IMPROVEMENT IN THE CONTINUITY OF SUPPLY DUE TO A LARGE INTRODUCTION OF PETERSEN COILS IN HV/MV SUBSTATIONS

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INTRODUCTION

The ENEL DISTRIBUZIONE planned activities are in progress according to “Petersen” and “Automation” projects and the results are compliant with the expectancies as far as continuity of supply improvements are concerned. In the meanwhile, new functions and upgrades have been introduced in the System in order to improve performances to overcome critical points, and to answer the arising new needs.

In fact, at the beginning of 2004, Italian regulator (Authority) made some changes in the rules regarding the Continuity of Supply. These new prescriptions, that are being applied to the period 2004-2007, have induced some deviations in the stated course of automation project and in the criteria for the connection of MV customers to the network.

PETERSEN PROJECT

The ENEL MV Network departs from the HV/MV substations (Primary Subs.). The HV level is 132/150kV and the MV is 10/15/20 kV. So far Enel Distribuzione used to operate the neutral point of MV networks isolated from earth but with the “Petersen” project a new system is being introduced.

The neutral point is connected to earth through an impedance (Petersen coil + resistor), usually connected to the neutral pole of the HV/MV transformer in the Primary substations. For each MV bar it is possible to switch from the “Compensated” configuration to “Isolated” one and vice-versa [2], [3].

After the positive results coming from the first experimentation phase (2000-2001), ENEL started a plan to extend the new grounding system to all its substations.

AUTOMATION PROJECT

The Petersen project combined with the existing remote control system of the main secondary substations (MV/LV subs) along each MV line, let introduce another big project called “Automation”. This is a system capable to perform automatically the faulty branch detection, its isolation and the supply restoration on the healthy branches located upstream the faulty one.

The relation with remote control of secondary substation comes from the fact that the process is based on automatons located in the Remote Terminal Units (RTUs) of the MV/LV substations. As a matter of fact these techniques were already adopted in the past, but, for not being supported by telecontrol, they often presented malfunctions or side effects that could not be quickly detected by the operators.

In case of perturbations of the electric system involving large areas with a high number of outages per time unit, automation allows supply restoration of the healthy main branches of the network without any delay due to the operator service times. Since the perturbation cited above can be frequent enough during the year, the advantage of automation should be relevant.

From another hand, the new neutral grounding system, thanks to the low phase to ground current values, makes possible a new technique not applicable before: an earth fault is isolated without the tripping of the circuit breaker at the MV line departure.

FIGURES OF THE PETERSEN PROJECT

The installation activity is in progress according to the trend shown in the following diagram.

About 25% of the MV bus bars have been already equipped, therefore the number of the installations and the time of operation are now sufficient to determine a reliable evaluation of the benefits, the critical points and the possible improvements.
Evaluation of the results

Principles adopted in the analysis are the following:
- each bar is compared with itself in the same period of the previous year;
- to remove the effects of other sources of improvement (whether conditions, telecontrol, etc) from recorded data, improvements of service quality of the traditional substations in the same area and in the same period have been disregarded.

The net reduction of the number of interruptions only due to Petersen coil can be found in the following table. Data are referred to the period 2001-2003 but the most reliable percentages are in the third row (128 coils – 3010 month*bar equivalent to an average value of 24 month/bar).

The introduction of the new grounding system

<table>
<thead>
<tr>
<th>Interrupt. type</th>
<th>Transient (t ≤ 1&quot;)</th>
<th>Short (1&quot; &lt; t ≤ 3&quot;)</th>
<th>Long (t &gt; 3&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period/bars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001, 77 coils, 431 month*bar</td>
<td>-48%</td>
<td>-46%</td>
<td>-36%</td>
</tr>
<tr>
<td>2002, 163 coils, 1614 month*bar</td>
<td>-55%</td>
<td>-37%</td>
<td>-22%</td>
</tr>
<tr>
<td>2003, 128 coils, 3010 month*bar</td>
<td>-51%</td>
<td>-38%</td>
<td>-26%</td>
</tr>
</tbody>
</table>

Mobile vs fixed coils

Of course tunable coils give better performances then fixed ones and the comparison brought the following percentage of improvement.

