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Analysis of the Use of Surge Arresters in Transmission System Using MATLAB/Simulink

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ABSTRACT: Lightning strikes to overhead transmission lines are reason for unscheduled supply interruption in the modern power system, In an effort to maintain failure rates in a low level, providing high power quality and avoiding damages and disturbances, plenty of lightning performance estimation studies have been conducted and several design methodologies have been proposed. The protection of overhead transmission lines is achieved using shield wires and surge arresters. Surge arresters should be insulators at any voltage below the protected voltage, and good conductor at any voltage above to pass the energy of the lightning strike to ground. The line is protected with only surge arresters and the current simulation of surge arrester is implemented on the sending end and receiving end of the network. By increasing the tower footing resistance, the lightning failure ratebecome greater. Smaller arrester intervals decrease the failure rate and is considered for the case study.

KEYWORDS : Surge arrestors, Simulation, Transmission lines, Failure probability, Models

I. INTRODUCTION

Lightning causes the travelling waves to different devices connected to both sides of transmission line system which is harmful for insulators of lines and devices connected to 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 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 outage and damage of equipment.

Because of high frequency range associated with lightning transients, adequate electrical models are required and simulation studies require detailed modeling of the lightning phenomena and of the network components.

Lightning is the most harmful for destroying the transmission line and setting devices. The use of surge arresters to decrease or eliminate lightning flashovers or switching surge on transmission and distribution lines are essential in power system overvoltage protection.

In the past, a type of surge arrester called protector tube was used. With the advent of the metal oxide arrester with its increased energy capability, and with the development of a no ceramic housing, the use of arresters for protection of lines has received a renewed impetus and popularity. Thus the arresters are now in a very hostile environment, where large current magnitude strokes can impinge on the arresters.

II. MODERN SURGE ARRESTER AND ITS CONSTRUCTION

Surge arresters (or lightning arresters or surge dividers) are installed on transmission lines between phase and earth in order to improve the lightning performance and reduce the failure rate. Surge arresters are semiconductors with nonlinear resistance from a few Ω to several MΩ.

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Several different types of arresters are available (eg. gapped silicon carbide, gapped or non-gapped metal-oxide) and all perform in a similar manner: they function as high impedance at normal operating voltages and become low impedances during surge conditions. Even though a great number of arresters which are gapped arresters with resistors made of silicon-carbide (SiC) are still in use, the arresters installed today are almost all metal- oxide (MO) arresters without gaps, something which means arresters with resistors made of metal-oxide[2].

1. An ideal lightning arrester should:
   a) Conduct electric current at a certain voltage above the rated voltage;
   b) Hold the voltage with little change for the duration of overvoltage; and
   c) Substantially cease conduction at very nearly the same voltage at which conduction started.
2. The main characteristic of a surge arrester are:
   a) Maximum continuous operating voltage (MCOV), which must be greater than the maximum network operating voltage with a safety margin of 5 %;
   b) Rated voltage, which must be 1.25 × MCOV;
   c) Protection level
   d) Capacity to withstand the energy of transient over-voltages.
3. Types of Lightning Arresters
   a) Expulsion type
   b) Nonlinear resistor type with gaps (currently silicon-carbide gap type)
   c) Gapless metal-oxide type
   d) Rod Gap type

Figure 1 Cutaway of a typical metal-oxide surge arrester

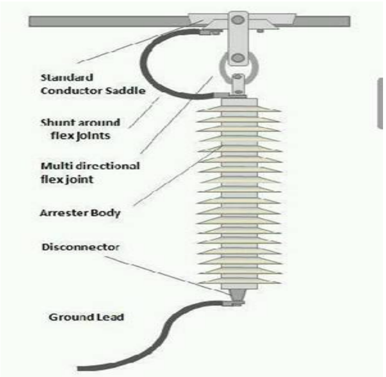

Figure 2 Typical suspension lightening arrester [5]

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 20mm and 45mm.

A. Components

1. Saddle Clamp
2. Flex Joint
3. Shunt
4. Arrester Body
5. Disconnector
6. Ground Lead

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B. Operating Principle

The currents passing through the arrester within the range of possibly applied power-frequency voltage are so small that the arrester almost behaves like an insulator. If however, surge currents in kilo ampere range are injected into the arrester, such as in the case when lightning or switching over-voltages occur, then the resulting voltage across its terminals will remain low enough to protect the insulation of the associated device from the effects of overvoltage. At the same time, the leakage current flows through the arresters. This consists of a large capacitive and a considerably smaller, resistive component.

