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Selection Guide for Low Voltage Surge Protector

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***Abstract*—Proper sizing the low voltage surge protective device (SPD), fabricated by metal oxide varistor (MOV) technology, will guarantee protection efficiency, so this paper focused on researching and developing in-deep study of some main points as follows: The coefficient of conversion between the surge rated current of 8/20µs waveform and of 10/350µs waveform, based on the equivalent of energy absorption; the ageing characteristic of MOV for 8/20µs waveform (instead of 2ms square waveform); determining the surge rated current of low voltage SPD, fabricated by multi block MOV technology, based on the attenuation coefficient of surge dissipation ability between metal oxide varistors, connected in parallel with different tolerance of threshold voltage.**

Keywords—*Metal oxide varistor; the coefficient of conversion; the ageing characteristic; 8/20µs waveform;10/350µs waveform; multi-block MOV technology.*

I. INTRODUCTION

Vietnam is located in the center of East Asia, one of the three centers in the world with strong thunderstorms with about 120 days of thunderstorm per year. Therefore, the overvoltage protection for low voltage electrical and electronic devices by SPD is always concerned.

There are many researches on SPD, fabricated by MOV technology before. However, some problems, related to properly size this type of low-voltage SPD, have not been fully studied, such as: the conversion between the lightning current amplitude surge rated current of 8/20µs waveform and 10/350µs waveform, the building of aged characteristic of MOV for 8/20µs waveform and the determine attenuation coefficient when manufacturing the low-voltage SPD by multi-layer MOV technology.

II. THE AMPLITUDE CONVERSION OF LIGHTNING SURGE CURRENT FROM 8/20µS WAVEFORM TO 10/350µS WAVEFORM

A. The Problem

Currently, due to the promotion of their products, the low-voltage SPD manufacturers usually provide products with 8/20µs waveform. It is difficult for user when the low-voltage SPD is installed in direct lightning strike areas on the power line. This means that it will withstand 10/350µs waveform (Cat D, E in Fig. 1) [1]. Therefore, it is necessary to find the amplitude conversion of lightning surge from 8/20µs waveform to 10/350µs waveform.

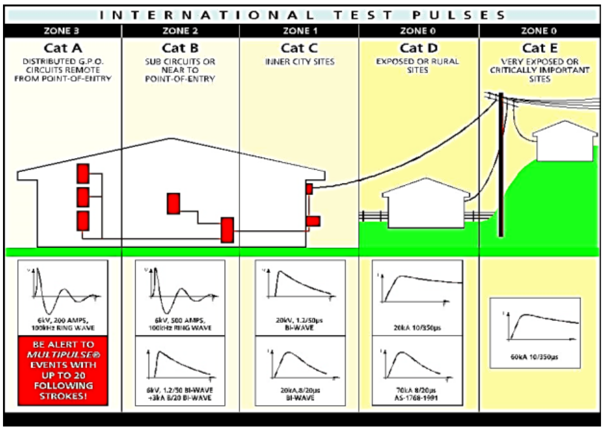

Fig. 1. Standard lightning impulses corresponding to the different installation locations of SPD.

B. The Conversion Method

The conversion of the surge current of 8/20µs waveform into 10/350µs waveform of the low-voltage SPD is carried out by the principle of equation absorptive energy of MOV [3, 4]:

$$W = \int_{t0}^{t1} v(t)i(t)dt \qquad (1)$$

Where: *v(t)* is the voltage across MOV, *i(t)* is the current going through the MOV.

To simplify integration, the conversion method is carried out by modeling and simulation by Matlab software. Then, record the results by making simulation results table for MOVs and find the conversion factor equivalent surge rated current of 8/20µs waveform into 10/350µs waveform.

C. Calculation Model

To simplify integration, the conversion method is carried out by modeling and simulation techniques with the functional block diagram shown in Fig .2.

