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Capability of existing of ZnO lightning arresters with different dielectrics

Er. Rohit Khare[1], Er. Lipika Sharma[2], Er. Shweta Singhai[3]
[1,2,3]Assistant Professor, Department of Electrical and Electronics Engineering,
Takshshila Engineering College, Jabalpur, India

Abstract: The housing of zinc oxide lightning arresters are playing major role for discharging the lightning surges. Previously porcelain and silicon rubber housings were mainly used depending on the atmospheric conditions but in practice a lot of problems are faced with these housing. Hence this paper presenting the ZnO blocks performance characterizes with different dielectrics such as air, transformer oil and SF6. According to these performances the arrester is able to design the Gas insulated and Oil insulated arresters.

Keywords: ZnO Arrester blocks, Test cell, Non-linear co-efficient (β), Reference Voltage, Minimum Continuous Operating Voltage (MCOV) & Residual Voltage.

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1. Introduction

The gaps less ZnO lightning arrester blocks are having the non-linear characteristics. Under the surge conditions these arrester acts as a low resistance for discharging the high frequency surges to ground and acts as a high resistance for transmitting the power frequency voltages that are traveling along the transmission lines.
The V-I characteristics of ZnO arresters are shown in fig1. It is a non-linear resistor consisting of three Zones which are shown below,

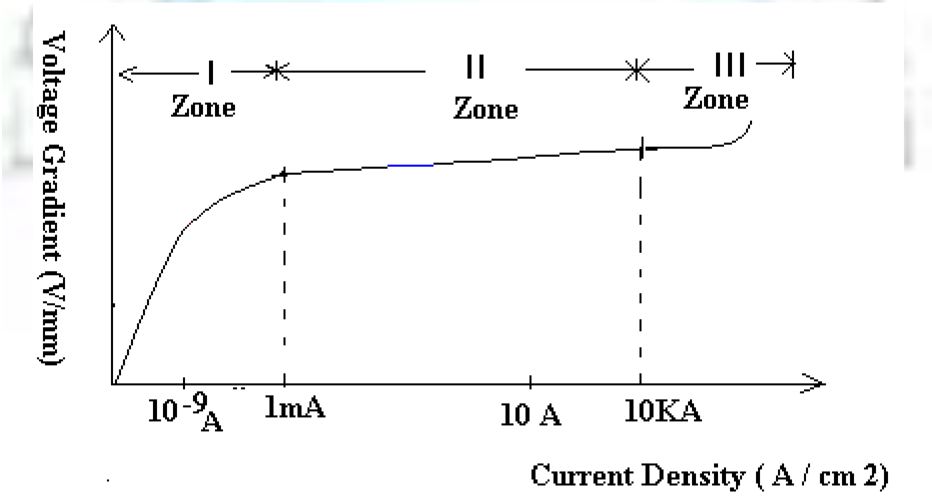


Fig 1: V- I Characteristics of Zn O Arrester block

I-zone: Before saturation zone, leakage current through the arrestor is in the order of 10^{-10} A to 10^{-6} A.
II-zone: Saturation zone, the leakage current through the arrester is in the order of 1mA to 100A.
III-zone: After the saturation zone, the leakage current through the arrester is 100A to 100,000A.

Non-Linear Co-efficient (β): The non –linear co-efficient of the arrestor is expressed as,

$$I = K V^{\beta} \qquad \text{------ (1)}$$

I = Discharge current (KA)
V= Voltage across the arrester (KV)
β = Non –linear co-efficient (> 1)

The linearity of the characteristics mainly depends on the value of non –linear co-efficient (β).
At any two current reference values the value of non-linear co-efficient calculated as,

$$\beta\,(cal) = \frac{\log(I2) - \log(I1)}{\log(V2) - \log(V1)} \qquad \text{--- (2)}$$

I1, I2 are the two reference currents of arrester.

V1, V2 are the reference voltages at the same reference currents .The V-I characteristics of the arrester vary with the temperature. If the temperature of the arrester is raised then the leakage current through it is also raised. When the lightning surge is discharged through it then the temperature of the block is increased hence the temperature is considered into account for constructing the V-I characteristics at the various voltage levels.

The paper presents the performance of the arrester blocks at different temperature levels with different di-electrics such as air, transformer oil and SF6. The various testing that are performed on the arrester blocs as per standards and testing as follows,

- IEC 99-1 to IEC 99-5.
- IS: 3656, 7650, and 7652.
- JEC standards.

