Lightning Attachment to Wind Turbine Blades

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Abstract. The lightning receptor is a device attached to the wind turbine blade which is purposely used to attract electric field from the lightning strike and assist the flow of the lightning current to the ground to protect the wind turbine blade from damage. As the objective of conducting this research, we are aimed to develop a new shape of wind turbine blade lightning receptor to maximize the probability of lightning protection to the wind turbine blade. To achieve the objective, we are required to investigate the practical parameters of the lightning protection system, including the relationship for the number of receptor needles in affecting the electric current strength accumulated around the receptor, and the relationship rotational degree of wind turbine blades in affecting the electric current strength accumulated around the receptor. Thus, the Finite Element Method (FEM) has been used for this research, with simulating a different number of receptor needles as the manipulated variable, while electric current strength accumulated around the receptor as the response variable for the project research study.

Keywords: Lightning receptor, Electric current strength accumulated, Finite Element Method.

1 Introduction to the Project

1.1 Introduction

The wind turbine is a generator where it is used to produces electricity from wind energy. Wind will turn the propeller-style turbine blades, where the rotor will follow on rotating, resulting in spinning on the generator shaft. The generator will function and produce electricity due to the kinetic energy of the shaft rotating in the magnetic field creating electromagnetic induction.

A lightning protection system is a special conductor metal attached or mounted on an object or structure which purposely used to protect the object or structure from a lightning strike. The lightning strike is very dangerous as it has a very high current and it can happen randomly anywhere and anytime. As the era is getting modern, there is a lot of object and structure nowadays installed with lightning protection system as human start knowing the importance of risk management, for example, aircraft, building, power transmission tower and generator.

For our project, lightning attachment to wind turbine blades, lightning protection system is installed purposely to protect the wind turbine from getting damaged by a lightning strike and conduct the overcurrent electricity through the lightning protection conductor to the earth. This is to reduce the damage made by a lightning strike to the external layer of wind turbine and wind turbine internal systems where financial loss and time loss due to the repairing can be minimized.

1.2 Project Background

Nowadays, alternative energy has become a new trend of energy source in the world as it is renewable energy despite the fossil fuel energy. Fossil fuel energy is producing energy from petroleum, coal, and natural gas where it is going to run out one day in the future with overcommit of it. There are many types of alternative energy in the world, such as solar energy, wind energy, hydropower, biomass, biofuel, and geothermal energy. In those alternative energy mentioned, solar energy and wind energy are more popular and used everywhere.

Wind farms are built to collect wind energy for energy generation purposes. From what we observed, there are more offshore wind farms established than onshore wind farms in the world. This is because offshore having higher and more consistent wind speeds where offshore wind farms have the potential to generate more electricity at a steadier rate than onshore wind farms.

However, lightning strikes have always become a problematic threat ever at offshore wind farms. Besides, the thermodynamic process generally started near shore with the potential of evolving into open water events where rising temperatures worldwide are causing frequency and severity of lightning strikes taking part in the offshore area. Therefore, the lightning protection system is needed and important to offshore wind farms especially the wind turbine blades as the blades are rotating all the time.

1.3 Problem Statement

Over a few decades, many types of research in lightning protection system for wind turbine had been done to configure the best method in protecting the wind turbine from getting damaged by the lightning strike, however, the character study of the wind turbine blade receptor is not easy and very challenging as it is related to many factors such as cloud charge and potential, electrical field and induced charges where the characteristic of lightning nature is difficult to determine and understand. Furthermore, it is more difficult to be applied in practice. Therefore, the high voltage electrical stimulation method would be suitable for application simulation. As the lightning strikes are natural and unmanipulated, therefore what we can do is design the lightning protection system of the object to protect the object from the lightning strike.

Problem statement. Is the design of the lightning protection system applicable to protect the wind turbine blade from lightning strikes effectively?

1.4 Objective

From the problem statement of the project listed above, the objective for this research, lightning attachment to wind turbine blades, had been developed to solve the problem occur. The objectives of the research project are listed down and explained as stated below.

Objective 1. To investigate the relationship for the number of receptor needles in affecting the electric current strength accumulated around the receptor.

1.5 Scope / Limitation

To achieve the objective stated above, we are required to set some scope or limitation as there are a lot of variables that may affect the outcome results. The scope or limitation that had set are listed as below.

- Wind turbine blade at 90 degree
- Length of the lightning receptor at 0.5 meters for each pin
- The same design of wind turbine blade
- Same material for lightning receptor as copper
- Same material for wind turbine blade as carbon fiber reinforced polymer

2 Technology

2.1 Introduction

We are using Comsol Multiphysics simulation software to analyze and simulate the project titled “lightning attachment to wind turbine blades”. Below showed the steps on running the software simulation for the project.

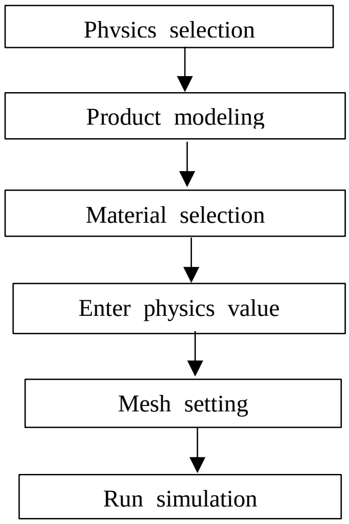

Fig. 1. Steps of software simulation.

3 Results and Discussion

3.1 Simulation Results

The Number of Receptor Pins. Under the condition of controlled variable as wind turbine blade at 90 degrees, length of the lightning receptor at 0.5 meters for each pin, the same design of wind turbine blade, same material for lightning receptor as copper and same material for wind turbine blade as carbon fiber reinforced polymer for every experiment, we have researched to investigate the relationship of the number of lightning receptor pins toward cumulative electric potential. Below showed the results of the simulation for the lightning receptor with 0 pins, 4 pins, 8 pins, 12 pins, and 16 pins.

