ON LINE MV DIAGNOSTIC METHOD FOR FAILURE PREVENTION: CASE OF APPLICATION

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ABSTRACT

The on line diagnostic system allowing large-scale MV underground network survey with accurate decision for failure prevention while minimising number of measurement points for economic reasons is in progression but seems not really available yet. By the time, specific application of on line diagnostic tools based on partial discharges measurements can be used for restricted and clearly defined failure prevention cases. Through online diagnostic applications examples, this paper underline the condition needed to target accurate replacement decision. The first case dedicated to T joint failure prevention illustrate the importance of the diagnostic device set up adaptation to the problem. The second one, dedicated to termination failure prevention shows that behaviour before failure have to be characterised to trigger pertinent replacement decision during monitoring.

INTRODUCTION

Underground MV network asset management is a major issue for the EDF Group to ensure a high level of Distribution performance. Diagnostic tools can usefully help to detect and remove weak points and avoid short-term failure as to support cable replacement medium and long-term policy. While off line tools are currently used, on line solutions have been studied. Systems have been used to precise and characterize component behavior before failure (knowledge rules) while an assessment of the different available tools is provided.

The device reached by ERDF has to combine large-scale survey of underground network and minimize the number of devices (typically one by substation) for economic reasons. Meanwhile a good level of accuracy in failure prevention is requested. That is a real challenge because it is well known that accuracy of diagnostic is related to accuracy in location of pd source. Up to now, it is necessary for that to have multiple measurement points that means to place sensors the closer possible of the focused component. This is a real problem for underground cable sections that are not accessible by definition. It is also a problem on an economic point of view because that means that most of the RMU unit of the network have to be equipped if a global survey is reached.

Even if developments are needed to reach the device that will complies with all the ERDF specifications, some online solutions based on partial discharges measurements can already be applied.

This is particularly true for specific cases of failure prevention for which risk is identified and clearly defined. Those can be done on accessible components that are most of the time termination, and components of cable section in tunnel or basement. The paper deals with two cases of application of failure prevention chosen in order to illustrate importance to have a detection method adapted to the focused problem.

The first one describes elaboration of a method dedicated to prevent failure of MV network T joints in basement or tunnel. Adaptation of the device set up needed to produce an on line detection is underlined. The second example present a method dedicated to failure prevention of termination in urban HV MV substation. It shows that degradation mechanism evolution need to be accurately enough characterised as clear decision criteria had to be given to operators and or asset managers.

FAILURE PREVENTION OF T JOINT IN BASEMENT

Context

Failure rate of T joints existing in the MV network operated by ERDF is not specifically high in comparison with other type of joints. Nevertheless ERDF aim to eradicate a specific risk when this type of component is in basement or tunnel. In certain cases failure could lead to fire ignition with possible associated risks that cannot be allowed. As component is accessible in basement, on line pd measurements can be fairly considered. The focused components are resin filled T joint named D 1200 used in branched MV networks in the early 80's.

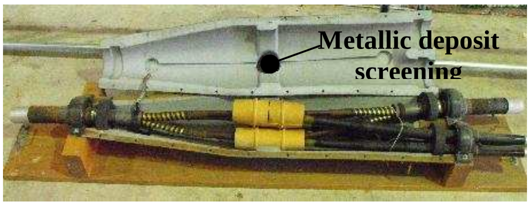


Figure 1 : T joint type D1200

On site initial measurements

Off line partial discharges (pd) measurements were initially performed in order to verify pertinence and range of application for measurements performed at a single point of the cable section (i.e. with the measurement system connected to the circuit breaker termination). Indeed, T joint diagnostic implies obviously measurements on a branched network structure. Location of pd sources in such a structure remain complex due to attenuation and reflexion caused by derivation points. It was confirmed that off line pd measurements were possible but limitation for operational application were considered too much restrictive. Only T joint at the beginning of the cable section before the second derivation point could be assessed. More over, T joint with very short derived cable section due to network structure modifications have also to be excluded because of ambiguity to differentiate stop end pd sources on the short part of cable remaining. On line pd measurements at the same single point were also performed and confirm that difficulties to locate pd sources were much more higher. Nevertheless, as focused components were in basement and tunnel, then accessible, it was possible to target a detection based on on-line pd measurements with sensors very close to the T joint. Even if personnel safety restriction for local measurements was not stated, it was decided to investigate this way.

