 is approximately 45 m while the horizontal distance between B#9 and ESE#3 is approximately 20 m. These bypasses are clear evidence that the protection radius of the two ESE-AT is less than 20 m.

This installation also suggests that the proponent may have followed the actions taken by Universiti Putra Malaysia (UPM) in mitigating the failure of an ESE-AT at one of their residential colleges located about 1.5 km away from the UNIV360 Place. Two additional ESE-AT were installed at the Eleventh College building (*Bangunan Kolej 11*) a year after it was struck by lightning in 2010 (Figs. 16 and 17). http://kilatmalaysia.blogspot.com/2010/04/bangunan-kolej-11-upm-terbakar-disambar.html (In Malaysian language)

The college building is located just opposite the Faculty of Engineering (https://goo.gl/maps/CE5TbigyastnhCpQA) and the Centre for Electromagnetic and Lightning Protection (CELP).

D. *Conventional AT installation*

The case study also provides clear evidence that installing Franklin rods not in full compliance with the standard can lead to the occurrence of bypasses. Most of the rods installed did not fully comply with the standard since they were positioned about 0.5m away from the corners and edges of the roof.

This placement error suggests that the proponent had used a defective AT placement method taught by an academic in a local university [5]. He recommended that Franklin rods must be placed 24 inches (about 0.6 m) away from the corners and edges of the roof instead of directly on them. This recommendation had deviated from the normal practice of placing Franklin rods directly on corners and edges which is found in the former BS6651 and current IEC62305 standards.

Studies suggests that the rod placement method mentioned in the IEC62305 standard can intercept up to 98% of lightning strikes to a building [6][7]. This method is originally based on the rod placement method known as the Collection Surface Method (CSM) which was developed from a study of lightning strikes to buildings in Kuala Lumpur [8][9].

VI. CONCLUSIONS

The UNIV360 Place case study provides clear evidence that lightning can strike a tall building several times per year in Malaysia. This extreme situation suggests that climate change may have increased the vulnerability of buildings to lightning strikes in the country and surrounding tropical regions.

The study also provides clear evidence that the installation of a single pole-mounted ESE-AT at the centre of the rooftop cannot protect the periphery of the building from being struck by lightning repeatedly. Increasing the height of the ESE-AT mounting pole has no effect on the claimed protection radius either. Furthermore, adding more ESE-AT on the building will also not protect it from being struck by lightning repeatedly. (See Fig. 18 for their approximate placements on the roof)

The installation of Franklin rods near the corners and pointed features of the building seemed to have reduced the frequency and size of the bypasses. This suggests that placing them directly on those places in full compliance with the IEC62305 standard can result with better lightning interception and prevent the occurrence of sizeable bypasses altogether.

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Figure 1 View of UNIV360 Place from the East (highway) showing the location of ESE#1 (https://goo.gl/maps/HwJsuMdbxJYewCb2A)

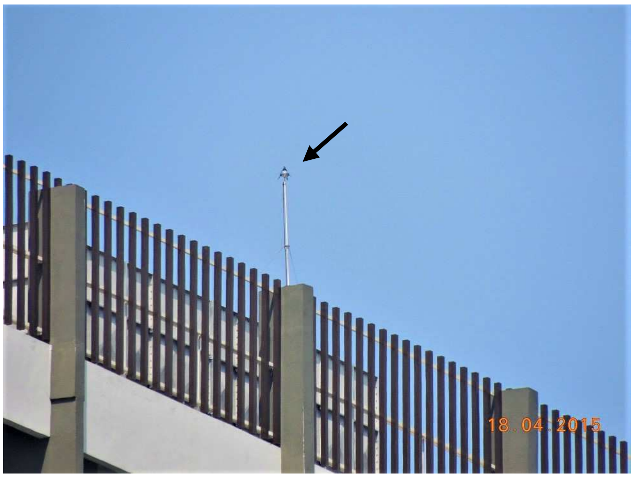

Figure 2 Close-up view of ESE#1 (Type: PREVECTRON ESE-AT)

Figure 3 View of UNIV360 Place building from the West showing the location of Bypass #1

