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Partial discharge measurement in solid dielectric of H.V cross-linked polyethylene (XLPE) submarine cable (Rasha Abdul-Nafaa Mohammed)

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ABSTRACT

A partial discharge described as a non-linear electrical break-down event that happened in a section of insulating area between two conduct which are at different potentials the damage of the insulating material, these conductors have a different insulating material potential of damage, under AC voltage discharge interval process. In this paper, we propose a Matlab/Simulation software. A detailed analysis of the partial discharge (PD) signal in the underground electric power conductor performed for monitoring, and investigation of numerous effects associated with the partial discharge event, such as heat, phonic and electrical. Thus, to gain the important data of the insulating material status.

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1. INTRODUCTION

XLPE power cable show a substantial character in the urban power system. The safe process is necessary to the grid power stability, as soon as the cable break- down power failure will occur [1]. PD is resident electrical discharges that happen inside high voltage equipment, such as transformers, high voltage switch, cable and electrical machines. Subsequently, PD are the main responsible insulation failure event for high voltage equipment [2]. PD usually, will results in weak electrical signals which will disordered with the noise, unstable system signals and interface signals [3].

Submarine cable structure is moderately more complicated than known conductors subsequently it operates under destructive environment of moisture and salinity conditions. Figure 1 is the traditional structure of submarine cable [4-12].

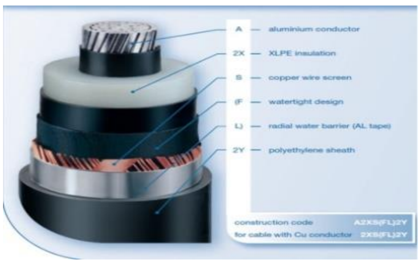

Figure 1. 132KV XLPE submarine cable

2. METHODOLOGY

A circuit diagram of PD measurement detection, according to SANS and IEC60270 standards, is shown in Figure 2. This circuit consists of the power supply, coupling capacitor (Ck), test object (Ca), and detection impedance (Zm). The charge that is injected through a very short time at the tested object terminals in a definite test circuit, is the apparent charge q_a. The apparent charge is frequently expressed in picocouloms (pc). In a nutshell, the main advantage of this method is its accuracy and accessibility of the information on about intensity, source and possible fault [13-20].

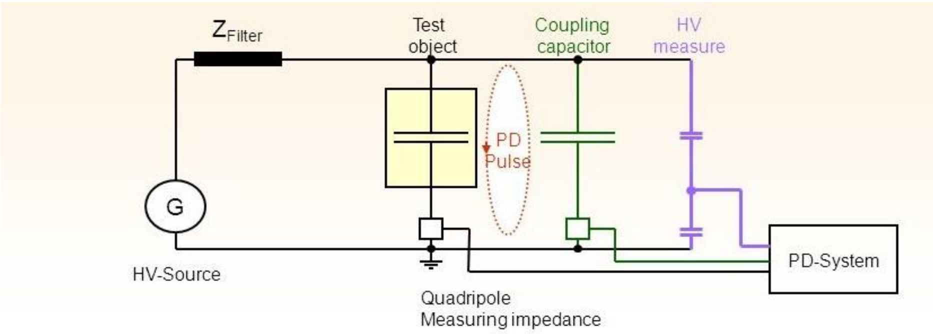

Figure 2. PD measurement circuit

2.1. PD Measurement in XLPE Cable

PD is electrical event that happen inside the void under applied high voltage on the XLPE insulation specimen test. By determining the wave producing from PD zones in XLPE insulation object corresponding light, sound, chemical and electrical signals, PD test will become completed. A suitable sensor must be used for this prepossess like high frequency current transformer (HFCT), that can confine hefty frequency gestures along the path of pulses by balding them round the cable earth band or the core of the cable, this way represents a common technique of PD recognition in the cable. The HFCT sensor has frequency band from hundreds of KHZ to thousands of MHZ, it can be put easily, safe and reliable test method [21, 22].

2.2. Break- Down in Solid Dielectric

The main factors which lead to insulation break-down of in solid dielectrics are by thermal, intrinsic, treeing phenomenon, electromechanical and the presence of voids. The break-down of solid insulation not only depend on the applied voltage magnitude but also on the time, for which voltage is applied [23].

