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KRL Lightning Protection System Network of Catenary Electricity Units Top Flow at The UPT Resort Region of Pasar Senen, Jakarta

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Abstract: The modes of transportation are currently very diverse with the development of an area and mass transportation is an absolute solution to the problem of congestion in urban areas. In metropolitan Jakarta, the Electric Rail Train (KRL) moves through several stages, starting from the supply of a 20 kV AC PLN distribution substation adjacent to the KAI traction substation and then being lowered through the KAI traction substation stepdown transformer to 1200 V AC. The AC power is then converted to DC using a silicon rectifier, and finally generates a voltage of 1500 V DC which supplies the KRL from the traction substation via Overflow Electricity (LAA) with a catenary network transmission that runs across the top along the KRL route. LAA technical problems, called equipment malfunctions, causes train travel disruptions resulting in crossing and overcoming transfers, trip cancellations or delays of 10 minutes or more. This is due to damage to the catenary network, so certain sections of the road cannot be finally passed by KRL. The catenary network must then be safeguarded with protective facilities to secure other catenary network equipment from damage due to lightning strikes and induction. This study maximizes the protection system on the catenary network in the area of the Technical Service Unit (UPT) Resort LAA 1.7 Pasar Senen PT KAI (Persero) Operation Area 1 Jakarta and is expected to be a reference for railway infrastructure employees of the LAA unit. There are, 3 methods used, namely the method of observation, interviews, and literature study. The results showed that the optimum OHGW (overhead ground wire) angle of protection for the concrete/pole type was 67.45˚, while the iron pole was 65.95˚ and both met the requirements for the protection angle of 65˚-68˚. However, the distance for grounding the catenary network poles on existing poles that are installed every 5 poles and is 250 m apart needs to be renovated to avoid induced voltage disturbances and high lightning strikes and hence endangering humans and surrounding equipment. Finally, to avoid cases of theft of the copper grounding rod and its down conductor, it is necessary to install a new grounding rod made of iron.

Keywords: Traction substation, catenary network, lightning protection system.

INTRODUCTION

Upstream Electricity (LAA) is a unified electrical system that is intact to be able to meet the operational needs of Electric Rail Trains (KRL) Jakarta and the main source of signaling. With the catenary network transmission, KRL can receive electrical power that has been processed by the traction substation with a power conversion system that produces electrical power with a voltage of 1500 V DC. Minimizing technical disruptions to the catenary network is very important in the operation of rail travel. This is because it can be detrimental to the organizers of railway infrastructure and business entities that operate railway facilities as well as customers of rail transportation services [1]. Therefore, the author aims to analyze the reliability of catenary network protection facilities in order to minimize technical equipment disturbances and further equipment damage to railway infrastructure.

The catenary network protection facilities in question are overhead ground wire, lightning arresters, arching horns, and grounding equipment. The lightning protection equipment in the catenary network as intended must function as much as possible to neutralize the overvoltage caused by the lightning surge to earth and transmit the remaining overvoltage to the earth. In this study, the author wanted to find out whether the protection system installed in the catenary network in the area across the UPT LAA Pasar Senen DAOP 1 Jakarta was reliable and in accordance with the standards of the International Electrotechnical Commission (IEC) and the standards of the Institute of Electrical and Electronics Engineers. Functionally, lightning protection equipment on the catenary network must be able to protect against induced voltages due to direct lightning strikes on the installed network components. The reliability of the protection system that is less reliable can cause damage and loss to KAI. This research activity has 3 stages. The first is a visual inspection of the catenary network, the second is the measurement of the components of the protection equipment, the third is to evaluate the repair of the catenary network components.

From the background above, it can be seen that the identification of the problem in this research is if the lightning protection system installed on the catenary network is not reliable and does not comply with the standards, it will result in several disturbances including the Operation of the Electric Rail Train (KRL) is hampered, the failure of the lightning protection system to the network. catenary and damage to catenary tissue components. Based on the existing identification, to be more focused on the problem of the scope of the research, the authors have a problem boundary zone on the problems studied specifically to discuss the optimum protection angle distance on the overhead ground wire, the distance for the installation of grounding on the catenary network pole in the calculation method. used a linear approach, as well as visual testing and grounding resistance measurement tests to determine the reliability of grounding equipment in the area of UPT LAA Pasar Senen DAOP 1 Jakarta. Based on the discussion above, the authors found the formulation of the problem including determining the optimum protection angle distance on the top grounding wire (OHGW) according to the International Electrotechnical Commission (IEC) standard; Determining the distance of grounding installation on the pole based on lightning strikes on the ground wire in the middle of the goal and Visual and technical testing to determine the reliability of the lightning protection system on the catenary network. The objectives of this study are a) To determine the optimum protection angle distance of OHGW across the area of UPT LAA Pasar Senen DAOP 1 Jakarta, b) To determine the distance of grounding installation on catenary network poles across the area of UPT LAA Pasar Senen DAOP 1 Jakarta and c) To determine the reliability of the lightning protection system installed on the catenary network across the area of UPT LAA Pasar Senen DAOP 1 Jakarta.

The benefits of this research are a) to be useful for the development of electrical science, especially on the application and understanding of lightning protection systems on catenary networks that stretch along the railway line b) to become a reference for railway infrastructure employees of the LAA unit if there is a plan or installation of a protection system lightning on the new catenary network and evaluation of the working area of UPT LAA Pasar Senen DAOP 1 Jakarta and c) to add reading material and references for further research related to this research. It is hoped that this final project can provide the benefits of science and technology regarding lightning protection systems on the catenary network of railway infrastructure.

