A review of studies on Early Streamer Emission and Charge Transfer System conducted in Malaysia.

Z. A. Hartono, I. Robiah

Lightning Research Pte. Ltd., Kuala Lumpur, Malaysia. E-mail: hartono@pc.jaring.my

Abstract — **Studies that compared the performances of the early streamer emission (ESE) air terminals and the charge transfer system (CTS) with that of the Franklin rod (FR) system have been conducted in Malaysia since 2003. The results from these studies suggest that the ESE and CTS systems were more effective than the FR system. However, a review of the available information shows that the results were based on bizarre and flawed analyses of research data and that they were carried out by proponents of the ESE and CTS systems.**

I. INTRODUCTION

The modern non-conventional lightning protection (LP) systems have been in the global market for over thirty years. They are classified into two main groups: (1) the lightning attracting air terminals such as the radioactive and ESE devices and (2) the lightning strike prevention air terminals such as the CTS and similar devices.

In the South East Asian region, the earliest non-conventional LP systems to be used were the radioactive air terminals in the 1970s. A field study on the performance of these devices in Singapore by Darveniza et al [1] showed that buildings that used them had been struck by lightning. They were replaced by the ESE air terminals when radioactive materials were banned from consumer products for safety reasons in the late 1980s.

A field study conducted on the ESE devices by Hartono and Robiah [2] in Kuala Lumpur also showed similar results. Hartono and Robiah also provided before and after event photographs that showed lightning strike damages well within the ESE claimed zone of protection.

In a seven year long investigation using ESE and FR terminals of various tip geometries, Moore et al [3] showed that blunt tipped FR were repeatedly struck by lightning while nearby sharp tipped FR and ESE air terminals were never struck. The blunt tipped FR has been included in the NFPA 780 standard since 2002.

Proposed standards for the ESE systems (eg. draft NFPA781) have been rejected by CIGRE, IEC and the NFPA [4] in 1995. An independent review [5] of the ESE technology by the NFPA in 1999 again found it to be without scientific basis and was unproven.

In France, the ESE vendors published a document, known as the NFC 17-102, which provided the guidelines for the manufacture, test and installation of the ESE devices. This document, which has been popularized as a "French standard" by the vendors, has been criticized by INERIS [6], a French scientific agency, for failing to conduct tests on the ESE air terminals. The document also did not comply with either the IEC or CENELEC lightning protection standards which are already being used in France and throughout the European Union.

A proprietary Australian method of ESE air terminal placement, known as the field intensification method (FIM), was also rejected by Standards Australia in 2003. The FIM is similar to the collection volume method (CVM) which is being used to install a proprietary Australian ESE air terminal globally.

With the apparent popularity of the non-conventional LP system in the region, the CTS devices were introduced in the early 1990s. A field study [7] on the performance of the dissipation array system (DAS), another name for the CTS, showed that the system failed to prevent lightning strikes. This failure was also mentioned in a book [8] that is still being used as a reference by lightning protection engineers worldwide. Since then, there have been several studies that show that the DAS/CTS are incapable of preventing lightning strikes to the protected structures or areas.

A draft lightning protection standard for the CTS was rejected five times by the NFPA between 1989 and 2004 due to insufficient scientific basis. A similar draft standard, known as the PAR1576, was also proposed to the IEEE in 2000 but was rejected in 2004 due to similar reasons.

To better understand the scientific issues involved, readers are recommended to read a critical review of the ESE and CTS that was written by Uman and Rakov [9][10].

II. THE ESE STUDY

The summaries of these studies can be found on the electrical engineering website (http://web.utm.my/fke/) of Universiti Teknologi Malaysia (UTM). To view the related summaries, click on the high voltage research link "IVAT" under the "Research" column, and then click on "Research" link while on the IVAT webpage. Thereafter, click on the links that referred to the ESE studies. Copies of these web pages are also available on request.

