SMART GRIDS: PRELIMINARY MV NETWORK MODEL USING REAL TIME DIGITAL SIMULATOR AND REAL DEVICES IN A CLOSED LOOP CONTROL

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ABSTRACT

The wide diffusion of Distributed Generation (DG) represents a possible development of modern electrical systems that can evolve towards "Smart-grids.
In fact, Smart-Grids should manage energy production and loads in a smart way, through appropriate communication systems and applications to be designed for the scope.
Moving in this direction, Enel Distribuzione, built up a new centre in Milan to carry out research and development activity on mart grids, adopting simulation systems and innovative instruments.
In particular, a real time digital simulator (RTDS) is being used to study the behaviour of the network in critical situation and to test the interaction with the devices to be developed.
This paper is focused on the simulation activity taking place on RTDS and some preliminary results are presented.

INTRODUCTION

The continuous growth of DG, in particular based on non-dispatchable renewable resources (i.e. photovoltaic and wind energy) must be managed in spite of the fact that actual distribution networks have been projected taking into account passive loads and unidirectional power flow (from HV to MV nodes). This philosophy has impacts not only the structure of the network, but also the protection, automation and control systems, the producer protections and finally communication systems.
Therefore, a definition of a new system architecture is necessary for both the HV/MV substations and the MV nets connected to them.
The real time digital simulator RTDS is the ideal tool for this activity: thanks to its multi-processor computation capabilities, it has the possibility to simulate the dynamic behaviour of any power device installed on-the-field, including new equipment based on power electronics. At the same time it can be physically interfaced to real devices, such as protection relays, regulators and control devices, to test them as if connected to a real network.

NETWORK STRUCTURE TO BE SIMULATED

The MV distribution network has been simulated first, adopting all the device models necessary to describe a ENEL standardized HV/MV substation, equipped with four MV feeders (see Figure 1).
In the next months this configuration will be extended further, in order to obtain a wide network model capable of cover all the relevant network conditions.
The primary substation is described through a pair of HV/MV transformers, equipped with tap changers and Automatic Voltage regulators, each feeding its own MV busbar.
The transformer MV neutral point is connected to the earth trough a Petersen Coil in parallel to a resistor (ENEL standard neutral impedance).
The lines are modelled using an equivalent model based on concentrated parameters (π model); these lines supply some loads and generators (both static or rotating generators).

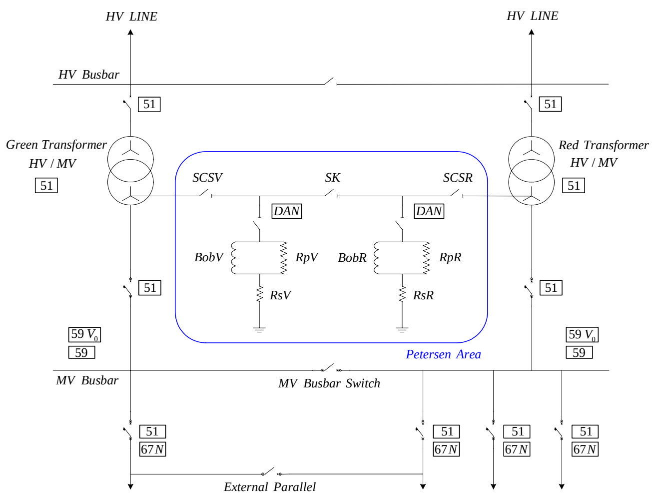

Figure 1: Diagram of the ENEL Primary Substation used in the simulations

In particular, each MV feeder departs from the Primary

substation with a circuit breaker and supplies three MV/LV automated substations according to present ENEL standards.
In this standard configuration, switch-disconnectors provide the input and the output of energy in a configuration with one MV/LV transformer. The loads/generators are located on the secondary winding of the transformers (LV) or connected to the MV busbar through a switch. For substation automation Fault detectors and Remote terminal units RTU are also needed (see Figure 2).

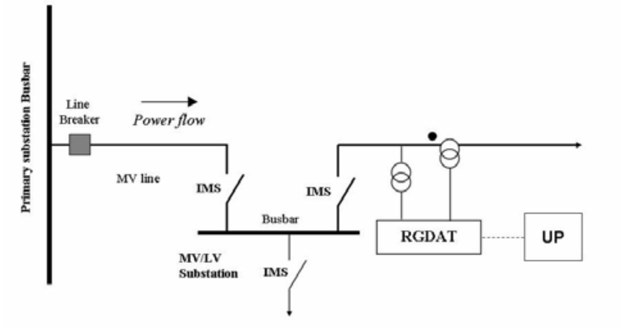

Figure 2: Diagram of ENEL Secondary Substation used for the simulations

DG and loads are connected to the MV lines through appropriate transformers (see Figure 3).
In order to represent the possibility to supply a MV feeder from a different substation, a boundary switch is placed at the end of the lines.
By means of this model is possible to analyze any generation/load condition, simply changing the internal simulate model of each generator/load.

