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Lightning Impact on the Transmission Line and Its Mitigation using Matlab Simulink

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Abstract: Transmission lines are a power system component (PS). Lightning strikes, for example, are a natural impact that transmission lines are constantly subjected to. Humans are powerless to stop the occurrence. Lightning strikes the PS, causing an impulsive transient and affecting the transmission line's equipment's power quality. The industrial sector might be a victim of this issue and suffer a considerable loss. Equally, as a solution to this problem, mitigating techniques may be used in the system to assure PS's long-term viability and high performance. In this paper, this project aims to simulate a surge arrestor in transmission lines to reduce the effect of lightning strikes. MOSA (Metal Oxide Surge Arrestor) is the mitigating technology employed in this project. MATLAB Simulink software was used to simulate the MOSA. The project's results include steady-state output waveforms, surge waveforms caused by lightning strikes, and mitigation results applying the suggested mitigation approach. To obtain the best result for this project, one recommendation for future work is to use different simulation tools like PSCAD to mitigate the lightning impact on the transmission line.

Keywords: Lightning, Transmission Line, Surge Arrestor

1. Introduction

Lightning can influence the electrical system, including direct strikes to the PS, near strikes, or far strikes to the structure that can induce voltage surge into the electrical system [1]. Direct lightning strikes may intercept line conductors, towers, or shielding wires. The probability of a direct strike in a given region increases with line height [2]. Next, lightning affects the performance of transmission lines where the transient high voltages may cause a flashover on the electrical equipment on the power line. Overall, lightning causes many PQ problems that can affect people, buildings, and power lines [3].

Lightning causes one of the famous PQ problems in PS: impulsive transients. A surge arrestor prevents exposure to sensitive equipment and guards the facility against damage from impulsive transients [4]. Metal Oxide Surge Arrestor (MOSA) was chosen for this project because it can handle high voltage up to 450 kV and is suited for the distribution system.

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This project is to investigate the PQ problem of impulsive transients in a test case transmission line system. MATLAB software designed the test case for the steady-state case, impulsive transient case, mitigation technique case, and the transparent case to achieve the objective. Then, design the mitigation technique of MOSA from the investigated PQ problem. Lastly, the designed MOSA to mitigate the harmonic problem.

2. Methodology

2.1 Mitigation using MOSA

MOSA can stabilize the transmission lines' state after being struck by lightning. An ideal MOSA must conduct electric current at curtain magnitude above the rated voltage, hold the voltage with very little chance for the duration of overvoltage and substantially cease conduction at very nearly the same voltage at which conduction started.

MOSA is suitable for transmission lines because it may have endured temperatures higher than the transmission lines during a lightning strike. The connection MOSA must be connected parallelly to the ground to intercept the exceeded charges from lightning

2.2 Mathematical modeling for MOSA

Procedures to determine the MOSA are by calculating the inductive element of the MOSA using equations 1 and 2. This step is essential for assuring the final design fits all the required specifications [4].

$$L_1 = \frac{1}{4} . \frac{V_{r1/T2} - V_{r8/20}}{V_{r8/20}} . V_n \quad Eq. 1$$

$$L_0 = \frac{1}{12} . \frac{V_{r1/T2} - V_{r8/20}}{V_{r8/20}} . V_n \quad Eq. 2$$

2.3 Parameter of MOSA

Table 1 shows the datasheet [5] used for the selected MOSA transmission line. The datasheet selection decides by selecting the value of the max system voltage.

Table 1: Selected MOSA parameter

Type of surge arrester	Max. System Voltage $Vm, kVrms$	Rated voltage $Vn, kVrms$	Continuing operating voltage $Vc, kVrms$	Residual voltage with different waveforms for discharge current values, kV		
				$r1/T2\ s$	$8/20\ s$	
				$10\ kA$ $kVpeak$	$5\ kA$ $kVpeak$	$10\ kA$ $kVpeak$
PREXLIM P	170	162	108	372	351	369

The datasheet also states the type of MOSA physically. Figure 1 shows the selected MOSA type and the number of MOSA columns. From the information given, the number of selected MOSA contains 20 columns.

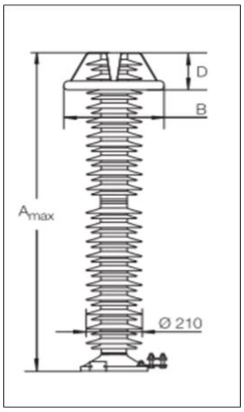

Figure 1: Type selected of MOSA physically

2.4 Test Case Model

Test case models were created to show the arrangement of the equipment for this project, shown in Figure 2. The first test case is a steady-state condition. The transmission line selected is a long transmission line type. The parameter for the test case area voltage of 275 kV, the system's frequency is 50 Hz, and the length of the transmission line is 200 km and connected to a load of 1000 MW.

