Shiyala Village Solar Electrification Project: 2014 Upgrade

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30 August - 10 September 2014

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1 Introduction

In September 2014, a team from Cardiff School of Engineering visited Zambia to upgrade the solar power supply in Shiyala Village, Chongwe District. The team was composed of Dr Dan Rogers and Mr Lee Thomas, both staff members within the School, and Mr Chris Corkill, Mr Gwilym Jones, Mr Rhys Roberts, Mr Alex Stubbs, and Mr Kieron Tarrant, all undergraduate students of Engineering at Cardiff University.

The original solar power supply was designed and installed in 2012 by Dr Dan Rogers and Mr Lee Thomas, with the purpose of supplying electricity to a computer classroom. This was done in partnership with the charity Mothers of Africa, who aim to improve maternal and infant mortality rates in Sub-Saharan Africa through medical education, in line with the UN Millennium Development Goals.

In 2013, the electrical provision was extended to provide 230 volt AC power to the surrounding buildings in Shiyala, including the Health Post, the house of the local Nurse, and the ABESU (Women's Housing Co-operative) admin building. The work was carried out by Dr Dan Rogers and Mr Jon Stevens, a PhD student in the Institute of Energy.

'Blackouts' were reported in early 2014 by Ms Stella Phiri, the ABESU Housing Coordinator. A visit in April 2014 by Mr Jon Stevens and Mr Gwilym Jones confirmed that these had been occurring due to an imbalance between the amount of electricity generated by the solar panels, and the energy demand from lights and sockets. This led to the design of a larger power system, and its installation in September 2014 (again in partnership with Mothers of Africa) is the subject of this report. The key features of the upgrade are the 12 polycrystalline solar modules of 280 Watts peak each, and the 8 deep-cycle lead-acid batteries of 220Ah each. The panels have been mounted on an aluminium frame, which sits on a concrete plinth to the North of the ABESU admin building.

2 Objectives of September 2014 visit

The key objectives for the visit were to:

- replace the original solar array and battery bank with a larger solar array and a larger battery bank
- extend the provision of security lighting around the Shiyala centre
- educate and inform the Shiyala community about the solar power supply
- inspect and update the computers in the classroom
- scope out the community school for potential work in the future

3 Electrical work

From the data obtained during the April 2014 trip it was concluded that the daily load on the system was approaching approximately 10 kWh. It was evident that the existing 1.2 kWp solar panels were not capable of charging the batteries sufficiently during the rainy season. The data also indicated that the batteries (total 10.56 kWh storage) were frequently being heavily discharged. The findings of the April trip suggested that a significant increase in panel output and battery storage was required.

Previous phases of the project had seen significant investment in power conversion equipment, namely the DC/AC Inverter, DC/DC Converter and Maximum Power Point Tracker (MPPT). This equipment was still in good working order and had available capacity to handle a higher power system than that already in place. To avoid unnecessary expenditure it was decided that the system upgrade would not include the replacement of this equipment and thus the new panels and batteries would need to be compatible with the existing system.

The solar power equipment brand, Victron Energy, had been used in a previous phase of the project. It was deemed by the design team to be a trusted manufacturer and one that was stocked by SunTech in Lusaka. As a result it was decided that the batteries and solar panels would be sourced from their product range and bought from SunTech. The equipment required for the general 230V lighting/power was obtained from Edmundson Electrical and Screwfix.

The previous batteries and panels were decommissioned and left in storage in Shiyala.

3.1 Solar panels

It was decided that the lower-efficiency, flexible amorphous panels would be completely replaced with rigid poly-crystalline panels. Victron's largest type of panel, rated at 280Wp (model number SPP28024), was selected for the upgrade. The new array is positioned around 40m away from the battery room, with the output power transferred via an underground cable. To reduce losses, the array voltage has been set higher than that of the previous system. The MPPT is at its most efficient (∼99%) when the input to it is at 48V. However the MPPT is capable of handling an input open circuit voltage up to 150V with efficiency reduced to around 97.5%. It was calculated that the losses from a higher-voltage, lower-current system would be considerably lower than the loss of power due to lower MPPT efficiency. It was concluded that each string would comprise three panels connected in series to produce a maximum power voltage of 108Vmpp. A problem faced during installation was that SunTech specified the wrong connection type for the interconnection of the panels, meaning the panel interconnecting solar cable had to be soldered together and insulated with tape at the joints.

The TriStar MPPT (rated at 3.2kW) was underused in the previous system. It was agreed that the MPPT should be operated nearer its maximum rating to fully utilise its potential. Fortunately this amount of power (approximately 2.7x that of the existing system) is expected to be sufficient to charge the batteries throughout the entire year. It was decided that the array should be slightly oversized to allow for losses and poor solar irradiance during cloudy days and the rainy season.