Sensors selection

Acoustic sensors

Tests were performed in laboratory from T joint removed from the network with artificial defects in order to define suitable sensor available for measurements.

Acoustics sensors were tested in priority because such detection method could be easy to manage. Test performed with acoustic detector with a 30 kHz sensor shown that it was not possible to pick up the 5 nC discharges produced by the artificial defect under 15 kV. The low acoustic sensibility was not surprising in regards of the large volume of filling resin and its poor acoustic transmission features. Tests were performed in order to precise acoustic transmission in the different materials constitutive of the joint for sensor with central frequency from 100 kHz to 2 MHz. Attenuation values measured, higher than 50 dB, disqualified definitively acoustical detection option.

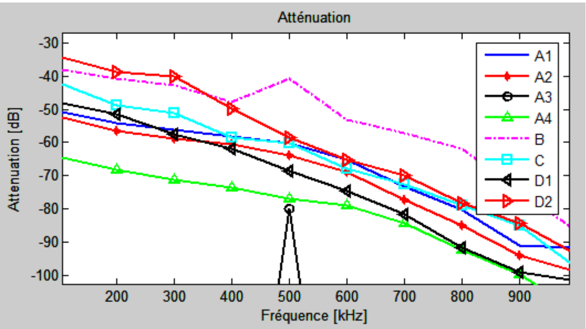


Figure 2 : Acoustic attenuation versus frequency and materials of the joint (C, D1 and D2 are the different filling resin used in the T joint).

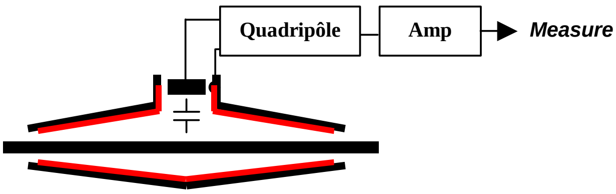
Capacitive sensors

As the other type of joint used by ERDF, T joint are screened and grounded. In that case, screen is obtained by a metallic deposit at the inner surface of the plastic joint envelope. Despite of the screening, capacitive detection aimed to capture electric field leakage and/or transient earth voltage propagating through the screen.

Systems designed for TEV measurements on switchgear were tested, integrated detectors and also capacitive sensors with oscilloscope measurement.

Detection was coherent with the reference given by the conventional pd measurements. Nevertheless sensibility of capacitive sensors to external noise makes them difficult to use.

An adapted capacitive sensor had been tested in order to improve this type of measurement. For that, tap for resin filling on the top of the joint was used to create the electrode of the coupling capacitor. Measurement provided by this kind of sensor were very close to the reference but were not accepted because tap removal was not finally authorised.



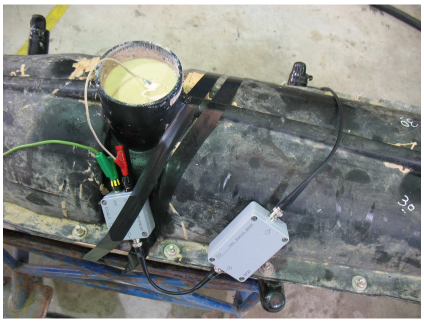


Figure 3 : Tests with specific capacitive electrode.

HFCT couplers

Configuration is not favourable for using high frequency current transformers (HFCT sensors) because it can only be set around the cable and no access to ground connexion is possible. Measured current is vectorial sum of phase and screen current then detection is made on reduced pd pulse amplitude. Sensor proximity with the focused pd source make favourable use of sensor in a higher frequency range than currently used, typically over 100 MHz in order to take benefits of small high frequency attenuation. However experiment shows that correct sensitivity can be performed with a 0.1 to 50 MHz frequency range sensors. As rather large sensor inner diameter (100 mm) is needed, impact on sensor cost is not negligible. For thoses sensors, the main problem comes with saturation when load current is high (typically higher than 200 A but depending on the sensor used).