2.3. Practical Solid Insulating Materials

Solid insulation is contained cavities and voids, these voids are usually filled with a liquid are gaseous medium with electrical strength lower than that of the solid, also the void medium dielectric constant is less than the insulation. When the electrical field that applied on the void exceed break-down value then the break-down will occur inside the voids. The dielectric across voltage can be calculated which may be initiate. The discharge inside a gaseous cavity. The cavity or void is assumed to be of thickness (c) and the gap space represent the distance(d)as given in Figure 3 [24, 25]. The equivalent circuit of void in the solid dielectric is depicted in Figure 4.

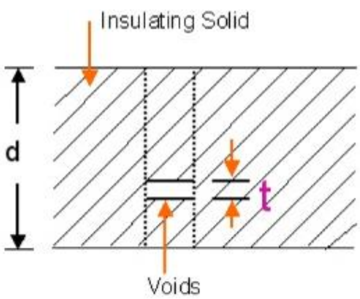

Figure 3. Void in the solid dielectric

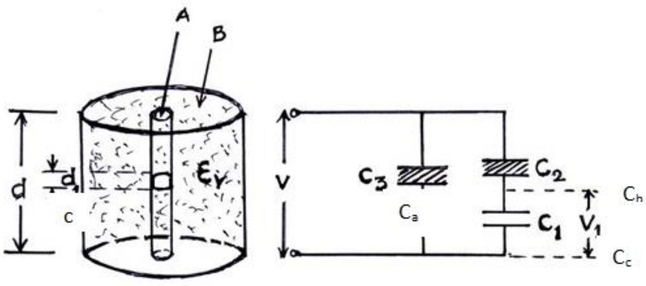

Figure 4. Equivalent circuit of dielectric with void

2.4. Explanation of the Void in an XLPE Cable

The capacitor configuration inside the XLPE cable insulation is illustrated in Figure 5. [26-28]. The Void location is illustrated in the XLPE cable cross sectional area [see Figure 6].

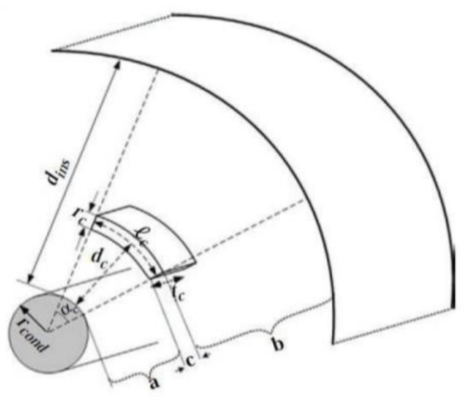

Figure 5. Capacitor configuration comprehensive simulation model

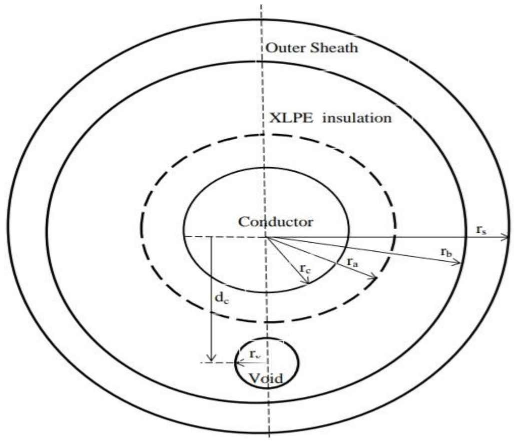

Figure 6. Cross- sectional area of XLPE cable indicating the Void location between the core and outer- sheath

The insulating medium and the void maybe represented by three capacitances:
Cc: void capacity.
Ca: dielectric capacity.
Cb: capacitance of the rest of the dielectric.

$$Cc= \varepsilon_0 r^2 \pi / h \quad (1)$$

$$Ca=\varepsilon_0 \varepsilon_r (a-2b)b/c \quad (2)$$

$$Cb=\varepsilon_0 \varepsilon_r r^2 \pi / h \quad (3)$$

Where
h:height of void.
r: radius of void.
ε_r: relative permittivity of the solid.

