Technische Universität Berlin

Fakultät VII Wirtschaft & Management

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Bachelorarbeit

Title

Subtitle

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Berlin, Thursday 11th October, 2018

Statutory declaration

Hereby, I declare that I have developed and written this research completely by myself and that we have not used sources or means without declaration in the text. Any external thought, content, media, or literal quotation is explicitly marked and attributed to its respective owner or author.
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Berlin, Thursday 11th October, 2018

Maximilian Eissler

Abstract

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1 Introduction

In this document the topic, motivation and approach of my bachelor's thesis shall be outlined. The aim is to give the reader an idea of what I try to accomplish with the choice of topic and methods, as well as a look at the first iteration of the mathematical model I am aiming to build.

1.1 Motivation

As the technological requirements for a decentralized energy system increasingly mature, the importance of understanding smaller units within the electricity system grows. There is a possibility of increasing reliance on small, partially autonomous grid units (microgrids) in the future. This calls for a better understanding of how such systems might operate. Especially the possible efficiency gains over a centralised system and the circumstances on which these efficiency gains might depend should be of interest to science and will be the focus of thesis.

1.2 Research Question

In my thesis I want to create a model of a small electricity grid with a single point of access to the main grid. The microgrid will contain 25 households of different types that will aim to reduce their total electricity costs. To attain this goal there will be two possible courses of action available:

1. First, the option to invest in electricity generation and storage facilities, in this case only solar pv and battery storage.

2. Secondly, the possibility of unrestricted trade within the microgrid, meaning there will be no variable transaction costs, as they would usually occur in the form of fees and levies on electricity being transferred.

The aim of this approach is to determine the cost-saving potential in comparison to pure electricity consumption from the main grid in subject to the characteristics of the main parameter types to this model, which are:

1. The environmental conditions, primarily pertaining to the availability of renewable resources - in this case, solar irradiation - as well as temperature and changing seasonal energy demand.

2. The 'behaviour' of the participants in this microgrid, primarily their willingness to shift or avoid

loads depending on the current price of electricity within the microgrid or the main grid.

3. The price of power from the main grid as a function of the time of day and season, as well as the price of power generated by the households themselves.

1.3 Methods

To model the outlined situation I want to use the computational modelling language 'Julia' and construct a linear optimisation model which can be solved with it. The goal is to minimise the cost of electricity for the households in the microgrid. It is notable at this point, that the non-consumption of electricity as well as the delay of consumption will be seen as a cost to the actor forgoing her demand. There will be an investment opportunity at the beginning of the examined timeframe of 20 years. The number of timeslices considered in the optimisation will be depending on performance of the model and can therefore not be determined yet.
As a case study for this thesis I want to apply the model to the example of a community in Northrhine-Westfalia. With environmental variables set, I will then construct a number of scenarios with variations in electricity price and actor behaviour parameters.
Another goal of this project is to make this a functional piece of research by reducing performance requirements as far as possible and creating an intuitive user interface that enables the user to 'play' with different scenarios. I prefer this approach over a few detailed and rigid scenarios because the future external factors are presently highly uncertain, which drives me to the conviction that an understanding of the dynamics involved in the examined system is of greater value than an exact solution to an unlikely scenario.

1.4 Expected Results

The result should be a tool that enables an intuitive understanding of the characteristics and the potentials of microgrids, even to non-economists. I intend an exemplary application of the model to the case of a Northrhine-Westfalian community. From this application I expect an insight into the efficiency gains achievable by microgrids in the German context. Also the required external factors for these efficiency gains to materialise should become evident. Under the right conditions I expect a double digit percentage drop in electricity costs compared to a purely consumption-based system. I hope to arrive at practical conclusions regarding present use cases for microgrids and required future regulation.

2 Literature Review

In this section I shall attempt to give an overview over the current status quo regarding the optimizaton of microgrids and more especially the tools available to do so. I will pursue this by answering a number of broad question, which I think are crucial regarding my subject. The procedure will be structured by utilizing a consistent and reproducible methodology described in detail below. In addition to scientific literature other sources will also be taken into account at my discrection if they are neccessary or helpful in answering a question.

2.1 Key Questions

This literature review will attempt to answer the following key questions in the context of my subject:

1. What are the most eminent scientific standards for modelling a microgrid allocation and dispatch?
2. What is usually within the scope of such a model (what types of generation assets, only electricity or also thermal energy and so on)?
3. What are the common methods used to determine some of the key variables required in such a model such as interest rates, CAPEX and OPEX of assets and so on?
4. What are the most commonly used (commercial) tools for optimizing a microgrid? Are there any free or open source solutions?

