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Voltage-Current Characteristics Of Metal Oxide Varistors For Low Voltage Telephone Lightning Protector Under The Application Of Multiple Lightning Impulse

MM Yaacob RA Ghani

Institute Of High Voltage & High Current (IVAT)
Faculty Of Electrical Engineering
Universiti Teknologi Malaysia
Locked Bag 791, 80990 Johor Bahru
Malaysia

Abstract

Surges resulting from lightning strikes could propagate not only into the power line but also into the low voltage line such as the telecommunication system and could cause damage to the equipment. In order to protect this highly sensitive equipment, a telephone lightning protector (MOV) has to be installed to the telephone set. Since the natural characteristics of lightning are a multiple stroke/flash, the response of the protector under this condition has to be investigated. This paper presents the experimental studies on the voltage and current characteristic of the MOV under the application of multiple lightning impulse voltage and current.

1.0 Introduction

Lightning is a natural phenomenon, which generates simple unidirectional double-exponential impulses, which has a significant effect on power transmission system and equipment. The overvoltage or overcurrent resulting from a lightning incident will propagates not only into the power line but also into the low voltage line such as the telecommunication system. These surges of exceptional severity could cause damage to the highly sensitive equipment and also danger to the telephone user. In order to protect this equipment and the users, a proper protective measures has to be taken by installing telephone lightning protector such as the MOV into the system.

Field studies and experimental surveys on lightning parameters have shown that the natural characteristics of lightning is different from the standard testing procedures which caters only a single impulse with a specific impulse waveshape [1]. It has been shown [2] that between 60% to 70% of ground flashes consist of more than one stroke with an average of 3 or 4 strokes/flash. A multiple stroke ground flash is a sequence of multiple pulses separated by time interval of tens of milliseconds.

Before equipment is installed into a new system, it is usually type tested to existing standard on lightning impulse. These tests are meant to predict the adequate performance of the equipment against breakdown due to lightning surges. Test procedures on lightning impulse testing in the presently adopted standards require effectively only single stroke tests. This is clearly different from the natural characteristics of lightning. Since the parameters of a lightning flash such as the inter-stroke time, peak magnitude and waveshape are different from flash to flash, it is likely that the MOV responds differently due to variation in these parameters. Since these MOV's are exposed to the lightning surges, it is important to study their response under the application of multiple lightning impulse.

This paper describes the experimental studies on the voltage and current characteristics of the MOV by applying multiple lightning impulse voltage and current. A comparison on the response of the MOV is made between the standard testing procedures and multiple impulse testing. The design and development of the multipulse voltage and current generator, which employs an electronic triggering system, is also presented. From the results, it is found that the multiple lightning impulse has a significant effect on the MOV by causing damage to device.

2.0 Multiple Impulse Generator Design And Construction

Generating high voltage for laboratory experiments has always been a challenging task, from both a technical and economic point of view. An impulse generator essentially consists of capacitors, which is charged to a required voltage and discharged through a waveshaping circuit. For an impulse current generator, the capacitors are discharged through a series R-L circuit into the test object. A basic equivalent circuit of an impulse generator is shown in Figure 1.

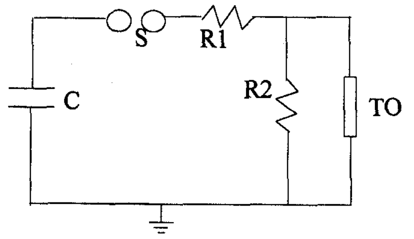

Figure 1

In order to generate the multiple lightning impulse a multiple impulse generator has been designed and constructed. The schematic circuit of the generator is shown in Figure 2.

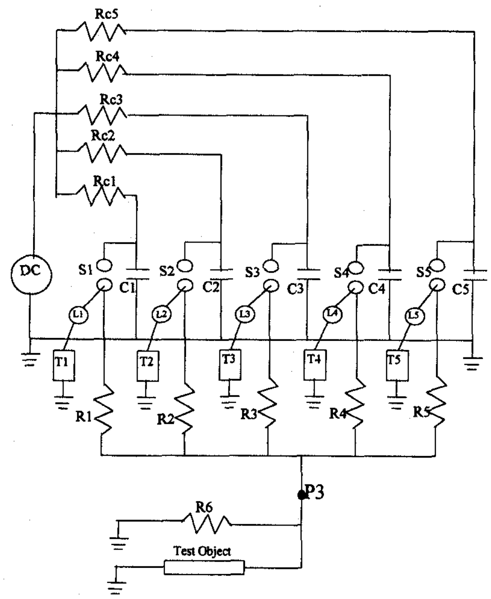

Figure 2

The principle of operation of the generator can be described as follows;

The charging capacitors C_1 to C_5 are charged to a specific value from a high voltage dc supply through charging resistors Rc_1 to Rc_5. When a trigger pulse is applied to the spark gap, breakdown will occur, applying the charged voltage and the specific wareshape across the test sample. The variations in the output waveforms can be achieved by changing the values of the waveshaping circuit R_1 to R_6.