If a voltage (V) is applied across the dielectric, then the voltage across the void Vv is given by:

$$Vv=Ca\ V/Ca+Cc = V/1+1/\varepsilon r\ (d/c-1) \quad (4)$$

The capacitors values for three location inside the XLPE insulation are given in Tables 1, 2 and 3.

Table 1. Void Near the Conductor

C_a	0.022e-9
C_b	0.026e-12
C_c	0.011e-12

Table 2. Void in the middle XLPE Insulation

C_a	0.016e
C_b	0.026e-12
C_c	0.011e-12

Table 3.Void Near the Sheath

C_a	0.0013e-9
C_b	0.026e-12
C_c	0.011e-12

3. PD CIRCUIT MODELING

The PD electrical circuit that developed in Matlab/Simulink Package is shown in Figure 7. As the circuit is energized with AC voltage, PD pulses can be observed across the measuring instrument (MI). The void capacitance C_c is charge which is responsible for occurrence of PD. The parameters that used for simulation are shown in Table 4.

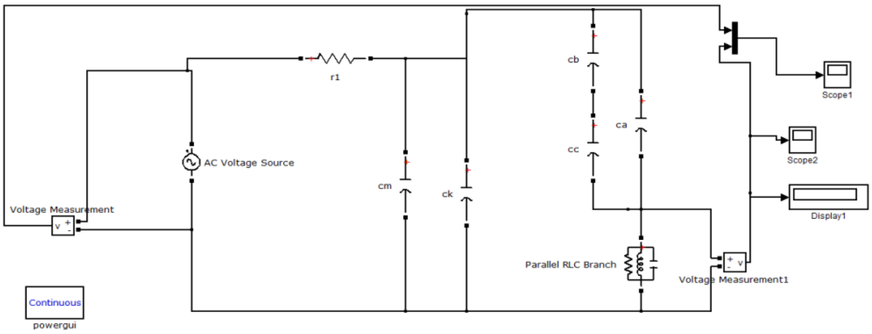

Figure 7. PD circuit established in simulink

Table 4. Simulation Parameters

SINO.	Parameter	Symbols	Rate	Unit
1	measuring capacitor	C_m	1000	pF
2	Coupling capacitor	C_k	1000	pF
3	Permittivity	ε_0	8.85e-12	F/m
4	Relative permittivity	ε_r	3.5	F/m
5	Resistance	R	50	Ω
6	Inductance	L	0.60	mH
7	Capacitance	C	0.45	µF

4. RESULTS AND DISCUSSION

Simulation results of PD in a Void near the conductor are shown in Figure 8 for each applied voltage (70, 80, 90) KV respectively. The PD voltages values with respect to the input voltages at Void near the conductor are illustrated in Table 5.

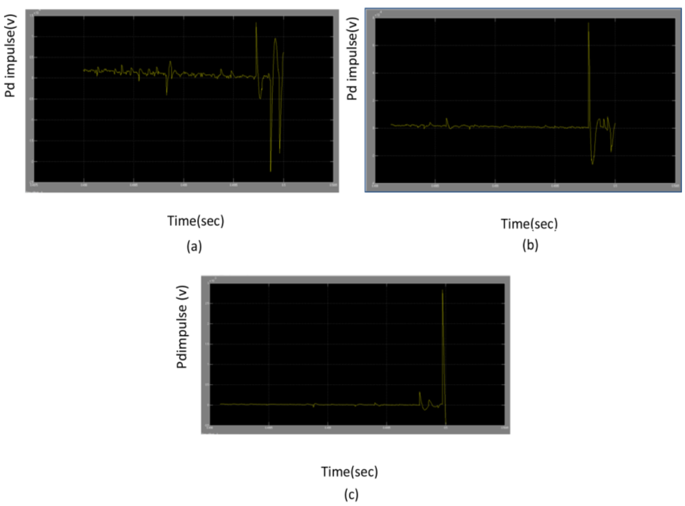

Figure 8. PD impulse voltage. a) At 70kV applied voltage, b) At 80kV applied voltage, c) At 90kV applied voltage

Table 5. PD Voltage Values as Respect to the Input Voltage

Applied input voltage (KV)	PD (V)
70	1.35e-4
80	7.8e-4
90	2.83e-3

Simulation results of PD in a Void middle the XLPE insulation are shown in Figure 9 for each applied voltage (70, 80, 90) KV respectively. The PD voltages values with respect to the input voltages at a Void middle the XLPE insulation are illustrated in Table 6.