Detection principle

The detection principle is based on a synchronous acquisition of HFCT signal with sensors set on each branch of the T joint. Decision is taken by analyse of the time sequence on the different sensor as time delay is related to the position of the sensors and provenance of the analysed pulse. Sensor position is defined in order to clearly identify pulses coming from inside joint. Sensor position is depending on real on site condition and variation of distance from the joint have to be managed.

On site test had been performed in order to verify the detection efficiency. Only one of the 4 joints measured presents a pd activity that remain very low. A 100 pC sensibility was considered as sufficient in order to identify joint with problem. As shown in fig 4, higher sensitivity can be reached (2 mV amplitude, 30 ns duration and 10 Ohm HFCT transfer impedance).

Inner PD source is identified by the relation between time delay in signal acquisitions and distance between shifted sensors.

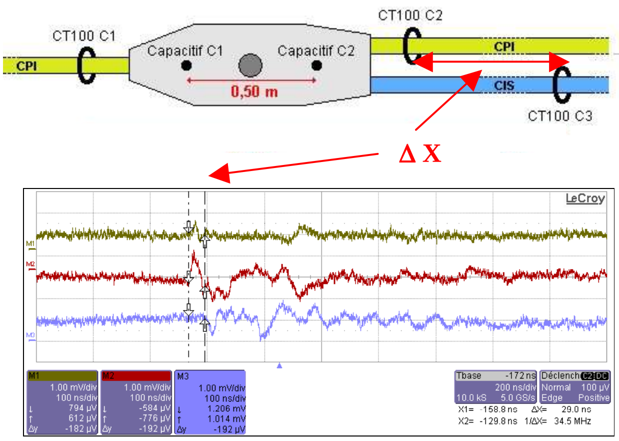


Figure 4 : Time delay based detection

Other wise if sensors are triggered simultaneously by external signal, no discrimination can be done in case of equal distance sensors position (fig 5).

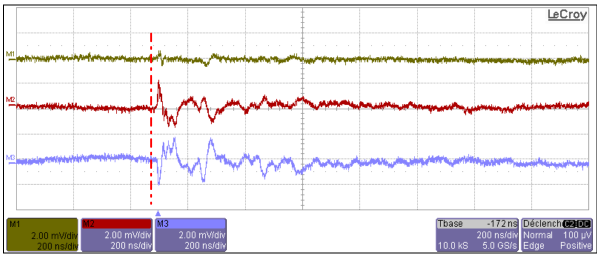


Figure 5 : Equal distance sensors position

Application perspective

Detection can be done by using an oscilloscope and a manual analyse of time delay on an appropriate triggering level chosen by skilled operator. Nevertheless analyse automation is needed for application deployment. For that, the system that will be used must be compliant with some requirements and particularly:

- minimum of 3 channel for accurately synchronised data acquisition,
- 12 bits resolution to avoid quantification noise,
- sampling frequency over 100 MS/s to measure delay of few nanoseconds,
- signal treatment to select significant pulse to be compared.
- automatic calculation of the time delay.

Test of existing systems was scheduled but not completed at time for this publication. On an other side, with the help of GIPSA Lab (Grenoble INP Laboratory), we defined a multi sensor algorithm able to compare three synchronised signals. For pulse detection, different signal treatment algorithms can be chosen and applied (Spectrogram, Higher order statistics and Wavelet combined or not). That aim was to give a pre evaluation of signal treatment algorithms applied in tested devices.

For time delay, automatic calculation had been performed by using an algorithm based on signal correlation. Time between the correlation max and the origin give the time delay between the signal on each sensors.

