2012 International Conference on Lightning Protection (ICLP), Vienna, Austria

Lightning Accidents in Nigeria: With Special Attention to Aviation Mishaps

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***Abstract*—Lightning related accidents in Nigeria, a country of high lightning density, have been collected and analyzed. Results show that lightning related human injuries and deaths are very high in Nigeria, where the actual figure may reach as high as 500 deaths per year. However, due to the social stigma attached to lightning incidents and the lack of unbroken news chains reaching media, collection of accurate statistics has become a daunting task. Apart from human and livestock related hazards; property damage is also of high concern due to probable devastating consequences of such incidents. Extra attention has been paid on collecting damage records related to aviation industry as there are several serious accidents related to lightning have been reported in this area. The data collected and analysed is used to develop a set of national level recommendations for lighting safety and protection which can also be applicable in neighbouring countries, as they also experience extremely high lightning occurrence density.**

Keywords-lightning; aero planes; Nigeria; step potential; direct strikes; aviation accidents

I. INTRODUCTION

Nigeria is a country in West Africa at 10°N and 8°E. The country is bound by Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. Its coast in the south lies on the Gulf of Guinea on the Atlantic Ocean (fig.1).

Although, Nigeria is located within tropical zone, it has diversified climatic variations based on regions of the country. Seasons are not well defined in the coastal belt where temperatures rarely exceed 30-32° C. However, the excessively high humidity makes nights unbearably hot. There are two distinct seasons in the interior parts of the country: a wet season from April to October, with generally lower temperatures, and a dry season from November to March. During the dry season the daytime maximum temperatures may exceed 38° C. However, the nights are cooler with temperatures that may drop to even, 10-12° C. Average annual rainfall along the coast varies from about 1800 mm in the West to about 4300 mm in certain parts of Eastern side. The rainfall in the interior of the country is less with average value rarely exceeding 1300 mm over most of central Nigeria and that only up to 500 mm in the extreme north.

Two principal wind patterns are observed in Nigeria. The Harmattan, from the northeast, is hot and dry. It most often carries reddish dust from the desert which causes high temperatures during the day and low temperatures at nights. The southwest wind brings cloudy and rainy weather.

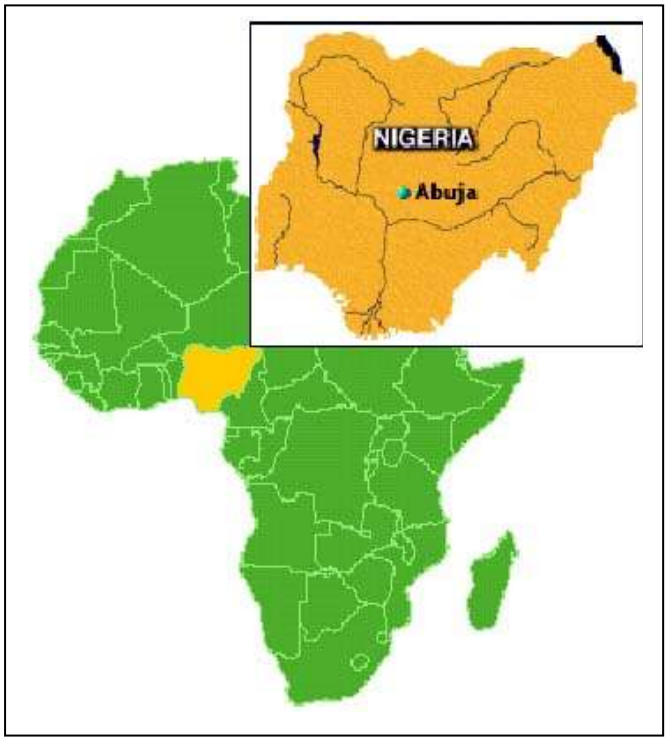

Figure 1. Location of Nigeria in African continent

Nigeria records very high lightning density which reads as 30-40 strikes km^{-2} yr^{-1} as per the 1995-2003 observations of NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments [1]. Such values correspond to almost year long isokeraunic level [2]. The country has experienced several of the worst lightning related accidents in the history of mankind.

In the lightning science circle Nigeria is well known for its Yoruba tribe, which worship lightning in the capacity of a divine entity named Sàngó (also written as Shango). In rural societies of Yoruba tribe a lightning strike to a house or a human being is a curse of Sàngó, as they believe even today.

