

# Comparison of Induced Voltages in Different Cases Describing the Effect of High Voltage on Transmission Line

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**Abstract:** This paper describes Matlab based simulation. Voltage induced on overhead transmission lines due to lightning phenomena is one of the major reasons for the flash over and outages. The basic insulation levels of the transmission lines are lower; therefore the problems caused by the lightning strokes in the vicinity of the transmission lines become more apparent. Determination of the maximum voltages induced on the overhead line by direct stroke is a complex problem. Distribution circuits typically are not insulated to withstand direct lightning strokes, as a result, direct strikes will cause a flash over between phase to phase or phase to ground depending upon the arc path. 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 different conductor sizes ,terminal impedances ,variation in span lengths ,addition of a cable and surge arrester ,etc. It is observed, with simulation of different models on EMTP, that these factors have considerable effect on the voltage induced on transmission lines due to lightning phenomena. This will be helpful for further research investigations about each factor affecting the induced voltage.

**KEYWORDS:** lightning, flash over, EMTP.

## I. INTRODUCTION

On many transmission lines lightning impulse is the main cause of unscheduled supply interruption. A number of methods for estimating trip out rates have been deployed. The voltages produced on overhead lines by lightning might be due to indirect or direct strokes. Therefore a lightning stroke to a transmission line conductor injects a transient current of several thousand amperes. Our aim is to obtain maximum over voltage value that might occur on the transmission system for analysis purpose. Various circuit configurations is selected from the existing 11KV transmission system. The objective is to calculate induced over voltage from lightning. As a consequence, their evaluation has been for years, and is still, one of the most important problems in designing and coordinating the protection of overhead transmission lines. A better knowledge of the over voltages experienced on a simple 11KV circuit could improve our ability to select equipment such as switches, arresters and BILs level of transformer. It would also provide input into the design parameters for live line tools, cover up equipment, insulation levels and barriers used to build or maintain such transmission systems.

## 2.METHODOLOGY:

Arresters have been introduced for the protection of transmission lines as an alternative to overhead ground wires. They are placed out at intervals on the poles or towers. Voltage across the line insulator at the point of installation is controlled by the MOV( Metal Oxide Varistors) and kept below flashover voltage of the insulator to avoid back flashover which is most frequent form of lightning outage. The voltage across the line insulation is greatly influenced by the high tower footing resistance.

The entire lightning event is referred to as a flash and the individual pulses are referred to as strokes and when this current injects on phase conductor, voltage waves radiate from the point of contact in both directions along the conductor and down the tower if flashover occurred across insulator to tower. These waves rapidly encounter discontinuities which initiate reflected waves, which generate another waves when they return to the stricken point. In this way a large number of waves are generated in short order. The effect of these waves will depend on the change of surge impedance at this discontinuity.

The potential difference across the suspension insulators is of particular concern since a flashover can occur and a fault be placed on the phase if this voltage becomes excessive.

When direct lightning strikes on overhead phase conductors ,magnitude of the current and high frequency nature of the stroke causes voltage surges to be propagated in both directions from the point of strike and the two travelling voltage waves originates having magnitude:

$$e = \frac{1}{2} * Z * I$$

Where,

e= voltage induced

Z= Surge impedance

I = current

## 3. ASSUMPTION OF DATA:

In lightning surge studies many simplified assumptions are made since the waveshape and amplitude of the current source represents the lightning stroke which is obviously not well known.

- ✓ Lightning wave assumed (as per IEEE Standard, 1947)1.2/50 μsec with 30 K Amp of current magnitude.
- ✓ Inductance of surge arrester lead was assumed 0.001 mH.
- ✓ Wave speed are approximately equal to speed of the light with surge impedance in phase quantities.
- ✓ Only six spans near to surge arrester assumed with different span lengths, reflections from the other section whose surge impedance assumed to be 37.6 Ω and 300.0 Ω.
- ✓ Six spans of 11 KV & tower no ranging from Po to P6 is taken.
- ✓ Travel time is the min time taken by the wave to travel between two node and 10% of shortest travel time for o/p time scale is supposed so that better o/p is obtained from analytical point of view.

