ENEL'S LARGE SCALE DEMONSTRATION PROJECT INSIDE GRID4EU: THE CHALLENGE OF RES INTEGRATION IN THE MV NETWORK

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ABSTRACT

The paper describes the main features and the state of the art of the demonstration project Enel Distribuzione is implementing in Italy (area of Forli-Cesena) in the framework of the European Project Grid4EU. The objective is to increase the hosting capacity of Medium Voltage (MV) network for Renewable Energy Sources (RES), realising an advanced control system.

INTRODUCTION TO GRID4EU PROJECT

The project Grid4EU is an innovative 4-years Smart Grids project started in November 2011, co-funded by European Union under the 7th Framework Program. It has been proposed by a group of six Distribution System Operators (Cez Distribuce from Czech Republic, Enel Distribuzione from Italy, ERDF from France, Iberdrola from Spain, RWE from Germany and Vattenfall from Sweden) in close partnership with a set of electricity retailers, manufacturers and research organizations. ERDF is the coordinator with Enel Distribuzione as Technical Director and Iberdrola chairing the General Assembly. The core of Grid4EU is the implementation of six, strongly integrated, large scale demonstration projects in the abovementioned EU Countries, to test innovative system concepts and technologies, highlighting and helping to remove some of the most important barriers to the Smart Grids deployment. The main issues addressed are:

- Maximizing the integration of small and medium-size distributed energy resources
- Increasing energy efficiency
- Enabling and integrating Active Demand
- Enabling and developing new electric energy usages (e.g. electric vehicles, heat pumps, etc)

The six demonstrations are briefly described below [1]:

German Demo in Reken, North-Rhine Westphalia, will implement a "multi-agent system" for MV network that will allow integration of DG in the MV and LV network. Partners are RWE, ABB and Technical University of Dortmund (TUD).

Swedish Demo in Uppsala will target monitoring and controlling LV networks via existing and enhanced "advanced meter management technology" for the Nordic region. Data from the system will help improve the quality of service and DG integration. Partners are Vattenfall, ABB, EMeter, Swedish University KTH and Telvent.

Spanish Demo in Castellion will implement a control system for MV and LV network in connection with a multi-layer solution for smart metering to enhance monitoring and controlling of distribution networks. Partners are Iberdrola, Current, Itron, Landis&Gyr, Ormazabal, Siemens and Ziv.

Italian Demo in the Emilia Romagna region, area of Forli-Cesena, will develop an advanced control system to increase the MV network hosting capacity of RES. Partners are Enel Distribuzione, RSE, Selta, Siemens and Cisco.

Czech Demo in Vrchlabi will look at how running a MV network portion in islanding mode with the power supply of combined heat and power DG. Electric vehicles and AMM system will be also addressed. Partners are Cez Distribuce, ABB, Cez Group, Cisco, Current and Siemens.

French Demo in Carros, near Nice, will validate the design and the operation of a new architecture for MV and LV distribution networks located in smart urban districts. Partners are ERDF, Alstom Grid, Armines and EDF.

Finally it is important to underline that, thanks to the fact that these demonstrations are implemented on large-scale real networks, with project structures that cover a wide range of technical, economical, societal and regulatory conditions, Grid4EU pursues the maximisation of the scalability and replicability potential of the solutions.

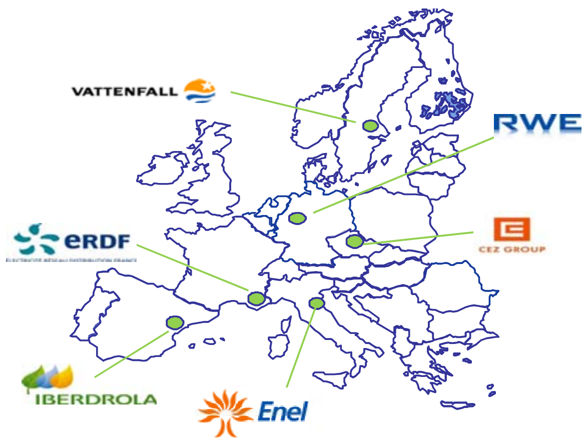

Fig.1: Demonstration projects mapping

ITALIAN DEMONSTRATION IN FORLI-CESENA

One of the main barriers for further increasing distributed generation in Europe is the hosting capacity of the electricity grid. Since the existing grid was designed for mono-directional power flows, there is a limited capacity to integrate Distributed Energy Resources (DER). In fact connecting a large number of DER can cause problems such as unacceptable level of power quality, generation-load imbalances, protection problems and congestions in the grid. In order to avoid the aforementioned problems and to maintain the necessary level of availability and power quality, the management of distribution networks in the presence of variable generation requires the development of advanced:

