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Back flashover Analysis Improvement of a 220KV Transmission Line

G.Radhika[1], Dr.M.Suryakalavathi[2]

[1] (Department of Electrical & Electronics Engineering, VNR VJIET. Hyderabad - 90)
[2] (Department of Electrical & Electronics Engineering, JNTU Hyderabad - 85)

ABSTRACT

The performance of a power system mainly depends on the performance of the transmission lines for which continues operation of transmission lines without sudden outages is important for the performance in the view point of power delivery as well as system stability. Lightning effects on transmission lines are one of the major reasons which lead to sudden line outages. The objective of this paper is to design a 220kV transmission model, which includes all the components of the Transmission line with a surge of 100KA, 4/10 µs. Tower with two OHGW was taken in this work. Back flash over mechanism is modeled and triggered to the existing system by an external control module with powerful electrical tool PSCAD/EMTDC. Metal Oxide transmission line arresters were used in this work as a solution for the back flashover. However, considering acceptable probabilistic failure as one outage per year per 100km line length, and suggested basic insulation level (BIL) of 1050KV, the arrester rating was calculated to be 196KV and its parametric determination for a one column arrester with an overall length of 1.45 meters is done. Simulation is carried out by placing line arresters in one phase and recovering the string voltage without interrupting power to the consumers.

Keywords - Back flash over, Line Arresters, Transmission lines, Tower footing resistance, PSCASD/ EMTDC.

I. INTRODUCTION

Lightning could causes the traveling waves to different devices connected to both sides of transmission line and causes temporary over voltage in transmission line system which is harmful for insulators of lines and devices connected to the transmission line. Thus it is essential to investigate a lightning surge for a reliable operation of a power system, because the lightning surge over voltage is dominant factor for the insulation design of power system and protection of equipment in power system and substation. Whenever lightning strikes the top of a transmission tower, a lightning current flows down to the bottom of the tower and causes a tower voltage to raise and results in a back-flashover across an arc horn. This causes transmission line outages and damage of equipment. Because of high frequency range associated with lightning transients phenomena, adequate electrical models are required for which reasons, and simulation studies require detailed modeling of the lightning phenomena and of the network components, including towers and insulators that are not usually considered in the other models. Hence the method used to analyze the increase in voltage due to lightning was done by using the application called PSCAD/ EMTDC.

Back flashover occurs when lightning stroke terminates on the overhead ground wire or tower. A stroke that so terminates forces currents to flow down the tower and out on the ground wires. Thus voltages are built up across the line insulation. If these voltages equal or exceed the line critical flashover voltage (CFO), flashover occurs. Study on back flashover is very important to evaluate lightning performance as majority of lightning strokes terminate on shield wire than phase conductor. The objective is to protect the power system equipments from Back flashover [6]. As per analysis the occurrence of faults is more in overhead transmission lines, so this paper study is mainly based on transmission line protection rather than other equipments. The ideal approach to study the transient phenomena in a power system is to capture and record the transients using wide bandwidth transducers and recording equipment and then analyze those waveforms [8].

II. MODELING OF FOOTING RESISTANCE

Tower footing resistance is determined using current dependence of tower footing resistance [1, 4].

Tower footing resistance is given by

$$\mathbf{R_t} = \frac{\mathbf{R_0}}{\sqrt{\mathbf{1}+\frac{\mathbf{I}}{\mathbf{I_g}}}} \qquad (1)$$

$$I_g = \frac{1}{2\Pi}\frac{E_0}{R_0^2}\,\rho \qquad (2)$$

Where, parameters

R_t = tower footing resistance,
R_0= tower footing resistance at low current and low frequency,
I = lightning current, kA,
I_g = limiting current, kA,
ρ = soil resistivity, Pm,

E_0 = soil ionization gradient,
(≈300kV/m)
Tower footing resistance depends on
1. Type of electrode configuration
2. Soil resistivity
Soil resistivity has the following ranges

Table 1: Soil Resistivity of

Sea water	10 Ωm
Moist soil	100 Ωm
Loose soil and clay	1000 Ωm
Rock	>100 Ωm

Tower with one OHGW leads to high overvoltage across insulator compared to two OHGW [6]. If the tower footing resistance is high then occurrence of back flash over is also high and vice- versa because of which we considered two OHGW transmission system in this paper.

III. Modeling of Insulator

The insulator string model can be based on the leader progression model. Streamers propagate along the insulator string when the applied voltage exceeds the corona inception voltage, if the voltage remains high enough these streamers will become a leader channel. A flashover occurs when the leader crosses the gap between the cross-arm and the conductor [7]. The total time to flashover can be expressed as

$$T_t = t_c+t_s+t_l \qquad (3)$$

Where,
t_c is the corona inception time,
t_s is the streamer propagation time,
t_l is the leader propagation time.

