

Off-Grid Systems Modelling with MicroGridsPy

Hands-on 5

GitHub repository for source code:

<https://github.com/MicroGridsPy/MicroGridsPy/tree/Online-Course>

MicroGridsPy is an open-source project, currently under active development, check out the detailed online documentation for usage guidance and updates:

<https://microgridspy-docs.readthedocs.io/en/latest/>

Learning outcomes

By the end of this exercise, you will learn how to:

- 1) Explore the MicroGridsPy User Interface functionalities
- 2) Understand how to initialize and input Renewables parameters
- 3) Understand how Renewables parameters affect results

Important requirement

Ensure that MicroGridsPy is correctly installed and functioning within the dedicated conda environment. It will be also required a stable internet connection. Additionally, it is suggested (though not strictly required) to have Gurobi installed for improved performance of the model optimization. Refer to the installation procedure and guidance provided in Hands-on 1 for detailed instructions.

Introduction

Launch the Application: Recap

Let's briefly recap how to launch the user interface after having correctly creating the MicroGridsPy environment using conda and downloading the MicroGridsPy folder.

- Launch Spyder Using Anaconda. To launch Spyder, an integrated development environment (IDE) for Python, users can proceed this in two ways:
 1. Using Anaconda Prompt: Open the Anaconda Prompt, activate the mgpy environment (if not already activated), type the command *spyder* and press enter to open Spyder.
 2. Using Anaconda Navigator: Launch Anaconda Navigator, activate the mgpy environment from the "Environments" tab. Then, in Anaconda Navigator's "Home" tab, find "Spyder" in the list of available applications and click "Launch" to open Spyder.
- Launch the Interface within Spyder: Once Spyder is open, follow these steps to launch the MicroGridsPy interface:
 1. Check if the default layout is suitable; if not, set it from the "View" button.
 2. Locate the MicroGridsPy working folder using the Spyder interface's "File" menu.
 3. Open the project folder by double-clicking on it.
 4. Navigate to the "Code/User Interface" folder within the project folder.
 5. Look for the *app_main.py* file and double-click on it to open it.
 6. Run *app_main.py* by pressing F5 or using the "Run" button in Spyder's toolbar.

Upon completing these steps, the MicroGridsPy interface will launch within Spyder resulting in this situation:

Hands-on objective

In this hands-on session, we will delve into the Renewables parameters page of MicroGridsPy interface to master its usage. Our goal is to understand how to manipulate and analyze renewables parameters within the software effectively.

Default configuration

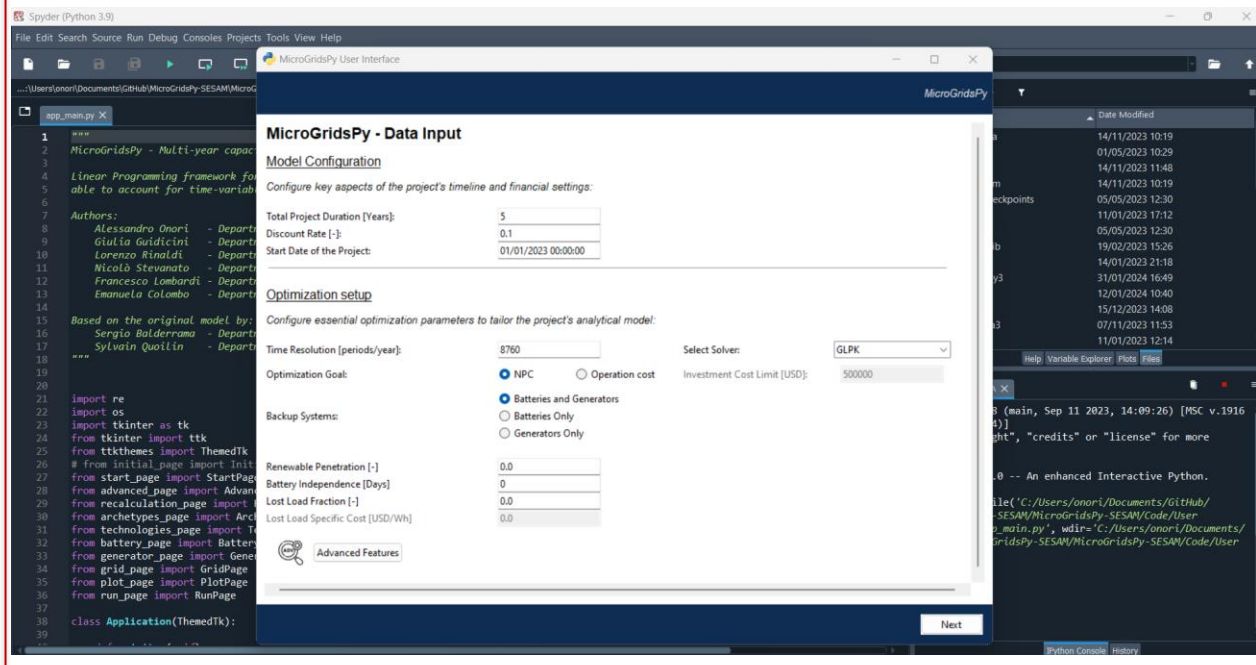
To recap, the default configuration we'll work with includes a 20-year model horizon, hourly operation, a 10% discount rate, and a focus on minimizing net present costs. The model is

