Case study of Lightning Stroke on Wind Turbine Blade in Middle Taiwan

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***Abstract*-- Due to lack of natural resource and the potential to develop wind farm, Taiwan has built more than 100 sets of wind turbine generators. According to globe statistics, the majority of wind turbine generator failure is lightning stroke. Taiwan also faces on this threat even though the wind farms are away the high lightning flash density area. A lightning stroke case is illustrated to explain how lightning stroke damages wind turbine generator, and the withstand lightning current test is recommended.**

***Index Terms*—lightning stroke, wind turbine, lightning current**

I. Introduction

Taiwan is one of the nations without natural energy sources, and the energy development is hence restricted. Due to the area with the average wind speed up to 5 m/s is about 3,000 km^2 in Taiwan and the Taiwan Strait has the potential to be a good wind farm, the wind energy is suitable for Taiwan to generate electrical power. Besides, the total amount of wind turbine generators is increasing in Taiwan complying with the progress of wind turbine. Up to May, 2008, the amount of installed wind turbine generators is more than 100 sets.

In Taiwan, the common reasons causing the wind turbine generator failures are wind turbine blade damaged by strong season wind, IGBT breakdown caused by the heavy pollution of salt fog, and wind turbine damaged by lightning. According to the statistics, the most threat to the wind turbine generators is lightning. Therefore, this paper addresses the influence of lightning on wind turbine generator, and an wind turbine generator event is taken as an example.

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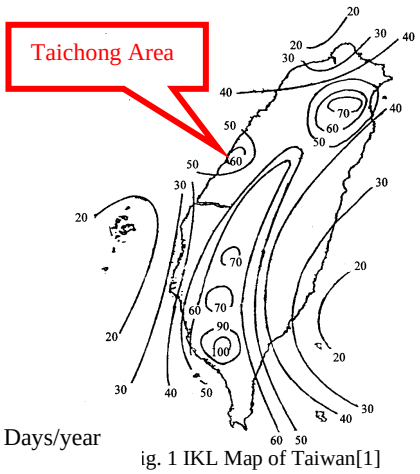
Figure 1 shows the isokeraunic Level of Taiwan, and figure 2 is the lightning flash density of Taiwan. Fig. 1 and Fig. 2 show that Taiwan is a high lightning density area. Because the wind farm is usually located close to the coast, the probability of wind turbine generator stroke by lightning is higher.



ig. 1 IKL Map of Taiwan[1]

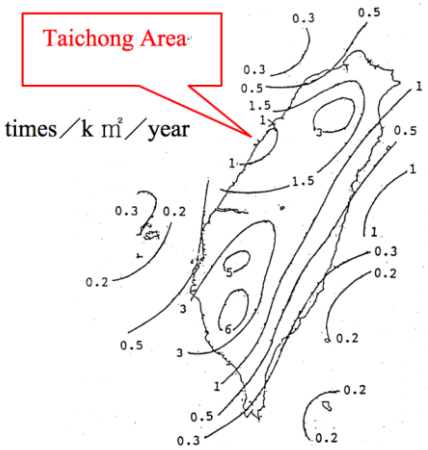
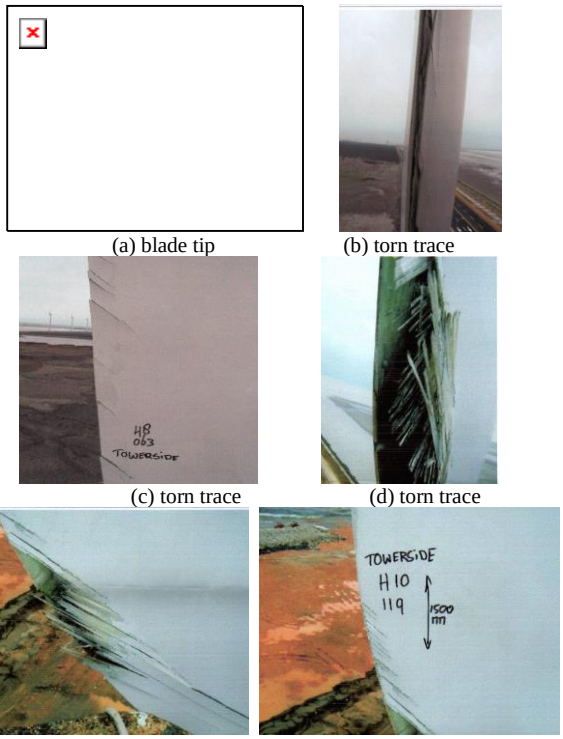


