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VARISTORS – OPERATING AND CHOICE TO PROTECT TELECOMMUNICATION EQUIPMENT

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Abstract – **Operating of zinc oxide varistors takes place according to a nonlinear characteristic, which have few zones each of them being specific to a certain functional mode, presented for the beginning. It is provided then a way to choose the main dimensions (height and diameter) of such varistors to be used as low voltage surge arrester to supply telecommunication equipment. The paper finishes by an example of an overvoltage protection module as an application of these varistors.**

Keywords**:** *zinc oxide varistor, overvoltage protection, dimensioning.*

1. INTRODUCTION

Together the liberalization of the telecommunication market, the new operators have begun to invest massively for equipment, but seated in open places, containers, on the roofs of the buildings, or in buildings without increased overvoltage protection. Supplying of this equipment, of the satellite centers, has performed with trend to cover an area as bigger as possible of customers, directly from the civil network.

The reverse of these practices was the multiplying of the failures due to the overvoltages, both of atmospheric and commutation caused. The main problem is not the cost of the destroyed equipment but the paralyzing of this equipment served communications (a single satellite center can serves till 100,000 telephone users), and the replacement intervention of a back-rack can be a very expensive operation, which also needs time to be done.

Removing the overvoltage failures of the telecommunication modules is not possible using only protection relays or fuses. It is proved [1] that the solution is the use of the nonlinear resistance arresters, and for low voltage the most suitable are the zinc oxide varistors, which can ensure in addition to the protection function a filtering function too.

2. OPERATING ZONES

Varistor is an electric component whose resistance varies nonlinear with voltage. That of the zinc oxide in fact is a ceramic one, made up from ZnO granules separated by intergranular spaces. The ZnO granules have an *n*-type semiconductor structure with a strong donor concentration. The intergranular space includes other material oxides (Co, Sb, Bi, Mn, Cr) being of $10^{-1} \ldots 10^{-3}$ μm dimension, behaving as a dielectric with relative permittivity $\varepsilon_r = 8.5$ and having the voltage drop of about 3 V accordingly the introduced potential barrier [2].

Operating zones of the zinc oxyde varistor can be pursued on current density *J* versus electric field intensity *E* diagram (Fig.1) according to the relation:

$$J = K \cdot E^{\alpha} \tag{1}$$

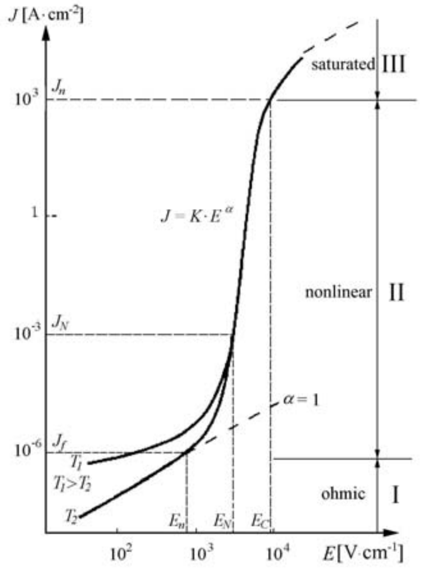

Figure 1: The *J(E)* characteristic of a zinc oxyde varistor.

Three zones can be here distinguished:

- ohmic resistance zone, I. Complies with the small current intensities, varistor resistivity being $10^4 \ldots 10^{10}$ Ω·m, it behaving as an insulator. Electric conduction depends on temperature, *T*. The J_f, E_n values fix the leakage current intensity I_f (< 100 μA) of the varistor while it is subjected to the rated voltage U_n of the equipment to be protected;

- nonlinear zone, II. Complies with the operation as a protection element. The nonlinearity coefficient

$$\alpha = \frac{d(\log J)}{d(\log E)} \qquad (2)$$

usually has values between 20 …50, but it could reach even 70. The J_N, E_N values fix for the conventional current intensity 1 mA the threshold voltage U_N of the varistor. Electric conduction here is mainly thermoelectric one [3];

- saturated zone, III. Comply with the high current intensities, varistor resistivity being $0.5 \cdot 10^{-2}$ Ω·m, it behaving as a conductor. To J_n value corresponds the rated current of the varistor, I_n.

