# Factors Influencing the Selection and Installation of Surge Protecter on Low-Voltage Power Line

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***Abstract:*** **To reduce the risk of damage due to lightning for electrical and electronic systems within a structure, lightning protection system have to be properly designed. This paper illustrate the influence of the main factors and parameters which affect the selection and installation of surge protective device (SPD) in protecting against surge on power line. The two types of SPD are manufactured according to the most typical technology are considered, namely Metal Oxide Varistor (MOV) and Triggered Spark Gap (TSG). From there, the basic recommendations are given in the effective selection SPD in protecting against surge on power line.**

***Keywords: Lightning Protection, Surge Protective Device (SPD), SPD Protection Level.***

## 1. INTRODUCTION

The risk of damage caused by lightning is very serious [1]. Lightning strike to or near the structure and the service lines connecting to the structure may cause the failures for electrical and electronic systems inside the structure. These failures can be caused by all or a part of the lightning current created overvoltage impulse propagation on low-voltage (LV) power line. To limit these overvoltage impulse below the rated impulse withstand insulation of the protected apparatus and devert surge current to the ground, the installation of surge protective devices (SPDs) on LV power line should be applied.

Currently, the SPDs is produced with more and more different technologies by different manufacturers. However, some manufacturers are known to only provide the data that will support the benefits of their product, not the weakness [2]. Thus, making it difficult for the selection of SPDs to achieve the best protection.

For a proper selection and installation of SPDs, it is of essential and importance to know about the working mode, which an SPD will experience under deverting surge current to the ground. This working mode is underlined by the standard [3, 4], is a function of many complex and interrelated factors. These include: SPD manufacturing technology, the lightning current waveform, the lightning current amplitude, the rated current of MOV, the threshold voltage of MOV, the coordinated protection of SPDs.

## 2. DESCRIPTION OF SURGE PROTECTION SYSTEM

To evaluate the factors and parameters that influence the selection and installation of SPD as well as the effectiveness of protection in protecting against surges on LV power line, the diagram simulating surge protection system is shown in Figure 1. In this diagram, lightning stroke has been simulated as an ideal current generator, according to the equation describing the current wave shape as follows [3, 5]:

$$I = \frac{I_P}{k}.\frac{(t/\tau_1)^{10}}{1+(t/\tau_1)^{10}}.exp(-t/\tau_2) \qquad (1)$$

where I: peak current, k: correction factor for the peak current, t: time, $\tau_1$: front time constant, $\tau_2$: tail time constant.

The values of the parameters in (1) vary depending on the lightning protection level and the lightning type. In the paper, two types of typical lightning current is 8/20 µs and 10/350 µs have been simulated with different impulse amplitude.

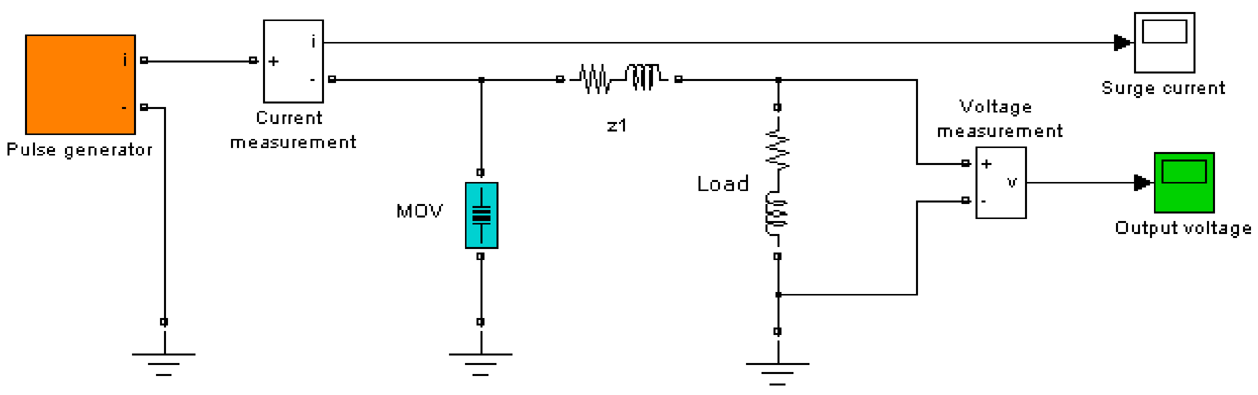


Figure 1. Model of surge protection.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

