Sizing optimization of multi-vector energy systems: Studying the influence of model level of detail on the control strategy

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1 Introduction

Multi-vector local energy systems refer to integrated networks that leverage various energy vectors like the example in Figure 1.

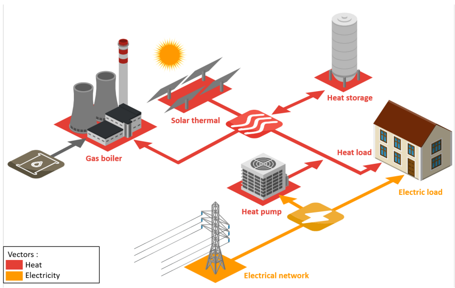

FIG. 1: Multi-vector local energy system

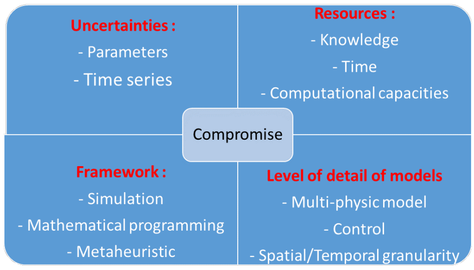

FIG. 2: Compromise of techno-economic studies

Future energy systems will integrate ever various energy vectors and have a larger share of inflexible renewable energy sources. Storage and conversion technologies are increasingly assuming a predominant role in adding flexibility to energy systems. The management of such systems cannot be limited to the immediate satisfaction of needs, but must integrate medium-term optimization (optimal control) to make the best use of storage capacities and resources. These two aspects, new technologies and more advanced control strategy, are adding an important computational burden to computer models. Thus a trade-off between model accuracy and model complexity must be found [1]. All studies have to make a compromise between (i) levels of details, (ii) extensive study of uncertainties, (iii) computational capacities and (iv) the framework where the study places itself (Fig. 2).

Some publications quantify the influence of different levels of details of model on the results of a study [2], [3]. However, the control strategy is rarely studied. Usually studies rely on an open-loop optimization of control with perfect foresight and knowledge of the system. In real systems, the control is in closed-loop with uncertain previsions and knowledge of the system.

A toy model is used to show how overlooking the effect of this level of detail may lead to poor decisions. We also propose a methodology to quantify the influence of this level of detail.

2 Optimization problem and control strategy

The toy model is based on the work of Cuisinier [4] and includes: a flexible co-generation source powered by biomass, a inflexible thermal solar source, a heat storage, a electric storage and a conversion device with a heat pump. Two flexible sources represent a connection to electricity network and a heat gas boiler. The optimization problem balances energy and matter flows in an energy system to meet demands d_{vector} on a time horizon H of one year while minimizing the total economic cost of the system (with an actualization coefficient τ). A linear version of the problem is as follows. Indices are k (element of the physical system) and t (time step). Decision variables are power flows or matter flows ($x_{k,t}$) and sizes of elements (s_k). I_{inv} are sized elements with OPEX o_k, CAPEX c_k and prices $p_{k,t}$. I_{src} are sources with load factors $x_{k,t}^{max}$. I_{sto} are storages with stored energies $e_{k,t}$, loss factors μ_k, efficiencies η_k.

$$\begin{aligned}
\min_{X,S} \quad & \textstyle\sum_{k \in I_{inv}} c_k s_k + \tau(\sum_{k \in I_{inv}} o_k s_k + \sum_{k \in I_{src}} x_{k,t} p_{k,t} dt) \\
\text{s.t.} \quad & d_{elec,t} = \textstyle\sum_{k \in I_{elec}} x_{k,t} \\
& d_{heat,t} = \textstyle\sum_{k \in I_{heat}} x_{k,t} \\
& \forall k \in I_{sto}, t \in H, e_{k,t} = \mu_k e_{k,t-1} + \eta_k x_{k,t}, e_{k,t} \leq s_k \\
& \forall k \in I_{src}, t \in H, x_{k,t} \leq x_{k,t}^{max} s_k
\end{aligned} \tag{1}$$

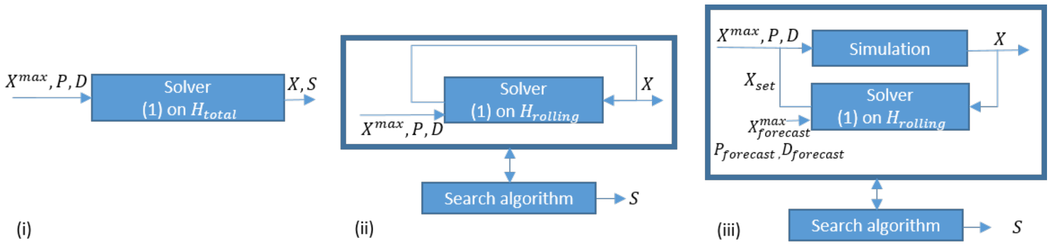

FIG. 3: Level of details of model on control strategy.

Figure 3 presents the three levels of details considered in this work : (i) the baseline formulation on complete horizon H_{total}, (ii) perfect control on rolling horizon $H_{rolling}$, (iii) simulation with feedback control on rolling horizon $H_{rolling}$. The problem (1) is solved using CPLEX. The problem (1) is solved using CPLEX and the simulation is done with Dymola (a framework for dynamical system based on differential equations).

3 Preliminary results

In (ii) and (iii), the sizing found is different with lower storages capacities and smaller inflexible source. This shows how the model of the control strategy can impact the decisions.

For level of detail (ii), the total cost of the system is higher than for (i) because the system has to extract more power from the grid and use the gas boiler compared to the baseline results. This is because, the optimal control only accounts for a limited horizon $H_{rolling}$. This effect is even larger in (iii), the elements of the system cannot follow perfectly the command X_{set} as this command is based on a simplified linear model.

References

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