- ✓ It is very important to know that electrically which section is treated as one span for lightning stroke but mechanical supports are supposed at different intervals.
- ✓ Surge impedance on 11 KV line are calculated for conductor type Panther, Rabbit, Dog & Osprey which are mostly used. Input data required to calculate the surge impedance on EMTP.

#### DATA INPUT

<u>S.No</u>	<u>Conductor Type</u>	<u>Panther</u>	<u>Rabbit</u>	<u>Osprey</u>	<u>Dog</u>
1.	Diameter of conductor	21.0	10.05	22.35 mm	14.15
2.	Resistance at ambient temp	0.1363	0.5426	0.1022	0.273
3.	Height of conductor at pole			9.448 m	
4.	Height of conductor from ground in mid span			9.144 m	
5.	Tower footing resistance			0.5 Ω	

These data were fed & simulated with EMTP. Following results for surge impedance were used for selected conductor type's further computations in different cases:

#### 4.CASE STUDY:

Following ten cases were selected, in which location for lightning is different; therefore we have different outputs for each case at different locations. The outputs for each case are summarized in a table and only one sample output is attached.

**Case No.1.** Lightning stroke striking on conductor [Panther] away from substation and surge arrester is not enabled.

**Case No.2.** Lightning stroke striking on conductor [Panther] away from substation and surge arrester is enabled.

**Case No.3.** Lightning stroke striking very close to surge arrester approximately one span away from the arrester enabled.

**Case No.4.** Surge impedance of conductor increased by approximately 100 Ω with arrester enabled.

**Case No.5** Surge impedance of conductor decreased by approximately 100 Ω with arrester enabled.

**Case No.6.** Lightning stroke striking on conductor [Panther] away from substation with surge arrester enabled. Underground cable supposed in last two spans.

**Case No.7.** Lightning stroke striking on conductor [Rabbit] away from substation with surge arrester enabled and span lengths changed.

<u>CONDUCTOR</u>	<u>SURGE IMPEDANCE</u>
Panther	306.26 Ω
Rabbit	342.7 Ω
Dog	322.2 Ω
Osprey	294.76 Ω
Velocity of wave	2.8449 05 m/sec

**Case No.8.** Lightning stroke striking on conductor [Dog] away from substation .Terminal impedance changed with change in span lengths.

**Case No.9.** Lightning stroke striking very far away from substation on conductor [Osprey].Terminal impedance and span length again changes.

#### 5. DISCUSSION ON OUTPUT

Surge arrester effectively reduced the induced voltages as can be seen by comparing case No.1 & 2. In case No.1, one end is open and voltage is almost at constant level .however, in case No.2 by the installation of arrester, the induced voltage reduced at all the locations .This is because the voltage at the terminals of arrester are set at the preset value that is about 11.2 kV.

In each case at different locations rise to its peak value and then decreases because these waves rapidly encounter discontinuities due to change of impedance which initiates reflected waves.

A large number of waves are generated in short order. The effect of these waves depends upon the change of surge impedance at the discontinuity like terminal impedance. In some cases there is a negative dip in the wave front because that moment surge impedance of the conductor is lower than the terminal impedance, the reflected and incident waves having opposite signs and act to reduce for a very period otherwise vice versa.

In each case there is a time delay at each location other than the strike point, it is because the time taken by the wave to travel that particular distance between the stricken point and the point where the output is obtained ,it travels approximate with the speed of light.

Following possibilities might be possible after lightning surges originate on the transmission lines as discussed above:

1. Flashover between phase due to breakdown strength of air that is 30kV/cm and minimum phase spacing of 72 cm for 11kV suspension type structure 106 cm for tension type structure.

#### EXAMPLE

30kV/cm\* 72 CM = 2.16 MV, it means 2.16 MV voltage magnitude required for two closed phases for flashover. In this way the flashover between the two phases would be occurred when the lightning falls away from the arrester installed point.

2. Flashover from insulator to tower.

Basic Impulse Insulation Level ( BIL ) for 11kV transmission line = 95kV.

Withstand voltages of insulators used in the system are:  
Pin type suspended insulator

Critical Impulse positive voltage = 90kV.  
Critical Impulse negative voltage = 110kV.

Ball and Socket type tension insulator

50% impulse positive = 120 kV.  
50% impulse negative = 125 kV.

