FENT2900 - Bachelor´s Thesis,
Renewable Energy Engineering

Preliminary project

Birk Ferdinand Lillebo
Lars Fredrik H. Hansen
Markus Hatlo

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NTNU
Norwegian University of Science and Technology
Department of Energy and Process Engineering

Preliminary project for bachelor thesis

The Thesis Working Title: **English:** Investigations on the accuracy of DVA analysis as a measure for predicting self-discharge in LIBs **Norwegian:** Undersøkelser om nøyaktigheten av DVA-analyse som et vektøy for å forutsi selvutladning i LIBer	**Field of Study** Engineer, Renewable Energy
Project Number 24BIFOREN24-08	**Due Date** 21.05.24
Group Participants Birk Ferdinand Lillebo Lars Fredrik H. Hansen Markus Hatlo	**Principal** FREYR
Internal Supervisor Odne Stokke Burheim odne.s.burheim@ntnu.no	**External Supervisor** Daniel Tevik Rogstad daniel.rogstad@freyrbattery.com 454 64 006

Preface

This preliminary project lays the groundwork for a bachelor´s thesis. The bachelor´s thesis is made in spring 2024 by three third year students, forming the group 24BIFOREN-08 at NTNU. The students have backgrounds in renewable energy engineering and specializations in water and wind energy, and energy storage.

The preliminary project was prepared in january and february 2024. The goal of the preliminary project is to plan the work and execution of the bachelor project. The work has lead to discussions and started the groups work on defining the working title, problem definition, goals and progress plan.

The problem definition has been formulated and produced by the group members in collaboration with FREYR and the internal supervisor. A big thanks therefore goes to Daniel Tevik Rogstad at FREYR for providing the group with this opportunity. The group also wants to thank internal supervisor, professor Odne Stokke Burheim at the institute of energy and process engineering, and post doctorate Ejikeme Raphael Ezeigwe for providing direction, insight and interest in the project.

Contents

1 Introduction

This is the preliminary work for a bachelor's thesis and will present the contributors, the approach to the work and the aims of the thesis. The assignment is about improving the process of making lithium-ion batteries using DVA analysis. The client for this assignment is Freyr, and the supervisors are from the Department of Energy and Process Engineering at NTNU.

1.1 Background

Freyr is a battery company focusing on environmentally friendly, large-scale, and efficient production. During the production of batteries, the aging process is the most time consuming. It can take up to three weeks for a battery to complete aging. Additionally, an analysis of the batteries must conducted to determine parameters such as np-ratio, lithium consumption, and battery capacity. Often, these analysis methods can be destructive as it involves opening the cell. This presents an opportunity for optimization that Freyr is interested in. dV/dQ analysis, or Differential Voltage Analysis, is a non-destructive analysis method that can be performed during the formation stage of the battery. This analysis can provide us with both np-ratio, lithium consumption, and battery capacity. Furthermore, it is a mostly underutilized method in the battery industry. Freyr is keen to explore this analysis method, and if the bachelor's thesis concludes that the analysis is both accurate and time-saving, Freyr will consider adopting it.

1.2 Limitations and assumptions

It has been chosen to perform a mostly standard production and formation of the batteries. The analysis has been limited to only one anode materials and three cathode materials. In addition, the c-rate of the formation process has been limited to C/20. This is a compromise between speed and accuracy. The degradation has been limited to a maximum of 4 weeks. A longer degradation time will be to time consuming. These limitations have been set in order to complete the task within the time frame, as more variables will generate more data that takes longer to analyse. Additionally more variables will makes it more difficult to find decisive results.

1.3 Project members

Lars Fredrik Hansen (him)
Phone: 949 76 665
Email: lfhansen@ntnu.no
Third year at bachelor in renewable energy, with an immersion in wind and water energy.
Competence within renewable energy, electrical engineering, mathematics, physics, chemistry, electrical power systems, mechanics, thermodynamics, electrical machines and electromechanical energy conversion, heat and mass transfer, energy storage, fluid mechanics, wind energy, project managment, materials technology, and programming.

Birk Ferdinand Lillebo (him)
Phone: 949 84 030
Email: birk.lillebo@ntnu.no
Third year at bachelor in renewable energy, with an immersion in energy storage.
Competence within renewable energy, electrical engineering, mathematics, physics, chemistry, electrical power systems, mechanics, thermodynamics, electrical machines and electromechanical energy conversion, heat and mass transfer, energy storage, fluid mechanics, wind energy, control engineering, and programming.