- Network Operation capabilities (i.e. maintaining the voltage level and frequency on every node)
- Energy Management capabilities (i.e. optimizing the energy flows in the network)

Addressing that, Enel's demonstration project goal is to demonstrate, under real operating conditions and on large scale, how DER (including –in addition to generators– controllable loads and storage), Active Control and Demand Response can increase the MV network hosting capacity of renewable energy resources, helping the distribution network to become more flexible.

The project, currently close to the start of the field installation phase, aims at realising an advanced control system communicating with MV DER, HV/MV and MV/LV substations and a storage facility, through an "always on" IP standard-based communication system for real-time data exchange, using both wireless and wired technologies and IEC 61850 standard. The new system will allow increasing the MV network hosting capacity, through:

- Implementing Voltage Control (at all nodes) and Power Flow Control in the MV network
- Developing new procedures for managing efficiently and reliably generation units disconnection in the event of unwanted islanding
- Enabling Ancillary Services for MV Network operation
- Enabling the dispatching of renewable generation on the MV network, including the use of a storage facility

The "key factor" of the project is the direct involvement of DER, that will become "active actors" in network management and operation.

DEMONSTRATION SITE DESCRIPTION

The demo project is located in Forlì – Cesena (Emilia Romagna, Italy), which is an area with a high penetration of renewable energy production, mostly photovoltaic (about 40 MW, with 24 MV producers over 500kW), along with low consumption.

In particular, the portion of electrical grid involved consists of 2 HV/MV Substations, over 20 MV lines, about 160 MV/LV Substations and at least 5 MV Distributed Generators and Customers directly involved in the experimentation. The project will also impact on about 35000 LV customers, that will benefit from the experimentation, even thought not directly involved.

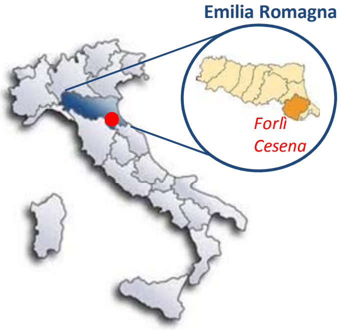

Fig.2: Italian project location

The 2 HV/MV Substations involved are named "Cesena Ovest" and "Quarto". In the following table are summarised load and generation figures of "Cesena Ovest" and "Quarto".

		HV/MV Sub. "Cesena Ovest"	HV/MV Sub. "Quarto"
MV "Active" Customers	**[n°]**	45	32
	[kW]	19.846	19.225
MV "Passive" Customers	**[n°]**	111	26
	[kW]	52.175	8.345

Tab.1: HV/MV Substations main figures

The HV/MV Substations have been chosen taking into account the critical aspects related to the high penetration of DER; Figure 3 shows the back-feeding phenomenon that happened on August, 19th 2012 in the "Quarto" HV/MV Substation, with reverse power flow from MV to the HV side, due to MV generation exceeding load. This phenomenon was observed several times over the past few months and it is a clear indicator of high DER penetration.

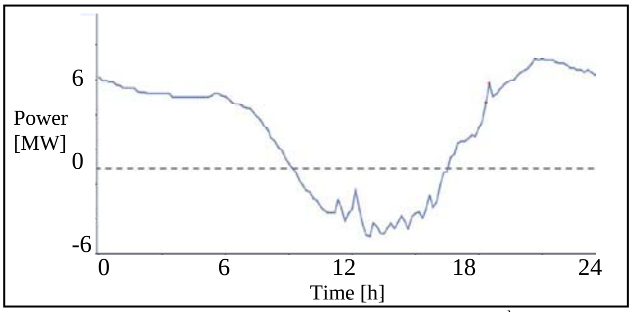

Fig.3: Back-feeding phenomenon – Aug, 19th 2012

ARCHITECTURE OF THE SYSTEM

The architecture of the system [2] is shown in the next Figure (Fig.4) and it is composed by 5 main functional blocks linked by the Communication System: Operation Control System, Substation Control System (HV/MV Substations), Integrated Transformer Protection (HV/MV Transformer), MV Control System; Customer Control System (MV customer). The red line represents the Electrical Link, whereas the dotted line the

Communication Link.

