PARTIAL DISCHARGE DETECTION - AN OVERVIEW

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ABSTRACT: ***The reliability of electrical systems depends on the quality and availability of the power apparatus. Insulation failure is one of the major causes of catastrophic failure of high voltage apparatus. It is important for the study of partial discharge behavior in electrical apparatus to know the degradation of insulating materials. In this paper physics of partial discharge has been discussed along with different PD detection methods and its comparison.***

Keywords— partial discharge, acoustic emission, insulating oil.

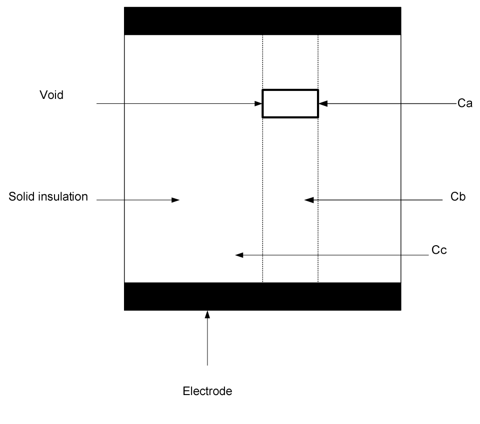
I: INTRODUCTION

Partial discharge is a phenomenon in high voltage insulation system. This phenomenon is a discharge in a void or cavity in an insulation layer. The discharge does not break the full mass of the dielectric layer and does not affect the momentary dielectric strength and momentary breakdown voltage of the dielectric layer. The dielectric strength and breakdown voltage of the dielectric layer are affected and lowered by subsequent partial discharge activities. These long-term PD activities will be monitored and the result will be used for diagnostic purposes and for repairs planning [1]. Partial discharges are defined in IEC 60270 as localized electrical discharges that only partially bridge the insulation between conductors and which can or cannot occur adjacent to a conductor. Partial discharges are in general a consequence of local electrical stress concentration in the insulation or on the surface of the insulation. Generally, such discharges appear as pulses having duration of much less than 1 µs [2].

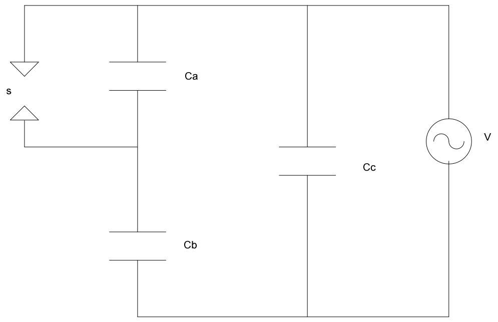
PD is a factor in 85% of substation failures [4].The process of building or formation structure involves several stages starting from selection and preparation of raw materials, process of application of raw materials, thermal or chemical treatment. The total process of providing electrical insulation involves men, materials and machines and also different environmental conditions. It is therefore, practically not possible to achieve a perfect electrical insulation without defects as it may get contaminated and disturbed during material handling, processing and manufacturing of electrical equipment [3]. So, it is necessary to detect and analyze the PD.

II: FUNDAMENTAL OF PARTIAL DISCHARGE IN SOLID CAVITY

Electrical insulation with voids leading to partial discharges can be represented by an electrical equivalent circuit (fig. 1).



(a) Physical modeling of void



(b) Equivalent circuit of PD

FIG. 1: PD model

V = applied voltage at power frequency
S = spark gap representing discharge of Ca
Ca = capacitor representing the cavity
Cb = capacitor representing insulating material around cavity
Cc = capacitance of the remaining insulating material

A capacitor with a void inside the insulation (Ca) series with the rest of the insulation capacitance (Cb). The remaining void free material is represented by the (Cc). When the voltage across the capacitor is increased, and it will reach across the capacitor Ca (more than insulation withstand capacity) a discharge occurs through the capacitor it represented by the closer of the switch [5].

III: PARTIAL DISCHARGE

A. Classification of Partial Discharge:
Partial Discharge phenomenon is divided into two types:

i. External Partial Discharge: External Partial discharge is the process which takes place outside of the power equipment's. Such type of discharges occurs in overhead lines, on armature etc. [7].
ii. Internal Partial Discharge: The PD which is occurring inside of a system. It is arising in cavities or voids which lie inside the volume of the dielectric or at the edges of conducting inclusions in a solid or liquid insulating media [7].

B. Type of Typical Partial Discharge:

i. Corona Discharge: PD around a conductor in free space is called corona discharge [3]. Corona discharge takes place due to non-uniform field on sharp edges of the conductor subjected to high voltage. The insulation provided is air or gas or liquid.

