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Optimization methods for energy storage integration in smart grids

Kari Mäki, Riku Pasonen, Atte Löf

VTT Technical Research Centre of Finland
Finland
kari.maki@vtt.fi

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I. INTRODUCTION

This publication will present research work on grid integration of energy storages and optimization of storage selection in different use cases. The methodology includes interface to forecasting of renewable energy resources, especially solar power. The publication will present different smart grid applications of energy storages, some control strategies developed for these applications and optimization methods for storage dimensioning and control. Example cases utilizing these developments will be presented. Results will be shown for a case where storage units are integrated on different levels of distribution network and for a case in which viability of storage is considered in a new urban area built according to Smart City principles.

II. CONTENTS

A. Smart Grid applications

The publication will cover different applications (fig. 1) which can be serving different smart grid stakeholders [1]. The applications can be set to serve for instance local user, generator unit owner, energy retailer, distribution network operator or energy markets. The viability of different options strongly depends on regulative framework and market structures.

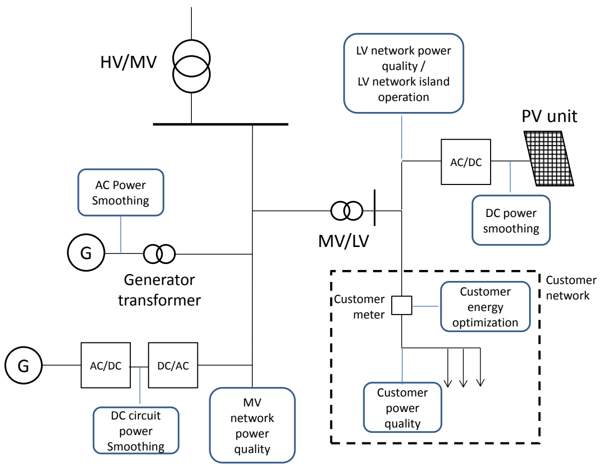

Figure 1. Overview of storage applications

B. Control strategies

The publication will also review different control approaches for the applications. A more detailed look will be taken on local voltage control (fig. 2), which will be gone through on operation logic level, describing the methods, used parameters, constraints, etc.

C. Optimization methods

The publication will discuss dimensioning and controlling storage units as a linear optimization problem. The optimization is conducted on techno-economic basis to determine the optimal storage unit size, type and control strategy. The applications described form the basis for the analysis. The optimization problem is presented on a formula level. The optimization process uses input from PV forecasting [2]. The practical implementation and interfaces (fig. 3) will be explained.

D. Example cases

Example results will be shown from two different cases. The first one is a distribution network case where storage units are integrated on different levels for different purposes. Dynamic modelling is used to assess the potential benefits of storage units. Chosen results on customer level applications will be shown for instance for local voltage support.

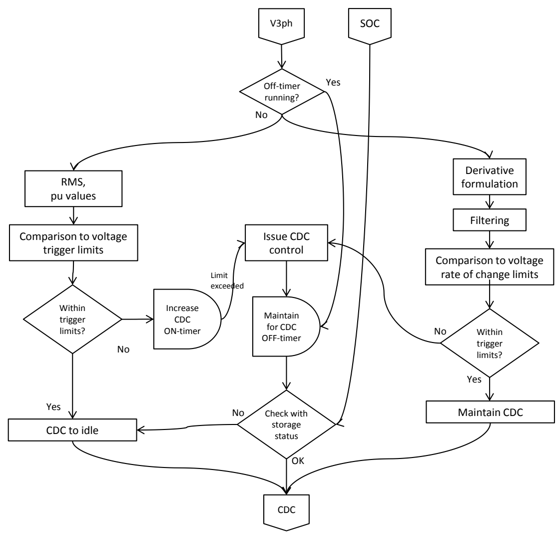

Figure 2. Example of local voltage control logics

Further results will be shown for a case where storage units are applied on new district being built as a smart city area. The study utilizes realistic data for and PV production on the area. Based on this, the optimization methods described are applied to study the viability of energy storages on different levels. The studies are looking at storage solutions on district level, on building block level and on individual building level, seeking for optimal solution.

