Improvement of Reliability of Electronic Components of Photocopying Machines and Facsimiles

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Abstract

Troubles of photocopying machines and facsimiles led us to measure the power line voltages at the interior wirings in general homes and plants over six months. Data of abnormal voltages, such as a repetitive surge of 430 V and 170 μs, and an overvoltage of 345 Vrms, was obtained. A device which can simulate the measured voltage waveform was developed to reproduce the abnormal voltage for analyzing the cause for failure or malfunctioning. A method of evaluating a varistor connected across AC power lines by superimposing a surge on the line voltage was developed, and no-fire electrolytic capacitors which had already been put to practical use were verified by applying an overvoltage to them.

Introduction

Examination of products which had failed revealed that the varistor used as a lightning surge prevention component was broken down, or that the safety valve in the smoothing aluminum electrolytic capacitor for the switching power supply (hereafter abbreviated to the electrolytic capacitor) was actuated. In USA, observation of the lightning surge and the transient overvoltage has been sufficiently performed on a national scale by the cooperation of the electric power industry and the EPRI (Electric Power Research Institute) [1]. The results of the observation has been reflected to the IEEE standard. The photocopying machines and facsimiles which failed or malfunctioned were designed to meet the specifications as given in IEEE 62.41 and IEC 61000. The cause for the failure or the malfunctioning can be presumed to be application of a switching surge or an overvoltage which has a waveform different from that as specified in these standards.

This paper has been written to achieve the following three purposes:

1) Showing a method for measuring the abnormal voltage, such as a surge and an overvoltage, which can cause damage to components of photocopying machines and facsimiles, and the results of the measurement using the method.
2) Carrying out a simulation of the abnormal voltage for investigating the waveforms which can cause failure or malfunctioning of products.
3) Offering a design means firstly for preventing spread of a fire from an electronic component ignited, and secondly for lowering the probability of the photocopying machine or facsimile failing or malfunctioning.

Abnormal Voltage Measurement

Measuring Instrument

The measuring unit used consists of a line monitor (Memory Hi Coder Type 8808, manufactured by Hioki E. E. Corporation), a personal computer (hereafter abbreviated to a PC), a memory, and an isolation transformer. One measuring unit was designed such that a surge of as short as 2.5 μs in duration can be measured over 2 ms, while the other was designed so as to be able to measure a surge or an overvoltage of 250 μs over 1000 ms. Because two units are operated at the same time, measurement can be made if either a surge or an overvoltage comes into the equipment under test. In USA, it has been reported that a voltage as high as 2500 V was applied across the power lines. [2] On the basis of this, a high-voltage probe of 100 to 1 was used to measure up to 2500 V.

Procedure for Measurement

We visited general homes, plants, hotels, and the like, including houses where product failure or malfunctioning was actually caused. A power quality measuring instrument (Power Quality Analyzer Type 658 manufactured by Dranetz-BMI) which can measure up to 6000 V was used to check for voltage value and duration, and then the measuring places were selected. Then, for the two different line monitors, the voltage threshold values were set before starting the continuous measurement. When events could be accumulated

in three months of measurement, and no events could be accumulated, the set of two measuring instruments was moved.

Results of Measurement

Data of typical types of abnormal voltage, such as surge, overvoltage, voltage fluctuation, voltage dip, and voltage distortion, was acquired, and the results are given in Table 1. The voltage dip meets the specifications for photocopying machines and facsimiles, and thus it can be concluded that this event was not responsible for the failure and the malfunctioning.

Figure 1 shows a part of the repetitive surge data acquired in the location where a photocopying machine malfunctioned. The repetitive surge of 430 V and 170 µs across the power lines does not meet the specifications as given in IEEE 62.41. An overvoltage which continued for 1 min or longer was recorded 26 times between 404 V to 488 V. An overvoltage having an RMS value of 345 V continued for 29 min. That overvoltage is as high as 157% of the nominal power line voltage of 220 V.