allowed to consider both batteries as storage system and generators as backup system and there are no additional constraints implemented. The exemplary case study focuses on Sub-Saharan village in Zambia with an annual growth rate of 5%, leveraging NASA Power Project data for resource assessment (specifically solar and wind). Technology characterization includes photovoltaic modules, wind turbines, battery banks, and diesel generator with exemplary but not realistic parameters.

Note

If you have Gurobi installed with an activated license, you can choose to leave Gurobi as the default solver for your MicroGridsPy simulations. This solver is known for its capabilities and speed, which can significantly expedite the optimization process.

However, if you don't have a Gurobi license, you can opt to use the open-source free-to-use solver option, "GLPK," but making a specific adjustment. Please select "GLPK" from the solver dropdown menu and set the time horizon to 5 years. While this configuration may result in slight variations in the results (though not significantly), it substantially reduces the computational effort and the time required for solving. You can expect the solving time to be approximately 45-60 minutes (depending on your system computational performance), striking a favorable balance between result accuracy and computational efficiency.



Renewables Parameters

Renewables Characterization in MicroGridsPy provides a dynamic interface for setting and adjusting a range of parameters specifically for renewable energy technologies. This includes the ability to define the type and capacity of renewables such as solar PV and wind turbines, their efficiency, investment and operational costs, lifespan, emissions, and the expected operational output.

Each column maps to a renewable source's output

	1	2
1	0	432812,5
2	0	461477,8
3	0	430550,8
4	0	318517,4
5	0	156753,5
6	0	346411,4
7	21,26435	612342,8
8	193,8794	589845,4
9	382,0014	455267,6
10	561,6518	302666,6
11	708,8004	186153
12	805,386	101622,2
13	840,2869	52911,46
14	810,5032	28713,44
15	718,4495	26851
16	574,5458	55376

CSV

Code/Inputs/RES Time Series

Types

RES Sources [unit]
Number of Renewable Energy Sources (RES) types to be included within the possible generation sources

RES Names [text]
RES name for each sources within MicroGridsPy

Energy conversion

RES Nominal Capacity [W]
Capacity per unit of electricity production provided in the RES time series data csv file

RES Inverter Efficiency [fraction]
Efficiency of the inverter connected to each RES (1 in case of AC bus)

Costs

RES Specific Investment Cost [\$/W]
Specific investment cost for each type of RES

RES Specific OM Cost [fraction]
O&M cost for each type of RES as a fraction of the specific investment cost

Sustainability

RES Lifetime [years]
Lifetime of each RES

RES unit CO2 emissions [kgCO2/kW]
Specific emissions of capacity installed (indirect emissions)

With the provision of activating advanced features, users can enable or disable parameters based on specific project needs, such as greenfield or brownfield investments. This flexibility allows for precise modeling in various development contexts, tailoring the simulation to the unique characteristics of the site and the renewable resources available.