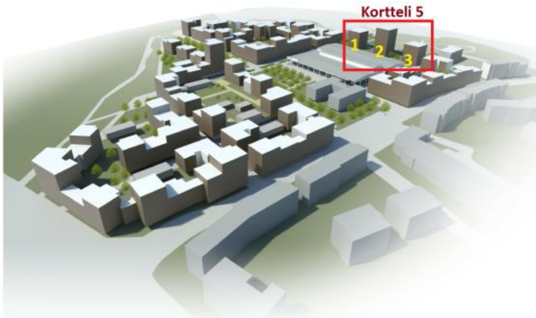

Figure 4. Example smart city area; specific attention is on marked buildings

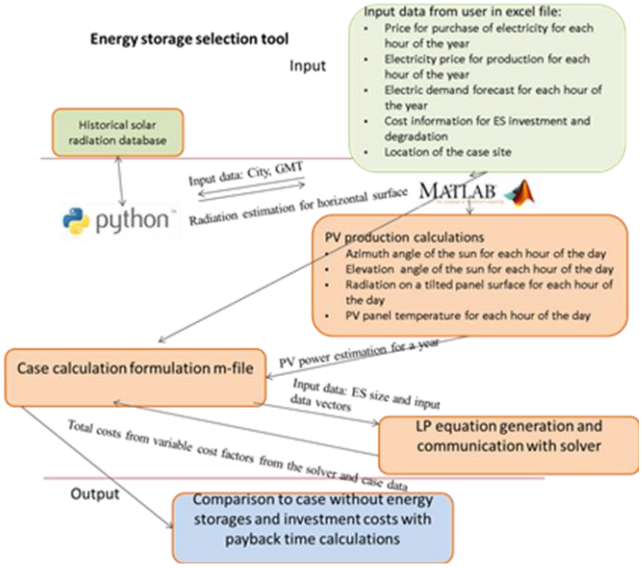

Figure 3. Practical implementation of the optimization method

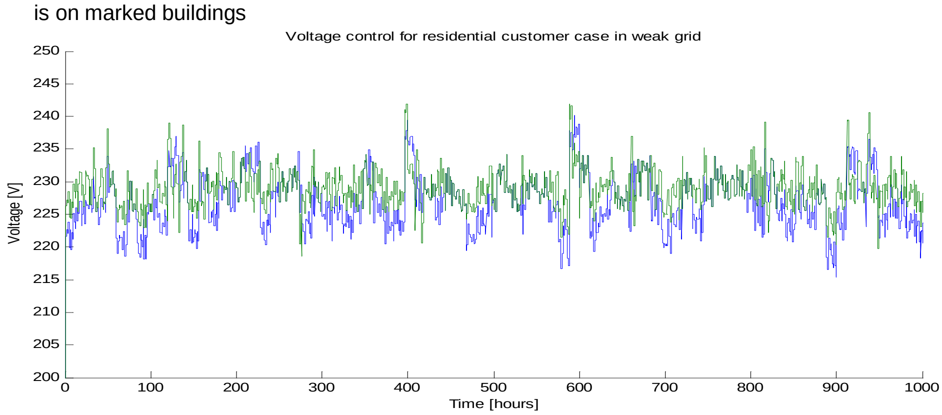

Figure 5. Example of customer voltage profiles (green graph: with storage).

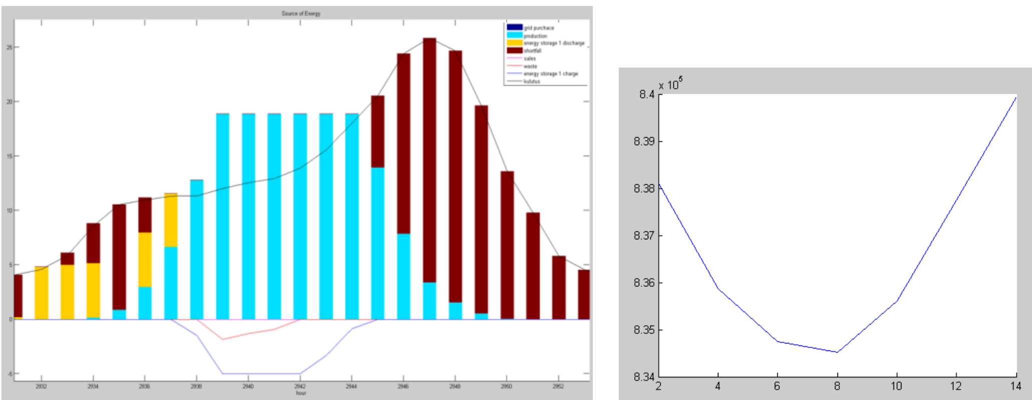

Figure 6. Example results for optimization in smart city case. Daily control stretegy / optimization curve for storage dimensioning.

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REFERENCES

[1] K. Mäki. “Application of storage systems for Smart Grid purposes”, EERA Smart Grids R&D Workshop, Milan Italy, June 2012

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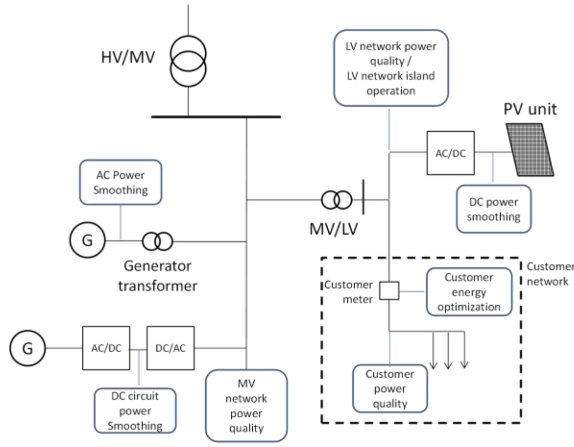
TECHNOLOGY FOR BUSINESS

Introduction

Research work on grid integration of energy storages and optimization of storage selection in different use cases has been conducted. The methodology includes interface to forecasting of renewable energy resources, especially solar power. The work presented covers different smart grid applications of energy storages, control strategies developed for these applications and optimization methods for storage dimensioning and control. The methods have been utilized for a case where storage units are integrated on different levels of distribution network and for a case in which viability of storage units is considered in a new urban area built according to Smart City principles.

