QUALITY OF SERVICE TARGET PLANNING AND RISK ANALYSIS FOR EFFECTIVE ASSET MANAGEMENT – THE ENEL DISTRIBUZIONE CASE STUDY

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ABSTRACT

Asset management has become a major challenge for electricity distribution companies. The national regulations are encouraging a better quality of service provision, lowering both the number and duration of interruptions. Moreover the energy market liberalisation and the company's privatisation boost attention towards customer service and costs reduction. Moreover, most Western European distribution grids were built more than 30 years ago, so the need for assets renewal is widespreading. All these factors make effective asset management a difficult job for Distributors.

This paper describes how companies can face the major challenges described above from the viewpoint of asset management. The proposed methodology, implying a transition from traditional asset management to a risk-based asset approach, is thought to be easily implemented and to quickly commit people involved in the process. In this paper the focus is on investments to improve quality of service, and the related method for investment prioritisation in order to optimise capital expenditure. Technical intervention to improve service provision and quality targets are considered as given inputs/parameters. Risk analysis is the key tool to reach the planned quality of service targets, even in a changing scenario with mutable targets. The implementation of the methodology is shown as a case study of one of the major European distribution companies, Enel Distribuzione.

INTRODUCTION

The last 10 years have seen significant changes in the European power sector, which have also involved Distribution System Operators (DSOs). In particular, Italian legislation has led to greater electricity market liberalization, including the privatization of the largest industry operator (Enel), and has established a regulation and control agency, the Authority for Electric Power and Gas (Autorità per l'Energia Elettrica e il Gas - AEEG).

According to the new authority rules in force since January the 1st 2000, the Italian DSOs have been subject to a regulation system of the continuity of electricity supply and distribution tariffs with a Regulatory Period of 4 years, which is sufficiently long and stable. The regulatory framework of continuity of supply provides a set of *indexes* (SAIDI, SAIFI, MAIFI), measurement rules (weighting methods, duration calculation), classification rules (type, cause, origin, etc), geographical classification (High, Medium, Low Concentration Districts), and a progressively challenging *incentive scheme* based on:

- since 2000, SAIDI reduction;
- since 2006, max number of Long Interruptions for MV Customers;
- since 2008, SAIDI , SAIFI , MAIFI reduction;[1]
- since 2009, Very Long Interruptions reduction.

A radical change in the DSOs' previous quality improvement strategy was required.

In this paper we will focus on how Enel has addressed this challenge so far, implementing a risk-based asset management methodology with a view to creating value.

METHODOLOGY : ANALYSIS, IMPLEMENTATION AND MONITORING

Investment history analysis

Enel's investments in the electric power distribution grid were particularly significant in the 60s and 70s as part of the Country's electrification, and in the 80s and 90s as a driver of industrial development. The period that followed saw a downward trend in investments, mostly due to the transformation from governmental body to listed limited company (Fig. 1).

This reduction in capital available for investments coincided in time with the new regulatory framework on continuity of supply.

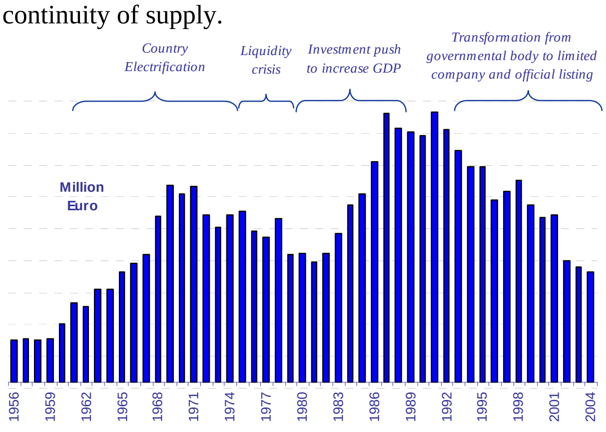

Figure 1 – Investments trend in Enel's electricity grid

Quality of service: impact of the Authority's rules

After the introduction of quality of service regulations, Enel reduced its SAIDI considerably (Figure 2).