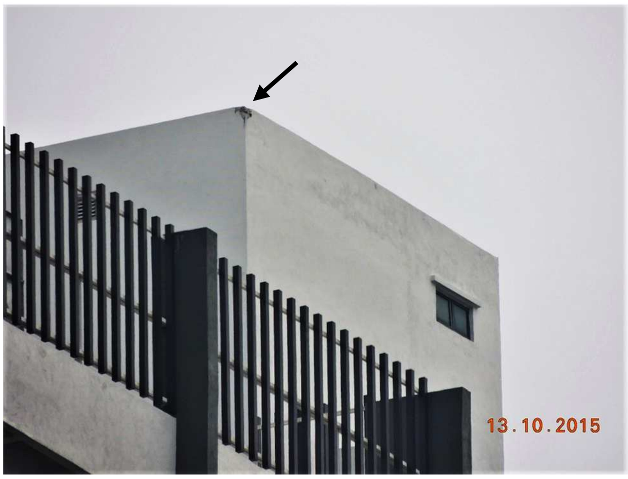

Figure 4 Close-up view of Bypass #1

Figure 5 Bypass #2

Figure 6 Bypass #3 (Note: Bypass #2 has been repaired)

Figure 7 Bypass #4

Figure 8 Bypass #5

Figure 9 ESE#1 before it was remounted on a taller pole

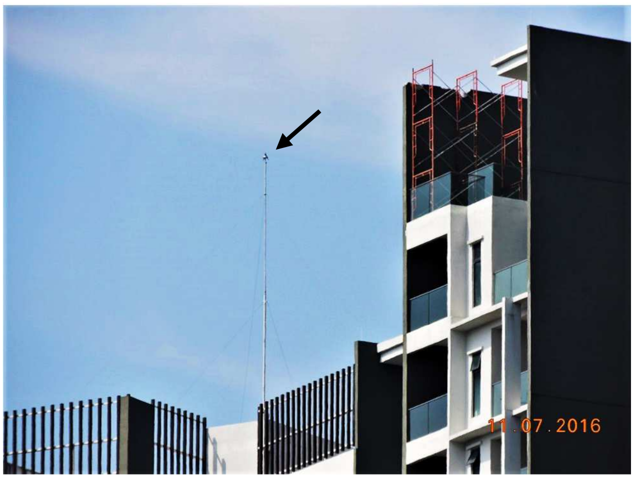

Figure 10 ESE#1 after being remounted on a taller pole (Note: Bypass #4 was under repair)

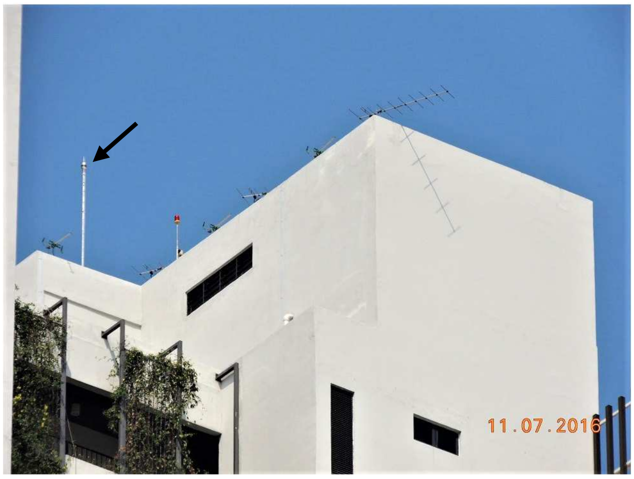

Figure 11 ESE#2 (Type: SCHIRTEC ESE-AT)

