PRACTICAL EXPERIENCE OF A PARTIAL DISCHARGE MONITORING APPLICATION ON AN EXPERIMENTATION MV DISTRIBUTION NETWORK

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ABSTRACT

Partial discharge (PD) measurement and monitoring of networks is an important and increasingly accepted tool, forming part of asset management programmes of distribution network operators. In order to develop a PD monitoring system, it is important to have knowledge of PD's from different sources and characterize them in real-life situations. This is difficult as it would require access to a network operator's grid to carry out experiments, as well as having the grid characterized itself. Ormazabal has recently completed the construction of its own private medium voltage (MV) distribution demonstration and experimentation network and this article presents some practical experience of developing a PD application with the use of this highly configurable installation.

INTRODUCTION

Asset management and the tools required for this activity are growing in importance for network operators. Indeed in Europe, investment in R&D in this area has been identified as key for the future of networks [1]. Among the many different tools available for asset management of networks and components is online partial discharge (PD) measurement and monitoring [2-5].
Ormazabal has developed an online PD monitoring system principally for integration into switchgear. This system is designed such that equipment can be installed in switchgear cubicles with safe access to both high frequency and power frequency signals through connections in an attached control box. This leaves open the option to make periodic measurements, attaching measurement equipment when necessary, or leaving equipment installed for measurement and/or monitoring at more regular intervals. Development work has been carried out in Ormazabal's laboratory installations and some field work has been possible. However, for measuring PD's from different sources and characterizing them in real-life situations, development is difficult due to requirements for access to a network operator's grid, as well as having the grid characterized itself.
The recent completion of its own private MV distribution demonstration and experimentation unit - UDEX ('Unidad de Demostración y Experimentación' in Spanish) - has given Ormazabal the unique capability to develop and test new technologies, products & services in a highly configurable medium voltage network independent from the utility grid in a safe and controlled environment.

DESCRIPTION OF UDEX

The main purpose of the UDEX is to facilitate access, be it from Ormazabal or a third party, to a MV smart grid network having a high degree of flexibility, *independent* of the utility network, for the development and testing of new technologies. It is able to reproduce normal conditions of existing worldwide MV networks as well as anomalous situations, such as network failures.

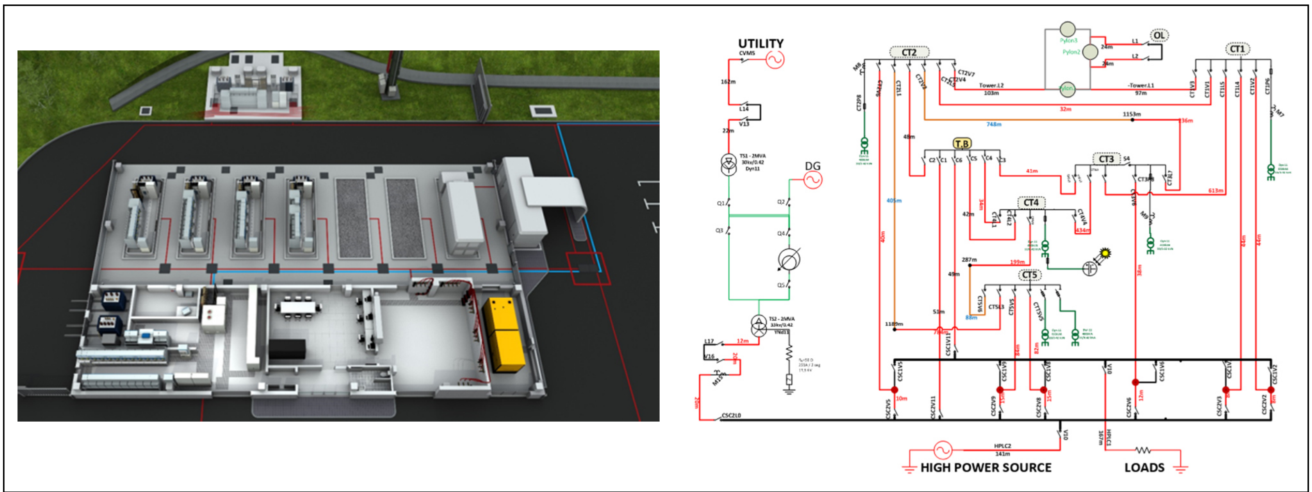

Figure 1 CGI of Remote Operating Laboratory of the UDEX and single-line diagram of available interconnections

The principle characteristics of the network are:

- Underground cables (approximately 15km)
- Overhead cables (approximately 450m)
- 71 switchgear cubicles, distributed over,
- 5 permanent substations
- 2 temporary substation bays
- 4 different power sources,
  - Utility Grid: 30kV/630kVA, continuous
  - Diesel Generator: 630kW, continuous
  - HPL Generator: 2500MVA, short duration
  - Photovoltaic: 100kW, intermittent

  Moreover, the HPL (High Power Laboratory) connection [6] allows us to perform short circuit faults on this network: up to 21kA for 3s
- Controlled voltage up to 36kV
- Variable frequency, including standard 50 or 60Hz operating conditions.
- Local and/or Remote operation (dedicated Remote Operating Centre)
- Electric vehicle (EV) charging station
- Energy Storage substation
- Wind turbine
- Test bay area for test objects

This concept of a highly configurable medium voltage network for development and testing of new technologies not only contemplates equipment testing, as with standard laboratory testing, but also embraces solutions and applications for network infrastructures. These include: electrical protections and automation, power line communications (PLC), advanced metering infrastructure (AMI), integration of EV and storage. One significant application has been network diagnostic systems, and in particular, a PD monitoring application.