According to the incentive scheme set out by AEEG, each district (Enel Distribuzione includes almost 300 districts)

1 It should be noted that in Italy SAIDI (*System Average Interruption Duration Index*) and SAIFI (*System Average Interruption Frequency Index*) are calculated for "long" interruptions (with a duration of more than 3 minutes), while MAIFI (*Momentary Average Interruption Frequency Index*) is calculated for "short" interruptions (with a duration of more than 1 second and less than or equal to 3 minutes).

is assigned target performance levels of the grid which generate premiums or penalties ("*Incentives*") for meeting or failing to meet the set targets. This required Enel to use different criteria in evaluating investments in quality of service improvement, selecting each investment on the basis of maximum profit considerations, in order to generate revenue (the 'premiums') or avoid 'penalties'.

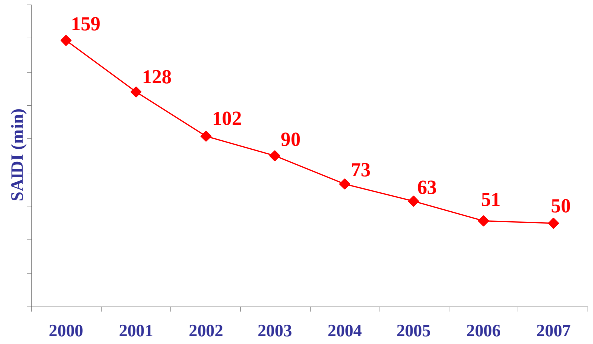

Figure 2 – *Enel's quality of service trend (SAIDI)*[2]

Thanks to this incentive scheme and improvements in grid performance, Enel's premium balance for the 2000 - 2007 period was approximately €876 M. As shown in figure 2, improvements, in absolute terms, were more significant in the first than in the second four-year period (69 min. vs 23 min). The main drivers of this performance were remote control of secondary substations and automation of the medium voltage (MV) grid. Once the benefits from these technological innovations had been obtained, to achieve further grid performance improvements and optimize the use of available resources the company choose to adopt a risk-based asset management methodology.

<u>The risk-based asset management methodology (Atlante Project)</u>

In-depth analyses to assess grid conditions were conducted and appropriate indicators were determined to define the correct "methodology"; specifically, a risk indicator was created to estimate how much each asset (MV line) contributed to the incentives earned for each district.
According to the rules currently in use, the incentive is a function of several parameters, including average duration of long interruptions per LV customer (SAIDI), and the average number of long and short interruptions per LV customer (SAIFI+MAIFI)[3] .
K1 and K2 coefficients are determined for each district, as follows:

- K1= "theoretical" district incentive calculated considering one minute gained per LV customer, compared to the target for the year [€/(min*customer)];
- K2= "theoretical" district incentive calculated considering one interruption gained per LV customer, compared to the target for the year [€/(n. interruption*Customer)].

The "*RISK*" indicator is defined as follows:

Rs_tot = Rs_D + Rs_ N

The same indicator can be calculated on a territory-based (e.g. region or province) or power-based aggregate (e.g. MV line) .
Below is a description of how it is calculated for each low voltage line: "j-nth MV line".

$\boldsymbol{Rs\_D_j}$ represents the "historical risk" related with the j-nth MV line's SAIDI, and is calculated as follows:

$$Rs\_D_j = \sum_i K1_i * SAIDI_{ji} * NC_{ji}$$

where *i*= i-nth district where the j-nth MV line passes through; NC_{ji} = no. of LV customers in the i-nth district served by the j-nth line, and $SAIDI_{ji}$= SAIDI generated by the interruptions that affected LV customers served by the j-nth MV line of the i-nth district.

