Krangpower: a smart grid simulation package

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Background

In the context of smart grid studies, facing complex simulation scenarios for research purposes - involving, for example, co-simulation of buildings and district heating and/or complex algorithmic agents connected to the grid - typically implicates a substantial amount of scripting and programming tailored to the problem at hand, with limited modularity and direct code reuse capability.
On the other hand, fast, industry-grade power flow software such as the OpenDSS[1] is freely available, and can be used as a foundation tool for developing general-purpose smart grid simulation packages granting easy extension and integration capabilities.
It is from these premises that our tool, called krangpower, was developed. Krangpower (**https://github.com/supsi-dacd-isaac/krangpower -- see QR code below)** is a freely available Python package aiming to provide a set of high-level tools to the user interested in smart-grid simulation, enhancing the capabilities of the OpenDSS. Some of the most prominent features are the possibility to easily create agents that algorithmically decide their power absorption and injection with the option to use grid "measurements" (previous-step simulation results) to take their decision, a grid description system based on json files and the possibility to easily extract custom grid data as attributes on a Networkx[2] graph.

Case study

In this poster, we showcase krangpower's capabilities and usefulness through a simple case study.

- An industrial area served by underdimensioned electrical distribution infrastructure;
- An idealized ancillary service provider (ASP) in the same area with access to PV and electro-chemical storage.

The ASP has the target of stabilizing voltage levels in the area. We will evaluate the effects of the following criterion to manage the power injected to the grid:

$$\frac{W}{W_{max}} = \left[\frac{1}{2} + sign(\Delta V)\cdot\left(\frac{1}{2} - SOC\right)\right]\cdot\boldsymbol{\sigma}\left(\alpha\cdot\frac{\Delta V}{V_{tgt}}\right)$$

where ΔV is the difference between ASP bus voltage and V_{tgt}, α is a dimensionless coefficient («aggressiveness») and $\boldsymbol{\sigma}$ denotes the *standard logistic function,* introduced in order to ensure smooth operation in corner cases. V_{tgt} is chosen as the median historical value of V, in order to aim to a balanced charge/discharge operation.
The loads are defined by a yearly energy absorption profile based on true cases of mid-to-large industrial plants, from a few hundreds kW to a few MW. We will optimize α for minimum voltage variance over one year at the ASP's connection bus, using the *simultaneous optimistic optimization*[3] global optimization technique.

