THE SMART TERMINATION: AN INNOVATIVE COMPONENT TO ENABLE SMART GRIDS DEVELOPMENT

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ABSTRACT

Up to now MV grid intelligence was concentrated in a few nodes, but, to enable Smart Grid's development, the presence of broadly distributed intelligence is a must; accordingly the installation of distributed measurement at several points of the MV grid is critical.
In this context Enel Distribuzione and 3M have worked together on a very innovative component to retrofit existing installations: a sensored termination (called "Smart Termination" in Enel Distribuzione's specification document) for air connection switchboards, with pre-calibrated, highly accurate, passive current and voltage sensors embedded. These components have been developed to be connected to the RGDM, the Enel Distribuzione smart device installed in secondary substations for protection, automation and MV Distributed Generation management.
In the first part of the paper the Enel requirements for Smart Grid devices (general functional and specific sensors requirements) are described, then the 3M product developed to meet these requirements is presented, and lastly the first sensored termination test and pilot installation results are presented.

INTRODUCTION

For a DSO intending to upgrade a classical MV grid to a real Smart Grid, an unavoidable precondition is to significantly increase the measurement points on the MV grid.
This can be more easily performed for new installations, but is not as easy when retrofitting an existing installation, in particular for switchboards with air connection, which are widespread in the Italian MV grid. This retrofit challenge is what led Enel Distribuzione to look for a suitable, simple and cost effective solution to upgrade its MV switchboards.
Another basic consideration is the choice between full integration of electronics and sensors, or separating the two parts. Considering Enel Distribuzione's well experienced practice to standardize grid components and guarantee their full interoperability, the objective was also to define the interface between sensors and electronic device (RGDM) in order to separate their supply.

ENEL FUNCTIONAL REQUIREMENTS FOR SMART GRIDS DEVICES

The Enel Distribuzione need was to have suitable sensors to measure line current and voltage, that were able to interface with the Enel **"RGDM"** Smart Grids devices (see Figure 1).

Figure 1: the Enel Distribuzione "RGDM" device

The RGDM processes current and voltage signal outputs from the sensors for the following functionalities:

- detecting polyphase and phase-to-ground faults, with insulated or grounded by impedance neutral;
- detecting line voltage absence;
- metering voltage and active and reactive power on the MV line;
- metering voltage and current THD (for PQ monitoring purpose);
- driving the circuit breaker opening and closing in case of faults or remote control commands;
- interfacing with the MV grid generators in order to coordinate the line voltage regulation, manage the generation (Reactive Power) and remote disconnection signals.

In order to comply with these requirements, and, in particular, to correctly detect phase-to-ground faults, the sensors' accuracy alone is not sufficient to guarantee the correct system operation, but it is also necessary to reduce the variability of ratio errors and phase displacement.

SENSOR REQUIREMENTS

The sensor requirements have been fixed considering the functionalities described in the previous section and the physical constraints resulting from the Enel Distribuzione standardized MV switchboards.

Physical requirements

The Enel Distribuzione objective was to find as minimally invasive solution as possible, in order to easily retrofit existing MV Switchboards, minimizing interventions on these pieces of equipment.
Considering the Enel Distribuzione particularity to have mainly switchboards with air connection (air insulated or mixed air/SF6 insulated) in service, a solution consisting of a termination for air connection (Enel standardized type NCDJ4457) with current and voltage sensors embedded was identified as the most suitable.
Moreover, considering the increasing diffusion of SF6 insulated MV Switchboards with plug-in connection, a further solution consisting in a plug-in termination (Enel standardized type DJ4155) with current and voltage sensors embedded, has also been identified to cover this application.

Sensor accuracy requirements

Enel Distribuzione has decided to consider that accuracy compliance is reached, whether attained by the sensor alone or through constant electronic compensation by the RGDM.
According to IEC standards, these accuracies have been requested in compliance with frequency and temperature variations (taking into account the maximum operating temperature expected for the installed solution).
Furthermore, for PQ monitoring purpose (THD measurement), the current and voltage harmonics accuracy has been requested according to EN 50160 and IEC 61000-4-7.
The required current accuracy is shown in Table 1, together with the standard deviation requirement, aimed to reduce error variability.
Voltage measurement accuracy, has been requested as 0,5 – 3P class with standard deviation 0,1.

Sensor/Electronics interface requirements

In order to guarantee the full interoperability of sensors and RGDM devices manufactured by different suppliers, the connector and the secondary circuit impedances have been defined and standardized.

