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Desıgn Of Matchıng Impedance And Amplıfıer Cırcuıt For Partıal Dıscharge Measurement

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Abstract

Partial discharges are consequence of local electrical stress concentration in the insulation. The detection of partial discharge at the early stage is useful to predict the condition of the power equipments. The discharge appears as pulse of duration of much less than one micro seconds. PD measurements are important diagnostic tools to monitor the insulation condition. Measuring impedance are used to decouple the PD Current pulses appearing in series with a coupling capacitor to convert it into voltage pulses for analysis with PD measuring circuit.

The paper deals with design of LCR circuit as matching impedance and as per IEC standard design of suitable amplifier circuit to amplify signal. The designed circuit is tested observe PD signal appearing across pigtail specimen inserted in liquid insulator.

Keywords: *partial discharge, matching impedance, amplifier, filter.*

1 Introduction:

Partial discharge or PD is an electrical discharge that connects a small portion of the insulation between conducting electrodes. Depending on the breakdown strength of particular insulating material, Partial Discharge may appear at any point in the insulation system, in which electric field strength greater in void of solid dielectric material or bubble in liquid dielectric material compare to other parts. Partial Discharge may result in surface of insulating material or gas bubbles in liquid insulation, may be in voids of solid insulation or at the edge of electrode in gas referred as corona discharge.

If Partial discharge is not detected correctly results in damage to the electrical equipment which may cause serious hazard in the event of fault. Partial discharge can easily be detected by various methods such as non electrical and electrical method, Electrical straight detection method is found to be more effective way to determine the PD.

In order to detect PD impedance may be connected to the sample in series or impedance may be connected in series with coupling capacitor [5]. The impedance can be of two types either resistor shunted with capacitor called RC network or combination of parallel inductor, resistor and capacitor commonly referred as LCR circuit. The voltage impulse appearing across the LCR impedance is calculated based on Laplace transformation[1] RC combination gives unidirectional shape of pulse varies as LCR circuit pulse appear as attenuated oscillation.

The amplifier plays important tool in pd measurement, amplifier cancels noise, fix the bandwidth, increases the amplitude of the signal so that pulse can be measured accurately in oscilloscope and for further study of computer based analysis of PD pattern
The designed circuit is verified by connecting measuring circuit to high voltage source as per IEC60270 connection and high voltage is applied in steps to obtain partial discharge inception pulse.

2 Design of LCR Circuit as Matching Impedance

The partial discharge detection involves appearance of PD pulse at the terminal of test object. PD occurs due to insulation defects such as void in solid dielectric or bubble in liquid dielectric when the electric field is locally ahead of their breakdown strength. The detection circuit often mentioned in the paper

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published by Quinn [6] involve LCR circuit connected in series with device under test but these methods as low resolution. A modified LCR circuit proposed by mole [7] published in the year 1952 in which LCR circuit is connected in series with Discharge free coupling capacitor. By varying capacitor C, the frequency of the oscillation can always be tuned to the midband frequency of 500Hz.

The figure 2.1 and 2.2 shows LCR parallel circuit. Suitably elements are selected so that they will not induce very low noise and will not damage easily. Four terminal inductor are used so that it gives isolation from input high voltage. Wire wound high wattage resistor and Polyester type capacitor is connected parallel to secondary of the inductor. Resistor and inductor value is fixed and capacitor value varied to get suitable bandwidth as per IEC standards. The output pulse can be tested by connecting it to high bandwidth oscilloscope. The output is protected by connecting protection components such as MOV or paper gap arrangement or by using neon lamp. Partial discharge pulse is not viewed correctly because of low magnitude and presence of noise and other interferences of circuit components. These drawbacks is overcome by designing suitable low pass and high pass filter. An amplifier is designed to amplify partial discharge pulse with required gain setting.

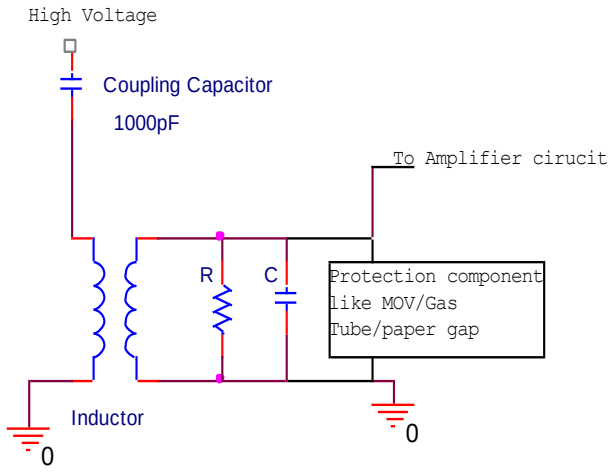

Figure 2.1 LCR Circuit connection.

