7. Dielectric Spectroscopy Test

SAFETY MEASURES: Interlocks are **not** provided to prevent high voltage to be switched on while the gates/ doors are open. Therefore only one student is allowed to be inside the high-voltage cage, taking special care of high-voltage equipment. Special safety rules for the High Voltage laboratory must be read, understood, signed and always followed to every detail!

7.1 Objectives

The student must gain the following knowledge and comprehension in the following topics:

- Discuss the aim for conducting dielectric response measurements and describe the theoretical approach.
- Describe the dielectric spectroscopy equipment.
- Evaluate and understand the basics of the loss angle frequency dependence and the concept of the complex permittivity.
- Measure the moisture content and oil conductivity of the inductive voltage transformer.

7.2 Why dielectric spectroscopy?

The goal is to evaluate the condition (e.g., amount of degradation) of the inductive voltage transformer insulation, which can be obtained by means of dielectric frequency response tests. The effects of moisture and ionic contamination lead to the degradation of the oil-paper and therefore accelerate the insulation aging. There are three dangerous situations: i) it decreases the dielectric withstand strength, ii) accelerates cellulose aging, and, iii) causes the emission of gas bubbles at high temperatures.

In order to measure the moisture content and the oil conductivity, the DIRANA device from OMICRON will be used. DIRANA derives the moisture content in paper or pressboard from properties such as polarization current, complex capacitance, and dissipation factor. Each of these parameters is strongly affected by moisture. The dissipation factor plotted together with the frequency range can give information about the moisture content as shown in Figure 1.

- **Frequency range: 10 Hz – 1000 Hz.** Dominated by the cellulose insulation, cables and connection techniques.
- **Frequency range: 0.01 Hz – 1 Hz.** Dominated by the oil conductivity.
- **Frequency: 0.003 Hz.** Dominated by insulation geometry.
- **Frequencies bellow 0.0005 Hz.** Dominated by the cellulose insulation.

Moisture will be determined basically by this low frequency range.

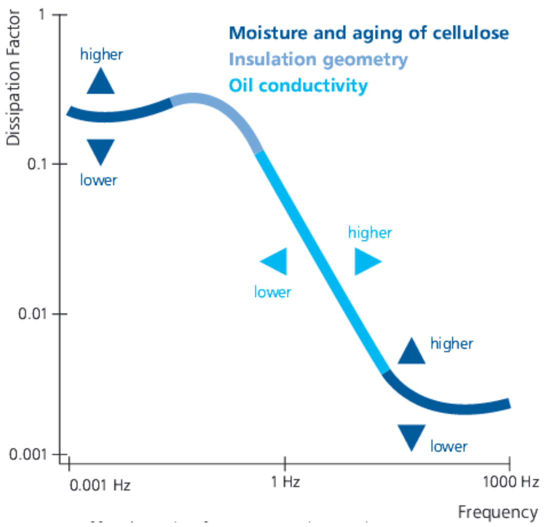

Figure 1. Factors affecting the frequency-dependent dissipation factor.

On this basis, the **student** must describe how the previous curve shifts in case of:

A. Different moisture content.
B. Different aging conditions.

7.3 Test setup

Figure 2 illustrates the setup containing DIRANA device and the test object: ABB inductive voltage transformer. The student should provide a description of the electrical connections between DIRANA and the test object.

Figure 2. Dielectric spectroscopy laboratory setup.

Please draw the schematic of the dielectric spectroscopy test setup.

7.4 Experimental results: moisture content and conductivity.

DIRANA is used to conduct dielectric spectroscopy test to analyze the properties of insulation systems across a wide frequency range (e.g., 1000 Hz to 0.0001 Hz).

The student will be able to measure:

- Dissipation factor for a wide frequency range.
- Moisture content of the solid insulation.
- Oil conductivity.

At the end of the experimental test, the student must be able to:

- Define the moisture category. Is it necessary to apply any dry methods?
- Discuss the results and give an assessment of the condition of the voltage transformer.