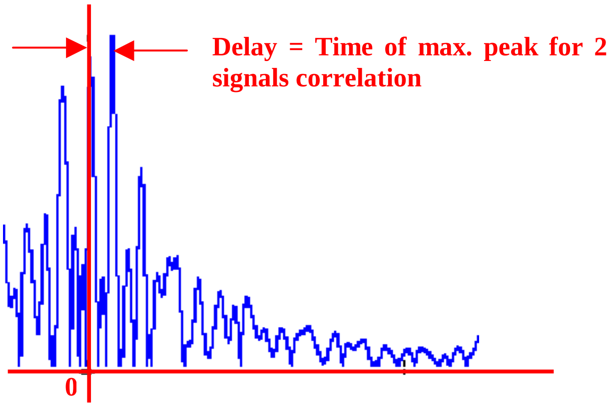


Figure 6 : Time delay automatic calculation using statistic signal correlation

Up to now decision had been taken to replace all the focused joints. On the other side no further measurements had been authorized for personnel safety prevention reasons. No application is scheduled for this case. Nevertheless principles for failure prevention on accessible components remain applicable. Several manufacturers are skilled to adapt some existing solutions and some of them to comply with multi sensors synchronized measurements.

FAILURE PREVENTION FOR TERMINATION IN MV/HV SUBSTATION

Context

This example is mainly mentioned to underline importance of accurate characterization of behaviour before failure for the definition of an on line method dedicated to prevent failure of MV cable terminations in HV/MV substations. Such failures are very rare but material and service quality impacts could be heavy. A specific type of termination had been identified and removal operations are planed. Even if number of replacement is limited, important and complex work are needed and during the progression failure must be avoided. As cable sections are rather short and accessible, on line partial discharges measurements can be fairly considered.

Decision criteria definition

In a first stage, feasibility of partial discharges detection had been verified. Degradation mechanism had been analyzed in order to confirm that it could lead to partial discharges generation. Laboratory tests had been performed on components removed from network. Several degradation levels were observed and a specific relation between load evolution and pd activity have been stated to characterize behavior on component on which failure occurred.

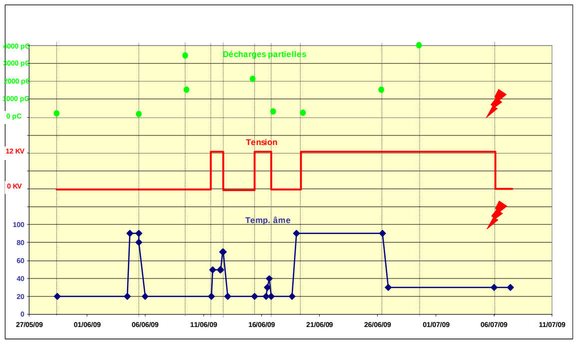


Figure 7 : Pd activity versus load and voltage before break down.

Application

As criteria had been defined, replacement decision can be triggered on the base of permanent monitoring. An increase of pd activity while a load current re increasing is focused. Following during the time pd activity and load current on numerous terminations is necessary. Pd measurement can be done by HFCT on cable earth connection of the termination. For that a monitoring device has been installed in a HV/MV substation in Paris to cover a winter period where important load variations are expected.

CONCLUSION

Some online solutions based on partial discharges measurements can already be applied for underground cable diagnostic. As accuracy is synonym of multiple measurement points, synchronised and sometime permanent acquisitions, economic conditions are not present for large-scale failure prevention on a whole underground network. Applications have to be dedicated to focused components or limited or parts of the underground network. In a first stage the compromise reached by ERDF combine large-scale survey while minimizing measurement points in order to prevent short time and distance failures.
It is predictable that diagnostic functions will be present in future "clever" network components as switchgears and circuit breakers so each RMU will be equipped. Even in this case, progresses are needed to deploy accurate and low price sensors and to integrate knowledge rules for automatic analyse performed by the future clever component.
We can also imagine that the large amount of measurements could be used to describe behaviour before failure and re inject information in a self-teaching process!