PERFORMANACE ANALYSIS OF METAL OXIDE SURGE ARRESTERS USING PSCAD

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Abstract : This paper demonstrates the importance of a surge arrester in the power system. It includes design of a surge arrester, calculation of lightning current and the simulation results. The intension of designing a surge arrester is to protect the substation equipment's and to provide stability to the power system. Over voltages in the transmission line are reduced using Metal Oxide surge arresters. This paper also demonstrates the significance of having an appropriate location of surge arresters. This is done by measuring the voltage at the equipment for different locations of surge arresters. The 1.065kA, 2.662kA and 5.325kA of surge with impulse of 8/20µs is generated and passed through the three phase 132kv transmission system. Arrester is placed at different locations (10m, 30m and 75m from transformer) and the simulation results are noted. The Simulation model is simulated using PSCAD software.

***Index Terms* - Generated lightning current, Over voltage, Metal-Oxide (MO) surge arrester, Surge arrester placement.**

I. INTRODUCTION

Power system stability is defined as its ingenuity to accomplish an un-fluctuating or a normal state after having been subjected to disturbance. Disturbance may include short circuit condition or change in load condition etc. In the power system, when the system loses its synchronism it is known as unstable system or this condition is known as instability [9]. One major condition which affects the stability of power system is discussed below.

Lightning is defined as discharge of electricity. It is a natural phenomenon or in other words, it is an unpredictable phenomenon [1]. It is considered to be a major cause of instability in the power system. Because when the lightning hits the transmission line, surge travels towards the substation equipments and passes to the ground through the equipments. Subsequently damaging the equipment and results in instability of the power system. So, in order to protect the equipments from damaging, it is necessary to provide the power system with surge arresters.

Modeling of surge arresters are done depending upon its equivalent frequency dependent circuit [3]. Normally, arresters are an air gap. Length of air gap depends upon the value of surge arresters to be designed. When the voltage in the transmission line reaches a value for which an air gap is designed, an arc occurs causing an ionized path for over voltages to ground (short circuit). Circuit breakers are opened in order to extinguish the ionized path [8].

In the power system, any number of surge arresters can placed and it is placed between transmission line and ground (parallel to the equipments to be protected in power system). Surge arrester has high voltage terminal and ground terminal. When the voltage in the transmission line is smaller than the designed value of surge arrester, then the surge arrester acts as an insulator. When the voltage in the transmission line is greater than the designed value, then the arrester acts as a conductor and tries to limit the voltage to a designed value [3].

Surge arrester module consists of nonlinear resistors, capacitors and inductors. Nonlinear resistors which are made up of Zinc Oxide Semiconductors are called Metal Oxide (MO) surge arresters. MO surge arresters provide protection to the equipments in power system from over voltages (internal and external) [4]. It has high stability and high energy absorbing capacity.

II. SYSTEM ANALYSIS

The developed system consists of a lightning generating module, surge arrester module, transformers (step up and step down) and a transmission line as shown in Figure 1.

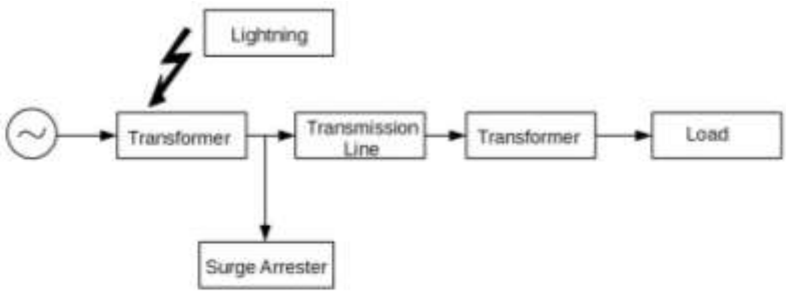

Fig. 1. Block diagram

Generated lightning current is fed to the transmission line. Voltage in the transmission line increases (surge voltage) and travels towards the equipment's. Surge arresters present in the system protects the equipments and insulations by reducing the over voltage. Over voltage at the terminals of the equipments are reduced by switching the path of flow of current from towards the equipment to the ground through the surge arrester.

2.1. Lightning Generator Module

Lightning are the transient over voltages that cause disturbance in overhead transmission and distribution lines. Lightning is represented as a negative polarity current source. Lightning generating module is shown in Figure 2.

