SMARTLIFE : A EUROPEAN COORDINATION PROJECT IN NETWORKS ASSET MANAGEMENT

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ABSTRACT

Planned as a 2-year activity (2009-2010) the so-called SmartLife initiative is a European coordination project relating to the asset management of distribution and transmission networks. After a short introduction to the SmartLife objectives, this paper highlights the main results achieved in the first year of works.

<u>Participants in SmartLife</u> :

- *Austria (WIEN ENERGIE STROMNETZ),*
- *Belgium (LABORELEC, EANDIS, SIBELGA, ORES, ELIA),*
- *France (EDF R&D, ERDF, RTE),*
- *Italy (ENEL, ERSE, University of Bologna),*
- *The Netherlands (KEMA, University of Deft, TENNET, ENEXIS),*
- *Norway (SINTEF, STATNETT, HAFSLUND, EBL),*
- *Portugal (EDP),*
- *Spain (IBERDROLA, REE),*
- *United-Kingdom (EDF ENERGY, NATIONAL GRID, University of Manchester).*

CONTEXT

Significant parts of European networks have been developed in the 60-70s and are now getting close to their expected lifetime. Utilities thus have to anticipate investment waves to come. Further, it is expected that the networks will undergo changes as a result of distributed generation and market changes.

For this purpose a **better knowledge of ageing mechanisms and diagnostic tools** on the one hand and **asset management processes** on the other hand, is essential. Today studies on networks asset management are carried out separately by each utility, so it is useful to gather knowledge and skills of their experts to benefit from sharing of resources/efforts, data, tools and methods enabling findings of relevant ideas and best practices.

ORGANIZATION OF SMARTLIFE

SmartLife was launched at the end of 2008 for a **2-year duration with 26 European partners gathering TSO's, DSO's, R&D institutes and universities from 9 countries** : France, Italy, Spain, Portugal, Norway, The Netherlands, Belgium, United-Kingdom and Austria.

SmartLife is organized around a decisional Consortium Committee and a Core Group ensuring the follow-up of works (EDF R&D acting as coordinator).

Exchanges and works are performed in 5 user-groups gathering around 60 experts and asset managers, 3 of them focussing on the main networks components (cables and accessories, overhead lines, transformers) and the 2 others on the asset management practices of TSO's and DSO's.

OBJECTIVES AND EXPECTED RESULTS

SmartLife has two main complementary objectives :

- optimise the management of (ageing or future) assets considering ratio Network performance/Renewal cost,
- modernize current networks through innovations.

The work performed on components aims at :

- **identifying critical technologies of equipment and key factors influencing failure and ageing mechanisms** through a large-scaled analysis of the experience outcome,
- **targeting high value on-site diagnostic methods, labs expertises and ageing methods** in order to better estimate the failure risk and thus the residual lifetime of equipment,
- **deducing methods reflecting the health index of equipment** to facilitate decisions in asset management (support to criteria for maintenance and/or renewal of equipment),
- **identifying best practices and technological innovations** enabling to specify (with optimization of the global cost) new components intended to ensure transition towards future networks.

The work performed on the asset management practices aims at :

- **analysing current practices in asset management of networks** : methods, tools, data (implementation of relevant data bases),
- **identifying needs and define common strategies** taking into account specificities of each company in order to optimize management of current networks and prepare management of future networks,
- **deducing methods for investments optimization based on risk management and defining requirements and data** necessary to these methods related to risk analysis (models of data bases, information treatment, tools for data collection, higher level health indices, total cost of ownership…).

UNDERGROUND CABLES & ACCESSORIES

The user-group produced and circulated questionnaires asking for service experience for all voltage classes from 6 kV and up to the highest voltages. The answers got showed that the collection of failure statistics is handled in different ways throughout Europe : details are quite good in some cases while other replies are only indicating some major trends. The main results in the medium voltage range (6 to 42 kV) can be summarized as follows :

- **Both paper and polymeric links are ageing in a good way**, except for some poor designs such as early XLPE cables and **some transition joint failures** with weak water-tightness.
- **Accessories are generally the main issues** with failure rates higher than for cables. The main identified causes are water ingress, poor assembling and mechanical stresses.

In parallel of the statistical approach, reports presenting the major failure mechanisms for paper and polymeric cables have been worked out. General considerations are confirmed : **dominating cable ageing phenomena are partial discharges in paper cables and water-treeing in polymeric cables**.

In addition, **with the objective of sharing efforts between utilities to increase knowledge and experience in a better estimate of the remaining life, recommended procedures have been proposed for laboratory test common methods (**when a cable or a cable accessory is to be evaluated after removal from service). These procedures will be proposed to European utilities as a recommended way to perform and share laboratory evaluation of test samples removed from service.

Failure statistics shall be addressed in such a way that it can be optimised for health index considerations. **Health indexes will be developed so as to take into account the actual quality of the available failure statistics**.