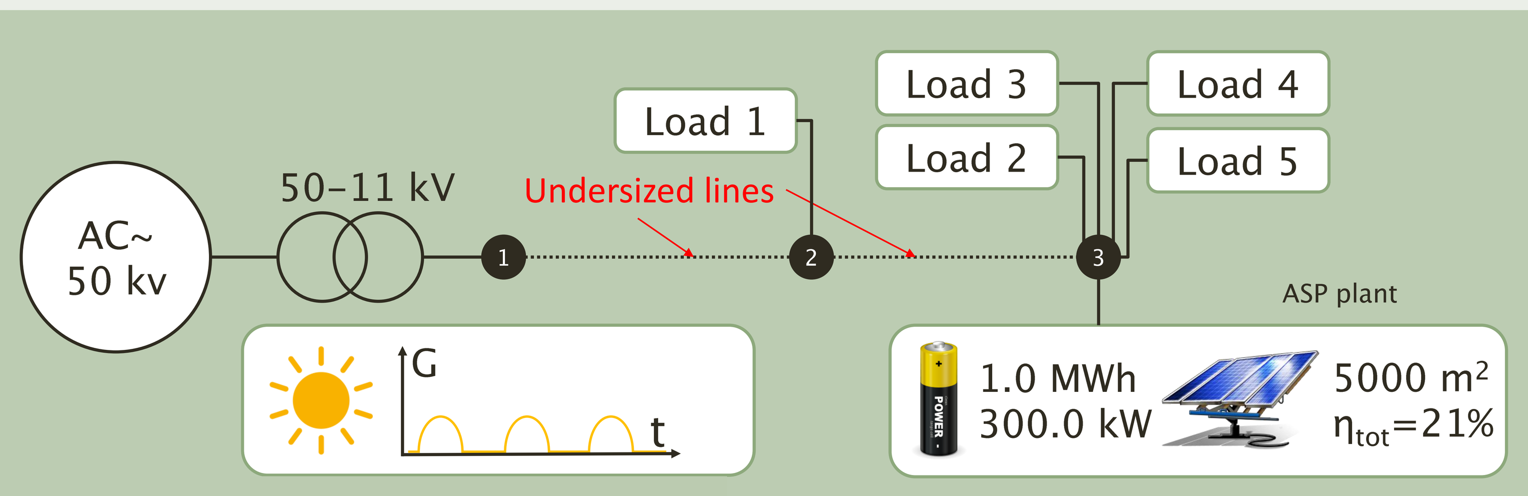


Figure 1: Case study circuit

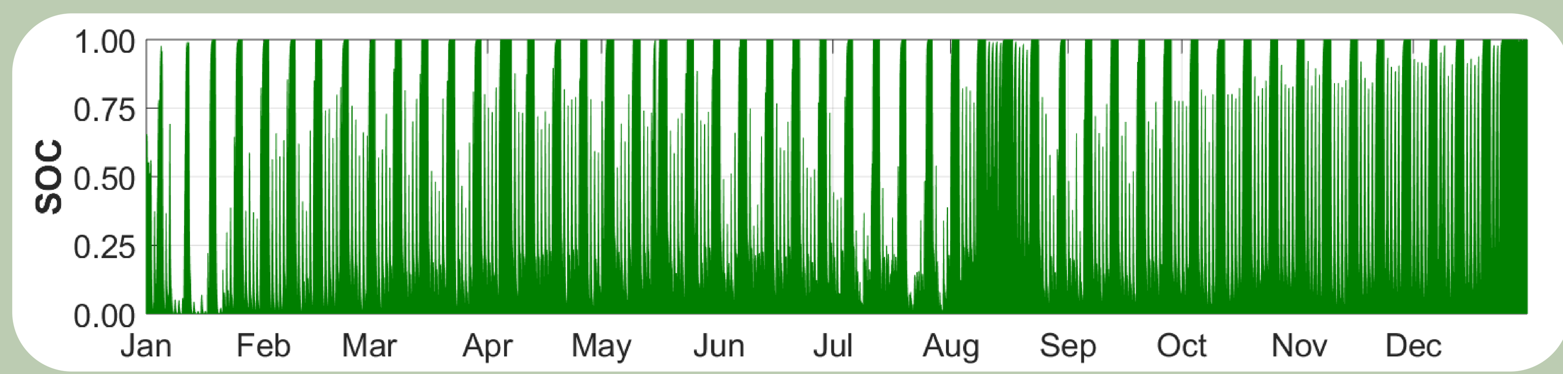
Simulation results

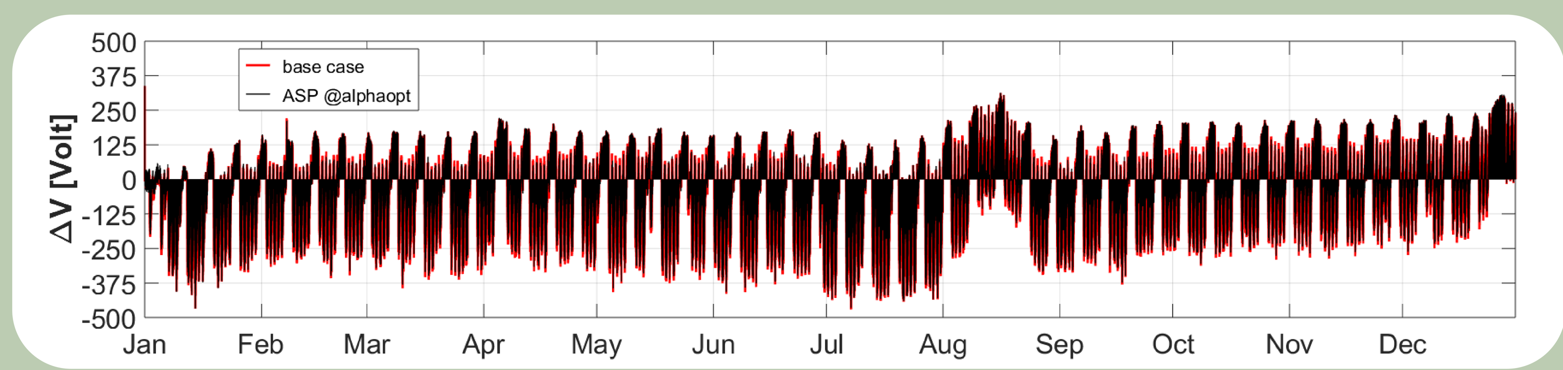
The simulation results obtained are here synthesised:

$$Var(\Delta V)\Big|_{nobatt} = 25.5e3$$

$$Var(\Delta V)\Big|_{\alpha=\alpha_{opt}} = 23.8e3 \quad (-7\%) \qquad \alpha_{opt} = 4.27$$

Battery SOC and ΔV (base case and ASP active) are plotted below.





Advantages

The simulation can be run without explicit flow control and/or recurring to any customized update of the electrical entities after every step. After essential, boilerplate-free definition of the smart agent behavior, the execution of the smart agent scripts is managed autonomously and the results requested are automatically computed, extracted and recorded at each step as return value of the simulation. All quantities are provided complete with a unit measure (pint[4] package). Furthermore, the user is able to load the base circuit from a structured json file, modify it as needed in the script and save/load it in complete packages, including smart entities and load profiles. Advanced analysis modes are readily available through the extraction of the circuit graph, filled with references to the circuit components, and with the subpackage *graphview* (gv).

Future development

In the future, efforts will be made in enabling parallelized smart agent simulation and providing a more extensive toolset for drawing circuit, allowing for visualization both immediate and customizable. Another key development will be integrating the dynamic behavior of the components, in order to allow dynamic simulations in addition to power flow.

References:

[1] http://smartgrid.epri.com/SimulationTool.aspx
[2] Hagberg, Aric, et al. "Networkx. High productivity software for complex networks." *Webová strá nka https://networkx. lanl. gov/wiki* (2013).
[3] Munos, Rémi. "Optimistic optimization of a deterministic function without the knowledge of its smoothness." *Advances in neural information processing systems.* 2011.
[4] https://pint.readthedocs.io/en/latest/

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GitHub