MAINTENANCE MANAGEMENT SYSTEM FOR ELECTRIC INSTALLATIONS IN ENEL DISTRIBUZIONE

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ABSTRACT

The deep changes in maintenance policy of Enel Distribuzione, since the privatization of the company, are illustrated in order to show the way the target of a higher efficacy and efficiency has been achieved, both in HV and MV/LV installations. The attention is focused on the adoption of a condition based maintenance, supported by dedicated informative tools and by the integration of employees to all levels of competence. Results obtained in terms of the parameters fixed by the Italian Authority for Electric Power and Gas (AEEG), demonstrate the validity of the actions taken and encourage to improve the system, by means of a more predictive maintenance strategy.

INTRODUCTION

Enel Distribuzione (ED), the major electricity distribution company in the Italian liberalized market, with 30 mln customers, has been recently reconsidering the entire policy of maintenance of its electric installations.
When a monopolist, ED allowed the development of local maintenance policies, quite different among them and far from a standard reference model.
In the 90's, the privatization of ENEL required a deeper and more central oriented control of all processes.
Thus for maintenance, the comparison and evaluation of the best practices of local Operational Units led to the unification of working methods.
The optimization of the maintenance process has been further improved in 2000, when the market liberalization encouraged to sensibly improve the efficiency and effectiveness of human and financial resources. Moreover, this improvement was stimulated by a "premium and penalty" system for the quality of service, established from the AEEG.
In this way two different periods can be individuated on:

- 1995-1999, when the first criteria and quality of service control parameters were introduced in ED for the optimization of maintenance, versus a decrease of employees;
- 1999-today, when the external environment and the institution of the AEEG, moved ED to a comparison with the best practice of other utilities, increasing the effectiveness in parallel to the efficiency.

The main purpose of this paper is the description of the maintenance management process in ED, starting from the approach and directives chosen by the Company Corporate and then focusing on specific HV and MV/LV installations.

MAINTENANCE MANAGEMENT SYSTEM IN ENEL DISTRIBUZIONE

The major change introduced in recent years, with respect to
the entirely cycle based traditional methods, has been the increasing of "condition based maintenance" strategy (CBM), inspired from the Reliability Centered Maintenance policy (RCM) [1,2], as follows:

- the know-how present in ED set the intervention priority criteria and the consequent actions to be taken according to specific data received from the field (inspections and remote control system);
- the maintenance system has been oriented to a continuously improving approach and by a management structure appropriately provided.

A synthetic survey of interactions among different maintenance interventions is given in the figure below [3]:

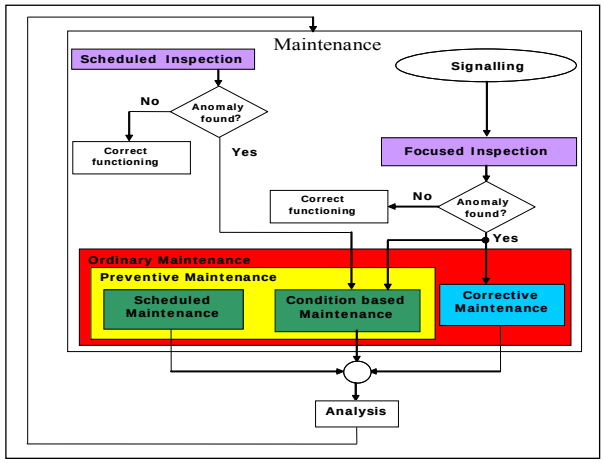

Figure 1: Schematic representation of interactions among different maintenance typologies in Enel Distribuzione

Furthermore the new approach to the maintenance management system carried out the SGQM (quality system of maintenance in use in ED), ISO 9001:2000 certified. In this way maintenance process has been indeed reorganized coherently to the principles P-D-C-A of the standard ISO, where every step was realized as follows:

1. standardization of the activities in terms of timing and proper documentation, like operational instructions and procedures (Plan);
2. diffusion of the maintenance system to all levels through internal channels, focused training and identification of responsibility figures (**D**o);
3. control of accuracy and efficacy of actions taken, by

means of typical indicators and dedicated informative tools (**C**heck);

4. reprocessing of maintenance system for a continuous improvement (**A**ct).