Moisture Categories	**Value**
Dry	< 2.2 %
Moderately wet	>2,2 % and < 3.7 %
Wet	>3.7 % and < 4.8 %
Extremely wet	>4.8 %

7.2 Why dielectric spectroscopy?

How the previous curve shifts in case of:

A. Different moisture content.

B. Different aging conditions.

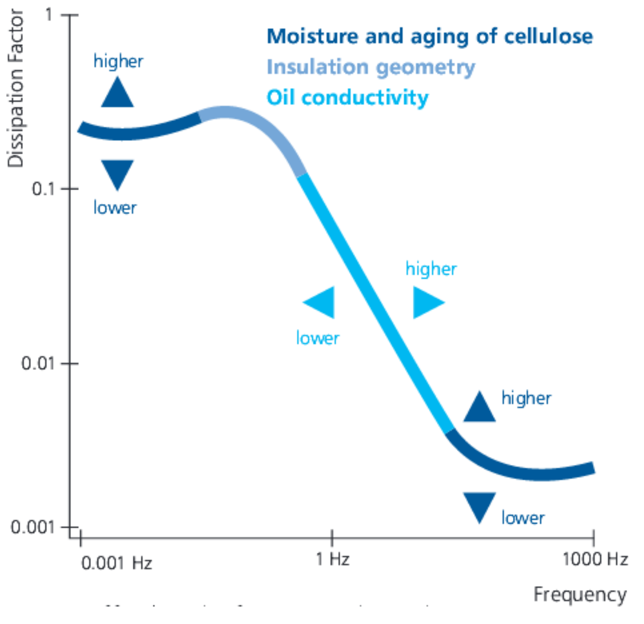

Figure 7.1: Factors affecting the frequency-dependent dissipation factor[1].

A: For a high moisture content (4%) the dissipation factor will increase in low and high frequency range as you can see in figure 7.1. In this two ranges the moisture content a high impact to shift the curve. Low moisture content shifts the curve to lower dissipation factor in low and high frequency range.

B. If the aging process is advanced on the insulator, the curve will shift to the right. This means that the dissipation factor for the medium frequency range (1 Hz) will increase compared to an isolator that does not show aging yet. In low frequency range the dissipation factor will have the same value. For high frequency range (1000 Hz) the dissipation factor will increase because of the shift to the right of the curve.

7.3 Test setup

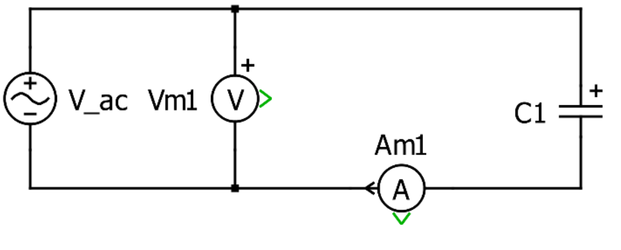

Figure 7.2: Schematic of the dielectric spectroscopy test setup.

For the dielectric spectroscopy test an insulator is used instead of a transformer. This is shown in the diagram as a capacitor, see Figure 7.2. For the power supply the DIRANA device is used, which also serves as an analyzer. The DIRANA can generate voltage at different frequencies. For the dielectric spectroscopy test the isolator is supplied with voltage in the frequency range from 1mHz to 5kHz. Since DIRANA is also an analyzer, the voltage and the current can be measured simultaneously. From 100 mHz, the supply is switched from 100 V AC to 100 V DC to accelerate the process. In addition, the calculation method changes from FDS to PDC. PDC measures the polarization current and the depolarization current and transfers the currents to the frequency domain to obtain the dissipation factor.

7.4 Experimental results: moisture content and conductivity

Define the moisture category. Is it necessary to apply any dry methods?