The results showed that the optimum protection angle distance of the overhead ground wire/OHGW (Overhead Ground Wire) for the concrete pole/pole is 67.45˚ and for the iron pole 65.95˚, the two angles of protection still meet the protection angle protection requirements of 65-68 degrees. The results in the field show that grounding of catenary network poles on existing poles is installed every 5 poles with a distance of 250 m and has an impact on the occurrence of very high lightning strike induced voltages and endangers humans and surrounding equipment. To avoid theft/damage of the grounding rod made of copper and the down conductor that is not connected to the grounding rod, it is necessary to build a new grounding rod made of iron.

LITERATURE REVIEW AND THEORY

The railway infrastructure consists of train tracks, train stations and train operating facilities, namely, electrical telecommunication signals and overhead electricity so trains can be operated properly [1]. Upstream electricity or what is often called LAA is a system consisting of a traction substation and an upstream electricity network or catenary network that functions to distribute electrical power from the source to the load, the Electric Rail Train (KRL). In this distribution, there are two processes of changing the voltage, namely, the voltage will be increased using a step-up transformer to (70 kV, 150 kV or 500 kV), after it is transmitted and when it approaches the load then the voltage is lowered with a step-down transformer into a distribution system (20 kV). The incoming voltage at the DC substation is 20 kV and is then converted to a voltage of 1500 V DC using a silicon rectifier and is used to supply KRL through the catenary network along with other supporting components. The comprehensive distribution of KRL electrical power can be seen in Figure 1 [2].

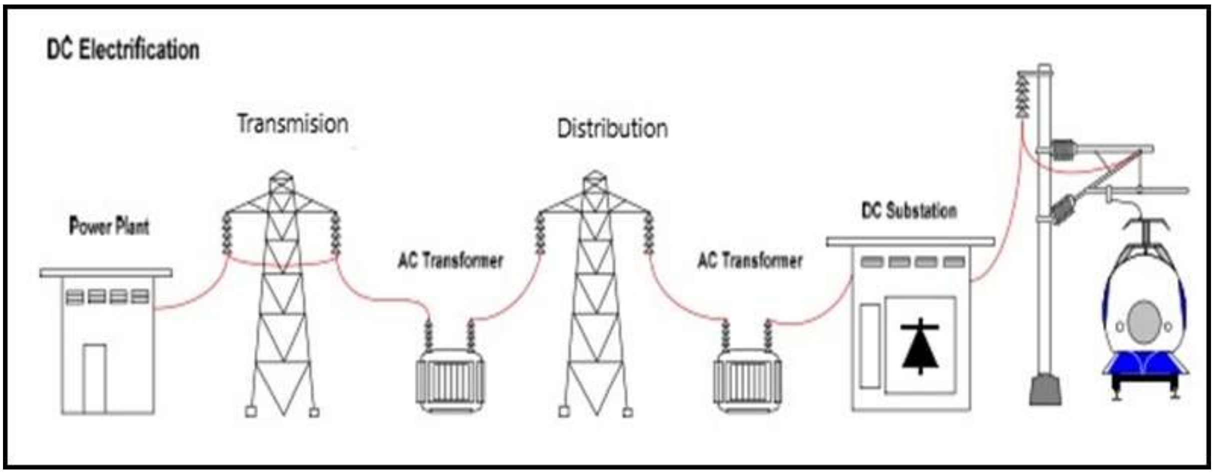

Figure 1. Distribution of KRL electrical power [2].

Main Components of LAA

Broadly speaking, the equipment for the overhead power supply is the Traction Substation and the electrification system for KRL operations in Indonesia is a DC 1500 V DC voltage system. One of the equipment in the electrification system is an upstream electric substation and an electric traction substation is a traction current converter substation which consists of electrical power supply equipment that has an electrical power source originating from PT. PLN or other power sources and all of the above is also shown in Figures 2 and 3 [2].

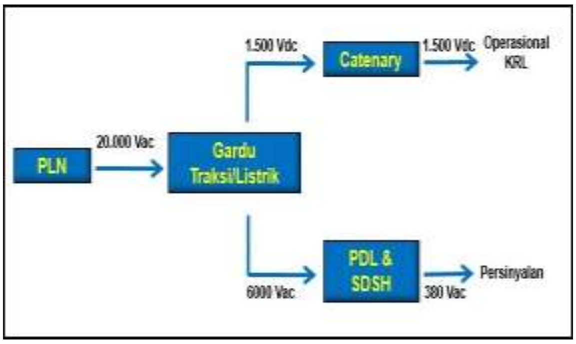

Figure 2. Conversion of overhead electric power [2].

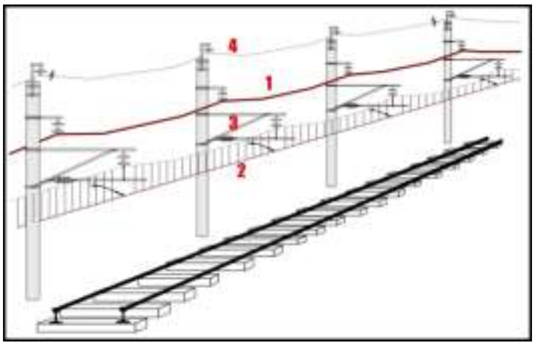

Figure 3. Catenary network [2].

The catenary network is an electrical power delivery network in the form of an overhead catenary with a voltage of 1500 V DC along the electrification line used for KRL operations. The KRL transportation electrical system consists of a feeder system (consisting of feeder wire and feeder branches), overhead contact wire (consisting of contact wire), supporting facilities (messenger wire, steady device, pull off arm, pole) and protection facility (top grounding wire, lightning arresters, grounding equipment). There is also a PDL or Power Distribution Line, which is a power distribution network part of the catenary network which functions to distribute electrical power and then supplies SDSH (Supply Power Signal Hut) near the station for signaling, telecommunications and crossing gates [2].

