# Progress Report Milestone 2 & 3

**Project:**

**Multiphase injection optimization using GPT method**

Prepared for SANEDI and MLT Inverters

09-06-2022

## Contents

**Background**

MLT Inverters (formerly known as MLT Drives), a proudly South African company, has been in the industry of high efficiency inverters and battery chargers since 1984.

We currently manufacture four ranges of chargers, namely the PowerStar AC Charger/Inverter, the Oasis AC Charger/Inverter, the Nomad Solar Charger, and the Karoo Solar/Battery Hybrid Inverter (see Figure 1). In 2017/2018 we were awarded a bid from SANEDI to further upgrade some of our products to accommodate the redundancy and complexity required for larger solar and solar/battery hybrid systems (see **Error! Reference source not found.**).

In previous activities relevant to our SANEDI project, the PowerStar (referred to as the Namib in our original proposal) inverter and the Nomad Solar Charger had their hardware upgraded to allow them to interface with Battery Management Systems (BMSs) on an CAN (Controller Area Network) communication bus. CAN has become the *de facto* standard for communication with Battery Management Systems. Subsequent to this, the hardware on these devices was successfully tested and lead us on to activities (1.2), (1.5) and (2.1) of the project. These activities included writing and testing the necessary software in the Nomad and PowerStar to allow them to communicate over the CAN communication bus.

Many battery manufacturers were excited to see this topology in action and as a result we have gotten equipment and support from PylonTech, FreedomWon. Hubble and BlueNova. We have successfully interfaced with all these battery types and have been registered on their approved list for compatibility.

We now aim to extend the single phase 10kW into a 3-phase 30kW LV (Powerstar30H) and 3-phase 50kW HV (60kVA). We also aim to add new 3 phase measurement techniques to allow for multiphase variable current injection.

Traditional inverters inject the same current on all 3 phase in a 3 phase topology. The new generation of smart inverters can redistribute power to increase line capacity and line losses. They will do this in real-time with the aid of specialized line impedance measurement techniques developed by professor Trevor Gaunt and Professor Michel Malengret.


Figure 1. MLT Inverters' product range

**Abbreviations, Acronyms and Technical Terms**

| | |
|---|---|
| Mini-grid | Local power network. Not the mainline utility network (Eskom). A mini-grid can be grid assisted or completely independent from the utility. |
| PCB | Printed Circuit Board |
| PCBA | Printed Circuit Board Assembly. It is the PCB populated with the necessary components including the microchip which contains the high-level software. |
| TRL | Technology Readiness Level |
| LV | Low Voltage |
| BMS | Battery Management System. The interface whereby 3rd party devices interface with the intelligent battery controller to ensure all charging and discharging specifications are adhered to. |
| CAN | Controller Area Network. A communication protocol that allows multiple controllers (i.e. little computers or sensors) to communicate with each other on a single communication bus. |
| HMI | Human Machine Interface. This could be a local touch screen or a device such as a PC or Mobile accessing the device remotely via our server. |
| IPP | Independent Power Producer. Not Eskom. For example, a solar or wind power plant. |
| HV | High Voltage |
| | |
| 1PH | Single Phase AC 230V line to line |
| 3PH | 3 Phase AC ~400V line to line |

**Project Summary**

Traditionally, power in a multi-line system is injected into a network equally in magnitude and in phase with the voltage at the point of connection. However, this is not necessarily the most efficient way for power to flow to its point of consumption as the resistance and reactance characteristics as well as the voltage of each line may not always be the same.

The invention relates to frequency domain-based determination of currents for injection into a power network so as to reduce transmission losses associated with delivery of an amount of power.

UCT has spent R3M on patenting this technique. Professor Michel Malengret and Professor Trevor Gaunt are the inventors. We have signed an agreement for exclusive use for now. Full patent can be seen here:

https://www.sciencedirect.com/science/article/abs/pii/S0378779611001283

This technique will be specifically integrated with our new generation Powerstar3. The 3ph 30kW Powerstar3 will use this technique to optimize both injection into and draw out of the network.

This can be installed along with traditional inverters to optimize the top 5% of the power transmission. This equates to lower transmission losses and higher capacity on the lines. Such a device would be very well suited to large solar plants and even traditional power plants.

The powerstar3s can reattribute the currents as seen by the utility via their own inverting and by directing the solar park to increase or decrease its injection on each phase.

- Transmission losses are minimized
- Capacity of transmission is maximized
- Energy arbitrage can also be optimized
- Smart grid assistance at the substation level by introducing batteries with inverters at each station.