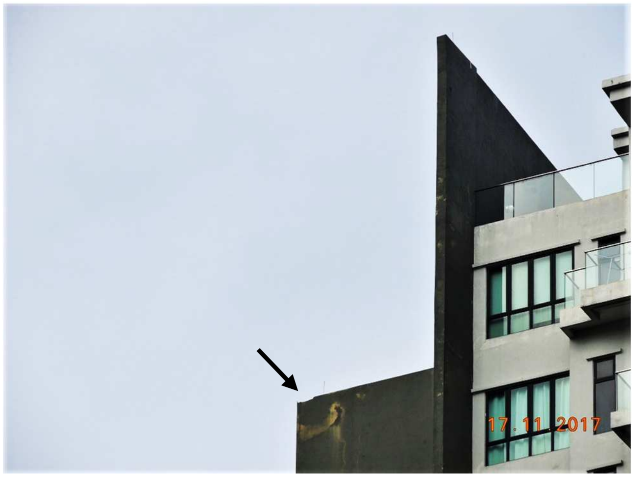

Figure 12 Bypass #6 (Note: Bypass #3 has been repaired)

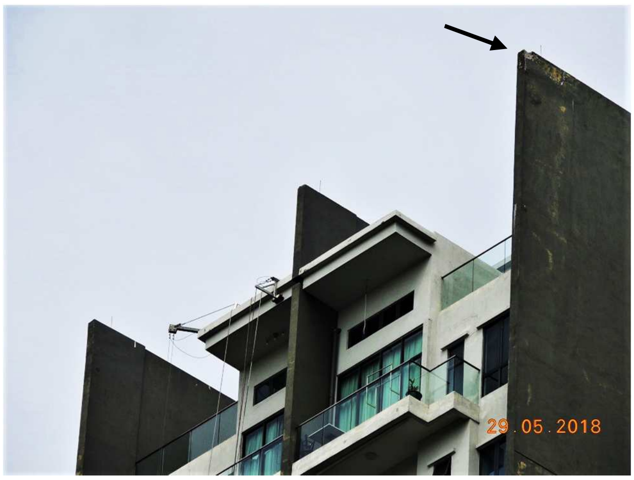

Figure 13 Bypass #7

Figure 14 Bypass #8

Figure 16 Screen grab of the smoldering roof of one of the building's two water tank towers soon after the lightning strike in April 2010

Figure 15 Bypass #9 (Note: Bypass #7 still not repaired)

Figure 17 Two new ESE-AT were seen installed at the water tank towers a year later. (https://goo.gl/maps/kS95jTgfCZs1iLu2A)

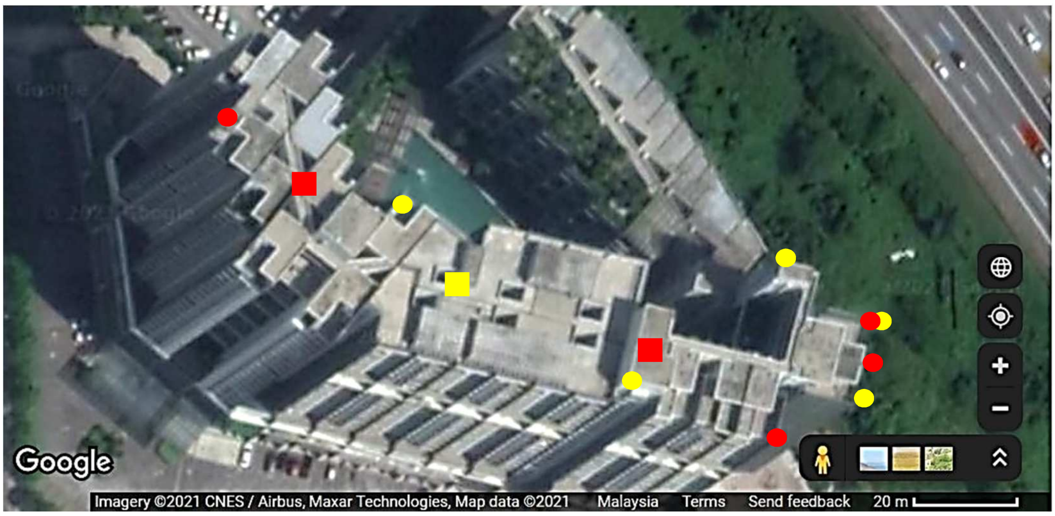

Figure 18 Google satellite view of the UNIV360 Place showing the approximate locations of ESE#1 (yellow square) and ESE#2/#3 (red squares). The locations of the Phase 1 (yellow dots) and Phase 2 (red dots) bypasses are also as shown above.