The array is configured as 4 parallel strings of 3 series panels and produces a peak output of 3.4kW. Each string is protected with a double pole 10A MCB which also acts as a means of isolating individual faulty strings. In the event of a single string being damaged, it can be switched out leaving the remaining healthy strings in operation. To save time and avoid any potential problems the 'combiner box' which houses the MCBs and electrical connections, see Figure 1, was pre-built in a weatherproof enclosure before departing to Zambia. The combiner box was mounted on the panel frame assembly. As part of the preparation process, an electrical schematic was produced for the solar power supply which can be found in Appendix A.

The power from the panels is transferred to the MPPT in the battery room via an underground Steel Wire Armoured (SWA) cable. In previous phases of the project it was found that larger gauge SWA cable was difficult to work with and so it was agreed that it would be more convenient to work with a smaller gauge multicore cable. A 4 core 6 mm^2 SWA, PVC insulated cable was chosen for the task using 2 cores for positive and the other two for negative. A 600 mm deep trench was dug from the panel base to the corner of the classroom building, and the cable was laid in this trench along with warning tape. The frame was bonded to the underground cable armour which in turn was bonded to the system earth. No additional earth rod was installed at the panel location.

The system was left in working order with limited data on performance figures obtained in the remaining days before departing from Shiyala Village. It was observed that the array was producing up to 3.4kW at times, indicating that the system worked to the design specification.

3.2 Batteries

Several potential solutions were considered for the battery storage method including long life flooded tubular plate, lithium and VRLA AGM batteries. It was concluded that 220 Ah, Deep Cycle AGM Batteries (Victron model number BAT412201080) would provide the most economical and maintenance free solution. The existing system voltage was 48V and therefore restricted the battery configuration to banks of four in series. Two such banks were connected in parallel to provide 21.12kWh of storage, effectively doubling that of the previous system. To accommodate the additional batteries the existing plinth was extended by local builders on the day of arrival. The existing schematics remain unchanged as the system was not modified beyond the rotary isolator located in the battery room.

Figure 1: Inside the solar combiner box

Figure 2: Members of the community digging the trench for the underground cable

Figure 3: Eight new batteries in the battery room

3.3 Additional electrical work

In addition to the solar power system, the following were also installed at Shiyala Village:

- 15 x 10W LED Security Lights with PIR and daylight sensors (ontimes ranging from 5 seconds to 6 minutes) installed with switches on every exterior side of all buildings, except for the rear of the Medical Post. The lighting on the front of the Medical Post and rear of ABESU building were set to be permanently on during the night.
- Emergency Light in Maternity Ward giving 3 hour battery backup lighting with two directional lamps, operating as follows:
  - Switch ON + Power Supply ON $\longrightarrow$ Light ON
  - Switch OFF + Power Supply ON $\longrightarrow$ Light OFF
  - Switch ON + Power Supply OFF $\longrightarrow$ Light ON
  - Switch OFF + Power Supply OFF $\longrightarrow$ Light OFF
- Emergency Light in Observation Room giving 3 hour battery backup fixed lighting, operating as above, except with Light ON when Switch OFF, Power Supply OFF.
- 1 additional double socket in IT room
- 1 additional double socket in classroom

Figure 4: Mr Corkill installing one of the new external lights

4 Teaching

4.1 Lessons

Before the trip a lesson plan was set up and sent to Ms Stella Phiri, she made adjustments to the plan to fit with the community. The first lesson was run with head women from each tribe forming the ABESU board, this was the only lesson that required a translator. There were local teachers that were there and ready to help translate. The rest of the people who attended lessons spoke a good level of English.

The computer lesson plans were too complex to start, only one of the teachers had used spreadsheets before, some were not able to turn off the computers. So the first couple of lessons focused on getting them comfortable and ready to use the basics of spreadsheets and word-processing on the computers.

By the end of the trip the students were competent enough with the spreadsheets to open a spreadsheet, set up basic records, change colours, create graphs and use the maths functions.

Ms Janice Newport, a professional language teacher, was training the teachers and had brought some books for the teachers to use to help teach the children how to read. One teacher, Elizabeth, had used spreadsheets before so she was taught separately how to make a reading list on the spreadsheet so that they could keep track of the what books each student has read. Ms Newport also helped with the computer lessons, and made the process easier by providing advice and support. The teachers and the other members of the community were very eager to learn and they picked up on everything they were shown very fast.

Things to note that could be improved on if attempted again would be contact with the larger group before the trip to organize a timetable that works around them as well. There was a lot of activities for the teachers and the community to be involved with other than the lessons, so it would be better if there was no conflict of time between both to maximize the amount of time available.