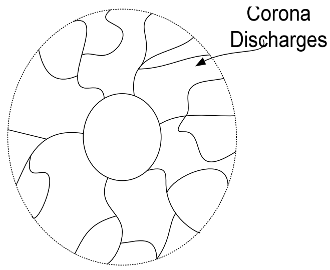


FIG.2: Corona discharge

ii. Surface Discharge: Surface discharge takes place on interfaces of dielectric material such as gas/solid interface as gets over stressed times the stress on the solid material.

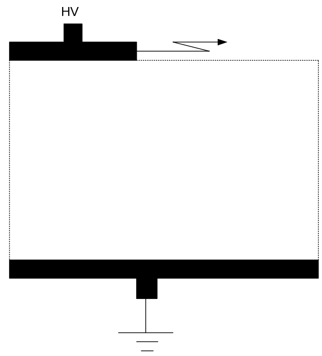


FIG.3: Surface discharge

iii. Cavity Discharge: The cavities are generally formed in solid or liquid insulating materials. The cavity is generally filled with gas or air. When the gas in the cavity is over stressed such discharges are taking place.

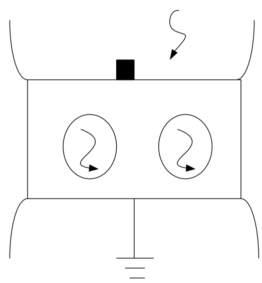


FIG.4: Cavity discharge

iv. Treeing Channels: High intensity fields are produced in an insulating material at its sharp edges and it deteriorates the insulating material. That is responsible for production of continuous partial discharge, called as treeing channel.

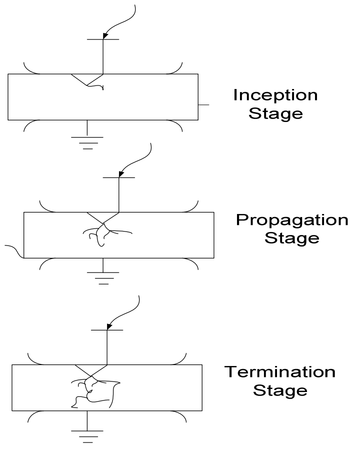


FIG.5: Treeing channel

IV: TYPE OF PARTIAL DISCHARGE DETECTION METHODS

1. Electrical Detection
2. Chemical Detection
3. Acoustic Detection
4. UHF Detection

1. Electrical Detection: Electrical PD detection method is widely employed method for all type of electrical equipment like transformer, cables, gas-insulated system (GIS). Electrical is standard (IEC - 60270) and convenient method. It has certain limitations particularly, when applied to test object with large capacitance and on-site testing. The detection of electrical pulses produced by partial discharges tends to be more convenient and sensitive then non-electrical methods [3]. Electrical detection focuses on capturing the electrical pulse created by the current streamer in the void. This method or system is more convenient, standardized, accepted, sensitive and simple to apply compared to other methods. This system is able to measure the internal discharge, surface discharge and corona discharge.
Limitations of Electrical method,
   a. Requirement of huge electrical apparatus and elaborate arrangements like PD free voltage source and blocking capacitor.
   b. Elaborative and expensive electromagnetic shielding for laboratory measurements.
   c. Site measurement demands shut down of at least a part of the power station together with the necessity of disconnection of the test object from the circuit.
   d. Lack of control over background noise.
   e. Lower sensitivity for measurement on long lengths of UG cables and power capacitors.
   f. Difficult in localization the PD sources [3].

2. Chemical Detection: The current streamer across the void can break down the surrounding materials into different chemical components. The two primary chemical tests employed by power companies today are Dissolved Gas Analysis (DGA) and High Performance Liquid Chromatography (HPLC). DGA is based on oil sampling, and the modern technology of on-line gas monitors. Major diagnostic gases have been identified as hydrogen (H2), ethane (CH4), methane (C2H6), ethylene (C2H4), acetylene (C2H2), carbon monoxide (CO) and carbon dioxide (CO2) [6]. The Health Index Factor (HIF) of DGA can be achieved subsequently for each % DGAF factor given in (table: 1)

HI Factor	Condition	Description	Color Band
4	Good	DGAF< 20%	Green
3	Acceptable	21%< DGAF< 30%	Blue
2	Need Caution	31%< DGAF< 40%	Yellow
1	Poor	41%< DGAF< 50%	Orange
0	Very Poor	DGAF > 51%	Red

Table 1: Health Index [6].

