MANUFACTURING AND TESTING HIGH VOLTAGE FILTER CAPACITORS

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Abstract: This paper presents the manufacturing and testing methods of 30kV and 33nF high voltage filter capacitors. One of the biggest advantages of small companies is that they are able to produce a high diversity of capacitors in small quantities. One of the prices of this flexibility is a higher level of manual manufacturing process in production. But this higher level of manual manufacturing does not mean lower quality in the final product. For high quality products in the high voltage industry, it is necessary to do routine tests in all of the products. For high voltage capacitors the following three tests must be done to ensure quality: voltage strength test, partial discharge test, capacitance and dissipation factor test. The capacitance and dissipation factor test have to be done at different voltage levels. The voltage strength test has to be done at least 20% higher than the rated voltage. This kind of test gives us information not only about the quality of the product itself, but about distribution of the capacitance for example, or about the strength of the production process, and about the quality management system of the company.

Keywords: high voltage filter capacitors, partial discharge, voltage strength, capacitance, dissipation factor

1. INTRODUCTION

High –voltage capacitors are very important components for electrical devices, as capacitive voltage dividers and coupling capacitors. From a power supply networks point of view, the high voltage capacitors are used in electrical substations, protection and monitoring systems, circuit breakers. These can be divided into six groups: high-voltage capacitors, high-power capacitors, starting capacitors, energy storage capacitors, filter capacitors and discharge capacitors [1]. In Table 1 is presented the history of capacitors [2].

Before the 1970s in high voltage capacitors manufacturing the most important dielectric was the impregnated kraft paper [3]. One of the most important advantages of the transition from impregnated paper to polymer film was

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represented by reducing drying time before impregnation [4, 5]. There are two manufacturing methods for high voltage film capacitors, one is the coil technology, which is which uses a capacitor winding machine, and the second is the stacking technique, which stacks the dielectric films [6, 7]. The capacitors analysed in this paper were built with coil technology.

In the following, partial discharge tests and capacity and dissipation factor tests at different voltage levels will be presented.

The work is organized as follows: section 1 presents a brief introduction regarding high-voltage capacitors; section 2 presents the technology for making condensers with coils; section 3 presents the high voltage tests for this type of capacitors; section 4 presents the conclusions of the work.

Table 1. History of capacitors.

Capacitors	**Years**
Water in Leyden Jar	1746
Franklin’s glass–metal foil	1750
Paper	1876
Electrolytic capacitor	1887
Wax paper–metal foil	1876
Self-clearing capacitor	1900
Mica	1909
Wound electrolytic capacitor	1927
Lacquer on paper	WWII
Polymeric films	Starting from 1954

2. COIL TECHNOLOGY CAPACITORS

This type of capacitor consists of a minimum of two thin 5 to 6 μm thick aluminium films, separated by an insulating material and impregnated with a dielectric liquid. Winding insulating material and aluminium films form the coil. There are some very important requirements for aluminium electrodes like, must be clean, mechanical strength, regularity. It is forbidden to use electrodes with folds and tears [8]. Capacitors manufactured with foil-film technique have to be dried. This is necessary to remove possible moistures. The next step is to encapsulate the capacitor. The dielectric liquid is introduced in the capacitor with help of an automatic mixing machine which does not introduce air and degasses the liquid under vacuum to remove possible air bubbles. It is very important to eliminate all air bubbles from dielectric liquid. The most negative effect of air bubbles is that, during the capacitor functioning in air bubbles appear partial discharges, which decrease the maximum applicable voltage and determine a fast aging of the capacitor [9].

3. TESTING OF HIGH VOLTAGE CAPACITORS

3.1. Partial discharge test

The partial discharge is a dielectric breakdown which appears in small portions of dielectrics. The partial discharge appears when the strength of the electric field is higher than the insulation of the dielectric material in that point [10]. This situation appears when the dielectric contains an inner impurity like an air void for example. In Figure 1.a is presented as an energized dielectric material without any impurity or structural defect. The electric field inside the dielectric is homogenous. In Figure 1.b there is an air void impurity. Typically, the electrical permittivity of air is lower than electrical permittivity of a dielectric material, this is the reason why the electric field will be higher in air-void. That means in place there should first appear an electric discharge phenomenon if the level of electric field reaches the necessary strength. Another result of this impurity is that the electric field is nonhomogeneous.

