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DIAGNOSTICS OF ENDURANCE FOR HIGH RELIABILITY INTERFERENCE SUPPRESOR CAPACITORS

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Abstract: Non-linearity and noise phenomena, also partial discharge properties of a capacitor have been analysed to established criteria for segregation of interference suppressor capacitors into different endurance (sustainability) and reliability groups. It can improve the process of quality estimation of high reliability capacitors. The system for production testing of high reliability interference suppressor capacitors with implementation of this testing technique has been described. Selected experimental results of measurements for capacitors produced by MIFLEX (Poland) have been presented.

Keywords: interference suppressor capacitor, nonlinearity measurement, technical diagnostics, system for production testing.

1. INTRODUCTION

There are two general approaches to reliability problems in electronics: traditional (measurement results or times to failure are the basis to statistical calculations of reliability indicators) and contemporary one (parameters are measured before a failure enabling to built-in reliability to elements by means of the proper modification of the technological process (table 1). Quality and endurance tests are required for interference suppressor capacitors during production process. Such tests are destructive and long-lasting environmental (endurance) trials for selected samples. Therefore a simple, non-destructive and fast approach is needed for this pur s.

The problem can pose be solved by implementation into the production testing system some direct (nonlinearity or/and noise measurement) tasks. A dependence between these two phenomena was identified in the case of other electronic elements [1], and furthermore an explanation of the observed relation has been found to apply with the similar success to the both magnitudes. The choice of third harmonic index (TH), noise parameter (method and electrical circumstances of their measurement) and rules of classification into reliability group gives a possibility to predict a reliability of tested capacitors individually.

Table 1. Statistical and physical problems of reliability

matters	statistical theory of reliability	physics of reliability
assumptions	object reliability conditions are time function	object reliability conditions depends on its physical conditions
tested object	statistical sample	individual element
test method	long-term destructive testing	non-destructive testing
model of failure	random events	failure caused by hidden defects
main goals	reliability indicator evaluation, hypotheses verification about failure distribution	identification of the physical conditions of objects, searching hidden defects, analysis of object conditions before failure (in situ), evaluation of materials and technological processes influence on physical properties of the objects
results	statistical reliability prediction	individual reliability prediction, identification of degradation mechanisms

Increased level of TH in capacitors is mainly caused by instability of contacts, improper adhesion, electrodes and dielectric heterogeneity, weak contact between an electrode and a terminal, ferric oxide existence in dielectric particles, slow processes of insulating layer degradation or mechanical instability of a capacitor. Therefore these defect factors have direct influence on the lower endurance of capacitors.

It was established the correlation between TH and long term reliability (in foil capacitors it can be related to gas bubbles as defects). The TH is proportional to the extent of elementary nonlinearity. It comprises a built-in component (its level is to be considered as a nonlinearity mean value), excessive component (due to high contact resistance of any junction affecting the U-I curve, physical properties of the base material, defects and inhomogeneities in the material structure or interaction with the environment; equal zero at no defect present) and capacitor instability in time. It can be proved that TH is dependent on the signal rms value by the

third order and on the second order of the foil thickness. Therefore the dependence of the foil thickness is a good tool to find capacitors with weak spots. In case of polystyrene capacitors the utmost stability is required and it is fulfilled at the TH measurement.

2. MEASUREMENT OF NONLINEARITY AND FLUCTUATIONS

Interference suppressors are a special class of capacitors for use on the AC power line inputs to electronic or electrical equipment to eliminate or attenuate interference voltages originated in the units connected to the same AC power branch and prevent them from mutually disturbing their operations. Therefore they must endure very severe conditions existing on the AC power lines, especially including high voltage transients. There are two classes of these capacitors: Line-to-Line X2 Class, and Line-to-Ground Y2 Class. Polypropylene and polyester series are compatible, however polypropylene dielectrics are more popular worldwide and have smaller dissipation factor (tangent of loss angle measured at 1kHz). At large tangent of loss and operation above specified limits loss power may cause significant internal heating leading to destructive breakdown..

