Safe zone analysis of lightning protection system in antenna using radome

Arif Hidayat¹*, Dedi Irawadi¹, Alfin Hikmaturokhman²,³ and Andrianingsih⁴

¹ Pusat Teknologi dan Data Penginderaan Jauh
² Department of Electrical Engineering, Universitas Indonesia
³ Institut Teknologi Telkom Purwokerto
⁴ Universitas Nasional

*arif.hidayat@lapan.go.id

Abstract. One of the natural disturbances avoided by the remote sensing satellite data reception system is the lightning bolt. Direct or lightning strike disturbances or induction or capacitance can reduce the availability earth station system. Maximum protection is needed to keep the antenna and earth station equipment from experiencing fatal damage if hit by a lightning strike. Existing external protection methods are franklin rod, mesh, and rod with link wires. Antennas using radome have 2 system protection, namely Franklin rod and taud wires in the following paper will be analyzed the effectiveness and capability of the system in protecting the antenna.

1. Introduction

The receiving antenna at the earth station remote sensing functions functions to receive multi mission satellite data [1]. This antenna is capable of tracking satellite tracking and receiving remote sensing satellite data [2]. Satellite data of various low and medium high resolutions is very high. The satellite is received by the antenna then the data is recorded using the recording computer[3]. The data from the first recording is called raw data because the data does not yet show the actual data of satellite imagery[4]. The data processed using a computer using an image processing application so that satellite image data is obtained according to the level of each. All of these data required protection against external and internal [4],[5].

One of the external disturbances that must be avoided by the earth station antenna is a lightning strike. Based on data from BMKG in the Parepare region of South Sulawesi, including moderate to high areas. The higher the surface of the earth, the lower the air temperature which causes condensation to occur at a certain height. After reaching the condensation temperature, the water vapor points contained in the upper part of the cloud turn into ice crystals. Because of the wind upward, sideways and downward, collisions or friction between the ice crystals that cause the formation of positive ions at the top and negative at the bottom of the cloud occur. According to John Gookin, 2010 , the process of lightning is divided into doward leader, upward leader, return stroke.
1.1. Downward Leader
The ionization process in the lightning cloud will produce an electric and earth field. If the resulting electric field reaches the breakdown voltage level of approximately 100 million volts to the earth, there will be an electron release from the lightning cloud to the earth (Downward Leader) [6].

1.2. Upward Leader
The formation of a Downward Leader with this high speed causes an increase in the electric field produced between the tip of lightning and the surface of the earth. So that it imposes the formation of Upward Leaders originating from the highest peaks of the earth's surface. This process continues until the two meet at a certain third point, known as the Striking point.

Figure 1. Illustration Of Lightning Strike [6]

1.3. Return Stroke
Return Stroke which is termed the back stroke is the actual lightning current that flows from the earth towards the lightning cloud through the ionization channel that has been formed above. Figure 2. The Process of the Lightning Strike

Figure 2. The Process of the Lightning Strike [6]

1.4. Light Induction Mechanism
Lightning strikes indirectly cause induction because of the potential increase in electronic equipment, this induction process is referred to as a resistive coupling, capacitive coupling and inductive coupling [1].

Resistive Coupling, When a material near the device is hit by a lightning strike, the lightning current flowing into the ground generates a voltage that can reach thousands of volts. This lightning current
seeks the easiest media to deliver high voltage into the ground. This condition causes some of the current to flow in the outer conductive part of the electricity network such as cables connected to the building and continue to the ground [1].

Inductive Coupling, Lightning current flows in a conductor will produce a magnetic field. Like an effect on electromagnetic wave induction on the coil and on the transformer. So that the electrical equipment or network can be induced and the voltage in the electricity network becomes high due to the electrical loop [6]

Capacitive coupling occurs because the lightning channel near the lightning strike can cause a high capacitive field in the conductor equipment such as a very large capacitor with air as its dielectric. In this way there is an increase in high voltage on the cable even though the structure of the building is not exposed to a direct strike. In accordance with the nature of the capacitor which can discharge its electric charge[7].

