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Lightning Safety Psyche

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***Abstract*— How is lightning protection ranked in the field of safety science? What is the general perception of the public with regard to the risk of receiving a lightning strike to their building? How do business entities manipulate the psyche of the public in upsizing financial gains? What is the true risk of public adopting lightning protection techniques that have not been included in major international standards? Is the research presented so far in condemning the lightning protection systems rejected by the scientific community, well-conducted? Is tabooing of some lightning protection technologies a productive strategy in driving the public to adopt protection systems recommended by international (IEC) standards? This paper makes comprehensive attempts to answer these questions.**

Keywords- lightng protection; safety science; IEC Stanadards

I. INTRODUCTION

Lightning protection is treated as an important aspect of human safety and economic loss prevention in the field of lightning sciences. However, what is the true position of lightning protection in the standpoint of safety science? The answer to this question is essential in understanding various aspects of this field such as planning future research, strategizing business plans, re-modulating the scientific and professional struggle against systems that have been rejected by major standards, developing models to take the lightning protection and safety into root layers of the society etc.

In contrast to the public perception on electrical safety, fire safety, fall safety, chemical safety etc., the same on lightning safety is insignificant as a matter of concern, in most parts of the world [1-3]. Interestingly the awareness of correct lightning safety and protection techniques is quite poor even among the electrical engineering communities and commercial sector on lightning protection business itself [4]. This lack of awareness may facilitate fraudulent system manufacturers to deceive the public as any person without a sound knowledge on lightning protection could not discriminate right product from wrong. It is also of interest to analyze the techniques adopted by various sectors of the scientific community in branding products and techniques as acceptable and unacceptable. These techniques, sometimes may produce negative outcomes with respect to the anticipated objectives. Under such backdrop, this study has been carried out to understand the current status of lightning protection in the perceptions of public, and to scientifically analyze various investigations reported in the literature, judgments that have been passed by the researchers on products and techniques in the market.

II. LIGHTNING PROTECTION AS A SAFETY CONCERN

The Table-1 depicts the significance given to lightning in the periodicals and one-time journals listed in SCOPUS database of which the title bears the term 'safety'. The data shows that the term lightning is included in only one journal paper [5] and one book chapter [6] for the entire period covered by the data base. It has appeared in the abstract of a paper only twice [5, 7]. Lightning has been mentioned 81 times in the text. Other than in [5-7], in each paper lightning has been mentioned only once or few times, mostly to say that it is one of the natural hazards or an insignificant phenomenon for safety concerns. None of the safety papers that we came across in the Thomson Reuters Web of Science (formerly ISI Web of Knowledge) database that have worked on the development of safety modules, take lightning into account other than only one paper [3].

TABLE I. INCLUSION OF TERM 'LIGHTNING' IN TITLE, ABSTRACT AND MAIN BODY (TEXT) OF JOURNALS IN SCOPUS DATABASE WITH WORD 'SAFETY' IN THE JOURNAL TITLE.

Journal & period	Term 'lightning' in		
	Title	Abstract	Text
Journal of Safety Research	0	0	11
Safety Science	1	2	37
Fire Safety Journal	0	0	24
Safety at Work	0	0	3
Safety Culture	0	0	0
Safety Critical Systems Handbook	0	0	2
Safety Design for Space Operations	1	NA	1
Safety and Health Essentials	0	0	2
Safety and Health at Work	0	0	1

The above information indicates that lightning has not been treated as a serious safety concern by the safety research community, both academic and professional levels, so far.

At administrative level, we again find that lightning has been totally overlooked in almost every safety guideline in

both government and non-governmental sectors. For an example, Occupational Safety and Health Act of Uganda [8], a comprehensive document of 89 pages, covers almost every aspect of occupational safety risks, except lightning, a term which has not been even included once in the document. Note that Uganda has one of the highest lightning ground flash densities in the world and recorded the worst single-event lightning accident in the recent history where 18 students were killed while they were inside their school building [16]. The neighbouring Kenya has published a 128 page document under the name Occupational Safety and Health Act of Kenya [9] where the term 'chemical', 'fire' and 'lightning' has been mentioned at 38, 28 and zero times respectively. Similar observations have also been found in the developed countries. For an example 416 page, Occupational Safety and Health Regulations of Western Australia [10] does not contain the word 'lightning' at least once.

The authors have also conducted an informal data gathering for 15 years by enquiring the participants of over 100 training programs, regarding the concerns of lightning protection of the administration level of their work place. The programs have been conducted in 12 countries, mainly in Asia and Africa under various titles; lightning protection, electrical safety, grounding and bonding and EMI/EMC. Out of 1008 participants, only 17 have mentioned that their safety guidelines include the procedures to be taken under thunderstorm conditions. These 17 respondents represent four power companies.

