OpTIStore: fast optimal sizing of PV and storage system

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Introduction

The **OpTIStore** tool (OST) is a web interface providing **a simple and fast** framework for the optimal sizing of PV systems combined with electric storage for domestic and industrial consumers. It is a **free** and **open-source** software. Its main focus is usability: it has to provide a fast feedback to the end user about the best sizing, taking into account the internal rate of return (**IRR**) of the investment and the net present value (**NPV**). The main input data used by OST are the user power profile and the typical meteorological year (TMY) for a building at a given location. To allow a response time of a few seconds, a new sizing methodology has been developed, based on an optimizer meta model.

Fast design problem

The optimal sizing of a combined system (PV and storage) is based on two main steps: the **creation of a parametric model** of the target system and its **parameters optimization** based on an appropriate metric. In case of the optimal sizing of a **PV plant**, we can use a simple deterministic model:

$$P_{pv,t} = f_{pv}(\mathrm{GHI_t}, \mathrm{Ta_t}, \theta_{PV})$$

where $\mathrm{GHI_t}, \mathrm{Ta_t}, \theta_{PV}$ are the global horizontal irradiation at time t, the ambient temperature at time t and a set of parameters characterizing the PV installation (e.g. nominal power, tilt, degradation factor, etc.). Then NPV is used as the target metric to maximize:

$$NPV_N(P_{pv}, \alpha|\theta_{PV}) = \sum_{y=0}^{N} \frac{FCF(P_{pv,y}, y)}{(1+\alpha)^y},$$

Where FCF is the free cash flows at year y, α the interest rate and $P_{pv,y}$ the PV power profile at year y. We can finally optimize $NPV_N(P_{pv}, \alpha|\theta_{PV})$ for the free parameters of θ_{PV} and retrieve the certain-equivalent optimal model.

Regarding the **storage**, a dynamic system has to be managed. Thus, the control logic must be modeled and simulated. This is usually a highly nonlinear function of the system inputs, being function of the system state:

$$P_{b,t} = f_b(\mathrm{P_m}, \mathrm{GHI_t}, \mathrm{Ta_t}, \theta_b, SOC_t(P_{b,t-1}))$$

where P_m is the power at main and SOC_t the battery state of charge, describing the system state, obtained via the control logic of the battery.

The optimal sizing is usually carried out using a **master-slave** optimization, in which the underlying optimization solves the battery actions $P_{b,t}$, while the master optimization solves the battery parameters θ_b. Even in case of one-shot optimization, when perfect information about the future is assumed, the evaluation of f_b for a single set of parameters θ_b can require several seconds. Considering that f_b has to be evaluated for each change of the overall set of parameters $\theta = [\theta_{pv}^T, \theta_b^T]^T$, the total time of the optimization can require several minutes.

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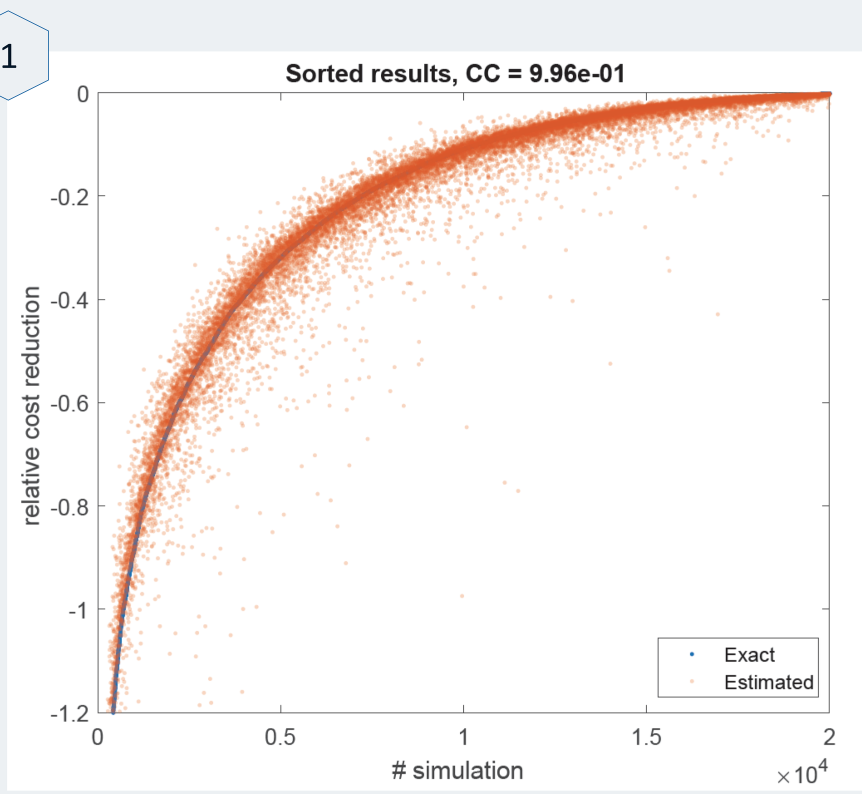