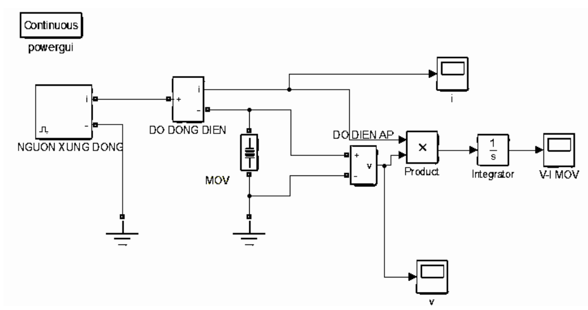

Fig. 2. Calculation model the absorption energy of MOV with 8/20µs waveform and 10/350µs waveform surge rated current.

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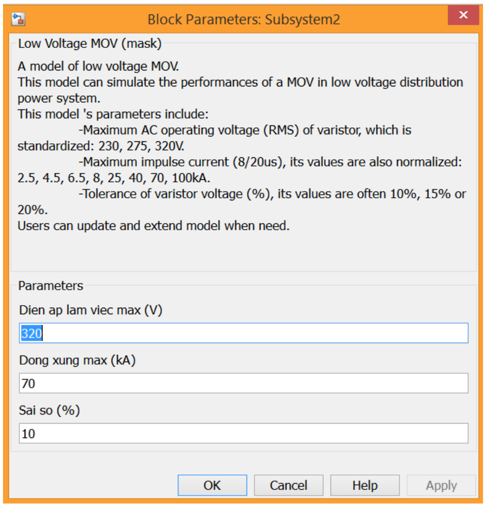
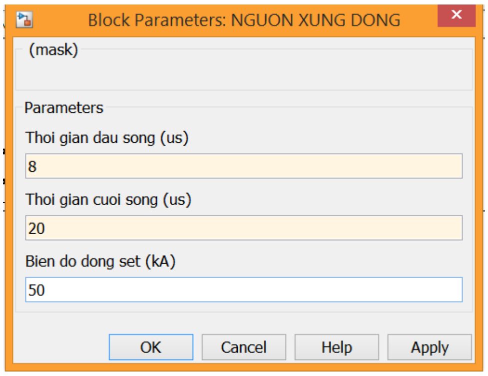
D. Make conversion for MOV S20K275

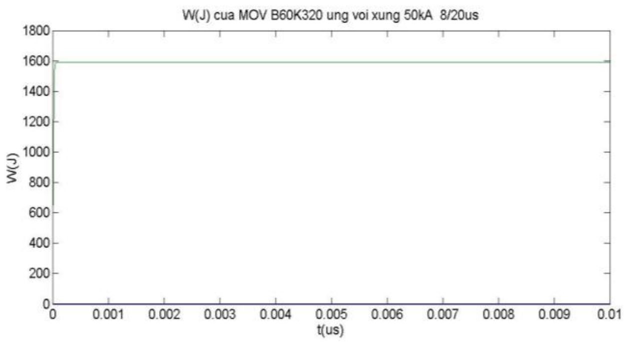
Step 1: Select MOV B60K320 of Siemens with I_{max} (8/20µs) is 70kA [5].



Step 2: Set the amplitude value of the standard surge current I_1 = 50kA, 8/20µs.

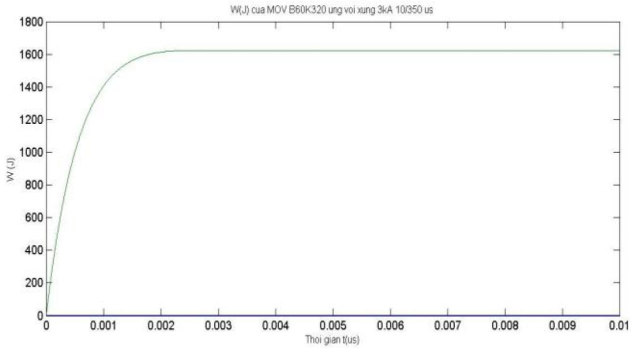


Step 3: The absorption energy of the MOV B60K320 displayed on scope V-I MOV is 1600J.