The maintenance system can be then configured as represented in the following diagram:

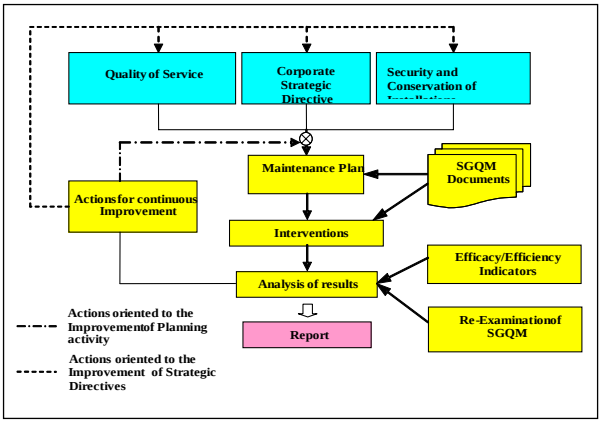

Figure 2: Flowchart of the whole maintenance management system in Enel Distribuzione

Maintenance reprocessing started in HV substations (HV lines are not contemplated as maintenance is performed by an outsourcing contract), where traditionally the maintenance service is more specific and critical, especially because the consequences in case of total or partial loss of energy supply would affect a very high number of customers [2]. This system applied to HV plants, has been extended to MV and is going to be widened to LV installations, as a consequence of the relevant results obtained in the last three years of applications.

The idea of the huge estate involved in this process is given in the following table:

HV Network (132 kV, 150 kV)	19.000 km
MV Network (15 kV, 20 kV)	335.000 km
LV Network	801.000 km
HV/MV Substations	2.000
MV/LV Substations	412.000

Table 1: The estate of Enel Distribuzione

More details of specific applications are given in the following sections.

HV MAINTENANCE

In the past years, the approach of ED to HV/MV substations maintenance remained mainly conservative, based on standard and strictly determined cycles of interventions or inspections [1,2,3]. In this phase the timing was consistently influenced by manufacturers' instructions, which were always set on worst use conditions, but no critical return was assessed to evaluate the efficacy of the maintenance actions taken. Moreover, the described approach was expensive in terms of human resources and materials.

On the other side, the advantage of this strategy was the creation of highly specialized figures, as a consequence of their continuous relationship with manufacturers and for the heavy interventions practiced, like assembling and dismantling most of the HV components.

New Maintenance Strategies

The know-how accumulated during past years, has been enlarged to all levels of responsibility, through procedures and operational instructions, coherently to the ISO 9001:2000 certification, creating a vertical integration of employees.

One of the first tasks was the classification of the activities, on the basis of experience, in two different classes: periodical and condition-based (respectively occupying 60% and 40% of the resources).

The first category is essentially based on:

- controls required by the Italian law (15%);
- visual checking or instrumental inspections (60%);
- scheduled maintenance (25%).

Cyclic maintenance is adopted for components with no possibility of economic replacement, i.e. on-load tap changer (almost every 100.000 manoeuvres), oil circuit breakers (oil replacement every year), open vase batteries (control of water level every 3 months).

The second category takes into account all the consequent actions deriving from inspections and remote control system, both on and off line. CBM has been recognized as essential by one side to face up the reduction of people involved, on the other to focus on equipments critical for the continuity of service [1,2,3]. For instance a HV circuit breaker showing, on respect to specific values, constant circuit breaking time, constant contact resistance and absence of mechanical problems, is more properly managed by condition-based intervention, when characteristic parameters start drifting, in order to concentrate maximum attention in pre-alert situation. This approach would have unlikely reached such an important role without the achievement of new equipments (Petersen grounding system, digital protection devices, etc.) and the evolution of new systems for remote control of primary plants, anyway. Such systems provide a higher number of data concerning the state of components, in particular to GIS breakers and HV/MV transformers. Still, human experience has been crucial to change cyclic intervention into on condition ones, when results demonstrated this choice acceptable [1,3].