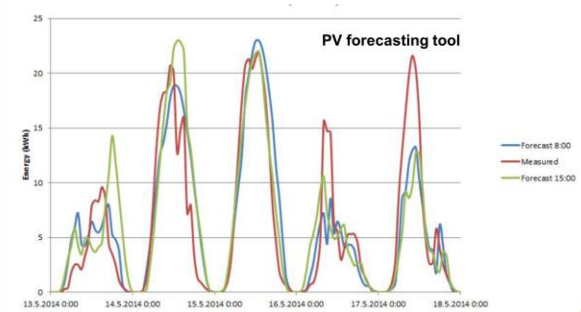


Details

The objective of this work has been to develop optimization methods and tools for different storage applications, taking into account parameters such as PV production, energy tariffs, etc.

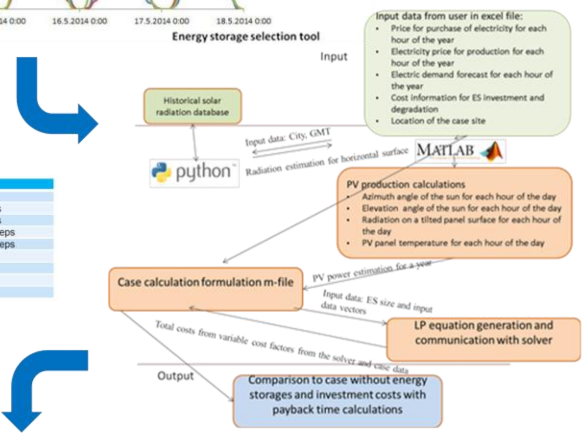
Potential energy storage applications in smart grids

- Network power quality improvement
- Power generation smoothing – especially RES
- Grid load smoothing / peak shaving
- Temporary islanded operation of public grid or customer appliances
- Customer-level energy optimization
- Customer-level quality improvement



Solar production forecasting tool

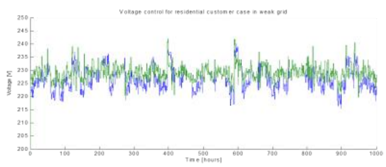
- Solar production forecast for any location in Europe
- Can forecast next 36-40h for actions on day-ahead markets
- Based on the HDKR model (Hay, Davies, Klucher, Reindl)
- Can also be used as input data for optimizing local energy
- system control



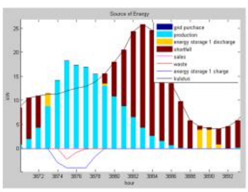
Energy storage selection tool

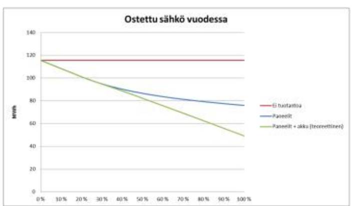
- Based on linear optimization of hourly usage
- Operative costs and investment costs with net present cost method
- Algorithm operating on realistic timeframes
- Target case must be defined for configuration of the tool

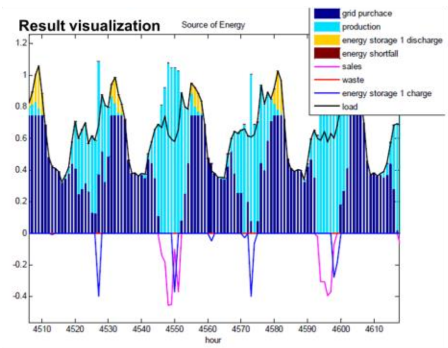
List of configurable parameters	
Grid connection size	kW
PV production data for year	time series in kW with hourly steps
Power demand estimate	time series in kW with hourly steps
Price for energy purchases	time series in €/kWh with hourly steps
Price for energy sales	time series in €/kWh with hourly steps
Cost for degradation of battery	€/(for every kWh used)
Efficiency of the battery (over a cycle)	e.g. 0.85
Range of battery capacities	e.g. 0.5 ->4kWh
Range of batter inverter sizes	e.g. 0.1 ->2 kW



Smart City case:







Contacts

Kari Mäki
Tel. +358 40 142 9785
kari.maki@vtt.fi