OUTCOME OF SMARTLIFE : A EUROPEAN COORDINATION ACTION IN ASSET MANAGEMENT OF T&D NETWORKS

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ABSTRACT

Planned as a two-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 key results achieved by all the partners through the presentation of the important lessons learned and the main recommendations worked out. As prospects, it is also proposed to continue SmartLife in the next two years 2011-2012 with an associated work programme.

Participants in SmartLife : 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 Delft, TENNET, ENEXIS), Norway (SINTEF, STATNETT, HAFSLUND, Energi Norge), Portugal (EDP), Spain (IBERDROLA, REE), United-Kingdom (EDF ENERGY, NATIONAL GRID, University of Manchester).

INTRODUCTION

Significant parts of European power networks have been developed in the 1960s and 1970s and are now approaching the end of their expected lifetime. Utilities thus have to anticipate investment waves to come. At the same time, it is expected that the networks will undergo changes to evolve towards the so-called "Smart Grids" placing networks under greater stress, resulting for example from the increased variability of energy flow due to renewable energy sources or new loads such as electric vehicles that may increase peak demand. Management of existing aging networks together with the new developments in progress clearly raise key issues in asset management (AM) for utilities.

With regard to this situation, we can note that studies on networks AM are carried out separately by each utility today. So it is useful to gather knowledge and skills of utilities' experts to benefit from sharing of resources and efforts, data, tools and methods, so as to enable findings of relevant ideas and best practices.

This is why a two-year initiative called SmartLife was launched at the end of 2008 among a number of European utilities, laboratories and universities to coordinate activities related to the AM of distribution and transmission networks.

THE SMARTLIFE INITIATIVE

SmartLife brings together 26 European partners representing transmission system operators (TSOs), distribution system operators (DSOs), R&D institutes and universities in nine countries : Austria, Belgium, France, Italy, the Netherlands, Norway, Portugal, Spain and the United-Kingdom. EDF R&D acts as a coordinator of the initiative, which is animated through a strong core group of utilities and key institutes : EDF R&D, ENEL, ERDF, IBERDROLA, KEMA, RTE and SINTEF.

The initiative is made up of five groups, gathering together approximately 60 experts and asset managers. Three groups focus on the principal network components (cables and accessories, overhead lines, transformers). The other two groups are concerned with the AM practices of TSOs and DSOs.

OBJECTIVES AND EXPECTED RESULTS

The priority objective of SmartLife was to optimize the management of both current aging and future assets by considering the ratio of network performance to renewal cost. For this, maintenance, renewal and refurbishment of components must be optimized, and general methods, policies and strategies need to be examined. The SmartLife initiative was investigating both of these tasks.

The work performed on components aims to :

- identify critical equipment technologies and key factors influencing failure and aging through a large-scaled analysis of the experience outcome,
- target high value on-site diagnostic methods, laboratory expertises and tests and aging model methods in order to better estimate the risk of failure and thus the residual lifetime of equipment,
- deduce methods reflecting the health index of

equipment to facilitate AM decisions by helping define criteria for maintenance and/or renewal of equipment,
- identify best practices and technological innovations enabling the specification – while optimizing the global cost – of new components that will ensure smooth transition to future networks.

The work performed on AM practices aims to :
- analyze current practices in network AM relating to methods, tools and data (including the implementation of relevant data bases),
- identify needs and define common strategies taking into account the specific needs of each company, in order to optimize the management of current networks and prepare that of future networks,
- deduce methods for investment optimization based on risk management and define the requirements and data related to risk analysis (database models, information treatment, tools for data collection, higher-level health indices, total cost of ownership…) necessary to adopt these methods.

UNDERGROUND CABLES & ACCESSORIES

FAILURE ANALYSIS - The surveys done on service experience for all voltage classes (from 6 kV and up to the highest voltages) have shown that utilities set up statistics on the different technologies used and their failures in service. This data collection is handled in different ways throughout Europe : information levels vary from "quite good" to "poor" (no basic data !) going through "just sufficient to indicate major trends". Anyway information is not enough detailed to enable a thorough analysis.

The main results in the medium-voltage range (6–42 kV) can be summarized as follows :
- Both paper and polymeric links are aging well, except for some cases : first generation of polymeric cables and some transition joints with weak water-tightness.
- Accessories (joints and terminations) are generally the weak point with failure rates higher than those of the cables : identified causes are water ingress, poor assembly and mechanical stresses.

FAILURE / AGING MECHANISMS - In parallel with the statistical approach, major failure mechanisms for paper and polymeric cables have been examined and some general trends have been identified. The predominant cable aging phenomena are :
- partial discharges in paper cables, resulting from thermal and mechanical constraints,
- water treeing in polymeric cables, resulting from the conjunction of water ingress and insulation imperfection (surface defect or inclusion).

In addition, with the objective of sharing efforts between utilities to increase knowledge and better estimate the remaining lifetime of cables in service, common test procedures have been defined to test in laboratories cable samples removed from the field. These procedures will be proposed to European utilities as a recommended way to perform and share laboratory evaluations. This will allow to share test results by means of a common database.