Lightning Receptor with 0 Pins.

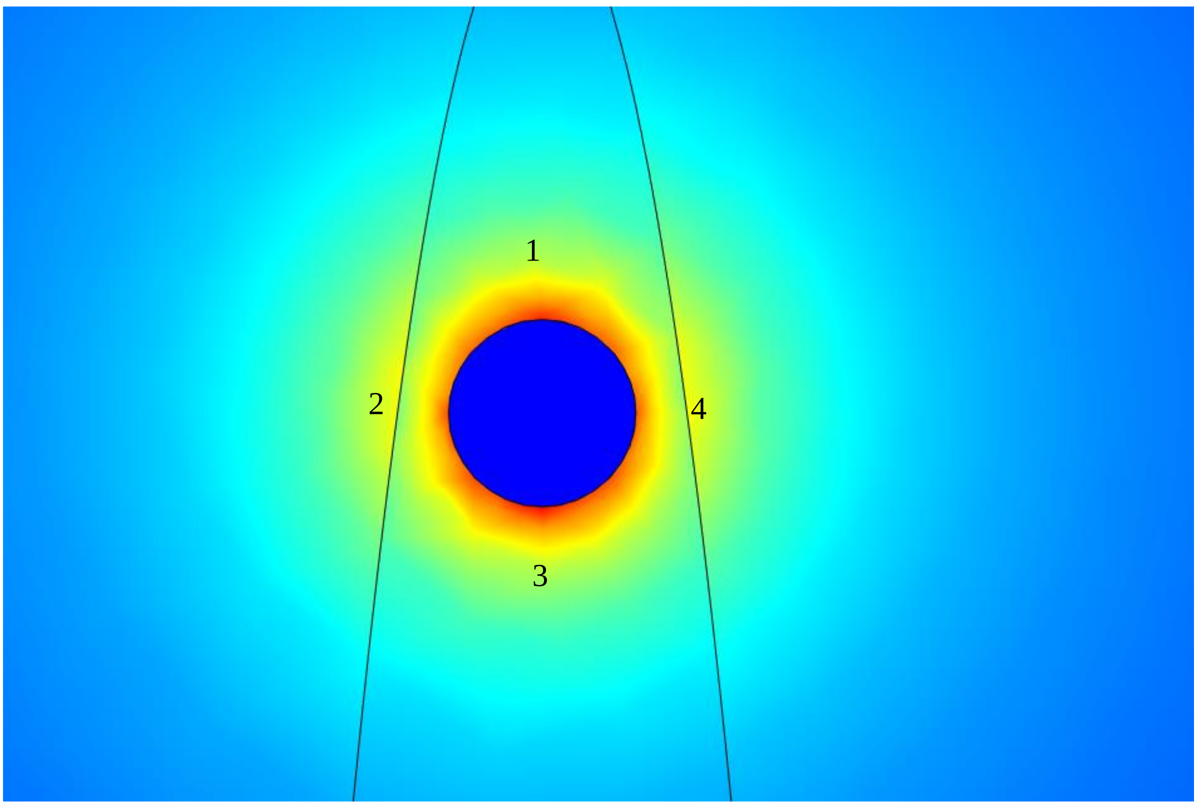

Fig. 2. Simulation result from lightning receptor with 0 pins.