$\mathbf{Rs\_N_j}$ represents the "Historical Risk" related with the sum of SAIFI and MAIFI of the j-nth MV line, and is calculated as follows:

$$Rs\_N_j = \sum_i K2_i * \left(SAIFI_{ji} + MAIFI_{ji}\right) * NC_{ji}$$

where *i*= i-nth district where the j-nth MV line passes through; NC_{ji} = no. of LV customers in the i-nth district served by the j-nth line, and $SAIFI_{ji}$, $MAIFI_{ji}$ = SAIFI and MAIFI generated by the interruptions that affected LV customers served by the j-nth MV line of the i-nth district.

The indicator (in €), is therefore calculated on the basis of the interruptions which occurred on the j-nth MV line (during the relevant period – one or more years) and of the economic impacts (K1, K2) resulting from the interruptions for each district.
The core of this methodology is to measure, for each MV line, the Rs_tot value in order to identify the worst performing assets and select the actions required to improve each asset's performance. Using this indicator, MV lines can be sorted ("*merit order list*") starting from the one with the highest Rs_tot so as to concentrate investments on the highest risk lines, which are the ones that most contributed to the district's incentive. Therefore, reducing risk for each line ensures the highest economic

2 data calculated according to the rules applicable in the 2nd regulatory period.

3 The latter was introduced by AEEG in 2008.

return, and at the same time helps to reduce the number of interruptions and disconnected customers that cause that risk.
In this way, the allocation of investments in quality of service can be optimized, in line with the direction indicated by the AEEG through its “incentive scheme”.
As regards the optimization of improvement actions, it is possible to analyze, for each line, the weight of each risk element (Rs_N and Rs_D): in order to reduce Rs_N, the actions must be aimed at reducing failure rates and the average number of disconnected customers per interruption, while to reduce Rs_D the actions must be aimed at reducing the average duration of each interruption and the average number of disconnected customers per interruption.
One advantage of the Rs_Tot indicator is that it can be used as the sum of the Rs_Tot of several plants (of different types) and of several years or periods, providing a performance comparison between different assets and broader aggregates for analysis.
It is an objective, easily measurable indicator, and allows *a posteriori* measurements of the effectiveness of the improvement actions.
This indicator is closely linked to the rationale of the AEEG’s “incentive scheme”, and should therefore be revised and adjusted whenever the targets and rules are changed at the end of each regulatory period (4 years).
Obviously this calculation, while simple, takes into account a wide range of factors, since the MV line is comprised of a large number of components subject to failure. Therefore an effective support software tool is required to calculate the indicator rapidly, update it frequently according to new failure events, and show it in aggregate form, so as to provide summary data that can be immediately interpreted by the functions responsible for deciding on appropriate improvement actions.
In effect, asset management requires a large amount of data and accurate analysis in order to make the “best decision”, which is ultimately left to the planner’s responsibility. To make this important activity possible and effective, a tool has been created to support the planner throughout each step in the process.

THE SUPPORT TOOL: ATLANTE

In parallel with defining the methodology, a software application, Atlante, was developed to support and optimize the entire investment planning process. Created as a practical response to the need to plan grid investments, Atlante consolidates and optimizes technical and financial information stored in the different tools already available, supplementing it with new functions and effectively creating a new work methodology. Atlante is a comprehensive and integrated window on the Electric Grid.

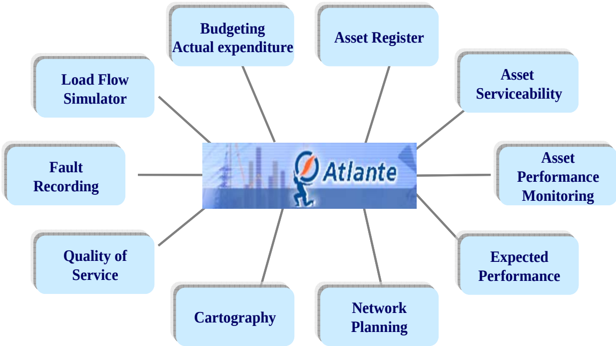

Figure 3 Main functions and information integrated within Atlante

The tool

Atlante helps to act on three key investment planning phases:

- analysis of the electrical and physical state of the grid
- selection and planning of works
- performance monitoring

