End of Master project at the Western Norway University of Applied Science in Bergen



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icam

Høgskulen på Vestlandet

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INTRODUCTION

Solar panels and associated technologies are quite a new field and a fast-growing industry… even in Norway. Where at first sight it is not the best place to develop this technology, reality is different and the demand in solar energy is rising.

Regarding this interest for solar energy, the Western Norway University of Applied science has invested in the creation of a solar laboratory. My project is directed towards the creation of this solar laboratory. Specifically, tasks require the mounting of solar panels on specially created frames, network layout and installation, and mounting and connection of electronic devices (inverters, battery unit...). The centre of this laboratory is based in a demonstration passive house.



I/ Methodology

The laboratory requires that the facility is highly adaptable whilst allowing the wiring to be understandable to the researcher and student alike.

The passive house, which is originally a mobile home has been designed and transformed by students, directed by Anne-Sofie Handal Bjelland. For the solar technology side of the system, the school dealt with Simona Petrochini who has dimensioned and ordered the all lot of equipment.

The system will work with 3 inverters “SMA sunny boy”, 1 battery unit, 3 firefighter switches from Santon. 12 crystalline technology and 14 thin flexible technology panels will harvest the solar energy. Each panel is equipped with Tigo Optimisers, which are in fact Maximum Power Point trackers (MPP Technology); it is the process of optimizing the system by changing the load characteristic to keep the power transfer at highest efficiency.

The all system will be connected with a cloud connect controller from the same company; it is a compact, powerful data logger and the communication hub of the Tigo smart platform. It powers the monitoring and safety capabilities of Tigo smart modules.

In order to have a general idea of the power production, here is a simple calculation: each crystalline panel is supposed to produce 285W and each thin technology panel can produce about 120W. So the total energy harvested can be **12*285 + 14*120 = 412 kW** in standard test condition.

My job, in reflection with the technician and my tutor was to install those devices. First I needed to understand how a solar installation is working and the choices of Simona. The course we had last semester at Icam, in the energy specialisation module has been really helpful. Also I needed to find all the datasheets, for each device.

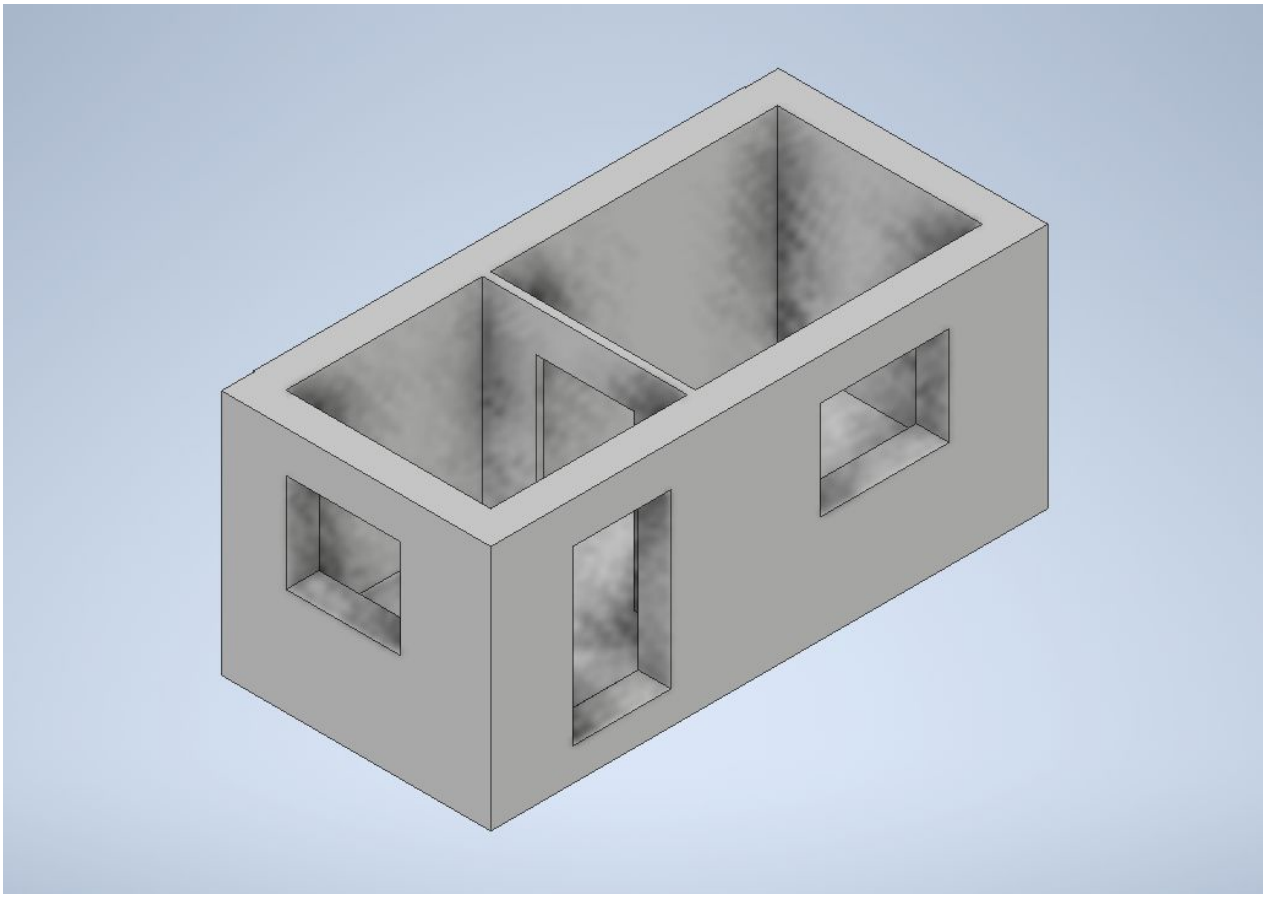
Richard invited me to follow his lecture about solar energy along the semester; those lectures have been really interesting and helpful for the project. Also it was a great source of knowledge and culture about this emerging technology.

II/ Result

Aside from the overall comprehension of the system, the work asked is, as expected, very practical; some installation needs to be done to welcome the different equipment.

One of the first things to do is to have an idea of how all the equipment will be mounted and fit together in the passive house.

Below a sketch of the passive house; it is important to picture it to understand the explanation that will follow!



A/ how to mount the firefighter switches



I decided to install the domestic firefighter switches outside, as it's recommended to fix them as close to the panels as possible. They are conceived to be mounted outside, but may not be installed "in direct sunlight or be in direct contact with (continuous) ingress water." (quoted from the datasheet).

Sun is not the main problem in Bergen, but I worried as the rainy conditions are a bit unusual and above normal.

So I created and mounted a small shed to protect the firefighter switches. A thin metal sheet is screwed on the roof, bended at the end to create a little drip edge.

Then, as we can see below, a wooden plate has been added to protect the cable between the flexible pipe and inside the firefighters.



B/ How to link the outside to the inside equipment ?

