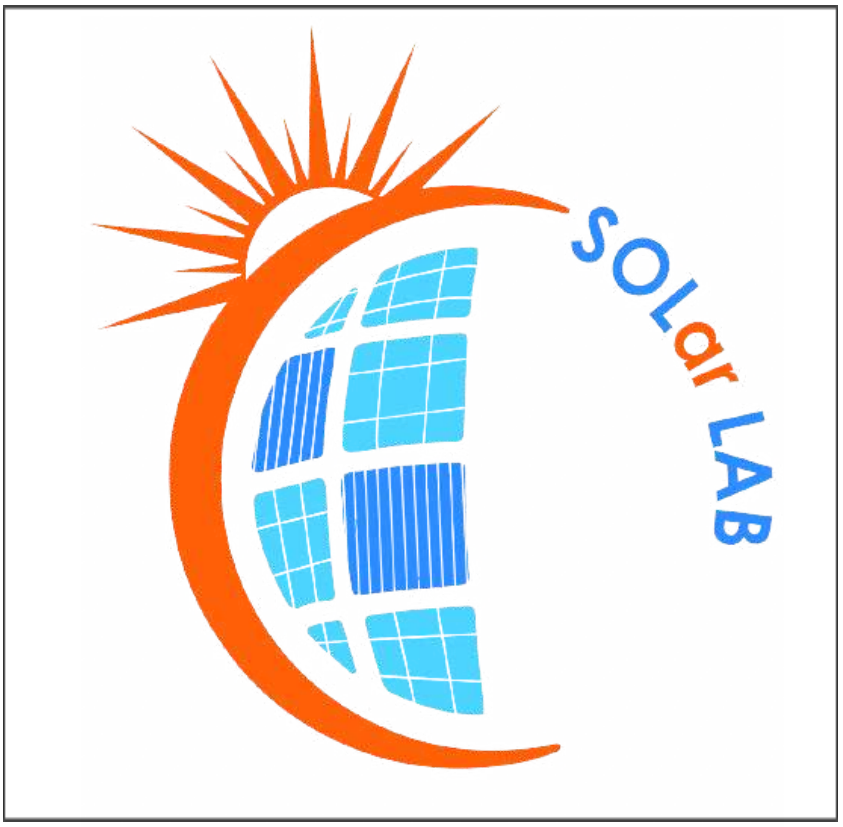
Esther BONNIN

RESEARCH THESIS

SOLAR LAB



Supervisor : Mr Richard J. GRANT

August - December 2024

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Acknowledgement

First of all, I would like to thank my supervisor Mr Richard J. GRANT for giving me the opportunity to do my research thesis at the Western Norway University of Applied Sciences in Bergen. I am also grateful for his support throughout the period.

Moreover, I am thankful to the entire research team, especially Harald and Nafez, for their warm welcome and for making themself available when I had questions.

Finally, I thank the people at Icam who made this exchange possible, the Bergen university, the rector Gunnar Yttri, for welcoming me to his establishment, as well as Cathrine Palmstrom.

Introduction

As part of my final year of the master's program, I was offered the opportunity by ICAM to conduct my research thesis abroad. This unique chance allowed me to combine academic learning with an enriching international experience. After careful consideration, I chose Norway as my destination, drawn by its reputation for innovation and sustainability in architecture and engineering. My research focuses on passive houses, an innovative concept in sustainable building design aimed at minimising energy consumption, a field where Norway stands out due to its advanced practices and commitment to energy efficiency. This experience not only aligns with my academic interests but also offers an ideal environment to deepen my understanding of sustainable building solutions.

My project centered on different facets of the Passive House, such as its electrical systems, the integration of solar panels, and its overall energy performance. Throughout this period, I faced numerous challenges, ranging from technical obstacles to language barriers, all of which played a significant role in my personal and professional growth.

In this report, I will present an overview of my project, detailing the tasks I completed, the challenges I encountered, and the strategies I employed to overcome them. Additionally, I will outline the outcomes of my work and reflect on the expertise and skills I acquired throughout this rewarding experience. By sharing these reflections, I aim to highlight the importance of this opportunity and its influence on both my professional growth and personal development.



I. Use of renewable energy technologies in Norway and at the University of Bergen

A) In Norway

Global warming and environmental challenges have emphasized the urgent need for a global transition to sustainable energy sources. With electricity generation responsible for 41% of CO2 emissions worldwide, driven by fossil fuel use, the shift toward renewables like solar, wind, and hydropower is critical. In 2023, only 12% of global electricity comes from renewable energy, underscoring the need for more significant progress. Housing also plays a significant role in greenhouse gas emissions, with 27% of emissions attributed to the electricity and heat used in buildings. This highlights the importance of rethinking our energy consumption practices.

