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Analysis of Lightning Surge Condition Effect on Surge Arrester in Electrical Power System by using ATP/EMTP Program

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Abstract**—**The condition of lightning surge causes the traveling waves and the temporary increase in voltage in the transmission line system. Lightning is the most harmful for destroying the transmission line and setting devices so it is necessary to study and analyze the temporary increase in voltage for designing and setting the surge arrester.

This analysis describes the figure of the lightning wave in transmission line with 115 kV voltage level in Thailand by using ATP/EMTP program to create the model of the transmission line and lightning surge. Because of the limit of this program, it must be calculated for the geometry of the transmission line and surge parameter and calculation in the manual book for the closest value of the parameter. On the other hand, for the effects on surge protector when the lightning comes, the surge arrester model must be right and standardized as metropolitan electrical authority's standard. The candidate compared the real information to the result from calculation, also.

The results of the analysis show that the temporary increase in voltage value will be rise to 326.59 kV at the line which is done by lightning when the surge arrester is not set in the system. On the other hand, the temporary increase in voltage value will be 182.83 kV at the line which is done by lightning when the surge arrester is set in the system and the period of the traveling wave is reduced, also. The distance for setting the surge arrester must be as near to the transformer as possible. Moreover, it is necessary to know the right distance for setting the surge arrester and the size of the surge arrester for preventing the temporary increase in voltage, effectively.

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Keywords**—**Lightning surge, surge arrester, electrical power system, ATP/EMTP program.

I. INTRODUCTION

NATURAL phenomenon like lightning could cause the traveling waves to different devices connected to both sides of transmission line and cause the temporary increase in voltage in the transmission line system. The increase in voltage is harmful for the insulator of lines and devices connected to the transmission line. Therefore, it is necessary to analyze such increase in voltage in order to design the surge arrester (or the insulator) suitable for the investment, the good performance of the system and the reliability of transmission line system [1-6].

The method used to analyze the increase in voltage due to lightning was done by using the application called 'ATP/EMTP'. This software could be used to analyze electric system in different aspects, including transition state and steady state. Therefore, it could be used to analyze the transmission line system. This project would analyze the lightning on phase line by stimulating electric devices for both instances in order to represent the measurement in the software and then simulation was made to analyze the occurrence.

The result arisen by using the software ATP/EMTP in analyzing the electric system was that the effects were known, that is to say, the temporary increase in voltage due to lightning on ground line. The resistance of ground line root should be little in order that the temporary increase in voltage is little as well. In the other case, or lightning on phase line, the surge arrester could be used to prevent and reduce the temporary increase in voltage.

This simulation made use of the data of the surge arrester by metropolitan electrical authority and compared it with the data calculated. The outstanding difference could be seen due to numerous factors which would be discussed later.

II. SIMULATION PROCESS

Lightning on phase line of transmission line system might cause insulation breakdown of important devices. Therefore, this occurrence must be avoided as much as possible. The way to reduce the risk is the use over voltage shield line on the phase line where there is lightning. This could be calculated by lightning current (I_o) and line surge impedance (Z_S). Lightning is current source with high impedance. The circuit is shown in

Fig. 1 where load is equivalent surge impedance **(Z_{eg})**. Therefore, over voltage due to lightning **(V)** in Fig. 1 a is as follows[7]:

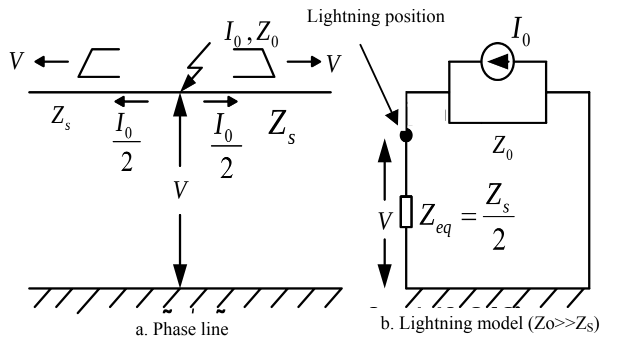

Fig. 1 Circuit of Lightning on Phase line

$$V = \frac{I_0 \times Z_{eq} \times Z_0}{(Z_0 + Z_{eq})} = \frac{I_0 \times Z_{eq}}{\left(1 + \frac{Z_{eq}}{Z_0}\right)} \quad (1)$$

if $Z_0 >> Z_{eq}$, $V = I_0 \times Z_{eq}$ and if Z_{eq} is equivalent surge impedance of line = $\frac{Z_s}{2}$ Therefore,

$$v = \frac{I_0}{2} \times Z_S \quad (2)$$

Equation 2 indicates charge transfer of current **(I_o)** half to each side, making over voltage **(V)** move leftwards and rightwards of phase line.