The load is simulated as a common synthetic load in the structures and has a power of P=1760W, Q=1320Var (corresponding to the load I=10A, V=220V, cosφ=0,8). The protective device is manufactured by the technology of MOV or TSG and installed in main switch board (MSB) at the entry point of the structure. The line connected between source and load has a length of 10m, cross section is 4mm$^2$ with $r_0$=4,61Ω/km and $x_0$=0,08Ω/km.

To evaluate the effectiveness in protecting against surges on LV power line is mainly based on the residual voltage across the apparatus during the lightning dissipation. The lower this value is, the better overvoltage protection for the apparatus.

## 3. FACTORS INFLUENCING THE SELECTION AND INSTALLATION OF SPD

### *3.1. SPD manufacturing technology*

The following, two main types of lightning protection technology are MOV and TSG to be considered.

MOV is a type of non-linear resistor depends on voltage, this technology uses metal oxide varistor plates play a role of lightning dissipation element [6] sandwiched between two metal plates acting as electrodes. MOV has advantages such as high nonlinear coefficient, small leakage currents, good lightning dissipation, fast response time. Therefore, the structures in urban areas with tolerance induced voltage by indirect lightning strike with lightning current 8/20µs, installing MOV at entrance point of the structure is reasonable.

TSG is a device manufactured by self-triggering spark gap technology [6]. This device works on the principle of triggering spark between the spark gaps. TSG has advantages such as high-dissipation capability of the lightning current, impact with any overvoltage impulse, operating effectively in all types of electrical system. When overvoltage protection by TSG technology, the surge energy dissipation capability will be better. Thus, TSG appropriate for protection structures in suburban areas with the ability of direct lightning strike, lightning current 10/350µs and large lightning current amplitude.

To compare the protective effects of the surge protection technology, conducting simulations with the standard surge current 10kA, wave shape 8/20 µs. SPD technology is manufactured by MOV technology with $V_{ref}$=275V, and $I_n$=40kA in surge protection models as in Figure 1 and SPD technology is manufactured by TSG technology as in Figure 2 with voltage discharge is 1200V and response time is 20ns. The residual voltage curve across the load in the case of using MOV and TSG are shown in Figure 3, the peak voltages across the load are presented in Table 1.

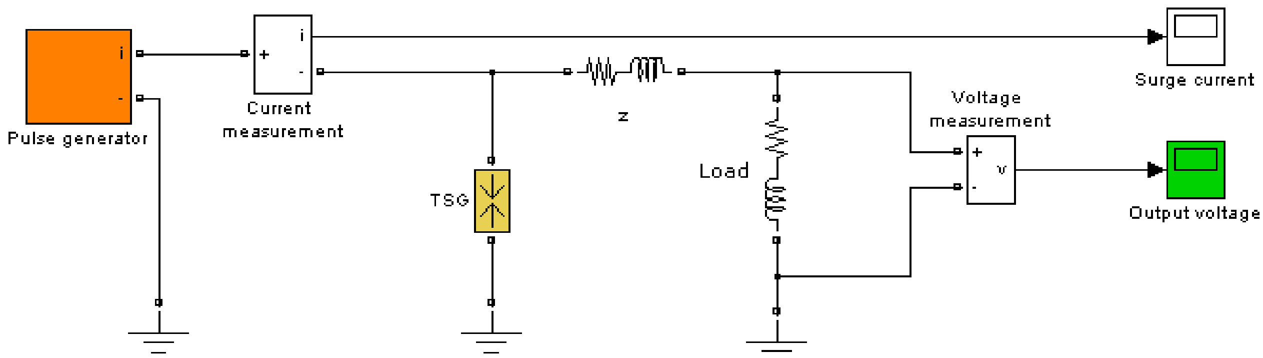


Figure 2. Model of overvoltage protection by TSG.

