WIND TURBINES LIGHTNING PROTECTION

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ABSTRACT

In the paper the statistics of the wind turbine damages caused by lightning strikes is presented for three European countries with longest experience in exploiting of wind turbines. The statistics show that nearly every second wind turbine is damaged due to the lightning discharge during the period of 10 years. The proposed solutions of the lightning protection of the wind turbines according to International Electro-technical Commission is presented. The example of the damaged 0,5 MVA wind turbine placed in Montenegro hit during winter thunderstorm is presented.

1. INTRODUCTION

After more than decade of experience of extensive application of wind turbines in some of European countries it was found that they are extremely vulnerable to the lightning discharges. On the other hand, wind turbines rated power, height and price are increasing, leading to great harm in the case of the lightning damage. From this reason a standard IEC TR 61400-24 is published in 2002. There are three aspects in lightning protection of the wind turbines described in that standard.

- Protection rotor blades of the wind turbines from damage due to the direct lightning strikes
- Providing the current path to the grounding avoiding bearings and other important parts
- Overvoltage protection of the main electrical circuit and auxiliary commanding, measuring and automation circuits.

Lightning turbine blades are made of insulating materials, but they can attract the lightning strike due to the great height and conduct the lightning current due to the wet surface during the thunderstorms, but it can also conduct due to the great electrical field causing forming ionization channel across the

surface or through the interior of the blade. The lightning damage of the first mounted wind turbine in Montenegro is described in the paper.

2. STATISTICS OF LIGHTNING DAMAGES IS EUROPEAN COUNTRIES

Statistics of lightning damages are published in number of papers proving that lightning protection of wind turbine is an extremely important subject. In [1,2] the collected statistical results are presented for Germany, Sweden and Denmark. In these analyses the statistic of damage parts is presented.

The results of statistical analyses from [1,2] are presented in Table 1.

Table 1: The results of statistical analyses of the lightning damages for Germany, Denmark and Sweden

Country	Observed time-period	Number of damages	Total number of wind turbines	Faults per 100 turbine-years
Germany	1991-1998	738	1498	8
Denmark	1990-1998	851	2839	3.9
Sweden	1992-1998	428	850	5.8

In Table 1 the percentage of direct or indirect lightning strikes damages are not presented. It can be expected that direct lightning strikes are very dangerous for blades and equipment in the nacelle. Indirect lightning strikes to nearby object are not dangerous for construction of wind turbine, but mostly for electrical equipment sensitive to overvoltages.

In the databases formed in above three countries, the components damaged by lightning are identified. The component damage distribution is given in Figure 1, according to [1,2].

The component damage distribution is given in histogram in Figure 1 based on the Danish database.

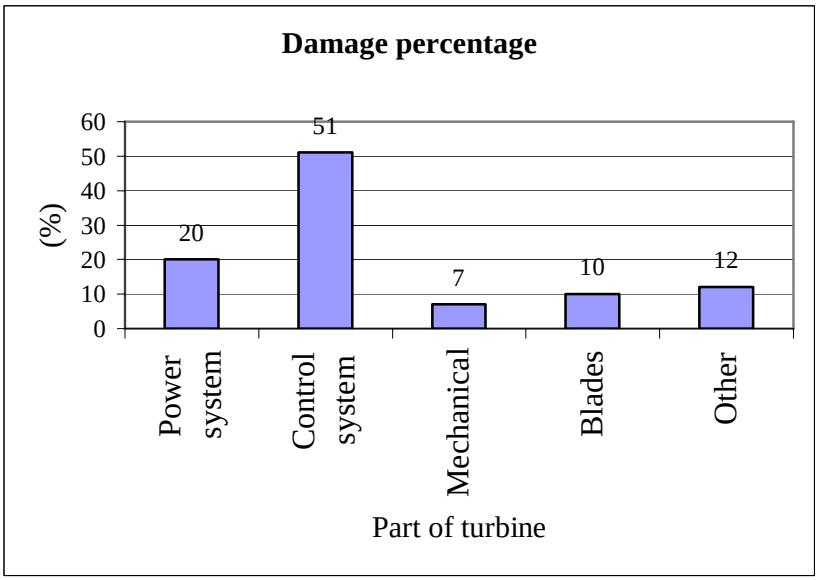

Figure 1: Damage percentage distribution of the various wind turbine parts

When analyzing the wind turbine damage parts distribution, it was found that there is a difference between small and great wind turbines. The difference seems to appear due to the lightning protection application in newer and greater wind turbines.

In Figuge 2 the damage of wind turbine distribution is presented during the year in Denmark.

