UPGRADE OF ENEL MV NETWORK AUTOMATION TO IMPROVE PERFORMANCES IN PRESENCE OF FAULTS AND TO DEAL DG

Alberto CERRETTI
ENEL Distribuzione – Italy
alberto.cerretti@enel.com

Giorgio SCROSATI
ENEL Distribuzione – Italy
giorgio.scrosati@enel.com

Lilia CONSIGLIO
ENEL Distribuzione – Italy
lilia.consiglio@enel.com

ABSTRACT

The MV automatic system for fault location and supply restoration of the healthy branches of the feeder located upstream the faulty section is widely diffused and consolidated on Enel Distribuzione Network. A number close to 20.000 feeders have at least one MV/LV substation equipped with automation devices, thus leading to excellent results in terms of cumulative duration of short and long interruption to the customers. Due to national Regulator request, though, also the total number of supply interruption (even transient ones) must be reduced. This is the driver that led Enel Distribuzione to develop a new kind automation, that not only implies a modification to the mere logic, but also requires for new devices able to communicate to each other, exploiting communication networks and for a new kind of circuit breaker along the feeder to be strategically installed instead of the existing on-load switch disconnectors.

INTRODUCTION

The Enel Distribuzione MV network automation system performs fault location and supply restoration of the healthy branches of the feeder located upstream the faulty section; it is widely diffused and allows to reach excellent results on the Italian Network. In Figure 1 a graph representing the increasing performance achieved by this kind of automation (together with simple remote control operation) over the years in terms of supply interruption duration is shown.

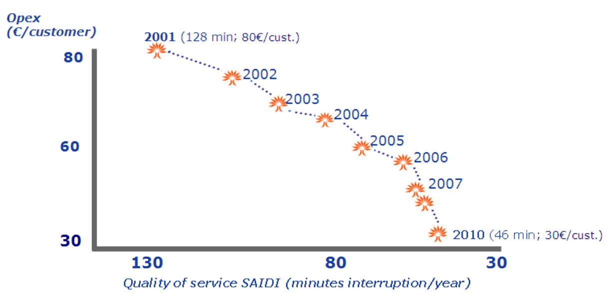

Figure 1 – continuous improvement of the cumulative interruption time to the customers over the years

Today, after more than 10 years of experience, a number close to 20.000 feeders have at least one automated MV/LV substation capable to lead to excellent results in terms of cumulative duration of short and long interruption to the customers. In spite of this, due to national Regulator request, not only the cumulative interruption time (sum o duration of both long and short interruptions) is taken into account, but also the total number of supply interruptions (long and short, even transient ones) must be reduced. This is the driver that led Enel Distribuzione to develop new automation procedures, named Logical Selectivity (LS) and Voltage Recovery (RT), that not only implies a modification to the logic of the remote terminal unit (RTU) installed along the MV line in the MV/LV substations, but also requires for new kind of Fault Passage Indicator (FPI) able to communicate to each other, fully exploiting the existing broadband communication networks. Also a new kind of circuit breaker (CB), named DY 800, must be strategically installed along the feeder in place of the current on-load switch disconnectors (IMS), in order to obtain the benefits promised by the new automation.
In other words, a new architecture for the MV network automation system is required to accomplish the new request of the national Regulator.. The paper describes the general architecture of the new system, the advantages concerning automatic fault location, performances concerning operation of the network in presence of large amount of DER and main features of new devices already defined and under realization to realize the new system on Enel Distribuzione network. Also a brief description of RT and LS techniques is presented.

