FIRST RESULTS OF ENEL DISTRIBUZIONE EXPERIMENTATION

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ABSTRACT
To achieve the quality of service objectives set by the Italian energy market regulation authority, Enel implemented an efficient and highly effective automatic fault detection system in its MV (Medium Voltage) network. Its performance and upgrade possibilities are influenced and sometimes limited by the characteristics of the switchgears currently installed in the network. To overcome these limits, different network components are needed, hence the specification, test and adoption of a new high performance MV switchgear.
These new switchgears have been installed on Enel network since the beginning of the year 2008 and all the feedback coming from the field are encouraging and completely in line with Enel first expectations.

CONTENT
Nowadays the energy regulated market is characterized by a rising attention towards quality of service and customer supply continuity. In Italy, the AEEG, Authority for Electric Energy and natural Gas, sets the rules for the energy market and controls the performance of the energy suppliers, enforcing the quality of service requirements by means of a fine-reward mechanism based on various key performance indicators, KPI. One of the most important KPIs used by the AEEG to assess the utilities’ performance is the cumulative duration of long lasting supply interruption per customer. The time limit for a supply interruption to be classified as “long” is currently set at 180 s. As a consequence, it is absolutely crucial to limit long duration supply interruption to the furthest possible extent.

To do this, two simple strategies can be used: to reduce the time necessary to find and isolate the fault keeping it as short as the 180 s deadline and, once the fault is found, to minimize the number of customers affected by the fault, that is, roughly, to minimize the length of the network section that must be shut off to isolate the fault.

Those two strategies are reflected in the automatic fault detection system which Enel has implemented and has successfully been using for many years in its medium voltage network. Depending on whether the network has neutral ground or not, one among two comparatively simple algorithms is automatically operated thus allowing to detect and localize any fault within a single section of MV power line. Such a system has proved itself to be extremely effective, dramatically reducing the cumulative duration of customer supply interruptions per customer.

TECHNOLOGICAL ISSUES
Notwithstanding the effectiveness of this system there are some limitations to its performance, reliability and, above all, to the possibility of upgrades and evolutions, because of the characteristics of the network components, which therefore are of critical importance. We will focus on the characteristics and limitation of MV switchgears and the solution that has been proposed to overcome these obstacles.

Basically, there are three limiting factors: switching time, making-and-breaking rated currents and the electrical and mechanical endurance of the switchgear.
The switching time, i.e. the interval between a command and the completion of the correspondent operation (opening or closing), limits the spatial resolution of the fault detection essentially to the ratio between the maximum time available for fault detection and isolation, and the switching time.
Considering the limit set by AEEG for a long duration power shut off this time is 180 s, but the worst-case limit can be significantly lower: for example, if the network is run with a Petersen coil earthed neutral, the limit is essentially given by the withstand of the Petersen coil itself (approximately 20 s in Enel networks).
The making and breaking ratings are related to the possibility of using procedures where it is required to make or break fault currents. The extended endurance switches currently installed in Enel MV networks are tested to perform up to 5 short-circuit making operations, but cannot brake short-circuit currents, therefore it is necessary to operate the line circuit-breaker any time it is required to break the short-circuit current.
The electrical and mechanical endurance of the MV switchgears obviously determines the lifetime of the device: the higher the operation frequency the shorter the residual lifetime. Automatic operation implies higher usage ratios, thus decreasing the expected lifetime of the device and increasing the frequency of periodic replacement and, as a consequence, maintenance costs.

OBJECTIVE
To overcome these limits, and therefore open the way towards extended network automation and new, faster and more efficient fault searching algorithms, in order to achieve quality of service results always in line with expectations, a network component with significantly...
higher performances must be available: a goal is to make available of who build, maintain and run the MV network, a new MV switchgear which could represent a good trade-off between the need for the expected performance and lifetime costs.

With this goal in mind, we specified and adopted a new low cost, high performance MV switchgear for use in automatic MV-LV substations.

REQUIREMENTS AND CONSTRAINTS

The new switchgear is intended for use in MV/LV substations, built according to a standard incoming-outgoing electric scheme, so its basic performance consists of simple ordinary functions such as busbars disconnection and line grounding. In order to overcome the previously listed limitations, the additional obvious requirements that the new switchgear has to meet are fast switching time, short-circuit current making and breaking capability and extended mechanical and electrical endurance. All these characteristics must be implemented at the reasonably lowest cost possible. Besides, in order to minimize installation costs, this device must be dimensionally interchangeable with currently installed switchgear and fully compatible with the command and control interface of the remote control smart unit installed in MV/LV substations.

Of course, safety and environment protection are a major concern. Therefore this new device must guarantee the highest safety standards, in order to safeguard the health and safety of the community and the workers, and must be environmentally-friendly.