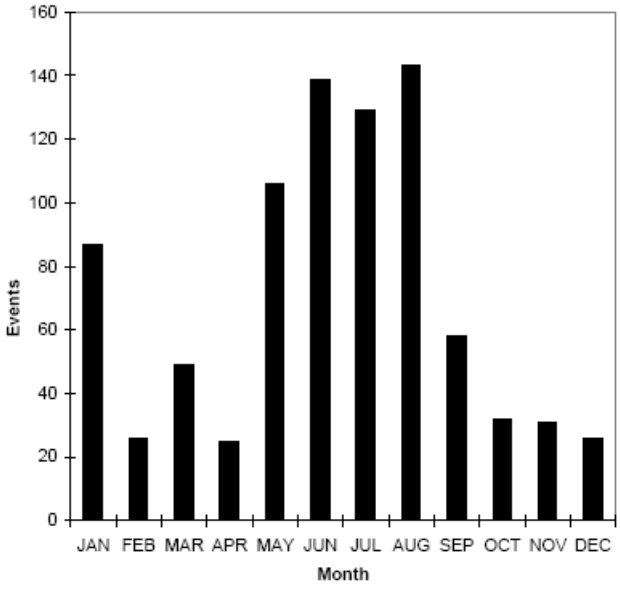

Figure 2: The damage of wind turbine distribution during the year

It can be noticed that the most important thunder activity leading to wind turbine damages happen in summer, but winter thunder activities are also significant, specially in January.

3. WIND TURBINE LIGHTNING PROTECTION

3.1 BLADE PROTECTION

Modern wind turbine blades are made from composite materials as glass or carbon reinforced plastics, or combination of wood and plastics. Blades are made from two separate surfaces with internal carrying construction glued together at leading and trailing edge making hollow core along the whole blade. The blade material is very inflammable.

In the case of direct lightning strike to the blade surface, lighting current can penetrate through small hole at a surface into inner hollow volume, propagate towards shaft causing the high temperature arc, melting material and increasing pressure giving the possibility the blade to explode.

From this reason it is very important to protect blade from direct lightning strikes. It can be done by mounting one or more of metal pieces like buttons called receptors at the blade surface near tips, connected with internal down conductors along the blade to the blade root, like in Figure 3.a. The main concern is about protection efficiency of the unprotected blade surface between receptors. It was found that for blades shorter than 20 m one receptor near the blade tip is enough, and for longer blades more receptors should be applied. Receptors can be also made as metal wires fixed at the blade surface, connected to the blade root, like in Figure 3.b. The application of this kind of protection shows week point due to the erosion and corrosion of the metal wires. It is also possible to install metal mesh at blade surface or just under it, connected with down conductors to the blade root, like in Figure 3.c.

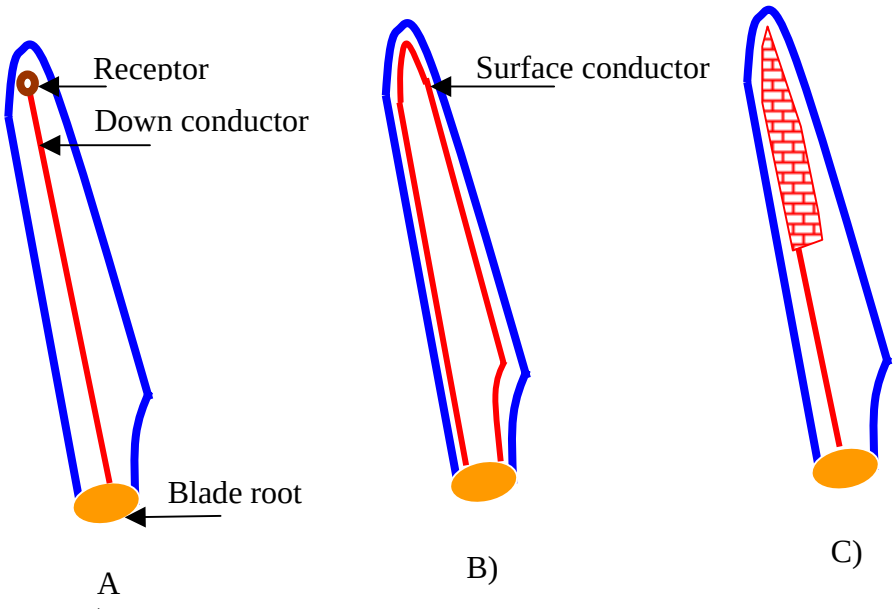

Figure 3: Blade lightning protection: a) surface point receptors,
b) Linear receptors, c) mash receptors

One of the solutions of blade lightning protection instead of placing lightning air termination system at the blade surface, is to make blade surface conducting. This solution is applied in aircraft industry. Lightning protection of glass and carbon fiber composite materials for wings is applied by adding conducting materials to the wing outer layer. The damage due to the direct lighting strike is reduced to a very small area around the attacked point and the rest of wing is completely protected.

If wind turbine blades are made without any kind of lightning protection system, it is possible later to cover the blade surfaces with adhesive metallic tapes. It can be applied for couple of months and for single lightning strike. After certain period or lightning a new adhesive conducting tapes should be applied.

In Figure 4 the photography of blade surface equipped with button receptor is presented.

Figure 4: Blade surface with button receptor

In Figure 5 the wind turbine blade lightning impulse voltage test in high voltage laboratory is presented.

Figure 5: Wind turbine blade lightning impulse voltage test

3.2 BEARING PROTECTION

The second important requirement in lightning protection of the wind turbines is to conduct lightning current from blade by down conductor to the tower and grounding of the wind turbine avoiding all sensitive parts like bearing, gearbox or generator. One of the easiest ways to solve this problem is to conduct lightning current across the sliding contact at the main shaft, and bearing base. like in Figure 6.

