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Modeling and Analysis of Lightning Arrester for Transmission Line Overvoltage Protection

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Abstract:, The grounding of a conductor etc. Most of the over voltages are not of large magnitude but may still be important because of their effect on the performance of circuit interrupting equipment and protective devices. An appreciable number of these over voltages are of sufficient magnitude to cause insulation breakdown of the equipment in the power system .Lightning is one of the most significant source of over voltages in overhead transmission lines. The lightning over voltages could lead to failure of the devices connected to the transmission line. Surge arresters are an important means of lightning protection in distribution systems. Therefore, it is necessary to analyze influence of such over voltages in order to applying the line surge arrester for improving the reliability of transmission line system. Determination of the maximum voltages induced on the overhead line by direct stroke is a complex problem. For estimating the flashover due to direct strokes, it is necessary to calculate the maximum voltage induced on the line. The effect of direct lightning on transmission lines have been analyzed with and without the help of surge arrester.

Keywords: Lightning overvoltage, Basic insulation level, Lightning arrester, Overvoltage protection, Discharge current

1. INTRODUCTION

Lightning overvoltages occurring in an electrical power systems are very dangerous phenomenon, which may cause damages of insulation systems in electrical devices installed in the electrical network. For this reason, from insulation coordination viewpoint limitation of overvoltages values occurring during lightning strokes is very important to increase supply reliability in electrical network.There are two main ways in which a lightning may strike the power system are direct stroke and indirect stroke. In the direct stroke, the lightning discharge (i.e. current path) is directly from the cloud to the subject equipment e.g. an overhead line. From the line, the current path may be over the insulators down the pole to the ground. The overvoltages set up due to the stroke may be large enough to flashover this path directly to the ground. Indirect strokes result from the electrostatically induced charges on the conductors due to the presence of charged clouds. For this purpose, special devices such as Metal Oxide Surge Arresters (MOSA) are installed in electrical power networks for protection against overvoltages. Estimation of overvoltages values occurring in power system is necessary to predict effects of lightning strokes. However, because of lightning strokes randomness and inability to precise measurement of lightning overvoltages in real power system, calculations of overvoltages in power systems during transient states is the only method to estimate expected values of overvoltages in electrical power system. Thus, in order to analyze and calculate lightning transient states in power networks, dedicated simulations are necessary. This paper deals with frequency-dependent surge arresters models and transmission lines models utilized for overvoltages studies by means of Matlab simulation software. In this work an analysis of the lightning performance of 230 kV Taungdwingyi - Myaungdakar transmission line.

2. LIGHTNING OVERVOLTAGE IN TRANSMISSION LINES

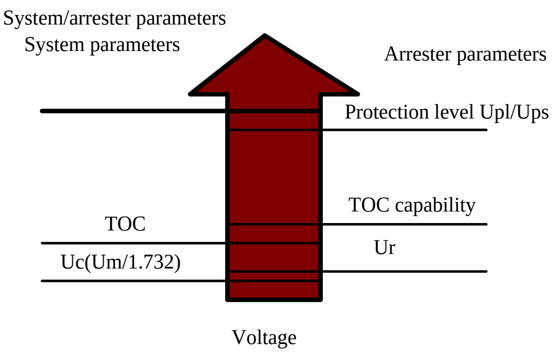
In case of indirect lightning stroke in overhead lines, part of lightning current flows to the ground through tower constructions and shielding wires. Lightning phenomenon is caused by a peak discharge during which the charge accumulated in the clouds discharges into the neighboring cloud or to the ground. The mechanism of charge formation in the cloud and their discharge, as well as the numerous the factors which help the formation or accumulation of charge in the clouds are complex, and unpredictable. But during thunderstorms, positive and negative charges become separated by heavy air currents with ice crystals in the upper parts and rain in the lower parts of the clouds, and this clouds separation depends on the height of the clouds[1]. Lightning overvoltages are caused either by direct strokes to the phase conductor of as a result of strokes to earth very close to the line which produces induced lightning surges. Overvoltage induced by indirect lightning on overhead lines can cause damage to the power system. The current waveform is generally a unidirectional pulse rising to a peak value in about 3 s and falling to small values in several 10 s. In this paper describe insulation level and selection of arrester.