As an essential part of studies on the transition from service to the end-of-life, the application of diagnostic tools in the utilities was asked for through a dedicated questionnaire. The conclusions show that **diagnostics are still being used as indicators only** : in most cases it is not the diagnostic result that decides that the end-of-life is reached. However, **most utilities are evaluating some diagnostic methods in order to be a part of the development of such methods**.

The best practice for qualification of new components is also discussed in the user-group. It was observed that **the international standards are missing some tests considered as important in order to exclude equipment that do not have the necessary quality for installation in the network** (especially for joints).

Discussions will also address the quality requirements of the cable statistics if it shall be used as background for asset management through health index considerations.

OVERHEAD LINES

The user-group produced and circulated different questionnaires to gather information on the current technologies and service experience. Four questionnaires were thus set up to analyse the different designs and characteristics of the main components, the specification practices and the outages statistics (identified by causes and component involved) : one on inventory and outages statistics, one on supports and foundations, one on conductors and fittings and one on insulators.

Two voltage ranges were considered : from 60 to 170 kV and greater than 170 kV (due to the participation of only TSO’s representatives in the user-group).

Practices related to inspection methods adopted by TSO’s were collected with reference to the different components analyzed. At this regard, **even if visual inspection from ground remains the most diffused method, there is a tendency to partially shift to helicopter inspection and new inspection methods** (thermo camera, LIDAR, UV camera, etc.) **are more and more becoming part of periodic inspections of the lines**.

As regards exchanges of information on failure statistics and failure causes relevant to the different components, some difficulties were encountered due to the high number of components involved and the lack of failure records. However from the answers on the questionnaires it is evident that **environment is the determining factor for the majority of failures**. The great variability of environment characteristics from one country to another involves difficulties to compare failure rates statistics. However it emerged that **failure rates on the lower voltage range (60-170 kV) are on average about 2.5 to 3 times higher than on the other voltage range (>170kV)** and that **the component responsible of the majority of the OHL permanent outages is the conductor assembly** (conductors and fittings).

To also cope with the problems of medium voltage lines a new DSO sub user-group was created at the end of 2009. At this regard a simplified questionnaire was circulated.

TRANSFORMERS

The user-group produced the main following results :

- **a simple statistic focussing on dominating major failures** that can be used to monitor trends and analyze differences between populations due to design, operation, etc. ;
- the identification and description of **long term ageing processes important for the end-of-life estimation** (also including a more detailed statistic on failures attributed to such phenomena) ;
- **specifications of diagnostic databases** to facilitate experience sharing ;
- **protocols for scrapping and post-mortem analysis** related to improvement of diagnostics and condition assessment schemes.

The main challenge therefore is to combine demands for details to be informative and at the same time to keep questionnaires simple enough to get input data. The fact that transformers vary widely in design depending on voltage levels, manufacturers etc., is a complicating factor. It was therefore decided **to split the statistics in 3 classes** :

- transformers for the low voltage distribution networks (class 1) ;
- transformers for higher voltage distribution and regional grids (class 2) ;
- transformers for the higher voltages representing transmission grids and transformers connected to this grid (class 3).

As transformers of class 1 are numerous with a low capital cost, they will be treated separately in a simplified statistic. Classes 2 and 3 representing high voltage power transformers will be treated in the same way but the statistics will be kept separately as technological challenges are expected to be voltage dependent. The on-load tap changers and bushings have to be considered for class 3 (statistic and diagnostic). The high number of class 1 transformers provides valuable statistical trends while the high value of class 3 units justify more diagnostics and some forensic studies. The user-group analyzes all these class results and information.

As a general trend about the current situation, the user-group noted that failure rates for transformers are quite low and normally thermal stresses are well below rated values. Even if age of the transformer populations can be around 30 years in average, their condition does not call for immediate replacement. To allow for a full utilization of these investments without increasing the hazards for increased failure rates, one needs to follow their condition both by relevant failure statistics and by condition diagnostics. The diagnostic methods need improvement and verification to give more accurate end-of-life estimates. **The future "smart grids" operating conditions will have various impacts on the transformer health, of each of these 3 classes. The temperatures appear as a key data among the information to be shared.**

DSO's NETWORKS ASSET MANAGEMENT

The objective is to develop and validate a methodology of risk analysis for distribution network asset management. It aims at creating the basis for the development of a decision support system intended to facilitate a better network planning, maximise investments effectiveness and efficiency and guarantee network reliability.

The work done has been focused first on the current AM practice used by the DSO's and on the requirements and objectives of an AM methodology.

The current asset management practice has been analysed surveying, with a qualitative questionnaire, the actual methods, tools and data used by the DSO's for AM. A particular highlight has been given to companies' best practice to let every participant benefit from each other's experience. The more relevant findings are as follows.

On the decision level all the companies have a complex set of values for AM. The mix of values differ from a company to another, the ones shared by all are "**Safety**" and "**Continuity and Quality of Supply**". The first one is a universally shared value and indicates a strong attention to companies' employees. The second is a new value consequent to the market liberalisation, companies' privatisation and the strong intervention of the national regulation authorities. Because of these market changes "**Meet shareholders and regulator expectation**" and "**Development of the network to meet demand**" have become very important values too.

