Lightning Protection of Wind Turbine Blades

Glòria Solà

Diploma these (2005)

In the last years, renewable energies are taking an important role in our society. Wind energy is one of the most important renewable energies. At the moment, the commercialization of wind turbines is increasing and it will increase more with the new rules restricting the CO_2 emissions. In recent years, the trend in the wind turbines technology of building larger wind turbines, require the use of carbon fiber reinforcement to obtain more resistant materials which makes them conducting materials. That changes the characteristics of the blade and its susceptibility to lightning strike. The aim of this project is to get a first approach to what is the effect of the presence of carbon fiber in the blades. This project presents a low frequency analysis through a theoretical approach to study the electromagnetic coupling between the lightning down conductor and parallel conducting wires, representing the carbon fiber stacks. The current induced in the parallel wires and the potential difference between them are obtained in time- and frequency-domain. A sensitivity analysis using this approach shows that the parameter that affects more the response of the current is the length of the parallel conductor. Decreasing the distance between the conductors, as well as, increasing frequency, conductor's length or conductor's radius, will result in an increase of the magnitude of the current. In order to assess the validity of the theoretical approach, some experimental tests were also carried out in the high voltage laboratory of EPFL. However, due to the limited length of the conductors and the relatively-low value of the injected current, the induced current was embedded in noise.

Another concern of the wind turbine designers is the energy dissipation due to the circulation of electrical currents in carbon fiber stacks. The energy levels associated with induced currents were found to be relatively low. On the other hand, the dissipated energy associated with Eddy currents, evaluated in Chapter 3, was found to be more important and it is necessary to take this phenomenon into account when the lightning protection system for reinforced wind turbine blades is designed. Based on the results obtained, in order to reduce the risk of overheating of the carbon fiber stacks two methods are recommended: (1) the use of two lightning down conductors, instead of one, and, (2) arrangement of fiber stacks so that they are perpendicular to the plane formed by the two lightning conductors. These two measures are very efficient in reducing Eddy currents and their associated energy dissipation in carbon fiber stacks.

Finally, in Chapter 4, a lightning protection system based on a mesh-like structure which covers the blade is presented. This method is particularly interesting because it would ideally protect wind turbine blades against both direct and indirect lightning strikes. Simulations with Numerical Electromagnetics Method (NEC-2) were carried out to see if this structure could reduce the electric and magnetic fields in the center of the blade. The simulation results show indeed an important reduction of the electric field inside the blade. For the magnetic field, such a structure is found to be efficient for high frequencies (about 1MHz and above).