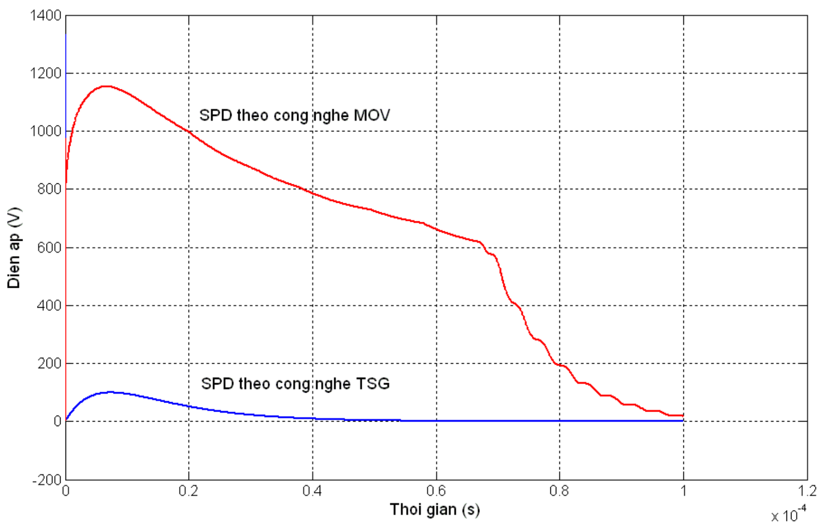


Figure 3. Residual voltage across the load, SPD type MOV and TSG repectively.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

Table 1. The value of residual voltage across the load, SPD type MOV and TSG

| Standard lightning current | Residual voltage across the load (V) | | Deviation (%) |
|---|---|---|---|
| | Protected by MOV | protected by TSG | |
| 8/20µs 10kA | 1153 | 1334 | 13.57 |

From the simulation results in Table 1. Recognizing that, the residual voltage value across the load when using MOV is 1153V, lower than 13.57% compare to using TSG is 1334V. Therefore, overvoltage protection by MOV is more effective than TSG.

*3.2. Lightning current waveform*

To evaluate the effect of lightning current waveform to effective protection of SPDs are manufactured according to technology in MOV and TSG with the parameters as above. Conducting simulation with changing lightning current waveform corresponding to 8/20µs and 10/350µs. The different residual voltage curve across the load in the case of lightning current waveform 8/20µs and 10/350µs are shown in Figure 4 and Figure 5, the peak voltages across the load are presented in Table 2.

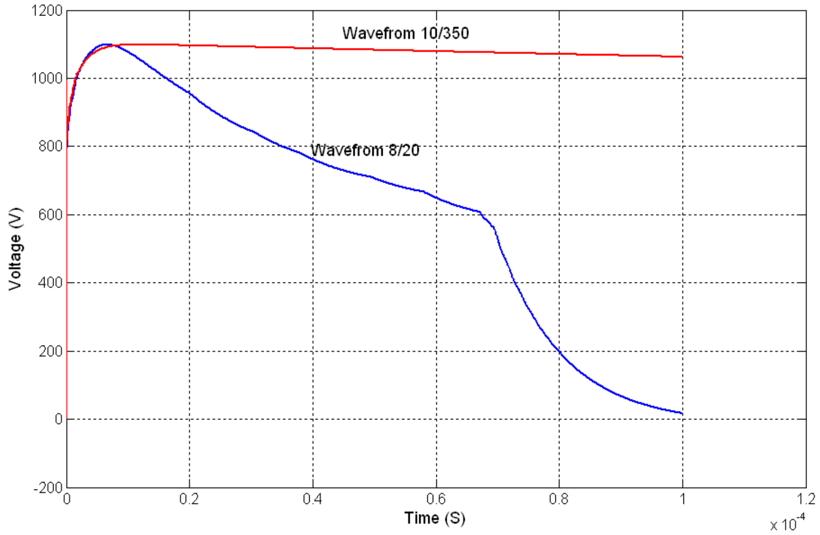


Figure 4. Residual voltage across the load with lightning current waveform 8/20µs and 10/350µs, SPD type MOV.