Lightning is one of the most dramatic and most common natural activities that occur in the atmosphere. Lightning strikes may cause severe damage to physical structures and claim human and animal lives. It may ignite fires that may bring an entire structure down to ashes or create cracks, and at a lower degree of damage, it may destroy electrical, electronic and communication equipment beyond repair. Transmission lines, communication towers and tall physical structures including residential houses and monuments are more vulnerable to lightning activities. However one of the most significant losses that it may cause as far as the industries are concerned is the downtime. A couple of hours of obstruction of normal operation or a loss of some important data stored in a computer may cause a company a huge economic loss. Thus, there is an urgent need to launch national and international level programs in the non-aligned and other developing countries such as Nigeria as well as in developed countries to create awareness among masses and educate the engineering, technical, scientific and civil communities on the subject of lightning safety and protection [3]. Further details of lightning phenomena are presented in many research papers and other research communications that can be found in the literature. [4-5]. Despite many such research on lightning carried out in the world, there are very few, if it is not zero, studies on the subject that has been conducted in Nigeria. Even lightning accidents have not been properly documented. In this paper, an attempt is made to present some documented incidents caused by lightning strikes which involves individuals and livestock, and also air accidents with the aim of finding whether the cause is closely or remotely related to lightning or weather conditions.

II. METHODOLOGY

The information gathered in developing this paper is from reliable sources such as research papers, aviation accident reports issued by national and international bodies and the news reports in reputed mass media. In all cases, we have given our utmost attempt to cross examine the information for the accuracy. The data gathered has been compiled and presented by approaches of qualitative analysis.

Based on the outcome of our information analysis a set of guidelines are proposed to reduce the lightning related accidents in Nigeria. This paper will be an eye-opener type in a country that experiences one of the worst lightning accidents in the world, yet keep blind eye on the matter.

III. RESULTS AND DISCUSSION

A. Reported cases of lightning incidents in Nigeria

During the rainy season of every year which lasts for averagely six months in the Northern part of Nigeria commencing from May through to October, lightning activity is a common occurrence and is often accompanied by wind and sand storms which causes a lot of damage to economic trees and residential structures (rooftops) amounting to substantive economic loss. Sometimes the incidents involve loss of human life and livestock. Most cases involving lightning incidents are not reported and documented because of lack of awareness of lightning safety education and reporting procedures. Additionally, the rural community does not report such incidents to government agencies responsible for disaster management such as National Emergency Management Agency (NEMA), mostly due to social stigma. Another reason is lack of presence of journalists or their representatives in remote locations. Even those media personnel and freelance journalists who have access to rural information give prominence to news items on politics and violence.

Due to these above reasons, as we were gathering information it was found that accurate facts and figures of lightning deaths and injuries in Nigeria is almost impossible to be obtained. However, some efforts have been made by medical personnel to document cases of victims of lightning strikes. Our estimates, although rather crude, show that the annual lightning hazards in Nigeria may reach as high as 500 deaths. As per the equations described in [2] the number of injuries may reach 5000. Actual figures may be greater than these values as ours are lower estimations. In this paper, few reported cases of lightning incidents involving humans and livestock are presented. Also, the incidents of air accidents in Nigeria from 1969 to date is presented with a view of assessing if the reported causes of such accidents are related to lightning or weather events.

On 26th of February, 1996, lightning struck and 3 killed women in Ota town about 80 km from Lagos. The incident was accompanied by traditional beliefs which generated argument between the residents who believe in traditional Sango and the family members of the victims [6]. On 20th July 2002, 180000 bbl. (one blue barrel is equal to 42 gallons) were lost at an oil storage facility when fire fighters failed to gain control of a rim fire caused by a lightning strike [7]. Asuquo et al. [8] reported the case of a patient who received medical treatment for cutaneous burns sustained from lightning injuries. On June 30, 2011, Red Cross and local officials reported that 11 people were killed by lightning in two communities in Northern Nigeria during torrential rains [9]. In another lightning incident, a Nigerian Red Cross official Bala Ahmed reported that eight peasant farmers were killed and 12 others were injured during a thunderstorm outside Balanga village in Gombe State. The farmers were working on their farms when it started to rain and they sought shelter under a tree which was struck by lightning [10]. In a

separate incident in Damaturu, the Yobe state capital, Abbati Muhammad who is the head of a market, reported that lightning struck three people who had come to buy firewood during a downpour at the timber market and died on the spot. On 30th June, 2011, Gbadamosi and Shobayo reported that lightning has killed 4 persons and 9 cows in Bauchi which is located about 154km form the location of the incident the previous day [11]. Within a period of only three days, 26 fatalities for humans alone were recorded as a result of lightning strike. The most recent event occurred on 30th May, 2012, where rain storm destroyed over 80 structures comprising of houses, churches, farms, schools and electricity poles with damages estimated at over 4 billion Naira ($800,000) in Papalanto town of Ogun state [12].

