EXPLORING IED DATA MANAGEMENT AND IEC 61850 FEATURES TO INTRODUCE A CONDITION BASED MAINTENANCE APPROACH IN THE PORTUGUESE DSO

Luís CANDEIAS
EDP Distribuição – Portugal
luis.candeias@edp.pt

Helder HEITOR
EDP Distribuição – Portugal
helder.heitor@edp.pt

Paulo RIBEIRO
EDP Distribuição - Portugal
paulo.ribeiro@edp.pt

Miguel VERISSÍMO
EDP Distribuição – Portugal
miguel.verissimo@edp.pt

Carlos CURA
EDP Distribuição – Portugal
carlos.cura@edp.pt

ABSTRACT

From many years, protection systems play a crucial role in power substations of electrical grids worldwide. Due to the criticality of those systems, it is highly recommended to keep them working with high availability and accuracy, which implies the adoption of an adequate maintenance policy. This paper aims to present the Portuguese DSO (Distribution System Operator) EDP Distribuição (EDPD) reality and experience in maintaining in-service Protection System units, on the one hand, focusing on the actual maintenance strategy approach and possible future changes, in order to provide highest levels of service and security within the electrical system, and, on the other hand, considering a strict alignment with operational and economic efficiency as these are an ever-increasing concern for every utility company.

1. PRATICES AND CHALLENGES TO THE PORTUGUESE DSO

Although protection equipment should be in sound condition when first put into service, problems can develop unchecked and unrevealed because of its infrequent operation. **Regular inspection and testing of a protection scheme is therefore required** [1].

Even with modern equipment, some maintenance and inspection are needed to avoid system failures. A second aspect is an increasing scrutiny culture, as Stakeholders are more attentive and demanding than ever. With regular inspections, utilities can prove to a third party that their systems are well maintained.

<u>Our vision and practices</u>

EDPD has an ageing protection unit asset base, that spans along several generations and technologies, with different requirements in terms of health and performance surveillance. The main maintenance tasks during Protection Systems life cycle are focused on faulty system components replacement, new components installation and reconfiguration, repaired system testing as well as Protection & Control periodic functional testing performed in each equipment (Figure 1).

Several different approaches were taken in the past to deal with this concern, and since 2011 a **Time-Based Maintenance (TBM)** policy is used in EDPD [2] (Table 1), following a recommendation internal report [3] and the best practices in the industry.

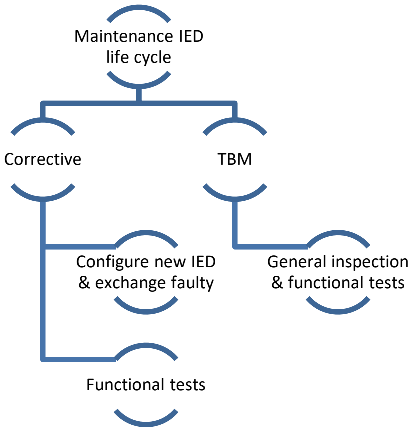

Figure 1 – IED maintenance strategy at EDPD DSO

In the context of these maintenance routines, similar operational practices are followed regardless of the technology to be inspected. When not applicable, certain action is classified as not applicable. In summary, the actions are classified as follows:

- **Check analogue, digital I/O and its connections to field equipment;**
- **Perform Protection and Control functions tests, including trip, open and close commands;**
- **Check HMI / Control Center signals;**
- **Check important information exchanged between Bays.**

Technology	Interval
Mechanical	every year
Static	every 2 years
Digital and numerical	every 5 years

Table 1 – TBM maintenance policy at EDPD and tasks

All inspections results are documented in standard inspection forms. The documentation of these tests by means of a test protocol is necessary for several reasons, ranging from legal aspects, safety and security

considerations to insurance in case of accidents.
Additionally, **the functional tests of the protection devices, are performed using calibrated secondary injection test equipment**.

