Project Report: New solar and general electrical system at Mulanje Mission Hospital

2021-2024

By: Dr. Arie Glas, Medical Director for MMH management team
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Introduction

In 2021, MMH embarked on a project to renovate and reinstall the solar power system and upgrade the general electrical system at the hospital. This had become a priority for several reasons:

- The existing solar system was built with domestic class, low quality inverters and inadequate cabling sizes with poor connections.
- The solar panels already present had exposed, crumbling cabling without adequate connections
- Large parts of the existing solar system including two solar trees were not functional despite being installed less than 3 years ago
- A large hybrid inverter was not functional and in state of disrepair despite having been used less than 6 months when procured
- The hospital faced increasing utility bills and struggled to keep the budget balanced; at the same time prior investments in solar energy did not bring significant cost reductions
- The general electrical system has been evolving over many decades and was not logical, making fault-finding and ensuring safety difficult to achieve, with losses due to excessive resistance on poorly dimensioned and connected cables
- A central distribution board in the hospital was absent making fault finding and management hard.

Hospital management therefore decided to replace the existing solar system with a new system, thereby aiming to reuse as many parts as possible, including lithium-ion batteries, cabling, and existing solar panels. A second aim was to improve on logic distribution and safety of the electrical system.

Preparation

A Scope of work was developed by the medical director and maintenance supervisor in cooperation with the Dutch solar company SolarTeam NL, and with input from several Malawi-based electrical engineers.

The Scope of work was shared with 4 Malawian solar companies, who were all asked to share their best solution within the bandwidth of the scope of work with an aim of contracting out the work to a Malawian firm. Two of these companies did not have the technical know-how to design the necessary improvements, whilst one proposed to discard all existing capital assets, which was not acceptable. The last company was heavily overpriced and not amenable to include a proper warranty period and quality guarantees.

Therefore the hospital decided to work directly with Michael Cocquyt from SolarTeamNL, who provided services on a 100% voluntary. Fundraising was handled by the hospital.

Implementation – Phase 1 (January 2021 – January 2022)

Once a list of materials was prepared, the necessary parts were imported from South Africa (duty-free), and some were bought in the Netherlands.

Installation began in October 2021 when Michael arrived in Malawi. Over a period of ten weeks, the following steps were taken:

1. The existing solar panels were all removed, cleaned, tested, and reinstalled with new cable.
2. 72 extra solar panels, 445 Wh each (total 32kW capacity) were installed on rooftops
3. All solar panels were connected to three new Fronius Symo solar inverters (15kW each).
4. Cabletrays were installed across the hospital to hold solar cable, but also data and phone cable
5. A large central distribution board was designed, built and installed in cooperation with a local electrical company, Fixtech. The board received a direct national grid (Escom) connection.

6. Three dedicated battery inverter/chargers (Victron Quattro, 15kW each) were connected to ten existing lithium-ion batteries.
7. The solar house containing all equipment was renovated by closing doors and windows and installing airconditioning to reduce dust.
8. Software from both Fronius and Victron was installed which allows for remote monitoring of system performance and troubleshooting.

Implementation – Phase 2 (January 2022 – May 2023)

During this phase MMH was supported by two other technicians Jan Pieter van Driel and Gerwin Habermehl, whilst Michael continued to advise from a distance.

9. More materials were procured in South Africa and imported. A large solar array was placed on two sides of Female Ward.
10. The two existing solar trees were cleaned, rewired and voltages were checked. One solar tree had to be decommissioned due to poor quality panels.
11. Three more dedicated battery inverter/chargers (Victron Quattro, 15kW each) were installed and connected to a total of 29 Li-ion batteries that were already at MMH. Five more Fronius Symo solar inverters were installed too.
12. Connections from the new main distribution board to all departments was completed and the sub-distribution board in all departments was checked and upgraded or replaced where needed. The cable trajectories were made robustly with cable tray and underground crossings, and also allow for other utilities such as internet cable, telephone and other wires.
13. A second grid connection via a pre-paid meter was removed.
14. All overhead cables on campus were removed as they now run 3-phase underground
15. Following completion of the installation, many hours were spent tweaking settings of the system. Victron software allows many settings including cycling of batteries at night and recharging during the day. We can also switch of part of the hospitals' supply during conditions of loadshedding, little solar energy and a low battery level by switching off two of the three phases using a contactor (large automatic switch).
16. The entire overhead line to the transformer (over 200m) was replaced as it was very thin and therefore led to large losses and unstable voltages. Transformer connections were upgraded too.
17. Following tropical storm Freddy in March 2023, it was found that at times of loadshedding and little sun, the load on the inverters was at times too high. To circumvent this an extra switch was placed that allows part of the electrical system of hospital to be bypassed whilst maintain critical circuits and preventing overload. The bypassed areas are the laundry department, mortuary and youth centre.
18. A second extra switch now allows the entire solar/backup system to be bypassed by the diesel generator, in case of technical faults and system failure.
19. Both DC and AC overvoltage protection was installed, with an extra voltage monitor+switch before the main board.
20. A smartphone for 24/7 remote monitoring handed over to the Maintenance Supervisor.