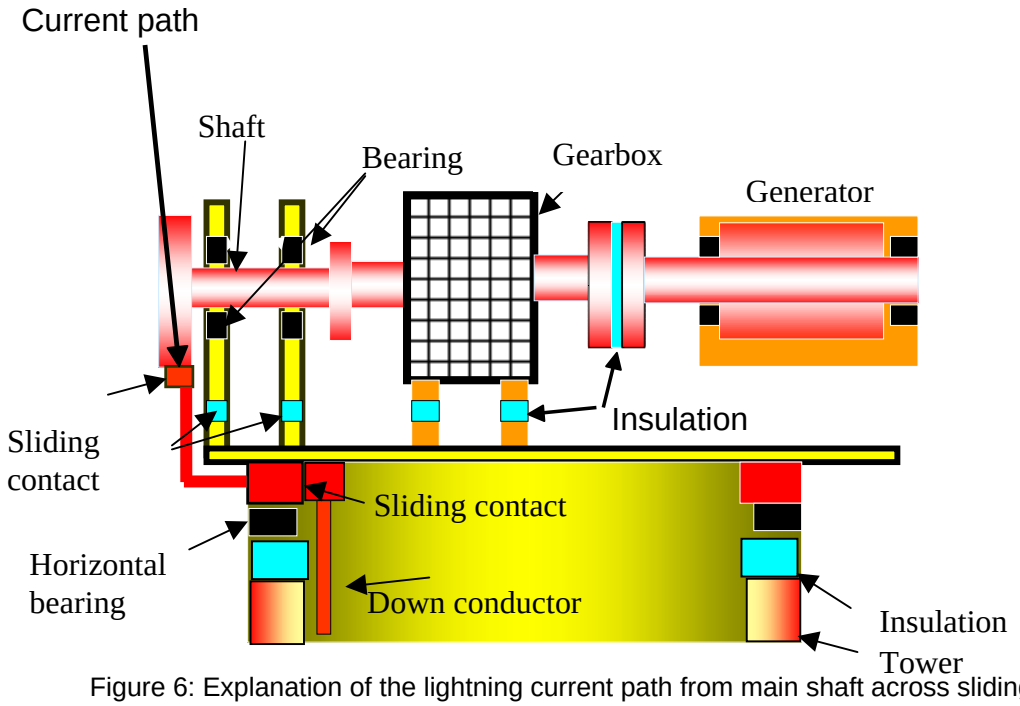

Figure 6: Explanation of the lightning current path from main shaft across sliding contact at shaft and at tower above horizontal bearing

In Figure 6 it is presented the current path from main shaft, avoiding bearing by insertion of the insulation barriers under horizontal main shaft and under horizontal bearing at the tower. Current passing the bearing can cause acceleration of the aging of the bearing. It is non evidented that lightning strike immediately damaged bearing, but erosion can significantly short bearing life.

3.3. OVERVOLTAGE PROTECTION OF ELECTRICAL CIRCUITS

Overvoltages generated by direct lightning discharges can damage power, control and command circuits insulation and different control and measuring instruments Overvoltage protection can be

performed in a same way as any other low voltage electrical circuit installation, applying surge protective devices (SPD). Main elements applied in SPD are:

1. Spark gaps
2. Surge arresters
3. Gas arresters
4. Varistors
5. Overvoltage diodes
6. Electrical filters

4. PRESENTATION OF THE DAMAGE OF THE WIND TURBINE OF 0,5 MVA

Wind turbine placed at place Vilusi was manufactured in 1997, before the IEC technical report concerning lightning protection was published. It was not equipped with any lightning protection system, except a small lightning rod above the generator, about 20 m below the blade tip when it is in vertical position. It was mounted in October 2004, but it was not in operation because it was not technically accepted. In January 1995 during snowstorm it was a strong thunderstorm. A lightning strike to one blade of wind turbine happened. It damaged completely one blade, which fall down, like in Figure 7.

Figure 7: Wind turbine without one blade struck by lightning

In Figure 8 the blade root of the damaged blade is presented. It can be seen that a strong fire completely destroyed hub.

Figure 8: Destroyed wind turbine hub

Other blades have damaged surfaces couple of meters from hub, like in Figure 9.

Figure 9: The damaged surfaces of the other blade

The hit blade found at ground has a small entrance hole nearly without damage at surfaces. Going to the blade root the damage increased, melting the inside material of the blade, separating blade sides due to the high pressure and producing stronger fire closer to the blade root. In Figure 10 the entrance hole is presented.

Figure 10: Entrance hole at blade surface

It was found that the main reason of wind turbine damage was the absence of any lightning protection system at the blades. No damage to low voltage instalation and equipment in tower base and in transformer substation was found.

5. Conclusion

The lightning protection of the wind turbines is an extremely important requirement. Blades protection can be performed by various methods, like discrete receptors connected by down conductors to blade root, surface wires or conductive surface. It is also important to protect bearings from direct lightning current flow. The example of the destroyed wind turbine struck by lightning is presented.

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