Electricity Protection Facility for KRL

Protection facilities on the catenary network serve to protect other catenary network equipment from damage due to lightning strikes and induction. The protection facility is in the form of an overhead ground wire (OHGW), which is a ground wire placed at the end of an electric power transmission line and stretched parallel to the feeder wire as shown in Figure 4 [3]. Overhead ground wire functions to transmit lightning surges to ground and protect power lines and catenary network equipment. The principle of using this ground wire is that the ground wire will be the target of lightning strikes so as to protect the feeder wire and other catenary network equipment with a certain protected zone area.

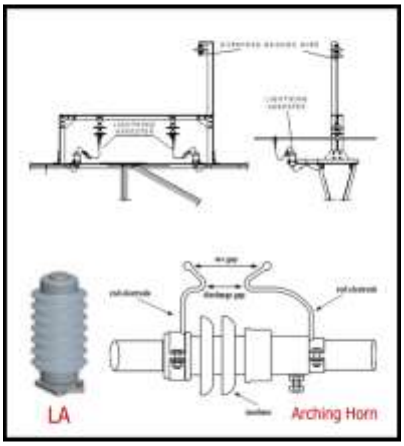

Figure 4. OHGW on catenary grid [3].

Figure 5. Lightning arrester and arching horn [3].

Lightning arrester is a component of the equipment used to protect the catenary network electrification system against lightning surges, while the arching horn is a protective device used to protect the insulator or equipment on the catenary network from damage during flash over. Lightning arrester and arching horn function to cut and forward the lightning surge voltage and impulse voltage from the feeder wire to the grounding equipment without causing damage to the equipment as shown in Figure 5. Meanwhile, grounding equipment is a protection facility, part of the protection system on the catenary network which functions to transmit lightning surges which had been cut by the lightning arrester to the ground. The grounding equipment as an intended must function as much as possible to neutralize the overvoltage caused by the lightning surge to earth and transmit the remaining overvoltage to the earth [3].

Periodic maintenance of grounding equipment in the LAA unit consists of 2 (two) treatments, namely ground maintenance at the traction substation and ground maintenance at the catenary network. Periodic maintenance of grounding equipment at the traction substation is carried out periodically at least once a year including physical inspection and grounding measurements. Meanwhile, periodic maintenance of grounding equipment in the catenary network is carried out periodically at least once a month including physical inspection and if there are findings, follow-up repairs are carried out along with grounding measurements. All of these meet Ministerial Regulation No. 12 of 2011 concerning Technical Requirements for Railway Electrical Installation [4].

Grounding system and factors affecting grounding system

Grounding is the transmission of the unit connection of the equipment to the earth and is a key aspect in any action for the protection of the electric power system. The system connects conductors and equipment bodies from electrical installations to the earth so that they can protect humans from electric shock and secure installation equipment from the dangers of abnormal voltages or currents [5, 6]. According to IEEE Std. 142-1982, which is very influential in reducing the value of the grounding resistance is the depth of the electrode [7, 8]. Research on soil characteristics related to the measurement of resistance and soil type resistance greatly affects the amount of ground resistance so that the fault current flows quickly to the earth. In fact, soil resistivity values vary depending on the composition of the soil. For this reason, direct measurements at several locations to obtain accurate soil resistivity values need to be carried out. Lightning is a threat to the safety of KRL equipment and occurs under certain conditions in the earth's atmosphere so that the movement of the wind carries moist air upwards. Atmospheric instability conditions can arise because the charge separation does not occur completely. Indonesia has a fairly large forest area so that the air is quite humid so that lightning often occurs when it rains and the formation and release of lightning can be seen in Figures 6 and 7 [9]. The release of electric charge from the cloud, once the tip of the lightning tongue moves closer to the ground, the electric field strength at the ends of the structures above the ground will increase and air ionization will occur leading to the cloud. Lightning is formed when the jumps of the light point (leader) and the streamer meet in the final jump, about 10 meters. The return stroke through an already ionized path with a total charge transferred on the return stroke of about 5-200 coulombs in 0.05-1.5 seconds of lightning will connect through the same path. According to the hypothesis of Wagner and Hileman, the step leader consists of two parts, namely a thin, high-conducting core called a channel and surrounded by a negative space charge called the corona and the striking distance can estimated using the following formula:

1. Amstrong and Whitehead formula : $r_{S} = 6{,}7.I^{0{,}8}$ m (kA)
2. Standar of IEC 62305/2010 : : $r_{S} = 10.I^{0{,}65}$ m

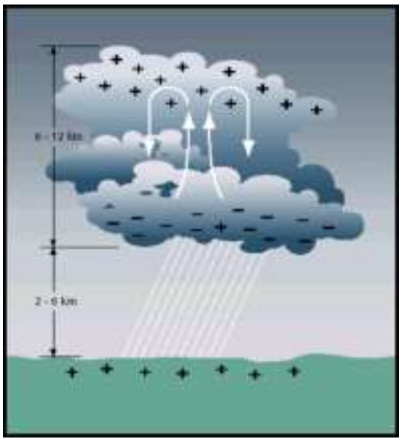

Figure 6. Lightning storm formation and natural ionization [9].

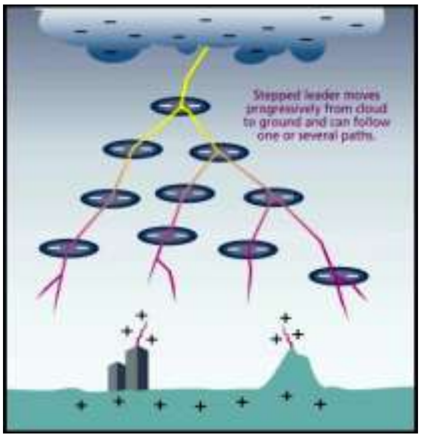

Figure 7. Discharge of electricity from clouds [9].