OUTSTANDING ASPECT OF NETWORK SIMULATION ON RTDS

One of the noteworthy point of the simulation activity was the integration of the Petersen tuneable coil controller (in ENEL this tuner is called DAN). Thanks to RTDS capability to drive real equipment, the tuner has been inserted inside the closed loop simulation model as a real device.
Since DAN interacts with some power devices and sensors, exchanging both analog and digital signals, in the laboratory conditions, these signals must be provided in input and/or in output by RTDS. In particular (see Figure 4), the signals to be managed are the following:

- phase voltage
- zero sequence voltage
- injection current
- coil position
- coil upper/lower limit position
- inclusion/Exclusion of the series Resistance of the coil
- busbars coupler position
- increase/decrease in coil position
- state of insertion of supplementary coil
- external parallel condition.

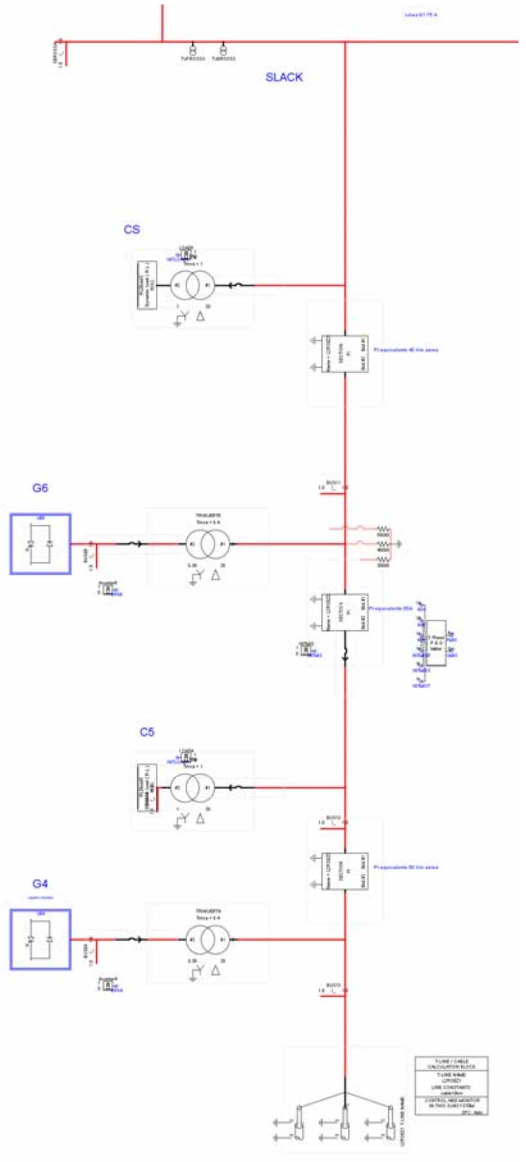

Figure 3: MV feeder model

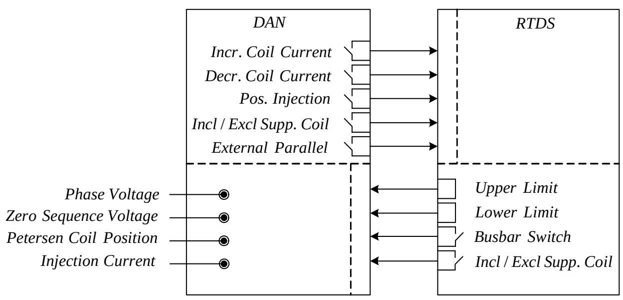

Figure 4: Scheme representing signals exchanging between DAN and RTDS

Another important step was modelling the generation by static converters using PWM technique (see Figure 5).
Other important models introduced in the simulation network were the following:

- the automatic voltage regulators acting on HV/MV transformers by "On load tap changers";
- modelling the generation by static converters (see Figure 5).
- synchronous generators;
- asynchronous generators;
- synchronous generators connected to the grid by means of static converters;
- doubly fed induction generators (DFIG) based on asynchronous generators.

This last two kinds of systems are referred to the wind energy generation.

Of course the work is not finished and the simulation activity is still in progress to complete the network model introducing the ENEL devices for network automation and remote control.