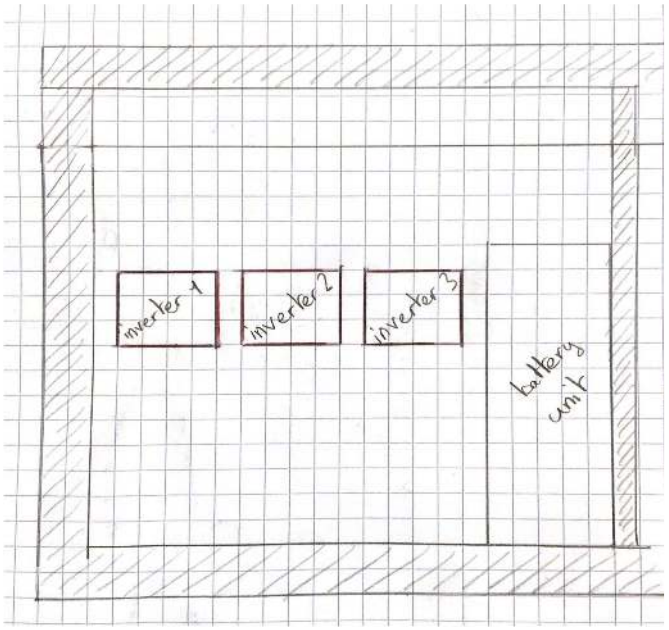
To link the panel to the system, it was needed to bore holes for the cables. The problem of boring holes through the wall of a passive house (and in every kind of house in fact) is that you create a way for the outside atmosphere and that can interfere in the thermal performance. So it is important that the junction has to be nicely cealed. For that we used a silicone paste.

So the first idea was boring holes in the walls, but my first thought was to drill them through the floor, and I decided to do so. Two 50mm and one 40mm diameter holes were drilled. For the DC side, only one 50mm hole is really needed for the moment, but still for the purpose of being far-sighted, two have been bored. Then, to have a clear separation between AC and DC, the smaller one is for the AC side.



For the sake of having all the equipment nearby each other, I made the decision of mounting all the equipment in the first room, at the entrance, a kind of “technical room”.

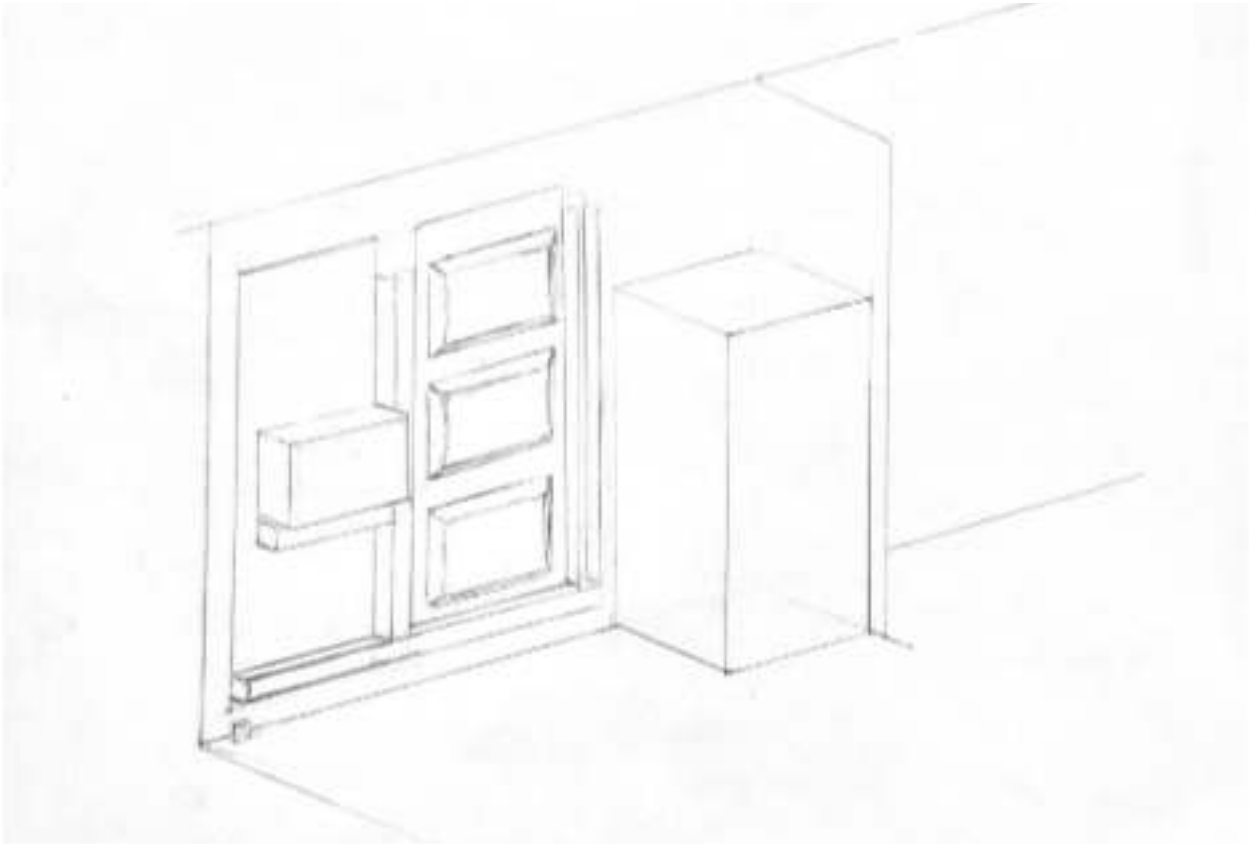
C/ The inverters and the battery unit



First my thought was to install the inverters horizontally and the battery near them. But this would not respect the mounting distance clearance. Effectively, inverters emit heat when they are running, so it's important to keep a certain distance between them.

It was before the idea of the patching board, and in fact with hindsight, that would have been not possible because of all the other equipment, like the fuse box.

So I opted for a second solution; mounting the inverters vertically, this solution lets enough space between them and for the other equipment in the room.



It was necessary to fix the plywood's board on the wall. Then the plywood would support all the devices, as the standard which is recovering the walls is thin and would not support their weight.

The inside structure, as most of the wooden buildings nowadays, is supported by wooden uprights placed every 60cm. So I screwed the boards on those uprights.
Finally, to fit nicely in the room, Richard asked me to paint the board.

The reason why I choose to mount 2 boards is to make a clear separation between the inverters and the rest of the system. Later, the space between the 2 boards will be used to fit one of the electrical channels.





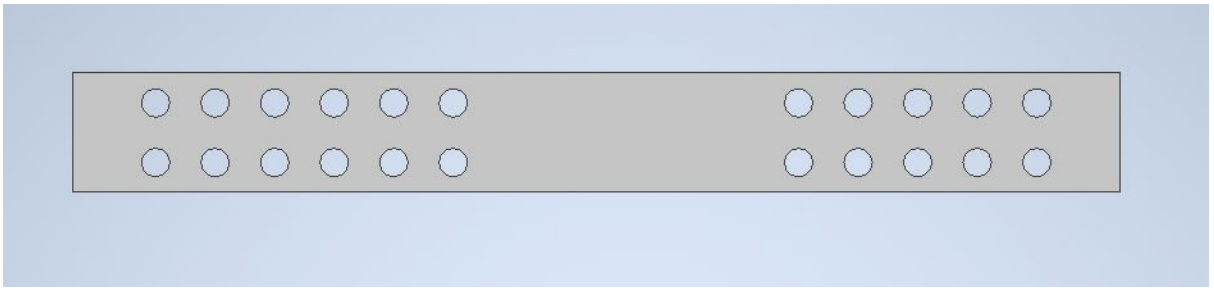
Simona advised me to add a distance between the board and the inverter, to prevent heat emission. That is not compulsory and not written on the datasheet (mainly because they were part of the first inverter generation produced by the company), but clearly advised now. So, as we can see on the right photo, I had aluminium sections to add about 2cm space.