The characteristics of the lightning current surge have the effect of cloud polarity where the bottom of the cloud has more negative charge but there is also a positive charge. Under positive cloud, the lightning strike current ranges from 1000-3000 A and under negative cloud it ranges from 50-300 A. Lightning strike current ranges from 8-150 kA under negative cloud and up to 300 kA under positive cloud [9].

Impact of lightning strike

There are several effects of lightning strikes, including direct lightning strikes and the impact has a very large danger and even causes explosions, fires and damage to the power grid on earth. Indirect lightning strikes that point to the earth can hit parts of the power grid but the induction of the lightning can penetrate or be received by the electrical wiring network. If lightning strikes transmission poles, catenary network poles, transmission towers, other tall structures, the current and voltage waves will be divided into three, namely, to the left and right of the pole, and to the ground through the transmission pole [9]. he catenary network along the railway line must then be protected by a lightning protection system including overhead ground wire (OHGW) installed in the highest structure on the catenary network pole with a protection angle of 65-68 degrees as shown in Figure 8. The striking distance from the tip of the lightning tongue to the object above the ground using the following formula [9]:

$$r = 6.7 \times i^{(0.80)} \quad (1)$$

where r (m) is the radius of the rolling ball, the striking distance from the tip of the lightning tongue and i is the lightning peak current in kA and Figure 9 shows the distribution of the lightning peak current in the Jakarta area. To estimate the angle of protection according to the International Electrotechnical Commission (IEC)-62305 standard, the following Hasse and Wiesinger equations are used [9]:

$$\text{Alpha } (\propto^\wedge{}^\circ) = \text{Sin-1 } [\, 1 - (h/r) \,] \quad (2)$$

where, h(m) is the height of the pile structure and r(m) is the lightning strike distance.

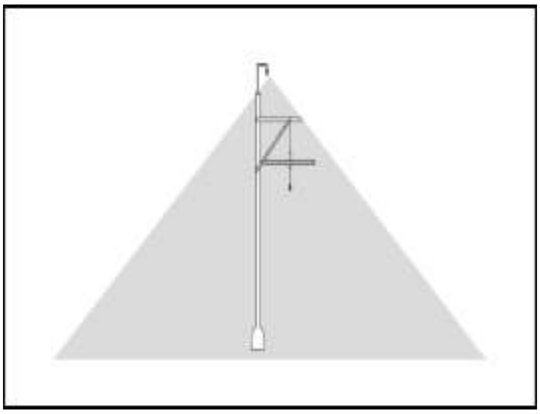

Figure 8. OHGW protected angle [9].

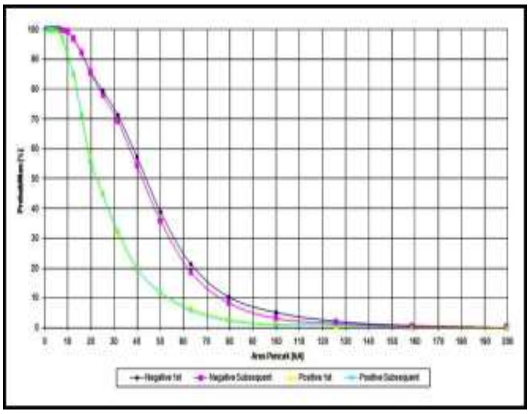

Figure 9. Data distribution of peak lightning currents in the Jakarta area [9].

Grounding installation distance and grounding resistance testing

The installation of grounding on the catenary network pole must of course be installed with a lightning down conductor component which functions to distribute lightning currents to the ground through concrete poles or iron poles of the catenary network, which is connected to the OHGW and then channeled to the grounding equipment. To protect the equipment on the catenary network poles against lightning strikes, the installation of a lightning protection system on the catenary network poles should be provided. Lightning strikes on catenary network transmission with 1 OHGW wire, then the current will be divided by 3 according to the surge impedance of the ground wire and pole. The current flowing through the pole will go through the pole which has a down conductor inductance on the pole (L). The following lightning parameters are used to calculate the steepness of the current wave (di/dt) or kA/µ, namely the inductive voltage on the conductor [9, 10]:

$$u = L \, di/dt \quad (3)$$

where L (Henry) is the inductance of the pole containing the down conductor and di/dt is the steepness of the current wave. Catenary grounding equipment on piles must have good ground resistance. This grounding resistance test uses a grounding resistance measurement tool called the earth resistance tester. In addition, a visual test was carried out during periodic inspections to determine the condition of the grounding equipment whether or not it is feasible to work [11].

METHODOLOGY OF RESEARCH

All research that has been carried out based on the line of thought is shown in Figure 10 below. The research stages mentioned above were carried out using manuals related to catenary network protection equipment from lightning surges, interviews with UPT employees, theoretical references and calculation formulas, and direct observations across the area of UPT Resort LAA 1.7 Pasar Senen. The type of research used in this research is descriptive research and descriptive methods are widely used in research.

Data sources, data collection techniques and research stages

Sources of data analyzed in this study are primary data and secondary data and to obtain complete information with a research focus, the data collection techniques used are a) interviews for data collection through direct question and answer with informants to obtain additional information related to this research; b) observing directly in the field by visual inspection and systematic recording of events, objects seen and other things needed to support the research being carried out and c) documentation of data collection through track records by reading literature, writings, and documents deemed appropriate to the research conducted.