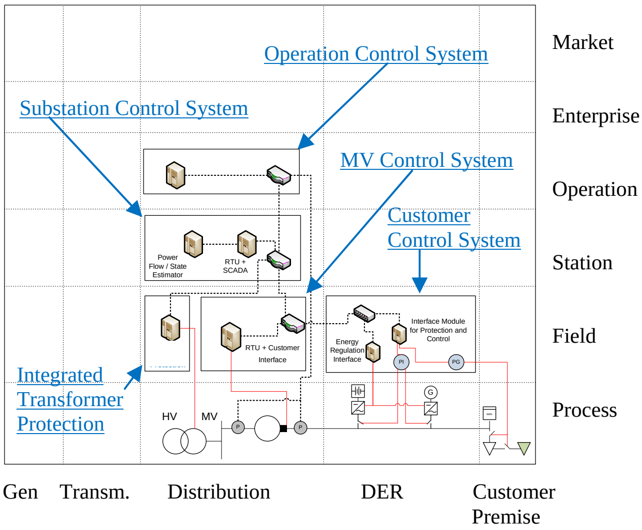

Fig.4: Overall system architecture (mapped on SGAM Component Layer)

The table below shows the manufacturer/developer partners related to each system. It has to be noticed that the system architecture is composed of several systems, which are, in turn, an aggregation of the ICT devices and equipment for grid operations.

System	Manufacturer/Developer
Substation Control System (SCS)	SIEMENS/RSE
Integrated Transformer Protection Panel (PIT)	SELTA
Power Line Communication System (PLC)	SELTA
MV Control System	ENEL
Customer Control System	ENEL/SIEMENS
Communication Network Devices (Routers and Switches)	CISCO

Tab.2: Systems manufacturer and developer

ICT infrastructure

The communication infrastructure is the "backbone" enabling all the new Smart Grids functionalities. Architecture shown in Figure 4 is based on an Information Communication Technologies (ICT) infrastructure allowing a real-time exchange (net of intrinsic delays of the system) of information between all the relevant nodes on the electric network and the Operation Control System. Different communication technologies will be tested, using public network (Wide Area Network-WAN) via fixed network (xDSL), wireless technologies (e.g. WiFi, 3G/4G, WiMAX meshed networks) and power line carrier (i.e. Power Line Communication-PLC).

Operation Control System (OCS)

ENEL DISTRIBUZIONE manages the MV grid by means of Control Centres, equipped with a SCADA (Supervisory Control And Data Acquisition) and a DMS (Distribution Management System), that performs computations. The **Operation Control System** is properly identified with the SCADA located in the Control Centres in charge of managing the MV grid (called STM – "Sistema di Telecontrollo rete MT"); it communicates with the Substation Control System located in the HV/MV Substation and sends/receives information to/from the devices located in the HV/MV and MV/LV Substations via SCS (Substation Control System). Moreover, it sends to the SCS the topological network description of the sub-network, which is under control of the HV/MV Substation System.

Substation Control System (SCS)

The HV/MV **Substation Control System** is composed by the following subsystems and is the "computational core" of the entire control system:

- Remote Terminal Unit - TPT 2020
    - Local Supervisory Control And Data Acquisition (SCADA).
- Algorithms for power flow management and DER control (voltage regulation, reactive/active power flows control, anti-islanding procedures) and storage device dispatching.
- Communication Network devices (Router and Switch).

The SCS is physically placed in the HV/MV Substation.

Integrated Transformer Protection Panel

The **Integrated Transformer Protection Panel** (the Italian acronym is PIT – "Protezione Integrata Trasformatore"), integrates the protection relays of the HV/MV transformer and On Load Tap Changer (OLTC). Moreover it is designed to manage the Tap Changers in order to implement the new voltage regulation algorithms and the new functionalities for DER management. PIT represents the "interface system" between SCS and transformers control actuators (Tap Changers), managing Tap Changers on the basis of setting signals received by SCS.

