ADVANCED MANAGEMENT OF DISTRIBUTED GENERATION ON MV NETWORK

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ABSTRACT

The paper describes the innovations introduced by an on-going project, founded by the Italian Ministry of Economic Development and leaded by "Enel Distribuzione", that represent a first step towards the Smart Grids. The project introduces a new advanced management of Distributed Energy Resources (DER) in order to avoid the problems coming from reverse power flowing and maintain the necessary level of availability and power quality.

INTRODUCTION

One of the main barriers to further increase in Distributed Generation (DG) in Europe is the hosting capacity of the electricity grid. Since the existing network was designed for mono-directional power flows, there is a limited capacity to integrate Distributed Energy Resources (DER). Connecting a large number of DER can cause problems such as unacceptable level of power quality, generation-load imbalances, protection problems and network congestions.

The new proposed management of DER, should avoid the aforementioned problems and improve the situation as far as the hosting capacity is concerned.
This project, named POI-P3, is funded by the Italian Ministry of Economic Development, within an Innovation Program carried out in 4 Regions of the South of Italy, in the framework of the "Programma Operativo Interregionale - Energie Rinnovabili e Risparmio Energetico".

The main points of the application are:

- a communication infrastructure based on a broadband, "always on" technology to connect MV producers, passive customers, main secondary substations along the feeder and supplying Primary Substations (PS); communication between PS and Control Centre is already active;
- a new protection and control system in Primary substations, adopting new criteria to manage the "On load" tap changer of HV/MV transformer (the current technique is not effective because of DER);
- a suitable HW/SW at peripheral and central level to implement control functions and data collection.

MAIN FUNCTIONS OF THE SYSTEM

The project will be the proof of concept of many Smart Grid functions and many others can be implemented over its HW/SW architecture.
The most important of them will be tested soon, the others will be developed later because they go beyond the scope of funding of the Italian Ministry.
Of course, for their realization a reliable and efficient communication system is the necessary background infrastructure, to allow the exchange of information between control systems and active (generators) and passive (load) nodes belonging to MV network.
Furthermore, in terms of regulation, other actions are needed, from one hand adjusting the rules for the connection of customers to the network (new devices must be required on their side), from the other hand enabling the distributor to perform all the necessary "Dispatching" activities.

Prevention of islanding and improvement of the Producers Protection Interface (SPI) towards distribution MV network

The two functions mentioned in the title can be obtained by changing the SPI devices, today bought and installed by the private producer inside his power plant.
The enhancements will consist in the improvement of the behaviour of the anti-islanding protection based on network frequency and voltage variations and the introduction of a remote tripping command coming from the control system of the Distributor.
The first intervention will prevent accidental tripping of the generator due to spurious frequency and/or voltage changes, the second will increase operation security, avoiding islanding operation in any network condition, thanks to a tripping signals from the Distributor.

Voltage control

The reversal of power flow in MV feeders due to DG can rise the voltage of some nodes, over the allowed value.
Through the modulation of active/reactive power produced/absorbed by each producer it is possible to cope with this effect producing two main benefits:

- increase in the hosting capacity of the feeder;
- improvements in the voltage quality on active MV distribution networks.

The realization of this function is based on special commands to be sent by the Distributor Control System to the generators along the feeders and on the possibility of these generators to change the active/reactive power according to these setting commands; the improvements, therefore, mainly impact the DG side that is outside the Distributors' influence.
In this phase of the project the regulation action will be made asking the producer to absorb reactive energy more

then active in order to avoid impact on annual incomings that are directly connected to this value. Later on, depending on regulation, also active energy could be asked.

Restriction of DG produced active power in emergency situations

The controlled variations in active power can be used both to control the voltage along the MV lines and to deal with dangerous situations such as network overloads, limits in electricity conductors, excessive reductions in the load, etc. The System provides this function but, obviously, its use is limited by the present regulation.

Monitoring of DG energy injections

The aim of this function is to collect "real time" information on the power generated by DG in the deep of the MV network and elaborate data in such a way to have the amount of generation aggregated by each feeder, transformer, substation and separated according to genaration technology (solar, wind, biomass, etc).

