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PRODUCTION TESTING OF HIGH RELIABILITY INTERFERENCE SUPPRESSOR CAPACITORS

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Abstract – The system for production testing of high reliability interference suppressor capacitors have been presented. The noise level and non-linear distortions in capacitors can be established as a new criteria for reliability selection of interference suppressor capacitors. New tasks (measurement of third harmonic and noise) and their realization in the system have been proposed. It can improve the process of quality estimation of high reliability capacitors.

Keywords: technical diagnostics, third harmonic measurement, noise.

1. INTRODUCTION

Appropriate standards demand quality and safety tests for all interference suppressor capacitors during their production. To assure a high flexibility of manufacturing and cooperation with a general management organization in the quality domain the system for testing capacitor parameters and classification of tested items should fulfil high functional requirements with possibilities of its easy reconfiguration and further development.

Investigations of interference suppressor capacitors reliability were carried out mainly using environmental trials. However they can not be applied in production testing due to their long duration and destructive character. Also accelerated tests do not give the accurate evaluation of their work in normal work conditions. A simple, non-destructive and fast quick approach is needed for reliability estimation.

The problem of reliability testing for capacitors can be solved by application of the production testing system realizing additionally non-linearity or/and noise measurements. It was considered appropriate to include measurements of both non-linearity and 1/f noise in the same programme because not only has a dependence between these two parameters identified in the case of other fixed elements, but also an explanation for the observed dependence on, for example, geometrical factors, has been found to apply with the similar success to the two magnitudes. The proper choice of third harmonic index, noise parameter (method and electrical circumstances of their measurement) and rules of classification into reliability group gives a possibility to predict individually reliability of tested capacitors [1].

2. SYSTEM FOR PRODUCTION TESTING OF HIGH RELIABITY CAPACITORS

The general block diagram of the production testing system is shown in Fig. 1. The system includes the measurement of selected parameter of 1/f noise and third harmonic index as measures of non-linearity (Fig. 2.). The software control of the system is organized as a set of virtual instruments enabling the following mode of works:

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

The Dynamic Data Exchange protocol enables of system data transmission to the general quality management system. The measurement of the capacitance and $\mathrm{tg}\,\delta$ is realized by means of the RLC Bridge 4263B Hewlett-Packard using HPIB interface. Breakdown and insulation strength tests are performed with special measurement comparators programmable from the system data base according to the IEC standards.

3. MEASUREMENT OF THIRD HARMONIC AND NOISE

The tests rely on the measurement of non-linearity for nominally linear parameters of interference suppressor capacitors, and we propose to use the level of non-linearity as a measure of reliability for a tested element. It has been proved experimentally that capacitors showing high non-linearity are less stable and have shorter lifetime. The dependence between reliability and non-linearity of capacitors is similar as between noise and reliability of the capacitors [2].

Any non-linearity consists of four components:

- unstable values in the time domain; in such a case the system should allow to overload components being tested for a short period what is useful for stressing the element ensuring an extended dynamic range of reliability measurements,