HEALTH INDEX - The health index methodology is a powerful tool to represent the overall heath of equipment and provide asset managers with a technical point of view (but this is not the only criterion), and rank the health condition of links from 'very good' to 'very bad'. However this methodology can only be used if data is available !

So failure statistics shall be addressed in such a way that they can be optimized for health index considerations. At the same time, the health index methodology must be developed to take into account the data quality : basic data must be collected to help asset managers define AM policies at national and/or regional area, while more detailed data is necessary to support decisions at a local area **(**to guide equipment renewal).

DIAGNOSTICS - The conclusions of a survey have shown that diagnostic techniques of underground links are applied by many utilities as they are considered as potentially useful to determine the link condition. But it is paradoxical to note that diagnostic results are only considered as indicators today as their interpretation is not really obvious. In other words, they do not bring the needed clarity yet enabling to take decisions for lifetime extension of equipment. Most utilities, however, are evaluating some diagnostic methods in order to be active in the development of such methods.

TECHNICAL SPECIFICATIONS - The qualification of new components is also a key aspect for underground assets. Members of the SmartLife initiative have observed that international standards only bring a minimum quality level of equipment. Complementary tests should be included in specifications to reach the quality level required by utilities and thus ensure the reliability of underground links, especially for joints and their installation : for example, a long duration test to check their water-tightness should usefully be specified.

OVERHEAD LINES

Transmission overhead lines

FAILURE ANALYSIS - The surveys done on service experience have shown that utilities set up statistics on the different technologies used and their failures in service. But we can note that the collection of failure statistics and their causes are difficult to obtain due to the high number of involved components : conductors and earth wires, insulators, fittings and accessories, supports and foundations. Moreover statistics of failure rates are difficult to compare due to the great variability of environmental conditions in the different countries.

However, we can retain the following results :
- Environment is the predominant parameter of the majority of failures.

- Conductor assemblies seem responsible of the majority of permanent failures.
- The failure rate of 60-170 kV overhead lines (OHL) is about three times higher than that of 170 kV ones.

MAINTENANCE AND DIAGNOSTIC TECHNIQUES - Even if visual inspection from the ground remains the most common method adopted by TSOs, there is a tendency to shift partially to helicopter inspection and new inspection techniques during time-based inspections : UV camera (detection of partial discharges), IR camera (detection of hot points), LIDAR (Laser measurement of OHL height)…

Distribution overhead lines

DATA COLLECTION - A questionnaire has been set up to collect the following data and information on :
- patrimonial data : distribution of OHL lengths per type of support and age.
- failure data : distribution of failure rates per type of component and age and of failure causes per age.
- diagnostic data : collection of diagnostic techniques used per type of component.

PROGRAMME OF EXCHANGES - A proposal has been set up to exchange on :
- aging and failures : causes and models of aging and remaining lifetime estimation per type of components ; solutions for improvement ; influential factors of OHL failures (age, environment, components).
- inspection, diagnostic, monitoring : practices and techniques used depending on components.
- optimization of CAPEX/OPEX : practices of arbitration between light maintenance, heavy maintenance, burying decision ; technical economical software tools associated to these practices ; criteria, volumes, frequencies for repairing vs. renewal of components ; possible map-based tools for decision making of AM policy (wood, wind, lightning, temperature maps).

TRANSFORMERS

Power transformers

FAILURES - A questionnaire has been set up to collect utilities' experience on the major failure modes of power transformers. The objective is to monitor trends and analyze failures according to the different transformer families, their design and their operational conditions.

AGING MECHANISMS - Long term aging processes important for lifetime estimation have been described according to experts' tells : thermal aging of cellulose, of oil, tank corrosion, defects of on-load tap changers…
In addition, a procedure for post mortem analysis has been defined to estimate the condition of scrapped power transformers so as to get the contamination level of insulation and analyze the polymerization degree of papers.

DATABASES ON POWER TRANSFORMER CONDITION / DIAGNOSTIC TECHNIQUES - The main diagnostic techniques for power transformers have been listed. A database defining the major diagnostic parameters to be collected has been set up so as to facilitate the sharing of information between utilities.

NEW TECHNOLOGIES / TECHNIQUES - Potential innovative solutions have been listed relating to new transformers (tap changers, bushings, synthetic esters, natural esters…) as well as old transformers (maintenance, diagnostic, monitoring…), and also innovative solutions possible for all transformers (sensors, digital protections…).

EXPERTS' TELLS RELATING TO POWER TRANSFORMERS - Failure rates of power transformers are quite low : despite their service duration reaches around thirty years on average, few aging effect is observed on their main components. Their good condition does not call for short term replacement : power transformers can probably be used for another tour of thirty years service (estimation by experts' tells). Thus there is a real opportunity of lifetime extension of power transformers.
However, to keep the control of failure risks, it is necessary to maintain/reinforce their maintenance and monitor their condition through the follow-up and analysis of their failure statistics, together with the use of on-line diagnostic techniques (temperature being a key factor).

