CONDITION BASED MAINTENANCE ASSESSMENT IN THE PETRO-CHEMICAL INDUSTRY

Xabier BALZA LÓPEZ
General Cable – Spain
xbalza@generalcable.es

ABSTRACT

There are still many paper insulated cable connections in service which are near their end of life stage, and of which grid owners need some information about their condition in order to plan their replacement or refurbishment.
On-line partial discharge measurements are proposed as most effective method to get valuable information about paper insulated cable systems in petro-chemical industries.
The real case of a 50 km mixed paper insulated and dry cable system's successful condition assessment and the used methodology is described.

INTRODUCTION

Paper insulated lead cables (PILC) installed during the 70s are known for their good behaviour in service, but now that their expected design life is well passed, some start to cause too many maintenance problems and their owners face the necessity of replacing them with dry insulation cables.
After some unexpected shutdowns due to failures in the 50 km long 8,7/15 kV PILC cable ring, which is the main MV grid connected to all the production facilities in a big petro-chemical industry, it was decided to launch a condition research program in order to be able to schedule replacement actions with some knowledge background due to the randomness of the failures.
Old PILC cables are usually tested measuring dielectric losses (tan δ), recovery voltage, and other parameters mainly affected by the presence of water.
The main limitations of these methods are that they measure overall parameters, and thus they give information about the situation of the bulk insulation, but some big punctual problems, like a sealing end without enough insulation mass in its vicinity, could be unseen in the overall measurement, and that they need off-line measurements with special voltage sources, which can be a big issue inside petro-chemical industries, with ATEX atmosphere and very controlled safe working procedures.
The approach required the minimum possible impact in the on-going production processes and the maximum of valuable information in order to schedule the replacement of the assets in worst condition.
On-line partial discharge (PD) measurements were proposed as the best solution, due to the easiness of installation of the PD sensors and system's ability to detect localized defects.
On-line partial discharge measurements were performed in all the accessible points, and after the analysis and comparison of all the measurements, a condition based substitution and maintenance program was defined in order to replace the accessories in worst condition and take periodical measurements of those accessories and cables not in perfect conditions.

I. CABLE SYSTEM

The system to be assessed was a 50 km length mixed cable system installed in the late 70s in a petro-chemical industry, being most of the cables 8,7/15 kV 3x150 mm^2 Cu with common lead screen and mass impregnated insulation.
After 40 years of service many maintenance operations and grid extensions have been done, which leads to the actual mixture of paper-oil cables with resin filled sealing ends and XLPE cables with dry sealing ends (figure 1) via transition joints.

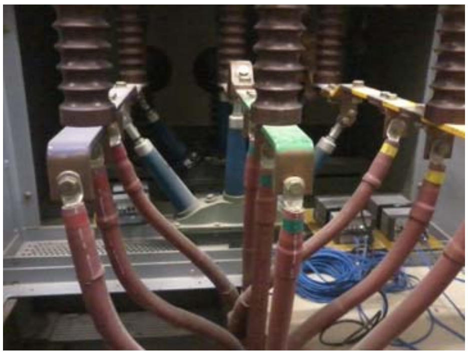

Figure 1

The system has ring type configuration so it can feed any production facility within the plant from two sides.
This eased the work allowing on-line measurements without interrupting production processes when the power had to be switched off to connect the PD sensors in the sealing end bays, but multiplied the number of measurements due to the quantity of connections, having in total 92 measuring points to be analysed.

Cables

Mass impregnated non-draining paper insulated cables were manufactured in the 70s; these cables have a common lead screen, and thus they do not have radial electrical field (figure 2) and any PD within them must be related to the system, being impossible to identify the origin by its cable phase.
On the other hand, mass impregnated paper insulation can sustain quite high PDs without failure and other factors must be taken into account before changing these cables due to PDs.
XLPE cables have been installed since the 90s whenever a repairing or an extension had to be done; transition joints have been installed to connect the PILC cables to single phase 8,7/15 kV 1x240 mm^2 Cu XLPE cables.