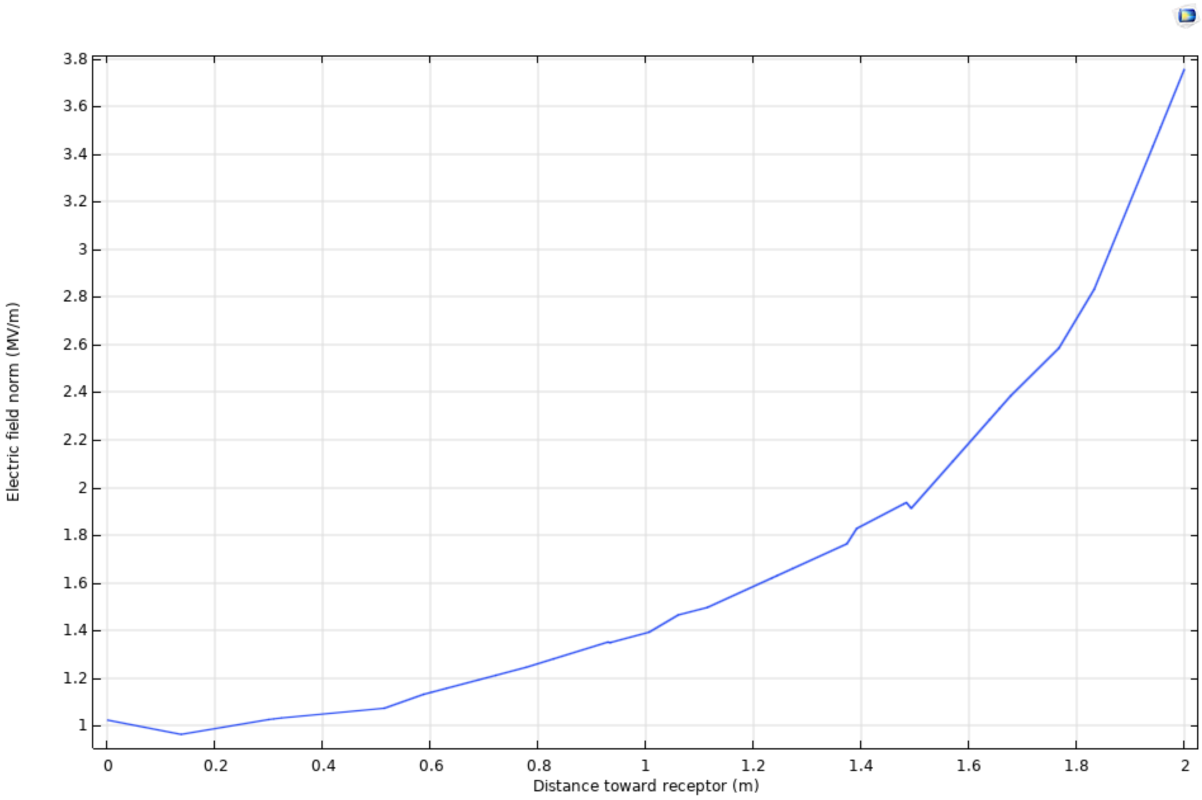

Fig. 3. Graph of the simulation result from lightning receptor with 0 pins.

0pins	Electric field norm (MV/m)	
Cut line 2D	min	max
1	1.024	4.0332
2	0.8861	3.8357
3	0.8575	3.4789
4	0.9011	4.3475
total	3.6687	15.6953
average	0.9172	3.9238

Table 1. Simulation result from lightning receptor with 0 pins.

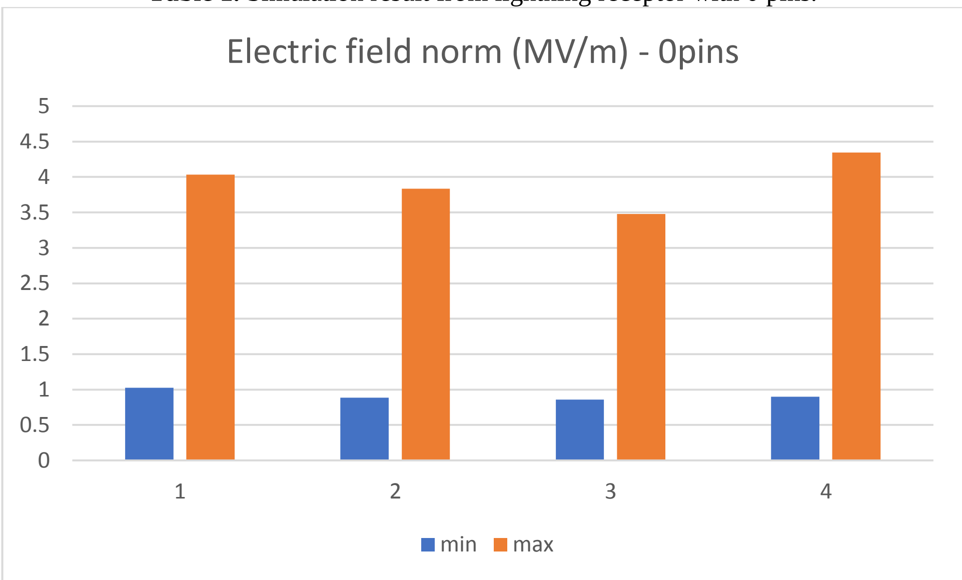

Fig. 4. Bar chart of the simulation result from lightning receptor with 0 pins.

Lightning Receptor with 4 Pins.