Installation of new solar panels on out-patient department

21. The previous system was decommissioned and reinstalled on the Thandizani Agricultural Resource Centre at the hospital.
22. Simultaneously a VoIP (internet protocol) based telephone system was installed too.

Technical details of the system

Fronius/Victron AC-coupled PV using the Victron Energy Storage System (ESS) design.

Component	Brand	Type	No	Detail
Battery inverter/chargers	Victron	Quattro Inverter/Charger 48/15000/200-100/100	6	2 on each phase in 3-phase configuration
Solar inverters	Fronius	Symo 15.0-3-M 15kW	8	2 on Quattro AC-input, 6 on AC-output
Controllers	Victron	Cerbo GX	1	Touchscreen, accessible remotely. Main computer.
	Fronius	Datamanager	1	
Gridmeters	Carlo Gavazzi	EM24	1	To prevent feed-in and optimize solar consumption
Battery monitor	Victron	BMV-712	6	One on each bank of 5 batteries
	Fronius	Smartmeter	1	To prevent feed-in
Solar panels	Longi, JA Solar, REC, Solar World	250-455 kWp	299 no.	Total kWp = 128.340
Solar panel rail and clamps	K2			Aluminium
Connectors	Staubli	MC4 connectors		On 6mm DC cable
Voltage protection	AC: Schneider DC: Fronius	Type I/II SPDs Built-in	1 1	3 phase In each Fronius Symo
Batteries	Leoch	100Ah LiFePO	28	Already present
Contactors	1. Himel	330A	1	To switch off 2 of 3 phases
	2. Schneider	265A, with AC/DC voltage window controller on grid input	1	Before main switch
Airconditioning		12 BTU and 24 BTU	2	To keep dust-free and at 20 degrees C

Partners

In this project we worked together with the donors as listed below under income and expenditure. We also benefitted from the advice and resources of SolarTeam NL and SunDriven from the Netherlands, Krannich Solar (South Africa) and Cedar Energy Ltd. and Mulanje Hydro Ltd, both from Mulanje. Fixtech Contracting and Powered by Nature provided support from Blantyre.

Income and Expenditure

Below is the summary I&E report in Euro. Please note that due to transactions in multiple currencies, some unstable over the projectperiod, exact figures in the original currency may slightly differ.

Donations	€	Expenditure	€
EMMS International (UK)	104.997	New solar panels and 14 new inverters	106.786
Action Renewables (UK)	28.673	3-phase electrical cable to each department	53.984
Exchange gains (MW)	18.000	New overheadline transformer-main board	11.843
Flow Traders Foundation (NL)	15.000	Central distribution board	10.591
The Belvedere Trust (UK)	9.756	Solar room upgrade, airconditioning	6.396
Ansbach fuer Malawi (DE)	7.500	Upgrade existing solarpanels	3.444
C. and S. Kennedy (Ireland)	6.000	Spare parts to keep on stock	3.000

Stichting Steun Malawi (NL)	4.738	Electrical sub-boards in departments	2.571
Individual donations (various)	3.641	Inverter repairs	1.531
MMH own funds (MW)	2.984	Transport and travel	1.315
SunDriven (NL)	1.000	Lightning protection	907
Tom Solar (NL)	1.000	Diesel for generator, miscellaneous	821
		Balance in account	100
Total	**€ 203.289**		**€ 203.289**

Outcomes

Patient safety - The hospital has a high quality emergency power system, able *to* manage critical loads (such as power for oxygen to sick patients), but also to keep other loads going in case of grid failure. This increases quality of care and productivity.