Interference suppression capacitors WXPC X2 0.1 µF, 0.68 µF, 0.22 µF and 0.33 µF 275 V~ produced by MIFLEX [2] were investigated. They have been made using a 7.5 µm thickness and 13.5 or 21 mm width polypropylene or polyester foil with a 2 mm margin.

The TH is proportional to the extent of elementary nonlinearity. It comprises a built-in component (a mean value of nonlinearity), excessive component (due to a high contact resistance, defects and inhomogenities in the material structure or interaction with the environment; equal zero at no defect present) and capacitor instability in time. If the first harmonic amplitude increases, the response of the modulated signal will grow allowing distinguishing the built-in from the unwanted nonlinearity components. The TH is dependent on the second order of the foil thickness.

The non-linearity of a capacitor is determined by a measurement of TH (30 kHz) generated by a capacitor when a 10 kHz signal is applied to it [3] – Fig. 1.

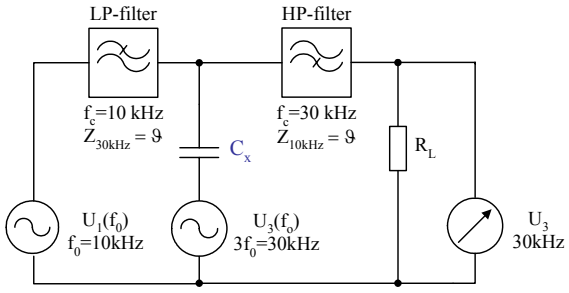

Fig. 1. Simplified diagram of the TH measurement

The third harmonic distortion is proportional to the m^{th} order of the applied voltage U_1. Experimentally measured mean values of the exponent m are equal 1.75 to 2.1 for measured capacitors, taking into account the mean value of the TH for all measured capacitors in the sample at the different voltage of stimulating harmonic signal $U_1[V]$. The mean value of the TH in the sample depends on the capacitance – the higher value of a capacitance the greater mean value of the TH distribution.

The THI value of capacitors (stemming from the same batch) with nominally the same capacitance should have the Gaussian distribution around the mean value. However, usually some components exhibit a higher level of TH due to defects or deviations in material composition. Exposing the batch to an accelerated life trial, the components having a higher value of TH will also be prone to exhibit inferior reliability. The actual value of TH in a good component should be found experimentally. The mean values of U_{3h}[µV] versus applied U_1[V] for several batches of MIFLEX capacitor samples (100 pieces each) and corresponding mean values is shown in Fig. . Third harmonic distortion is proportional to the m^{th} order of the applied voltage U_1. Experimentally measured mean values of the exponent m are equal 1.75 to 2.1 for measured capacitors.

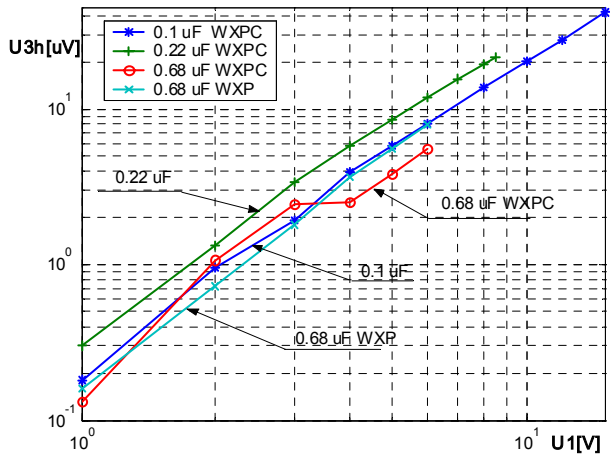

Fig. 2. U_{3h}[µV] versus applied U_1[V] for some type of MIFLEX capacitors

The actual distribution of the third harmonic level within the selected populations (stemming from the same batch samples 100 pieces each) is shown in Fig. 3.