Markus Hatlo (him)
Phone: 413 36 740
Email: markhat@stud.ntnu.no
Third year at bachelor in renewable energy, with an immersion in energy storage.
Competence within renewable energy, electrical engineering, mathematics, physics, chemistry, electrical power systems, mechanics, thermodynamics, electrical machines and electromechanical energy conversion, heat and mass transfer, energy storage, fluid mechanics, wind energy, control engineering, and programming.

1.4 Project contributers

Daniel Tevik Rogstad (Freyr)
Odne Stokke Burheim (NTNU)
Ejikeme Raphael Ezeigwe (NTNU)

2 Goals and framework

2.1 Orientation

This assignment was chosen because the group members wanted to work with lithium-ion batteries. After the subject was decided, next the group looked for companies to contact. FREYR came up quickly due to them being a leading battery company in Norway. The original assignment of investigating additives and determining a practical NP ratio came from FREYR and was inspired from the article, "Differential voltage analysis for battery manufacturing process control". Further the assignment was discussed between all participating members and Odne Burheim suggested to rather look at the self discharge of the batteries.

2.2 Problem definition

English:
This project is based upon how differential voltage analysis can be used as a measure for predicting self discharge. By such analysis, the thesis aims to shorten production and storage time. To understand this connection, coin-cell batteries will be produced, and in a portion of the batteries metal powder will be introduced to heighten self-discharge. The recorded data from the formation process will be analyzed. To verify our theoretical data predictions, the project will include a post storage test to inspect the practical self discharge. Further process improvements will consist of insuring accuracy and efficiency.

Norwegian:
Dette prosjektet er basert på hvordan differensialspenningsanalyse kan brukes for å forutsi selvutladning. Gjennom en slik analyse har oppgaven som mål å forkorte produksjons- og lagringstiden. For å forstå denne sammenhengen, vil knappcellebatterier bli produsert, og i en andel av batteriene vil det bli introdusert metal pulver for å øke mengde selvutladning. Dataene som er registrert under formasjonsprosessen vil bli analysert. For å bekrefte de teoretiske resultatene, vil prosjektet inkludere en test etter lagring for å inspisere den praktiske selvutladningen. Videre forbedringer i prosessen vil bestå av å sikre nøyaktighet og effektivitet.

2.3 Specifications

Instead of using complete pouch cell batteries, coin-cells will be produced from existing electrodes. This is both to increase the number of batteries and because coin-cells give more accurate results. LCO, LFP and lithium metal will be used as cathode materials. The metal powder will be used to make sure that some of the batteries have significantly higher self-discharge than the others, thus making them easier to differentiate.

2.4 Performance measures

The following sections defines the goals set for this bachelors thesis.

2.4.1 Result

The resulting discussion and conclusion concerning DVA-analysis will allow Freyr to consider the analysis method for usage on future batteries.

2.4.2 Process

The team will gain a greater understanding on how to create and analyze batteries, as well as a better understanding of batteries as a whole. Finally the process will teach the team how to work on similar tasks in the future.

2.4.3 Effect

The bachelor will give a greater understanding on the accuracy of DVA-analysis for predicting self-discharge. This in turn can shorten production and storage time for the battery production as a whole. Further, the cutting of storage time will result in a decrease of energy requirement per battery, and a reduction of storage area and cost.

2.5 Framework

This project requires the use of NTNUs battery lab. The research will use LCO and LFP batteries, which will be supplied by NTNU. The team will need time in the lab to practice making button cell batteries. After the button cell batteries are made, a storage time of two weeks and equipment to collect data is needed.

3 Approach

3.1 Phase 1: Startup

- Sign deal with Freyr, group members and supervisor
- Sign an internal cooperation agreement
- Read up on subject matter
- Define and limit the task
- HSE safety courses are carried out and a safety assessment is made.
- Lab tour with supervisor.

3.2 Phase 2: Preparations for data collection

- Group members practice making button cell batteries from pouch cell batteries. The most important factor is that the results are reproducible
- First draft of the code to process data is produced

3.3 Phase 3: Data collection and analysis

- Button cell batteries are produced
- During the formation, the voltage data is obtained
- The code to analyze the data is completed
- The batteries are stored for two weeks
- After two weeks, the self-discharge of the batteries is recorded
- The data from the formation process is analyzed in the form of DVA (DV/DQ).
- The data from DVA and self-discharge are compared and it is investigated whether there are connections that can predict which battery will self-discharge the most
- The statistical significance of the results are examined

3.4 Phase 4: Report writing

- Making discussion and conclusion
- Making first draft
- Proof reading
- Final thesis
- Making final presentation

