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Partial Discharge Detection in High Voltage Rotating Machines

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***Abstract*—Partial discharge monitoring is a effective tool for maintenance of motors and other electrical apparatus. This is beneficial for equipment analysis and diagnostics in normal production. At initial stage, corrective actions can be implemented and unscheduled shutdown can be overcome. Partial discharges can be seen in various forms and can be detected using different techniques. Some of the electrical and non-electrical techniques are presented in this paper.**

Keywords*— *Partial Discharge, Detection Mechanism, Rogowski Coil

1. INTRODUCTION

Partial discharge is an electrical discharge or pulse on a dielectric surface of insulation system or in void. Figure 1 shows a representation of a discharge occurring within an insulating material that can occur internally or externally to the insulation.

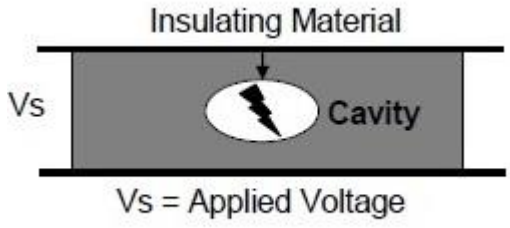

Figure 1: Representation of partial discharge

2. TYPES OF PARTIAL DISCHARGE

Based on the location and nature, partial discharges can be classified into the four categories:

- Internal discharges- normally occur in cavities or voids in liquid or solid dielectrics
- Surface discharges- appear at the boundary of any insulating material
- Corona discharges- occurs in presence of non-homogeneous fields in gas dielectrics
- Electric treeing- in solid dielectrics it forms a discharge channel due to impact of discharges.

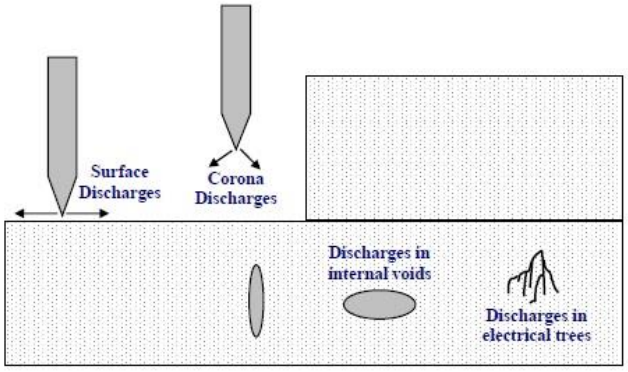

Figure 2: Different types of discharges [1]

In general, partial discharges are of mainly three types i.e. internal discharge, surface discharge and corona discharge.
With respect to stator windings, discharges are classified based on their locations i.e. slot discharge and end-winding discharge. Because of manufacturing tolerances, some discharges will always be presented.

3. PARTIAL DISCHARGE DETECTION

Partial discharge detection can be done using various techniques as PD is associated with several phenomenons. Very large range of techniques is now available with each measuring certain specific quantities. The use of each technique is greatly dependent on nature and type of equipment to be monitored. PDs are associated with several phenomenons like light, heat, noise, gas pressure, electromagnetic radiation, dielectric losses and electrical impulses. Therefore, PD can be detected by measuring any of these physical quantities by various methods. The PD detection mainly categorised into two categories:

1. Non-electrical detection techniques
2. Electrical detection techniques

- Non-electrical detection techniques

The most common non-electrical techniques are:

a) Chemical detection
b) Acoustic detection
c) Optical detection

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a) Chemical detection: The method is best suitable in gas insulated switchgear (GIS) and GIS substations where analysis of SF_6 is used. The PD activity in power transformer generates gaseous compounds as hydrogen, methane, ethane, ethylene in transformer oil which can be detected by performing chemical analysis. Dissolved Gas Analysis (DGA), Furan Analysis and Duval Triangle are the most popular technique used for on-line testing of power transformers at present. The limitation associated with this method is that it provides only little information about the nature, intensity and location of PD.

b) Acoustic detection: The acoustic waves are generated when the gas expansion takes place near the discharge. This discharge may results in the release of energy resulting in the vaporising of material. The intensity of the wave is proportional to the energy released in the discharge. The advantage of acoustic detection is that the identification of location of discharge can be possible using sensors at multiple locations. Secondly, it's susceptibility to Electromagnetic Interference. It has also some disadvantages. Also it can detect any loose components, track of the surface, pressure leaks. The limitation of this method is the complex nature of acoustic impedance between PD source and detector and very low intensity.

c) Optical detection: Discharges are associated with various excitations, ionisation and recombination process and this leads to production of light. There are two ways to implement this method. One is use of HV corona imaging camera for the detection of discharge on the surface of the electrical equipment. This technique is suitable in high voltage transmission line and in power stations. Second one is use of fibre optic cables as sensors for optical signal. This technique is best suitable for transformers and GIS. Limitation of this technique is the cost of the equipment.