One solution that addresses these challenges is the concept of passive houses. These homes are designed to minimize energy consumption by incorporating strategic features such as high-quality insulation, optimal building orientation, energy-efficient windows, and appliances, alongside the integration of solar panels. This approach ensures minimal reliance on external energy sources while reducing environmental impact.

Norway serves as a prime example of a country embracing renewable energy and sustainable practices. Already powered by hydropower for 88% of its electricity needs, the nation is also expanding its use of wind and solar energy, with the latter reaching an installed capacity of 597 MW in 2023. Against this backdrop, passive houses in Norway exemplify innovative solutions for reducing carbon footprints. By combining energy-efficient designs with renewable energy, they represent a promising pathway toward a greener and more sustainable future.

B) At the Western Norway University of Applied Sciences in Bergen

At the Western Norway University of Applied Sciences in Bergen, a dedicated branch focuses on advancing renewable energy technologies, supported by the SolarLab. This specialized laboratory features a 12-square-metre passive house located directly on the university campus. Designed to meet strict energy efficiency standards, the SolarLab integrates a CMV2 system for ventilation and heating. Its primary objective is to function entirely off-grid, utilizing solar panels to generate electricity and a battery system for energy storage. The SolarLab serves as a platform for in-depth calculations and experiments, contributing to innovative research in solar energy and sustainable building practices.

The passive house is equipped with:

- **Solar panels:** 6 monocrystalline modules of 285 W each and 6 polycrystalline modules of 275W each.



Monocrystalline modules are made from a single, continuous crystal structure. This gives them a uniform black color and makes them more efficient at converting sunlight into electricity, especially in low-light conditions, they are typically more expensive to produce.
Polycrystalline modules are made by melting multiple silicon fragments together, resulting in a blue-speckled appearance. While they are less efficient than monocrystalline modules, they are more affordable.

- **Sunny Boys:** we need to convert the direct current of the PV array to alternative current, that's why we use 3 inverters named Sunny Boys. One inverter is connected to the monocrystalline panels and the other to the polycrystalline panels, one is currently unused (for another project).



- **Sunny Island:** it acts as the control center for managing energy produced by solar panels. It efficiently stores this energy in batteries and converts it into usable power for households. Its key functions include energy conversion, optimizing battery charging, and ensuring a smooth transition to backup generators when solar energy supply is inadequate.





- **Battery:** the TS 25 48V 14.4 kWh by TESVOLT has a nominal voltage of 48 volts and a capacity of 14.4 kilowatt-hours. It employs lithium-ion technology to provide high energy density, a long lifespan, and reliable performance.



- **Energy meters:** In our system, we use energy meters, both mounted in a central distribution fuse box, to monitor the energy consumption at specific points in the passive house. There are two energy meters installed, one connected to monitor the internal/local 230V 50Hz laboratory grid (for lights, socket outlets, HVAC), and the

other is dedicated to monitor a spur feeding a car charging wall box (located outside the house).



- **Sunny Home manager 2.0:** it's like the brains of a solar power setup. It monitors how much solar energy the home is producing and how much electricity the household is using. Then, it smartly manages things like charging batteries with excess solar power and deciding when to use that stored energy to power the home. It allows us to make the most of the solar energy system without having to rely on the traditional electricity grid.