2. Protection Method

The simple idea is to catch the lightning rod and then channel it into the ground, and make the entire body of the device connected to the ground so that the phenomenon of inductive coupling, capacitive coupling and resistive coupling can be eliminated. According to Schneider Electric - Electrical installation guide 2010, the lightning protection method was discovered by Benjamin Franklin. Some methods for counteracting lightning include

2.1. Franklin Rod

Franklin rod is the longest-used lightning rod method, the most optimum method is used for tall buildings such as towers, minarets, church towers. This tool makes an imaginary cone with a peak angle of 112°. A series of copper wires that function as a path or flow for lightning to the earth's surface or ground, so that lightning will not damage the objects that pass [8],[9].

There are 3 main parts on the Franklin rod lightning rod: Franklin rod lightning rod, conductor rod of Franklin rod lightning rod, earthing for Franklin rod lightning rod. Franklin rod lightning rod is a pure copper rod whose copper end is pointed. Franklin rod lightning rods are made into sharp rods of Franklin rod lightning rods because the electric charge has properties that are easily assembled and loose on the metal end [8].

2.2. Faraday Cage

Lightning Rod Faraday cage is a series of electrical paths from the top of the building to the ground / ground with several cable drop paths, resulting in a cage-shaped conductor path that protects the building from lightning strikes.
2.3. Lightning Rod with Taut Wires
This cable extends above the structure that will be protected. This method protects special structures such as rocket launch areas, military applications and protection of high voltage airways. This method will be used in radome shielded antennas for maximum protection. Figure 5: Lighting with link wires [3]

3. Protection needs analysis
According to PUIP, electricity needs can be categorized into several categories. Based on the type of building can be calculated and categorized from the value of -10 to 15. That is starting from those that do not need a protection system to the very need of a protection system [9],[10].

3.1. Types based needs building

| Implementation and volume                                      | A Index |
|---------------------------------------------------------------|---------|
| Ordinary buildings that are not secured are both buildings and contents. | -10     |
| Buildings and their contents are rarely used, such as loom in the middle of rice fields or ladan, towers or metal poles. | 0       |
| Buildings that contain day-to-day equipment or housing such as houses, small industries and fire stations. | 1       |
Buildings or contents are quite important such as water towers, valuables and government offices 2

Buildings that contain lots of people, such as cinemas, worship facilities, schools and important historical monuments. 3

Gas, oil or gasoline installations and hospitals. 5

Buildings that explode and can cause uncontrollable hazards for their surroundings such as nuclear installations. 15

3.2. Index based on building materials

| Building Construction | B Index |
|-----------------------|---------|
| All buildings are made of metal and are easy to deliver electricity. | 0 |
| Buildings with reinforced concrete construction or iron frames with metal roofs | 1 |
| Buildings with reinforced concrete construction or iron frames with non-metal roofs | 2 |
| Wooden building with non-metal roof | 3 |

When viewed the antenna using radome is 2

3.3. Hazard index based on building height

Another analysis is based on the height of the building. The analysis can be divided into several parts.

| Building height Up to (m) | C Index |
|---------------------------|---------|
| 6                         | 0       |
| 12                        | 2       |
| 17                        | 3       |
| 25                        | 4       |
| 35                        | 5       |
| 50                        | 6       |
| 70                        | 7       |
| 100                       | 8       |
| 140                       | 9       |
3.4. Danger index based on building situation

Table 4. Result index building situation [11]

| Building Situation                                      | D Index |
|---------------------------------------------------------|---------|
| On flat ground at all altitudes of 0                    | 0       |
| At the foot of the hill Up to ¾ high hill               | 1       |
| or in the mountains to 100 meters                       |         |
| At the top of a mountain or a mountain of more than 1000 meters | 2       |

The parepare remote sensing earth station is on a top a hill with the height of about 87 meters. So that it can be concluded that index D is worth 1. If you see the height of the building more than 12 meters so that the value 2 is taken.