3.5 Milestones

Official dates for different deliverables

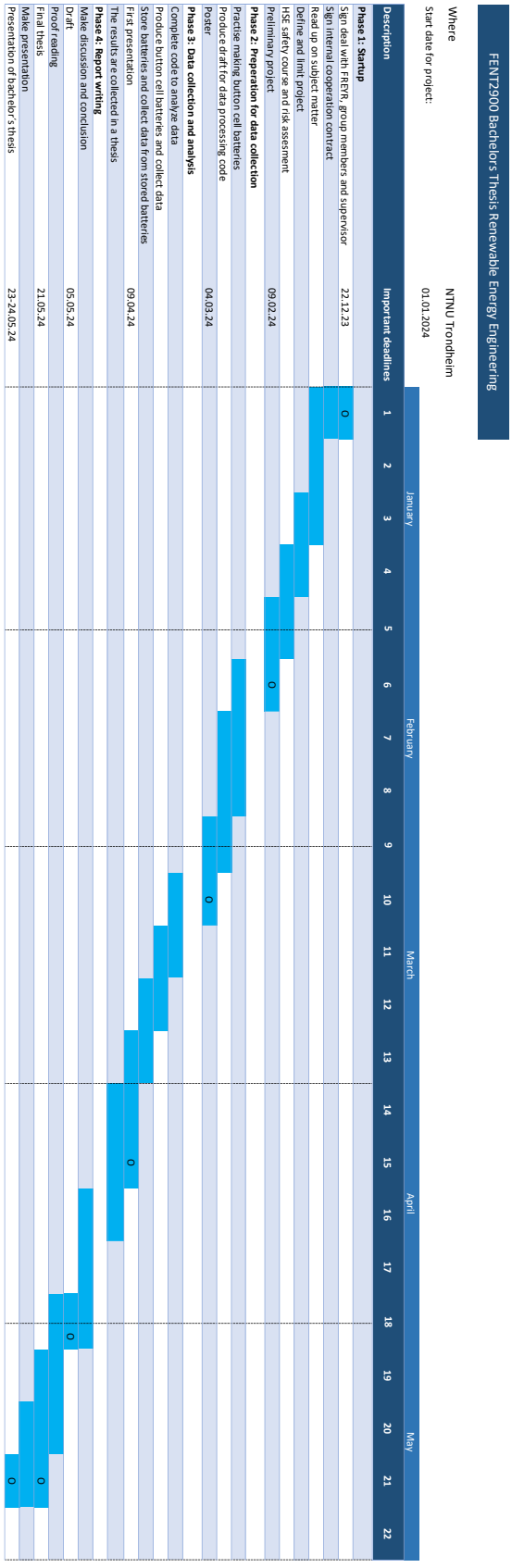
What	When
Submission of agreement	22.12.2023
Submission of preliminary project	09.02.2024
Submission of poster	04.03.2024
First presentation	09.04.2024
Submission of the final report (via Inspera)	21.05.2024
Final presentation	23-24.05.2024

3.6 Quality assurance and reporting

It is important for the group that the result of the project is of a high quality. This is ensured by having regularly meetings with supervisors and contributors. Meetings with the supervisors happen on a weekly basis, where progress is discussed and any possible problems are addressed. About every third week there is a meeting with the supervisors and the outside contributors, where the progress is presented and feedback is given. The group also has internal meetings every week, to discuss what needs to be done, and resolve any conflicting opinions. Lastly the quality of the lab work is ensured through good training by the supervisors, and a practice period where the group members battery making skills are improved.