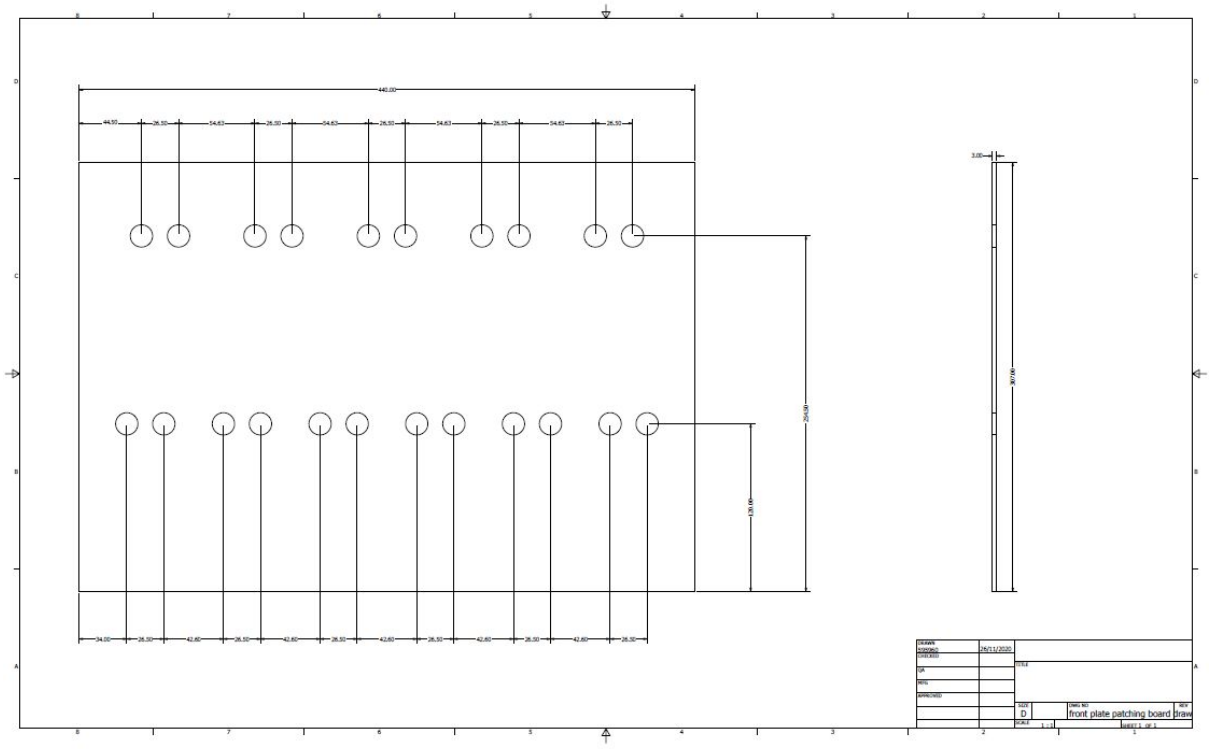
D/ The patching board

As making the laboratory adaptable is the main objective, in concertation with Harald (the technician) and Richard, the idea of a “patching board” was born. Inspired by the phoning patching board which has been used back in the time....

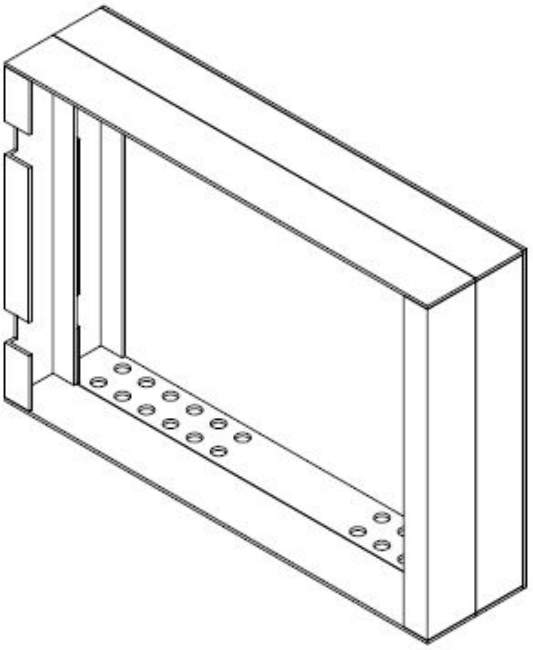
The purpose of this board is to direct the current either through the inverters or in the battery, to be able to connect the panels differently…

The different parts of the patching board have been made using a plasma cutter; for the technical pieces (the front board and the bottom part have holes to fit the electrical gland) Harald needed me to design them on the computer for the plasma cutter. I used the software Autocad Inventor to create those pieces.



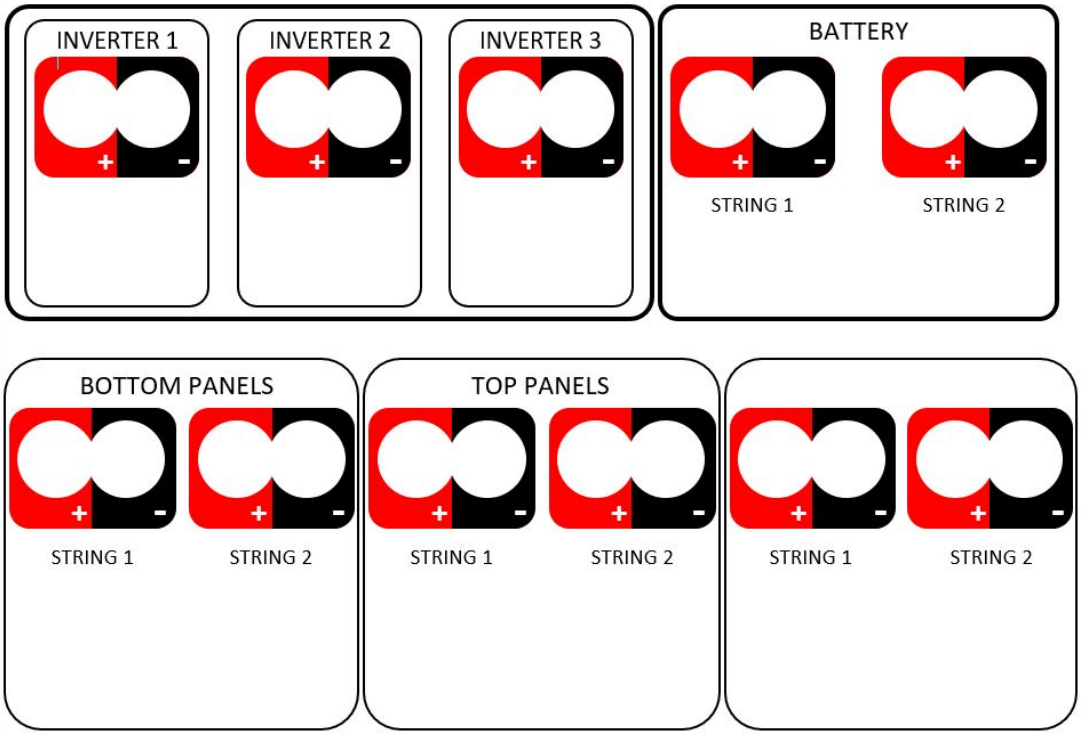


One thing I haven’t thought about, was the deepness of the box; because of the rigidity of the cables and the fact that part of the connectors are inside the box. Hopefully, the deepness can be easily increased, by creating and adding another “box”. Here is the final result (without screw holes on each corner of the box).