3.5. Index Based on lightning day

Table 5. Lightning days around parepare [11]

| Region                   | Day of Light | Level    |
|--------------------------|--------------|----------|
| Majene Sulawesi          | 38.1         | Medium   |
| Makassar Sulawesi        | 41.76        | Medium   |
| Gorontalo                | 58.08        | High     |
| Masamba- Sulawesi        | 67.88        | High     |

Table 6. Result index E with lightning day per year [11]

| Lightning Day Per Year   | E index |
|--------------------------|---------|
| 6                        | 0       |
| 12                       | 2       |
| 17                       | 3       |
| 25                       | 4       |
| 35                       | 5       |
| 50                       | 6       |
| 70                       | 7       |
| 100                      | 8       |

From the table data can be concluded has a value of 6.
3.6. Estimated dangers of lightning strike
Based on PUIPP the danger value of lightning

| R          | Estimated Safety | Hazards        |
|------------|------------------|----------------|
| Under 11   | Ignored          | No Need        |
| Same as 11 | Small            | No Need        |
| Same with 12 | being          | Recommended    |
| Same with 13 | rather large   | is recommended |
| Same with Big 14 | Very       | Recommended    |
| More than 14 | Very            | Large Needs    |

The total value of R which is obtained based on the calculation in subchapter 3.1 to 3.5 is:

\[ R = A + B + C + D + E \]
\[ = 3 + 2 + 3 + 1 + 6 \]
\[ = 15 \]

4. Random antenna protection analysis

Radome antennas use 2 methods: faraday cage and Franklin rod. Faraday combined protection design and fast cable lightning rod. A lighting rod is installed at the top of the antenna. Connected with 2 cables that traverse the inside of a circular radome with a copper crossing area of 50 mm² All cables are connected using a copper plate. The illustration can be seen in Figure 7.
4.1. Analysis of protection zone razevig

To find out whether the protection of the antenna diameter of 6.1 has met the needs, it is necessary to do an analysis. According to Dadan Hermawan 2010, SNI 2004 definition of razevig protection method is a method used to calculate the area of lightning protection protection, as follows [11],[12].

\[ r_x = \frac{1.6}{1 + \frac{h_x}{h_t}} \left( h_t - 1 \right) \]  

(2)

where :

\( r_x \) : radius protection (m)
\( h_x \) : maximum object height (m)
\( h_t \) : total lightning rod height (m)

\[ L_{final} = 0.5 \text{ m} \]
\[ L_{penyatur} = 14.25 \text{ m} \]
\[ L_{elektroda} = 2 \text{ m} \]
\[ h_t = 0.5 + 14.25 + 2 = 16.75 \text{ m} \]

\[ r_x = \frac{1.6}{1 + \frac{14.25}{16.75}} \left( 16.75 - 1 \right) \]
\[ r_x = \frac{1,6}{1,85} (15,75) \]
\[ r_x = 13,62 \text{ m} \]

Then you can get a lightning protection protection radius on ... is 13.62 m. The extent of protection is

\[ A_x = \pi r_x^2 \]
\[ A_x = 3,14 \times (13,62)^2 \]
\[ A_x = 582,48 \text{ m}^2 \]

4.2. Corner protection zone

Based on SNI 2004 Corner protection can be seen in table 8:

When we look at the height of the radome is 9 meters from the bottom of the foundation and the width of the antenna dish is 3.2 meters is 4 meters below the lightning rod point. The angle incised is 37.67 degrees. Based on table 8 is included in the zone III.

| Protection Level | h(m) | 20 | 30 | 40 | 50 |
|------------------|------|----|----|----|----|
| I                | 20   | 25 | *  | *  | *  |
| II               | 30   | 35 | 25 | *  | *  |
| III              | 40   | 45 | 35 | 25 | *  |
| IV               | 50   | 55 | 45 | 35 | 25 |

