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SELECTION CRITERIA FOR LIGHTNING ARRESTER SYSTEMS IN NIGERIA

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Abstract

Electrical equipment is subject to overvoltage hazards, especially lightning hazard. Effective protection of equipment from lighting-induced overvoltage is dependent on correct arrester selection and installation. In Nigeria, there have been many reported cases of electrical hazards attributed to lightning which has led to loss of lives and equipment. This can be attributed to the fact that Nigeria being close to the equator is on high lighting density area, thus it is important that Nigerians understand the characteristics of standard arrestors. This paper takes a survey of the arrestors found in the Nigerian market and came out with recommendations on the best approach towards selection of lighting arresters for effective electrical protection.

Keywords: lighting, surge, arrestors, protection and selection

Introduction

The typical lightning arrester has a high-voltage terminal and a ground terminal. When a lightning surge travels along the power line to the arrester, the current from the surge is diverted through the arrestor to earth. Typically, a lighting arrester provides a low resistance path for surges to the ground. Lightning introduces thousands of kilovolts that can damage electrical or electronic equipment. It can also endanger the lives of those within its radius of operation. Effective protection against lightning-induced over-voltages is mainly dependent on; correct arrester selection, arrester installation and earthing. Therefore it is important to understand these requirements for effective selection of lighting arrester. Nigeria is close to the equator in the region of high thunder density as shown in figure 1 [2]. This fact has accounted for periodic lighting hazards experienced in the country.

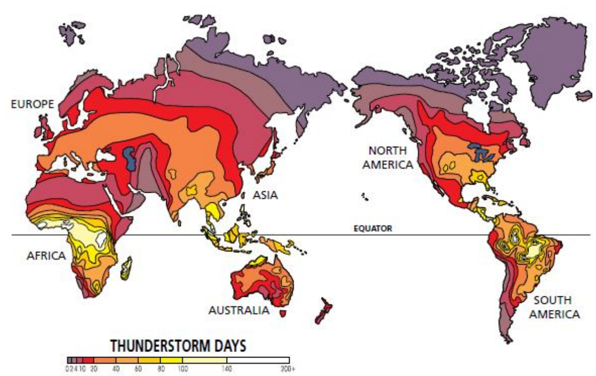

Figure 1: World thunder day map (www.erico.com)

Effect of Lighting Current

Where a lighting arrester has been wrongly selected, installed or not available, some of the following effects are noticed within the radius of lighting discharge operation:-

- Thermal effects: fusion at the lightning impact points and joule effect, due to the circulation of the current, causing fires.

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- Electrodynamic effects: When the lightning currents circulate in parallel conductors, they provoke attraction or repulsion forces between the wires, causing breaks or mechanical deformations (crushed or flattened wires)

- Combustion effects: Lightning can cause the air to expand and create great pressure which stretches over a distance of a dozen meters resulting in a blast effect breaking windows or partitions and projecting animals or people several metres away from their original position. This shock wave can at the same time be transformed into a sound wave in form of thunder.

- The elevation of the earth potential by the circulation of the lightning current in the ground. This explains indirect strokes of lightning by step voltage and the breakdown of equipment

This effect has led to physical and catastrophic failures initiating industrial/domestic fire outbreaks, equipment failure, loss of lives and downtime revenue loss.

Hence it is of great importance to understand these dangers and provide best protection practice against lighting hazards using international standards [1].

Arrestor Selection

There are many arrestor types used against lightning hazards and selection is based on the maximum discharge current and protection level. *Maximum discharge current (Imax)* is the maximum discharge current that an arrester is required to withstand once in its life span, corresponding to exceptional conditions. *Protection level* is the protection voltage level compatible with the susceptibility of the equipment to be protected [3][4]. It is also important to take into account the sensitivity of the equipment to be protected (overvoltage withstand strength of equipment), the cost of such equipment, the level of site exposure to lightning. In Nigeria, the common type of Lightning Protection System (LPS) are the power line protection system and the air-termination type made of aluminum, titanium, zinc, lead copper and steel. Another special type of LPS is the Early Streamer Emission (ESE)

Table 1: Classification of LPS

LIGHTNING PROTECTION LEVEL (LPL)	CLASS OF LIGHTNING PROTECTION SYSTEM (LPS)	TYPE OF LIGHTNING PROTECTION SYSTEM
I	I	Station
II	II	Intermediate
III	III	Distribution
IV	IV	Secondary

Table 2: Class of LPS in relation to the corresponding positioning method

	PROTECTIONMETHOD		
CLASS OF LPS	ROLLING SPHERE RADIUS (r)	Mesh Size W (m)	PROTECTION ANGLE (α^0)
I	20	5 x 5	See figure 2
II	30	10 x 10	
III	45	15 x 15	
IV	60	20 x 20	