Also I decided to add hinges on the left side, that was easier to plug the cable and to have an access inside the box.

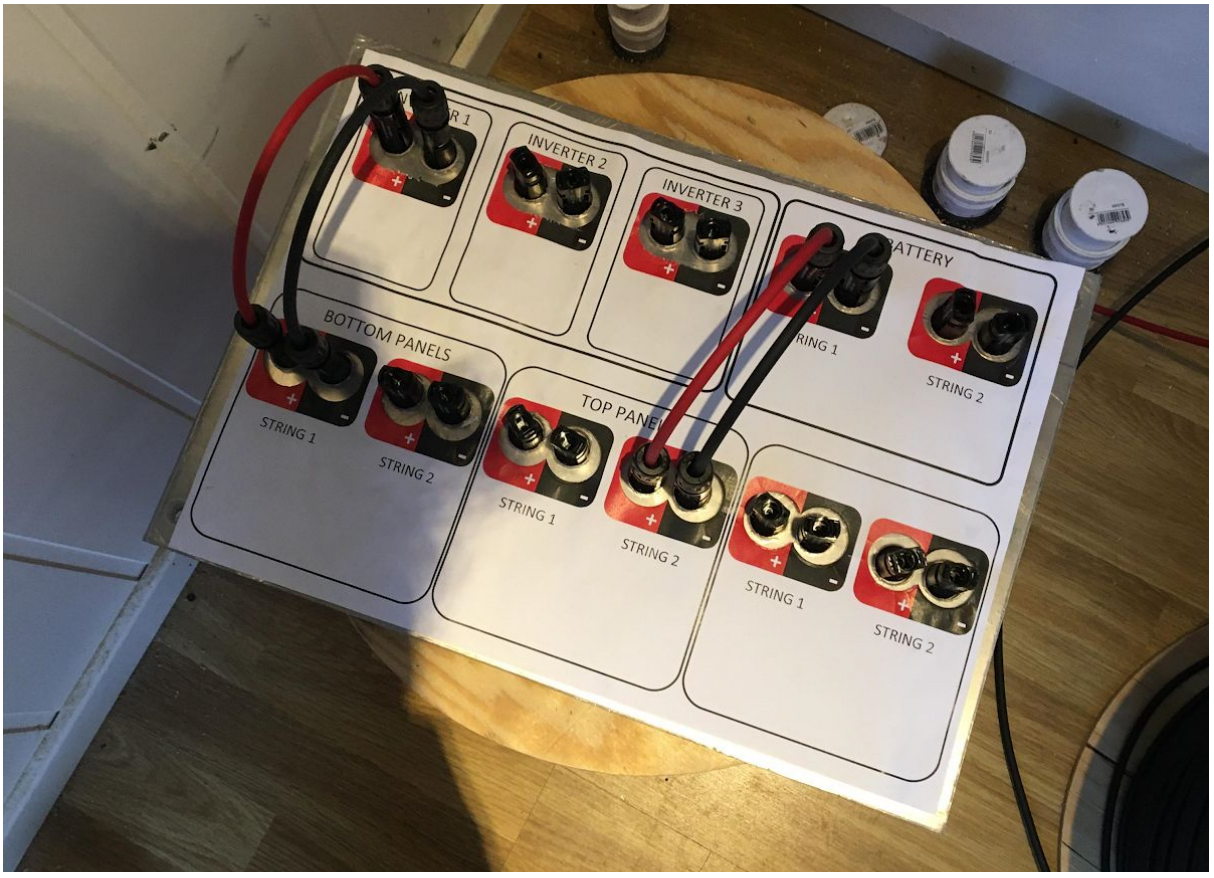
A plexiglass plate is placed above the aluminium plate to protect against the current that can circulate through the metal. Then a printed paper sheet (laminated with plastic to protect it) will be placed to labelised the different out/input. This sheet is meant to be removed in case the labels change.



For me this labeled paper is very important to avoid error in the wiring, and to have an “educational” vision of it. For example, it was not obvious for me that a red cable is for the positive side, and a black one for the negative. Based on this observation, it is evident to me that all the students are not aware either of those electrical uses. The use of color in my opinion is the key of comprehension for this board.

It is important for me too to have a clear separation between the different equipment on the draw. To have a schematic representation of their “disposition”. Some spare space is available underneath every plus and minus “couple” of connectors, to add information if needed.

As it is easier to pull off a “male” MC4 connector, “female” MC4 connectors will be fixed on the patching board for every out/input, and the “male” ones are used to create the linking cables.

