A two-step energy management method guided by day-ahead quantile solar forecasts: cross-impacts on four services for smart-buildings

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The research work hereby presented, emerges from the urge to answer the well-known question of how the uncertainty of intermittent renewable sources affects the performance of a microgrid and how could we deal with it. More specifically, we want to evaluate what could be the impact in performance of a microgrid intended to serve a smart-building (powered by photovoltaic panels and with battery energy storage), when the uncertainty of the photovoltaic-production forecasts is considered in the energy management process. For this, several objectives (or services) are targeted based in a two-step (double-objective) energy management framework that combines optimization-based and rule-based algorithms. The performance is evaluated based on four particular services proposed as performance indicators: (i) improving the energy cost (EC), (ii) the CO_2 cost, (iii) the grid peak power (GPP) and (iv) a grid commitment (GC). Simulations are performed using data of a study-case microgrid (Drahi-X Novation Center, Ecole Polytechnique, France). The use of quantile forecasts (obtained with an analog-ensemble method) is tested as a mean to deal with (i.e. decrease) the uncertainty of the solar PV production. The proposed energy management framework is compared with basic reference strategies and the results show the superior performance of the former in almost all the services and forecasting scenarios proposed. The contrasting nature among some of the target services is one of the main conclusions of this work, as well as the different requirements in terms of forecasts when optimizing for different services and seasons of the year. This fact highlights the usefulness of the quantile forecasting approach, as a tool to deal with the intrinsic uncertainty of PV power production.

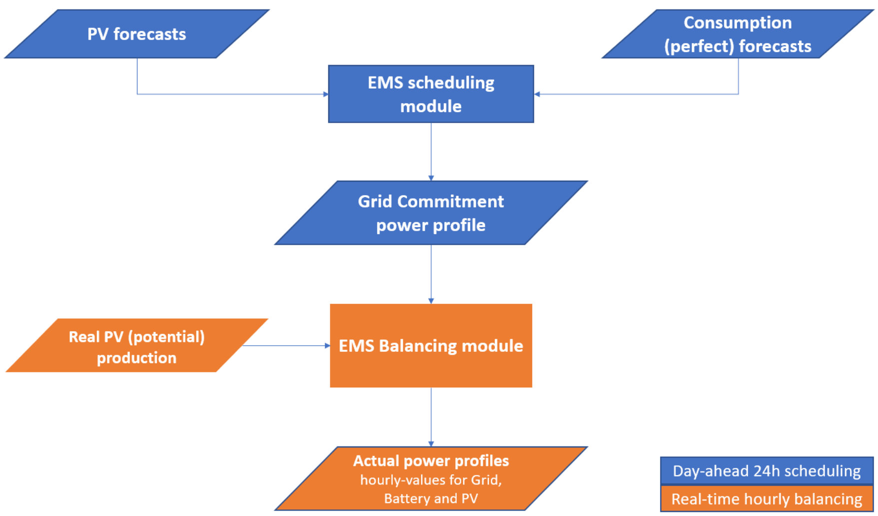

Figure 1 - Two-stage EMS proposal

In more detail, in a first stage of the energy management system (EMS), an optimal scheduling is performed, where three different target objectives (TOs) are possible: EC, CO_2 or GPP. During the scheduling stage, only one TO is targeted (i.e. set as optimization objective), depending on the strategy chosen. By definition, all the other services that are not being targeted are called Non-Target Objectives. During this first scheduling stage, the GC service cannot be targeted. The scheduling module takes PV quantile forecasts which are used to decide the hour-by-hour energy exchanges with the grid for the following day.

In the second stage of the EMS, once the scheduling module has generated given grid and battery profiles (i.e. scheduled profiles) -while favoring one of the possible TOs-, it broadcasts the scheduled grid profile to a second module called: the balancing module (BAL). This module targets only one objective: the grid-commitment. This module runs in real-time and therefore is in charge of compensating the forecasting errors of the PV production. This means that, the BAL module will modify the scheduled battery profile or perform PV curtailment, in order to preserve the scheduled grid profile untouched, as long as physical constraints allow it (i.e. available capacity on the battery). This proposal is different to common multi-objective optimization EMS approaches, where the optimal compromise between the different objectives is searched simultaneously during the optimization execution.

Results show that an EMS with optimization-based scheduling strategies, as the ones hereby proposed, is able to outperform the different reference strategies in every service, with improvements up to 50% in some cases, with the exception of the carbon footprint, where having no microgrid produces, in average, 4.9% less carbon emissions.