Benefits and results

In consequence of the work that our teams are developing in terms of maintenance, possible future malfunctions and failures are avoided. One interesting conclusion is that all the revealed problems were only detected trough the inspection itself. **The "watchdog" functionality, doesn't cover all the malfunctions.**

Malfunction Type	%
Protection Function Configuration/Setting error	23%
Circuit Breaker/Auxiliary CB Circuit malfunction	13%
IED HMI Malfunction	13%
Protection Measurement/Calibration Error	8%
SCADA/Central Unit signalling / alarm error	29%
Non-existent Watchdog signalling	6%
Auxiliary Circuit Error	4%
Voltage/Current circuit problem	2%
Protection BI/BO damaged malfunction	2%

Table 2 - Detected malfunctions during TBM (data from 38 installations during 2018)

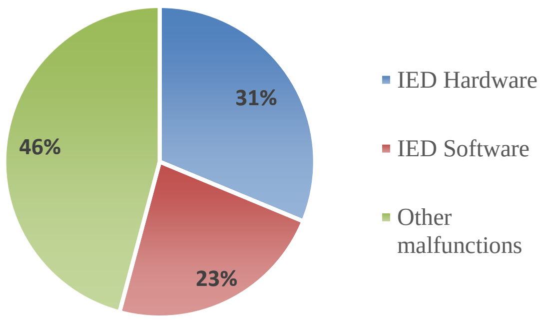

Figure 2 - Detected malfunctions during TBM (data from 38 installations during 2018)

Another interesting conclusion is that **54% of the nonconformities were due to hardware malfunction or software error.** In most cases, our experience shows that after commissioning, the first maintenance intervention is of great value and helps to purge most of systems infant problems and commissioning errors.

Constrains and challenges to overcome

Despite all the benefits of the TBM process, there are some issues and challenges that we face with our approach to maintenance, such as the need for a **high availability of work force, high maintenance costs and the unknown risk profile related to its frequency.**

The periodicity that we practice in our maintenance routines in conjunction with the high number of assets that we dispose, makes that every year we must schedule a high number of preventive maintenance works (Table 3). The numerous maintenance tasks, implies **high availability of work force and considerable costs.**

Year	Number of installations scheduled	Number of protection devices tested	Workforce (hours)
2016	79	1193	5690
2017	95	1535	6810
2018	84	1465	6556

Table 3 – TBM data from last 3 years total

Another fact to consider is that, nowadays, our practices and *modus operandi* demand that the primary assets such as circuit breakers connected to protection equipment to test, need to be disconnected from the grid by a certain amount of time, in order to perform the described tests (Table 1). **In most cases, due to electrical network configuration and requirements, many operations and tests can only be performed on non-working days (less load, less industrial clients and requirements) which increases the work-related costs.**

Finally, in terms of challenges and constrains, it is a fact that there are some risks associated to the systematic maintenance selected periodicity. The exact situation of the systems is not known until inspections are performed, because some problems or behaviours are only revealed at that time. That's why the periodicity subject is widely discussed. Nowadays the challenges and constrains previously mentioned are becoming a major subject in EDPD, making us to rethink the maintenance process as we conduct it today.

Despite the good technical results achieved with our maintenance practices (TBM), the drivers of operational and economic efficiency are important, making us question the existence and **possibility to explore new paths, such as the introduction of Condition Based Maintenance (CBM) procedures so we can confidently make changes in our TBM practices, majorly in terms of periodicity and tasks performed.**

2. EXPLORING THE ROAD TO EVOLUTION

Nowadays new possibilities must be considered, resulting from a group of practices that are already in use and new processes or technologies to be explored.

Commissioning practice

The commissioning stages, **Factory Acceptance Tests (FAT) and Site Acceptance Tests (SAT)**, are very important stages in the life cycle of Protection Systems. These two stages are performed to configure and setup all systems, ensuring that **functionalities and behaviours are tested and in accordance with existing protocols and requirements.**

Nowadays, maintenance teams have an active and important role in the commissioning phase, thus guaranteeing a quality increase and error decrease in this step of the process. With this involvement, maintenance teams also ensure that the **know-how required for operation and maintenance (corrective or preventive) of the assets is updated.**

Settings and protection data management

To achieve an optimized and cost-efficient asset maintenance, it is a must having not only a clear and reliable access to Protection Data, but also continuously ensuring a good data quality.