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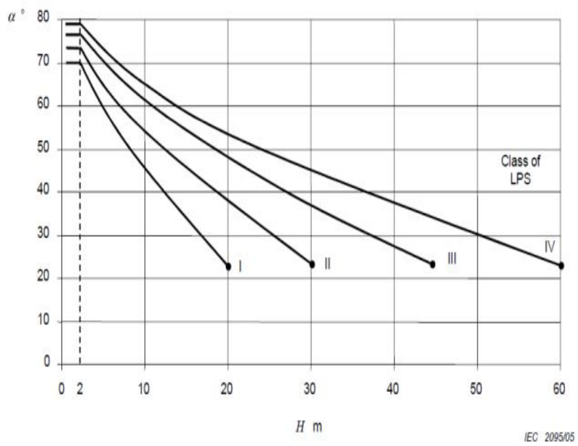

Figure 2: Protection angle method (IEC 62305)

Table 2: Lightning Parameters according to Lightning Protection Level (LPL)

Interception Criteria				**LPL**			
	Symbol	**Unit**	**Frequency**	**I**	**II**	**III**	**IV**
Maximum Peak current	I_{max}	**kA**	**First short stroke**	**200**	**150**	**100**	
			Subsequent short stroke	**50**	**37.5**	**25**	
			Long stroke	**200**	**150**	**100**	
			Flash	**300**	**225**	**150**	
Minimum Peak current	I_{MIN}	**kA**	**-**	**3**	**5**	**10**	**16**
Rolling Sphere	**R**	**m**	**-**	**20**	**30**	**45**	**60**

radius							

Table 3: Protection level according to termination height

Level	**R(m)**	**α (h = 20)**	**α (h = 30)**	**A (h = 45)**	**α (h = 60)**	**d(m)**
I	**20**	**25**	**-**	**-**	**-**	**5**
II	**30**	**35**	**25**	**-**	**-**	**10**
III	**45**	**45**	**35**	**25**	**-**	**15**
IV	**60**	**55**	**45**	**35**	**25**	**20**

Method of Lightning Protection System (LPS) Selection

In other to make a proper and effective selection, the following procedural steps may be followed:

1. Determine the lightning exposure level of the area where the site (or equipment) to be protected is located. The exposure level is defined by the number of lightning strokes per km^2 (Ng) in the area or by the keraunic level (Nk) of this zone (how many times thunder is heard in one year). Ng and/or Nk are data that regional meteorological offices can provide.
2. Choose the table corresponding to the previously defined Ng value. For each Ng value there is a corresponding maximum probable current (Imax) that may flow through the lightning arrester. The table corresponding to the value of Ng provides information on the required protection level (Up) according to the sensitivity of the equipment to be protected. This allows you

to select the proper arrestor type needed for your protection.

Choose the best installation position method that allows for maximum protection. There are three installation positioning methods; Protection angle method, the mesh method and the rolling sphere method. The rolling sphere method is recommended as the universal method, the mesh method is suitable for flat surfaces and the protection angle is used for limited vertical distance [5]. From fig 4, it is clear that the aerial antenna is not protected from lightning due to wrong position determination.

3. Select a proper down earth conduct with the minimum corrosion effect.
4. A lightning protection is as good as its earthing; therefore ensure that the best earthing method is used as it applies to the soil type.

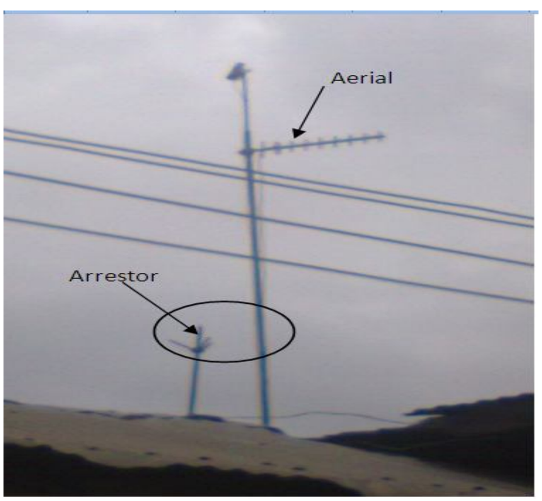

Figure 4: Common Lightning rod installation (wrong Positioning)

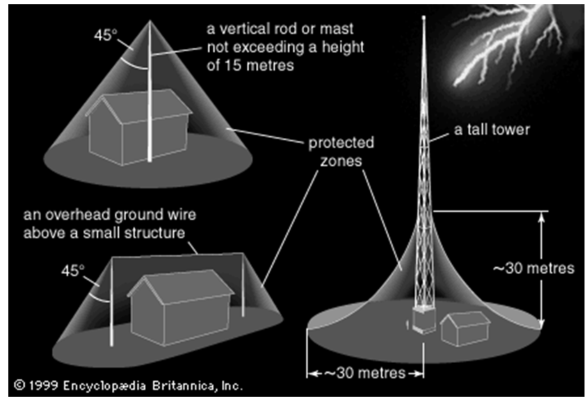

Figure 5: Arrester height in relation with Protection radius

LIGHTING ARRESTER TYPES IN THE MARKET

We considered two broad arrester types common in our market; 1. Arresters used for power line protection and 2. Air termination system for structure protection.

