PARTIAL DISCHARGE IN PLANAR TRANSFORMER

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ABSTRACT

Planar design is advantageous mainly in cases where is a need for high current and high frequency, high repeatability or special features as low leakage inductance and high number of terminals. Planar transformer can also minimizes corona and partial discharge (PD).

1 INTRODUCTION

The PD is a spark discharge with very low power which is formed inside isolation, or on the surface, in the equipment of an average and high pressure. Duration of PD is units to tens nanosecond. PD appear in a weak place of a transformer under influence of a variable pressure and lead to gradual development of defect and destruction of isolation.

2 PLANAR TRANSFORMER

The solid insulation of planar transformer excludes air from the construction and greatly minimizes corona and PD, enhancing reliability and longer life. Recently many designs adopted planar transformer which utilize solid insulation throughout the printed circuit board. Planar transformer have coils encapsulated within multilayer printed circuits board (PCB), sandwiched between low-profile ferrite cores. In planar design there is much better possibility to have large number of windings and arbitrary arrangement of output taps.

The windings can be interleaved reducing thus leakage inductance and enabling an operation in high frequency range. It is also possible to have a high level of insulation between transformer windings if required.

2.1 DESIGN OF THE PLANAR DEVICE

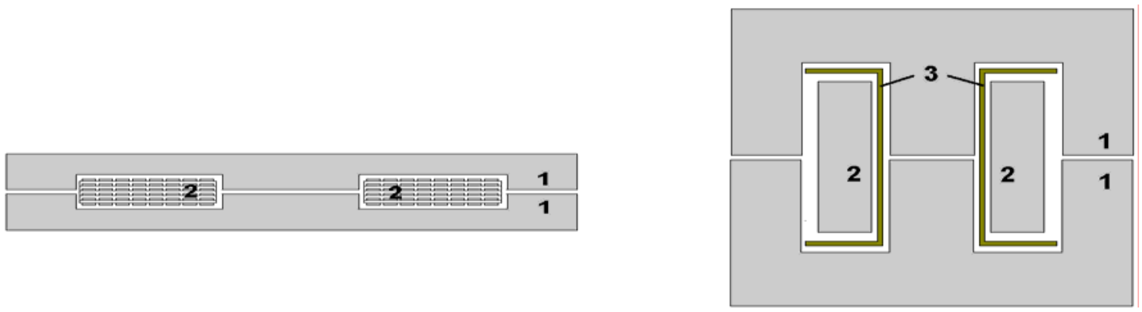
There is a plenty of applications where planar technology provides enhanced performance. The benefits of planar technology and their contribution to more efficient magnetic components are as follows.

Cost savings. There is no bobbin and transformer winding process – the cost of the windings included to mainboard is negligible and connections are eliminated. The assembly process has few stages and is highly repeatable.

Excellent mechanic properties and electro-magnetic compatibility. Planar design gives the height lowest. Pin positions can be more easily optimized and high current connections can be made more easily. The mechanical nature makes planar components easy to screen against EMI and RFI, so common EMC compliance is more easily achieved.

High frequency performance is very good. When leakage inductance is low the magnetic coupling between windings is very good and makes planar transformers well suited to high frequency operation.

Insulation. The insulation excludes air from the construction and greatly minimizes PD, enhancing reliability and longer life. Using planar magnetics in the voltage range of some hundred volts or higher – PD testing should be incorporate to ensure the meeting of safety standards.



a) b)

Fig. 1: *Comparison of planar A) and classic B) arrangement (1- Core; 2- Winding; 3 – Bobbin). Using the bobbin as a winding support there is large unused space in the classic core window.*

Repeatability. In a planar transformer, turns ratio is guaranteed as the circuits are etched within PCB layers. Thus also winding polarity is guaranteed.

3 MEASUREMENT CIRCUIT

By partial discharge testing any measurement circuit requires the following components:

- The specimen (can be treated as a capacitance C_x).
- A coupling capacitance (C_k) PD free.
- A high voltage source, PD free, characterized by a low background noise level.
- The measuring impedance.
- A voltage divider, in order to acquire the synchronism signal

A measurement circuit (Indirect type) can be schematically represented as shown in figure 2.

