A LOW-COST HIGH-PERFORMANCE MV SWITCHGEAR FOR USE IN REMOTE-CONTROLLED MV/LV SUBSTATIONS

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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.

CONTEXT

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: our goal is to offer at disposal 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 are simple ordinary functions such as busbars disconnection and line grounding. In order to overcome the previously listed limitations, the additional requirement that the new switchgear has to meet obviously 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, to minimize installation costs, it 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 ensure outstanding protection of people's health, and must be environment-friendly.

TECHNICAL SOLUTIONS

To assure 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 assured 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 SF_6 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 SF_6 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.

CONCLUSIONS

The result of our specification is a compact modular MV circuit-breaker with disconnector and grounding switch, suitable for installation in MV/LV substations.
At present various suppliers manufactured prototypes of this new device. Mainly the manufacturers exploited previously existing sub components (vacuum circuit-breaker module, disconnector, earthing switch, motor drive) to produce these prototypes, in order to keep prototyping and testing costs as low as possible. These prototypes are under assessment and will soon accomplish type test cycle.
A first batch of 1.000 items will be experimentally installed in our MV network and tested on 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 extended use of this device: about 100.000 MV/LV substations are eligible for retrofitting with at least one of these new units.