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Performance Analysis of Light Arrester (LA) Protecting Power Transformer at Distribution Substation MH284 Buha Manado

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Abstract

North Sulawesi (Manado) is located in the equatorial region with a tropical climate and high humidity, causing the density of lightning strikes in this area to be quite large yearly. Lightning strikes can cause overvoltage, which can endanger the insulator on the line as well as other electrical equipment if allowed to flow into the system and channel to the load. Therefore, a protection system is needed to handle these disturbances. One of them is by installing a Light Arrester (LA). Light Arrester is safety equipment from overvoltage disturbances by surges lightning or surges switching . The arrester works at a specific voltage above the operating voltage to dispose of the electric charge from surges lightning or surges switching. Under normal conditions, the light arrester acts as insulation. However, if there is any available surges lightning or surges switching , the arrester acts as a conductor that functions to pass high currents to the ground. The failure rate of arrester protection is highly dependent on the Basic Insulation Level (TID) of the equipment, the working voltage of the lightning arrester, and the location of the light arrester placement itself.

Keywords: Light Arrester (LA), current, voltage, surges lighting, surges switching , protection, transformer, equipment, fault, overvoltage

1. Introduction

There are two types of lightning strikes, direct lightning strikes (direct stroke) and indirect lightning strikes (indirect stroke). Direct lightning strikes occur when lightning strikes the phase wire or protective wire directly. Meanwhile, indirect lightning strikes occur when lightning strikes objects near the channel. Lightning strikes can cause failure in insulators, back flashover voltage, and induced voltage. Lightning strikes that hit the power system will cause overvoltage, both direct and indirect strikes. This overvoltage can endanger the insulator on the line and other electrical equipment if allowed to flow on the system and channeled to the load. Therefore, a protection system is needed to handle these disturbances. One of the protections is the installation of a Light Arrester (LA). Arresters can secure electrical equipment from lightning surge interference. This security tool has a resistance value that is not linear at each voltage and current level. The arrester's performance is mainly in response to the overvoltage that comes to its terminals.

Therefore, it is essential to know how the arrester works to respond to overvoltage on various wavefronts. To determine the ideal distance between LA and the equipment to be protected by LA. Due to the existence of negatively charged clouds and positively charged clouds, lightning has a high chance of occurring between clouds with different charges. Lightning occurs because there is a potential difference between the cloud and the earth or with other clouds. On the airline, interference due to lightning consists of interference due to direct strikes and indirect strikes, also known as induced strikes. Indirect strikes or induced strikes on medium voltage overhead lines are more common than direct strikes; this is due to the extent of the induced strike area. When there is a lightning strike to the ground near the line, there will be a transient phenomenon caused by an electromagnetic field that causes induced voltage on the line. As a result, overvoltages and traveling waves propagate on both sides of the wire where the strike takes place. Direct strikes are lightning strikes directly on the phase wire (for lines without ground wire) or on the ground wire (for lines with ground wire).

Distribution transformer substations are located close to consumers. The transformer is mounted on a power pole and is integrated into the power grid. The substation is equipped with safety units. Because the high voltage cannot be used to supply the load directly, except for specially designed loads, a step-down transformer is used to reduce the 20kV medium voltage to 380/220Volt low voltage. This distribution transformer substation consists of two sides, the primary part, and the secondary part. Light Arrester (LA) is an equipment protection device in an electric power system that works by limiting lightning surges or overvoltage solar circuits that come by channeling them to the ground.

