Validity of low voltage varistor models when subjected to fast transients

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Threats from HPEM and IEMI are today taken seriously and to estimate the threats from different transient waveforms with a high dI/dt (high frequency content and large bandwidth) it is important to properly model the behavior of surge protective devices (SPDs) when subjected to this kind of transients. In the literature several different models for the response of varistors are presented (e.g. the simplified varistor model, Durbak's (IEEE)-, Pinceti's- and Diaz's varistor model). This work uses fast transient (current and voltage waveforms with nanosecond rise-time) to investigate the accuracy of these models, by studying the behavior of low voltage ZnO varistors, when subjected to fast transients. The standard 8/20 μs lightning current waveform is used to parameterize the varistor models (as a reference impulse) and then the models validity is investigated with faster transients. The studied fast transient cases are:

1. Exponentially damped oscillating current waveshape with an approximate rise-time of 10 ns and first period of 60 ns, and amplitude up to approximately 1.5 kA (producing dI/dt of 150 kA/μs).
2. Double exponential voltage waveshape with rise-time between 5 - 35 ns, and full-width-half-maximum time of 100 – 3000 ns, and amplitude up to 2.5 kV.

The nominal clamping voltage of the tested varistors ranged from 77 V to 650 V. The parameters of the models are obtained through an optimization routine that uses the applied current through the varistor as an input and minimize the error function between the measured clamping voltage and the voltage across the varistor calculated with the model. From these results the validity of each examined model is examined and the different varistor models are compared with each other. Improvement of existing models, by e.g. changing or adding elements (linear or non-linear) or branches are investigated and discussed. Also it is important to remove any numerical oscillation that arises from the digitalization in the measured signals, which is done by using a modified Savitzky-Golay filter. The overall performance of varistors when subjected to transients with large dI/dt is examined and compared to the response when subjected to standard 8/20 μs lightning current waveform. Large dI/dt gives rise to parasitic components from the packaging (both L, C and R) that changes the overall response of the varistor as compared to normal lightning and ESD waveshapes. The dominating response of the packaging in the overall varistor component response when subjected to UWB pulses or other high frequency transients is discussed. The justification of using varistors as SPDs towards fast transients is discussed.