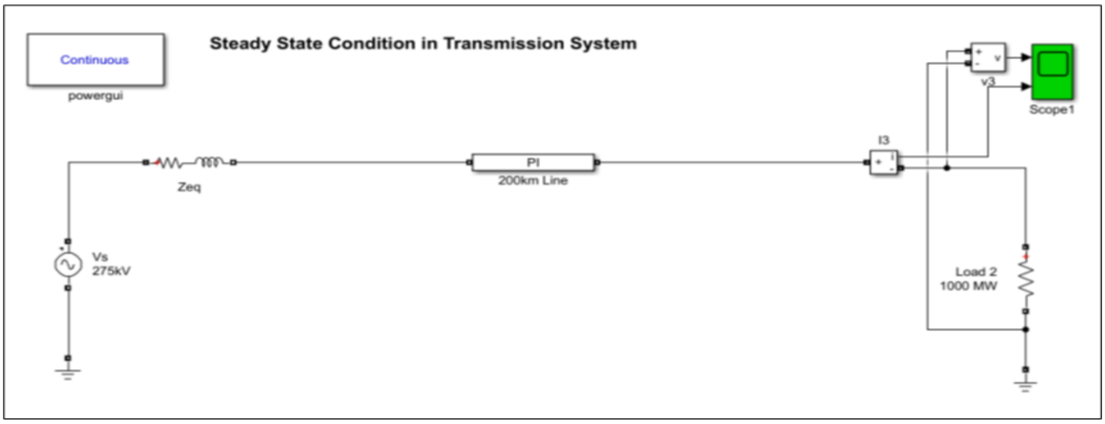

Figure 2: Steady-state condition in transmission line system

The test case in Figure 3 shows the fault condition of the transmission line. The model is identical to steady-state but has fault inserted into the system. The fault created is an impulsive transient caused by lightning. The lightning created from a current source block injects a lightning current inside the test case. The peak amplitude for the lightning strike inside the test case is 30 kA.

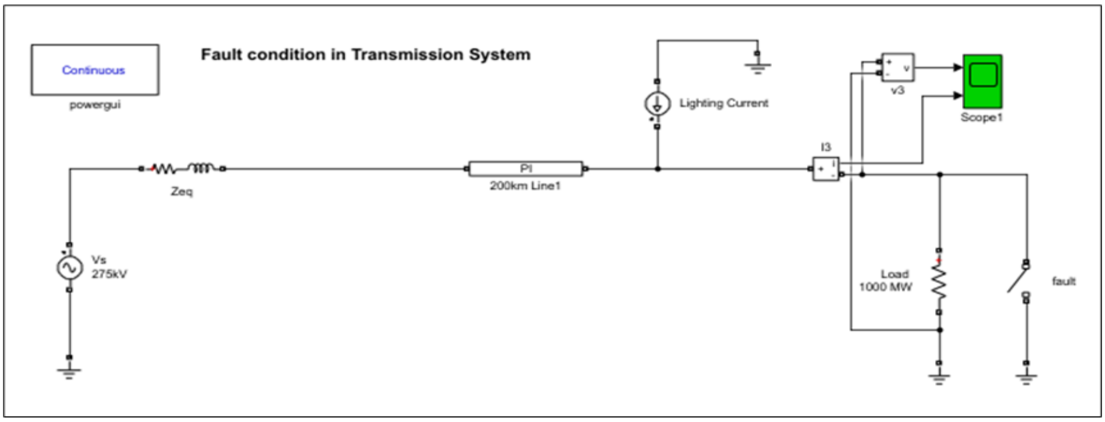

Figure 3: Fault condition in transmission line system

Figure 4 shows the mitigation test case. The mitigation method is by installing MOSA on the transmission line. The MOSA connected parallel to the load to the ground.

