# ASPECTS REGARDING THE DETERMINATION OF THE TANGENT OF THE DIELECTRIC LOSS ANGLE TO THE 400 MVA POWER TRANSFORMERS ENTERING IN THE CONFIGURATION OF EVACUATION ELECTRICAL POWER STATION

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**ABSTRACT**: *The paper has as a reference point, the importance of monitoring the value of the dielectric losses angle tangent of the power transformers, in order to prevent the occurrence of defective modes. For this reason, the norms in force establish annual prophylactic verifications, materialized by drawing up checklists, on the basis of which a database can be compiled, showing the history of the evolution of dielectric losses.*

**KEY WORDS**: *power transformer, dielectric measurements, dielectric loss angle tangent, electrical transformer station.*

## 1.INTRODUCTION

From a theoretical point of view, the exposure of dielectrics to the action of the electric field has the effect of converting some of the electrical power into heat. The amount of power lost through thermal effect is called loss of dielectric power or dielectric losses. These dielectric losses have two components[1-4]:

- A component identified by the electrical conductivity of the dielectric, the value of which is proportional to the square of the conductivity current $i_{cond}$ and represents the Joulle effect losses. This component occurs irrespective of the nature of the electric field (continuous current or alternative current).
- The second component is characteristic only to the variable electric field, and it is identified with the losses due to the friction between the dielectric particles in their direct reorientation in the polarization process. This component is typically much larger than the first component and frequently, is the one that reflects the dielectric losses.

In the case of the dielectrics where relatively small losses appear, the angle(φ) between the electrical current and voltage has a value as close as possible to $90^0$. The dielectric loss value increases at the same time as the angle φ decreases, relative to the value of $90^0$. For this reason, for the loss analysis in a dielectric, a complementary angle (δ) is used, which value is below $90^o$, known as "tgδ" [1-4]. Dielectrics for which tgδ has a relatively small value are characterized by relatively small losses, and dielectrics for which tgδ is relatively large, are characterized by relatively large losses. The complementary angle tangent (tgδ) can be defined as the tangent of the dielectric loss angle [1-4].

The loss of active power($P_a$) in the dielectric of a real capacitor can be determined by the expression [4]:

$$P_a=U_aI=RI^2 \qquad (1)$$

The value of the electric current intensity associated with the convector can be determined by the expression [4]:

$$I=\frac{U}{\sqrt{R^2+\left(\frac{1}{\omega\cdot C}\right)^2}}$$

where:

$\omega=2\pi f$ – the pulse.

By replacing the value of the electric current (I) in relation (1) we obtain:

$$P_a = \frac{U^2 \cdot R \cdot \omega^2 \cdot C^2}{R^2 \cdot \omega^2 \cdot C^2 + 1} \quad (3)$$

The tangent of the loss angle in the capacitor capacitance C of the dielectric, is determined by the expression:

$$tg\delta = \frac{U_R}{U_C} = \frac{I \cdot R}{I \frac{1}{\omega \cdot C}} = R \cdot \omega \cdot C \quad (4)$$

In this case, from expression (3) we obtain[5]:

$$P_a = \frac{U^2 \cdot \omega \cdot C \cdot tg\delta}{1 + tg^2\delta} \quad (5)$$

Since tgδ is a small number, it can be admitted that $tg^2\delta \approx 0$ and for the losses in the dielectric it is definitively obtained that [5]:

$$P_a = U^2 \cdot \omega \cdot C \cdot tg\delta = 2\pi \cdot f \cdot U^2 \cdot C \cdot tg\delta \quad (6)$$

If the above expression is divided by the dielectric volume, the losses for the dielectric volume unit can be obtained. Without this, however, according to the relationship (6), the conclusions can be drawn for the cases where the dielectric losses have the same value.

These are cases where voltage (U), frequency (f) or both have relatively high values. In order to avoid high dielectric losses at high frequencies and in some cases relatively high voltages, it is necessary to use dielectrics where the tangent of the loss angle is very low (tgδ <0.001), these dielectrics known as high frequency dielectrics [5].

Dielectrics in which the loss angle tangent has a very low tangent to the loss angle is more than 0.001, which is called the low frequency dielectrics [5].

# 2.HOW TO DETERMINE THE DIELECTRIC LOSS ANGLE TANGENT TO 400 MVA TRANSFORMERS

The monitoring of the tangent of the loss angle (tgδ) in the dielectric of a power transformer, which enters the configuration of the electrical transformer stations, is a prophylactic check which, along with other reference indicators (insulation resistance, absorption coefficient, dielectric rigidity of insulating oil) establishes at the time of the inspection the insulation condition of the electrical transformer as a whole.

This set of prophylactic checks shall be interpreted by the maintenance personnel as a whole and not individually except for the insulating oil (from the transformer tank) which, following specific checks, may be reconditioned or replaced if the reference parameter values exceed the values established by the norms in force.

The determination of the tangent of the dielectric loss angle to the electrical power transformers requires, as a preliminary phase, the measurement of the insulation resistance and the determination of the absorption coefficient at time intervals of 15 seconds and 60 seconds respectively [5]. Measurement of the insulation resistance and determination of the absorption coefficient at time intervals of 15 seconds and 60 seconds, respectively, is carried out in a compulsory manner and after determining the tangent of the dielectric loss angle.