The listed various tests are conducted on arrester blocks in air, transformer oil and SF6 dielectrics. The Arrester blocks those are manufactured by Crompton Greaves pvt. (Ltd), in NASIK based on HITACHI Technology having their characteristics are listed below,

D5-type No: 2002121268(Class –B)
D7-type No: 2002124268(Class-A)

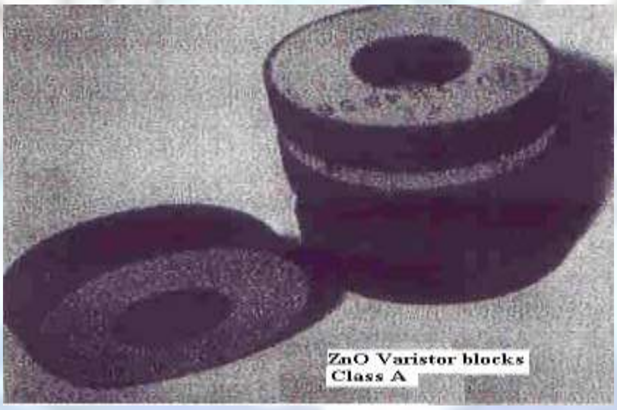


Fig 2. The ZnO Varistors (type Class-A)

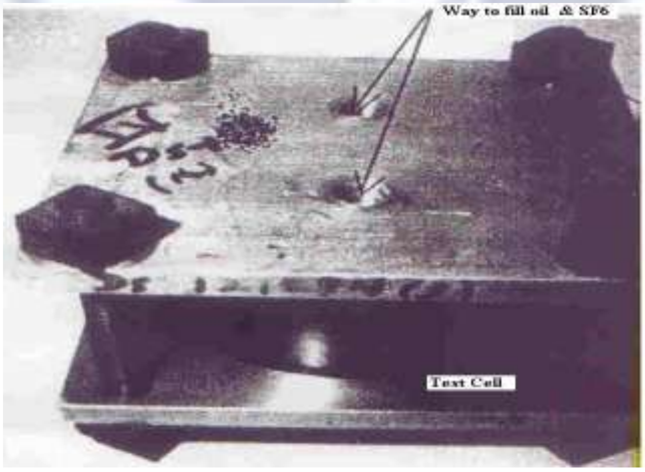
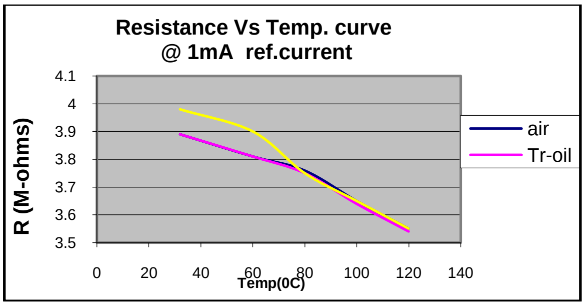


Fig 3. Testing Chamber

2. The reference voltage test

The voltage across the arrester block when the 1mA current flowing through it is called reference voltage. The test was completed in above three media at various temperatures from 30°C to 120°C and measured the voltage across the varistors and calculated the resistance at 1mA and 4mA also for calculating the non-linear co-efficient (β).

S.No	Temp	Vdc @ 1mA(KV)			Vdc @4mA (KV)			R(M-ohms)			β
		air	Tr-Oil	SF6	air	Tr-Oil	SF6	air	Tr-Oil	SF6	
1	32	3.9	3.88	3.8	4	3.98	3.85	3.9	3.89	4	54
2	60	3.8	3.85	3.7	4	3.94	3.85	3.8	3.81	3.9	45
3	80	3.8	3.75	3.8	3.9	3.91	3.9	3.8	3.75	3.8	35
4	100	3.6	3.65	3.6	3.9	3.84	3.84	3.7	3.64	3.7	24
5	120	3.6	3.54	3.6	3.8	3.84	3.85	3.6	3.54	3.5	18



The following observations are recorded from the above reference voltage test of a non-linear resistor.

i) The non-linear co-efficient is independent of di-electric media i.e. there no change β with respect to media change.
ii) The non-linear co-efficient value is reduced with respect to temperature in pre-breakdown region, increasing the temperature reduces i.e. the non-linearity.
iii) The non-linear co-efficient is higher value for high-energy blocks & vice versa.
iv) The non-linear co-efficient is maximum at 1mA reference current.