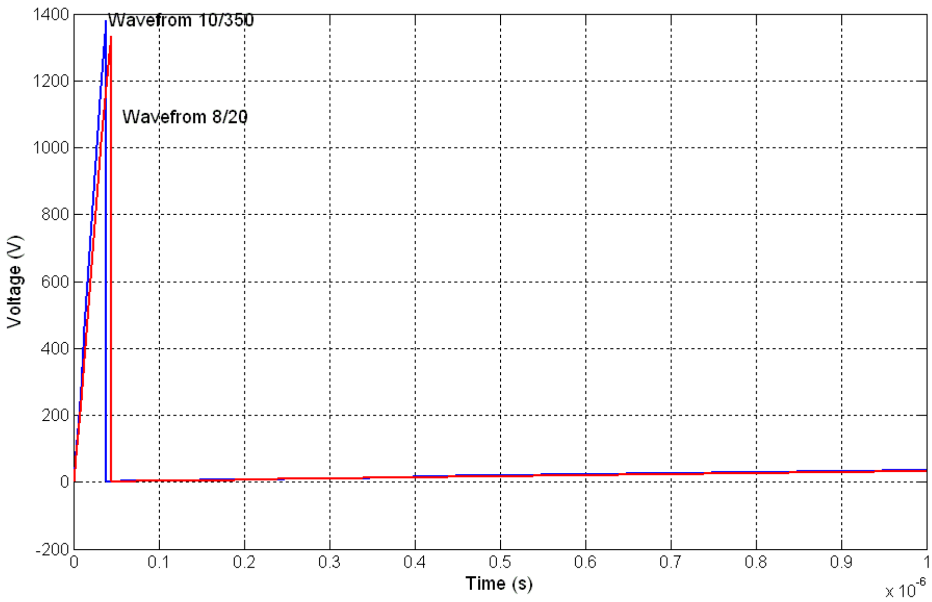


Figure 5. Residual voltage across the load with lightning current waveform 8/20µs and 10/350µs, SPD type TSG.

Table 2. The value of residual voltage across the load with lightning current waveform 8/20µs and 10/350µs

| Standard lightning current | Residual voltage across the load (V) | |
|---|---|---|
| | SPD type MOV | SPD type TSG |
| 8/20µs, 10kA | 1153 | 1334 |
| 10/350µs, 10kA | 1153 | 1379 |

From the simulation results in Table 2. Recognizing that, when SPD is manufactured by MOV technology, the peak value of the residual voltage across the load with lightning current wavefrom 8/20µs and 10/350µs is 1153V, in the case SPD is manufactured by TSG technology, the peak value of the residual voltage across the load is 1379V with lightning current wavefrom 10/350µs greater than the peak value of the residual voltage across the load with lightning current wavefrom 8/20µs is 1334V.

However, with both technologies of SPD the lightning current wavefrom 8/20µs has the value of the residual voltage across the load faster decline than the lightning current wavefrom 10/350µs so little more dangerous for load.

*3.3. Lightning current amplitude*

To evaluate the effect of the lightning current amplitude ($I_s$) changing to effective protection of SPD is manufactured by MOV technology with $V_{ref}$=275V and $I_n$=40kA. Conducting simulation with the values of lightning current amplitude vary according to $I_s$= 3; 5; 10; 20 kA, lightning current waveform 8/20µs. The different residual voltage curve across the load in the case of different lightning current amplitudes are shown in Figure 6, the peak voltages across the load are presented in Table 2.