Usually t_c is neglected, while t_s is calculated as

$$t_s = \frac{E_{50}}{1.2E-0.95E_{50}} \qquad (4)$$

The leader propagation time t_l, can be obtained using

$$\frac{dl}{dt} = k * v(t) * \left[\frac{v(t)}{g-l} - E\right] \qquad (5)$$

Where,
V (t) is the voltage across the gap,
g is the gap length,
L is the leader length,
E is the critical leader inception gradient and k is a leader coefficient and is given in reference.
The insulator (string) voltage is given by

$$V_{ins} = V_{cnt} - V_b \qquad (6)$$

Where,
V_{cnt} = cross arm voltage
V_b = line voltage
The number of insulating discs used for a 220KV tower are14 as per the IEEE standards.

IV. Modeling of Back flashover

Line insulators from tower to conductors can be represented as a capacitor. In this study, the tower to conductor has equivalent capacitor of 80 pf per unit. The transient-voltage withstands level of a power apparatus is not a unique number [1]. An apparatus may withstand a high transient voltage which has a short duration even it has failed to withstand a lower transient voltage with longer duration. This characteristic of the insulator is known as the volt-time characteristic of the insulation however, simplified expression for the insulator voltage withstands capability can be calculated as

$$V_{fo} = K_1 + \frac{K_2}{t^{0.75}} \qquad (7)$$

Where, V_{fo} is a flashover voltage (kV),
K_1 is 400*L, and K_2 is 710*L,
L is insulator length, (meter),
t is elapsed time after lightning stroke, µs

The back flashover mechanism of the insulators can be represented by volt-time curves. Whenever back flashover occurs, a parallel switch is applied and also if the voltage across the insulator exceeds the insulator voltage withstand capability, the back flashover occurs. The back flashover is simulated by closing the parallel switch. Once the back flashover occurs, the voltage across insulator goes down to zero [2].

V. Modeling of the tower

The configuration of a transmission line tower depends on:
(a) The length of the insulator assembly.
(b) The minimum clearances to be maintained between conductors and between conductor and tower.
(c) The location of ground wire or wires with respect to the outermost conductor.
(d) The mid span clearance required from considerations of the dynamic behavior of conductors and lightning protection of the line.
(e) The minimum clearance of the lower conductor above ground level.

From safety considerations, power conductors along the route of the transmission line should maintain clearances to ground in open country, national highway, rivers, railway tracks, tele-communication lines, other power lines etc. as laid down in the Indian Electricity Rule or standards or code of practice in vogue. Minimum permissible ground clearance for a 220KV as per IE Rules, 1956, Rule 77(4) is 7.01m. The maximum working tension under stringent loading conditions shall not exceed 50 percent of the ultimate tensile strength or conductor. Sag-Tension computations made for final stringing of the conductors therefore must ensure that factor of safety of 2 and 4 are obtainable under maximum loading condition and every day loading condition, respectively.

VI. Selection of Transmission Lightening Arrestors

A line arrester is a one which reduce the risk of insulator flashover during surge events [7].Arrestor Voltage rating shall not be less than product of system highest voltage x co-efficient of earthing [6].

In a 220 kV effectively earthed system
Highest system voltage = 245 KV
Co-efficient of earthing = 80%
Arrestor voltage rating = 245x0.8 = 196 KV.
In this paper, only the electrical parameters of the arrester are taken for the modeling.

VII. Proposed Model of 220KV Transmission System and Results

The below model shows a 220KV transmission system with two wires, whose sub-circuit of the tower further consistutes of five sub-circuits. These five sub-circuits includes the three insulator strings and the two cross arms as shown in the figure. These five sub-circuits have to be designed seperately. Over the system a lightning surge of 100KA was induced and the resulting simulation was carried out in powerful electrical tool PSCAD.

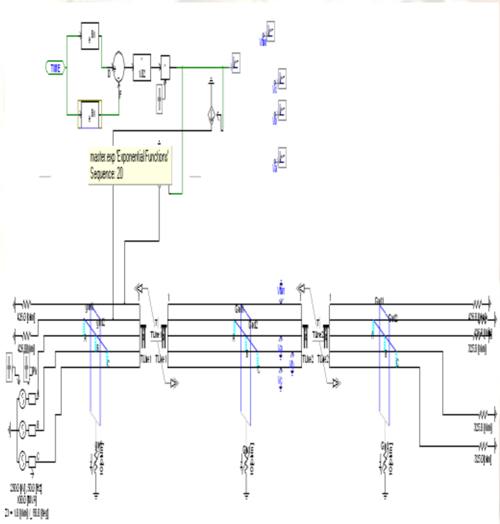

Figure: 1 Proposed Model

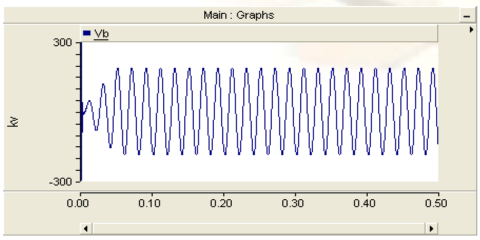

Figure: 2 Output of Phase B

The sub circit of the tower structure shown below, to which when flashover is turned ON, the outputs of tower, line and string voltages can also be observed below. The insulator sub-circuit has metal oxide surge arresters as a part of the circuit to provide protection against back flashovers . Since the line has to be protected from back flashovers, effective operation of the breakers is essential. To control the operation of the two breakers in the sub-circuit logic was implemented. With this we have designed one insulator. Three such insulators were designed as per the tower sub-circuit. As our model includes three such towers, we have designed a model with three towers in it.