3. LIGHTNING ARRESTER FOR OVERVOLTAGE PROTECTION

The earthing screen and ground wires can well protect the electrical system against direct lightning strokes but they fail to provide protection against travelling waves which may reach the terminal apparatus. The lightning arresters or surge diverters provide protection against such surges .A lightning arrester or a surge diverter is a protective device which conducts the high voltage surges on the power system to the ground .The action of the lightning arrester or surge diverter is as under (i) Under normal operation, the lightning arrester is off the line i.e. it conducts **no current to earth or the gap is non-conducting. (ii) On the occurrence of overvoltage, the air insulation across the gap breaks down and an arc is formed, providing a low resistance path for the surge to the ground. In this way, the excess charge on the line due to the surge is harmlessly conducted through the arrester to the ground instead of being sent back over the line.(iii) It is worthwhile to mention the function of non-linear resistor in the operation of arrester. As the gap sparks over due to overvoltage, the arc would be a short-circuit on the power system and may cause power-follow current in the arrester. Since the characteristic of the resistor is to offer high resistance to high voltage (or current), it prevents the effect of a short- circuit. After the surge is over, the resistor offers high resistance to make the gap non-conducting.

4. SELECTION OF LIGHTNING ARRESTER FOR HIGH VOLTAGE TRANSMISSION LINE

The Metal Oxide resistor column, together with the accompanying supporting construction, comprises the actual active part of the arrester. The column consists of individual Metal Oxide resistors stack on top of each other. Their diameter decisively determines the energy absorption and the current carrying capability. It is within a range of about 30 mm when used for distribution system, and up to 100 mm or more for high-voltage and extra-high voltage system. Metal Oxide resistors vary in height between 20 mm and 45 mm.



Vocabulary
Um =Maximum system voltage ,
Uc=Continuous operating voltage
Ur =Rated voltage ,
TOV =Temporary overvoltage
T =TOV strength factor,
K=arth fault factor Ups Switching impulse protective level
Upl=Lightning impulse protective level ,
Uw=Switching impulse withstand level
Uwl=Lightning impulse withstand level

$$\text{System voltage} = 230\text{kV (ph to ph)},$$

$$\text{Maximum voltage, Um} = 1.1 \times 230 = 253\text{kV}$$

$$\text{Fault clearing time} = 1\text{s},$$

$$\text{Creepage distance} = 14300\text{mm}$$

$$\text{Ur} = 0.72 \times 253 = 182.16 (\text{from table1})$$

According to the available arrester ratings, the rated voltage is selected as 228Kv (from table 2)

Table 1. Arrester Ratings

System Earthing	Fault Duration	System Voltage Um (kV)	Min. Rated Voltage, Ur (kV)
Effective	≤ 1 s	≤ 100	≥ 0.8 x Um
Effective	≤ 1 s	≥ 123	≥ 0.72 x Um
Non-effective	≤ 10 s	≤ 170	≥ 0.91 x Um ≥ 0.93 x Um (EXLIM T)
Non-effective	≤ 2 h	≤ 170	≥ 1.11 x Um
Non-effective	> 2 h	≤ 170	≥ 1.25 x Um

