Measurement of Partial Discharge In Xlpe Cables of Electrical Power System

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Abstract- Partial Discharge (PD) measurement is a new approach to find out insulation condition in power cables.Partial discharge (PD) inception test using conventional techniques covered in IEC 60270 and perform on the newly produced Cross linked poly ethylene XLPE cable. This test carried in PD lab Faraday cage where outer noise and electromagnetic fields not disturbed for testing fundamental condition. In PD testing main resonance reactor or HV transformer (LVDT) required for applying high voltage on cable, coupling capacitor, blocking capacitor with inductor for filtering harmonics.

Keywords – Partial discharge, History XLPE, PD tests methods, PDEV, PDIV, Discharge patterns.

1. INTRODUCTION

Partial discharges are defined in IEC 60270 as: "a localized electrical discharge that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor. Partial discharges are in general an effect of local electrical stress concentrations in the insulation or on the exterior area of the insulation. Generally, such discharges appear as pulses having duration of much less than 1micro sec."[1]
A Partial Discharges are short release of current caused by the buildup of electric field intensity in a finite region or void & crack creation. In high voltage cables PDs can be symptomatic of problems within the device such as floating components and insulation flaws.

1.1 Objective

In current scenario of power system need smart transmission, Generation and distribution system. In INDIA smart GRID now grow stronger compare to previous 10 years. Electrical power system up gradation and more stability required with frequency now GRID frequency varies 49 to 50 Hertz band only.

To make Electrical power system stable and healthy all auxiliary like Generator, transformer and cable are must be ensure healthy and routine testing & monitoring online or of line required for prediction for damage of failure of the equipments.

Electrical equipment routine and preventive maintenance required for checking of healthiness. Hence various types of test conducted on equipment to ensure and protection of the auxiliary for example Insulation resistance measurement, TEN DELTA, Resistance, Impedance, SIL and Partial discharge test, etc.

Partial discharge test perform both mode online and of line. Most of time we perform offline PD testing but if equipment not available for offline testing due to continuous service then online testing carried out on it.

Electrical equipment insulation resistance values deteriorate and ageing effect and same equipment lead to failure side. For prevention of failure of the equipment due to insulation resistance value deterioration PD test must be conducted for prediction of time and same auxiliary can be replace before its failure.

2. HISTORY OF CABLES

EPR (ethylene propylene) rubber cables became more popular in the 1980s. A breakthrough had occurred in the mid-1970s with the introduction of a grade of EPR that could be extruded on the same type of equipment as XLPE insulation The higher cost of EPR cables, as compared with XLPE, was a deterrent to early acceptance even with this new capability.

In 1981, another significant change took place: the introduction of "dry cure" cables. Until this time, the curing, or cross-linking, process was performed by using high-pressure steam. Because water was a problem for long cable life, the ability to virtually eliminate water became imperative. It was eventually recognized that the "dry cure" process provided faster processing speeds as well as elimination of the steam process for XLPE production.

Another major turning point occurred in 1982 with the introduction of tree resistant cross linked polyethylene (TR-XLPE). This product, which has supplanted conventional XLPE in market volume today, shows superior water tree resistance as compared with conventional XLPE. By 1984, the

market was approximately 65 percent XLPE, 25 percent TR-XLPE and 10 percent EPR. Half the cable sold had a jacket by that time. During the second half of the 1980s, a major change in the use of filled strands took place. Although the process had been known for about ten years, the control of the extruded "jelly-like" material was better understood by a large group of manufacturers. This material prevents water movement between the strands along the cable length and eliminates most of the conductor's air space, which can be a water reservoir, In the late 1980s, another significant improvement in the materials used in these cables became available for smoother and cleaner conductor shields. Vast improvements in the materials and processing of extruded, medium voltage power cables in the 1980s has led to cables that can be expected to function for 30,40, or perhaps even 60 years when all of the proper choices are utilized. In 1995, the market was approximately 45 percent TR-XLPE, 35 percent XLPE, and 20 percent EPR.

Table-1: Comparative table for characteristics between PILC and XLPE cables

Sr. No	Characteristics of Cables	PILC Cable	XLPE Cables
1.	Insulation Material	Impregnated paper	XL Polyethylene
2.	IR value	High	Very Higher
3.	Voltage stress	Higher, occurrence of tree	lower and negligible chances to create tree
4.	Mechanical stress	it create cracks in insulation and weak the strength and initialize of tree and lead to failure of insulation and cable	negligible chances to creation of tree and failure of insulation
5.	Temperature effect	High temperature affects the insulation value, deteriorates it and void occurrence & lead to failure.	Temperature up to 90 degree not affect to the IR value and no harm
6.	Age effect	Ageing criteria	ageing not affect

Various terms used in cables:

- Conductor, Bare. A conductor having no covering or electrical insulation whatsoever.
- Conductor, Covered. A conductor encased within material of composition or thickness that is not recognized by this Code as electrical insulation.
- Conductor, Insulated. A conductor encased within material of composition and thickness that is recognized by this Code as electrical insulation.