Over voltage which reaches electric insulator near lightning position will overlap insulator or rod gap of insulator to the ground if and only if over voltage is more than critical flashover voltage of insulator or **V_{era}**, which could be seen in Fig 1. Therefore, the least lightning current **(I_{min})** which cannot cause overlap could be found using equation 3. Zinc Oxide Surge Arrester equation used in the software.

$$i = \left[\frac{|V|}{c}\right]^a \quad (3)$$

The calculation of over voltage which could be prevented due to surge pressure if 96 kV zinc oxide surge arrester is used [8]. Therefore, the level which could be kept is

$$96 \times 1.414 \times 17 = 230.765\,kV$$

$$y = ax^b$$

$$\log\ y = \log a + b \log x$$

$$y' = a' + bx'$$

$$y' = \log y$$

$$x' = \log x$$

$$a' = \log x$$

$$na' + b\sum x' = \sum y \quad (4)$$

$$a\sum x' + \sum y' = \sum x'y' \quad (5)$$

Surge Arrester uses 96 kV (rms). The value was input in Equation 1 and Equation 2 as shown in Table 1.

$$10a' + b(52.119587) = 5$$

$$(52.11987)\,a' + b(271.8164) = 29.62205$$

Yielded

$$a' = -105.96414$$

$$b = 20.42678$$

Then

$$c = 153996.4495$$

$$a = 20.42678$$

TABLE I DATA OF 96 KV SURGE ARRESTER

Current [A]	Voltage [P.U.]	Voltage = 1.414*96*P.U.	y'	x'	x'^2	y' * x'
0.0001	0.6875	93324	-4	4.9699	24.7008	-19.8799
0.001	0.9583	130083.4752	-3	5.11422	26.1552	-15.3426
0.01	1	135744	-2	5.1327	26.3448	-10.2654
0.1	1.083	147010.752	-1	5.1673	26.7014	-5.1673
1	1.125	152712	0	5.1838	26.8725	0
10	1.2083	164019.4752	1	5.2148	27.1951	5.2148
100	1.2708	172503.4752	2	5.2367	27.4240	10.4735
1000	1.416	192213.504	3	5.2837	27.9183	15.8513
10000	1.625	220584	4	5.3435	28.5537	21.3742
100000	2.1875	296940	5	5.4726	29.9501	27.3633
		∑	5	52.1198	271.8164	29.6220

TABLE II DATA OF 115 KV SURGE ARRESTER

Current(A)	Voltage(KV)	Current(A)	Voltage(KV)
65600	322.7799	1.02	153.8715
40500	291.6761	0.0422	147.6919
20000	255.2165	0.00672	143.5722
9970	234	0.00312	141.3063
5000	216.6972	0.00083	134.9208
1050	191.5669	0.00045	129.3592
522	183.1215	0.0001	97.01937
50.2	169.9384	0.00005	70.03521
10.2	162.3169	0.00001	25.33627
5.17	159.0211		

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TABLE III DATA OF 24 KV SURGE ARRESTER

Current(A)	Voltage(KV)	Current(A)	Voltage(KV)
0.00001	3.657702	9.96	16.0978
0.00005	8.547677	50	16.86064
0.00009	10.36675	506	18.26895
0.00042	12.9291	1110	19.2665
0.00075	13.41809	5200	22.16137
0.0029	13.98533	9990	24.1956
0.00647	14.14181	19200	26.22983
0.0415	14.55257	39800	30.96333
1.07	15.15892	61600	34.03423
5.07	15.78484		

