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Partial Discharge Detection Techniques: A Review

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Abstract - *partial discharge techniques occurs in high voltage equipments. This paper present a different techniques of partial discharge and case study of one equipment. High voltage equipment monitoring is compulsory because of the many failures during the operation. The protection of high voltage equipment is more important things because its cost is very high. There are many techniques to detect the partial discharge to increase the realibity of the system. The partial discharge can be tracked by the acoustic emission, chemical reactions and many more. The high voltage equipments like power transformer, cable installation, gas insulated substances, etc. This paper reviews the available partial discharge detection methods like electrical detection, thermography, chemical detection, acoustic detection. The case study represent the process of partial discharge technique in the system. Advantages and disadvantages of partial discharge explained in this paper. The analysis of each method is explained in the paper and mathematical modeling also explained to analysis of partial discharge.*

***Key Words*: Partial discharge, insulation, breakdown, overhead lines, transformer**

1. INTRODUCTION

The partial discharge is a localized form of electrical engineering. Its consist a not completely bridge the space between two conductors. Partial discharge detect in gaseous, liquid or solid insulating medium. Its is short release of current. The high voltage equipments are localized by the partial discharge. Partial discharge detection is used to monitoring the equipment for the health of the system.

It is a important tool for insulating conditions in high voltage equipments. The insulation breakdown due to mechanical, electrical or thermal occurs the failure in high voltage system. In this paper author explained about different techniques of partial discharge. There are three types of detection techniques

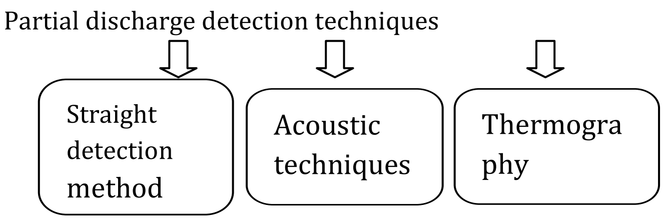

FIGURE 1: Classification of partial discharge techniques

Partial discharge measurement system consists;

- the system being tested
- the inductor and capacitor design
- low background noise in high voltage supply
- connection of high voltage
- filter is use for reduce the background noise from the power supply
- detector of partial discharge
- software analysis system
- high power equipments
- phase resolved analysis system bandwidth range
- ultra high frequency sensor detection is 300 khz-50 MHz
- high frequency current transformer 500 khz-50 kHz
- acoustic sensor 20 khz-300 kHz
- ultrasonic microphone 40 kHz
- coupling capacitors 3 mhz-100 MHz

Insulating breakdown is the main thing to electrical failures for high voltage equipments. This is happened at 84% of transformer and 89% of insulating cables due to the partial discharge. Partial discharge occurs when insulating breakdown exited in insulating parts with appropriate amount of electrical stress.

Partial discharge happened in high voltage equipments when incomplete breakdown occurred between two conductors by existing electrical stress and finally insulating failure.

The partial discharge term refers that the incomplete flow of current in high voltage system. It occurs specially in overhead lines and insulators. It happens when voltage is more than 3.3 kv. It is typically occurs in transformers, switchgears, stators, etc.

Partial discharge harm insulating materials in high voltage equipments like cables, transformers, switchgear boards, etc. Partial discharge present can result major failures and energy losses. Electrical engineers are monitoring partial discharge because of the health of high voltage system.

In this review paper, the author explained about the current methods of partial discharge and strengths and weakness.

1.2 Mathematical modeling

Nomenclature

Ca Insulation without defect

Cb Dielectric in series with the gaseous capacitance *c*

Cc Cavity or part of the surface in which the PD occurs

A Capacitor area

d Insulation thickness

***ε*0** Permittivity of free space

***ε*r** Relative permittivity of the defect

t Defect thickness

q External charge displacement

***q*1** Real charge displacement

V Voltage in dielectric

Vi Instantaneous PD inception voltage of the cavity

U across the cavity before a discharge of *c*

_***V*** Drop voltage over *c* caused by the discharge

E(Ωk) Local entropy in the neighborhood *Ωk*

L Maximal gray scale

Mk × ***Nk*** Window size

ni Pixel number with gray scale *i* in the neighborhood

Pi Probability of gray scale *i* that appears in the neighborhood *Ωk* (gonzales, 2015)