COMPARISON BETWEEN PAPER INSULATED LEAD COVER (PILC) AND CROSS LINK POLYETHYLENE (XLPE)

In initial stage when XLPE not intentioned PILC cables are used in High voltage power system. When XLPE invented then its advantage found very high, which attract to utilities for replacement of PILC cables with XLPE.

3. PARTIAL DISCHARGE DIFFERENT FACTORS ARE INVOLVED FOR RECOGNITION.

Partial Discharge measurement terms:

PD measurement various terms are used PD, PD Pulse, Apparent charge q, pulse repetition rate & freq. n & N, Phase angle ϕi, avg. discharge current I and discharge power P etc.[3][1]

Partial discharge inception voltage (Ui):

Partial discharge voltage is applied voltage at which repetitive partial discharges are first observed in the test object, when the voltage applied to the object is gradually increased from a lower value at which no partial discharges are observed. In practice, the inception voltage is the lowest applied voltage at which the magnitude of a PD pulse quantity becomes equal to or exceeds a specified low value.

Partial Discharge Extinction Voltage (Ue):

Partial discharge extinction voltage is applied voltage at which repetitive Partial discharges cease to occur in the test object, when the voltage applied to the object is gradually decreased from a higher value at which PD pulse quantities are observed. [7] In practice, the extinction voltage is the lowest applied voltage at which the magnitude of a chosen PD pulse quantity becomes equal to, or less than, a specified low value. [1]

Factors involved in recognition.

-Discharge pattern:

Partial discharge responses from individual discharge are superposed on an elliptical time-base that represents the sine wave test voltage. The position of the voltage peaks and valley (zero) and the rotation of the time base are indicate in fig. 1.

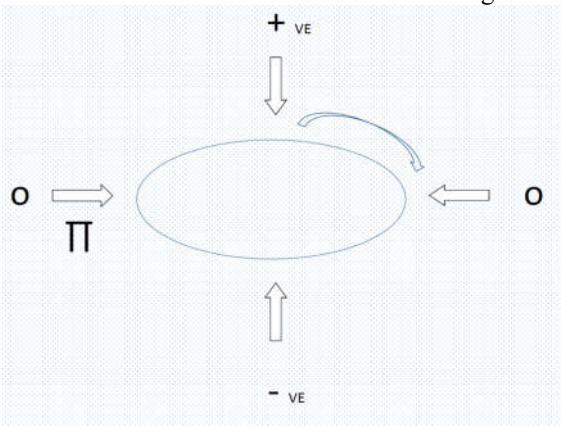

Figure 2: Elliptical Time Base Discharge Pattern

If discharge patterns are displayed on a Sine wave time base the positions of the voltage peaks and valley (zero) and the direction of the trace as indicate in Fig. 2.[5][8]

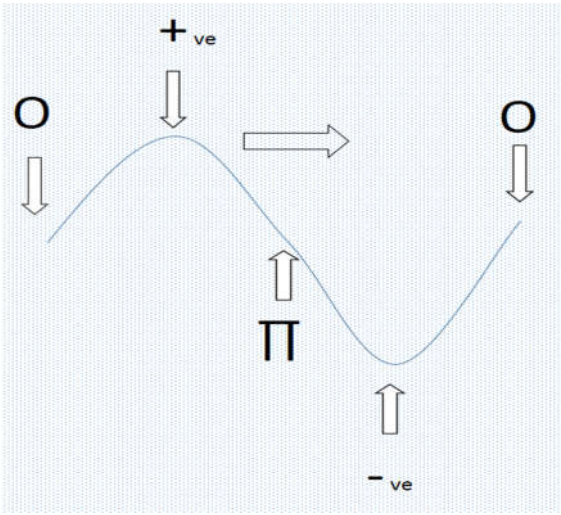

Figure 3 : Sine Wave Time Base Discharge Pattern

4. PARTIAL DISCHARGE TEST EXPERIMENTAL SET UP

Partial Discharge testing perform at the manufacturing Unit of M/s. GEMSCAB INDUSTRIES LIMITED, Village-Bhiwadi, District- Alwar, Rajasthan. M/s. GEMSCAB finally manufactured cables vaious types of test conducted by company or as per demand by client. Following test performed on cables.

1. Type test,
2. Routine test,
3. Special test etc. (Partial Discharge)

Above test conducted on cables as per IS (Indian Standards) Or IEC (International Electro-technical Commission).

