Development and testing of adaptive control of battery storage in housing association

WP4 GEC Report

ACES project

Adaptive Control of Energy Storage

Final Version

Glava Energy Center

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ABSTRACT

Introduction

The overall objective of the ACES project/WP4 GEC is to create a test environment to develop, implement and test advanced measurement technology and adaptive control algorithms for energy storage systems in order to allow for improved economics of operation.

Background

Controlling of battery energy storage depends on in which environment the battery is placed and to which business models the battery is operated for. Level of controlling complexity depends on business model and in general, controlling parameters is set manually.

Methodology

GEC created a Living Lab space at HSB Kontrollanten, a housing association in Karlstad, for the project testing and development. A Ferroamp battery system was moved from GEC and installed at HSB Kontrollanten Ferroamp PV power electronics. Also, a Metrum PQX measuring unit was installed.

GEC has been focusing on two areas:

1. Forecast of electrical load
2. Operation and profitability in different business models

Results

By testing different prediction algorithms and parameters, forecasting of energy consumption can be developed and improved gradually.

When analysing operation and profitability of using different business models, the benefit and potential of adaptive controlling is clearly shown.

The GEC test site at HSB Kontrollanten also enabled successful testing and development of the Adaptive Controlling System, see separate report from Rejlers/Embriq.

Conclusions

The studies show that it is possible to achieve good performance for the prediction of energy consumption using historical data and deep-learning algorithms. Also, the potential to use developed algorithms in buildings with different load profiles is identified.

From practical operation of the test system, studies also show the potential in adaptive controlling of battery systems. Setting control parameters for peak shaving can be (at least for systems with smaller battery sizes) dynamically changed as peak sizes differs between seasons. By using adaptive controlling, the potential of using multiple business models is identified.

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TABLE OF CONTENTS

1. ACRONYMS 1

2. INTRODUCTION 1

Purpose 1

Goals and research questions 1

3. BACKGROUND INFORMATION 2

GlavA Energy center, GEC, with partners 2

4. METHODOLOGY 2

GEC living lab demonstrator – HSB kontrollanten housing assosiation in Karlstad 2

Data collection 5

Work process 5

5. RESULTS 6

6. CONCLUSIONS 8

Report Conclusions 8

Recommendations for Future Studies 8

REFERENCES 9

1. Acronyms

ACES	Adaptive Control of Energy Storage

2. Introduction

The "Testing of adaptive control of battery storage in housing association" is created as part of the Adaptive Control of Energy storage (ACES) project.

The Adaptive Control of Energy storage (ACES) project has been performed by a consortium of ten [10] partner organisations: lead partner Metrum Sweden AB (Sweden), Glava Energy Center (Sweden), RISE Research Institutes of Sweden AB (Sweden), Insplorion AB (Sweden), Rejlers Embriq A/S (Norway), MINcom Smart Solutions GmbH (Germany), Fraunhofer Institute for Factory Operation and Automation IFF (Germany), Krebs engineers GmbH (Germany), VänerEnergi AB (Sweden), ABB AB (Sweden).

The ACES project has received funding from the Swedish Energy Agency, The Research Council of Norway and the German Federal Ministry of Economic Affairs and Energy in the framework of the joint programming initiative ERA-Net Smart Grids Plus, with support from the European Union's Horizon 2020 research and innovation programme.

The overall objective of the ACES project is to develop, implement test advanced measurement technology and adaptive control algorithms for energy storage systems in order to allow for improved economics of operation. By reaching the project objectives, the ACES project aim to contribute to an affordable 100% renewable power system with smart battery storage solutions using artificial intelligence.

More information on the ACES project can be found on: http://www.acesproject.eu/

PURPOSE

The ACES project has been organized in six [6] different work packages with multiple dependencies and collaborations in-between. This purpose of this very report is to present the findings and conclusions related to project goals of work package 4/GEC. In addition, a general description and evaluation of the project execution is given, in order to share not only findings related to the project objectives, but also learnings about project methodology and tools in order to further contribute to the research community regarding successful project design.