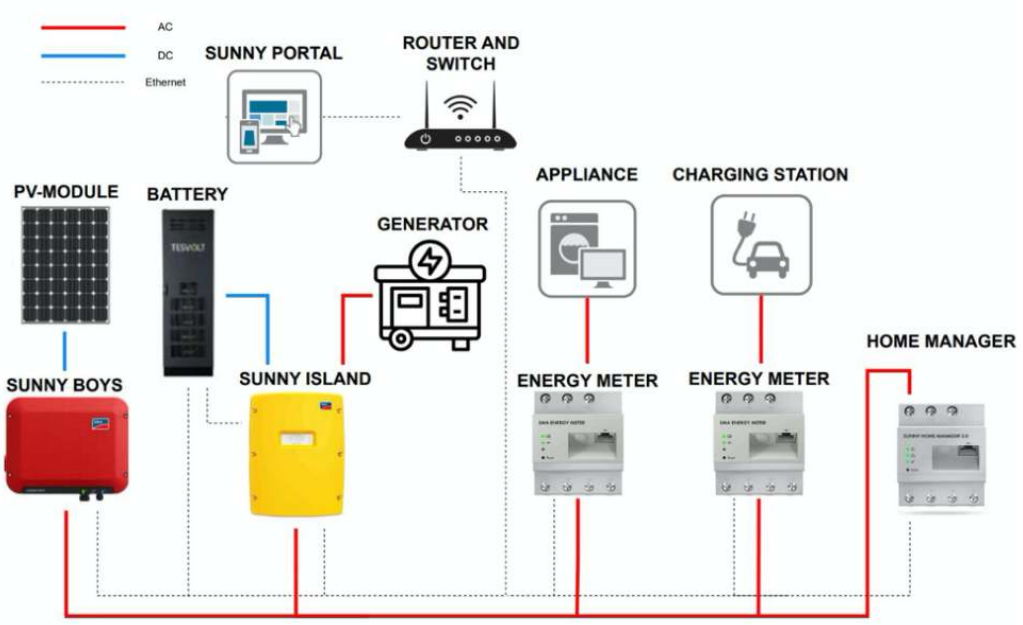
- **Generator:** in case the solar panel is unable to provide sufficient energy it is necessary to have a generator in place. In the passive house, the generator input is supplied with (backup) power from the university's main electrical grid (230v, 50Hz). This is purely a means of simulating a backup generator.



- **<u>Tigo Cloud Connect Advanced:</u>** an essential device for managing photovoltaic systems. Modules placed behind each solar panel collect accurate data on the performance of each module.



A schematic layout of the systems is as follows :



II. Passive house projects

Since 2020, Icam students have been actively engaged in the SolarLab project. My role in this initiative involves building on their efforts and contributing to its advancement. The majority of my tasks involved gaining a comprehensive understanding of how the system operates and reviewing the work completed by previous students. The remaining objectives depended on the system's performance, so I focused on identifying potential areas for improvement and implementing the necessary enhancements to optimize its functionality. By building on the foundation laid by former contributors, I was able to contribute effectively to the system's progress and address any challenges encountered.

A) Using an alternative source: the generator

As part of managing and monitoring the energy system in the passive house, I used **Sunny Portal by ennexOS**, an intelligent management platform developed by SMA Solar Technology. This tool allowed me to verify the system's proper functioning in real-time and identify any potential anomalies. Sunny Portal by ennexOS provides detailed monitoring of energy data, such as solar energy production, household consumption, and the status of the battery...

With its advanced features, the portal enabled me to analyze the system's performance. For example, it offers detailed graphs showing energy production by time of day, consumption peaks, and periods of energy surplus. By monitoring performance indicators, I was able to quickly detect unusual deviations, such as a drop in solar production or an issue with energy recovery.

This allowed me to respond promptly and address malfunctions before they impacted the system's overall efficiency.

Coming into the period when the days were getting shorter and there was less light, it was clear that the most challenging part of the project was managing the use of the generator.