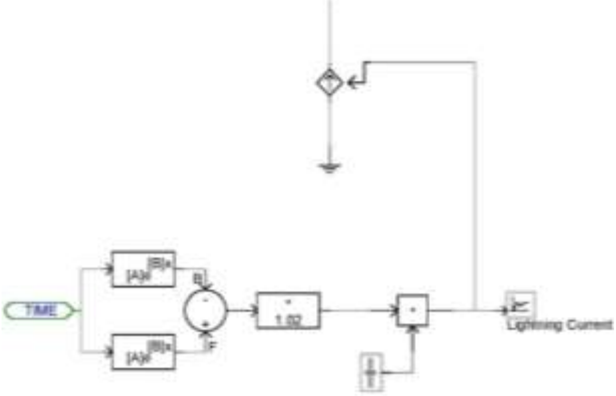

Fig. 2. Lightning generator module

Double exponential current waveform is generated from a current source which is controlled by external control circuit. It consists of two parallel branches with exponential expressions and their difference is connected in series to multiplying factor which determines the magnitude and shape of waveform which is externally controlled by multiple run simulation components. The differencing component generates an instantaneous value of double exponential waveform and feeds to the current source which in turn generates the complete waveform based on instantaneous values that is fed to external control circuit.

2.2. Surge Arrester Module

The surge arrester used is metal oxide surge arrester. It is type of resistor which has non linear volt ampere characteristics, with resistance characteristics. These arresters offer high resistance i.e, it allows small amount of current to pass through them when the voltage applied across them is less than the threshold voltage and when voltage is increased its allows high current to pass through them and offering very less resistance hence reduces the voltage in the circuit and protects them. It makes sure that there is no much fluctuation in the voltage in the main circuit. The surge arrester cannot be modeled by only using non liner resistance it also includes inductance, linear resistance and capacitance. Arrester is a frequency dependent device whose voltage across arrester depends not only on the rate of rise of current but also depends on the magnitude of current and behaves according to the wave shape of the surge applied. Surge arrester module is shown in Figure 3.

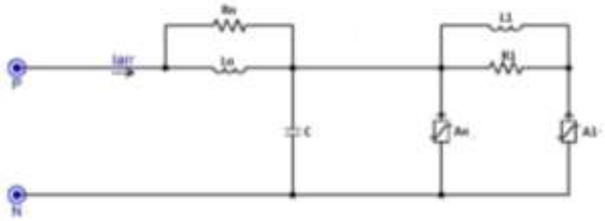

Fig. 3. Surge Arrester Module

From Figure 3, A_0 and A_1 are the non linear resistance in parallel and separated by the R-L filter that is R_1 and L_1. For fast front surges filter applies high impedance and current flows through non linear resistance [7]. According to their characteristics, the non linear resistor has higher frequency and high voltage across them and higher residual voltage for the given current. R_0 is used for stabilizing the numerical calculation and L_0 is in reference to the magnetizing effect in the vicinity of the arrester. Terminal to terminal capacitance is represented by C.

III. Design Calculation

Generation of lightning impulse is important for testing purpose and in this project lightning surge of 1.065kA, 2.662kA and 5.325kA with 8/20µs impulse is generated. Impulse of 8/20µs depicts that the current pulse reaches its maximum value in 8 microseconds and decays to half of its value in 20 microseconds. Impulse is generated using a double exponential expression,

$$i(t) = I[e^{(-\alpha t)} - e^{(-\beta t)}] \qquad (1)$$

In this expression, the parameter β is associated with the front (rise) time and the parameter α with the tail (fall) time. Where fall time is measured when the peak value reaches 50%. The value of α is generally less than β. This equation represents unidirectional wave that rises quickly and slowly falls to zero. Lightning current along with standard values of parameters are shown in Table 1 [6].

Table 1 STANDARD VALUES

I (test)	I	α	β
1.2/50	1.02E1	1.3E4	4.4E6
8/20	4.00	8.66E4	1.732E5
300/1000	1.75	1233	6781.5
8/50	1.23	2.0E4	4.0E5

When lightning is struck on the transmission line it induces high voltage which travels as a waveform on the both side of transmission line and can be calculated as,

$$\text{Over voltage} = \frac{i}{2} * Z_s \qquad (2)$$

- $\text{Over voltage} = \frac{1.065}{2} * 709.85$
  $= 377.99\text{kV}$
- $\text{Over voltage} = \frac{2.662}{2} * 709.85$
  $= 944.81\text{kV}$
- $\text{Over voltage} = \frac{5.325}{2} * 709.85$
  $= 1890\text{kV}$

The value of the parameters of surge arresters can be calculated as follows:

$$L_1 = \frac{15d}{n}\ \mu\text{H} \qquad (3)$$

Where, d = Length of arrester column in meters
= 1m
n = Number of parallel columns of metal-oxide disks
= 1

$$L_1 = \frac{15d}{n}\ \mu\text{H} = 15\ \mu\text{H}$$

$$R_1 = \frac{15d}{n}\ \Omega = 65\ \Omega \qquad (4)$$

$$L_0 = \frac{0.2d}{n}\mu\text{H} = 0.2\ \mu\text{H} \qquad (5)$$

$$R_0 = \frac{100d}{n}\Omega = 100\Omega \qquad (6)$$

$$C = \frac{100n}{d}\text{pF} = 100\text{ pF} \qquad (7)$$

Surge arrester module with calculated values is shown in Figure 4.