Current (I/Ipr)	Ratio error (%)	Phase displacement (degree)	Standard deviation for 3 current sensors
0,01	± 5	± 2	0,8
0,05	± 1		0,2
1	± 1		0,01
20	± 5		-

Table 1: current accuracy (Ipr is the rated primary current, equal to 300 A)

3M DEVELOPED SENSORED TERMINATION

Building on over 40 years experience in the design and manufacture of cable accessories for MV networks, and on their broad technology platforms, 3M has developed an innovative solution that integrates very high accuracy sensors with a MV cable termination (see Figure 2).

Figure 2: the sensored termination from 3M

Taking into account the Enel Distribuzione requirements, the new 3M solution consists of pre-calibrated, highly accurate, passive current and voltage sensors, embedded into an indoor termination.
The innovative 3M connection enabled the development of a "one piece" plug & play MV cable accessory, answering to the key requirement of a cost effective, retrofittable solution, that can be easily installed without the need for field calibration, and is suitable for the most commonly used MV cable types and sizes.
The sensored termination from 3M is suitable for retrofitting a large variety of existing MV switchgear, without the need to upgrade structures, and is designed to provide reliable data in challenging environments which may present variability of frequency and temperature.
The current load measurement is obtained through a very accurate Rogowski coil, specifically designed for integration into the termination body.
The voltage measurement is obtained through a passive voltage divider sensor, that compensates for temperature variation.

Finally the sensored termination's assembly has been designed in order to protect the system from the influences of the ambient conditions present inside the switchboard (i.e. electro-magnetic field).
Furthermore the modular system design on which 3M has built their sensored termination enables application extension to plug-in interfaces, while maintaining the same "plug & play" connection and sensor module characteristics and performances (see Figure 3).

Figure 3: the plug-in sensored termination from 3M

The connection to the RGDM is obtained through electro-static and electro-magnetic shielded wiring terminated with a standard RJ45 plug.
The manufacturing process and quality controls performed for each produced part thoroughly support the consistency of the required measurements and application performances.
Both the sensored termination and plug-in sensored termination are designed by 3M and are manufactured in 3M's Marcallo Plant located in the North of Italy.

TESTS AND PILOT INSTALLATIONS

The first tests on the Smart Termination prototypes were carried out in 3M Marcallo's Laboratory (for initial sensor accuracy checks) and in Enel Distribuzione Milan laboratory (to verify the coupling with the RGDM) (see Figure 4).

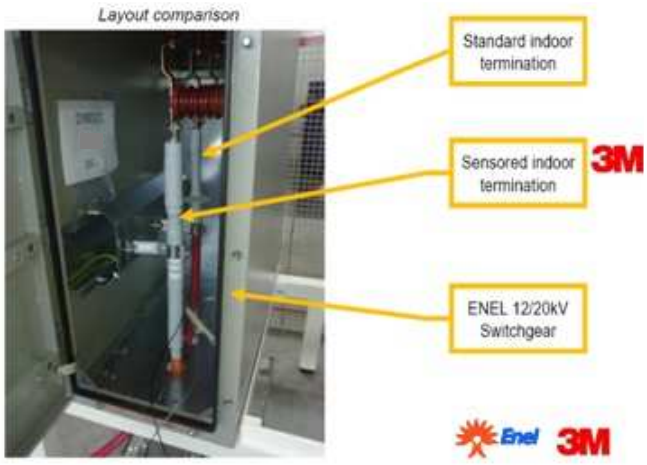

Figure 4: installation for initial tests

Afterwards, several pilot installations have been carried out on the Italian Enel Distribuzione distribution grid, which show very satisfactory performance of the sensor and electronics system. The new system has been installed in parallel with the previous Enel Distribuzione standardized system, consisting in a simplified electronics + CTs integrated component, provided of 2 phase CTs and a toroidal homopolar CT: in the first months all operations noticed by the old system have been correctly noticed and executed by the new system, consisting in 3M Smart Terminations connected to the RGDM.
Finally, the type tests, according to CENELEC standard for the termination and to IEC standard for the sensors, were performed in accredited laboratories proving compliance to the Enel Distribuzione requirements.

CONCLUSIONS

The main advantage of this component, suitable for the most commonly used MV cable types and sizes, is to allow the quick and cost effective upgrade of a large variety of existing MV switchboards, with high accuracy sensors, while maintaining separate electronic and sensors supply, without any intervention on the MV switchboards structure.
The results achieved give us good confidence about the industrialization of the identified technical solution, making the Smart Termination one of the first Smart Grid real components, tested, installed and ready for wide diffusion on the MV network.