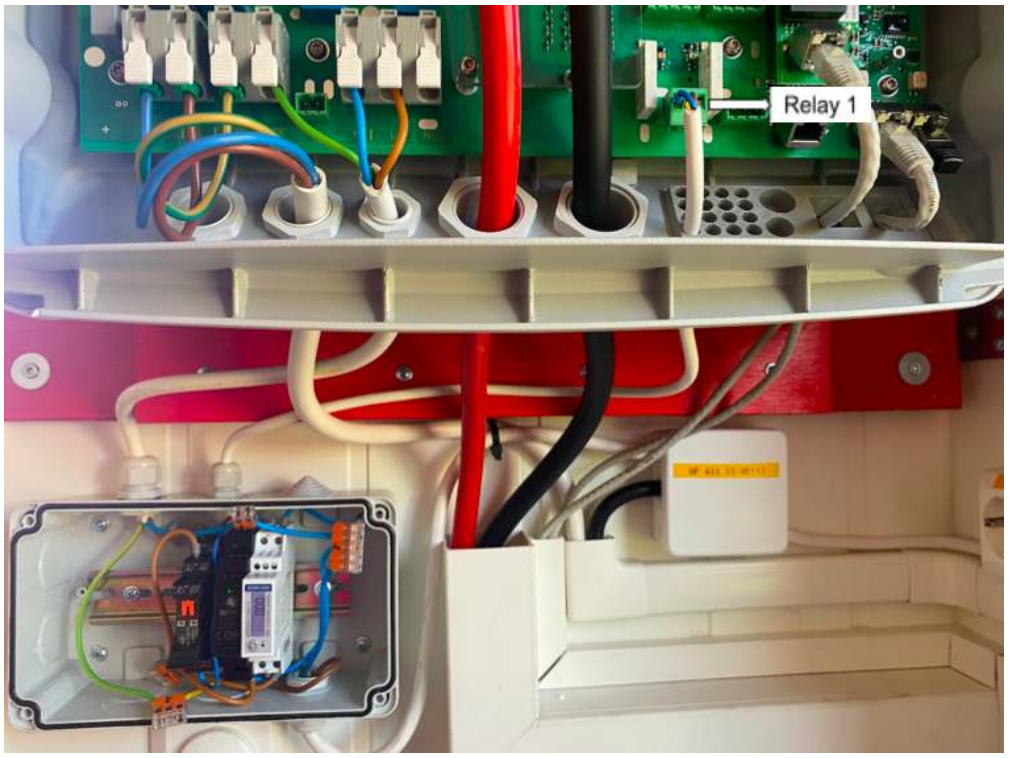


Fig 1 : Connexion between Sunny Island and generator relays

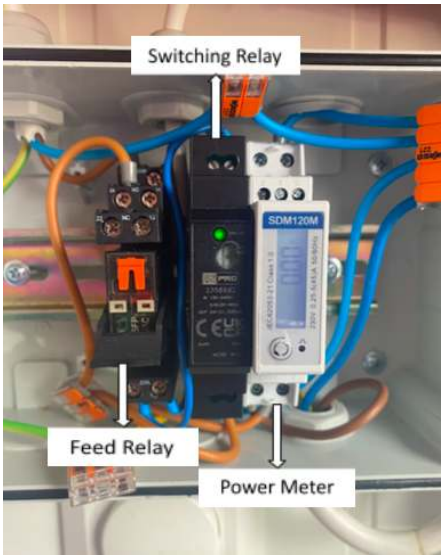


Fig 2 : Generator power switching relays

In Sunny Island, multifunction Relay 1 is connected to a Switching Relay (RS PRO 2358692), which in turn switches a Feed Relay (HF115FP) in the generator feed (*Fig 3*). This first relay is switched by multifunction Relay 1 (SI) which acts as a decisionmaker based on the battery's SOC. The relay power supply ensures the correct voltage is delivered to operate the main 'gen' Feed Relay.
The on/off function of the SI controls the Feed Relay so allowing the simulated generator feed to provide power; allowing the generator to turn on when the battery is low and off when the battery is sufficiently charged. This setup ensures that the generator is being controlled in sync with the battery's SOC, optimising its operation based on energy needs.