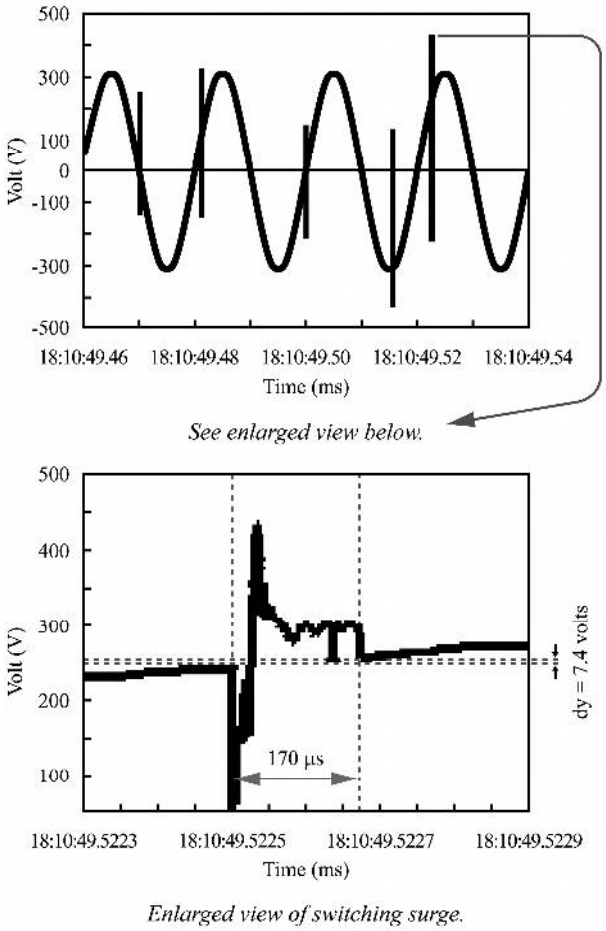

Figure 1. Repetitive switching surge of 430 V and 170 µs, recorded.

Table 1. abnormal voltage data.

Type	Example of waveform data
Power line surge	551 Vp, 525 µs single-shot surge
	541 Vp, 150 µs single-shot surge
	430 Vp, 170 µs repetitive surge
	542 Vp, 2 ms single-shot surge
Voltage fluctuation	265 to 345 Vrms (+44%) for 29 min
	170 to 203 Vrms (−23%)
Voltage dip	Voltage sag for approx. 60 ms
	100% voltage dip for 40 ms
Voltage distortion	Sinusoidal waveform changed into triangular one
	Distortion (superimposed near zero cross)

Reproduction Experiment

Waveform Generator

As shown in Figure 2, the data acquired with the line monitors and the power quality measuring instrument is transmitted to a waveform generator (Analyzing AC Power Supplies Type ST8000 manufactured by Takasago, Ltd.). This device, being used with a PC, has a simulation function and an arbitrary waveform generation one, being capable of generating a voltage waveform of 46 µs or longer, ±1000 V or lower, and 40 A or lower.

The waveform generator can invoke a stored waveform to reproduce the waveform. With the use of a PC, one waveform of an arbitrary surge is created on the screen, and the surge image is pasted to a sinusoidal wave at an arbitrary phase angle. An experiment to superimpose this surge on the 220-V line voltage can be carried out.

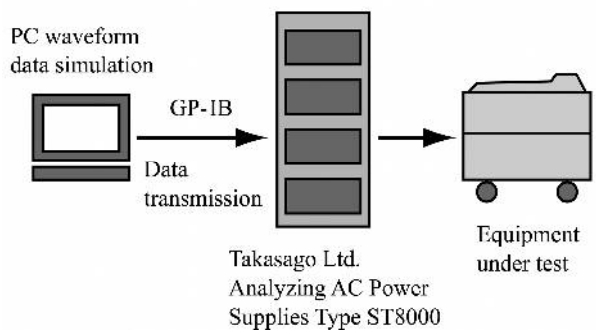

Figure 2. Reproduction experiment system, used.

Method of Experimentation

To the same type of photocopying machine or facsimile as that which has failed or malfunctioned, a waveform of the simulated surge or overvoltage is applied for examining whether failure or malfunctioning is caused or not.

Figure 3 provides an example of the same voltage waveform as that recorded. Figure 4 shows a waveform consisting of a sinusoidal waveform to which a part of the recorded single-shot surge waveform of 550 V or lower and 2 ms is pasted. On the basis of the data of the single-shot surge, an experiment on the assumption of a repetitive surge was carried out. Further, a surge of 430 V and 100 µs was created

to be superimposed on a sinusoidal waveform at the points of phase angles of 0 deg, 90 deg, 180 deg, and 270 deg for carrying out a repetitive surge test.

