Effect of Voltage Harmonics Content on Arrester Diagnostic Result

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Abstract: Diagnoses of HV arresters are usually based on an analysis of total leakage current harmonics. The fact that the harmonics content in the supply voltage can be a source of errors is seldom taken into account when routine diagnostic measurements are made. In this paper the effect of harmonics in the voltage signal on the diagnostic result is analysed using Matlab computer simulations.

INTRODUCTION

Arresters without spark gaps are modern overvoltage protection devices. An overvoltage arrester is a stack of ceramic oxide varistors enclosed in a tight porcelain or composite housing. This design makes leakage current flow through the arrester operating at the mains working voltage. As the oxide ceramics age, the leakage current increases. One of the commonly used methods of diagnosing overvoltage arresters – particularly arresters in power networks with a rated voltage of 110 kV and higher – consists in measuring the conduction current below the mains voltage without disconnecting the diagnosed arrester. The conduction current in 90% consists of a capacitance component and the rest is a resistance component. The size of the latter is determined not only by the voltage value, but also by the changes caused by ageing. Methods of diagnosing HV arresters are usually based on the analysis of the harmonics content in the total leakage current. The reason is that this current's third harmonic is proportional to its resistance component. In order to determine the value of the resistance component (a diagnostic parameter), the measurements must be rescaled and this is often a source of errors. Another source of errors can be the harmonics content in the supply voltage, which is seldom taken into account when routine diagnostic measurements are made.

Equivalent circuit diagrams of oxide varistors are made to analyse their service performance. Numerous equivalent circuit diagrams of ZnO varistors can be found in the literature on the subject [1-5]. They differ in their complexity, the kind of voltage used or the limitation of description to a particular range of the voltage-current characteristic. For alternating voltages within continuous duty operation voltage Uc in such models the equivalent circuit diagrams usually have the form of connections between both linear and nonlinear elements R and C.

SIMULATIONS AND THEIR RESULTS

Computer simulations were run using the varistor model described by authors in [6] where it was demonstrated that the shape of a current characteristic simulated on the basis of the model was in good agreement with the actual trace. The computations were performed using an application running in the *Matlab* environment. The implementation of the program is shown in Fig. 1. The application was designed to perform a spectroscopic analysis of the current signal.

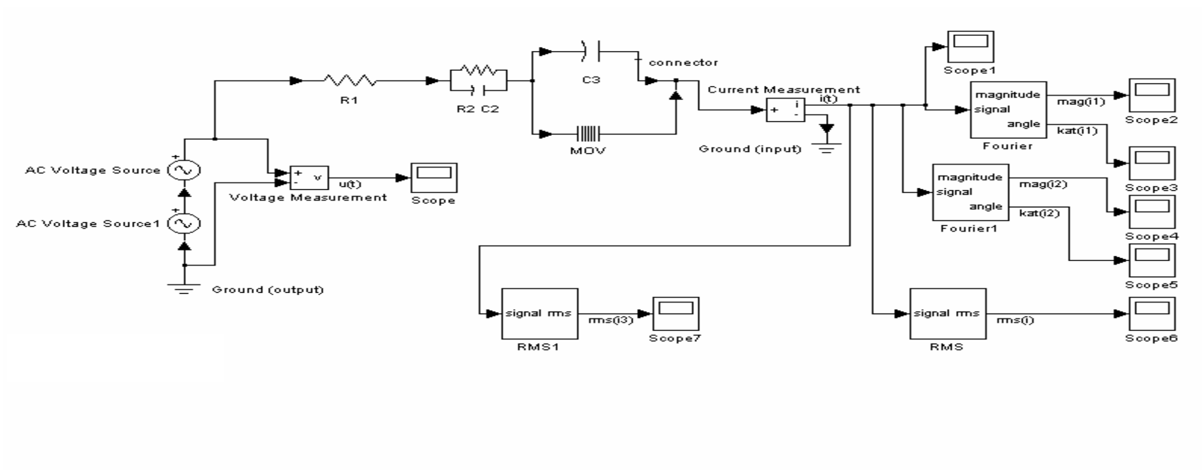

Fig. 1. The implementation of varistor model in Matlab program.

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The investigations were carried out for different supply voltages and different odd harmonics contents in the voltage signal. The results of the simulations are shown in Figs 2-4.

