SMART FAULT SELECTION THROUGH SMART PROTECTION DEVICES USING IEC61850

Luca DELLI CARPINI
e-distribuzione – Italy
luca.dellicarpini@e-distribuzione.com

Antonio CAMMAROTA
e-distribuzione – Italy
antonio.cammarota@e-distribuzione.com

Gianluca SAPIENZA
e-distribuzione – Italy
gianluca.sapienza@e-distribuzione.com

Pietro PAULON
e-distribuzione – Italy
pietro.paulon@e-distribuzione.com

ABSTRACT

e-distribuzione, the main italian distribution system operator, starts the first pilot projects on 2010 testing the fast fault selection logic over the medium voltage network. The experience grew up through several pilot projects until the first large scale deployment on 2016 in Apulia region with the European project NER300 - Puglia Active Network. Related to the medium voltage network the project involves 8000 secondary substations and 200 primary substations fully covered by a high-speed wireless communication system based on LTE technology. The using of IEC61850 standard communication protocol over wide area networks to exchange informations between protections devices has allowed the smart fault selection logic in the e-distribuzione network.
This paper shows the results of a real fault in Apulia medium voltage network.

INTRODUCTION

The European standard EN 50160 defines the very short interruption (VSI) which are the interruptions shorter than 1 to 5 seconds. The effects on the low voltage customers of a VSI within 1 second or between 1 to 5 second could be considered the same. The Smart Fault Selection (SFS) has the aim to operate in less than 1 second. This technology allow the possibility to change the strategies of awards/penalties applied to e-distribuzione by the regulatory authority.
The SFS is a self-healing technology performed by the devices installed in the field through the high-speed communication network. The devices exchanging informations eachother like in a community are able to self-decide which are the best disconnection point of the electrical network that has to be connected or disconnected. It is important to mark that the smart fault selection doesn't require any remote action by operator or system and operates in less than 1 second.

NETWORK

The Figure 1 show a portion of the electric network of Apulia region. The electric network is composed by a primary substation with HV-MV transformation, some medium voltage lines that feed three automated and remote controlled secondary substations. Breakers controlled by relay protections protect the medium voltage lines in primary substation and secondary substations. The protection devices both in primary substation than in secondary substation are IEC61850 compliant and connected to the wide area network (LTE). The communication network has to satisfy some requirements in order to perform the smart fault selection logic:

- Logic connection flow secondary substation to secondary substation and secondary substation to primary substation
- Transport and handling of the goose messages over a wide are network
- Latency protection device to protection device less than 100 ms
- Secure transport of the informations (goose-MMS)
- Handling of a large number of devices, about one hundred for every primary substation

The communication network has a hub-spoke architecture, every devices belong to a specific bridge domain that has to guarantee the correct message transportation.

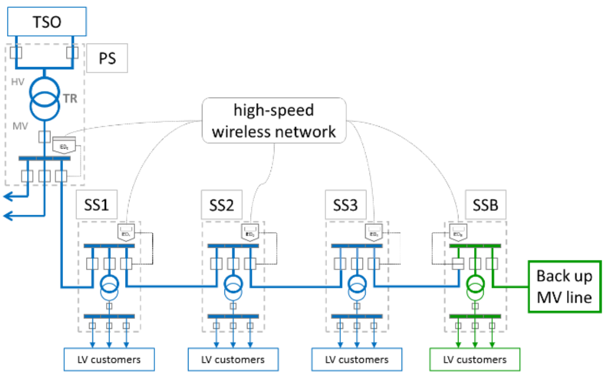

Figure 1 – e-distribuzione network

OPERATION

The smart fault selection base its operation on the exchange of goose messages between the protection devices.
The goose messages transport the information of the topological position, which is expressed by a univocal