**Strategic Alignment and Project Objectives**

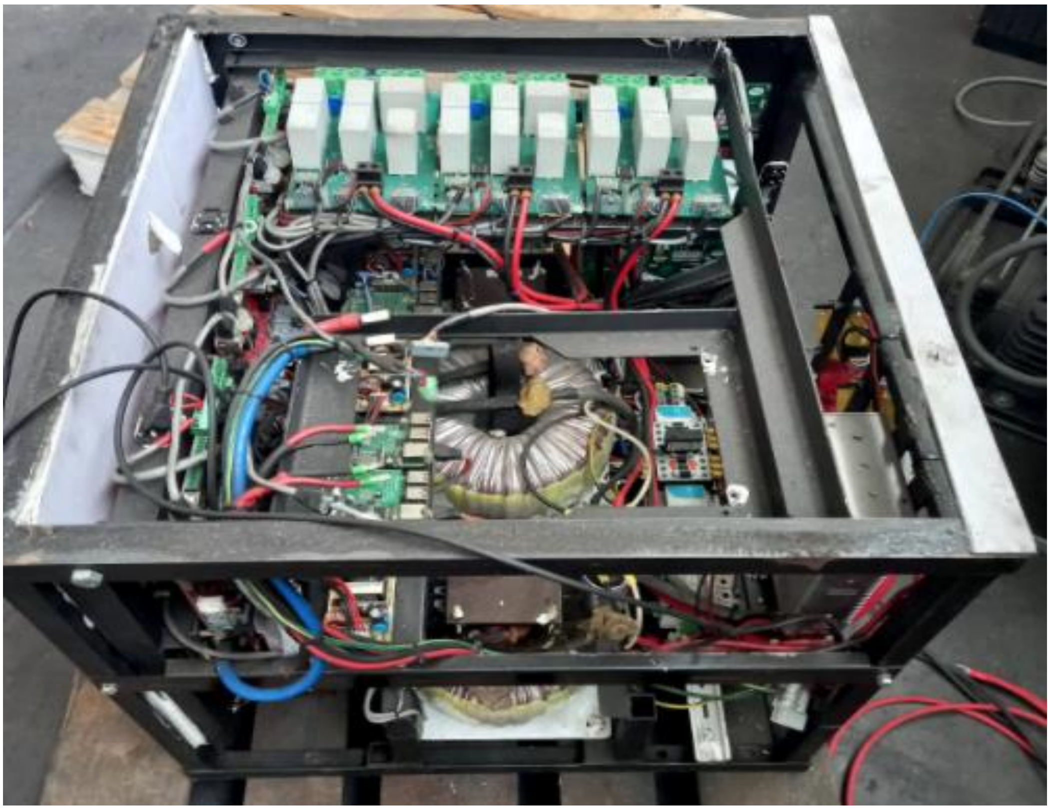
| Strategic Plan Element | Project Objectives | Success Criteria |
|---|---|---|
| 1. 30kVA inverter | 30kW LV inverter that can Implement injection optimization into a power network. | Measure and deliver variable current on 3 phases with improved line capacity and line losses. |
| 2. 60kVA inverter | 50kW HV inverter that can Implement injection optimization into a power network | Measure and deliver variable current on 3 phases with improved line capacity and line losses. |
| 3. Commercial instrument | Implement a standalone instrument that can predict energy savings at a plant before upgrading injection control. | Reliable instrument and generated data to motivate plant upgrade. |

**Original Milestone Audits Dates and claims schedule**

| Milestone/Deliverable | Estimated Dates | Invoice Claim | Responsible individual |
|---|---|---|---|
| 1. Inception Report | **1st June 2021** | *R 90 000* | *Jean-Claude Malengret* |
| 2. Report on Powerstar30 prototype. | **1st July 2021** | | *Jean-Claude Malengret*<br>*Peet Nel* |
| 3. Report on Powerstar30 TRL8. Physical Audit in Cape Town | **1st July 2021** | *R 416 268.75* | *Jean-Claude Malengret*<br>*Peet Nel* |
| 4. Report on 60kVA prototype. | **28th December 2021** | | *Jean-Claude Malengret* |
| 5. Report on 60kVA TRL8. Physical Audit in Cape Town | **28th March 2022** | *R 649 801.25* | *Alex Shutz* |
| 6.Report on certification results from TUV lab | **28th March 2022** | | *Peet Nell* |
| 7. Site test report and Final project report | **28th March 2022** | *R 890 667.75* | *Jean-Claude Malengret* |

**Previous Milestone 1 single module**

For milestone 1 we demonstrated a combined 30kVA 3ph unit starting a load a 65kW inrush load. It was electrically modular but combined in form factor.



**Current Milestone 2 multinodular 60kVA 3ph**

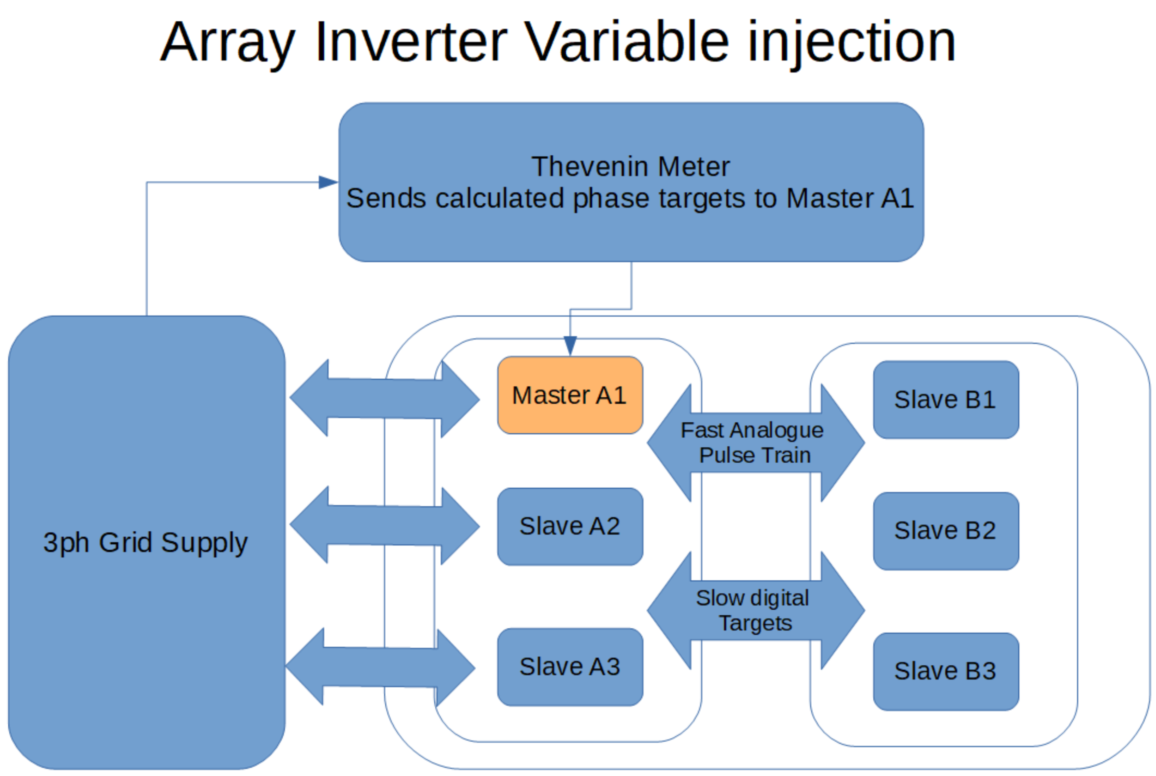
The 60kVA was designed in mind with expansion  up to 120kVA with 12 modules. In this case we used 6 modules. The system can be divided into essentially 2 3ph inverters. Each set of 3 has a sub master controlling its group with one of the groups being a master group.