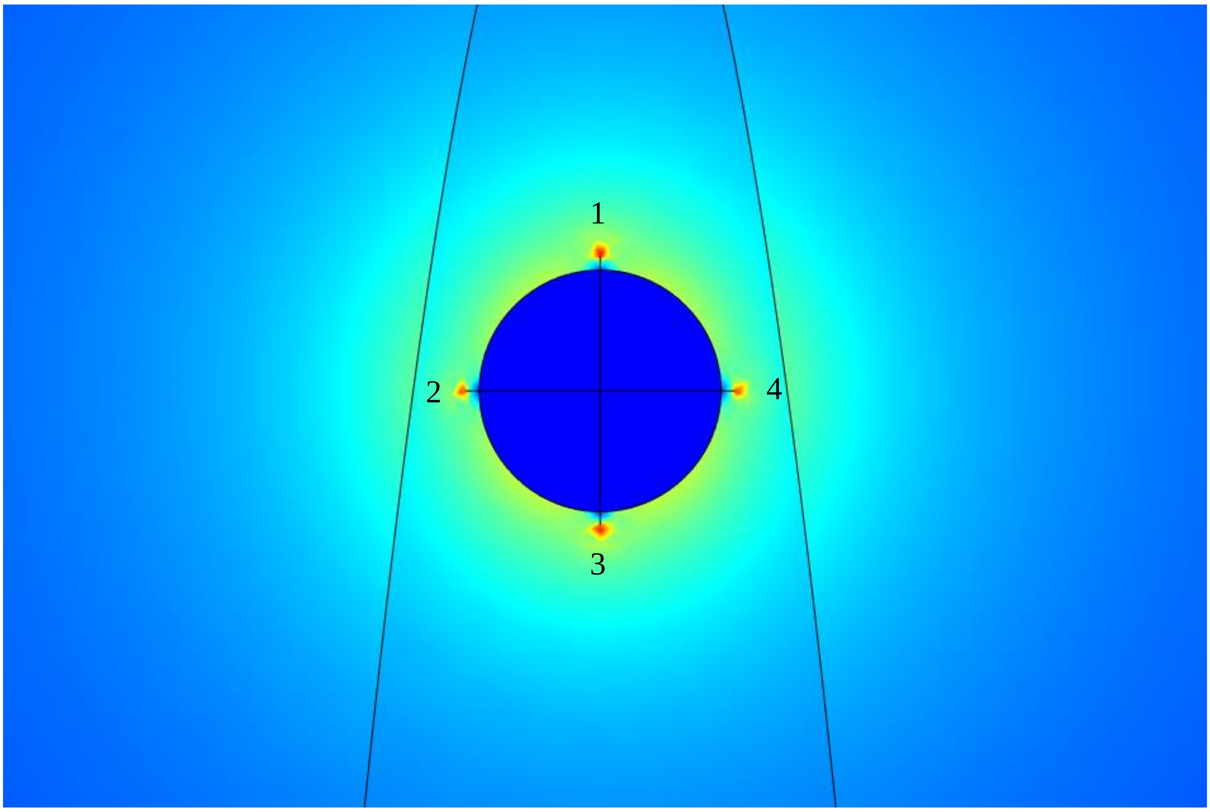

Fig. 5. Simulation result from lightning receptor with 4 pins.

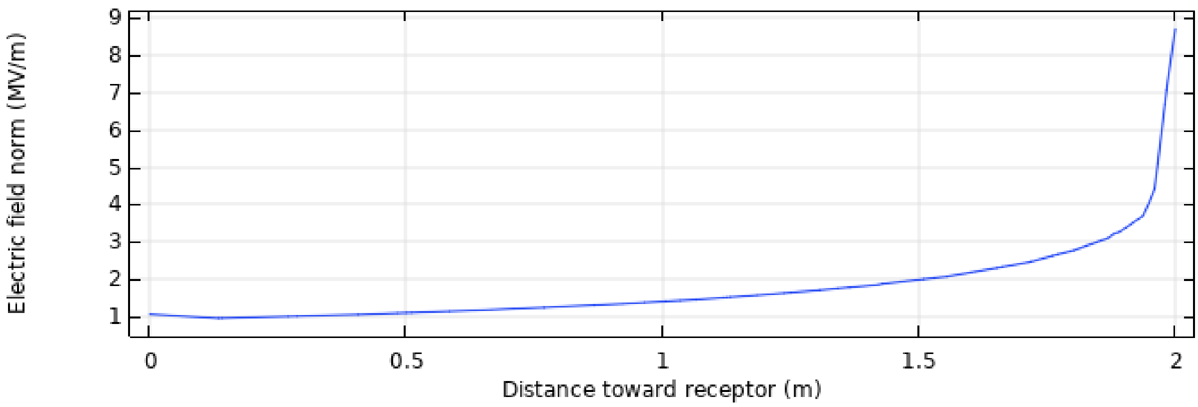

Fig. 6. Graph of the simulation result from lightning receptor with 4 pins.

4pins	**Electric field norm (MV/m)**	
Cut line 2D	**min**	**max**
1	1.0514	7.8672
2	0.8962	8.4244
3	0.852	6.7937
4	0.8958	7.6153
total	3.6954	30.7006
average	0.9239	7.6752

Table 2. Simulation result from lightning receptor with 4 pins.

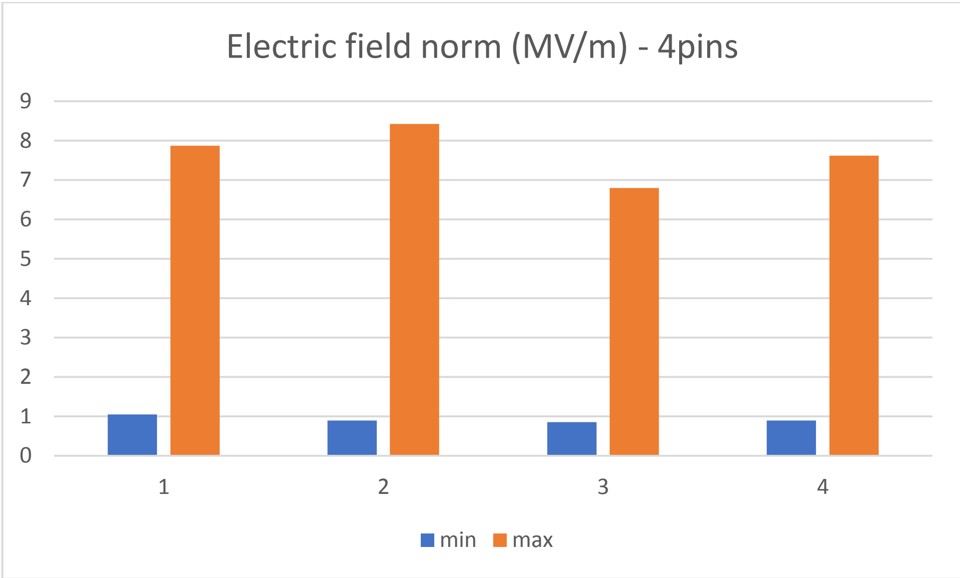

Fig. 7. Bar chart of the simulation result from lightning receptor with 4 pins.

Lightning Receptor with 8 Pins.

