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Design of Lightning Arresters for Country Boats and Rural Houses in Bangladesh

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Abstract- The consequences of lightning strikes, which have a huge impact on the socio-economic situation of a country can be reduced by taking necessary precautions, as well as proper design and placement of arresters. Due to majority of the population of Bangladesh living in rural areas, emphasis has to be put on rural structures and boats to mitigate damage from lightning. There are different types of lightning arresters which have already been designed in many developed countries for buildings and speed boats but rural houses and small boats did not receive much focus in this aspect. In this research, designing the lightning arresters for rural houses and country boats in the context of Bangladesh has been addressed. The cone of protection method has been used in this thesis work with some adaptations. The effectiveness of the lightning arresters has been verified using PSCAD software.

Keywords- *Lightining Impulse, Isokeraunic Level, Cone of Protection Method*

I. INTRODUCTION

Lightning is a natural phenomenon that occurs due to high static charge density in clouds. In Bangladesh, due to its geographical location and climate conditions lightning occurrence is quite frequent. In rural areas the frequency of lightning is higher and so the amount of damage and fatality rate due to lightning is more severe than urban areas. In rural areas of Bangladesh every year huge number of people are affected by lightning. Also a number of people are affected by lightning when they travel by boat. Situated around 24°N and 90°E, Bangladesh has mostly tropical monsoon climate with heavy seasonal rainfall, high temperatures, and high humidity, blended with some subtropical features as well. In Bangladesh lightning occurs almost in every month but the frequency of lightning phenomena increases in the monsoon when thunderstorm starts to occur. Thunderstorm starts from middle of April and becomes terrible in the months of May-June. With these thunderstorms, lightning strike occurs. Lightning can strike at any time of the day. In daytime most of the people stay outside for different kinds of activities. As a result, the number of fatalities is higher during daytime. When lightning strikes at an open place like a river, it is difficult to take shelter and avoid the devastation. Also rural houses are affected by lightning due to insufficient number of trees. According to the annual report published by “Disaster Forum” [1] at least 203 people died and other 951 people were severely injured due to lightning in the year of 2010. In the year of 2011 fatality rate increased to 280 people and more than 1425 people got injured. According to the report most of the occurrences took part at rural areas. In addition, the report also showed that most of the victims were in houses or outside places like boats and field. With decreasing amount of trees, insufficient safety measures and unavailability of lightning arresters in rural areas, the death and injury toll as well as the socio-economic damages is increasing each year in Bangladesh.

Introduction of lightning arresters in rural areas for houses and boats can provide safety and decrease the damage and fatality rates. Hence preventive measures are to be taken to mitigate lightning related consequences. The preliminary step for lightning protection is to use lightning arresters. A lightning arrester is a device that intercepts the lightning impulse and bypasses the huge amount of current to ground and thus protects the structure and neighboring objects. Appropriate design of arresters by suitable placement and parameter selection can sufficiently reduce lightning related consequences and fatalities significantly.

II. SCOPE AND OBJECTIVES OF THIS RESEARCH

This research addresses the design of lightning arrester system for typical rural houses and country boats in Bangladesh. The design steps include lightning arrester placement, finding out suitable materials that can provide both security and economy, calculating the parameters of the different parts of arrester and making a bypass route for current to the ground. After designing, the effectiveness of the arrester system was tested using PSCAD software.

III. DESIGN METHODOLOGY

To design lightning arrester system relevant theories, methods and procedures need to be followed. In our research, lightning characteristics and environmental condition is considered based on typical condition of Bangladesh. Cone of protection method is used to design the lightning arrester system.

A. Lightning Impulse Characteristics

The damage that an object suffers in being struck by lightning depends on both the characteristics of the lightning and the properties of the object, particularly the ability or inability of the object to conduct electricity and to dissipate heat. In more than 50% cases [2] the peak value (I_p) of lightning impulse reaches up to 30kA. In this design a lightning impulse of 27.4 kA is considered. According to International Electrotechnical Commission standard [3] IEC-62305:1 the front time of a lightning impulse is defined as 1.25 times the time interval between the instants when the 10 % and 90 % of the peak value are reached as shown in Fig. 1. Pulse width is defined as the time interval between 10% and 50% of peak values are reached.