The above outcomes describe evidently the non-proactive perspectives of the professional and academic bodies on lightning related risks. Many research work reported in the past [11-16] attributed such observations to the lack of awareness and educational programs on lightning safety among the public and urge the escalation of such programs. However, before making such conclusions, it is of importance to investigate the actual reasons for the lack of concerns of lightning protection of both general and professional public. The reason may be the non-requirement of such due to the negligibly low risk from lightning compared to other threatening safety issues. Thus, it is worth studying the percentage of lightning related accidents in working and general environments with respect to the losses due to other hazards.

III. QUESTIONABLE LIGHTNING PROTECTION APPLICATIONS

Five cases of questionable lightning protection scenarios have been presented in this paper to develop an argument on the requirement of understanding the actual risk of lightning and consequently make the public aware of the reality. Thus, they can make reasonable decisions to avoid unnecessary expenditure and/or adopt appropriate solutions whenever there is a realistic issue.

Case-1: Protection of students that occupy open space

The picture in Figure-1 depicts a school playground in Selangor, Malaysia, where a lightning protection system has been installed for the purpose of protecting children that play in the ground. Figure-2 shows an open hill slope of the same school that has been installed with a lightning air-termination. The intention of the two systems are to give protection to the children as they occupy these open spaces during thunderstorm periods. Age of the students of the school ranges between about 7 years to 17 years, from both genders. An informal interview with several students revealed that they have not been given formal instructions to refrain from outdoor extra-curricular activities during overcast conditions. The air termination fixed is an Earlier Streamer Emission (ESE) type finial fixed on a metal support of nearly 30 m in height. Apparently the coverage has been calculated according to the formula given in French Standards NF C 17-102 [17].

The psychological background of the school authorities in investing for the lightning protection system could easily be explained. The Selangor area in Malaysia experiences approximately 250 thunderstorm days per year according to the isokeraunic level maps issued by the Department of Meteorology, Malaysia. This leaves very limited time period during the year for the children to use the playground for their recreational activities. Another issue is the picking up of children by their parents after the school activities are over. This period, usually from 3.30 pm to 4.30 pm, is characterized by heavy thunderstorm during most parts of the year in the region. As the children are not allowed to leave the sturdy school buildings to reach the vehicles of their parents during thunderstorms, a very heavy traffic jam develops in the whole road network in the area due to accumulating numbers of vehicles. Thus, school administration is encountered with many complains from the parents and public. Such stressful psychological environment may have tempted the school authorities, who are mostly from management and other non-natural science spheres, to look for a feasible solution [18-21]. A vendor may have capitalized on this situation to provide the questionable lightning protection scheme. The system is questionable as a lightning protection system, according to almost every standard, is to protect a building and its occupants rather than people in an open space. A lightning has struck once a few-step open staircase made of concrete about 10 m away from the lightning rod as per the eye witnesses of the incident (security personnel) during after-hours. The authorities have raised their concerns about the safety recommendations of the vendors after the incident, however, the protection systems could be visible up to date.

Case-2: Protection of guests and staff that uses the roof-top terrace of a hotel

The Figure-3, shows the roof-top terrace of a hotel in Sri Lanka, which joins the main restaurant and spa of the premises. The isokeraunic level of the region is around 80-90 thunder days per year as per the information issued by the Sri Lanka Meteorology Department. One of the authors who visited the site found that the hotel, which is more than 1 km in width and about 100 m in breath has been installed with several similar ESE type air-terminals. Interviews conducted with hotel management and the technical personal revealed that the lightning protection system for the open terrace has been installed due to the demand for using the open space by guests and staff even under overcast conditions. The no-accident record (due to lightning) for a period of about 15 years has boosted the confidence of the system on the management, thus,

they have enquired the possibility of protecting several outdoor swimming pools (most of them made on solid natural rock) in the premises to be protected with similar devices. However, on explaining the inability of such systems in protecting the people who use the open spaces, the management agreed to remove the air-termination and set up warning signs informing the guests and staff to avoid using the open space under overcast conditions. It is a rare case that the management of a hotel opts to seek expert advice on their lightning protection network irrespective of zero damage/injury record.