According to the prophylactic verification norms, the determination of the insulating state parameters (insulation resistance measurement and tgδ for insulation of windings, respectively dielectric rigidity and tg δ for oil in the tank and conservator) will be performed at intervals of [5]:

- ➢ 1 year for transformers with nominal apparent power $S_n$ <63 MVA, and rated voltage <110 kV;
- ➢ 6 months for transformers with nominal apparent power $S_n$ > 63 MVA, and rated voltages 110 kV, 220 kV, 400 kV.

The results of the measurements shall be recorded in a test report, indicating the temperature of the insulation at which the measurements were made.

According to the verification norms, the measurements are carried out at an insulation temperature of not less than $10^oC$.

Table 1 shows the admissible limit values for tangent dielectric loss angle (tgδ) [5], depending on the nominal voltage of the windings of an electrical transformer (in service).

Table 1

| ***Crt. no.*** | ***Rated voltage of the transformer windingsi [kV]*** | ***Values tgδ for temperatures of 20º C and 50º C*** | |
|---|---|---|---|
| | | 20º C | 50º C |
| 1. | < 10 | 4% | 11% |
| 2. | 10-60 | 2,5% | 7% |
| 3. | 110-220 | 2,5% | 7% |
| 4. | 400 | 1,5% | 2,5% |

The measurements of the dielectric loss angle tangent to the two-winding power transformers refer to the following working variants:

IT – (JT + ground)
JT – (IT + ground)
where:
IT-high voltage winding,
JT-low voltage winding

If the determination of the tangent of the dielectric loss angle can not be achieved at the measured temperature in the manufacturing plant, it is necessary to recalculate the tangent of the dielectric loss angle, according to a correction coefficient (determined by the temperature difference Δt, set between the factory temperature and measured temperature) whose values are shown in Table 2 [5]:

Table 2

| ***Δt [ºC]*** | 1 | 2 | 3 | 4 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***k*** | 1,03 | 1,06 | 1,09 | 1,12 | 1,15 | 1,25 | 1,51 | 1,75 | 2 | 2,3 | 2,65 | 3 | 3,5 | 4 | 4,6 | 5,3 | 6,1 | 7 |

The recalculation of the tgδ value for a certain winding temperature of a power transformer is made by means of the expression[5]:

$$tg\delta_r = tg\delta_m/k \qquad (7)$$

where:

$tg\delta_r$ - the tangent of the recalculated dielectric loss angle

$tg\delta_m$- the tangent of the measured dielectric loss angle

k- correction coefficient

The scheme for determining the dielectric loss angle tangent is shown in the figure1[6].

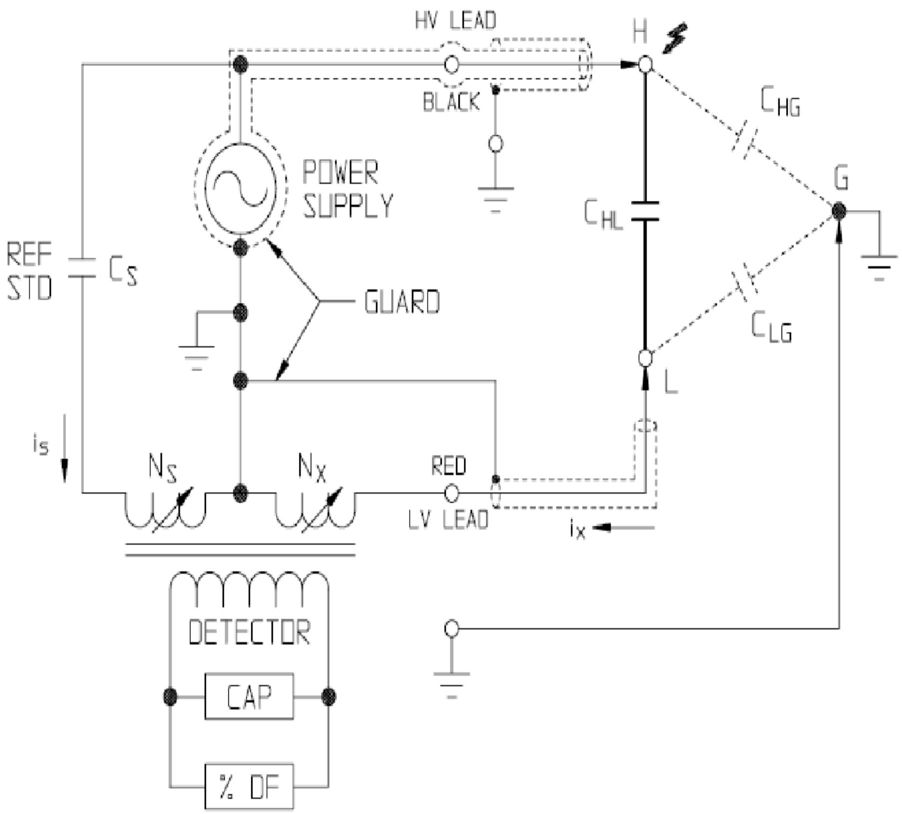


Figure 1. Simplified scheme for determining tgs using a Delta-2000 kits

In the paper we started from the dielectric loss angle tangent values measured at a temperature of 18 ºC for an electric transformer with a nominal apparent power of 400 MVA and the transformation ratio of 400/24 kV:

IT – (JT + ground) = 0,985 %

JT – (IT + ground) = 1,94 %

The values of the tangent of the measured dielectric loss angle must be recalculated according to the temperature (20 º C) at which measurements were made in the factory.

