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LIGHTNING PROTECTION SYSTEM FOR WIND TURBINE BLADE

Naumanulhaq Barkatullah Shaikh[*1], under Guidance of **Prof. Jumed Khan**[2]
[*1]Student of Mechanical Engineering. DSQIE&T, Aurangabad (M.S) India
[2]Asst. Prof. Department of Mechanical Engineering. DSQIE&T, Aurangabad (M.S) India

ABSTRACT

The number of direct lightning attachments has risen dramatically in the past decade, along with the increased size of wind turbines and the trend toward placing them in harsh environments, particularly offshore. The object of this paper is to provide a system which in a simple, inexpensive and reliable to protects a wind turbine blade against strokes of lighting.

Keywords: *receptor, metal foil, down conductor, segmented metallic diverter.*

I. INTRODUCTION

In early wind turbine (windmill) installations was often not considered as a threat, or the nature of the threat was not well understood; however over recent years there have been a large number of lightning strikes reported to wind turbines and in many of these there have been instances of severe damage.In order to operate efficiently, and extract the maximum useful energy from wind, wind turbines are necessarily situated in relatively windy regions whenever possible. Modern wind turbines are often very large structures towering above the landscape, and many wind turbines are subjected to strokes of lightning every year. A stroke of lightning can involve extremely strong currents of the magnitude 10 to 200 kA within a very short period. Damages caused by strokes of lightning vary from short interruptions of the production due to for instance blown fuses, to severe damages where one or more of the blades are damaged, which in turn can cause damages on the entire structure. During recent years systems for protection of wind turbines against strokes of lightning have accordingly been developed.

However, such regions tend to be located in the more inhospitable and remote parts, and further often suffer from a relatively high incidence of thunder storms. Topology and geography dictate the incidence of lightning, creating large regional differences with notable hot spots of activity. Some extreme wind turbine sites experience 10 strikes a day, with lightning typically attaching to one of the blades. In such situations, both the current flowing through the turbine and the magnetic field created by it can interfere with the electronic equipment in the nacelle, the housing that covers the drive components in a wind turbine. This makes is desirable to provide such wind turbines with lightning protection to mechanical as well as electrical and electronic parts in order to minimize the downtime and number of repairs that might be needed.

WO 96/07825 discloses a lightning protection system for wind turbine blades, where the blade tip has been provided with a so-called lightning receptor of electrically conducting material. This lightning receptor can "catch" a stroke of lightning and lead the lightning current downwards through a lightning down conductor which extends in the longitudinal direction of the blade and which is earthed through the wind turbine hub. This system proved to provide a particularly efficient protection.

II. OVERVIEW OF LIGHTNING PROTECTION SYSTEM

The generic problem of lightning protection of wind turbine blades is to conduct the lightning current safely from the attachment point to the down conductors, in such a way that the formation of a lightning arc inside the blade is avoided. This can be achieved by diverting the lightning current from the attachment point along the surface to the blade root using metallic conductorseitherfixedtothebladesurfaceorinsidetheblade.Anothermethodistoadd conducting material to the blade surface material itself, thus making the blade sufficiently conducting to carry the lightning current safely to the blade root. Variations of both these methods are used with wind turbine blade.

III. COMPONENTS

Lightning Receptor with Segmented Lightning Diverter:

A lightning protection system for wind turbine blades, where the blade tip has been provided with a so-called lightning receptor of electrically conducting material. This lightning receptor can "catch" a stroke of lightning and lead the lightning current downwards through a lightning down conductor which extends in the longitudinal direction of the blade and which is earthed through the wind turbine hub. This system proved to provide a particularly efficient protection.

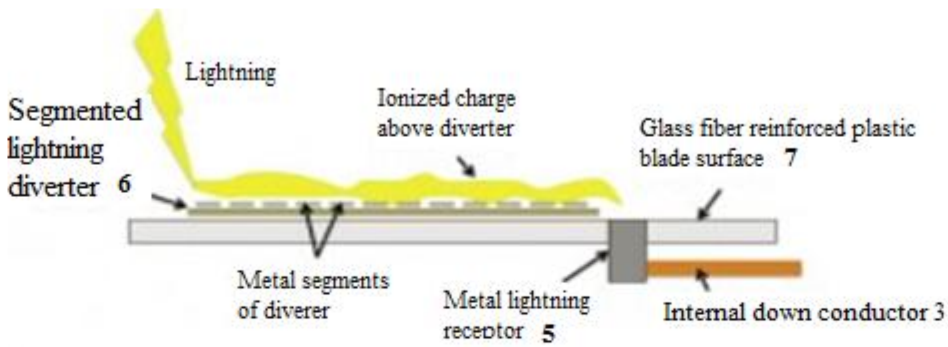

Figure a -Segmented metallic diverter (flow of lightning current)

Blades have used heavy-duty lightning receptors 5 spaced along the blade's span 7 with a large internal down conductor 3 located through the center of the blade, providing a low resistance path from the receptors to the nacelle. The receptor and down conductor approach has shown success at conducting lightning energy. However, lightning punctures of this blade design are, unfortunately, still a common occurrence. The yellow lightning has struck the tip of a blade where it is guided by the lightning diverter to a down conductor beneath the surface of the blade.

