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EXPERIMENTAL STUDY for WIND TURBINE BLADES LIGHTNING PROTECTION

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Various lightning protection measures are used for the wind turbine blade. Although in a lot of wind turbines, lightning protection measures which consist of lightning attachment points and down-conductors for allowing lightning current to flow to the earth safely are generally adopted, the influences of shape and the size etc. of the receptor on the effect of the lightning protection are slightly reported. In this paper, the results of the high voltage impulse tests to understand the difference of manner of lightning attachment are reported. Actual 29.5m length wind turbine blades are used for some tests.

Keywords: wind turbine, blade, lightning protection, receptor, down-conductor

INTRODUCTION

In recent years, lightning damages to wind-power plants are increasing as the number and size of installed wind turbines are becoming rapidly larger. Lightning damages to the wind turbine blades are quite serious since the cost for replacements is remarkably high and long repair time is necessary. It is worried as an obstruction factor to the expansion of the wind turbine installation[1].

Especially, it is well known that winter thunderstorms of the coast of the Japan Sea in Hokuriku and Tohoku where wind condition is good have unusual energy (100 times as such as or more than that of usual summer thunderstorms). Therefore, the damage to wind turbine is also extensive[2].

It is generally said that the phenomenon responsible for the severe structural damage to wind turbine blades is the formation of a pressure shock wave around an arc of lightning inside the blade[3]. Namely, it is important to prevent lightning streamers from entering the blade cavity in order to decrease the damage to wind turbine blades.

In a lot of large wind turbines, lightning protection measures which consist of lightning attachment points and down-conductors for allowing lightning current to flow to the earth safely are adopted. However, the influences of the shape and the size etc. of the receptor on the effect of the lightning protection are slightly reported, and the information to design the blade lightning protection are insufficient. In the IEC technical report etc., only design criteria for the receptor and down-conductor are described, and the shape and the arrangement etc. of the receptor are not described.

Therefore, we have investigated more effective blade lightning protection measures through the high voltage impulse tests to understand the difference of manner of lightning attachment due to parameters of the receptor's shape and size, blade attitude, discharge polarity and so on. These valuable experimental results have contributed the lightning protection blade development[4],[5].

HIGH VOLTAGE IMPULSE TESTS USING BLADE MODEL

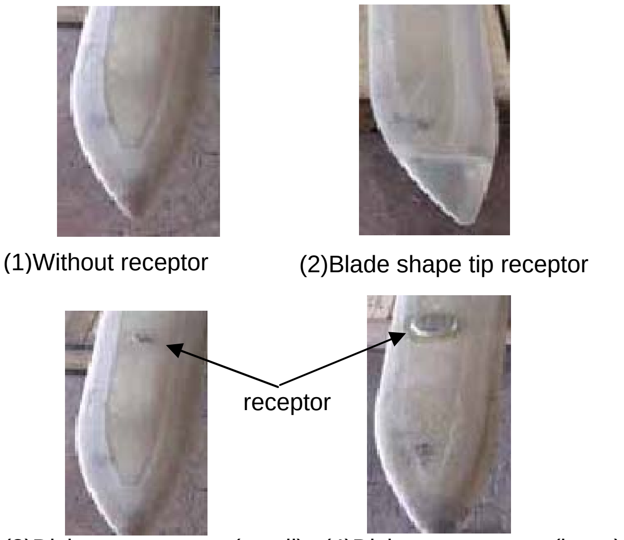
High Voltage Impulse Tests

In order to understand the difference of manner of lightning attachment due to the influences of shape and the size etc. of the receptor, the high voltage impulse tests were executed by using 3m-length partial blade models of 300kW-class wind turbine blade made of GFRP.

Different configurations of blade models were equipped, such as (1) a blade without any lightning receptor, (2) a blade with a tip receptor of blade shape and a down-conductor, (3) a blade with disk type receptors (small ones) and a down-conductor, (4) a blade with disk type receptors (large ones) and a down-conductors shown in Fig.1. The specifications of each blade model are shown in Table 1.

Table 1. Specifications of each blade model

	Specifications
model1	There are no receptor and down-conductor.
model2	The receptor of blade shape made of aluminium is prepared for from the blade tip to 245mm.
model3	The disk type receptor of 40mm in the diameter is screwed in the base plate of 150mm in the diameter in blade. The material of receptor is SUS. The receptor is at the position at 960mm from blade tip.
model4	The disk type receptor of 110mm in the diameter is bolted to the base plate of 110mm in the diameter in blade. The material of receptor is SUS. The receptor is at the position at 960mm from blade tip.



(1)Without receptor (2)Blade shape tip receptor

(3)Disk type receptor (small) (4)Disk type receptor (large)

Fig.1. Blade models for high voltage experiments

The experiments were performed by simulating lightning discharge with a 12 MV Impulse Generator at Shiobara testing laboratory of CRIEPI. In the experiments, the distance between the electrode and the blade model was 3m to 4m, and a relative position of the electrode and the blade model and the electrical discharge polarity have been changed. The switching impulse waveform was used for the tests. Experimental conditions are shown in Fig.2 and Table 2.