Distribution transformers

DATA COLLECTION - A questionnaire has been set up to collect utilities' experience on failures and aging of distribution transformers. The following data are expected :
- Technologies : distribution of transformers per type (pole/cabin), characteristics (power, level of losses, type of oil…) and per age.
- Operational conditions : collection of temperatures (ambient, oil) and load which are key parameters.
- Failures : distribution of failure rates and failure causes.

The objective is to collect the different technologies used with their operational conditions and their failure statistics.

AM IN THE DISTRIBUTION NETWORK

REGULATION / INVESTMENT STRATEGIES – We can note that the System Average Interruption Duration Index (SAIDI) is widely used by utilities and efforts are made to improve it with network automation installing remote-controlled switchgears on the networks.
Pressure by regulators is higher and higher due to the increasing control of performances for continuity of supply through indicators and incentive mechanisms : number of failures and short interruptions (>1s) and focus on areas with special incentive to improve the quality (even for areas with already a good quality level). This leads to a better selection of investments for reliability increase with renewals and improvement of network structure, also

through simulations of failure impact.
There is also evaluation and experiment of new devices such as MV circuit-breakers to avoid short interruptions.
New criteria for investment prioritization are also defined : either not supplied energy (criteria not much widespread still) or calculation of penalties applied by regulator.

QUALITY / METHODOLOGY - A general trend for continual improvement programme is observed. The quality system PASS 55 is widespread for network AM : it is in use in the UK and the Netherlands while in progress in Portugal.

AM TOOLS / METHODS - DSOs need two complementary levels :

- a strategic level to define amounts of CAPEX/OPEX expenditures on the long term,
- a decision level to optimise decisions of expenditures on the short term (next 3 years), with the support of an operational tool (e.g. ATLANTE tool used by ENEL) enabling optimization of CAPEX / OPEX allocation, realization, follow-up and feedback loop.

DATA COLLECTION - This is the key point of asset management ! Recommendations on data to be collected have been made thanks to the interaction between Components and Asset Management groups of SmartLife.
We can note that some utilities are examining the opportunity of mobile tools for an efficient data collection.

AM IN THE TRANSMISSION NETWORK

CURRENT PRACTICES - TSOs have adopted an AM process, including business values, key performance indicators and risk management. In spite of great similarity on a high level there is diversity in the details (e.g. KPI used). Risk management is strongly developing but there is no common practice yet for risk assessment, prioritization and reduction. Maintenance and renewal policies are mostly component oriented, often time- or condition-based, rather than risk-based. There is no common health index / condition approach. There is a lack of actual and accessible asset data and condition and health information. Databases are being developed, but the type and number of indicators are diverse. Capabilities of ICT systems for data and trend analysis are not fully utilized.

IDENTIFICATION OF THE NEEDS - Coping strategies must be set up to face realistic reinvestment waves of equipment on a global scale.
The development of enabling methodologies is proposed to meet future challenges : health and risk indexing techniques, dynamic loading schemes and methods and total cost of ownership.

CONCLUSIONS & PROSPECTS

Management of current aging networks and the evolution towards future “smart grids” call for the optimization of network AM and rely on a solid knowledge of aging mechanisms, a useful characterization of equipment performance and relevant AM processes. This can only be done via widespread collaborative exchanges among utilities and R&D entities. The SmartLife initiative has enabled to develop in 2009-2010 a comprehensive collaborative framework in Europe that has brought the following benefits :

- a shared vision among leading asset managers and experts from both utilities and R&D entities,
- a description of the state of current activities and data available for key European utilities and institutes,
- first collaborations and data exchanges across Europe.

Works initiated in SmartLife must now be continued by taking into account the specificities of the transmission and distribution networks.
At the same time, to optimize efforts of companies, we must benefit from the evolving European context in terms of exchange and working platforms. For this reason, the SmartLife members have proposed to pursue the initiated cooperation by distinguishing activities relating to transmission and distribution networks.

- On the one hand, TSOs participate in an association (ENTSO-E) whose organization is today well structured and active with dedicated working groups. Recommendations on transmission issues made within SmartLife can usefully be dealt within ENTSO-E.
- On the other hand, given that such an equivalent European organization does not exist to exchange on distribution issues, it is proposed to pursue in a dedicated organization so-called SmartLife 2 gathering motivated partners (mainly DSOs-based) for a 2-year duration (2011-2012).

The basic principle of SmartLife 2 is to continue under the form of exchanges and information sharing, which are considered as the best added value by all the partners. Based on this, two annual workshops are suggested on dedicated topics, to deepen and implement the recommendations identified in SmartLife but also to deal with new items, especially those linked to the network evolutions.
The forecast programme of exchanges is as follows :

- Underground links : diagnostic techniques ; technical specifications ; cable sample tests ; data collection, health index.
- Overhead lines : failures, aging ; optimization of CAPEX/OPEX ; inspection, diagnostic, monitoring.
- Power transformers : maintenance, diagnostic, monitoring ; new technologies ; aging, failures, lifetime.
- Distribution transformers : new technologies ; aging, failures, lifetime.
- Asset management of distribution networks : network automation ; impact on networks of distributed generation integration and of Electrical Vehicles ; update about the AM of existing aging networks.