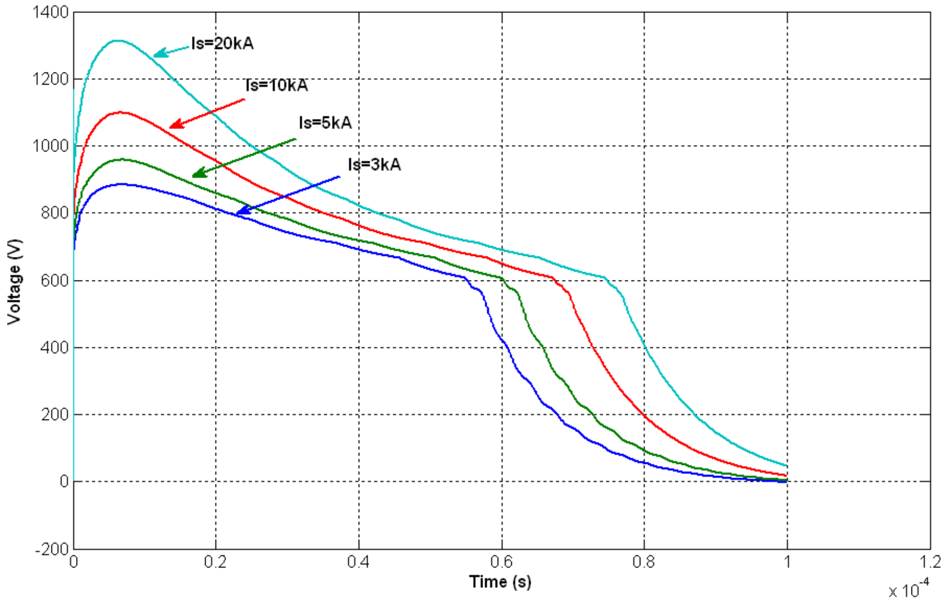


Figure 6. Residual voltage across the load with different lightning current amplitudes.

Table 3. The value of the peak residual voltage across the load with with different lightning current amplitudes.

| No. | MOV Rated voltage (V) | MOV rated current (kA) | Lightning current amplitude 8/20µs (kA) | Residual voltage across the load (V) |
|---|---|---|---|---|
| 1 | 275 | 40 | 3 | 884 |
| 2 | | | 5 | 958 |
| 3 | | | 10 | 1153 |
| 4 | | | 20 | 1312 |

From the simulation results in Table 3. Recognizing that, with the same MOV configuration, the higher the lightning current amplitude, the greater residual voltage across the load is. So the more dangerous for the protected apparatus.

*3.4. The rated current of MOV*

To evaluate the rated current of MOV ($I_n$) with $V_{ref}$=275V to effective protection. Conducting simulation with the values of the rated current of MOV vary according to $I_n$=4,5; 8; 25; 40; 70; 100 kA and unchanging lightning current waveform with $I_s$=10kA, 8/20µs.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

The different residual voltage curve across the load in the cases of different rated current of MOV are shown in Figure 7, the peak residual voltages across the load are presented in Table 4.

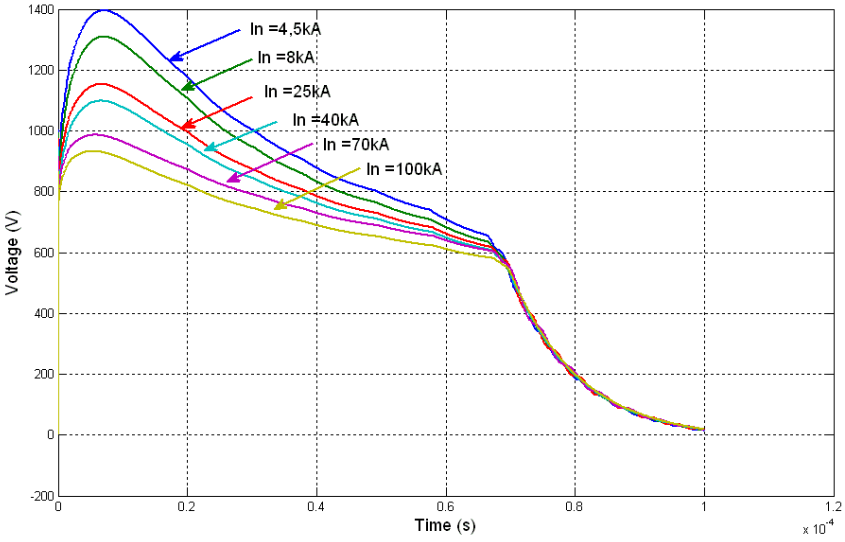


Figure 7. Residual voltage across the load with different rated current of MOV.