Simulation results of PD in a Void near the sheath are shown in Figure 10 for each applied voltage (70, 80, 90) kV respectively. The PD voltages values with respect to the input voltages at Void near the sheath are illustrated in Table 7.

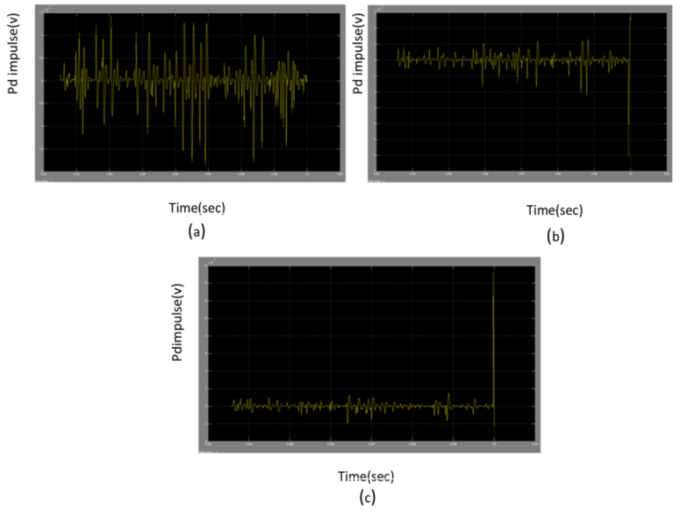

Figure 9. PD impulse voltage vs time. a) At 70k applied voltage, b) At 80k applied voltage, c) At 90k applied voltage

Table 6. PD Voltage Values as Respect to the Input Voltage

Applied input voltage(kV)	PD (V)
70	1.4e-3
80	2.8e-3
90	15e-3

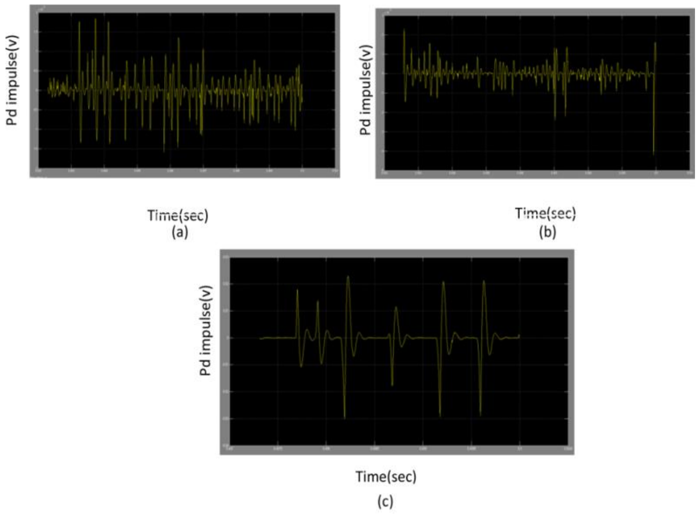

Figure 10. PD impulse at (90KV input voltage). a) At 70k applied voltage, b)At 80k applied voltage, c)At 90k applied voltage

Table 7. PD Voltage Values as Respect to Input Voltage

Applied input voltage (KV)	PD (V)
70	1.75e-3
80	2.4e-3
90	30e-3

5. CONCLUSION

For the same dimensions of the cavity with different location of this cavity. The PD voltage level of the cavity has different value at each location. PD voltage value is increased as a cavity fall away from the conductor, explanation of this increasing revert to the location of cavity from the conductor. As a cavity fall far away from the conductor the PD voltage value became less because this cavity needs higher voltages in order to carry out PD in it. As fall far from conductor reaching to the sheath.

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