Figure 5: A spreadsheet demonstration

4.2 Educational games

The games package 'GCompris' was installed on the two new machines before they went out and then installed on the rest within the first two days. Throughout the time in the village the children were encouraged to play the games, After a couple of days the children were comfortable playing the games by themselves and helping each other set up the games and complete levels. Many of the people struggled to use a keyboard and mouse, the game package includes a lot of games that will help with these skills. There was noticeable improvement after very short periods of time with the ability to use the keyboard and mouse. The games package also includes many other games that can be used to improve other skills such as counting and basic maths etc. For future projects it is worth trying to find other educational games that can compliment the current package.

4.3 Troubleshooting folder

On the first day Ms Stella Phiri was given a new up to date troubleshooting folder. She found the old one useful so the new one should be beneficial, there is more material and it has been laid out better than the previous folder.

Figure 6: Children learning how to use the computers and discovering the educational games

4.4 Usage board

Before the trip a plan to create a usage board with Kalinosi, a local artist, was set up. The usage board would have been used by Stella and the teachers to tell people that they should only use certain items at certain times dependent on weather and time of day.

After being at the village it didn't seem necessary as it was all well maintained and there wasn't much usage by people other than the computers and some phones being charged.

4.5 School documents

It became apparent, during the trip, that the teachers would benefit from learning how to use the computers to create registers and student profiles, and store exam results. This could help them get funding in the future. A simple version was created on Libra Office Database to store registers and keep student profiles, there is room for improvement with these as they were made in a very short time.

The school documents database can be made more functional by the next trip. At present there are two separate systems for student profiles and registers but there is no system for storing the exam results, by the next trip the three databases will have to be made to so that they are all combined in one database.

5 Concrete foundation for supporting solar panels

5.1 Design brief

The purpose of the foundation was to anchor the frame and prevent movement of its components to allow the solar panels to remain in place as a permanent installation. Initially the design for the foundation was conceived so that the slab would be as small as possible, reducing the resources required and allowing ease of construction in Zambia by the team.

To anchor the frame suitably it was the mass of the slab that was the major design criteria, not the compressive capability of the concrete as would normally be the case. The frame had already been designed and so the compressive action of the assembly were known, a wind action of 100mph was applied to the frame and this provided the uplift force that the slab was required to counteract. This initially led to a minimalist design that is shown in Figure 7.

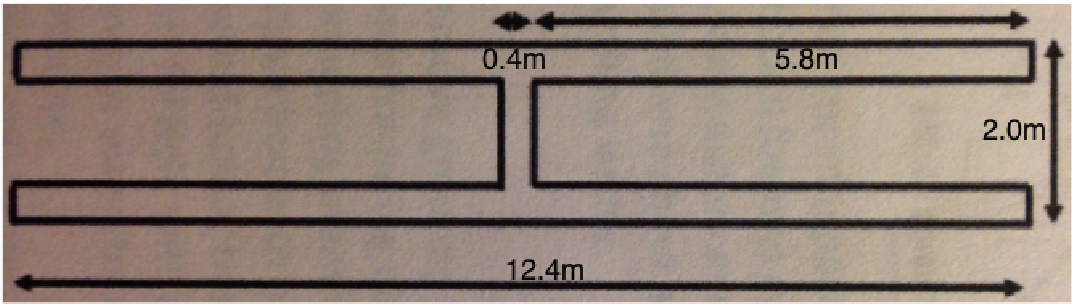


Figure 7: Initial slab design

However, upon finalisation of the teams duration on site and the realization of how many other tasks had to be done it was decided that members of the Shiyala community would complete the slab ahead of our arrival on site. This change in plan altered the design and brought about the final design.

5.2 Final design

Since the team would no longer be able to oversee or facilitate the construction of the slab in Zambia, the design was changed to make it simpler for the community to construct, the final design is shown in Figure 8.

Although the final design required more concrete than the initial design, being a simple cuboid meant it was easy to construct and the likelihood of the final slab not being what was required due to miscommunication or misunderstanding by either the team or the local community was greatly reduced.

5.3 Expectation

The team was particularly concerned that the surface finish of the slab would prevent location of the frame uprights so that they would be vertical. Therefore, it was highly stressed to the people building it that the surface needed to be smooth and level in all directions. All the same, a plan of mitigation was formed which meant that should the surface not be adequate upon the teams arrival to site, chisels would be used to scabble the affected areas and potentially mortar would be used to cap the area, thus providing a localised smooth, level area where an upright could be fixed.

The strength of the slab and the quality of the concrete were not raised as an issue prior to travel out to site as the team was aware that people in Shiyala construct houses, classrooms, health posts, etc themselves and on previous trips these had been seen to be of high enough quality that no concerns were raised.

5.4 Outcome

Upon initial inspection, the slab, shown in Figure 9, seemed to meet the design requirements. However, concerns were quickly raised about the construction technique when the first bolt-hole for the uprights was drilled.