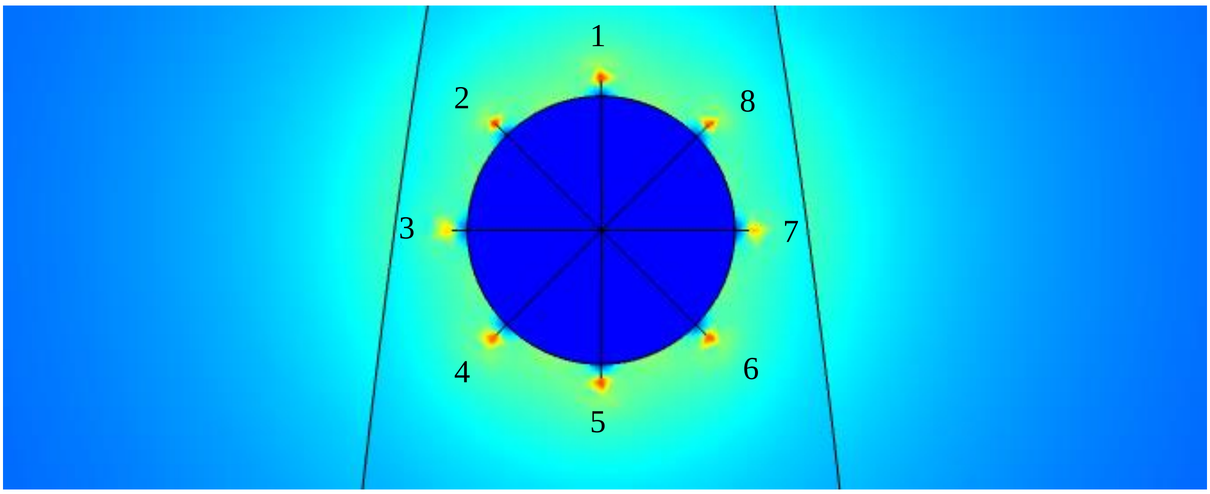

Fig. 8. Simulation result from lightning receptor with 8 pins.

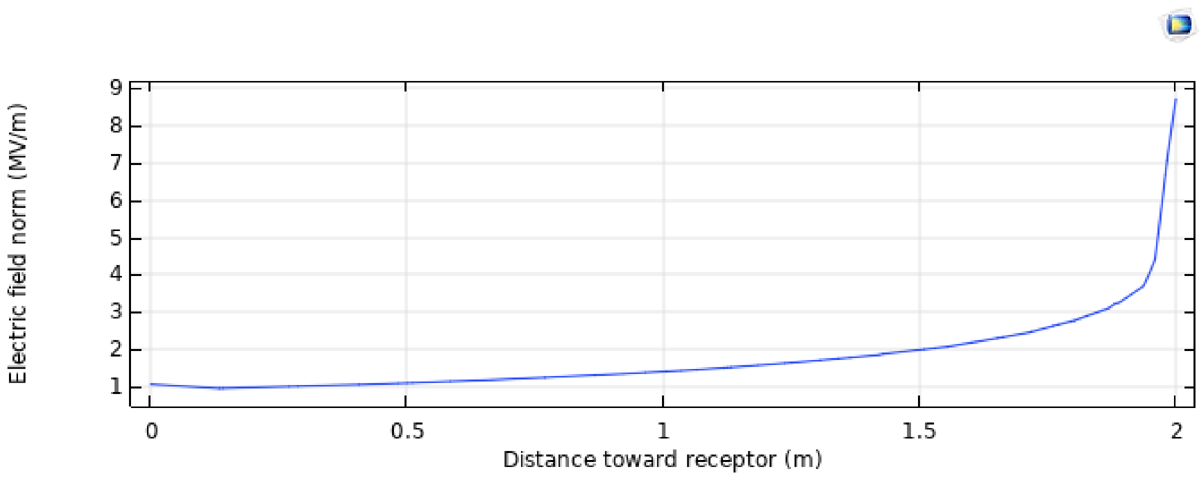

Fig. 9. Graph of the simulation result from lightning receptor with 8 pins.

8pins	Electric field norm (MV/m)	
Cut line 2D	**min**	**max**
1	1.0598	8.727
2	0.8062	8.9215
3	0.8932	6.7302
4	0.9763	8.1519
5	0.8551	6.848
6	0.7849	6.975
7	0.9021	7.1597
8	0.8232	9.1819
total	7.1008	62.6772
average	0.8876	7.8347

Table 3. Simulation result from lightning receptor with 8 pins.

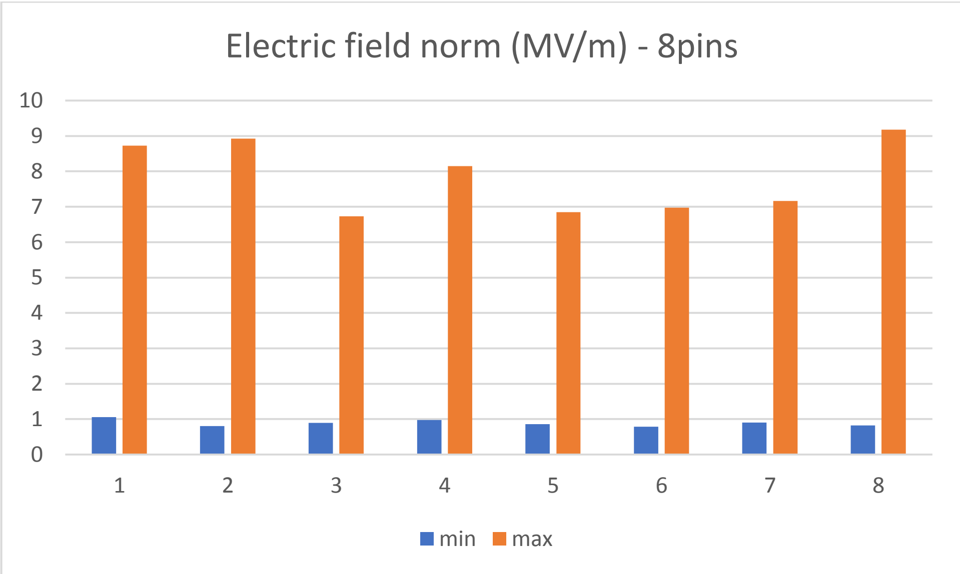

Fig. 10. Bar chart of the simulation result from lightning receptor with 8 pins.

