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Modular Energy Management System Applicable to Residential Microgrids

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***Abstract*—In this paper, an energy management system is defined as a flexible architecture. This proposal can be applied to home and residential areas when they include generation units. The system has been integrated and tested in a grid-connected microgrid prototype, where optimal power generation profiles are obtained by considering economic aspects.**

I. Introduction

A microgrid (MG) is an aggregation of distributed energy resources (DER), such as renewable energy sources (RES) and energy storage systems (ESS), as controllable entities to supply loads which can operate either in grid-connected or islanded mode. When homes or residential neighborhoods install DERs in order to reduce their dependence on the main grid, they can be considered as residential microgrids. On top of that, for ensuring self-consumption and more profitable operation of the microgrid, it should be complemented with appropriate energy management system (EMS) [1]. The (EMS) defines set points for the DER in order to achieve optimal dispatch regarding specific objectives and limiting generation, demand or stored energy. Additionally, the EMS deals with the power exchanged with the utility grid when the microgrid operates in grid-connected mode, buying or selling the shortage or surplus of power to or from the main grid [2].

Moreover, the integration of DERs, control strategies, standard-based communication technology and management of data into microgrids is a current challenge [2], [4]. Additionally, the available technologies should be used to gather, analyze and manage the information provided by the metering devices to control the resources in an intelligent and optimal way [4]. In fact, the option of deploying this technology to have economically self powered homes is a close future.

This paper presents the implementation of an Energy Management System (EMS) as a modular approach that integrates the substation monitoring, forecasting, database and scheduling module. The specific study case is a hybrid PV-wind-battery microgrid that exchanges energy with the main grid in an economically optimal way.

II. Description of the System

A flexible structure integrated by independent modules has been designed and implemented as shown in Fig. 1. The modular structure of the EMS allows to use specialized programs and share information between modules by accessing the common database management system. The microgrid is deployed in one MG setup in the Microgrid Research Laboratory of Aalborg University [3] whereas the Energy Management System is implemented in a MG central computer.

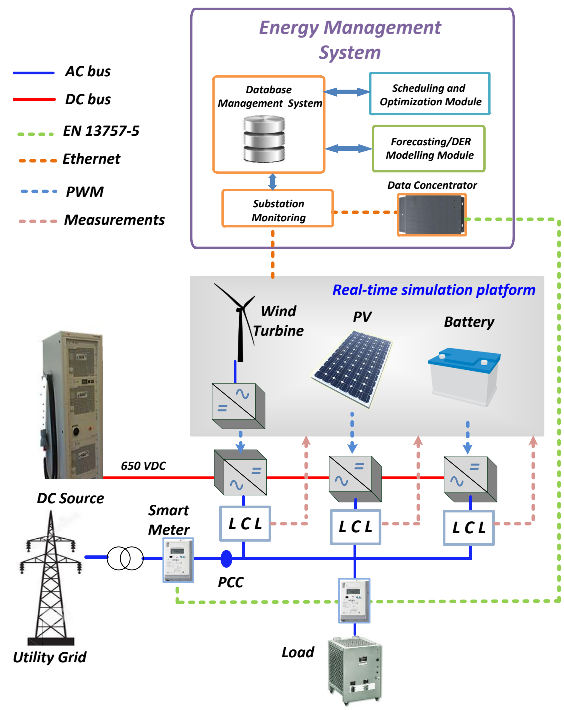

Fig. 1. Implemented system

The MG implemented as case study is composed of two renewable energy sources (RESs) a photovoltaic panel, a wind turbine and a battery connected to the grid supplying a fixed load. The DERs with their local controllers are emulated by means of a real-time simulation platform[1]. In a physical level, the inverters with LCL filters are connected in parallel to a constant load and to the main grid though a transformer. Since the microgrid is grid-connected, the utility grid imposes the conditions of the common bus (amplitude and frequency) while the power inverters work in current control mode as grid-following units [5], [6].

In the EMS, the database has several tables which consider the executed functions: location and hardware data, forecasting data, measurements and scheduling results. Besides,

[1] dSPACE

in the substation monitoring module[2], the measurements of RESs power, variables related to the battery and the cost of buying/selling energy to the grid are monitored by using ethernet connection. Simultaneously, measurements from the smart meters are being registered.

