NEW MV CABLE ACCESSORY WITH EMBEDDED SENSOR TO CHECK PARTIAL DISCHARGE ACTIVITY

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ABSTRACT

This paper presents a new cable joints for medium voltage power networks. It embeds a sensor featuring bandwidth and sensitivity characteristics suitable for the monitoring of the partial discharges activity. A portable measurement units being connected to the sensor allows then a fast and accurate check of the partial discharge activity in the joint both just after its first energization or even periodically. Depending on it the joint can be then reworked or not.

INTRODUCTION

It is well known that the whole installation of cable accessories is entirely man made. So the possibility that the electricians who install the cable accessories make some mistakes, the ambient constraints and the needs to repair the cable link (in case of joints) in the shortest time lead sooner or later to electric failures.

There are different types of cable joints on the market with different insulation characteristics.

In order to avoid the occurrence of faults caused by operators and therefore to limit human interferences in the network reliability index, there is a growing interest in having available systems that check the activity of partial discharges in cable accessory starting from the first cable energization with the intent of verifying and assuring over time a given degree of installation quality.

Different measurement instruments featuring lightness, transportability and simplicity of use are already available for this purpose [5, 6]. They usually measure acoustic noise or electric/magnetic fields on the outer side of the accessory. Unfortunately there are some circumstances where this procedure experiences drawbacks like when the accessory is shielded. This is the case, for instance, of a shielded cable joints. In this case the shield plays a fundamental role in suppressing most of the useful signals for diagnostic coming from the inner side of the joint strongly affecting, hence, the sensitivity of the instrumentation.

In the present paper a new joint is presented embedding a sensor with suitable characteristics of bandwidth and sensitivity for monitoring the level of partial discharge arising inside. It will be presented also a light, battery powered, portable measurement equipment, which, connected to the embedded sensor, allows to check at a glance if partial discharges are present or not in the joint. It must be highlighted that this operation can be performed just once, after the first energization, or even periodically. In the former case the sensor-output cable is cut and discarder, while in the latter case the cable is left available for further monitoring.

PROPOSED JOINT WITH EMBEDDED SENSING TECHNOLOGY

The monitoring of partial discharges in joints results often ineffective due to the presence of grounded shields that do not allow using partial discharge sensors based on capacitive effects. Moreover the unavailability of ground wires does not allow the installation of magnetic partial discharges sensors (HFCT). The adopted and here presented solution has been to embed a high-bandwidth capacitive sensor inside the joint and condition the output signal by means of a proper designed electronic device. The main challenge has been to keep unchanged all the insulation as well as electric characteristics of the joint, like the distribution of the electric field, the distances among parts at different potentials, and so on. In order to fulfill this constraint an important property of the semiconductive materials has been exploited and now summarized. In [1] it has been demonstrated that the semiconductive materials feature a different impedance behavior vs. frequency. More in detail in the case such a material is referenced to ground the electric field lines at industrial frequencies (50/60Hz) leaving a given source will close to it. In other words it behaves like a metallic shield. Their impedance per mm^2 per m is in this case very low. However as the frequency of the electric field get higher such impedance increases in a nonlinear way. Just at frequencies of some tens of kHz the semiconductive material tends to loose its shielding properties. This leads to the conclusion that very high frequency phenomena, like the electromagnetic fields emitted by partial discharges, are not shielded at all by such a material and can then be read by sensing devices.

This way while the electric field at industrial frequency is shielded, electric fields at very high frequencies are not.

For this reason the most suitable location for embedding a capacitive sensor was found to be between the semiconductive layer that surrounds the insulation material across the live conductor and the external grounded net, as shown in Fig. 1. This way it can sense the electromagnetic signals due to partial discharges that arise in the inner side of the joint and without affecting the electric field lines distribution at industrial frequency (all kept between the live conductor and the

semiconductive material).
The signal from the sensor is then carried outside the joint by means of a thin-shielded cable; this last in order to avoid that external disturbances couple with the sensor signal. The connection of such a cable with an external instrument is performed safely given that the sensor is located inside the joint in-between two layers at ground potential.

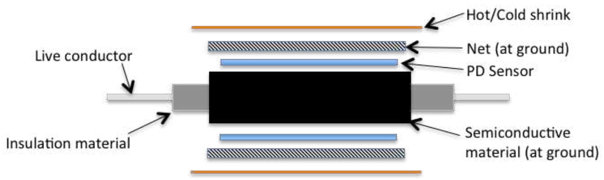

Fig. 1 – Schematic representation of the new joint embedding the partial discharge sensor

Due to the cylindrical shape of the joint the sensor has been designed according to a pad-shape in order to be easily wrapped and stuck around the semiconductive material (Altea pad-sensor).
Fig. 2 shows a picture of the sensor for partial discharge detection to be installed inside the joint.