Table 2.Available arrester for HV and EHV system with important parameters

Max. System Voltage	Rated Voltage	Max. continuous operating voltage		TOV capability 2)		Max. residual voltage with current wave		
		as per	as per			30/60 µs		
U_{mkVrs}	U_{rkVrs}	U_{ckVrs}	$MOOV_{kVrs}$	$1s_{kVrs}$	$10s_{kVrs}$	$1KAKV_{peak}$	2KA KV_{peek}	3KA KV_{peek}
245	180	144	144	209	198	354	364	371
	192	154	154	218	207	389	380	387
	216	156	174	246	233	416	427	435
	228	168	180	259	246	438	451	459
300	228	182	182	259	246	438	461	459
	240	191	191	273	258	461	475	484

$$\text{Discharge class} = 3 (\text{from table3})$$

$$\text{Nom discharge current} = 10\text{kA}$$

$$U_{pl} = 2.350 \times 228 = 535.8\text{kV}$$

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$$\text{Lightning impulse voltage level, } \frac{U_{ps}}{U_r} = 1.981(\text{table4})$$

$$Ups = 1.981 \times 228 = 451.668kV$$

Table3. Selected arrester parameters

Arrester type	Line discharge	Energy capability(2 impulses)	Normal application range(U_m)
EXLIM R	2	5.0	≤ 170 kV
P EXLIM R	2	5.1	≤ 170 kV
EXLIM Q	3	7.8	170 - 420 kV
P EXLIM Q	3	7.8	170 - 420 kV
EXLIM P	4	10.8	362 - 550 kV
P EXLIM P	4	12	362 - 550 kV
HS P EXLIM P	4	10.5	362 - 550 kV
EXLIM T	5	15.4	420 - 800 kV
HS P EXLIM T	5	15.4	420 - 800 kV

Table4. Switching impulse protective, Lightning impulse voltage level

Arrester type	Nom Dischargecurren	Up/Ur at 10kA$_p$	Up/Ur at 20kA$_p$	Ups/Ur
EXLIM R	10	2.590		2.060 at 0.5 kAp
P EXLIM R	10	2.590		2.060 at 0.5 kAp
EXLIM Q	10	2.350		1.981 at 1.0 kAp
P EXLIM Q	10	2.350		1.981 at 1.0 kAp

With 253kV Maximum system voltage, the insulation levels are selected as:
Basic insulation level (BIL) Uwl=900Kv (from table 5)
Basic switching level (BSL) Uws=720Kv (from table 5)

Table5. Insulation level of substation

Max system voltage,kV		IEC(10)		ANSI (11)	
IEC	ANSI	BIL,kV	BSL,kV	BIL,kV	BSL,kV
72.5	72.5	325	-	300,350	
100		450	-		
123	121	550	-	450,550	
145	145	650	-	550,650	
170	169	750	-	650,750	
245	242	950	-	750,900	-,720
300		1050	850		
362	362	1175	950	900,1050	720,825
420		1300	1050		
525	550	1425	1175	1300,1550	1050,1175
765	800	1800	1425	1800	1425

$$\text{Margin for lightning impulse} = \left[\frac{U_{WL}}{U_{PL}} - 1\right] \times 100$$

$= 67.973$

$$\text{Margin for lightning impulse} = \left[\frac{U_{WS}}{U_{PS}} - 1\right] \times 100\,\%$$

$= 59.409$

Since protection margin is greather than 20%,arrester can provide adequate protection to substation.

5. MODELING OF OVERVOLTAGE PROTECTION SYSTEM

Table6.Transmission line parameters

SN	Name	Parameter
1	Line Length	143.43km
2	Positive/negative Sequence Impedance	6.798+j45.0504ohm
3	Zero Sequence Impedance	44.076+j157.7079 ohm
4	Positive/ negative Sequence Susceptance	1.6193247µS
5	Zero Sequence Susceptance	1.094355124µS
6	Load at Taungdwingyi Bus	12 MW (0.82 lagging)
7	Load at Shwedaung Bus	8 MW (0.8 Lagging)
8	Type Conductor	605M

The detailed study for lightning protection is executed at Shwedaung-Taungdwingyi 230 kV single bundled single circuit transmission line. Two generators of 230 kV are used in the study, each located at each ends of line to study and simulate the lightning protection on transmission line 143.43 km in length. The important parameters for the model are shown in Table 6.