Production samples of capacitors are subjected to a periodic life endurance testing to comply with international safety approval standards. These tests specify that the suppressor shall have 1.25 x rated voltage (X2) and 1.7 x rated voltage (Y2) applied for a period of 1,008 hours at an elevated temperature eg. of 100°C. In addition to the above voltages applied constantly, 1000 VAC is applied once each hour 100 miliseconds. Both the steady state and momentary (0.1 sec) 1000 VAC voltage is applied through a resistor simulating the impedance of AC mains. The combined stress of both voltages applied is proof that these suppressors are capable of withstanding high line conditions that are often present on the AC mains.

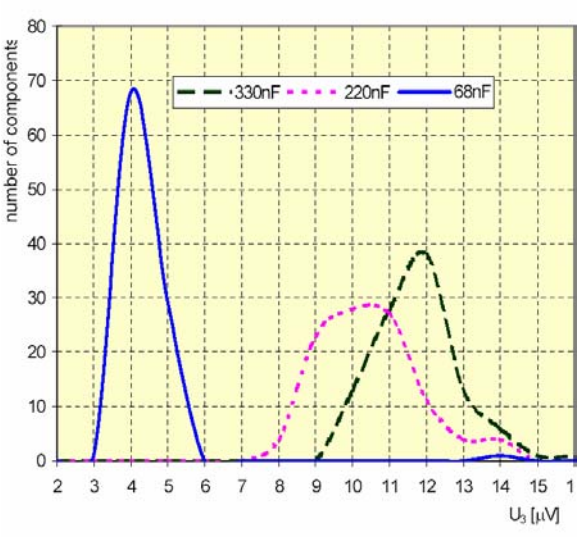

Fig. 3. Statistical distribution of the TH for selected single batches of foil capacitors

Standard endurance test was performed in the test chamber. Class X capacitors submitted to an endurance test of 1000h at upper category temperature and with 1.25 Voltage Rating (once every hour the voltage is increased to 1000 V_{rms} for 100 ms). After such a trial the mean malue of *m* parameter increases slightly (Fig. 4).

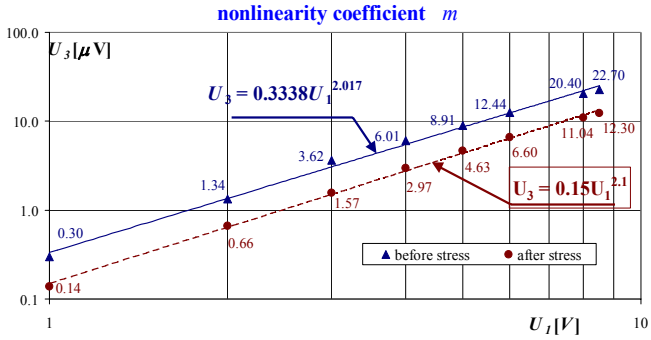

Fig. 4. The change of the U_{3h} slope versus applied U_1[V] (log-log scale) after the endurance test for the 0.22 µF capacitors

After the endurance test the capacitance and the TH values were again measured. The changes of C and TH distribution for the 220 nF capacitors are shown in the Fig. 5 and Fig. 6.

Generally, the capacitance after stress was decreased not more than 2% and the spread of C value remained at the same level. However the mean value of TH lowered about almost 50% but the standard deviation increased more than two times. One can expect that the capacitors having higher value of TH after such a trial are potentially more unreliable. The mean value of the TH in the sample depends on the capacitance – the higher value of a capacitance the greater mean value of the TH distriution.