Transfer function is given by

$$\frac{I_O(s)}{I_I(s)} = \frac{1}{LCs^2 + \frac{L}{R}s + 1}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad Q_f = R\sqrt{\frac{L}{C}}$$

Where f_r is resonating frequency

Qf is quality factor

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Fig 2.2: parallel LCR circuit practical circuit

3 Design of amplifier circuit

After LCR circuit, the pulse obtained has a frequency spectrum as shown in figure 3.1 with midband frequency ω.

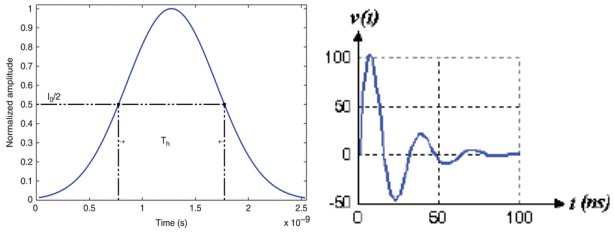

Figure 3.1 Frequency spectrum and oscillatory pulse of LCR circuit

The resonant frequency of the LCR Circuit is also influenced by main test circuit elements such as coupling capacitor and device under test capacitance hence RLC input unit is changed according to specimen capacitance to achieve a bandwidth within limits[2]. By connecting additional amplifier increases sensitivity and gain to input signal. Amplifier bandwidth is equal to or broader than that of the signal. More sensitivity is obtained if the bandwidth is more than thirty times the bandwidth of the signal [2].

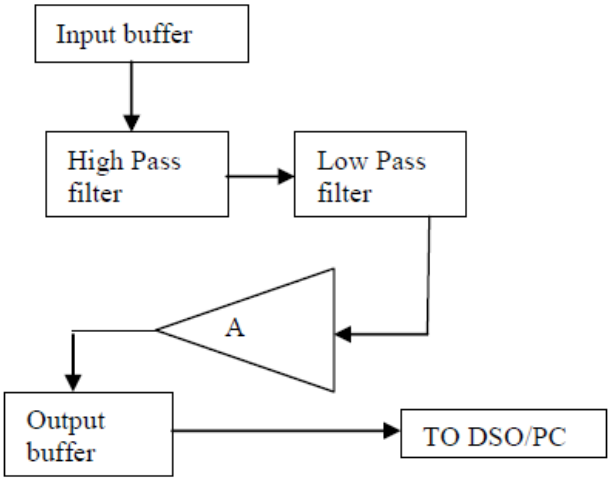

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Figure3.2 block diagram of amplifier circuit

The output signal from LCR circuit is communicated to amplifier circuit as shown in figure. A voltage follower followed by low pass filter, high pass filter to set the bandwidth as per standards and The filters are used to suppress the noise and also reduce external interferences in PD measuring circuits. An amplifier is designed using wide bandwidth dual JFET amplifier with a gain setting upto 100.

Figure3.3 practical of amplifier circuit implementation.

For the measurement of the apparent charge in the frequency range of 9kHz to 1MHz. The PD instruments are characterized by a small bandwidth and a mid-band frequency, varied over a wider frequency range.

Amplifier response:

Input sine wave applied through signal generator with a peak to peak voltage of 100mV and gain of the amplifier is set some desired value with potentiometer. The clear sinewave is observed in oscilloscope when the frequency is raised above 4khz and bandwidth of the signal is 400khz

4 Assembling Circuit for PD Measurement

Figure 4.1 shows the complete experimental setup implemented for measurements of PD in the laboratory as per IEC 60270. PD free HV transformer, coupling capacitor, test specimen arrangement, PD Detection circuit (RLC), Amplifier circuit and oscilloscope

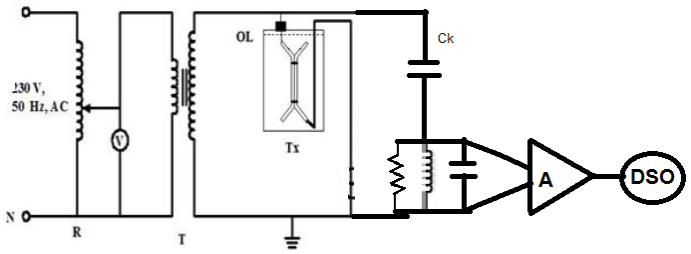

Figure4.1 Experimental PD Setup

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Figure 4.2 laboratory image

Figure 4.2 actual laboratory image showing connection of HV transformer, coupling capacitor and test specimen setup

