Hybrid Mini-Grid Sizing with micrOgridS

An Open-Source Tool for Optimizing Renewable Energy Components within Mini-Grids

By Sarah Berendes

This article represents a summary of the paper *Sizing and Optimization of Hybrid Mini-Grids with micrOgridS – an Open-Source Modelling Tool* (Berendes et at.) which was accepted for the 3rd International Hybrid Power Systems Workshop in Tenerife, Spain, May 9th/10th 2018. An edited version appeared in Windtech International Magazine, Issue No.5, Vol. 14 in August 2018.

Hybrid Mini-Grids (HMG) are an ideal solution for remote settlements without energy access. HMGs are typically sized and optimized with commercial software that comes with the usual limitations and lacks of transparency. Reiner Lemoine Institute has attempted to develop an open-source alternative to standard software for modeling and sizing HMGs.

For rural and remote areas, Hybrid Mini-Grids (HMG) present a cost-effective and fuel-saving electrification option. IEA estimates that new electrification projects will comprise by 30% to 50% of mini-grids[1]. Especially island communities cannot supply their inhabitants with electricity by the conventional approach of grid extension, as it is unprofitable or even impossible, due to their geographical location. The energy supply on small islands is thus widely realized through a set of diesel generation units that operate an isolated distribution grid. The introduction of additional energy sources, preferably renewable-based, into such a system is called hybridization. Successful hybridization leads to a reduction in fuel consumption and greenhouse gas emissions as well as decreasing dependency on oil price volatility and a general shift towards modern energy technologies.

Sizing for cost-effectiveness

In order to design HMGs in a truly cost-effective and sustainable way, they need to be sized with regard to a set of variables. In what quantities are renewable resources, such as sun and wind, available throughout the year? What is the community's electricity demand? What load profiles typically occur during the day? The standard software for sizing HMGs is Homer Pro® by HOMER Energy LLC., which generates very reliable results. However, Homer Pro® is a commercial product and is operated as a black-box. This means it needs to be paied for and its code is not open, making it impractical for electrification or hybridization researchers to use Homer Pro® for modifying and improving the project development and sizing process.

Workarounds for individual needs

In practice, many research groups and companies have ended up developing their own HMG sizing tool, as their specific needs were not met by the standard commercial software. But these

[1] http://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf

home-made tools are often neither validated nor maintained professionally. The Reiner Lemoine Institut (RLI) has therefore compiled the requirements for a comprehensive open-source software tool for the purpose of optimized HMG system sizing and operation management as an alternative to the standard commercial software. Based on these findings, the open-source tool micrOgridS was developed and validated in a case study of a Pacific Island. RLI built the software on basis of the Open Energy Modeling Framework (oemof), which is an open-source tool for modeling and analyzing energy systems. For micrOgridS, oemof was successfully adapted for a Mini-Grid setting.

oemof functionality

oemof is a generic, open-source toolbox that features a range of useful functions to describe and optimize energy systems. The term generic refers to oemof not being programmed for specific applications that follows one specific mathematical approach, but rather that it can be utilized for various optimization problems. omeof's developer community has its roots in the Open Energy Modelling Initiative, which follows strict open-source, open-data, and open-science policies. The framework is programmed in the object-oriented programming language Python, and its development follows scientific standards.

Nodes and Flows

oemof uses a graph-based approach to describe energy systems. Its components are basically represented by Nodes-objects that are connected via Flow-objects. Due to the generic character of oemof, no units are assigned to the Flows by default. Instead, the user is requested to determine the units and to ascertain their consistency. For the micrOgridS model, all flows are regarded as power flows in kW, except the Flows being connected to the Bus-object representing the Fuel bus. These Flows represent actual fuel flows in litres.

MicrOgridS functionality

Being based on oemof, mircOgridS is also programmed in Python. It uses oemof as a toolbox to model HMGs and is in its current status suitable for sizing HMGs that add photovoltaic (PV) and battery components as well as respective inverters to an existing grid of up to three diesel generators. The sizing process works as follows: A set of equations and constraints is formulated, including minimum and maximum load of diesel generators, spinning reserve, and generator order. This set, in combination with the objective function, allows the formulation of a mathematical Mixed Integer Linear Problem (MILP) which is then processed by the mircOgridS model. The objective function represents the minimum total system cost which correlates with minimum LCOE (USD/kWh) and its result represents the optimized sizing of the HMG. In this case it answers the question "How much PV and battery capacity should be added to the mini-grid?". A second result is the optimized dispatch of power flows for each time step.

Lifuka as an example setting for testing micrOgridS

The micrOrgridS model was tested in a case study for the Pacific island Lifuka, Tonga, located North of New Zealand, and compared with results from Homer Pro®. Both tools were fed the same input parameters for sizing a HMG with the components PV, battery system, and diesel generator with the goal of achieving the lowest power generation costs. The results, which are found in Table 1, showed that the micrOgridS optimization calculated lower values for all compared parameters than Homer Pro®. The highest absolute deviations were found in the battery size (-392 kWh compared to Homer Pro®, which equals 46.9 percent relative deviation) and excess energy (-20,739 kWh which equals 35.7 percent relative deviation). It is noteworthy, that micrOgridS and Homer Pro® have come to very similar results in diesel-only scenarios. Deviation increased with growing complexity, as PV and batteries were added to the grid step by step. It can be taken as a first indicator, that micrOgridS in its basic outline is on a par with Homer Pro®, but that the requirements for added hybrid components call for further validation.

Table 1:

	Pr pv (kW)	**Pr batt (kWh)**	**LCOE (USD/kWh)**	**RE share (%)**	**Fuel (l)**	**Excess (kWh)**
micrOgridS	264	338	0.31	33.1	212,419	37,415
Homer Pro®	288	730	0.34	34	266,012	58,154

Open-source as empowerment in energy access efforts

As Homer Pro®'s code is not open, it is impossible to determine, which tool performs "better" and where exactly different assumptions are made. But this also illustrates the necessity for an open-source modeling tool: HMGs are almost ideal solutions for providing electricity in a sustainable way for communities, who cannot rely on superordinate institutions to supply them. These are most of the times located in developing countries and their on-site situation may differ from scenarios in commercial standard software. Providing these communities with an open tool for sizing their individual electrification scenarios is also a form of empowerment for the people who live there. It is in line with the United Nations' Sustainable Development Goal Number 7: To ensure access to affordable, reliable, sustainable and modern energy for all.

Conclusion

An adaptation of oemof for sizing HMGs seems to be a promising pathway in creating an open-source alternative to standard commercial software. By utilizing oemof the integration of wind turbine models is rather simple. micrOrgridS has not yet reached a stage in which it could be used for actual hybridization projects, as it does not cover all complexity requirements and still needs adjustment. However, it is a very promising basis for future development. In the next phase, micrOrgridS should be validated under real-world conditions and expanded in its functionality. This can be achieved with an active developer community and collaborative development – a way that has already been led by the oemof project.