



SOLUTIONS INNOVANTES POUR L'INTÉGRATION DES ÉNERGIES RENOUVELABLES DISTRIBUÉES SUR LE RÉSEAU ÉLECTRIQUE TUNISIEN

INNOVATIVE SOLUTIONS FOR THE INTEGRATION OF RENEWABLE ENERGIES ON TUNISIAN AND SICILIAN ELECTRICAL GRIDS



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Abstract—The spread of distributed generation from renewable energy sources, combined with their unpredictable behavior, requires the continuous monitoring and control by the Distribution System Operator, in order to guarantee the stability and efficiency of the distribution network. Thus, in this paper a new measurement and communication architecture is proposed, which foresees the use of innovative devices and different technology-oriented solutions, even redundant ones, which allows the transition from passive to active electricity distribution network, with minimal structural changes. The architecture has been developed in the framework of the SinERT project (Italy-Tunisia cross-border cooperation program 2014-2020), which is aimed at proposing innovative solutions to integrate renewable energy on Tunisian electrical grid, sharing knowledge and experience of two demonstrators built in Elgazala Technopark (Ariana, Tunisia) and Ustica (Sicily, Italy).

Proposed Communication and Management Architecture for DG and ESS connection

The proposed architecture is shown in Fig. 1. As previously mentioned, it aims at addressing the specific needs of various actors involved in power distribution network, i.e. DSO and users/prosumers. The key devices composing the architecture are: Interface Protection Systems (IPS), Power Quality Analyzer (PQA), Intelligent Electronic Device (IED), Innovative power converters, Hybrid PLC/RF communication system. The architecture also includes the use of properly developed control strategies of ESSs coupled with RES DGs. These control strategies aim at finding an optimal solution for both users and DSO needs, in terms of optimising energy management while taking into account grid stability requirements. Grid stability parameters are monitored through the deployment of interface protection systems (IPS) and power quality analysers (PQA), which are connected in specific points of the grid. These devices are able to provide real-time measurements of grid voltage, load currents, frequency, harmonics and total harmonics distortion (THD), when queried by the control centre. Moreover, control strategies are also implemented for DG involvement and active interaction with DSO's remote supervision systems (SCADA). The key element to achieve this is the use of innovative power converters, which can change their operating mode in real time. The converters are remotely controlled both in terms of active and reactive power values exchanged with the network. The converters are interfaced with the SCADA system by means of a new developed device called Interface Electronic Device (IED). The developed device uses different available interfaces (both wired and wireless) to communicate with power converters, as well as with DSO SCADA and measurement and protection devices. In order to have a complete connection of the devices located throughout the electrical grid with the SCADA system, the architecture provides a communication infrastructure that makes use of hybrid communication technologies based both on Power Line Communication (PLC) and Radio Frequency (RF), allowing flexible and reconfigurable connections based on network topology. This architecture has been already implemented in Ustica island [1]. The same architecture is the basis of the demonstrator to be installed in the Tunisian site of Elgazala technopark at Ariana city. The architecture of the Tunisian demonstrator is shown in Fig. 2, where also the contributions, roles and synergies among SinERT project Partners are highlighted.

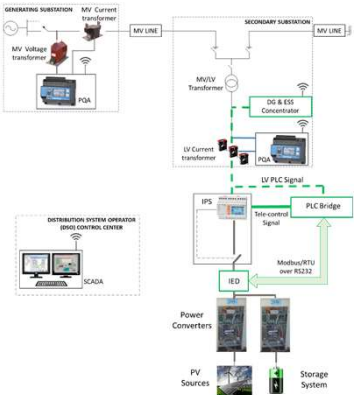


Fig. 1 Proposed communication and management architecture for DG and ESS connection to LV network

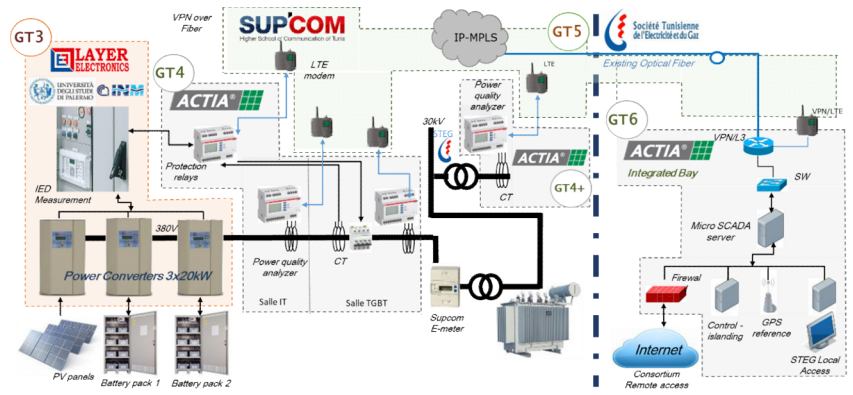


Fig. 2. Communication and management architecture implementation in Tunisian demonstrator.

