Optimizing the use of a multi battery energy storage system to participate in the electricity market

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1 Introduction

The electricity market has widely evolved over the decades, especially with the emergence of the smart-grids. Dynamic battery storage systems and renewable energy sources together with new information and communication technologies allow those of consumption and production agents to participate collaboratively in the electricity market [7].

In telecommunications companies, it is common to use batteries as a backup in the case of power failures, since such companies provide critical services and must therefore keep their network always active [6]. These batteries are used in conjunction with antennas and other equipment, and, in order to ensure that they are always operating in the case of a power failure, strict safety management rules must be considered. In addition, the company may use those batteries to participate in the electricity market as a coordinated battery storage system, ensuring that the grid is properly reliable as long as the safety use rules are respected.

Indeed, as the energy price changes over time, batteries may be used to avoid buying energy when the price is high, which is known as the demand-response mechanism [3], has been widely studied over the last decade [5]. The batteries will then be recharged when the energy price is low, generating savings [1]. This mechanism can be defined as the changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the energy prices over time.

The main challenge is the use of multiple Battery Energy Storage Systems, requiring more efficient control strategies for optimal management. In this context, recent studies propose different methods to treat the multi-battery problem efficiently [2, 4]. We quote the work of Babazadeh et al. [2] who propose a multiple battery management system with different types of battery focusing on the minimization of the total system cost and considering the impact of the usage on the lifetime of the batteries.

2 Problem Definition

We now formally describe the considered problem which is defined in a deterministic setting with a single telecommunication site. Let us consider a site with a power demand W_t, given in kW, at each time period t of discrete a horizon $\mathcal{T}$ of T equally-sized time periods of duration Δ minutes.

The cost (given in monetary units) for purchasing one unit of energy power at time period t is denoted by E_t. This cost is fixed by the distributor, as is the maximum amount of power $P^{\max}$, given in kW, that can be bought at any time period.

With respect to the battery assets, a site is equipped with a set $\mathcal{B}$ of batteries. For safety reason, a minimum amount of energy $B_b^{\min}$, given in kWh, must always remain in each battery $b \in \mathcal{B}$. In addition, to improve its lifespan, and for network security purposes, each battery $b \in \mathcal{B}$ must be immediately recharged after each use, up to its maximum energy capacity, denoted by $B_b^{\max}$ and given in kWh, with a constant power rate P_{B_b} given in kW. Note that the battery recharge process is not linear and depends on factors such as the depth of discharge, and the battery power level. However, a linearization of the battery power level during the recharging process is commonly considered. Moreover, a minimum power discharge per time period, denoted by $D_b^{\min}$ and given in kW, is imposed when a battery b is in discharge mode. Moreover, each battery has a maximal power rate, denoted by $D_b^{\max}$ and given in kW, that it can release at each time period due to current and voltage limitations. Note that $D_b^{\min} \in [0, D_b^{\max}]$, and that the power demand W_t is higher than $D_b^{\min}$ at all time periods t over the horizon. Each battery must also be fully charged at the beginning and at the end of the planning horizon.

Concerning the battery life cycle, the number of times that each battery can be used is limited. In this context, each battery b can be used at most N_b times over the time horizon.

The total amount of energy savings that can be obtained is provided by the difference between the energy prices during a battery use and its recharge. The amount of energy not bought during the battery use is equal to the battery discharge. Furthermore, we consider only one energy supplier without renewable energy sources. The batteries are ready for use, and hence no installation cost is considered.

Our goal is to manage optimally the use of the batteries while respecting both the usage rules and the electricity market rules at optimal cost.

3 Contributions

Our first contribution is the modeling of the market rules and battery safety usage rules through a mixed-integer linear program for the problem under study, whose optimal solution provides the best way to generate savings for the company, i.e., to reduce the total energy cost.

We also propose a graph-oriented temporal decomposition heuristic which can be used as a workaround method for solving large-scale instances, based on:

- The decomposition of each instance into sub-instances that are individually solved;
- The selection of a subset of the solutions obtained for the sub-instances that respects the maximal number of battery uses N_b, and that yields a solution to the complete instance.

Our third contribution is the validation of our algorithms on instances based on real datasets from the mobile 4G network of the French telecommunications operator Orange.

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