

# Power Dissipation of ZnO-based Metal Oxide Varistors (MOVs) for Electronic Circuit Protection

Shahrom Mahmud\*, Mat Johar Abdullah, Zakaria Mohd. Amin  
University of Science, Malaysia – KDU College, 10400 Penang, Malaysia  
\*E-mail: [shahrom@kdupg.edu.my](mailto:shahrom@kdupg.edu.my)

**Abstract** — Power dissipation in the high-current (upturn) region of the current-voltage characteristic of ZnO-based metal oxide varistors (MOVs) has been observed to be influenced by the ZnO grain resistivity and nonlinearity. Power dissipation lower than 20kW was observed in samples with lower grain resistivity values (less than  $1\Omega\cdot\text{cm}$ ) and higher coefficients of nonlinearity ( $\alpha$  above 3.2). High concentration of intrinsic defects in ZnO powder could be the underlying cause of the higher grain resistivity, lower  $\alpha$  and larger power dissipation.

**Index Terms** — Transient surge, metal oxide varistor (MOV), upturn, high current, nonlinear coefficient, grain resistivity, power dissipation, zinc oxide (ZnO), low-voltage, intrinsic defects.

## I. INTRODUCTION

TRANSIENT voltage surge suppressors (TVSSs) manufactured today are mostly metal oxide varistors (MOVs) that are primarily made of semiconducting zinc oxide (ZnO) grains. Commercial ZnO varistors are normally fabricated in a disc form, electroded at both faces, lead-soldered and coated with epoxy resin. Due to its high resistivity, the MOV behaves like an open circuit when it is connected to an electronic circuit [1,2,3].

If the MOV encounters an overvoltage transient that carries a voltage value that exceeds its characteristic switch voltage, the MOV becomes highly conductive and transient current is drawn into it, thus preventing the hazardous transient from entering the electronic circuit being protected. For electronic application, with operating voltage of below  $25V_{\text{rms}}$ , the threshold switch voltage may occur at a current density in the vicinity of  $0.1\text{mA}/\text{cm}^2$  [2]. Below this value, the MOV is ohmic, highly resistive and is said to be in a standby mode or open-circuit state. This resistive region is known as pre-switch region [4].

Two other regions exist above the switch voltage, namely switched and upturn regions which are highly conductive; and in these regions, the MOV functions as a very effective surge absorber. A world class ZnO-based MOV should be able to handle an energy level of  $250\text{J}/\text{cm}^3$  throughout its working life [4,5,6].

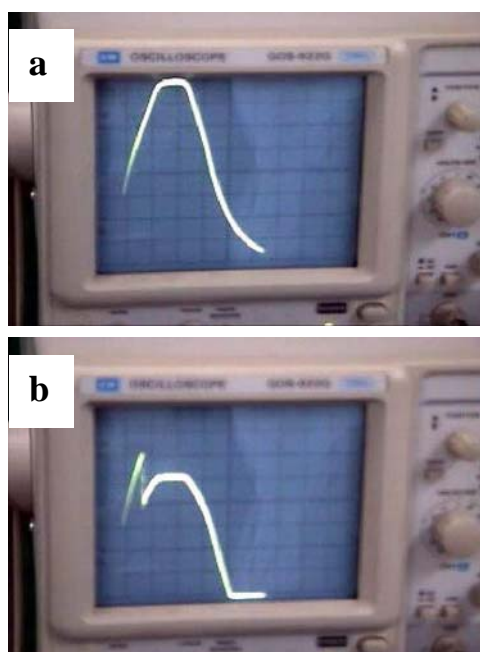


Fig. 1. Demonstration of varistor action showing

- (a) a transient simulation of 38V peak voltage
- (b) varistor action triggered.

Fig. 1 demonstrates the varistor action. A half-wave rectifier circuit is built to simulate the transient shown in the oscilloscope screen in Fig. 1(a), with a peak voltage of 38V and a duration of 12ms. The x-axis scale is 2ms/div while the y-axis scale is 5V/div. At about 3ms from the left end, the MOV is connected to the circuit, and immediately the voltage drops sharply from 31V to 20V, after which it clamps at 25V as shown as the flat plateau at 4-6.5ms range.