Define the number and type of renewable sources to be considered:

RES_Sources	1	Update Parameters Configuration
RES_Names	Solar PV	Wind Turbine
RES_Nominal_Capacity	1000.0	1670000.0
RES_Inverter_Efficiency	0.98	0.95
RES_Specific_Investment_Cost	0.95	1.9
RES_Specific_OM_Cost	0.018	0.05
RES_Lifetime	25	20
RES_unit_CO2_emission	0	0
RES_capacity	0	0
RES_years	0	0

The interface includes an "Update Parameters Configuration" button for applying new settings to renewable energy sources. In particular:

1. Set the number of renewable sources in **RES Sources**
2. Press the button to update the entries for each parameter
3. Visualize the **new set of default values** for each parameter
4. Edit the values as preferred

Define the number and type of renewable sources to be considered:

RES_Sources	1	Update Parameters Configuration
RES_Names	Solar PV	
RES_Nominal_Capacity	1000.0	
RES_Inverter_Efficiency	0.98	
RES_Specific_Investment_Cost	0.95	
RES_Specific_OM_Cost	0.018	
RES_Lifetime	25	
RES_unit_CO2_emission	0	
RES_capacity	0	
RES_years	0	

For instance, users can input the names of the renewable sources, like "Solar PV" or "Wind Turbine," and specify nominal capacities that reflect the intended scale of the project. Efficiency figures are adjustable to mirror real-world performance metrics, while investment and operational costs can be calibrated to current market rates or specific financial frameworks. The interface also includes fields for the lifespan of the renewable technologies and their associated CO2 emissions, ensuring that sustainability metrics are considered in the model. Additionally, the renewable capacity factors are crucial inputs, as they directly influence the anticipated energy output, which is particularly important when renewable generation is calculated endogenously within the software.

Renewables Characterization

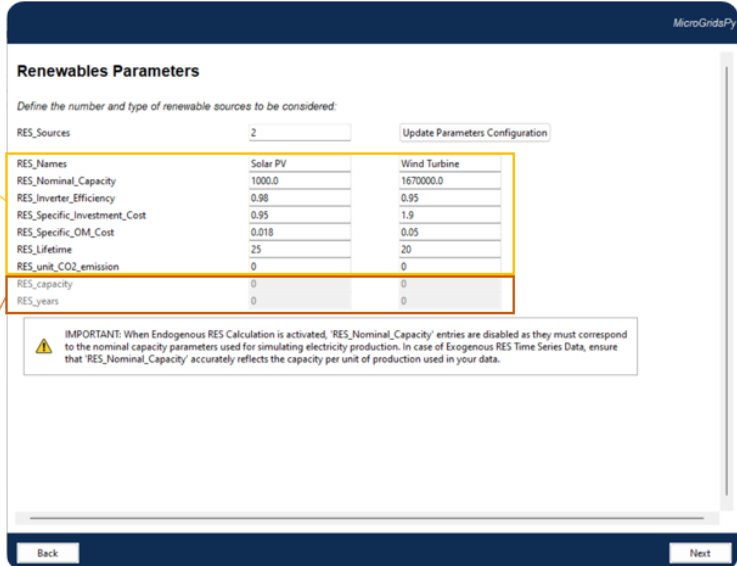
It allows setting types, capacities, efficiencies, costs, lifespans, emissions, and expected operational output for renewable energy technologies

Parameters that would be enabled or disabled according to *specific advanced features activated* (brownfield in the example)

Advanced Features

Advanced Modeling Options

Type of Investment: Greenfield Brownfield



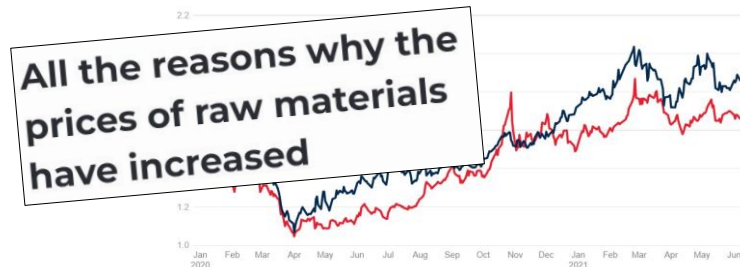
Parameter	Solar PV	Wind Turbine
RES_Nominal_Capacity	1000.0	1670000.0
RES_Inverter_Efficiency	0.98	0.95
RES_Specific_Investment_Cost	0.95	1.9
RES_Specific_OM_Cost	0.018	0.05
RES_Lifetime	25	20
RES_unit_CO2_emission	0	0
RES_capacity	0	0
RES_years	0	0