* Rolling sphere and mesh only apply in these cases

![Figure 9](image.png) Result the angle incised is 37.67 degrees

4.3. Protection zone scroll method

Because Franklin Rod's terminal water method has not been maximized, additional protection is needed. That is a lightning rod using lightning with link wires. With this method the analysis is done using a
scroll ball can be seen in the following figure. The radius used is to use a height radius from the bottom to the top of the lightning rod electrode. In this method, it looks like the picture below:

![Figure 10 Lightning rod using lightning with link wires](image)

5. Conclusion
From the calculation of the risk level of the antenna seaspace has a high risk of being hit by lightning which is 15. Protection against the radome antenna uses two methods, namely Franklin rod and Lightning Rod with Taut Wires. Both systems are merged. From the results of the protection calculation using the angle method and the scroll ball the minimum protection area has been obtained. Thus, this antenna protection protection system is resistant to lightning strike.

References

[1] A. Hidayat, A. Suprijanto, P. R. Ramadhan, and S.T. A. Munawar, “Kajian Kebutuhan Spesifikasi Antenna untuk Penerimaan Data Resolusi Sangat Tinggi Study of Antenna Specification Requirements for Very High Resolution Data Reception,” pp. 117–124, 2017
[2] A. Hidayat, S. Takdir, A. Munawar, A. L.Hadiyanto, and P. R. Ramadhan, “Kalibrasi Arah Antenna Dengan Metode Sun Pointing Pada Antenna 3 Sumbu,” Pros. Semin. Nas. Penginderaan Jauh 2014, pp. 89–96, 2014
[3] E. Palantei, S. Syarif, A. Hidayat, and S. T. A. Munawar, “Low-cost switched array-wide band antenna for Search and Rescue disaster management,” Proceeding - 2017 3rd Int. Conf. Sci. Technol. ICST 2017, pp. 131–135, 2017.
[4] A. Hidayat, S. T. A. Munawar, S. Syarif, and A. Achmad, “LEO Antenna Ground Station Analysis Using Fast Fourier Transform,” IEEE INAES 2017, Yogyakarta, pp. 1–5, Jul-2017.
[5] A. Hidayat, S. Munawar, A. Suprijanto, and N. Setyasaputra, “Design And Implementation Web Based Expert System For Analizing Performance Of Antenna Seaspace 5.1,” Teknol. Dirgant., vol. 12, no. 2, pp. 154–162, 2014
[6] J. Gookin, 2010. Backcountry Lightning Risk Management , 21st International Linghning Detection Conference, Orlando Florida, USA.
[7] IEEE Guide for Surge Protection of Equipment,How to Protect Your House and Its Contents from Lightning , IEEE, New York, 2005
[8] Schneider Electric. (2015). Electrical installation guide According to IEC international standards. Schneider Electric, France, Paris. [Online]. Available https://www.schneider-electric.com/en/work/products/product-launch/electrical-installation-guide/.
[9] A Syakur, Yuningtyastuti (2007). Sistem Proteksi Penangkal Petir Pada Gedung Widya Puraya. Transmisi [Online], Vol. 11, No. 1, Juni 2006 : 35 – 39. Available: : https://ejournal.undip.ac.id/index.php/transmisi/article/view/1580/1342.
[10] D. Ajiatmo, A. Yodhas, T. Arga Prabowo, M. Ali (2012). Analisa Sistem Instalasi Penangkap Petir Pada Bangunan Bertingkat. Jurnal INTAKE Vol3. Nomor 1 April 2012.
[11] Badan Standardisasi Nasional. (2004). Sistem proteksi petir pada bangunan gedung, Jakarta, 2004
[12] P.Velmurugan, K.Dhayalasundaram, K.Ilangovan (2011), Application of IEC 62305 to a large Power and Desalination Plant - Lightning Protection System, 2011 1st International Conference on Electrical Energy Systems, Newport Beach, CA, USA.