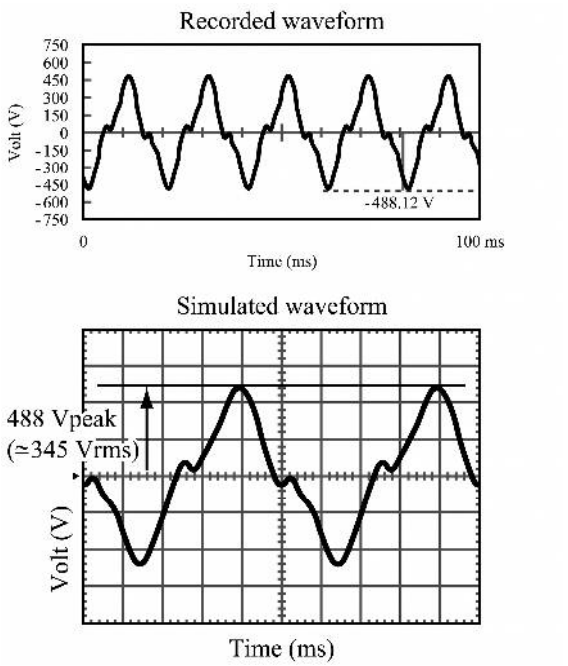

Figure 3. Recorded waveform and waveform simulated to it. (Vert: 200 V/div, Horiz: 4 ms/div)

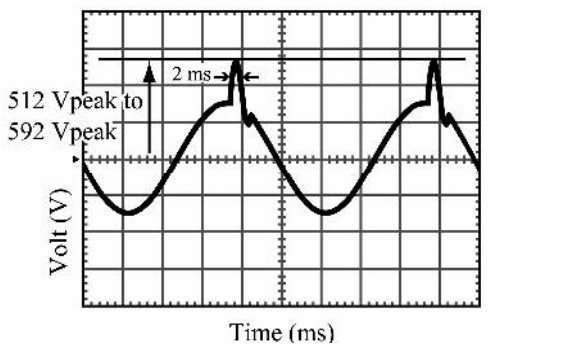

Figure 4. Voltage waveform of simulated repetitive switching surge. (Vert: 200 V/div, Horiz: 4 ms/div)

Experimental Results (Refer to Table 2)

Varistor

The voltage ratings of varistors vary in the range of ±10%, and when a varistor having a voltage rating of 470 V –10% was selected, varistor breakdown or firing occurred (Table 1). When a varistor is subjected to an overvoltage or a continuous surge, the current is concentrated on a local place of the element, resulting in overheating. The overheated local place breaks down the varistor element, resulting in short-circuiting, and the Joule heat of the short-circuit current overheats the varistor, which results in the epoxy resin enclosure being burnt at approximately 850 deg C.

Table 2. results of reproduction experiments.

Waveform / Object	Overvoltage	Repetitive switching surge	
	Figure 3	Figure 4	430 V, 100 µs
Varistor	Breakdown or firing	Breakdown or firing	No problem
Electrolytic capacitor	No problem	Rated for 400 V Safety valve functioning	No problem
Photocoupler	No problem	No problem	Malfunctioning

Electrolytic Capacitor

In a 512 V and 2 ms repetitive surge test, the safety valve of an electrolytic capacitor with a voltage rating of 400 V functioned in the open mode. If an overvoltage as high as 1.5 or more times the rated voltage or a repetitive surge on the order of seconds is applied to the oxide film of the anode, the leakage current from the defective portion of the oxide film is increased, resulting in the electrolyte being vaporized by the Joule heat due to the internal resistance, which causes the space inside the capacitor and the element to be expanded, resulting in the safety valve being actuated. If, at that moment, a short-circuit is caused inside the capacitor with sparking, the vaporized gas is ignited, which fires the electrolytic capacitor.

Photocoupler

In a 430 V and 100 µs repetitive surge test, the controller of the heater in a photocopying machine malfunctioned. The photocoupler controls the heater by detecting the time when the voltage crosses the points of phase angles of 0 deg and 180 deg. When a surge having a large amount of energy occurs at either of these phase angles, the detection of the photocoupler is interfered, resulting in an erroneous signal being fed to the control system for the heater.