Step 4: I_2 = 3kA, 10/350µs, corresponding to the absorption energy of MOV is 1600J.

E. Result Table and Analysis



Do the same with other MOVs of Siemens, the simulation results are shown in Table I. Analyze this result, we find that to convert surges rated current of 8/20µs waveform into 10/350µs waveform, it is necessary to divide the value of surges current amplitude for the coefficient 16.6 ≈17, and the error of absorption energy is from 0% to 15%.

TABLE I. SIMULATION RESULTS OF ENERGY ABSORPTION OF LOW-VOLTAGE MOVS

Types of MOV	8/20µs waveform			10/350µs waveform		Error of energy absorption (%)	Coefficient of surge current (I_2/I_1)
	I_{max} (kA)	I_1 (kA)	Energy absorption (J)	I_2 (kA)	Energy absorption (J)		
S20k230	8	8	180	0,5	152	15	16
S20K275	8	8	150	0,5	140	6	16
S20K320	8	8	210	0,5	178	15	16
B32K230	25	10	178	0,6	172	3	16,6
B60K230	70	50	1130	3	1150	2	16,6
B32K275	25	10	213	0,6	198	7	16,6
B60K275	70	50	1330	3	1345	1	16,6
B32K320	25	10	260	0,6	225	13	16,6
B60K320	70	50	1600	3	1600	0	16,6

III. THE AGEING OF LOW-VOLTAGE SURGE PROTECTIVE DEVICE MOV

A. The Problem

The ageing of the low-voltage SPD depends on the surge current amplitude and the number of times the lightning impulse going through. Currently, manufacturers usually provide the number of times of repeated lightning dissipation that SPD can withstand in the form of 2ms square impulse. However, the parameters of given impulse current are usually corresponding to 8/20µs waveform. Therefore, it is need to build-up the lifespan characteristic of low-voltage SPD according to the amplitude and the number of times of repeated the 8/20µs waveform.

B. Determining Method [5, 6, 7]

The maximum allowable current impulse of MOV depends on the time of the lightning impulse going through and the number of repeated times has been defined. These parameters can be read from the attenuation characteristic of low-voltage surge protective devices MOV, provided by the manufacturer. To identify the number of repeated times corresponding to the intensity of actual surge current (for all waveform), it is necessary to convert the actual waveform into equivalent square impulse. This method is called "rectangular method". If $\int i^* dt$ is known, t_r^* is calculated according to the formula:

$$t_r^* = \frac{\int i^* dt}{\hat{i}^*} \qquad (2)$$

Where: t_r^* is the pulse width on the characteristic line; $\int i^* dt$ is the current integral depending on t and $\hat{i}^*$ is the maximum current amplitude.

C. Determine the Allowable Repeated Times of Low Voltage SPD Device Siemens B40K275

Step 1: Build the simulation circuit for MOV B40K275 [5] and carry out simulation on Matlab (Fig. 3).

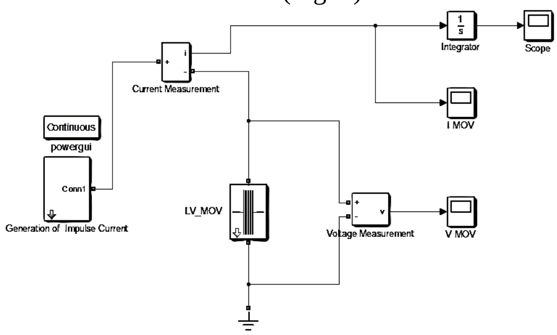


Fig. 3. Simulation circuit for determine the allowable repeated times of low-voltage SPD device Siemens B40K275.

From the simulation result in Fig. 4, we can determine the maximum current amplitude values $\hat{i}^*$ =20kA and from the simulated result in Fig. 5 we can calculate $\int i^* dt$ =414mAs.