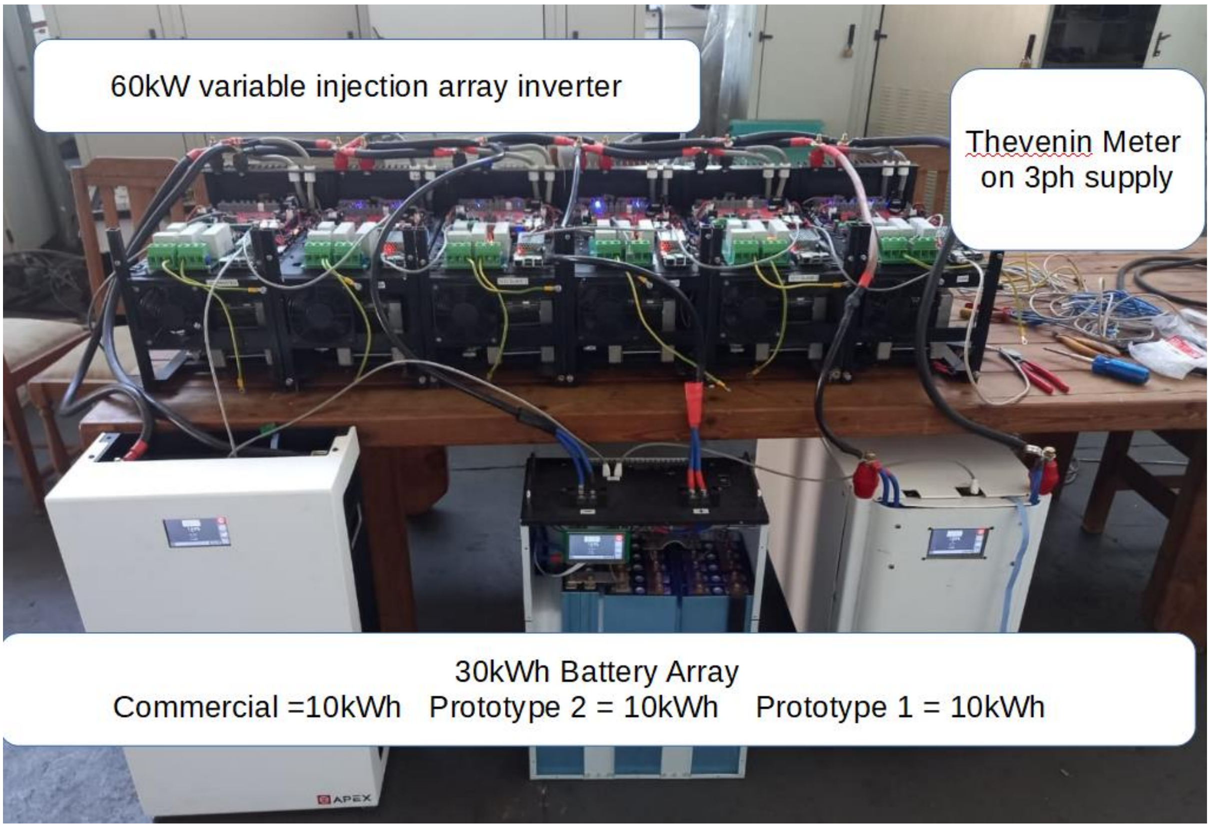
There are 2 communications busses running in parallel to synchronise the groups in phase and current targets. There is a high speed analogue square wave generated by master A1. All invererters use this for phase locking.

The there is a slower CAN based bus giving setpoint data such as phase and current targets to all the slave modules.

The inverter array interacts with the utility grid, the battery array and the load. The master receives information about the network from the thevenin meter and this allows for optimum current targets to be calculated for power from the grid, power to the grid and even power to the load.

