Miniproject: Description of 60 kV voltage transformer and assessment of the insulation quality

HV engineering -

Project Report

Intro760

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Abstract:

Description of 60 kV voltage transformer and assessment of the insulation quality

Contents

Chapter 1

Introduction

Power systems equipment should be capable of withstanding not only the rated voltage of the system but also the over voltages that may occur. Inorder to ensure this, all h.v equipments should be tested before commissioning for suitability. This study involves testing of one such H.V equipment - ABB EMF 72kV inductive type voltage transformer. The various test setups , tests conducted, results and conclusions are covered below after a brief introduction about the laboratory test specimen.

1.1 ABB EMF 72kV inductive type voltage transformer

A high Voltage transformer is generally intended to step down the voltage level from a high level to a safe low level for subsequent connections to measuring and control(relay) Circuits. Some of the main factors that are to be considered while selecting a voltage transformer are :-

-> Rated Primary Voltage

-> Rated secondary voltage

-> Transformation ratio

-> Rated voltage factor

-> Insulation level

-> Burdens (outputs) and accuracy for each winding

-> Pollution levels (creepage distance)

-> Standard – IEEE,IEC

Thus the data sheet for voltage transformers will contain information regarding the above factors and the following are the definitions for the same.

Rated Primary Voltage

This is the value of High Voltage to which the primary winding of the transformer can be connected. Voltage transformers for outdoor applications are normally connected between phase and ground. The standard values of rated primary voltage are $1/\sqrt{3}$ times of the value of the rated system voltage. Thus for a system voltage of 60kV line to line, we get the required rating for the Primary winding as $60/\sqrt{3}$ equal to 34.64kV phase to ground.

Rated Secondary Voltage

This is the value of Voltage that should appear at the secondary winding of the transformer when the rated primary voltage is applied to the primary. The rated secondary voltage is chosen according to local practice. In European countries often $100/\sqrt{3}$ V or $110/\sqrt{3}$ V.

Rated Voltage Factor

It is important that the voltage transformer, for thermal and protection reasons, can withstand and reproduce the continuous fault overvoltages that can occur in the net. The IEC standard specifies a voltage factor of 1.2 continuously and simultaneously 1.5/30 sec. for systems with effective grounding with automatic fault tripping, and 1.9/8 hrs for systems with insulated neutral point without automatic ground fault systems. Because of the above-mentioned requirement the voltage transformers operate with low flux density at rated voltage. The voltage transformer core must not be saturated at the voltage factor.

Burden

It is defined as the external impedance in the secondary circuit in ohms at the specified power factor. It is usually expressed as the apparent power – in VA , which is taken up at the rated secondary voltage.

Accuracy Class

It is a measure of the accuracy with which the transformer should function depending on the type of secondary connection viz. metering or relaying(for protection). The accuracy class for measuring windings, according to IEC, is given as 0.2, 0.5 or 1.0 depending on the application. A rated burden of around 1.3-1.5 times the connected burden will give maximum accuracy at the connected burden. For protection purposes the class is normally 3P or 6P.

The metering classes of IEC 60044-2 are valid for 80-120% of rated voltage and 25-100% of rated burden. The protective classes are valid from 5% to Vf times rated voltage and for 25-100% of rated burden (Vf = voltage factor).

Rated Insulation Level

The combination of voltage values which characterize the insulation of an instrument transformer with regard to its capability to withstand dielectric stresses. The rated value given is valid for altitudes $\leqq$ 1000 m above sea level. A correction factor is introduced for higher altitudes.

Thermal limit Burden

Thermal limit burden is the total power the transformer can supply without excessively high temperature rise. The transformer is engineered so that it can be loaded with the impedance corresponding to the load at rated voltage, multiplied by the square of the voltage factor.

Ambient Temperature

Average 24 hours ambient temperature above the standardized $+35^0C$ influences the thermal design of the transformers and must therefore be specified.

Installation altitude

If installed >1000 m above sea level, the external dielectric strength is reduced due to the lower density of the air. Always specify the installation altitude and normal rated insulation levels. Internal insulation is not affected by installation altitude and dielectric routine tests will be performed at the rated insulation levels.

Creepage distance

The creepage distance is defined as the shortest distance along the surface of an insulator between high voltage and ground. The required creepage distance is specified by the user in mm (total creepage distance) and mm/kV (creepage distance in relation to the highest system voltage).

Pollution level

Environmental conditions, with respect to pollution, are sometimes categorized in pollution levels. Five pollution levels are described in IEC 60815-1. There is a relation between each pollution level and a corresponding minimum nominal specific creepage distance.

Wind load

The specified wind loads for instrument transformers intended for outdoor normal conditions are based on a wind speed of 34 m/s.

Design features and advantages

The design corresponds with the requirements in the IEC and IEEE standards. The transformers are designed with a low flux density in the core and can often be dimensioned for 190% of the rated voltage for more than 8 hours.

Primary windings

The primary winding is designed as a multi-layer coil of double enamelled wire with layer insulation of special paper. Both ends of the windings are connected to metal shields.

Secondary and tertiary windings

In its standard design the transformer has a secondary measurement winding and a tertiary winding for ground fault protection, but other configurations are also available. (2 secondary windings in a design according to IEEE standard). The windings are designed with double enamelled wire and are insulated from the core and the primary winding with pressboard (presspahn) and paper. The windings can be equipped with additional terminals for other ratios (taps).