TECHNICAL SOLUTIONS

To ensure operation under fault conditions the switchgear can only rely on the energy supplied by the 24 V lead acid batteries installed in MV/LV substations. Batteries are also responsible for the power supply of the remote control smart unit. Since the health conditions of the batteries are not guaranteed, it is not a good practice to directly absorb the substantial amounts of energy needed for fast operation. A far better option is to adopt a stored-energy drive, which assures virtually instantaneous operations and needs external power only to recharge an energy accumulation device, whatever a spring or a capacitor.

A 12.5 kA short-circuit breaking current is ensured by a vacuum circuit-breaker. Extended experience and good feedback with line circuit-breakers suggested the use of this, now mature, technology, which also allows compact dimensions and smaller drives. E2 electrical endurance class and M2 mechanical class requirements (IEC62271-100) guarantee extended duration with limited or even no maintenance.

Interchangeability with MV switchgears which are currently installed in MV/LV substations is essential to keep substitution costs low. In fact, to install the new device it is enough to simply remove the old one detaching busbars and cable terminals connections and substitute it, without the need to modify the other substation components. In order to obtain interchangeability with the most widespread devices in use in our substations, both a 700 mm and a 500 mm wide units are needed. The 700 unit is used to take the place of Enel standard air insulated medium voltage switches, while the 500 mm clad is compatible with our modular switchboards with SF6 insulated switch and disconnector. An additional 500 mm unit is obtained modifying the standard 500 unit by adding bushings in the upper part of the device.

The bushings functionally substitute busbars and allow to connect the upper part of this special unit by means of push-fit connectors, while the low end connection is obtained using traditional MV cable terminals. This solution allows to easily install this device in stand-alone mode inside tower-type substations, where it will replace one of the wall mounted switchgears traditionally installed in these special substations. Tower-type substations are very common in Italy, and in past times were installed along overhead lines, where they function both as overhead conductor support and as a substation housing.

Mechanical and electrical interlocks avoid improper using, preventing the operator from performing dangerous operation. Moreover, the device is internal arc classified (12.5 kA for 0.5 s), according to IEC 62271-200. Classification is IAC-AF for 500 mm and 700 mm units, while the special unit for tower type substation is IAC-AFL classified. In comparison to the IEC 62271-200 test requirements, some special requirements have been added, in order to reproduce the actual operating conditions. In particular, special attention has been paid to the testing condition of stand-alone unit because of its peculiar installation type and operating conditions.
The use of SF₆ for insulation purposes is reduced if not completely avoided. Inspired to the criteria of the Kyoto agreement, this requirement helps to reduce greenhouse gas emissions. The result of our specification is a compact modular MV circuit-breaker with disconnector and grounding switch (referred to DY800 from now on), a piece of equipment that is faster, more accurate, more reliable and easier to adapt into existing systems than previous generations of equipment for installation in MV/LV substations. During 2007 Enel made a tender for 1000 items that was assigned to 4 manufacturers. The first 300 have already been installed to be tested on the field. Despite the modest quantity, the purchase cost of these first experimental batch is encouraging and in line with our expectations. In future we expect that higher volumes will translate into a further price decrease, therefore promoting extensive use of this device.

**FEEDBACK FROM THE FIELD**

With the initials batch of installed devices it has been possible to appreciate the good results of our technical solution. The adoption of an air insulated solution confirms a high level of performance and economy, reliability and operational safety and last but not least our commitment to environmental issue. Despite the brevity of the experimentation it has been possible to appreciate higher reliability of this device in comparison to a traditional motorized switch-disconnector. The shorter switching time has allowed to increase the number of automated knots installed along a single line, in comparison to what was possible with the use of former traditional motorized switch-disconnector, thus reducing the number of clients involved in the more extended phase of the fault detection (i.e. the phase of manual operation). Such a solution brings to a reduction of the cumulative duration of long lasting supply interruption per customer that for the single line is about 10% - 15%.

For the same reason an even smaller reduction of the number of interruptions per customers can be equally appreciated, since neutral grounding and network automation in some cases allow (with single phase earthing fault on the last section of the line) the line to remain in operation, with the opening of the only automated switchgear before the faulty section.

**NEXT STEPS**

The good results obtained by the use of this new device have prompted us to develop two new projects:

- a new Ring Main Unit (RMU) isolated in SF6 with circuit breaker on the line side with the same characteristics of the DY800.
- a new switchgear with a control panel which enables the re-closing function to contain the over-current faults.

The first new project will consist of two lines equipped with a circuit breaker and a traditional protection transformer with fuses (2LEi+1T). The board will be immersion resistant and can be extended by adding other lines. Such solution will respond to the demands of MV/LV substations in areas where only small spaces are available or where a high-level of pollution is present and finally in areas at high risk of flood.

Currently the specifications of this new project of RMU with circuit breaker are being defined in partnership with EdF and Endesa.

The second project aims at using this type of new switchgear in order to realize small satellite centers equipped with the same protection device used in primary substations, thus virtually dividing a single MV line in two ones and achieving an appreciable reduction of the number of interruptions for a single customer, therefore containing also the effects of over-current faults.