These cables facilitate the PD detection by phase but do not sustain PDs for long, so any PD signal with origin in the XLPE insulation must be studied with the maximum attention.

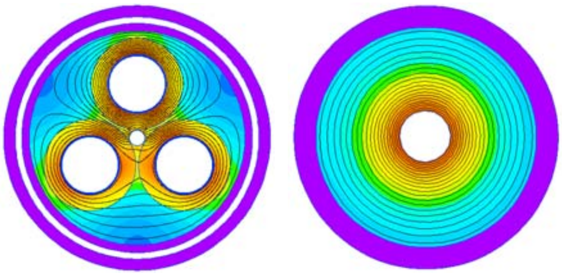

Figure 2

Sealing ends

Crady type resin filled sealing ends (figure 3) are installed in the PILC cable ends in unipolar and three-pole configuration, being the latest the most usual.
Resin insulation is very likely to have PDs within it if the filling process is not properly controlled, but, despite this, it can sustain hundreds of pC for years without failure.
These PDs plus lead's crystallization and mass' flux due to gravity are the perfect conditions for unexpected failures.
Indoor dry sealing ends have cold-shrinkable type field control and do not show measurable PDs in overall.

Figure 3

Transition joints

Where dry cable was to be connected to the PILC cable, transition joints were installed.
As end point of the PILC insulation and transition edge from non-radial electric field to radial electric field they are origin of PDs, but not known failure is related to them until now.

II. ASSESMENT METHOD

Among the possible assessment methods available nowadays, partial discharge measurement was selected due to the easiness to measure and record PDs and then isolate the different signal clusters and associate them to certain type of defect or origin through Phase Resolved Pattern Distribution (PRPD) technology.
Even if tan δ has big potential for condition assessment of PILC cables, it is a distributed condition assessment, and does not allow the evaluation of accessories' condition.
After studying system's characteristics and possibilities, a semi-on-line PD measurement was chosen as method.
Thanks to the ring configuration each connection between bays to be assessed was first isolated and then connected to ground to open the bays and connect the High Frequency Current Transformers (HFCT) to cable terminals or cable earth connections when possible (figure 4).
Service voltage was applied again to the cable connection and PDs were measured and recorded at different frequencies.
This methodology was used for the 92 measuring points during one month and a half, having then a huge PD signal row data to analyse by the experts at the office.

Figure 4

III. DATA ANALISYS

The use of phase resolved pattern distribution techniques with origin based clustering allows the dissembling of measured signals during the analysis, which was crucial to define four PD signal families in the grid under study (figures 5 to 8).

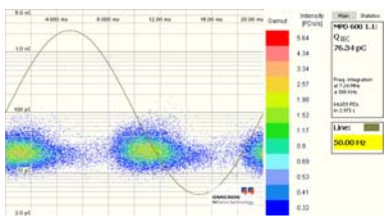

Figure 5

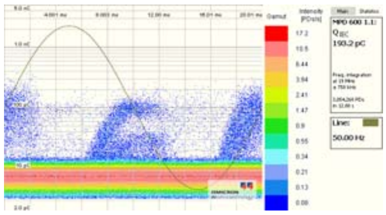

Figure 6

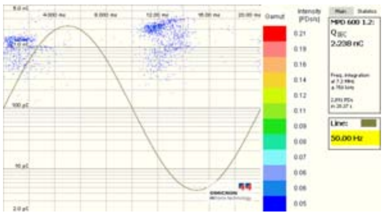

Figure 7

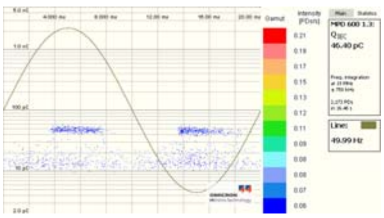

Figure 8

Each measured signal was then decomposed in a particular combination of the four main families and flat noise.
A risk assessment matrix was created then with each measuring point's family composition, pC range of each of them, PD signal density, and the relative importance between PD patterns, being the latest the most important factor for a correct assessment.
Every measuring point was then rated within a 1 to 5 scale being 1, cable system in good shape and 5, cable system very deteriorated, immediate replacement is recommended (table 1).