PD MONITORING APPLICATION

The idea behind the UDEX is that any new equipment or technology, proprietary or third-party, may be tested. In this case, the PD system used has been developed in-house.

PD Monitoring Equipment

The Ormazabal PD monitoring equipment consists of several key components:

- MV coupling units

  In this case, Ormazabal MV capacitive coupling units plugged into the cable terminations within the MV switchgear cable compartment. Note that the system is also compatible with high frequency current transformers (HFCTs).
- Safe access plug board in LV cabinet

  Plug board for safe point of access for operators carrying out measurements without having to de-energize the network. This is located within a cabinet normally associated with the MV switchgear.
- PD signal detection and processing units

  These are 6U Eurocard format data acquisition cards designed to plug into existing Ormazabal programmable controller equipment enclosure. The units have connections for 3 high frequency signals, 3 low frequency power signals (50/60Hz), 3 reference injection signals, Ethernet, GPS and USB.

  Also available are RS232 and RS485 interfaces with the following communication protocols available via IP:
  - HTTP for web configuration and graphical measurement presentation
  - Modbus/TCP for SCADA system access
  - File Transfer Protocol (FTP) for data recording access
  - Secure Shell (SSH) for system configuration and control
  - Network Time Protocol (NTP)

Monitoring Application Interface

The monitoring application interface is on two different levels:

- Interface directly to the PD equipment

  The most practical method is via the web interface and is useful for both configuration and graphical presentation of measurements, e.g. phase resolve PD patterns

Figure 2 Web interface to PD equipment allowing configuration and visualization of measurements

- High level SCADA interface

  This is a practical system for control centres where simple representative PD data and alarms can be presented. Should further detail be required from any specific equipment, access is also made available through this interface.

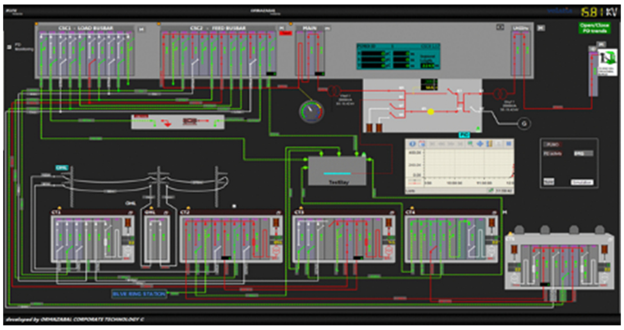

Figure 3 SCADA interface for UDEX network including PD application (PD levels, location, alarms, etc.)

Figure 4 SCADA PD application detailed information.

PRACTICAL EXPERIENCE

Case 1: Installation and Commissioning

Apart from continuous monitoring of PD activity, the system can be used for one-off and periodic measurements, e.g. commissioning tests. Indeed before starting any testing activities, the UDEX network was characterized to confirm it was free from PD's. It was during this characterization that the practicality of the PD system was demonstrated when a source of PD was detected whilst a section of the network was energized. Thanks to the flexibility of the UDEX network, the PD source was quickly located to a specific substation. The phase affected was easily identified and surface discharge activity was observed as the defect type. On investigation of the affected substation and cubicle, an earth braid was seen to be resting upon a section of an isolator. Upon removing this braid from the isolator the PD activity disappeared on subsequent energizing of the network and so confirming this as the source.

Figure 5 Earth braid on isolator

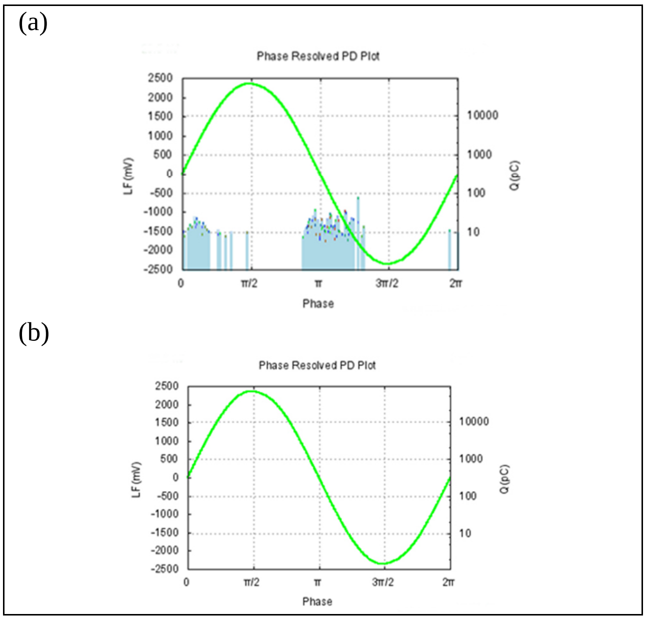

Figure 6 PRPD plots (a) before and (b) after repositioning earth braid

Although not considered a high risk of failure in this case, it is a source of PD that could be encountered in a typical network and should be taken into account and provides more data for our growing database.