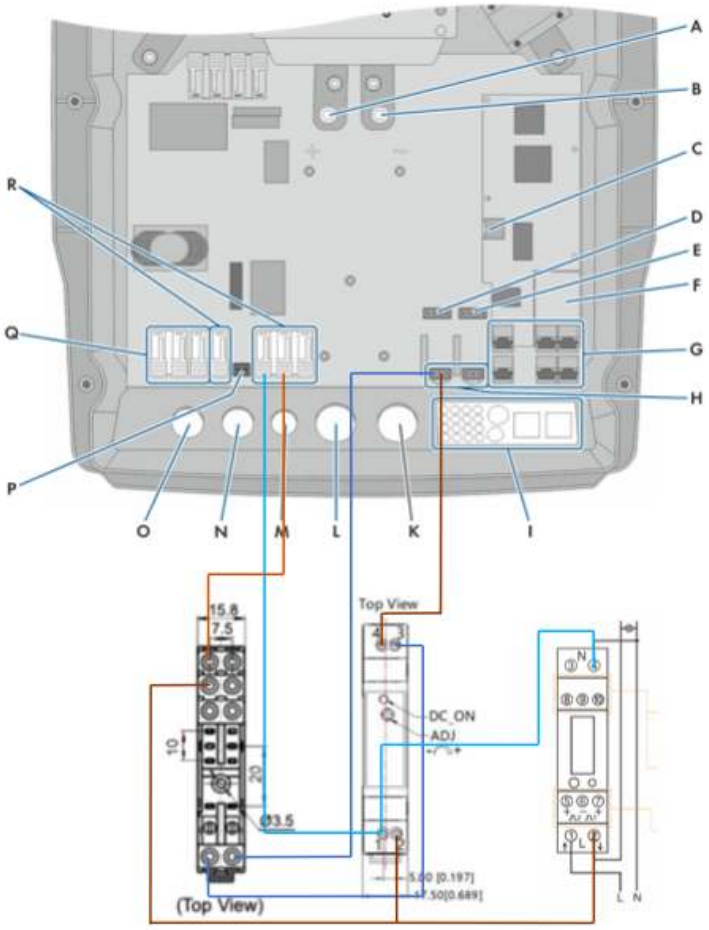


Fig 3 : Electric diagram

During periods when the solar panels did not produce enough energy to meet the house's needs, it required careful adjustments to ensure the system operated reliably without unnecessary energy waste. On the Sunny Island Interface I had to fine-tune the system's parameters, such as the thresholds for generator activation and deactivation. This involved balancing energy storage levels, current consumption, and generator output to guarantee smooth transitions and optimal performance.

Once the parameters were adjusted, I performed multiple tests to verify that the generator responded as expected. These tests ensured that the system could handle fluctuations in energy demand and supply without interruptions.



Fig 4 : Generator activated

I had difficulty monitoring the running of the generator because when the SI Relay 1 switches, due to a low battery SOC, the Feed Relay is seen to allow current to flow to the SI (evident from the Feed Relay LED indicator *Fig 4* and also the Power Meter located next to the Switching Relay). However, this is not shown in the Sunny Portal app (android or PC) with the indicated current flow always shown as zero. In the case shown, the sum of battery charging plus house power correctly equates to the PV input as the generator input was zero (*Fig 5a*); but if there was a generator input it would still show "0 w", with the summation of battery charging and house power not equating to the shown inputs (PV plus generator) (*Fig 5b*). No flow arrows have been seen from the generator (or Grid graphic) at any time.

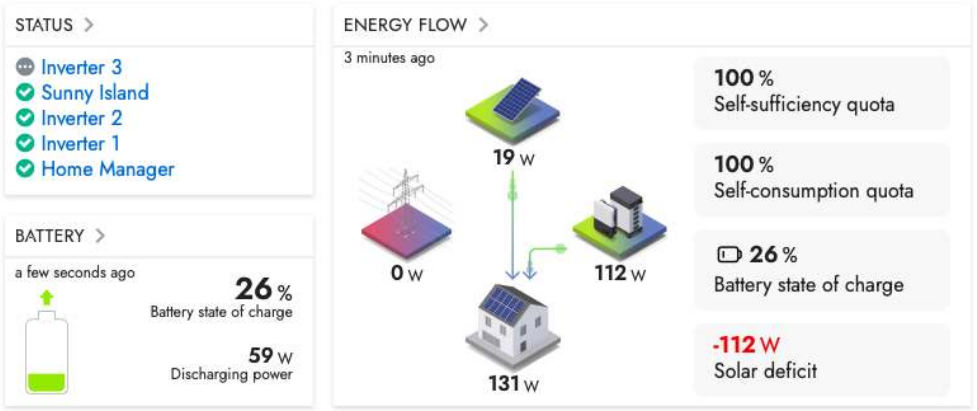


Fig 5a: Sunny Portal app



Fig 5b: Generator's working (Sunny Portal app)

Similarly, as can be deduced from *Fig 5c*, the generator provides power when the battery SOC reaches 21% (as prescribed in the SI setup); not that the graph indicates this specifically, but the battery is receiving approximately 5A (certainly no PV input at 2:00am in the night). The graph should show a curve derived from the generator input and indicated as so.

