PARTIAL DISCHARGE MEASUREMENT ANALYSIS ON RING MAIN UNIT

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ABSTRACT

As per IEC Standard 62271-200 we carried out testing on ring main unit or disconnector cum earthing switch (AC metal-enclosed switchgear and controlgear), The measurement of partial discharges may be appropriate as a routine test to detect possible material and manufacturing defects especially if organic insulating materials are used therein and is recommended for fluid-filled compartments. PDs are thus localized electrical discharges within any insulation system as applied in electrical apparatus, components or systems. In general PDs are restricted to a part of the dielectric materials used, and thus only partially bridging the electrodes between which the voltage is applied. The insulation may consist of solid, liquid or gaseous materials, or any combination of these. The term 'partial discharge' includes a wide group of discharge phenomena: (i) internal discharges occurring in voids or cavities within solid or liquid dielectrics; (ii) surface discharges appearing at the boundary of different insulation materials; (iii) corona discharges occurring in gaseous dielectrics in the presence of inhomogeneous fields; (iv) continuous impact of discharges in solid dielectrics forming discharge channels (treeing).So to avoid the economical losses, and better life cycle of component or product in transmission system, SF6 Gas type ring main unit system having the DIN type of bushing and fuse holder (as an insulation) to protect the system in crucial condition and to withstand the High voltage stress, So to avoid the economical losses, and better life cycle of component or product in transmission system, Partial discharge is very important as an electrical aspects, so this paper deals with the partial discharge measurement effect on Ring main unit after power frequencies test; having protective parts of Fuse holder at cable end termination and Bushing

Keyword : - *Concept of partial discharge, measurements and analysis, electrical test partial discharge measurement, Results*

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1. INTRODUCTION

In most of the high voltage (HV) power equipment's are made of with different type of high quality insulation to protect against the high voltage tress. A variety of solid, gaseous, liquid and combination of these materials are used as insulation in high voltage power equipment. Among those the solid insulation like epoxy resin is widely used, not only as a component of complex insulating system such as HV rotating machine insulation but also in indoor insulators, in transformers and in many different high voltage power equipment's. To access the quality of such insulation is a challenging task to the power engineers while the same power equipment is under operating with high voltage stress for a long period. The quality of such insulation plays an important role on HV power equipment in view of quality assessment. However, the insulation of power equipment's are gradually degrades due to the cumulative effects of electrical, chemical and mechanical stresses caused by the partial discharges (PDs). Partial discharge is a localized electrical discharge that only partially bridges the insulation between electrodes. It is studied from the several articles that most of insulators are not hundred percent perfect in nature and always contains some impurity. During the manufacturing process the presence of air/gas bubble in the insulating material is one of the causes for making the insulation imperfect.

1.1 Concept Of Partial Discharge

According to IEC Standard 60270, Partial discharge is a localized electrical discharge that only partially bridges the insulation between conductors and which may or may not occur adjacent to a conductor. In general partial discharges are a consequence of local electrical stress concentrations in insulation or on the surface of insulation. Such electrical discharges are appeared as impulses i.e., various forms of voltage impulse and current impulse having duration of much less than 1sec. PD activity usually observed in high voltage power equipment like transformer, cable, bushings etc. Most of insulators are in impure form. Due to presence of air impurity bubbles (void) are created within the insulating material. It weakens the insulation region and responsible for appearance of PDs. The reason behind it is, the dielectric constant of the void is less than of its surroundings. So it causes insulation failure in high voltage equipment's. Partial discharges are always occurs at void, bad conductor profiles in HV equipment's. Though such discharge has less magnitude but it is responsible for degradation. Due to occurrence of discharge ultimately failure occurs in the insulation system. Because of the above reason PD detection and measurement is necessary for prediction of insulation life for HV power equipment's.

PD usually starts within the voids or void enclosed within a solid dielectric. Void is the main source or main cause for appearance of PDs. Such discharges only partially bridges the distance between the electrodes. PD can also appear along the surface of different insulating materials. Appearance of partial discharges within an insulation material is usually initiated within gas-filled voids within the dielectric. The reason behind it is, the dielectric stress of the void is considerably less than the dielectric stress of its surrounding. Due to this reason the electric stress across the void is more than across an equivalent distance of dielectric. It is studied that if the voltage stress across the void exceeds the inception voltage of the gas within the void, then PD activity will take place. PD activity can also appear along the surface of solid insulating materials if the surface electric field is high enough to cause a breakdown along the insulator surface.

1.2 Classification of Partial discharge

Partial discharge phenomenon is divided into two types

2.2.1 External Partial discharge

External partial discharge takes place outside of the power equipment's .Such types of discharges occur in overhead lines, on armature etc.