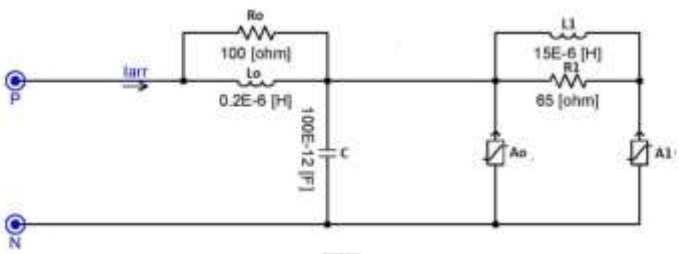

Fig. 4. Module with calculated values

Rating of the non linear resistance is decided by the V-I characteristics of the resistances as shown in Figure 5.

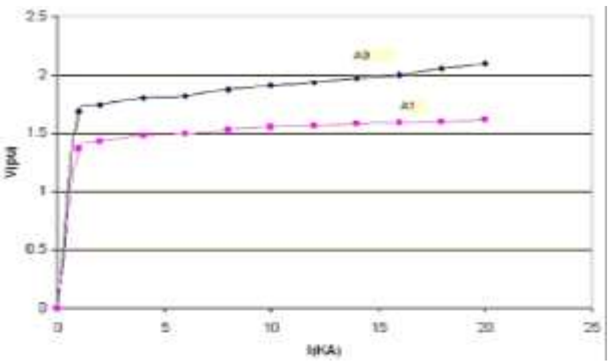

Fig. 5. V-I relation of non linear resistor

Each of the V-I points for the nonlinear resistors is found by selecting a current point and then reading the relative IR in pu from the plot. This value is then multiplied by (V'/l.6) to determine the model discharge voltage in kV for the associated current. For A_0,

$$\text{Discharge KV} = [\text{Relative IR in pu for } A_0 \text{ (i)}]*\frac{V'}{1.6} \qquad (8)$$

For the surge arrester, the associated V-I voltage fora 5.4kA current for the nonlinear resistor, A_0, is determined by reading the "Relative IR" for a 5.4kA current. Examination of the plot shows that the "Relative IR" for a 5.4kA current is 1.9pu. Therefore the discharge kV for A_0 associated with 5.4kV.

$$\text{Discharge KV} = 1.9 * \frac{248}{1.6}$$

$$\text{Discharge KV} = 294.5$$

Similarly, For A_1,

$$\text{Discharge KV} = [\text{Relative IR in pu for } A_1 \text{ (i)}]*\frac{V'}{1.6}$$

$$\text{Discharge KV} = 1.55* \frac{248}{1.6}$$

$$\text{Discharge KV} = 240.25$$

IV. SIMULATION

Accuracy of simulation depends on the characteristics of the designed module. Before implementing the module, it is necessary to validate the design which is done with the help of simulation. Simulation model is shown in Figure 6. Model consists of lightning generating module, arrester module, transformers and transmission line. The lightning current is generated in the lightning generating module and passed through the 132kV transmission line. The value of the lightning current can be controlled using control panel. Surge arrester module is connected to the transmission line in parallel with transformers. The model is simulated using PSCAD software.