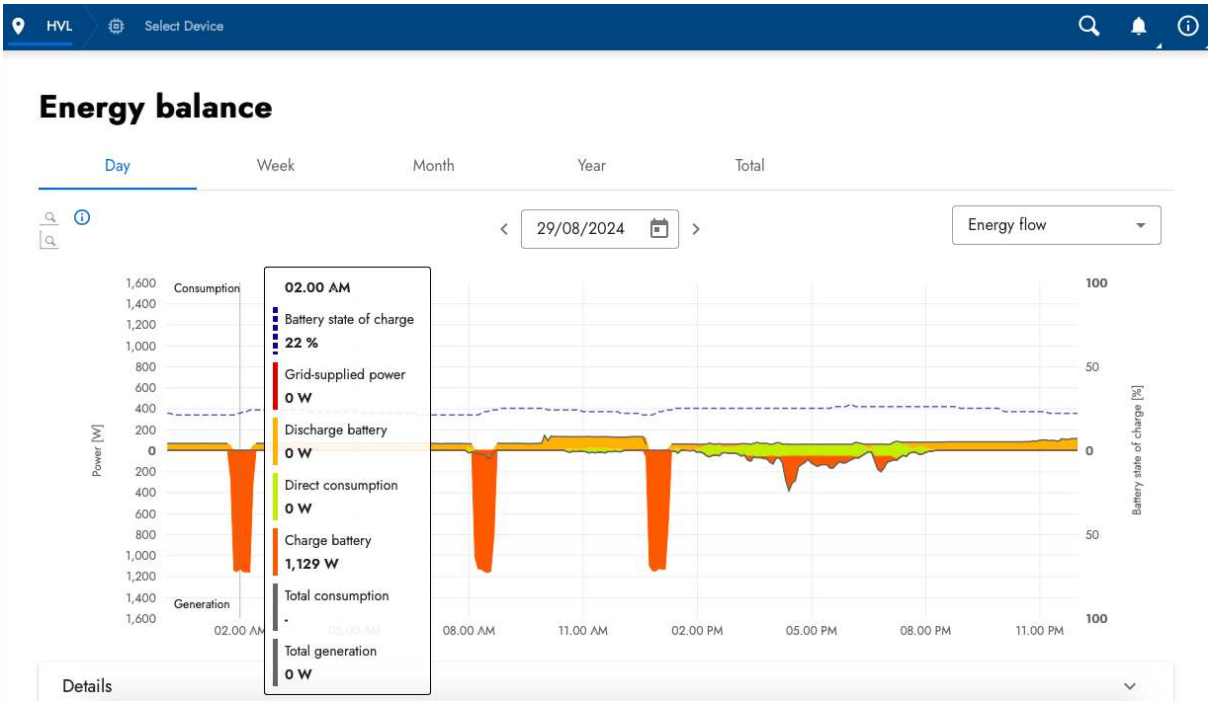


Fig 5c: Energy balance (Sunny Portal app)

I could only check it into the SI UI which shows a generator graphic which indicates the power i/p from the generator (measured) *Fig 6*.

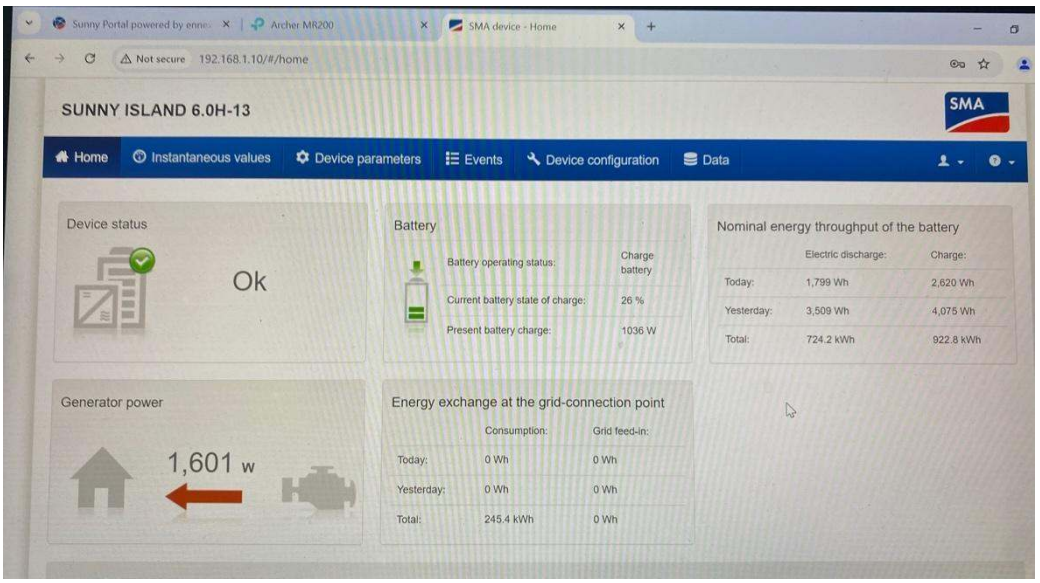


Fig 6: Generator power (Sunny Island interface)

We initiated exchanges with SMA's technical team to seek clarification and potential solutions. While we managed to start the dialogue and gather some initial insights, the issue remains unresolved due to time constraints. Consequently, it will fall to the next person taking over the project to continue this process and work towards a definitive solution with SMA's assistance. Just need to go to SMA Online Service Center, Harald's account gives direct access to the exchange with SMA.