It was found that the slab had a soft capping of mortar approximately 50mm thick above the remaining depth of slab containing concrete which was made up of very large aggregate. The aggregate used was found to be made

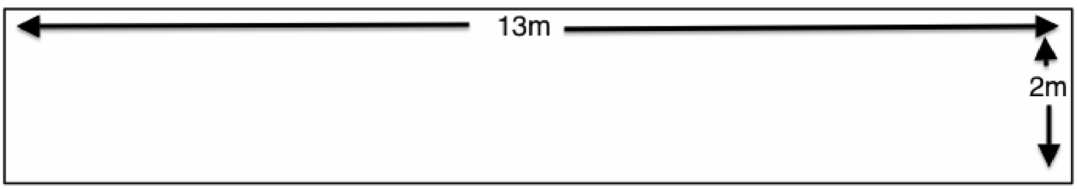


Figure 8: Final slab design

Figure 9: Overview photo of the slab

up of mainly broken up hand made clay bricks and quartz-based rocks. Usually concrete would be made up of 4 constituent parts which are; water, fine aggregate (sands), coarse aggregates (of varying diameter) and cement. Having coarse aggregates that can be compacted creating voids between them, which can be filled with a mixture of cement, and fines is what gives concrete its strength. Therefore, the mortar capping, containing only water, cement and fines, was indeed very soft and the below concrete, containing only very large aggregate, cement and water, relied on the strength of the aggregate and not the concrete as a whole. As discussed in Section 6.3, this resulted in the bolts the team had taken out to site failing to anchor the uprights effectively as the concrete was to weak to prevent pulling out of the bolts.

Should a concrete structure be required for future projects, the main purpose of the structure should be carefully assessed and compared to the knowledge and expertise of the construction team. The workers that constructed the slab created an adequate foundation like any other foundation in the area, primarily to be used to prevent the above structure sinking into the softer soil below. The purpose of the solar slab in preventing uplift and therefore, the construction techniques required, were unfamiliar to the workers and could not have been expected to be exactly what was required. However, through the sourcing of larger bolts, as discussed in the following section, the problem of the slab being too weak to prevent the pull out of the bolts was prevented.

6 Aluminium frame for solar panels

6.1 Design brief

As mentioned previously, the system upgrade was to include the installation of 12 polycrystalline solar panels. The existing solar panel array had been mounted upon the roof of the IT classroom, however it was decided that the new array would be best mounted upon a self-supporting frame. This decision was taken mainly due to safety considerations, the higher weight of the new panels and the higher energy yield that could be achieved by positioning the panels in their optimum orientation.

The frame was designed to achieve the following criteria:

- Adequate support for 12 solar panels, each with dimensions of 1956 x 992 x 50 mm and a mass of 24 kg.
- A panel angle of 12° from horizontal.
- Resistance to dust and rain water.
- Ease of transportation on a pallet measuring 1.2 x 1.0 x 1.6 m.
- Ease of assembly.

6.2 Final design

The final design of the frame is illustrated in Figure 10. Items 02, 03, and 04 were manufactured from lengths of stock aluminium cross sections, all of which needed to be shorter than the maximum 1.6 m dimension of the pallet. These items were manufactured by Cross Water Jet Services Ltd, based just outside of Swansea. Items 05 and 06 are both standard parts which are manufactured by Schletter and were supplied by Swithenbanks. These parts provided a simple and secure method of attaching each solar panel to the frame. Each item was assembled to the frame using either M8 or M10 nuts, bolts and washers. The assembled frame was to be fixed onto a pre-laid concrete slab using 26 x 10 mm through bolts, item 07, one for each leg of the frame. Attaching the tensioning cables, item 08, was to be the last step in the assembly. The cables were included in the design in order to increase the frame's stiffness, reducing any potential swaying under load.

