ADVANCED MANAGEMENT OF A CLOSED RING OPERATED MV NETWORK: ENEL DISTRIBUZIONE'S P4 PROJECT

Simone BOTTON
Enel Distribuzione - Italy
simone.botton@enel.com

Roberto CALONE
Enel Distribuzione - Italy
roberto.calone@enel.com

Luigi D'ORAZIO
Enel Distribuzione - Italy
luigi.d'orazio@enel.com

Alessandro FATICA
Enel Distribuzione - Italy
alessandro.fatica@enel.com

Luca GIANSANTE
Enel Distribuzione - Italy
luca.giansante@enel.com

Simonetta MOREL
Enel Distribuzione - Italy
simonetta.morel@enel.com

Riccardo LAMA
Enel Distribuzione - Italy
riccardo.lama@enel.com

ABSTRACT

The paper presents an innovation project, based on a Smart Grid architecture in which standard network devices and systems have been specialised for a closed-ring operated plant, focusing on innovative components, on the communication technologies which will be possibly adopted to support operations in different environmental conditions and on the requirements for a fault management system supporting advanced closed ring operation.

The project is being funded by the Italian Ministry of Economical Development, within an Innovation Program carried out in 4 Regions of the South of Italy in the frame of the Programma Operativo Interregionale (POI) "Energie Rinnovabili e Risparmio Energetico".

INTRODUCTION

In conventional planning and design, Distribution networks are regarded as passive elements connecting the transmission system to final customers and therefore, no matter what their structure is, are operated radially in order to ensure unidirectional power flows, allowing simple protection schemes and devices. However, planning criteria often already imply meshed architecture and structure in MV network development to ensure reverse supply in case of single fault (n-1 condition); in these cases the network is operated in open ring configuration.

The increasing amount of distributed generation (DG) connected to distribution networks is gradually challenging conventional transmission and distribution network planning and operation criteria; in distribution, an increasing amount of network awareness (according to the "Smart Grid" paradigm) is required in order to manage bi-directional power flows related to an active grid.

In principle, the adoption of meshed network operation can lead to a better management of DG in terms of voltage profile, power losses and grid reliability, thus allowing easier connections for RES-generation plants; however, a real, effective meshed operation in MV networks requires new devices, new protection schemes, a new communication infrastructure and, finally, a different approach to operation which has to be tested and validated in everyday conditions.

The paper describes the design process related to the project, starting from the definition of the characteristic and functionalities of the pilot plants, summarizing the general architecture and the core components of the system and describing the protection and fault management system.

CHARACTERISTICS AND FUNCTIONALITIES OF THE PILOT PLANTS

Enel Distribuzione's P4 ranks among a set of innovation projects which have been selected to test non-conventional features for MV networks, such as advanced automation, DG dispatching and MV voltage regulation.

All these projects adopt more or less the same set of innovative components and devices, which have been developed for a Smart Grid environment. In order to evaluate the practical possibility to transform the present MV network in a Smart Grid, parts of existing MV network have been selected to test innovative functionalities.

In the case of P4 project, these functionalities include:
- in <u>ordinary network conditions</u>: closed-ring operation;
- in <u>case of fault</u>: fault selection along MV loop.

<u>Closed-ring operation in ordinary network conditions</u>

The capability of a MV network to be managed in everyday conditions is somehow taken for granted; however, closed-ring operation represents, at least for Enel Distribuzione, a new experience and needs to be extensively tested.

Different kinds of network have been chosen to test new devices and systems in different operating condition; in fact, it can be expected that lines supplying rural areas, which are usually longer and smaller in sections, may bring to attention different operational phenomena and criticalities than lines feeding urban areas.

Fault Management

In P4 project it is meant to implement a fault selection technique through which, in a closed-ring configuration and regardless of the kind of fault occurring (phase-to-earth, short-circuit), only the smaller possible part of the network is put out of operation, meaning that the unsupplied network portions must be limited to the one confined by two adjacent MV/LV substations.

This implies that, in order to ensure immediate and secure fault selection, new functionalities are needed.

First of all, it is required to detect faults along a MV line; that means that the equipment installed in MV/LV substations must be able to perform as a protection relay while maintaining the characteristics of easiness of use and cost-effectiveness required for high volume applications.

Secondly, the power equipment installed in MV/LV substation must be able to open and establish short-circuit currents; this is - in general - not the case of existing components and the adoption of standard MV circuit breakers could lead to unacceptable costs.

Thirdly, the system must be able to operate real-time evaluations of network events to ensure the timely intervention of the switchgears: this means all the relevant components of the protection system must be connected through a cost-effective, reliable and always-on communication infrastructure.

Finally, protection devices must be able to fulfil their duties in operational condition completely different from conventional, radial, network environment; this is probably the hardest challenge among all.