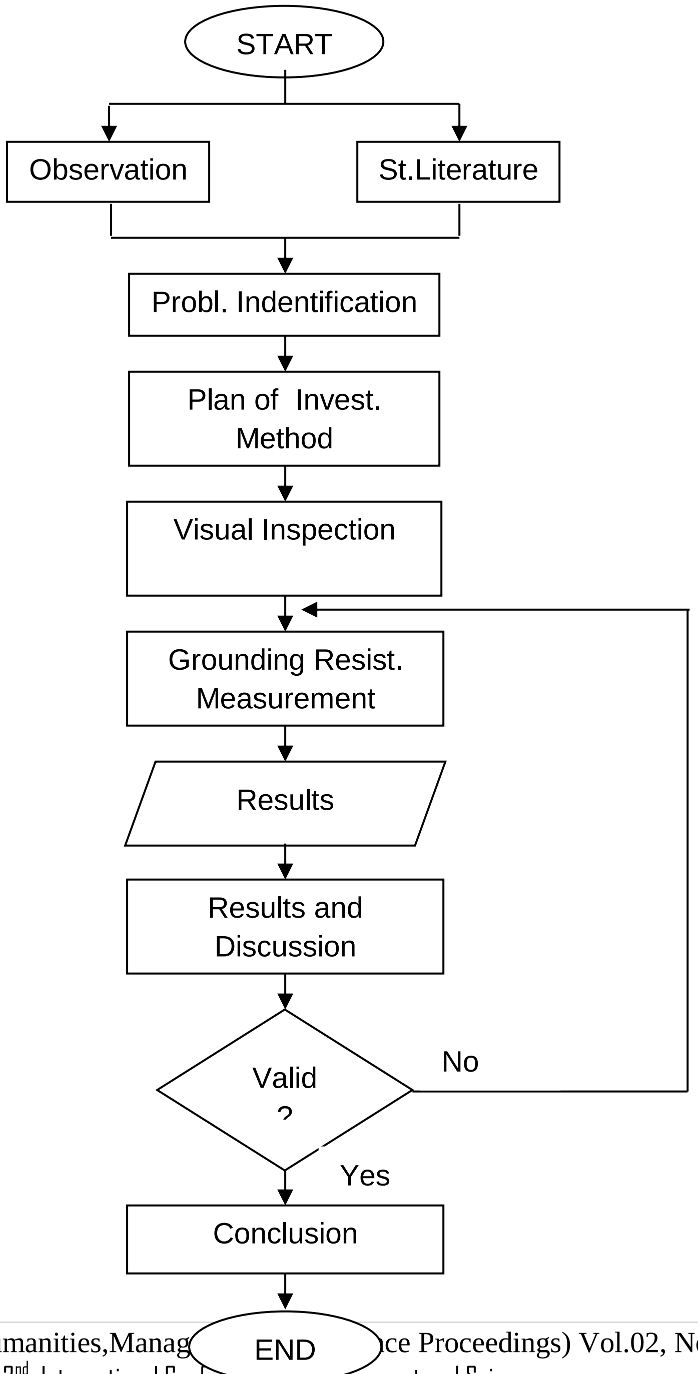

Figure 10. Flow chart of research activities.

In this research, several stages of research were carried out according to the flow chart including, a) observation, namely conducting research by coming to the location of UPT Resort LAA 1.7 Pasar Senen; b) library studies by searching and collecting literature and studies taken by looking for reference books, related journals, and books on lightning protection systems; c) identification of problems containing analysis of problems that occur then the cause will be searched for to be resolved; d) planning of test methods, namely planning what methods are carried out for testing lightning protection equipment on catenary networks; e) visual inspection carried out visually and a checklist on the catenary network lightning protection system equipment to determine whether or not the equipment is operating; f) measurement of grounding resistance to show the results of proper operation, at this stage the equipment is not feasible then measured ground resistance on the equipment penta holding in the catenary network poles to determine the magnitude of the soil resistance; g) analysis and discussion and at this most important stage, analyzed the results of visual and technical tests as well as discussion of repair methods and h) conclusions which are the final results of this research.

Research design

This study refers to several research designs, namely the calculation of the OHGW protection angle installed on the pole, calculating the distance of lightning strikes and looking at the peak lightning current data that occurs in the Jakarta area. Calculation of lightning protection angle was utilized the standard IEC-62305 Hasse and Wiesinger equation. The following is to calculate the distance of the grounding installation on the pole and the optimum distance of this installation is very important to avoid lightning strikes to the OHGW and the structure. The following is a research design on OHGW as shown in Figure 11.

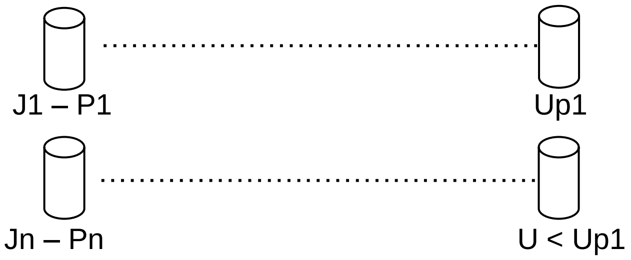

Figure 11. Research design for OHGW.

Information:

1. J1 – P1 = is the distance between the poles of the catenary network of 50 m, the number and optimum distance of lightning protection installed is 250 m.
2. Up1 = Calculation of the induced voltage from the lightning strike against the pole on the 250 m safety protection.
3. Jn – Pn = is the distance between the poles of a certain catenary network, the number and optimum distance of a certain protection until it reaches the lowest induced voltage result.
4. U < Up1 = The value of the induced voltage to be achieved by the safety protection is as low as possible.