The analysis phase is made possible and effective through the use of a database, periodically populated with data regarding all the interruptions occurred on the systems (from 2000 to the present).
This huge amount of data is automatically processed by the system and translated into summary reports, which are then used to perform both macroanalyses (at territory level) and microanalyses (detailed analyses of individual systems). This allows the planner to identify with extreme accuracy the types of criticalities affecting the grid and to evaluate the appropriate solution for each one. The tool includes an interactive topography of the existing (operating) network that helps to conduct an accurate analysis of the grid, showing the technical features of the network itself and of the relevant territory. Through Loadflow calculations (automatically run at intervals by the system or performed online directly by the planner) it is also possible to assess the utilization state of MV lines (e.g. following requests to connect to the grid by passive and active customers - producers).
In addition to information on grid state, failure proneness, etc., Atlante also allows analyses of potential criticalities on the MV grid detected during inspections. During periodical inspections on the MV grid, operating personnel may detect criticalities, which can be described and uploaded in a dedicated maintenance application. This software communicates with Atlante, transferring these important necessary information to the planner in order to perform appropriate capex and opex trade-off analyses.
Atlante is therefore an intelligent platform that communicates with, and processes information from, other databases and systems to help planners to make the best decision, eliminating the need for subjective evaluations.
All the grid improvement actions that are decided and planned are designed within the system using cartography

mediums, and then stored (planned/future grid). In other words, the MV network planning tool is a mapping system that shows the existing network and allows to draw the future network on a topographic cartography medium. The planner describes each work indicating the start and end dates, and draws the relevant part of the network on a cartography layer setting it to be shown on the date of completion of the work.

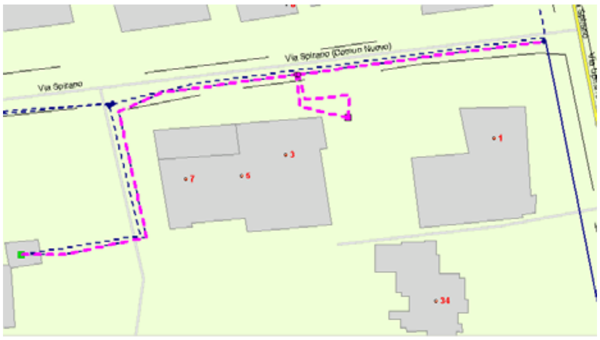

Figure 4: Representation of a planned work

Thus, Atlante enables steady and continuous planning of the future network, allowing planners to have a comprehensive picture of network developments of any nature (customer connections, network enhancements, performance improvements, etc).
Moreover, in order to choose the right work, the planner can compare alternative solutions using the costs versus benefits analysis tool: the cost is the preliminary budget and the benefits are the expected premium or lower penalty related to the network's expected quality performance indicators.
In addition to technical planning, Atlante also provides financial planning functions including:

- Economic panel to define budget
- Monitoring panel to verify actual spending vs. the approved budget

Lastly, a panel to monitor activity progress, the benefits resulting from the investments, and quality of service improvements.

<u>Concrete evidence</u>

Electric grid investment planning is a practical example of application of the *risk-based asset management methodology*: every year the Enel Distribuzione Central Management determines the budget assigned to each territorial unit (top-down approach), but the unit itself is responsible for the correct allocation of investments in order to improve distribution grid performance.
Atlante combines all the capabilities to carry out this activity in a single tool, including network state analysis (e.g. number of failures, location, components, etc.), identifying and selecting actions to ensure reliability, continuity of supply, and electric grid performance improvement. Through the "*merit order list*" of MV lines provided by Atlante, planners can focus their analyses on the lines with the lowest performance levels. These are individually analyzed using all the information available in the system; the actions to be implemented are then planned on this basis, determining the cost of each work. Expense progress and work progress are subsequently monitored, and grid performance improvement is verified after work completion.
A sample investment allocation in a district managed by Enel Distribuzione is presented below together with performance improvement margins. In the chart (Figure 5) the x-axis shows the number of MV lines in a district (in percentage), ordered by decreasing risk level; in correspondence with each MV line, it is possible to intercept the risk curve (risk related to the MV line as a % of the total risk of the area) and the amount of quality improvement investments for the same MV line, expressed as a percentage of the total investments for the area, both shown on the y-axis. This provides evidence on the direct relationship between the cumulative risk percentage of all MV distribution lines and the investments planned on these lines.