2.2 Methodology

To arrive at a dataset of scientific literature that is reproducible I use the methodology described in :

add reference to papers here

1. Define a search string
2. Choose scientific databases to which to apply that search string
3. Due to the possibly large amount of papers brought up by this kind of search I am only considering the 100 most relevant papers from each database.
4. Define keywords, which have to occur in the abstracts of the publications. All publications that

lack a keyword are discarded.

5. Define Inclusion as well as Exclusion criteria. A publication must satisfy all inclusion criteria as well as none of the exclusion criteria to be included in the literature review.

Due to the nature of some of the questions I am trying to answer in my literature review it is additionally necessary to include further non-scientific sources at my discretion. The search strings, used databases, as well as the dataset of literature at each step will be included in the appendix.

include info and datasets in the appendix

2.3 Descriptive Analysis

After filtering the original dataset of 275 unique publications in the way described in the last chapter, I arrive at a set of 61 publications. The publication year, as can be observed in Figure 1 is for most publications quite recently: 27 out of 61 papers were published 2017 and after. This could indicate a rising interest in the subject, but is probably at least partly due to the way the different search engines employed compute relevancy.

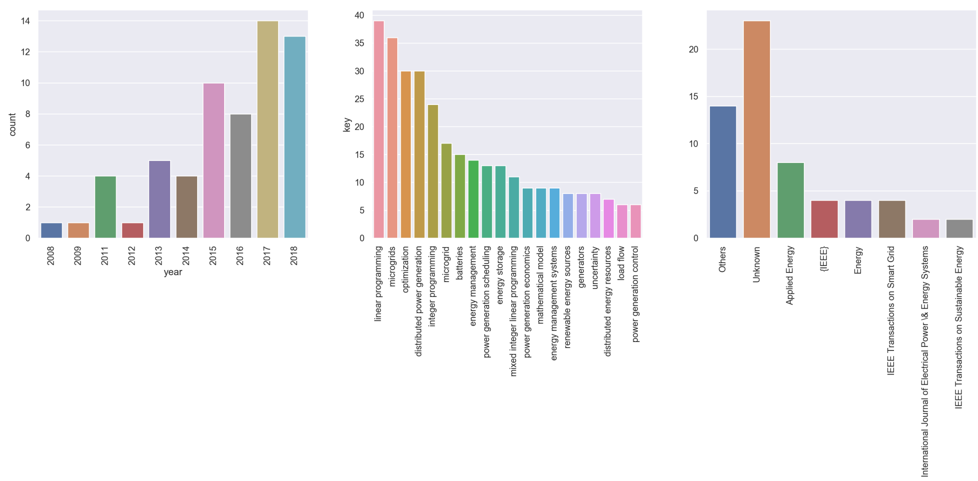

Figure 1: Results of an automated Descriptive Analysis

Source: Own illustration.

Looking at the keywords used to describe the publication shows that, unsurprisingly, the most often occuring keywords are the ones used in conducting the search: 'linear programming', 'microgrids' and 'optimization'. 'distributed energy generation' and 'distributed energy resources'are mentioned 37 times, 'batteries' and 'energy storage' a total of 28 times, and 'renewable energy sources' and 'generators' a total of 16 times. This illustrates the focus on decentralized energy sources and storage, more specifically renewables and small scale combined heat and power generation that prevails throughout the literature.

The publication chart is not very enlightening. This is due to the fact 28 out of 61 publications are conference papers which either appear under others because there is only one instance of that particular conference or unknown. From a more general point of view though almost all papers are published either by Elsevier or IEEE, with very few exceptions.

2.4 Literature Overview

3 Appendix

3.1 Literature Review

The used search String was: [microgrid AND (optimization OR opimisation) AND linear programming]
The used databases are ScienceDirect, IEEE Xplore and Google Scholar.
The original dataset consistet of 300 publication of which 275 remained after duplicates where merged.
The search string for the Abstract Keyword Search was [(microgrid OR micro-grid OR off-grid) AND (optimization OR optimisation OR optimise OR optimal OR optimally) AND (linear programming OR linear program OR mixed integer)
After the abstract keyword search was conducted 106 publications remained.
The inclusion criteria were:

1. An optimization model is employed.
2. There is some discussion about the design of the model.
3. The objective of the model is the optimization of design or dispatch of a single microgrid.
4. There is some sort of case study conducted.

The exclusion criteria were:

1. The publication is not in English language.
2. The full text is not obtainable for this author with reasonable effort.
3. The publication is a Work-In-Progress / Conference Paper version of a publication published in a journal and also included in this dataset.
4. The mathematical model designed is non-linear.
5. The mathematical model designed only considers a specific aspect of dispatch or design, not the entirety.
6. The mathematical model is mostly focused on heat generation/distribution rather than electricity.

After the filtering by inclusion and exclusion criteria 61 publications remained.