International Conference on Lightning Protection
33rd International Conference on Lightning Protection
25 - 30 September 2016
Estoril, Portugal

Concerns of the Application of Lightning Protection Risk Assesment for Small Structures

Chandima Gomes
Center for Electromagnetic and Lightning Protection
Universiti Putra Malaysia, Serdang,
Selangor, 43400, Malaysia
chandima@upm.edu.my

Foster Chileshe Lubasi
National Institute for Scientific and Industrial Research, Zambia
fclubasi@yahoo.com

Ashen Gomes
Center for Electromagnetic and Lightning Protection,
Universiti Putra Malaysia, Serdang,
Selangor, 43400, Malaysia
chandima@upm.edu.my

Myagmar Doljinsuren
Institute of Meteorology, Hydrology and Environment
Juulchny Gudamj-5,
Ulaanbaatar 210646, Mongolia
dosharty@yahoo.com

***Abstract*—International Standards on lightning protection risk assessment (IEC 62305-2: 2010) are well accepted and applied in many parts of the world. During the last few years a large number of lightning related accidents, especially due to direct strikes, have been reported from Asia and Africa where the lightning struck objects are small structures. Information gathered from several investigations done on these cases have been used to determine the level of protection needed for these structures as per the standard risk assessment. In many cases the outcome was the none-requirement of any LPS for such structures or a risk factor for direct strike probability which is less than the critical value. As there are millions of similar structures in these regions, we propose the development of a separate risk assessment algorithm for such structures, especially in underdeveloped countries.**

Keywords-Small strctures; lightning injuries; risk assesment, IEC

I. INTRODUCTION

During the last few years a large number of lightning related accidents have been reported from developing countries, both in mass media and research literature [1-9]. A significant percentage of indoor accidents pertinent to these studies are related to direct strikes on small structures. In few cases relatively large buildings, still with rudimentary structure, such as rural schools and churches have been struck, resulting multiple casualties. Due to the unprecedented number of deaths and injuries resulted by these lightning incidents, there was a dialogue started at international level on the need for methodical investigations on the lightning environment of these regions to address the issues within scientific peripherals (Eg; Special meeting at ICLP-2016 on Lightning safety in Africa; International symposia on lightning related issues in developing countries held in Kathmandu in 2011, Uganda in 2013 and 2014, Zambia in 2015 and Colombia in 2016). Many of these event reports recommended immediate supply of lightning protection systems (LPS) to the vulnerable structures in this region after conducting a scientific survey. Thus, amidst many challenges and strategic issues, several scientific investigations have been done on several of these accidents in few countries and information has been gathered on the incidents. One of the major requirement for designing affordable LPS for these structures was to determine the level of protection by conducting a standard risk assessment.

This paper discusses the fundamental issues that were raised during the risk assessment of these small structures and the consequent application of the results to lightning struck buildings.

II. METHODOLOGY

Lightning risk assessment algorithms described in IEC 62305-2: 2010 [10] have been applied to several lightning struck structures in Zambia, Uganda and Mongolia to find the requirement of LPS and comparison of risk factors with critical values. The structures studied in Zambia have been personally visited by one of the co-authors to collect necessary information. Some details of these cases have been reported in Foster et al. [4]. Details of the structures in Mongolia have been collected by the staff of the meteorological observatories belong to Institute of Meteorology, Hydrology and Environment, Mongolia. The incidents have been reported in the statistical studies of Doljinsuren and Gomes [11]. The structure in Namibia has been mentioned in several reports of printed and electronic media and latter investigated by a co-author who visited the site. The building dimensions are roughly estimated as per the available data. The ground flash density for each region has been adopted from Christian et al. [12].

III. RESULTS

Case-1: Lightning has struck a small thatched roofed house (Figure-1) in Kasansama village, Mkushi, Zambia (14.00° S, 29.50° E). Five people of a family (out of six members) who occupied the house at the moment of strike were killed as the thatched roof caught fire after lightning struck the structure. The only survival was a three year old boy. The wall materials were cement blocks and the floor was pressed clay. A neighboring building, very similar to the affected house, is shown in Figure-1c for the purpose of comparison. It is a flat area with typical village structure (houses are spread but not isolated). The dimensions of the affected building has been estimated as 5 m × 4 m x 3 m with highest point about 4 m.

