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Study Of Lightninig On Transmission And Influence Of Arrester And Tower Footing Resistance For Damping These Transient Overvoltages

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ABSTRACT*:* One of the important problems of power systems is lightning that has always been the main challenges of transmission lines. In this paper, overvoltages caused by lightning on the insulator chain, and transformer will be examined. Then arresters and footing resistance in this process will be studied. In this study, insulators chain overvoltages will be used in two modes: (1) at the moment of thunderstroke on tip of tower (2) thunderstroke on guard wires between two towers in substation terminal towers. After this, in the process the influence of overvoltages on the footing resistance, transformer and influence of arrester in overvoltages reduction will be calculated. Simulations have been implemented on EMTP software. The study was carried out on an actual power network in south of Iran (between Bandar Abbas power plant and substation-wing) at 400 KV voltage level.
Keywords: Thunder stroke, Tower Footing Resistance, Insulator Chain, Overvoltage, EMTP Software

INTRODUCTION

When slightest problem occurs in transmission lines, power quality factors affect or in the worst case is occurs a national blackout .One of this problems are overvoltage and over current generate in the transient state that occurs in effect of phenomena such as lightning and switching. Main characteristic of this phenomenon is that it is very fast and is within the micro-to milliseconds.

One of the phenomena that lead to very large overvoltages is struck by Lightning usually struck to transmission lines that have a wide geographic area and through it may be transferred to substations in two sides and generate overvoltages in the power transformers of these substations. In this paper are modeled lightning wave, transmission lines, transformers and surge arrester. The overvoltage and towers of transmission lines of the back of the insulator chain and also the location of the power transformer had been analyzed and then used arrester for reduce and damping of overvoltage generated on power transformer and be studied influence of tower footing resistance over these overvoltages. The transmission network of Bandar Abbas in south of I.R.Iran has selected for this study.

The EMTP software used for variety targets, such as: lighting surge analysis [1], lightning-induced voltages [2], transient switching over-voltages [3], modeling of saturation in induction machines [4], chain link STATCOM [5], evaluate active power filters for harmonic compensation [6], implementation of current differential relay and directional comparison relay [7], modeling short overhead lines and cables [8], simulation of shunt reactor switching transients [9], simulation of a non conventional high current low voltage power converter [10]. In [11] A novel methodology to be applied in the design of tower-footing electrodes to ensure a defined outage rate of transmission lines is proposed It uses the critical peak currents (obtained from a first stroke distribution and from the application of the Disruptive Effect model on the waveforms of first-stroke over voltages of direct strikes to the line simulated using an electromagnetic model) to determine the minimum electrode length require to ensure the defined outage rate for any given electrode arrangement and soil resistivity.

Modeling Of Lightning

Lightning in fact is an electrical discharge that occurs between clouds and ground. In rainfall that perseverance of air insulation is low, because presence of humidity, create a path through which the flowed electrical charges in cloud toward earth. Thus we can models lightning as a current source [12]. Standard wave of lightning is current source that interval 1.2 microsecond reaches to peak value and is damped in during 50 microseconds. This lightning at 1.2 microsecond reaches to peak value, 30 kA. This lightning is damped at 50 microseconds. In this project impedance of lightning is considered 1500 ohm.

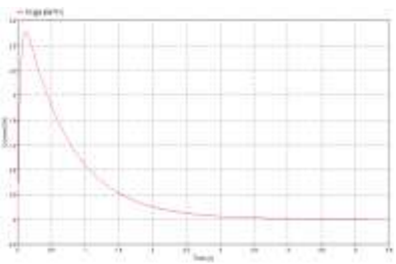


Figure.1 lighting waveform

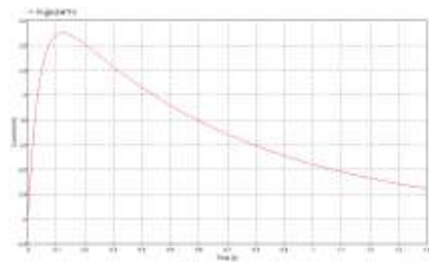


Figure.2 lighting waveform

Study Of Overvoltage In Actual Network

The voltage level of transmission line is 400kV. The lightning in 1.2km to substation strike on phase a and leads to overvoltage on this phase in site of power transformer. In this case supposed circuit is open. The open circuit model for transformer is worst status existent in modeling and on other hand also characteristic impedance is large .Characteristic of transmission line and towers listed in Tabs.1 and 2 [3].