In Figure 2 the partial discharge measurement system is presented. It contains the following components:
- voltage regulator from 0V to 400V;
- step up transformer up to 200kV;
- Coupling capacitor 200kV 1n;

- PD detector and measuring impedance.

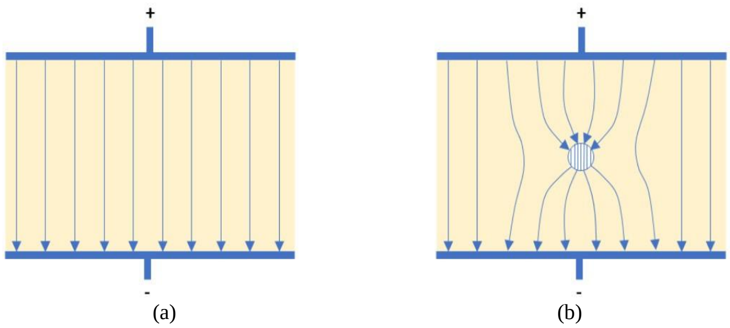

Fig. 1. Two energized solid dielectrics [11].

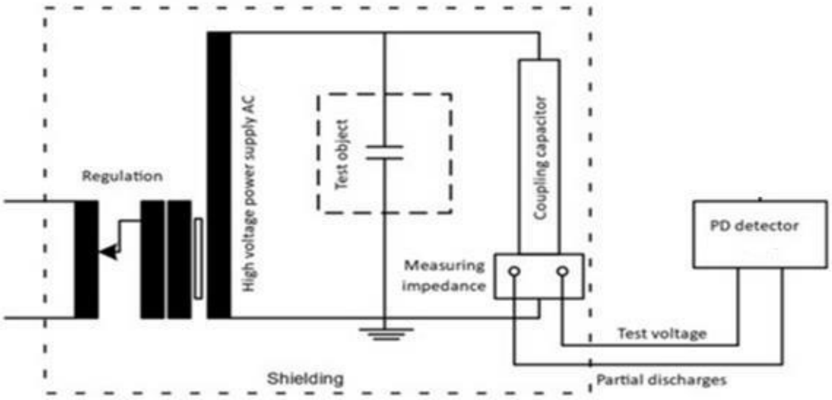

Fig. 2. Partial discharge measurement system.

Because the measurements are very sensitive to electromagnetic noises, all the measurement systems are located in a shielded room. An important step in the measurement of partial discharge tests is the calibration of the system. The partial discharge appears inside of the capacitor. The measurement system does not have direct access to the inside of the capacitor however, it has indirect access through the capacitor body. This is the reason why, before the measurement of a capacitor type, the measurement system has to be calibrated. The calibration has to be done with measurement setup from Figure 2, and the system does not have to be not switched on. The calibrator, which is a known impulse generator, has to be connected in parallel with the capacitor. The level of impulse depends on the capacitance of the capacitor. For example, in the case of a 1nF capacitor, a 20 pC impulse is enough, but for a 33 nF capacitor a 100-pC impulse has to be used. During the calibration test the measurement system gives information about background noises too. The background noise is influenced by the capacitance of the measured capacitor. Figure 3 presents the calibration and measured background noise in the case of 1nF 100kV capacitor. The influence of the capacitor is low, and the background noise is under 1pC. Figure 4 presents the calibration and the measured background noise in the case of 33nF 30kV capacitor. From this figure one should note that in this case, the background noise is influenced by the capacitor. The noise is around 20pC. Figure 5 presents the measurement result of a capacitor free from partial discharge. Figure 6 presents a measurement result of a capacitor with partial discharges.

3.2. Capacitance and dissipation factor test

In the case of an ideal capacitor, the dissipation factor is zero and the current vector is faster, with 90° to voltage vector. In the case of a real capacitor there are loses determined by surface currents or dielectric losses due to polarization and conduction. Figure 7 presents the high voltage capacitance and dissipation factor measurement system. The measurement system contains the following components:
- voltage regulator from 0V to 400V;
- step up transformer up to 200Kv;
- C1- the unknown capacitor;
- R1 - a series resistance representing dielectric loss in the C1 capacitor;
- R3 – a non-inductive resistor;
- R4 – a variable non-inductive resistor;

- C2 – a standard lossless capacitor filled with SF6 gas;
- C4 – variable capacitor in parallel with R4.