Rise time, T_1 = time to reach from 10% of peak value to 90% of peak value

Pulse length, T_2 = time to reach 10% of peak value to 50% of peak value

A typical lightning impulse can be expressed using double exponential equation [4]. According to it, the current equation for typical lightning impulse is expressed as

$$I(t) = I_o (\exp(-\alpha t) - \exp(-\beta t)) \quad (1)$$

Where

I_o = peak current

$\alpha = 1/T_2$

$\beta = 1/T_1$

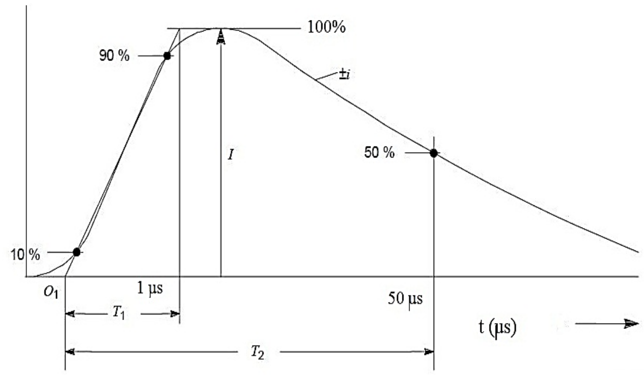

Figure 1. Typical Lightning Impulse

B. Effectiveness of the Designed System

After the simulation is done it is required to check whether the generated voltage at various points of the system is less than the breakdown voltage of neighboring atmosphere. For the typical rural house system the neighboring atmosphere is air. Breakdown voltage of air is 500 kV/meter. If the generated voltage is less than the breakdown voltage then it is to be checked that within which distance the arrester provide security that is sideflash may occur. For country boats the surrounding atmosphere is water. Breakdown strength of fresh water is 1000 kV/m. In this case the effectiveness of the designed arrester has to be tested similar to the previous one.

C. Parameters of Lightning Impulse

Using the double exponential formula, the lightning impulse has been formed [3] to use in PSCAD. Parameters of lightning impulse described in equation (1) have been calculated. The lightning impulse used in the design is a 1:50 impulse as shown in Fig. 1. The result is given in Table I.

TABLE I. PARAMETERS OF LIGHTNING CURRENT

Parameters	**Unit**	**Value**
Peak Current (I_o)	kA	27.4
Rise Time (T_1)	µs	1
Time to reach half value (T_2)	µs	50
$\alpha = 1/T_2$		20000
$\beta = 1/T_1$		1000000

D. Dimension of Typical Rural House

The following dimensions are considered for a typical rural house (slanted CI sheet roof) to set up a lightning arrester system:

Length = 24 feet (7.3 metres)

Width = 12 feet (3.65 metres)

Height = 12 feet (3.65 metres)

For the rural house, the roof of the house is divided into 6 equal segments each of which is 4 ft in length. 3 Air terminals are placed upon the roof at the locations as shown in Fig. 2.

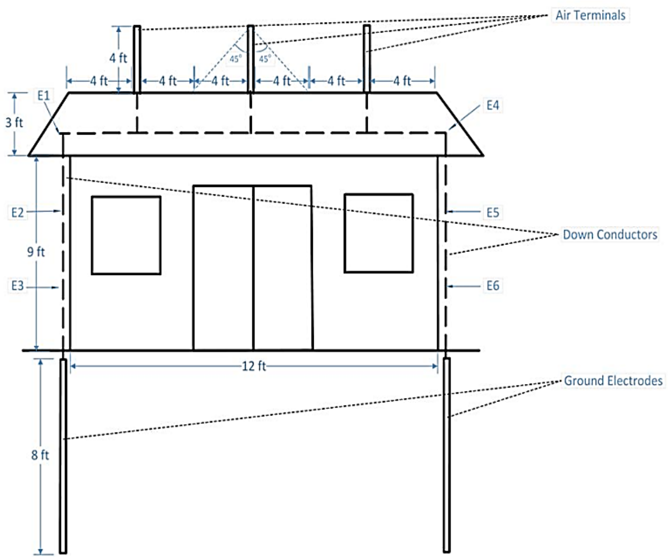

Figure 2. Lightning arrester system designed for typical rural house of Bangladesh

E. *Dimension of Typical Country Boats*

For country boats, same procedure is followed for air terminal placement. Two air terminals have been used on the boat in lateral positions in the way shown in Fig. 3. For boat purpose solid round aluminium conductor is also used to construct air terminals for its great conductivity and light weight.