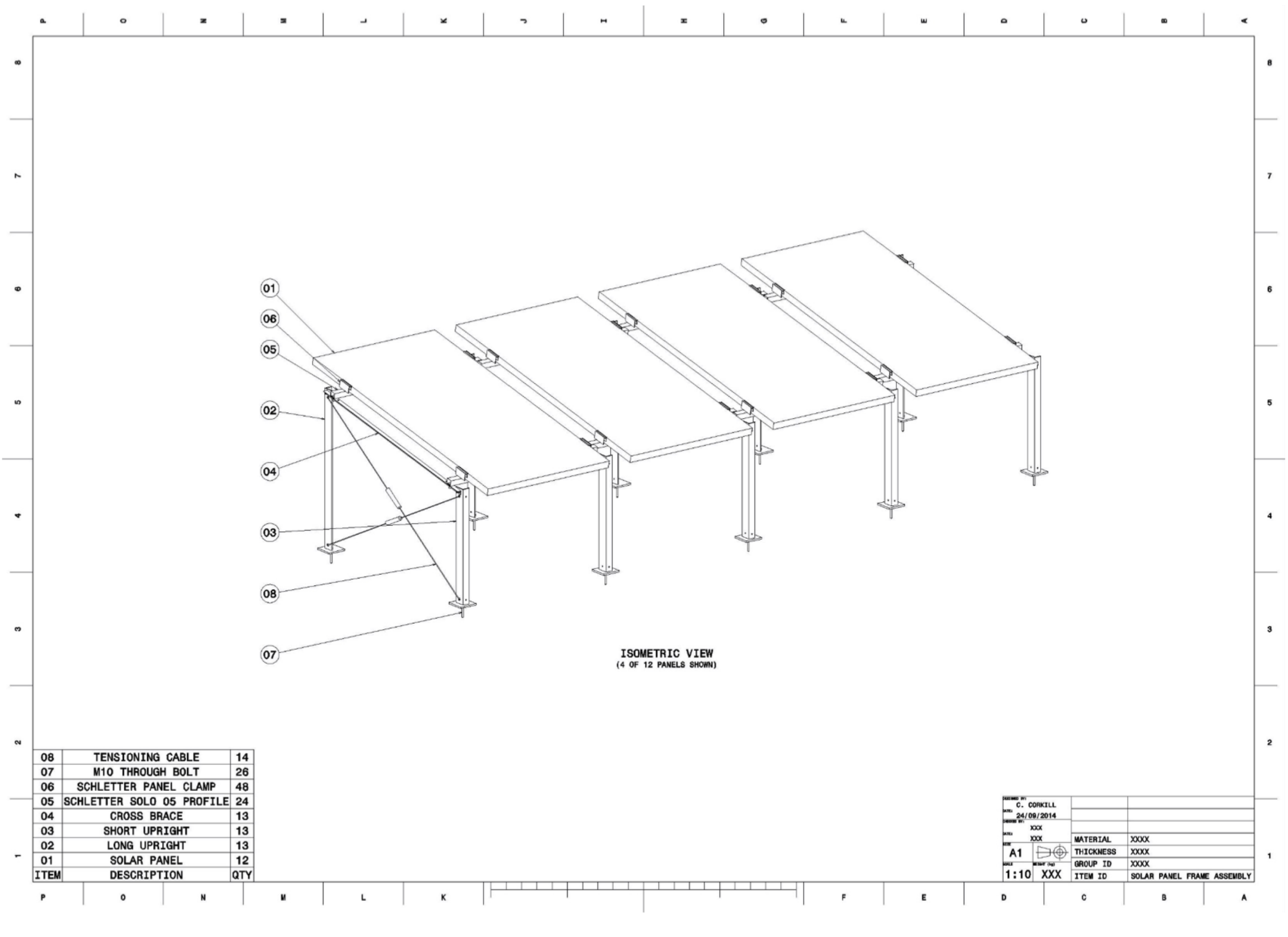


Figure 10: Final frame design

Figure 11: Frame assembly in full swing

Figure 12: A rawl bolt similar in design to those used to attach the frame to the concrete slab

6.3 Frame assembly

The concrete slab on which the frame would stand was constructed by the local community prior to the team arriving in Zambia. This ensured the concrete would be fully set when the team arrived on site, allowing the assembly of the frame to commence immediately. The assembly began with measurements being taken of the slab's dimensions and orientation with respect to North. It was found that the slab was facing roughly 10° away from North and was 3 m shorter than the 15 m length expected. Whilst the error in the slab's orientation was not considered as a significant issue, the 3 metres of missing slab proved to be more of a concern as the assembled frame length would be close to 14 m. Fortunately, both the frame and the slab had been designed with large tolerances. As such, it was possible to reduce the space between each panel, which allowed the whole assembly to fit onto the slab with a modest amount of space to spare.

The next step involved marking out positions on the slab for each of the 13 rear legs. Once the position of a leg was marked, a hole was drilled into the slab in which a through bolt was to be placed. After drilling the first hole and attempting to attach a leg it became clear that the concrete was too soft to allow the through bolts to operate effectively. As a result, once the leg was attached it would sway significantly with even a gentle push. An alternative solution was found in the form of a rawl bolt, similar to the one shown in Figure 12, a small number of which were brought out with the team. The larger diameter and different operation of the rawl bolt provided a much more robust attachment in the soft concrete. As such, it was decided proceed with the assembly using rawl bolts that were purchased from the supermarket in Chongwe town.

The remainder of the frame assembly proceeded with no other unforeseen problems. The frame components fitted together easily and the Schletter mounting system proved to be a very easy and effective method of fixing the panels to the frame. It was decided not to attach the tensioning cables as the rigidity of the assembled frame proved to be more than satisfactory. The completed assembly can be seen in Figure 14.

