Simulation of Surge Protective Devices for Low-Voltage Systems Connected to Digital Subscriber Line Access Multiplexer

Pramuk Unahalekhaka and Siamrat Phonkaphon

Abstract— *This paper presents a simulation of lightning surge voltage in distribution system. As a result, the low voltage system in the cabinet for Digital Subscriber Line Access Multiplexer (DSLAM) used the Alternative Transient Program - Electromagnetic Transient Program (ATP-EMTP) that simulated on the power distribution system with a low voltage system, lightning arrester model (LA) and surge protection device model (SPD). The simulation was used for the lightning impulse current 8/20 µs at 20 kA 40 kA and 80 kA that stroked to overhead ground wire (OHGW). The simulation results in case of low voltage with and without surge protective device as zone, the lightning impulse current at 20 kA comprised the surge voltage 21.188 kV and 2.391 kV, the lightning current at 40 kA comprised the surge voltage 41.607 kV and 1.588 kV, the lightning current at 80 kA comprised the surge voltage 82.290 kV and 2.451 kV respectively. The lightning current at 40 kA and 80 kA comprised the surge voltage upward than standard. The surge protection device had been installed between the cabinet. The surge voltage had not been exceeding of voltage protection zone (IEC 61312-1 standard).*

Keywords— **Distribution system, lightning surge, lightning arrester, surge protection device.**

1. INTRODUCTION

In general, the cabinet for Digital Subscriber Line Access Multiplexer is usually installed in the economic and the community areas. The installed protective devices are necessary in these cabinets because it supports the loss of service in these sites that can cause loss of high revenue generated per hour, Currently the electronic equipments in the factory and the office buildings are often damaged in the raining, lightning in the distribution system. It causes the transient over voltage, which it is also known as a surge voltage, into the excess electrical devices, electronics and communications equipments in order to endure it. The aim of this paper is to simulate the effects of lightning indirectly with the affects of the surge voltage to the devices by simulating installed lightning arrester. Surge Protection Device (SPD) was the different lightning protection zones which was known as Lightning Zone of Protection (LZP) as followed the standards of IEC 61312-1:1995 [1], including the simulation the cabinet for Digital Subscriber Line Access Multiplexer In addition, using Alternative Transient Program – Electromagnetic Transient Program (ATP-EMTP) was applied for simulating and analyzing the surge of low voltage system from lightning. Also the cabinet included a transmitter for the Digital Subscriber Line Access.

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2. PARAMETER ASSOCIATED

Parameter associated could be divided into three parts; firstly, a distribution system model and the communication equipments cabinet, secondly, lightning arrester and thirdly, protection zone.

Model of Distribution System and Communication Equipments Cabinet

The distribution system was 22 kV, single circuit layout as shown in Fig.1. which was contained with all aluminum conductors on 185 mm² per phase. Overhead Ground Protective wire was 25 mm² with the spiral wire in 50 mm². These were in the low voltage system installed including installation of the communication equipment and cabinet as shown in Fig. 2.

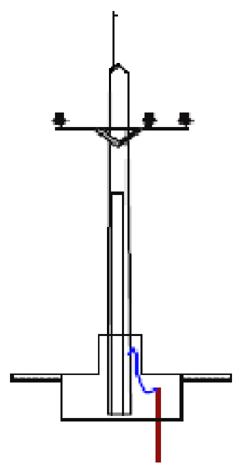

Fig. 1. Concrete polesof the distribution system and the communication cabinet.