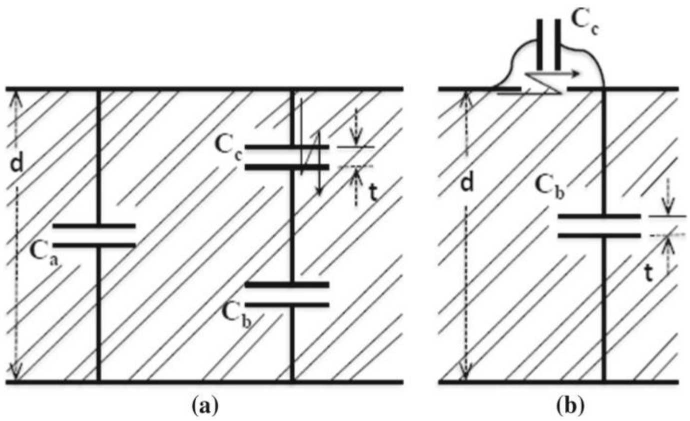

Figure 2: Electrical representation of (a) internal partial discharges and (b) superficial partial discharges (gonzales, 2015)

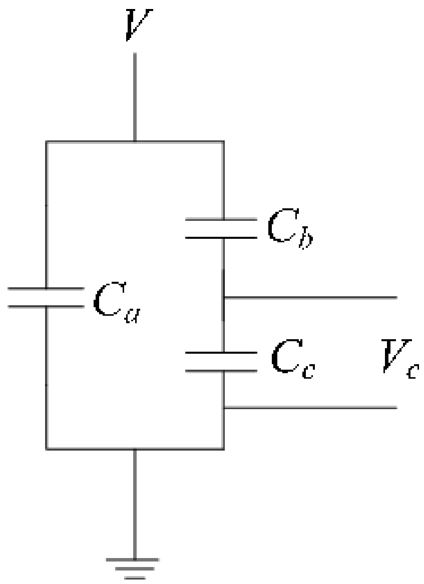

Figure 3: PD electrical model (gonzales, 2015)

Capacitance Cb= $\frac{\varepsilon 0 \varepsilon r A}{d-t}$

Cc= $\frac{\varepsilon 0 A}{t}$

Voltage across the cavity U= $\frac{Cb}{Cc+Cb}\Delta V = \frac{\Delta V}{1+\frac{1}{\varepsilon r}(\frac{d-t}{t})}$

Voltage across the dielectric sufficient to intimate the discharge process in the cavity

Vi= Ec $[1 + \frac{1}{\varepsilon r}(\frac{d-t}{t})]$

Energy stored in Cc , WCc= $\frac{1}{2}CcU^2$

After discharge energy stored in Cc , WCc= $\frac{1}{2}CcV^{2}$

Total dissipated energy in cavity,

Wi= $\frac{1}{2}Cc(U^2 - V^{2}) = \frac{1}{2}Cc\Delta V(U + V)$

Cb<<Cc then dissipated energy becomes,

Wi= $\frac{1}{2}Cb\Delta VVi = \frac{1}{2}qVi$ (gonzales, 2015)

2. Different types of detection method

2.1 Straight detection method

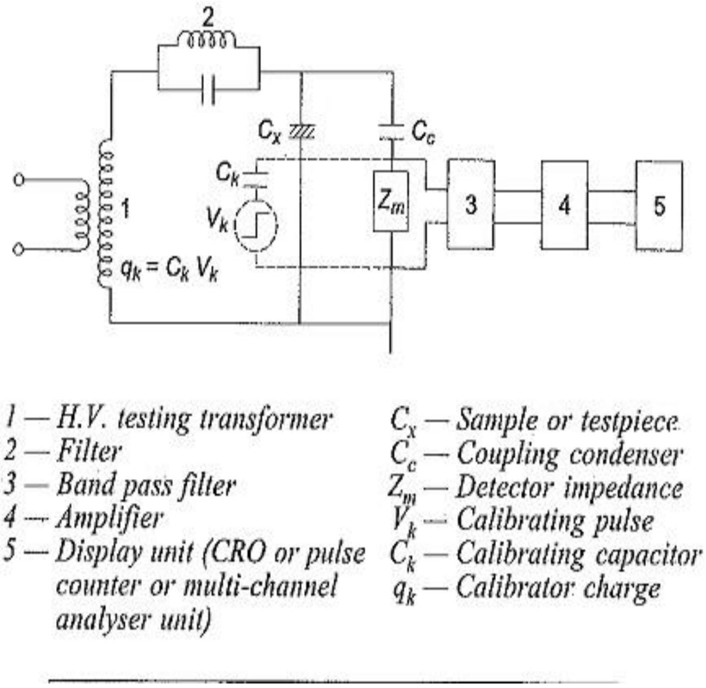

Figure 3: Representation of straight detection method (htt)

Most of the partial discharge detection systems are according to the circuit shown in figure.

Within this straight detection circuits the coupling device Cc with its detector impedance Zm forms the input end of the detection system.

Coupling condenser Cc is in series with the test piece Cx. Here a stray capacitance of all element of the high voltage side to ground potential will increase the value of Ck calibration capacitor providing a higher sensitivity.

The disadvantage of this is the possibility of damage to the partial discharge detection system.