Depending on the difference between factory temperature and the measured temperature in Table 2, a correction factor of 1.06 is obtained. Applying this correction coefficient to the measured values results:

1. For high voltage winding in relation to low voltage winding and ground IT – (JT + ground):

$tg\delta_r$ = 0,985/1,06=0,929 %

2. For low-voltage winding in relation to high voltage winding and ground JT – (IT + ground):

$tg\delta_r$ = 1,94/1,06=1,83 %

## CONCLUSIONS

Based on the measured and recalculated values for the tangent of the dielectric loss angle established between the windings of the transformer and its vessel connected to the grounding belt, we constructed the graph shown in Figure 2.

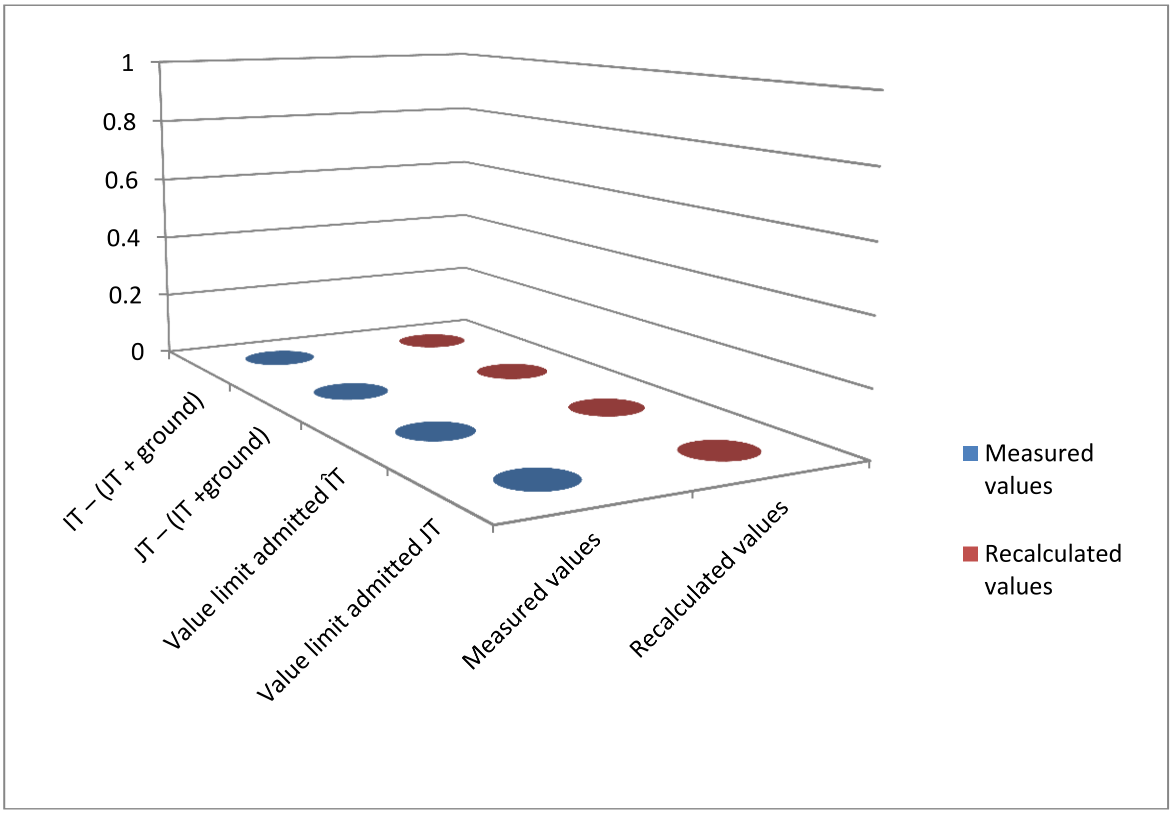


Figure 2. The variation in the tangent of the dielectric loss angle

Starting from the presented aspects and taking into account the measured and recalculated values for the tangent of the dielectric loss angle, the following conclusions can be drawn:

1.The monitoring of the tangent of the loss angle (tgδ) in the dielectric of a power transformer together with other reference indicators (insulation resistance, absorption coefficient, dielectric rigidity of the insulating oil) determines the insulation status of the electrical transformer in its entirety.

2.If the determination of the tangent of the dielectric loss angle can not be achieved at the measured temperature in the manufacturing plant, it is necessary to recalculate the tangent of the dielectric loss angle, depending on a correction coefficient.

3.The tangent value of the dielectric loss angle is directly proportional to the value of the temperature.

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