This is fundamental for network operation and dispatching from the point of view of the Distributor but also of the Transmission Network Operator (TSO).

In fact to manage the network correctly it is necessary to know information about the real load, the amount of production, how much this energy is unpredictable.

To enable this function, the System needs:

- measures taken directly from the producing equipment in the deep of the MV network;
- a system to receive and aggregate the measures in the right way;
- a big Data Base to store and elaborate, even temporarily, all data;
- an interface to access the collected data from the operators in the control centres;
- a direct link with TSO control systems to exchange information.

Of course, time is needed to collect all data from the network and to elaborate them: this means that the meaning of the word "Real time" must be considered in a relative way, accepting a 15-20 minutes sampling time.

GENERAL ARCHITECTURE

This chapter describes the main components that we plan to develop according the current view of the System, taking into account that, with the progress of the activities, some solutions might not be suitable or inefficient and therefore others may arise.

Computing logics in Primary substation

It is a sub-system for monitoring and control that concentrates all information from the substation protection system, peripherals in the deep of supplied MV network, and from the DG. It manages the synchronization of peripheral components, monitors the operation of the communication network, aggregates and distributes the measures from the network, etc.

It is connected directly with the local Remote Terminal Unit (RTU) and communicates with the Control Centre via a dedicated IP network. On the other side, it communicates with all the new peripherals installed in MV/LV substations, MV customers and DG along the supplied feeders.

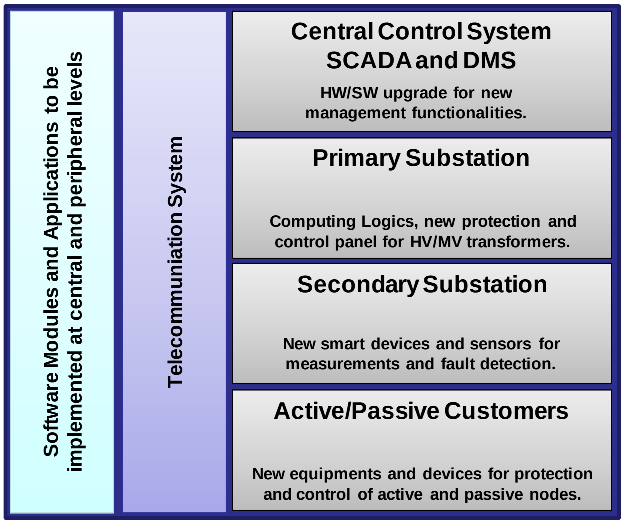

Figure 1: General Architecture

New protection and control panel for HV/MV transformers

A new panel has been developing to control the transformers and the corresponding tap changers in Primary substation.

This new panel integrates the present protection devices installed in correspondence of the HV (primary winding) and MV (secondary winding) circuit breakers respectively, and the Automatic Voltage Regulator (AVR) acting on tap changer.

The new three-in-one panel has the capability to be connected via Ethernet to the substation new computing logics, using IEC 61850 standard protocol.

Among the new advanced embedded functions, it is important to highlight the possibility of receiving and actuating the values for setting the MV bus bar voltage.

This values will be calculated by suitable state estimation and optimization algorithms and sent to the panel in advance, day by day or in real time.

Communication Equipment Primary Substation

HV/MV substations must be connected to the Control Centre (CO), from one hand, and to the equipment installed in the deep of the supplied MV network, from the other hand.

Devices of different technologies (optical fibres, Power line carrier, wireless networks, etc.) can be adopted; routers and Ethernet switches complete the network inside and outside the substation.

Other device could be necessary to ensure the security of the connections e.g. firewalls, backup connections and power reserve in case of lack of primary energy supply (UPS, batteries, etc).

Central Control System SCADA and DMS

The central system of remote monitoring (SCADA) should be upgraded in terms of hardware and software, adding all the functions and protocols required to handle all new peripheral devices and the information coming from these. To perform the new applications it needs a DMS (Distribution Management System) that allows to evaluate the network behaviour in both connection states ("simulated" and "real") and in two distinct modes ("off line" and "real time"). The main functions of the computations provided by the DMS range from a simple load flow, to state estimation, optimization for loss reduction, and so on.