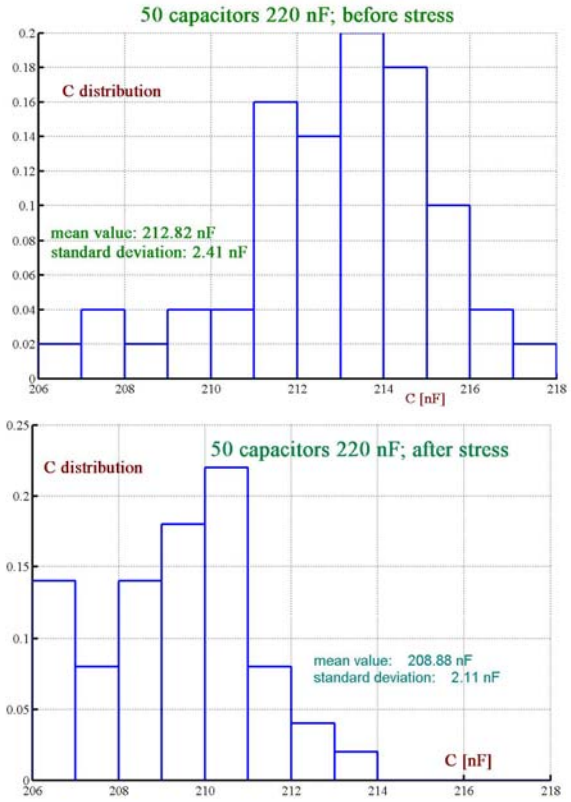

Fig. 5. The capacitance C distribution in the sample of 220nF capacitors before and after the endurance test

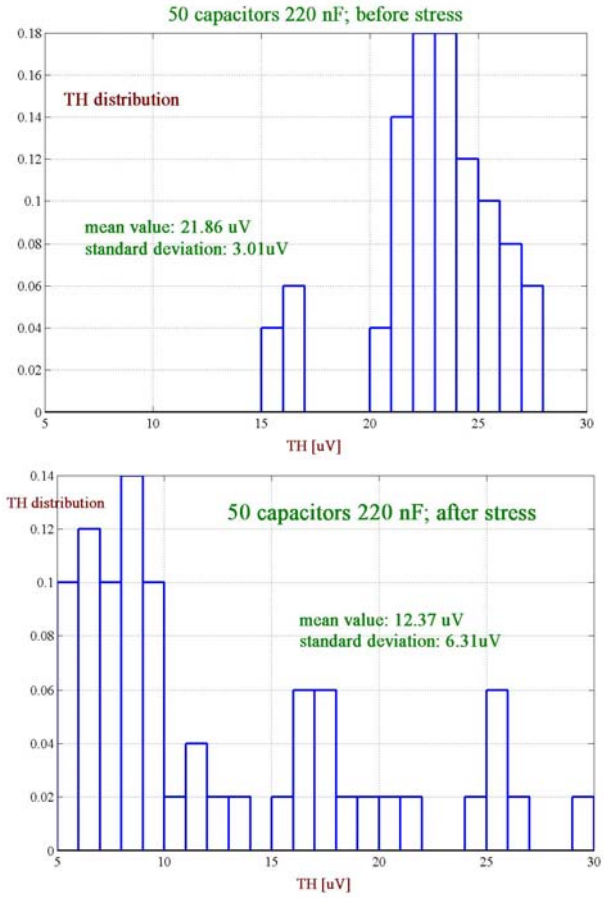

Fig. 6. The third harmonic TH distribution in the sample of 50 capacitors 220nF before and after the 1000h endurance

The TH fluctuations were measured (Fig. 7) using main modules of the instrument for TH measurement. Such a technique is especially useful instead of $1/\Delta f$ noise measurement when the appropriate resolution of noise power spectral density is extremely hard for obtaining at large amplitudes of a stimulating signal.

