

A Case Study of Risk Analysis due to Lightning for Wind Power Plants

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Abstract. This paper briefly describes the Portuguese Lightning Location System, and presents an overview of wind energy in Portugal. The method for risk assessment due to lightning flashes to earth, proposed by the International Electrotechnical Commission, IEC, is used. A wind power plant is characterized for a case study, and the standard IEC 62305-2 is applied. Results obtained are able to support the advantage for investors to take into account the lightning activity in the region where the wind power plant shall be installed. Also, the use of a well established risk assessment method allows the adoption of adequate protection measures.

Key words

Wind energy systems, lightning protection, lightning location system, risk analysis.

1. Introduction

The escalating number of wind turbine power plants in many countries makes their reliability an increasing problem. Particularly, in Portugal the first wind turbine with 20 kW was installed in 1985, but in September of 2007 the total capacity in operation reached 2037 MW and continues growing.

One of the main causes of damage on wind turbines is lightning [1]. Areas of favourable location for wind turbines often coincide with areas of lightning activity. Hence, it is expected that the increasing number of wind turbines and the increasing height of the towers installed will result in an incidence of lightning damages greater than anticipated with significant repair costs.

The influence of lightning faults on operational reliability becomes a concern as the capacity of individual wind turbines increases. In a study completed in 2002 [2] it is expected that up to 8 out of 100 wind turbines could be damaged by one direct lightning strike every year. Between 1992 and 1995 Germany alone reported 393 accidents with damages due to lightning: 124 direct strikes to the turbine, and the remainder through the electrical distribution network [3].

Direct and indirect effects of lightning can produce severe damages on electrical and mechanical components of wind turbines, being responsible for considerable unplanned downtime. The question is not “if” but “when” the wind turbine will be stroked.

Lightning is formed as a result of a natural build-up of electrical charge separation in storm clouds. How clouds form is well understood. How the cloud separates its charge is not. Many theories have been put forward but everyone seems to agree that in a thunder-cloud, ice crystals become positively charged while water droplets carry a negative charge. When the voltage difference between the cloud base and the ground or a structure on the ground becomes so great that it causes a breakdown of the air's resistance, we have a lightning discharge. The most common lightning in what regards to wind turbine lightning protection, is cloud-to-ground (CG) lightning [4].

Wind turbines typically have two or three blades with a diameter up to 100 m or more, rotating above the ground. In addition, there is extensive use of insulating composite materials, such as glass fibre reinforced plastic, as load-carrying parts. The lightning protection system has to be fully integrated into the different parts of the wind turbines, ensuring that all parts likely to be lightning attachment points are able to withstand the impact of the lightning. Also, the lightning current should be conducted safely from the attachment points to the ground without unacceptable damage or disturbances to the systems. Wind turbines are excellent attachment points because they are often in exposed locations and significantly taller than adjacent objects. It is the blades that are by far the wind turbines most likely attachment points. However, almost any spot on the turbine is susceptible to direct lightning strikes including: air terminals, the nacelle, protuberances near the top of the structure, and the tower.

Although the increasing concern with wind turbine lightning protection is evident, there is no standard specifically written. The closest document is the technical report IEC/TR 61400-24 [5] which is purely informative, but it should be regarded as an important breakthrough.

In January of 2006 a new four parts standard document has appeared (IEC 62305- 1 to 4) [6-9], providing the general principles of protection against lightning, risk management, protection measures against physical damages to structures and life hazard, and protection measures against damages to electrical and electronic systems within structures.

In order to perform the risk management proposed in [7] the CG lightning frequency per kilometre square and per year is needed. This parameter could be achieved with a network of appropriate sensors connected to a computer which is responsible to validate and record data events.

In Portugal the first Lightning Location System (LLS) is working since June of 2002 operated by the Institute of Meteorology (IM). In December of the same year Portugal began sharing its data with Spain. The system has now eighteen IMPACT sensors: four in Portugal and fourteen in Spain, of which Portugal share information with the nearest five.

This paper briefly describes the Portuguese Lightning Location System, and presents an overview of wind energy in Portugal. The method for risk assessment due to lightning flashes to earth, proposed by the International Electrotechnical Commission, IEC, is used. A wind power plant is characterized for a case study, and the standard IEC 62305-2 is applied. Results obtained are able to support the advantage for investors to take into account the lighting activity in the region where the wind power plant shall be installed. Also, the use of a well established risk assessment method allows the adoption of adequate protection measures.

2. Characterization of the Case Study

The wind power plant under study has 25 wind turbines with 2 MW of rated power. In Fig. 1 a wind turbine is represented. The wind turbines were modelled in 3D with AutoCAD.

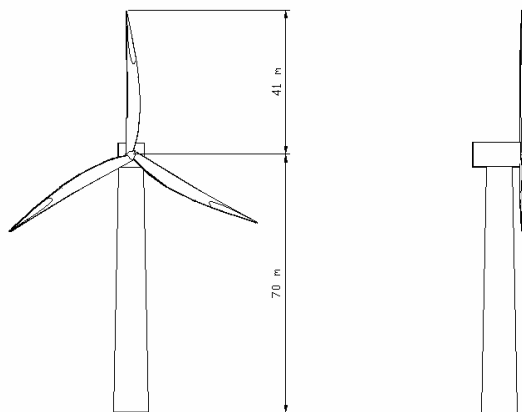


Fig. 1. 3D model and dimensions of a wind turbine

Ensuring proper power feed from wind turbines into the grid requires grid connection monitoring, shown in Fig. 2.

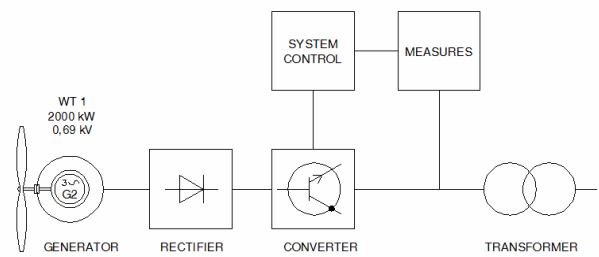


Fig. 2. Grid connection monitoring on wind turbines

3. Conclusion

This paper presents a brief characterization of the Portuguese LLS. Based on data from LLS, the lightning activity over Portugal is presented and discussed. An overview of wind energy in Portugal in what regards: the installed capacity; the capacity under construction; and the geographical location, is also presented. The method for risk assessment due to lightning flashes to earth, proposed by IEC, is presented. As a case study, a wind power plant is characterized and the standard IEC 62305-2 is applied. Results attained are in favour of supporting technical and economical decisions able for taking into account the lighting activity in the region where the wind power plant is installed. Also, the use of a well established risk assessment method allows the adoption of adequate protection measures.

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