Appendix

A Gant chart



NTNU

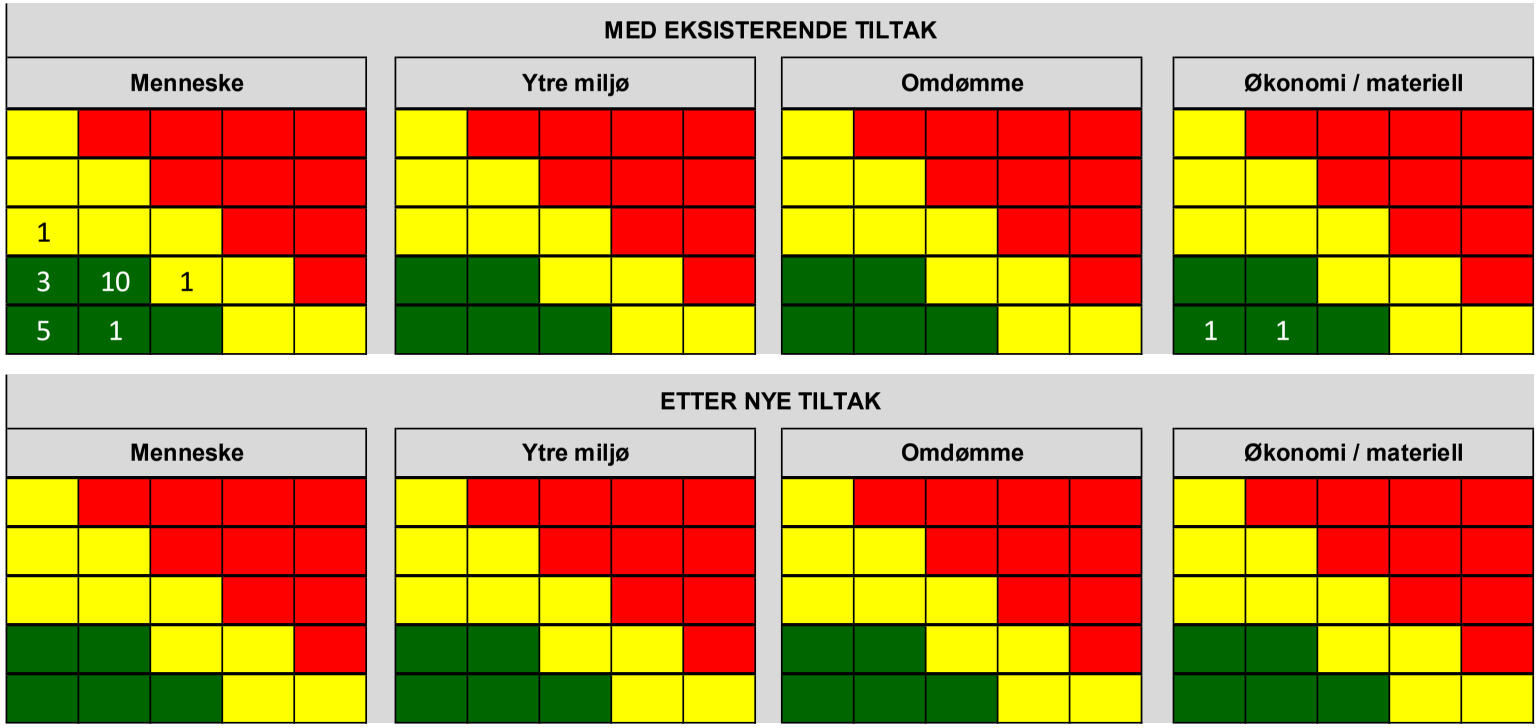
Organisatorisk enhet Institutt for energi og prosessteknikk (EPT)
Lokasjon Varmeteknisk battery lab
Utstyr / Aktivitet Glovebox, battery cycler, fume box

Dato 2024-02-09
Deltagere Birk Lillebo, Lars Fredrik Hansen, Markus Hatlo
Linjeleder Terese Løvås

Delaktivitet	Mulig uønsket hendelse	Eksisterende barrierer	Risikoverdi med eksisterende tiltak				Nye barrierer / risikoreduserende tiltak (handlingsplan)	Risikoverdi med nye tiltak				Ansvarlig	Dato	Status
			Menneske	Ytre miljø	Omdømme	Økonomi / materiell		Menneske	Ytre miljø	Omdømme	Økonomi / materiell			
The use NMP (N-Metyl-2-Pyrrolidon)	Get in the eye(s), Get on the	Using safety glasses	B2											
	Get on the skin	Use rubber gloves and lab coat	B2											
	Inhalation	Handling the substance under a fume hood	B2											
	Fire	Avoid heating it	B2											
	Get in the mouth and swollowing it	Do not touch face when handing substance	B1											
	Explosion	Avoid heating it	C1											
The use of Lithium iron phosphate (LiFePO4) and LCO (LiCoO2) extracted prefabricated electrodes	Get in the eye(s)	Using safety glasses	B2											
	Get on the skin	Use rubber gloves and lab coat	B2											
	Inhalation	Handling the substance under a fume hood	B2											
	Get in the mouth and swollowing it	Do not touch face when handing substance	B1											
	Fire		B2											
The glovebox	There is a leakage and the substance gets in the outside air. Also causing the atmosphere inside to be "infected".	All pressure gauges and indications are functioning and are within accaptable ranges.	B1											
The use of the fume box	The ventilation is not working	Inspect prior to use, check if the ventilation is working.	B3											
Electrochemical characterization, battery cycling	Fire	Defined safety limits for the cycling of the batteries. Batteries tested inside fireproof cabinets.	B2			A2								
	Electrcal shock	Avoid making contact with others electronic components of the machine	A2											
Battery (less than 10mAh)	Fire	Avoid opening, avid overcharging and discharging	B2			A1								
Lithium metal	Fire	Only kept and used in glovebox	A1											
Electrolyte	exposure	Only kept and used in glovebox	A1											
LiPF6	exposure	Only kept and used in glovebox	A1											
EC ethylcarbonate	exposure	Only kept and used in glovebox	A1											
DMC dimethylcarbonate	exposure	Only kept and used in glovebox	A1											