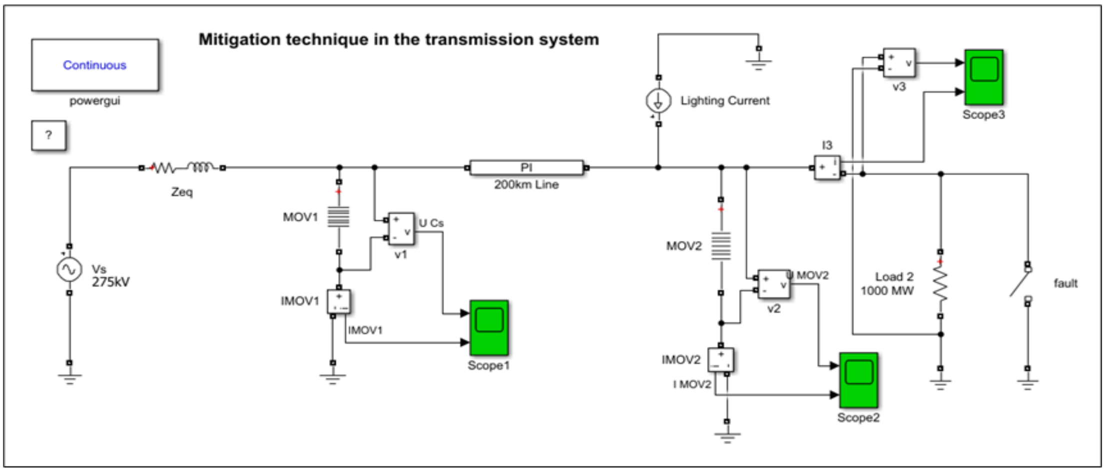

Figure 4: Mitigation condition in transmission line system

Finally, Figure 5 shows the transparent test case. The transparent test case was created to observe the system installed and the MOSA's behavior.

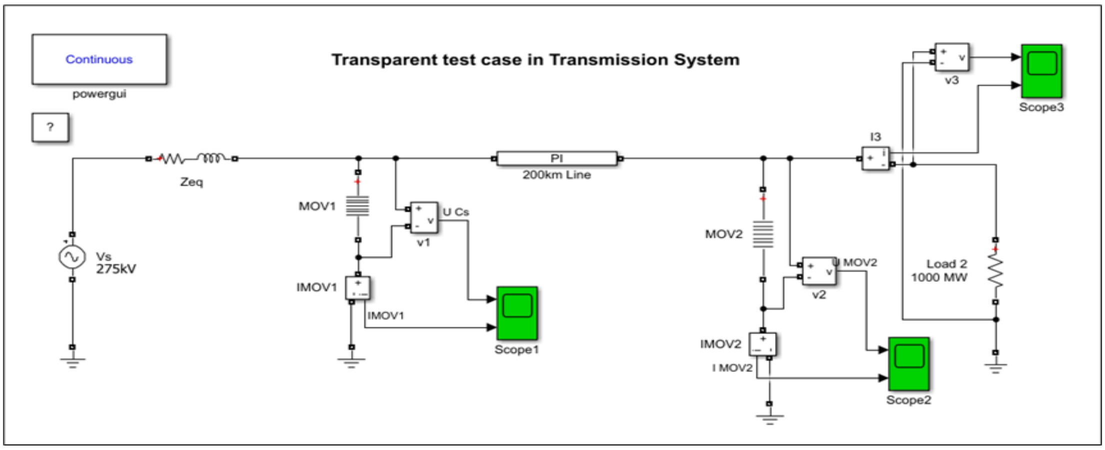

Figure 5: Transparent condition in transmission line system

3. Results and Discussion

The result shows PQ problem conditions, wherein the system shows the disturbance produced by lightning strikes. Mitigation techniques were applied to the test case to eliminate impulsive transients. The test cases were simulated for 0.4 seconds.

3.1 Steady-state condition result

Figure 6 shows the output voltage waveform of a steady-state transmission line. The value of max voltage output is 264 kV and the current is 1.164 kA in 0.4 seconds—the voltage loss due to the transmission line's cables impedance.