To determine the distance of the grounding installation, the calculation of lightning strikes on the pole with ground wire was taken into account using the calculation of the steepness of the current wave (di/dt) or kA/µ, namely, the inductive voltage on the conductor, and the charge released by lightning during a direct strike on the phase wire. Finally, a physical or visual test was carried out and this visual check list of the catenary network includes checking activities on certain param in order to diagnose abnormalities or substandard conditions. Some of the catenary network equipment were also inspected, such as, OHGW, cable clamp, grounding wire/down conductor, grounding rod/ grounding ring, arrester and arching horn. Grounding resistance test was conducted to determine the soil resistance in the catenary network pole area of the UPT Resort LAA 1.7 Pasar Senen. According to applicable standards, a maximum of 5 Ohm has been set. The materials and equipment used for testing the catenary network lightning protection system include a grounding electrode or grounding rod made of 16 mm threaded iron, down conduction wire made of ST 90, ST 55 to ST 90 clamps (U bolt clamps), down lead wire clamps (steel band), ST 90 clamp to rod (U bolt clamp) and tools, such as, hammer, crowbar, drill and others. Another research tool used is binocular zoom up-close binoculars which were applied to zoom in on distant objects with two sets of lenses and prisms side by side.

RESULT AND DISCUSSION

Research Implementation

Disturbances due to lightning strikes on catenary network equipment have an impact on train travel in Jabodetabek and Banten, so the conditions in question require research by analyzing the reliability of the lightning protection system on the currently installed catenary network. The problem of the lightning protection system on the catenary network as a whole has not been repaired/normalized, both for the installation of grounding, lightning arresters and overhead ground wire. The current condition of grounding installation has not been carried out by every pole and some of it is damaged due to vandalism, the condition of the lightning arrester that has a life time and the OHGW network that has rusted or the corner of protection against the network is uneven. Based on these problems, the researchers conducted research in the area of UPT Resort LAA 1.7, Pasar Senen by performing calculations, repairs and testing both visually and technically on the object of research.

UPT Resort LAA 1.7 Pasar Senen is a Technical Service Unit in the Railway Infrastructure department of Operational Area 1 Jakarta which has 5 traction substations located near Kramat Station, Pasar Senen Station, Rajawali Station, Ancol Station, and Tanjung Priuk Station with a catenary network length stretching 59,444 m and has 8 stations, namely Kampung Bandan Station, Ancol Station, Tanjung Priuk Station, Rajawali Station, Kemayoran Station, Pasar Senen Station, Gang Sentiong Station, Kramat Station and Pondok Jati Station. With such an area, it is very important to have lightning protection equipment for the protection of equipment and people in the vicinity. The following is data on catenary network assets in the area of UPT Resort LAA 1.7 Pasar Senen consisting of the number of NASPAN (Upstream and Downstream), Location and length. Kampung Bandan to Kemayoran from Km 0+990 m up to

Table 1. Catenary network asset data [12].

Naspan	Route	Location(km)	Length (m)
Naspan12	BackandForth	Kampungbandan-RajawaliKM0+990S.DKM2+510	2260
Naspan345	BackandForth	Rajawali-KemayoranKM2+340S.DKM5+620	8440
Emplacement	Track2 3456	Empl.Pse2km5+750s.dkm6+340	5630
Naspan6789	BackandForth	Pasarsenen-Gangsentiong-	6390

		Kramatkm6+780s.dkm8+950	
Naspan12	BackandForth	Kampungbandan(atas)–Ancol-TanjungPriokkm2+225s.dkm3+970	5687
Naspan345	BackandForth	Ancol-Tanjungpriuk(Jak)km4+720s.dkm7+600	6020
Naspan1234	BackandForth	Ancol-Tanjungpriuk(Kmo)km3+690s.dkm7+600	8470
Emplacement	Track1-8	EmplasemenTanjungpriukkm7+600s.dkm8+100	500
Naspan1234	BackandForth	Ancol-Rajawalikm0+000s.dkm$+930(km)	11360

Catenary Network Protection Data

Catenary network protection includes overhead ground wire, lightning arrester, arching horn and grounding. The following is the protection data installed in the catenary network of the UPT Resort LAA 1.7 Pasar Senen area.

Table 2. Data of Catenary protection network [12].

Naspan	Jalur	LokasiDanKm	Grounding	Arrester	ArchingHorn
Naspan12	BackandForth	Kampungbandan-RajawaliKM0+990S.DKM2+510	9	5	10
Naspan34	BackandForth	Rajawali-KemayoranKM2+340S.DKM4+270	26	10	10
Naspan5	BackandForth	Kemayoran-PasarsenenKM4+190S.DKM5+620	7	7	4
Emplasemen	Track123456	Empl.Pse1km5+750s.dkm6+960	9	18	10
Naspan67	BackandForth	Pasarsenen-Gangsentiongkm6+780s.dkm8+550	41	8	7
	BackandForth	OutgoingGTKmt		2	
Naspan89	BackandForth	Gangsentiong-Kramatkm8+315s.dkm10+140	13	10	14
Naspan123	BackandForth	Kampungbandan(atas)–Ancolkm2+225s.dkm6+100	24	26	10
Naspan45	BackandForth	Ancol-Tanjungpriuk(Jak)km6+030s.dkm7+600	11	10	8
Naspan1234	BackandForth	Ancol-Tanjungpriuk(Kmo)km3+690s.dkm7+600	15	21	18
Emplacement	Track1-8	EmplacementTanjungpriukkm7+600s.dkm8+100	1	4	3
Naspan1234	BackandForth	Ancol-Rajawalikm0+000s.dkm4+930(kmo)	29	37	19

With a catenary network spanning 59444 meters, a total of 20 lines upstream - downstream and 2 station emplacements with 14 lines, UPT Resort LAA 1.7 Pasar Senen has installed protections, namely Grounding 185, Arrester 153, and Arching Horn 113.