B Risk assessment

Utstyr/aktivitet Glovebox, battery cycler, fume box
Dato 2024-02-09



C Cooperation agreement

Cooperation Agreement

[Baklar Spring 2024]

Goals for Delivery, Well-Being and Learning

Delivery

1 We contribute to executing our areas of responsibility

We agree that everyone should contribute to the work of fulfilling our purpose and follow up on tasks from meetings. Everyone has a responsibility for their areas of responsibility and for updating each other and keeping group members informed about their work.

2 We arrive punctually and notify in case of abcense

Everyone arrives at the agreed time. If you are delayed, you inform the rest of the group in the chat. If more than 15 minutes late, the delayed member buys coffee/cocoa for the rest of the group. In case of recurring delays by an individual, the situation should be discussed collectively with the group.

3 We plan together and collaborate to achieve common goals

We start each office meeting by summarizing what has been done since the last meeting, where we go through the to-do list from the previous meeting and the upcoming calendar, before we plan and set goals for the coming week. After each meeting, we summarize the period since the last meeting and evaluate it. At the same time, we look at the major issues leading up to the next meeting. During the meetings, we can discuss any planned absences and ask each other for help with preparations and potentially stepping in for each other in case of excessive workload for any individual. The purpose is to ensure progress and encourage collaboration.

Well-Being

4 We work for a good atmosphere and give each other recognition

We want to have fun throughout this spring. It is easier and more motivating to work when there is a good atmosphere and energy in the group. We value laughter, good spirits, and give each other positive attention. We praise each other and strive for mutual trust.

5 We are open if we have a bad day, and we show consideration.

If one does not feel well on a day, we want them to notify, preferably at the beginning of the day. The group tries to consider the person having a bad day. The person experiencing a challenging day should also be mindful of their own behavior and demeanor in the work environment.

6 We set milestones and adhere to realistic deadlines.

Milestones are set at the beginning of the project, but we also work towards milestones established throughout the year. The purpose of this is to avoid excessive workload on each individual group member. It is important for the well-being of the group that everyone completes their part of the work on time.

7 Conflict resolution

In situations where we experience conflict within the group, it is important that we communicate before the irritation becomes too significant. We address this together. We act honestly, directly, and respectfully in the conflict. In the conflict, we listen to each other and try to interpret the others in the best possible way. In situations where it seems appropriate, a supervisor is included to have a neutral third party involved in the dialogue.

Learning

8 Constructive feedback

We provide each other with constructive feedback and evaluate the project collectively, allowing us to develop as much as possible. We communicate in a proper manner and facilitate an open dialogue in meetings. Most things can be communicated as long as it is done constructively and with good intentions.

9 We challenge ourselves, ask for help, and assist each other.

We will challenge each other to take on tasks we are not entirely comfortable with, in order to learn something new. Additionally, we will assist each other with the roles and responsibilities we have distributed among ourselves. This means both asking for help and offering help to others who are stuck, so that we can learn and support each other. This should be done in a low-threshold manner to help us achieve our common goals.

10 We work for consensus and good compromises.

As far as possible, we will reach agreement on common decisions. In cases where we disagree, we will try to find good compromises and alternative solutions. We will be open to listening to each other's ideas and solutions. In disagreements, we will show consideration for each other, while distinguishing between the issue at hand and personal matters.

11 We evaluate the collaboration and revise the cooperation agreement.

We want to learn from the experiences we gain along the way. At the midpoint of the period, we evaluate the collaboration and the points in this collaboration agreement. Revision of the collaboration agreement can also be done if needed.

PLACE: TRONDHEIM **DATE:** 09.02.2024

Birk Lillebo

Birk F. Lillebo

Lars Fredrik H. Hansen

Lars Fredrik H. Hansen

Markus Hatlo

Markus Hatlo