Core

The transformer has a core of carefully selected material, to give a flat magnetization curve. The core is over-dimensioned with a very low flux at operating voltage.

Impregnation

Heating in a vacuum dries the windings. After assembly, all free space in the transformer approximately 60%) is filled with clean and dry quartz grains. The assembled transformer is vacuum-treated and impregnated with degassed mineral oil. The transformer is always delivered oil-filled and hermetically sealed.

Tank and insulator

The lower section of the transformer consists of an aluminum tank in which the winding and core are placed. The tank consists of selected aluminum alloys that give a high degree of resistance to corrosion, without the need of extra protection. The sealing system consists of O-ring gaskets. The insulator, in its standard design, consists of high quality, brown glazed porcelain.

Expansion system

The EMF has an expansion vessel placed on the top section of the porcelain. The EMF has a closed expansion system, without moving parts and with a nitrogen cushion, that is compressed by the expansion of the oil. A prerequisite for this is that the quartz sand filling reduces the oil volume, and the use of a relatively large gas volume, which gives small pressure variations in the system. The expansion system based on the nitrogen cushion gives superior operating reliability and minimizes the need of maintenance and inspection of the transformer.

Ferro-resonance

The design of the EMF notably counteracts the occurrence of ferro-resonance phenomena. The low flux in the core at the operating voltage gives a large safety margin against saturation if ferro-resonance oscillations should occur. The flat magnetization curve gives a smooth increase of core losses, which results in an effective attenuation of the ferro-resonance. If the EMF transformer will be installed in a network with a high risk for ferro-resonance, it can, as a further safety precaution, be equipped with an extra damping burden, on a delta connected tertiary winding.

Climate

These transformers are designed for, and are installed in a wide range of shifting conditions, from polar to desert climates all over the world.

Quartz filling

Minimizes the quantity of oil and provides a mechanical support to the cores and primary winding.

Resistance to corrosion

The selected aluminum alloys give a high degree of resistance to corrosion without the need of extra protection.

Seismic strength

EMF is designed to withstand the high demands of seismic acceleration.

1.2 Data/Specifications of ABB EMF 72kV inductive type voltage transformer

The specimen used in the laboratory is shown in Figure 1.1.

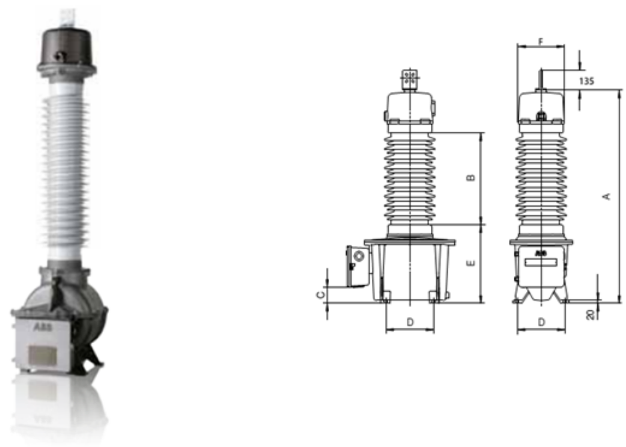

Figure 1.1: ABB EMF 72 kV

The specifications of the lab specimen used for conducting the various HV tests are now given below in Table 1.1:-

Table 1.1: ABB EMF 72kV Data Specifications

Voltage Transformer	EMF 72
Norm	IEC 186
Installation	Outdoor
Design	Inductive type
Insulation	Oil-paper-quartz
Dielectric Strength	12kV/mm
Highest voltage for equipment	72.5kV
Rated Primary Voltage	$60000/\sqrt{3}$
Rated Secondary Voltage	$100/\sqrt{3}$
Lightning Impulse Withstand Level	325 kV(1.2/50 μs)
Voltage factor (Vf)	Up to 1.9/8 hrs
Insulators	Porcelain
Creepage distance	2248mm ($\geq$ 25 mm/kV)
Service conditions Ambient temperature	-40 ^{0}C to +40 ^{0}C
Design altitude	Maximum 1000 m
Protected creepage distance(mm)	1020 mm
Total height(A)	1464 mm
Flash-over distance(B)	630 mm
Height to terminal box(C)	114 mm
Ground Level Height (E)	540mm
Grounding	Equipped with a ground terminal with a clamp of nickel-platted

Chapter 2

Measure transfer ratio full range

A transfer ratio is a very important characteristic of a transformer. It can be measured by calculating the ratio between the primary and the secondary side voltage as

$$\frac{V_{low}}{V_{high}} = \frac{N_{low}}{N_{high}} = n$$

where n is called a transfer ratio.
In the mini-project laboratory, the primary and the secondary side voltage are measured as shown below.2.1

V_{high}[kV]	V_{low}[V]	Ratio[10^{-3}]
3.87	7.15	1.858
7.94	14.65	1.845
10.33	19.15	1.854
12.15	22.55	1.856
16.06	29.96	1.866
20	37.3	1.865
23.95	44.47	1.857
28.09	52	1.851
32.09	59.37	1.850
35.89	66.6	1.856

Figure 2.1

We have $n \approx 1.856x10^3$

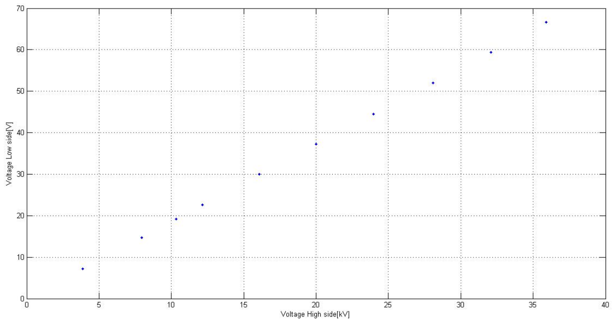

Figure 2.2: Low voltage vs High voltage

Chapter 3

Power frequency and lightning overvoltage test

3.1 Theory

Overvoltage test is an important procedure for the insulator testing in order to find a withstand voltage during the operation. The standard lightning impulse voltage can be divided into three types : Full LI, LI chopped on the tail and LI chopped on the front as shown in figure 3.1.