Figure 13: Attaching a solar panel using the excellent Schletter mounting system

Figure 14: The completed frame with panels

7 Project cost

Table 1 shows a breakdown of the total cost of equipment for the project. The £10860 total is within the budget estimated after the April 2014 visit. A more detailed list of equipment can be found in Appendix B.

Item	Price total / GBP
12 x 280Wp Solar panels	3720
8 x 280Ah AGM batteries	2260
Aluminium panel frame w/ structural fixings	1700
Electrical fittings, fixings, and cabling	1100
2 x Aleutia T1 computers w/ screen	700
Air freight of pallet	1380
Equipment total	10860

Table 1: Summary of project equipment cost

Other costs incurred during the project are summarized in Table 2. These costs were kindly covered by the School of Engineering.

Expense type	Price total / GBP
Travel	8408
Accommodation and Subsistence	2402
Vaccines	582
Consumables	91
Total	11483

Table 2: Summary of additional project costs

8 Data logger

In June 2013, a data logger was installed to record the direct current power flows at various points in the system, at one second intervals. This was a success, and in April 2014, ten months of data were retrieved from the logger. These data were used to inform the design of the solar power system upgrade. On the April 2014 trip, the logger was replaced by an upgrade that included improvements such as signal filtering, and the ability to log the alternating current side of the system. This was to give additional information such as the proportion of energy used by each building.

However, when the data from this new logger were retrieved in September 2014, it was found that the real-time-clock of the logger had stopped soon after the April 2014 visit. This, along with the fact that the logger had been turned off for a period between April and September, meant that it is not possible to match the data retrieved with a time or date. Upon discovery, the issue was investigated, but the cause of the stopped clock remains unknown. Possible causes are an intermittent fault in the new hardware, or an error in the programming of the micro controller. The clock was reset, and over the following five days, the fault did not recur.

Progress was made in connecting the data logger to one of the computers in the classroom. The goal of this is to clearly present information about the solar power system in a graphical format, including:

- how much energy was used during the previous day
- how much solar energy was harvested during the previous day
- the proportion of 'good' consumption to 'expensive' consumption, where 'good' consumption is that which takes place during the day, when there is surplus coming in from the panels, and 'expensive' consumption is that which comes from the batteries (usually at night)
- the proportion of energy going to each building

This interface is not yet functional however, and is work in progress.

9 Performance of the system

The new batteries and panels were installed in good time, and this allowed four days of data about the new system to be retrieved from the logger, prior to the team's departure. Figure 15 shows the system performance over a 24 hour period on the 6th of September 2014, from midnight to midnight. This was captured by the data logger after the upgrade was completed. Figure 16 shows the corresponding information from exactly one year earlier, on the 6th of September 2013.

Notable differences between the two days:

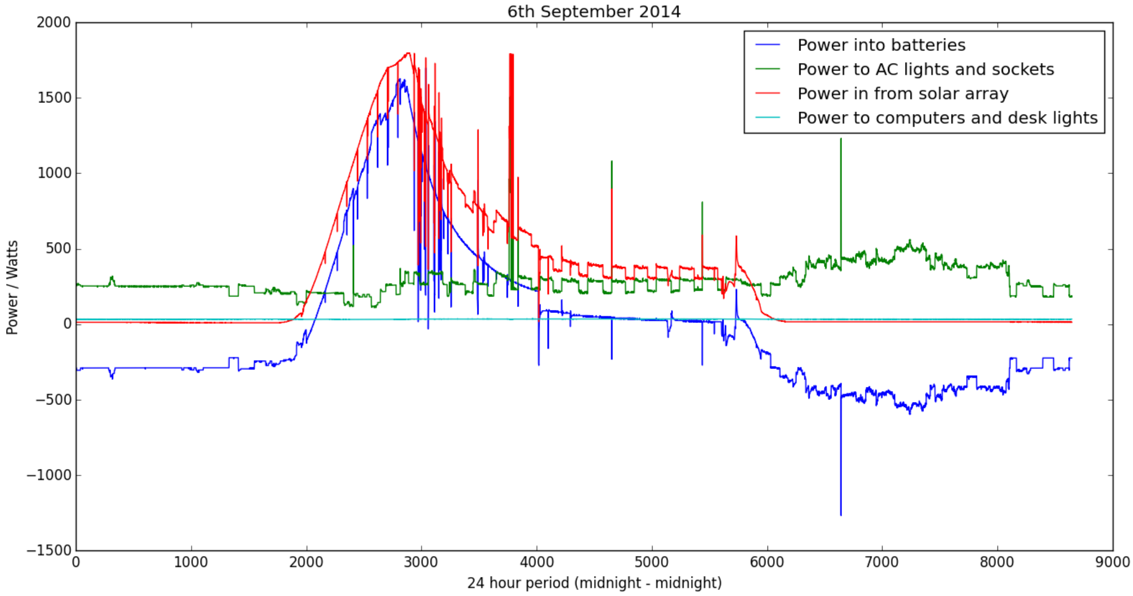


Figure 15: Electrical power flow in upgraded system

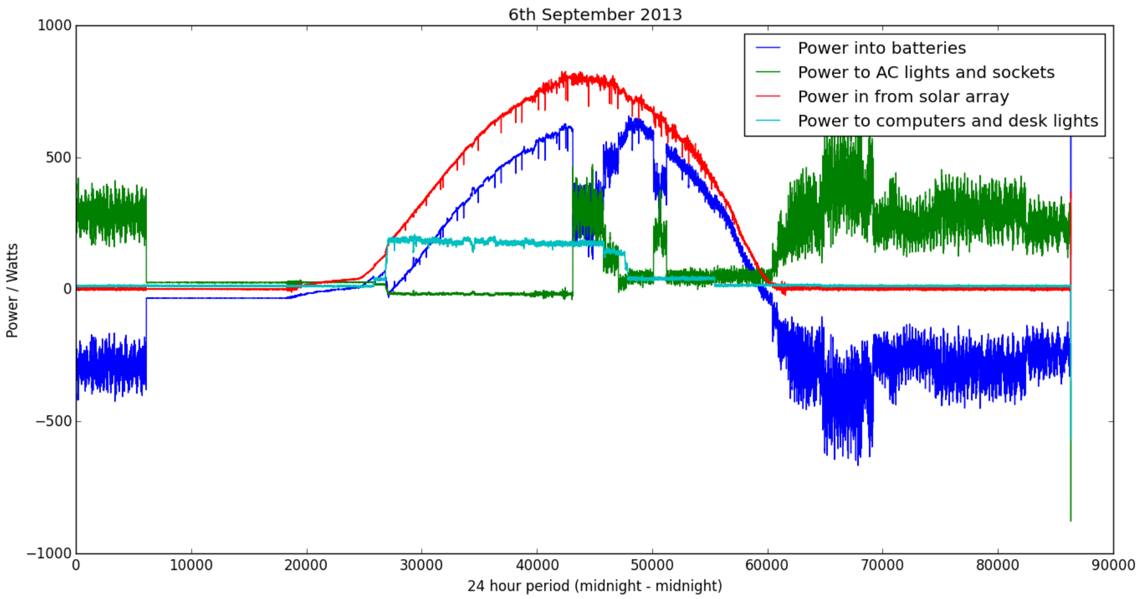


Figure 16: Electrical power flow in original system

- The peak solar input of the upgraded system is over double that of the original system.
- The upgraded system is fully charging the batteries by midday, causing a sudden drop in solar input and battery current, whereas the charging of the original system is fairly symmetrical, suggesting the batteries did not reach full charge.
- The solar input rises much earlier in the day on the upgraded system than on the original, reflecting the change in panel orientation (the panels now face North instead of West).
- The signals from 2013 have much more electrical noise (even after a simple moving average has been applied) than those from 2014, showing the success of the RC signal filtering on the April 2014 data logger upgrade.

This data, along with the absence of 'blackouts' since the upgrade, provides reassurance that the upgrade has been successful.

10 Computers

Two new Aleutia T1 fanless computers were installed in the classroom alongside the five older computers of the same type. These were all re-imaged to install on them the latest version of LUbuntu (14.04) and various programs and files, including the software and worksheets necessary for the teaching described in Section 4. Prior to this the computers were inspected and four were found to be in good working order, and one of them was found to have an intermittent fault (which was repaired by the re-imaging process).

The re-imaging process restores the computers to a known state, allows the software to be updated, and fixes any software errors that have occurred. However, re-imaging deletes user files, so unless they are backed-up beforehand, they are lost. The backing up of files makes re-imaging a time consuming process, especially when some of them are full-length films of large file size. This has meant that the person doing the re-imaging has been the arbiter of what stays on the computers and what is removed. Generally, only the things that are relevant to the educational objectives of Mothers of Africa have been retained. However a better alternative, instead of one of the Cardiff team doing this, would be for designated members of the community to administer the computers. Given the teaching success of this visit, it looks promising that soon there will be members of the community who are competent to do this.

During the visit, Ms Stella Phiri learnt how to reset the user configuration files to the default, which will allow her to restore the look and feel of the computers to normal. This will be useful because those learning to use the computers have in the past unwittingly changed settings that render the computers difficult or impossible to use. Unlike re-imaging, this process does not affect users' files.