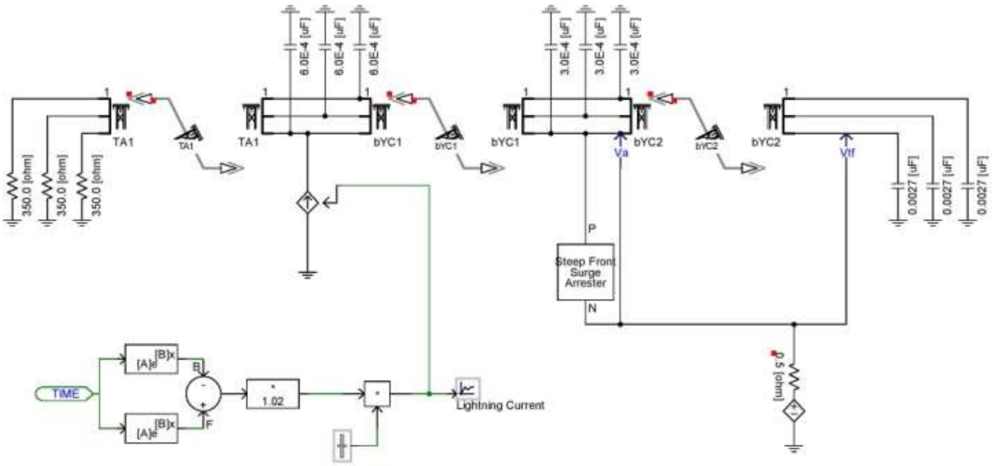

Fig. 6. Simulation module

V. SIMULATION RESULT

For various placements of surge arresters and for different values of lightning current simulation was done. This was done to demonstrate the effective placement of surge arresters in the power system. And the results are presented below.

CASE 1: When there is no surge arrester.

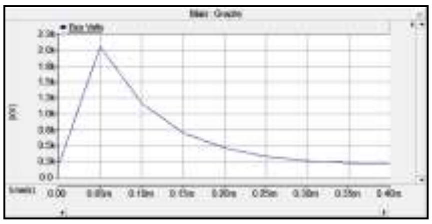

Fig. 7. Bus voltage

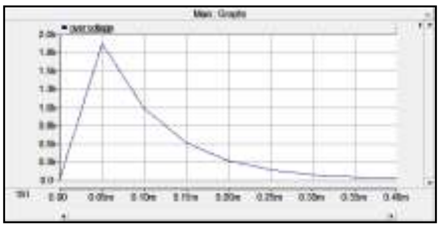

Fig. 8. Over voltage

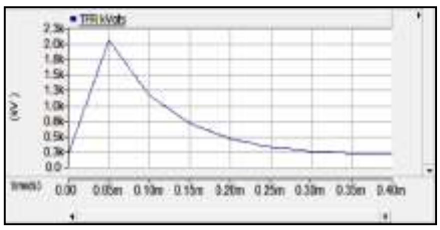

Fig. 9. Voltage at the transformer

Table 2 shows the results with no surge arrester.

Table 2 VALUES

Bus Voltage (MV)	*Over Voltage (kV)*	*Voltage at Transformer with Arrester (MV)*
2.08	1.9	2.08

The generated lightning current of 1.065kA is passed through the system. The system is tested by positioning the MOV 10, 30 and 75m away from the transformer. The Bus voltage, arc voltage and voltage at transformer is simulated and the results are shown in tables below. It shows that as we move away from the transformer the effect of surge arrester reduces significantly.

Table 3 shows the results of different arrester positions for 1.065kA of lightning current.

Table 3 VALUES

Surge arrester is set at (in meter)	*Arc Current (kA)*	*Bus Voltage (kV)*	*Over Voltage (V)*	*Voltage at Transformer with Arrester (kV)*
10	0.860	250.226	71.843	250.001
30	0.862	250.270	71.421	250.056
75	0.864	250.338	70.846	250.108

Table 4 shows the results of different arrester positions for 2.662kAof lightning current.

Table 4 VALUES

Surge arrester is set at (in meter)	*Arc Current (kA)*	*Bus Voltage (kV)*	*Over Voltage (V)*	*Voltage at Transformer with Arrester (kV)*
10	2.429	260.587	83.353	259.906
30	2.429	260.629	82.131	259.978
75	2.436	260.725	80.529	260.346

Table 5 shows the results of different arrester positions for 5.325kAof lightning current.

Table 5 VALUES

Surge arrester is set at (in meter)	*Arc Current (kA)*	*Bus Voltage (kV)*	*Over Voltage (V)*	*Voltage at Transformer with Arrester (kV)*
10	5.042	273.338	98.033	272.812
30	5.051	273.378	95.484	272.817
75	5.085	273.491	92.164	273.005

VI. CONCLUSION

For different lightning current and for different locations of surge arrester, voltage at the transformer was noted. As the distance of surge arrester from the transformer increases the voltage at the transformer also increases. It is also noted that, when there is no surge arrester even a small increase in voltage (surge) in transmission line leads to dangerous effects on the power system. Metal Oxide surge arrester was used to reduce the over voltage. Advantages of MO surge arresters are presented below:

- It eliminates the risk of flashover
- It eliminates the risk of shock in the power system
- Dynamic over voltages are controlled

Therefore, it can be concluded that, placing a surge arrester in the power system reduces the risk of damage of the substation equipment's and also placement of surge arresters close to the substation equipment's have more effectiveness than placing it away from the equipment's.

VII. ACKNOWLEDGMENT

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