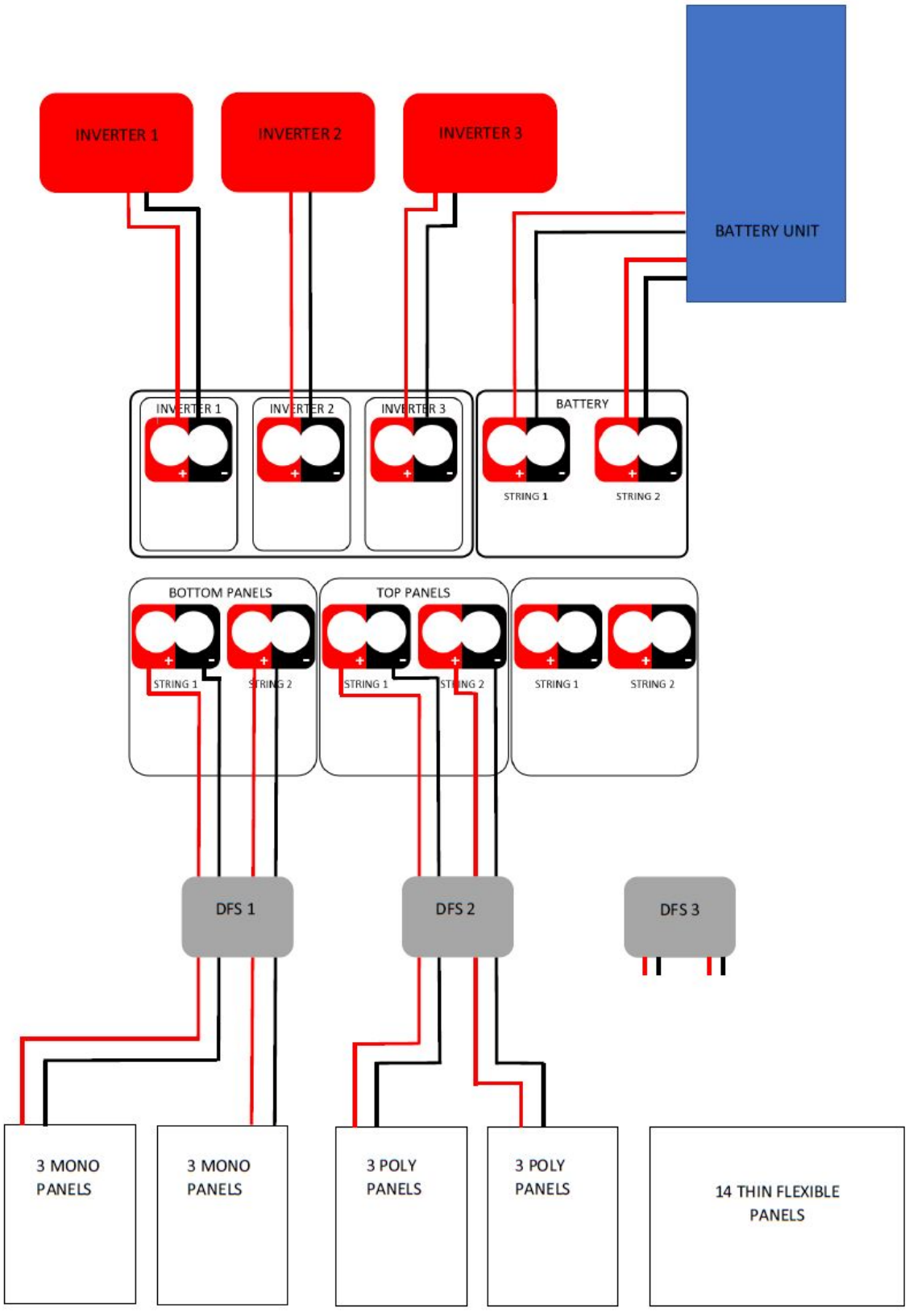


Counting the input and the output, it is highly noticeable that there is not the same amount of connectors. It will not be possible to link everything from + to + / - to -, so at least one “special” cable will be used, to link a positive and a negative entrance. To clarify this difference, the cable will be half red and black.

Then, the patching board is fixed on the wall at a correct “up breast height”, and I have added two hinges on the left side to hold the front board when it is opened.

E/ The electrical part

Here is a simple schematic for the DC wiring.



It has been defined which configuration could be done, regarding the maximal voltage and current accepted by the inverters and the battery unit.

Each group (by group in mean technology) of panels will be divided in 2, to form a set of 3 panels, linked in series. Depending on what we want, that means harvesting solar energy or doing tests (obviously harvesting while doing tests…), an entire group of panels (that means 6 panels) could be linked together in series.

Dispositions	Voltage (standard conditions)	Current (standard conditions)
1 crystalline panel (285W)	31.65V	9.09A
1 set of panels: 3x panels linked in series	94.95V	9.09A
6x panels linked in series	189.9V	9.09A
2x set of panels linked together in parallel	94.95V	18.18A

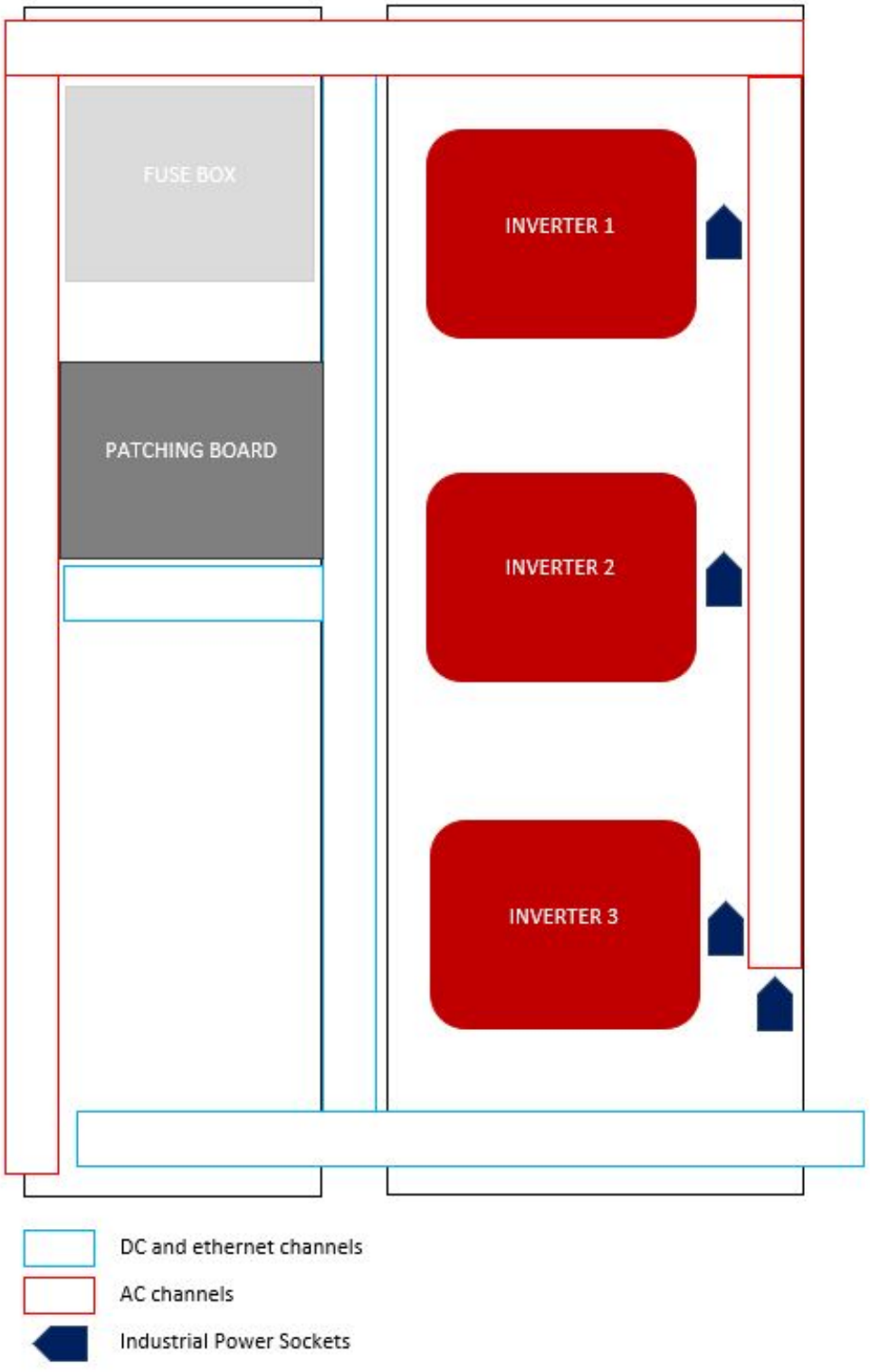
Devices	Voltage (V)	Current (A)
Fire Fighters (per string)	600	32
Inverters	Min: 50 Initial: 80 Maximum: 600 MPP range: 160 to 500	Maximum: 10
Battery (per string)	Initial: 85 Maximum: 150 MPP range: 70 to 140	Maximum: 39

Comparing the datas of each panel, it is noticeable that not all the combinaison can be done, it is important to refer to the maximum voltage and current allowed by the inverters and the battery. For example if we want to link 6 panels together in series, the battery will not support the amount of energy (189,9V harvesting, and the voltage limit is 150V in input.). Another example; if we want to use the inverters, we can not link in parallel 2 sets of panels, because the current provided will rise 18.18A, and the limit admitted by the inverters is 10A.