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The next student will also need to address the issue of excess energy production. With the arrival of sunnier days, it is likely that the solar panels will produce more energy than the system can consume or store.
We already have a fan heater installed by the last student but the objective is to develop an automatic system that activates when there is an excess of energy. This system should efficiently manage the surplus, either by redirecting it to specific uses, storing it in auxiliary systems, or safely dissipating it to avoid overloading the system. Implementing such a solution will be essential for optimizing the overall performance and reliability of the energy management system.
We had considered the option of sending excess power produced by the solar panels back to the electrical grid. However, the house is designed to remain completely autonomous, operating independently without being connected to the grid. While this option is not aligned with the current goal of full autonomy, it remains an interesting avenue to explore for future improvements or alternative use cases.

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B) Ventilation and heat recovery



Heating in a passive house relies on advanced ventilation and heat recovery. Indeed, passive houses are built to retain heat efficiently. High-quality insulation in walls, floors, and roofs, combined with airtight construction, minimizes heat loss. This design ensures that any heat generated inside the house stays indoors for as long as possible.

In our passive house a Heat Recovery Ventilation (HRV) is being used. It works by extracting warm, stale air from the house and bringing in fresh, cool air from outside. Instead of wasting the heat in the outgoing air, the system passes it through a heat exchanger. Overall, this system ensures a consistent indoor temperature with excellent air quality, making passive houses both energy-efficient and comfortable to live in.

The units can be controlled automatically or regulated directly via the control panels, Flexit CI 600. I programmed and adapted its operational parameters to align with the house's usage patterns. My goal was to reduce energy consumption while maintaining indoor comfort and air quality. For example, I configured the Flexit CI 600 to operate at higher ventilation rates during the day when the house is occupied. During the night, when the house is unoccupied (or when residents are typically sleeping), the system runs at a reduced capacity. This adjustment ensures minimal energy is wasted on heating or ventilating unused spaces while maintaining adequate air circulation. Since the house's thermal envelope retains heat efficiently, the lower ventilation rate does not compromise indoor comfort or temperature stability.

C) Irradiance during the year

On the roof of the tiny house is a device called a pyranometer (Kipp & Zonen SMP11 Pyranometer) that can read the sun's irradiance. This device sends the data to a nanocomputer, a Raspberry Pi, via another device (Kipp & Zonen PMU485) capable of converting an RS485 connection into a USB 2.0 connection. The goal is to use the raspberry to save the data and create graphics with them.

A former student developed a Python program to visualize data collected by the pyranometer. The program processes the data and generates three distinct graphs to provide insights into solar radiation patterns. Over a three-day (72-hour) period, providing a broader perspective on trends and variations, over a single day, offering a more detailed view of daily fluctuations and the third graph zooms in on solar radiation throughout a single day, presenting data hour by hour to highlight short-term variations. These visualizations help analyze the performance of the solar energy system and understand how solar radiation changes over time, supporting better decision-making for system optimization.

As the Raspberry Pi has been recording solar radiation data for nearly a year, I needed to develop a Python program to generate a graph displaying the entirety of this data over the one-year period. Unfortunately some data errors didn't allow me to build the graph.

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In addition to creating the irradiance curve over the year, it is important to note that when there is a power outage, the graphs generated by the program reset to zero, even though the previous data is still stored in an Excel file. This means the graphs only display new data from the moment the system restarts, losing the continuity of the earlier visualizations. To address this issue, the program would need to be modified so that it retrieves and includes the previously stored data from the Excel file when generating the graphs. This improvement would ensure that the visualizations remain consistent and display a complete history, even after interruptions.

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D) Harmonious ceiling

One of my tasks was to complete the ceiling of the house. I used interlocking wooden panels to create a clean and durable finish. The most challenging part of this project was working around the ventilation pipes, which required precise measurements and adjustments to ensure a seamless result. A special thanks goes to Nafez, who provided invaluable help throughout this project. His support was essential in overcoming the more difficult aspects of the task.







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Additionally, this experience highlighted another issue: the thermometer we are using is not suitable and proved to be impractical. This will need future improvements in the equipment used.

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E) Access to device's configuration

To simplify the use of the hardware interfaces, we modified the IP addresses to facilitate working on the configuration, particularly for the generator within the Sunny Island interface. This adjustment made it easier to manage and adapt the settings for the system.