Solutions to Problems

Varistor

Conventionally, whether or not the varistor is degraded or fired when a surge is superimposed on the power line voltage has not been discussed as a performance of a varistor. We have developed a "varistor superimposition test method" consisting of three different tests; the test which superimposes a lightning surge of 1.2/50 µs at 6 kV on the power line voltage, the test which superimposes 500 V and 500 µs at a phase angle of 90 deg, and the test which applies an overvoltage of 1.5 to 2.0 times the nominal voltage. The varistor has been constructed such that the enclosure is made of a phenolic resin, being covered with a glass. Instead of relying on the fuse for current shutting-off, we have reduced both height and duration of the flame to 1/10 or less of those for conventional varistors.

To minimize the frequency of malfunctioning of the photocopying machine and facsimile due to an instantaneous

surge in the power line, it is reasonable to select a varistor having a low voltage rating. However, a varistor rated for a voltage of 470 V may be broken down by an overvoltage. If a varistor with a rating of 620 V is selected, there is practically no possibility of the varistor being broken down, however, a surge may get in a subsequent circuit, resulting in the photocopying machine or facsimile malfunctioning. In consideration of prevention of firing due to a varistor being broken down, and that of occurrence of malfunctioning, selection of a nonflammable varistor rated for a voltage of 510 V can be a measure.

Electrolytic Capacitor

The measure against firing is to use a no-fire electrolytic capacitor. In 1991, we reported a DC overvoltage test method for aluminum electrolytic capacitors, and in 1993, we realized volume production of the no-fire electrolytic capacitor. For it, a long-lasting overvoltage which can be caused in a trouble of wire breakage of the neutral line in the interior wiring is assumed. The DC overvoltage test method involves momentarily applying a DC overvoltage 1.5 to 2.0 times higher than the rated voltage for an electrolytic capacitor with the current being limited in accordance with the capacitance (Table 3). At an overvoltage, the capacitor will not short-circuit, but the safety valve functions, thus the capacitor will not fire. In an experiment in which a 592 V and 2 ms surge is repetitively superimposed on the line voltage of 220 V, the safety valve of the no-fire electrolytic capacitor functioned in 2 min after the start of the test, but the capacitor did not fire.

To lower the probability of the safety valve of the electrolytic capacitor functioning at an overvoltage, it is recommended to select an electrolytic capacitor the anode foil of which has a high dielectric strength. For a given nominal voltage rating, the dielectric strength value may vary depending upon the manufacturer. The investigation of the overvoltage values at which the safety valve will not function after the application of the overvoltage is continued for one min revealed that there is a discrepancy of as high as 35 V (8.7%) for capacitors having a voltage rating of 400 V.

Table 3. DC overvoltage test method.

Rated voltage	Nominal capacitance	Current limiting	Applying voltage
200 Vdc	under 330 µF	4 A	300/375 Vdc
	330 to under 470 µF	5 A	
	470 µF or over	7 A	
400 Vdc	under 100 µF	2 A	500/600 Vdc
	100 to under 220 µF	4 A	
	220 µF or over	7 A	

Photocoupler

The factors which allow a surge to cause malfunctioning of the photocoupler are the relationship between the maximum voltage level and the amount of energy, the rise time, and the phase angle. If the voltage level is high, but the amount of energy is small, malfunctioning will not be caused. To absorb the energy of a 430 V and 170 µs, a set of C and R was connected in parallel with the photocoupler for solving the problem of malfunctioning of the heater of the photocopying machine.

Conclusions

1. To provide firing prevention, which must be a basic capability of any product, a solution should be considered on the concept which grasps the features and cost of a particular electronic component, on the assumption of the conditions under which an overvoltage or surge is applied to the actual power line.
2. A method for checking a varistor for degradation and firing that superimposes a lightning surge or a switching surge on the power line voltage has been developed. By constructing the varistor such that the basic enclosure made of a phenolic resin is covered with a glass, the size and duration of the flame in firing has been reduced to 1/10 or less.
3. It has been proved that the no-fire electrolytic capacitor, which will not short-circuit at an overvoltage, will not fire if a 592 V and 2 ms surge is repetitively superimposed on the power line voltage.
4. The measure against malfunctioning of the photocopying machine may vary depending upon the method of controlling the heater in it, thus, measures against its malfunctioning resulting from a surge or a voltage distortion are left as subjects for research in the future.

References

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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.