GOALS AND RESEARCH QUESTIONS

The goals of work package 4/GEC have been to:

- **Create a physical test and development environment for adaptive controlling of battery storage**
- **Develop control algorithms using pattern recognition**
- **Test controlling and adaptive controlling of battery system in practice.**

3. Background information

Controlling of battery energy storage depends on in which environment the battery is placed and to which business models the battery is operated for. Level of controlling complexity depends on business model and in general, controlling parameters is set manually.

The practical tests done early in the project shows clearly the need of adaptive controlling to maximise profitability and usability of battery storage.

GLAVA ENERGY CENTER, GEC, WITH PARTNERS

GEC is an innovation-, test- and training centre for solar energy and energy systems and is placed in Arvika municipality in Värmland, Sweden. GEC has been operating since 2009 and is a spin-off from REC PV Module factory at the same site. GEC uses a Living Lab Concept to which more than 70 innovation-, development- and test projects has been applied since 2009. At GEC site a test park is situated with more than 50 PV systems including battery storages, weather stations and micro grids.

Karlstad University is a member of GEC and is an active partner to GEC in this project. Professor Jorge Solis is participating as supervisor to student projects connected to the project and as author to papers for publishing.

4. Methodology

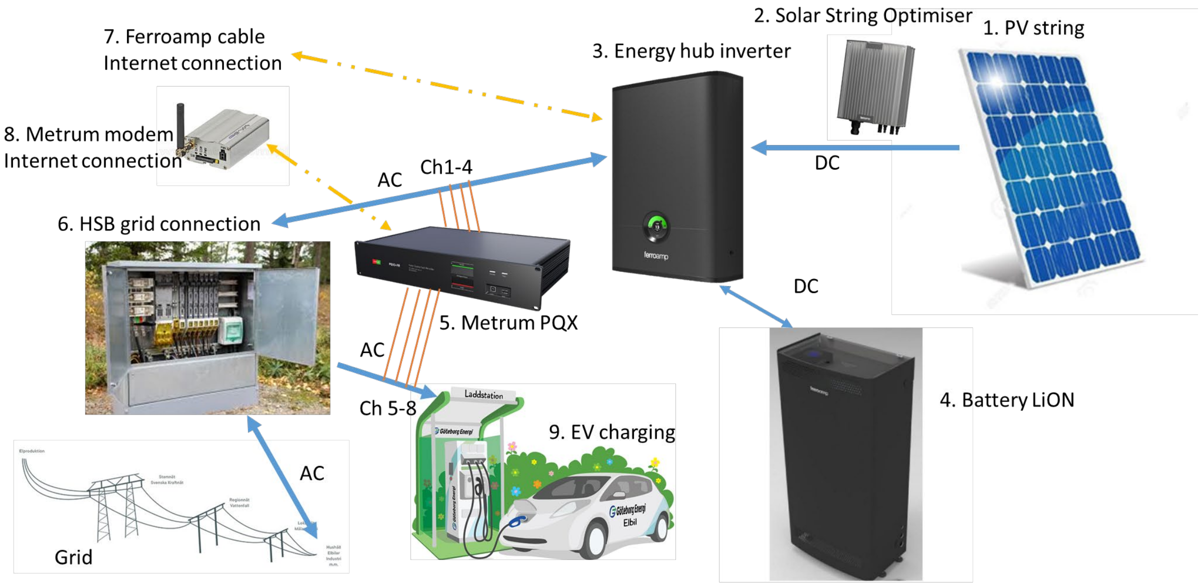
GEC LIVING LAB DEMONSTRATOR – HSB KONTROLLANTEN HOUSING ASSOSIATION IN KARLSTAD

Early in project GEC produced an overview of potential test environments at GEC for adaptive controlling of energy storage. GEC uses mostly battery storages but also have hot tap water storage. One of the more interesting technologies available is from Swedish company Ferroamp to which GEC has been performed several development projects with since 2011 and there are several Ferroamp systems at GEC test site. Ferroamp