ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Measurement and Detection of Partial Discharge in Power Systems

Raafe Karim Khan, Akash Basia
Department of Electrical & Electronics, Manipal Institute of Technology, India
raafe.karim@gmail.com

Abstract

Power systems are the life line of the 8.3 billion people who currently inhabit the world. As the population of the world increases the need for power system protection and maintenance and up gradation is of grave importance to both electrical utility companies as well as end consumers. In the context of power system protection, insulation plays a pivotal role in isolating the transmission lines from the external environment in which they were present. This makes the study of insulation or dielectric breakdown even more important because transmission lines run into several hundreds and in some cases thousands of kilometres. Hence we shall be enlisting the need for partial discharge detection devices; so that insulation failure can be detected on line and be given attention by engineers for due replacement and or maintenance. Most incipient faults are due to partial discharge and this phenomenon has many effects on the health of the system, hence measurement and detection are an important step in taking corrective action.

Keywords: Power systems, protection, transmission lines, insulation breakdown, partial discharge, detection, measurement, replacement, maintenance.

Introduction

In today's scenario, with the advancement of technology and increasing demand for electricity, also comes the need to protect electrical equipment. The simplest for of which is insulation. This comes under the category of primary protecton. Insulation is basically an isolating medium, in the sense it isolates the environment from the imeediate electrical activity within the conducitng wire or in other words transmission lines. Since transmission lines are capable of carrying a few thousand amperes on short circuit, it is necessary to have an optimized and some sort of restrictive protection. Since insulation breakdown is not within our control, there must be a mechanism which can help engineers detect the breakdown of insulation, and if breakdown is severe, that portion of the wire must be replaced. Prevention of breakdown helps both consumers as well as energy utility companies, as it amounts to many benefits including keeping the power system in healthy condition.

Partial discharge

What is partial discharge

In electrical engineering terms partial discharge is nothing but localized dielectric breakdown of material under voltage stress. Partial discharge can occur in any state of matter. It is measured in terms of its capacitance i.e. in Coulombs.

This discharge at local inhomogenities emits a spectrum of electromagnetic waves or radiation and transmits information about the energy level of the discharges. For the measuring physical effects like optical, electrical and acoustical appearances are used.

This phenomenon however can range from pico-Coulombs or micro-Coublombs. Hence, strictly speaking on a signal level, an instrumentation amplifier will be required to tap these values, even if it is to be in cascaded. The effects of partial discharge are detrimental to humans. According to a report by the World Health Organisation , almost 1/3rd of deaths due to electrical shock have been rooted to partial discharge. Since this phenomenon can alone destroy electrical systems and sub systems of not detected in the right stage and treat, it can be also referred to as the cancer of electrical power systems.

Table 1. Causes of partial discharge

Intrinsic	Extrinsic
Electric field capacity exceeded	External field if present
Excessive current harmonics	Lightning strikes on the surface of insulating

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

	material
Internal short circuit	Operating period or age of conductor and or conducting material
Open circuit conditions for time period greater than the time constant of the capacitance of the insulating material i.e. T(s) > τ(s).	External human interferance
Voltage spikes in the system	Dielectric variance
Poor inner insulation	Poor external insulation

The basic evidence of partial discharge is seepage of pale yellow liquid from the conducting material. It is a very common sight in regions where extreme climatic conditions prevail. For example the northern belt of Inda experiences a maximum temperature of 47°C and minimum of about 2°C. Another evidence of partial discharge is the evidence of corono. Corona is detrimental to the load side as it suppresses the line voltage considerably thus affecting sub system peripheries.