THE EVOLUTION OF ENEL DISTRIBUZIONE AUTOMATION SYSTEM – GENERAL ARCHITECTURE

In order to overcome the new national Regulator request, an important evolution of both the automation system and the network infrastructure have been defined. Two completely new fault isolation automatic procedures have been studied and developed, to be used superimposed to the existing one, that will continue to be used as a backup.
With the current automation, when a phase to earth fault occurs, only customers connected to the faulty and downstream sections are interested by a long interruption. This is possible because MV network is operated with arc suppression coil in parallel with high ohmic value resistors, thus limiting, in the worst fault condition, fault current to less than 50 A (at 20 kV), with high power factor (15 A capacitive/inductive current plus 35 A resistive current). In these conditions also IMS are able to interrupt fault current, without any action from CB in the HV/MV substation. Possible load current, superimposed to the fault current, can further increase the power factor, maintaining total current that IMS has to interrupt within its limits. As IMS may operate in 4 s maximum, and a maximum number of three IMS in series is foreseen in

the system, a fault clearing time of 20 s is obtained [1].
In spite of this, ENEL automation system guarantee the complete respect of the curve (admissible touch voltage/fault clearing time) defined in HD 637 S1-1999 [2] and is also compliant with future developments of the Standard Body, in particular new project FprEN 50522:2009 [3] which will replace HD 637 S1. The situation, in fact, will be even more favorable, as U_{TP} will increase from 75 V to 80 V for very long fault clearing time.
Different is the case where a short-circuit fault occurs: in this case all the feeder is involved by a reclosing cycle, with a short interruption (< 3 mins) for customers located upstream the faulty section and with long ones for those located downstream. Short circuit currents are high, with low power factor; in this case IMS are not able to interrupt this current, and, consequently, they have to operate in voltage absence, after the opening of the upstream CB. The same behavior is present in case of phase to earth faults on networks operated (even temporary) with insulated neutral. This is the main drawback that is going to be overcome by RT and LS.
The new system, in particular for the operation of the LS technique, is strongly based upon the exploiting of an always-on communication network between all the involved MV/LV substations, and this is very different from the current way of operation in which the communication between the central system and the remote terminal units is established only at the end of the automatic selection and only if necessary using the GSM switched network. The new automation system main actors are an improved MV protection relay and an advanced FPI located along the MV feeder and in correspondence of all MV customers, both traditional (passive customers) and with local generators (active customers). Another fundamental component, already available and deployed on several areas over the nation, is the DY 800 device: a new vacuum circuit breaker able to interrupt high short circuit currents and extinguish the fault in less than 80ms, conversely from the traditional on-load switch disconnector. By equipping a feeder with these devices it is possible to fulfill the LS automation technique. LS guarantees, regardless the type of fault (earth fault or short circuit between phases) to disconnect only a minimum number of customers, without involving any of the upstream sections, not even with transient interruptions (only voltage dips with duration equal to total fault clearing time in case of poliphase faults). In case of problems related to the communication between fault indicators, LS cannot be applied and the existent automation, used as a backup, will however guarantee a short interruption for all the sections upstream the faulty one. Anyway, until the new IEDs will be realized, RT automation technique, that is not based on a real-time communication between the IEDs, can effectively resupply in less than a few seconds all the upstream sections, with respect to the faulty one, and with a great save of time if compared to the existent automation procedure.

THE NEW AUTOMATION SYSTEM ARCHITECTURE AND FUNCTIONALITY

The new fault passage indicator RGDM

The new automation system is based on a really complete evolution and enormous performance improvement of the MV/LV fault locator (former RGDAT, now called RGDM). RGDM is an advanced IED (intelligent electronic device) with several functions:

- protection against earth or short-circuit faults
- V-I-P-Q measuring
- DG managing (anti islanding detection/disposal and voltage regulation functions)
- programmed load reduction
- automation functions.

RGDM measures V-I at the installation point and separately the incoming and outgoing P-Q flows where a DG is present: this data is required by the TSO in order to have a better understanding of the overall power exchange. The TSO may also require for a load reduction and the RGDM can serve this purpose by disconnecting a portion or the entire load of its competence. Finally, the automation function (with reference to LS in this case), performed by a fast exchange of elementary signals between the RGDMs along the same MV line and with the MV protection relay, is based on the availability of an always-on connection between all this devices. This communication network is physically realized with several technologies (WI MAX, WI FI, Optical Fibers, ADSL, etc) and must be reliable and assuring opportune data transfer throughput, and is fully based on IEC 61850 protocol.
RGDM uses integrated combined sensors for voltage and current, one per phase, able to assure, in association with the electronics which performs the signals conditioning, an extremely high accuracy.
RGDM is an evolution of the innovative Outdoor Fault Passage Indicator [4], already installed in some thousands pieces on ENEL DISTRIBUZIONE networks, with excellent results.