Fig. 2 – Partial discharge sensor to be embedded inside the joint (Altea pad-sensor)

According to the above description the partial discharge capacitive sensor is of cylindrical type and its realization and description are sketched in Fig. 3. The live conductor realizes the first electrode of the capacitance; the sensor, which is made by a thin metallic foil enveloped in a rubber-made cover, realizes the second electrode. The dielectric material, at the high frequencies of interest, is given by both the insulation element, represented by silicon rubber material, and by the semiconductive material.
In Table 1 the electrical characteristics of both the joint material and of the embedded sensor are reported.

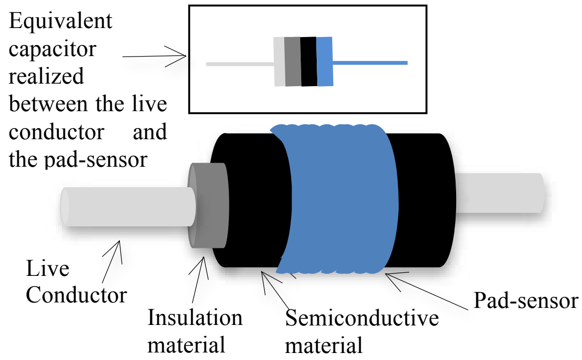

Fig. 3 – Capacitor realized by the live electrode and the pad-sensor

Table 1 –Electrical characteristics of the new proposed joint

Reference Standard	Cenelec HD 629.1 S2
Technical Specifications ENEL NCDJ4388	
Rated Voltage (Uo/U)	12/ 20 kV & 18/30 kV
Maximum voltage for the equipment (Umax)	24 kV & 36 kV
Live conductor cross-sections	70 ÷ 240 mm^2 Al/Cu
Partial discharges sensor characteristics	Capacitance: 30pF PD Sensitivity: 5pC Frequency response (flat bandwidth): 20kHz-20MHz

The Instrument

The output of the sensor is then connected to an instrument for the further elaboration as stated in the previous Section. It consists of the Altea TLS-PD, a partial discharge Detection Unit whose picture is shown in Fig. 4.
The instrument is a portable battery-powered device and allows checking the partial discharge activity in a very easy and simple way.
Three sensors (it has been designed for monitoring three joints at a time) are connected to the Detection Unit via the RJ45 plugs “VS-PD IN” on its bottom side (see Fig. 4). The Unit acquires the output signals of the sensors and monitors the peak level of partial discharges.
Three LEDs, one per each phase, are located on the front panel for partial discharges monitoring. When the level of them in a given phase overcomes a pre-set threshold, the corresponding LED indicator turns on. It turns off as soon as the amplitude of the partial discharges level gets lower than the threshold.
The value of the threshold is set at the factory site: the default value corresponds to a partial discharge level of

80 pC. Different values can however be set.

The TLS-PD Unit provides three BNC analogue output connectors “VS-PD OUT” in Fig. 4, located on the topside. The signals from the three sensors are also available on the three connectors “VS-PD OUT” and can be acquired by other instruments. This feature allows operators to monitor in a deeper way the partial discharges by means of Digital Signal Oscilloscopes, Frequency Spectrum Analyzers or partial discharges Measurement Equipments. The output impedance of the three VS-PD OUT is 50Ω.

Fig. 4 –Altea TLS-PD for partial discharges detection

In Table 2 the technical characteristics of the TLS-PD device are given.

Table 2 –Technical characteristics of the Altea TLS-PD

Power Supply	Lithium ions battery
Temperature Range	-20 ÷ +55 °C
Dimensions [mm]	120x100x35
Weight	300 g
Partial Discharges detection Bandwidth (-3 dB)	50 kHz ÷ 30 MHz
PD detection Threshold Level (different values can be set)	80 pC
VS-PD OUT	Single ended BNC connector (50Ω output impedance)
Protection	IP65

EXPERIMENTAL RESULTS

A measurement campaign has been carried out in order to verify the performance of the designed partial discharges detection system. For this purpose different cold-shrinkable cable joints by REPL International Ltd (embedding the sensor) have been realized; some of them with ad-hoc, although realistic, defects and some others without any defect. This way also the operation of the joint with no-defects, but embedding the sensor, has been also investigated. In particular the inception of partial discharges has been observed. The power cable length before and after the joint was 2m.