Case 2: Database Construction

The UDEX installation and the PD monitoring application are being used to build a database of known defect types commonly found in distribution networks.

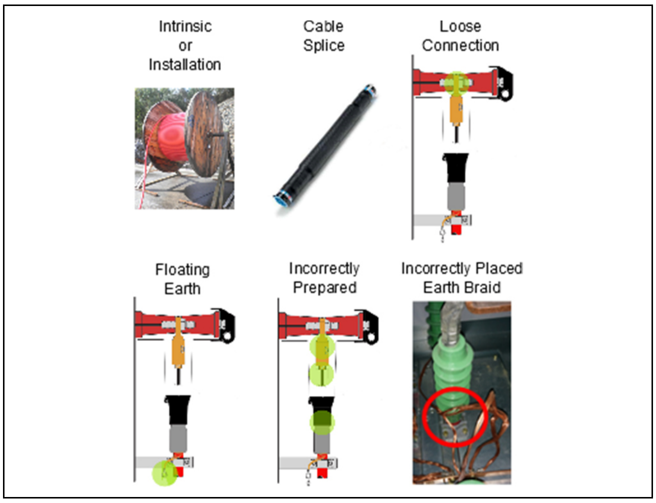

Figure 7 Typical sources of PD in different components in a distribution network.

With this database, algorithms for the identification of PD sources are being optimized.

The flexibility of the UDEX allows for a multitude of network configurations such that the effects of cable length, type, presence of substations and switchgears, etc. upon PD signal propagation, attenuation and dispersion can be logged for different PD types.

PD application on the UDEX is also used as a demonstration tool, able to reproduce actual phenomena observed by network operators, highlighting the usefulness of PD monitoring prior to, and so being able to avoid, failures. The data collected from these phenomena also contribute to the growing database.

Case 3 : Multiple PD Sources

Having access to different points on the UDEX network allows us to introduce various defects simultaneously.

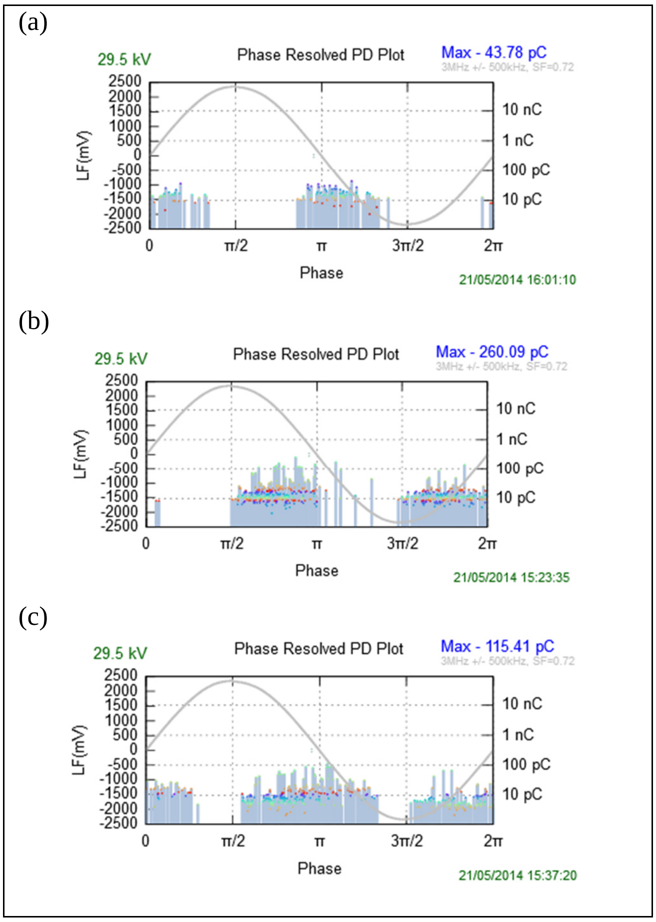

Figure 8 Different PD sources on the UDEX network: (a) earth braid on insulator; (b) Loose earth connection; (c) combined faults.

Expanding upon the optimization of algorithms for PD source identification is discrimination of different types and sources when there are multiple PD sites.

This is useful not only in terms of PD sources but also the discrimination from noise generated on the network from other sources such as rotating machines, power electronics, and even powerline communications.

CONCLUSIONS & FUTURE WORK

For the development of tools for asset management, the reproduction of anomalous situations in real network operations is extremely difficult. The UDEX provides this opportunity to develop and test new tools and technologies in normal operating conditions.

Designed considering different applications and solutions, here it has been shown to be useful in the development of a partial discharge monitoring application.

Work continues on expanding the database of typical PD sources that can be found on networks in different 'real-life' situations. This database is being used to continually improve upon algorithms designed for the early identification and localization of possible faults.

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