2.1 The Distance for Setting Surge Arrester

As for substation with system 115 kV = 550 kV (according to IEC), the increase in voltage value of arrester will be 5 kA = 264 kV when it is not connected to the ground, and the wave incline of surge will be $1550 = \text{kV}/\mu\text{s}$ [9]. If the system is not connected to the ground

$$l \le \left[\frac{BIL}{1.2} - Up\right]\frac{V}{2S}$$

$$l \le \left[\frac{550}{1.2} - 264\right]\frac{300}{2\times1550}$$

$$l \le 18.80 \quad m$$

If the system connect neutron directly to the ground

$$U_r = 191 kV$$

$$l \le \left[\frac{550}{1.2} - 191\right]\frac{300}{2\times1550}$$

$$l \le 25.87 \quad m$$

2.2 Simulation Selection and Simulation Result Collection in ATP/EMTP Software III

During the experiment or the modeling of transmission line system with 115 kV, ATP/EMTP software had to understand the principles and related theories as cited above. The focus was on case study examination in order to apply the data in setting the elements for 115 kV cable transmission line and setting the form of voltage source or electric current source, including over voltage surge or transient voltage in ATP/EMTP software. In order to set the elements for modeling, the cable line arrangement and the size of transient voltage as two parameters must be real information given by metropolitan electrical authority. The calculation must be done according to the reference documents in order to find the accurate value for modeling [10]. Then, the parameters in the software can be changed.

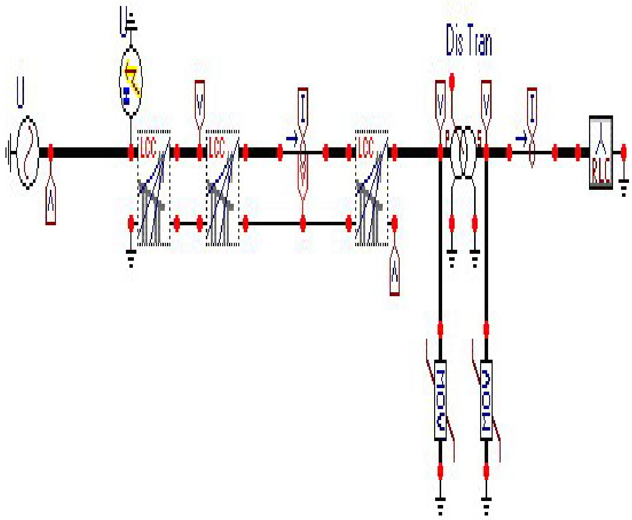

Fig. 2 Selected Model

According to Fig 2, overhead line model was selected by the researchers because it could represent constant parameter of 3 phase electrical cord and it was suitable for electric induction with 3 phase one circuit. Moreover, it could represent many other lines. Simulation results are shown in Fig. 3-5.

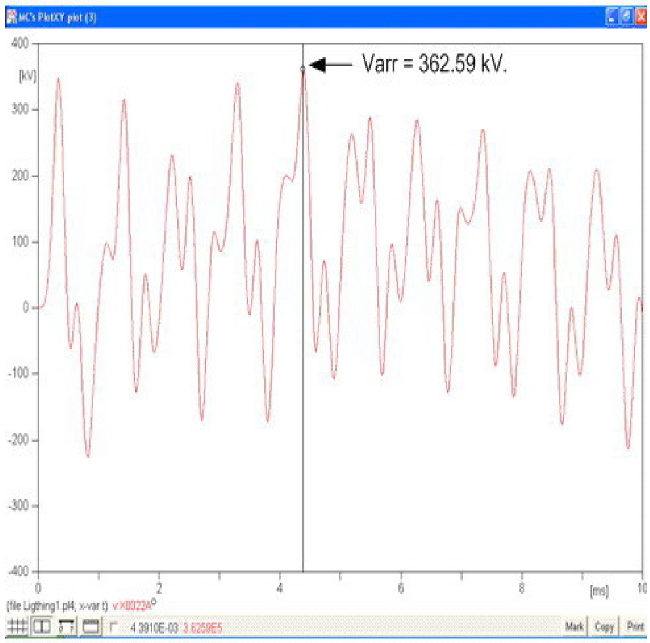

Fig. 3 Primary Voltage Wave of Phase A Transformer (Surge Arrester is not set)