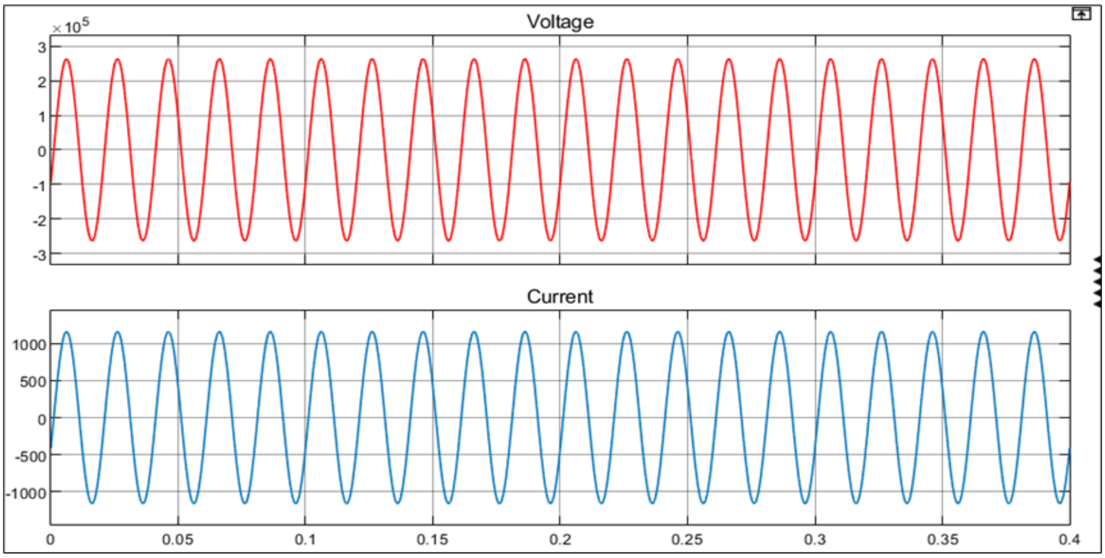

Figure 6: Steady-state condition output waveform

3.2 Fault condition result

Figure 7 shows the fault condition output waveform. The voltage at the load side had been increased to 2.4 MV and this problem is named transient overvoltage. Overvoltage only presented for 0.1 seconds before the breaker opened and the system became an open circuit. The transient effect also appeared in the current waveform. The voltage had been increased drastically. After 0.1 seconds, the system is blackout. The injected lightning causes the fault in the system. This fault must be mitigated.

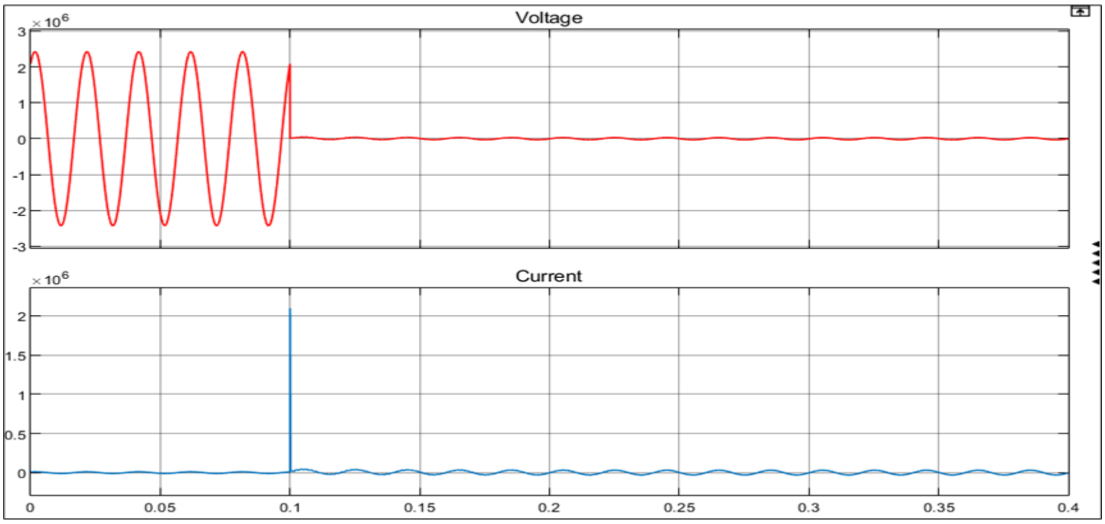

Figure 7: Mitigation condition output waveform

3.2 Mitigation condition result with MOSA

The MOSA was connected parallelly to the transmission line and load to act as protection to the system. Figure 8 shows the voltage and current are cleared from impulsive transient because of MOSA after 0.1 seconds. MOSA has a variable resistance depending on voltage. When the voltage level of transmission lines is at the rated voltage for the arrestor, MOSA will create a very high resistance. If the voltage level exceeds the rated voltage, MOSA will act differently and create a low resistance path that leads the very high value of current caused by lightning to the ground system.