Voltage Recovery description

As afore mentioned, RT is not based on a real time communication between IEDs, but is able to exploit all the benefits derived from a feeder equipped with several DY 800. For this reason it can be applied with the available devices (RTU and RGDAT), before the production of the new RGDM. With a minor modification to the logic of the RTU installed in each MV/LV substation, the feeder can be seen as divided in sections, each one headed by a DY 800 breaker with fast reclosing feature. One of these DY 800, typically the one placed in an intermediate position along the MV line, is configured to work as “MASTER”, while all the remaining work as “NORMAL”. The difference between the two is that the MASTER is selective with respect to a NORMAL.

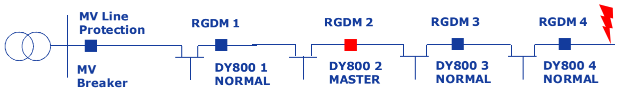

Figure 2 –RT scenario

With reference to the example depicted in Figure 2, when a fault occurs, for instance at the end of the feeder, the MASTER will open. As a consequence, leaded by fault detection coupled with a lack of voltage (both information from RGDM), also DY 800 n.3 and n.4 will open. A fast reclosing is performed by each DY 800 detecting an incoming voltage presence and only the one that feeds the fault will open again. As a result, the sections between RGDM 2 and RGDM 4 are resupplied in a very short time and the remaining section downstream RGDM 4 is interested by a classic reclosing cycle, performed by DY 800 n.4 (with a long interruption in case of a non transient fault). Eventual on-load switch disconnectors installed along the line continue to work with actual automation. In case of a fault located upstream the MASTER, the intervention of the MV line breaker is necessary.

Logical Selectivity description

The general idea that underlies the LS functionality can be described as follows: in the HV/MV substation an improved MV protection relay (with IEC 61850 communication protocol functionality) is used for each automated feeder. The relay, in case of fault detection, waits before tripping, and within an appropriate time window, for a so called BLIND signal, coming from at least one of the RGDMs located downstream along the feeder, which has detected the fault condition as well (refer to **Figure** 3). If the BLIND is received, the relay will not open the MV line CB: in fact a received BLIND assures that at least another device along the feeder is going to open its breaker and clear the fault. The same strategy is used to coordinate the maneuvers between MV/LV substations: each DY 800 along the MV line is driven by its relative RGDM and in case of fault, each RGDM waits before tripping for BLIND signals coming from downstream RGDM. The only RGDM not receiving a BLIND, corresponding to the one protecting the DY 800 that directly feeds the faulty section, is asked to open its CB. In any case, even if a RGDM has received a BLIND, the operation of the switch is ensured if the fault condition does not fall within an appropriate time-out.

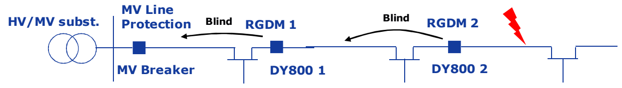

Figure 3 –SL scenario

Thanks to the always-on connection, each RGDM can be quickly reconfigured in case of network topology variation. The reconfiguration process updates the list of "preceding IEDs" (the recipients of the BLIND signal sent by this RGDM) and the list of "successor IEDs" (list of IEDs from which to accept a BLIND signal), thus ensuring a great reliability of the overall fault location procedure at any time, and without the need of any intervention by an operator.