B. Reported cases of avaiation disasters in Nigeria

The aviation sector in Nigeria has also incurred heavy losses both in terms of financial losses and loss of life as a result of weather related accidents although few were specifically linked to lightning and storm. Comprehensive accounts of air accidents in Nigeria from 1969 to date are presented in [13-24]. In a 43 year period, 45 cases of air accidents have been recorded leading to the death of 1,127 persons and 37 injuries although casualty figures were not available for 11 incidents. Majority of the air accidents occurred in 2005 where 10 incidents were recorded followed by 1991, 2004, and 2006 with three incidents each.

In 2005 a DC-9 air plane was crashed near Port Harcourt, a southern city of Nigeria, killing 103 passengers. The plane went through a severe thunderstorm immediately before the accidents and post-investigations attributed the incident to a lightning strike. In the same year a Boeing 737-200 was crashed near Lagos killing all on board; 117 passengers and crew. The accident was again attributed to a severe thunderstorm and the aircraft has been suspected to be struck by lightning soon after taking off.

Among the reported modes of these air accidents, mid-air crash to the ground accounted for 28 incidents which may likely have been caused by lightning strike or wind shear. This is followed by crash landing due to mechanical or other type of failure accounted for 13 incidents while three cases were specifically attributed to lightning and storm as reported in [25]. In Nigeria, the Accident Investigation Bureau (AIB) is the agency that is charged with the responsibility of investigating all air accidents and publishes the report. Majority of the cases described in the literature were reported by the media where only a few cases were published at the AIB website, and this is one of the reasons why aggressive measures have not been taken by the relevant authorities to avert such massive loss life.

Despite such major lightning related accidents and many thousands of less eye catching incidents, there are no significant investigations that have been done in Nigeria to develop a data base on the information on lightning related damages, injuries and deaths in Nigeria. Such database and analysis of information will contribute immensely to the development of safety and protection schemes / road maps in Nigeria to curb lightning caused accidents and their aftermath in Nigeria.

C. Mechanism of lightning interaction with aircrafts

The electrical conditions which produce lightning, together with the mechanisms of lightning strike attachment to an aircraft can be considered in relation to, electric field effect, charge stored on the aircraft, and air craft initiated lightning strike. At the beginning of a lightning flash formation, a stepped-leader propagates outward from a cloud charge centre towards an opposite charge centre in the cloud or on the ground which is not initially certain. The difference of potential normally exists between the stepped leader and the opposite charge(s) which establishes an electrostatic field between them, represented by imaginary equipotential surfaces as shown in Fig. 2. The field intensity, commonly expressed in kilovolts per meter, is greatest where equipotential surfaces are closest together and it is this field that is available to ionize air and form the conductive spark called a leader.

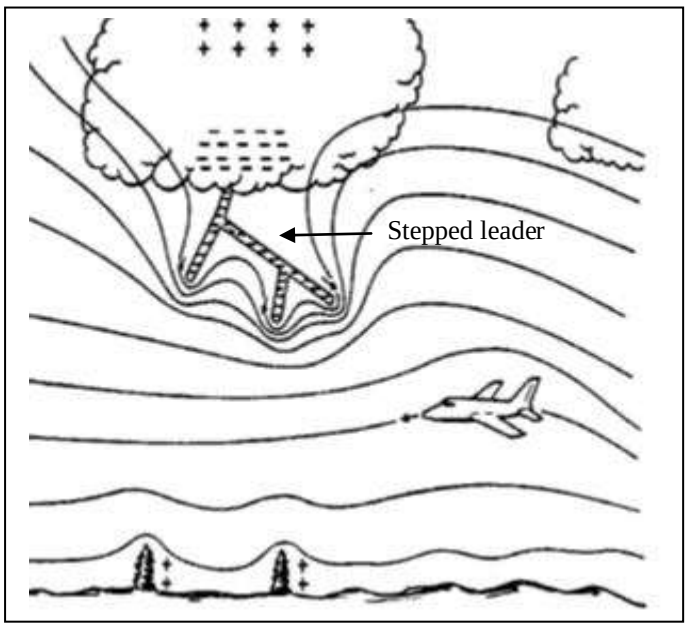

Figure 1. Equipotential lines around an aero plane in the presence of lightning stepped leader

As the direction of electrostatic force is normal to the equipotential and strongest where they are closest together, the leader is most likely to progress toward the most intense field regions.