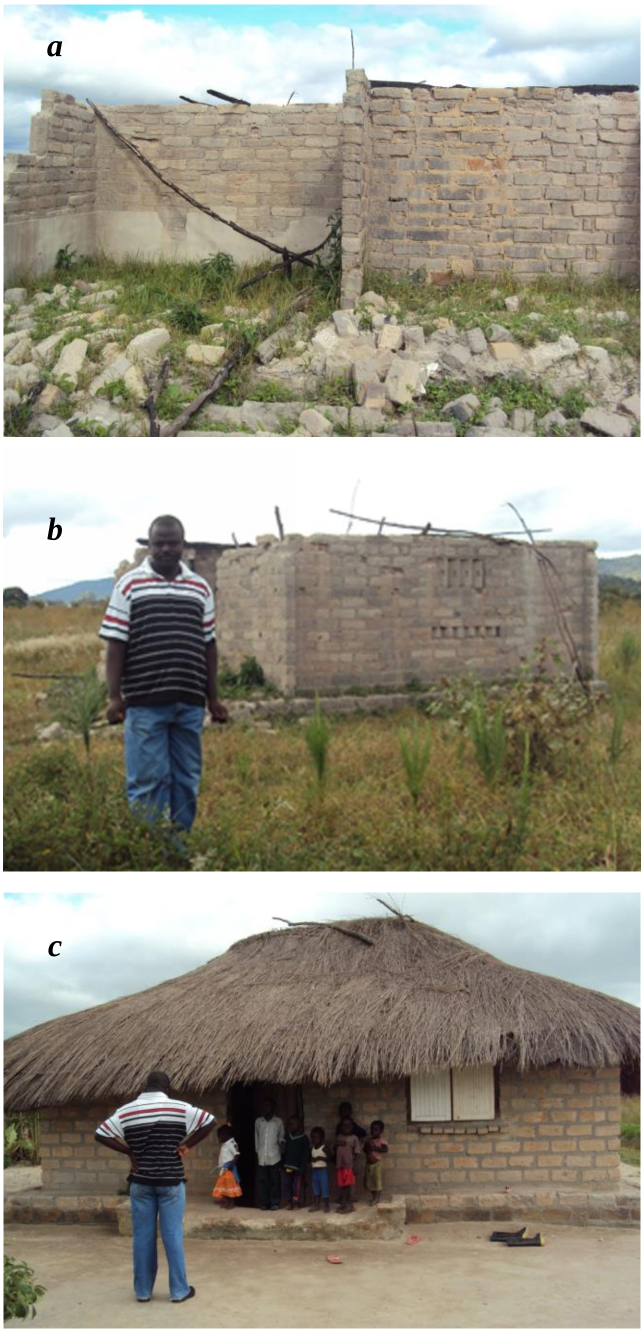

Figure-1: The lightning struck structure in Kasansama village, Mkushi, Zambia. *a.* The close up of the building. *b.* Building at a distance. *c.* A neighboring building, very similar in dimensions and structure to the affected one (Adopted from [4]).

The ground flash density has been adopted as 8 flashes yr^{-1} km^{-2} for the region. The floor material has been considered as ceramic. As the occupants usually go out during the day time, together with their children, the occupancy period was considered as 15 hours × 7 days (a week). The risk assessment software which is based on [10] provided the following output for the risk for loss of human life (for no LPS)

Risk of direct strike (R_d): 1.098×10^{-7}
Risk of indirect strike (R_i): 9.713×10^{-6}
Calculated risk for loss of human life (R): 9.821×10^{-6}
Tolerable risk for loss of human life (R_T): 1.005×10^{-5}

Thus, as per the risk assessment no protection system is required for the said building.

Case-2: Lightning has struck a small tin roofed school building (Figure-2) in Chibombo, Zambia (14.68° S, 28.10° E). According to the district police reports five students in the age of 12-13 years have been affected by a lightning strike to the building. All of them were injured while one have been found with severe burns. Eye witness and other observations revealed that lightning has struck a nearby tree and a side flash or surface current has been directed to the building. Damage marks visible on the cement floor inside the building (Figure-2b) indicates that a heavy lightning current has traversed into the building. The building is usually occupied by about 20 people for about 8 hours on every weekday. The area is flat with several buildings in the near vicinity. The dimensions of the affected building has been estimated as 10 m × 8 m x 3 m with highest point about 4 m.