Secondary substation Equipment

Some secondary cabin along the MV feeders and certainly those which connect big passive customers and producers, must be provided with new equipment, including:

- Circuit breakers to operate in case a short circuit occurs;
- Communications equipment towards customers and towards distributor systems (RTU, modems, fiber optic RTX, Routers, etc);
- Sensors for measurements and fault detection;
- Computing device to implement control logics and automation;

Equipment inside the passive customer premises

At least the large customers have to be connected to the System in order to disconnect them in the event of failure or to command variation of power consumption, etc. This implies:

- an optical fibre connection to the communication network of the distributor;
- Ethernet switch;
- General protection device (PG) suitable for the planned new applications;
- Emergency power supply for such equipment.

Equipment inside the active customer premises

Even producers have to be connected to the System to be disconnected, to receive commands for the variation of the produced power parameters, to provide measurements needed for network operation and so on. This implies (see Figure.2):

- Optical fibres for the connection to the communication network;
- Ethernet switch;
- General protection device (PG) suitable for the planned applications;
- Producer Protection Interface (PI), to assure appropriate frequency thresholds, remote command actuation, telesetting, etc..
- Production supervision system or Inverter controllers capable to receive setting commands from the Distributor and actuate the variation of power parameters, in accordance with the requests coming from the Distributor;
- Inverters allowing the modulation of active/reactive power, in a reasonable range to comply with Voltage control function and Active/reactive power control functions, as state in the previous chapter.
- Emergency power supply for such equipment.

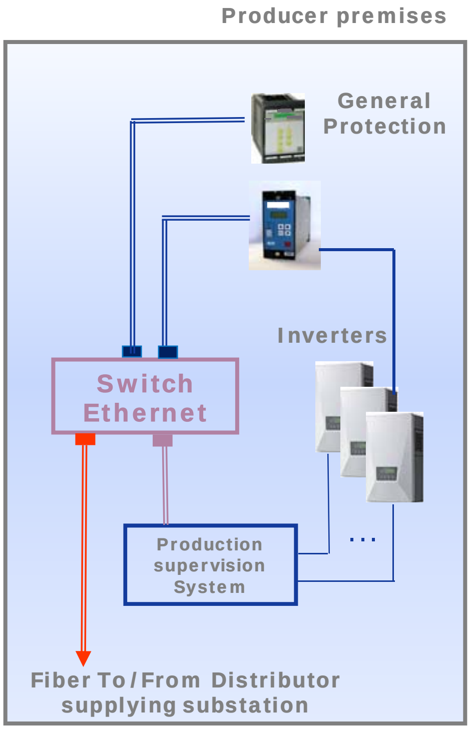

Figure 2: Producer equipment

Software modules and applications to be implemented at central and peripheral levels

Of course, in addition to the physical equipment to be installed on the network, it is necessary to develop a lot of application software implementing the functions described above.
These SW modules will be an integral part of the various devices and components and must be integrated together in order to build a single management system.
A short list of the main application is the following:

- Optimal Switching functions to find the best Network connection status to reduce losses and increase production from renewable sources;
- MV voltage control in all nodes of the MV network, in coordination with MV bus bar setting in Primary substation;
- Control the flows of active and reactive power;
- Frequency threshold control of producer SPI and Anti-islandig;
- Dispatching loads and DG;

Telecommunication System

The component/system, which is the necessary background for the implementation and proper functioning of the system described so far, is the telecommunication system.
For the connection between the Central Control System and primary substations, a point-to-point virtual connection is currently adopted, using a private IP network managed by public providers.
Already being a modern broadband communication network, this infrastructure can support efficiently even the

future needs. Security constraints have been solved using Virtual Private Network (VPN), secure IP protocol (IPSEC) and firewalls.
With reference to the links with secondary substations and customers/producers, wireless communication technology such as WiMAX or 3G can be used (see FIG.3).
In addition, it is also planned the adoption of optical fibres whenever possible. In particular the new technology called ADSS (all-dielectric self-supporting), is being adopted. This allows the installation of fibres on existing overhead energy lines up to 52 kV, without changing power conductors or poles.
The problem of communication security measures will be solved through the authentication of terminals and data encryption.
As far as protocols are concerned, apart from TCP-IP the application standard will be IEC61850, which will be applied not only inside the Primary Substation (LAN) but even outside, to communicate with equipment in the deep of the supplied MV network (extension of Primary substation).