Electrical safety - The system provides an uninterrupted power supply function with filtering of bad voltages so that electrical equipment and computers will last longer.
Since the removal of overhead lines and installation of overvoltage protection, not a single lightning strike has caused damage. This was previously quite common during the rainy season.

Financial savings - Solar power is being generated and consumed directly, reducing the utility bills. During April, 2023 total consumption was 15154 kWh, which came from the grid - 7295 kWh - and solar – 9609 kWh. This means that 63% of all electricity consumed was generated by solar. From 1 January until 31st May, 51% of all consumption was solar. This represents a saving of about 800 Euro per month on the electricity bill, with an additional 200 Euro for diesel for the generator.

Less ecological damage – less conventionally generated electricity used means lower CO2 emissions, less noise and air pollution, more is available nationally for Malawian households to be connected to the grid, and a working example of what can be achieved in a challenging setting.

A real-time view of the system can be had here: http://www.mmh.mw/solar-electricity-system-realtime/

Challenges

Grid-feed in - A major challenge to a system like this is that feed-in to the grid is not allowed in Malawi. This leads to more complex system design (with grid-meters) and loss of efficiency as the solar inverters are shut down in case the batteries are full and solar production is higher than consumption. For optimum use of solar inverters many highly expensive batteries are needed.
Grid supply - The extremely poor quality of electricity supply is a challenge too. Not only are there frequent black-outs, but also when power is available it cannot always be accepted by the inverters due to under- or overvoltage, phase rotation problems and frequencies exceeding safe limits. This is especially a problem during the rainy season, though it seems to have improved after upgrading our transformer connection.
Low standards - Previous solar and other electrical connections done at MMH were of poor quality, reflecting the generally poor standards of electrical work in the country. Even when doing new work with with qualified electricians this needed frequent correction.
Logistics - It was a logistical puzzle to get all parts into Malawi in time, especially as not all funding was secured from the start of the project. Basic electrical parts, cables, and pieces of equipment are extremely hard to find locally, most must come from abroad. It proved challenging to get the distribution board up to the required standard.

Recommendations

To donors interested in solar - demand inclusion of maintenance contracts of at least five years when commissioning contracts to suppliers, and invest in independent, adequate technical knowledge and supervision so that installations are done with acceptable quality materials and workmanship.
To Malawi government - start allowing feed-in to the grid to make solar energy more economically feasible and reduce demand on Escom.

To other hospitals with interest in solar - plan carefully what the aim of solar investments would be. (Emergency supply only or also cost-savings). This decision needs to be made at the start of system design. Careful consumption readings are essential to dimension the system adequately.

It is worth considering the use of DC MPPT chargers instead of some of the solar AC inverters, as this requires less AC-DC conversion.

Maintenance plan

Spare parts for the next five years such as fuses and breakers are on stock.
The maintenance team has access to remote information via a smartphone and follows a strict cleaning and checking schedule for the panels and equipment. Support is available from Krannich in South Africa, the supplier, and we are working on a maintenance contract with a Malawi-based solar company. A contribution for maintenance for the next two years has been committed by Action Renewables and savings from electricity bills can be used too.
It will be important to follow the logic of the current set-up when adding new departments and users of electricity at the hospital.

Future plans

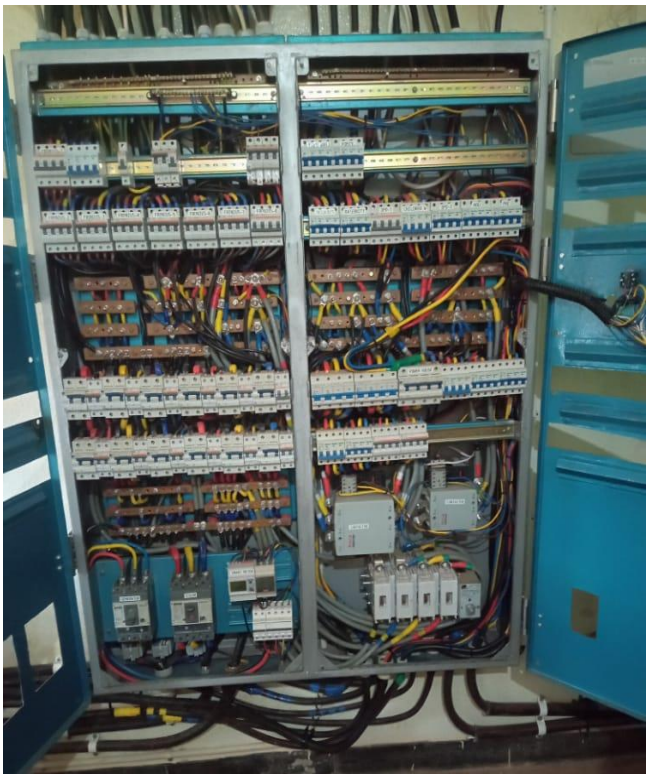
We would like to invest in 17 more Li-ion batteries, to bring the total capacity to 45 batteries (4500 Ah). With this expansion we expect to reach >80% independence from the grid. It will allow for more efficient use of the already installed solar panels, further lower utility bills, virtually eliminate the cost of diesel and offer greater stability of the system. The investment required is €34.000 and this can be implemented as soon as funds have been identified.

