Pre-Lightning Strikes and Aircraft Electrostatics

Joseph Fisher[1], Paul. R. Hoole[2,a], Kandasamy Pirapaharan[1], and Samuel H. Hoole[3]

[1]*Electrical and Communication Engineering Department, PNG University of Technology, Papua New Guinea*
[2]*Department of Electrical and Electronic Engineering, Universiti Malaysia Sarawak, Malaysia*
[3]*Department of Electrical and Computer Engineering, Michigan State University, USA*

Abstract. An electric storm is a source of electrostatic charge that can induce high current and electric potential on a surface of an aircraft through direct effects. It can also be a source of radiated electromagnetic pulses on an aircraft in flight through indirect effects. Both direct and indirect effects can have adverse effects on flight safety. Thus, it is vital to gain good understanding of the pre-lightning strike and the electrical characteristics of a thunderstorm in order to quantify lightning threats to aircraft. Since lightning parameters are not easily measurable, predictive modeling can be applied to model the pre-lightning strike and aircraft electrostatics. In this paper, we applied the 3D dipole model in predicting the electrostatics build up along an aircraft extremities as it approaches an ambient electric field of a charged cloud. The results give a quantitative evaluation of the threats during pre-lightning strikes and electrostatics buildup on the aircraft. This is vital in designing and coordinating shielding measures to mitigate the threats and to harden the protection systems for aircraft.

1 Introduction

As an aircraft becomes part of a natural lightning discharge process, the direct and indirect effects due to lightning strikes are recognized as a threat to flight safety. The severity of the threat is heightened further for modern aircrafts made up of composite materials and equipped with the latest digital state of the art technologies. Such modern aircraft design is a double-edged sword. On one side is the advantage of composite materials that provide cost, weight, and safety advantages, and the ease of flight control through the state of the art of technologies in control, communications, and command systems. While on the other side are the issues of dissipating the electric charges and or current induced away from a non-conductive surface and the susceptibility to electromagnetic interferences (EMI) induced through indirect effects of lightning radiated electromagnetic pulses (LEMPs).

In this paper, we apply a novel and innovative computational tool using the 3-dimensional (3D) dipole analysis to determine the voltage, charges, and electric field induced by lightning on an A380 airbus. We have chosen the airbus to expound on the previous work highlighted in [1].

2 Thundercloud and aircraft electrostatics

Cloud electrification process begins with a charge build up and the separation of the charges of opposite polarities within the cloud [2]. The cloud electrification is simply a result of electrostatic charges of different polarities that buildup within the cloud. There are four major stages of the lightning stroke which are the pre-breakdown, the leader, the attachment process as it reaches an object on the ground, and the return stroke [3].

When an aircraft enters an ambient electric of a thundercloud during the pre-breakdown stages, it will modify the electric field [4]. The entry of an aircraft into an ambient electric field can be regarded as a sudden introduction of a conductor into an electric field which intensifies the local electric fields [4].This enhances the local electric field buildup. The electric field enhancement will reach maxima along the aircraft extremities that are oriented towards the ambient fields. Typically for an ambient electric field of 100 kV/m, the fields at the extremities such as the radome and the tip of the stabilizers, and rudder could be enhanced to 1 MV/m [5].The charging of the aircraft produces a potential gradient between it and its surroundings. The potential gradient builds up to a sufficient level that corona discharge results. The corona discharges occur at the extremities of the aircraft and initiate a bi-directional leader that connects the cloud charge electrically to ground. There are two distinct phases to lightning-aircraft interaction. First is the development of streamers and leader sets develop at the field enhanced parts of the aircraft. The second phase is the high currents produced by first and subsequent return strokes. The second phase therefore induces the high energy transient current pulse, subsequent re-strikes and the long duration of the slow currents.

[a] Corresponding author: prphoole@gmail.com