An aircraft will always assume the electrical potential of its location since the aircraft is typically a large conductor, whose surfaces are all at this same potential, it will divert and compress adjacent equipotential, thus increasing the electric field intensity at its extremities and especially between it and other charge sources, such as the advancing leader. If the aircraft is far away from the leader, its effect on the field near

the leader is negligible; however, if the aircraft is within several tens or hundreds of meters from the leader, the increased field intensity in between may be sufficient to attract subsequent leader propagation toward the aircraft. As this happens, the intervening field will become even more intense, and the leader will advance more directly toward the aircraft.

The highest electric fields incident on the aircraft will occur around extremities, where the equipotential lines are compressed closest together as illustrated in fig.3. Typically, these are the nose, wing and empennage tips, and also smaller protrusions, such as antennas or air data probes. When the leader advances to the point where the field adjacent to an aircraft extremity is increased to about 30 kV/cm (at sea level pressure), the air will ionize and electrical sparks will form at the aircraft extremities, extending in the direction of the oncoming leader. Several of these sparks, called streamers, usually occur nearly simultaneously from several extremities of the aircraft. These streamers will continue to propagate outward as long as the field remains above about 5 to 7 kV/cm. One of these streamers, called the junction leader, will meet the nearest branch of the advancing leader and form a continuous spark from the cloud charge centre to the aircraft. Thus, when the aircraft is close enough to influence the direction of the leader propagation, it will very likely become attached to a branch of the leader system.

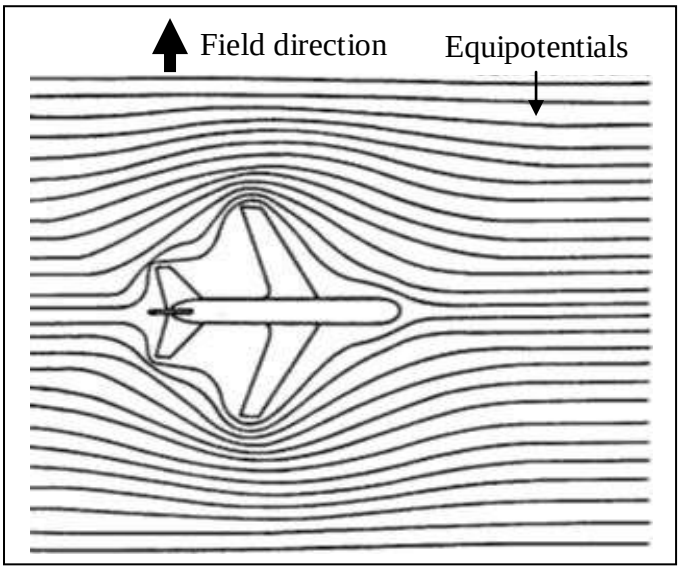

Figure 2. Equipotential around the aero plane (enlarged view)

Streamers may propagate onward from two or more extremities of the aircraft at the same time. If this happens, the oncoming leader will split, and the two (or more) branches will continue from the aircraft independently of each other until one or both of them reach their destination. When the leader has reached its destination and a continuous ionized channel between charge centres has been formed, recombination of electrons and positive ions occurs back up the leader channel, and this forms the high-amplitude return stroke current. This stroke current and any subsequent stroke or continuing current components must flow through the aircraft, which has now become part of the conducting path between charge centres. If another branch of the original leader reaches the ground before the branch which has involved the aircraft, the return stroke will follow the former, and all other branches will die out. No substantial currents will flow through the aircraft in such a case, and any damage to the aircraft will be minimal. There is also clear evidence from previous studies that lightning flashes was triggered by research aircrafts that were intentionally flown into clouds to observe lightning phenomena, but it is not clear how often aircraft in normal service trigger lightning [26, 27].

Another factor which causes air accidents and which is barely mentioned is wind shear. It has been defined as a rapid change in wind direction or speed which is caused by drastic changes to weather conditions such as geography, temperature inversion layer, sea and land breeze, fronts, and the most severe variation rain and thunderstorm. The air in thunderstorm would turn the airflow downwards called downdraft, which then strikes the Earth's surface and spreads out along the boundary layer that forms a ring vortex. Statistical report on weather related aviation accidents issued by International Civil Aviation Organization (ICAO) from 1970 to 1985 indicated that the accidents caused by or related to weather is about 30% of the fatal accidents. The report further stated that low clouds, fog and wind are the most hazardous factors, in which gust, wind shear, and turbulence being most dangerous. International aeronautics and meteorology society generally acknowledged that low-level wind shear is a severe hazard to aircraft during take-off, approach, and landing. Twenty-three out of twenty-eight accidents were in the process of approach and landing.