The application of CBM required initial threshold values fixed on control parameters (even tough a continuous revision is being applied on the analysis conducted on the updating data store) and a system for storing data related to dynamic behaviour trend of equipment monitored (usually one year time).

Once exceeded the threshold values, the priority of intervention is a function of different factors like the state of network (network redundancy) and the possibility of malfunction turning into a permanent failure. Nevertheless, guidelines for the priority of intervention [3] are given in

the list of standard activities, according to:

- priority 1: controls required by the Italian law (i.e. grounding system);
- priority 2: situations with technical limitations (i.e. GIS or neutral compensation system);
- priority 3: deferred activities, that can't admit drifting over 30% on respect to their cycle.

Reports from inspections and interventions, especially if condition based, are also particularly taken into account for detecting defectiveness on components and alerting, in this way all, the operational units about possible risks associated to similar equipments, if present on their plants.
Operational data, defectiveness and reports related to specific activities are nowadays monitored by a central workforce, in order to analyze maintenance system on the whole and for a reprocessing of timing and management of the standard activities.
Informative systems for handling with this kind of data become crucial in such a various and complex asset like the one owned by ED. This is why ED is aiming at customizing specific tools running automatically data, focusing on more sophisticate analyses and for a predictive maintenance approach [1,3].

MV MAINTENANCE

Up to the end of 90's, maintenance in MV/LV network was mainly based on inspections and on fault interventions, as the customers connection management required most of the resources present in local units.
Nevertheless, general and common criteria for the basic distinction of the activities into scheduled inspections, preventive and corrective maintenance, were already present. The efficacy of maintenance activities and, in a general way, the state of the network, was monitored by the number of interruption every 100 km on network lines per year (λ), too.
Still, the system on the whole wasn't organically structured and sufficiently taken into account. Since then, several progressive steps have been made consequently to the increasing importance assumed by ED estate conservation.

New Maintenance Strategies

The change in maintenance methodology has interested MV installations, while LV network has still remained on corrective maintenance managed.
First of all the attention has been focused on the Maintenance Plan annually prepared by every local unit. These plans provide the list of MV lines, comprehensive of the secondary substations, which have to be submitted to scheduled inspections.
This activity is possible in two different ways:

- operator's inspections
- inspections with helicopters

both of them are not requiring shutdown of the installations, preserving the continuity of service.
Eventually, the important aspect of information sharing, in order to check the efficacy of actions taken in different local units, has been solved by means of a common use of the guidelines and the language for critical situations individuated during the inspections.
Three different levels of malfunctioning [3] have been individuated for every kind of component (or part of it) and plant typology (line or substation), so as not to establish the urgency for restoring the correct state of functionality, as indicated here below:

- Urgent (within a week)
- Middle term (one to three months)
- Long term (within a year)

Also in this case, the activity has been supported by providing operational figures of a practical check-list manual, to be used during the inspection activity and reporting examples of intervention and evaluation criteria for every component.
This ranking is then used to plan periodic maintenance, which is comprehensive of controls requested by the Italian law (i.e. grounding system, etc.).
Other interventions are planned keeping into account:

- indications of component manufacturer (maintenance manuals);
- characteristics of the environment where installations are placed (vegetation, atmospheric agents, ceraunic level, pollution, etc.);
- experiences on similar equipments.

Recently the experimental organization, in a local operational unit, of a pool of workers, expert and qualified in maintenance, is performing good results on the convenience and practicability of conducting corrections contemporarily to inspections.
In order to reach a higher efficacy and efficiency the maintenance system previously described is being integrated with possibilities provided by new technologies, moving in this way toward a CBM.
As a dedicated support, an informative tool has been realized in order to process signals from remote control system and operational data from network monitoring.
On the basis of the bulk of information collected in this way, singular or combined specific inspections can be planned selecting among the ones indicated in the following [1]:

- visual checking;
- thermographic inspections;
- cable diagnostic.