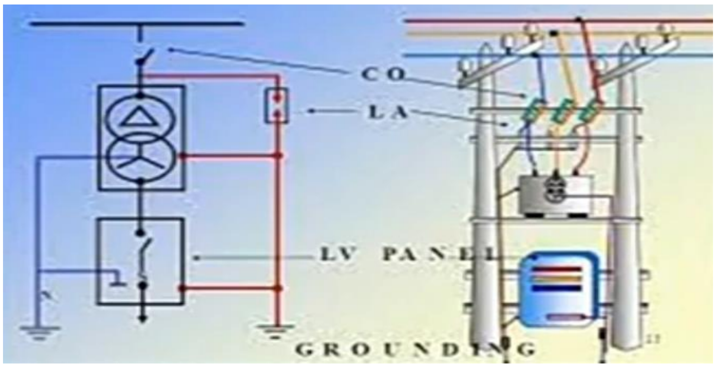

Figure 1: 20 kV/380; 220 Volt Distribution Substation and its components

When normal, the arrester acts as an insulator, and when there is surging lightning or overvoltage, the Light Arrester acts as a conductor. After the surge is gone, the light arrester must quickly return to being an insulator so that the power breaker does not work or open.

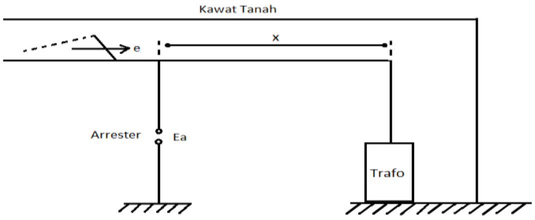

Figure 2 (a): Light Arrester (LA) polymer type 24 kV; 5 kA, (b): Light Arresster distance with transformer as far as x meters

The selection of light arresters is intended to obtain a basic insulation level that matches the TID or BIL (Basic et al. Level) of the protected equipment so that suitable protection is obtained.

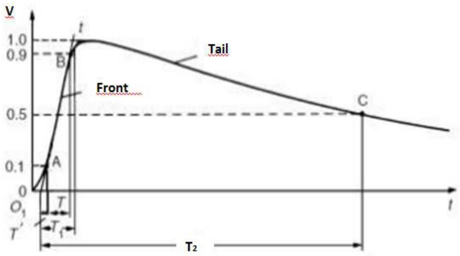

Figure 3: Current waveforms, voltage from surges lightning

Surges lighting is generally described as t1/t2 Lightning strikes in the form of lightning currents with impulse waveforms, with wavefront times of 1_10 us and tail waves of 50_100us with lightning currents of up to hundreds of kA s presented in Figure 3. Damaging lightning strikes can occur many times (multiple strokes), and positive lightning strikes are usually only once and are called multiple strokes. Positive lightning strikes usually only once and is called thunder bolds. Facts about lightning: The voltage between the cloud and the ground can reach 100 MW. The highest negative lightning current ever recorded was -800 kA in the Jakarta area (1995); temperatures in the lightning channel can reach 10,000 ^{0}C.

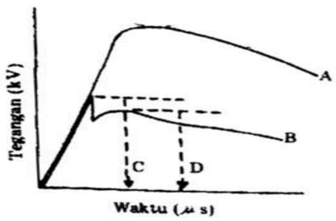

Figure 4: Effect of light arresters on surges lightning

Image description: A is the surges lighting at the distribution substation without a light arrester, B is the surges lighting at the distribution substation with a light arrester, C is the spark voltage waveform on the light arrester, and D is the discharge voltage waveform on the light arrester.

Lightning can travel and strike horizontally, reaching distances of up to 15 km. Indonesia has the most thunder days, 322 days a year in Bogor. Most of the lightning strike interference on SUTM (80%) is caused by induction due to lightning strikes on structures close to SUTM, including lightning strikes on trees, buildings, tall structures, cellular telecommunication towers, and poles, among others. Another portion (20%) is due to direct lightning strikes on the SUTM, especially on overhead lines located in open and vast areas. The main threats of lightning strikes or the effects of lightning strikes on SUTM are Induction from direct lightning strikes on the phase wire due to the absence of a ground wire and the selection of the installation location of light arresters that do not meet the distance arrester protection distance. Selection of an arrester class that does not match the system working voltage. Disturbances arising from direct and induced lightning strikes on SUTM include Phase wire breaks either without insulation or with rubber or plastic insulation, Damage or rupture of insulators on the line, Power transformer damage, Damage to the sealing-end (mof) of the cable, Damage to the power breaker (CB) in the power cabinet (cubicle) inside the substation.