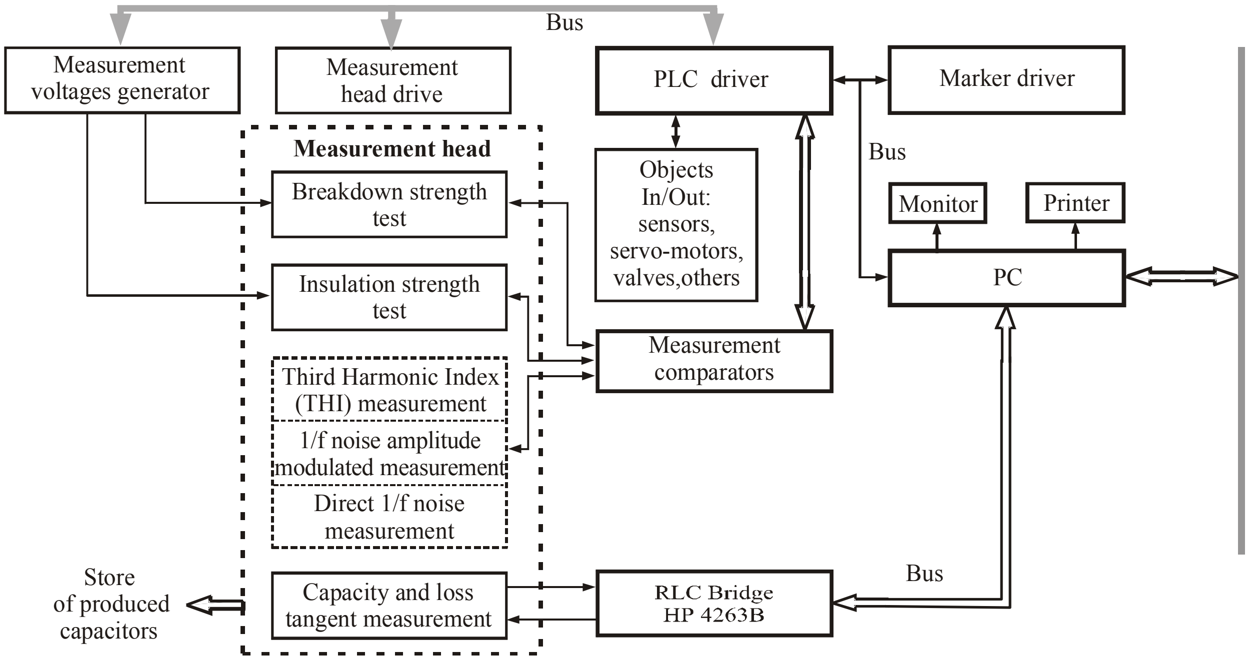

Fig. 1. General block diagram of measurement system for interference suppressing capacitors manufacturing

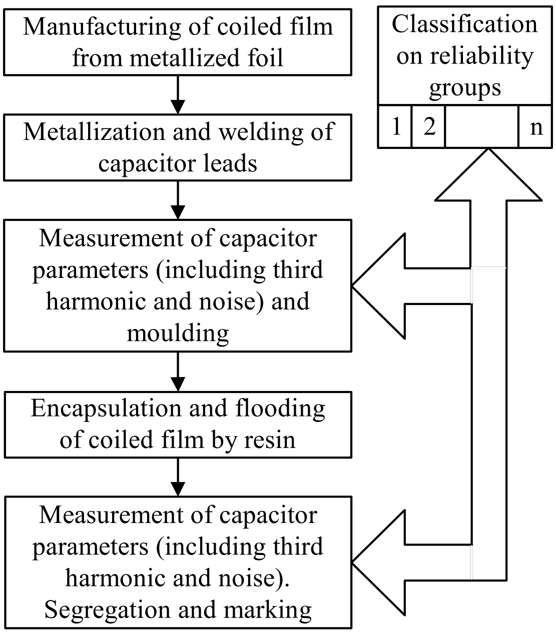

Fig. 2. Noise and non-linearity measurement procedure during manufacturing of capacitors

- unwanted – excessive or additive; too high contact resistance affected the shape of the V-I characteristics, physical properties of the material (defects, inhomogeneities), interference with the environment,
- built-in – additive, present to a certain extent in any device and should be considered as a non-linearity mean value,
- none (minimal) – e.g. contacts are disconnected (non-linearity drops to the background level).

A non-linearity is measured by stimulation of a tested capacitor using the pure harmonic signal and a selective measurement of the third harmonic of the stimulating voltage. It can be expressed (in decibels) as a ratio of the voltage of third harmonic to the voltage of applied sinusoidal signal. It was found that only a third harmonic has a non-negligible level and higher harmonics have not to be taken into account. A residual non-linearity should be assumed as no higher than –140 dB (-120 dB can be established as an acceptance level).

In such a way it is possible to select the capacitors with higher level of reliability. The determination in production process of the statistics for the Third Harmonic Index (THI) and noise distribution enables the improvement of a production technology.

The third harmonic voltage is proportional to the number or extent of non-linearities (non-linearity performance) as well as to the first harmonic. If the first harmonic amplitude increases, the response of the modulated signal will grow, following the power function. This allows often to distinguish the built-in and the unwanted non-linearity components from each other. However, this only works if the built-in non-linearity exponent is lower than that of the unwanted component.

Non-linearity and noise was measured for a total of 102 samples of WXP-224K X2 0,22 µF 10% 275 V~ foil interference suppressor capacitors (Fig. 3) produced by MIFLEX. They are intended for a suppression of common mode interference signals occurring mainly in power lines of both direct and alternate current.