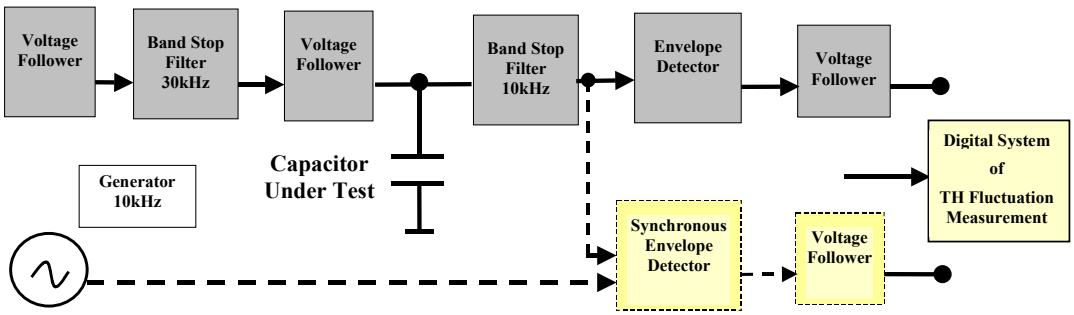

Fig. 7. The simplified block diagram of the system for TH fluctuation measurements

Additionally, partial discharges were measured using direct and bridge method of fluctuation measurements in the TETTEX 9120 system for effective noise suppression. For all capacitors 0.68 μF WXPC the inception voltage was equal 230-25 V - expectedly slightly greater (about 10V) than the extinction voltage. More immune to electromagnetic noise is PD detection based on acoustic emission

The correlation between the TH value and the breakdown voltage for these capacitors was also measured. It was proved that the correlation increases for higher amplitude of stimulating signal during TH measurement.

3. SYSTEM FOR PRODUCTION TESTING

To assure a high flexibility of manufacturing and cooperation with a general management in the quality domain, the system for testing capacitors [5] should fulfil high functional requirements with possibilities of its easy reconfiguration (Fig. 8 and 9) enabling to predict reliability of an every tested capacitor individually. The required effectiveness depends on the volume of produced capacitors. However it should be assumed that the total time needed for the single measurement cycle can not be longer than 1.5 s (including transportation time about 0.3 s).