1. POWER LINE ARRESTER TYPES

- Rod arrester: This arrester has two rods of 1.5cm length bent at right angles and separated by a gap. One rod is connected to the line circuit and the other rod is connected to earth. The gap distance is such that the insulator will not be damaged by high voltages. Generally, the gap length is so adjusted that breakdown should occur at 80% of spark-voltage in order to avoid cascading of very steep wave fronts across the insulators. On the occurrence of a high voltage surge on the line, the gap sparks over and the surge current is conducted to earth.

- Horn gap arrester: This arrester has two horn-shaped metal rods separated by small air gap. The rods are placed on porcelain insulators and their resistance increase as they rise from the gap. The resistance regulates the level of current into the arrester. Electric lines are connected to one of the

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horn which grounds excessive current to the earth and also controls reactivity of the arrester when transient frequency occurs [7][8].

- Multigap arrester: This type has series of metal cylinders which are insulated from each other and separated by an air gap. One cylinder is connected to the electric line while the others are grounded through series of resistances. At the event of lighting sparks, some of the gaps weaken the effect of the excess current to the ground through their shunt resistors.

- Expulsion type lightning arrester: This arrester type is commonly used on voltage lines up to 33KV, it is made of two rod gaps enclosed in a fiber tube. The gap in the fiber tube is formed by two electrodes. The upper electrode is connected to rod gap and the lower electrode to the earth. One expulsion arrester is placed under each line conductor.

- Valve type lightning arrester: This arrester type is more applicable in high powered electrical systems. They consist of series of non-linear resistor disc and spark gaps. They work when excessive voltage cause the spark gaps to touch, the current is driven to the ground through the non-linear resistors [7][8].

2. AIR TERMINATION SYSTEM FOR STRUCTURE PROTECTION

- Early Streamer Emission (ESE) Type

This is an improved version of the normal lightning rod. It also works in accordance with the French NFC 17-102 standard. This lightning rod is designed to attract lightning to itself at the event of any flash. When lightning flashes, an electrical field is developed at the ground level with an increasing intensity as downward leader approaches ground. At a level between 50 and 100 kV/M, the Corona effect, which develops naturally at the top of any high structure, allows discharges (upward leaders) to rise toward the cloud. The position of the ionized path which will allow the lightning current to pass is determined by where the upward leader comes into contact with the first downward leader from the cloud (this becomes the striking point). An early streamer emission lightning rod is designed to provide optimal conditions for the formation of this rising (upward leader) discharge. For this, the following conditions are necessary:

• The presence of primary electrons at the top of the rod : these electrons, given off in the form of plasma, encourage the start-up of the rising discharge.

• Ionised plasma being formed at the right moment when lightning is about to strike, in other words, in phase with the rising electric field at ground level.

The ESE lightning rod can be mounted on an elevation pole, mast or tower with two down conductors linking the E.S.E. lightning rod to earth. Two earthing points are provided to channel and dissipate the lightning current. A number of separate ESE may be necessary to protect a large construction. A typical ESE type is shown in fig 3. Installation of ESE still follows the same positioning method for other types of lightning rod as in the rolling sphere method, protection angle method and the mesh method [6].

Figure 3: A typical ESE Lightning Rod

- Franklin Rod: This air termination system is made up of a 2-8m high tapered metal, a down earth conductor and an earthing system. At a protection of level of 4 and height of 60m, the radius of coverage is limited to about 30m as shown in figure 5. It is normally only used to protect small structures or zones such as pylons, chimneys, tanks, water towers, aerial masts, etc. [9].

- Faraday Mesh: This arrester type consists of a mesh that covers the roof and walls of the structure to be protected and recommended for flat surfaces. The down earth conductors are connected to the roof mesh and separated by a distance of 10-25 meters before terminating it at a dedicated earthing system. The majority of lightning current is conducted and dissipated by the conductors and earthing systems closest to the point of impact of the lightning strike [9].

RECOMMENDATIONS FOR ARRESTER SELECTION

1. Climatic conditions and excessive arc affect the performance of most arresters especially rod arresters. Therefore international standards should be consulted in the design and selection of arrester type for any chosen type. For instance, rod arrester is recommended as a back-up arrester due to its climatic limitations.
2. Working Voltage: Arresters should be employed according to their voltage rating. For instance the working voltage should not exceed 33KV.
3. Good earthing system is recommended for all arrester type. Good arrester systems is determined by the perfection of the earthing system.
4. Risk assessment of the protection zone is highly recommended for best arrester type selection. For instance military zones, hospitals, factories prone to explosions should be protected with high quality arresters.

Conclusion

Nigeria being at the high thunder density region is prone to lightning flashes that can cause devastating effect on life and equipment. Earthing, arrester types, position and composite materials constitute a lot to the efficiency of any lighting system installation. This paper has surveyed some of the arrester types available in the market and has also recommended risk assessment, equipment evaluation and other good practice considerations for best arrester selection.

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