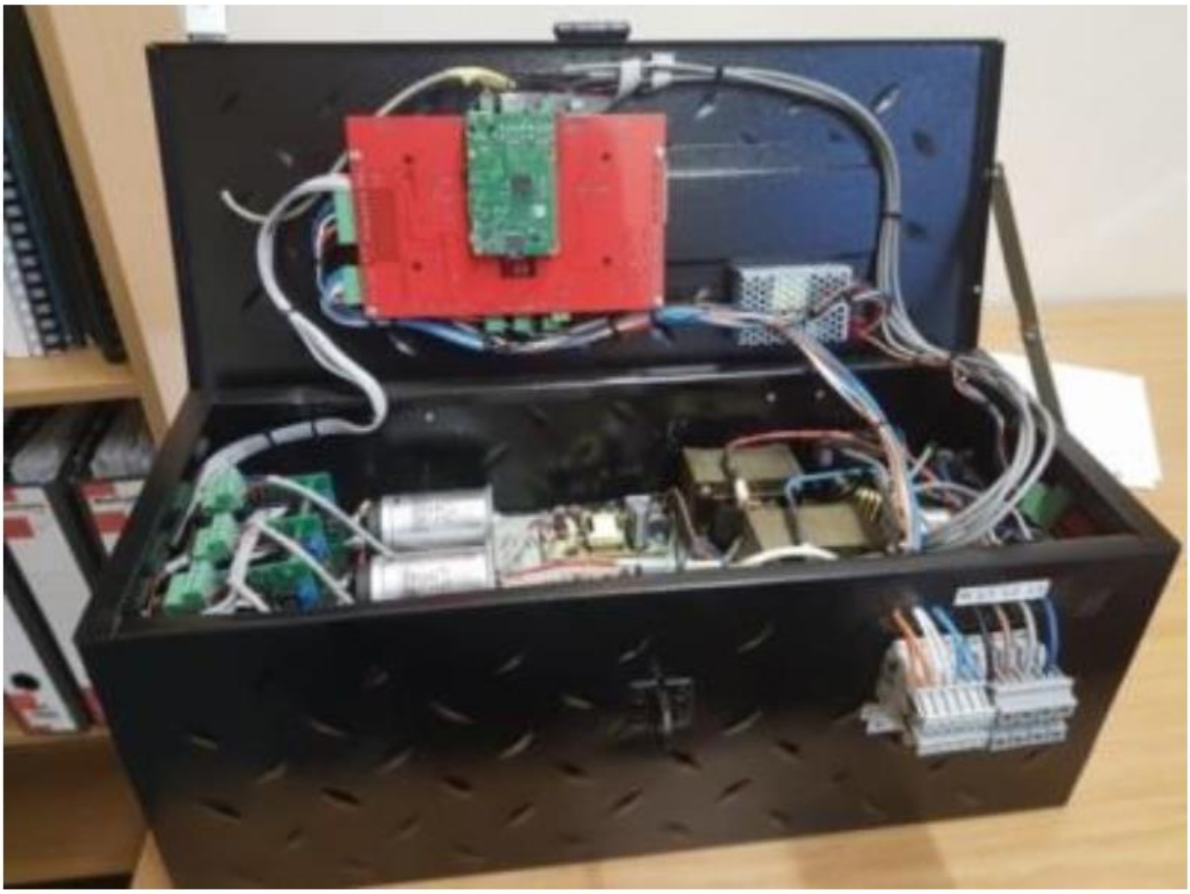
The mathematical method used by the thevenin device to calculate the targets from the thevenin measured impedances is called the GPT method. This was developed by Professor Michel Malengret and Professor Trevor Gaunt at the unvercity of Cape Town.



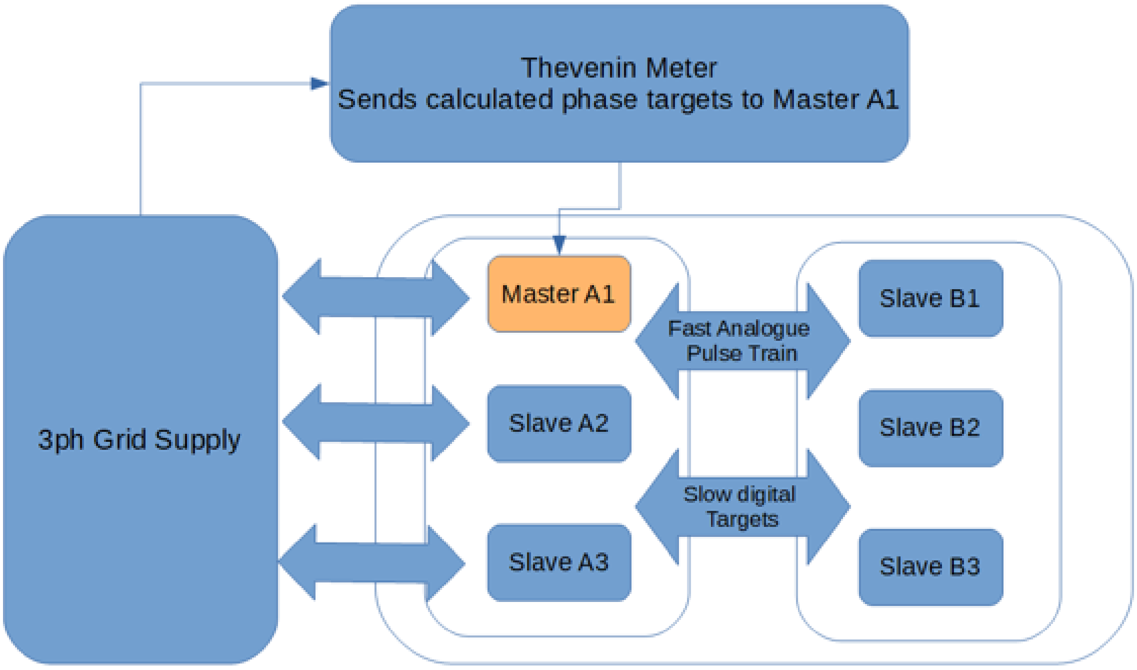

60kW variable injection array inverter
Thevenin Meter on 3ph supply
30kWh Battery Array
Commercial =10kWh Prototype 2 = 10kWh Prototype 1 = 10kWh