The scheduling and optimization module is the core of the EMS and, in this case, the data processing [3] works as interface with an algebraic modeling language (AML) [4]. Specifically, a mixed integer programming (MIP) optimization model is included in the AML which calls a linear solver [5] to perform the scheduling. In this project, the objectives are related to minimize the energy absorbing from the grid and maximize the profits for PV generation, maintaining proper battery charging. The energy generated by the WT has to be used just for local consumption.

III. Results

To illustrate the performance of the proposed EMS, a 24-h ahead scheduling is performed. The experimental results obtained after setting the initial condition of state of charge (SoC) of the battery as 90% are shown in Fig. 2, where the SoC of the battery, battery voltage, PV power, WT power, battery power and power injected/absorbed from the main grid are presented. Particularly, the RESs power figures include the maximum available power and the measured power.

In the first hours of the day (I in Fig. 2), the energy requested by the load is supplied by the WT and the battery because there is enough energy in the battery at the beginning of the day (SoC(0)=90%). As a result, it is not needed to absorb energy from the grid in this period. When there is energy provided by the PV array (II in Fig. 2), all this energy is sold to the utility to increase the profit whereas the load is still supplied by the WT and the battery. Afterward, when the battery is charged (III in Fig. 2), there is a change in the operation mode of the ESS for avoiding overcharge. Because of that, the power-grid compensates the transient behaviors and mismatches between generation and consumption. Also, if there is surplus of WT energy generation (IV in Fig. 2), some curtailment is scheduled. And finally, to maintain the energy global balance in the battery, (V in Fig. 2), the algorithm schedules the use of the power grid during night time (less price), since a differentiable price profile has been considered.

IV. Conclusion

A flexible structure of EMS integrated by independent modules has been designed and implemented to manage microgrids. Each module can be designed in different software and they are aggregated by means of the database management system. The system has been tested in a grid-connected microgrid and the scheduling process is programmed to provide optimal set points to the distributed energy resources in an economical way. This system can be modified easily and more modules can be added to include more functions.

[2]Implemented in Labview
[3]performed in Matlab
[4]In this case GAMS
[5]CPLEX solver

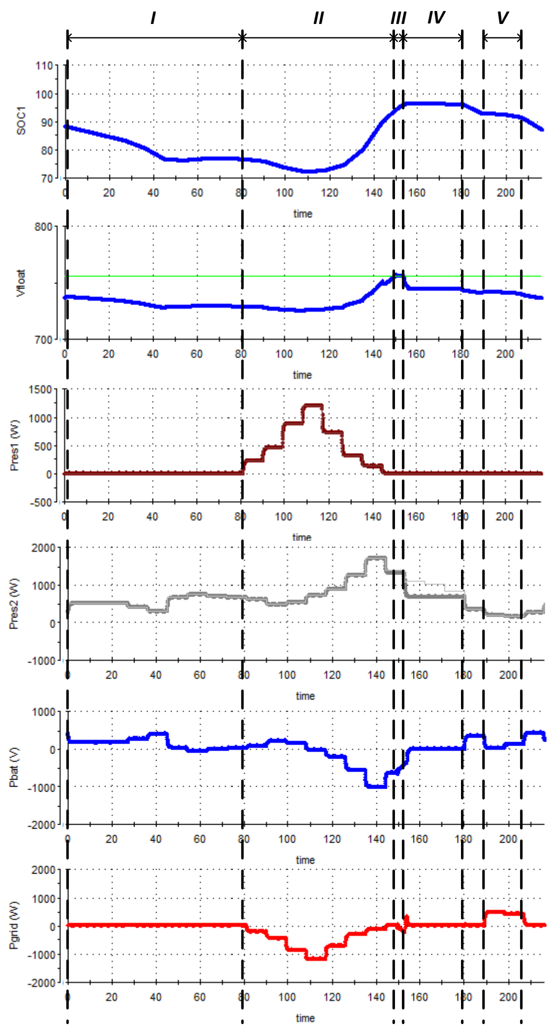

Fig. 2. Results

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