Lightning Receptor with 12 Pins.

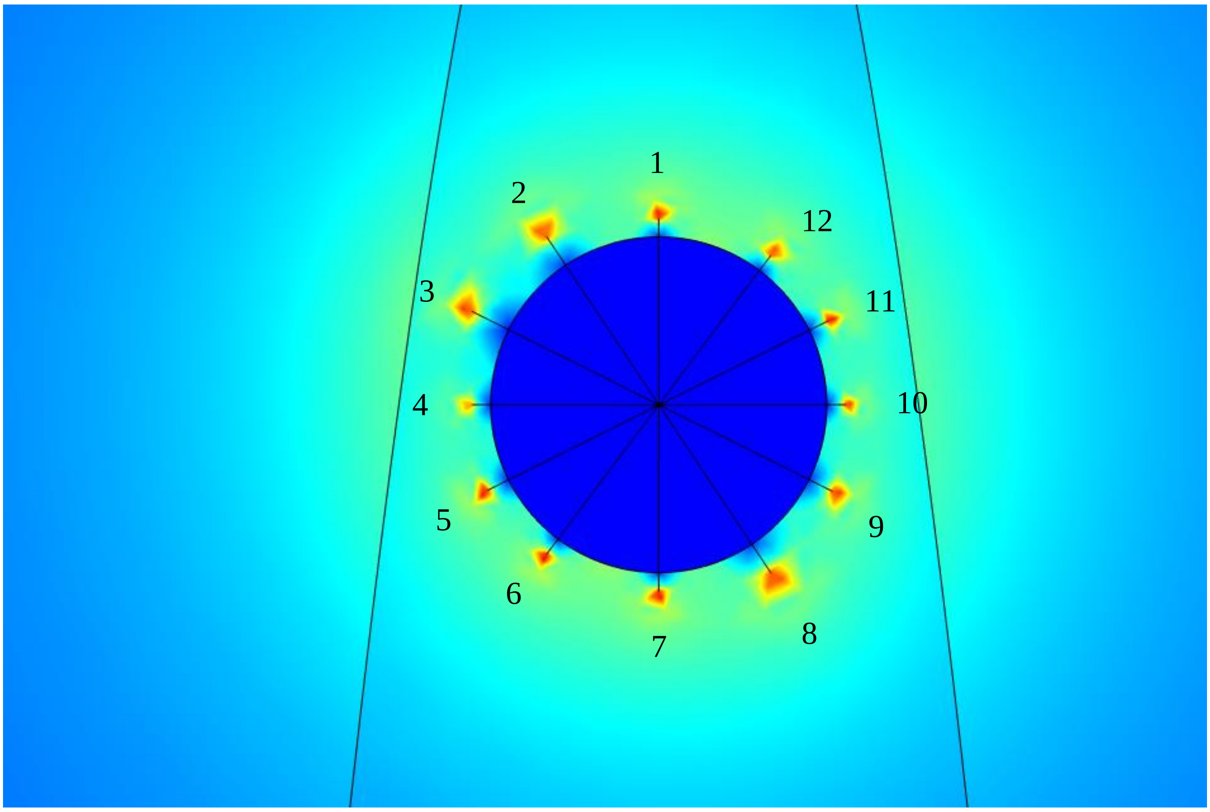

Fig. 11. Simulation result from lightning receptor with 12 pins.

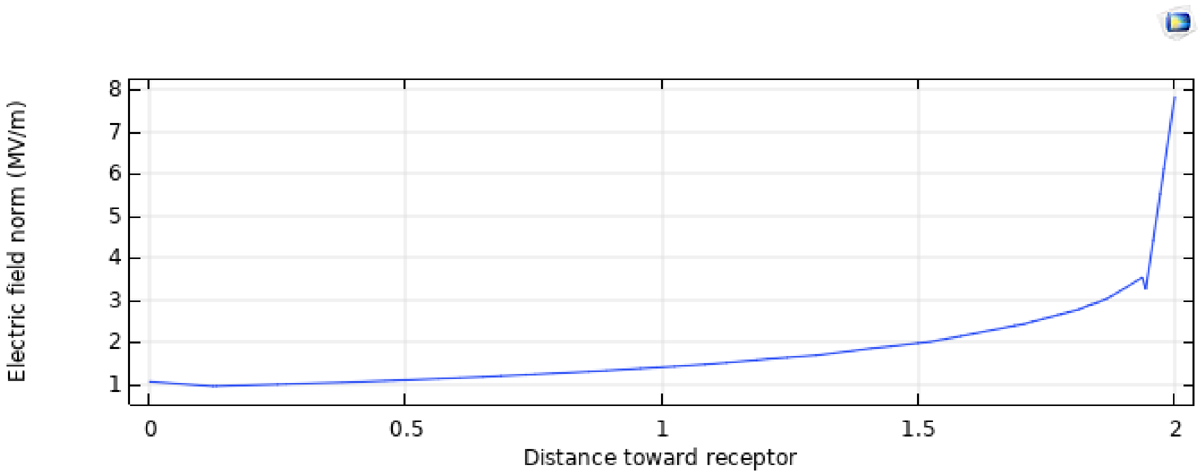

Fig. 12. Graph of the simulation result from lightning receptor with 12 pins.

12pins	Electric field norm (MV/m)	
Cut line 2D	min	max
1	1.0925	8.2908
2	0.9227	8.0292
3	0.83	7.9988
4	0.9019	5.206
5	0.8879	9.3182
6	0.8841	8.6171
7	0.8578	6.675

8	0.8831	8.1295
9	0.9226	8.0352
10	0.8966	7.5653
11	0.8958	8.4537
12	0.9245	7.3365
total	10.8995	93.6553
average	0.9083	7.8046

Table 4. Simulation result from lightning receptor with 12 pins.

