SMS++: a Structured Modelling System for (Among Others) Multi-Level Stochastic Problems

Antonio Frangioni Rafael Durbano Lobato
Dipartimento di Informatica, Università di Pisa, Italy
frangio@di.unipi.it rafael.lobato@di.unipi.it

Key words: Modelling Systems, Energy Optimization, Decomposition, Stochastic Optimization

Handling vital, large-scale infrastructures like energy systems is an extremely complex task. They have to be constructed and upgraded, over the span of multiple decades, to satisfy current needs while adapting to technological, societal and political changes, all at the least cost (not only economical, but also societal and ecological). In order to provide decision-makers with tools to manage these systems, extremely complex mathematical models have to be constructed and solved. These have to span long periods of time, which means that they are subject to high levels of uncertainty that cannot be disregarded. However, they also have to represent the system under analysis with an appropriate degree of accuracy, to avoid that phenomena left out by approximations lead to substantially different outcomes in reality. Thus, these models have to capture phenomena at time resolutions spanning from decades to minutes, accounting for different forms of uncertainty description. Decomposition methods are the only way to tame the corresponding huge-scale optimization problems. Actually, what is needed is not just one decomposition approach, but a hierarchical combination of heterogeneous decomposition methods (say, Lagrangian and Benders' ones). Efficiently implementing such an algorithm is a daunting task, especially if modelling flexibility is required and distributed computation is used to exploit HPC systems, which is necessary to tackle real-world instances.

Under the auspices of the H2020 project "plan4res", devoted to the strategic assessment of the whole European energy system for the next decades, the innovative, open-source *Structured Modeling System++* (SMS++) is being developed. Aim of SMS++ is to facilitate the implementation of general and flexible algorithms for optimization problems with several nested layers of structure. In the Case Studies envisioned in the project, the lower layer is the Unit Commitment (UC) problem, which is a hard (especially when uncertainty is considered [1]) Mixed-Integer Nonlinear optimization problem regarding the short-term (say, daily) scheduling of electrical generators. Higher layers concern the mid-term (say, yearly) management of energy reservoirs (water, gas, ...) in the face of several uncertainties (climate, demand, ...), and the long-term evolution of the energy system (construction/decommissioning of generators and energy lines, investments in different generation technologies, ...). Tackling models of this scale is perhaps nowadays technically possible, but an Herculean task in terms of the necessary programming, as current modelling systems are not designed for supporting this kind of approaches, especially if modelling flexibility and maintainability of the model over long periods of time is necessary. We will present the current state of the SMS++ system, focussing in particular on recent developments concerning the representation of uncertainty, which are meant to facilitate the transformation of complex deterministic models into stochastic ones. Specific SMS++ facilities for "general-purpose decomposition techniques" will then allow to efficiently produce multi-level decomposition approaches to these problems.

References

[1] W. van Ackooij, I. Danti Lopez, A. Frangioni, F. Lacalandra, M. Tahanan "Large-scale Unit Commitment Under Uncertainty: an Updated Literature Survey" *Annals of Operations Research*, 271(1):11–85, 2018.