Voltage Rating or Light Arrester (LA) Rated Voltage:

The voltage rating or rated voltage of a light arrester is the maximum effective line-to-line voltage multiplied by the earthing coefficient, as shown in the equation.

$$\text{Rated voltage LA} = V_{L-} \text{ x } 110\% \text{ or } (1,1) \quad (1)$$

Characteristic work arrester for current 10 kA and 5 kA can be seen in the following

Table: 1: Character LA

Rating Arrester (KV)	FOW (KV/μdet)	10 kA and 5 kA	
		STD (kV)	FOW (kV)
12	100	43	50
15	125	54	62
18	150	65	75
21	175	76	88
24	200	87	100
27	225	97	112
30	250	108	125
33	275	119	137
36	300	130	150

STD is the maximum impulse spark voltage, and FOW is the wavelength impulse spark voltage.

Table 2: TID (Basic Insulation Level) or BIL

highest Voltage rms (kV)	TID or BIL		Withstand Voltage (kV)
	List 1 (kV)	List 2 (kV)	
3,6	20	40	10
7,2	40	60	20
12	60	75	28
17,5	75	95	38
24	95	125	50
36	145	170	70

Capacity or Ability of LA to pass surges lightning current

Light Arrester working voltage is also called discharge voltage or residual voltage. The arrester must be able to distribute current according to its capabilities to determine the amount of discharge current. To determine the Light Arrester discharge current is shown in Equation 2.

$$I_a = \frac{2V_p - V_a}{Z} \quad (2)$$

Where Vp is the Peak Voltage, Va is the Nominal voltage, Z is the Impedance

Protection Factor

The protection factor is the voltage difference between the BIL (Basic Impulse Insulation Level) of the protected equipment and the working voltage of the arrester. Generally, this protection factor is 20% of the BIL of the equipment for arresters installed close to the protected equipment. The following equation can be used to determine the protection factor,

FP=(〖TID〗 _Trafo- TP)/ 〖TID〗 _Trafo x 100% (3)

Where TP is the Protection level, and TP can be determined using the following formula:

TP = Va x 1.1

Determination of light arrester (LA) Shielding Distance:

The arresters are placed as close as possible to the protected equipment. However, to get a better protection area, there are times when the arrester is placed at a certain distance from the protected equipment. Protected equipment. The distance between the arrester and the protected equipment affects the magnitude of the voltage arriving at the equipment. If the arrester distance is too far away, then the voltage arriving at the equipment may exceed the voltage it can bear. In practice, the voltage may be more than expected due to the occurrence of isolation due to the inductance of the conductor connecting the arrester with the transformer and the capacitance of the transformer: Transformer and the capacitance of the transformer itself. In addition, when the arrester works to flow the surge current to earth, there is a voltage drop in the resistance of the connecting voltage drop in the resistance of the conductor connecting the arrester with the network and connecting the arrester with the earthing electrode. This voltage drop is affected by the increase in surge current and will increase the voltage rise between the terminals of the arrester and the earth. There is a difference in the earthing potential of the transformer, and the earthing potential of the earth potential of the arrester also increases the transformer's voltage.

Therefore, making the connecting conductor as short as possible and connecting the earthing electrode to the earth is better. Moreover, connect the arrester earthing electrode to the transformer earthing electrode. Transformer. The earthing resistance is tried to be as low as possible, but it would be better if it could be made below one Ohm. It would be better if it could be made below one, Ohm. If the maximum voltage that the transformer can carry (BIL) is known in kV, the maximum distance of the arrester from the equipment can be determined as:

$$U_t = U_a + 2.\frac{du}{dt} + \frac{L}{V} \quad (4)$$

Atau :

$$L = \frac{U_t - U_a}{\frac{2du}{dt}} x\, V$$

where Ua is the Arrester working voltage (kV), Ut is the TID of transformer / 1,2 (kV), du/dt is the surges lighting steepness towards the light arrester (kVμs), L is the distance between light arrester and transformer (m), and V is the speed of wave propagation in the air duct (m/μs)