Fig 2 Lightning flush denisity of Taiwan[1]

In 26th May 2008, one wind turbine is stroke by lightning and the blade is damaged. This paper takes this case as an example to explain how can lightning damage wind turbine blade. By the inspection of damaged blade and by the review of the lightning data from lightning location system(LLS), the main cause of the blade damaged is the insufficient capacitance of the withstand lightning current, and the blade is damaged by the electromagnetic force resulting from lightning current.

II. Case Description

At afternoon in 26th May 2008, the wind turbine blade located at TaiChung thermal power plant is broke by unknown reason.The broke blade is shown in figure 3. Fig. 3 shows that there was a lightning stroke on the tip of the blade, and the broke blade is torn by specific force instead of burned by heat.



(a) blade tip (b) torn trace (c) torn trace (d) torn trace (e) torn trace (f) torn trace

Fig. 3 damaged blade caused by lightning stroke

From the data gathered by LLS, there were lightning adjacent TaiChung thermal power plant as shown in figure 4. According to the lightning data, the lightning time and the event time is coincided. However, there is about 1 km mismatch between the location of lightnings and TaiChung thermal power plant as shown in figure 5. Because the timing system is synchronized by the network and the location always has certain system error, the lightning location is treaded as locating at the broken wind turbine generator.

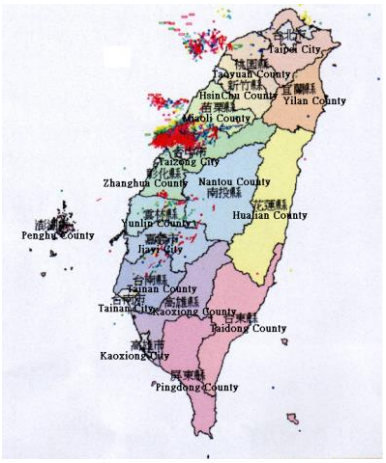


Fig. 4 lightning flash distribution recorded by LLS

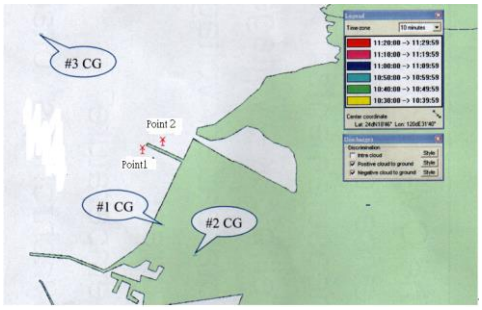


Fig. 5 recorded lightning flash location near Taichong

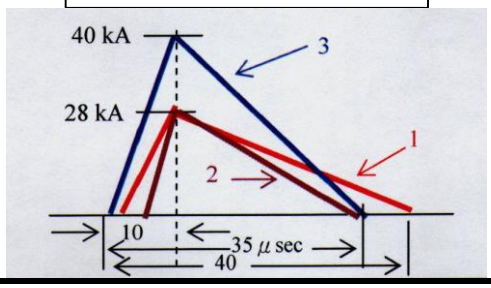
Table 1 shows the lighting data at that period, including lightning time, lightning current, lightning waveform, and lightning energy. Based on table 1, the amplitudes of these lightning currents is 27.5 kA, 28.5 kA, and 38.0 kA. Compared with the statistics of lightning in Taiwan, there is nothing special between average lightning current (33 kA) and the recorded lightning current.