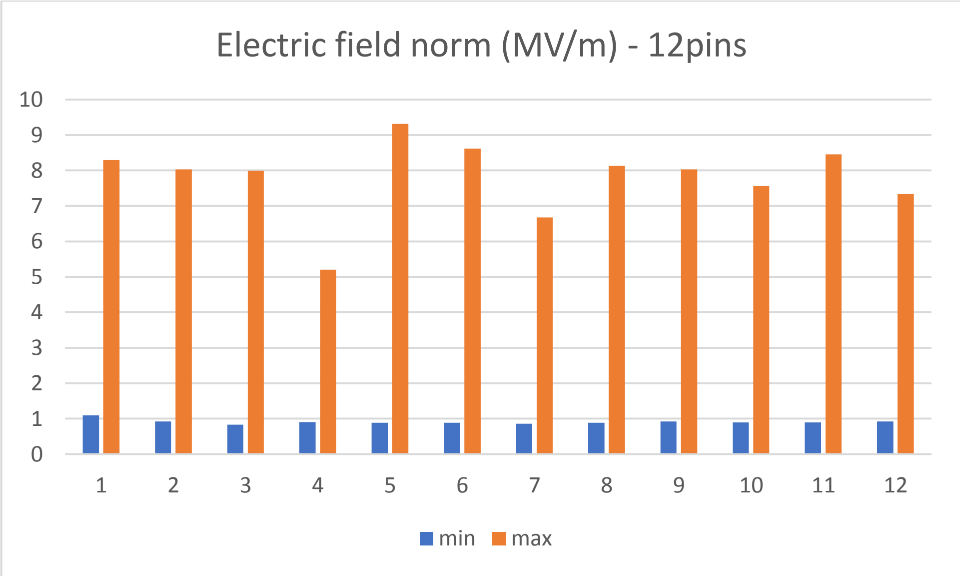

Fig. 13. Bar chart of the simulation result from lightning receptor with 12 pins.

Lightning Receptor with 16 Pins.

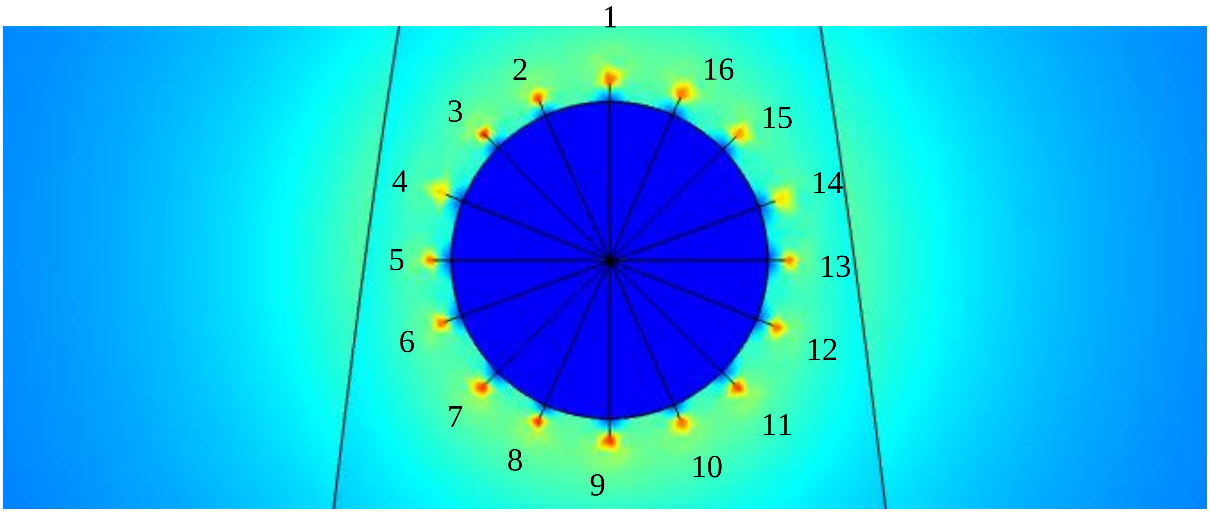

Fig. 14. Simulation result from lightning receptor with 16 pins.

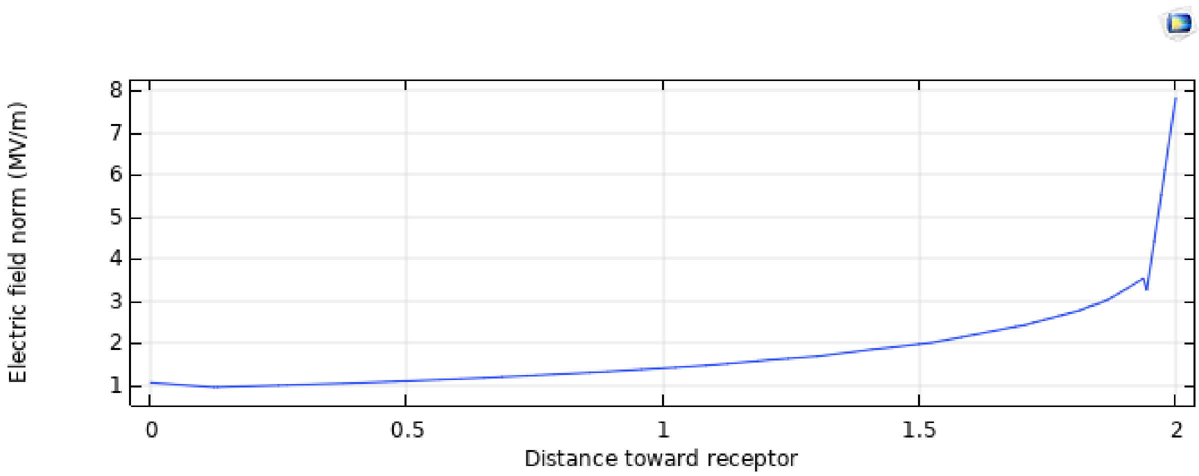

Fig. 15. Graph of the simulation result from lightning receptor with 16 pins.