3. Acoustic emissions from the electrical discharge source were detected as early as 1939. PD activity is associated with instantaneous release of energy along with other micro and macroscopic processes. A fraction of the released energy heats the material adjacent to the PD location creating a small explosion, which excites a sound wave.
The wave propagates through material media enclosing the region of emission, before reaching the enclosure of the electrical equipment. High frequency AE sensors mounted on the walls of the container pick up these vibrations of the surface wave and convert it into electrical signals, which could then be captured by appropriate instrumentation and analyzed by a processing system. The shape of the detected signal depends on the source, the propagation media, the detection equipment, and the AE sensors (Fig: 6) [3].

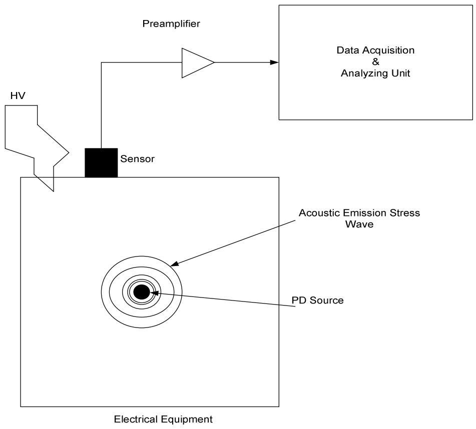


Fig. 6: Principle of AE technique [3].

Substance	Longitudinal velocity, c (m/s)
Aluminum	6400
Steel	6000
Brass	4280-4700
Copper	4700
Water	1484
Mineral oil	139
Caster oil	1500
Nitrogen	333
Oxygen	315

Table 2: Acoustic longitudinal wave velocity of some engineering materials [3].

Acoustic method has certain advantages over other methods,

a. Non-destructive and non-invasive in nature.
b. Easier and quicker instrument setup at site.
c. No disruption of power system operation is required.
d. Possibility of localization of acoustic source [3].

4. In recent year, there has been a fast development in UHF detection technology. Discharge can be understood as electromagnetic events which are extremely fast, transient pulses. The disturbance, being of the order of nanoseconds, causes a pulsed radiation, having measurable energy levels in the gigahertz range. PD is detected by means of the electromagnetic transients radiated within the frequency range 300-3000 MHz (UHF). UHF sensors measure these signals which can be further analyzed and processed. The UHF frequency range in particular is adopted in gas insulated system.

Electromagnetic technique	Frequency ranges, MHz
HF	3-30
VHF	30-300
UHF	300-3000

Table 3: Frequency ranges [3].

Electro- -magnetic technique	Cable	Transformers	GIS	Gener- -ators
HF	+	-	-	+
VHF	+/-	+	+	+
UHF	+/-	+	+	-

Table 4: Frequency ranges used in different power equipment [3].

It is applied to GIS, with a working frequency range of PD between 0.3 and 3 GHz, capacitive sensors of antenna type are employed to capture the PD signals. Cylindrical collar sensor and conical collar type capacitive sensor are used. High frequency current transformer (HFCT) sensor of the Rogoskowki coil (fig: 7) type have been used for fast transient measurements.

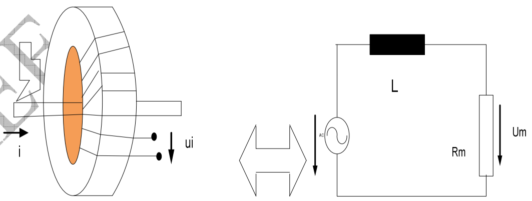


Fig. 7: Rogowski coil and its equivalent circuit [3].

The UHF and associated measurement has certain advantages over electrical and acoustic methods. A particular importance is the irrelevance of complicated noise suppression methods [3].

Component	% of Insulation Failure
Transformers	84%
Circuit Breakers	21%
Disconnect Switches	15%
Insulated Switchgear Bus	95%
Bus Duct	90%
Cable	89%
Cable Joints (Splices)	91%
Cable Terminations	87%

Table 5. Persentage failure rate [8].

V: CONCLUSION

This paper highlights the theoretical background of PD, its classification and type of detection methods.

Also give the idea of advantages and disadvantages of different detection methods relatively. Older days Electrical and Chemical methods where used. In electrical method we have to isolate the equipment from the system but it is standard method. While in chemical method we need expert comment. Now a days, UHF and acoustic methods are widely used. It is on line detection method so isolate of equipment from system is not require. In UHF we don't recognized the location of the PD source while in Acoustic give location of the PD source. So, Overall combination of method gives good result.

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