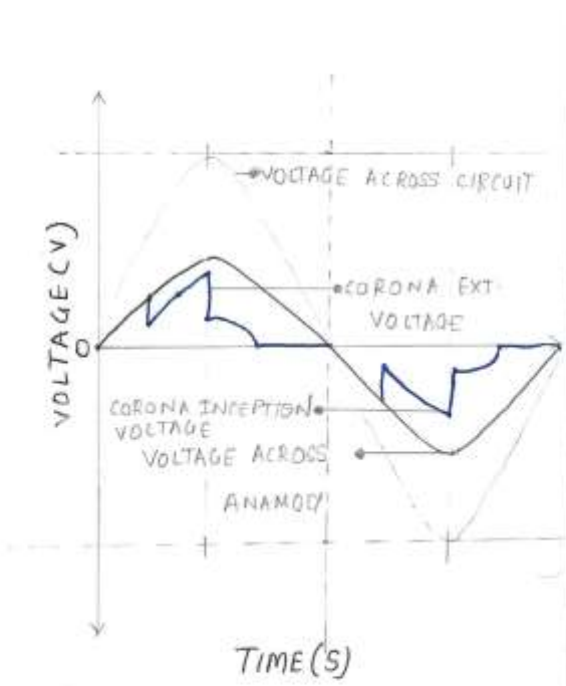

Fig. 1. Corona discharge voltage

Corona is a type of partial discharge. It is characterized by a purple color emitted from the conductors insulation. It can be seen that corona follwos a similar pattern to the original line voltage. Corona detection is simple but at the same time expensive. This can be offset by re-engineering a web-cam to capture thermal images in real time. This will ensure that heat signature of corona is detected. It is obvious that as discharge continues to increase with time, the surrounding temperature in the immediate vicinity of the damaged insulation also increases, i.e. there is a linear relationship between the two analog quantities.

Why partial discharge testing?

There are many tests which gives us an indication of insulation health. However these tests do not much up qualitatively to a PD test. There are three other tests in addition to a partial discharge test viz. Meggers test, Polarization Index test and High Pot Test.

The Megger test is very vague in nature, i.e. it gives very little information regarding the health of the insulation material. More like a binary indication of the prevelant status. Polarization Index Test is one step ahead, but still lacks any qualitative measure. High Pot Test has qualitative measure, much more than the previous two tests stated. However this test is meagerly a shadow when it comes to partial discharge test. PD testing is holistic in nature and is a complete indication of the insulation breakdown, if it has taken place. The figure below compares the four tests in details, taking into account each insulation model in detail.

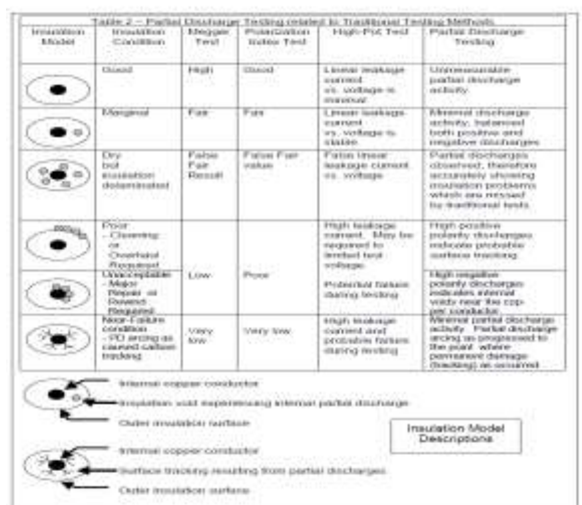

Fig. 2. Comparison of each test in detail

How to measure partial discharge

There are three stages to measure partial discharge. The first stage is to measure magnitude of TEV. The second stage is to distinguish partial discharge from noise. In order to do this we have to teach the system what noise looks like in the system and induce a sense of neglecting this unwanted piece of signal. The last stage is locating the discharge. It is

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

important that the circuit developed is able to locate the discharge within 8cm of its source. This can be pictorially depicted as

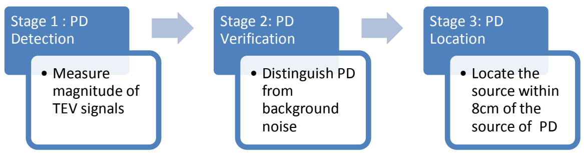

Fig. 3. Generalized stages of partial discharge sensing

The circuit which we propose is not only lower in cost compared to its contemporaries but its also effective at the same time. It includes a hall effect sensor, temperature sensor, capacitive plates and a peltier cooler(optional). The hall effect sensor will give us the current in the discharge. This is important incase short circuit takes place and last value of current is important for logging and maintenance purposes. We already know the temperature and discharge voltage magnitude hold a linear relationship, therefore temperature will give us an overview of the degree of discharge taking place. Capacitive plates will give us an idea of the capacitance of the line. Since PD is primarily measured in coulombs it is also quite widely measured in terms of voltage. However, capacitance will help us determine average TEV and also give us an indication of the health of the line.

Fig. 4. Block diagram of control system for measurement of partial discharge

Another way of detecting discharge is by using an optical sensor grid. Discharge is a source of energy in a way of speaking. It emits radiation, thereby produces spurts of energy and heat. It also increases localized temperature and emits photons. Due to this property many researches have proposed the use of optical sensor grid calibrated against standard models for detection of partial discharge.

Results and discussion

We developed a circuit using parallel plate capacitors to sense change in dielectric strength and a combination of hall effect sensors and temperature sensors using Multisim, a circuit development suite produced by National Instruments. We already know that

$$C = A * \frac{\varepsilon}{D}$$

Where C is the capacitance in Coulombs, A is the area in square meters and ε is the permeability of the medium and D is the distance between the two plates in meters. Keeping A and d constant, we can detect change in dielectric strength of the medium.