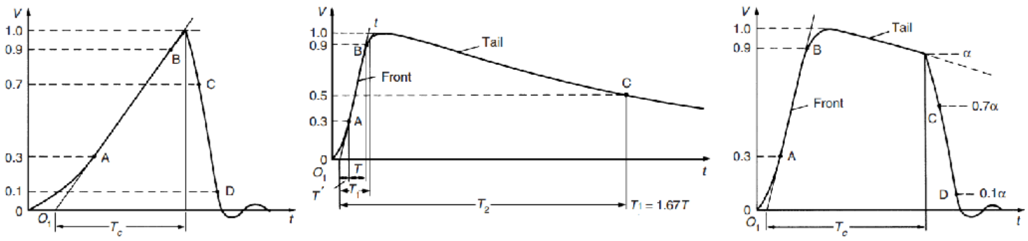

Figure 3.1: (a) Full LI. (b) LI chopped on the tail. (c) LI chopped on the front.]

These lightning impulse voltages can be generate by the circuit shown in figure 3.2

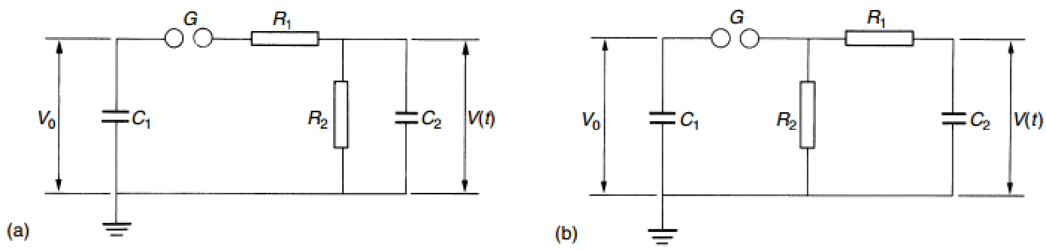

Figure 3.2

Since the capacitor can be difficult to measure, the type(b) circuit is more prefered. By choosing an appropriate element in the circuit, an impulse voltage can be generated according to the two terms of exponiential as shown in 3.3 In practical

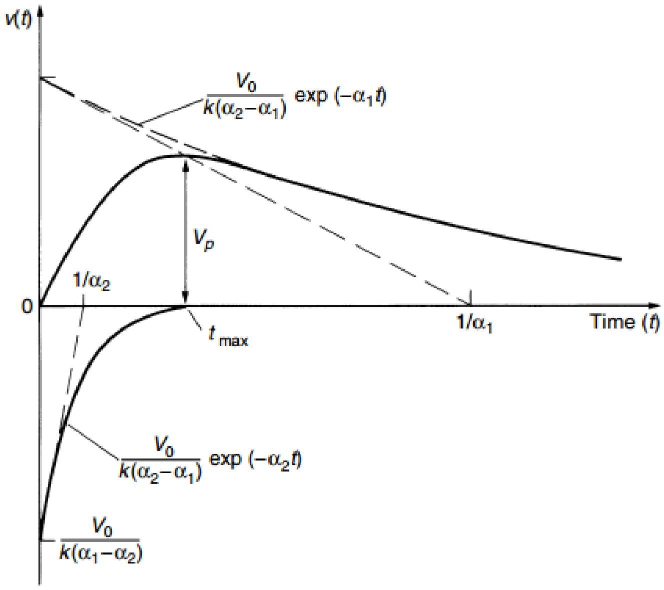

Figure 3.3

testing, the behaviour of the insulation testing, for example, the breakdown voltage of the sphere gap, is difficult to be derived by characteristic parameters. It can be noticed that the observation of the physical process inside the insulator during the test may not be obtained accurately. Thus, due to the randomness of the test result, the statistically approach is more convenient to determine the characteristic of the insulation system.

When the testing voltage V is applied to the insulator, the probability that the insulator will discharge is given as a fraction p which is a function of the testing voltage p=p(V). The insulator discharging behaviour can be considered as a normal distribution which has a density function as a fellow equation.

$$p(f) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(f_k - f_{av})^2/2\sigma^2}$$

For a testing voltage V, we may find the density function of the discharge behaviour as

$$p(V) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(V - V_{50})^2/2\sigma^2}$$

Thus, by knowing V_{50} and σ we can calculate p(V).The standard deviation σ can be obtained by the test data so the only parameter we have to estimate is V_{50}. The 50