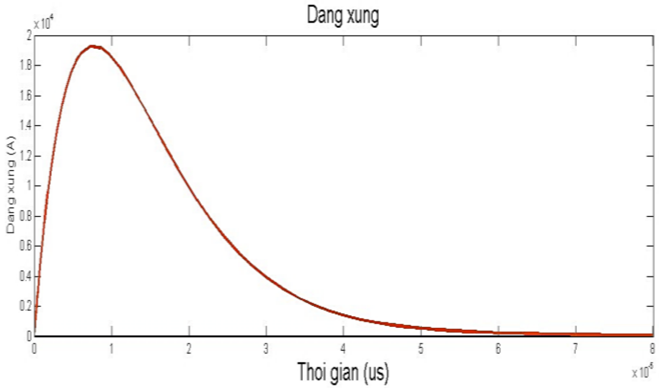


Fig. 4. Current waveform of MOV B40K275.

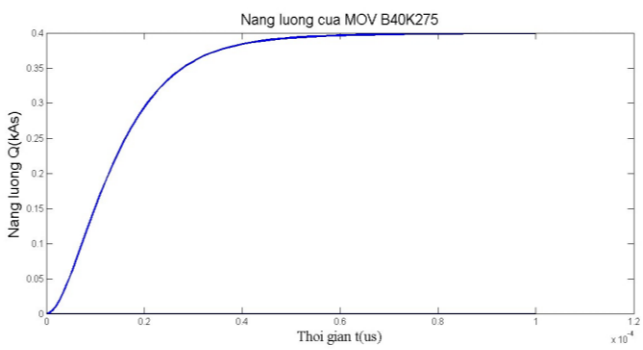


Fig. 5. $\int i^* dt$ of MOV B40K275.

Step 2: Calculate the pulse width:

$$t_r^* = \frac{\int i^* dt}{\hat{i}^*} = \frac{414}{20} \approx 21\mu s$$

Step 3: From Fig. 6, with $t_r^* = 21\mu s$ and $\hat{i}^*$ =20kA, we can find out the number of impulse repeated times that MOV B40K275 can withstand is n = 1.

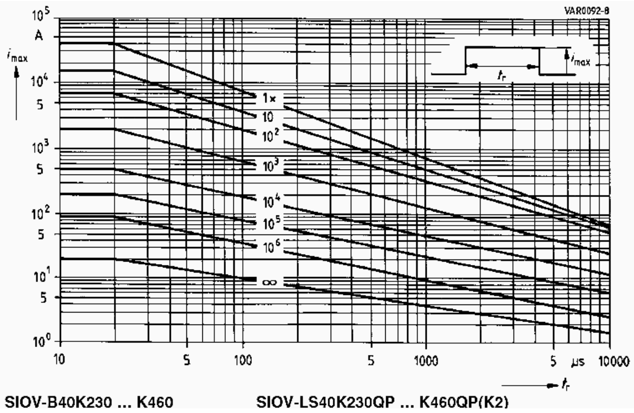


Fig. 6. The number of impulse repeated times of MOV B40K275.

Do the same for current impulses 5kA, 40kA, the results are shown in Table II.

TABLE II. RESULTS OF REPEATED TIMES OF CURRENT IMPULSE THAT MOV CAN WITHSTAND.

Current impulses (kA)	$\hat{i}^*$ (kA)	$\int i^* dt$ (mAs)	t_r^* (μs)	The number of times of repeated current impulse n (times)
5	4.842	104.5	21	100
20	20	414	21	10
40	40.35	845	21	1

Thus, with the method of determining allowable repeated times of lightning impulse as above, users can define the potential of repeated lightning dissipation (the repeated times of lightning impulse) corresponding to the 8/20µs standard impulse, but with not the 2ms square impulse.

D. The Summary Table for the Number of Impulse Repeated Times of SIEMENS Low Voltage SPD

From the result of pulse width is $t_r^* = 21\mu s$ and Fig. 6, we build a summary table for the number of impulse repeated times that MOV B40K275 can withstand (Table III).

TABLE III. RESULTS OF IMPULSE REPEATED TIMES CORRESPONDING TO THE IMPULSE CURRENT THAT MOV CAN WITHSTAND.