number calculated by the scada system that knows the real time network topological. The pay load of the goose message is not fixed, it changes when the network changes for operation, maintenance or fault reasons.
The subscription of goose are fixed and they take into account every connection of the faced secondary substation. If we refer to Figure 1, the protection in the secondary substation 2 (SS2) will subscribe the goose messages of the protections installed in secondary substation 1 and 3.
The operating principle of SFS is done in three steps: fault selection, insulation of the faulted branch of the network, close the breaker of the border (SSB).
Considering having a fault between SS2 and SS3. The fault is detected by the protections installed in primary substation and in the secondary substation 1 and 2. The delay time of every protections is set with the same value, the protection in SS2 sends a goose messages to the protections in SS1 and PS. Every protections compare the pay load with the own topological position, in order to self-decide if it is necessary to reset the delay time (block of protection operation) or not (protection free to trip).
The goose is a broadcast message so also the protection in SS3 receives the goose and make the comparison.
The result is: the protections in PS, SS1 are in block state (delay time reset), the protection in SS2 is not blocked, the protection in SS3 is not blocked and doesn't detect the fault. After the delay time only the breaker in SS2 is opened by the protection command.
The second step of the SFS is to insulate the fault. The protection in SS2 checks the open state of the breaker and the absence of the line voltage. If these conditions are met the protection sends a remote-trip command via goose to the faced protections (SS3 and SS1). The protection that receives the remote-trip goose checks the absence of the voltage, if the condition is validated it sends an open command to the breaker. Following the Figure 1 only the protection in SS3 opens the breaker isolating the branch of the network affected by the fault.
The third step of the SFS is to close the breaker of the border. The protection that has insulated the fault sends a remote-close goose to the protection installed at the border (SSB). It checks the absence of the voltage and sends the close command to the breaker. At this stage, the border breaker feed back energy to the portion of the electric network that is not affected by the fault.
The SFS follow the same steps if the fault occurs between PS and SS1 or SS1 and SS2. If the fault occurs between SS3 and SSB, the border breaker is not closed by the SFS logic. In this case only the protection in SS3 opens the breaker, the restoration of the energy is not possible.

RESULT

The fault occurred between the secondary substation SS2 and SS3, it was a phase to ground fault.
In Table 1 and Table 2 are shown the goose latency measured taking into account the time-stamp of published and subscribed goose in the protections of the secondary substations. The time consider not only the latency of the communication network but also a part of elaboration time of the protection device. The latency is important in order to set correctly the delay time of the protection in accordance with the constraints of the setting of the power system protection. Every protection in the network is synchronized with a network time protocol (NTP) server located in primary substation.

Table 1 - measure of goose latency, publisher SS2

	Subscriber	
Publisher	PS	SS1
SS2	183 [ms]	157 [ms]

Table 2 - measure of goose latency, publisher SS1

	Subscriber	
Publisher	PS	SS1
SS1	166 [ms]	-

The Figure 2 is the oscillography of the protection installed in the secondary substation SS3. It is possible to see that in the electrical network there was a phase to ground fault, the phase 3 has about 0 V whereas the phase 1 and 2 have about the value of the phase-phase. The protection in substation SS2 operates the selection of the fault and open the breaker. It is recorded at the first marker of the Figure 2, all the phases voltage goes to 0 V.
After 267 ms from the left marker, the protection installed in the secondary substation SS3 receives the remote trip goose message and operates the opening of the breaker. It is possible to see the open-close limit breaker which change the state. The protection in SS3 sends the remote-close goose message to the protection installed in SSB. After 607 ms from the left marker the breaker of the border is closed and the energy is fed back from the back up medium voltage line.

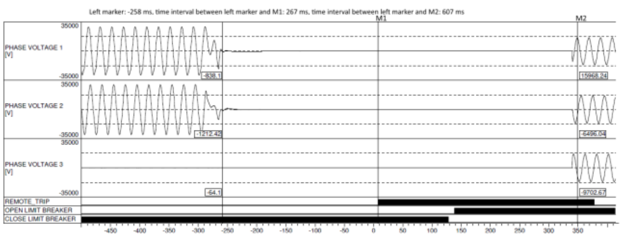

Figure 2 - oscillography of the protection installed in SS3

CONCLUSION

The aim to select, insulate and restore energy in less than 1 second is demonstrated by the field experience. This new technology is a step forward on the long automation experience of e-distribuzione. The classic automation system is not discarded but continues to operate in back up mode.

It is important to mark that the concept of chronometric coordination, between the protection devices is overcome by the use of the communication network. The communication network is not only used to monitoring the network but also to protect the electric network.

REFERENCES

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