Regarding protection information, until recently EDPD was using an in-house protection database that allowed to archive the in-service primary settings of the main protection functions of all relays. For other protection information, such as, firmware, protocols, or even network-related data, several, dispersed, lists and databases were used in addition. Those solutions proved to be important in the past, however, current needs and future demands require a robust database that centralizes all relay information with as much detail as possible, handles relay and testing history and manages protection-related business processes. EDPD made an important investment towards a power protection software, that includes the Management of Data, Setting, Testing and Life Cycle of Protection Relays.

As can be seen in Table 2, Protection Function Configuration/Setting error are one of the main malfunctions detected during TBM. This issue can be better handled with such a tool, since makes it possible to implement quality control methodologies to help detection settings implementation errors.

The implementation of protection software, is a large-scale project that will follow different stages:

Figure 3 – Implementation of protection software stages

The implementation of this new solution allowed us to revise and define new processes and procedures for the interaction between different departments, ensuring a higher efficiency in the way the protection relay configuration and maintenance is carried out at EDPD.

Post-mortem fault analysis and corrective maintenance

Even with the best available systems that implement robust databases and routines, it is not possible to disregard corrective maintenance works that result from post-mortem fault analysis. EDPD's organizational structure includes a Department that is responsible to perform such analysis to faults that occur in the whole EDPD's grid. Centralizing those duties into a team enhances grid observability and response, however, communication with geographically-distributed maintenance teams needs to be permanent. On a regular basis, post-mortem fault analysis is performed to all outages whose cause are suspected to be a relay malfunction and to all major faults, which includes all substations power equipment faults and permanent faults in High Voltage Lines. Other analyses are performed as a result of specific requests and/or customers complaints.
Following the conclusions and recommendations of those analyses, tests and corrective interventions in the relays must be performed by maintenance teams. There are cases where major interventions need to be carried out, for instance, when an improvement is detected in some specific relay type or technology and it has to be replicated to several assets within several substations. For this case, a robust protection database is an essential tool since it can help to rapidly identify the location of all relevant assets.

IEC 61850 and new opportunities

The recent technical advances in Substations Automation (SA), from where it raised a high scale replacement of conventional Protection Systems by Intelligent Electronic Devices (IEDs) and the pervasive introduction of systems according to IEC 61850, where a lot of data is made available, brings major opportunities in terms of assets condition monitoring and new forms to perform routine checks.

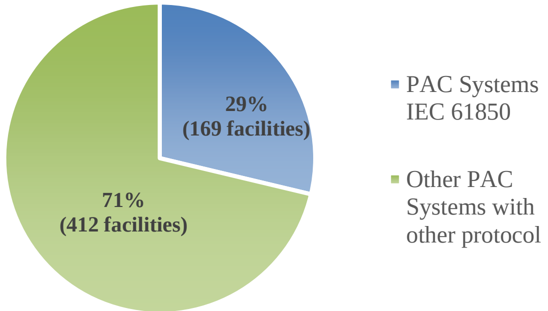

Figure 4 – EDPD PAC (Protection Automation and Control) Systems in operation

In EDPD this growing number is a fact, were 29% of the systems are functioning according to IEC 61850, as can be seen in Figure 4. Although there are already systems with IEDs certified according to the edition 2, it is important to note that most of said IEC 61850 systems were designed with IEDs according to the edition 1 of the standard.

The expectation in the future is that the majority of new outcoming systems (new facilities/systems or refurbish of older systems) will integrate IEDs according to Edition 2.

Self-monitoring

In terms of IEDs hardware condition, the supervision nowadays is mainly focused in the "watchdog" information. In order to obtain more information of the hardware status and behaviour, one of the interesting features [4], according to the standard IEC 61850-7-4[5], is the information available in data objects from the Logical Node **Physical Device Information (LPHD)**.
The full node has several objects available which can provide added value beyond the "watchdog" information.

