Smart Grid and Microgrid Cooperation in a Real Distribution Network under Emergency Conditions

Abstract—**The paper presents a feasibility study regarding the ability of an existing rural microgrid to supply an islanded portion of the MV distribution network. Based on load and generation measurements in a six-month period, a statistical parametric analysis is carried out with the aim to check the ability of the microgrid to carry out such a service whenever requested. Also the possibility to supply the islanded portion of the MV grid during the whole six-month period is investigated. The existing microgrid is currently off-grid but in the near future will be connected to the MV distribution grid.**

Keywords—microgrid; flexibility; islanded operation; MV distribution network; distributed generation

I. Introduction

The increasing penetration of renewable energy sources (RES) into MV/LV distribution grids asks for a deep review in the energy infrastructure design, control and regulation logics. Nowadays, a great interest in microgrids is raising, mostly due to the possibility of RES utilization in conjunction with the achievement of reduced carbon emissions, increased energy efficiency through CHP, improved power quality and reliability of the grid [1],[2]. EU commission activated many H2020 projects about this topic. InteGRIDy (www.integridy.eu) is one of such H2020 projects. InteGRIDy aims at realizing and demonstrating a solution that helps to meet the challenges related to RES under a variety of environmental, market and societal conditions. Within the inteGRIDy project, 10 pilot sites all over the EU are developed to the test on field the actual performances of new solutions devoted to support the distribution system operation, with respect to four thematic pillars, namely: demand response; smartening the distribution grid; energy storage technologies; electric vehicle integration.

Among the 10 pilots, the one developed in Terni (in the Center of Italy) is related to a microgrid, characterized by localized loads, battery energy storage system (BESS) and distributed generators that can operate connected to the traditional centralized electrical grid, but can also disconnect and function autonomously. The main goal of Terni pilot is developing a hybrid cooperative business model between independent and privately owned microgrids, as the rural one present in Terni pilot, based on their unexploited potential as flexibility providers and/or energy surplus providers to the local Distribution System Operator (DSO), which is A.S.M. Terni S.p.A. (ASM in the following).

The paper focuses on a specific aspect of the inteGRIDy thematic pillar "smartening the distribution grid", namely the feasibility for a microgrid to supply an islanded portion of the MV distribution network. Based on energy consumptions and generations measured in a six-month period, randomly selected periods of islanded operation are simulated with the aim to verify the capability of the microgrid resources to carry out such a service whenever requested. Moreover, also the possibility to supply the islanded portion of the MV grid during the whole six-month period is investigated. A RES control strategy is proposed in order to guarantee the matching between load and generations. Only a feasibility study is presented in the paper, whereas the technical-economic optimization of the system will be addressed in further works, according to the solutions proposed by a closely related concurrently submitted work [3]. Section II describes the pilot case in Terni, whereas Section III details the modeling of the system. A microgrid resource control strategy is proposed in Section IV and the results of the statistical parametric analysis are presented in Section V. Finally, Section VI concludes the paper.

II. Terni Pilot Description

The ASM MV/LV distribution grid is characterized by a large number of distributed RES connected to MV and LV level: 1 biomass plant, 5 hydro power generators and 1,234 solar photovoltaic (PV) units, reaching an overall installed capacity of about 70 MW. It is worth pointing out that the yearly energy demand in the ASM grid is about 380 GWh: 196 GWh are produced by RES systems connected to the MV/LV grid, of which 26 GWh are from photovoltaic power plants, and the remaining 184 GWh are acquired from the HV Italian Transmission Network. ASM MV grid is connected to a SCADA system, whereas more than 95 % of ASM customers are equipped with smart meters.

Terni Pilot is going to be developed on the border between Terni and Rieti municipalities. The pilot site comprises the already existing farm "Il Moggio", which is at present a stand-alone microgrid, and the local energy infrastructures managed by ASM. An MV/LV secondary substation (SS) is going to be deployed and the necessary hardware and software equipment will be set up in order to monitor and control the microgrid resources. The farm covers an area of 14 hectares, in which 9 buildings are devoted to agricultural and commercial activities (basically primary and tertiary sectors).

"Il Moggio" microgrid comprises a significant amount of distributed generation: a 30 kWp rated PV plant, two 31 kVA – 25 kWt biomass CHP generators and a 60 kWh battery energy storage system (BESS). In detail, apart from internal loads due to the agricultural and commercial activities, the generation and energy storage units are as follows:

- The PV power plant is composed of 7 strings; each one has 14 modules (300 W), for an overall 29.4 kWp.

The PV plant can feed simultaneously both the microgrid load and the battery storage system through a static inverter made up of a DC/AC converter, a series-connected transformer and a DC/DC converter.

- 2 CHP generators, each 31 kVA – 25 kWt, connected without a static converter, whose fuel is supplied by two gasifiers. They are able to supply fuel for both electrical and thermal uses and require only dry organic materials (as wood chips, walnut shells, agricultural waste) to provide their services.
- The battery energy storage system consists of 50 series-connected 12 V - 100 Ah rated lead batteries, for an overall 60 kWh rated energy, responsible for the management of distributed generators without curtailments.

The connection of the "Il Moggio" stand-alone microgrid to the MV distribution network is under deployment. A 250 kVA SS will be built by ASM and connected to an existing overhead MV feeder. The SS will be connected to the SCADA system, whereas the technical-economic management of the microgrid flexibility will be carried out by a dedicated calculation platform [3].