systems fits very well in private houses and apartment buildings. For controlling of battery storage, electrical load in the actual building is of high importance for setting control parameters. As the Ferroamp systems at GEC are not placed in buildings with realistic loads, a dialog was created with HSB Energitjänster, a consultancy section in HSB Värmland. The dialog resulted in a contact with a member association for HSB Värmland: HSB Kontrollanten in Karlstad, who was positive to serve as test environment for the project. HSB Energitjänster has been very active to develop their members in installing PV and in most cases Ferroamp was selected as supplier for power electronics. Approx 70 Ferroamp systems have been installed in HSB Värmland, including HSB Kontrollanten. The test environment selected fits the requirements specified by the ACES project.

Picture: Photo of HSB Kontrollanten Housing Association with PV in two orientations

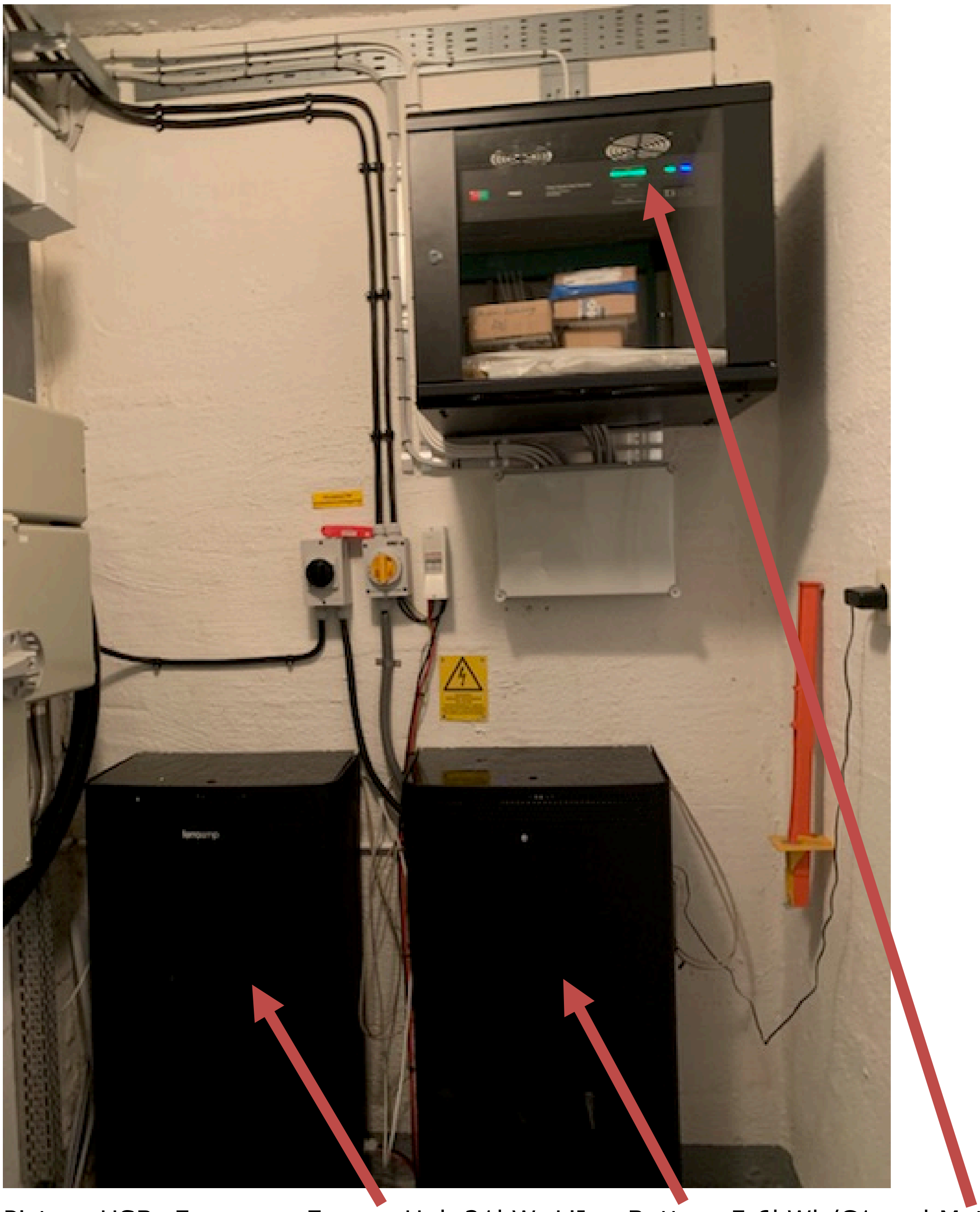
To achieve the most realistic test environment, GEC Living Lab was extended to HSB Kontrollanten Housing Association in Karlstad. HSB Kontrollanten consists of 3 building complexes with 126 apartments in total. Each building complex has its own electrical grid connection and on the roofs 308 PV modules are installed with a power of 84,7kWp, in both south and west direction. For the project, the PV power electronics for one of the building complexes (house 21) was upgraded with a Li-Ion battery energy storage. During the project execution, the heating system for the housing association was modified and heat pumps for all buildings were installed in house 21, to run in combination with district heating. Also, a carpool of 2 EVs (Renault Zoe) was introduced during project execution through another energy project. This results in different varying loads in different time periods during project execution. The grid operator Karlstad El- och Stadsnät has a power tariff related to the highest average peak hour per month with an additional rate for high load season November to March.