LPHD class				
Data object name	Common data class	Explanation	T	M/O/C
Data objects				
Descriptions				
PhyNam	DPL	Physical device name plate		M
Status information				
PhyHealth	ENS	Physical device health		M
OutOv	SPS	Output communications buffer overflow		O
Proxy	SPS	Indicates if this LN is a proxy		M
InOv	SPS	Input communications buffer overflow		O
NumPwrUp	INS	Number of power-ups		O
WrmStr	INS	Number of warm starts		O
WacTrg	INS	Number of watchdog device resets detected		O
PwrUp	SPS	Power-up detected		O
PwrDn	SPS	Power-down detected		O
PwrSupAlm	SPS	External power supply alarm		O
Controls				
RsStat	SPC	Reset device statistics	T	O
Sim	SPC	Receive simulated GOOSE or simulated SV		O

Figure 5 – Logical Node LPHD (from the standard IEC 61850-7-4)

There are several valuable information's in this node, such as the mandatory object **PhyHealth** (Figure 5). The status value of this object offers the possibility to monitor with more detail, the "health status" of IEDs hardware.
Other objects such as **PwrSupAlm, NumPwrUp** or **WrmStr** can also represent an added value in terms of maintenance because their analysis can help to anticipate malfunctions and accelerated electronics degradation (Figure 5).

The IEDs loss of communication is also an important issue. Therefore, another node that can supply valuable information in terms of maintenance, is the Logical Node **Physical Channel Communication supervision (LCCH)** according to [5]. The mandatory object **ChLive** of this node, with proper analysis and treatment can anticipate problems concerning communication channel [4].

The standard also defines temperature related nodes [5]. External temperature impact over IEDs hardware performance / malfunction can have an important role, affecting the aging of the electronic components. In other hand if IEDs include internal temperature sensing and makes it available over protocol, the extracted information can be extremely valuable to correlate an already existing electronics degradation.

Hardware errors are one of the main malfunctions detected during TBM (see Figure 2). This issue can be better handled with the analysis and treatment of the information supplied by previous described logical nodes.

Information management under BI tools

Nowadays in EDPD, the IEDs "watchdog" information is already mapped in SCADA network. The information is available and treated as an alarm, in the workstations used by operators of the electrical network Dispatch Center, being forwarded to maintenance department. The final treatment that maintenance gives nowadays to this alarm is mostly of the corrective type, mostly ending in IED replacement.

With the increase of signals available, new challenges arise in terms of information management. Monitoring and reporting architecture of self-supervision information must begin with the selection of the signals considered important, within the ones available in the data objects of the IEDs. The processing path of the selected information can follow the one illustrated by Figure 6.

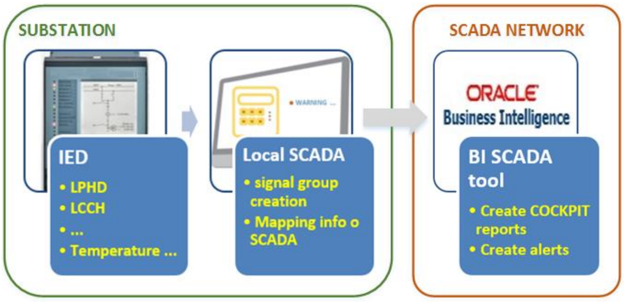

Figure 6 – IEC 61850 IED self-monitoring information mapping and reporting architecture

In EDPD with such kind of information available in SCADA network, useful reports can be created using tools that are already available, such as **Business Intelligence (BI)** software tool, which is an application software designed to retrieve, analyse, transform and report data for business intelligence.