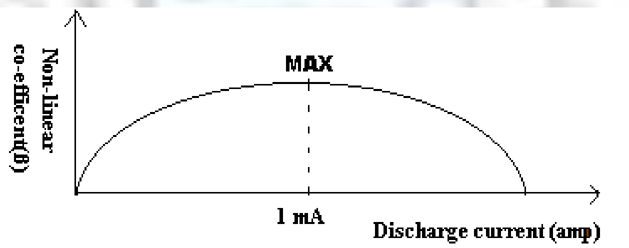


Fig 4. Non-Linear co-efficient Vs discharge current

3. Accelerated aging test

According to the IEC 99-4, the ageing test was conducted at minimum continuous operating voltage (MCOV) at 115 + 4˚C up to 1000hrs continuously. Then at the rated voltage of the varistor block the watt-looses also measured after the aging
and compared these results with the watt-losses before the aging test in different dielectric media shown in fig 6.

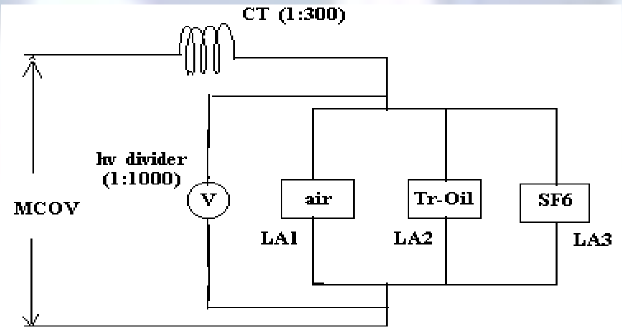


Fig 5: Accelerated aging test of varistor with Transformer oil

Before Aging (Watt-Loss)		After Aging (Watt-Loss)	
At MCOV	At Rated Voltage	At MCOV	At Rated Voltage
0.31	4.7	0.34	5.1
0.3	4.62	0.34	5.1

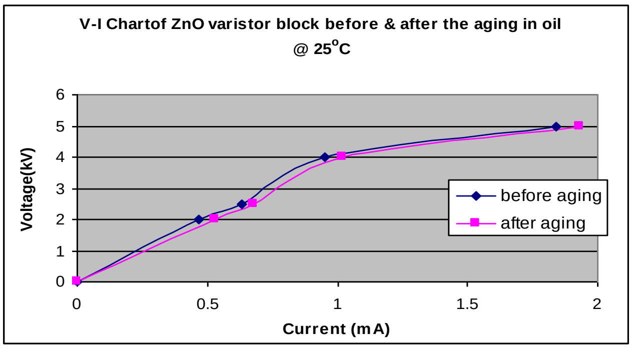
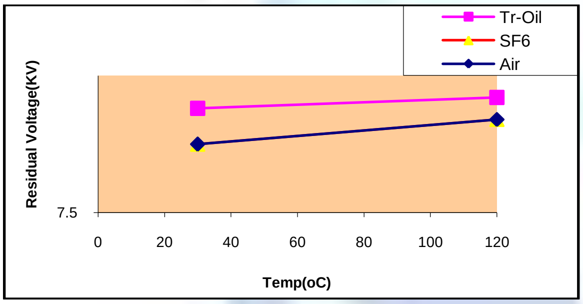


Fig 6. V-I Characteristics before and after aging in Tr-oil @ 25°C

4. Residual Voltage Test

As per IEC99-4, the rated current 10KA, 8/20 μ-sec passed through the blocks in three insulating media test cells, then the temperature of blocks is to be maintained and measured the voltage across the test cells. In the above table, the practical values of residual voltages of ZnO blocks at different voltages. The observations are as follows,

i) Residual voltage is a dependent on the temperature of the blocks i.e. if the block temperature is increased then the residual voltage is increased slightly.
ii) Residual Voltage is independent of di-electric media.
iii) There is no external damage of the arrester blocks.
iv) The V-I characteristics of the blocks don't changed.



Temp	Residual Voltage (KV)		
	Air	Tr-Oil	SF6
30 °C	7.86	7.88	7.75
120 °C	7.88	7.92	7.84

5. Degradation & Porosity Test

After the completion of aging in transformer oil, the varistor blocks were tested under the degradation and porosity tests. The quantity of oil volume absorbed by the varistors (in PPM) is not differing much more than in dry conditions.

6. Conclusion

The V-I characteristics of ZnO Varistor blocks (Class-A) are obtained in both dielectrics such as transformer oil and SF6 gas and compared with free air. The characteristics having the deviation of 2-3% of their original characteristics shown in fig 6. Hence the lightning arresters can design with transformer oil as insulating media against the problem of housing with solid dielectrics. It may also propose that the power transformer can build with arrester without housing by providing only transformer oil as insulating media.

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