It is important to underline that this informative system is hourly updated by warnings, thus assuming to be semi-on-line, reporting most significant events happened on network system in the last thirty days.
Lines are ranked by number and typology of events happened onto them [1,3], by the number and concentration (high, medium or low) of MV/LV customers served, so as not to make easier the analysis from operational units.
Furthermore these structured data can be used for checking the possibility of malfunctions turning into permanent failures, indicating the best localization and priority of

interventions.
An example of window of this monitoring tool is shown here below:

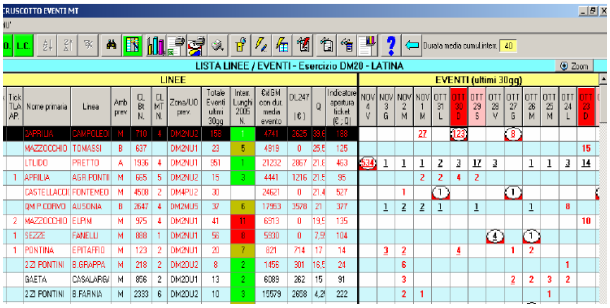

Figure 3: Example of window of the monitoring tool developed by Enel Distribuzione

RESULTS AND FUTURE DEVELOPMENTS

A survey of the main results obtained by the new maintenance policy in ED (comprehensive of the important contribution given by the investments in remote control system) can be given through the following parameters fixed by the AEEG:

1. cumulative duration of unplanned supply interruptions per LV customer;
2. number of unplanned supply interruptions per LV customer.

The clear improvement achieved, about the first and second parameter, is reported in the following figure:

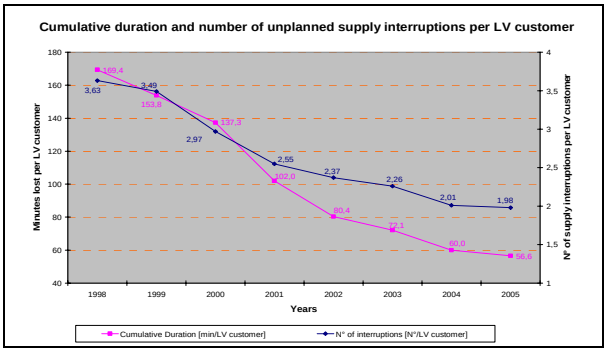

Figure 4: Cumulative duration and number of unplanned supply interruptions per LV customer

A final sight is dedicated to the improvement obtained in terms of efficiency, well represented by the cash cost per LV customer:

Year	2001	2002	2003	2004	2005
€/customer	153	150	137	125	119

Table 2: Cash Cost per LV customer in Enel Distribuzione

Taking into account the encouraging results achieved, ED is firmly convinced of the validity of the approach followed so that new developments are aimed to reach.
Thus, in the next years the attention on HV and MV sectors will be focused on:

- A higher application of condition based interventions through informative tools for the identification of fault causes and critical states of components;
- The optimization of inspections, performing simultaneous interventions, on the basis of results obtained from the maintenance pool of workers;
- The development of efficacy indicators in order to:
  a) allow the classification of more critical lines in reliability terms, through typical reference parameters, helping in this way local units in preparation of annual maintenance plan;
  b) analyze maintenance actions taken in comparison to the planned ones.

Furthermore, ED is taking into account the target of applying the SGQM to LV plants, where a rational maintenance management is crucial in consideration of the estate extension. For this reason a test on LV maintenance is actually in progress in a local unit; a year time will be necessary for the evaluation of results obtained and the potential widening to the entire territory.

CONCLUSIONS

The change of the scenery in which ED is to operate has created the conditions for a gradual and almost complete substitution of preventive maintenance toward a condition based one. The key factors that allowed such a change have been the know-how of personnel developed during the years and the proper extension of the new policy to all levels of competence through internal channels. Guidelines provided by the standard ISO 9001:2000 allowed the start up and the control of the new system but also indicated the way for a rational and organic actuation of the efforts for the continuous improvement. Operational and engineering activities have been supported by informative tools internally developed so as not to process data from the field in order to indicate the most proper interventions to be taken. Results obtained in terms of cash costs reduction and of higher quality of service encourage to continue on this way and to try out the application of predictive maintenance on most important components.

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