<p>| Reduction in the number of interruptions due to the tunable coil over the fixed |
|-------------------------------|-----------------|-----------------|---------------|</p>
<table>
<thead>
<tr>
<th>Interrupt. type</th>
<th>Transient</th>
<th>Short</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003, 128 coils, 3010 month*bar</td>
<td>-26%</td>
<td>-22%</td>
<td>-10%</td>
</tr>
</tbody>
</table>

With reference to fixed coils, apart from the performances, this system is doubtless more critical then the other. A periodic check is needed to verify the tuning status of the coil in order to improve the fault clearing capacity and to avoid problems with the earthing systems.

Improvements and advanced features

Thanks to the operation experience and the collaborative exchange of information between ENEL and manufacturers some improvements and advanced functions have been introduced.

Multifrequency current injection. So far in tunable systems a current injection has been adopted to improve the tuning function in networks with low values of zero-sequence Voltage (Vo). In the newest system this function is performed by means of several injections adopting frequencies respectively upper and lower the nominal value (50Hz). This feature improves the precision of the tuning function because 50Hz disturbances are avoided and both, network and transformer parameters, are better calculated.

Weak signals from the network. A possible side effect of massive Petersen coil installation can be the progressive network degradation without any warning towards the network management. Of course this effect is due to the fault clearing capacity of the coil that hides possible insulation defects produced along the network life. Therefore the detection of the “Weak signals” of degradation coming from the network is mandatory to address preventive maintenance interventions. The monitoring systems build up by ENEL can be divided in 3 main basic functions:
- fault clearing activity of Petersen coil is monitored continuously by a special panel installed in Primary substations and connected to the RTU: each fault cleared (or not cleared) by the coil produces a special event sent to the control center with the code of the MV line affected by the fault;
- the impedance between each MV line and the ground is measured periodically through a Software function embedded in “Neutral analyzer” installed in primary substations. If the value of this impedance falls down slowly under a threshold value, an alarm is sent to the Control center (the code of the MV line responsible for the loss of insulation is also transmitted);
- the interventions of fault detectors installed along the MV lines even if without any trip of the circuit breaker are recorded by the RTUs in secondary substations and transmitted to the centre periodically; this information is more precise that the others because the fault location is better localized (the fault is localized downstream the last of the fault detectors simultaneously activated).

Thanks to this information and statistic a back office activity can easily address the necessary maintenance interventions.

EXPERIMENTATION OF THE ENEL MV NETWORK AUTOMATION

The experimentation of “MV automation system” started with the activation of two different technique called respectively “FRG” and “FNC” on several MV lines all over the territory [2].

It is worthwhile to remember that:
- FNC technique consists of automatic selection of single phase faulty branch by means of switches and fault detectors along the MV line (without opening the circuit breaker at the line departure);
- FRG allows the automatic selection of faulty branch by means of reclosing cycle of MV line breaker and fault detectors along the line; this method is adopted also in the FNC technique in case of short circuits.

The system under test allows the automatic selection of the MV feeder faulty branch as well as the automatic supply of the healthy branches upstream the faulty one.

The scope of the experimentation was to check the percentage of success of the adopted techniques, to find malfunctions and weak points.
This monitoring took place in the period February 2002 – December 2003 and revealed:

- a percentage of positive conclusions of 93.6%;
- an average improvement in the selection and in the re-supply times of about 9.3 minutes with respect to simple dichotomies made by means of remote commands (pure telecontrol);
- a very good coordination between the sensibilities of the earth protection at the MV line departure and fault detectors (called RG-DAT) devices installed along the line [1], [2], [3].


Italian Regulator established new rules for the new monitoring period running from the year 2004 to the year 2007. In particular, it is important to emphasize the following points:

- further improvements are requested as far as cumulative duration of long interruptions (>3') are concerned [\(\sum \text{inter.} \times \text{duration of the interruption}\)];
- in order to create base statistics for the next regulatory period, the short interruptions have to be monitored (only counted in the current period);
- individual regulation (starting from the year 2006) has been introduced for MV customers with a subscribed power exceeding 50KW; this possibility means penalties proportional to the subscribed power if the number of the long interruptions exceed a threshold level.

To face this new challenge, in addition to the Petersen application plan, other actions have been undertaken:

- technical changes have been made in the automation procedures and application criteria for a further reduction of cumulative duration of interruptions;
- an application plan has been started to apply automation on larger scale;
- new criteria have been established for the connection of MV customers to the ENEL Distribution Networks.

AUTOMATION APPLICATION: CRITERIA AND PLANS

Reduction of reclosing time

The automation technique called FRG evolves according to the time intervals set for the Reclosing cycle of the MV circuit-breaker at the line departure. The goal was to select the faulty branch and to re-supply the healthy branches located upstream the faulty one in a time interval lower than 3 minutes (short interruption).

