SMART FAULT SELECTION: NEW OPERATIONAL CRITERIA AND CHALLENGES FOR THE LARGE SCALE DEPLOYMENT IN E-DISTRIBUZIONE'S NETWORK

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ABSTRACT

Continuity of supply determines the investment strategy for DSOs in terms of structure and technology. All interventions are oriented to improve the reference indicators. In Italy, the performances of network are evaluated by means: SAID and SAIF Indexes. From 2016 Italian Authority ended the awards and penalties regulation for Average Duration of Outages per LV customers, defining spent the period of "improving" for this indicator; from now is foreseen just "conservative" regulation oriented to preserve the reached levels. In the next years, the very challenge is set for the Average Number of Outages, for which the Regulator determined to reach the target levels for 2023.
Referring to this objective e-distribuzione has started to develop an innovative selection system of network failures, based on logic coordination between protection systems, in order to optimize the time equivalent of an electrical fault extinction and consequently reduce the equivalent customer moment [1]. The full development of such a system will be done through an appropriated integration and evolution of network protection and control systems, until now experimented from e-distribuzione in various financed projects [1], [2], [3] and [4]. This proposed solution will not modify the typical scheme of operation of MV distribution feeders.

SFS FUNCTIONING

The SFS technology relies on the availability of a short-latency communication carrier in conjunction with a series of high-performance devices. In such a way, it is possible to enhance the maximum current selectivity performance by increasing the number of fault's selection levels as well as allowing a drastic reduction in terms of number of customers affected by the outage, adopting a faster and completely automatic restoration of the remaining network.

In the figures below is represented the logical functioning of SFS automation: for clarity reasons, only HV/MV transformers, feeder bays and automatized MV/LV secondary substations are outlined in the schemes; obviously, between two automatized secondary substations there are in general several plants, like remote and not remote controlled substations, pole mounted transformers, spur lines and so on.

In details, as visible in Figure 1, when a short circuit happens, the fault passage indicator and measurement devices, named RGDM, [5], upstream the fault, activate themselves and send a "goose[1]" message (using IEC 61850 standard protocol [6]) to a communication Hub. In the same way, a "goose" message is received also from the MV bay protection device, if belongs to a DV7203 series.

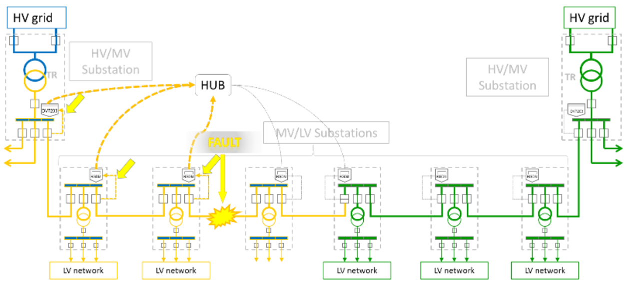

Figure 1- Activation and sending of a goose message by fault passage indicators

As shown in Figure 2, the goose messages are then received by the devices upstream the RGDM closest the fault and act like a "block" for themselves (and also for the bay protection device). So, at the end of a preset delay, the closest RGDM (the only one that does not receive any BLIND signal) will send an opening command to the circuit breaker, by means of the remote terminal unit (RTU) installed in the secondary substation.

1 Generic Object Oriented Substation Event

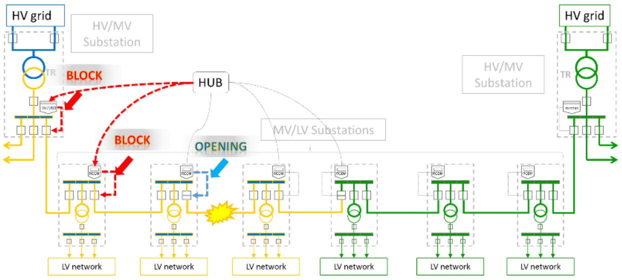

Figure 2 - Blocks logic and circuit breaker opening

In order to make an automatic dichotomy of the portion of the grid affected by the outage, the RGDM that commanded the opening will send also another goose message to the RGDM just downstream the fault. As shown in Figure 3, the command message will be sent by the RGDM upstream only after the successful opening of the circuit breaker. The reception of the goose by the RGDM downstream determines the opening of the related circuit breaker, with the same logic described before.