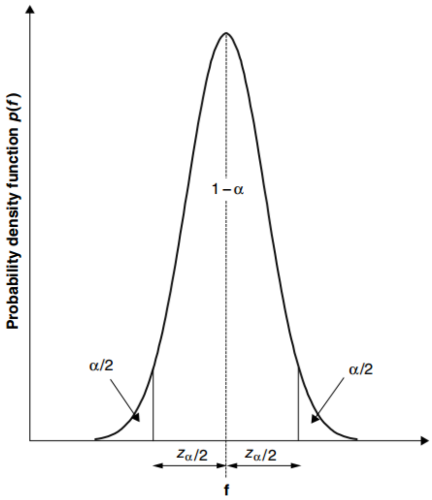

Figure 3.4

percent breakdown voltage V_{50} is a testing voltage level that the breakdown occurs as a probability of 50 percent. If we consider a cumulative distribution function as

$$p(V) = \frac{1}{\sigma\sqrt{2\pi}} \int e^{-(V-V_{50})^2/2\sigma^2} dx$$

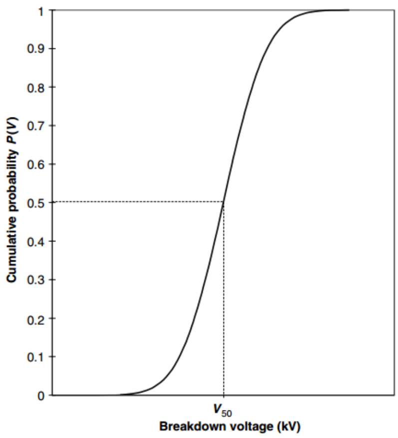

Figure 3.5

Figure 3.5 shows that V_{50} can be obtained from the cumulative distribution function where $P(V_{50}) = 0.5$.
A number of test methods can be use in order to obtain V_{50}. In the mini-project laboratory, a multi-level test method is used. The idea is to construct the cumulative distribution function of the breakdown voltage as been shown is figure 3.5. A

number of tests are required for a certain testing voltage level. We can calculate the probability of the breakdown by observing the number of the breakdown occur divide by the number of test.

$$p(V_{test} = \frac{nobreakdown}{notest}$$

If we vary the V_{test} in a suitable range, the cumulative distribution of the breakdown voltage can be constructed and, as a consequence, V_{50} can be obtained as shown in Figure

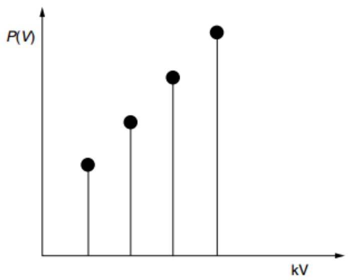

Figure 3.6: Probability of breakdown using the multilevel method

3.2 Laboratory work

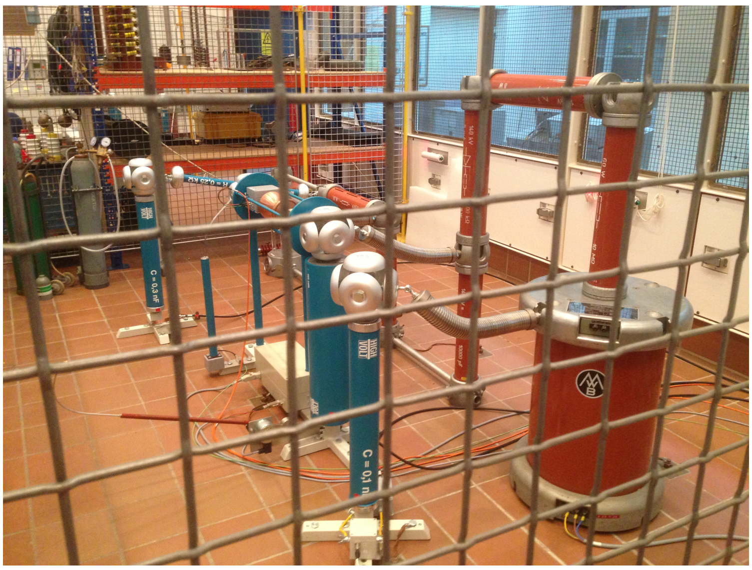

Figure 3.7: Impulse voltage generator circuit

The impulse voltages generated in the Lab are shown in figures 3.8 and 3.9. The breakdown voltage test results are shown in figure 3.10. Due to the problem

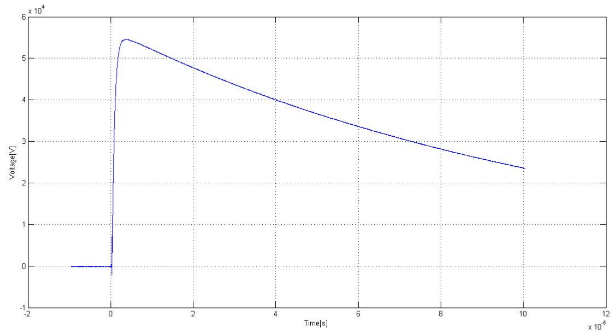

Figure 3.8

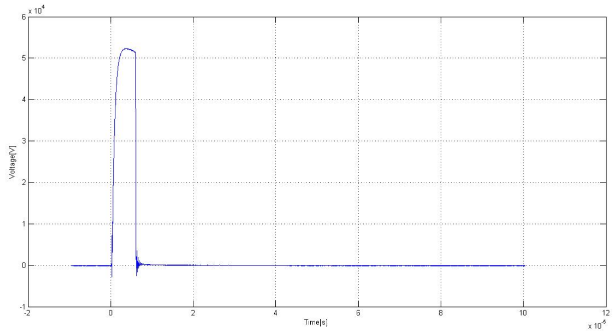

Figure 3.9

with the charging transformer during the test, we are only able to test with 50, 54, 58, 60 and 62 kV breakdown voltages. However, we can still calculate the probability that the breakdown occur by the equation:

$$p(V_{test} = \frac{nobreakdown}{notest}$$

We have:

$$p(V = 50) = \frac{0}{2} = 0, p(V = 54) = \frac{3}{5} = 0.6, p(V = 54) = \frac{3}{5} = 0.6, p(V = 58) = \frac{9}{10} = 0.9, p(V = 60) = \frac{1}{1} = 1, p(V = 62) = \frac{1}{1} = 1$$

From the result, it can be estimated that $V_{50} \approx= 53$ kV. However, due to the lag of data, this estimation may not be accurate.