The spare place available on the label will be used to prevent this by adding the maximum input current/voltage authorised, and these 2 tables will be printed and fixed next to the patching board.

It has been stated that the panels will not be linked in parallel, and most of the time grouped by 6.

One of the problems was that in the case of the inverters, the AC and DC cables would cross each other; the solution has been to have a completely different way, by the top and on the side for the AC, and by the bottom and on the middle for the DC.



Inverters and the battery unit will need an ethernet connection, and cables will be added on the DC channels. Harald had the idea to use sockets in order to disconnect the inverters and the battery unit easily from the AC. So 4 industrial sockets will be installed.

Then as we can see, I let some spare length on the right of the bottom channel, it meant to be adjusted once the battery is installed.

It is the same for the right vertical AC channel, as the power sockets will be mounted by the electrician, it is just fixed on the board by a few screws (like all the AC channels, that has been said with Harald). It will surely be needed to adjust the length.

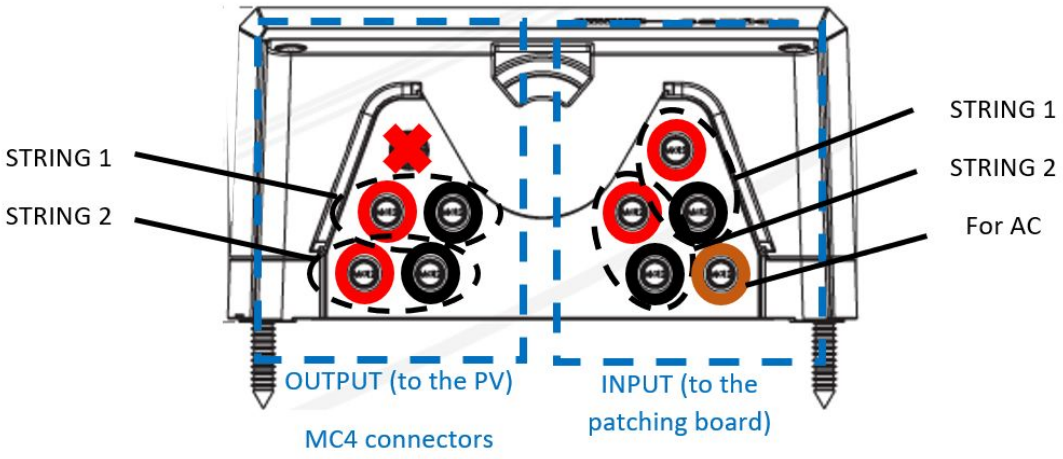
According to what has been agreed with Harald, I only linked the DC side of the system, then we will need the help of an electrician to do the AC side, including the connection to the grid, the fuse box and wire the inverters, the fire fighters and the battery unit. (As we can see on the left photo, a flexible pipe is used to protect the cables outdoors).

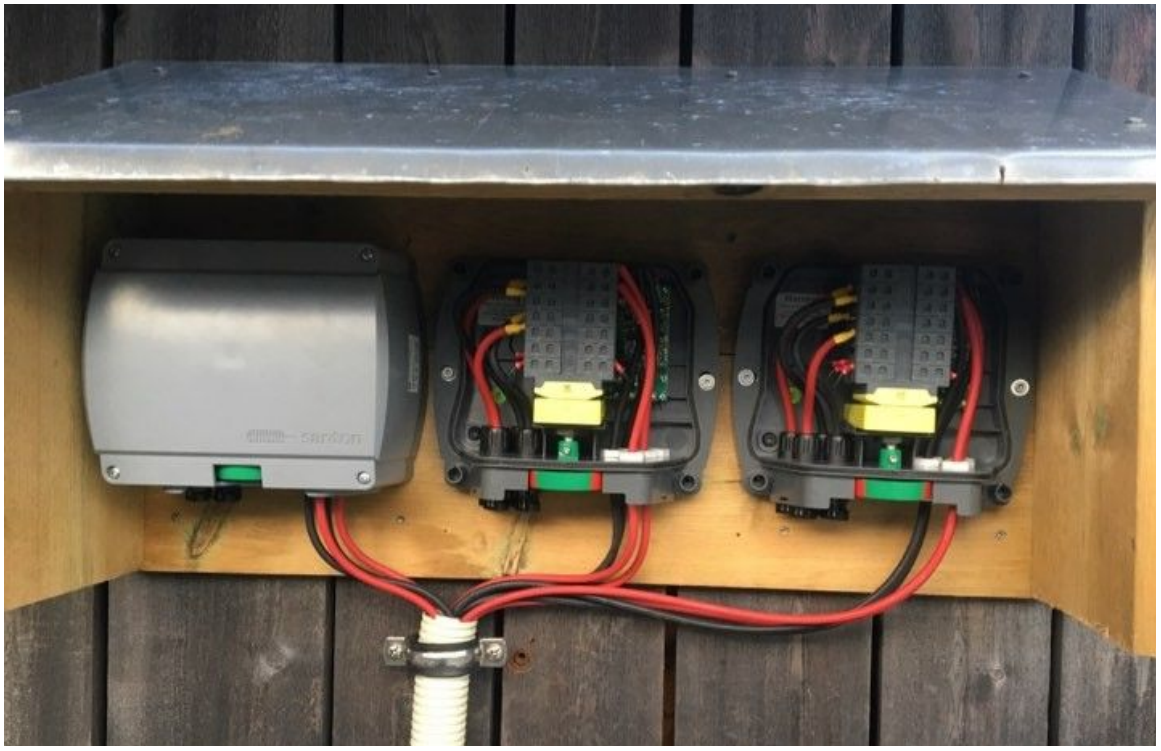




My ability to wire all the equipment has been discussed during all my semester, so I first prepare the right length of cable between the fire fighters, the inverters and the patching board. And placing them through the electrical channels.

Here is a schematic that shows how I have wired the firefighter; it is important to keep this drawing, because there is no label yet on the outside to differentiate the plus or minus on the MC4 connectors.





F/ What I achieved before leaving

I haven't connected the inverters, in case it is needed to move them again. Then sadly, I didn't have enough time to finish the wiring inside the patching board. To open the patching board: just unscrew the two screws on the right.

Then a bit of painting/cleaning might be good to do on the plywood board and electrical channels.



III/ What is planned for next ?

A/ The AC side of the installation

The next job is to deal with an electrician for the AC wiring of the devices. That means adding a fusebox (fuses dimensioning in the table below) and the connection to the grid. A rotary switch (not on the draw) will be added to cut off the AC when a changement is done on the patching board. This rotary switch will be added between the patching board and the firefighters. A light will be added next to the switch as a signal when the current is on.