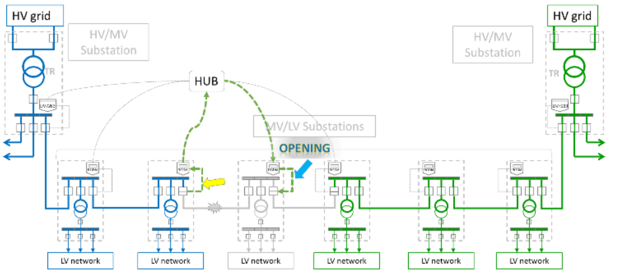

Figure 3 - Opening of RGDM downstream the fault

Finally, after the successful opening, the RGDM downstream the fault will send another goose message that will be received by the RGDM installed on the border secondary substation in order to command the closing of the circuit breaker. By means of this, as visible in Figure 4, the SFS automation has correctly disconnected only the portion of the grid between two RGDMs affected by the outage, while the restoration for all the rest of the grid will be in an automatic way. It is important to underline that this maneuver is executed directly from the RGDM involved, without passing through the RTU.

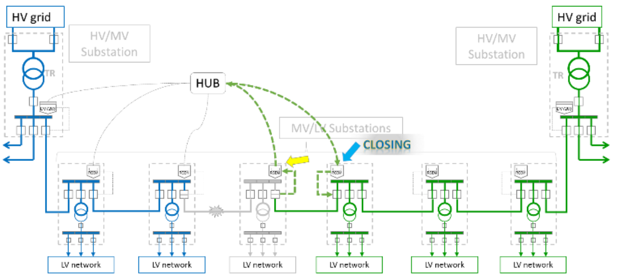

Figure 4 - Automatic restoration of the grid by automatic border reclosing

IDEAL BENEFITS RELATED TO SFS

In order to evaluate properly the benefits related to SFS, an analysis was made, comparing the effects of the current automation already operating in e-distribuzione with theoretical behavior of new automation system. This comparison was performed by making short and long interruptions really happened in e-distribuzione's network during 2014 and 2015, originated on MV grid. For each event, the number of LV customers involved and the neutral grounding system were considered.

In particular, trying to set a scenario as consistent as possible, the comparison was made with the following hypotheses inherent SFS' consistency:

- for grids with neutral grounded with Petersen coil, assuming a total of three automatized secondary substations, with a number of LV customers between two substations equal to the 25% of the total number of LV customers;
- for grids with isolated neutral, assuming only one secondary substation automatized, with a number of LV customers between the bay protection device and the substation equal to the 50% of the total number of LV customers;
- all the events not happened in standard configuration were not considered in the analysis.

Figure 5 shows the results, for each year, in terms of SAIDI and SAIFI percentage reduction that would be ideally obtained if the grid were already in operation with SFS automation.

As expected, the best performance is on the SAIFI indicator reduction and it is about minus 30% for each year. In fact, SFS is capable to execute the automatic closing of the border in less than a second so, for all the LV customers connected between the automatized secondary substation downstream the fault and the border, the interruption is just a transient one. Considering only the grid with neutral grounded with Petersen coil, results are not so much different.

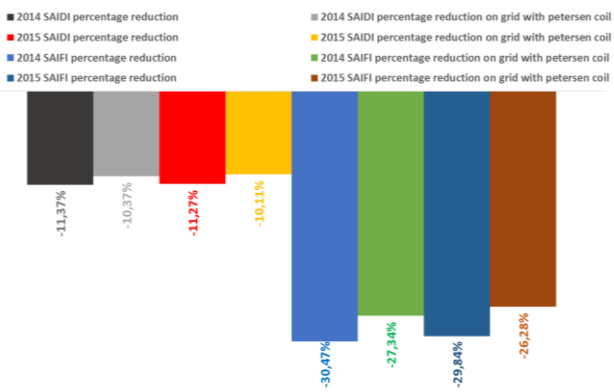

Figure 5 - SAIDI and SAIFI ideal percentage reduction using SFS automation

STEP-BY-STEP IMPLEMENTATION

This kind of automation uses extensively several innovative types of devices always capable to communicate with IEC-61850 standard protocol [6], like for example RGDMs, DV7203 digital protections and new processing units (UEL) in HV/MV substation. Unfortunately, not all of those are now available on market in the desired quantities and it must be taken into account that all the devices will be installed in an already automatized MV network, so it's crucial that SFS should be implemented step-by-step, maintaining high scalability levels without compromising current operating performances. For this reasons, the implementation of SFS has been planned in three phases:

- Phase 1: predisposition of secondary substations on MV main branches equipped with a Logical Selection Function (LSF) technology with boundary's circuit breaker remotely operated.
- Phase 2: upgrade of phase 1 in order to operate an automatic maneuver of boundary's breaker within a defined time (less than a typical time of transient interruption) in the event of fault.
- Phase 3: identification and development of equipment upgrades for protection, control and communication systems in order to address the system towards the future challenges of the network operation.