The triggering of the gap together with the time delay required between each pulse is controlled by an electronic delay circuit, which is shown in Figure 3.

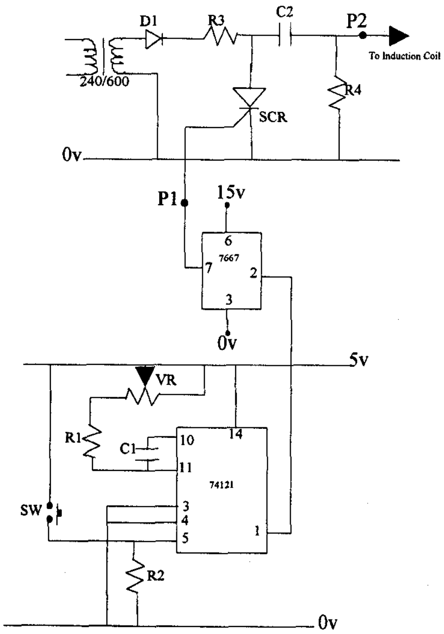

Figure 3

The triggering unit consists of an electronic delay circuit, dual MOSFET chips and HVSCR circuit. The operation of the circuit is initiated by the firing of the thyristor. The capacitor C_2 will then discharges through the induction coil generating a pulse at the gap. In order to delay triggering of the gap in subsequent stages, a delay circuit has been designed consists of IC 74121. The output from each delay circuit will trigger the triggering circuit according to the specified time thus giving the required time delay. The time delay can be achieved by varying the variable resistor in the delay circuit.

3.0 Experimental Procedure

Five different types of MOV's are used in the impulse testing where each group consists of 5 units of varistors. The characteristics of the MOV's are stated in Table 1. Each varistors is subjected to single and multiple impulse voltage of 2 kV, 1.2/50 us and current of 1.5 kA, 8/20 us waveshapes. The resultant voltage and current are measured by using a Yokogawa DL 1540 Digital Storage Oscilloscope. A typical waveshape of the single and multiple voltage is shown in Figure 4.

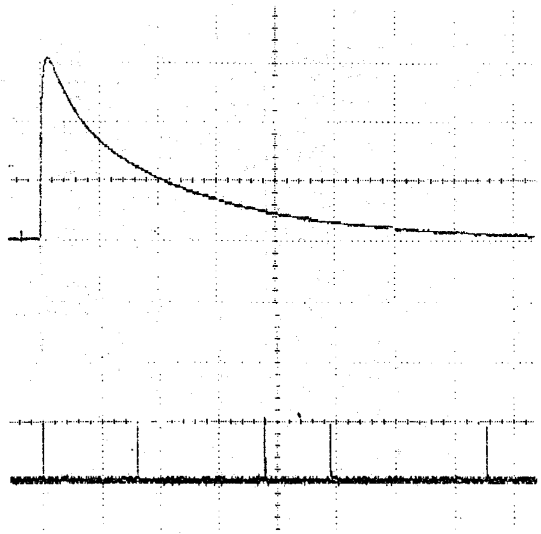

Figure 4

The characteristic of each varistor is first determined by measuring the V-I curve or the reference voltage when 1 mA DC current is flowing through the sample. The sequence of the testing is as follows;

1. Application of single positive voltage impulse to each sample
2. Application of multiple positive voltage impulses to each sample
3. Procedure (1) and (2) are repeated with negative voltage impulse
4. Procedure (1) and (2) are repeated with positive current impulse
5. Procedure (1) and (2) are with negative current impulse

After the application of the impulses on each varistors, the diagnostic tests are conducted to determine the V-I characteristics of the varistors.

4.0 Results

The results of the single and multiple voltage and current impulse testings on the MOV are tabulated in Table 2 to 5. From the analysis, it was found that material degradation has occurred on the MOV. This is shown by comparing the electrical characteristics of each sample tested ie. the V-I curve before and after tests being conducted. Varistors, which are subjected to multiple impulse current, result in higher damage than the single impulse. For example, sample B2, C2, D2, C5 and D5 (refer to Table 4) showed indication of burning on the material when multiple impulse current is applied.

5.0 Conclusion

Single and multiple lightning impulse voltage and current tests have been conducted to sample of MOV's used as telephone lightning protector. It has been found that the effect of the material on multiple impulse is move severe that the single impulse. In some cases the MOV's are found to be burnt out when subjected to multiple lightning impulse current. Further work is in progress to investigate the response of other low voltage equipment that is exposed to lightning surges.

