Real-time energy scheduling for microgrids based on the Contract Collaboration Problem [183]

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1 Introduction

Along with the advent of smart grids, we have witnessed several technological advances, including renewable energy sources and flexible loads, such as smart appliances and electric vehicles. Moreover, new electricity market rules and regulation mechanisms have been proposed [2]. Thanks to instant communication, control devices have become important elements, essential for managing the energy balancing of the grid. Based on a specific strategy, they execute real-time energy scheduling according to fluctuations in production (e.g. solar panels in cloudy weather) and consumption in different periods of time. Interesting examples involve the use of energy generators during a period of higher demand and, analogously, employing a set of batteries to store energy during off-peak times so as to ease high demand in peak periods.

In this work, we study real-time energy scheduling strategies to be used by smart control devices within a contract collaboration framework, established between two systems, both producers and consumers of the same kind of energy resource. One system is called the *client* (e.g. campus, hospital, hotel) and the other one the *partner* (i.e. energy company).

2 The Contract Collaboration Problem

Connected via the main energy grid, the *client* and *partner* systems have to collaborate in order to balance their consumption and production over a given time horizon. Such time horizon is divided into a set $\mathcal{I} = \{I_0, \ldots, I_{\bar{t}-1}\}$ of $\bar{t}$ time periods where $I_t = [T_t, T_{t+1})$, for each $t \in \{0, 1, 2, \ldots, \bar{t} - 1\}$.

Client-partner collaboration is established by the use of a set of contracts of consumption or production, both offered by the *partner*, each one having its own functional constraints and gain/cost functions. On each time period, the *client* is free to enter into a commitment with the *partner* through any subset of contracts. However, such commitments must be honored. The *client* also has the option to buy energy out of any engaged contract, but at a higher cost which can vary with the time period.

The *client's* microgrid is composed by subsystems that produce/consume the energy resource, each one with its own functional constraints and a cost/gain of consuming/producing over the time periods. In particular, the consumption/production can be *driven* for a subset of these systems (*drivable systems*) while the consumption/production is already planned for the *non-drivable systems*. Drivable systems are devices that allow being turned on/off or that must be loaded/unloaded from time to time (e.g. batteries, electric car, fuel-powered generators), whereas non-drivable systems (e.g. always-on appliances like refrigerators) must be permanently turned on. Additionally, some of the drivable systems can store the energy resource under a capacity constraint and provide it when needed, thus being called *storage systems* (e.g. batteries). The uncertainty considered in the problem lies in a subset of the *non-drivable systems*, for which only uncertain previsions of the consumption/production are known. The so-called *uncertain non-drivable systems* include, for example, renewable generation and variable energy consumption.

The Contract Collaboration Problem (CCP) consists in determining a cost-optimal contract subscription from the client to the partner which not only satisfies any client-side consumer demands over the time horizon (even in the worst case scenario), but also in such a way that each commitment taken by the client with the partner is honored. Additionally, the list of engaged contracts, for the whole time horizon, has to be determined beforehand and it cannot be altered.

3 Real-time energy scheduling

In order to properly manage the client's microgrid, as a complement to the contract subscription, energy scheduling decisions have to be made in order to balance demand and supply. From a real-time point of view, inside each time period $I_t \in \mathcal{I}$, the instantaneous production/consumption of each system is measured every Δ time units. It is also at this time scale that drivable systems are driven, i.e, every Δ time units a scheduling decision has to be taken, according to the state of the client's microgrid, such as :

- turning on/off a producer/consumer drivable system ;
- determining if a storage system will absorb or refund energy ;
- buying/selling a quantity of energy under an engaged contract ;
- buying an amount of energy out of engaged contracts.

4 Solution method

The novelty in our work is the incorporation of a bilateral flexible multi-contract subscription framework, which allows the trading of energy at different prices and in flexible amounts. The problem solution is established at two levels. First, a time-decomposition-based CCP model provides the list of contracts the client will engage in each period. Two versions of the model were developed for this purpose : deterministic and robust. For the deterministic version, uncertain devices consumption/production fluctuation is ignored, and their average power values are assumed. The robust version aims to minimize the energy cost against the worst-case scenario of production/consumption of electricity. In a second level, in order to balance demand and supply, different real-time energy scheduling strategies are proposed.

Experimental data were collected from a microgrid located at Université de Technologie de Compiègne (UTC) [1], with the following elements : 2 drivable systems (one electric car and a group of diesel engine-generators), 1 non-drivable system representing the invariable building consumption, and 2 uncertain non-drivable systems (one photo-voltaic production system and the uncertain consumption of the same building). We will present preliminary results based on simulations, comparing the performance of the proposed real-time energy scheduling strategies, when using either the deterministic or robust model solution as input.

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Références

[1] Atelier projet : Smart-house et micro-réseaux. Technical report, Université de Technologie de Compiègne, June 2015.

[2] Pierluigi Siano. Demand response and smart grids – a survey. *Renewable and sustainable energy reviews*, 30 :461–478, 2014.