Improvement of Reliability of Laser Beam Printers, Copiers, and Facsimiles

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Abstract

This paper proposes an improvement of the reliability of varistors that can limit the fire to the varistor and prevent fire from being spread to the entire machine. With this research, the conditions for varistor firing were determined by use of the varistor voltage V_{1mA} as the index; the relation between V_{1mA} and the data of the surge voltage and overvoltage which were observed was verified; and the test conditions for confirmation of the concept of measures against firing of varistors were determined. The epoxy-based plastic, which is the exterior part material of the ZnO varistor, was changed into a material containing a large amount of silica or calcium carbonate. By this, the height and duration of the flame were reduced to a level of one tenth, as compared to those of conventional varistors.

Introduction

Semiconductor components, such as ICs and LSIs, which are incorporated in pieces of electronic equipment, are extremely susceptible to a lightning surge, a switching surge, and the like, thus pieces of electronic equipment are faced with problems of malfunctioning and failure. One of the electronic components which can solve these problems is the ZnO varistor. Although phenomena including the ZnO varistor itself being broken down or firing, and pieces of electronic equipment burning out have been reported [1, 2], the research of the reliability and safety of the varistor on the basis of the observation data obtained in the market has not been sufficiently carried out.

This paper, being based on the data for the overvoltage, repetitive surge voltage, and the like which were observed by the author et al., reports that the height of flame and the duration of the flame when the varistor is fired can be reduced to one tenth of the conventional values, resulting in improvement of the reliability for laser beam printers, copiers, facsimiles, and the like.

Establishing Test Conditions for Varistor

Test Setup

1) Samples: 100 bismuth ZnO varistors with a varistor voltage of 470 V_{1mA}, Type A
2) Test apparatus: Analyzing AC power supply (AA2000XG manufactured by Takasago, Ltd.)
   This apparatus can superpose the output voltage of 800 V or lower as an injection level on the basic output waveform over a duration of 50 μs or more at an arbitrary angle.

Conditions for Varistor Firing with Repetitive Surge

In this paper, the percentage of the surge voltage V_p to be applied to a particular varistor voltage V_{1mA} is referred to as impression rate (V_p/V_{1mA}).

The impression rates at which the varistor fired were substituted by the repetitive surge voltages (V_p) which were actually applied, then the relationship between the repetitive surge voltage (V_p) and the repetitive surge duration (ms) was determined, and expressed as a curve with the values of the observed voltages being added (Fig. 1 shows the experimental result). The varistor tends to fire at an impression rate of 120%.

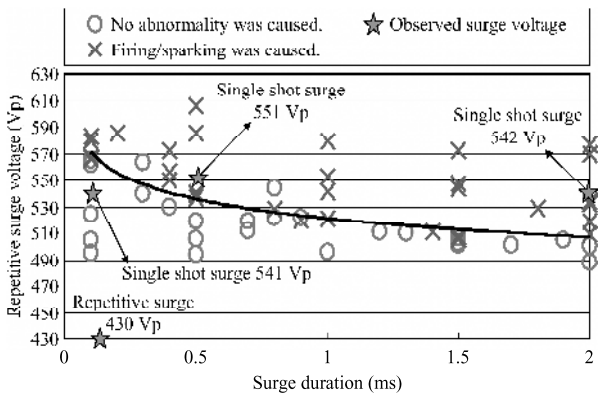


Fig. 1 Surge voltages which caused varistor firing, and observed surge voltages Type A (470 V_{1mA}, 10 mm dia)

Conditions for Varistor Firing with Overvoltage

In this paper, the term "overvoltage rate" is defined as the ratio of the root mean square value of the overvoltage to the varistor voltage V_{1mA}, expressed as V_{rms} / V_{1mA}. The overvoltage rates at which the varistor fired were substituted by the voltages (V_p) which were actually applied, then a graph was prepared, the values of the observed overvoltages being added (Fig. 2). The varistor tends to fire at an overvoltage rate of 80%.