2. Methods

This research uses a quantitative method, which is a method or way of solving problems using numerical data that is processed and calculated, of course, from data collection. Data collection is carried out by direct observation of the object under study, literature study, interviews, and literature study to obtain, collect, and study all theoretical perspectives from various reference sources regarding the SUTM protection system, distribution substations, and their equipment from solar lightning, solar circuit Observation is carried out to collect data by plunging and seeing objects in the field. After the desired data is available, then data processing/analysis is carried out by entering the data into the equation or formula by the reference / standard library (standard). The research was conducted at PT PLN (Persero) ULP Paniki at the MH284 Buha Manado distribution substation.

3. Results and Discussion

In principle, LA forms a path that will be traveled by a solar lightning connection so that there is no high overvoltage in the distribution network. Under normal conditions, the light arrester acts as insulation while a surge arrester acts as a conductor, channeling the flow of high overvoltage to the ground. After the surges current disappears, the light arrester must quickly return to being an insulator.

Determining the light arrester (LA) as a protector from surges lightning

The rating voltage or rated voltage of the light arrester is the voltage at which the arrester can work according to its characteristics. The arrester must not work at the maximum voltage of the system but be able to effectively disconnect the aftershock current from the system. The rated voltage of the arrester is the maximum line-to-line voltage multiplied by 110% or (1.1) then the voltage rating or rated voltage of the light arrester is:

$$V_p = \text{Line to line voltage} \times 1.1$$

$$V_p = 20\ KV \times 1.1 = 22\ KV$$

The rated voltage of an arrester is close to 22 kV is 24 kV as given in Table 1.

Light Arrester (LA) Working Voltage:

Working Voltage or LA discharge voltage is the most important characteristic of an arrester for equipment protection. This working voltage determines the protection level of the light arrester. The arrester discharge voltage for a rated voltage of 24 kV with a discharge current of 5 kA and 10 kA, according to tables 1, 2, and 3 in the appendix, is 87 kA.

Light Arrester (LA) Release Current Selection

The 20 kV SUTM system that supplies the MH270 Buha distribution substation has a total of 3 insulators. From Table 5 in the appendix, the voltage obtained was a running wave voltage of 355 kV. Taking the conductance impedance of 500 ohms, the impulse discharge current of the light arrester (LA) is:

$$I_a=(2V_p - V_a)/Z$$

Where Vp is the Peak Voltage, Va is the Nominal voltage, and Z is the Impedance, then. I_a=([2(355)- 87] KV)/(500 Ohm), With Ia = 1.25 KA, The value of the release current is 1.25 KA so that the selection of the five kA current class is appropriate.

Protection Level (TP)

The protection factor is the ratio between the difference
TID voltage of the protected equipment with the working voltage of the arrester: According to the previous discussion, the working voltage of the lightning arrester for the 20 kV system is set at 87 kV, the protection level of the arrester with the factory tolerance added 10% so that:

$$TP = V_a \times 1.1$$

$$= 87 \times 1.1 = 95.7\ KV$$

The protection level (TP) of the light arrester is 95.7 kV. And TID transformer = protection level (TP) + 20% protection level or TID Transformer = TP x 1.2 = 95.7 x 1.2 = 114.84 KV, from table 7, the TID (Basic Insulation Level) of the Transformer is selected which is greater than or equal to 114.84 KV, namely 125 KV, then obtained also from table 7 the network resistance voltage of 50 KV. Determine the circuit overvoltage and temporary overvoltage as follows: Overvoltage = (20 KV)/√3 x 6.5 = 75.1 KV, and Temporary Overvoltage = (20 KV)/√3 x 3=34.64 KV

The circuit overvoltage and temporary overvoltage are checked as follows: It turns out that the circuit overvoltage (75.1 KV) < TID equipment (125KV), It turns out that voltage more temporary (34.64 KV) < voltage (50 KV). TID for power breaker equipment, measuring transformers, closing switches, and others amounted to 125 x1.1 = 137.5 KV. A higher level of equipment TID was selected, which is 145 KV. The TID of the breaker switch is 145 x 1.1 = 159.5 KV; a standard TID is selected from the table, and a TID value of 170 KV is obtained.