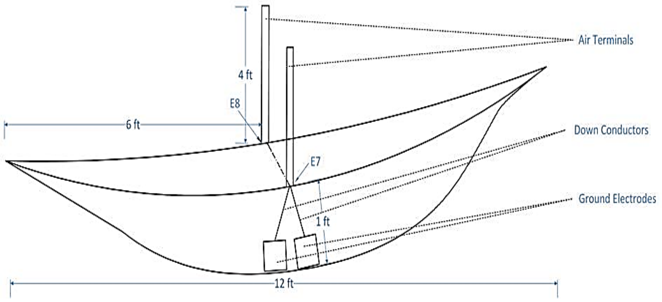

Figure 3. Lightning arrester system designed for typical country boat in Bangladesh

F. *Parameters of Different Parts of Lightning Arrester*

Parameters of the designed parts of lightning arrester are calculated. Each segment is supposed to be 4 feet long. Resistance, Inductance, Capacitance per segment of air terminals, connecting wire and down conductor is calculated.

For the typical rural house two down conductors are designed at two lateral side of the house as shown in Fig. 2. Each of the down conductors is 12 feet (3.65 metres) long. So, each of the two down conductors are divided into three segments to check voltage developments at various points. Solid round conductor of copper is used as connecting wire down conductors. Each segment is 4 feet long. For the typical rural house in Bangladesh solid round copper is used as ground electrodes. Two ground conductors are connected at the end of the two down conductors. Each of the ground conductors are buried 20feet (6 metres) under the earth level. Ground electrode resistance decreases with the depth of ground conductor beneath the soil level. NFPA 780:2004 [5] specifies a minimum length of 8 feet (2.4 metres) for the buried rod. According to that document, for rods of less than 3metres length requires the top of the ground rod to be buried below ground level.

The summary of parameters for rural house is shown in Table II. Parameters for different parts of arrester for country boats are calculated similarly.

TABLE II. PARAMETERS FOR LIGHTNING ARRESTER OF THE RURAL HOUSE

Part of an Arrester	Used Material	Parameter	Unit	Determined Value
Air Terminal	*Aluminium*	*Diameter*	mm	8
		Circular area	mm^2	50
		Resistivity	Ω-m	$2.65x10^{-8}$
		Inductance	μH/segment	1.4
		Resistance	mΩ/segment	1
Connecting wire and Down conductor	*Copper*	*Diameter*	mm	8
		Circular area	mm^2	50
		Resistivity	Ω-m	$1.68x10^{-8}$
		Inductance	μH/segment	1
		Resistance	mΩ/segment	0.4
		Shunt Capacitance	pF	8.25 (at 12 feet) 8.6 (at 8 feet) 9.7 (at 4 feet)
Ground Electrode	*Copper*	*Diameter*	mm	8
		Circular area	mm^2	50
		Soil Resistivity	Ω-m	50
		Resistance	Ω	10

IV. RESULT

Using the parameters the lightning arrester systems for typical rural house and country boats were formed. The equivalent circuits are simulated in PSCAD software.

For the typical rural house, generated voltage was tested at six points- E1, E2, E3, E4, E5 and E6. Generated voltage at E1 curve is shown in Fig. 4.

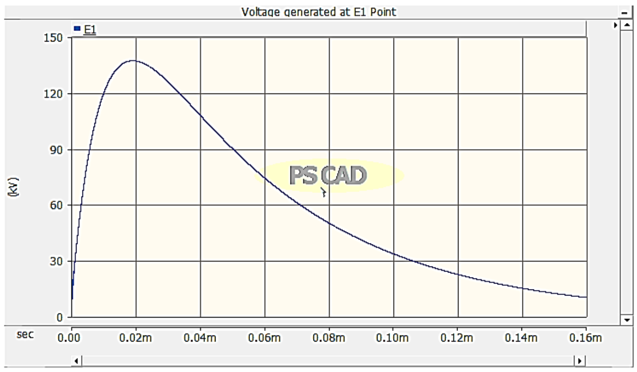

Figure 4. Voltage Generated at E1 point on down conductor

Voltage generated at various points at the down conductor of typical rural house is shown in Fig. 5.