The extracts from the summaries are given below:

A. Laboratory and field study of ESE system

In this study [11] by Darus and Ngu, the following claims were made:

- ESE is a relatively new approach in solving the perennial problem of lightning damage.
- Lightning damage has been associated with the use of FR.
- ESE is believed to be providing more effective protection against lightning than a FR system.

- Slightly rounded air terminal, which is typical of ESE system offer better interception ability than that of sharp terminals, which is the typical FR design.
- Results have been obtained from field monitoring of real FR and ESE system installed in the university campus.
- It is also shown that ionizing the air around the tip of the terminals can enhance its effectiveness.
- ESE system has been found to intercept more lightning strikes than that by the FR.

Review:

The claim that the ESE is a "new approach" is misleading since it had been used in Malaysia for more than a decade and that the technology had been disproved in several published studies conducted within and outside the country. Some of the other claims are also similar to those made by Nelson et al [12] in 2000.

The claim that the blunt tipped ESE device demonstrated better interception ability than the sharp tipped FR is expected since it had already been shown by Moore et al [3]. However, the claim that the blunt tipped ESE air terminal is the typical ESE air terminal is untrue since this type of air terminal was only introduced in Malaysia recently and it probably constitute less than one (1) percent of the total installed ESE systems in use.

The claim that ionizing the air around the tip of the terminals can enhance its effectiveness was supported by the lightning counter readings of the installed ESE systems. However, Hartono and Robiah [13] had reported that lightning counter readings were very unreliable since some of them registered more lightning strikes than expected from the lightning flash density of the area.

Surveys of buildings in the UTM campus carried out by Hartono and Robiah also showed that many buildings that were equipped with the ESE system have been struck and damaged by lightning, some repeatedly (Figs. 1 to 3). They also observed that buildings that were installed with correctly positioned FR had shown no signs of being damaged by lightning strikes even though some of these buildings were located on higher grounds and hence more exposed to lightning.

Fig. 1. The UTM electrical engineering building (Block P08) that was struck and damaged by lightning at the southern ridge end.

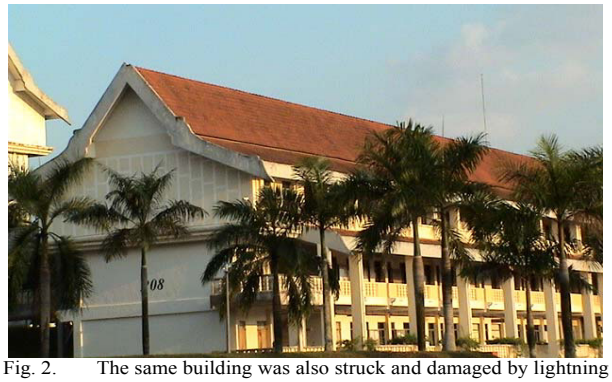

Fig. 2. The same building was also struck and damaged by lightning at the northern ridge end. The silhouette of the ESE system can be seen on the roof at right about 20m away.

Fig. 3. Close-up photographs of the lightning damaged ridge ends.

B. Development of a new ESE air terminal using laser radiation ionization process

In this study [14] by Ahmad and Sidik, the following descriptions/claims were made:

- The description of the time advantage, delta T, and the length, L, of the triggered discharge of the ESE was correctly made.
- The protection is designed using the Rolling Sphere Method (RSM).
- The description of the controversy surrounding the NFPA draft Standard 781 on ESE devices was explained.
- A new type of ESE lightning protection shall be designed, developed, and tested that use the laser radiation ionization process to further enhances the creation of upward streamer from the lightning rod to the coming downward streamer.

Review:

Although the mechanism of the ESE discharge was correctly explained, no mention was made about the claimed streamer velocity of 10^6 m/s which most ESE vendors claimed in their marketing brochures. This velocity, when multiplied by the observed streamer initiation advancement, will give a claimed protection radius of up to 100m. This velocity figure had been disputed by scientists when studies showed that the early streamers observed in the laboratory and in nature have velocities that are at least one order of magnitude lower than that mentioned by the vendors. Since 1995, when CIGRE highlighted this matter, the ESE vendors have not been able to provide any new evidence that the streamer velocity used in their commercial and technical literature is correct.

