Lightning Surges on Wind Power Systems: Study of Electromagnetic Transients

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1. Brief introduction

The need to control climate changes and the increase in fossil-fuel costs stimulate the ever-growing use of renewable energies worldwide. Concerning renewable energies, wind power is a priority for Portugal's energy strategy.

In Portugal, the wind power goal foreseen for 2010 was established by the government as 3750 MW and that will constitute some 25% of the total installed capacity by 2010 [1]. This value has recently been raised to 5100 MW, by the most recent governmental goals for the wind sector. Hence, Portugal has one of the most ambitious goals in terms of wind power, and in 2006 was the second country in Europe with the highest wind power growth.

As wind power generation undergoes rapid growth, lightning incidents involving wind turbines have come to be regarded as a serious problem. Because of their distinctive shape and the fact that they are very tall, open-air structures, wind power generators are often struck by lightning [2].

Nevertheless, no known studies exist yet in Portugal regarding lightning protection of wind turbines. Also, surge propagation during lightning strikes at wind farms is still far from being clearly understood. Thus, much work remains to be done in this area.

Direct and indirect events can indeed produce damages and malfunctions of electrical and mechanical components. Concerning mechanical components, blades and bearings are the most involved parts [3]. Apart from serious damage to blades, breakdown of low-voltage and control circuits have frequently occurred in many wind farms throughout the world. According to IEC TR61400-24 [4], the most frequent failures, more than 50%, in wind turbine equipment are those occurring in low-voltage, control, and communication circuits. The events on low-voltage circuits are not triggered by only direct lightning strikes but also induced lightning and back-flow surges propagating around wind farms just after lightning strikes on other wind power generators [5].

Scale models of electrical systems have been a popular tool, especially in the past, to predict power system transients after different types of perturbations [6]. For instance, a 3/100-scale model of an actual wind turbine generation system was considered in [7] for experimental and analytical studies of lightning overvoltages. However, in recent years, scale models have been progressively replaced by sophisticated numerical codes, capable of describing the transient behaviour of power systems in a rather accurate way, such as the Electro-Magnetic Transients Program (EMTP) [8].

Key words: Lightning surge, wind turbines, transient analysis, protection.

2. Wind Farm Description

The wind power plant under study has five wind turbines with 2 MW of rated power. Rotor blades are manufactured using the so-called sandwich method. Glass fibre mats placed in the mould are vacuum-impregnated with resin via a pump and a hose system. The rotor diameter is about 82 m. The rotor hub and annular generator are directly connected to each other as a fixed unit without gears. The rotor unit is mounted on a fixed axle. The drive system has only two slow-moving roller bearings due to the low speed of the direct drive. The annular generator is a low-speed synchronous generator with no direct grid coupling. Hence, the output voltage and frequency vary with the speed, implying the need for a converter via a DC link in order to make a connection to the electric grid. The hub height varies between 70 to 138 m. The tubular steel tower is manufactured in several individual tower sections connected using stress reducing L-flanges.

The LV/HV transformer is placed at the bottom of the tower. It has 2500 kVA of rated power and has a special design to fit the reduced dimensions and working conditions of the tower.

In Fig. 1 a wind turbine is represented. The wind turbines were modelled in 3D with AutoCAD.

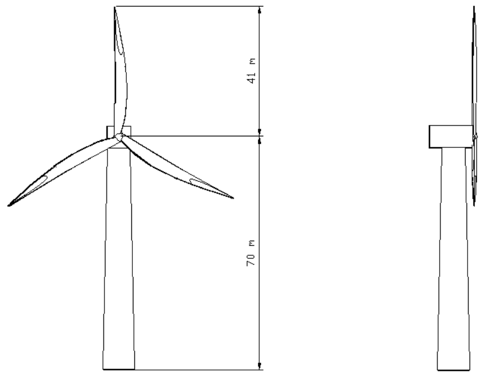

Fig. 1. Dimensions of a wind turbine.

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

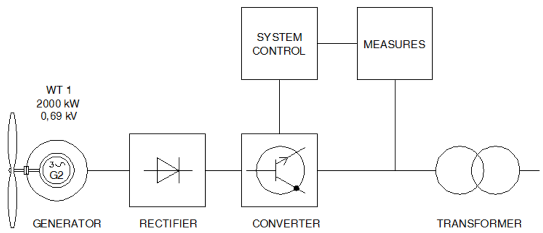

Fig. 2. Grid connection monitoring on wind turbine.

Fig. 3 shows the electric schema of a LV/HV substation near the tower. Distance among towers is about 350 m.

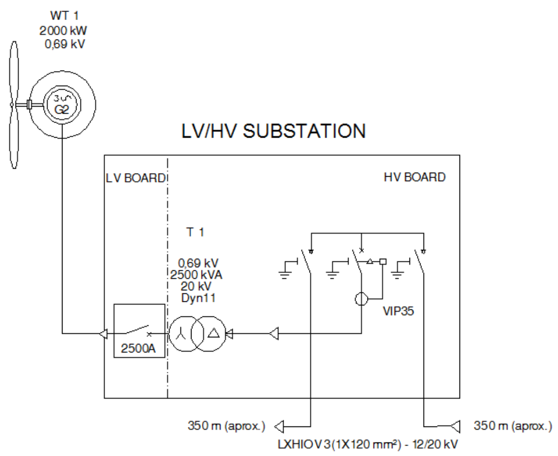

Fig. 3. LV/HV substation near the tower.

Fig. 4 shows the electric schema of the external part main substation with surge protective devices (SPD) installed.

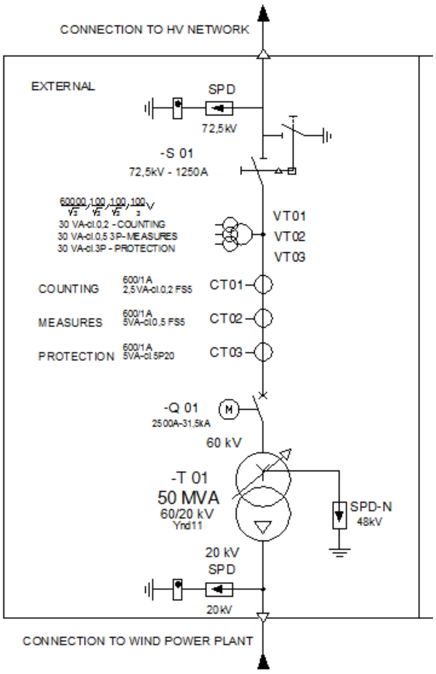

Fig. 4. Electric schema of the external part main substation with SPD installed.

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