Act.no.	Uset [kV]	Up[kV]	T1[μs]	T2[μs]	Tc[μs]	State	Eta	charging v.[kV]
1	50.0	39.66	1.891	83.594		o.k.	0.793	50.0
2	50.0	50.59	1.892	83.454		o.k.	0.803	63.0
3	62.0	59.37	1.506		1.923	Breakdown	0.803	78.2
4	60.0	60.26	1.753		2.816	Breakdown	0.803	75.7
5	58.0	58.10	1.772		2.868	Breakdown	0.803	73.1
6	58.0	59.22	1.896	83.664		o.k.	0.810	73.1
7	58.0	57.66	1.666		2.417	Breakdown	0.810	73.1
8	58.0	58.46	1.800		3.043	Breakdown	0.810	73.1
9	58.0	59.05	1.897		5.081	Breakdown	0.810	73.1
10	58.0	58.52	1.830		3.358	Breakdown	0.810	73.1
11	58.0	57.15	1.680		2.431	Breakdown	0.810	73.1
12	58.0	57.52	1.696		2.504	Breakdown	0.810	73.1
13	58.0	58.49	1.847		3.869	Breakdown	0.810	73.1
14	58.0	57.99	1.767		2.857	Breakdown	0.810	73.1
15	54.0	54.65	1.872	83.844		o.k.	0.802	68.1
16	54.0	54.76	1.873		3.824	Breakdown	0.802	68.1
17	54.0	53.42	1.706		2.529	Breakdown	0.802	68.1
18	54.0	54.65	1.880	83.631		o.k.	0.803	68.1
19	54.0	54.08	1.783		2.955	Breakdown	0.803	68.1

Figure 3.10

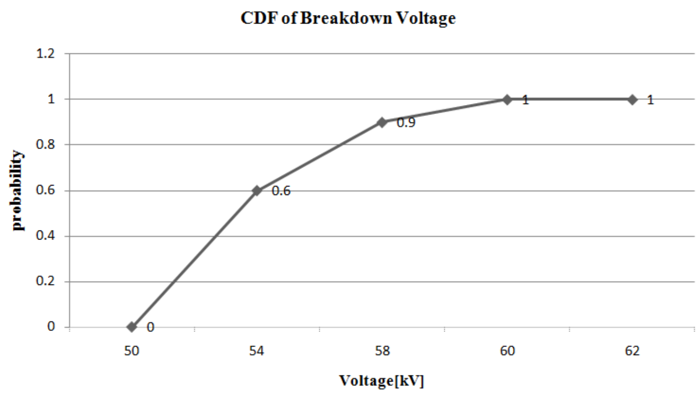

Figure 3.11

Chapter 4

Dielectric loss angle measurement

4.1 Theory

Real dielectrics have some losses, these are divided in conductive losses, polarization losses and ionization losses.

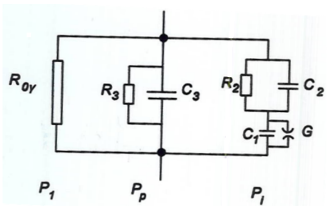

Figure 4.1: P1 conductive losses, Pp polarization losses, Pi ionization losses

Dielectrics and insulation material can be characterized by a capacitance C and a magnitude of power dissipation (dielectric loss) quantified by the loss factor tan δ, that is defined as the ratio of active current I_w and reactive current I_{wl}:

$$tan\delta = \frac{I_w}{I_{wl}} = \frac{P_{diel}}{Q} \tag{4.1}$$

One of the post popular methods for measuring the capacitance and loss tangent is the high voltage Shering bridge.

The capacitance C_x and loss angle δ of the device under test, are measured by comparing with a gas-filled standard capacitor C_n(characterized by a low loss over a wide frequency range and it can built to work in the megavolt range). The current due to the dielectric loss leads the voltage by an angle (90 - δ), this current produces

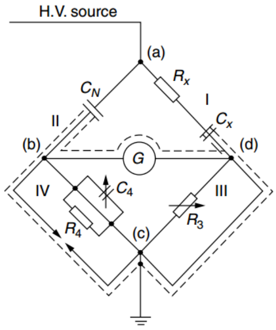

Figure 4.2: The Schring bridge

a voltage drop across R_3. The purpose of the elements in the IV leg is to balance the bridge. For equivalent series circuit R_x-C_x the loss angle tan δ can be define as

$$tan\delta = \omega R_s C_s \tag{4.2}$$

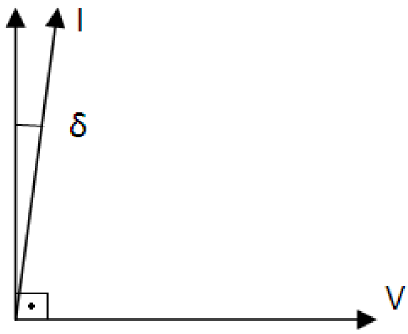

Figure 4.3

4.2 Test procedure

For this test the device used to take the measure is the "Capacitance and dissipation factor measuring bridge tg-3mod" manufactured by PRESCO AG. In the first test the transformer is the device under test. The loss angle and capacitance have been measured in the range 5-45 KV with 5 KV volt step and the results are the following:

The values obtained should be constant with increasing voltage, as it can be appreciated from the results there is a minimum of tan δ at around 35 KV called "ionization knee" and it can be an indicator or partial discharges.

