Hybrid microgrid planning using selected Open-Source frameworks

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elena – electricity network analysis

Our Vision: Enabling Renewable Power Grids
with grid planning based on Open-Source Software

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Founding partner

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Chief Software Architect

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Chief Project Manager

Winners of Leibniz Gründerpreis
Company Profile

Our Services:

• assembly of weather and load data to understand your power system better
• simulation models of your power grid to improve your grid planning
• optimal sizing of storage, generation and transmission capacities
• cost-effective operational strategies with unit-commitment modeling
• control solutions for a stable and reliable RES integration
• transient frequency and voltage stability analysis
Outline

1. Motivation for Hybrid Microgrids
2. Why Open-Source?
3. Hybrid Microgrids Design & Stakeholder Requirements
4. Selection of Open-Source Power System Planning Tools
5. Evaluation & Take-home message
1. Why Hybrid Microgrids?

- to decrease electricity prices, gain independence from diesel price fluctuations & transportation
- a cost-efficient energy transformation
- to reach high shares of renewables
- maintain grid stability and increase infrastructure lifetime
Central Question

What are adequate Open-Source frameworks for hybrid microgrid planning?
2. Why Open-Source?

- Harmonization (across software tools)
- Flexibility (modifiable & extendable)
- Transparency (no black-box modeling)
- Data security
- Cutting-edge (R&D, maintenance from Open-Source community)
- No licensing costs
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5. Evaluation & Take-home message
3. Design & Stakeholder Requirements

- Load and renewable time series data

Step 1: System sizing

- Generation, storage & transmission capacities

Step 2: Identification of optimal operational strategies

- Generation & storage profiles/ time series

Step 3: Grid analysis

- Grid stability functions (e.g. spinning reserve requirements)

S. Berendes et. al. HPW (2018)
Input Data for Step 1 - System Sizing

secondary functionality (couple with resource data and load profiles, update uncertain parameters over the course of optimization horizon).

Solar irradiance

Demand data
Step 1: System Sizing

What microgrid components should a model contain?

- high: PV, battery storage (lead acid, Li-ion), multiple diesel generators, controller strategies, inverters, AC- and DC coupling
- medium: wind, biomass, hydro-turbines, thermal storage, fuel cell, grid
- low: geothermal components, tidal sources, high-temp. battery storage
Step 1: System Sizing

“Copper plate”
- Optimization
- no power flow
- Simple power balance

Linear Optimal Power Flow
- Linear cost function
- linearized power flow as constraint

Optimal Power Flow
- Nonlinear cost function
- Nonlinear power flow as constraint

Increasing complexity/ nonlinearity

- to include storage in this optimization it is necessary to model a multi-period optimization
Step 2: Unit-Commitment Modeling

Generation, storage & transmission capacities fixed

→ how to dispatch generators? What are operational strategies?
Step 3: Grid Analyses

Choose snapshots from these Generation & storage profiles/ time series For Grid Analyses

• DC Power Flow
• AC Power Flow
• Short-circuit analysis
• Harmonic analysis
• Transient frequency and voltage stability analysis
Outline

1. Motivation for Hybrid Microgrids
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4. Selection of Open-Source Power System Planning Tools
5. Evaluation & Take-home message
4. Selection of Open-Source Tools

...for planning Hybrid Power Systems/ Microgrids

- Open-Source frameworks that take grid constraints into account
- tools available in Python or Julia
- no ready-for-use tools but demand a certain level of programming expertise

<table>
<thead>
<tr>
<th>General Information</th>
<th>PyPSA</th>
<th>PowerSimulations.jl</th>
<th>Open-Source Frameworks</th>
<th>PowerModels.jl</th>
<th>Julia</th>
<th>OEMOF</th>
<th>GridCal</th>
<th>pandapower</th>
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PyPSA* / EnergyModels.jl

“Python for Power System Analysis”, by the Karlsruhe Institute of Technology
(EnergyModels.jl - Julia correspondent, WIP)

Strengths:

- Preimplemented features for system sizing and unit commitment modeling with LOPF
- Sector coupling possible
- DC & AC Power Flow Analysis
- Components like solar, diesel & storage implemented

Weaknesses:

- No nonlinear optimal powerflow (WIP)
- No short-circuit, harmonic or transient stability analysis

*github.com/PyPSA/PyPSA
Oemof*/ micrOgridS

.. is an "Open Energy System Modelling Framework" in Python by the Reiner Lemoine Institut and the Center for Sustainable Energy Systems. micrOgridS was developed by applying the Open Energy Modelling Framework.

Strengths:

• System sizing and unit commitment modeling
• Sector coupling
• Input data can be generated with demandlib (load profiles for electricity and heat) and the feedinlib (PV and wind feed-in data)

Weaknesses:

• no integration of grid constraints
  - no DC or AC power flow
  - no optimal power flow
  - no short circuit analysis etc.

*github.com/oemof
.. combines data analysis library pandas and the power flow solver PYPOWER to analyze and optimize power systems, developed by the University of Kassel and the Fraunhofer IEE,

Strengths:

- Predefined objectives like maximization of generation or loss minimization.
- DC & AC Power Flow as well as Linear & Nonlinear Optimal Power Flow with different solvers
- Short-circuit analysis

Weaknesses:

- No preimplemented features for unit commitment and system sizing
- no harmonic or transient stability analysis

*github.com/e2nIEE/pandapower
5. Take-home message(s)

• Open-Source frameworks can cover planning process (from system sizing to unit commitment modeling and power flow analyses)

• depending on the focus of microgrid planning we choose and combine different frameworks

• frameworks are under strong & continuous development → further improvement

• In this review tools for transient stability excluded, here we choose PowerDynamics.jl (co-developed and maintained by elena)