16pins	**Electric field norm (MV/m)**	
Cut line 2D	**min**	**max**
1	1.0592	7.8438
2	0.8858	8.0231
3	0.8248	8.8443
4	0.7271	6.6518
5	0.8933	6.3628
6	0.7108	7.4369
7	0.7848	7.4973
8	0.7983	6.8619
9	0.854	6.8003
10	0.82	5.8758
11	0.7836	6.6771
12	0.6858	7.5571
13	0.902	7.4531
14	0.7255	6.476
15	0.5556	7.2828
16	0.7349	7.4453
total	12.7455	115.0894
average	0.7966	7.1931

Table 5. Simulation result from lightning receptor with 16 pins.

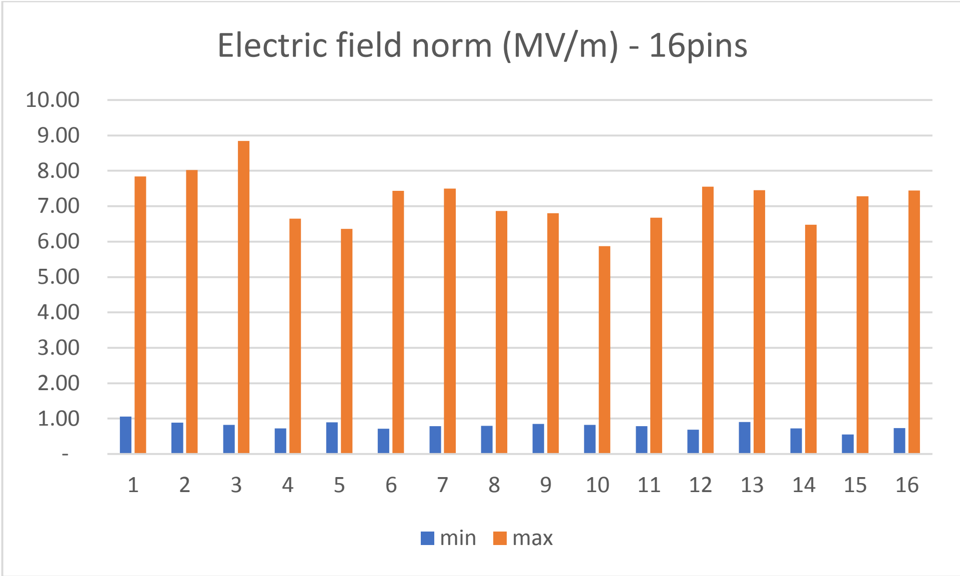

Fig. 16. Bar chart of the simulation result from lightning receptor with 16 pins.

3.2 Discussion

From the simulation results above, we can know that there are different colours in the simulation figure. The colours are illustrating the cumulative electric field normal around the pins. Therefore, the receptor pins successfully function as a lightning protection system to attract the electric field from the lightning strike.

From the graph, we can see that when the distance toward the receptor pin is shorter, the cumulative electric field normal is getting higher. Therefore, this showed that the receptor pins are successfully design and function as the lightning protection system and able to attract the electric field from the lightning strike.

Number of pins	Min (MV/m)	Max (MV/m)
0	0.9172	3.9238
4	0.9239	7.6752
8	0.8876	7.8347
12	0.9083	7.8046
16	0.7966	7.1931

Table 6. Summary of simulation result from number of receptor pins.

For the number of receptor pins, we can know that there are huge different in the maximum cumulative electric field for 0 pins as compared to 4 pins, showed that an increase in receptor needles will help in attracting the electric field from the lightning strike which will provide better protection to the turbine blade. The highest maximum cumulative electric field-collected is 8 receptor pins with a record of 7.8347MV, where more pins than 8, the cumulative electric field result will slightly decrease.

4 Conclusion and Recommendation

4.1 Conclusion

As a conclusion, from the results of the number of receptor pins, we know that when the number of lightning receptor pins increases, the potential of the maximum cumulative electric field is also increased, where it can provide better protection for the wind turbine. However, after a certain point of receptor pins is achieved, the result of the maximum cumulative electric field will start to decrease.

4.2 Future Recomendation

We know that there are still a lot of variables that may affect the outcome such as material, size, and position of receptor and wind turbine, where we can continue the research for obtaining a perfect design of lightning protection system for wind turbine blade for life long learning.

Besides, we can also research lightning to find out if the lightning is affected by a surrounding factor such as location geography and the lightning potential at each place for data collection purposes for more accurate and realistic research.

4.3 Impact to Society and Environment

The impact of this research on society and the environment can be separated into several stages such as people, company, country, and environment. With the research and improvement of the lightning protection, for the nation people and country, they can enjoy better power quality with lower interruption caused by the lightning strike for the wind turbine. For the benefit of the company, the company staff life is ensured and protected. Besides, the risk of wind turbines damaged by lightning strikes is decreased where the company can save a lot of money from repairing and maintenance. As for the environment, the increase in usage of renewable energy such as wind energy s more eco-friendly and reduces carbon emission from the power generation sector. Thus, we can conclude that research and improvement n alternative energy such as this research, “lightning attachment to wind turbine blade”, are valuable and potential n improving the future.

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