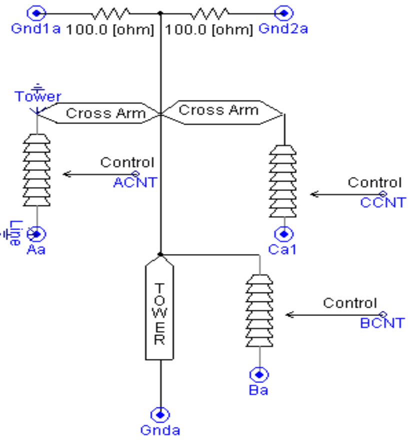

Figure: 3 Tower Sub Circuit

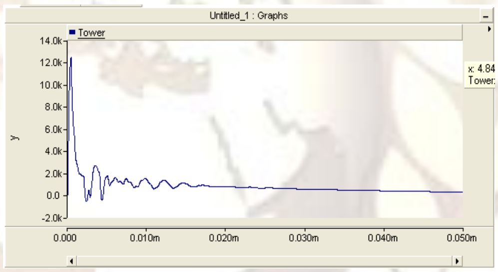

Figure: 4 Tower voltage

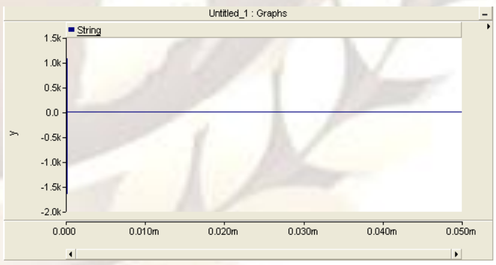

Figure: 5 String Voltage

As the string voltage become zero, which means that an arc is being formed. This means that flashover is occuring. Hence, that particular line is going to the outage state. This is undesirable as it interrupts the power supply to the consumers. So we take the next set of observations with the Line Arrestor turned ON along with flashover in all the three phases. The wave form with flash over and arrestor turned ON on phase B are observed:

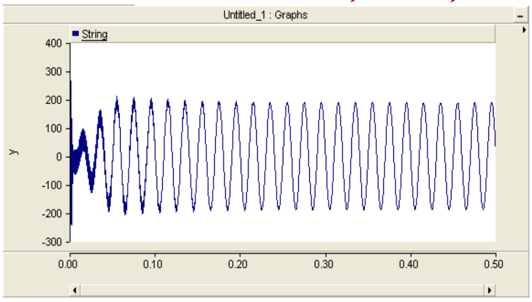

Figure: 6 Recovered String Voltage after placing TLA.

VIII. CONCLUSION

The tower footing resistance is an extremely important parameter in determination of lightning flashover rates which was taken as 10Ω in this work for all the towers.. The lower the tower footing resistance, the more negative reflections produced from tower base towards the tower top and these hence help to lower the peak voltage at the tower top. Soil resistivity also plays a very important role in determining lightning flashover rates which was 100 Ωm and relative ground permeability was 1.0 in this work. Surge arrester selection plays vital key role in arresting the insulator flashovers which was calcualted to be 196KV in this work. The placement of transmission line arrestors and design of arrestor is crucial in arresting the flashovers. From the above simulated resulsts, when arrester and flashover were OFF the tower voltage, string voltage were normal and when flashvoer was ON and arrester was OFF the string voltge of phase B was gone outage as seen in Fig.5 which is undesirable as it interrupts the power supply to the consumers. Hence when arrester was ON in phase B, the string voltage of phase B was recovered as shown in Fig. 6. Hence by placing one arrestor on each phase and by using two ground wires, we can completely eliminate the flashover, which means zero probability of flashovers.

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BIOGRAPHY OF AUTHORS

Mrs.G.Radhika is working as Senior Assistant Professor in Electrical and Electronics Engineering Department at VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, India. She is pursuing her Ph.D at J.N.T.University Hyderabad.

Dr.M.Suryakalavathi is professor in Electrical and Electronics Engineering Department at Jawaharlal Nehru Technological University Hyderabad, India. She received her Ph.D from J.N.T.University Hyderabad and Post Doctoral degree from prestigious Carnegie Melon University U.S.A.