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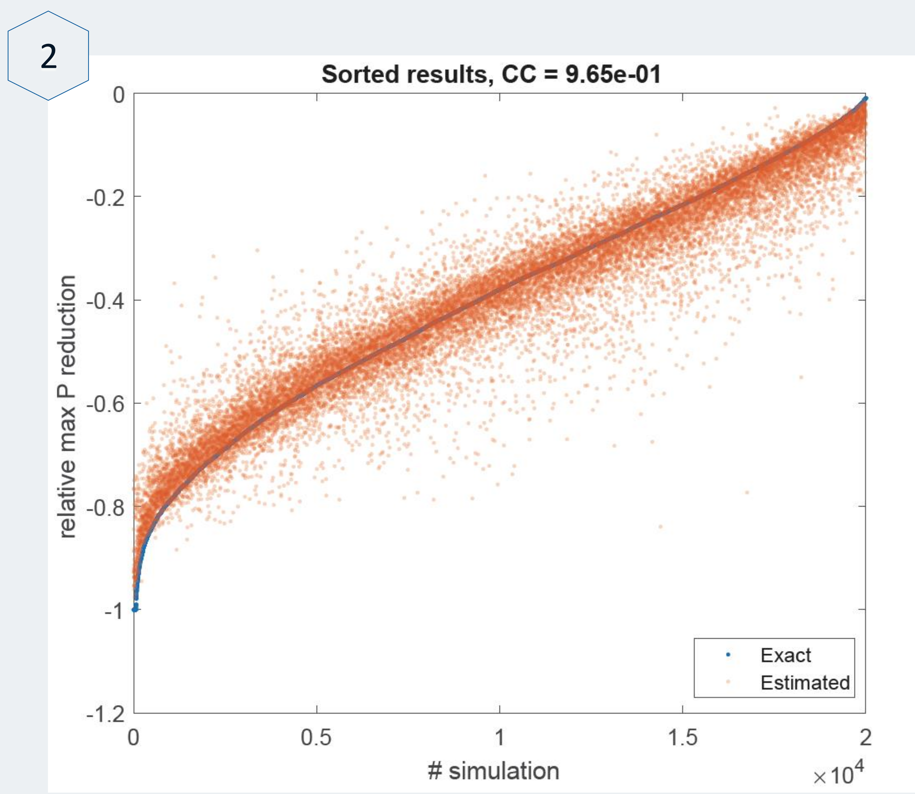

Conclusions

The OpTIStore tool provides an easy way to check the economic feasibility of a PV installation combined with a storage system. It can be used both for residentials houses/building and industrial cases. The fast response of the design allows the user to easily compare different solutions in terms of the chosen technology and to optimally size the PV and storage systems. Currently the beta version of OptiStore is online at http://optistore.supsi.ch:8080/ and is still under development. It is available in English and Italian languages, German and French will be available up to the end of April 2018.

Sizing methodology

In order to speed up the process, we build a meta-model to retrieve the battery operations. The basic idea is that f_b, although a non-trivial function of its inputs, can be approximated with a regressor. Thus, $P_{b,t}$ and its effect on the FCF can be estimated without explicitly retrieving the SOC of the battery. The following scheme shows the methodology.

DATASETS BUILDING — **20000 datasets are created, each of them representing a weekly power profile, obtained from real consumption and simulated data**

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DATASETS SOLUTION — $$\underset{P_b^\nu}{argmin}\ c(P_m^\nu) + k\|P_m^\nu\|_2^2$$ $$s.t.\quad P_m^\nu = P^\nu + P_{pv}^\nu + P_b^\nu \quad P_b^\nu \in C_{set}\ (*)$$

↓

QUANTILE RANDOM FOREST REGRESSOR — **Features of $P + P_{pv}$ to the expected economic reduction of the weekly FCF given by the battery operations**

(*): ν is the index of the current entry of the dataset, P the uncontrolled power at main, C_{set} a constraints set (e.g. maximum power, ramping, SOC, etc.)

Figures 1 and 2 show the performance of the regressors in a specific case with the target values (blue dots) sorted for visualization reasons. The regressor estimation is shown by the red dots. Negative values represent a reduction (in economic costs and maximum power value, respectively). Values below -1 are possible since in some cases the battery operations can revert the sign of the total cash flow by lowering the power-based tariff costs.