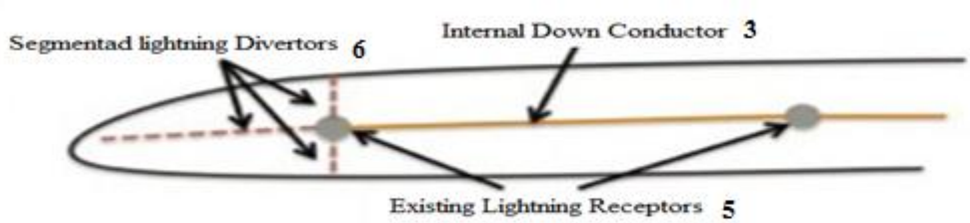

Figure-b: Typical lightning diverter configuration

Recent lightning research has found that lightning strikes tend to occur at the blade tip and rarely attach further than 4 or 5 meters from the tip. This conclusion follows common logic that lightning will tend to strike the highest object (Ben Franklin's lightning rods are a good example of this.) In fact, most lightning attachments occur within the first one to two meters of the blade's tip. As turbines and blades grow taller, they will initiate more lightning events, showing increased damage near the tip. These specifically designed devices consist of a line of small metal segments on a flexible substrate that, when exposed to lightning conditions, form an ionized channel above their surface to direct the lightning energy toward grounded metal structure. Segmented diverters are approximately 0.3 mm thick and 10 mm wide and can conform to the complex curvatures of the blade. A typical installation of segmented diverters to an in-service blade, the figure shows, segmented diverter from the outermost receptor to the tip, leading edge, and trailing edge of the blade. A standard two-part epoxy or double-sided tape is commonly used in the field to bond the diverters to the blade surface. Capable of conducting multiple lightning strikes, these segmented diverters force the lightning energy to the existing receptor. This simple modification can significantly reduce lightning punctures to the tip of the blade thereby keeping it in-service longer.

Down-conductor:
A solution to the problems with conductors placed on the blade surface is to have the lightning conductors placed inside the blade. Metallic fixtures for the conductor penetrate the blade surface and serve as discrete lightning receptors. Such protection systems are usedon aircraft. The lightning protection system used on many blades currently in manufacture has discrete lightning receptors placed at the blade tip (types A and B in Fig.3).

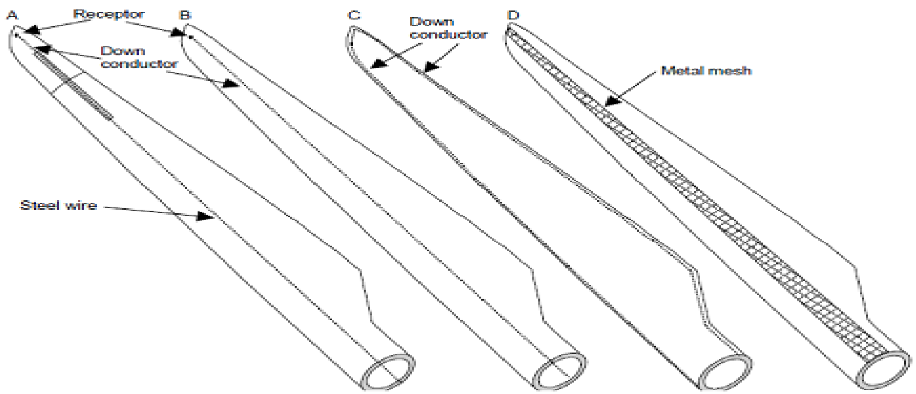

Figure-c. Down conductor

From the receptorsat the tip, an internal down conductor system leads the lightning current to the blade root. For blades with tip brakes, the steel wire controlling the tip is used as a down conductor (type A). If the blade is without tip brake, then a copper wire placed along the internal spar is used as a down conductor (typeB).

Several thousands ofblades with this lightning protection system (types A and B in Figure-c) have been produced. The experiences with this lightning protection system for blades as long as 20 m are very positive. The principle with one or more external air terminations connected to an internal down conductor has been used widely by many manufacturers for blades up to 60 m. For such long blades, experiencehas shown that there is a risk of direct lightning attachment through the laminate to the internal down conductor causing severe blade damage. These problems appear to be linked to uncontrolled partial discharges developing from the internal conductive parts (the down conductor, connection components,etc.).