Voltage [Kv]	tan δ	C_x [pF]
5.02	0.2278	59.613
10.42	0.0527	79.04
15.19	-0.0062	86.098
20.09	-0.0427	89.449
25.25	-0.06519	90.70
29.93	-0.0781	90.32
35.10	-0.0836	87.922
39.75	-0.06980	82.439
44.90	-0.0055	69.947

In the second measurements the device under test is a 20 pF "home made pure capacitor" . The voltage range varies from 4-20 KV and result obtained are following:

Table 4.1: In this case both tan δ and C_x are constant

Voltage [KV]	tan δ	C_x [pF]
4.09	0.0315	19.629
7.93	0.0324	19.638
11.99	0.0332	19.65
15.92	0.0343	19.66
19.86	0.0352	19.67

Chapter 5

Partial discharge measurement

The IEC defines partial discharge as a localized electrical discharge that only partially bridges the insulation between the conductors and which may or may not occur adjacent to the conductor. In general partial discharges are limited to only parts of the dielectric used thus bridging partially the electrodes between which the voltage is applied 1. PDs can be classified into three:

- Corona(external discharge)
- Internal discharge
- Surface discharge(external discharge)

5.1 External discharge

External discharge consists mainly of corona and surface discharges. Corona is the discharge in a gaseous dielectric caused due to the inhomogeneous field distribution. Surface discharges are partial discharges along the boundaries of different dielectrics. Our study here focuses on the corona. Corona is occurs in high voltage overhead power lines where non uniform fields are unavoidable where field at a particular point in space exceeds the critical field strength [2]. Corona causes losses in HV transmission systems and also deterioration of the dielectrics caused by the combined action of the discharge ion bombardment on the dielectric surface and action of chemical compounds formed during the discharge. They are also responsible for interference in communication systems. They can either be visible or appear as an audible discharge [1] To study the properties of corona we can simulate the system through an equivalent scheme (circuit) comprising of capacitors, resistance and a spark gap as shown in Figure 5.1 In the equivalent scheme shown C1 is the capacitance of the gaseous volume which breaks down when the applied voltage exceeds the ignition voltage. G is the sparking gap which breaks down when the capacitance volume C1 breaks down. R2 is active resistive losses caused by the conduction of gases. C3 is the normal capacitance of the electrode gap setup. Assuming R2 » 1/wC1 current

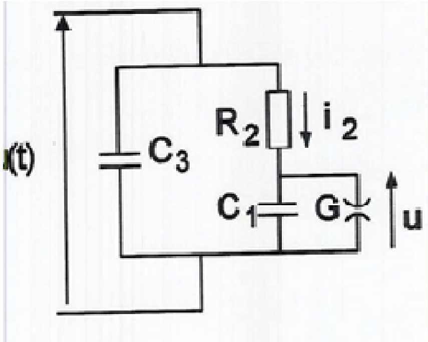

Figure 5.1: External PD equivalent

i2 through the R2 is

I2 = u (t)/R2

Where u (t) = Um sin(wt)

The voltage across capacitance $C1 = Xc1 * i2$ which is phase shifted 90^0 is

$U_{10} = Umsin(wt - \pi/2)/wC1R2$ – not broken down voltage

If the voltage U (t) is increased i.e. if the Um is increased such that the it exceeds the ignition voltage of the spark gap(Uut) then the spark gap breaks down resulting in corona. This happens for $Um = U_{ut} = w * C1 * R2 * Ut$

The breakdown of the spark gap will cause the discharge of the capacitor and U_{10} (not broken down voltage) becomes zero. The capacitor will recharge based on $+ - du/dt$. If the voltage is further increased above the breakdown voltage the capacitor will charge based on du/dt and cause multiple discharges. As a result we can say that the discharges occur near the maximum du/dt of capacitor voltage which is near peak of U(t) as shown in Figure 5.2. this is an important property which we will be verifying in the experiments[2]

5.2 Internal discharge

Internal partial discharges are the ones that occur inside a dielectric material mainly in cavities inside the material which occur during the manufacture.

The cavity maybe filled with a medium of lower breakdown strength than the surrounding dielectric. They will usually be of lower permittivity than the surrounding material causing the field in the cavity to go above the critical field even under the normal working stress of the insulation system. Internal discharges like in external discharge can cause deterioration of the dielectric leading to its breakdown.[1] Internal discharge phenomenon can be studied though an equivalent scheme like in

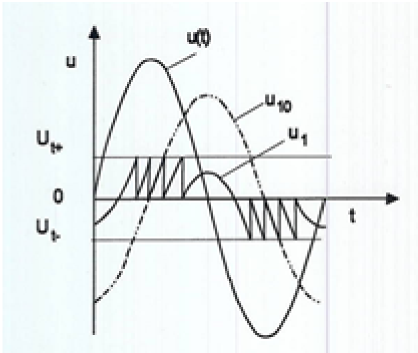

Figure 5.2: External PD

external PD.