6.0 References

1. A Carrus and LE Funes, "Very Short Tailed Lightning Double Exponential Wave Generation Techniques Based on Marx Circuit Standard Configurations", IEE Trans. on PAS, Vol. PAS- 103, No. 4, April 1984.

2. Anderson RB and Erikson AJ,"Lightning Parameter for Engineering Application", Elektra, Vol. 69, 1980.

3. Darveniza M and Mercer DR,"Laboratory Studies of the Effect of Multiple Lightning Current on Distribution Surge Arresters", IEEE PES Summer Meeting, Seattle, July 1992, Paper 92 SM 355-8 PWRD.

4. MM Yaacob et al, "A Versatile Multiple Stroke Lightning Impulse Generator", UPEC'95, September 1995, London.

List of Tables

MOV Type	Diameter	Test Withstand	Maximum Operating	Voltage at 1 mA	Maximum Energy	Maximum Discharge (8/20µs)	Ambient Temperature (Celcius)
1505	12 mm	2.5kV	150V rms 200V dc	212 - 268V	25 J	2.5kA	55 to 85
100Z15	16 mm	2.5kV	60V rms 81V dc	90 - 110V	20 J	4.5kA	55 to 85
180Z10	16 mm	2.5kV	115V rms 153V dc	162 - 198V	35 J	4.5kA	55 to 85
275L20	15 mm	2.5kV	275V rms 369V dc	389 - 473V	75 J	4.5kA	55 to 85
275L40	20 mm	2.5kV	275V rms 369V dc	389 - 473V	140 J	6.5kA	55 to 85

Table 1 : MOV Characteristics

Diagnostic Test

The ratio of voltage after and before impulse tests are conducted. This is the reference voltage across the MOV when 1 mA current is flowing through it.

MOV types	Label	Rated		Ratio A/B Positive Voltage Impulses					Status
		kV	kA	1	2	3	4	5	
275L40	A1	2.5	6.5	0.979	1	1	1.003	1.003	o.k
	B1	2.5	6.5	1	1.003	1.003	1	1.003	o.k
	C1	2.5	6.5	1	1.006	1	1	1.005	o.k
	D1	2.5	6.5	1	1.005	1.002	1.002	1	o.k
275L20	A2	2.5	4.5	•	•	•	•	•	
	B2	2.5	4.5	1.046	1.002	1	0.997	1.002	o.k
	C2	2.5	4.5	1	1	1.002	1	1.002	o.k
	D2	2.5	4.5	1	1	1.002	1.002	1.002	o.k
	E2	2.5	4.5	•	•	•	•	•	
180Z10	A3	2.5	4.5	1.046	1.007	1.007	1	1.007	o.k
	B3	2.5	4.5	1	0.959	0.991	1.016	0.983	o.k
	C3	2.5	4.5	1	0.969	0.984	1.039	1.031	o.k
	D3	2.5	4.5	1	0..984	0.984	1.031	0.969	o.k
100Z15	A4	2.5	4.5	1.071	1.013	1.013	0.987	1.013	o.k
	B4	2.5	4.5	1	1	0.986	1.041	0.96	o.k
	C4	2.5	4.5	1	1	0.986	1.028	0.958	o.k
	D4	2.5	4.5	1	0.985	1	1.014	0.971	o.k
1505	A5	2.5	2.5	•	•	•	•	•	
	B5	2.5	2.5	1	1	1.005	1	1.005	o.k
	C5	2.5	2.5	1	1	0.981	1.024	0.981	o.k
	D5	2.5	2.5	1	1.017	0.96	1.023	0.977	o.k
	E5	2.5	2.5	•	•	•	•	•	

Table 2

Note :

1. Acceptable Ratio (between 0.9 and 1.1)
2. A = After Impulse Test
3. B = Before Impulse Test
4. • = Without test
5. ## = Unacceptable Ratio