MV Control System

This system performs the control of the MV Network in coordination with SCS and OCS. The **MV Control System** is comprised of the following equipment installed in MV/LV substations:

- Remote Terminal Unit (RTU)
- Customer Interface Equipment
    - Directional Fault Detector and Measurements Acquisition device (RGDM)
    - Customer Interface device (IC)
- Communication Network device (Router).
- Power Line Communication system (PLC).

Customer Control System (CCS)

The **Customer Control System** is the "interface system" between the DSO Control System and the MV Customers, to implement reactive power control and to

enable active power regulation. The CCS receives input signals from the MV Control System and sends output commands to Customers internal control system.
The CCS is composed of the following modules:

- Energy Regulation Interface (IRE)
- Interface Module for Protection and Control (DV7300)
- Communication Network Switch

STORAGE FACILITY

Enel will install, close to MV Substation "Smistamento", a battery storage system (1 MVA – 1 MWh ca) that, due to the electrical scheme of the Substation, can be connected to several MV feeders. The goal is to study a new centralised/decentralised solution for voltage regulation to increase the network hosting capacity of RES. In particular, there will be the possibility to switch the storage over several feeders, depending on the results of an optimisation algorithm able to determine the optimal storage set-point and connection.

SYSTEM USE CASES BRIEF DESCRIPTION

The use cases methodology has been used to describe new system requirements, constraints, performance, security and data requirements. Four use cases have been identified and mapped using the SGAM (i.e. Smart Grid Architecture Model proposed by M/490 Reference Architecture Working Group) layers representation: "Voltage Regulation", "Anti Islanding", "Demand Response" and "Measurement Acquisition".

Voltage Regulation

In case of voltage limits violation due to the strong penetration of DER, the voltage control function regulates the voltage profile computing and sending appropriate set point commands to the distributed energy resources (generators, controllable loads and storage facility) and to the On Line Tap Changer (OLTC) of the HV/MV substation transformers. The algorithm is based on an AC Optimal Power Flow (OPF) where grid losses and integral constraints are taken into account. The status of the grid, required by the control algorithm, will be computed with a State Estimator function based on actual measurements and network topology. Load and generation forecasts are also used to optimise the management of distributed resources.

Anti-Islanding

When an outage occurs on a section of MV grid with DERs, generators protections –acquiring only local measurements– could not detect it in case of a local balance between generation and load.
In that condition the generators remain connected to the MV grid, creating an undesired islanding operation. In order to avoid unsafe and unsecure islanding operation in case of HV/MV Substation circuit breaker (MV side) opening, the system sends a disconnection command to the generators, thus assuring their disconnection from the grid.

Demand Response

This use case is related to controllable loads (MV customers with no generation) management; for voltage regulation purposes and for network security in case of HV or MV shortages, requests of temporary load reduction are sent to controllable loads in order to solve critical situations. The Demand Response use case is strongly related to the Voltage Regulation one.

Measurement Acquisition

Measurements are the basic information for performing all the control strategies. Thus, the acquisition of the MV measurements is strictly related to the other Use Cases (i.e. Voltage regulation, Anti-islanding and Demand Response) as a fundamental input for the algorithms calculation. The actors that exchange information with the system (i.e. SCS) performing Measurement Acquisition are: MV Control System, CCS and OCS.

The table below summarises the systems involved in each use case.

	Voltage Regulation	Anti-Islanding	Measurement Acquisition	Demand Response
OCS	x	x		
SCS	x	x	x	x
PIT	x			
MV Control Sys	x	x	x	
CCS	x	x	x	x

Tab.3: Use Cases related systems

CONCLUSIONS

Considering the huge amount of RES that has been connected over the past few years and having a look to future scenarios in Italy, the need to increase the distribution network hosting capacity of RES is imperative. A very impressive and significant result was achieved in 2011, when Italy registered the greatest increase of PV installed capacity in the world (9 GW ca, 32% of the overall), reaching the second largest PV installed capacity at world level. The Italian demonstration project will address this topic, realising an advanced control system for MV network and involving the MV customers (generators and customers with no generation) in network management. The field installation phase is planned to start in the second part of 2013 and the first field test results are expected to be available in 2014.

REFERENCES

[1] GRID4EU, Description of Work (DoW) – ANNEX I of Grant Agreement.

[2] GRID4EU, 2012, "Documentation for technical coordination", Deliverable dD4.1 – Demo4