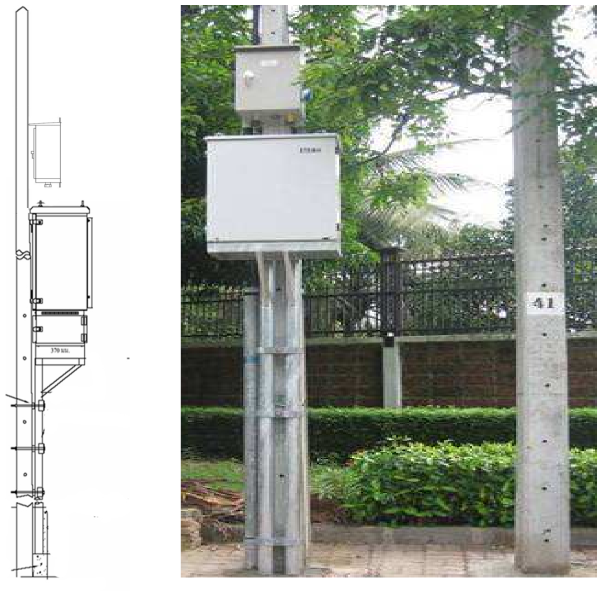

Fig. 2. Position installed the communication cabinet.

The model of distribution system, the communication cabinet and the lightning arrester include SPD created by ATP-EMTP program. In the part of the distribution system was selected the models of J.Marti which was the simulation system by a 400 meter long, distance between the poles 40 meter and was grounding at every 200 meters.

Surge Impedanceof Concrete Poles

Concrete poles were 12 meters height. It was divided into two parts in simulation: a concrete pillar at the height of 10 meters above ground and two meters in the buried ground. Also, the surge impedance of above the ground was given by equation 1.

$$Z_{pole} = \frac{60}{\sqrt{\varepsilon_r - j\dfrac{\sigma}{(\varepsilon_0 \omega)}}}.\ln\left(\frac{h+\sqrt{h^2+R^2}}{R}\right) \quad (1)$$

when ε_r is dielectric constant of material

ε_0 isdielectric constant of air

σ is electrical conductivity (S/m)

ω is angular frequency (rad/s)

h is height of the poles (m)

R is thickness of the concrete (m)

The resistance of the concrete pole in the burial ground was given by the equation 2 [2].

$$R = \frac{1}{2\pi L}.\left(\rho_C.\ln\left(\frac{D_C}{d}\right) + \rho.\left[\ln\left(\frac{8L}{D_C}\right) - 1\right]\right) \quad (2)$$

when R is resistance (Ohm)

L is the total length of all connected grid conductors (m)

D_C is the diameter of the concrete shell (m)

d is the diameter of the ground rod (m)

ρ is the soil resistivity (Ω·m)

ρ_C is the resistivity of the concrete (Ω·m)

Surge Impedance of Grounding Conductor

The conductor 7 grounding wires with spiral were 50 mm² in diameter of 9 mm for surging the impedance grounding of conductor that was given by equation 3. [3]

$$Z = 60.\ln\left(\frac{h}{e.r}\right) - k.\ln\left(1+\frac{r_C}{D}\right) \quad (3)$$

when Z is surge impedance (ohm)

h is length of the cable conductors (m)

e is natural logarithm (2.718281828)

k is constant

r is radius conductor grounded external (m)

r_C is radius concrete poles (m)

D is distance pole to the grounding conductor. (m)

Lightning Arrester and Surge Protection Device

The lightning arrester and the surge protection device were based on the installed location in the distribution system, lightning arrester and surge protection device in the low voltage. The details were as follows below.

Lightning Arrester (LA)

Nowadays, Lightning Arrester (LA) is a Metal Oxide which contained the qualify as non-linear resistance (Non-linear resistor). The position installed was between the LPZOA and LPZOB zones by a simulation lightning arrester model that was the PK model [4] as shown in Fig.3.

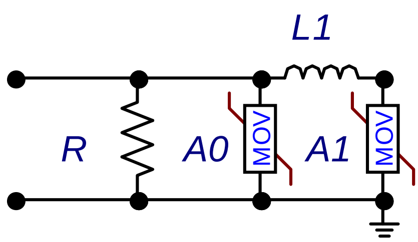

Fig.3. Lightning arrester model (P-K model).

Lightning Arrester in the Low Voltage and Surge Protection Devices (SPD)

The surge protection devices (SPD)in the low voltage was the device to protect the damaged. Lightning arresterin the low voltage was in LPZ0B zone while the surge protection device was in LPZ 1and LPZ 2zone. The model was shown in Fig.4 [5].