PV power electronics are from company Ferroamp and PV strings (1) are connected through Solar String Optimiser (SSO) (2) to Energy Hub (3), to which the Li-Ion battery (4) is connected in house 21. Between Energy Hub and grid connection (6) Metrum PQX (5) is installed. Data connection to Metrum PQX is via GSM modem (8) to GEC server and to Energy Hub via cable (7) to Ferroamp server. By changing charge and discharge levels, business models can be changed between own consumption, peak shaving and peak shifting. Hardware wise, reactive power can be produced but software is not adapted for this at the moment.



Picture: Schematic overview HSB installation

Picture: Schematic picture of Ferroamp concept with DC nanogrid; enabling to minimise DC/AC/DC losses (and costs) by using DC as much as possible and enabling DC grid between buildings. At HSB test site, this potential is not used fully as EV car charging is done with AC.



Picture HSB: Ferroamp Energy Hub 21kW, LiIon Battery 5,6kWh/C1 and Metrum PQX. Energy Hub uses a phase equalisation concept to level all phases to same current level, which can reduce power tariffs if unbalanced phases are present (which is very common).

DATA COLLECTION

Data is collected through Ferroamp cloud service and by Metrum PQX to GEC Server. Most of the analyses was done with data from Ferroamp system as all energy flows are available and later controlling is to be made through Ferroamp.

WORK PROCESS

GEC has been focusing on two areas:

3. Forecast of electrical load
4. Operation and profitability in different business models

Forecast of electrical load has been studied from different aspects by BSc Thesis student Johan Ericson (Karlstad University), exchange MSc student Tomohiro Oka (Tokyo Tech) and BSc Thesis student David Sjöberg (Karlstad University), all supervised by Professor Jorge Solis (Karlstad University) and Magnus Nilsson (Glava Energy Center).

During their work, different deep-learning methods and algorithms have been tested for optimisation of prediction of electrical load.