C. Functions

1. operation of the system i.e., to hold off the system voltage,
2. To limit the transient voltage to a safe level with the minimum delay and fitter, and
3. To bring the system back to its normal operation mode as soon as the transient voltage is suppressed, i.e., to interrupt the power-flow current and to reseal itself.

The normal operation or operational mode includes the system under faulted condition. Under several faults, such as the single line-to-ground faults, the voltage to ground across the unfaulted phases will rise above the normal voltage level. The arrester must not go into conduction during this fault condition. It should also be able to interrupt the power-follow current and reseal itself under system fault conditions when the power-frequency voltage across it rises.

III. CLASSIFICATION OF TRANSMISSION LINE SURGE ARRESTER

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:

1. Selecting the arrester voltage rating. This decision is based on whether or not the system is grounded and the method of system grounding.
2. Selecting the class of arrester. In order of protection, capability and cost as follow:
   a) Station class
   b) Intermediate class
   c) Distribution class

   The station class arrester has the best protection capability and is the most expensive.
3. Determine where the arrester should be physically located.

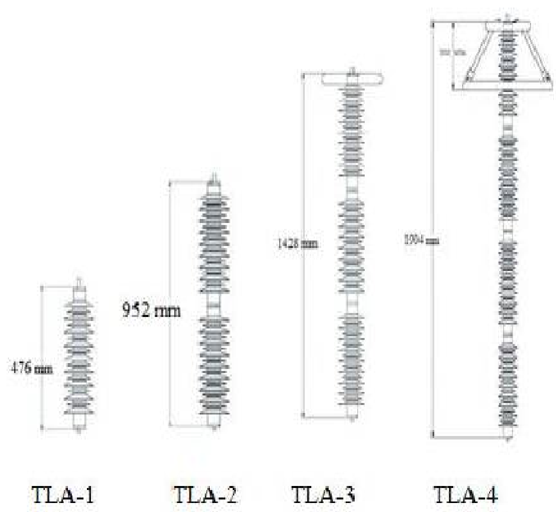

Figure 3 Dimension of Transmission Line Arresters [6].

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TLA 1	15-45 kV
TLA 2	48-96 kV
TLA 3	108-144 kV
TLA 4	150-192 kV

Table 1 Line discharge class andtransmission line voltage rating

IV. TYPICAL TRANSMISSION LINE SURGE ARRESTER INSTALLATION

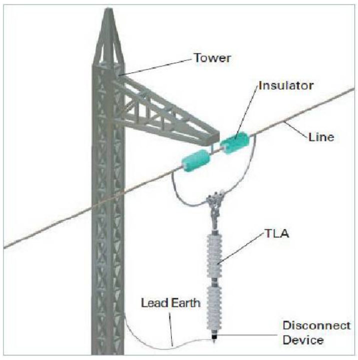

Figure 4 Transmission Line Arrester installation in tower: Case (b) beside the insulator.

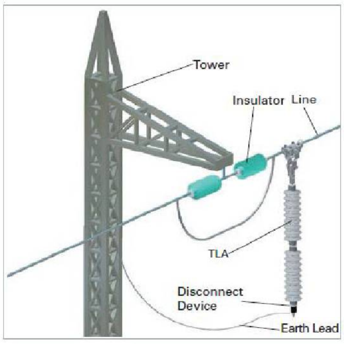

Figure 5 Transmission Line Arrester installationin tower: Case (a) across the insulator.

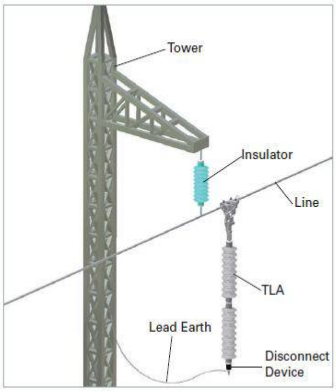

Figure 6 Transmission Line Arrester installationin tower: Case (c) parallel to the insulator.

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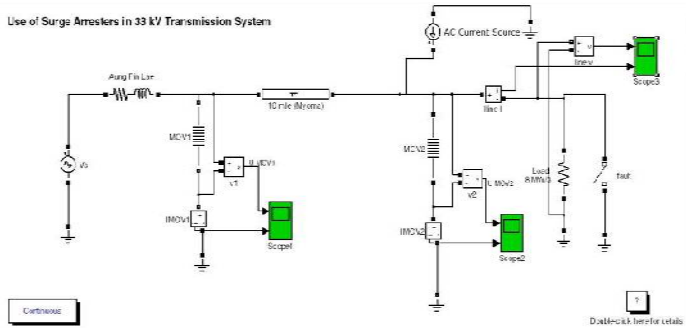
Figure 7 Photograph installing line surge arresters

V. PROPOSED MODEL OF 33 KV TRANSMISSION LINE

Below figure shows a 33 kV transmission system with two transmission line arrester placed at the sending end and the receiving end of the line. Over the system a lightning surge of 20 kA was induced and the resulting simulation was carried out by using MATLAB software.