MOV Types	Label	Rated		Ratio A/B Negative Voltage Impulses					Status
		kV	kA	1	2	3	4	5	
275L40	A1	2.5	6.5	0.96	1.01	1.01	1	1	o.k
	B1	2.5	6.5	1	1	0.99	1.01	1	o.k
	C1	2.5	6.5	1	1	0.99	1	1.01	o.k
	D1	2.5	6.5	1	1	0.99	0.99	0.99	o.k
275L20	A2	2.5	4.5	•	•	•	•	•	
	B2	2.5	4.5	0.98	1	1.01	1.01	1.01	o.k
	C2	2.5	4.5	1	1	0.99	1	1.01	o.k
	D2	2.5	4.5	1	1	0.99	1.01	1.01	o.k
	E2	2.5	4.5	•	•	•	•	•	
180Z10	A3	2.5	4.5	0.93	1.03	1	1	0.99	o.k
	B3	2.5	4.5	1	1	0.95	0.98	1.32	##
	C3	2.5	4.5	1	1.02	0.94	1.01	1.33	##
	D3	2.5	4.5	1	1	0.97	1.02	1.32	##
100Z15	A4	2.5	4.5	0.97	1.01	1.01	1	1.01	o.k
	B4	2.5	4.5	1	1.03	0.92	1.01	1.37	##
	C4	2.5	4.5	1	1.04	0.9	1.03	1.35	##
	D4	2.5	4.5	1	1.03	0.91	1	1.42	##
1505	A5	2.5	2.5	1.06	0.99	1	0.99	0.98	o.k
	B5	2.5	2.5	•	•	•	•	•	
	C5	2.5	2.5	1	1	1.29	0.78	1.29	##
	D5	2.5	2.5	1	1.02	0.98	1	1.27	##
	E5	2.5	2.5	•	•	•	•	•	

Table 3

MOV Types	Label	Rated		Ratio A/B Positive Current Impulses					Status
		kV	kA	1	2	3	4	5	
275L40	A1	2.5	6.5	1.02	1	1	1	0.99	o.k
	B1	2.5	6.5	1	1	1	1	1	o.k
	C1	2.5	6.5	1	1	1	1	1	o.k
	D1	2.5	6.5	1	1	1	1	1	o.k
275L20	A2	2.5	4.5	•	•	•	•	•	
	B2	2.5	4.5	0.98	1.01	1	1	burn	fail
	C2	2.5	4.5	1	1	0.99	1	burn	fail
	D2	2.5	4.5	1	1	1	0.99	burn	fail
	E2	2.5	4.5	•	•	•	•	•	
180Z10	A3	2.5	4.5	1.05	1	0.99	1	1	o.k
	B3	2.5	4.5	1.32	1.35	1.35	1.35	1.36	##
	C3	2.5	4.5	1.34	1.34	1.34	1.36	1.36	##
	D3	2.5	4.5	1.32	1.34	1.45	1.45	1.45	##
100Z15	A4	2.5	4.5	0.96	1	1.01	1.01	1	o.k
	B4	2.5	4.5	1.37	1.4	1.4	1.4	1.39	##
	C4	2.5	4.5	1.35	1.39	1.39	1.39	1.39	##
	D4	2.5	4.5	1.42	1.45	1.45	1.45	1.45	##
1505	A5	2.5	2.5	•	•	•	•	•	
	B5	2.5	2.5	0.99	1	burn			fail
	C5	2.5	2.5	1.29	1.31	1.29	0.78	burn	fail
	D5	2.5	2.5	1.27	1.31	1.31	1.3	burn	fail
	E5	2.5	2.5	•	•	•	•	•	

Table 4

MOV Types	Label	Rated		Ratio A/B Negative Current Impulses					Status
		kV	kA	1	2	3	4	5	
275L40	A1	2.5	6.5	0.996	1.003	1.006	1.003	1	o.k
	B1	2.5	6.5	1	1	1.006	1	1	o.k
	C1	2.5	6.5	1	1	1.003	1	1	o.k
	D1	2.5	6.5	1	1	1	1	1.009	o.k
275L20	A2	2.5	4.5	1.044	1.006	1	1	burn	fail
	B2	2.5	4.5	•	•	•	•	•	
	C2	2.5	4.5	•	•	•	•	•	
	D2	2.5	4.5	•	•	•	•	•	
	E2	2.5	4.5	1	1	1.006	1.029	burn	fail
180Z10	A3	2.5	4.5	0.971	1	0.993	1.007	1.007	o.k
	B3	2.5	4.5	1.32	1.36	1.36	1.36	1.36	##
	C3	2.5	4.5	1.36	1.36	1.36	1.36	1.36	##
	D3	2.5	4.5	1.36	1.36	1.36	1.36	1.36	##
100Z15	A4	2.5	4.5	0.948	1.027	1	0.987	1	o.k
	B4	2.5	4.5	1.41	1.41	1.41	1.4	1.39	##
	C4	2.5	4.5	1.39	1.39	1.39	1.39	1.39	##
	D4	2.5	4.5	1.45	1.45	1.45	1.45	1.35	##
1505	A5	2.5	2.5	0.988	burn				fail
	B5	2.5	2.5	•	•	•	•	•	
	C5	2.5	2.5	•	•	•	•	•	
	D5	2.5	2.5	•	•	•	•	•	
	E5	2.5	2.5	1	1	1	1	burn	fail

Table 5