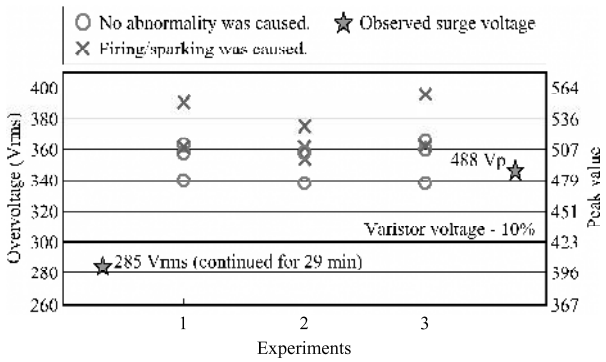


Fig. 2 Overvoltages which caused varistor firing, and observed overvoltages Type A (470 V_{1mA}, 10 mm dia)

Verification of Concept of Measures against Firing

Sample

The Type A sample of the bismuth ZnO varistor was prepared by changing the material of the exterior part from epoxy to a phenolic resin material containing silica by 90 wt%. This sample is referred to as a Type A* one. For both Type A sample and Type A* one, the element, the manufacturing method, and the like are approximately the same.

Test Method

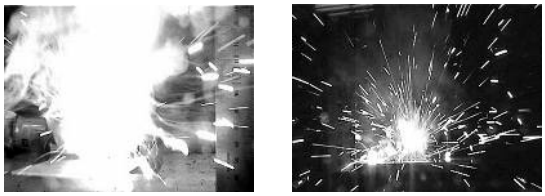
The impression rate for the observed surge voltages (551 V_p, 541 V_p, and 542 V_p) is approximately 120%. Further, in consideration of the data in the market, it was determined that the surge duration is 0.5 ms. In the overvoltage test which was verified in 2.3, the varistor fired, starting from the overvoltage rate of 79%, thus it was determined to apply the voltage for an overvoltage rate of 80% or higher. Table 1 summarizes these test methods.

Table 1 Observation experiment for flame height and duration for varistor

Test item	Conditions	Samples
AC over-voltage test	RMS voltage of 80% or higher of varistor voltage is applied.	50
AC super-posing surge test	A square waveform (having a width of 0.5 ms, and an application start phase angle of 90 deg) of 120% or higher of varistor voltage V_{1mA} is super-posed on commercial power.	50

Test Results

The height and duration of the flame when a varistor is fired depend upon the type and amount of the external plastic material, and the conditions of coating the plastic resin to the element. At right in Fig. 3 is given an example in which 50 samples were successfully tested.



Type A varistor whose exterior part is made of epoxy

Flame height: 80 mm max.
Duration: 9.5 s
Polyacetal part 2 cm above varistor caught fire.

Type A* varistor whose exterior part consists of phenol resin and 90% silica

Flame height: under 10 mm
Duration: 1.0 s
Polyacetal part 1 cm above varistor did not catch fire.

Fig. 3 Comparison of flames from bismuth ZnO varistors with each other.

Conclusions

1. For a varistor rated voltage of 470 V, if a single shot surge of 551 V_p or 542 V_p, for example, repetitively enters the product, the varistor may be degraded, broken down, or fired.
2. The value of the peak overvoltage observed is 488 V_p, which is 13% higher than the maximum allowable circuit voltage 420 V_p, thus, application of the same overvoltage as that observed may cause the varistor to fire.
3. By changing the material of the exterior part to that containing large amounts of inorganic substances, i.e., calcium carbonate and silica, holding the flame height to 1 cm (one tenth) or less and the flame duration to 1.0 s (one tenth) or less has been achieved.

Reference literature

1. Alex McEacherm (2000): Designing electronic devices to survive power-quality events, IEEE industry Applications Magazine Vol. 6, No. 6, pp. 66-69
2. Dev Paul (2001): Low-Voltage Power System Surge Overvoltage Protection, IEEE, vol. 37, No. 1, pp. 223-229

Biography

Toshinori Watabe born in May 8, 1949. He graduated from Department of Electrical Engineering, Faculty of Engineering, Ibaraki University in 1973. After hired by Copyer Co., Ltd., he was employed in 1982 by Canon Inc. At present, belonging to the Quality Management Headquarters, he is engaged in research and evaluation of the quality assurance, electrical safety, and reliability of photocopying machines, facsimiles and printers, being also a part-time student in the doctorate course at Ibaraki University.