I(A)	20	90	200	500	2000	7000	20000	40000
n (times)	∞	10^6	10^5	10^4	1000	100	10	1

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From the results in Table III, we build the ageing characteristic of MOV B40K275 according to the amplitude and the number of repeated times of the 8/20µs waveform (Fig. 7).

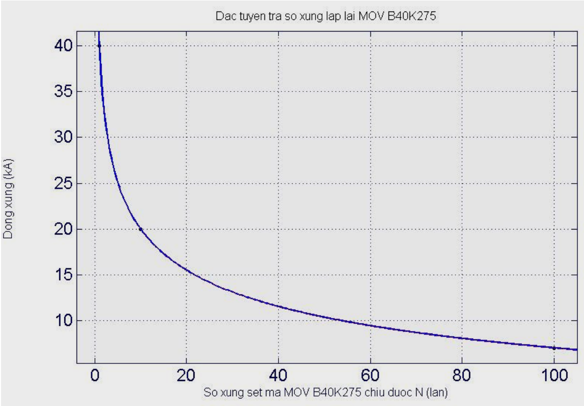

Fig. 7. Characteristic line for checking the number of impulse repeated times of MOV.

Similarly, we can build the summary table as Table IV and the ageing characteristic (Fig. 8) of MOV B32K230.

TABLE IV. RESULTS OF THE NUMBER OF IMPULSE REPEATED TIMES CORRESPONDING TO THE IMPULSE CURRENT THAT MOV CAN WITHSTAND.

I(A)	20	70	200	400	2000	5000	20000	25000
n (times)	∞	10^6	10^5	10^4	1000	100	10	1

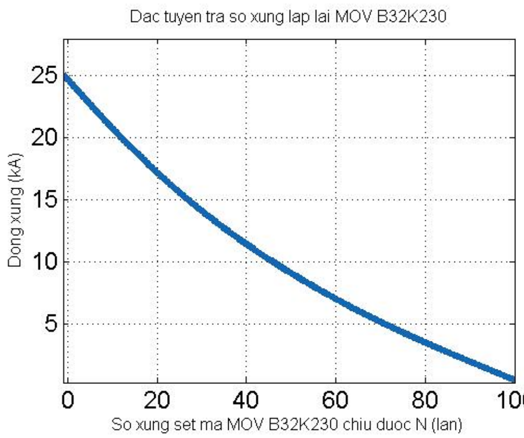

Fig. 8. Characteristic line for checking the number of impulse repeated times of MOV B40K23.

IV. DETERMINE THE RATE LIGHTNING CURRENT IMPULSE OF SPD MULTI-LAYER VARISTOR MLV

A. The Problem

When manufacturing the low-voltage SPD by MLV technology, connection parallel MLV is necessary in order to increase the rated current impulse. In this case, the rated current impulse of SPD by MLV is not equal to the sum of the rated surge current of the MOVs due to the uneven current distribution in these of MOVs. Therefore, it is necessary to determine the attenuation coefficient of the surge rated current [2].

B. Multi-block MOV Test Model

Determine attenuation coefficients is carried out by simulation on Matlab with parallel low-voltage MOVs. This single MOV has a maximum surge rated current of 8kA 8/20µs and tolerance of threshold voltage is ± 10% (Fig. 9).

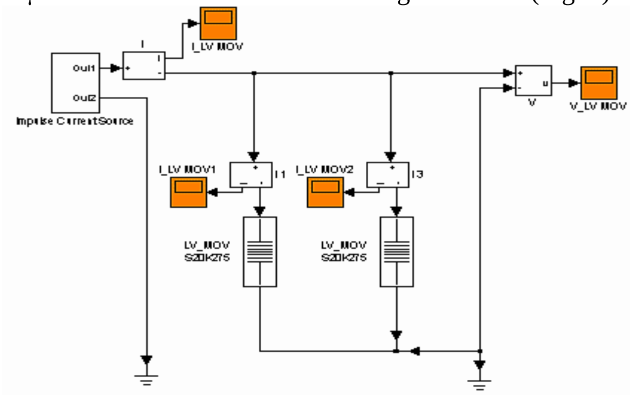

Fig. 9. Simulation of the current impulse going through elements of MOV 8kA and residual voltage respectively.