The claim that the ESE system is designed using the RSM is not true since most, if not all, ESE systems were designed using proprietary methods that are very different from the RSM or the Protection Angle Method (PAM).

Although the controversy surrounding the draft NFPA 781 standard was mentioned, they failed to mention that the draft standard had been rejected after a prolonged scientific debate that lasted several years.

The study proceeded to design, develop and test a new ESE device that uses laser radiation to trigger the upward streamer. If this novel method of streamer initiation is successful, the protection coverage provided by this new invention is still expected to be as small as all the other existing ESE devices in the market i.e. just a few meters.

Unless this study can show that the streamers produced by the laser radiation method have a velocity of 10^6 m/s or more, the new device will join the existing ESE devices that failed to perform as claimed by their vendors.

III. THE CTS STUDY

This study by Ramli et al first appeared as an abstract [15] in a conference brochure in 2003 but the full paper was not published. A revised version of the paper was later presented in the EMC Zurich 2005 conference [16].

In this study, a lightning video system (LVS) and Rogowski coils were used to photograph lightning flashes near a 75m telecommunication tower and to measure the current of the lightning flashes that struck the tower. The tower had been installed with one DAS at the top of the tower and 16 ball shaped ionisers down the sides of the tower.

The following claims were made:

- Photographs from the LVS showed that the return strokes occurred several meters away from the tower.
- The measurements from the Rogowski coils showed that the total surge current values observed at the tower legs, ladder and gantry exceeded 1.0 kA.

Review:

In the study, Ramli et al claimed that the return strokes photographed by the LVS occurred just several meters away from the tower. However, in two of the photographs shown, the ends of the return strokes could be seen fading into the cloud base (Fig. 4).

If the return strokes were claimed to be only "several meters" away from the tower, then it is logical to deduce from the photograph that the cloud base is just above the tower. This conclusion is ridiculous since the base of the cloud is usually several hundred meters above the ground level. Therefore, the erroneous claim above was the result of a faulty deduction that mistook cloud-to-cloud flashes for return strokes.

Another erroneous claim is that of the return strokes "crossing" the tower i.e. the lightning flash passed very close to the tower without striking it (Fig. 5). It is more probable that the "return strokes" were just cloud-to-cloud flashes or the upper segments of distant ground flashes that occurred with the tower in the foreground.

Ramli et al could have used two LVS to photograph the lightning flashes from different angles in order to determine their heights and distances from the tower. One possible method of doing this had been described by Hartono and Robiah [17].

The measurements made by using the Rogowski coils indicated that the tower had been struck by lightning even after it was installed with a DAS and more than a dozen ball shaped ionisers. Annuar et al also recorded damages to the telecommunication equipment after the DAS was installed. This result was not surprising since Kuwabara et al [18] also obtained similar results after the CTS and ball ionisers were installed on a telecommunication tower in Japan. However, unlike Annuar et al, Kuwabara et al concluded that no significant improvement in lightning protection was achieved by using the CTS.

Ramli et al [15] also claimed that lightning flashes within a 250m radius of the tower were reduced after the installation of the CTS. However, the LDS used during the period of observation was a magnetic direction finding system that had a resolution that is much bigger than the observed area. Hence it is not possible to conclude that the CTS were responsible for the reduction in lightning activity around the station.

In addition, Yahaya et al [19] reported that there was a significant drop in lightning occurrence nationwide in 1997 due to the onset of the El Nino phenomenon where the region experienced a severe drought and hence a reduced thunderstorm activity.