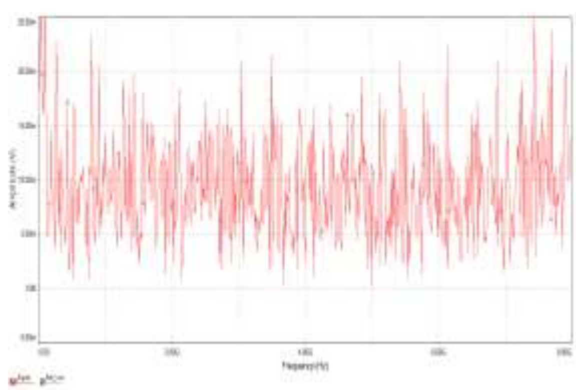

Fig. 5. Spectrum of partial discharge

The figure above shows the spectrum of the wave, which is discharge. It can be seen that discharge pattern follows the sine wave to a certain extent. It is also seen to be a very high frequency wave with inherent spikes in the voltage profile. The nature of the above profile is clamped and pulsating in nature indicative of high ripple content and spirulousity.

It is to be noted that the result obtained above was for a perfectly healthy line under ideal conditions of pressure and temperature. The insulation considered is AWG-545 and it is seen that even under ideal testing there is a small high frequency discharge which can still occur. However, this is speculative as discharge may not occur at all. We have considerd a small test charge to be invariably present to see changes which occur in the line.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

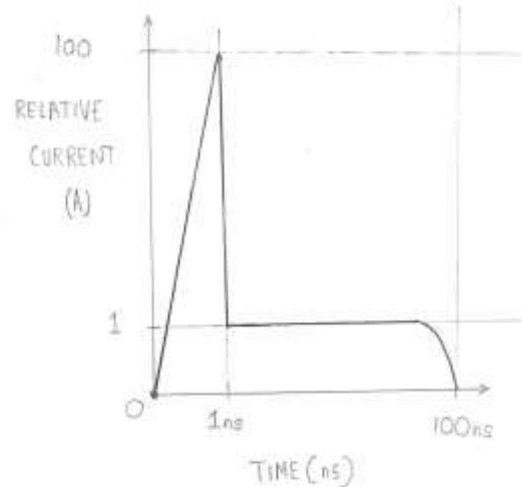

Fig. 6. Relative current (A) vs. time (ns)

If we see discharge in terms of relative current, we observe a large spike almost instantaneously like a ramp. Such a high current spike can even inititate an internal electric tree and by extension result in a short circuit.

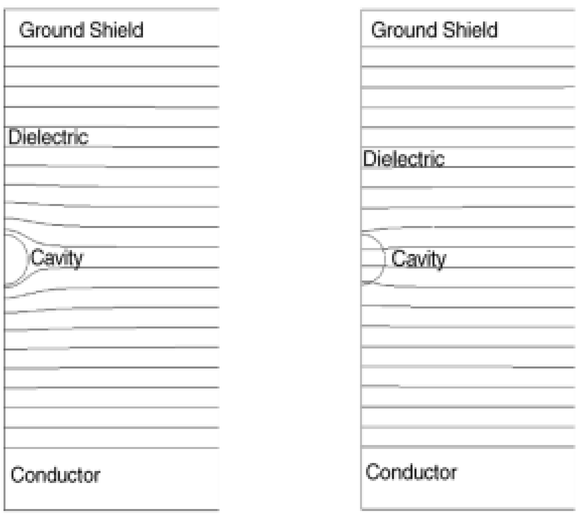

Fig. 7. Post and pre discharge periods

The right most figure above corresponds to pre discharge period, whereas the left most corresponds to post discharge period. It can be seen that post discharge, the cavity increases and slowly moves in to the conductor. This is an unwanted condition and shoud be avoided at all costs. Cavities may exist due to production faults however they may not increase even during partial discharge as the magnitude of current may not be high enough to cause expansion. Ideally speaking cavities should not exist. And dielectric strength should be uniform and spaced well.