2.2.2 Internal Partial discharge

The partial discharge which is occurring inside of a system .The discharge in void is belonging to such type of partial discharge and necessary for PD measurement system .PD measurement system gives the information about the properties of insulating material used in high voltage power equipment's. Different methods are employed for measurements of PDs. The principle behind for measurement of PD is generation/dissipation of energy associated with electrical discharges i.e. generation of electromagnetic waves, dissipation of heat energy, light and formation of noise etc. PD phenomena include several types of discharge which is surface discharge, cavity discharge, corona discharge, Treeing channel.

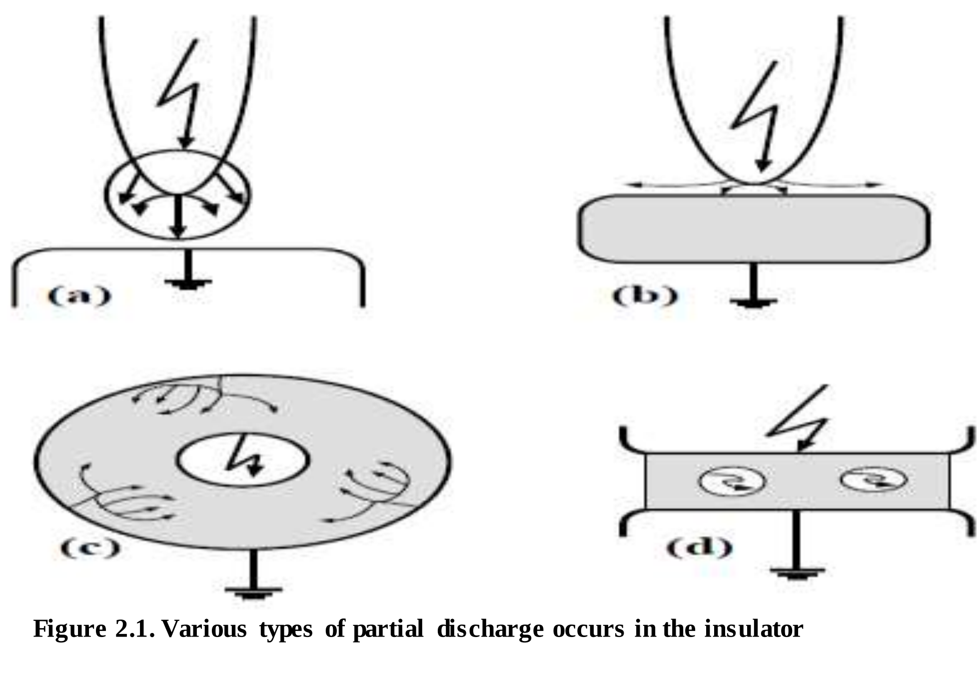


Figure 2.1. Various types of partial discharge occurs in the insulator

2. PARTIAL DISCHARGE METHOD

There are various methods are explored for the PD measurement based on both electrical and non-electrical phenomena. The methods which have been popularly known for measurement of PDs are,

(i) Optical detection method
(ii) Acoustic detection method
(iii) Chemical detection method
(iv) Electrical detection method

2.1 Factors influencing the dielectric strength of insulating material

The essential properties of the insulating materials used for high voltage power equipment's are:

1. Insulation resistance should be high.
2. Dielectric strength should be high.
3. Should have good mechanical properties.
4. Materials should be unaffected by any other chemicals.

It has been studied that some factors or conditions make effect on dielectric strength of insulating materials. The dielectric strength of insulating material depends upon temperature, impurity, spacing between electrodes etc. and some other factors are also responsible for it.

2.2 Partial discharge Analysis

Partial discharge theory involves an analysis of materials, electric fields, arcing characteristics, pulse wave propagation and attenuation, sensor spatial sensitivity, frequency response and calibration, noise and data interpretation. It is obvious from the above that most plant engineers will not have the time, or available energy, to pursue such a course of study

In an effort to promote a better understanding of partial discharge (PD), this paper attempts to provide simplified models and relate the characteristics of these models to the interpretation of PD test results. First, we will present a few technical concepts relating to partial discharges. Partial Discharge can be described as an electrical pulse or discharge in a gas-filled void or on a dielectric surface of a solid or liquid insulation system. This pulse or discharge only partially bridges the gap between phase insulation to ground, and phase to phase insulation. These discharges might occur in any void between the copper conductor and the grounded motor frame reference. The voids may be located between the copper conductor and insulation wall, or internal to the insulation itself, between the outer insulation wall and the grounded frame, or along the surface of the insulation. The pulses occur at high frequencies; therefore they attenuate quickly as they pass to ground. The discharges are effectively small arcs occurring within the insulation system, therefore deteriorating the insulation, and can result in eventual complete insulation failure.