GENERAL SYSTEM ARCHITECTURE

Future Smart Grid architectures will possibly support any kind of advanced network functionalities. It is therefore quite natural that the system presented in this paper strongly resembles the architecture described in other papers from Enel Distribuzione [1] although, due to the still on-going development of Smart Grid technologies, some of the functionalities which are needed for close-loop operation shall be set up for this specific project.

The architecture adopted requires the installation of new devices in some of (eventually all of them) MV/LV Substations along MV loop and the connection of all of them to a central system through a communication infrastructure always on.

In Figure 1 the general configuration of the system is outlined.

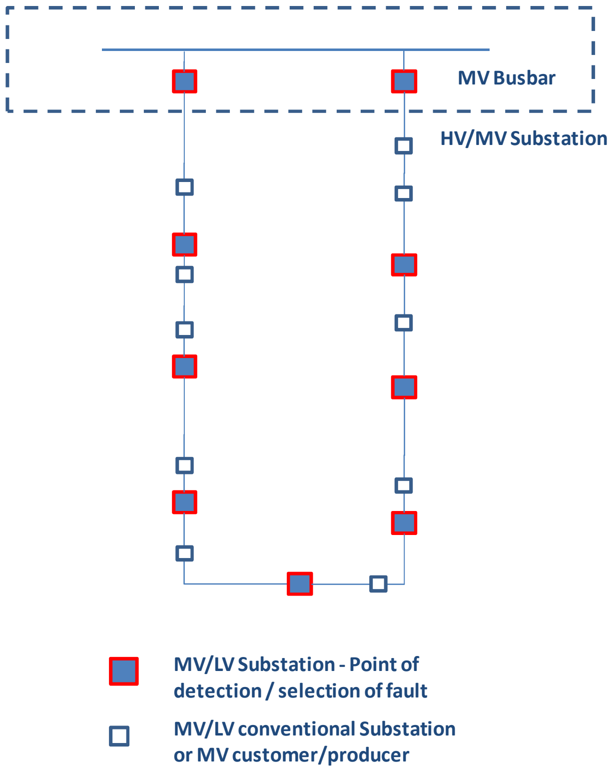

Fig 1: General System Configuration

Communication Equipment in HV/MV Substation

In future Smart Grids, network intelligence will be more distributed than it is now in order to avoid unnecessary complexity to perform those functionalities that can be carried on locally.

In P4 project the most important functionalities are related to the protection system, whose "intelligence" typically resides in MV/MV Substations.

To ensure online connection between HV/MV Substation and the equipment installed along MV loop, communication equipment (routers, etc.) will be installed inside the Substation itself.

The application protocol for this connection will be IEC 61850, while TCP-IP protocols are currently already adopted for the connection between the Central Control System and HV/MV Substations.

MV/LV Substation Devices

Sensors/Fault Detectors
(Smart) Sensors are a standard component of any Smart Grid architecture: it can be said that the whole Smart Grid concept is based on the capability of measuring, sharing and managing real-time information on network condition.

As said, in a closed-ring operated MV network the availability of those measures is also needed to ensure the protection system is effectively able to interpret network events, allowing an accurate selection of faults which enables to put out of operation only the faulty part of MV feeder.

Enel Distribuzione has developed a new Sensor/Fault Detector for installation in MV/LV [2] which allows reliable fault detection both in case of phase-to-earth fault and in short-circuit events: those fault detection capabilities are able to support clearance functionalities of any kind of fault (transient, permanent, phase-to-earth, phase-to-phase) with the involvement of the circuit breakers closest to the fault itself.

Peripherals for MV/LV Substations
MV/LV Substations which will be chosen to implement the control functions related to closed-ring operation will be equipped with new peripherals (modems, routers, etc.) able to support the measurement and control information flows required by the system.

The application standard protocol will be IEC 61850 .

Power components
As a general condition, it can be assumed that innovative power components are needed to meet future Smart Grids' requirements.

In fact, existing MV switches for MV/LV Substations can ordinarily perform a number of cycles which is not in line with the performance which general Smart Grid functionalities (e.g. automatic/suggested reconfiguration) may require.

Furthermore, MV switches could not be able to perform the selection of short-circuit occurrences along MV feeders: this feature, which can be relevant in any state-of-the-art MV network, is even more important – not to say crucial – in a closed-ring operated one, whose expected benefit are mostly related to enhanced connectivity and continuity of supply.

The adoption of circuit breakers instead of switches in MV/LV Substations can fulfill both above requirements in terms of reliability and performance.

Enel Distribuzione has recently standardized and adopted a new generation of equipment for MV/LV Substations [3]. These new devices, dimensionally interchangeable with currently installed switchgears and fully compatible with the command and control interface of the remote control smart unit installed in MV/LV Enel Distribuzione's substations, are no less than circuit breakers with all related characteristics in terms of switching time, short-circuit current making and breaking capability and extended mechanical and electrical endurance.