The performance can be reached reducing the time TN (see the picture below) from 120s to 70s.

This reduction could be applied immediately thanks to the programmable capacity of the implied devices, the only parameter to be verified carefully is the working cycle of the MV breakers (O-0.4-CO-30-CO-70-CO-70-CO).

Through a campaign of test all the models capable to withstand the new cycle have been selected.

As a matter of fact, all the new models standardized by ENEL are compliant as well as the majority of the older ones.

New automatic sequence in the FRG technique applied to a Neutral compensated network in case of a heart fault on a overhead line.
Automation application directives

The first phase of the fault management (faulty branch-isolation and the healthy-branches re-supply) is fundamental in the reduction of the “Cumulative duration of interruption”. In fact, in this phase most of the supplied customers are involved in the outage; afterwards the duration of the activities has a lower impact on this index due to the small number of customers without supply. For this reason the FNC technique, that:
- in case of an earth fault performs the isolation of the faulty branch without any tripping of the MV breaker,
- in case of short circuit performs the isolation of the faulty branch with a short interruption on the client located upstream the faulty one;
became the preferential technique to be applied wherever possible.

Where the FRG technique is applied, the 70s cycle must be adopted. In this case, whatever is the fault, the isolation of the faulty branch is performed with a short interruption for the customers located upstream the faulty one.

To find the priority of the MV lines to be automatized for the best results, the following parameter must be taken into account:
- a MV line index computed as follows: (foreseen number of interruptions) x (number of clients);
- subscribed power of the MV customer supplied by the line;
- time to reach the secondary substations along the line (logistic times).

Application plan

The application plan is shown in the next figures. By the year 2007 the gain connected to this application should be 6min of the mean value of the “Cumulative duration of interruptions”.

Requirements for the connection of customers to MV networks

Continuity of supply is affected by faults occurring in DNO networks as well as in customer premises. With reference to MV networks, “responsible” of around 90% of the continuity of supply (minutes lost per customer), Enel Distribuzione experienced that 40% of the faults that bring to long (>3”) interruptions are “not- localized”: i.e. slow reclosure attempts (say after 5-10”) of the MV circuit breaker are successful. It is very likely that a large part of “not localized” faults are those occurring in customer premises. In the past, Enel Distribuzione used to require, for the connection of small MV customers (one MV/LV transformer up to 400kVA, short MV cable, no overhead “private” MV lines) only a switch with a fuse protection.
Fuses ensure a “selective” protection only for short circuits that are around 40% of MV faults: in case of phase to ground fault in the customer premises, the fault is cleared by the circuit breaker installed at the beginning of the MV feeder. This affects the continuity of supply of all the customers connected to that feeder.

This is not acceptable in case of regulation of the number of interruptions for MV customers that the Italian Authority is introducing. The new “Regulation” also leaves out the possibility to take out from the calculation of continuity of supply indexes the faults due to “Third parties”.

For this reason Enel Distribuzione was forced to update the requirements for the connection of customers to its MV networks.

To ensure the selectivity between Enel and customer protection systems for any type of fault, the following is required for any “new” MV customer:

- a circuit breaker equipped with a protection against short circuit and phase to ground faults;
- limited number and size of MV/LV transformers.

For the correct behaviour of the overall protection system, requirements for CT’s and VT’s are also prescribed.

With reference to the “old” customers, Enel Distribuzione has been allowed by Authority only to impose the updating of the 67N relay, if installed, in order to make it suitable for compensated networks.

All the old small MV customers (around 50% of the total number), even if allowed to be connected to Enel Distribuzione network by means of a fuse protected switch, participate to the above mentioned regulation. This will cause serious problems to Enel Distribuzione in ensuring the requested maximum number of interruptions for all MV customers.

CONCLUSIONS

The planned investments to improve the continuity of supply according to the new needs coming from the Italian Authority rules, should assure 10 min of reduction in the average value of “Cumulative duration of interruption” (Adding the gain due to the “Petersen project”, ant that due to “MV Automation”). Results obtained in the last years are compliant with the expectancies, so the outlooks for the end of the program are promising.

The Regulation of the MV customers’ continuity of supply will be a challenge the next years.

REFERENCES


4] Sergio Rogai - “Le scelte dell’ENEL Distribuzione per il telecontrollo e l’automazione della rete”, ANIE’s Meeting, Cagliari, September 1999