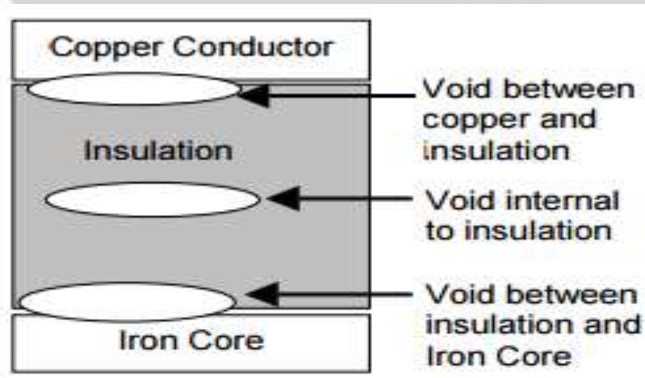


Figure 2.2 – PD within Insulation System

The other area of partial discharge, which can eventually result, is insulation tracking. This usually occurs on the insulation surface. These discharges can bridge the potential gradient between the applied voltage and ground by cracks or contaminated paths on the insulation surface

The above can be illustrated by development of a simplified model of the partial discharges occurring within the insulation system.

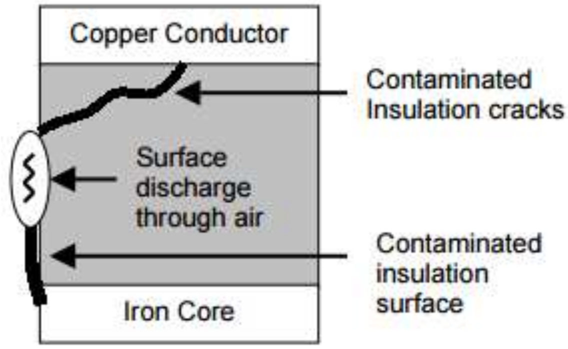


Figure 2.3 – Surface Partial Discharges

A. Insulation System Model simplified model of an insulation system can be represented by a capacitance and resistance in parallel. This is the concept employed in the use of power factor testing of insulation systems. The leakage current is split between the resistive and capacitive paths. The power factor is the cosine of the phase angle between the total leakage current and the resistive component of leakage current.

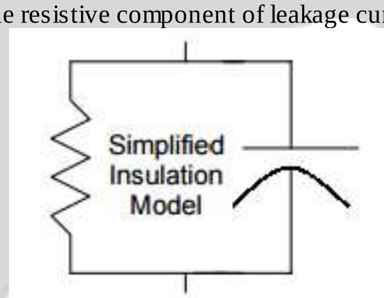


Figure 2.4 – Simplified Insulation Model

B. Partial Discharge Void Model Simplified models of the area of the void have been described as consisting of capacitors only. A review of the progressive failure mode of these voids indicates an additional resistive component in parallel with the capacitive component. An electrical equipment design handbook states: "Discharges once started usually increase in magnitude with stressed time, but discharges can become short circuited by semiconducting films inside the void and discharging is terminated." The referenced semiconducting films can also consist of carbonization of the organic insulation material within the void due to the arcing damage. Therefore the model of the partial discharge void is similar to that of the insulation medium itself.

Actual failure modes have indicated a drop in partial discharge intensity shortly prior to complete failure. This would occur when the internal arcing had carbonized to the point where the resistive component of the model was low enough to prevent a build-up of voltage across the void. This new low resistive component would also allow higher current flows, and additional heating and resultant insulation damage. The above model, including the resistive component correlates to the actual failure mode of a partial discharge void, with the resistive component passing more leakage current as the partial discharges increase with time. One form of this resistive component is visible tracking on the surface of insulation. An explanation of tracking, and how surface partial discharges are related to the development of tracking follow.

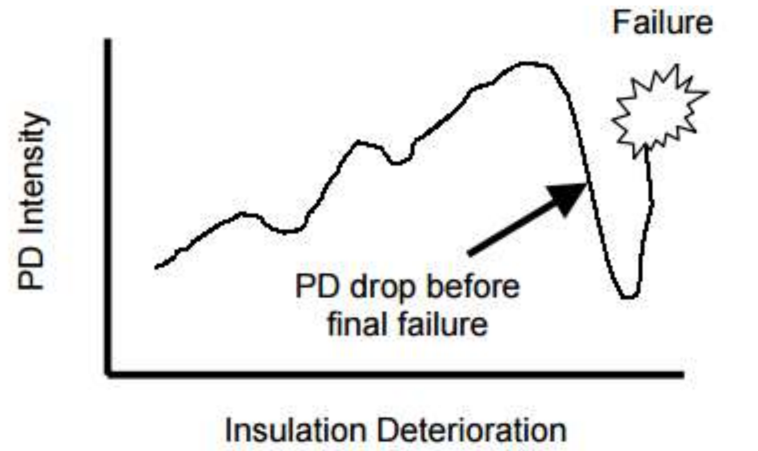


Figure 2.5 – PD versus Insulation Failure Mode

Figure 2.8.4 illustrates a circuit breaker bushing which as progressive tracking highlighted for presentation purposes. At the point near eventual failure, the tracking and resistive component of the insulation have increased to the point where partial discharges have been reduced, since the "tiny arcs" have caused the carbonization and tracking, therefore providing a direct path for current flow. At this point, evidence of insulation deterioration is usually detected by traditional methods of insulation resistance, or megger testing. For the above reason, partial discharge on-line testing and traditional insulation resistance testing are complimentary. On-line partial discharge testing can detect insulation in the progressive phases of deterioration, with trending identifying problems long before eventual failure. Traditional insulation resistance testing provides a "current-state" of the insulation system.