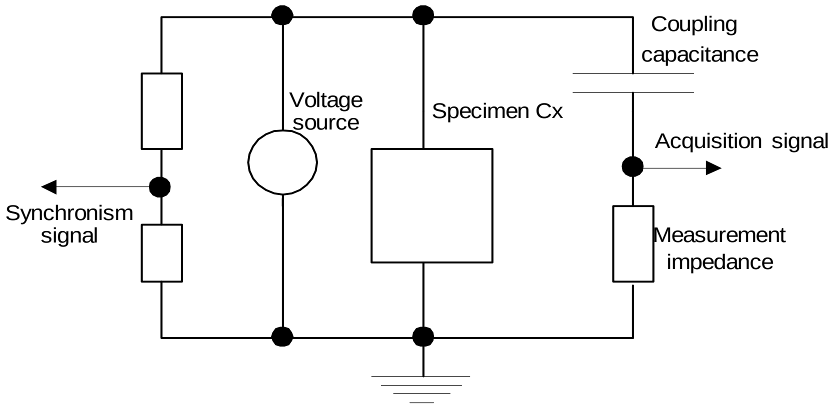


Fig. 2: *Measurement circuit scheme (Indirect type).*

The circuit with the coupling capacitance – measuring impedance series (Indirect type), the PD have opposite polarity with the respect to the test voltage figure 3 . This test circuit is mentioned in the IEC 60270 standard for PD measurement. Indirect type should be preferred for safety reasons.

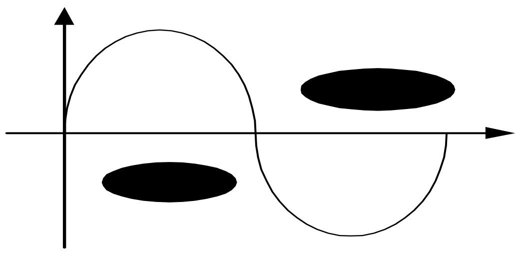


Fig. 3: *Influence of the measuring circuit on the polarity of the discharges Indirect type.*

3.1 CALIBRATION

The calibration of the acquisition system consists in correlating the pulse voltage amplitude estimated by the instrument to the apparent charge associated to the PD. In turn, the apparent charge is the effect that the real charge transfer inside the defect induces at the electrodes of the system.

In order to perform calibration the following components are required:

- A calibrator (as specified in IEC 60270 Standard).
- The specimen (C_x), the coupling capacitor (C_k) and th measuring impedance (Z_m) that will be used in the measurements.

Calibration circuit scheme for Indirect-type measurement circuit shown in figure 4.

Inject pulses having known apparent charge and measure the pulse acquired by the acquisition unit. A special feature of acquisition program allows to perform the correct set-up in order to calibrate the system.

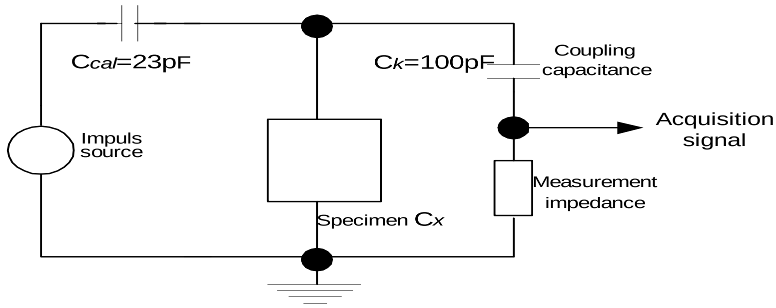


Fig. 4: *Calibration circuit for indirect- type*

4 MEASUREMENT OF PARTIAL DISHARGE IN PLANAR TRANSFORMER

Circuit diagram for measurement PD in planar transformer is shown in figure 5. During measurement we establish that PD will be detect in planar transformer by voltage amplitude of 3 kV about.