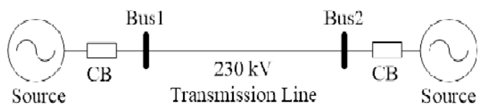
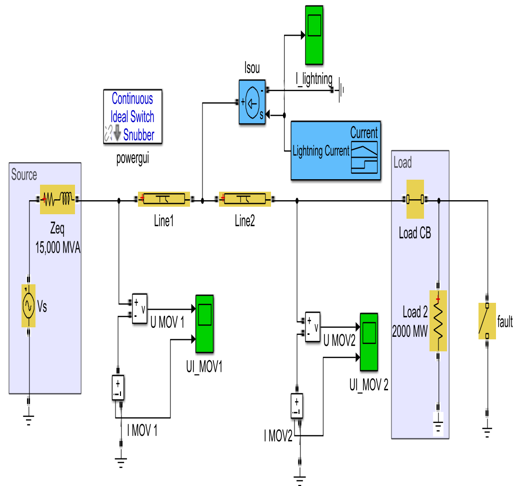


Figure 2. Transmission line

Below figure shows a 230 kV transmission system without two transmission line arrester placed at the sending end and the receiving end of the line. Over the system a lightning surge was induced and the resulting simulation was carried out by using MATLAB software.



5.1 SIMULATION RESULT WITHOUT LIGHTNING ARRESTER

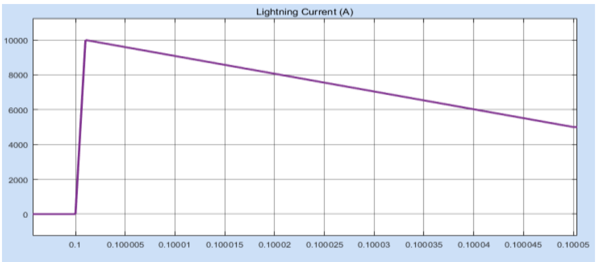


Figure4. Simulation result of without lightning arrester for lightning current

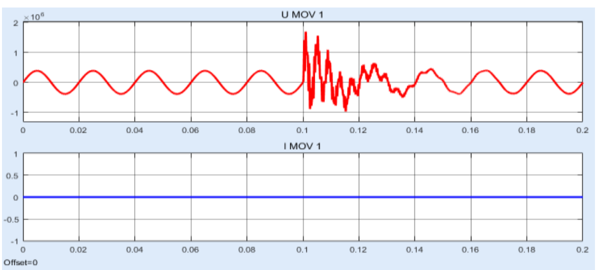


Figure5. Simulation result of without lightning arrester(MOV1) for lightning voltage

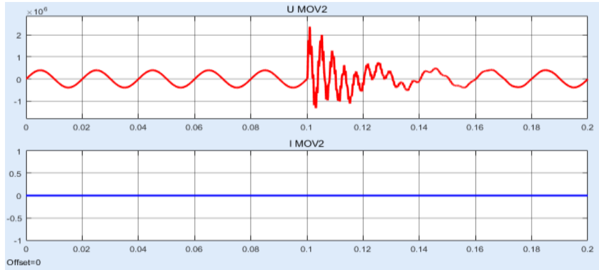


Figure6. Simulation Result of Without Lightning Arrester(MOV2) for Lightning Voltage

5.2 SELECTION OF LIGHTNING ARRESTER PARAMETER

The objective of arrester application is to select the lowest rated surge arrester which will provide adequate overall protection of the equipment insulation and have a satisfactory service life when connected to the power system. A higher rated arrester increases the ability of the arrester to survive on the power system. Both arrester survival and equipment protection must be considered in arrester selection. The proper selection involves decisions in three areas:Selecting the arrester voltage rating. This decision is based in whether or not the system is grounded and the method of system groundingSelecting the class of arrester. In order of protection, capability and cost as follow: (i)Station class (ii) Intermediate class (iii) Distribution class.

