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

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ABSTRACT

The full opening of most of the European electricity market has led to a growth in research on the improvement of power quality provided to customers.
Enel Distribuzione has been employing Medium Voltage network remote control apparatus for several years, obtaining excellent results in terms of the reduced duration of customers supply interruptions.
Analyzing the network operation data, it is possible to notice that the contribution of the Low Voltage network to the total customer supply interruptions duration is constantly growing especially in rural and in metropolitan areas reaching values comparable to Medium Voltage network interruptions duration.
For this reason it could be profitable to extend the remote control technology to the Low Voltage network.

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). For this reason it is important to reduce the supply interruptions duration to the lowest possible value.
The data used by AEEG to evaluate premium and penalty that must be applied to the utilities is obtained considering the duration of interruptions excluding exceptional events and faults not caused by the utility itself.
In table 1 some of the last three years main data of the cumulative duration of long lasting supply interruptions per customer are indicated.

	Cumulative duration of long lasting supply interruptions per customer (minutes)		
	Year 2004	Year 2005	Year 2006
Enel Distribuzione total value (MV and LV network) excluding exceptional events and faults not caused by Enel	60,05	62,58	(*)
Enel Distribuzione total value (MV and LV network)	88,77	78,58	(*)

(*) These data will be published within the end of April 2007

Table 1- Cumulative duration data

In table 2 the last three years main data of the Low Voltage network cumulative duration of long lasting supply interruptions per customer are indicated.

	Cumulative duration of long lasting supply interruptions per customer (minutes)		
	Year 2004	Year 2005	Year 2006 (*)
Enel Distribuzione total value (LV network)	17,02	17,03	15,33
Enel Distribuzione total value (LV network) excluding exceptional events and faults not caused by Enel and considering only the interruptions with no fault detection	5,32	6,13	5,11

(*) Provisional data

Table 2 – Low Voltage network cumulative duration data

The data indicated in the last line of table 2 are referred to the cases in which there is no detection of any fault when a supply interruption occurs. In these cases a circuit making operation by a workman is sufficient to restore the supply. 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.
In table 3 the number of Low Voltage network interruptions with no fault detection occurred in the last three years is indicated.

Number of LV network interruptions considering only the interruptions with no fault detection		
Year 2004	Year 2005	Year 2006 (*)
68.335	77.151	70.534

(*) Provisional data

Table 3 – Number of Low Voltage network interruptions with no fault detection

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.

TECHNICAL CONTEXT

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

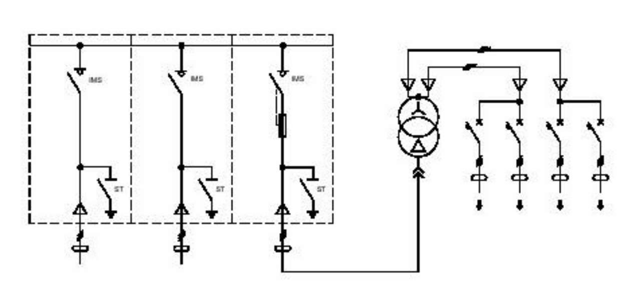

Figure 1- Layout of a generic MV/LV substation.

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 SF_6 insulated switch and disconnector 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 new Enel Distribuzione technical specification.
These new 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.

MOTOR DRIVEN CIRCUIT BREAKER CHARACTERISTICS AND SYSTEM CONFIGURATION

Enel remote controlled circuit breakers are motor driven circuit breakers directly connected to a remote control unit (UP) already installed in secondary substations.
The motor drive is mounted on a traditional 250 A four-pole circuit breaker with thermal and magnetic releases and three available positions of the main contacts (open, trip, close). This circuit breaker must be suitable for isolation, molded case type with organic material enclosure without accessible metallic parts and maintenance free. The main characteristics of Enel traditional circuit breakers used for the LV network remote control are reported in table 4.

Traditional CB's Main Characteristics:	
- Rated voltage	400 V
- Rated insulation voltage	690 V
- Rated impulse withstand voltage	8 kV
- Rated uninterrupted current at 40 °C	250 A
- Rated service short-circuit breaking capacity at Ue 400 Vac	16 kA

Table 4 – Main Characteristics of traditional CB

The motor drive is designed to ensure that the duration of motor driven operations (for both making and breaking operations) are shorter than 5 seconds.
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 is designed to have three buttons for

manual operations (closing, opening and trip). As 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 5 the main characteristics of the motor drive are indicated.

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

Table 5 – 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 mm^2 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 fig. 2).

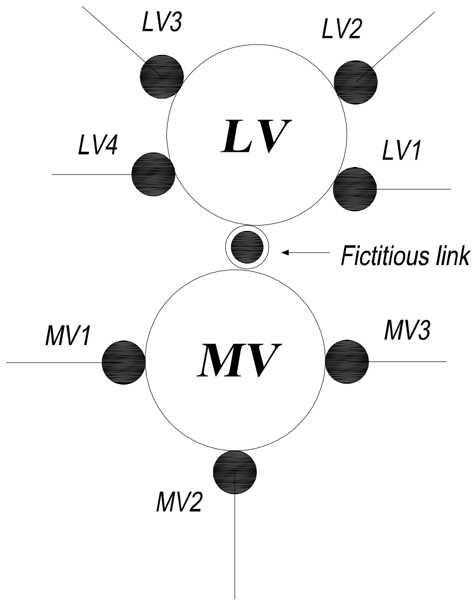

Figure 2 – STM substation representation

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).

CONCLUSIONS

The first four pilot circuit breakers produced by two different manufacturers have already been successfully installed in Lametia Terme (Calabria) and in Ginostra (Stromboli Island – Sicilia).
The installation of about 1000 remote controlled circuit breakers is in progress for an experimentation that will involve the entire Italian national territory.
After about one year of experimentation, the advantages due to an extended application of this technology will be evaluated in terms of the reduced duration of supply interruptions and of the number of workmen interventions.