1	Cable system in good shape
2	Not as new but in good condition
3	Deteriorated cable system, keep control of it
4	Degradation process well advanced, schedule replacement
5	Cable system very deteriorated, immediate replacement is recommended

Table 1

Study case

During the measurements and due to some grid reconfiguration works, already measured two resin type three-pole sealing ends and three dry sealing ends had to be moved and replaced by dry type sealing ends and transition joints, giving the chance to verify the correctness of the assessment.

After the first measurement, the sealing ends of the five parallel circuits were classified as 3 the two resin type three-pole sealing ends, as 2 one dry connection and as 1 the other two dry connections.
Wave type patterns were detected in the resin type sealing ends, with pC values going from 15pC to 100pC with medium density of PD pulses in one of them, and 300pC to 700pC in the second with low density of PD pulses.
These patterns were related to the terminals, recommending, if the problem would increase, the replacement of the terminals, and not necessarily the replacement of the whole cable system.
Once the 5 systems were installed in the new position by means of transition joints and new short dry cables connections and sealing ends, the classification changed to 1 for the new dry connections of the PILC cables and remained the same for the others, hence confirming the correctness of the previous assessment and the origin of the PD pulses.

IV. MAINTENANCE PLAN

Thanks to the risk matrix, the Electrical Department has a real mapping of all the 8,7/15 kV installation's condition and a replacement, maintenance and periodic measurement plan is being developed for this distribution grid.
The summary of the risk matrix results was 31 points classified as 1 (33%), 14 points classified as 2 (15%), 25 points classified as 3 (26%), 17 points classified as 4 (18%), 6 points classified as 5 (6%) and 2 points without classification due to the lack of readable signals in those points when the measurements were performed.
A replacement plan has been scheduled for the next years with known budget and power interruption dates, which eases the relation between maintenance and production, avoiding sudden energy interruptions and all the related risks during a short-circuit or an explosion in a petro-chemical installation.
PD measurements will be performed periodically and after replacements, in order to update installation's PD map and keep trace of the possible evolution of the cable systems classified as 3.

CONCLUSIONS

Partial discharge measurement has been used successfully to get an insulation condition map of the 8,7/15kV grid of a petro-chemical industry working under the safest conditions and obtaining very valuable information of system's insulation condition.
This information allows scheduling a maintenance plan based in asset's condition rather than the undesirable incident/replacement scheme used up to now.
PD measurement has still a very important data analysis process to be done by experts on site or at the office that cannot be taken for granted. On site expertise and

laboratory research are required skills for a good condition assessment.
When the correct working procedures, equipment and personnel are used to perform the work, very valuable information can be obtained from on-line PD measurements on old PILC cable systems.

REFERENCES

[1] CIGRE WG D1.17, 2010, "TB 420- Generic guidelines for life time condition assessment of HV assets and related knowledge rules"

[2] CIGRE WG B1.04, 2005, "TB 279- Maintenance for HV cables and accessories"

[3] S. Boggs, J. Densley, 2000, "Fundamentals of partial discharge in the context of field cable testing", IEEE Electrical insulation magazine vol. 16, 13-18.

[4] D.W. Gross, M. Söller, 2007, "On-site partial discharge testing of distribution class cables using VLF and power frequency excitation", *Proceedings Jicable*, session C.7.2.9, paper 0151.

[5] C-H. Lee, Y-C. Lin, M-Y. Chiu 2008, "Recognition of partial discharge defects in cable terminations", *Proceedings International Conference on Condition Monitoring and Diagnosis*, 1242-1245.

[6] Y. Muramoto, E. Gulski, F.J. Wester, J.J Smit 2001, "PD inception conditions and PD pattern of defects in PILC ", *Proceedings International Conference on Solid Dielectrics*, 369-372.