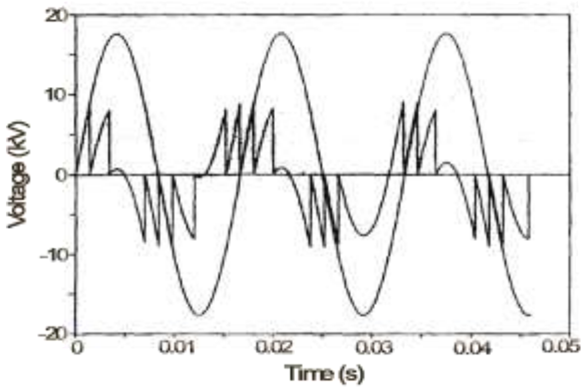

Fig. 8. Typical partial discharge pattern for a high voltage transmission line

In the figure above, we can see that discharge follows a particular pattern here. It was found that discharge casues reactive power to increase thereby reducing the efficiency of the power system at large. This means that as discharge continues, capacitive nature of the line increases therefore if we look up an impedance triangle, we will observe that total impedance of the line decreases. Due to this resonance starts setting in to a certain extent.

In simpler terms post discharge period we can expect charges to settle at the surface of the insulating material.

Conclusion

The circuit which we developed after repeated trials proved to be useful on many accounts. There were major developments in some areas,while there were minor improvements in other areas as well. Some of them are as follows

- Power factor improvement was seen to be a maximum of 0.13329 and a minimum of 0.091.
- Power loss in the circuit is lesser compare to other circuits developed for the same purpose. This means efficiency is higher.
- Quadrature loss compensation is imporved.
- False alarms for DG sets are averted.

Conclusively XLPE, TR-XLPE,EPR, PILC cables should be used for better efficiency and longer life. Also in this regard time domain testing gives better result of partial discharge.

Laslty not all partial discharge is dangerous and water trees alone are not an indication of partial discharge. Therefore, they must not be considered as partial discharge itself. It is thus proved that partial discharge is a unipolar process and a dynamic phenomena. This should promote research in the area

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

of dielectrics and insulation material as better insulation will not require frequent maintenance, thus saving recurring costs for the power system operator.

Acknowledgements

I would firstly like to thank Mr. Suhas P. Suryawanshi, General Manager, Kirloskar Oil Engines Ltd. For giving me this opportunity to explore this domain of power system engineering. I would like to express my heartfelt gratitude to Dr. Vinod V. Thomas, Director, Manipal Institute of Technology, Dr. Savitha G. Kini, Head of Department of Electrical & Electronics Engineering Mr. Gururaj Rao HV, Dr. R Shivarudraswamy and Mr.Ganesh Kudva, for their timely assistance and encouragement in my activities. I would also like to thank the support staff of Kirloskar Oil Engines Ltd. and Manipal Institute of Technology for ensuring that this research moves smoothly. Last but not the least, I thank the divine, my parents and my sister, for without them I would not be where I stand today.

References example:

- *[1] G.C. Stone, "Partial Discharge Diagnostics and Electrical Equipment insulation Condition Assessment", IEEE Transactions on Dielectrics and Electrical Insulation Vol.12, No.5; October 2005*
- *[2] M.H Michael, S. Robert, "Partial Discharge Impulse Characteristics of Different Detection Systems"*
- *[3] N.C Sahoo, M.M.A. Salama & R. Bartnikas,(2005),"Trends in Partial Discharge Classification: A Survey", IEEE Transaction on Dielectircs and Electrical Insulation", Vol.12, No.2, pp248-264.*
- *[4] M.Muhr, R.Schwarz,(2009) "Experience with Optical Partial Discharge Detection", Materials Science-Poland, Vol.27,No.4/2, pp1139-1146.*
- *[5] J.Anderson, S.Gubanski, H.Hillborg, "Properties of Interfaces between Silicone Rubber and Epoxy", IEEE Transactions on Dielectrics and Electrical Insulation Vol.15, No.5, pp. 1360-1367, 2008.*
- *[6] B.X.Du, L.Gu, "Effects of Interfacial Pressure on Tracking Failure between XLPE and Silicon Rubber", IEEE Transactions on Dielectrics and Electrical Insulation Vol.17, No.6, pp. 1922-1930, 2010.*
- *[7] www.partialdischargeacademy.org*

Author Biblography

	**Raafe Karim Khan** Raafe Karim Khan completed his B.E in Electrical & Electronics Engineering from Manipal Institute of Technology. He is one of the prominent researchers in the field of illumination, thermal and environmental engineering. A great supporter of the open source movement, he plans in introducing open source hardware and software design into engineering curriculum. Email: raafe.karim@gmail.com
	Akash Basia Akash Basia is a final year student of Electrical & Electronics Engineering from Manipal Institute of Technology. His areas of interest include automation, and is currently researching on Quantum Dots Infrared Photo Detectors. He aims to work towards bringing piezoelectricity closer to the point it can become a viable solution to the energy crisis the world faces today. Email: akash.mu1107@gmail.com