Conclusion

It is possible to make an investment in solar energy for an African mission hospital work. At MMH this required considerable time, intensive senior staff involvement, technically competent advisors and volunteers and significant fundraising efforts but can then bring great benefits.

MMH management and staff would like to thank all our partners for their generous donations which have made the installation of this great electrical system possible, and will benefit patients in Mulanje and beyond for many years to come.

Pictures on following pages



New main distribution board under construction

Maintenance team working on underground cable conduits

Michael Cocquyt working on new main board

Transformer connection upgrade

Vocational skills trainees in MMH Teenage pregnancy prevention programme working on solar arrays

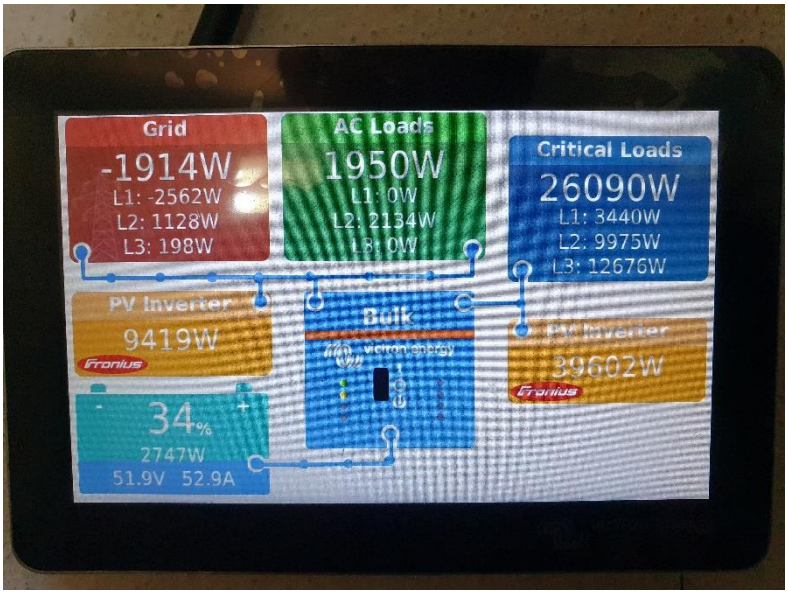
New, thick overhead line installation (over 200m)

Laying underground cable to wards

Solar panel connection on female ward

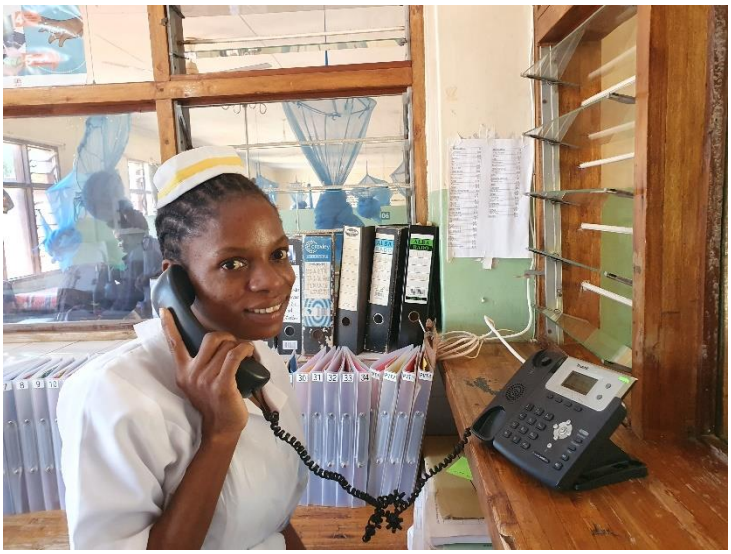
Victron Quattro battery inverter/charger