Table 2. Experimental conditions for high voltage experiments

relative position of electrode and blade	under back, forth, right and left 30 & 45 degrees (refer to Fig.2)
azimuth angle of blade	0, 30, 45, 90 degrees (refer to Fig.2)
electrical discharge polarity	positive and negative

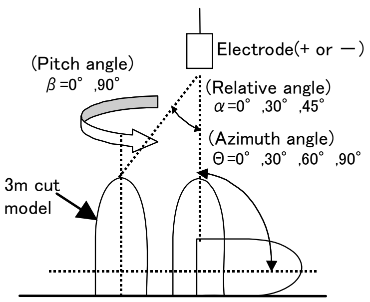


Fig.2. Experimental setup for blade model

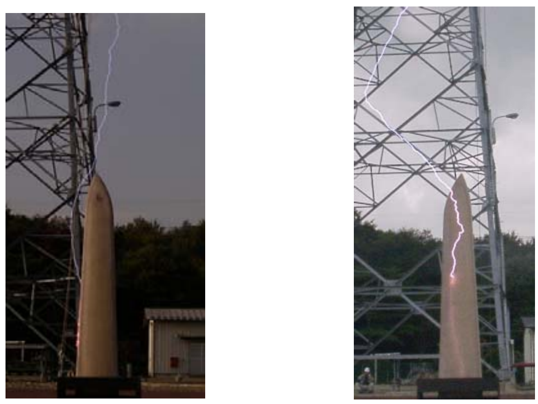
In this experiment, it is assumed that the electrode is a downward leader.

The results in which the blade model was under the electrode in case of the positive polarity are shown in Table 3 as a typical case, because there were a lot of examination cases.

Table 3. Experimental results

	Flashover frequency to blade	Flashover frequency to inside of blade
model1	8	0
model2	20	0
model3	11	2
model4	9	3

In model1, the electrode-to-ground discharge was observed frequently, and creeping discharges along the surface of the blade sample were also observed several times as shown in Fig.3. Moreover, the penetration discharge into the blade was occasionally generated.



(1)Creeping discharge along trailing edge (2)Penetration discharge into the blade

Fig.3. High voltage experiment for no receptor blade

(a)Discharge manner to blade shape receptor (b)Discharge manner to small disk receptor (c)Discharge manner to large disk receptor

Fig.4. High voltage experiment for receptor blade

In model2, almost discharges attached to the tip receptor. However, discharges on the boundary of receptor and outer skin were seen as shown in Fig.4(a).

In model3, a lot of electrical discharges that invaded the inside from the blade point and got to the receptor base plate were observed as shown in Fig.4(b).

In model4, a lot of electrical discharges that invaded the inside from the attachment point and got to the receptor base plate as well as model3 as shown in Fig.4(c) were observed.

The frequency of direct discharges to receptor increases in model2-4 in the tests of a negative polarity as for the same condition.

The following can be said from these examination results.

1) The electrical discharge may invade the blade not via receptor.

2) The electrical discharge with positive polarity invades easily into blade compared with the negative polarity electrical discharge.

3) The receptor on the blade tip is easy to receive a direct electrical discharge.

4) The electrical discharges that invade from tip of blade and reaches an internal conductor are generated when the disk type receptor is installed in outer skin of blade.

Experiments by Real Blade

In the experiments using 3m-length partial blade model, all downward leaders were simulated. However, upward leaders are observed in actual lightning, and they are frequently observed especially in winter of Japan.

Then, upward leader experiments were executed by using real blade, and the data of the electrical discharge aspect were acquired.

Fig.5. High voltage experiment for real blade

Blades used to experiment are for 1000kW wind turbine, and the length of blade is 29.5m. In the blade tip, receptors of the disk type and the rod type are equipped, and in the middle of blade, disk type receptors are equipped. The receptors are connected to the down conductor, and the one end of down conductor is connected to the high voltage impulse generator.

Fig.5 shows the photograph of the experiment. High impulse voltage was applied to the down conductor, and we confirmed where the electrical discharge was generated.

The experiment results were shown in Table 4. In the experiments of positive impulse voltage, the rate of electrical discharges from receptors was 100%. However, in the experiments of negative impulse voltage, the rate of electrical discharges from receptors was 70%, and the remainder was the electrical discharge from the down conductor.

Table 4. Experimental results for real blade

Discharge polarity of blade receptor	Electrical discharge frequency	Electrical discharge frequency from except receptor	Receptor Capture Rate
Positive	30	0	100%
Negative	30	9	70%

Notice: In this experiments, it is assumed that the earth is a thunder-cloud.

The polarity of the electrode shows the polarity of the downward leader in the preceding experiments. On the other hand, the polarity of this experiment is a polarity on the blade side, and it is necessary to note that the polarity of the thunder-cloud is opposite. Moreover this experiment showed that the discharge stroke the side receptors occasionally.

Lightning currents are measured for real wind turbine equipped with such receptors. Fig.6 is a photograph when 600kW wind turbine was struck by lightning strike. Lightning strike point was the blade tip receptor. The wind turbine was not damaged. Moreover, although lightning with the total charge of 739C was received by the receptor of the 1000kW wind turbine at another site, the blade had no damage.

Fig.6. Photo on the lightning attack to 600kW wind turbine in Japan

We will improve the lightning protection method for wind turbine by piling up results in the future.

CONCLUSION

In this paper, the experiments to confirm the lightning aspect to the wind turbine blade using the high voltage impulse generator were conducted, and the following results were obtained.

1) The electrical discharge might invade an insulated surface of a blade instead of receptors.

2) The receptor on the blade tip is easy to receive a direct electrical discharge.

3) The discharge of a positive polarity easily attached to an insulated surface of a blade, on the other hand the discharge of a negative polarity attached to the receptors.

We will continue the lightning current measurement of actual wind turbines and develop improved lightning protection method for wind turbine blades.

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