IMPORTANT: When Endogenous RES Calculation is activated, 'RES_Nominal_Capacity' entries are disabled as they must correspond to the nominal capacity parameters used for simulating electricity production. In case of Exogenous RES Time Series Data, ensure that 'RES_Nominal_Capacity' accurately reflects the capacity per unit of production used in your data.

Exercise 1

In light of the current global supply chain disruptions, the renewable energy sector, particularly solar photovoltaic (PV) panel manufacturing, has faced significant cost pressures. The recent raw materials crisis has led to an increase in the price of key components for PV panels, such as polysilicon, steel, aluminum, and copper. The cost of PV-grade polysilicon, for example, has seen a more than fourfold increase since the beginning of 2020. Similarly, the prices for steel, copper, and aluminum have all risen considerably, by 50%, 60%, and 80% respectively, affecting the total investment costs of solar developments. These rising costs could impact the entire value chain, from manufacturers adjusting the price of their products to developers facing higher contract prices in government-led competitive auctions. The situation may also be exacerbated by geopolitical tensions, supply chain bottlenecks, and concerns around tightening supply, particularly for critical minerals and metals essential for clean energy technologies.

Critical minerals threaten a decades-long trend of cost declines for clean energy technologies



In this exercise, we will test a solar hybrid mini-grid (no wind considered) using the default configuration of MicroGridsPy but increasing the investment cost of the PV panel up to 3 \$/kW.

Once set the described (exemplative) scenario, run the model while keeping other parameters that are NOT affected by this new scenario (not necessary all) unchanged. Refer to the previous hands-on guides for detailed steps on running the model.

After the optimization process, take note of key results and the relevant plots generated by MicroGridsPy.

Exercise 2

In this exercise, we will delve into the environmental aspect of renewable energy systems, focusing on minimizing direct emissions. We will simulate a solar hybrid mini-grid, similar to the previous exercise, but with a crucial modification: the energy storage system will solely consist of batteries, excluding the use of a diesel generator. This approach aligns with the growing emphasis on reducing carbon footprints and promoting cleaner energy solutions.

The objective is to explore the performance of two distinct types of battery technologies – Lead Acid and Lithium-Ion – under this constraint. Participant is required to run MicroGridsPy model twice, once with each battery type, to compare their efficiency, sustainability, and overall impact on the mini-grid system.

- **Lead Acid Batteries:** These are traditional, widely used batteries known for their reliability and low upfront cost. However, they have a shorter lifespan and lower energy density compared to modern battery technologies. Their efficiency drops significantly in high discharge scenarios, and they require regular maintenance.
- **Lithium-Ion Batteries:** These batteries are gaining popularity due to their higher energy density, longer lifespan, and minimal maintenance needs. They can handle deep discharge cycles better than Lead Acid batteries. However, they are more

expensive in terms of initial investment and have concerns related to sourcing of materials and recycling.

Here the parameters required (exemplative):

Parameter	Lead-Acid	Lithium-Ion
<i>Specific Investment Cost</i>	0.15 \$/kWh	0.3 \$/kWh
<i>Specific Electronic Cost</i>	0.05 \$/kWh	0.1 \$/kWh
<i>Specific O&M Cost</i>	3%	2%
<i>Charge & Discharge Efficiency</i>	85%	95%
<i>Depth of Discharge</i>	50%	80%
<i>Charge & Discharge Time</i>	5 h	3 h
<i>Cycles</i>	3000	5000

Use the Load Demand time series data provided in “Material” folder.

Participants should pay close attention to how each battery type influences the overall performance and sustainability of the solar hybrid mini-grid. After running the model with both battery configurations, note the key results.

As in the previous exercise, keep other parameters that are not affected by this new scenario unchanged. Refer to the hands-on guides for detailed steps on running the model.

Well done on completing the hands-on 5!



This document was updated on 01.11.2024