The ground flash density has been adopted as 8 flashes yr^{-1} km^{-2} for the region, as in the previous case. The floor material has been considered as concrete/cement. The risk assessment provided the following output.

Risk of direct strike (R_d): 1.317×10^{-6}
Risk of indirect strike (R_i): 4.000×10^{-5}
Calculated risk for loss of human life (R): 4.132×10^{-5}

The outcome shows that the building needs protection, basically, due to the risk of indirect strikes. Thus, if such school building is a point of concern, the lightning protection engineer could develop a suitable design. However, there are two major issues arises with the above result and consequential outcomes.

a. It can be seen that when the risk assessment is redone with the modification of providing SPDs according to IEC 62305-4: 2010 [13], R reduces to 1.337×10^{-6} even under the condition of no external LPS. Thus, the risk assessment implies that the building is safe with surge protection. However, the observations on the above incident clearly show that surge protection could not avoid the lightning mishap, as it is related to a direct strike followed by side flash or surface current. On the other hand most such rural buildings in Africa do not have electricity.

b. The second issue is the safety of similar buildings which are not categorized under schools/ hospitals/ hotels etc. There are many buildings of similar structure, number of occupants, hours of operations etc. in the region, which come under industrial / commercial structures. For such option the risk assessment produce an R value of 9.837×10^{-6}, for no LPS and no SPD condition. This outcome raises serious doubts about the applicability of the existing risk assessment to this type of structures.

Figure-2: The lightning struck structure in Chibombo, Zambia. *a*. The building. *b*. Damage mark on the floor of the structure suspected to be due to lightning current

Case-3: This is also a structure from Zambia located in the village Katuya in the township Senanga (16.12° S, 23.27° E). Lightning has struck the building while the single occupant who used to live in the house alone (during the night time) was sleeping. He was killed and the building was completely destroyed creating even a small crater at the location (Figure-3). The house was similar in size and structure to the one adjacent to that where his siblings live.

The structure is made of clay and roofed with corrugated metal sheets. Its dimensions were approximately 4 m × 3 m × 3 m with maximum height of the roof is about 3.5 m. The ground flash density was considered as the same as in the previous cases. The following results have been obtained in the risk assessment.

Risk of direct strike (R_d): 1.089×10^{-7}
Risk of indirect strike (R_i): 5.550×10^{-6}
Calculated risk for loss of human life (R): 5.659×10^{-6}

Again $R < R_T$ indicating that the structure does not need any protection.

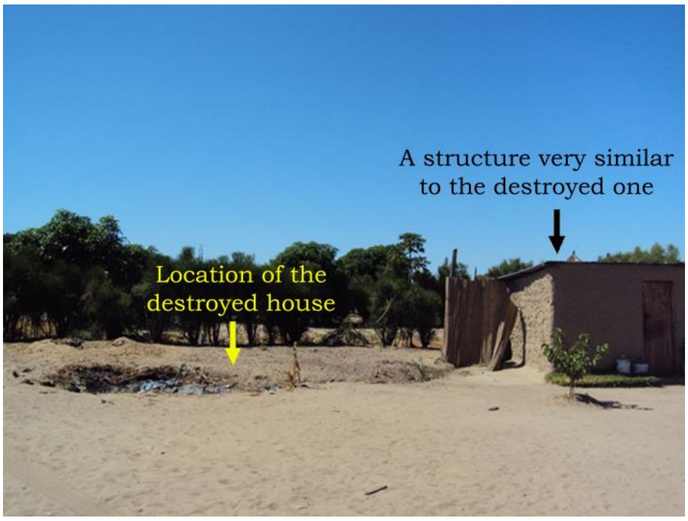

Figure-3: The lightning struck structure in Katuya, Zambia.

Case 4: Mongolia is a country with comparatively low lightning density that varies between 0.6 to 6 flashes yr^{-1} km^{-2}. Most of the rural houses in the country are cotton surrounded structures named ger (Figure-4). These structures could be seen even in townships. As it is reported in [11], during the last decade, several lightning related accidents have occurred while people were inside such gers. As the details of each case are not extensively available, we consider one on the incidents from central province where a nine year old child was killed by lightning while the family was inside.