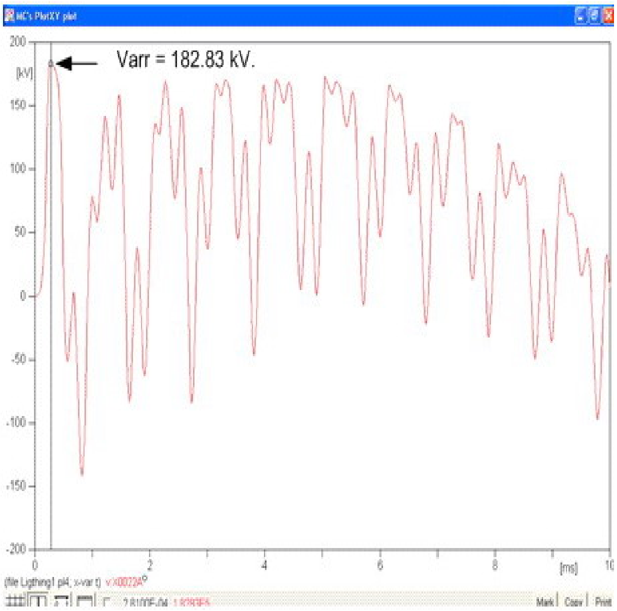

Fig. 4 Primary Voltage Wave of Phase A Transformer (Surge Arrester is set)

When surge arrester is set according to the information given by metropolitan electrical authority, the result from the experiment was as shown here:

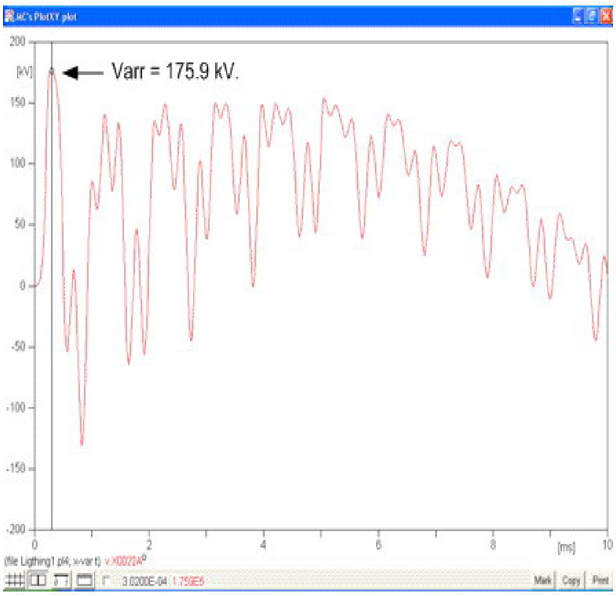

Fig. 5 Primary Voltage Wave of Phase a Transformer (Metropolitan Electrical Authority's Surge Arrester is set)

The analysis of the case in which surge arrester was neither primarily nor secondarily set with the transformer as shown in Fig 3., showed that when lightning took place at Phase A position, 75 km away from the transformer, the highest remaining over voltage is 362.59 kV, as for Phase B, 260.91 kV, and as for Phase C, 222.24 kV.

The case in which surge arrester was both primarily and secondarily set with the transformer as shown in Fig. 4 showed that when lightning took place at Phase A position, 75 km away from the transformer, the highest remaining over voltage is 182.83 kV, as for Phase B, 177.28 kV, and as for Phase C, 174.84 kV.

From the comparison as shown in Fig 6, it could be found that surge arrester could help prevent over voltage with outstanding result because in the case in which surge arrester is not set, the traveling waves move back and forth, transient state is longer, and over voltage is higher, damaging the insulator immediately.

According to both pieces of information about over voltage, it could be found that when surge arrester is set, over voltage could be prevented to the acceptable level. The over voltage depends on the attribute of lightning and could be calculated. by

$$V = V_{arr} \times 1.414 \times 1.7 = 96 \times 1.414 \times 1.7 = 230.68\,kV$$

The case in which surge arrester is set using the model of manufacturer using in real transmission line system or metropolitan electrical authority as shown in Fig. 5 showed that when lightning took place at Phase A position, 75 km away from the transformer, the highest remaining over voltage is 175.9 kV, as for Phase B, 167.4 kV, and as for Phase C, 162.79 kV. It could be noted here that the remaining over voltage of metropolitan electrical authority's surge arrester model is slightly less than the one derived from the calculation. This is because the model used in real practice has tested the material for manufacturing surge arrester so that its qualification, over voltage curve and current are close to the real state [11-12].