Device	Maximum current allowed	Fuse
Inverter	7 A Max current under fault condition: 12 A	10 A (Important to check the datasheet p30 for the fuse)
Firefighter Computer, monitor and co	0.3 A	10 A
Battery	32.6 A	32 A

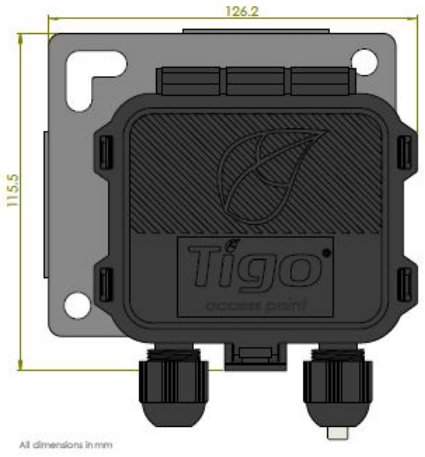
B/ The Tigo Access Point devices

Tigo “TPA” (Tigo Access Point) devices have to be mounted on the panels; 3 of them, each one for each different solar cell’s technology. They are used to collect the data of the optimisers, and are connected wireless to the main gateway (which will be installed inside).

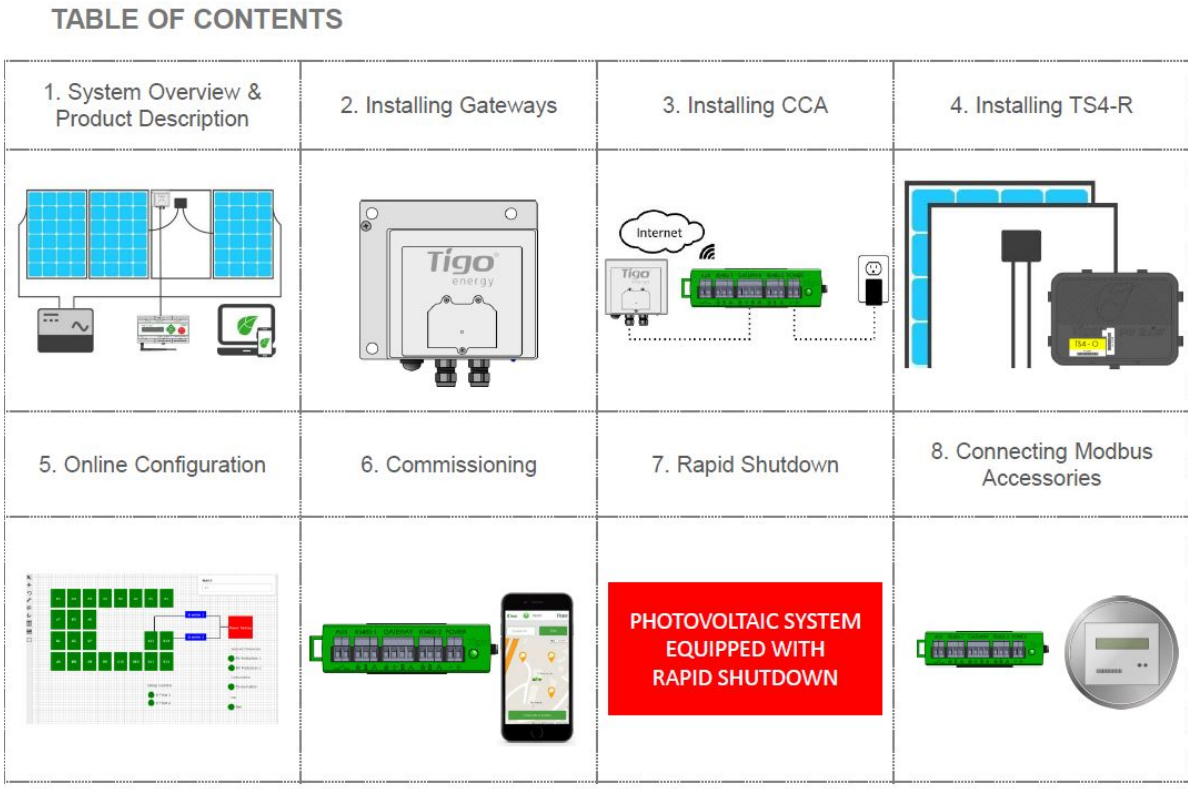
Gateway :



Tigo Access Point :