- Electrical detection techniques

These methods are more sensitive with respect to other methods and also are more popular and widely used. There are basically two types for electrical PD detection:

a) Power loss detection

b) Detection of current pulses

Like others, this technique also has some limitations. First one is its susceptibility. In some cases, it is very complicated or even impossible to differentiate between noise and PD because of short PD pulse width results in false detection. Also it is highly dependent on machine geometry.

4. SENSORS FOR PARTIAL DISCHARGE DETECTION

Various types of sensors are used to detect PD in different types of high voltage equipment. The choice of sensor is affected by factors like suitability, the cost involved and the type of application. Selected sensors should follow the following points:

a) should not impact the service condition of the equipment

b) should have at least the same life performance as the equipment on which it is installed

c) easy installation of sensors

d) essential against climate on-site conditions

- **Classification of sensors:**

The sensors used for electrical PD detection are classified as:

a) Inductive type sensors

b) Capacitive type sensors

a) Inductive type sensors

The inductive type sensors are designed to detect the magnetic field of the transient PD current. Some popular inductive sensors used at present are Rogowski coil and a RF current transformer. Some of the characteristics of inductive sensors are as follow:

- Well suited for on-line measurement with compact portable equipment
- Provide galvanic isolation
- Can be easily installed around the cables due to simple construction
- Installation doesn't require machine to be shut down
- Sensitivity is reduced compared to the capacitive probes

b) Capacitive type sensors

These sensors are designed to detect the electric field energy of PD pulses with a metallic electrode and metallic foil layers in electric field. Some of the characteristics of capacitive sensors are as follow:

- Well suited for on-line measurement with compact portable equipment
- Don't provide galvanic isolation and the sensor is subject to HV
- Pre-installation is recommended
- Machine needs to be shut down for installation
- Sensitivity is better than inductive type sensors

Some of the most popularly used sensors are listed as follow:

1. Rogowski coil
2. Radio frequency current transformer
3. Capacitive coupler
4. Stator slot coupler

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A comparison of these sensors is described in the following.

Parameter	Capacitive Coupler	RFCT	Rogowski Coil
Types	1) Cable type 2) Epoxy Mica insulated type	1) Solid core ferrite 2) Split core ferrite type	1) Solid core 2) Split core type
Sensitivity	Has the best sensitivity	Better than Rogowski coil	Has the least sensitivity
Performance	Sensitivity depends on the value of the capacitance and has a directly proportional relationship	Sensitivity depends on the type and grade of the ferrite material used.	Sensitivity depends on the number of windings and has a directly proportional relationship.
Installation	Requires direct connection to the HV terminals. Shut down required for installation.	Installed around the cables and require no direct connection to the HV terminals. No shut down required for installation.	Installed around the cables and require no direct connection to the HV terminals. No shut down required for installation.
Size	Smallest compared to the other two types	Comparatively bigger for the similar specification of Rogowski coil	Comparatively small for a similar specification of RFCT
Linearity	N/A	Less linear compared to Rogowski coils	Output is very much linear
Saturation Limits	N/A	Saturates at high currents; thus not suitable for machines with high current rating.	Being air-cored, it does not saturate at high currents making it suitable for machines with high current rating.
System Capacitance	The larger the system and plant capacitance's, relative to the coupler capacitance, the lower the sensitivity of the coupler technique.	The higher the system capacitance, the higher the sensitivity.	Same as RFCT
Application	They are best suited for plants that are connected to system by bus bars.	Best on system that uses cables as the means of connection.	Same as RFCT

Table 1 comparisons of various electrical PD detection sensors

5. LATEST PD DETECTORS IN MARKET

Given below is the list of manufactures of PD detection equipment:

1. IRIS Power Engineering (North America)
2. ADWEL International Limited (Canada)
3. PD Diagnostix Systems (Germany)
4. M&B Systems Power Test Equipment (UK)
5. TECHIMP (ITALY)
6. Tettex Instruments (Switzerland)
7. HIPOTRONICS (USA)
8. Robinson Instruments (UK)

6. CONCLUSION

Electrical detection techniques are most popularly used for rotating machines. On-line techniques are preferred over offline techniques for reasons well established. Different sensors are available for electrical detection of PD each having some advantages over the other. The study of various commercially available PD detectors was essential and proved useful to get familiarized with the latest trends in PD detection techniques and provided inputs for new system design.

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