Communication System

It can be said that a Smart Grid results from the interface of two systems: a (more or less) conventional electric network and an ICT system. While this definition is not completely accurate, it is true that the real innovation needed for enabling all Smart Grid functionalities is the implementation of a comprehensive and effective communication system to link all relevant network components and devices.

As the first system (the electrical network) is generally already in place, the real challenge is to build the second in a reasonable amount of time, at reasonable costs, possibly everywhere.

Presently, the most obvious choices for a proprietary infrastructure are optic fibres and Wi-Fi technologies.

To be able to test both of them, it has been decided to adopt:
- optic fibres in combination with existing overhead lines, which have been transformed in overhead cable lines to accommodate on the same poles the optic fibres as well. This usually occurs in more rural areas, where distances are longer and Wi-Fi (Wi-Max) communications might require additional infrastructures;
- Wi-Fi (Wi-Max) in combination with existing underground lines. This mostly occurs in urban areas, where distances are shorter and it would be difficult to build new underground facilities for optic fibres.

PROTECTION SYSTEM

The protection system is probably the real innovative feature of this project.

In fact, an advanced closed-ring operation as it is meant in this project requires a new way of thinking MV line protection: in this configuration, circuit breakers are not located at the beginning of the feeder but distributed along the feeders themselves. Therefore, in order to be effectively operated, each one of them must be regarded as single point of fault detection/protection.

This means that any closed loop requires a protection system which is able to manage a large (typically 8-10 for each loop) number of field signals, each one related to a "point of detection/protection" (PoDP), getting the information, interpreting it and giving the appropriate commands.

The general concept behind that, which would imply the overcoming of present protection philosophy, linked to the "feeder" concept, in favour of a new one, based on a "network" paradigm, is far beyond the scope and possibilities of this document. But in the case of a closed-ring configuration this result can be achieved by means of a (nearly) conventional component.

Enel Distribuzione has recently certified and adopted a new protection device for HV/MV Substations, in which all transformers and MV feeders protections, among others, are managed by a single device; protection functionalities and logics are performed by programmable processors.

The functionalities of the protection system for the pilot plants to be tested will be therefore achieved by transferring all fault detectors' signals to one single central protecting unit; the fault interpretation rules will be implemented in the processor of the unit.

NEXT STEPS AND FURTHER DEVELOPMENTS

Evolution of the Project

The project started in 2010, but the main activities to put the system into operation are expected in years 2011-2012.

Five pilot plants will be realised on field, and will be operated as a close ring for at least one year, experiencing different network condition in everyday operation as well as in emergency and fault management.

Enel Distribuzione will be able to evaluate whether the presumed effects in terms of voltage profile, power losses and grid reliability will be actually accomplished; in the same time, the innovative components and functionalities will be fully tested and validated. All experiences will be tracked and translated into operation codes.

A final report will be produced in order to summarize the "pros" and "cons" of closed-ring operations, e.g. compared with conventional and/or innovative ways of planning and managing the same MV network.

Possible extensions

As a first step towards new possible ways of network management, P4 project has been intentionally focused on operational and protection issues, trying to limit the complexity of the system itself; that's why the closed loop involves two existing feeders starting from the same MV busbar and no other advanced functionalities (e.g. DG dispatching or voltage control, etc.) are going to be experienced in the same pilot plant.

In case the system proves itself stable and reliable enough to encourage a significant adoption in existing networks, it can be thought to test it in different conditions, e.g. in closed-ring configuration of two MV feeders starting from two different MV busbars belonging to the same HV/MV Substation.

An even further step could be the testing of meshed operation in case of two feeders starting from different HV/MV Substations; this would anyway require a much wider approach to network protection and an epoch-defining change in philosophy and technology.

ACKNOWLEDGEMENTS

The authors would acknowledge the Italian Ministry of Economical Development, which has funded the project described in this paper within an Innovation Program carried out in 4 Regions of the South of Italy in the frame of the Programma Operativo Interregionale "Energie Rinnovabili e Risparmio Energetico".

REFERENCES

[1] G. Di Lembo, A. Cerretti, L. Consiglio, A. Fatica, CIRED 2011, Frankfurt, June 6-9, 2011, Paper 0465 "Advanced management of Distributed Generation on MV Network";

[2] R. Calone, A. Cerretti, A. Fatica, CIRED 2011, Frankfurt, June 6-9, 2011, Paper 0507 "Evolution of the Fault Locator on MV distribution networks: from simple stand alone device, to a sophisticated strategic component of the SMART GRID control system";

[3] L. Giansante, M.C. Dota, CIRED 2009, Prague, June 9-11, 2009, Paper 0446 "A Low-Cost High Performance MV Switchgear for use in Remote Controlled MV-LV Substations: First Results of Enel Distribuzione Experimentation".