Master's thesis – track Advanced Matter and Energy Physics

'An Analytical Model for the Configuration of Sustainable Off-Grid Power Stations'

Abstract:

Sustainability has been one, if not the major, hot topics of science and (western) society in the past few decades. Sustainability as a starting point still has to cope with a lot of opposition because it isn't competitive with traditional and proven technologies. Alternatives to fossil fuels are at first sight less reliable and additionally more expensive, especially in the short-run, hence the resistance by many. In the course of time sustainable energy components are becoming cheaper, partly due to research and partly due to economies of scale; together with rising diesel price, due to scarcity, conflicts and carbon tax measures, sustainable energy is becoming more and more interesting as an alternative and sound energy source. Off-grid locations, currently being provided of electricity by diesel generators, pay elevated diesel prices due to their remoteness. In fact, most interesting off-grid locations have quite favourable weather conditions in terms of Capacity Factor, making price per kiloWatt-hour (kWh) lower than average. We study a hybrid powerstation configuration consisting of: wind-turbines, solar PV panels, a batterybank, a multi-source hybrid inverter, and a diesel generator. A general method for studying the optimal system set-up for a target location is by means of iterative simulation. For such a study an incredible amount of accurate data is essential, regrettably such data is hard, and sometimes impossible, to obtain. Alternatively one can base optimisation on average figures, making results less exact, but more relevant in terms of coincidences. Taking chance instead of a specific profile as a starting point makes optimization results much more general. As a tool for non-standard optimisation we have worked out an analytical optimisation model, which is based on the concept of in- and outflow of energy and its equilibrium within certain time domains which are to be specified by the optimiser. A relationship is formulated between the domain and the daily expectations. To correct for causality and extremes, factors are added within the basic relationships which account for the information which is lost when flattening the data into averages within the chosen domain. Finally a price-tag is attributed to each component delivering the optimal set-up by means of minimising total costs. Apart from formulating a method which allows any time domain to be considered, we have also worked out a method for extracting information from average data. This method, called the distribution method, is needed for good functioning of the correction terms. consequentially, good usage of the model expects very accurate knowledge on local climate from the optimiser. Our analytical model proofs to be a very powerful tool for fast and robust optimisation, making it quite easy to figure out regions of interests depending on the prices of the components. The model also allows effective sensitivity studies on break-even points based on price changes of diesel, or any component. Optimisation isn't only a physics and economics problem, politics, sociology, geology and many more factors play an important role. Normally optimisation is studied merely by specialists in the field. One of the interesting points of our model is its very straightforward and visual usage, making cooperation with and between experts in different fields possible at a much earlier stage, consequentially allowing much more in-depth optimisation. We consider to have put the pillars to ground, on both the analytical optimisation model, which we made in mathematica, and the method for average data usage. New components can be added if the necessary study is done. The model should be compared to iterative studies to further improve the correction factors, we believe the model can prove very handy in the fast (re-)electrification of rural off-grid areas and maybe even in the industrialised world.