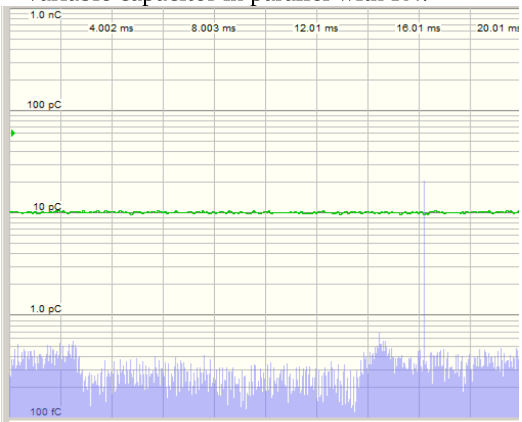

Fig. 3. Calibration and background noise of a 1nF 100kV capacitor.

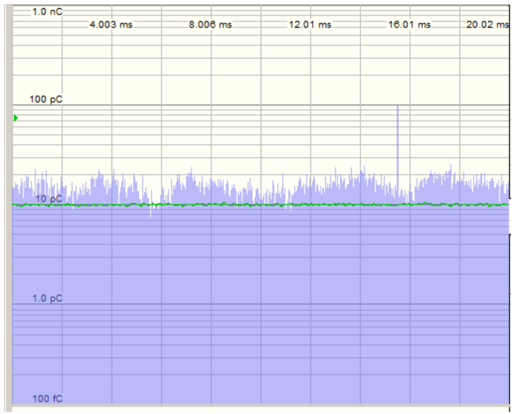

Fig. 4. Background noise of a 33nF 30kV capacitor.

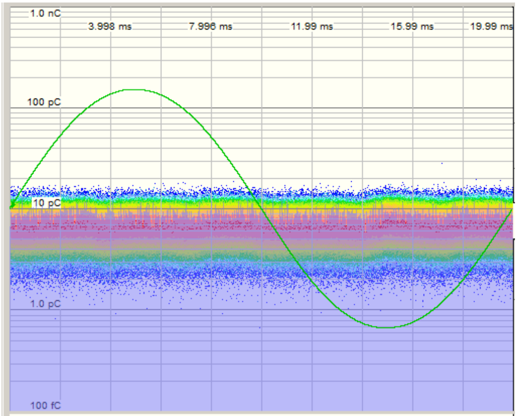

Fig. 5. Capacitor without partial discharges.

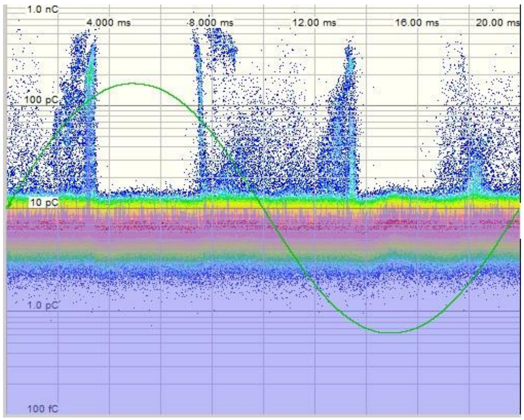

Fig. 6. Capacitor with partial discharges

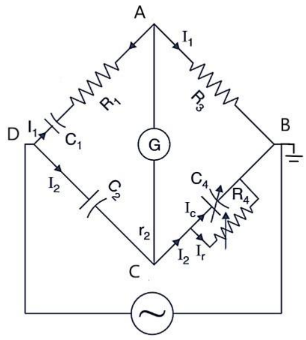

Fig. 7. Schering bridge measurement system.

The difference between high voltage and low voltage Schering bridge measurement system is given by the ground connection from B point. This is very important aspect from a safety point of view. The C1 and C2 capacitors have high impedances. The A-D and the C-D arms are under high voltage. The dissipation factor of C2 capacitor has to be zero. For this reason, this capacitor is an SF6 gas capacitor. The C1and R1 constitute the capacitance and the losses of the test capacitor. R3, C4, R4 have lower impedances and low voltage components. With the help of C4 and R4 the bridge should be balanced. After the balancing of the bridge, the capacitance and the dissipation factor have to be measured. The measurements have been completed at five different voltages.