From the insulator data it is clear that flashover path from conductor to tower through insulator is more frequent and quicker than any other flashover only when insulators are earthed.

3. Flashover between two circuit:

It is not practically possible because circuit spacing between two circuits are more than the top circuit to earth i.e tower in this case and it is recommended that resistance should not be more than 0.5 Ω to provide resistance free path from conductor to tower in case of flashover occurred.

The above results are summarized in table 1:

6. RESULTS :

<u>S.No</u>	<u>Variation In Parameters</u>	<u>Effect Of Induced Voltage</u>
1.	% change in surge impedance	% change in voltage
	i) Increase by 33%	i) Increase by 24.35%
	ii) Decrease by 33%	ii) Decrease by 26.4%
2.	Terminal impedance decreases by 20.2% and conductor surge impedance by 6%.	Voltage decreased by 7%.
3.	Introduction to underground cable	Voltage decreased by 97%.
4.	Effect of surge arrester	Voltage decreased by 62%.

Hence, it can be said that:

By introducing different types of conductor, it has been found that change in conductors surge impedance directly affects the induced voltage from 2.84 MV to 3.86 MV, also about 4.8MV in some cases.

By introduction of surge arrester induced voltage effectively reduced from 10.5 MV to 4.0 MV with same input conditions.

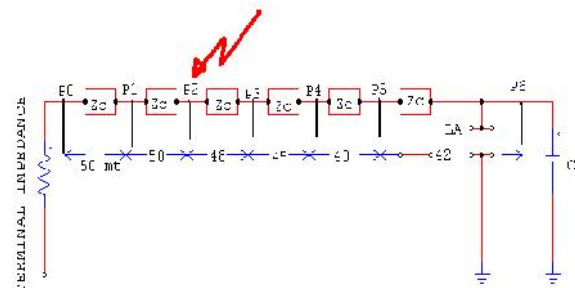
The decrease in terminal impedance results slightly decrease in induced voltage.

When the lightning strike away from the arrester, the induced voltage persists for more time as compared to surge striking near to arrester.

Introduction of an underground cable cause direct effect on induced voltage on the line. It has been found that the induced voltage is reduced from 3.04 MV to 62.53 MV.

7. CIRCUIT DIAGRAM :

Lightning wave striking on P2 and arrester is enabled at P6 ,surge impedance  $Z_c$  is decreased by 100 ohms that is 206.2 ohm from 306.2 ohms assumed in Case no.2.



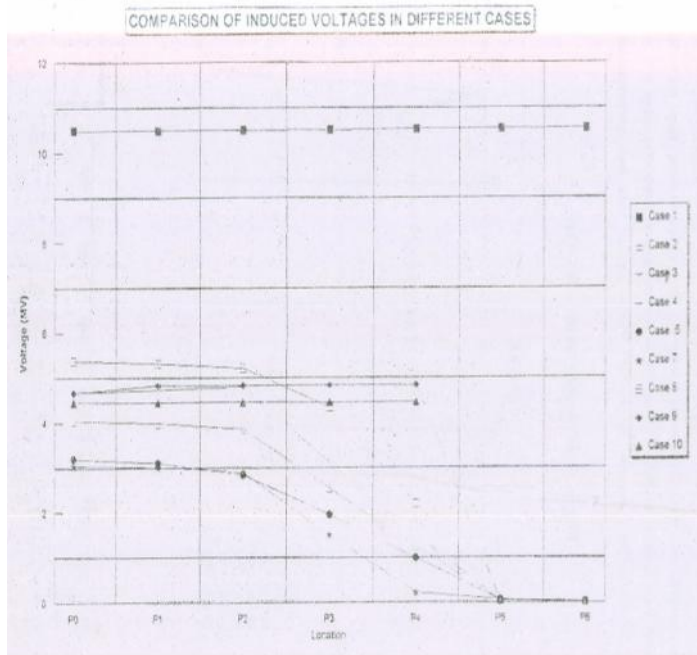
Terminal Impedance = 376.0 Ohms  
 $Z_c$  ( Panther ) = 206.2 Ohms  
 Lead Inductance Of = 0.001 mhenry  
 Lightning Arrester Capacitance = 0.003 μf.

