Optimizing Battery Usage for a Telecommunications Company with Energy Curtailing Incentives

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1 Introduction

The electrical energy market has been subject to intensive research especially with the emergence of smart-grids providing more complex energy grids with multiple power sources, storage systems and local eco-friendly energy production [Dang, 2009, Koutsopoulos et al., 2011].

The use of batteries as backup in case of power outages is frequent in telecommunications companies that provide critical services to keep their network equipment always active [Kiehne and Krakowski, 1984]. In this context, for each equipment in the network there exists at least one battery for backup use, and security rules on the battery usage must be considered. Firstly, each battery has to be immediately recharged to its full capacity B^{max} after each use. Furthermore, to increase the batteries' lifespan, they must be recharged with a constant boost power P_B.

However, those batteries could also be used for other purposes, such as participating in the energy market when they are not being used for backup. Since the energy price is not constant over time, batteries can be used in periods where the energy costs more, also called *peak-time* periods, and recharged when the energy costs less, as a strategy to reduce the electricity bill [Daryanian et al., 1989, Johnson et al., 2011, Mishra et al., 2012, Labidi, 2019]. Such an energy market is known as *Retail Market*. Since there exists a limited amount P^{max} of energy that can be bought at each time period due to the grid capacity, and since each battery has a given capacity, trivial strategies such as buying all the energy demand over the planning horizon at the cheapest period are not possible.

Batteries may also be used to participate in the *Curtailing Market*, introduced for the first time by Lee et al. [Lee, 1953]. In this context, a company can be asked to reduce its energy consumption by receiving a reward. Considering a typical energy production and distribution system usually composed by generators, transmission and distribution operators and clients, the transmission operator (TO) is the agent responsible for the energy transmission and for the grid stability. When the consumption demand in a system is larger than the energy production, the TO has either to use its electrical energy reserves (e.g. ask nuclear plants to produce more) or to ask the customers that have a huge energy demand to cut down their consumption for a period (performing a *curtailing*), giving them a reward in exchange [Baldick et al., 2006, Lee, 1953]. Usually, the reward depends on the amount of energy that is cut down during a curtailing, and rules to participate in this market are priorly contractualized [Chrysikou et al., 2015].

2 Problem Definition

The problem we study can be formally described as follows. Let us consider a customer with an electrical energy demand W_t in each period t over a planning horizon of T discrete time periods. We assume that the unitary cost C_t used to compute its electricity bill at each period t is given.

Moreover, each curtailing has a minimal (resp. maximal) duration D^{min} (resp. D^{max}) that must be respected. In addition, during a curtailing, a minimum amount of power must be cut down at each period of time. In other words, for each period t of a curtailing, there exists a maximal amount of energy p_t^{max} that can be bought from the supplier. The way such an amount is computed is imposed by the TO depending on the country. Our study is based on the french context, in which this amount is defined as $\overline{W} - P_{TO}$, where $\overline{W}$ is the mean of the demand forecast over the curtailing and the power bought at the time period immediately before the curtailing starting time, and P_{TO} is the contractualized power that must be cut down. Furthermore, a minimum amount of energy B^{min} must remain in each battery at any time, and each battery must be fully charged at the beginning and at the end of the time horizon for network safety purposes.

Managing batteries while respecting both usage and market rules is a key aspect to keep the network safe at optimal cost. Our paper addresses this aspect in a single battery setting. To the best of our knowledge, this is the first study where batteries are used for backup as well as to participate in the curtailing market.

3 Contributions

We propose a mathematical model to solve the addressed problem at optimal cost. The model is based on the enumeration of all curtailings that can possibly be performed, each curtailing been defined by its firt and last time periods, and by the amount of energy used from the battery.

We also formulate the problem as a longest path problem in a directed acyclic graph, provided that the amount of energy used from the battery during each curtailing can only take a finite number of values. We then provide several natural assumptions that ensure that this graph has a polynomial number of vertices, and thus that the associated variants of the problem can be solved in polynomial time. In general, though, this algorithm can be seen as an heuristic.

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