Table1. characteristic of example transmission line (400kV)

CURLLW	Name of phase conductor and guard wire		
0.032	R	Z+	Impedance(ohm per kilometer)
0.28785	X		
9.6	B		
0.376	R	Z0	
0.832	X		
6.54429	B		
S1KL, T1K15	Type of tower		
	Double circuit		Length of line(km)
214	Single circuit		
AJ900	Line type		
Jenah	From	Line Name	
Bandar Abbas	To		
1	No.		

Taleb.2 characteristics of tower of transmission line

Dg	4
Hg	26
Y1-Phase T	22
Y2-Phase S	22
Y1-Phase R	22
X3-Phase T	6.5
X2-Phase S	0
X1-Phase X1	6.5
Tap Changer	S1KL, T1K15

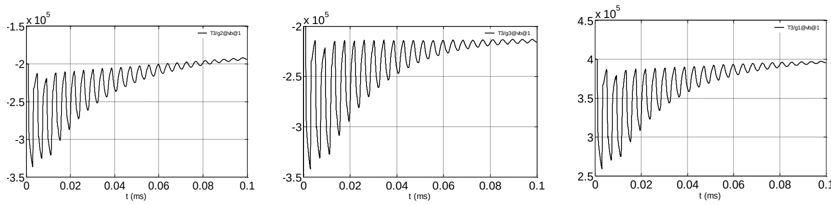
In this circuit, towers of transmission line modeling as characteristic impedance series connected with resistance of tower foot. Then has been models through three insulators have three gaps. The breakage voltages of gaps are 2300 kV. Also tower tip (characteristic impedance) connected to guard wires. Phase conductor has been modeled by model depended to frequency.

Study of overvoltage due to thunderstroke on two ends insulators

Strike lightning to guard wire

When lightning strike to guard wire, magnitude of voltage obtains from multiply by impedances that existing in lightning current. Impedance of strike point is equal: parallel composition of impedances lightning channel and two impedances of guard wire that there are in two sides of strike point. The resultant voltage moves along guard wire and reaches to tower tip. This voltage enters to tower via multiplied by transmission factor between guard wire and tower, multiplying by next transmission factor between guard wire and tower enters next guard wire and finally multiplying by repercussion factor between guard wire and tower, come back to same guard wire.

The entered voltage to tower encounters with tower footing resistance, portion of voltage is transferred and remainder again returns to tower tip [13]. This voltage reach tower tip is reflected for the second time and moves toward the end of the tower and is repeated this process. Voltages of guard wires also move along this wire and after reached to next tower again are reflected. Generally when any one of these voltages reached to point that characteristic impedance is varying, is transferred by respective repercussion factor and returns by respective repercussion factor. For determine generated overvoltage in two ends of insulators of transmission lines, assuming that a lightning wave has amplitude equal to 30 kA, strikes on midpoint of two towers to guard wire, resultant voltages waves in back of insulators chain after lightning strike location shown in Fig. 3.



(a) (b) (c)

Figure. 3 Waveforms of generated voltage in two end of insulator chain near to thunderstroke location: (a) first phase, (b) second phase (c) third phase

Maximum overvoltage appears on nearest tower and towers farther have less voltage with at a later time. The Delay time to this is because voltage wave must moves along line until reaches to towers farther. Reason of voltage reduction this is that when voltage is entered from a tower to other, only portion of voltage transferred as for transference factor and appeared on tower. Tab.4-4 showed maximum voltage on each of insulators chain and occurrence time of these voltage. If it is assumed that cross arm is 75% of these voltages and coupling factor between guard wire (tower tip) and conductors of phase is 0.25, then voltage due to lightning on insulators [(0.75-0.25)=0.5] equal is to tower tip voltage and in worst case may peak phase voltage is added to this voltage, also. If level voltage of transmission line is 400 kV, magnitude ($400\sqrt{2}/\sqrt{3}=327kV$) summed with half of any one of voltages of Tab.3. In worst case, voltages in Tab.4 lied on insulators of one of phases of towers.

Table.3 Maximum voltage on each of insulator chain and occurrence time of these voltages

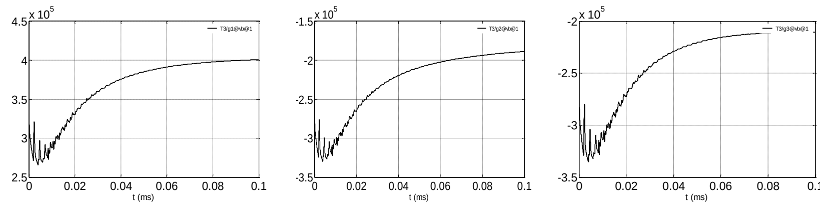
occurrence time of overvoltage (microsecond)	Maximum generated voltage(kV)	No. phase
4.9	385	Insulator chain of phase 1
3	-336	Insulator chain of phase 2
2.98	-341	Insulator chain of phase 3