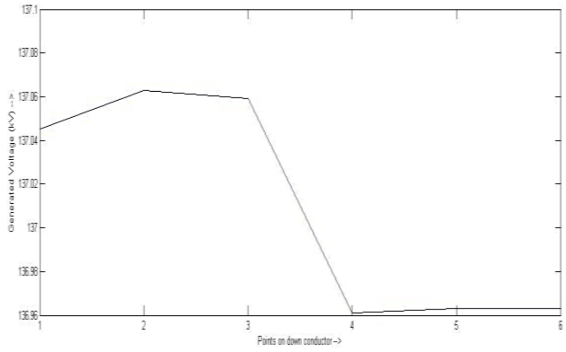

Figure 5. Voltage generated at E1, E2, E3, E4, E5, and E6 points on down conductor of typical rural house

Voltage generated at E7 point on the down conductor of the country boat is found from the output curve shown in Fig. 6.

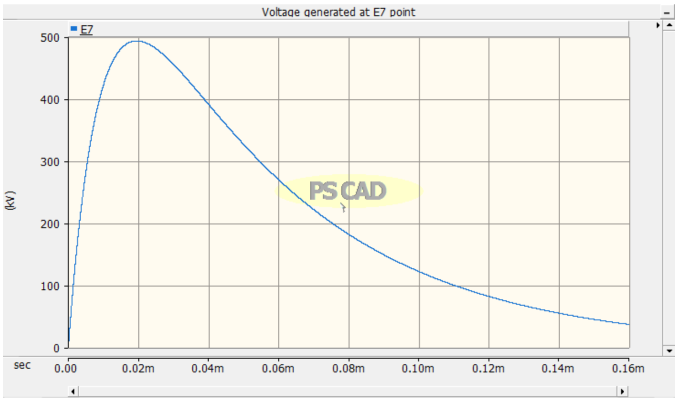

Figure 6. Voltage Generated at E7 point of a country boat

From the output curves it is found that in the lightning arrester system for typical rural house, maximum generated voltage is about 137 kV. In the lightning arrester system for country boats, maximum generated voltage is about 481 kV. These values are now to be compared with the breakdown voltage of the surroundings to find out the flashover occurrence possibility. Generated voltage depends on the conductor path impedance and the ground resistance. As metal conductors are used the path impedance is very low. So, in this case generated voltage mainly depends on ground resistance. With the increase of ground resistance, voltage increases and the possibility of side flashover increases.

V. Conclusion and Recommendation

For the lightning arrester designed for typical rural house, maximum generated voltage is about 137 kV and the breakdown voltage of surrounded air is 500 kV/m. So the voltage generated at the down conductor is much less than the breakdown voltage of air at 1 meter. Hence there is no possibility of side flashover at a distance of 1 meter. So, anyone staying within this distance will be safe form sideflash. But this value of generated voltage can be significant within a small distance. Suppose at a distance of 0.25 meter (25 centimetres) from the down conductor voltage per unit distance becomes $(^{137\ kV}/_{0.25\ m})$ or 548 kV/m which is greater than the breakdown voltage of air. So any person can get electrified due to side flashover if he/she reaches within a distance of 25 centimetres. Also the generated voltage can increase due to increased ground resistance. If the ground resistance increases to 40 ohms, then at 1metre distance side flash can occur as the generated voltage on the down conductor reaches 500 kV.

To remain safe from side flashes during lightning occurrence, a safety boundary or fence can be built up surrounding the structure at least at a distance of 25 centimeters. This can reduce lightning related injuries and fatalities significantly.

For the lightning arrester system designed for typical country boats, maximum generated voltage was 481 kV and the breakdown voltage of water is 1000 kV/m. Within a distance of 1 m (100 cm) side flashover occurrence is not possible. But at 0.5 m (50 cm) distance the voltage becomes 962 kV/m and it can easily generate a flashover. If anyone stays within a distance of 0.5m, he/she can get electrified in this case. So, in case of lightning occurrence, people travelling by boat should sit at least 50 cm away from lightning arresters so that side flash cannot occur.

Fresh water resistivity is higher than soil resistivity. So the induced voltage is higher in case of discharging through water. Salt water is more conductive than fresh water. Consequently side flash occurrence is less probable when amount of salt increases in water.

In this design, equivalent circuit is limited to 15 nodes only due to software limitations. If an equivalent circuit could be designed using more nodes, then additional segments could be added which would increase the path impedance. As a result the voltage generated at down conductor would be less compared to the present design. This would decrease the distance of side flash occurrence. Also several parallel path to down conductor could be added that would reduce the resistance of down conductor and flow the current to ground more easily. This would make the design more effective. In short, simulation with higher number of nodes will provide results on safe side.

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