Catenary Network Pole Data

UPT Resort LAA 1.7 Pasar Senen consists of several types of pole construction. The following is the data on the poles installed in the area of UPT Resort LAA 1.7 Pasar Senen.

Table 3. Catenary network pole data [12].

Pole							
Naspan	*Pole*	*StillMass*	Af	Q	Ar	Habim	#PolesPerNaspan
Ns1-5Upstream	106	2	48	11	0	2	189
EmplacemtentPse1	6	1	15	5	0	0	27
EmplacemtentPse23456	27	5	17	8	0	0	57
Ns678912UpstreamDownstream	84	1	83	10	0	6	188
Ns3451234UpstreamDownstream	81	0	93	13	0	3	198
Emp.Tpk1-8	31	0	5	8	0	0	44
Ns12UpstreamDownstream	1	0	45	2	0	0	50
Ns234UpstreamDownstream	20	1	18	10	0	0	63

UPT Resort LAA 1.7 Pasar Senen has a Japanese and Dutch type of pole construction which consists of Pole, Still Mass, AF, Q, AR, HABIM pole types with a total of 818 poles in all naspans and station emplacements. Thus, of the overall catenary network assets at UPT Resort LAA 1.7 Pasar Senen, the network length is 59444 meters, network protection; Grounding 185, Arrester 153, and Arching Horn 113 and Total mast 818 upstream – downstream.

Catenary network protection check results

Referring to the design of the inspection method on lightning protection installed in the catenary network, the calculation of the OHGW angle of protection installed on the pole was implemented. Referring to the distribution of peak lightning currents in the Jakarta area in 2019 can be seen in Figure 12 below:

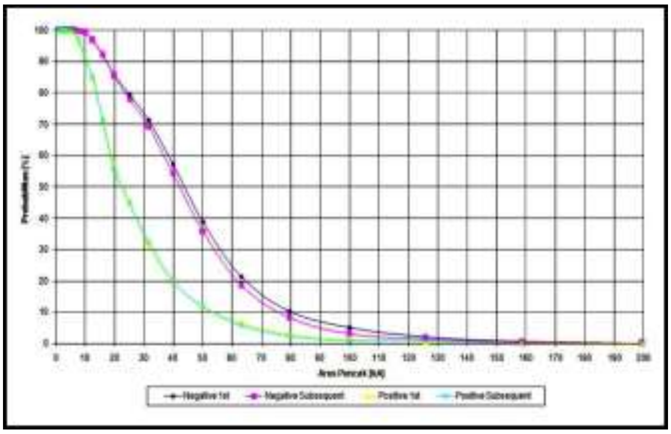

Figure 12. Distribution of current peak lightning in the Jakarta area in 2019.
(Sumber: Prof. Dr. Reynaldo Zoro, *Lightning Peak Current Probability at Jakarta*)

According to the distribution of peak lightning currents in the Jakarta area, the probability of 50% of the peak currents in the Jakarta area is 44 kA. The striking distance from the tip of the lightning tongue to the object above the ground was estimated using the following equation (1) formula:

$$r = 6.7 \times i^{(0.80)} \text{ meter}$$

With the existing data obtained, such as, r = 138.30 m, so the striking distance in the Jakarta area is 138.3 m. To calculate the angle of protection according to the International Electrotechnical Commission (IEC)-62305 standard, the equation (2) was applied. By entering the existing data, it is obtained that the angle of protection for concrete pillars in the Jakarta area has an alpha angle of 67.45 degrees and for the angle of protection for iron poles an alpha angle of 65.95 degrees is obtained.

Determination of the installation distance of the grounding on the pole

In accordance with the research design that J1 is the distance between the catenary network poles and P1 is the number of lightning protection installed, while Up is the result of calculating induced voltage from the lightning strike to the pole on the safety protection. To determine the distance of the grounding installation, a lightning strike on the pole with ground wire was calculated using the calculation of the steepness of the current wave (di/dt) or kA/µ. Given the height of the concrete pole/pole = 10 m and the down conductor and ground wire made of bc, with the inductance value = 0.8 H/m, then (di/dt) is 15 kA. To estimate the value of the voltage that occurs in the catenary network during a strike in the middle of the ground wire, the equation of u = L. (di/dt) was utilized.

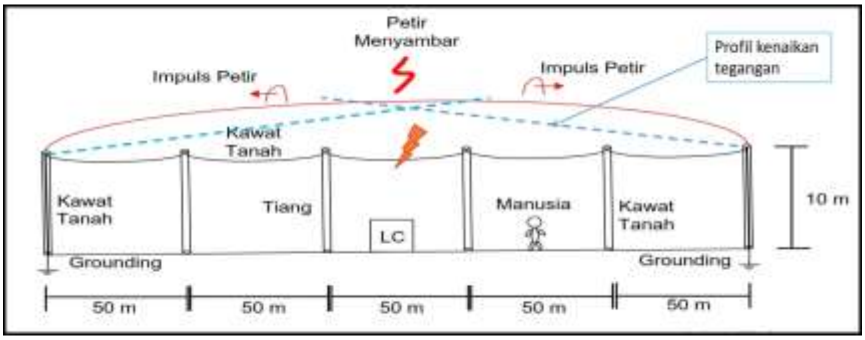

Figure 13. Illustration of an existing pole at the time of a lightning strike.

On the existing pole that J1 = 50 m and P1 = only 2 and is installed per 250 m, then Up is the result of the calculation of the induced voltage from the lightning strike against the pole on the safety protection of 1620 kV, the voltage that occurs on the 6 poles is very high and dangerous for humans and LC (location case) equipment under it.