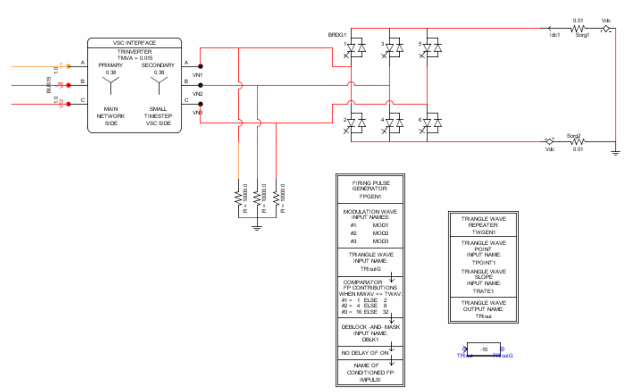

Figure 5: Model of a Static converter

SIMULATION AND FIRST RESULTS

The described network has been carefully tested in order to validate its behaviour in both, steady-state conditions and transients during faults.

Apart from the standard verification under fault conditions, a lot of tests have been done in order to analyse the correct operation of DANs.
The tests, executed on DANs belonging to two different brands and using different tuning techniques, validated the adequacy of the network models and the physical interface between DAN and RTDS.
It's important to remark that DAN uses a *current injection* into the neutral point of the transformer MV winding, in order to execute the measures to correctly find the tuning condition. Therefore, it is necessary to manage this injected current inside the model so as to allow DAN to measure the zero sequence voltage consequent to the injection.
One of the results of the simulation is shown in Figure 6, where the typical relation between the zero sequence voltage ($3V_0$) and the coil current (that indicates the coil position) is plotted.

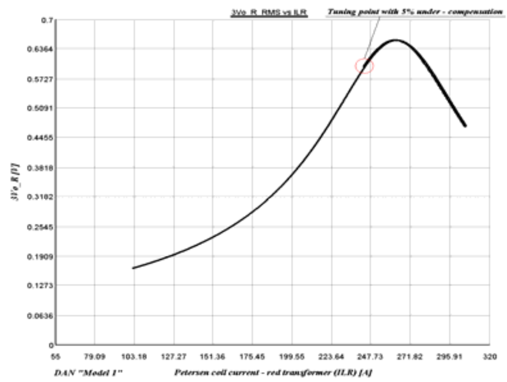

Figure 6: Zero sequence voltage vs coil current.

The following figures show results coming from the simulation of PWM (PLL-based) static converter (Figure 7 shows carrier and modulating waves from the converter controller, Figure 8 shows the currents supplied by it).

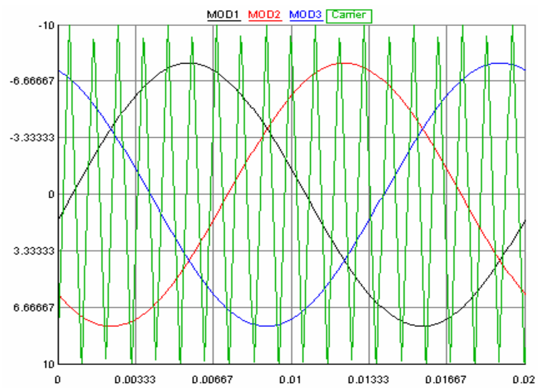

Figure 7 – Carrier and modulating waves

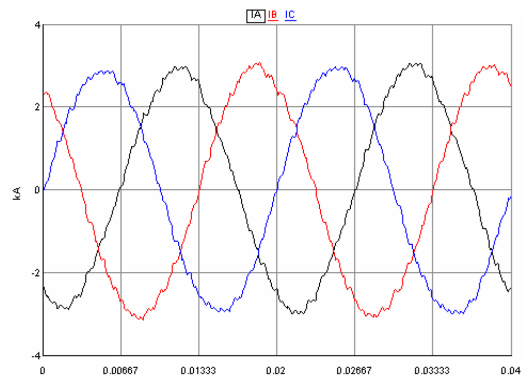

Figure 8 – Supplied currents by static converter

CONCLUSIONS

The growing diffusion of DG requires the evaluation of its impact on the power network in order to define smart management techniques to be adopted.

Enel Distribuzione started this hard work investing first in laboratory equipment and simulation activity in order to be able to study new application and test new devices.
The research aims to the definition of possible modifications in the architecture on distribution network and controlling devices and, on the other side, in the introduction of new operation technique to improve the distribution service quality.
RTDS is an essential tool for the job and it will help to find optimal solutions. Of course, at the end of the study carried on, a further step is scheduled to utilize the studied solutions in a real test field.

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