Fronius Symo solar inverter



Cerbo GX controller with touchscreen (also accessible remotely)

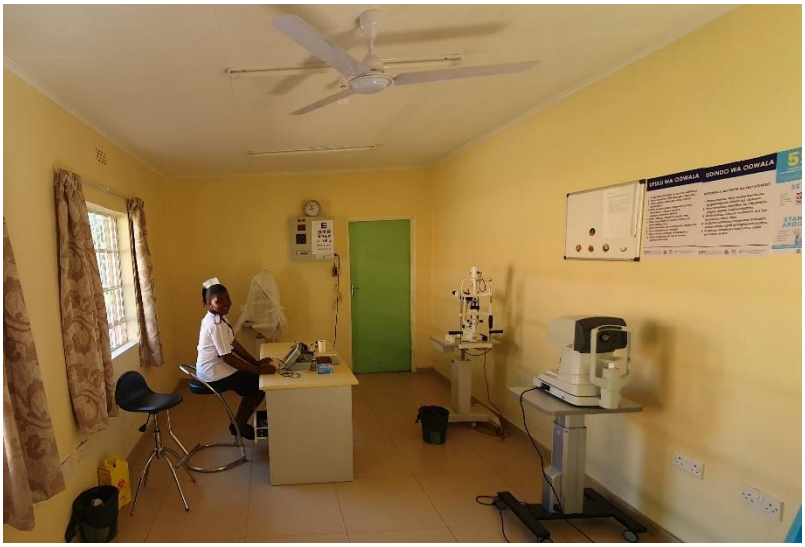
Solar room with inverters and batteries



Nurse using new phones

Cable trays safely holding solar cable, power cable, internet, telephone etc across campus

Solar panel arrays in North and East/West direction for energy during all day hours



Sensitive ophtalmology equipment now on safe electricity supply

Mulanje Mission Hospital
May 2023

Update 31-01-2024

Introduction

In 2023, it was decided that MMH would benefit from further upgrading of the energy storage capability. More lithium-ion batteries would result in increased cost-savings (more PV generated energy can be used at night) and even less consumption of diesel for the generator.

Methods

Through Averge Technologies (Durban, South Africa) compatible Li-ion 100Ah batteries were procured. This brought the total no. of batteries to 45 (4500Ah capacity for the total bank) – one was used to replace an existing battery. A duty waiver was granted.

A representative of Sundriven (NL) volunteered his time and travelled to MMH to do the installation. Three more metal batterybanks were locally procured. The additional list of materials included:

Component	Brand	Type	No	Detail
Battery monitor	Victron	BMV-712	3	One on each bank of 5 batteries
Batteries	Leoch	100Ah LiFePO	17	
Battery racks and fuses	Locally		3	One for each bank of 5 batteries

Once installation was completed, the batteries were remotely configured through a Teamviewer session with a representative from Averge. Installation took one week to complete, after which configuration and finalizing was done by MMH staff.

Results

The battery chargers are now able to run on their full capacity (1200A charge current now versus 580A initially) which has optimized return on the initial investment in inverter/chargers. This will allow for better use of available PV generating capacity to charge batteries.
The batteries have shown to be compatible: and equal amount of energy is charged/discharged across the now 9 battery banks. This addition has boosted the capacity of the battery bank to the extent that on clear, sunny days MMH can run on up to 90% solar generated energy. We do not have savings estimates yet as the system has only been running for a few weeks in the current configuration.

Donations	€	Expenditure	€
EMMS International (UK)	23.590	Batteries	18,801
		Battery racks	428
		Travel	1253
		Small installation items	3108
Total	**€ 23.590**		**€ 23.590**
XC £1 = €1,17			

Conclusion

An additional investment of almost € 23,590 has allowed MMH to make further savings on electricity bills and diesel. Volunteer technical support was crucial to achieve this. The modular approach to the design has now paid off well. We can provide a financial update once the system has run another year (after 31.01.2025).

45 Lithium-ion batteries, across 9 banks in the power house at MMH

Mulanje Mission Hospital
January 2024