60kW array inverter

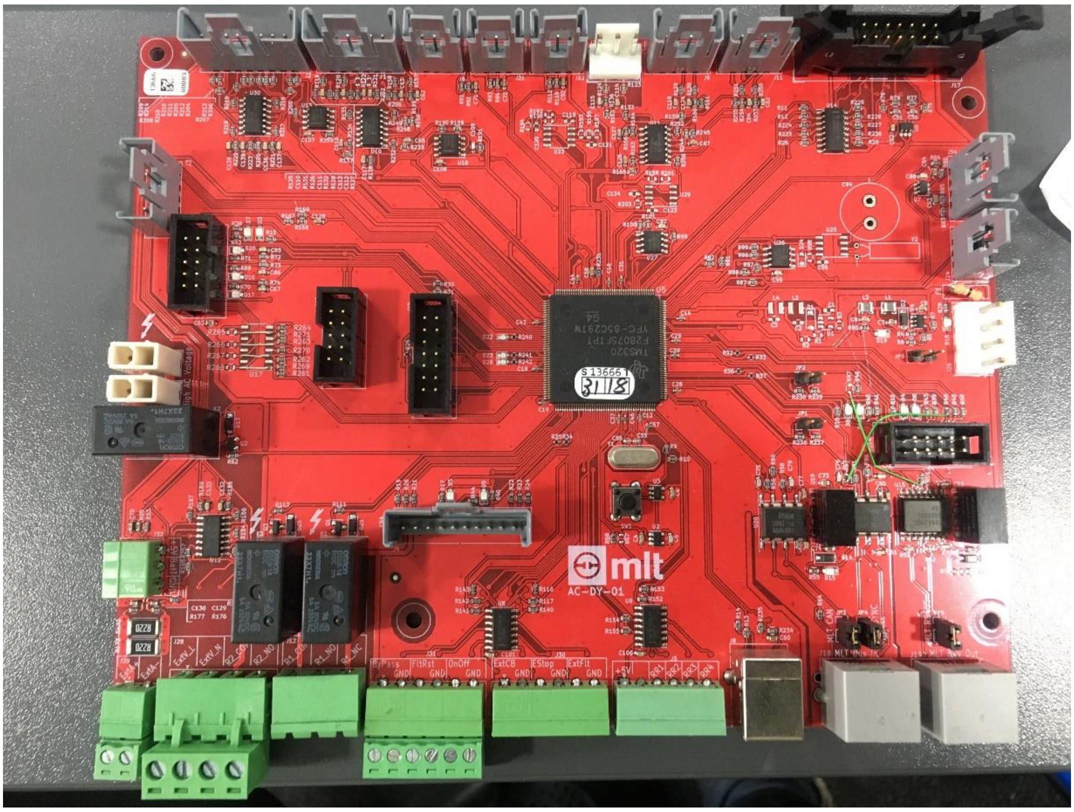
**Milestone 3 – Thevenin Impedance measurement instrument**