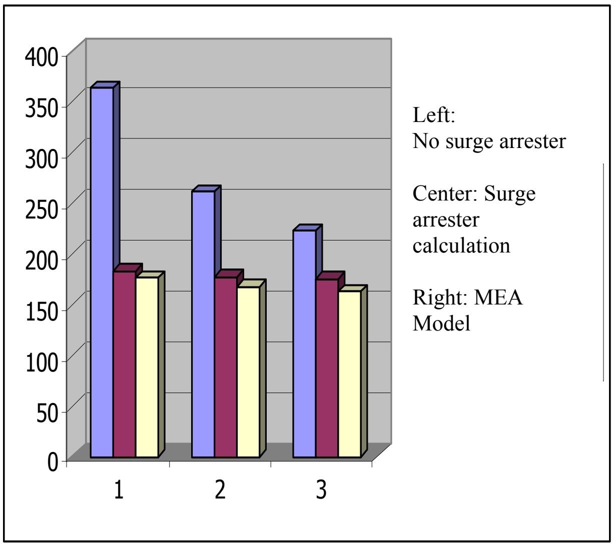

Fig. 6 Graph showing the relationship of primary V_{arr} (kV

III. CONCLUSIONS

The best way to prevent surge is to set the best distance, that is to say, to set the surge arrester as close as possible to the transformer and the transformer should be connected to the ground as well. The furthest distance from the transformer is 25.87 meters. According to the simulation, at such distance the surge arrester did not work best because it was too far from the transformer, making the traveling waves resound due to the increase in traveling range.

Surge arrester should be set in the direction where lightning takes place; however, in economical practice it should be set in the direction where lightning often takes place. The longer the transmission line, the higher the risk of lightning.

The distance for setting surge arrester affects the prevention of over voltage if it is set at the safest distance. (Safe distance is the furthest distance where insulator of the transformer could resist over voltage.)

In order to set shield line without high current lightning on phase, the design must focus on suitable shield angle and the resistance of ground root must be low. This is to prevent over voltage from high insulator and overlap from insulator to phase.

There should be space between electrodes of the devices to be protected, for example, insulator or transformer bushing. Electrodes help prevent flash over on the insulator surface; therefore, they prevent thermal shock. The property of electrode is constant and resistant to the over voltage with wave incline. However, electrodes could not prevent such over voltage surge which is different from surge arrester.

REFERENCES

[1] Vettayanon, Analysis of Lightning in Transmission Line System by ATP/EMTP.

[2] Tosak Tassanabutariya, Production and Distribution of Electricity, Bangkok, Se-education, 1997.

[3] Surapong Damrongkittikul and Praditpong Sukhasiritawonkul, Application of Electromagnetic Transients Program for Electrical Transients in Power System, Center for Specialization in Power Electricity, Faculty of Engineering, Chulalongkorn University, Bangkok, 1998.

[4] Samruay Sangsa-ad, High Voltage Engineering, 3rd Impression, Bangkok, 2006.

[5] Allan Greenwood, 1970, Electrical Transients in Power System, John wily & Inc, USA.

[6] Bernville Power Administration, Electromagnetic Transients Program (EMTP) Rule Book,Oragon , U.S.A.

[7] H.W. Dommel, EMTP Theory Rule Book, 2hd Edition Canada, Microtran Power System Analysis Corporation.

[8] John J. Grairger and William D.sterenson, IR, Power System Analysis, International Edition 1994, Singapore: McGraw, 1994.

[9] Kademstaja K.P., A study of operating conditions of lighting arresters installed on overhead line tower, Russia, Novosibirsk Statc Technical University.

[10] Micotran Power System Analysis Corporation,Electromagnetic Transients Program, Canada: Micotran Power System Analysis Corporation, 1992.

[11] Praditpong S., Data Collection and Switching Overvoltage in 500 kV system Case Study: Mae Moh 3 – Tha Tko, Chiang Mai University, 1995

[12] Trin Saengsuwan, Lighting Arrester Modeling using ATP-EMTP, Bangkok, Kasetsart University, 2004.

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