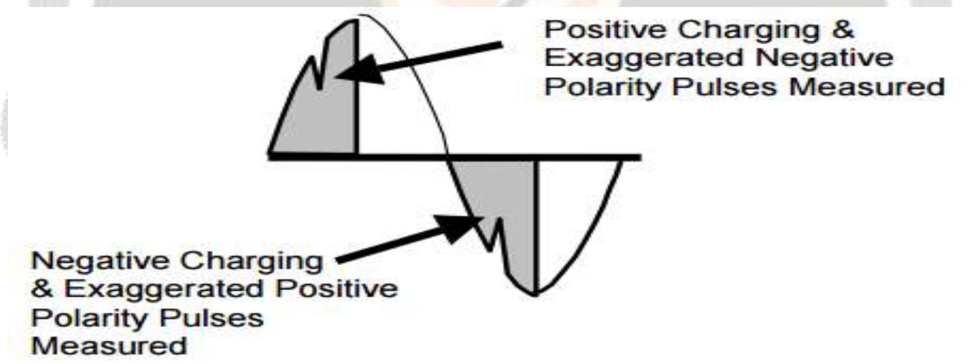


Figure 2.6 - Exaggerated Positive & Negative Polarity Pulses for Illustration Purposes

As stated, since the pulse of voltage change is being measured, the negative polarity pulses occur during the first quarter cycle, or during the rising positive cycle of the wave; and conversely, the positive polarity pulses occur during the third quarter cycle, or during the rising negative cycle of the wave. When viewing the results of partial discharge signals, the above will be illustrated, on a three dimensional graph, with two critical measurements plotted in relation to the 360 degrees of a typical cycle. The 360 degrees is usually split into four segments, therefore the level of partial discharge in the first quarter cycle, or negative polarity discharges, can be compared to the third quarter cycle, or positive polarity partial discharges. The differentiation of positive versus negative polarity partial discharge pulses will be related to a probable root cause and corrective actions. The two measurements illustrated on the two dimensional graph are partial discharge Maximum Magnitude, usually represented in millivolts, and Pulse Repetition Rate, represented by the number of partial discharge pulses during one cycle of an AC waveform. This is discussed further in Figure.

The partial discharge magnitude is related to the extent of damaging discharges occurring, therefore related to the amount of damage being inflected into the insulation. The pulse repetition rate indicates the quantity of discharges occurring, at the various maximum magnitude levels. Both play a role in determining the condition of the insulation under test. Whereas seldom possible with on-line motors, the maximum magnitude level should be calibrated to reflect the actual charge, measured in Pico coulombs. The benefits of such calibration are offset by the relative comparison of similar motors, and more importantly by trending of the partial discharge activity over time. On-line partial discharge testing allows for such trending and analysis of the electrical equipment. The illustration of the partial discharge activity relative to the 360 degrees of an AC cycle allows for identifying the prominent root cause of partial discharges, therefore appropriate corrective actions can be implemented.

