REDUCTION OF SUPPLY INTERRUPTIONS DURATION BY MEANS OF LOW VOLTAGE NETWORK REMOTE CONTROL: FIRST RESULTS OF ENEL DISTRIBUZIONE EXPERIMENTATION

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ABSTRACT
In agreement with the Italian Authority for Electrical Energy and Gas (AEEG) directives Enel Distribuzione is oriented to a fully improvement of power quality provided to the customers.

For this reason, remember the excellent results in terms of the reduction duration of customers supply interruptions consequent to the Medium Voltage network remote control employment, Enel Distribuzione has been implemented a Low Voltage network remote control.

This new and innovative system consent to reduce the duration of customers supply interruptions and is realized by means of low voltage motor driven circuit breakers. After this two years of experimentation the advantages due to a spread employment of this technology have been evaluated and analyzed in terms of the reduced duration of supply interruptions and of the number of workmen interventions.

TECHNICAL CONTEXT
In figure 1 the layout of a typical Enel MV/LV substation is represented.

![Figure 1- Layout of a generic MV/LV substation.](image)

Generally an Enel MV/LV substation layout is characterized by incoming-outgoing scheme. The MV section could be realized with three different technical solutions: RMU, switchboard with SF6 insulated switch and disconnecter and air insulated switchboard. Downstream the MV section there is an MV/LV transformer that feeds an LV switchboard with four LV lines each protected by an LV circuit breaker. The remote control section is realized by means of a GSM Peripheral Unit (UP) equipped with a 24 V battery for the switchgears motor drives feeding.

Low Voltage network remote control designed by Enel Distribuzione is realized by means of low voltage motor driven circuit breakers. The characteristics of these circuit breakers are defined in a dedicate Enel Distribuzione technical specification.

These components have been designed by Enel Distribuzione to be used in Enel standardized MV/LV substations with Enel standardized Low Voltage assemblies and with the remote control unit (UP) already used for Medium Voltage network remote control: no additional devices or operations besides the one for installation of traditional circuit breakers are required.

The remote control system and the motor driven circuit breakers are designed to send an immediate signal via GSM to the Enel Network Operating Centre (COR) in case of circuit breaking and to receive opening and closing commands by COR’s staff. With this system, in case of a transitory fault, the supply restart can be extremely fast and workmen intervention in substation is unnecessary, substantially reducing operating costs.

The motor drive is designed to ensure that the duration of motor driven operations (for both making and breaking
Remote operations are executed by means of the UP with a command that is held on for 300 ms. The circuit breaker is equipped with a three position manual selector: “remote controlled”, “manual” and “locked”. It is not possible to execute remote operations with the selector in “manual” and “locked” position (for safety reasons this condition must be realized by means of the motor circuit breaking and of a mechanical block). The “locked” position is available only with the circuit breaker in the open position. For safety reasons the “remote controlled” position allows the manual trip of the circuit breaker.

The circuit breaker is designed following the principle that the trip position must point out that a fault occurred; while open and close position are normal operating conditions. For this reason, when the circuit breaker is in trip position (after a fault) it must not turn automatically to open position but it must remain in trip position until a closing command is given. When this command is given, the circuit breaker turns to open position (to recharge the springs) and then immediately closes. The remote controlled closing operation has to be possible also when the circuit breaker is in the open position. When the circuit breaker is in the close position and an opening command is given, the circuit breaker must turn to the open position (not trip).

If the remote control system fails, the possibility to operate the Low Voltage network must be ensured. For this reason the circuit breaker must have three buttons for manual operations (closing, opening and trip). An alternative the opening operation can be achieved with a spring charging lever.

For security reasons the circuit breaker must be equipped with an antipumping device that prevents the closing operations successive to the first one in case of microswitch pasting.

For safety reasons, the lever of the traditional circuit breaker is not accessible when the motor drive apparatus is installed. In table of figure 3 the main characteristics of the motor drive are indicated.

<table>
<thead>
<tr>
<th>Main Characteristics of the Motor Drive:</th>
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<tbody>
<tr>
<td>- motor drive voltage</td>
<td>24 Vdc ±20%</td>
</tr>
<tr>
<td>- maximum allowable value of current (excluding the peak)</td>
<td>13 A</td>
</tr>
<tr>
<td>- maximum operation duration</td>
<td>5 s</td>
</tr>
<tr>
<td>- degree of protection</td>
<td>IP4X</td>
</tr>
<tr>
<td>- other motor characteristics</td>
<td>CEI EN 60034</td>
</tr>
<tr>
<td>- minimum operating temperature</td>
<td>-5°C</td>
</tr>
<tr>
<td>- maximum operating temperature (with average value in 24 h less than 35°C)</td>
<td>+40°C</td>
</tr>
<tr>
<td>- storage temperature</td>
<td>-25 ÷ +70°C</td>
</tr>
<tr>
<td>- humidity (without condensate and ice)</td>
<td>≤ 95%</td>
</tr>
</tbody>
</table>

Figure 3 – Main Characteristics of the motor drive

In order to save battery energy, in stand-by condition no current must flow in the motor drive circuit. The circuit breaker is equipped with three distinct auxiliary microswitches in order to communicate its position to the UP: one microswitch is used for the closing position signal, the second is used for the opening position signal and the last one for the trip position signal. The UP provides power supply to the motor drive and to the auxiliary circuits and acts as a transceiver for remote control commands and feedback signals to and from the circuit breakers.