Fig. 5 shows the test bed used for this measurement campaign.

The partial discharge activity has been monitored by means of the partial discharge measurement instrument TETTEX PD-Instruments, mod. 9132 WX. The used partial discharge sensor (HFCT) was provided by Bergoz Company (France).

A TETTEX partial discharge calibrator, mod. 6216 WX, has been used before every test for calibrating the whole instrumentation. A Digital Oscilloscope has been also used for the visualization and recording of the partial discharges activity sensed by both the HFCT and the sensor. Two separate channels with synchronous acquisition have been used. The signals from the sensor have been acquired through the TLS-PD output channel. The Oscilloscope is a LeCroy WaveJet 354A, Bandwidth 500MHz and 2GSa/s sampling rate. The Oscilloscope has allowed also a comparison of the sensitivity of both sensors. For this measurement campaign a single phase TDS-PD has been realized and used e shown in Fig. 6.

A first test has been carried out on a cable joint featuring production defects. They are shown in Figs. 7, 8. They are voids present in the hot-shrink tube used in the joint and some traces of semiconductive material left floating over the cable insulation material, respectively. These kinds of defects are actually present in man-made joints and represent some of the most important causes of failures. The sensor used for the experiments is shown in Figs. 9. Fig. 10 shows the complete joint ready to be tested. The output shielded cable from the sensor is visible on the right upper corner of the picture. The rated voltage for the realized and tested joint was 24kV. According to [3, 4] the test procedures for assessing the availability of a joint to operate in a network requires that the voltage be raised up to 24 kV for 1 minute. After that the voltage is decreased down to 20kV; at such a voltage the level of partial discharges must be lower than 10 pC. It must be considered that for a network at 24kV the nominal voltage is 20kV phase-to-phase and, in turns, 11.6 kV phase-to-ground. Starting from few hundreds of volts the voltage applied to the cable has been increased.

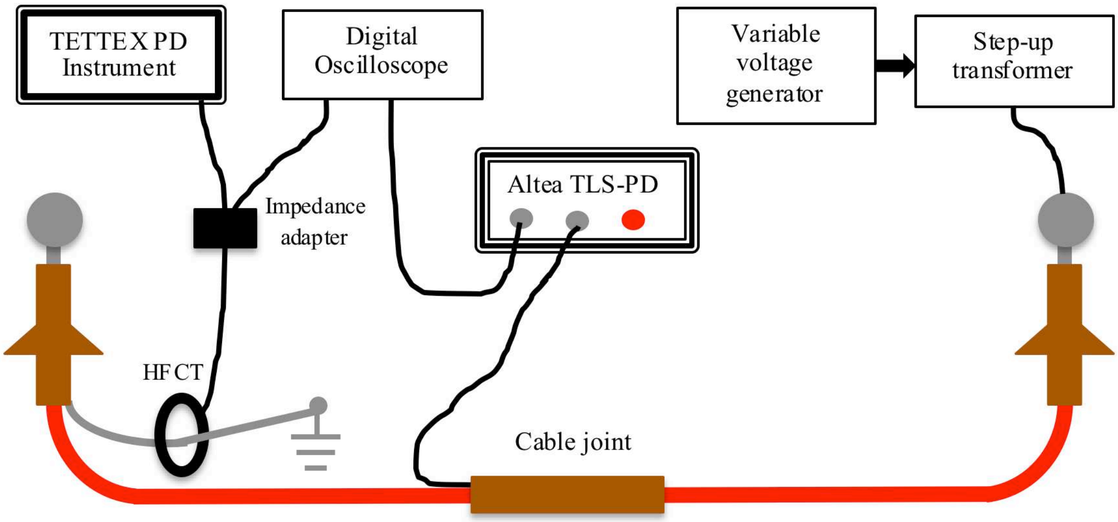

Fig. 5 – Schematic diagram of the test bed used for the experimental campaign

At a value of 9.6kV an inception occurred and the level of partial discharges measured by the instrument was slightly larger than 100 pC.