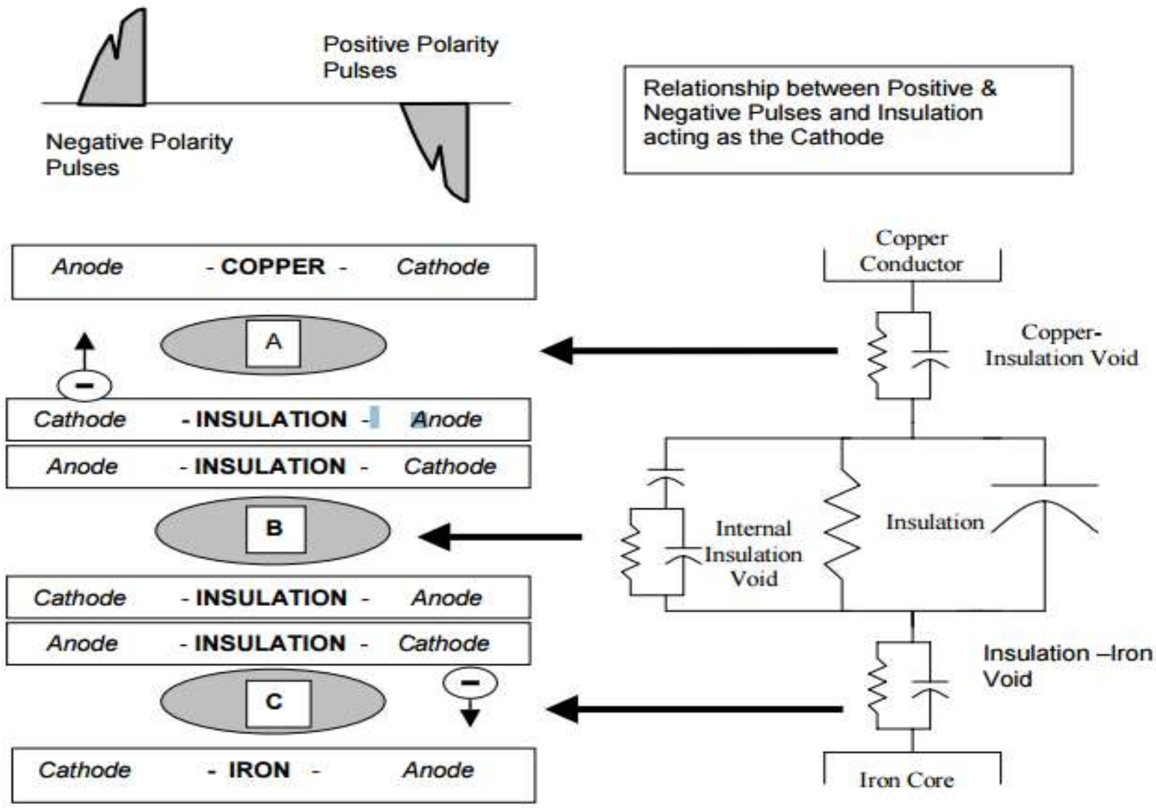


Figure 2.7 relationship between Positive & Negative Pulses

The above-simplified modelling attempts to provide an understanding of the measurement results of partial discharges, and their interpretation related to corrective actions. The following section shows the relationship to traditional testing methods and details the results, and associated corrective actions.

3. Partial discharge measurement system

3.1 For measurement of partial discharge required components are:

- High voltage supply having low quantity of noise is used so that it can pass the discharge magnitude which is to be measured for a particular input voltage.
- For the reducing the noise present in the high voltage supply a high voltage filter is used.
- A detector circuit consisting of resistance, inductance and capacitance is used for collecting the partial discharge signals. It is the major equipment for a partial discharge measurement system.
- A coupling capacitor having low inductance is used to keep low partial discharge pulses and it helps in measurement of partial discharge pulses. It acts as a filter for partial discharge measurement system.
- A measurement instrument is used across the detector circuit to measure the partial discharge pulses produced due to presence of void inside the test object.

3.2 Calibration of PD detectors in a complete test circuit

A calibration of measuring systems intended for the measurement of the fundamental quantity q is made by injecting short duration repetitive current pulses of well-known charge magnitudes q0 across the test object, whatever test circuit is used. These current pulses are generally derived from a calibrator which comprises a generator producing step voltage pulses (see ‘G’) of amplitude V0 in series with a precision capacitor C0. If the voltages V0 also remain stable and are exactly known, repetitive calibration pulses with charge magnitudes of $q0=V0C0$ are injected. A short rise time of 60 ns is now specified for the voltage generator to produce current pulses with amplitude frequency spectra which fit the requirements set by the bandwidth of the instruments and to avoid integration errors if possible.

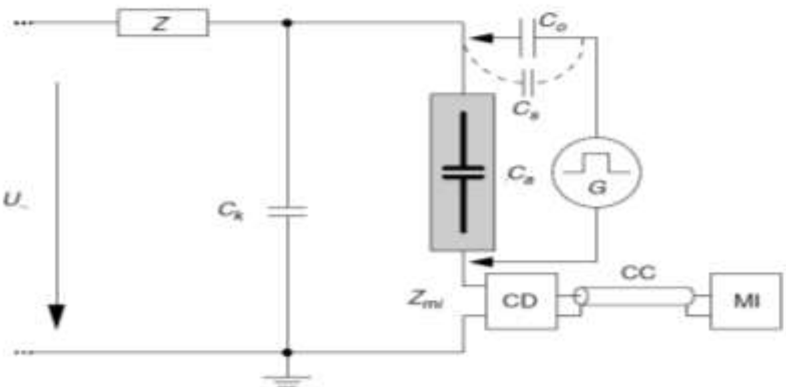


Fig 3.1 The usual circuit for the calibration of a PD measuring Instrument MI within the complete test circuit