Decisions are supported by risk management strategy. The latter is focused on "**Key performance indicator**" and "**Communication to relevant staff**", in order to measure the results and to get people's commitment and process improvement. These elements of strategy are typical of companies operating on competitive markets. This means that there is a trend for DSO's to behave not anymore as monopolies (even if by nature they are). Also the relevance of "**Trade off between capital expenditure and operational expenditure**" shows the increasing attention to a better management of economic resources.

Almost each company already has a structured approach to risk identification : **usually the "historical risk" is used for MV, and the "latent risk" for HV network/primary substation. The main factors used for risk calculation are failures** (components and causes), potential failures (unsupplied customers, location), **continuity of supply statutory rules, reliability conditions.**

Risk calculation helps in preparing a merit order list of works, which gives a priority of intervention, even it does not give a measure risk reduction. A future improvement of risk analysis can be made by combining the risk indicators with the sensitivity analysis.

Risk analysis in itself is a hard job if not supported by an adequate software support system and reliable data. Few companies have an integrated tool and historical data retrieve and **data collection still represents a refrain for more in depth analysis.**

On the other hand **companies' AM requirements are more complex than the present ones and will require new development in methodology and tools.** In the requirements and objectives of an AM methodology the requisites **to settle an AM policy (with associated tools)** have been defined. Two levels are needed :

- **Strategic : long term CAPEX/OPEX trajectories**,
- **Short term optimisation/decisions (3 years) and operational application**.

Besides risk assessment, decision making, profitability requirements include **effective data collection**, analysis and management, **integration of new technologies** (smart grids), **health indexes (**development of a generic methodology to evaluate assets operational categorization), **aging models** and **residual life estimation**, **risk evolution** in different investment scenarios, to perform a more accurate risk assessment.

Furthermore, **monitoring is a very important activity of AM**, technical indexes (continuity of supply indicators, voltage quality, critical parts of the network, failure rates and health indexes, health and safety, customer satisfaction) combined with the economic ones are surely more meaningful. Even though distribution is a natural monopoly in itself and is a regulated business, risk assessment and performance monitoring are fundamental tools for investments decision making in order to maximise companies' value.

TSO's NETWORKS ASSET MANAGEMENT

As a reference for future developments an inventory of current asset management practice has been worked out by the user-group. Without being comprehensive some results are reported hereafter :

- **There is great similarity in business values**, **and great diversity in KPI's**.
- **All TSO's have some form of risk management**, **but there is no common practice** for risk assessment, prioritization and reduction.
- **Maintenance and replacement is mostly component oriented**, often time/condition-based, with few risk issues taken into account.
- **There is no common health index/condition approach**, a large variety of indicators is being used.
- **The quality, availability and accessibility of data(bases) is being organized and improved**, but at this stage yet limited.
- **Capabilities of ICT systems are not fully utilized**.
- **The replacement wave is technically manageable**, **but may face budget and manpower constraints.**
- **Network capacity and asset management are closely related**, involving a trade-off between network extension and options such as controlled overloading, upgrading, uprating, load reduction, load transfer and regulatory/market instruments.

By means of questionnaires, issues to be addressed have then be identified to face the challenges ahead. Both generic issues (such as decision tools and information exchanges) as well as specific issues (replacement wave, capacity bottlenecks) and future issues (technology development, outside developments) were addressed. After ranking, the most urgent issues to be addressed are **options for safe overloading** (or maximizing loading capacity of existing connections), **development of high level health and risk indices** for substations and power connections, **implementation of the concept of total cost of ownership (TCO)**, **risk matrix methodology and risk monitoring** (best practices with regard to prioritization, risk acceptance/reduction, solution prioritization, scales for probability, impact and risk), **reliable identification and management of the replacement wave**.

For each of these issues the actual need case will be worked out in detail, including a substantiation of the reality of the need, the solution options and development requirements at hand, and the expected benefits. This will result in so-called specification documents for future development projects.

Special attention is being paid to define the need, the possibilities and limitations of data and information sharing. A distinction is made between different types of information : performance and benchmarking information on asset owner level, decision support and risk management information on asset manager level, operation, maintenance and equipment information on operational and services level.

2010 ACTIVITIES & PROSPECTS

This paper has summarized the main results got in 2009. For 2010 the asset management user-groups will complete the **development of methodology for risk based asset management** and the **guidelines for data management practices and for creation and good implementation of decision support systems (strategic and operational)**.

The component user-groups foresee to **discuss the observations and recommendations with the manufacturers in order to include new trends and equipment innovations. New techniques and services in the field of diagnostic and on-line monitoring will be considered as well as relevant maintenance and inspection methods**. Beyond finalization of the tasks within each user-group, a special emphasis will be put on some important issues (e.g. failure probabilities and consequences of failures for health index purposes, structure of common databases, lab test references, tools for data collection…) thanks to **interaction between component and asset management user-groups**.