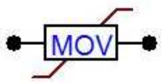

Fig. 4. Lightning arrester in the low voltage and the surge protection devices.

The Standard of IEC 61312-1: 1995

The Standard of IEC 61312-1defined the voltage surge due to lightning protection zone (Lightning Protection Zone: LPZ), it was divided into protection zones as shown in Fig.5.

Determining the standard of IEC 61312-1 for protection zone is as followed below.

LPZ 0A: Protection zone was getting a lightning strike directly.

LPZ 0B: External lightning protection zone was not got a lightning strike directly.

LPZ 1: Internal protection zone was not got a lightning strike directly. The lightning impulse current and switching surge were flown through the conductor and a size reduced in LPZ0A LPZ0B.

LPZ 2: Lightning impulse current and switching surge zone were flown through the conductor and a size reduced over LPZ 1 zone.

3. SIMULATION

Modeling The simulation was used for the lightning impulse current 8/20 µs at 20kA 40kA and 80kA that was strike to overhead ground wire (OHGW) that close to the cabinet. It was divided into three cases.

3.1 In case of low voltage system without protective device was shown in Fig.6.

3.2 In case of low voltage system with protective device in the zone was shown in Fig.7.

3.3 In case of low voltage system with the installedprotective device increased in the zone was shown inFig. 8.

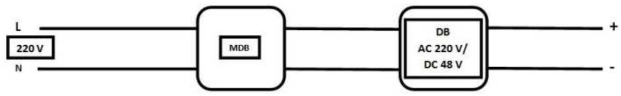

Fig. 6. The low voltage system without protective device.

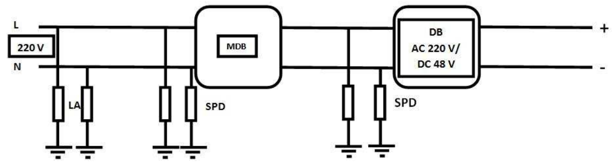

Fig. 7. The low voltage system with protective device as zone.

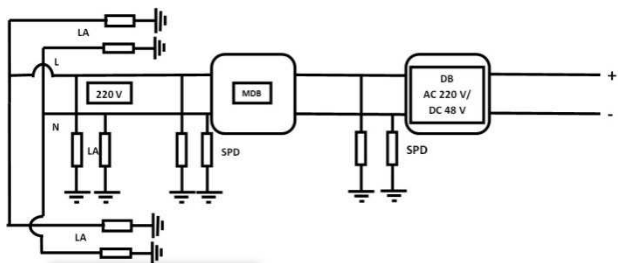

Fig. 8. The low voltage system installed protective device increase as zone.

4. SIMULATION RESULTS

The results of simulation were considered the surge voltage occurred in the low voltage that caused the lightning strike to overhead ground wire (OHGW) in the distribution system. It was used for the lightning impulse current at 8/20 µs 20kA 40kA and 80kA as shown in Table 1-3.