Whereas further details for the calibration procedures shall not be discussed here, the new philosophy in reducing measuring errors during PD tests will be presented._it has been known for some time that measuring uncertainties in PD measurements are large. Even today, PD tests on identical test objects performed with different types of commercially available systems will provide different results even after routine calibration performed with the same calibrator. The main reasons for this uncertainty are the different transfer impedances (bandwidth) of the measuring systems, which up to 1999 have never been well defined and quantified. The new but not very stringent requirements related to this property will improve the situation; together with other difficulties related to disturbance levels measuring uncertainties of more than about 10 per cent may, however, exist. The most essential part of the new philosophy concerns the calibrators, for which – up to now – no requirements for their performance exist. Tests on daily used commercial calibrators sometimes display deviations of more than 10 per cent of their nominal values. Therefore routine type, and performance tests on calibrators have been introduced with the new standard. At least the first of otherwise periodic performance tests should be traceable to national standards, this means they shall be performed by an accredited calibration laboratory. With the introduction of this requirement it can be assumed that the uncertainty of the calibrator charge magnitudes q0 can be assessed to remain within š5 per cent or 1 pC, whichever is greater, from its nominal values. Very recently executed intercomparison tests on calibrators performed by accredited calibration laboratories showed that impulse charges can be measured with an uncertainty of about 3 per cent.

3.3 Electrical Test Partial Discharge Measurement for fuseholder

Extinguishing voltage of the partial discharges Uext ≥ (1.1xUr)/√(3)

The test shall be performed with equipment whose sensibility is ≥ 10 pC.

As acceptance criteria we will use for calculation the highest standardized service voltage (Us) under the rated, meaning:

Uext≥ (1.1xUs)/√ (3)

For Ur=25Kv	For Ur=24kV
Us=22kV	Us=20kV
Uext≥ (1.1x22kV)/√(3) ≥ 14kV	Uext≥ (1.1x20kV)/√(3) ≥ 12,7kV

<u>Criteria for categories selection of fuse holder 24 kV</u>

Extinguishing discharges level from 0,0 kV to 12,7 kV	Reject
Extinguishing discharges level from 12,7 kV to 13,9 kV	APPROVED 24 kV
Extinguishing discharges level from 14,0 kV and above	APPROVED 25 kV