Typically a ger has a diameter of about 8 m, thus the area is approximately 50 mm^2. The number of people in the family who lives in the ger was considered as 4. The height of the lower roof plane and maximum height was considered as 3 m and 4.5 m respectively. The affected house was in a flat land in a village. Usually they have pressed clay floor. The family was assumed to occupy the house for 16 hours a day for the whole week. We considered the maximum ground flash density for Mongolia, 6, in our calculation.

Risk of direct strike (R_d): 2.118×10^{-7}
Risk of indirect strike (R_i): 7.400×10^{-6}
Calculated risk for loss of human life (R): 7.612×10^{-6}

This is another case of a lightning struck building which has been predicted as having no lightning risk, without implementing any class of lightning protection system, according to the risk calculation. There are thousands of such structures in same environment in Mongolia and the neighbouring countries with similar isokeraunic level.

Figure-4: Typical ger in Mongolia

Case-5: A lightning strike set fire to the visitors lobby Cheetah Conservation Centre, in Otjiwarongo, Namibia (20.46° S, 16.65° E), injuring an intern employee and burning down the building. There was only a single person in the building at the time. One of the authors who travelled to Namibia, has been informed that similar accidents are somewhat common in many parts of Namibia. Most often the lightning strikes cause lethal injuries both due to lightning current effects and burning of inflammable materials. The analysis has been done on a structure similar to the one that was destroyed at Cheetah Centre, we assume that a family of 4 lives in the building and it is located at Otjiwarongo, Namibia. The floor of the building was assumed to be concrete and the floor area was considered as 36 m^2. The selected housing structure is shown in Figure-5.

Figure-4: A structure similar to the one of concern in Namibia.

By considering a ground flash density of 3, the following output has been obtained.

Risk of direct strike (R_d): 1.603×10^{-7}
Risk of indirect strike (R_i): 3.150×10^{-6}
Calculated risk for loss of human life (R): 3.31×10^{-6}

IV. DISCUSSION

The outcomes of this study raises a grave question about the applicability of the existing risk assessment algorithm given in [10]. Note that we have selected the option 'ordinary' for the risk of physical damage, in all cases. When we change the selection to 'high' in all cases the R exceeded R_T, not due to the increment of R_d but R_i. Thus, when we selected 'SPDs provided according to IEC 62305', R was lowered below R_T indicating that no structural protection is needed.

We find this work as the only case where the risk assessment provided in [10] has been validated against any type of building that has been struck by lightning. Therefore, we cannot make conclusive remarks that the proposed method is only suitable for large (or comprehensive) buildings.

This study was motivated by several other studies conducted in Africa [4, 5, 6] which reported that in contrast to the observations in developed countries, in rural African communities, a majority of lightning related human accidents occur while the people are 'indoor'. A consequential investigation done in Uganda [13] revealed that the major reason for such observation is the unsafe nature of their housing structures. The two papers by Gomes and Gomes [14, 15] discussed that such observations should strongly be considered in developing promotional and awareness programs to eradicate lightning related myths and lightning safety guidance. Under such situation, low-cost lightning protection schemes for small structures, which are affordable for rural communities in developing countries is becoming a dire need in the future [16, 17].

It is not only of interest but also of grave importance to work further on this matter to find what factors influence the unexpected results pertinent to the risk of lightning to small structures, especially in rural areas.

V. RESULTS

Five cases have been analyzed to find whether the risk assessment algorithm provided in IEC 62305-2: 2010 [10] predicts the required LPS for the small structures that have been hit by lightning. Our results show that the risk assessment fails to recommend any LPS for the affected structures. When some risk factors are modified to increase the risk (such as physical damage), the computation indicated that a certain level of protection should be provided to the building as there is a risk of indirect lightning. However, such risk could be brought below the tolerable risk by providing surge protection instead of implementing any class of structural protection.

The outcome of this study strongly emphasizes that further revision is required for the risk assessment that has been recommended in [10]. We also highlight the urgent need to validate IEC 62305-2:2010 [10] against many types of unprotected buildings that has been struck by lightning to determine whether the computational algorithm is reasonable in predicting the required level of protection.