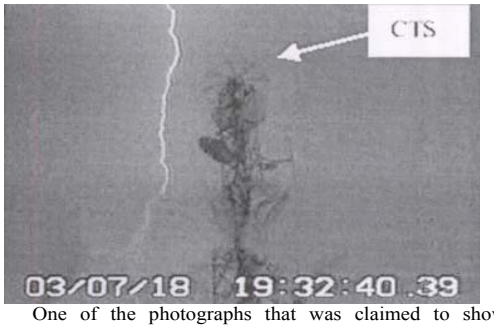

Fig. 4. One of the photographs that was claimed to show the lightning flash occurring "several meters" away from the tower. [Photo credit: Telekom Malaysia Research and Development]

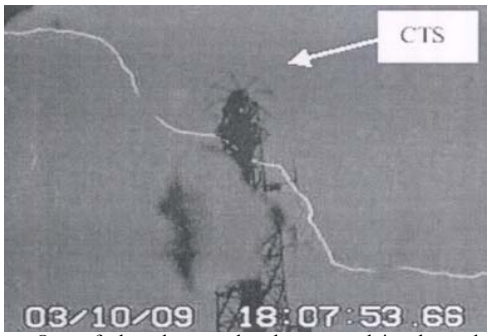

Fig. 5. One of the photographs that was claimed to show the lightning flash "crossing" the tower. [Photo credit: Telekom Malaysia Research and Development]

IV. Discussion

The above claims made in support of the ESE and CTS by UTM are not new. In a book [20] on lightning protection that was written in the national language, the CTS and ESE were described as "advancements" in lightning protection technologies (page 46). While the descriptions of the ESE and CTS were similar to those given by the vendors, no mention was made that these systems had already been rejected by CIGRE, IEC and NFPA. Surprisingly, the book also claimed that the FR system is being rejected by many standards organisations and that its use will attract more lightning to the structure (page 41). As it turned out, the ESE and CTS were rejected by the standards organizations a few years later. In addition, the book also claimed that the use of steel rods in buildings would lead to more lightning strikes and greater damages (page 49). This claim contradicted the accepted lightning strike mechanism that was known since Franklin's era i.e. that the presence of metal in a building reduced the damaging effects of lightning strikes. Extracts of these claims, with English translations, are available on request.

It is apparent that the studies described earlier were meant to provide the proofs that the ESE and CTS systems are effective in protecting structures from lightning strikes. However, these proofs have been shown to be flawed and unreliable.

It is interesting to note that in the USA, the claims of the ESE vendors have recently been rejected in the courts of law. The United States District Court of Arizona [21] prohibited the ESE vendors from claiming that the protective range of their devices is bigger than that of the FR.

At about the same time, the International Conference on Lightning Protection (ICLP) also issued a warning [22] on the ESE and CTS devices. The ICLP considered the use of these devices as dangerous and should be abandoned.

V. Summary & conclusions

This review shows that the claimed successes of ESE and CTS systems that were achieved in studies conducted in Malaysia were obtained through faulty analyses of observed data. These studies were also conducted by researchers who are known locally to be supporters of the ESE and CTS systems since the early 1990s.

With these systems being repeatedly disproved by scientific research conducted in the developed countries, it seemed that the inventors and manufacturers of the ESE and CTS are turning to the scientists and engineers in the developing and third world countries for assistance to obtain their elusive proofs.

As shown in this review, some of these scientists and engineers are proponents of the CTS and ESE and they did not hesitate to make bizarre and flawed analyses of their research data in order to provide the proof. Unfortunately, due to local regulations, they are able to keep the details of their works classified.

Consequently, it is recommended that any research findings that claimed to provide the proof for the ESE and CTS systems should be examined in detail to determine their accuracy and authenticity.

References

[1] M. Darveniza, D. Mackerras and A. C. Liew, "Standard and Non-standard Lightning Protection Methods", Journal of Electrical and Electronics Engineering, Australia, 1987.

