A Two-Timescale Decision-Hazard-Decision Formulation for Storage Usage Values Calculation in Energy Systems Under Uncertainty

Camila Martinez Parra[1,2], Jean-Marc Janin[1], Manuel Ruiz[1],
Michel De Lara[2], Jean-Philippe Chancelier[2], Pierre Carpentier[3]

[1] RTE-France
[2] Cermics, École des Ponts, France
[3] UMA, ENSTA Paris

Key words : *Energy system modelling, information structure, stochastic multistage optimization, dynamic programming.*

1 Introduction

The penetration of renewable energies requires additional storage facilities to deal with the intermittency of the system. Accordingly, there is growing interest in evaluating the *opportunity cost* associated with stored energy, that is, the *usage values.* At each time step, we compute usage values as a function of the energy storage level. Later, they are used in system simulations to represent the optimal operation of the energy storage.

Usage values can be obtained by solving a multistage stochastic optimization problem. Today, to compute them under uncertainties, an adequacy resource problem is solved using stochastic dynamic programming assuming a *hazard-decision* information structure. This modelling assumes complete knowledge of the realization of the coming week's uncertainties, which is not relevant to the system operation, as the intermittency occurs at a smaller timescale.

We introduce to the two-timescale problem a new information structure considering planning and recourse decisions: *decision-hazard-decision.* This structure is used to decompose the multistage decision-making process into a nonanticipative planning step in which the switch-on decisions for the thermal units are made with no knowledge of the uncertainties' realization, and a recourse step in which the power modulation decisions are made once the uncertainties have been disclosed.

2 Problem description and current practice

Traditionally, one computes the usage values assuming full knowledge of the week's uncertainties and full flexibility of thermal units. But in case of outages of thermal units, it takes time to switch them on. What happens if we take this temporal rigidity into account?

To formalize this question, we consider first a one-node energy system model to conduct long-term prospective studies under uncertainty (from a central planning point of view). The aim is to compute the usage values associated with the storage in the system. For that, we solve a sequence of weekly stochastic optimization problems to allocate, with an hourly time-step and over a year, the production means such that the demand is met while minimizing the overall cost. That is, a 168-hour stochastic optimization problem solved 52 times a year. This is the resource adequacy problem. To fix ideas, we consider a system with one storage, several dispatchable (thermal) units, fatal production, and a demand. However, the theoretical results studied can be extended to systems with many storage units. The uncertainties of the problem are the demand, the fatal production, and the availability of production means. Since we want to represent hourly decisions and constraints but keep a weekly "coordination" of the decisions, we consider a two-timescale timeline [1].

The dynamic constraint used to model the evolution of the level of stock introduces a temporal coupling. As a consequence, the problem has to be solved sequentially for the studied timespan, which is likely to result in a computationally intractable problem when we want to model, for example, one country's electrical system (many production means and uncertainty sources with hourly decisions and constraints over a year horizon with hourly decisions). For this reason, we turn to decomposition techniques [2].

Under suitable assumptions, Bellman-based methods [3] can be used to decompose the problem into a sequence of smaller problems, getting also the storage's usage values as a result [4]. During this work, we focus on the model used to obtain the weekly Bellman functions, but we do not focus on their resolution.

The information structures are used to model the information available when making the hourly decisions. We present the current practice for the information structure modelling when computing the usage values: *weekly fully anticipative* or also called weekly hazard-decision structure. This structure assumes that all the decisions (including the thermal ones) are made with full knowledge of the uncertainties' realization for the coming week. When the dispatchable units are "fast" to start, we assume that we can "wait-and-see" the uncertainties to make the decisions, in which case a hazard-decision structure is not far from reality. On the contrary, when the system has "slow" dispatchable units (nuclear or coal), "wait-and-see" decisions are not suitable because of the last time to decide constraints. These constraints reflect that "slow" units need more time to start producing. The adapted structure for this type of unit is *decision-hazard* which considers "here-and-now" decisions.

3 New information structure: decision-hazard-decision in a two-timescales timeline

We present the *decision-hazard-decision* information structure that considers both "here-and-now" and "wait-and-see" decisions. This structure is used to solve the adequacy problem with two timescales. Each stage (week) of the decision-making process is decomposed into a nonanticipative planning step and a recourse corrective step. While in the first step, the *slow* (weekly) decisions are made before knowing the uncertainties' realization, in the recourse step the *fast* (hourly) decisions are made once the uncertainties are known. It can be interpreted that the slow decisions are associated with the unit commitment step and that the fast decisions are associated with the unit power modulation. Therefore, we obtain a problem formulation that improves the information model by being less anticipative and allows us to apply temporal decomposition methods. Since we consider a two-timescale timeline, the decision-hazard-decision information structure leads to the *weekly partially anticipative* framework. Once the new information structure is described, we present the corresponding mathematical formulation of the problem and the associated Bellman equations needed to compute later the usage values.

References

[1] P. Carpentier, J.-P. Chancelier, M. D. Lara, T. Martin, and T. Rigaut, "Time blocks decomposition of multistage stochastic optimization problems," *Journal of Convex Analysis*, in press.

[2] R. E. Bellman, *Dynamic Programming.* Princeton, N.J.: Princeton University Press, 1957.

[3] D. P. Bertsekas, *Dynamic Programming and Optimal Control*, 2nd ed. Belmont, Massachusetts: Athena Scientific, 2000, volumes 1 and 2.

[4] G. Steeger, L. Barroso, and S. Rebennack, "Optimal bidding strategies for hydro-electric producers: A literature survey," *Power Systems, IEEE Transactions on*, vol. 29, pp. 1758–1766, 07 2014.