The pulse with rise time is produced in the circuit. The voltage is across the detection impedance fed into a CRO through the amplifier. The measurement impedance consists RLC circuits with flexible inputs. By varying capacitance the circuit is tuned to the midband frequency of band pass amplifier.

The magnitude of any discharge determined direct comparison with pulse, which produced by calibrator. Proper input is connected according to capacitance and adjusted to concerned charge with pulse generator.

The coupling capacitor bypasses the power frequency and allows partial discharge pulses to detect impedance.

2.2. Acoustic technique

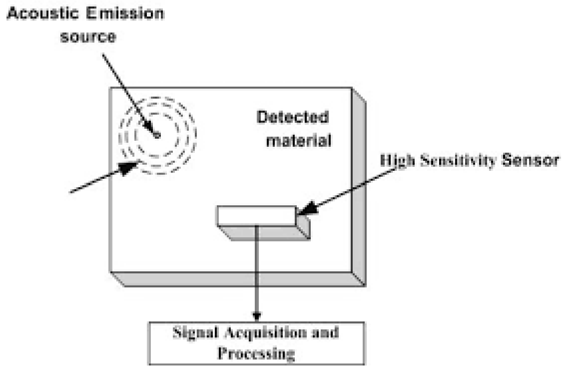

Figure 4: Representation of acoustic technique (htt)

In the substation, both the particles and partial discharge is capable of develop waves that stimulated signals. This waves are created by the partial discharge. Waves are shifted with various speeds and expressed in the boundary between the acoustic waveforms. This waveforms are detect by the acoustic sensors as in figure.

This is a non instructive procedure. Detection is performed by the integrating internal detectors and predict the partial discharge position. Multiple sensors maximum precision.

the advantages of this method is good result in real time, has noise immunity for application to do online partial detection, position of partial discharge is possible using multiple sensors.

Disadvantages are low sensitivity, interference of signals by environmental noise.

2. 3.Thermography

Thermal imaging camera detect the partial discharge in instritically partial discharge location. This methodology does not working for enclosure structure. This corona camera independent ultra violet video and visible camera captured independent image of discharge. Ultra violate gives low but high contrast pictures due to complete absence of background radiation.

This camera shows the ultra violet lights occurs when nitrogen comes into contact with power leak. As normal. Ultra violet lights is filtered out corona ca visualize in daylight. During the detection normal video image and ultra violet are shown simultaneously.

Inspection with corona cameras can be done without shutting the power lines which is advantageous in terns of cost, risk and time.

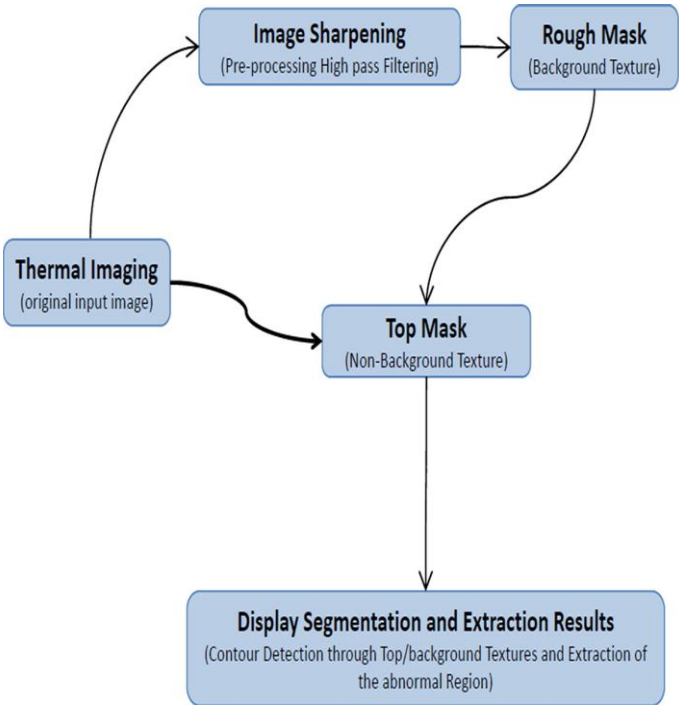

Figure 5: Flow diagram of the intensity-based texture segmentation algorithm (gonzales, 2015)

The experimental analysis of partial discharge using thermography is performed consider in the failure in the terminals. A transformer is simulated the high voltage applied transmission line and charge is included in the line by a current transformer.

The voltage between phase and ground terminal is 15 KV and suitable silicon terminals were used and this is for 1/0 power cables. A current of 60 A is circulated in system considering real charge in line.

A failure is include in the terminals having a small separation of stress cone and outer semiconductor layers. This separation gives superficial partial discharge in the terminals causing a temperature increment by charge transference and electrical activity. As shown current circulation in the cable figure shows a image of the outer semiconductor.