Most often the recreational industry seek lightning protection to facilitate the guests (and the staff that serve them) to enjoy their stay at the premises to the maximum, without having restrictions based on natural conditions. As there are many outdoor activities, designed for the clients, the management wants to develop an environment, sometimes even at high cost, to meet the expectation of the directors. This prompts many management hierarchies looking for new technologies that can address their needs. In the absence of expertise in a field that needs highly focused knowledge and frontier awareness on the technologies, the management has to make decisions on either the information available in mass-media or information provided by vendors [22, 23]. There are scores of web-based and product-catalogue based misinformation available to the advice seekers, thus, the management may often opt for making unwise decisions to select products that grossly overestimate their efficiency [24, 25]. These psychological complexities are again exploited by the business sector in impelling the potential customers to select inappropriate products for a given scenario.

In both cases 1 and 2, the situation outcomes are much more unwarranted than the financial issues that the erroneous choice of products and technologies incur. The scenarios may lead to lethal results which may be human injuries or even death, due to the false safety message conveyed to the public. It is of interest to analyze the party of guilt, in the event of a mishap, so that the relevant sectors could be educated and warned regarding their responsibilities. However, such work is beyond the scopes of this study.

Figure-1: The lightning protection system intended to cover a playground of a school in Malaysia. The red arrow indicates the ESE type finial on the tall supporting structure.

Figure-2: The lightning protection system intended to cover an open hill-slope of a school in Malaysia. The red arrow indicates the ESE type finial on the tall supporting structure.

Case-3: Over protection with unnecessary cost

Figure-4 depicts a low-rise building with archaeological value, in Beijing, China. The building has been installed with a lightning protection system, of which at least the air-termination system that covers all roof ridges have been designed apparently in accordance with IEC standards [26]. We have not conducted any testing on the connectivity of down conductors or earth resistance measurements. Interestingly two ESE type air termination systems have been installed at the corners of the roof, which are separated by approximately 7 m. Beijing has a ground flash density of 4.7 flashes per km^{-2} yr^{-1} [27]. Under such circumstances the air termination provided with the metal conductor that runs through the ridges is quite sufficient under the risk assessment proposed by IEC 62305-2 [28], provided that at least two down conductors and a comprehensive grounding system are integrated with the air-termination. This shows that the presence of the ESE rods are trivial and could not make any added advantage. Furthermore, if the claimed area of protection by the manufacture of the relevant ESE air-termination (over 100 m) is correct, then the presence of two rods within a separation of few meters is highly questionable. It seems that due to the high archaeological value of the building has prompted the

authorities to take additional measures on protecting the building, irrespective of the fact that the area experience moderate or low ground flash density. The nearly 1000 buildings in the vicinity, which are inside a popular tourist attraction of 72 hectares, have no records of being damaged by lightning for its entire history that spans over 500 years.

Figure-3: The lightning protection system intended to cover an open roof-top terrace in a hotel in Sri Lanka. The red arrow indicates the ESE type finial on the supporting structure.

Figure-4: The lightning protection system of a low-rise building with archaeological value, in Beijing China. Black arrows show the continuous air-termination system (an aluminium conductor with circular cross section) and red arrows show the ESE air-terminations.

Figure-5 shows a building in Selangor, Malaysia where a store house of machinery with no specific risk of fire has been installed with ESE type air-termination, irrespective of the fact that the building has a structure with strong vertical metal struts and metal sheeted roof of which the sheet thickness is about 1 mm. Thus according to the IEC standards [26], the building does not need a separate air-termination or even down conductors. The only requirement in such case is to ensure that the continuity of the whole structure is good and the system has been connected to a well-designed grounding system. The addition of ESE air-terminations and copper down conductors incur and extra cost without any uplifting of the level of protection. Instead, the presence of copper tapes on iron roof could lead to serious corrosion. Similar observations have been reported in Gomes and Kadir [4] as well who claims that such cases are very common in many parts of South and South East Asia. Sometimes the vendors who recommend the ESE system either paint the down conductors or use insulated down conductors, which in turn, further increases the cost of installation. The down conductors are most often extended right into ground level irrespective of the vertical struts.

These cases are good examples of administrative or management mindsets that has been manipulated by the business sector that market the products by two strategies;

a. raising the fears of failure of the potential customer by showing a risk that is non-existent and

b. convincing the customer regarding modern technology as a better alternate to the conventional technology.

The marketing of field legends, country of manufacture and terminologies such as ‘modern’, ‘latest’ and ‘newest’, instead of logic and reasoning has become increasingly popular in the sales sectors in the last few decades. It has been most often proven to be an effective marketing strategy [29, 30], although the acceptability is problematic under ethical ground. This, marketing mode is further boosted by the fact that at many workplace environments, the technical personnel who question the claimed applicability and superiority of so called ‘modern technologies’, are treated as over-conservative employees imprisoned in old-style mindset. As per the fear of being penalized by higher authorities and peers, technical staff may refrain from objecting to the investment on such technologies by the management, even if they are aware of the limitations of the systems to be purchased [31].