Web Interface

The interface of OpTIStore tool is based on the Django framework (www.djangoproject.com) and uses a MySQL DB for the data storage. As first step the end user inserts its location data using the Google Maps APIs (Figure 3). Thus, the TMY meteorological datasets are automatically downloaded and stored in the database. The user can then upload historical data about his energy consumption or choose predefined profiles, available roof area, roof tilt and azimuth, and several optional parameters.

Once all the parameters are set, the tool enables the user to launch the related optimization, obtaining a response after few seconds. The returned values (i.e. the sets of evaluated combinations of parameters θ) are saved in the database and the user can display their score in terms of NPV and IRR (Figure 4).

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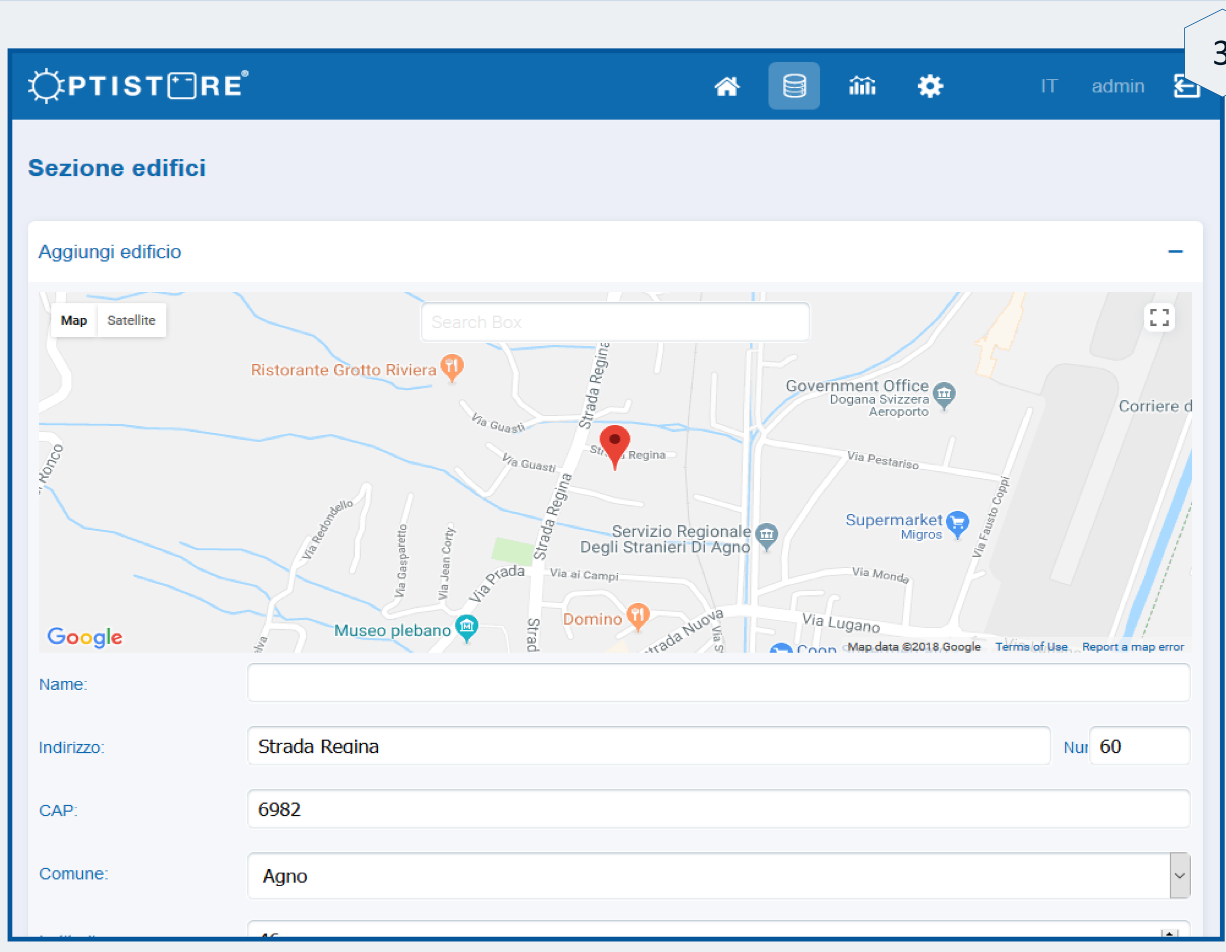

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