TECHNO-ECONOMIC OPTIMIZATION OF A HYBRID MINI-GRID USING A ONE-MINUTE TIME STEP APPROACH

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Motivation:
Power supply (PS) in off-grid mini-grids is mainly provided by diesel generator sets (GS) which leads to high generation costs [1]. Furthermore, GS have very high CO_2 emissions and thus contribute to climate change. Renewable energy systems (RES) offer a cost-effective hybrid solution for regions with sufficient wind and solar potential [2]. While the power generation by RES is emission-free, it is highly volatile and therefore a challenge for the system stability in combination with varying load demands [3], [4]. Other constraints, such as given topography, climate conditions, and local fuel costs also influence the configuration of an optimal hybrid system. Simulations become increasingly necessary handling the large amounts of input data and to optimize such systems. Special interest in those simulations lies in the interaction between the GS and the battery and in the improvement of a hybrid system connecting an energy storage system [5].
This work targets to include certain operation effects into a one-minute resolution simulation model which usually are covered within hourly simulations. By better understanding these effects, a more realistic result for the optimization of hybrid mini-grids can be achieved and the value of batteries for system stabilization can be assessed [5].

Approach and Methodology:
For the simulation a one-minute-model is developed including three different GS, PV and wind systems and battery storage (cf. Fig. 1).Within this model the sizes of PV systems, wind turbines and batteries are optimized to reach the lowest levelized cost of electricity (LCOE). Compared to an hourly simulation with only one GS it is extended by the following features for the GS: minimal operating time, spinning reserve, starting costs, partial load behavior, and a dispatch strategy [6]. Instead of a fixed time span the battery lifetime is based on cycles, which depend on the depth of discharge coupled with charge and discharge efficiencies [7]. An energy management system (EMS) is implemented enabling the battery to lead the GS in an optimal operation point [8], [9], [10]. Furthermore the battery can take part in providing spinning reserve to relieve the GS.

Results:
In a first optimization step a dispatch strategy for the GS, considering the minimal loading of each generator, is determined. For every possible load demand a look-up table shows the resulting partial load behaviors and costs per minute of the GS (cf. Fig. 2). After setting up the GS dispatch strategy the LCOE of a diesel-only system are analyzed over a time span of one year. In a further step, the optimal hybrid system will be calculated, taking several features (such as starting costs, minimal operating time and an operational strategy) into account. The results will reveal the potential of batteries to serve as spinning reserve and to support inflexible GS with long minimal runtimes. In addition, the optimized configuration for the Caribbean island Bequia, St Vincent, will be shown.

Scientific innovation and relevance:
Current simulation methods are usually based on a one hour time resolution (e.g. HOMER Energy) [11]. As aforementioned these simulation tools cannot properly reflect GS operational behaviors. Therefore it is necessary to use this one-minute-model for a more realistic feasibility study for hybrid mini-grids to find the techno-optimized configuration of PV systems, wind turbines and batteries [6].

(Abstract includes one explanatory page)

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Explanatory Page

Figures & Tables

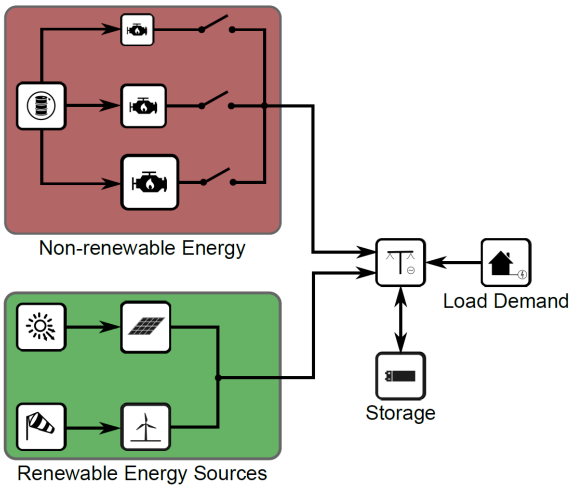

Figure 1: Hybrid mini-grid with generator set.

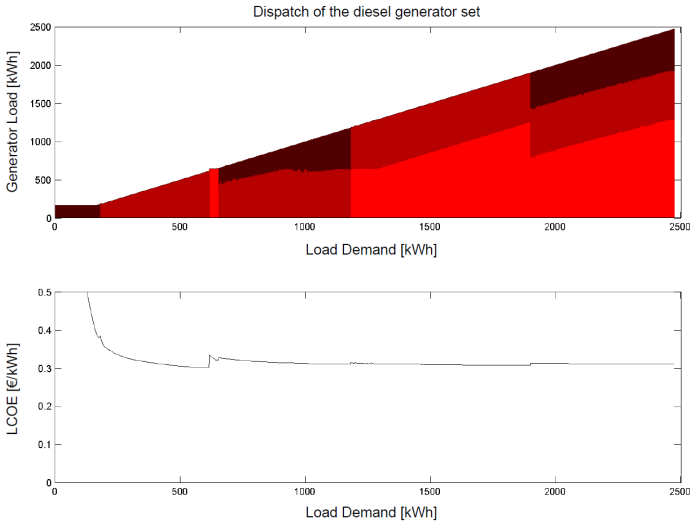

Figure 2: Dispatch strategy for the generator set.

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(Abstract includes one explanatory page)