[2] Z. A. Hartono and I. Robiah "A Long Term Study on the Performance of Early Streamer Emission Air Terminals in a High Isokeraunic Region", report submitted to the National Fire Protection Association (USA), February 1999.

[3] C.B. Moore, G.D. Aulich, and W. Rison, "Measurements of Lightning Rod Responses to Nearby Strikes", Geophysical Research Letters, Vol. 27, No. 10, pp. 1487-1490, May 15, 2000.

[4] NFPA Standards Council Decision of July 18, 1995, D #95-26.

[5] J. L. Bryan, R. G. Biermann and G. A. Erickson, "Report of the Third Party Independent Evaluation Panel on the Early Streamer Emission Lightning Protection Technology", report submitted to the NFPA Standards Council, September 1999.

[6] P. Gruet, "Etude des Paratonnerres a Dispositif d'Amorcage:", INERIS, October 2001.

[7] R. B. Bent and S. K. Llewellyn, "An Investigation of the Lightning Elimination and Strike Reduction Properties of Dissipation Arrays", in Review of Lightning Protection Technology for Tall Structures, Publication No. AD-A057, Office of Naval Research, Arlington, VA, 1975.

[8] R. H. Golde (editor), "Lightning - Volume 2: Lightning Protection", Academic Press, 1977, pp. 567 - 569.

[9] M. A. Uman and V. A. Rakov, "A Critical Review of Non-conventional Approaches to Lightning Protection", Bulletin of the American Meteorological Society, December 2002.

[10] V. A. Rakov and M. A. Uman, "LIGHTNING: Physics and Effects", Cambridge University Press, 2003, pp. 605 – 610.

[11] A. Darus and E. E. Ngu, "A Study on the ESE Lightning Protection System", summary of UTM research project.

[12] T. L. Nelson, K. L. Stricklett and R. J. Van Brunt "Early Streamer Emission Lightning Protection Systems: An Overview", IEEE Electrical Insulation Magazine, January, 2000.

[13] Z. A. Hartono and I. Robiah "The Field Intensification Method (FIM): An Assessment based on observed Bypass Data on Real Buildings in Malaysia", report submitted to Standards Australia Committee EL-024, September 2002.

[14] H. Ahmad and M. A. B. Sidik, "Study on the ESE Mechanisms aided by Laser Radiation Ionisation Process", summary of UTM research project.

[15] A. Ramli, N. Idris, B. Shariff and H. Ahmad "Analysis of the Effectiveness of Charge Transfer System intended for Lightning Prevention using Lightning Detection System, Lightning Video System and Rogowski Coils", International Conference on Lightning and Static Electricity (ICOLSE 2003), Blackpool, England, September 2003.

[16] A. Ramli, N. Idris and B. Shariff, "The Performance of Charge Transfer System against Lightning Rod at the Communication Towers Analyzed by Using Lightning Video System and Rogowski coils", EMC Zurich 2005, Zurich, Switzerland, February 2005.

[17] Z. A. Hartono and I. Robiah, "A Three Dimensional Study of Lightning Discharges", International Conference on Electromagnetic Compatibility, Kuala Lumpur, Malaysia, April 1995.

[18] N. Kuwabara, T. Tominaga, M. Kanazawa, S. Kuramoto, "Probability occurrence of estimated lightning surge current at lightning rod before and after installing dissipation array system (DAS)", 1998 IEEE EMC Symposium, Denver, Colorado, USA.

[19] M. P. Yahaya and S. A. F. S. Zain, "Characteristics of Cloud to Ground Lightning in Malaysia", Conference on Lightning Protection and Earthing Systems, Kuala Lumpur, Malaysia, 2000.

[20] H. Ahmad, "Kilat dan Perlindungan", Universiti Teknologi Malaysia Publications, 1998.

[21] United States District Court of Arizona, Order No. CV 96-2796-PHX-ROS, dated 9th September 2005.

[22] See the ICLP website: http://www.iclp-centre.org/