Table 4. The value of the peak residual voltage across the load with different rated current of MOV.

| No. | MOV Rated voltage (V) | MOV rated current (kA) | Lightning current amplitude 8/20µs (kA) | Residual voltage across the load (V) |
|---|---|---|---|---|
| 1 | 275 | 4,5 | 3 | 1395 |
| 2 | | 8 | | 1309 |
| 3 | | 25 | | 1153 |
| 4 | | 40 | | 1098 |
| 5 | | 70 | | 986 |
| 6 | | 100 | | 932 |

With residual voltage values across the load as shown in Table 4. Recognizing that, with the higher rated current of MOV, the lower residual values across the load is and this leads to higher effective protection.

*3.5. The threshold voltage of the MOV*

To evaluate the effect of the threshold voltage ($V_{ref}$) of MOV to effective protection. With $I_n$ = 40kA, changes the threshold voltage vary $V_{ref}$ = 275; 320$V_{rms}$ with lightning current amplitude $I_s$=10kA, waveform 8/20µs. Conducting simulation on MOV obtained residual voltage curves across the load shown in Figure 8.

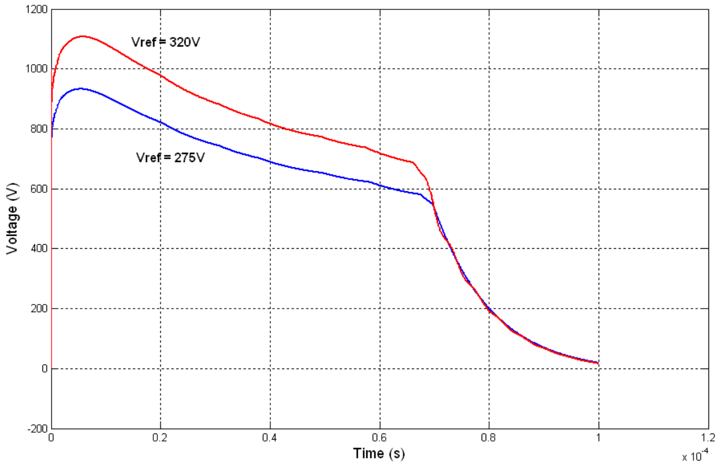


Figure 8. Residual voltage across the load with MOV has $V_{ref}$=275Vrms and $V_{ref}$=320Vrms.

Table 5. Residual voltage across the load with the threshold voltage values of MOV

| No. | Threshold voltage of MOV (V) | MOV rated current (kA) | Lightning current amplitude 8/20µs (kA) | Residual voltage across the load (V) |
|---|---|---|---|---|
| 1 | 275 | 40 | 10 | 932 |
| 2 | 320 | | | 1107 |

From the simulation results in Table 5. Recognizing that, with unchanging lightning current amplitude 10kA waveform 8/20µs. The peak value of the residual voltage across the load depend on the threshold voltage of the MOV. If the higher threshold voltage across the load, the more dangerous for apparatus to be protected.

*3.6. The coordinated protection of SPDs*

To evaluate the effect of the coordinated protection of SPDs in the cases of protected by two steps of MOV; protected by one step of MOV and one step of TSG. Conducting simulation on load has a power as in Section 2, current impulse source $I_s$ = 10kA, waveform 8/20µs. Protection device $MOV_1$ has $V_{ref}$ = 275V, $I_n$ = 25kA and TSG has voltage discharge is 1200V, response time is 20ns and they are installed in MSB at the entry point of the structure. Protection device $MOV_2$ has $V_{ref}$ = 275V, $I_n$ = 25kA and installed in essential main switch board (EMSB). The line $Z_1$ connects from the MSB to the EMSB and the line $Z_2$ connects from EMSB to the apparatus have a length of 10m, cross section is 4mm$^2$ with $r_0$=4,61Ω/km and $x_0$=0,08Ω/km. Simulation circuits shown in Figure 8 and Figure 9.