To measure the changes in electrical signals as failure occurs the system was instrumented with coil. As shown in figure the coil is connected with oscilloscope. Such as electrical current circulated through the part of the system affected by the included failure was continuously monitored.

Partial discharge activity was verified in both the terminals by mean sensor shown in figure. The signal plotted to see the difference between the terminals with a defect and the terminal without failure.

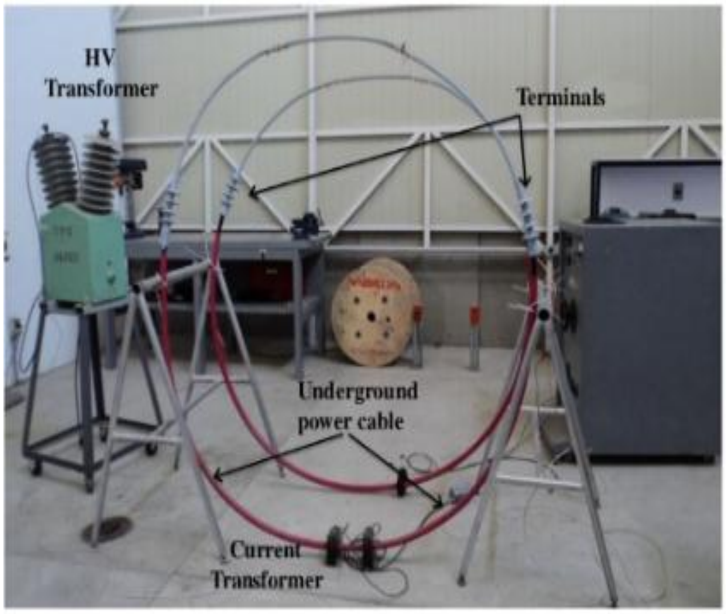

Figure 6: General test setup for electrical PD detection in underground power cable model (gonzales, 2015)

3. Comparison table

Techniques	Advantages	Disadvantages
Electrical	• Applicable for all type of high voltage system • Type, source, partial discharge location assemble • Suitable for online partial discharge	• High electromagnetic interference • High maintenance
Acoustic	• High sensitivity • Immunity against electrical noise • Efficient for localization of partial discharge	• Signal intensity is low • Not suitable for continues partial discharge
Thermography	• Non destructive and non contact type technique • Fast, reliable, accurate detection • Work in real time • Large area also covered	• Duality cameras cost is very high • Only measures surface areas • Not able to measure the inside temperature

Table -1: comparison of different techniques

3.1 summary table

No.	Author/publication year	Detection methodology
1	Rajesh h. Laniya Prof. K.k. dudam [2015]	PD Detection using acoustic emission technique
2	Linhai zhang Gang liu[2007]	PD detection in power transformer using acoustic sensors
3	Iln.c. sahoo m.m.a salama r. bartnikas[2010]	Trends in PD pattern classification
4	Zul hasrizal bohari Muzamir isa Ahmad zaidi Abdullah[2011]	PD detection for liquid and gas insulated high voltage equipment
5	Guangzhong xie Yadong jiang[2011]	Online PD detection using wireless network
6	Hum yaacob Ma alsaedi Jr rashed Am dakhil[2014]	PD detection using different sensors
7	m. boltze s.m. markelous[2009]	On line PD monitoring and diagnosis at power cables
8	g.s kill i.k. kim[2015]	Measurement and analysis of PD using acoustic sensor
9	Ammu anna Mathew Anoop j.r. s. vivekanand[2020]	Detection localization of PD in transformer oil and winding using UHF method
10	Alistair reid Martin judd Cart johnstone[2009]	Development of UHF transformer probe sensors for on line PD detection
11	Rajani memon s. kolambekar n.j buch [2002]	Application of acoustic emission discharge detection method for online monitoring of power transformer; ERDA's experience
12	Ron harrod[1993]	Ultrasonic sensing of PD within large capacitors
13	Kannan m Prof. P. Sreejaya[2013]	PD detection in solid dielectrics
14	Youichi natakatani Mikio adachi Toshihiro miyazaki Takashi noma[1996]	Development of PD measurement method for pre-mold cable accessories with separated shielding layers

Table -2: summary table

4. Conclusion

In his paper author explained about the different techniques of the partial discharge detection. The mathematical modeling explained the theoretical background of partial discharge detection. All type of partial discharge techniques explained in this paper. Comparison table of all the techniques has been presented in this paper. This overview concludes the details and development about the detection of partial discharge in high voltage system and also the reorganization and localization. Major benefits all the techniques explained in this paper. the fundamentals which are the via of theoretical partial discharge are outlined which cal help in simulation or experimental work. Based on the detection its not possible for signal itself to access the source of partial discharge. The online partial discharge detection is used for detect the partial discharge before the breakdown.

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