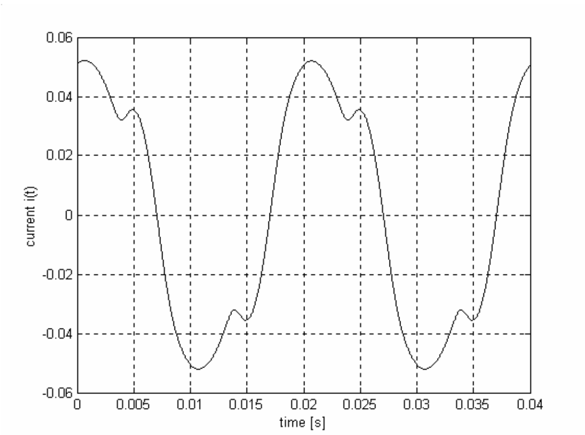

Fig. 2a. The varistor current for $U>U_c$

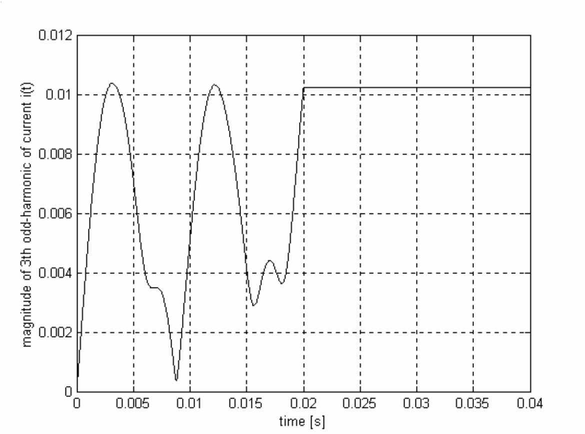

Fig. 2b. The magnitude of 3rd odd-harmonic of the varistor current for $U>U_c$

Figs 2a-b show respectively: the varistor current response and the third harmonic content in the studied voltage signal when the supply voltage is higher than U_c. Figs 3a-b show the same signals but for a voltage lower than U_c.

The results of a Fourier analysis of the third harmonics content in the varistor current response to the excitation voltage are shown in figs 2b and 3b. When $U>U_c$, one can clearly notice that the third harmonic is present in the varistor current signal. Special attention should be paid to Fig. 4 which shows the simulation results for a case when higher harmonics are present in the voltage lower than the continuous duty operation voltage. Also here the third harmonic is clearly visible in the varistor current signal. In Fig. 5 one can notice a significant increase in the third harmonic current as the harmonics content in the supply voltage increases. The high initial current value for voltage $U>U_c$ is a result of the operation of the varistor above U_c.

