CONTINUITY OF SUPPLY: THE EXPERIENCE OF ENEL DISTRIBUTUZIONE DURING THE REGULATORY PERIOD 2000-2003

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INTRODUCTION

During the first regulatory period (2000-2003) significant improvements have taken place in districts served by Enel Distribution: the average value of “Customer Minutes Lost per year” was reduced from 154 minutes, in 1999, to 72 minutes in 2003 (1), with an annual volume of capital expenditures in line with the previous years. After a preliminary description of the regulatory framework, the paper focuses on the action plan undertaken by Enel Distribuzione and the result obtained.

CONTINUITY OF SUPPLY REGULATION IN ITALY

Since January the 1st 2000, the Italian distribution operators have been subject to a regulation system of the continuity of electricity supply and distribution tariffs. The new regulatory framework of continuity of supply provides indices, measurement rules, and a bonus/penalty system based on specific targets for each district (about 300) in which the Italian territory is divided.

The aim of the regulation is:

- to eliminate the quality gap between Italy and the European best practices, achieving in most of the 300 districts the "national reference level" 60' for rural areas (low concentration); 45' for semi-urban area (medium concentration); 30' for urban (high concentration);
- to reduce the differences of continuity of supply among the geographical areas of the country (above all between north and south).

The continuity index which is the basis for the bonus/penalty system is “Customer Minutes Lost per year” (CML or SAIDI). The interruptions taken into account for the bonus/penalty system are:

- “long interruption” (which last more than 3 minutes) for which no notice is given in advance to customers involved, excluding Acts of God and Third parties damages;
- interruptions originated both on LV and MV network (HV network and transmission interruptions are not considered);
- to reduce the differences of continuity of supply among the geographical areas of the country (above all between north and south).

The regulation provides for each district a continuous improvement, according to a trend that depends on the starting level of CML (average value of 1998-1999) and the load concentration in the districts (high, medium and low concentration). If the yearly level of CML in a district is higher than the relevant annual target, the utility pays a penalty, otherwise it receives a premium.

An example of the calculation criteria for a medium concentration district is shown in figure 1.

Measurement rules and audit procedures have been also issued by the Italian Regulator (AEEG). Audits are carried out by AEEG on a randomly selected sample of districts. During the inspection a sample of interruptions (about 10%) are examined to determine weather they have been recorded, both automatically and manually, in compliance with specific rules. Particular attention is devoted to verify that:

- All the interruption events are recorded and manual recording is consistent with automatic recording via SCADA system (accuracy);
- The continuity indicator deriving from the sampled interruptions is sufficiently close to the declared indicator for the same interruptions (precision);
- The causes of the interruptions are correctly attributed and documented, especially for the clauses of measurement rule that allow to exclude interruptions from regulation when they are caused by acts of God or by users and third party damages (correctness). In this case in fact the distributor must provide documentation of the cause of interruption.

LEVEL OF SERVICE AT THE END OF 1999

Stable continuity targets and clear rules for their determination have been seen by Enel Distribuzione as an opportunity of establishing transparent relationship with the stakeholders and defining a new short term policy of quality improvements, even if the targets introduced have been considered particularly ambitious.

As a matter of fact at the end of 1999 the average value of CML for whole Enel Distribuzione, calculated as weighted average CML of all the districts managed by Enel Distribuzione (about 280), was 154'(1) while, according to the regulation, the corresponding national reference level was 45’ and the expected yearly trend of improvement, to avoid penalty, was about 9%. Furthermore the quality of service was very different among the 280 districts.

1 The index complies with the criteria recently issued by AEEG.
In order to better represent the status of quality of service delivered in the Regions managed by Enel Distribuzione in 1999, the index CML has been expressed as the product of two other indicators, very useful for selecting the appropriate strategy of quality improvement:

1. **number of interruptions per customer (SAIFI)**

   \[
   \frac{\sum_{i=1}^{n} U_i}{U_{tot}}
   \]

   whereas:
   - \( U_i \) is the number of customers affected by each interruption \((i=1\ldots n)\) in the area considered;
   - \( U_{tot} \) is the total number of customers supplied by the distribution operator in the area at the end of the period

2. **average duration of the single interruption**

   The average duration of the single interruption can be evaluated dividing the CML by the SAIFI.

   \[
   \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} (U_{i,j} \cdot t_{i,j})}{U_{tot}} \times \frac{U_{tot}}{\sum_{i=1}^{n} U_i}
   \]

   whereas:
   - \( m \) is the number of the customer cluster involved in the \( i \)-th interruption for the same duration;
   - \( U_{i,j} \) is the number of customers involved in \( i \)-th \((i=1\ldots n)\) interruption for the same duration of interruption \((j=1\ldots m)\);
   - \( t_{i,j} \) is the duration of the interruption for the group of customers \( U_{i,j} \)
   - \( U_{tot} \) is the total number of customers supplied in the area.