The THI measurements were performed using Component Linearity Test equipment CLT1 type produced by Telefonaktiebolaget L.A. Ericsson (Sweden).

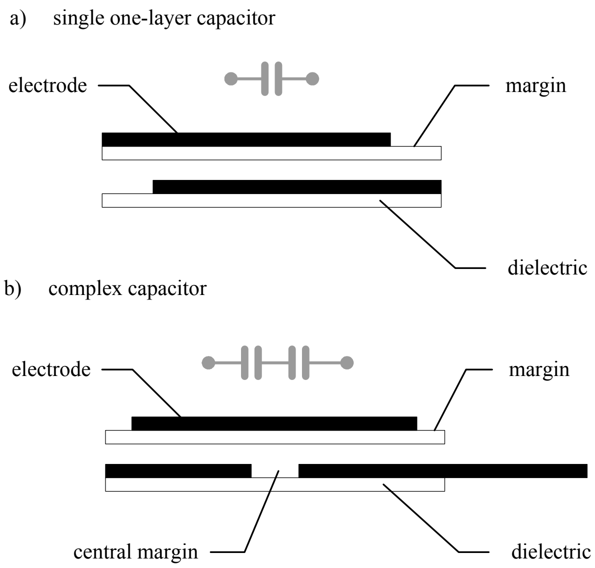

Fig. 3. Measured foil interference suppressor capacitor: a – single one-layer, b - complex

The harmonic signal $U_1 = 8.5\,V$ having frequency $f_1 = 10\,kHz$ was applied to the capacitor under test (Fig. 4a). The output voltage of tested component is achieved by multiplying the voltage of third harmonic by correction factor $F_c = Z_{30kHz} / N + 1$, where Z_{30kHz} is the impedance for the frequency 30 kHz, N – the ratio of the transformer. The special construction transformer with minimization of residual non-linearity and five ranges of transformation assures a matching of the generator and the selective voltmeter in the range from 3Ω to 10kΩ. The level of third harmonic was from 12.5 μV to 24 μV. Additionally, oscillations having the level between 0.5 and 3 μV occurred for about 20% of samples. The actual statistical distribution of the third harmonic levels within the population of measured capacitor samples fits the Poissonian distribution function provided that the parameter to evaluate is a voltage (the response in volts), or the Gaussian distribution function provided that the signal transfer function is processed.

The same signal can be used as a carrier for measurements of 1/f noise amplitude modulated (frequency translated flicker noise) as a 1/Δf noise. It enables the detection of noise fluctuations near a much large harmonic signal. Frequency conversion of shot noise and thermal noise in electronic elements under large signal periodic modulation has been well understood. However for 1/f noise the cyclostationary analysis can not be valid when the noise sources have a frequency dependence as in the case for 1/f noise. It is often assumed that 1/f noise is a stationary process even in the presence of a large signal carrier, but it has not been verified for modulation within the frequency range of 1/f noise. Our proposal of 1/Δf test circuit is based on the circuit used to measure frequency conversion in linear resistors [1]. However further investigation into the nature of 1/f noise under periodical large signal bias is required.

A direct 1/f noise measurement can be realised in the system using a test set-up shown in the Fig. 4b.

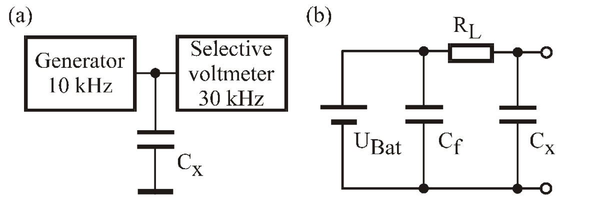

Fig. 4. Simplified diagram of (a) non-linearity and (b) noise test set-up (C_x – capacitor under test, C_f – filtering capacitor, R_L – load resistance, U_{Bat} – battery source)

Taking into account the preliminary achieved results, for the direct noise measurement the current noise spectral density divided by a square of the current is proposed as a quality indicator.

4. CONCLUSIONS

Accomplished production investigations enables to state that the increased level of THI 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
- mechanical instability of a capacitor.

The idea of quality and reliability control by noise and non-linearity testing has been already proved for resistors and semiconductors [2, 3].

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