Categorization of tools and methods for modeling and simulating hybrid energy networks

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Power Networks
- tools for system planning
- tools for design optimization
- tools for operation
- etc.

Heating / Cooling Networks
- tools for system planning
- tools for design optimization
- tools for operation
- etc.

Gas Networks
- tools for system planning
- tools for design optimization
- tools for operation
- etc.

Hybrid Energy Networks

???
Why are the tools we have used so far not enough?

• domain-specific tools for energy networks → single domain only
  – at best, only coupling points to other domains can be modelled

• established multi-energy modelling tools → no focus on energy networks
  – no network capacities, imports/export from/to external grid, etc.

Are there other tools available? What can we do with them?

1. started with online survey among tool developers and simulation experts
2. additional literature review for complementing the survey results
3. apply selection criteria on survey and literature review results
4. perform expert review based on classification categories
Selection criteria for considered tools and methods:

• focus on energy networks
  – at least two types of energy networks must be considered
  – energy networks must be considered at least on the level of energy balances (implicit network model)

• availability
  – an implementation of the tool / method must be publicly available
  – either commercially or otherwise (open source, freeware, etc.)

• documentation
  – an application in the context of hybrid energy networks must be publicly documented
  – for instance via a manual, a journal article or otherwise
Selected tools and methods (out of a total of 31 survey and literature review results):

- Pandaplan [1]
- Co-simulation of network simulators
  - for instance Dymola and pandapower [2]
- Modelica [3]
  - with dedicated libraries such as the IBPSA Library, DisHeatLib or Modelon Library Suite
- energyPRO [4]
- EHDO [5]
- EnergyPLAN [6]
- ESSIM [7]
- GasPowerModels.jl [8]
Classification categories for tools and methods:

- **spatial resolution of component models**
  - components, buildings, districts/settlements, cities, regions, nations, continents

- **temporal resolution of component models**
  - seconds, minutes, hours, days, weeks, months, years

- **targeted scale of system model**
  - components, buildings, districts/settlements, cities, regions, nations, continents

- **targeted time horizon of system model**
  - seconds, minutes, hours, days, weeks, months, years

- **application class**
  - technical, economical
Classification categories for tools and methods (continued):

• type of power network model
  – none, energy balance (implicit: no lines, cables, etc.), quasi-static (power flow), electro-mechanical, electro-magnetic transients

• type of thermal network model
  – none, energy balance (implicit: no pipes, etc.), quasi-static (pressure equilibrium), hydraulic transients

• type of gas network model
  – none, energy balance (implicit: no pipes, etc.), quasi-static (pressure equilibrium), hydraulic transients

• energy storages included
  – yes, no
<table>
<thead>
<tr>
<th>Tool / method</th>
<th>Power network model</th>
<th>Thermal network model</th>
<th>Gas network model</th>
<th>Energy storages included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pandaplan</td>
<td>quasi-static (power flow)</td>
<td>quasi-static (pressure equilibrium)</td>
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<tr>
<td>Co-simulation *</td>
<td>quasi-static (power flow)</td>
<td>hydraulic transients *</td>
<td>not modeled *</td>
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<tr>
<td>Modelica **</td>
<td>electro-mechanical **</td>
<td>hydraulic transients **</td>
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<td>energyPRO</td>
<td>energy balance (implicit: no lines, cables, etc.)</td>
<td>energy balance (implicit: no pipes, etc.)</td>
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<td>EHDO</td>
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<td>GasPowerModels.jl</td>
<td>quasi-static (power flow)</td>
<td>not modeled</td>
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</tbody>
</table>

* for approach described in [2]  ** for approach described in [3]
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<thead>
<tr>
<th>Tool / method</th>
<th>Application class</th>
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<tr>
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Rationale of intended purpose of tools and methods:

• **Characterization**
  – the state of a system is evaluated without changing its properties
  – example: perform load flow analysis for calculating the distribution of voltages and currents in a network

• **Optimization of planned networks**
  – methods useful for planning purposes
  – example: improvement of grid topology or plant and device positions to meet given criteria

• **Operational optimization (technical)**
  – methods for improving the system performance with focus on technical aspects
  – example: control algorithm for P2G plants, which maintains a given gas composition in the network

• **Operational optimization (economical)**
  – methods for improving the system performance with focus on economical aspects
  – example: algorithm deciding on how to use generated PV excess power (grid feed-in or self consumption) based on market price predictions.
<table>
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<tr>
<th>Tool / method</th>
<th>Characterization</th>
<th>Optimization of planned networks</th>
<th>Operational optimization (technical)</th>
<th>Operational optimization (economical)</th>
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Conclusions:

- **new tools and methods** have been developed that focus specifically on **hybrid energy networks**
  - not simply extensions of established domain-specific or multi-energy tools
  - cover a wide range of approaches for modelling and simulating hybrid energy networks

- based on their **modelling approaches** and **intended purposes**, these tools and methods can be grouped in **4 categories**
  - tools for technical assessments
  - tools for operational optimization (technical & economical)
  - tools for planning on the scale of cities / regions
  - tools for planning on the scale of nations / continents
References


[6] H. Lund: "Renewable heating strategies and their consequences for storage and grid infrastructures comparing a smart grid to a smart energy systems approach", https://doi.org/10.1016/j.energy.2018.03.010


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