Technological Solutions and Preliminary results

The proposed architecture makes use of different technological solutions that work in synergy to ensure not only a high degree of stability and efficiency of the electrical grid, which extends from the Distributor to the individual DG and ESS plants connected, but also the reduction of operating and installation costs related to industry standards.

A. Intelligent Electronic Devices for remote control of Innovative Bidirectional Power Converter

One of the innovative devices developed for the new measurement and control architecture is the IED, whose prototype is shown in Fig. 3. Its function is to collect information concerning the configurations of several converters in a generation and storage plant, as well as environmental information concerning the production sites. The IED then communicates with the innovative converters realised in the project both to acquire information regarding the current operation and to modify them in relation to the needs of the network. TABLE I shows the most significant information that can be read (R = Read) and modified (W = Write) by the IED on the connected converters. On the other side, the IED communicate with the DSO in different ways: XML SOAP 1.1, ModBus TCP/IP or ModBus RTU over RS232. The communication interface of the IED were tested using the PLC communication system configuration presented in Fig. 1 [2]. This configuration involves a "DG and ESS concentrator" and a "PLC bridge". These devices are linked together via a PLC link.

B. Innovative measurement and protection systems

The Interface Protection System (IPS) is designed to handle all islanding conditions in LV/MV traditional or distributed energy networks. The IPS includes 16 inputs and 12 relay driven outputs. The outputs are equipped with a programmable anti-bounce filter and designed to control security relays, switches, mains, etc., with an execution time less than 7 ms. The IPS module is interfaced to the power quality analysers (PQA) unit via CAN communication bus as well as to the CPU module. Once the PQA unit detects a fault, e.g., an islanding condition or an overcurrent event, the information is sent to the CPU module for processing. Subsequently, it requests to execute the protection protocol by the IPS during which the RES co-generation plant is isolated until fault condition disappear. Since the CPU module is equipped with embedded IEC 61850 and web servers, controls and countermeasures can be handled remotely as well. During UPS mode, as envisioned in SinERT project, IPS outputs can configure the privileged load setting and the logical IPS inputs verify the breakers and relays status for another layer of protection. In reference to Fig. 4, several IPS and PQA can be cascaded allowing for a flexible modular protection system.

C. The Hybrid Communication Infrastructure

A hybrid PLC/RF communication is proposed. The main purpose is to connect via PLC the data concentrator to the smart meters, installed in different points of the building to measure power consumption. The measured values are correlated to the meteorological condition and occupancy sensed then transmitted by RF mesh modules. The final goal is to build an IoT solution that allows to create a dataset of SUP'COM power consumption on which data analytics can be performed [3]. In the proposed application, the authors use PLC and 6LoWPAN communication protocol for PLC and RF media, respectively. Preliminary results of measured data are shown in Fig. 5.

TABLE I
IED Memory Map of DG & ESS Functional Parameters

Parameter Description	Parameter Type
PV Inverter operational mode	R/W
PV instantaneous power	R/W
ESS State of Charge	R
ESS State of Health	R
ESS operational mode	R/W
ESS Inverter operational mode	R/W
ESS instantaneous power	R/W
PV Nominal Inverter power	R
ESS Nominal Inverter power	R
ESS Nominal Energy	R
Contactors Status	R/W
Solar Irradiation	R
Ambient temperature	R



Fig. 3 The IED prototype.



Fig. 4 The IPS and PQA prototype set.

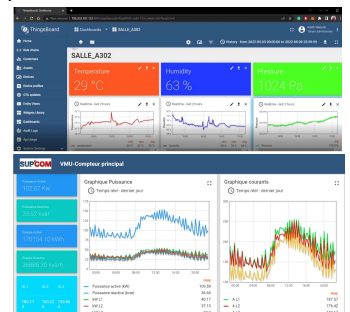


Fig. 5 (Up): Received data from the border router. (Down): SUP'COM power consumption sent by the installed smart meters.

[1] G. Artale et al., "Real Time Power Flow Monitoring and Control System for Microgrids Integration in Islanded Scenarios", in IEEE Transactions on Industry Applications, vol. 55, no. 6, pp. 7186-7197, Nov.-Dec. 2019.
[2] G. Artale et al., "A PLC based monitoring and remote control architecture for Distributed Generation and Storage systems in LV smart grids.", 2021 IEEE 6th International Forum on Research and Technology for Society and Industry (RTSI), 2021, pp. 255-260.
[3] A. Maalej and C. Rebal, "Sensor Data Augmentation Strategy for Load Forecasting in Smart Grid Context.", 18th International Multi-Conference on Systems, Signals & Devices (SSD), 2021, pp. 979-983.