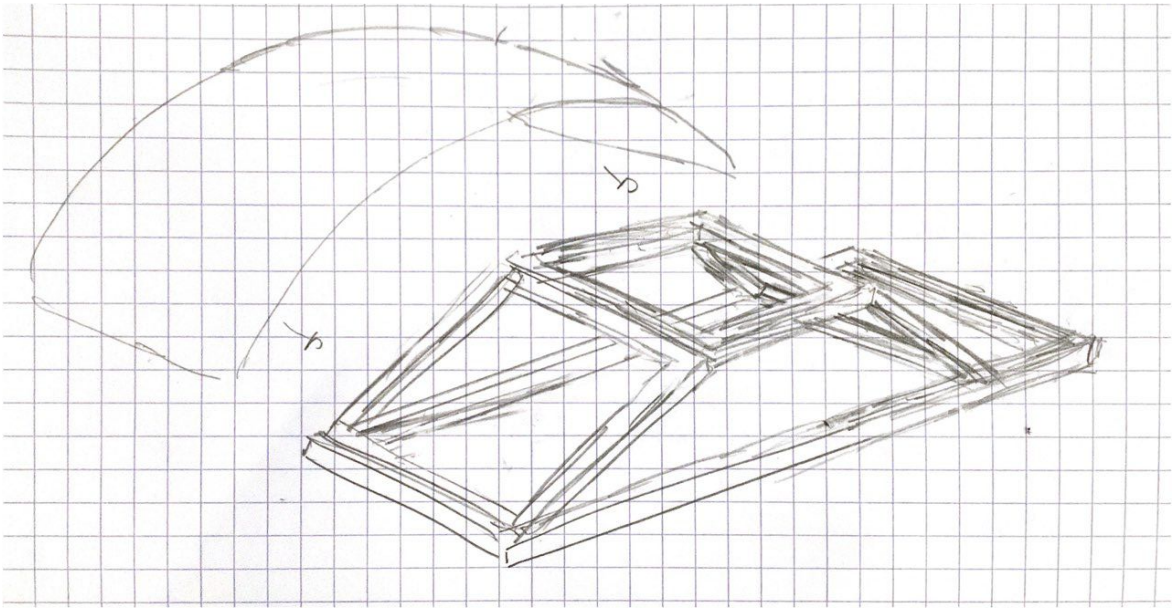


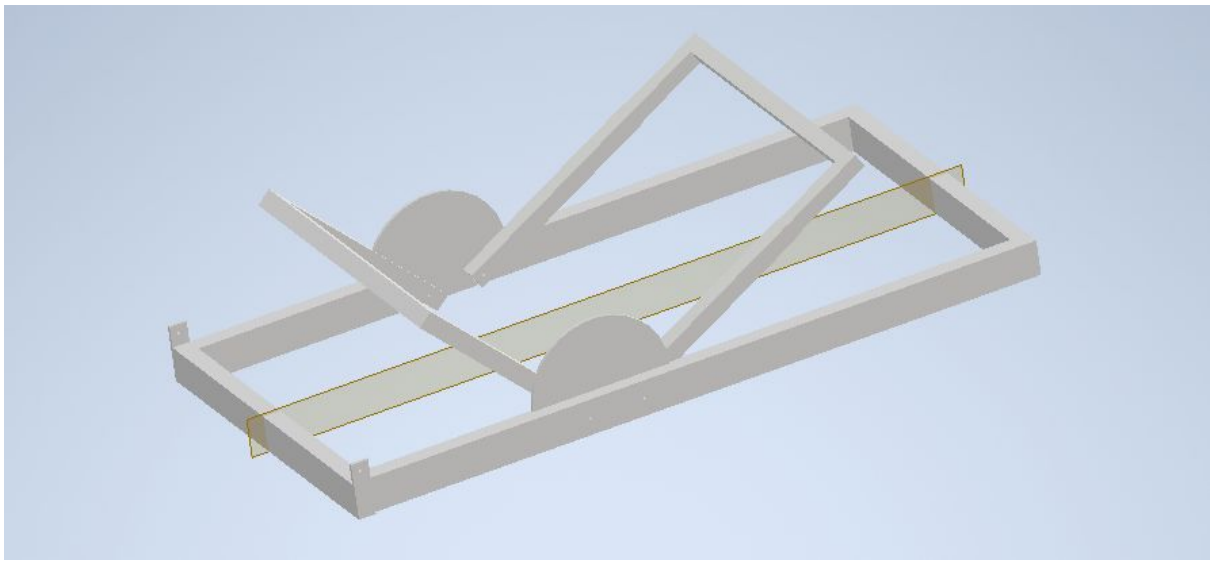
A datasheet “Installation Manual TS4 Platform” (Begin on p17; “Cloud connect advanced and gateway”) is on Teams.



C/ The thin flexible panels

The thin flexible panels are not yet installed, I have started to design some solution to keep the flexibility, and change the position easily.





A PV tracker is meant to be mounted too, and some of the flexible panels to be mounted on. The structure will be the same as the solar concentrator already in place. The panels have to be fixed and easily removable on the tracker's structure. Adding a thin metal sheet under the flexible panels and using scratch patches to fix it on the structures is for me the top one idea we had for the moment.

Otherwise, the flexible panels could be mounted on the laboratory's roof, but then it would be difficult to have access there, and to change their position with ease… A second solution would be to create another structure on the floor, nearby the actual ones.

For the electrical dimensioning, regarding the data supplied by the company (below), and comparing them to the table used before, we can notice that the voltage is quite similar to the crystalline's one. But the current is much lower, between 3.80 and 4 Amps. So it might be possible to do some parallel linking if wanted. (Notice that I don't know which panel of the range has been ordered).

ELECTRICAL PERFORMANCE AT STC[1]

			FLEX–02 110N	FLEX–02 115N	FLEX–02 120N	FLEX–02 125N	FLEX–02 130N
Nominal Power	P_{MPP}	[W]	110	115	120	125	130
Aperture Efficiency	η	[%]	14.4%	15.0%	15.7%	16.4%	17.0%
Power Output Tolerance		[W]	+5/-0	+5/-0	+5/-0	+5/-0	+5/-0
Maximum Power Voltage	V_{MPP}	[V]	28.9	29.7	30.5	31.3	32.0
Maximum Power Current	I_{MPP}	[A]	3.81	3.87	3.93	4.00	4.06
Open Circuit Voltage	V_{OC}	[V]	37.1	37.6	38.1	38.6	39.1
Short Circuit Current	I_{SC}	[A]	4.50	4.52	4.53	4.55	4.57
Maximum Series Fuse Rating		[A]	10				
Maximum System Voltage	(IEC/UL)	[V]	1000/600				

D/ The laboratory purpose: harvesting and analysing datas

Harvesting data is insignificant if there is no educational learning and analysis behind. The creation of an interface, through a monitor is very important, as much for the students and teachers as for the technicians. My idea is to have a monitoring system displaying the datas, visible from the front window. Then another smaller screen will be needed for the inside, in my point of view, more for the testing side of the installation.

All the monitoring/internet equipment will be installed in the biggest room, separated from the “technical room” at the entrance. My thought is to fix the Tigo gateway box, and other computing equipment on the wall, behind the door. Then as I said before, mount a monitor screen behind the window or on the wall but facing the window (in both cases, showing the data to the public is on purpose). Another little screen is maybe good, but only for the “maintenance” side, so no aim to let it visible.

Still in the optic of sharing the data, the creation of a website might be good, rather for the students/teachers than for the technicians.

Obviously, an internet connection is absolutely needed, that is on the hierarchy that the decision falls to.

Here is a drawing, to pictured what I wrote above, of how I see the installation and disposition of the devices in the laboratory:



E/ A new logo

As a little job asked by Richard, the old board has been removed from the wall, as it was dirty and the logo meant to be changed.



About the new logo, here is a little draft of my best idea; with colors or not, could be drawn on a metal sheet too.



It is just a draft obviously, a good design software would be needed to make it nicer, like bowing the “solar lab” label, to keep the continuity of the draw’s general round shape.

The HVL logo is not included, because it might change in the near future.

IV/ The difficulties

At the beginning, it took time to understand the functioning of all the devices together. Harald and I were new in the electrical solar installation field, and we had some trouble understanding all the details and the reasons why Simona ordered this equipment in particular. So a meeting with her has been necessary to accord our thoughts.

I had two weeks of waiting by mid October; I was not able to significatively go forward in my work. The reason was that I needed to buy some components at Ahlsell shop but Harald, the technician I am mainly working with, was sick and was the only one to have the card to buy parts for the school.

Finally after dealing through this problem with the help of my tutor, Frode, another technician, managed to get a new card and went buying the component needed with me.

I didn't have a large enough view of the entire mounting and layout of the devices, but it is partly because I was (Harald too) discovering and understanding things bit by bit alongst the project. For example I had not thought enough about the mounting of the electrical channels, so I had to change the inverters' position to let some more space. Then, as I explained before, Harald had the idea to fix industrial AC power sockets for each inverter and the battery, So I moved the inverters a second time to fit the power sockets.

Appart these particular problems, I didn't have any major ones, it is just that things take time to be done sometimes, when I need the help of the technicians, because they are most of the time busy with courses, or other student projects.

I think that the difficulty is mainly due to the fact that different people have been involved for each part (Simona for the ordering and dimensioning, me for the installation…), and maybe that the expectations had not been defined clearly (maybe it was just harvesting energy for Simona, more testing as it meant to be a laboratory for Richard), but all has been clarified along the project with the meetings and the talks.

CONCLUSION

This project is very interesting and educational. As it requires a lot of autonomy and some responsibilities, I feel that this project has rosen my degree of autonomy and confidence, on making choices, assuming my error…

I learn a lot about solar energy and solar installation, and about the general electrical installation. The difficulties that occured alongst my semester are, more or less, part of every project for me.

Making the laboratory as adaptable as possible is the guideline, as it will be in a continuous development, following the new technologies of solar panels. It could also one day welcome other inverters, a second battery unit…

The atmosphere is very nice in the mechanical department and in the workshop, I had been very pleased to work on this project with everyone. A big thanks to everyone, especially Richard and Harald who were here to direct, advise and help me on the project.