Table. 4 Maximum generated voltage on insulators

Maximum generated voltage(kV)	No. Phase
727	Insulator chain of phase 1
656	Insulator chain of phase 2
662	Insulator chain of phase 3

Lighting Strike to Tower Tip

In this case, impedance of strike point equal is parallel composition of lighting channel impedance, two impedances guard wire and characteristic impedance of tower. Because thunderstroke to tower tip, all waves entered to tower and are reflected from tower end. Whereas that time the wave sweep of wave in tower is lesser of rising time of wave, reflected wave in generated voltage on tower tip will be effective. The results of thunderstroke shown in Fig.5.



(a) (b) (c)

Figure.5 waveforms of generated in two ends insulators chain: (a) first phase (b) second phase, (c) third phase

As is clear from the results in Tab.5, in second case, generated voltage has increased on insulators chain. The voltage on insulators in worst case has shown in Tab.5.

Influence of Tower Footing Resistance on Amplitude of Overvoltage

In this section footing resistance varies from 10 to 100 ohm and is obtained waveform of generated voltage at top of insulator chain of first phase. As is clear increasing resistance of tower foot, damping of voltage reduced.

Study of Overvoltage Due to Thunderstroke on Power Transformer

The generated overvoltages in power transformer entered to substation. The power transformer in these studies have been modeled based on very large impedance, that is as impedance of open circuit and obtained voltage from this model has maximum value; because transmission factor of open circuit equal to 2. In first part has been study voltage due to thunderstroke on two side power transformer without arrester influence and in second part evaluated arrester influence.

Table.5 Maximum voltage on each of insulator chain and occurrence time of these voltages

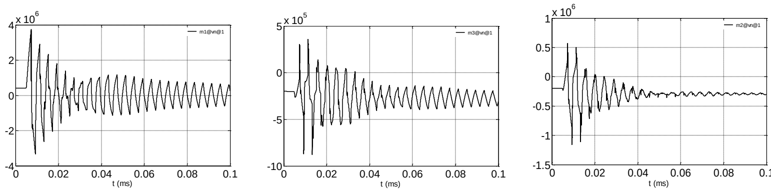
occurrence time of overvoltage (microsecond)	Maximum generated voltage(kV)	No. phase
0	400	Insulator chain of phase 1
4	-329	Insulator chain of phase 2
4	-335	Insulator chain of phase 3

Table. 6 Maximum generated voltage on insulators

Maximum generated voltage(kV)	No. phase
727	Insulator chain of phase 1
656	Insulator chain of phase 2
662	Insulator chain of phase 3

Study of Overvoltage Thunder stroke Due to On Power Transformer Without Presence Arrester

In Fig.6 has been shown maximum overvoltage on transformer. The overvoltages of phases of transformer are 3736, -1158, -868 kV, respectively.

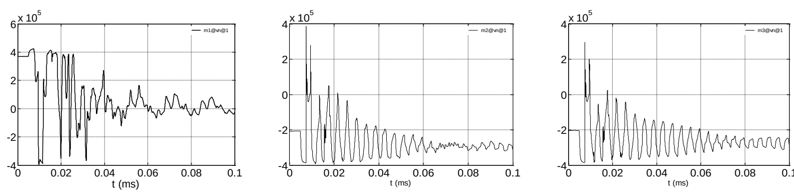


(a) (b) (c)

Figure.6 Voltage on transformer without arrester:(a)phase a, (b)phase b,(c)phase c

Study of Overvoltage Due to Thunderstroke on Power Transformer whit Presence Arrester

As for generated overvoltage on phases and particularly phase a that has struck to this, must used arrester for protect transfer against large over voltages [14]. Using of arrester, overvoltages of phases of transformer restricted to -394, 385, 294 kV, respectively. In Fig.7 has been shown maximum overvoltage on transformer.



(a) (b) (c)

Figure.7 Voltage on transformer with arrester: (a)phase a ,(b)phase b, (c)phase c

Overvoltage caused by lightning one of the fundamental problems in the transmission system, which has always been a significant challenge in this area. In this paper using of EMTP-RV software has been analyzed, over voltages due to thunder stroke to power network has been evaluated. In first section has been analyzed process of generation of overvoltage on insulators of transmission line. If increase this voltage of tolerable value of insulator, breakage occurs. In next section has been introduced overvoltage due to strike lightning to input lines of high voltage substation in power transformer site and role of arrester was evaluated in reduction this voltage.

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