Thevenin impedance measurement instrument

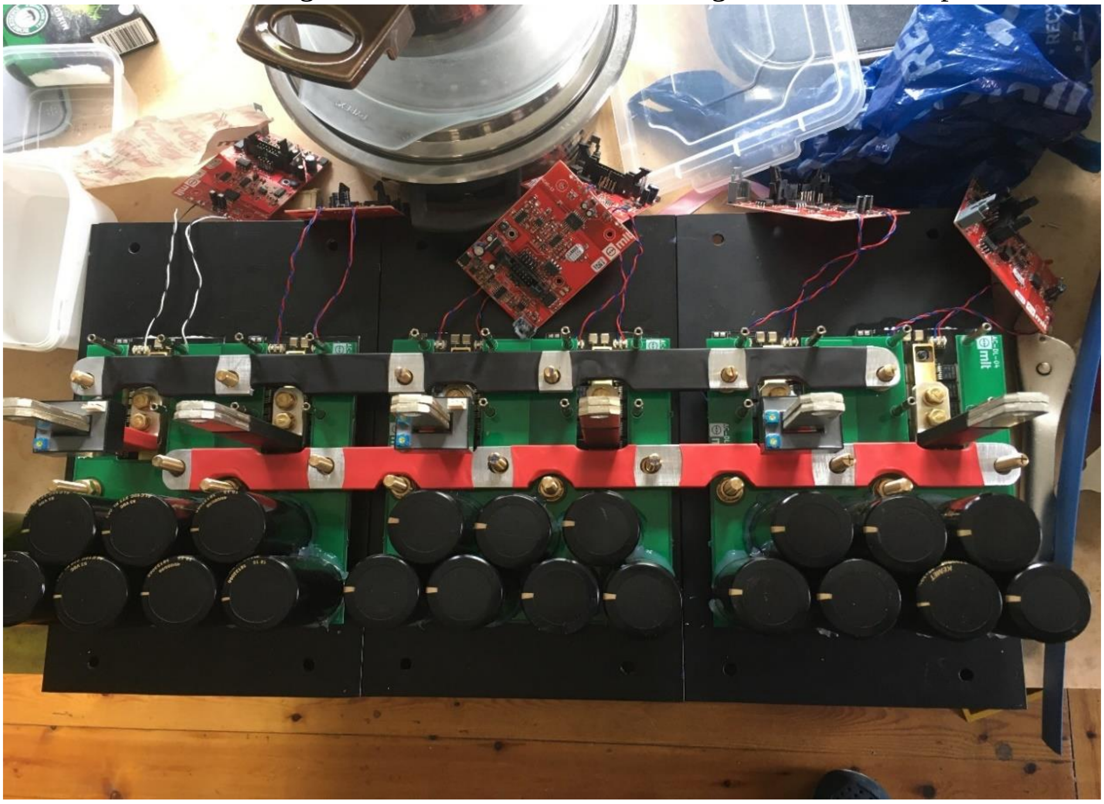


Building the array inverter

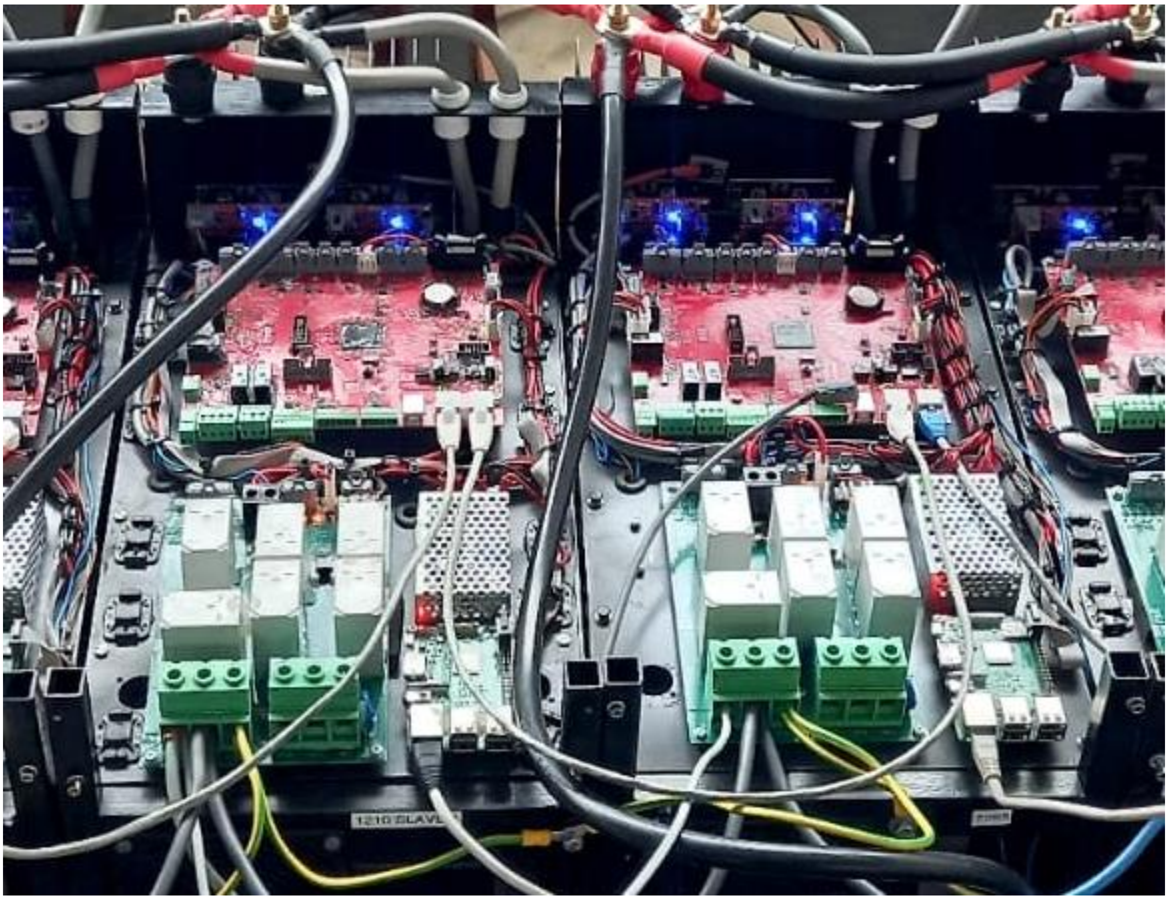



Control card that receives target currents and drives switch gear using TMS320 digital signal processor. DSP card takes care of all the signal processing, synchronising with source voltages, generating the PWM signals to drive the FETs, handle system communications as well as battery CAN comms, drives the HMI and connect the system to the network for remote monitoring and logging.

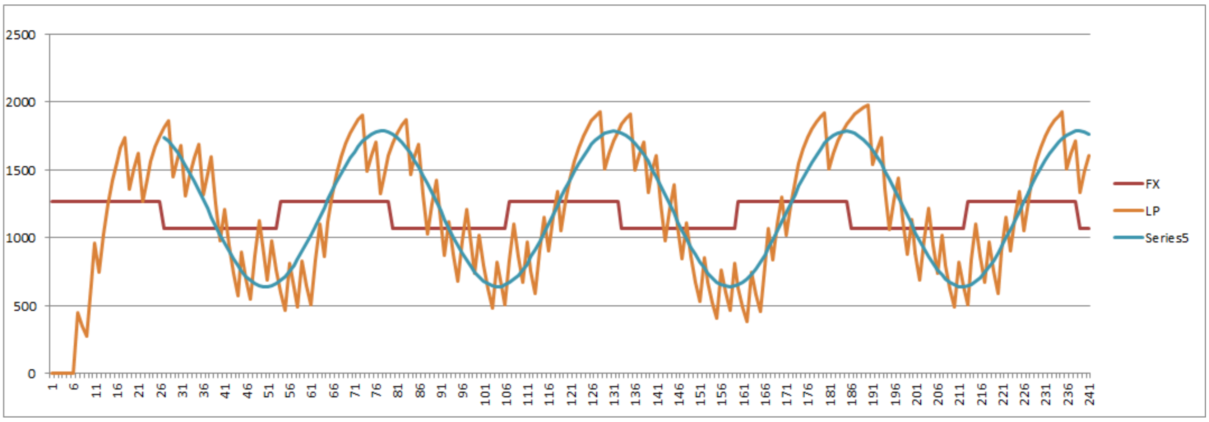
Construction of modular inverter units sharing DC bus . Custom bus bars were milled to connect the modules together, instead of the normal singe set of bus bars per module.



3 modules being assembled using shared DC bus bars. Custom bus bars were milled to connect the modules together.



Synchronisation control of the array inverter




Modules synchronise via 2 control communication bus lines. There is a fast control line that uses pwm with a software phase lock loop in each module to synchronise with the master module.

There is also a slower sync using CAN messages which gives less time critical data such as current targets.