Case-4: Haphazard protection system

Sometimes, the over-cautiousness of the building owners or responsible authorities create situations where the safety is a question even after investing much larger amounts of money than that is really needed. Such case is depicted in Figure-6. It shows an observatory building located on a hill top in Johor Bahru, Malaysia where the isokeraunic level is around 185 thunder days per year.

The building, which has dimensions about 12 m × 12 m × 8 m has been fitted with one conventional air-termination made of copper and three ESE type air terminations of two brands. The air-terminations are not interconnected and the appearance of the installation reflects that they may be installed at three

separate occasions by different parties. If the claimed area of coverage of the ESE systems is correct, it is highly questionable the need of three such systems separated by several meters. Even when one of them are struck by lightning the non-integration of the systems may cause arcing from one finial to the other. On the other hand, if the claimed performance of the ESE rods, which has not been recognized by the IEC Standards or most other national standards of the world, is correct, then the presence of three such items on a relatively small building is quite questionable. It is also of concern as to why only the left hand side part of the building is populated with finials leaving the right hand side portion with no such. Note that there are several communication equipment that have been installed in the roof terrace.

Figure-5: An all-metal structure used as a machinery store house in Malaysia. The red arrow indicates the ESE type finial on the roof and the yellow arrows show the copper down conductors painted white

Figure-6: An observatory building in Johor Bharu, Malaysia. The red arrow indicates the ESE type finial on the roof and the black arrow shows the conventional air-termination.

The reason of the management of this building for adopting this multiple air-termination systems for a relatively small building, yet located at a high risk topography, is not very clear. Possible educated guess is the unethical marketing strategies of the commercial sector, blended with ignorance from the administration of the building ownership. Many vendors of lightning protection systems may not have sound knowledge of the theories of lightning engineering [4], however, their principals are well aware of the basic protection scenarios, even if they genuinely 'believe in' the systems that they manufacture. Thus, the installation of meaningless number of air-terminations each with claimed coverage area of over 100 m, should be a deliberate violation of marketing ethics. The business communities sometimes enter these unethical dimensions of marketing due to extreme competitiveness, ignorance of the customer-end and low risk of failure due to low probability of risk phenomena [32-34].

Case-5: Unscrupulous theories that cause social chaos

During the period 2002-2016 one of the authors worked extensively on communication tower related lightning issues in several South and South East Asian countries. Some of the findings and solutions in this regard has been discussed in [35]. One of the major issues that has been investigated in detail during this period is the effects of lightning to the neighbourhood due to the presence of the towers. In Sri Lanka, strong protests were staged by residents of the tower neighbourhood, in many parts of the country over the fear of increased lightning effects due to the presence of communication towers. Their main concern, as per their belief, was the ability of the lightning protection system of the tower to divert the lightning into the neighbourhood. In their own terms "the tower throws the lightning into the buildings in the vicinity", a scenario that has never been proven scientifically.

Our public survey in the country showed that this belief of lightning protection system of the tower directing the lightning to the neighbourhood, has been originated by the advertising materials of the marketing campaigns of lightning repelling type lightning protection system vendors. The observation of lightning (light and thunder of close lightning) and the subsequent damage to their electronics (due to induced voltages, ground potential rise and diversion of lightning current through the neutral wire) may have strengthened this belief of the neighbourhood, as it has been described in psychological studies conducted on why people believe things [36]. The denial of accepting the claims of damage by the tower owners and service providers have fueled the anger of the neighbourhood, which finally lead to legal suits and small-scale riots demanding the removal of the towers from their neighbourhood. Various other social and financial factors also contributed to this chaotic situation. There were cases where the offers of improving the safety of the electrical systems of houses (by providing good earthing systems and installation of SPDs) by the tower owners/service providers have been vehemently rejected by the residents stating that those solutions could not protect them from the lightning that is thrown by the tower into their houses. In several areas this unnecessary situation has delayed the erection of towers at optimal locations and has also caused many unanticipated financial losses to both residents and tower owners/service providers.

The above incident is a clear evidence of the technical, social and financial chaos that may arise at community and national levels due to a single scientifically unsupported theory,

apart from its direct impact; an unproven theory that incur very high cost to the protection seeker.