In figure 1 are represented the two indices relevant to the concentration areas (High, Medium, Low concentration) of each Italian Region and the relevant curves corresponding to the national reference levels of CML.

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**Fig. 2 - Number and duration of interruption of Italian Regions in 1999**

The distribution of the value shows how:
- The average number of interruptions was dispersed in wide range of value (from 0.4 to 11.5) and it appeared correlated to the kind of concentration: higher in the low concentration area (eg. rural areas), lower in the high ones (urban areas)
- The average duration of the single interruption appeared more homogeneous around the value of 40', even if in one case it was above 80' minutes.

The main causes of higher average number of interruption resulted:
- **High rate of interruption per km of network**, due to,
  - 7% interruption on low voltage network;
  - 51% break of bare aerial MV conductors;
  - 28% lack of insulation on MV bare aerial conductors (weather conditions, break of insulators, contact with vegetation);
  - 14% lack of insulation on MV underground cables (joints, terminals)
- **High average length of MV lines** (MV network extent on the number of MV circuit breakers) and, as a consequence, high number of customers \( U_i \) affected by each interruption \((i)\).

The duration of a single interruption can be subdivided in three different phases:
- **Advice to the field operators**;
- **Selection of network section affected by fault**;
- **Restoration of fault**.

At the end of 1999 the following values were recorded for each phase (to be regarded as weighted average of the number of customer involved):
- Advice to field operators, 7 minutes;
- Selection, 26 minutes;
- Restoration, 7 minutes;

**STRATEGY OF QUALITY IMPROVEMENT**

Dealing with the new regulation, at the very beginning of 2000, Enel Distribuzione changed radically his previous strategy of quality improvements, based on a long term plan of network replacement, mainly aimed to reduce the number of interruptions.

The new strategy has been based on an integrated approach of technical and organisational interventions.

Among the interventions aimed to reduce the **average number of interruptions** the main projects have been:
- New planning criteria for maintenance interventions on MV network, based on monitoring “weak signals”, such the frequency of interruptions shorter than 3 minutes, rather than a “time base” approach (frequency of inspections per year);
- The adoption of MV network configurations more reliable through the addition of new HV/MV substations in order to reduce the average length of MV lines;
- The refurbishment of MV bare aerial network through a wide replacement of insulators (anti pollution pin insulators, suspension insulators) and conductors;
- The replacement of MV bare conductors with insulated ones:
  - overhead cables in worthy wooded areas, such as parks, or in areas, exposed to sticky snow (or neige
collante)

- The equipping of MV bars in HV/MV substations with Petersen coils.

Started in fall 2001 the wide installation of Petersen coils project could be considered the key stone of the strategy aimed to reduce the number of both short and long interruptions.

With reference to the **average duration of the single interruption**, the remote control of the switchgears in MV/LV substations has resulted to be the key project for achieving a noticeable reduction of this index.

In fig. 3 it is shown the effect of the remote control of MV/LV substations on the restoration time of service, in case of fault on a MV line, in comparison with the traditional approach, only based on field operations (dotted line).

![Fig. 3 – Process of fault selection through remotely controlled MV/LV substations (Percentage of customer supplied)](image)

In order to select the faulty section and to supply the other ones through another way, after the definitive opening of the Circuit breakers in the HV/MV substation, a procedure based on successive dichotomies is applied by the Control Centre (see below). The operations on switches are initially performed by remote control (T0-T1). During this phase, which usually lasts about 5', the majority of customers connected to the MV line affected by fault (about 60%) are supplied. Afterwards the field crews, advised and coordinated by the Control Centre, move towards the line (T1- T2) and start the field operations (T2 – T3), up to the selection of the faulty section. The interval T3-T4 represents the repairing time of the fault section. This phase usually affects few customers.

The main goal of the project was to remotely control 80,000 secondary substations within the year 2004.

The main features of the System are the following:
- motorised on-load switch in MV/LV substations (3-4 for each MV line);
- low cost/high performance Remote Terminal Units;
- telecom modules based on GSM system;
- 29 Control Centers for all the territory.

The organizational issues have played a key role in the action plan undertaken by Enel Distribuzione.

In order to focus the whole organization on the improvement of supply continuity on the basis of specific competencies, a clear separation of responsibility has been put in place between network overlooking and planning decision, from one side, and operational activities, from the other.