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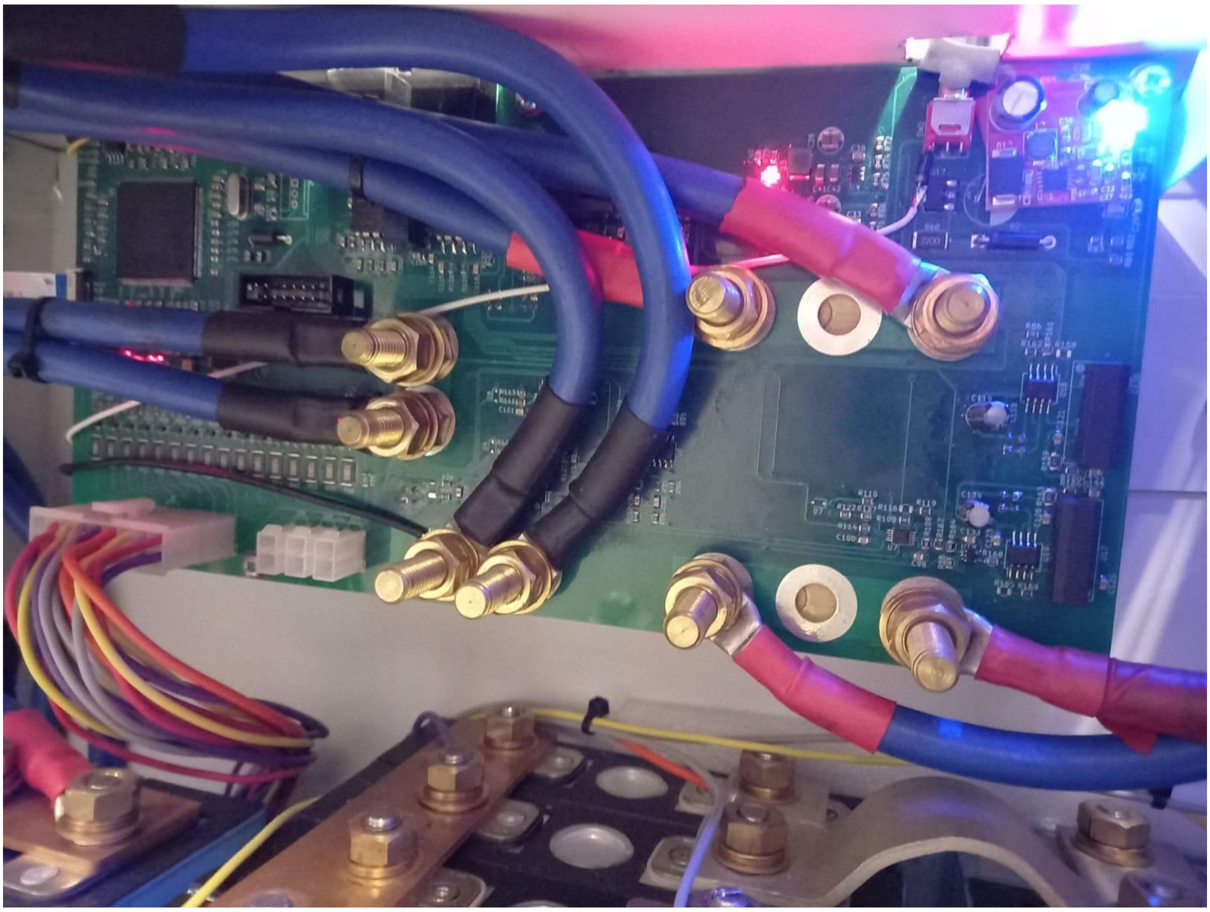
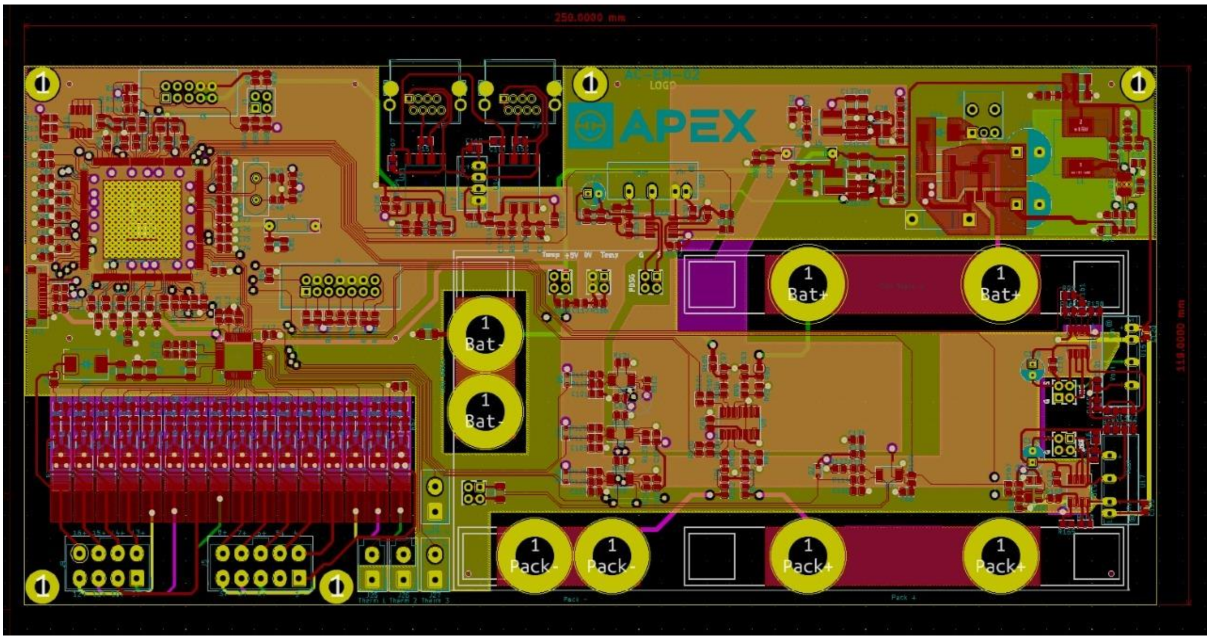
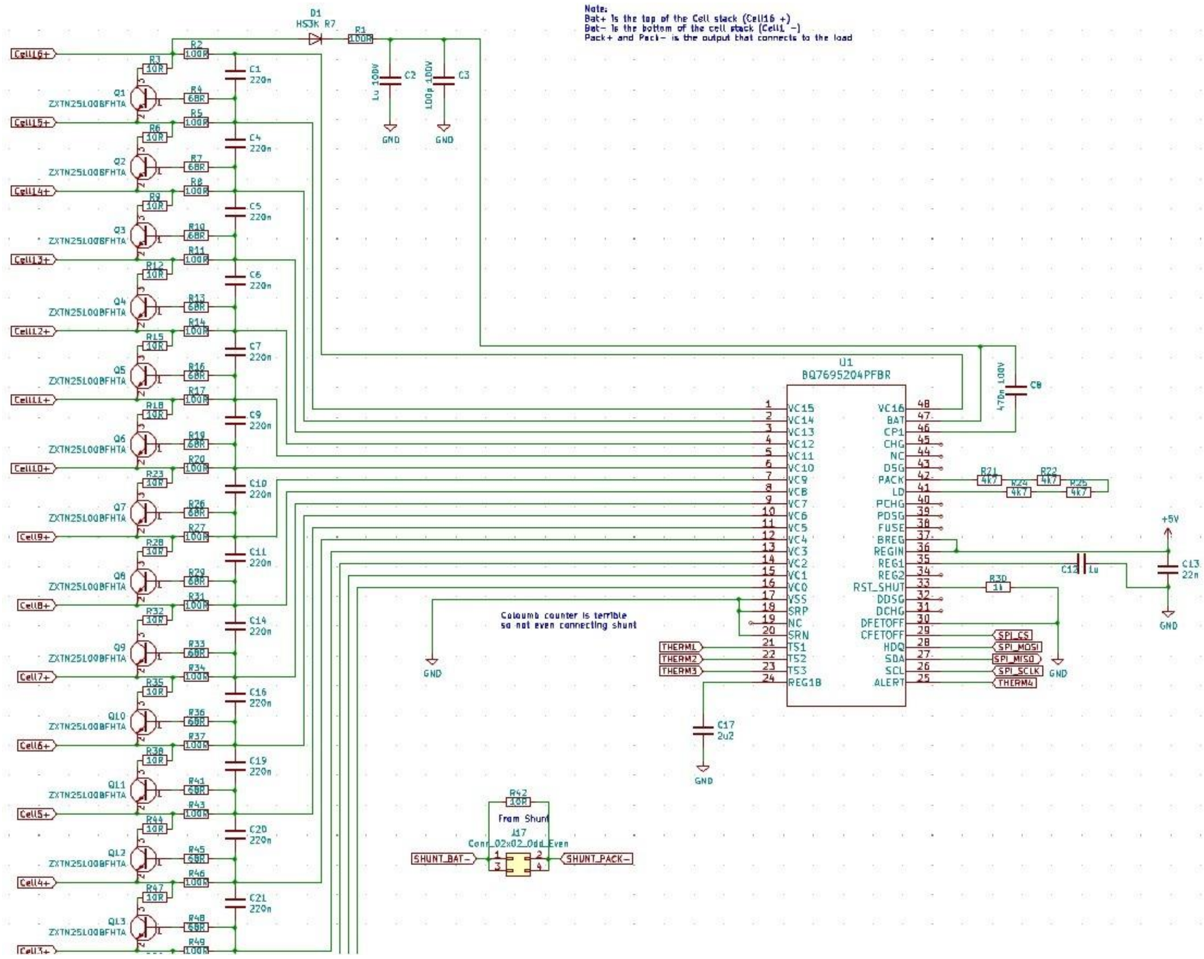
## 10kWh Array Battery Development