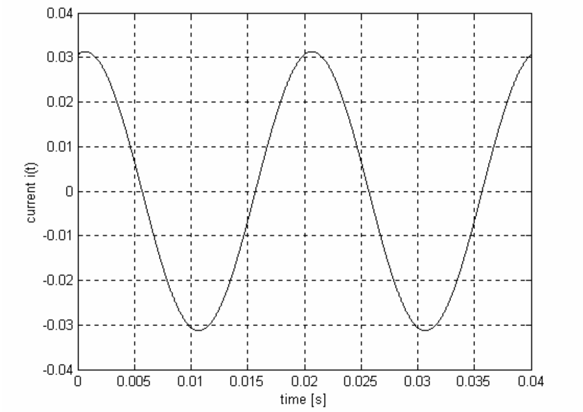

Fig. 3a. The varistor current for $U<U_c$

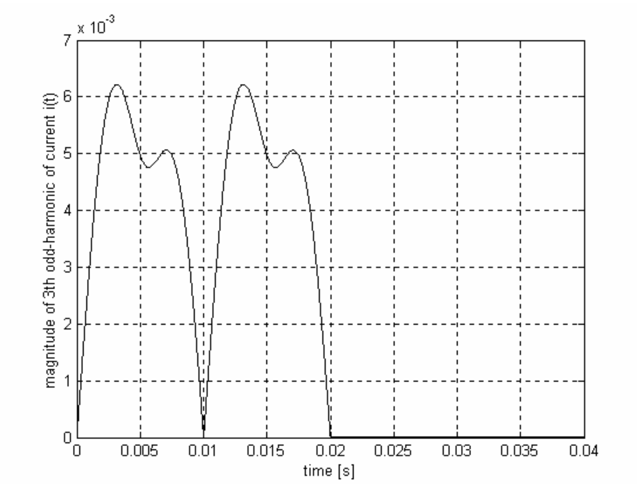

Fig. 3b. The magnitude of 3rd odd-harmonic of the varistor current for $U<U_c$

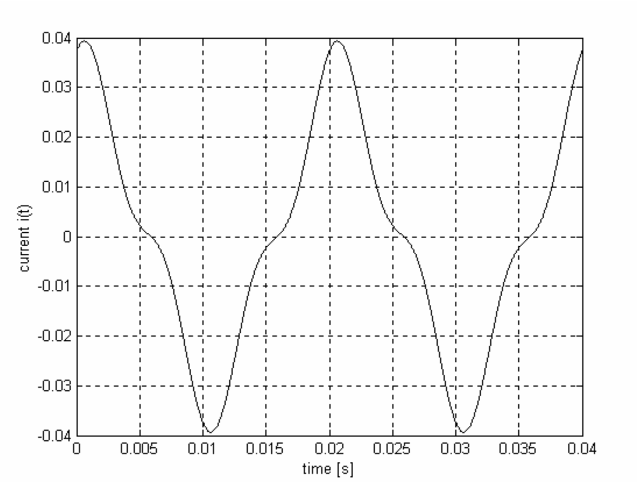

Fig. 4a. The varistor current (supply voltage U is distorted by 3rd odd harmonic)

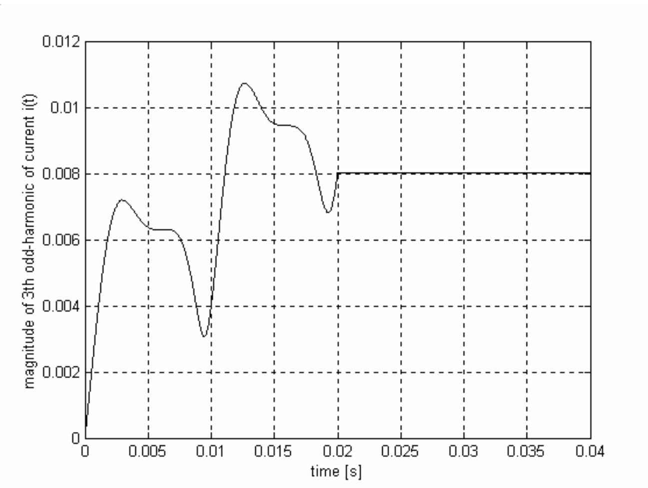

Fig. 4b. The magnitude of 3rd odd-harmonic of the varistor current (supply voltage U is distorted by 3rd odd harmonic)

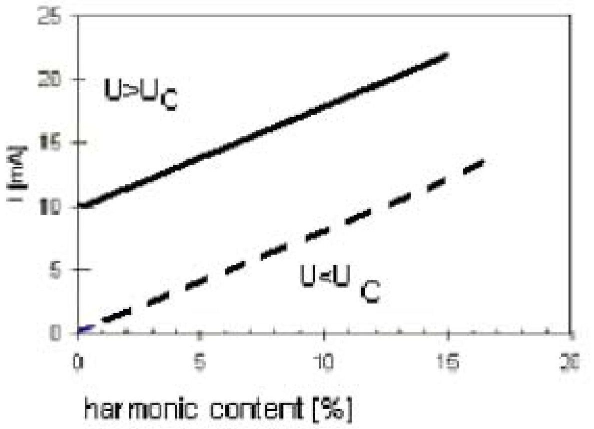

Fig. 5. Third harmonic current

CONCLUSION

The appearance of odd harmonics in the arrester's current signal may indicate the onset of ageing in the ZnO ceramics. It may also be caused by an increase in the voltage fed to the arrester above continuous duty operation voltage U_c. If higher harmonics appear in the supply voltage (as a result of the operation of wave converters, thyristor circuits, etc.) they cause errors in the measurements of the arrester conduction current resistance component. Thus an increase in the third harmonic current of the varistor conduction current is not always connected with ageing and may be due to measurement conditions. In the case of a diagnosis whose results indicate changes caused by ageing one should check the shape of the voltage curve. In this way erroneous interpretations of diagnostic results can be avoided.

It should also be noted that correct (stable) Fourier analysis results were obtained after 20ms since the beginning of computer simulation. This is a minimum time required for a Fourier analysis of the signal. The time can be reduced by applying other diagnostic techniques such as neural networks or wavelet transforms.

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