The circuit breaker is equipped with a 4x2+9x1 mm² multipolar cable for the connection between the circuit breaker and the UP. The cable is composed by 13 conductors: 11 conductors are related to the motor drive feeding and to the command signals while the last two conductors are related to the trip signal. The Low Voltage network remote operations are made by means of the same system already used for the Medium Voltage network remote control, called STM.

In order to avoid confusion between the MV and the LV sections, the LV section is configured as a new substation busbar linked with the first one by means of a fictitious link (see figure 4).
In STM, each circuit breaker is identified by a unique reference number and a channel is configured to receive, in case of protection intervention, the trip signal sent by the circuit breaker. The COR’s staff can remotely control the circuit breaker simply acting on its correlated graphic symbol. COR’s staff can also inhibit the STM remote operations of circuit breakers. This command must be used during live works on the related low voltage lines. In this way a closing operation after a trip is prevented.

STM system is able to record faults data and in particular the duration of interruptions (start and end).

SUPPLY INTERRUPTIONS DATA

The most important parameter set by the Italian Authority for Electrical Energy and Gas (AEEG), to evaluate utilities performance, is the Cumulative Duration of long lasting supply interruptions per customer (an interruption is classified as long lasting when it lasts more than 3 minutes). This “service indicator”, includes the interruptions originated in MV and LV networks and it’s measured in minutes.

The graph in figure 5 shows the Cumulative Duration due to LV and MV interruptions and the Cumulative Duration relatively to the LV interruptions, for the years 2005, 2006 and 2007.

Concerning to Enel Distribuzione results, in the last operation year (2007), the LV interruptions have a Cumulative Duration of 16.5 minutes, which is about 30% of the entire Quality indication.

From the point of view of the “cause” there are three kinds of interruptions:

a) Planned interruptions (defined “P”);

b) Accidental interruptions with localized fault (defined “C”);

c) Accidental interruptions without localization of the fault (defined “A”);

In the following figure 6 the incidence of number of events for the three different kind of interruptions is shown:
We focus our attention on the accidental interruptions without localization of the fault. Basically, with this kind of interruptions, we have a line out of service without a concrete and permanent fault, it means that a manually manoeuvre is necessary in order to re-supply the line.

This kind of interruptions lead to two negative effects: the increasing of cumulative duration of long lasting supply interruptions per customer with a consequent negative effect to the AEEG premium/penalty system (about 3.600 k€/minute lost) and a loss in terms of workmen working hours spent just for the circuit making operations.

The average loss of workmen working hours for each interruption is estimated to be of about 3 hours. About 70% of these interruptions occurs during normal working time (with a loss of about 100 €/hour) while the remaining 30% occurs outside normal working hours (with a loss of about 200 €/hour). The economic impact of this kind of interruptions is considerable especially in rural and metropolitan areas where warning and logistics time can be very high.

The duration of LV interruptions with no fault detection can be strongly reduced by means of a Low Voltage network remote control system.

**EXPERIMENTATION RESULTS**

During the years 2007-2008, 1000 remote controlled circuit breakers produced by two Enel qualified manufacturers have been installed for this experimentation on the entire Italian national territory.

The following two criteria have been applied for choose the distribution substations where install the Low Voltage motor driven circuit breakers: high concentration (this parameter identify the Low voltage substations localized in metropolitan area with a lot of customers supplied), and high performance (this parameter identify the Low voltage substations localized in rural area with a low number of customers supplied, but an high difficulty in terms of workmen intervention).

After about one year of experimentation, the advantages due to an extended application of this technology are encouraging both in terms of the decreasing of cumulative duration of long lasting supply interruptions per customer (with a consequent positive effect on the AEEG premium/penalty system - 3,600 k€/minute lost) and a reduction of loss in terms of workmen working hours spent just for the circuit making operations.

As for example for Latina distribution area (DTR LAM-Lazio, Abruzzo and Molise territorial division), that is an High concentration area (with reference to the number of clients supply by the Enel Distribuzione network) the cumulative Duration of long lasting LV supply interruptions per customer relative to the years 2006 and 2007 together was 5.64 minutes. After the installation of the LV remote controlled the reduction of the cumulative Duration of long lasting LV supply interruptions for the year 2008 is 2.54 minutes. It means an obtained reduction of the 45% for the total number of the cumulative duration of LV interruptions.

![Figure 7 – Example of LV remote controlled circuit breakers installation into a secondary substation in Latina.](image)

Relative to high performance criteria: that is low voltage substations localized in rural area with a low number of customers supplied but an high difficulty in terms of workmen intervention, 4 MV/LV substations localized into the Island “La Maddalena” (part of Sardegna territorial division) has been choose. These substations supply a low number of clients: 274, but by means of LV circuit breaker remote controlled the evident problems of workmen’s availability on the field has been overcome making the re-supply of the energy faster and less expensive in terms of average workmen working hours.