The Transformer belongs to the moisture category extremely wet (m. c.: over 4.8%). The figure 1 shows the measurement curve from the transformer (blue) comparing a simulate curve for a moisture content over 5.2% (red). The blue curve is located in large parts above the red curve. Based on these observations it can be concluded that the transformer has a moisture content of over 4.8 % and therefore belongs to the extremely wet category. Therefore it is necessary to use some dry methods to reduce the moisture content.

Discuss the results and give an assessment of the condition of the voltage transformer

In lower frequency you can see that the value of the dissipation factor from the transformer is higher than the red reference curve, as you can see in figure 7.3. The aging process in cellulose is well advanced. In the frequency domain 0.1 to 1 the red and the blue curve quit similar behavior.1 Hz and higher the dissipation factor from the transformer is higher than the dissipation factor from the simulation curve. This means that the oil conductivity from the transformer is higher than the simulation one.

The transformer is in not so good condition. If you compare the curve with a reference curve for a moisture content 5.2 %, the transformer dissipation factor is almost every frequency higher or equal to the reference value(red curve). The transformer should be subjected to a drying method so that it can continue to be used in the future.

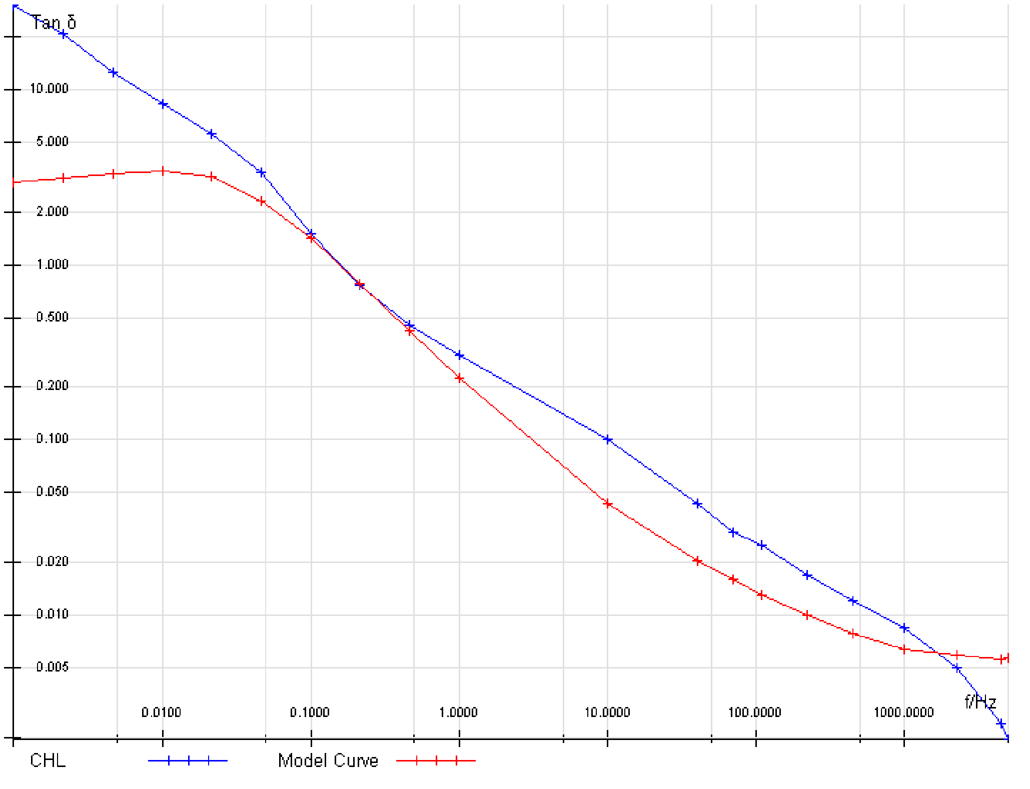

Figure 7.3: Result of the test.

Bibliography

[1] Lab exercise introduction 7