When such low-energy partial discharges are allowed to be incepted from the interior metal parts of the blade, they will propagate equally fast as the ones incepted from the receptors.Once these internal discharges strike the interior surface of the blade, they will, in connection with partial discharges on the blades' exterior, intensify the electrical stress experienced by the laminate. The increased stress might not be a problem for a limited number of rapid fieldchanges (lightning striking receptors or nearby structures), but when the blade is exposed to several impacts during its entire service lifetime, the stress might eventually develop into a complete electrical breakdown. The physical impact on the blade from such a high voltage breakdown channel is rather limited, but the damage associated with the following lightning current will be disastrous.

Such discharges may be **impeded or delayed by encapsulating the internal down conductor**and other conductive parts in the blade with electrically insulating material, thereby reducing the problem. Internal down conductors are mainly heavy duty metallic wires capable of conducting high intensity strokes or discharge current to earth.

IV. WORKING OF LIGHTNING PROTECTION SYSTEM

Wind turbine blade comprising, characterized in that said wind turbine blade 7 is provided with a lightning conductor system and comprising a lightning receptor 5 at the tip and along with blade surface of the wind turbine blade. A encapsulatedinternal down conductor 3 electrically connected to said lightning receptor 5. It is inserted in a cavity of the blade. The lightning receptor 5 is earthed 2 by the internal conductor 3. This earth connection 2 is, of course, provided through the hub 13 and the tower 1 of the wind turbine. Segmented lightning diverter 6 which is glued on external surface of blade electrically connected with receptor 5.

1. Internal conductor 3 is inserted in a cavity in the blade. It passes through the hub 13 the tower 1 of wind turbine.
2. The metallic fixtures penetrate the blade surface which work as a receptors 5 or externally arranged on the surface of the wind turbine blade 7.
3. Segmented Lightning Diverter 6 are made up of metal foil and glued on the wall or external surface of blade 4.
4. Segmented lightning diverter (6) are electrically connected to receptor (5).

Wind turbine blade is provided with a lightning conductor system and comprising a lightning receptor 5 along with segmented metallic diverter 6 at the tip 10 of the wind turbine blade and internal down conductor 3 electrically connected to said lightning receptor 5. When lightning strikes, segmented diverters 6 force the lightning energy to the existing receptor and this lightning receptor 5 "**catches**" a stroke of lightning and lead the lightning current downwards through a lightning down conductor 3 which extends in the longitudinal direction of the blade 7 and which is earthed 2 through the wind turbine hub 13. As a result a wind turbine blade element is efficiently protected against strokes of lightning. The lightning current being carried safely from attachment point to the internal down conductors, without formation of arc inside blade. This high voltage current leads to earth through the internal down conductor 3.

V. BRIEF DESCRIPTION OF THE DRAWINGS

The lightning protection system is explained in greater detail below by means of preferred embodiments illustrated in the drawing, in which
FIG. 1 is a front view of a wind turbine,
FIG. 2 is a front view of a wind turbine blade and a wind turbine hub,
FIG. 3 is a cross sectional view through a preferred embodiment of a wind turbine blade,
FIG. 4 illustrates the tip of a wind turbine blade,

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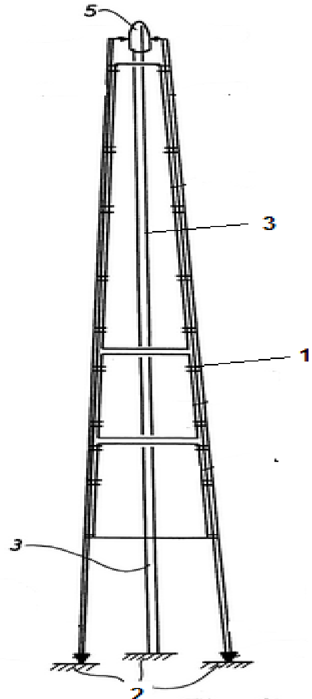

