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A Microgrid Energy Management System Based on the Rolling Horizon Strategy

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Operating reserve in microgrids: an approach to deal with uncertainty

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Summary— Uncertainty is an unavoidable issue when working with renewable generation and consumption forecasts; and it represents one of the big challenges to overcome in distributed generation schemes. Renewable microgrids are subject to this problem that poses different challenges for their management in terms of power quality, stability, planning and scheduling, among others[1]. Many of the current state-of-the-art energy management systems (EMS) deal with this issue from a predictive perspective. In other words, they perform the planning and scheduling based on forecasts, before the actual net-demand (ND) unveils[2][3][4]. This leads to unavoidable deviations between optimal and real scheduling. In the proposal presented in this work, the forecast-uncertainty problem is tackled in-deferred, once the uncertainty has revealed itself, so it can be taken into account, with certainty, in the optimization and scheduling process performed by the EMS. This objective is achieved by bringing down to microgrid-scale the concept of operating reserve (OR), known in utility-scale power systems, in a sort of closed-loop corrective control variation. The proposed approach allows including the errors between forecasts and real data, in an optimal way within the energy management loop, so that optimal performance can be achieved. In this work, two main objectives are sought: finding out the optimal time interval at which the corrections (optimization and scheduling) should be made; and study the performance and stability of the system when a real-time sizing of the operating reserve is held, based on estimations of forecasts uncertainty.

Fig. 1. Microgrid emulation module for experimental tests (*Microgrids group, Aalborg University*)

The core (and novelty) of the presented proposal is the inclusion of an extra energy storage (operating reserve), which is not 'seen' by the EMS. This element allows all the dispatchable resources in the microgrid to be optimally scheduled. This is achieved thanks to the compensation role assumed by this new element when net-demand deviations (from forecasted values) occur. Given the expected reduced-size of this unit (compared to the main energy storage), its technology can be chosen so that its cycling life is high enough as to consider its marginal cost negligible (i.e. supercapacitors/flywheels [5]). Deviations in ND are reflected as changes on the state-of-charge (SoC) of the OR which are included in the optimization process of the EMS every timestep $\boldsymbol{t}$. The required capacity of this OR unit is also recalculated every timestep $\boldsymbol{t}$, based on uncertainty estimations for the next timestep. When uncertainty is such that the total OR capacity is not required for compensation purposes, part of the OR capacity can be assigned to the system to be used as part of the main energy storage, increasing its capacity factor and providing the microgrid with a temporary extra-storage capacity. Net-demand uncertainty estimations are obtained using an analog ensemble method, which is also presented in this work.

An emulated microgrid consisting on photovoltaic production, household-type consumption, battery energy storage and a bi-directional grid connection is used to perform the tests. Preliminary experiments are performed in the microgrids laboratory of the Energy Technology Department of Aalborg University (Denmark) using a simple EMS as reference. The optimization performed by the EMS is intended to minimize the cost of energy bought from the main grid under a variable electricity-price scenario in Denmark. The system is emulated using fully programmable bi-directional 2.2kW inverters linked to a common bus controlled via dSpace/Matlab (Fig.1). Its output is the optimal power profile for the battery and grid connection, as seen in Fig.2.

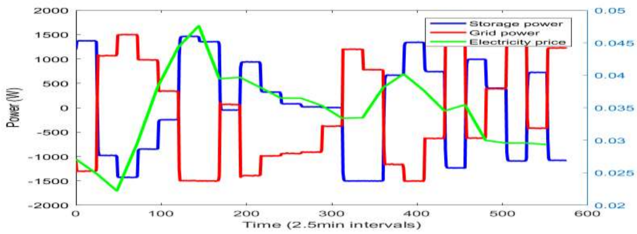

Fig. 2. EMS example of optimal power profiles for battery and grid

The results, under unlimited OR capacity, showed improved performance for two different ND scenarios (summer and winter weeks) with respect to the base case system (Table I).

TABLE I. WEEKLY OPERATION COST

Weekly operation cost(€)	**Reference case**	**Proposed approach**
Winter week	0.77	0.52 (+32.5%)
Summer week	-0.8	-1.05 (+19.3%)

As seen in Fig.3, the SoC of the OR showed stability for a timestep of one hour, for both net-demand scenarios (winter and summer weeks). Ongoing tests are held to validate stability for other timesteps as well as to find out the optimal timestep ***t*** *(*at which optimization and scheduling is performed), under the criteria of performance (operation cost), SoC stability and capital cost. The aforementioned aspects, along with real-time OR sizing tests (aiming to evaluate capital costs and economic feasibility), are the core of the present work.

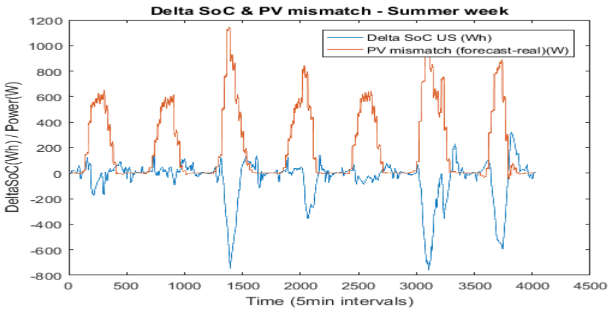

Fig. 3. Delta SoC for OR given PV production mismatch

Assumptions, conditions, limitations and future perspectives for further research on this proposal are also discussed to ponder its validity and usefulness in real-case microgrid systems, as a way to soften the negative effects of uncertainty with the aim to make renewable microgrids and distributed systems a more affordable and reliable source of clean energy.

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