Dealing the new automation with DG

A very important issue when dealing with DG is to avoid unwanted islanding. Indeed, when a faulty branch has been isolated by an automated procedure, there is a possibility for the DG located downstream the faulty section to maintain in island operation the disconnected section with non-standard frequency / voltage values. This can happen, in spite of interface protections [5], [6] when a balance between produced power from generators and requested power from loads is present; in addition, features of inverters for PV plants increase drastically the possibility of island operation [7].
The possibility of unmanaged island operation increase if the fault is phase to earth and, especially, in case of a disconnection of a feeder section required from operation needs, without any fault.
In order to avoid this, each time an RGDM open its DY 800, also a trip command must be sent to each DG protection relay that is located downstream its position, thus ensuring a forced disconnection of the interested DG from the network. When the supply of energy is restored, on the network, and after the automation process has completed its routine, the DG electronics shall restore the connection by means of an automatic or manual procedure, aimed to re-establish the proper operation, with the classical control of frequency-phase-voltage parameters. RGDM also periodically checks for the presence of the communication network by means of opportune keep-alive signals and accordingly to this is able to exchange the thresholds values of the DG frequency protection: when the communication is present, a wide threshold may be used (for example 49 ÷ 51 [Hz]), with the purpose to keep the DG connected to the network also in case of small perturbations (think about DG located upstream a faulty section). On the other side, when the communication is absent, a standard narrow frequency threshold of 49.7 ÷ 50.3 [Hz] can be used.

THE ADVANTAGES OF RT AND LS OVER EXISTENT AUTOMATION TECHNIQUES

The results that has come out from the last year underlines that the current automation on Enel Distribuzione network is able to lead to the excellent result with an average cumulated interruption time per customer and per year equal to 46 min, with an average number of 4.6 interruptions per customer and per year. The new RT and LS technique, taking advantage from the use of the new DY 800 and other IEDs over the MV network, promises to increase the above mentioned key performance indicators. By the use of LS a significant reduction of the total number of interruptions per customer and per year is expected.

ONGOING PILOT TESTING

Several main pilot installations are going to be implemented on the Italian field. Within the POI-P3 project (Progetto Operativo Interregionale) 6 HV/MV substations have been selected for this purpose. In particular, one of these substations, located in Puglia region, feeds two MV lines that have been specifically chosen for this new automation pilot testing, also thanks to the wide presence of DG (wind and PV). The IED that are going to be installed (improved MV line protection relay, RGDMs, DG protections, etc) are already defined and are under realization.

CONCLUSIONS

The research for a continuous performance improvement, driven also by the new requirements dictated by the Regulator, has led Enel Distribuzione for the development of a new kind of automation which aims to reduce the total number of supply interruptions to the customers. Exploiting all the available technology, in terms of intelligent devices, improved CB to be installed along the feeder, broadband communication technologies and protocols, a completely new system architecture has been defined and a set of new IED are currently under realization. These devices, and the RGDM on the frontline, not only are studied to perform automation features, but also must deal with a wide presence of DG onto the distribution network, which is the scenario we are seeing the growth day by day.

REFERENCES

For a Conference citation:

[1] A. Cerretti, G. Di Lembo, G. Di Primio, A. Gallerani, G. Valtorta, CIRED 2003, Barcellona, May, 12-15, 2003: “Automatic fault clearing on MV networks with neutral point connected to ground through impedance”

[2] HD 637 S1-1999 “Power installations exceeding 1 kV a.c.”

[3] FprEN 50522:2009 “Earthing of power installations exceeding 1 kV a.c.”

[4] A. Cerretti, R. Calone, G. Di Lembo, L. Giansante, CIRED 2009, Praga, June, 8-11, 2009: “An innovative integrated current/voltage sensor for outdoor fault detectors”

[5] A. Cerretti, E. De Berardinis, M. Delfanti, D. Falabretti, AEIT, numbers 5-6, 2010: “Le reti di distribuzione: dal paradigma attuale, alle reti attive, verso le smart grids”

[6] G. Monfredini, Academic Degree Thesis Politecnico di Milano, 2009, Analisi dinamica della generazione diffusa su reti MT: limiti e prospettive delle protezioni anti-islanding,

[7] F. J. Pazos, CIRED 2009, Praga, June, 8-11, 2009, Power Frequency Overvoltages Generated by Solar Plants