Function	Grid Portion	Available on Phase 1	Available on Phase 2
Logical Selection	Between two secondary substations	YES	YES
Logical Selection	Between feeder bay and the first downstream substation	NO	YES (only with DV7203 installed at the beginning of feeder)
Automatic border closing in less than 1 s	Border secondary substation's circuit breaker	NO	YES
Automatic Reclosure in less than 1 s	Secondary substation's circuit breaker	YES (only coupled with the short one)	YES
Automatic Reclosure in less than 1 s	Feeder bay's protection device	YES (just one attempt)	YES

Table 1 – Comparison between Phase 1 and Phase 2

Table 1 summarizes the relevant aspects of both Phase 1 and 2. It is evident that the lack of automatic closing of the border in Phase 1prevents to have a great benefit on SAIFI indicator. Anyway, Phase 1 it's extremely important because, having MV lines really operating in LSF automation, there will be a data collection regarding malfunctioning cases and this will provide the basis on which develop the Phase 3 upgrades.

CONDITIONS FOR SFS APPLICATION

As above-mentioned, the maximum current selectivity performance depends widely on the short-latency communication carrier, because SFS relies on sending and receiving goose messages from all the devices involved, determining blockings or opening command executions.
The main communication carriers that will be used by e-distribuzione during the project are LTE and ADSL and, for both of them, on-field tests proved that the total average latency measured between sending and receiving a goose is about 100 ms.
Therefore, before proceeding with the overall SFS implementation on e-distribuzione's network, it is crucial verify preventively if the series network equipment of MV lines withstands the thermal stresses due to the short circuit current flowing. This aspect is very relevant if the feeder bay's protection device is not a DV7203: in fact, in this case, the standard protection device[2] is not capable to communicate in IEC 61850 standard protocol, so only a chronometric selectivity is possible between the bay and the secondary substations. Table 2 shows the typical delay time to be considered in both scenarios, assuming only a single attempt of automatic reclosure operating with no time delay.

Device	Intentional time delay of the protection (ms)	Circuit breaker opening time (ms)	Duty cycle (opening)
DV901-A2NCI	500	70	First One
	50	70	Second One
DV7203 in presence of LTE or ADSL carrier	200 (precautionary)	70	First One
	50	70	Second One

Table 2 – Comparison between traditional and new digital protections

Using DV7203 protection device, the thermal stress is reduced by 40% compared to standard case, thus expanding the number of MV lines eligible for SFS application. Moreover, the need to set a delay time of 500 ms has adverse consequences on:

- Power quality, because of the doubled duration of voltage dips (in the standard set point plan of e-distribuzione the intentional time delay of the protection in case of maximum current is at most equal to 250 ms);
- Potential disconnection of the distributed generation (DG) connected on MV network, due to the minimum voltage threshold of protection systems imposed by regulatory acts (see Table 3 for a general overview).

[2] DV901-A2NCI and before series of digital protection

Threshold	DG connected before 30/06/2012	DG connected between 1/07/2012 and 31/12/2012 and with connection request sent before 1/04/2013	DG with connection request sent after 1/04/2013
27. S1 (kV)	0,7 nominal voltage	0,85 nominal voltage	0,85 nominal voltage
27. S1 (s)	0,3	0,5	1,5
27. S2 (kV)	-	0,4 nominal voltage	0,3 nominal voltage
27. S2 (s)	-	0,3	0,2
Number of plants (%)	77	11	12

Table 3 – DG minimum voltage protection set points

Finally, it must also be verified the capacity, in terms of thermal limit, of the faced MV line; in case of outages occurred on the first automatized portion, upstream of the first automation, the faced MV line must be able to resupply the entire SFS automatized MV feeder.

SFS MONITORING

Presently, SFS is still an experimental project, thus it is important to check if the whole system works properly during the operation. So, for every localized outage, e-distribuzione will analyze:

- The sequence of actual automatic maneuvers, in order to compare them with the “ideal” functioning;
- In case of different behavior, identify possible causes of malfunctioning;
- In case of performance decay of the communication carrier, the back-up functioning of the system.

The last point is relevant in case of single-phase-to-ground fault for grids with neutral grounded with Petersen coil. In fact, even if the latency is too big for goose transmission in standard times, thanks to a chronometric selectivity set-point definition, the SFS can work in the same way of the current automation (of course apart the automatic border closing) ensuring the opening of only the single protection device upstream the fault.

SFS FUTURE SCENARIOS

Results of large scale deployment of SFS technique will determine the conditions and references:

- to define the internal standards to build the distribution’s electrical stations in terms of technology and equipment;
- to determine the new operational rules and criteria;
- to develop instruments able to estimate, in an automatic way, the better condition to operate maneuvers finalized to arrange an optimal scheme of network.

CONCLUSIONS

Necessity to improve the continuity of service performances of the distribution network toward the LV and MV customers, in perspective to reach the targets fixed by the Regulator, in particular for SAIFI, has allowed the investigation and development of a new technique of network automation. The building of this revolution will be done thanks to the installation of new devices and technologies on the existing assets. The hope and will of all this is to reach the expected targets.
Preliminary results through few pilots and comparative simulations performed with continuity data, glimpse huge potential benefits of this new automation technology.

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