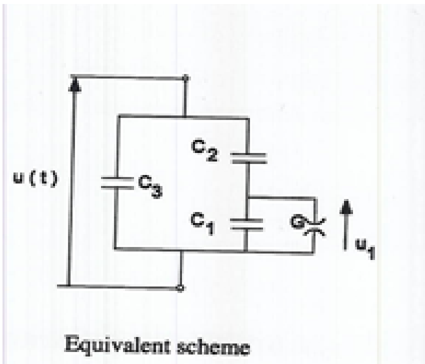

Figure 5.3: Internal PD equivalent scheme

Figure 5.3 shows the equivalent scheme for internal PD. Here C1 simulates capacitance of the cavity in the dielectric.C2 forms the healthy part of dielectric in series with cavity and C3 forms the remaining portion of the dielectric. Here C3»C1»C2.

When sinusoidal voltage is applied across the circuit the voltage across C1

$$U_{10} = C2/(C1 + C2) * U(t) = C2/(C1 + C2) * Um \sin(wt).$$

If the voltage U(t) is increased such that Um exceeds the critical voltage of the gap G the gap breaks down causing the capacitor to discharge into the gap and the now breakdown voltage equals

$$C1/(C1 + C2) * Ut$$

As with the case with the external discharges if the applied voltage is increased above the breakdown voltage multiple discharges occur caused by repeated charging and discharging of capacitor C1 according to $+ - du/dt$. The difference here in internal discharge is that the capacitor voltage is in phase with the supply voltage .

As a result when multiple discharge occurs at maximum du/dt of capacitor voltage they occur at the zero crossing of the supply voltage. This is another important property verified through the experiment [2]

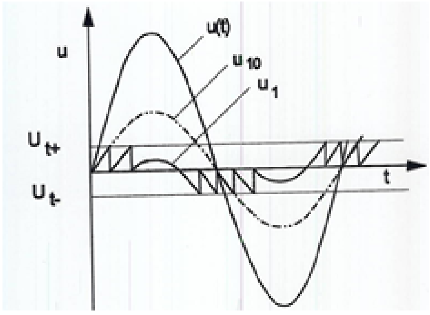

Figure 5.4: Internal PD

5.3 Test setup and measurement

The partial discharge measurement are made for the following

- ABB voltage transformer
- Homemade capacitor
- Rod to plane electrode

The test setup is illustrated in the Figure 5.5 The above test procedure makes

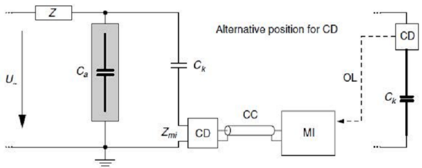

Figure 5.5: Test setup

use of the apparent charge method for measuring PD currents. Here the coupling capacitor C_k which is PD free which is connected across the test object is assumed to be greater than the test object which may not be case in real scenario. Under this situation the voltage drop across the test object during will be compensated by the coupling capacitor C_k which acts as a stable voltage source. Therefore capacitor C_k contributes for the apparent charge dissipated in the test object and this apparent is quantified by the measuring instrument whose input is formed by the input impedance of the coupling devise CD. The charges are usually in the range of pico coulombs.[1] In the lab the one of the test object was introduced in the circuit and high voltage was applied to it through the high voltage was applied to it from a high voltage transformer. The voltage was gradually increased until discharge was observed in the scope for the test object for a particular voltage. The recording of this was taken for a period of two minutes and analysed.

5.4 Results and interence

5.4.1 PD test on transformer

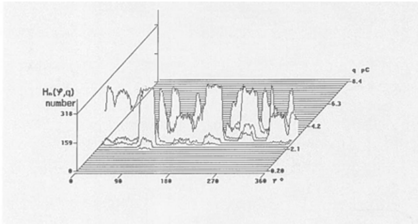

Figure 5.6: PD test on transformer

Figure 5.6 shows the result of the PD test on the ABB voltage transformer. The testing was done for transformer insulation. The test was done at 45 kV. It can be seen from the result that no measurable PD has occurred in the transformers. The above pulses ae in range of 2pC and are distributed along the whole sine wave($0^0 - 360^0$). These pulses can be attributed to noise. We can conclude from this result that the quality of the insulation in the transformer is good

5.4.2 PD test in homemade capacitor

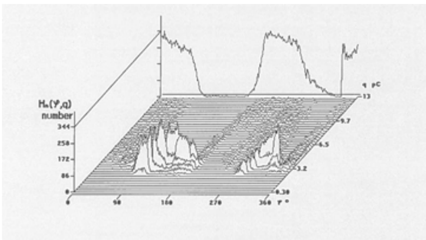

Figure 5.7: PD test on capacitor

Figure 5.7 shows PD test in a capacitor at 28kV. The internal discharge has occurred at the application of the voltage and recorded by the measuring. The discharge is mostly in the range of 3.2 pC. Here one thing to be noticed is that the discharge is between the zero crossing and the peak of applied wave. This shift can be due to the high voltage applied across the capacitor which has caused the discharges to shift from the zero crossings. From this we can conclude that the capacitor is not of good quality which can be expected as it is a homemade capacitor

5.4.3 PD test in rod to plane electrode

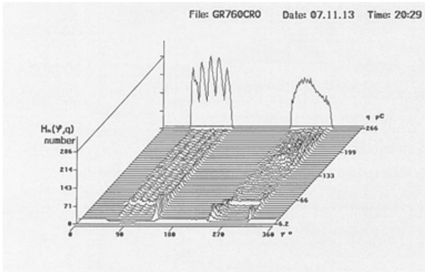

Figure 5.8: PD test on rod to plane electrode

Figure5.8 shows external PD measurement in a rod to plane electrode. The test was done at 24 kV. As discussed in the external PD phenomenon we can see here that the discharge is happening around the peak value of the applied voltage.