4.1 Experimental setup:

HV Transformer, coupling capacitor and pigtail specimen (copper conductor wrapped with 3 layer paper insulation) inserted in mineral oil , one end is connected to HV Side and another end connected to ground as shown in figure 4.3

Figure 4.3 Pigtail specimen

4.2 Output waveforms:

Transformer oil used is clear fresh treated mineral oil as per standard IS-335:1993. The partial discharge inception is observed at 2.9kV and figure4.1 and 4.2 shows clear PD pattern when input voltage is 3kV and 3.6kV respectively.

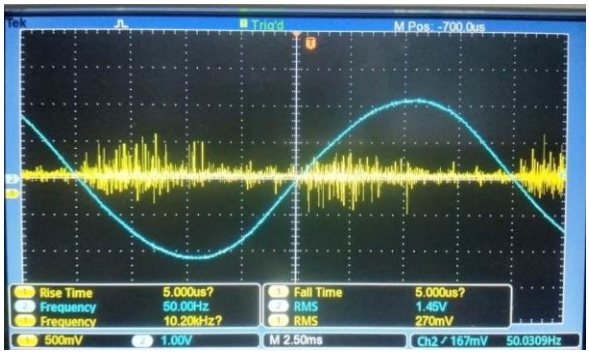

Figure 4.1: PD pattern for input voltage of 3kV

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Figure 4.2: PD pattern for stress level of 1.4 times the inception. Input voltage (4.06Kv).

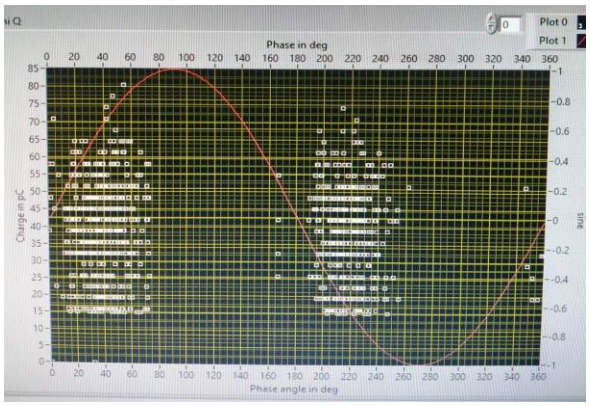

Figure 4.3 shows Phase angle in degree vs charge in pc plot observed in partial discharge acquisition system for PD inception.

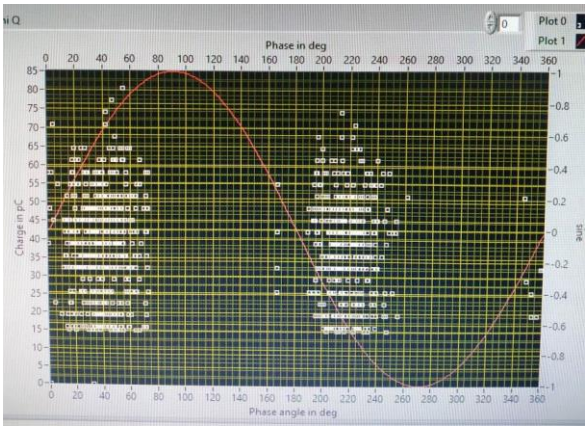

Figure 4.4

3D PLOT shown in figure 4.4 represents the information of phase vs charge vs No. of counts

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6 Conclusion:

The paper concerns with design of Matching Impedance (LCR) and amplifier circuit as partial discharge measurement as explained in various literature. LCR Circuit is correctly designed to capture the PD pulses. Using duel JFET operation amplifier high pass, low pass filters and amplifier circuit is designed and tested for bandwidth, resonance frequency for partial discharge measurement then the circuit applied with high voltage source to measure PD appearing in the pigtail specimen inserted in mineral oil. From the PD Pulse it is possible to measure various parameters of such as wave shape of PD, partial discharge inception voltage. With the help of computer based analyser it is possible measure no. of charge in Pc, number of count and various plots such as phase vs charge, phase-charge-Number can me measured. The testing results show that designed circuit is able to measure PD accurately.

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