With the use of BI for monitoring purpose, customization of cockpit / alert reports can be designed, providing maintenance planning teams a powerful set of quick analysis and decision tools, **allowing the introduction of CBM procedures.**

3. CHALLENGES TO COME AND THE MAIN DRIVERS TO CONSIDER

Main issues and questions

Despite the definition of the previously referred nodes in the standard [5], some objects implementation are optional, leading to a prior implementation necessity by part of the IED manufacturers

Next steps

Taking in consideration all the experience, results, new processes and opportunities available in terms of maintenance (see sections 1 and 2 of this article), EDPD can start designing a pack of scenarios, options and drivers to consider and to study changes in the field of IEDs maintenance (Figure 7).

The stability of commissioning, protection data and behaviour analysis, gives a good confidence over the IEDs well state in terms of software and other malfunctions. In terms of IED hardware malfunctions, its early detection can be empowered by exploring the IEC 61850 monitoring possibilities (hardware information and temperature nodes).

The merge of the previous points stated, opens the opportunity for CBM interventions with the major benefit of preventing malfunctions over the electrical network and becomes a major confidence support to revise the periodicity of our TBM actions in the IEDs.

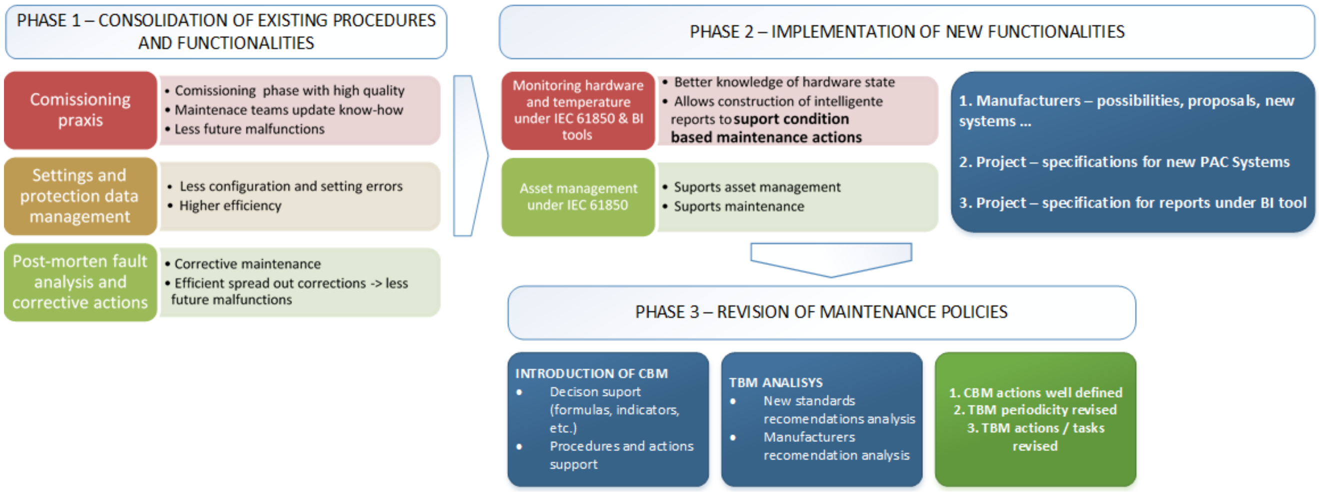

Figure 7 – Following actions for a new approach concerning maintenance policies and tasks

4. CONCLUSIONS

The adoption of a series of good practices all over the years (FAT/SAT well supervised and documented, solid protection database and fault analysis plus corrective actions), and the growing number of PAC Systems with IEC 61850 architecture, brings the opportunity to search for new approaches in maintenance field, that can result in an IED evaluation as rigorous and complete as possible.

In this paper we presented the current EDPD reality and our vision for the future in terms of maintenance policy alternatives, considering specific scenarios with the objective of taking advantage from the hardware and software available.

The expected approach will certainly allow a significant improvement in maintenance of IEDs performed by the system operator maintenance teams, resulting in a positive impact in terms of workforce **availability and in maintenance costs reduction, mainly from the assumption on a change of periodicity of TBM tasks expected.**

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