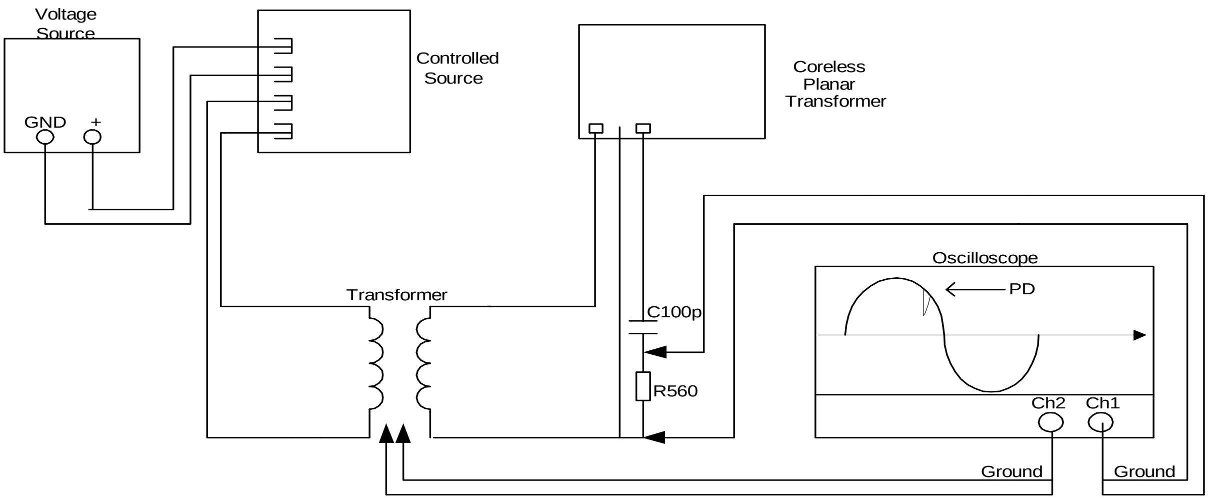


Fig. 5: *Circuit diagram for measurement PD*

For measurement PD in planar transformer, we used following components:

- Digital wave generator and voltage source.
- Controlled Power source (for controlling sine wave from generator).
- Transformer.
- Digital oscilloscope.
- Resistor of value 560 Ω.
- Coreless planar transformer.
- Capacitors of value 47 pF and 100 pF

The calibration procedure shown on the figure.4 is carried out by injecting a standard calibration pulse into the measurement circuit in parallel to the test object. In our case we used the calibration square wave pulse with amplitude 10 V and with frequency 100 kHz. Two capacitors 47 pF/5 kV were connected in series, therefore the calibration capacity was 23,5 pF.

Now we can calculate charge detected by the acquisition system.

$$Q = C * U = 23{,}5 * 10^{-12} * 2 * 10 = 470\,pC \tag{1}$$

By this charge value the amplitude of PD was 250 mV. By voltage amplitude from 2700 V up to 3000 V the measured PD pulse value was 450 mV up to 1000 mV giving thus PD charge value from 900 pC to 1900 pC about. By frequency of 33 kHz such PD intensity leads to isolation destruction in few minute time.

By voltage amplitude less then 2700 V by the acquisition equipment described the PD pulses detection is troublesome, because of random occurrence of PD events. For such purpose the acquisition system must be made other way – with single pulse detection possibility. Nevertheless it is obvious that by starting the PD process the charge transferred will be in the range of hundreds of pC. This means also that PD free condition can be stated for the charge transferred less than some tents of pC, which in our case gives the measured PD pulse amplitude of 10 mV about.

5 CONCLUSION

As a rule, PD source is located in an isolation bulk and to place there the measuring device it is impossible. The equipment for registration can be connected only to external parts of the controlled equipment. At passage through internal elements of the equipment the signal weakens, and his form disfigures. The degree of ceasing of a signal and distortion of his form depend on type of a signal source (defect), a place of his formation (which it is initially not known), a design of the equipment, a used range of frequencies, a way of connection, etc. Therefore to estimate precisely the extent of PD on the basis of measurement only sizes of a signal in a point of connection of the equipment it is practically impossible. The acquisition system calibration is therefore always necessary. In our case the charge transferred in single PD event was from 900 pC to 1900 pC about. The PD free condition can be therefore estimated for the charge transferred less than some tents of pC, which in our case gives the measured PD pulse amplitude of 10 mV

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