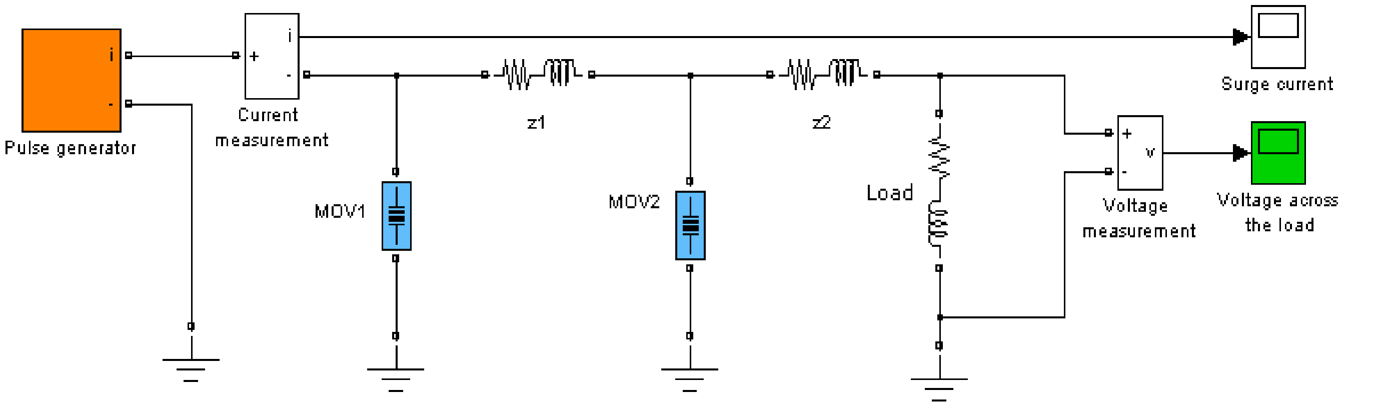


Figure 9. Model of the coordinated protection by two steps of MOV.

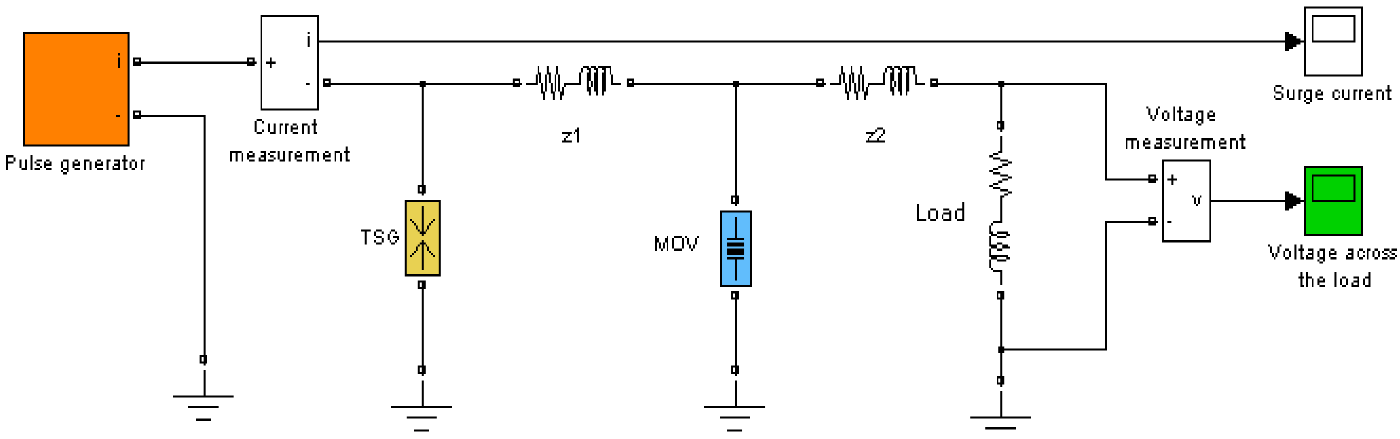


Figure 10. Model of the coordinated protection by one step of MOV and one step of TSG.