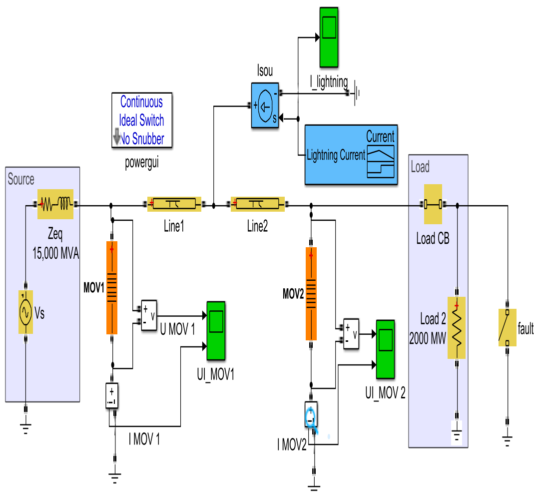


Figure7. Molding for lightning protection with lightning arrester

4.3SIMULATION RESULT (WITH LIGHTNING ARRESTER)

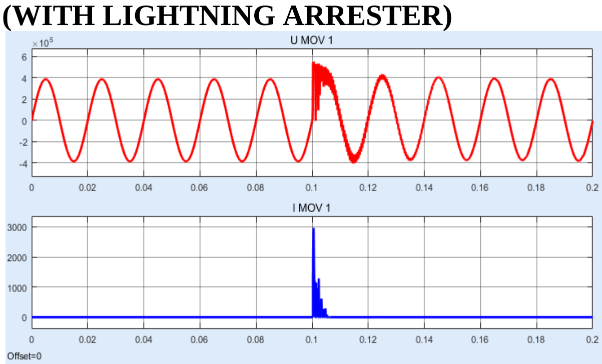


Figure8. Simulation result of with lightning arrester(MOV1) for lightning voltage

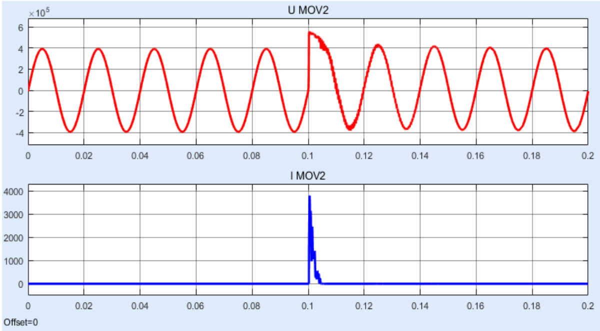


Figure9. Simulation result of with lightning arrester (MOV2) for lightning voltage

6. COMPARISON AND ANALYSIS

To evaluate the overvoltage protection performance of MOV, the voltage level at substation for without MOV and with MOV is compared. The comparison results is expressed in Table 7.

Table7. Comparison for voltage level at substation

SN	Case	MOV Name	V_MOV (kV)	I_MOV (A)
1	Without MOV	MOV1	1685.9	0
2		MOV2	2363.1	0
3	With MOV	MOV1	549.1	2964
4		MOV2	556.5	3800

According to the simulation results, the voltage levels at substations for without MOV are much larger than basic insulation levels. It means substation equipments will damage under lightning overvoltage. With MOVs, the substation voltage level is less than basic insulation level and thus the substation equipments will safe under lightning overvoltage condition.

7. CONCLUSION

For the analysis of surge arrester in 230kVtransmission line, MATLAB software is employed for the simulation of the selected transmission line as well as the lightning surge and MOV arrester. In the simulations, the lightning strike is applied at the middle of transmission line and the voltage levels at substations are observed. According to the simulation results, the suggested MOVs can protect both substations from lightning over voltages and can protect substation equipments. This paper will help and give the electrical knowledge of the overvoltage protection system by surge arrester in transmission lines and substation equipments.

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