The inverse of the above discussed issue has also been reported elsewhere in South Asia. As per the information collected from public in Sri Lanka and India, it has been found that many rural communities believe that a lightning protection system installed at one prominent building in a given landscape could protect the whole area. There are occasions, that a whole village or small township has collected money to install an ESE type finial on the Church or Temple of the village with the view of getting protection from lightning for the entire community. Although the respondents could not give very clear explanation for this belief due to their limitations in describing products, it was evident that some graphical description of the marketing materials of ESE type products and the non-denial of such large coverage by the vendors have mislead the communities to make such wrong conclusion. Vendors seems to make such approach when they get confirmed through their marketing surveys that a community could not afford individual protection systems for their own buildings.

IV. THE INSITE

It should be noted that in this study no attempts were made to analyze, criticize or recommend the performance of different types of lightning protection systems. Instead, we discussed the general consensus of lightning protection in the scientific community on safety aspects. The marketing concepts, strategies and ethics have been criticized based on the safety norms accepted by a majority of standards.

In the above backdrop we would like to pinpoint several major issues that arise from this investigation.

1. Only a very few studies have been done in comparing the losses due to lightning and that due to other natural calamities. A comparison done in Mongolia on few atmospheric extreme events show that lightning, among the list, does not make much impact on the society, in terms of both economic and human/animal losses as of the time of the investigation [12]. This may be a region-dependent outcome which should be repeated in each country before deciding the level of prominence that should be given to lightning in the safety budget at community and national levels.
2. False high level of prominence given to lightning related hazards may make the pathway for fraudulent lightning protection providers to outsmart the general public as they could attribute the lack of accidents (which may be the case even without protection) to the success of their products.
3. In the case of building protection, it should be psychologically accepted that the chances of having a major damage to a modern building made of reinforced concrete and bricks is extremely slim. Thus, Standard development bodies should consider reasonable relaxation of conditions to use the steel structure of the building as the passage of lightning current, together with purpose made or natural air-terminations properly bonded to the reinforcement steel [37].
4. Corruption at all levels and lack of business ethics could explain, at least in part, the installation of more protection than what is required for a particular building or the use of non-standard or questionable protection techniques. The lack of awareness of the absolute protection seeker (for an example, in a factory, the premise manager may act as the lightning protection seeker in calling quotations on behalf of the factory owner who is the absolute protection seeker) adds into the wide-spread success of such questionable vendors.
5. Careful investigations on the literature published on the failures of unconventional protection systems reveals that there are many lapses of a majority of these works as scientific investigations; there are no sound evidence to prove that the photographed damage at most buildings are due to lightning, proper investigations have not conducted to verify that the non-conventional protection system has been implemented as per the relevant standards and whether the system maintains recommended conditions such as the limiting earth resistance and the continuity of components. The scientific world itself has made an atmosphere that questioning such lapses a taboo. This psychological roadblock, which is systematically built up over the years, has prevented many scientists from conducting proper research that finally benefits the public (refer [38] to find the psychological background of such social taboo development in professional fields). The high rate of installation of non-conventional systems in many countries does not justify the worthiness of maintaining such professional taboo. Thus, it is the high time to discuss this matter in open if one truly needs to work towards social benefits. The once popular demand of the scientific community that it is the duty of the manufacturer to prove that his product meets the claims, is trivial as far as the social wellbeing is concerned. In real world, a client from the general public is highly unlikely to raise such question when he buys the product. The scientific community should solidly disapprove the claims and bring it forth to the standard developers and authorities to ban such product.
6. It is of interest to find that the well-known success of the business of marketing non-conventional systems in many countries is the low probability of lightning related incidents in many part of the world. Hence the above points no. 2 and 5 should be blended together to develop a new strategy in providing optimum benefits to the society with respect to lightning protection. This is much more of a psychological assignment augmented by technical backup.
7. It should be noted that the paper has focused totally on structural protection (external protection) rather than surge protection (internal protection). The reason is

that the threat due to lightning surges on the equipment is much higher than that to the structures and human beings thus, the safety psyche on surge protection among the public is different. This area has its own psychological battle based on the technical and professional aspects that should be discussed as a separate study.

V. CONCLUSIONS

This study developed an argument which depicts that lightning is not treated seriously as a concern of safety by the research community working on safety sciences. Even government policy documents and guidelines on occupational safety, in countries with very high ground flash density, do not address or at least mention the term 'lightning'. We emphasized that it is the high time to determine whether this lack of concern is due to the unawareness of the significance of lightning related threats by the general safety science spheres or is lightning truly an insignificant scenario compared with other safety issues. The answer to this question is important in addressing many current issues and determining the future of lightning research and educational programs that could enhance the awareness of lightning safety among public.

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