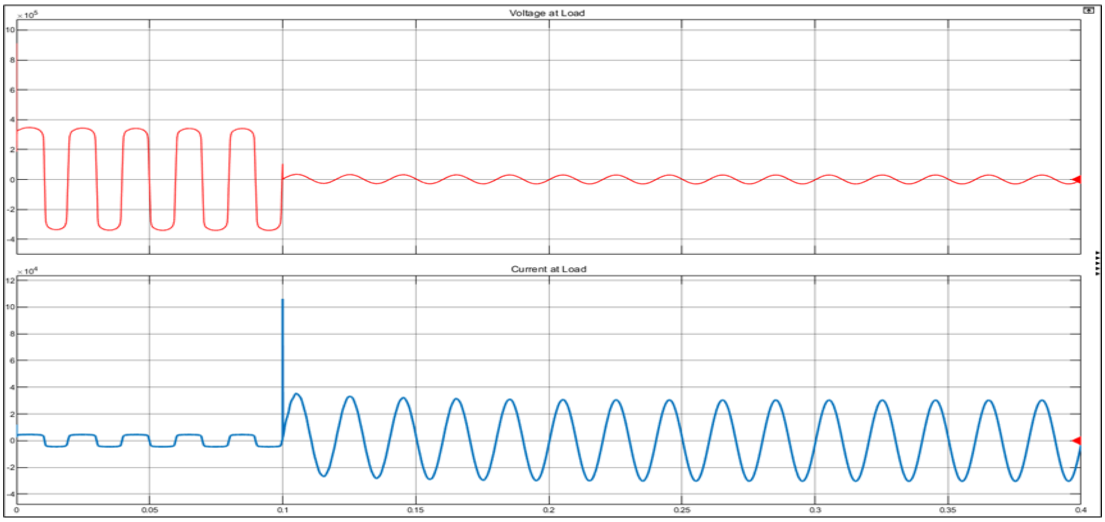

Figure 8: Mitigation condition output waveform

3.3 Transparent condition result

Figure 9 shows the voltage and current of transparent state conditions. The voltage and the current waveform are almost identical to the steady-state test case because there is no fault in the system. Both voltage and current waveform are a bit lower than steady-state test cases because of the MOSA in the system. This happens because MOSA acts as a load in the simulation and can be due to the error of the software.

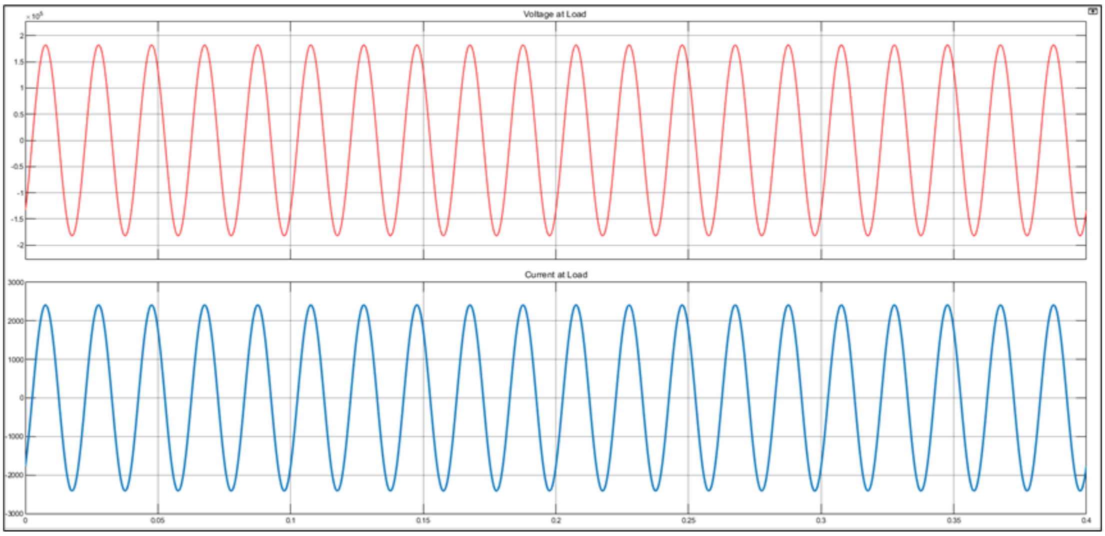

Figure 9: Mitigation condition output waveform

4. Conclusion

In conclusion, all the objectives were successfully achieved. Firstly, PQ problems related to the lightning effect on transmission lines and finding that impulsive transient problems on the transmission line mainly happen during lightning. After that, the test case steady-state circuit of the transmission lines system is designed and used in this project. The transmission line system carries 275 kV with a 200 km distance. For transient test case conditions, the lightning injected 30 kA to the steady-state condition of the transmission line system. Lastly, the test case mitigation technique used is MOSA connected parallelly to the transmission lines. The MOSA can discharge overvoltage to the ground. Lastly, this project can conclude that the MOSA can mitigate impulsive transient.

Acknowledgement

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