For Ur=36kV

Us=33kV

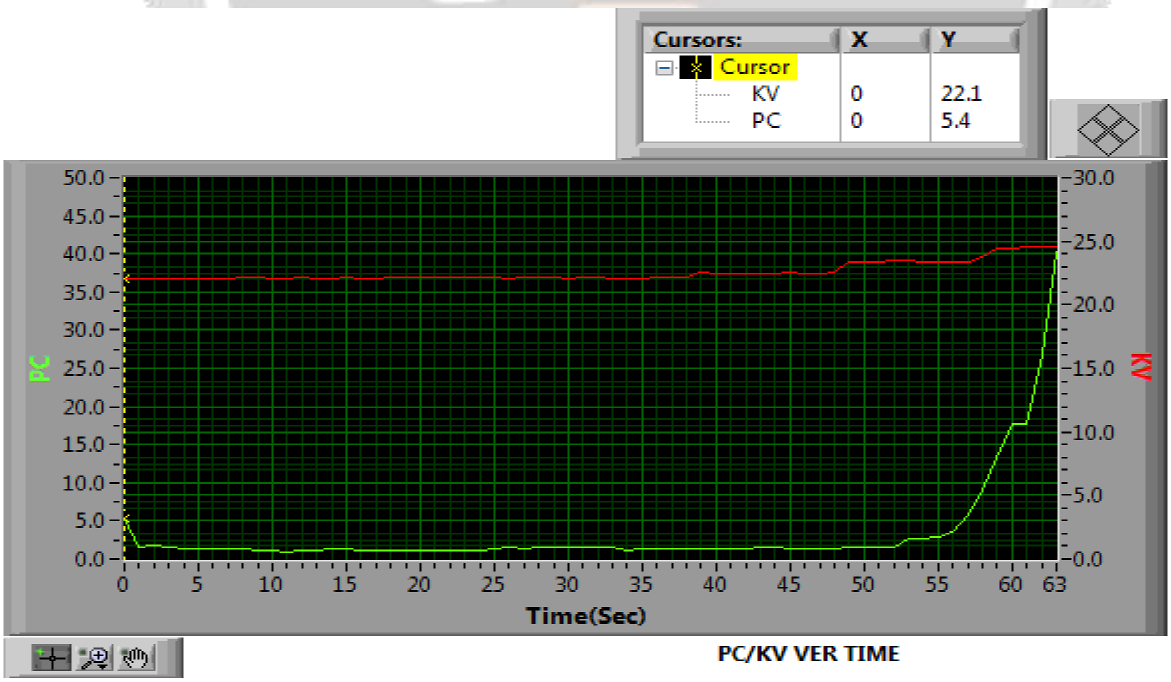
Uext≥ (1.1x33kV)/√(3) ≥ 21kV

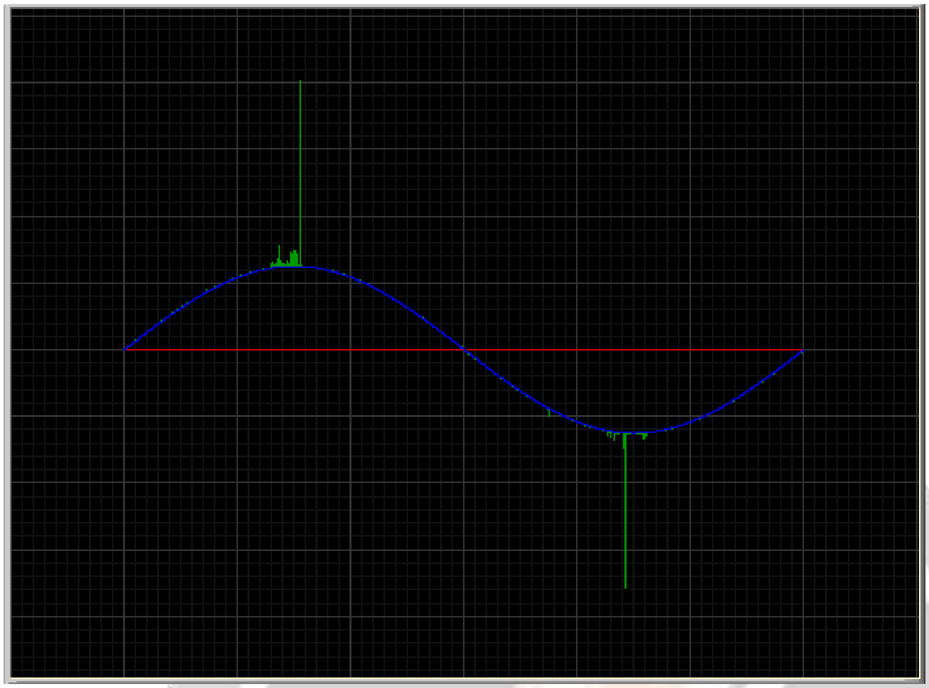
Extinguishing discharges level from 0,0 kV to 20,9 kV	Reject
Extinguishing discharges level from 21kV and above	APPROVED 36 kV

All the pieces that are not included in the mentioned conditions shall be rejected and issued a Non-conformity report. The potential recovery of the rejected pieces could only be performed after the analysis of the Non-conformity Report.

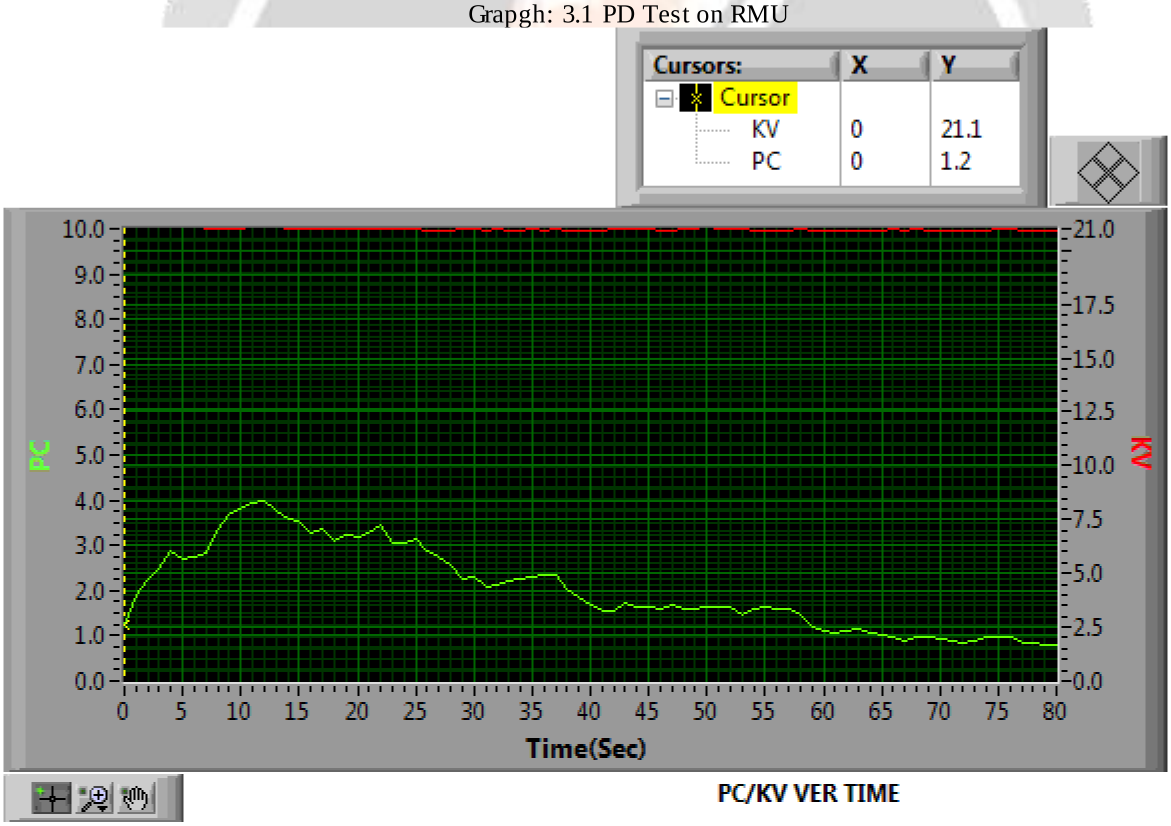
Note: If the relative humidity of the atmosphere is ≥ 70%, the rejected pieces shall be conserved to a new test when the relative humidity is under normal conditions 70% ≥ Hr. ≥ 50%.