Fig. 6 – Single Phase TLS-PD used for the experimental validation of the new joint

Fig. 7 – Typical defect in a joint: voids between hot-shrink insulations

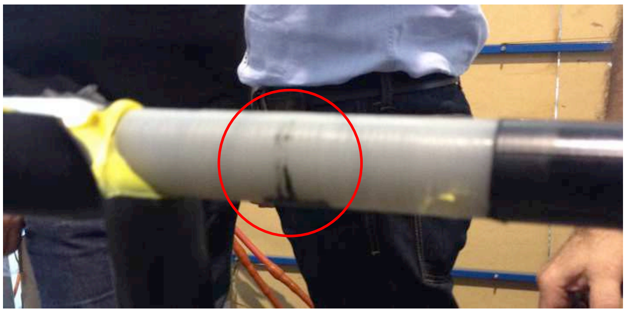

Fig. 8 – Typical defect in a joint: semiconductive material traces left on the cable insulation material

Fig. 9 –PD sensor: a) before installation; b) after installation on the joint

Correctly the TLS-PD switched on the red light (Fig. 6). At 12 kV the value of partial discharges measured by the

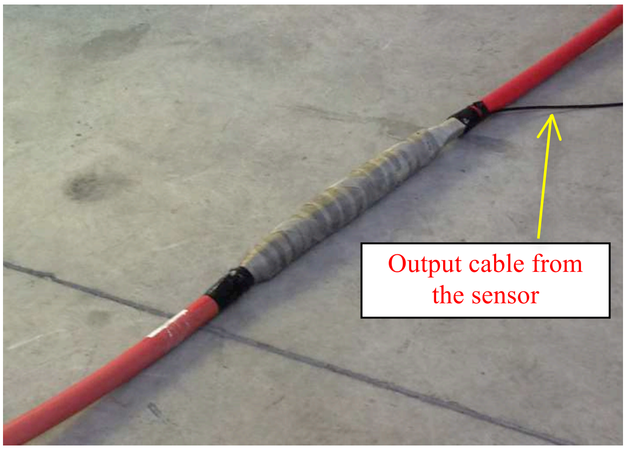

Fig. 10 The cable joint ready to be tested. The output cable from the sensor is visible

TETTEX PD-Instrument was of about 200 pC. The TLS-PD still kept the red-light on. The extinction of the partial discharges occurred at 8.6 kV during the voltage decreasing phase and the red-light on the TLS-PD system correctly switched off. The partial discharge activity shown by the oscilloscope is presented in Fig. 11 at 14 kV. The yellow trace refers to the output of the HFCT

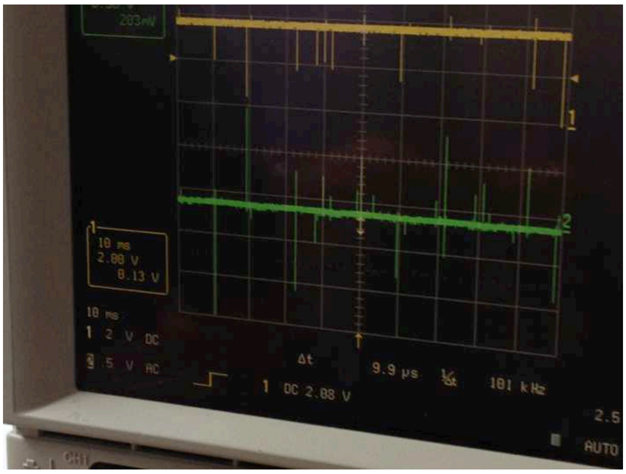

Fig. 11 Partial discharge activity displaied by the oscilloscope: yellow trace refers to the HFCT; green trace refers to the pad-sensor

while the green trace refers to the output of the sensor. For both channels the same vertical sensitivity has been set and equal to 2V.

A second joint has been then tested embedding the sensor but without any 'wanted' defect. The same operations have been performed like those described above and no partial discharge activity has been recorded up to 24kV by both the reference measurement system and by the TLS-PD.

CONCLUSIONS

A new cable joint for medium voltage cables has been presented in this paper. It consists of a joint embedding a capacitive sensor with suitable bandwidth for sensing partial discharge signals arising in the joint in the case it features manifacturing defects. A portable measurement instrument, the TLS-PD instrument is then connected to the output cable of the embedded sensor in order to detect partial discharge activity during the joint energization. This system allows to check the presence or not of partial discharges in new joints just after the subsequent first energization. In case the instrument detects a level of partial discharges equal or above a given threshold (presettable) then a optical warning is set (red-light on). The joint requires then to be replaced. However it must be observed that this system can detect the inception of partial discharges only if they occur at a voltage below the nominal one. It must be highlighted that such a system can also be used for periodic monitoring of partial discharges in joints, provided that the connection with the sensor is always available.

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