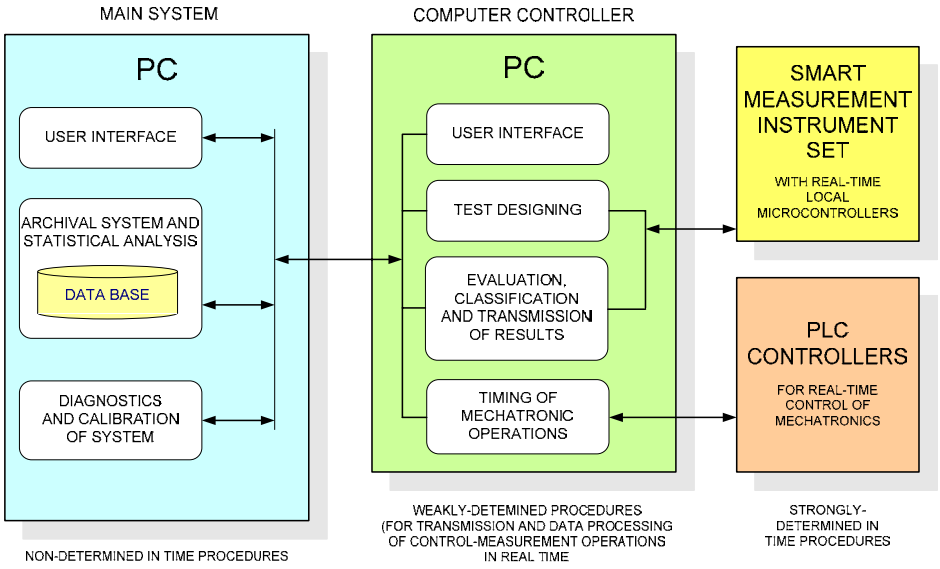

Fig. 8. Hardware-software framework of multitask measurement controlling system

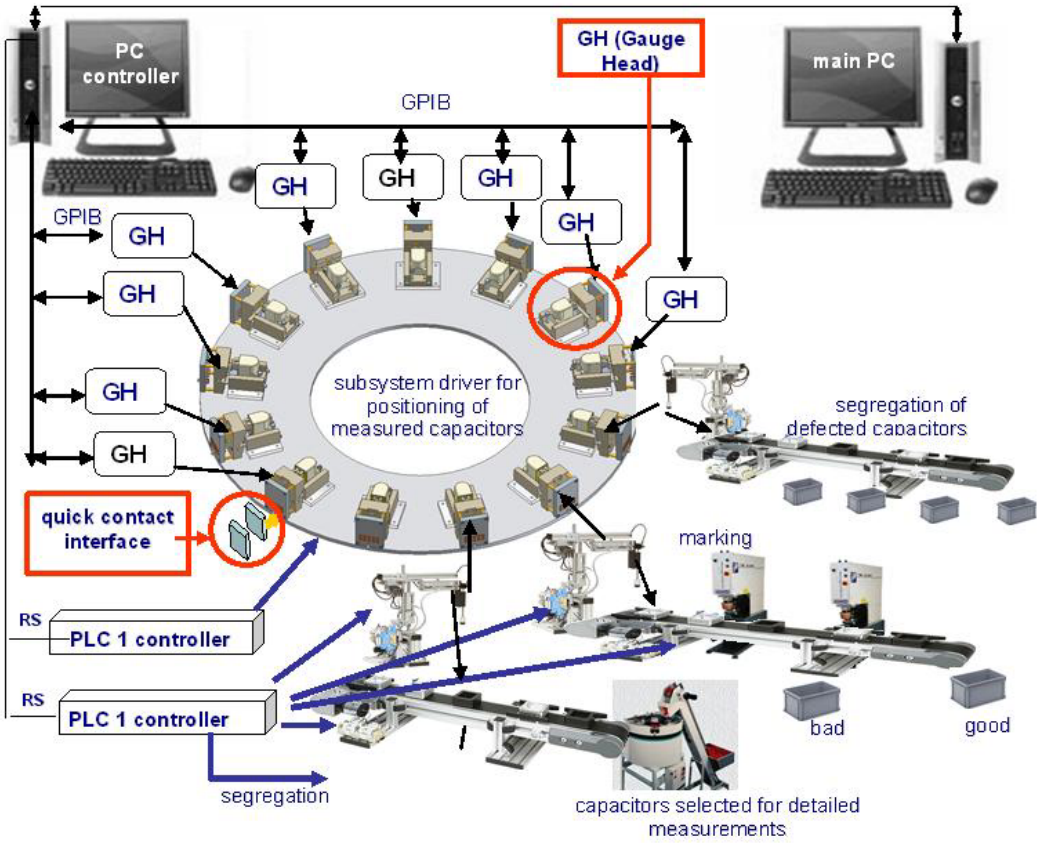

Fig. 9. Functional diagram of integrated system for diagnostics of interference suppressor capacitors

The system for kinematic control is equipped with the PLC microcontrollers having SAIA network interface. The measurement and the analysis of the result is realised by means of the interface IEEE 488.2. The software control of the system is organized as a set of virtual instruments enabling the following mode of works:

- control desk and visualization of manufacturing,
- programming of technological parameters,
- service mode,
- calculation of statistical parameters of tester work.

4. CONCLUSION

The experiments proved that for higher value of capacitance C the mean value of TH distribution for every batch of measured capacitors is also higher. The capacitors with a higher increment of TH level after stress have statistically a higher decrement of capacitance C.

The idea of quality and reliability control by nonlinearity and noise testing has been already proved for other electronic components [1,4,6]. To include the procedure of TH fluctuations testing for quality evaluation the detailed analysis of intensity and characteristic of fluctuations and the validation of the technique using the gradually increasing stress is needed.

The implementation of nonlinearity and fluctuation of TH measurements in the system for production testing of high reliability interference suppressor capacitors gives a possibility of individual testing of an every produced element for accepted criteria of testing and classification. In the presented production system the capacitors before encapsulation can be tested. It would result in earlier elimination of defected capacitors from the next operations.

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