Conducting simulation with unchanging standard lightning current $I_s$=10kA, waveform 8/20µs. The different residual voltage curves across the load are shown in Figure 11.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

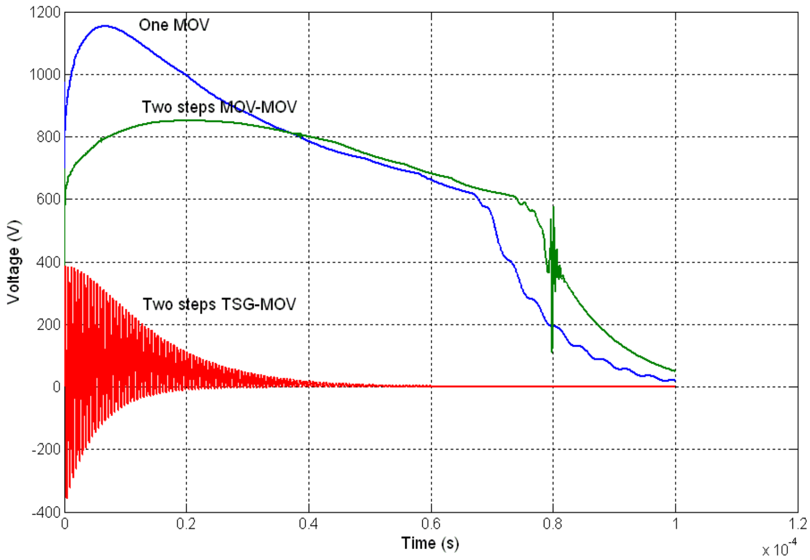


Figure 11. The residual voltage across the load in the protective cases.

Table 6. Comparison of residual voltages across the load corresponding to the protective cases.

| Standard lightning current wavefrom | Residual voltage across the load (V) | | |
|---|---|---|---|
| | Protected by one step MOV | Protected by two steps MOV-MOV | Protected by two steps TSG - MOV |
| 10kA, 8/20µs | 1153 | 850 | 385 |

From the simulation results in Table 6. Recognizing that, the residual voltage value across the load in the case of coordinated protection by two steps TSG-MOV is 385V, lower than 45.29% compare to the case of protection by two steps MOV- MOV is 850V. Therefore, the case of coordinated protection by two steps TSG-MOV will protect more effective than the case of protection by two steps MOV-MOV and the case of protection by one step of MOV. The selection of coordinated protection by two steps TSG-MOV would be appropriate for the electronics and telecommunications equipment, computer systems, PLC. The case of coordinated protection by two steps MOV-MOV will be considered for the electromechanical systems, refrigeration systems, lighting systems.

## 4. CONCLUSION

- The factors as: SPD manufacturing technology, the lightning current waveform, the lightning current amplitude, the rated current of MOV, the threshold voltage of MOV, the coordinated protection of SPDs all influence to effective protection against surge on LV power line. In particular, important factors include: SPD manufacturing technology, the rated current of MOV, the threshold voltage of MOV must be selected to suit the configuration and properties of the protected loads to ensure the highest effective protection under design requirements.

- Depending on the characteristics of the object to be protected, need to select the type of reasonable protection coordination. When the need to protect the electromechanical systems, refrigeration systems, lighting equipment can coordinate protected by many steps of MOV to increase the effective protection for the critical load; the need to protect sensitive electronic equipment such as: telecommunications equipment, computer systems, PLC systems can be combined with multi steps protection of TSG and MOV to achieve the highest effective protection.

- With the structures in suburban areas with the risk of direct lightning strike into incoming line with large lightning current amplitude should install SPD manufactured by TSG technology at the entry point of the structure. For structures in urban areas with tolerance induced voltage by indirect lightning strike installing SPD manufactured by MOV technology at entrance point of the structure is reasonable.

## ACKNOWLEDGMENTS

This research was supported by Ho Chi Minh City University of Technology and Education under a research at the Electrical Power System and Renewable Lab.

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