8. SIMULATION:

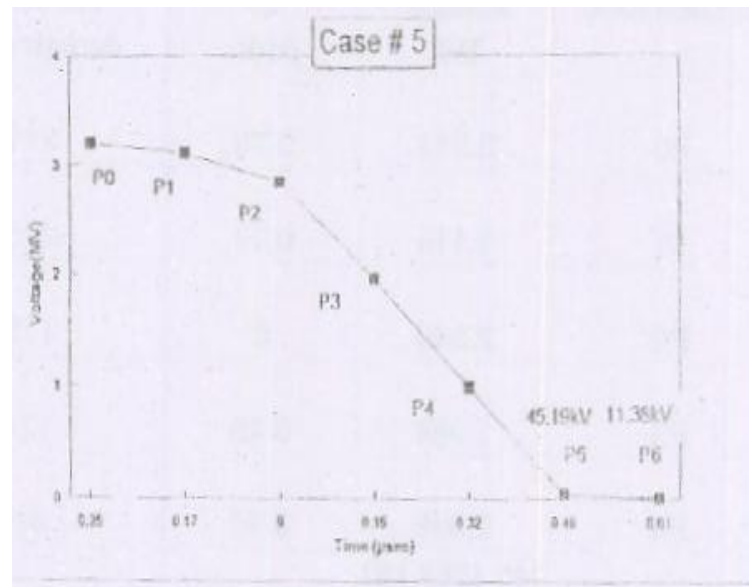


Output at P2 where lightning strike striking

**COMPARISON OF INDUCED VOLTAGES IN DIFFERENT CASES :**

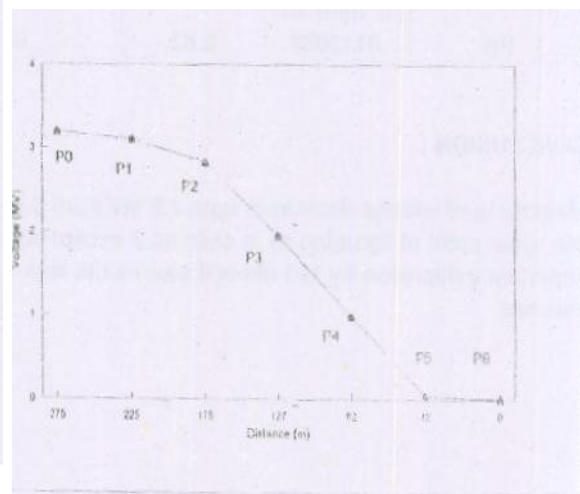


**GRAPH VOLTAGE vs TIME:**



In case no.5 the graph voltage vs time reveals that peak magnitude of voltage will decrease with delay as the distance from the surge arrester increase.

**GRAPH VOLTAGE vs DISTANCE:**



At

point P0 voltage will be at maximum. As this point is away from the surge arrester ,gradually the peak value decreases as it starts moving towards the surge arrester placed at point P6.

**9. SIMULATED RESULT:**

**CASE NO.5**

Surge impedance of conductor decreased by approximately 100Ωs with arrester enabled.

S.No.	Readings taken at location	Peak voltage MV	Time delay in usec.	Distance from the Surge Arrester(m)

1.	P0	3.211	0.35	275
2.	P1	3.115	0.17	225
3.	P2	2.849	0	175
4.	P3	1.964	0.16	127
5.	P4	0.996	0.32	82
6.	P5	(45.1968 kV) 0.0451968	0.46	42
7.	P6	(11.3867kV ) 0.0113867	0.61	0

As cited in case no.2 i.e lightning strike point is away from substation and surge arrester is enabled. Case no.5 is related with case no.2 except that surge impedance of transmission line is reduced up to 100  $\Omega$ . In that case, magnitude of lightning striking voltage reduces to 2.8MV from 3.8 MV. It means voltage reduces  $10^4$  volt when surge impedance reduces to 1 $\Omega$ . Hence, by using lightning arresters we can reduce the lightning voltage by reducing surge impedance of transmission line at the rate of  $10^4$  volt/  $\Omega$ .

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## X. BIOGRAPHY:

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