1. Visual testing

   In the results of the inspection of the protection system installed on the catenary network, it shows that the components installed in the emplacement and road plots are still in good condition and some are not. These components are OHGW, cable clamp, grounding wire/down conductor, grounding rod/grounding ring, arrester, arching horn, and lightning rod at the traction substation.
2. Grounding resistance test results

   The results of testing grounding resistance measurements carried out on grounding installations of traction substations and catenary networks, that GT (Rajawali, Pasar Senen and Kramat averages 1.08, 1.14 and 1.07 Ohms, respectively and each is good, meaning that the value still meets the standard according to the standard. from PUIL 2000 allows that the maximum resistance is 5.

From grounding measurements carried out every 6 poles with a distance of 50 meters per pole and grounding protection only installed 2 poles, the result is Pole 1 2.07 Ohm and Pole 06 2.84 Ohm. This shows that the average value still meets the resistance standard, but the lack of lightning protection is dangerous and has an impact on equipment damage.

Analysis Results

The angle of protection for concrete pillars in the Jakarta area is 67.45 and the angle of protection for iron poles is 65.95. Based on the requirements, the OHGW must be able to protect the lane and LAA with a protection angle of 65-68 degrees and the data and calculation of the OHGW angle of protection installed on poles, either concrete/pole or iron-type poles in the UPT LAA Pasar Senen area are appropriate. For the grounding installation distance on the pole and based on data and calculations of the grounding installation distance on the catenary network pole, the existing poles J1 = 50 m and P1 = only 2 and are installed per 250 meters, providing a down conductor that is too far away and it can cause high voltage elevations because the ground inductance is getting bigger (U=L di/dt). The induced voltage from a lightning strike to the pole on the safety protection of 1620 kV is very dangerous so the railway line is not safe and therefore the solution is to install grounding along with a down conductor for each pole that exists (installed per 50 meters). On each catenary network pole, all OHGW must then be connected to grounding with wire/iron. If each pole is grounded, the voltage occurs in the middle of the pole around 420 kV. It can be seen that by grounding all poles, the voltage that occurs during a lightning strike is greatly reduced, so grounding all poles is highly recommended.

In the visual test, it turned out that from the results of the visual inspection, the condition of the protection system on the catenary network poles was partially inadequate. The problem that occurs is as follows that the occurrence of vandalism (theft) of the grounding rod which generally uses copper. The absence of this grounding rod will cause the discharge of lightning current to the ground to be hampered. The inhibition of discharge to the ground causes the lightning current to continue to propagate in the ground wire, causing a high ground voltage elevation, and endangering humans due to the step voltage. The grounding rod material installed using copper is prone to theft, and according to the IEC standard 62305-1, the minimum dimensions of the lightning protection components are presented in the following table:

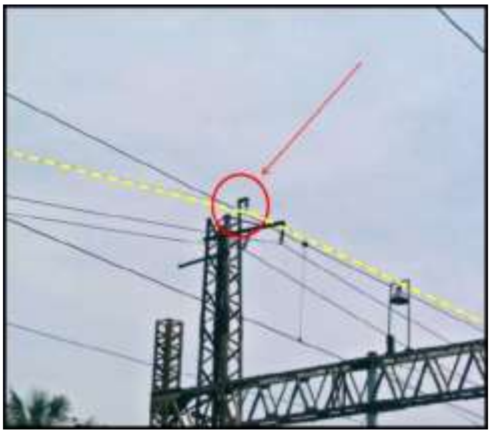

Figure14. Ground wire/OHGW ungrounded.

Table 3. Component dimension of lightning protection

Level Protection	Material	Air termination (mm²)	Down conductor (mm²)	Grounding electrode (mm²)
I-IV	CU	35	16	50
	Al	70	25	-
	Fe	50	50	80

For this reason, the repair solution can be done using a grounding rod with a minimum of 80 mm^2 iron material, in concrete, or using foundation grounding if the structure has not been built. Grounding is planted 50 cm from the ground surface, 3 meter deep, minimum 2 rods, minimum diameter 80 mm. Grounding rods are recommended only with a depth of ± 3 meters with the number of grounding rods 2 pieces per pole. In testing result of the grounding resistant, that there is a difference in the average value of the three traction substations but each grounding resistance of the traction substation still meets the standard. From the measurement of grounding resistance on existing poles, a distance of 250 meters is only installed with 2 groundings with the result that the resistance value still meets the grounding resistance standard. Meanwhile, according to the calculation of lightning strikes on poles with ground wire using the calculation of the steepness of the current wave (di/dt), the installation of grounding per 250 meters is less effective because the lightning induced voltage is very large.

CONCLUSION

Based on the results of the analysis above, it can be concluded that the optimum protection angle distance of the overhead ground wire/OHGW (Overhead Ground Wire) is 67.45˚ for the concrete type pole, while the iron type pole is 65.95˚ and the two corners of protection still meet the protection angle protection requirements of 65-68 degrees. The grounding distance of catenary network poles on existing poles is installed every 5 poles with a distance of 250 meters and this may result in a very high lightning strike induced voltage and very dangerous for humans and surrounding equipment. Cases of vandalism (theft) of the copper grounding rod are prone to theft and the down conductor that is not connected to the grounding rod requires a follow-up to the installation of a new iron grounding rod. Based on the research, it can be suggested that it is necessary to install grounding on each pole with a distance of 50 meters to secure equipment and people along the railway line due to down conductors on iron poles or concrete poles. Recommendations for replacement of single and double shielded types on station emplacements, while in traffic, using the ST 90 type is more economical, and for grounding rods made of copper, since the price is relatively expensive and the material is prone to theft, it is therefore recommended to use iron.

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