SOLARLAB IP ADRESS		
DEVICES	**SERIAL NO.**	**IP ADRESS**
Sunny Island	3013232271	192.168.1.10
Inverter 1	1930084389	192.168.1.11
Inverter 2	1930082576	192.168.1.12
Inverter 3	1930083676	192.168.1.13
Home Manager 2.0	3013349660	192.168.1.14
Energy Meter Lab local grid	1901450192	192.168.1.15
Energy Meter charger	1901449948	192.168.1.16
Raspberry Pi 3 Power Supply	5036793835	192.168.1.20
Tigo	22396T2005982	192.168.1.19

Unfortunately, we were unable to access the Home Manager 2.0 during the project.

The Home Manager 2.0 is a smart energy management system designed to optimize energy use in residential setups. It collects real-time data on energy production, consumption, and storage. This allows users to understand how energy is being utilized in the house. Based on the data, the Home Manager 2.0 prioritizes energy usage, ensuring that solar energy is consumed directly before drawing from the grid or using the generator.

Accessing the Home Manager 2.0 data would provide significant advantages. Such as real-time and historical data on energy production and consumption. That would help in identifying patterns, optimizing energy use, and diagnosing inefficiencies. Also understanding how energy flows within the system could allow for better configuration of the generator. So gaining access to the Home Manager 2.0 would be an essential step for improving the system's functionality and ensuring its long-term efficiency.

III. My Personal Reflections on This Experience

When I first started this project, I was surprised to learn that the topic was focused on energy rather than mechanics, as initially proposed by the school. Since I wasn't particularly drawn to the energy field, I didn't expect to be so interested in the topic. I ended up learning a great deal, especially about solar energy systems. The Tuesday courses I had the opportunity to attend were particularly valuable in helping me understand this complex and fascinating domain.

One of the most challenging aspects of this experience was working in total autonomy. While I don't usually enjoy working alone, this project pushed me out of my comfort zone in a positive way. It was a real challenge, but it helped me grow. Moreover, I was fortunate to have the support of Mr Richard J. GRANT and Mr Harald MOEN, who were always attentive and available whenever I faced difficulties.

Initially, I was concerned about potential communication barriers since everything was conducted in English. To my surprise, I found that I was able to understand everything quite well, even in technical discussions. Although there were moments when I had to ask my supervisor to repeat certain technical terms, this did not hinder my progress and even helped me build confidence in my language skills.

Overall, this experience turned out to be both challenging and rewarding, giving me the chance to develop new skills, broaden my knowledge, and grow personally and professionally.

Conclusion

Completing my research thesis in another country was an opportunity I couldn't miss. It allowed me to discover a new culture, experience a different way of working, and immerse myself in an academic environment that challenged me to grow. Working in a new university proved to be the perfect setting to expand my knowledge and expertise while improving my interpersonal skills.

Choosing Norway for this experience felt natural to me. Renowned for its amazing educational system and the high quality of its research programs, Norway offered everything necessary for the successful completion of my thesis. I had access to all the tools I needed to conduct my work effectively. These resources, combined with the Norwegian approach to learning, made it an ideal place to carry out my project.

To be honest, the journey was not without challenges. At times, I found it difficult to resolve some of the issues I encountered, especially as I was working independently. I also faced an unexpected surprise at the beginning, due to an error in the information provided by Icam, I ended up working on a subject that was different from what I had initially expected. While it was not a field where I had extensive expertise, I saw this as an opportunity to expand my knowledge in a new area. Given the growing importance of solar energy worldwide, I was excited to deepen my understanding of this critical topic.

One aspect of this experience that I particularly appreciated was the support of Mr Richard J. GRANT. He was always approachable and available to guide me, which was precious for someone like me who prefers to have a certain level of mentorship. I never felt pressured, and this supportive environment allowed me to focus on my work at my own rhythm.
I also benefited from the lectures my supervisor recommended. These sessions were not only helpful for understanding my research topic but also contributed to my personal growth and broadened my knowledge about the use of solar energy in the domestic environment.

Beyond the academic experience, living in Norway was truly enriching. I met extraordinary people who made my stay even more special, and I had the chance to explore breathtaking landscapes. I will miss it dearly.

This experience has been transformative, both personally and professionally. It has strengthened my confidence, expanded my skill set, and provided memories that I will keep forever. I'm deeply grateful for the opportunity to have lived and studied in Norway.