To the territorial units named “Esercizio” (29 units at Regional level) it was assigned the responsibility of:
- overlooking MV network through a number of Control Centres (remotely control of switch breakers on MV bars and switchgears in MV/LV substations, advice and coordination of restoration activities in case of fault, etc.);
- analysing reports on quality delivered (weak signals);
- selection, design and planning of the interventions on the MV network of each district, according the guidelines above mentioned.

To the territorial units named “Zona” (129 units) it was assigned the responsibility of:
- managing the operation through the workforce on field (field operators and contractors);
- executing of the action plans issued by the “Esercizio” on MV network;

To 11 HV centres it was assigned the responsibility of construction and operation of HV/MV substations.

Furthermore a bonus system for all the human resources involved in the process (from managers to workers), widely depending on the quality performance and the fulfilment of installation programs, has been put in place.

**RESULTS**

In tab. 1 are resumed the key figures of the strategy for quality improvement.

During the first regulatory period, more traditional interventions, such as the refurbishment of about 44,000 km of MV network (about 3% of yearly replacement), have been integrated, with innovative project like Petersen and Remote control plans, especially from 2001 (Tab.2).

<table>
<thead>
<tr>
<th>Tab. 1</th>
<th>1999</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average length of MV lines (km)</td>
<td>17.0</td>
<td>14.8</td>
</tr>
<tr>
<td>HV/MV substations on service (1)</td>
<td>N</td>
<td>1500</td>
</tr>
<tr>
<td>MV insulated conductors %</td>
<td>33%</td>
<td>39%</td>
</tr>
<tr>
<td>Petersen Coil on service</td>
<td>N</td>
<td>5</td>
</tr>
<tr>
<td>Remotely controlled MV/LV substations</td>
<td>N</td>
<td>2.161</td>
</tr>
</tbody>
</table>

(1) The figures take into account the spin off of the network in some urban areas.

<table>
<thead>
<tr>
<th>Tab. 2</th>
<th>Remotely controlled MV/LV substations</th>
<th>Petersen Coil on service</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>2161</td>
<td>3</td>
</tr>
<tr>
<td>2000</td>
<td>8806</td>
<td>29</td>
</tr>
<tr>
<td>2001</td>
<td>25476</td>
<td>146</td>
</tr>
<tr>
<td>2002</td>
<td>49194</td>
<td>411</td>
</tr>
<tr>
<td>2003</td>
<td>66242</td>
<td>871</td>
</tr>
</tbody>
</table>

The figure 4 shows the yearly quality improvement of CLM. During the year 2000 the action plans above described were only in part put in place, mainly through maintenance crash program which reduced the number of interruptions (Fig. 4)
From the years 2001 the remote control project got the steady state, with a yearly rate of installation of more than 20,000 Remote Terminal Units. The positive effect of this project on the duration of single the single interruption is noticeable (Fig. 5).

Capital expenditures
The four years capital expenditures related to the quality of service during the first regulatory period were about 2.4 billion € (not included the capex load related, eg new connections). In order to optimize this considerable amount of capital expenditures a procedure of investment evaluation has been introduced. The procedure takes into account the remuneration of invested capital through the tariff and the additional revenues (or cost avoided) deriving from the premium /penalty system, strictly related to the reduction of CML.

The efficient allocation of financial resources allowed Enel Distribuzione to partially finance the capital expenditures with the premium gained during the first regulatory period (about 350 million € as whole). As the effect of the single project above mentioned on CML can not be easily separated from the others ones, the effectiveness of the strategy of quality improvement has been evaluated through an index that considers the overall capex per customer in a given area and the relevant improvement of CML.

The index is expressed by an average cost per minute:

$$I = \frac{\Delta Q \cdot N_c}{\Delta \text{CML}} \text{[€/min]}$$

whereas:
- $\Delta Q$ is the reduction of CML (minutes) from the year 1999 to 2003;
- $N_c$ is the number of customer in the concentration areas of each Italian region and
- $I$ is the amount of the four year investment for quality of service in that area.
The figures show that the marginal cost of quality improvement is higher in the areas with lower CML starting level, except in rural areas (fig. 9), where the low number of customer (Nc) partially offsets the reduction of CML (ΔQ).

CONCLUSIONS
ENEL Distribuzione has planned important investments to improve the quality of service according to decisions made by AEEG. Results coming from the last four year have been even better than the expectancies, allowing Enel Distribuzione to achieve a quality of service in line with the European best practices, with the volume of investment in line with the previous years. That confirm the correctness of the strategy undertaken, offering an important well proved experience to replicate wherever it is necessary.

REFERENCES