Table 1 Lightning current recorded by LLS

	Time	I_{peak} kA	T_f μ ont	Tt μ ont	Energy kA^2 x μ sec
1	10:53:19	27.5	7.4.	41.0.	19.2
2	10:53:19	28.5	5.0	36.0	16.7
3	10:54:30	38.0	10.4	33.0	31.1

P.S. :1) the difinition of energy is $(I_{peak})^2 * (T_f + T_t)$

2) below chart shows the waveform of lightning current, and the area represents the lightning energy



III. PHENOMENA ANALYSIS

From fig. 3(a), the main cause of blade broke is lightning stroke. There are two ways lightning damaging wind turbine blade. One is burned by heat due to the lightning current alone the down conductors. Another is tore by the electromagnetic force induced by lightning current flowing alone the down conductors. There are no burning marks shown in fig. 3(b) to fig. 3(f), and the former reason can be excluded. The cracks shown in fig. 3(b) to fig. 3(f) are alone the down conductors, and are a kind of torn trace. Hence, the reason causing blade broke is the electromagnetic fore induced by the lightning current alone down conductors.

According to table 1, recorded lightning currents are not larger than the 200 kA lightning current specified in IEC 61400-24, and are closed to the average lightning current in Taiwan. Comparing recorded lightning waveforms with the lightning waveform specified in IEC, the recorded lightning waveforms is small as shown in figure 6. This implies that the withstand lightning current of the wind turbine blade is obviously insufficient.

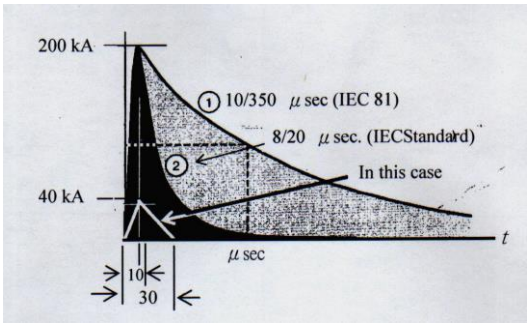
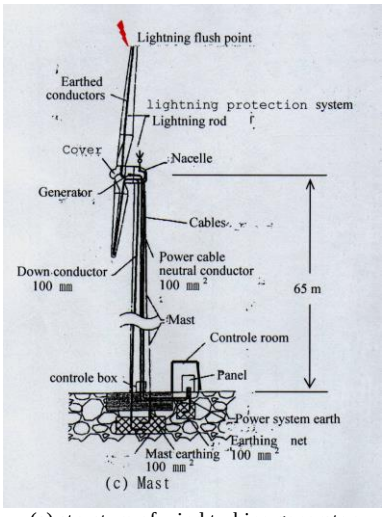
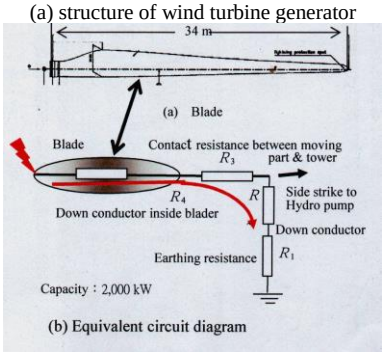


Fig. 6 Lightning current comparison between recorded data and IEC standard

Beside the wind turbine blade broke, there is side stroke happened between down conductor and hydro pump. Figure 7(a) is the structure of wind turbine generator, and figure 7(b) is the equivalent circuit of the ground path of the wind turbine generator. As lightning current flow through down conductors, the voltage distribution is formed by line impedance. Because the lightning current did not flow through the housing, the potential is close to ground potential. Hence, there is a large voltage drop between the down conductor and the housing, and the side stroke happened. This phenomenon verified that there was a lightning stroke on the wind turbine generator.



(a) structure of wind turbine generator



(b) equivalent circuit of wind turbine generator

Fig. 7 diagram of side stroke

IV. CONCLUSION

From fig. 1 and fig. 2, Taiwan is the area with high lightning flash density. Based on experience, the wind turbine generator can't prevent the lightning strike even if they are installed at the coast with normal lightning flash density.

In order to develop recycle resource, the amount of wind turbine generators will increase. Therefore, for improving the reliability of wind turbine generator, the lightning protection of wind turbine blade should be carefully mentioned to reduce the failure rate.

By the inspection of the damaged wind turbine blade, the main reason is the insufficient withstand lightning current of the wind turbine blade. In this case, the amplitudes of the lightning currents are under the average range. Hence, the wind turbine blade are recommended to be pass the withstand lightning current test, and the reliability of the wind turbine generator can therefore be improved.

V. REFERENCES

[1] Shih-Shong Yen "On Lightning Performance of Taiwan", The 5th Asian Conference on Electrical Discharge Singapore (Nov. 1992)