ACKNOWLEDGMENT

The authors would like to acknowledge the facilities and support rendered by National Institute for Scientific and Industrial Research, (NISIR), Zambia, the NAMEM, IMHE of Mongolia and the Centre for Electromagnetic and Lightning Protection, University Putra Malaysia in making this project a success.

REFERENCES

[1] M. Doljinsuren and C. Gomes, Lightning incidents in Mongolia, Geomatics, Natural Hazards and Risk, 6 (8), 686-701, 2015

[2] I. Cardoso, O. Pinto, I. R. C. A. Pinto and R. Holle, Lightning casualty demographics in Brazil and their implications for safety rules. Atmospheric Res. 135-136:374-379, 2014.

[3] M. B. Mulder, L. Msalu, T. Caro and J. Salerno, Remarkable rates of lightning Strike mortality in Malawi, PLoS One. 7, 1-4, 2012

[4] F. C. Lubasi, C. Gomes, M. Z. A. Ab Kadir and M. A. Cooper, Lightning related injuries and property damage in Zambia, 31st International Conference on Lightning Protection, Sep 2-7, Vienna, 2012

[5] A. K. Mary and C. Gomes Lightning accidents in Uganda, 31st International Conference on Lightning Protection, Sep 2-7, Vienna, 2012

[6] A. K. Mary and C. Gomes, Lightning safety of under-privileged communities around Lake Victoria, Geomatics, Natural Hazards and Risk, 6 (8), pp. 669-685, 2015

[7] M. G. Nicora, E. J. Quel, R. E. Burgesser, and E. E. Avila, Electric atmospheric activity in Argentina, a study for estimating the annual death rate by lightning, International Symposium on Lightning Protection (SIPDA), Belo, Oct 7-11, 2013

[8] C. Gomes, M. Ahmed, K. R. Abeysinghe and F. Hussain, Lightning accidents and awareness in South Asia: experience in Sri Lanka and Bangladesh, 28th International Conference on Lightning Protection (ICLP), Kanasawa, Sep 18-22, 2006

[9] M. B. Mulder, L. Msalu, T. Caro, and J. Salerno, Remarkable rates of lightning Strike mortality in Malawi, PLoS One, vol. 7:1, doi: 10.1371/journal.pone.0029281, January 2012

[10] IEC 62305-2:2010, Lightning risk assesment

[11] M. Doljinsuren and C. Gomes, Lightning related human casualties in Mongolia, 33rd International Conference on Lightning Protection, Estoril, Portugal, Septmeber, 2016

[12] Hugh J. Christian, Richard J. Blakeslee, Dennis J. Boccippio, William L. Boeck, Dennis E. Buechler, Kevin T. Driscoll, Steven J. Goodman, John M. Hall, William J. Koshak, Douglas M. Mach, Michael F. Stewart E. Gourbi-ere, Global frequency and distribution of lightning as observed from space by the Optical Transient Detector, Journal of geophysical Research (Atmospheres), Volume 108, Issue D1, pages ACL 4-1–ACL 4-15, 16, 2003

[13] Ahurra Kulyaka Mary, Chandima Gomes, Ashen Gomes and Wan Fatinhamamah Wan Ahmad, Lightning Hazard Mitigation in Uganda, 32nd International Conference on Lightning Protection-2014, pp 1619-1628, Shanghai, China, October 2014

[14] Chandima Gomes and Ashen Gomes, Lightning; Gods and Sciences, 32nd International Conference on Lightning Protection-2014, pp 1792-1801, Shanghai, China, October 2014

[15] Ashen Gomes and Chandima Gomes, Hierarchy of Hazard Control to Minimize Lightning Risk, 32nd International Conference on Lightning Protection-2014, pp 1218-1228, Shanghai, China, October 2014

[16] C. Gomes, M. Z. A. Ab Kadir and M. A. Cooper, Lightning safety scheme for sheltering structures in low-income societies and problematic environments, 31st International Conference on Lightning Protection-Vienna, Sep 2-7, 2012

[17] C. Gomes and Z. A. Ab Kadir, Efficient lightning protection: Optimization of economic, environmental and safety aspects, Environmental Engineering and Management Journal, Issue 8, Volume 14, 1975-1985, 2015