To explain the conduction of a zinc oxide varistor, a lot of models have been proposed: Matsuoka, Levine, Pike and Seager, Levinson and co., Bernascon, and the most appropriate to the experiment, Dorlanne. The degradation of a varistor subjected both to the rated voltage and to the overvoltages, and as a consequence the increasing of the leakage current, has also led to many models: Eda and co., Gupta and co., Shirley and Paulson. This phenomenon can be limited but not eliminated.

As regards the destroying of a varistor there are:

- pointshaped burn-through. It is due to the melting of the intergranular layers by establishing a preferential current passing channel when the varistor is subjected to a not very high current (a few amperes, tens of amperes) for a few hours;
- overall burn-through. It is due to the melting of the entire varistor for high current passing even it is short timed one;
- flashover. It is due to the appearance of a current on the lateral surface of the varistor, which leads to local or global melting.

2. VARISTOR DIMENSIONING

Technical literature does not give a complete algorithm to choice the zinc oxide varistor dimensions. Based on author’s experience, further is depicted an unsophisticated way, which allows obtaining the two dimensions of a varistor: its height and its diameter:

- electric computation. It started from the rated voltage of the equipment to be protected, U_p, and from the recommendations of literature for some voltage ratios, easily increased in accordance with the experience. It takes into consideration the operation in alternative current (a.c.) or in direct current (d.c.).

Thus, the **M**aximum **C**ontinuous **O**perating **V**oltage, that is the greatest permanent duty voltage to which a low voltage equipment have to withstand, would be:

$$U_{MCOV} = 1.06 \cdot U_P \qquad (3)$$

Practically the supply voltage may frequently reach a little greater value as U_{MCOV} is, without damaging the low voltage equipment. So the greatest permanent duty voltage at the terminals of the protection equipment (made from varistors), that is the **R**ated **M**ean **S**quare **V**oltage for a.c. and the **D**irect **C**urrent **V**oltage for d.c. respectively, will be:

$$U_{RMS} = 1.1 \cdot U_P \text{ or } U_{DC} = 1.1 \cdot U_P \qquad (4)$$

On the other hand the ratio between the varistor threshold voltage U_N and the greatest permanent duty voltage it is recommended to be [4]:

$$U_N/U_{RMS} = 1.5 \ldots 1.7 \text{ or } U_N/U_{DC} = 1.1 \ldots 1.2 \quad (5)$$

(the two domains differs by $\sqrt{2}$ who characterize the amplitude over the effective value for a.c.).

The reason why this ratio is greater than that of the relation (4) is that, each time when the voltage reaches the value around the maximum tolerated one U_{RMS}, respectively U_{DC}, still normal operation, if U_N should equals these, there should be the risk that the varistor starts to conduct. This fact should lead to its unavailing stress, bringing about its heating, which involves its degradation and decreasing of its life span. But the ratio cannot be taken too great, as the varistor has to remain still sensitive enough to open for as little as it is possible threshold voltages.

Having U_n from (5) the height of the varistor can be computed:

$$h = d_g \cdot U_N / u_N \qquad (6)$$

where d_g is the medium thickness of a ZnO granule, and u_N is the threshold value of an intergranular space, equal to the potential barrier between two adjoining granules. These quantities have to be listed by the producer among the characteristics of the varistor. Informative d_g = 10 … 25 µm, u_N = 3 … 4 V. The height of varistors is standardized, and because the threshold voltage affiliated being precisely adjusted by producers, it can cover the entire game of industrial application asked values;