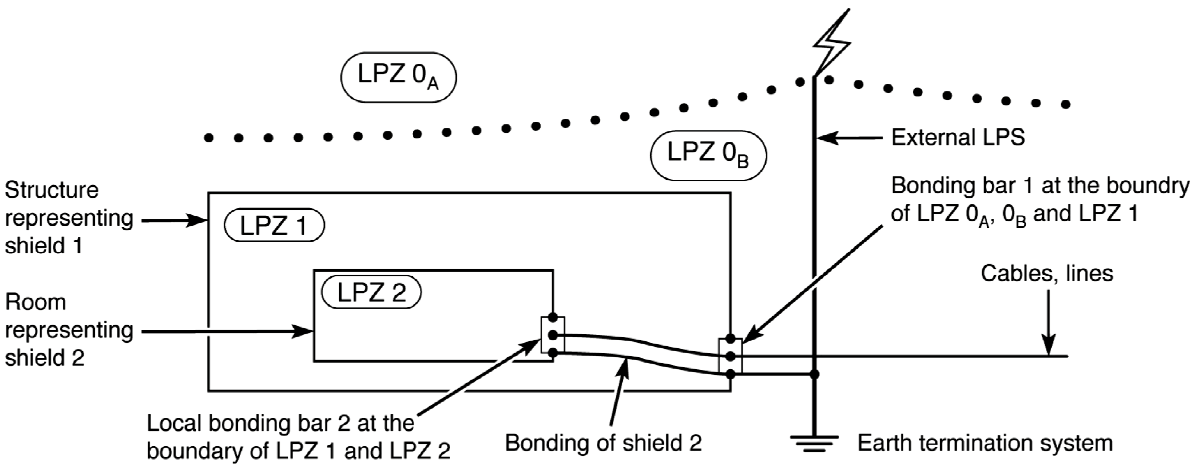

Fig. 5. IEC standard: Lightning protection zone.

Table 1. The surge voltage at lightning impulse current 8/20 µs20 kA (kV)

Protection of the low voltage	Position the lightning strike OHGW		
	Protection Zone		
	LPZ0B	LPZ1	LPZ2
case 1	21.188	21.188	21.188
case 2	2.391	2.391	2.391
case 3	1.015	1.015	1.015

Table 2. The surge voltage at lightning impulse current 8/20 µs40 kA (kV)

Protection of the low voltage	Position the lightning strike OHGW		
	Protection Zone		
	LPZ0B	LPZ1	LPZ2
case 1	41.607	41.607	41.607
case 2	4.076	4.076	4.076
case 3	1.588	1.588	1.588

Table 3. The surge voltage at lightning impulse current 8/20 µs80 kA (kV)

Protection of the low voltage	Position the lightning strike OHGW		
	Protection Zone		
	LPZ0B	LPZ1	LPZ2
Case 1	82.290	82.290	82.290
Case 2	7.400	7.400	7.400
Case 3	2.451	2.451	2.451

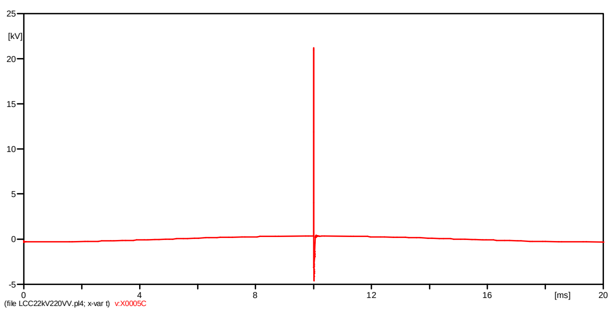

Fig. 9. The surgevoltage at lightning current 20kA without protective device in Case 1.

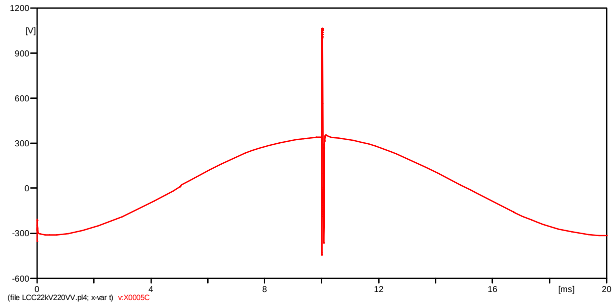

Fig. 10. The surgevoltage at lightning current 20kA with protective device in Case 3.

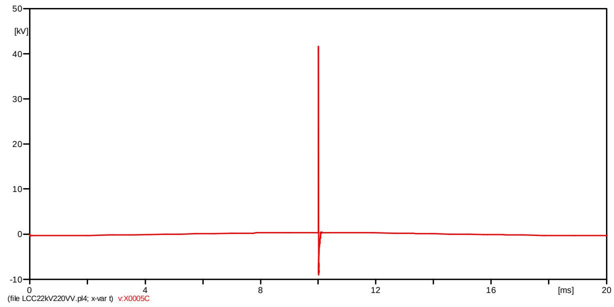

Fig. 11. The surgevoltage at lightning current 40kA without protective device in Case 1.