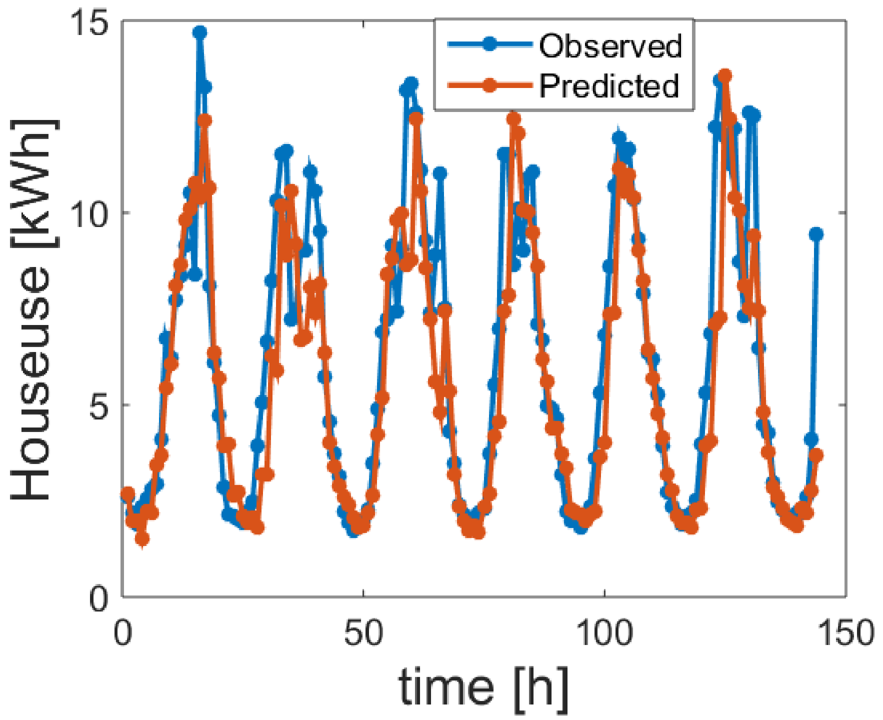
Operation and profitability have been studied by exchange MSc student Chihiro Kato (Tokyo Tech) supervised by Professor Jorge Solis and Magnus Nilsson.

During the work, different business models was practically tested to study the selection and operation of battery control parameters. In parallel, a profitability study was performed by simulating battery operation from historical data.

Workshop between GEC and Rejlers/Embriq was held to transfer knowledge from performed work regarding system controlling and load prediction for the development of the adaptive controlling at Rejlers/Embriq.

5. Results

By testing different prediction algorithms and parameters, forecast can be developed and improved gradually. An example of forecasting result is shown in picture below. The results from the work are collected in a paper that was presented in the international conference icSmartGrid2019, December 9-11, Newcastle, Australia and was recognized with Excellent Paper Award.