Also, according to statistics of Aviation Safety Network (ASN) of United States, from 1950 to 2000, there were 40 aviation accidents caused by turbulence or crosswind and 39 were wind shear or downdraft related accidents [28].

In the event of lightning strike to an aircraft, it would be affected in two ways similar to other ground based objects, that is, directly and indirectly. Direct effects will result to physical damage to structure of the aircraft in the form surface damage that will lead to creeps in airstream or with water or ice ingress. The high current generated during lightning produces arcs which cause massive damage from internal gas pressure rise. Also, high current arcs cause bending or puncture of metal resulting in mechanical damage. High current arcs also result in structural damage, puncture, hot spots, arcs and sparks which likely cause ignition of the fuel tank. Indirect effects of lightning strike to the aircraft includes electromagnetic interference that couples into the aircraft wiring system causing upset or damage to electrical and electronic equipments. High current conduction through the structure causes resistive, capacitive and inductive coupling of currents and voltages onto the wiring system and avionics resulting in system upset or damage [29].

Air transport is one of the most patronized modes of passenger and freight transport in Nigeria. The large size of the country, coupled with its geographically diverse resources

and potentials encourage extensive use of aircraft for speedy, long and medium distance carriage. Although air transportation in Nigeria dates as far back as the 1920s, commercial aviation actually started in 1930. The air network then was a simple linear structure that linked only six cities; Maiduguri, Kano, Kaduna, Minna, Oshogbo and Lagos. After a decade later, smaller airports which include Port Harcourt, Calabar, Enugu, Ibadan, Jos, Sokoto, Yola and Benin were constructed to provide link to both Lagos and Kano through feeder lines. [30]. Currently, there are seven registered airlines servicing the domestic air routes which include Aero Contractors, Arik Air, Chanchangi Airlines, IRS Airlines, Nicon Airways, Overland Airways and Virgin Nigeria Airlines.

It was reported in [31] that most governments in Africa are either too slow and incompetent or reluctant to release air accident investigation reports. But ultimately, a poor state of infrastructure, runways, broken down communications equipment such as air navigation aids and bad weather are responsible for the high rate of air crashes. While suffering the highest haul rate per million departures globally, the African continent is deficient in data collection and analysis machinery to certain causes of accidents. With high domestic air traffic, Nigeria is particularly prone to air accidents where early liberalization of the aviation industry saw an influx of operators who sometimes compromise on safety standards and regulatory authorities have been until recently slow in enforcing best air safety practices.

D. Recommendations to minimize accidents

From the data presented on lightning incidents and air accidents in Nigeria, it is obvious that lightning poses a serious threat that needs accelerated attention from the government for prevention and management. Therefore, we wish to make the following recommendations to the Nigerian authorities,

1. The functions of NEMA as an emergency relief agency should be expanded to include provision of lightning awareness and education centres to communities. This should include educating the rural populace on where to seek shelter in the event of rainfall, not to take shelter under trees, prevent children from playing outside during rainfall etc..
2. Database for documenting information related to lightning incidents should be established. This could involve the participation of health centres which provide medical services to victims of lightning strikes.
3. Advanced weather and navigational facilities should be installed at all Nigerian airports which should include lightning detectors, although this has been recently addressed by the Federal Government as reported in [detectors in 22 airports].
4. The regulatory authority of aviation in Nigeria, i.e. the Federal Aviation Authority of Nigeria (FAAN) should enforce strict maintenance procedures to airline operators to ensure their aircrafts are in good working condition, so that a nearby lightning may not lead to electronic mal functioning.
5. The infrastructure at the airports, specifically runways should be properly maintained with all signaling and warning systems protected with lightning safety devices.
6. International standards in terms of best practice and maintenance routine should be strictly followed and adhered to by all airline operators.

IV. CONCLUSIONS

Despite high lightning flash density in Nigeria, responsible authorities have not taken proper measures to improve the lightning safety of public and services. Hence large number of lightning accidents takes place in the country, of which most go unreported and un attended. Aviation sector is the worst affected by lightning as many accidents have taken place during the last few decades of which causes have been attributed to lightning effects.

Such accidents are summarized and discussed in brief to emphasize the need of lightning safety and protection in Nigeria. A set of recommendations are set forth for the responsible authorities to curb accidents in the future.

ACKNOWLEDGMENT

This research has been supported by Grant No: 05-01-11-1195RU/F-RUGS. Facilities provided by the Department of Electrical and Electronics Engineering, Universiti Putra Malaysia is greatly acknowledged.

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