Fig. 1

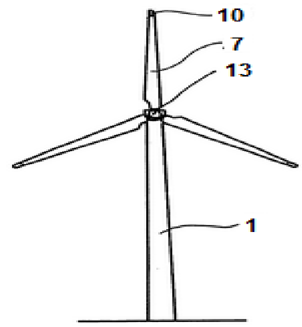

Fig. 1

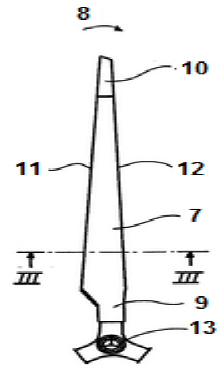

Fig. 2

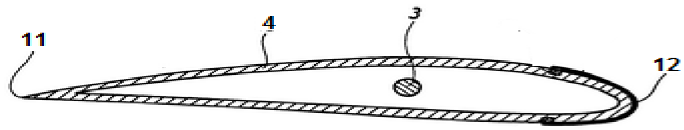

Fig. 3

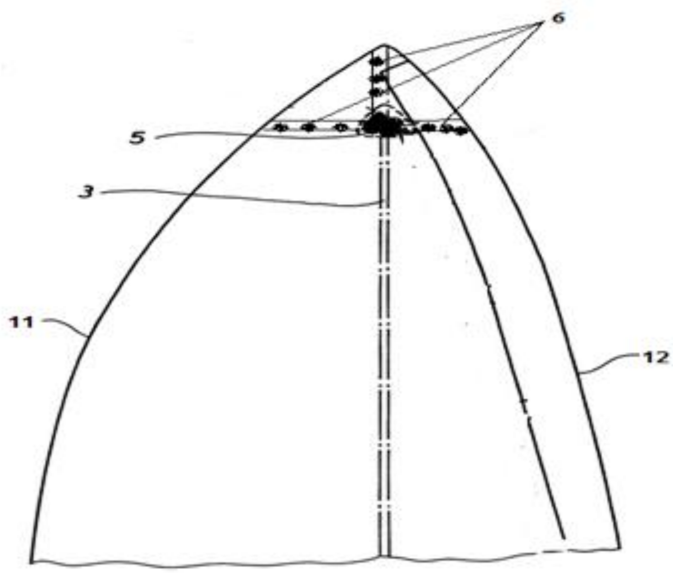

Fig. 4

The wind turbine shown in **FIG. 1** comprises essentially a tower 1, a wind turbine hub 13 and three blades 7, which in the illustrated embodiment are provided with a pivotal tip 10. The tip 10 can be turned 90° relative to the remaining portion of the blade and operate as an air brake. **FIG. 2** illustrates on a larger scale one of the wind turbine blades 7. The portion of the blade 7 adjacent the hub 13 is called the blade root 9. During operation of the wind turbine, the blade turns in a direction of the arrow 8. The rim positioned in front in the direction of rotation is called the front rim 12, and the rim positioned at the back in said direction of rotation is called the rear rim 11. The tip 10 can be rotated about its longitudinal axis relative to the remaining blade 7. The pivotal connection between the tip 10 and the remaining blade 7 is provided by means of a shaft 14, typically a carbon fiber shaft, in a manner known per se and which is therefore not described in greater detail here. Internal down conductor 3 does not appear from **FIG. 2**, but it extends internally in the shaft 14. The internal down conductor 3 which is insulated by high quality insulating material can be formed by a wire which is used for controlling the tip 10.

FIG. 3 is a cross sectional view taken along the line III—III through the wind turbine blade of FIG. 2. The blade is a monocoque construction with an internal cavity. The details shown in FIG. 3 will be explained below.

FIG. 1 is a diagrammatic view of a preferred embodiment of portions of a wind turbine blade. The portions illustrated are of a geometric extent corresponding to the geometric extend of the wind turbine blade, and they include a lightning receptor 5 at the tip of said wind turbine blade, internal down conductor 3, earthing 2. The lightning receptor 5, viz. the lightning conductor, is formed by a metal part exposed at the tip of the blade and capable of catching a stroke of lightning. The lightning receptor 5 is earthed 2 through the electric conductor 3. This earth connection is, of course, provided through the hub 13 and the tower 1 of the wind turbine. In case of strokes of lightning, segmented lightning diverter 6 force current to existing receptor 5 and the lightning current is immediately carried from attachment point to earth through internal down conductor 3.

FIG. 4 illustrates the blade tip and the segmented lightning diverter 6 which are connected with receptor 5. Receptors 5 are penetrated across blade surface are connected with Internal down conductor which insulated internally carries lightning current to ground. Segmented lightning diverter 6 (are connected to receptor 5) can also be glued onto the surface of the wind turbine blade without considerably changing the aerodynamic properties thereof. And receptor 5 which are either penetrated through blade surface or externally mounted on the surface.

VI. ADVANTAGES

- Minimize the downtime and number of repairs
- Protection of structure from lightning
- Very simple protection system
- Reliable structure
- Effective protection during lightning
- Strength to carry strokes current energy to earth
- Highly insulated internal down conductor causes no internal harm
- Light will be catch and force towards receptor by segmented lightning diverter due to which no stress formation inside or outside structure as well as less possibility of breakdown.

VII. CONCLUSION

It is necessary to LPS for each and every part of WT. Extensive measures are required to protect WT from lightning. For example lightning receptors incorporated into the blades, as well as other LPS elements introduced into different WT parts, particularly blades and nacelle, such as the low-inductance down-conductors circumventing crucial parts of the WT (e.g., generator and gearbox if present), low-voltage SPD equipment, etc. Intensive work is needed in field of improvements to LPS design, and siting of wind turbines

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