A 33 kV transmission system feeds a load (8 MW) through a 16.093 km transmission line as shown in fig.11. A transformer rating 3(5MVA) is connected at the sending end of the network. The results of the simulation show that the temporary increase in current at MOV 1 and MOV 2 which is done by the lightning when 20 kA lightning current is applied as shown in Figs.9 and 10. On the other hand, the temporary increase in voltage in each arrester. After 0.03 sec the arresters serve as the steady state condition. The load voltage is increased and the load current decreased during the time, where the lightning occurs.

ALGORITHM:

- In the command window enter Simulink.
- Open the Simulink library browser.
- Search for specific blocks.
- Open a new model in the Simulink editor.
- Add blocks to a model.
- Move & resize blocks.
- Simulink block connections.
- Draw signal lines between blocks.

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- Define simulation parameters.

VI. RESULTS AND DISCUSSION

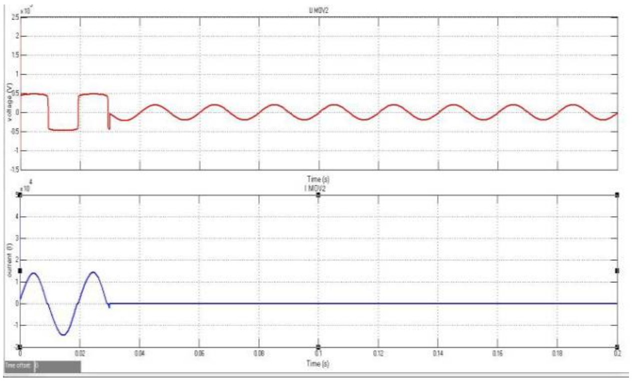

Figure 7 Voltage and Current waveform at MOV 1.
(before clearing the fault,waveform obtained at mov1)

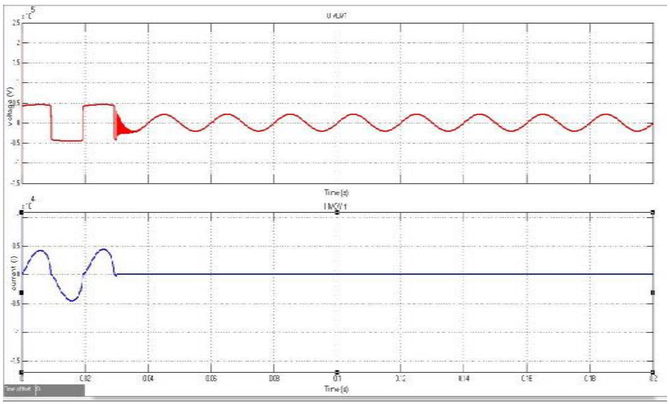

Figure 8 Voltage and Current waveform at MOV 2.
(before clearing the fault,waveform obtained at mov2)

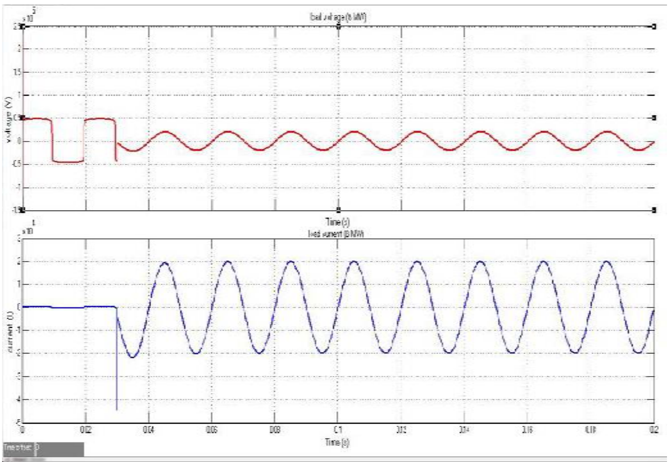

Figure 9 Voltage and Current waveform at load side (8 MW).
(After clearing the fault,waveform obtained at the load side)

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VII. CONCLUSION

For the analysis of surge arrester in transmission line, MATLAB software is employed for the simulation of the selected transmission line as well as the lightning surge and MOV arrester. The simulation is carried out near the receiving end of the transmission line. This paper will help and give the electrical knowledge of the overvoltage protection system by surge arrester in transmission lines.

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