Protection Factor (FP)

Protection Factor (FP) = TID – TP, FP = (125 - 95.7) KV = 29.3 KV, 20% of TID = 125 KV x 20% = 25 KV, FP (29.3 KV) > 20% TID value (25KV) based on this fact, the selection of light arresters can provide a good protection factor (FP) for transformers and other equipment at the MH284 Buha Manado distribution substation.

Determining the location of the Light Arrester (LA)

Determining the location of the Light Arrester (LA) Placement *is necessary to know the distance of the light* arrester. it is necessary to know the steepness of the incident wave (du / dt) and the magnitude of the incident wave voltage on the equipment (Ut). If the steepness of the incident wave is 1000 kV/μs, 1500 kV/μs, 2000 kV/μs, The magnitude of Ut = TID/1.2 =125/1.2 = 104 kV, the speed of wave propagation on the air wire = 300 m/μs, the steepness of the incident wave is 1000 kV/μs, then the maximum distance of the light arrester to the transformer and other equipment protected by the light arrester (LA) is:

$$U_t = U_a + 2.\frac{du}{dt} + \frac{L}{V}$$

$$L = \frac{U_t - U_a}{\frac{2du}{dt}} \; x \; V$$

a. du/dt = 1000kV/us

$$L = \frac{104 - 87}{2\,(1000)} \; x \; 300 = 2{,}6\; m$$

b. du/dt = 1500kV/us

$$L = \frac{104 - 87}{2\,(1500)} \; x \; 300 = 1{,}7\; m$$

c. du/dt = 1500kV/us

$$L = \frac{104 - 87}{2\,(2000)} \; x \; 300 = 1{,}3\; m$$

The calculation results for the maximum distance of LA to the equipment to be protected in this case, the 20 KV power distribution transformer with the steepness of the incoming lightning or surges wave 500KV / s then the max distance of LA to the transformer is 2.75 meters, if the wave comes 1000kV / s then the max distance of LA to the transformer is 1.37 meters and if the incoming wave is 1500KV / s then the max distance of LA to the transformer is 0.92 meters.

From the results of the above calculations, it can be concluded that the greater the steepness of the incoming wave at the substation, the closer the distance of the arrester placement to the transformer. In the case of the construction of its installation in the field, it is very close to the transformer, about 2 meters. With an overvoltage disturbance on the 20 kV distribution line, the lightning arrester can immediately secure it.

4. Conclusion

The Light Arrester is placed at the farthest location from the protected equipment (Distribution transformer) by 2.6 meters if the steepness of the solar wave coming to the SUTM line towards the light arrester is 1000 kV/us. From the field data taken, the distance from the Light Arrester (LA) to the installed transformer is less than 2.6 meters, which means it meets the criteria for dealing with lightning strikes on the line of 20 KV connected to distribution transformer MH284 Buha Manado.

The character of the Light Arrester (LA) of the 20 kV distribution overhead line at the MH284 Buha Manado distribution substation with an arrester rating or rated voltage of 24 kV is a discharge voltage of 87 kV with a nominal discharge current of 5 kA. The light arrester discharge current class for 20 kV medium voltage is five kA (8/20μs) and can withstand a surges lightning impulse of 65 kA (4/10μs). The average lightning surges impulse due to induced lightning strikes in Indonesia ranges from 30 kA to 40 kA. FP or Light Aarrester (LA) protection factor for distribution transformers and equipment around the MH284 Buha Manado distribution substation is more significant than 20% of the TID (Basic Insulation Level) of the equipment, so this Light Arrester has provided good protection for distribution transformers and other equipment around it from surges lighting and surges switching.

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