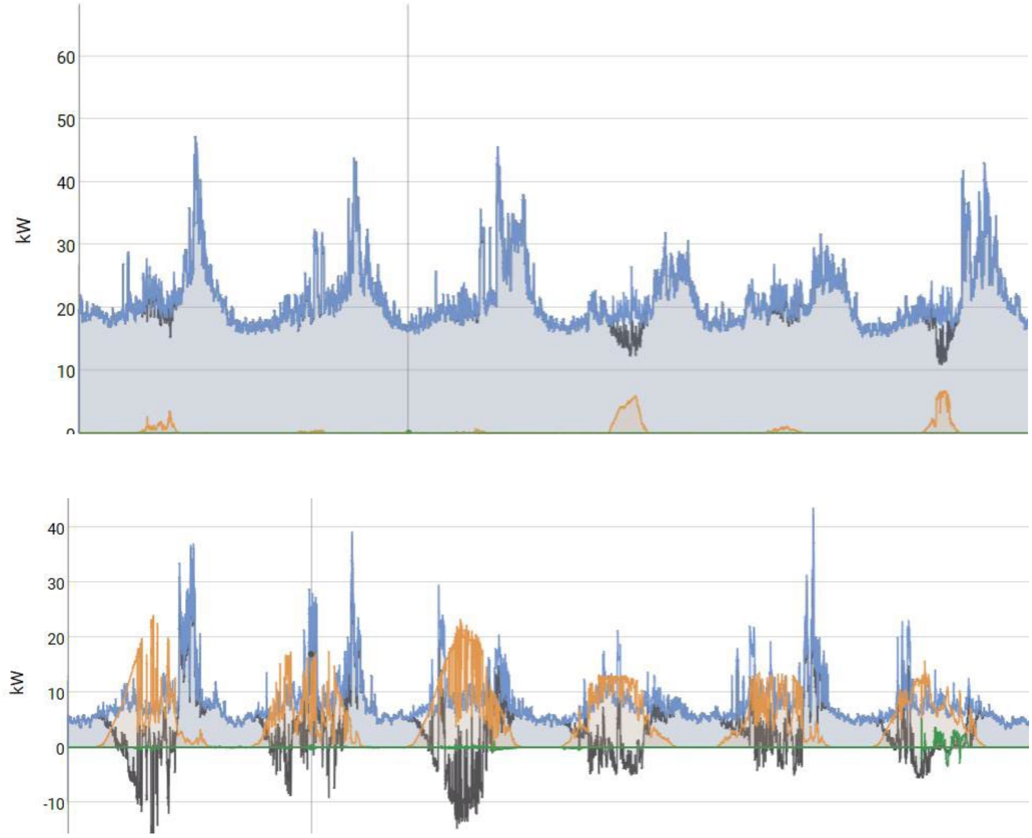


Picture: Prediction of electrical load at HSB Housing association (Tomohiro Oka 2019). Actual load: blue colour; predicted load: red colour.

Picture: Excellent Paper Award icSmartGrid 2019, Newcastle, Australia

When analysing operation and profitability of using different business models, the benefit and potential of adaptive controlling is clearly shown. Operation of system to maximise own consumption of PV energy is simple to operate as the battery is charged when PV production is present. Peak shaving and peak shifting are more demanding as consumption peak levels varies over year, see picture below. You need enough energy in battery to shave the peak and you should not start discharge the battery too early as you empty the battery thus not shaving the peak. This is the situation if you do not have very large battery but a small system as is present at test site. Setting of operational parameters for the system was done manually in these early tests.

Analysing of profitability when using different business models was done by simulating battery system operation from historical data from Ferroamp system, as battery only was installed for a short period when analyse was done. The building is connected to the local grid from "Karlstad El- och Stadsnät" which is applying power tariffs. Number of charge- and discharge cycles varies between different business models (low for peak shaving and high for maximising own consumption) and cost for battery usage is included in profitability analyse. The analyse shows that peak shaving is most profitable in autumn, winter and spring and maximising own consumption in summer. This is the situation for the HSB building in "Karlstad el- och stadsnät" local grid as they have a quite low power tariff. For other locations where higher power tariffs is present, situation may differ. With adaptive controlling, it is theoretically possible to use both peak shaving and maximising own consumption at the same time, thus doubling profitability. The result from this investigation is concluded in a paper presented in conference EU PVSEC 2020 Sept 7-11 "Cost Benefit Analysis for Business Model in a Grid Connected PV System with Energy Storage".



Picture: Curves from energy flows in test system operating to maximise own consumption of PV energy in December (top) and July (bottom) (Chihiro Kato 2019). Blue colour: building consumption, orange colour: PV production, grey: charging of battery

The GEC test site at HSB Kontrollanten also enabled successful testing and development of the Adaptive Controlling System, see separate report from Rejlers/Embriq.

6. Conclusions

REPORT CONCLUSIONS

The studies show that it is possible to achieve a good performance for the forecast in energy consumption using historical data and deep-learning algorithms. Also, the potential to use developed algorithms in buildings with different load profiles is identified.

From practical operation of the test system, studies also show the potential in adaptive controlling of battery systems. Setting control parameters for peak shaving can be (at least for systems with smaller battery sizes) dynamically changed as peak sizes differs between seasons. By using adaptive controlling, the potential of using multiple business models is identified.

RECOMMENDATIONS FOR FUTURE STUDIES

Interesting future studies is to test developed algorithms in practice to verify theoretical studies. An area for future studies is also prediction of solar production, which enables higher system performance. Profitability studies can also be made for other locations, giving a broader picture of potential.

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