We developed an array battery with our own BMS (battery management system) for this project. Under the inverter module array there are 3 batteries making up the battery array. On the right is our first prototype in a makeshift enclosure. In the middle is the first attempt at the commecial form factor and on the left is the final product.|








Schematic behind layout

Prototype 1

Prototype 2

Commercial 10kWh battery with inhnouse built BMS

**Current progress status on milestones**

| Milestone/Deliverable | Estimated Dates | Invoice Claim | Progress |
|---|---|---|---|
| 3. Inception Report | **1st June 2021** | *R 90 000* | *100% complete* |
| 4. Report on Powerstar30 prototype. | **1st July 2021** | | *100% complete* |
| 3. Report on Powerstar30 TRL8. Physical Audit in Cape Town | **1st July 2021** | *R 416 268.75* | *100% complete* |
| 4. Report on 60kVA prototype. | **28th December 2021** | | *100% complete* |
| 5. Report on 60kVA TRL8. Physical Audit in Cape Town | **28th March 2022** | *R 649 801.25* | *100% complete* |
| 6.Report on certification results from TUV lab | **28th May 2022** | | *50% complete* |
| 7. Site test report and Final project report | **28th May 2022** | *R 890 667.75* | *50% complete* |

| Strategic Plan Element | Project Objectives | Progress |
|---|---|---|
| 1. 30kVA inverter | 30kW LV inverter that can Implement injection optimization into a power network. | 100% complete |
| 2. 60kVA inverter | 50kW HV inverter that can Implement injection optimization into a power network | 100% complete |
| 3. Commercial instrument | Implement a standalone instrument that can predict energy savings at a plant before upgrading injection control. | 50% |