Special test are perform on cables as per customer requirement. In M/s. GEMSCAB Partial Discharge test facility available for Low tension and High tension cables for voltage range of 1KV to 66 KV.

M/s GEMSCAB cable manufacturing unit has Faraday Cage facility which contain contour type island of solid ground. Faraday cage property that isolate laboratory area from atmosphere disturbances of different types of waves.

M/s. GEMSCAB INDUSTRIES LIMITED, Village-Bhiwadi, District- Alwar, Rajasthan has experimental set up for PD testing facility up to 220KV HT cables testing equipment of "DIELEC TECHNIC-JIATE ELECTRIC (JZT DIELEC JIATE)".

Following auxiliary are used for Partial discharge testing.

- 3- phase power supply
- Power supply VARIAC
- Step up Transformer
- Coupling device
- Blocking Capacitor
- Measuring Impedance device
- PI filter Inductor
- complete set up for PD testing DIE ELEC-JIATE
- Pulse Generator

Table 2: Comparative Table For Insulation Thickness In Xlpe Cables

Nominal Size	XLPE Insulated	
Sq. mm	Copper	Aluminium
25	3.58	2.35
35	5	3.29
50	7.15	4.7
70	10	6.58
95	13.6	18.93
120	17.2	11.3
150	21.5	14.1
185	26.5	17.4
240	34.3	22.6
300	42.9	28.2

XLPE cables manufacture complete then different type of test conducted as per standards. Partial discharge is special test PD test. To perform Partial discharge test on XLPE cable both side cable termination done and remove semiconducting layer screen approx one foot.

Figure 1.3 : High Voltage Transformer and Coupling capacitor, Blocking capacitor with Inductor and Toroid.

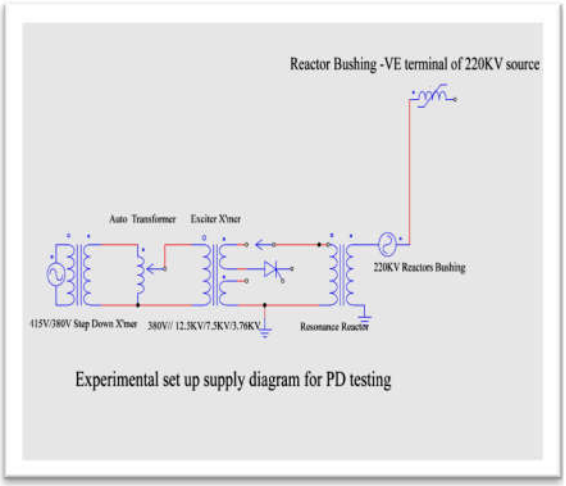

Figure 1.4 : Diagram of experimental set up for PD testing

-Coupling capacitor

The Coupling and blocking capacitor must be discharge free. In the differential circuit where two test objects are used and one object may be regarded as the coupling capacitor no separate coupling capacitor is needed.

TEST VOLTAGE CRITERIA FOR HV AND PD TESTING AS PER IS.

The cable shall not break down during high voltage test and the magnitude of partial discharge observed shall not exceed 10 pC for routine test and 5 pC for type test.

Figure. 1.5 : Partial Discharge test under progress on 185mm sq. 3-phase 33KV XLPE cable at M/s. GEMSCAB INDUSTRIES LIMITED, Village-Bhiwadi, District- Alwar

Table 1.3 : Voltage grade for HV and PD Testing as per IS.

Sr No.	Criteria Voltage for cable KV	PD Measurement Voltage (KV)
1	3.8/6.6	6.60
2	6.35/11	11.00
3	6.6/6.6	11.50
4	11	19.10
5	12.7/22	22.00
6	19/33	32.90

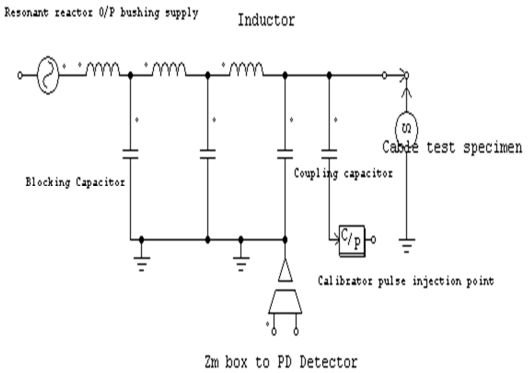

Figure 1.6 : Experimental set up diagram for Partial Discharge under test

5. RESULTS

Partial discharge test conducted on various cables at laboratory. Medium voltage cables 185 sq. mm 3-phase 33 KV XLPE cable, 1C X 400 sq. mm A2XWay and 630 sq. mm single core A2XWay 33 KV tested completion of manufacture. Cable specimen prepare before bring to test site then both end of cable side like two terminals insulation with

inner & outer sheath, armor, screen fully removed approximately 2 foot in each core of conductor.