Chapter 6

Dielectric spectroscopy test

6.1 Theory

An important aspect of maintaining a transformer is ensuring that it has low moisturing content, as moisture degrades the paper and accelerates insulation aging and reduces de dielectric strength of the oil and paper. These effects can shorten the life expectancy of the transformer and can cause premature failures. Dielectric Spectroscopy test the properties of the insulation system over a wide frequency range (0.001-1000 Hz), therefore different effects can be identified and it can be determined the moisture in the insulation.

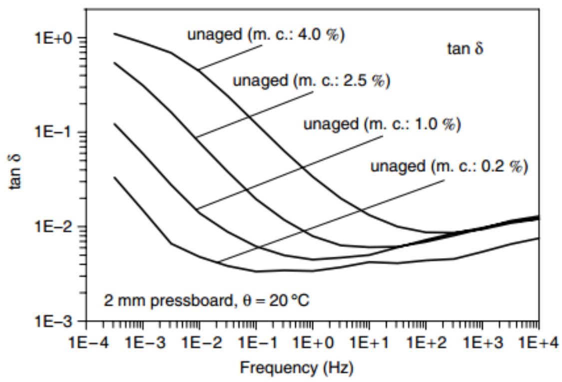

Figure 6.1

6.2 Test procedure

Test is done using DIRANA device,with the configuration shown in figure 6.2 a frequency sweep from 0.001 to 1000 Hz is conducted, and results are displayed in a laptop for further analysis. It takes around 21 minutes to perform the whole test. Once the test is finished the figure 6.3 is created, the blue curve is the data obtained in

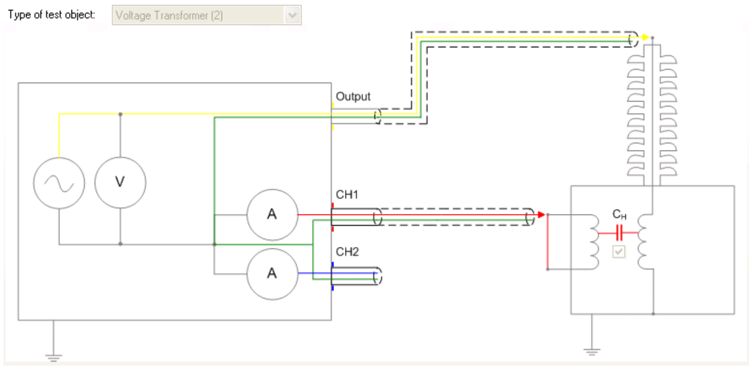

Figure 6.2

the test, while the red is a model curve. The device determines that the conductivity of the oil is very good, but the cellulose was extremely wet, which is not desirable.

The curve obtained is compared with book from lecture 6 from HV, in order to determined the age of the transformer, this it can be labeled as new. In addition it can noticed that dissipation factor in frequencies below 0.005 Hz are dominated by the properties of the cellulose, moisture and the manufacturing process. In the range 0.005-0.01 Hz the tan δ is influenced by the insulation geometry and the ratio oil-pressboard, in the range 0.1-1 Hz it is affected by the oil conductivity, and the range 10-1000 Hz it is affected by the cellulose insulation and the measurement setup.

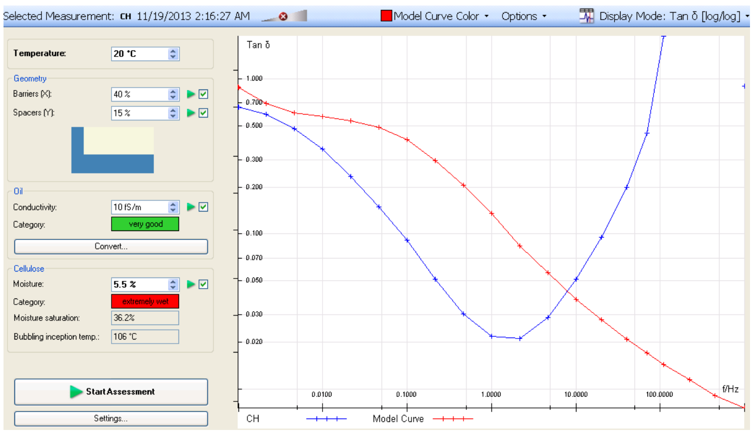

Figure 6.3: tan δ vs frequency

Bibliography

[1] E.Kuffel, W.S. Zaengl, J.Kuffel, *High voltage engineering fundamentals*, 2000.

[2]Claus Leth Bak, *High voltage engineering lecture slides*,Aalborg University, 2013.

[3]ABB, *Oil insulated, Outdoor instrument transformers buyer's guide*, 2012.

[4]ABB, *Instrument transformes application guide*, 2012.

[5]Maik Koch, Michael Krueger, Markus Puetter, *Advanced Insulation Diagnostic by Dielectric Spectroscopy*, Omicron.