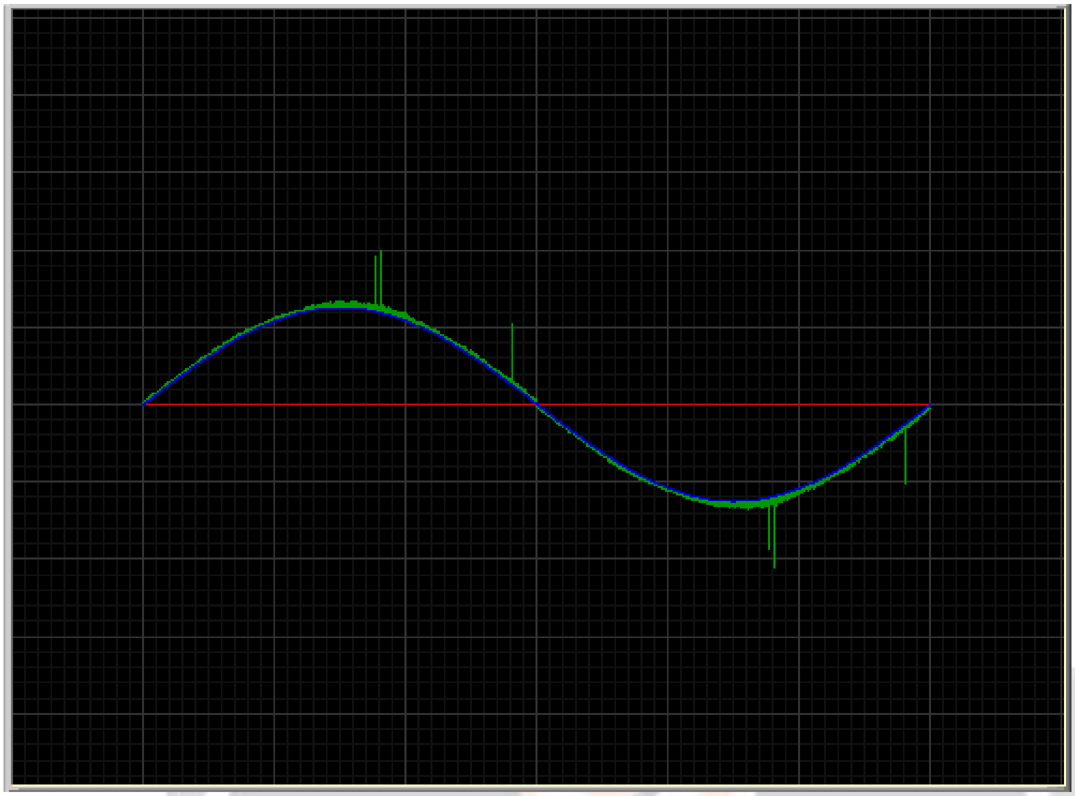
3.3Partial Discharge test results on Ring main unit (Bushing results)





Grapgh: 3.1 PD Test on RMU





Grapgh: 3.2 PD Test on RMU (Different Phase)

4. CONCLUSIONS

To know the PD activity inside the solid insulation with analysis of graph measurement software based model have used. Partial discharge is the main problem in high voltage power equipment system. Therefore, finding and measurement of partial discharge is necessary to maintain the power equipment's in healthy condition during their operation. In this work an epoxy resin is consider as a solid insulation material to monitor the partial discharge activity inside the solid insulation. It is found that with the increase in applied voltage to the void present inside the insulation, partial discharge changes. This study will ensure the power engineers to predict the quality of the insulation used for high voltage power equipment. The present work is to be extended for further study in different high voltage power equipment such as switch gear and circuit breaker.

- To withstand the High voltage stress
- To protect the system in crucial condition
- So to avoid the economical losses, and better life cycle of component or product in transmission system, Partial discharge is very important as an electrical aspects
- RMU system is much preferable than disconnector cum earthing switch
- Between the two Partial discharges values are within or boundary level, but by using RMU system PD values are much higher than Disconnector switch
- Also in RMU we used depends on incomer (customized) and one protection outgoing feeder

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