Test Result case study-I: - As we can see in the fig. 1.7 only 1.40 pC on voltage stress of 33KV. This PD charge value is within the limit.

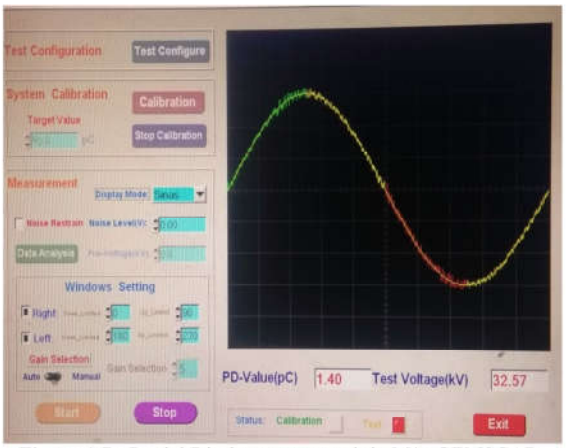

Figure 1.7 : Partial Discharge test result in M/s. GEMSCAB INDUSTRIES LIMITED, Village-Bhiwadi, District- Alwar, case study-I on XLPE cable drum tested.

At the time of PD test conducting before that each core of conductor semiconductor layer must be removed. Semi conductor black color silicon carbide semiconducting black layer coated at the time of manufacturing of cable and copper strip wrapped on each core. These both screens provide against protection from earth fault.

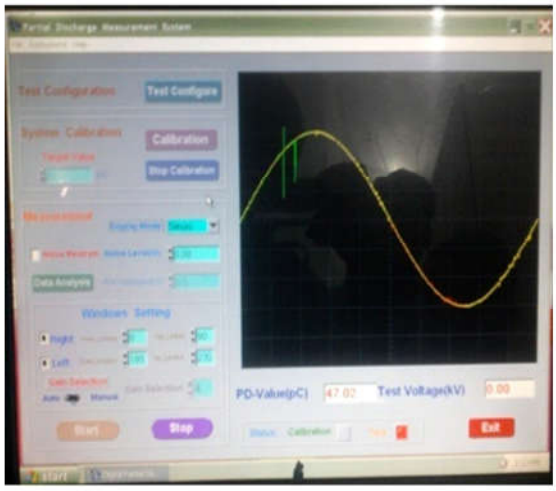

Figure 1.8 : Partial Discharge test result in M/s. Gemscab Industries Limited, Village-Bhiwadi, District- Alwar, case study-II on XLPE cable drum tested.

Partial Discharge testing in 33 KV cables.

In the HV and PD testing laboratory Hall (Faraday Cage) of M/s. Gemscab Industries Limited, Village-Bhiwadi, District- Alwar, on 33KV 300 meter length drum after manufacturing as per required by costumer.

Table 1.4: PD Test results of cable without artificial fault create.

Sr no	Input Volt	Input Amp	Output KV	Output Amp	pC	Remark
1	77	9.8	32.57	1.6	1.4	Normal test

Test Result case study-II:- As we can see in the fig. 1.8 only 47 pC on voltage stress of 33KV. This PD charge value is within the limit.

Table 1.5 : PD Test results of cable with artificial fault create.

Sr no	Input Volt	Input Amp	Output KV	Output Amp	pC	Remark
1	5.9	7.1	10.3	0.29	47.02	Normal test

6. CONCLUSION

Partial Discharge detection in medium voltage 3-phase cable is a fundamental analytical test to identify the various conditions of the health of equipment insulation resistance. Manufacturers are conducting different types of test on cables in the laboratory in for various industries.

Cable was also heated to increase the temperature then after tested and its result PD value must be found within the limit of less than 5 pC.

Additionally, Partial Discharge makes insulation damage badly because the incident adds more fault type's mechanical & electrical stresses to the developing electrons flow.

Consequently, precise detection and position are required to maintain various auxiliary, control the magnitude of the diagnostic and repair time required. This dissertation presents a conventional detection system consisting of high voltage cables and equipment with measuring instruments.

7. FUTURE SCOPE

With the help of the PD test, service utilizers can do proactive maintenance and found the weak point at the time of routine maintenance of equipment and its deterioration level.

- After conduct PD test and from its result, utility holder can able to attend the weak point or replace the cable or equipment before failure and save generation and production and avoid any potential of hazards.
- Partial discharge test provide best result to prevent failure and maintain electrical service sustainability.
- Partial Discharge test can conduct on all types of electrical equipment like generator, motor and

transformer and monitor their IR value trend then prevent the equipments from breakdown.

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