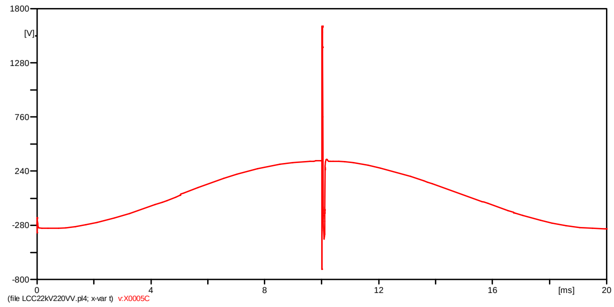

Fig. 12. The surgevoltage at lightning current 40kA with protective device in Case 3.

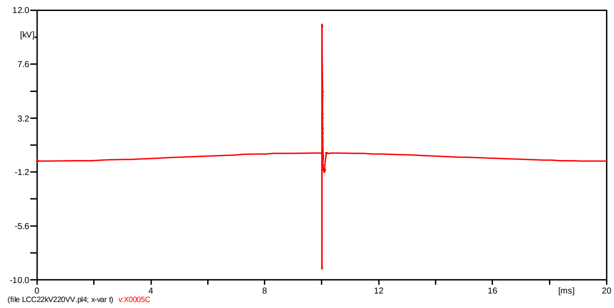

Fig. 13. The surgevoltage at lightning current 80kA without protective device in Case 1.

The simulation of the lightning strike current at 20kA, the voltage surge without protective devices appeared as 21.188kV which was more than the standard of IEC 61312-1as shown in Fig. 9. On the other hands, the voltage surge with protective device was 2.391kV which was in the standard of IEC 61312-1as shown in Fig. 10.

Including, the surge protection device was installed between the cabinet at the lighting current 40kA. Unless the cabinet without the protective devices was 41.607kV as shown in Fig. 11including with protective device was 1.588kV as shown in Fig.12and the lighting current 80kA. Unless the cabinet without protective devices was 82.292kV as shown in Fig. 13and with protective device was 2.451kV as shown in Fig.14.The surge voltage had not been exceeding of the voltage protection zone (IEC 61312-1standard).

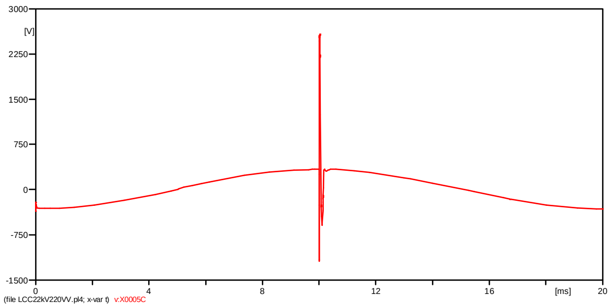

Fig. 14. The surgevoltage at lightning current 80 kA with protective device in Case 3.

5. CONCLUSION

The simulation of the lightning impulse current 8/20 µs at 20 kA 40 kA and 80 kA stroke to overhead ground wire (OHGW) that close to the cabinet. The simulation of the lightning impulse current at 20 kA the voltage surge with protective device as zone, the surge voltage had not exceeding voltage level protection zone. The lighting current 40 kA and 80 kA had the surge voltage of the low voltage upward than protection zone of IEC 61312-1 standard. The surge protection device had been installed between the cabinets. The surge voltage had not been exceeding of the voltage protection zone (IEC 61312-1 standard). The lighting zone protection was considered how to Bonding, Shielding and Grounding to reduce surge voltage that had declined the most.

REFERENCES

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[4] P. Unahalekhaka, K. Sirichunchuen, "Simplified Modeling of Metal Oxide Surge Arresters Using ATP-EMTP", EMSES 11th, December 2013.

[5] ATP Rulebook – XIX.I- "ZNO FITTER" to punch Type 92 ZnO branch cards.