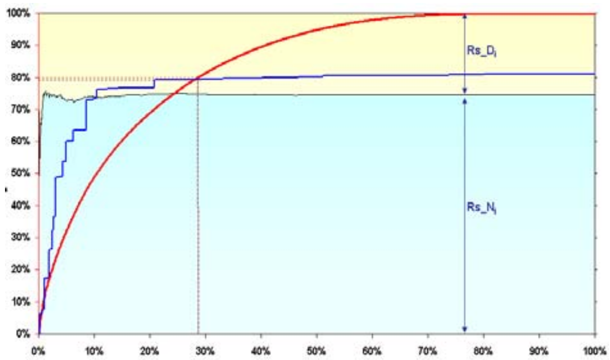

Figure 5 – Sample investment allocation on high-risk lines

In particular, the chart highlights that according to the risk-based asset management methodology, correct planning concentrates the largest part of the investment budget in MV lines with the highest risk levels, i.e. the lines with the lowest electric performance levels, which provide maximum return on investments. In the chart in Figure 5, the red curve represents cumulative risk %, while the blue curve represents the cumulative amount of investments in MV lines of the relevant geographic area. In this example, 80% of the risk (red curve) is concentrated in 28% of the district's MV lines; these lines have the highest risk levels, as the chart sorts the lines on the basis of decreasing risk level. Conversely, if we analyze the investment curve (blue curve), we observe that 79% of quality of service improvement investments in the geographic area are concentrated on the highest risk lines (28% of the total MV lines in the area).
The chart also shows, for each MV line in the district in question, the percentage value of both Rs_D_j (yellow area)

and Rs_N_j (blue area) vs. the total risk of each line. In the district used in this example, the % weight of Rs_N_j is very clearly predominant (approximately 70%) for nearly all MV lines, therefore the planned actions will be aimed at reducing SAIFI and MAIFI, by the reduction of the MV line failure rate and the number of average customers impacted by each failure.
Thus, the methodology helps to measure the correct allocation of assigned resources and to verify action planning effectiveness, and therefore provides an excellent tool in support of the management's decisions.

A winning implementation

In addition to the obvious improvement in quality of service and overall investment reduction, other important results have been achieved: introduction of a systematic analysis of capex vs opex trade-off in the selection of MV line improvement works, and most importantly, optimization of the entire planning process.
The development of an integrated investment planning application like Atlante provides a single support tool to all the people involved in the different steps of the "Investment Planning and Authorization" process.
Specifically, process optimization was achieved through:
a. consistent operating criteria and procedures, thanks to the use of a single tool;
b. easier, guaranteed information transfer, as all the information is stored in the system and therefore available at all times;
c. clarity of all the planned projects, through access to specific modules where future network developments are drawn (strategy sharing);
d. easy monitoring of the technical and financial progress of each individual work, and evidence of possible inefficient planning (deviations between planned and final results, measured on the individual work).
The introduction of a single integrated system has brought a significant change in work methods; this is why one of the key steps for the success of the project was intensive training activities conducted continuously and at grass root level throughout the national territory.

CONCLUSION

This paper describes the methodology adopted by Enel Distribuzione to optimize investments in its Italian distribution grid. The methodology uses a risk-based approach and is supported by a powerful software tool that integrates the main electric grid management systems/data/information. Correct process design and personnel training are equally important for effective implementation.
The case studied in this paper is undoubtedly a success, and has already allowed the efficient use of available financial and human resources, improving continuity of service year after year and earning incentives from AEEG.
The new challenge for the current regulatory period is to continue to improve quality of service, especially by reducing the number of interruptions (SAIFI and MAIFI).
The Authors would like to express special thanks to all team members cooperating on this project.

REFERENCES

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