- thermal computation supposes taking into consideration two duties:

a) rated duty. During this, for the rated voltage U_n, the leakage current I_f does not have to produce the thermal runaway. It is thought that the thermal runaway practically appears if the varistor will overheat with τ = 20 K referred to an ambient temperature of θ_a = 20 ºC. Starting from the balance of heat and assuming that the cooling surface of a disk shaped varistor is composed of the lateral surface and two base surfaces, the diameter will be:

$$d = -h + \sqrt{h^2 + \frac{2 \cdot U_n \cdot I_f}{\pi \cdot \alpha_\Sigma \cdot \tau}} \qquad (7)$$

where α_Σ [W·m^{-2}·K^{-1}] is the global thermal transmittivity and I_f can be taken to be 100 µA;

b) failure duty. The discharging of an overvoltage having *W* energy gives a short time current which stresses approximately by adiabatic heating, the varistor. According to the balance of heat, *W* = *Q*, the heat stored in varistor. Having in view that during the heating of the varistor till high temperature, its specific heat varies with temperature, for a disk shaped varistor of diameter *d* and height *h*:

$$Q = \rho_v \cdot \frac{\pi \cdot d^2 \cdot h}{4} \cdot \int_{\tau_n}^{\tau_s} c_a \cdot \left(1 + \beta_a' \cdot \tau\right) \cdot d\tau \qquad (8)$$

where ρ_v [kg·m^{-3}] is the mass density, c_a [J·kg^{-1}·K^{-1}] – the ambient temperature specific heat, β'_a [K^{-1}] – the coefficient of specific heat variation with temperature, and τ_n, τ_s [K] – the rated and the failure overtemperature. Performing the integral:

$$d = 2 \cdot \sqrt{\frac{W}{\pi \cdot h \cdot \rho_v \cdot c_a \cdot (\tau_s - \tau_n) \cdot \left[1 + \frac{\beta_a'}{2} \cdot (\tau_s + \tau_n)\right]}} \qquad (9)$$

A simplified, covering relationship will result if it is considered that the specific heat remains constant, β'_a = 0 (giving a little greater *d*).

Such dimensioned varistor has to be chosen to have the rated current, that is the peak value of the discharging current for an 8/20 µs overvoltage impulse, I_n < 2.5 kA. Also, it has to be according to the requirements referring to the greatest peak value of the voltage at the varistor terminals (kindling voltage, residual voltage etc.).

3. EXAMPLE OF VARISTOR USING

A protection module to overvoltages was performed at the "Politecnica" University from Timisoara by which it can supplies three phase modular sources for telecommunication (Fig. 2). The used varistors were dimensioned as it was earlier exposed.

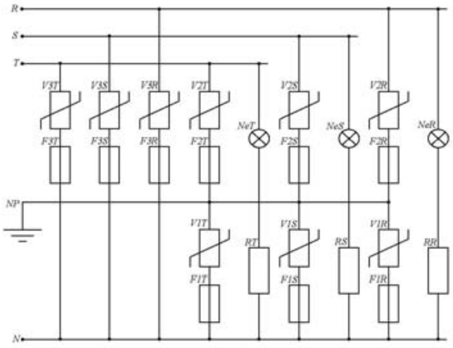

Figure 2: The three phased overvoltage protection module circuit diagram.

It is to remark the existence of series connected varistor-fuses sets, linked between each phase and the protective null, between each phase and the network null, and between the protective null and the network null. The lasts are dimensioned for smaller current than the firsts. The fuses are introduced to ensure the protection if the current peak overreaches the defaulted one of the varistors. Neon lamps indicate the presence of supply voltage of phases.

3. CONCLUSIONS

Varistors, as nonlinear resistive elements, can constitute the overvoltage protection of the low voltage equipment particularly for the telecommunication equipment. Their choosing assumes o dimensioning, which can be done accordingly to an unsophisticated algorithm exposed by the paper. This starts from the supply voltage of the equipment to be protected (alternative current or direct current) and the supposed energy of the overvoltage wave that have to be discharged. But a complex protection module has to be equipped with a great number of varistors and completed with fuses.

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