Simulate the current impulse 8/20µs waveform going through elements of paralleled MOV with amplitudes includes: 10kA, 15kA, 20kA, 25kA, 40kA, 70kA and 100kA. The simulation results are shown in Fig. 10 and Fig. 11. The attenuation coefficient is presented in Table V.

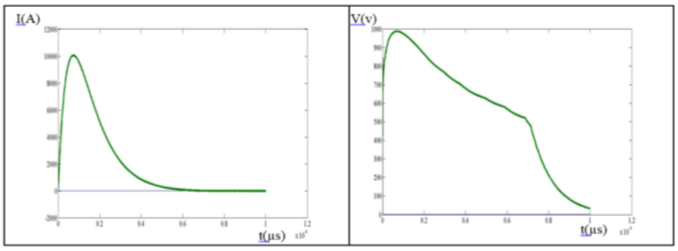

Fig. 10. Current and voltage of SPD model using two MOVs, 8kA (TOL = 10% and -10%), 10kA 8/20µs.

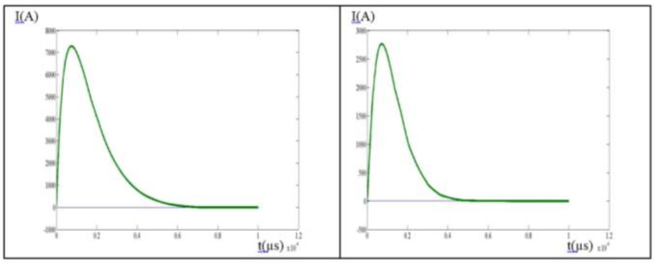

Fig. 11. Current going through MOV1 and MOV2, 8kA (TOL = 10% and -10%), 10kA 8/20µs.

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TABLE V. SUMMARY TABLE THE LOW-VOLTAGE SPD CONSISTS MULTIPLE MOV, 8KA CONNECTS IN PARALLEL.

Amplitude of test impulse (kA)	Types of MOV	Voltage tolerance of MOV (%)	Number of MOV	Current impulse going through MOVs (kA)	Residual voltage of MOV (V)	Attenuation coefficient
10	2×MOV-8kA	+10	1×MOV-8kA	2.8	988	1.6
		-10	1×MOV-8kA	7.2		
5	4×MOV-8kA	+10	3×MOV-8kA	3×2.63	982	2.13
		-10	1×MOV-8kA	7.1		
20	5×MOV-8kA	+10	4×MOV-8kA	4×3.05	1005	2.0
		-10	1×MOV-8kA	7.8		
25	7×MOV-8kA	+10	6×MOV-8kA	6×2.9	1010	2.24
		-10	1×MOV-8kA	7.6		
40	12×MOV-8kA	+10	11×MOV-8kA	11×2.93	1025	2.4
		-10	1×MOV-8kA	7.7		
70	23×MOV-8kA	+10	22×MOV-8kA	22×2.83	1085	2.62
		-10	1×MOV-8kA	7.7		
100	32×MOV-8kA	+10	31×MOV-8kA	31×2.99	1185	2.56

V. CONCLUSION

Proper sizing the low voltage surge protective device (SPD), fabricated by metal oxide varistor (MOV) technology, will guarantee protection efficiency, so this paper focused on researching and developing in-deep study of some main points as follows: The coefficient of conversion between the surge rated current of 8/20µs waveform and of 10/350µs waveform, based on the equivalent of energy absorption; the ageing characteristic of MOV for 8/20µs waveform (instead of 2ms square waveform); determining the surge rated current of low voltage SPD, fabricated by multi block MOV technology, based on the attenuation coefficient of surge dissipation ability between metal oxide varistors, connected in parallel with different tolerance of threshold voltage.

VI. ACKNOWLEDGEMENTS

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