III. System Modeling

The considered islanded system consists of the microgrid, a portion (12 kilometers long) of an MV feeder and 2 loads. A simple 3-bus model, shown in Fig. 1, has been developed and implemented in MATPOWER environment.

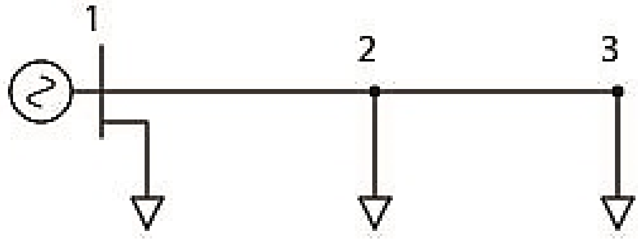

Fig. 1. The simulated islanded system.

The microgrid (bus 1 in the figure) has been simulated in the load flow as an equivalent generator and a load (the MV/LV transformer has not been simulated); bus 2 is a load bus (35 kW contractual power) representing three telecommunication antennas, whereas bus 3 is a load bus representing an aggregate civil load (4 users, 24 kW contractual power). A six-month period has been considered: both measured and simulated load and generation profiles are with a time rate of fifteen minutes (17280 quarter hours in total). Bus 2 and bus 3 load profiles have been taken from ASM measurements, collected every quarter hour. About bus 1 load profile (3.3 kW contractual power), no information was available from ASM, since microgrid is at present disconnected from the grid, so a six-month load profile of a similar customer has been used. Microgrid PV generation profile has been obtained by averaging measurements of 33 PVs installed in Terni and scaling according to the rated power. Fig. 2 depicts the PV generation profile along nine days in the simulated period. Lastly, the MV feeder is a three-phase, single circuit overhead line equipped with 70 mm^2 aluminum conductors: resistance, reactance and capacitance per unit length are 0.423 Ω/km, 0.37 Ω/km and 10 nF/km, respectively.

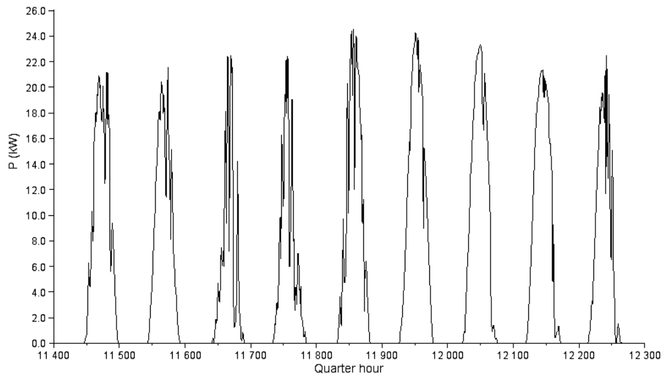

Fig. 2. PV generation profile along nine days in the considered six-month period.

IV. Microgrid Resource Control Strategy

In the randomly selected periods of islanded operation, PV is considered as the master component, since its production cost is null. When the islanded operation begins, the output power for each CHP is randomly chosen, taking into account auxiliary consumptions (1.1 kW for each CHP), minimum output power (4.72 kW for each CHP) and the maximum output power. Generator ramps are also considered during switch-off and switch-on of the CHPs. Also the BESS state of charge (SOC) is randomly selected. During islanded operation, BESS is charged whenever the PV generation exceeds the overall load, whereas is discharged whenever the overall load exceeds the available generation. If PV generation exceeds load and BESS is fully charged, PV curtailment is applied. If load exceeds generation and BESS is fully discharged, the islanded operation is not possible.

A more detailed description will be provided in the final version of the paper.

V. Results

A statistical and parametric analysis is presented, in which during the six-month period the following quantities are randomly selected:

- The quarter hour when islanded operation begins
- The duration of the islanded operation
- The CHPs output power
- The BESS SOC.

Based on the selected quantities and considering the measured load and PV generation diagrams, the islanded operation is governed by the control strategy described in Section IV. The final paper will report main results obtained, showing the capability of the microgrid resources to support the islanded operation of the system. Moreover, the possibility to operate the system in islanded mode for the whole six-month period has been investigated. Figure 3 reports the SOC (expressed in kWh) of the BESS during the time period: the operation is feasible if PV is curtailed when PV output exceeds the aggregate load and the BESS is fully charged.

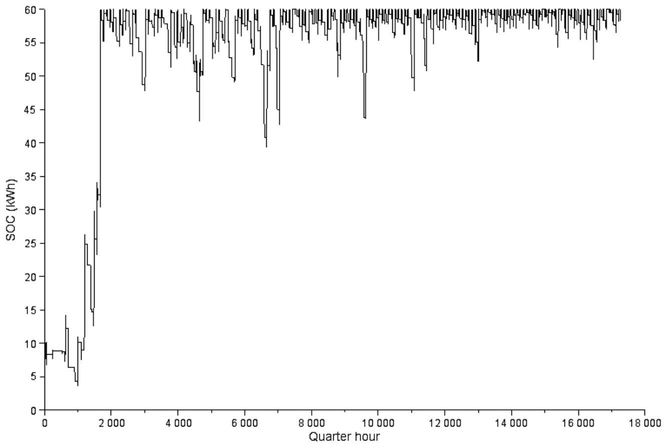

Fig. 3. SOC trend during the six-month period in islanded operation.

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[3] [Anonymous 2018] Under submission. Details omitted for double-blind reviewing.