3.2.1. Measurement results

During the test, 42 capacitors were tested. The capacitors were manufactured at four different times. The first 11 capacitors belong to the first group, the next 7 belong to the second group, the next 8 belong to the third group, and the last 16 belong to the fourth group. Figure 8 show the capacitors' values measured at five different voltages. Figure 8 demonstrates that the capacitances are not influenced by the different levels of the voltages. The nominal capacitance of the capacitors is 33nF, and the accepted tolerance is +10/-5%. The results show that the capacitances are higher than the nominal value and lower than 110% of nominal capacitance which is 36,6nF. The largest measured capacitance is lower than 35,5nF. The diagram also reveals that in the case of the first two groups, there ia a slight increase in capacity.

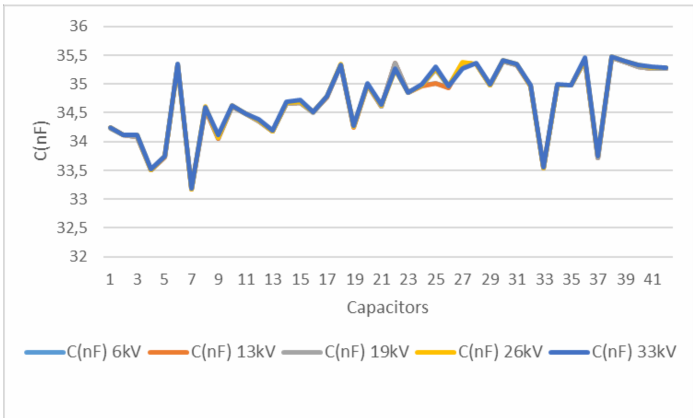

Fig. 8. Measured capacities at different voltages.

Figure 9 emphasizes the dissipation factor of the capacitors measured at five different voltages.

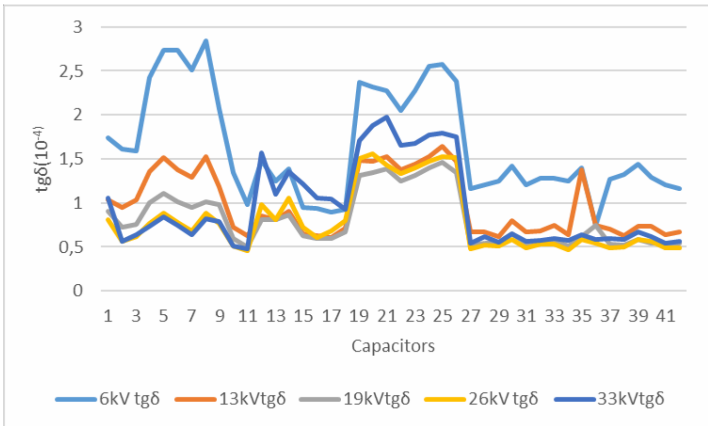

Fig. 9. Measured dissipation factor at different voltages.

The dissipation factor measured at 6kV is the highest compared with the rest of the results. The four groups of capacitors should be analysed from measurement results. Inside the groups the measurements results are quite constant. Another information regarding the measured dissipation factor at different voltages is that, at lower voltages, the dissipation factor is higher than in the case of high voltages. The highest dissipation factor is measured in the case of 6kV and it is 2,84 x 10^{-4}.

4. CONCLUSIONS

The present paper highlights the manufacturing method of foil-film high voltage capacitors and the necessary measurements to prove the quality of capacitors. The measurements were done on a 33nF, 33kV filter capacitors type. This type of capacitors should be used for example, on electric locomotives to filter the input signal from the power supply line [12-14]. Due to high capacitance, the background noise measured on capacitor is higher than in the case of a small capacitance. Typically, it is 20 times higher. In the case of partial discharge measurement, it is very important to have very good capacitor connections to the measurement system, because a poor quality connection produces a false measurement result. During capacitance measurement, the highest difference between the maximum and the minimum measured capacitance is 2,31nF. In the case of dissipation factor the difference between the maximum and the minimum dissipation factor is 2,38 x 10^{-4}. To conclude, during manufacture, the variation of capacitor characteristics is extremely low.

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