PROJECT TIME SPAN AND MANAGEMENT

The activities started in 2010 and should finish at the end of 2012, involving several feeders in the southern regions of Italy.
The feeders have been chosen taking into account the number and the power of the producers that are already connected and the pending requests of connection.
Of course the Producers are not obliged to participate in the project because there is no regulation issue on this matter, but they should be incentivated by the fact that all the expenses will be in charge of Enel and there are some benefits on customer side.

BENEFITS

Apart from the "Proof of concept" for larger application, the main benefits of this smart grid implementation are shortly described below.

Increase of MV network hosting capacity

Thanks to anti-islanding, voltage control, active/reactive energy control etc, it is possible to increase the DG connecting capacity of the MV feeders. Therefore the hosting capacity is the main benefit, but it produces, in turn, other benefits such as the ones listed below.

Reduction of greenhouse gas emissions

The increase in the energy produced by DER implies, the reduction of carbon dioxide emissions.

Increase of energy efficiency

The widespread increase in dispersed energy generation also leads to increased in energy efficiency, in line with the previsions of Directive 2006/32/EC.
In fact, in case of DG, the generation is very close to the load, so reducing the amount of power circulating in the network, lowering the current and losses, especially when the injected power is less than the total absorbed by the local loads.
In addition, testing the demand response leads to an increase in end-use energy efficiency, forcing customers to use energy at times when it is cheaper.

Optimization of investments in network expansion

In perspective, a further benefit, could be the reduction of investments necessary for network expansion. In fact, a greater amount of installed DG in the MV network leads to a better synchronization of energy consumption and production in a specified territorial area, reducing the load of the network, and then obtaining a deferral of network investment.

Participation of Distributor to the market for ancillary services.

Finally, the communication system and equipment deployed in the project can be used for a "Local dispatching". In particular, it is possible to act in real time on the generators in the network by increasing or decreasing energy production or the reactive power provided by them so as to ensure the proper management of the distribution system, including also services toward the national grid (TSO services).

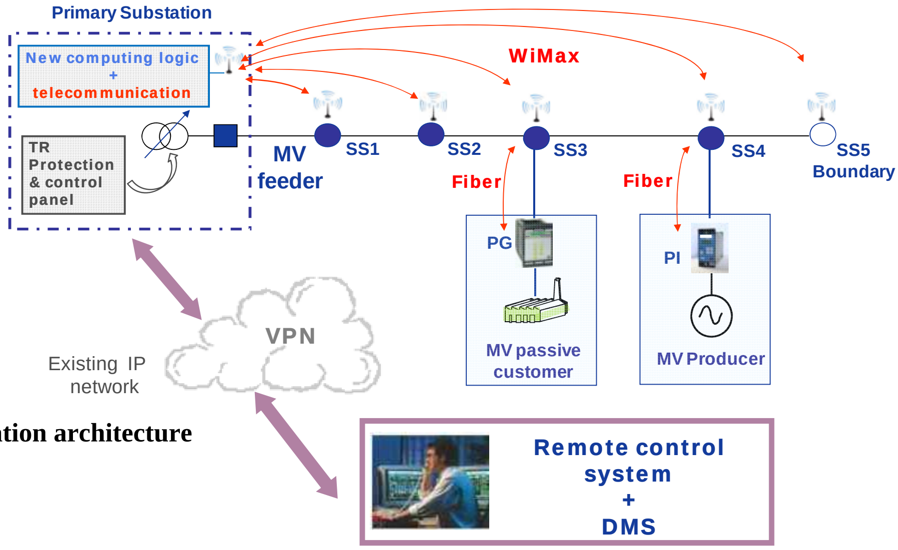

Figure 3: Communication architecture