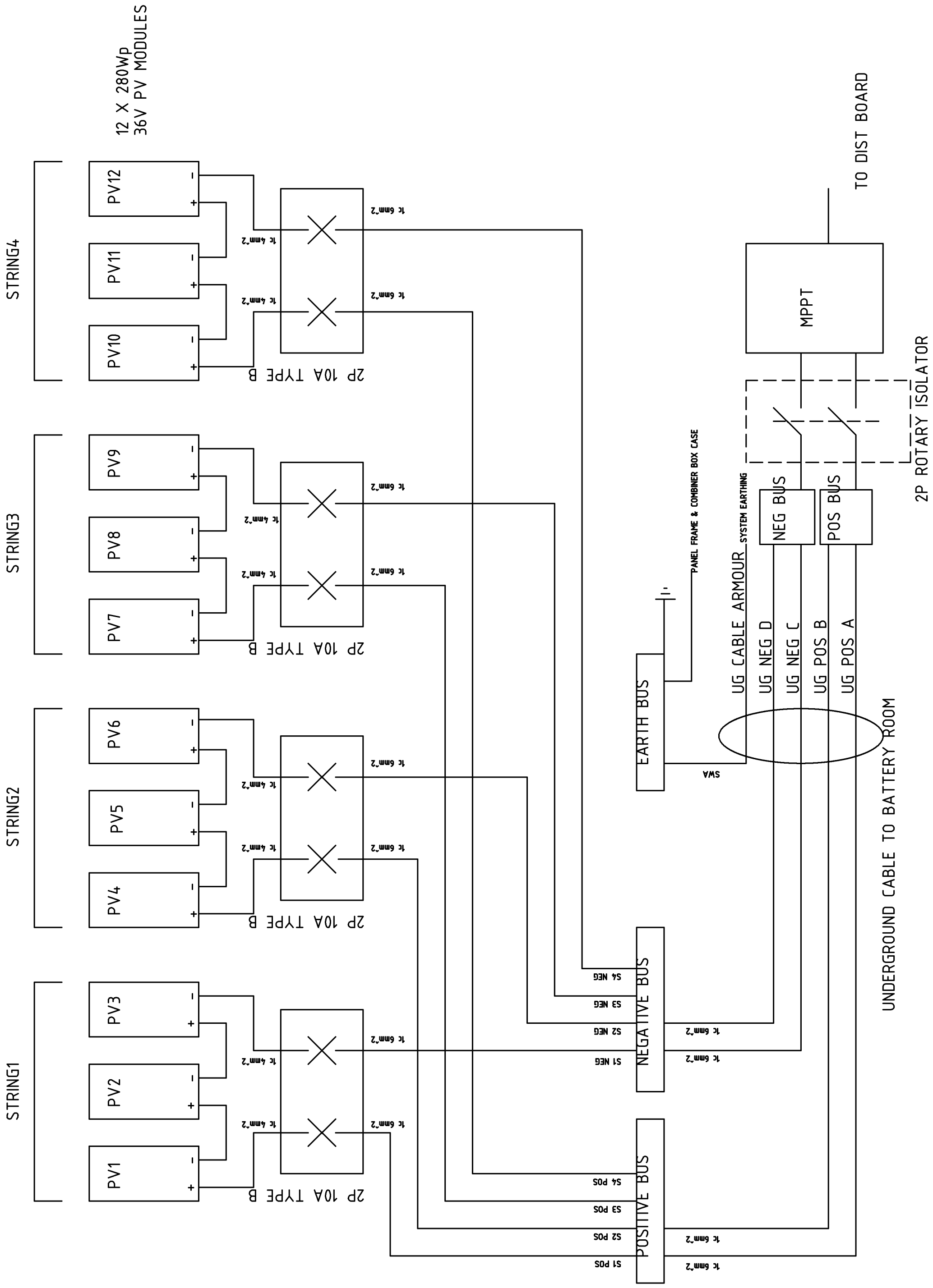
A consideration for the future is whether to connect the computers to the internet. There is a strong 3G internet connection available through one of the mobile providers, and it is technically feasible to connect the computers to the internet via this. For this to work, however, there needs to be good supervision of the internet use by appropriate and computer-literate members of the community. There are also economic considerations, as the connection is not especially cheap. Possible benefits of an internet-connected computer classroom include greater autonomy for the community in accessing learning resources and the possibility of video-chat link to Wales and elsewhere, amongst others. It requires careful thought and ultimately the decision needs to be taken by the community in dialogue with Mothers of Africa.

11 Acknowledgements

The team would like to thank all the people who helped make the trip a success. Special thanks go to Prof Judith Hall for organising the trip. Also thank you to Dr Charles Msiska, Dr Job Mwanza, and Ms Stella Phiri, for their instrumental role in facilitating things in Zambia. The ABESU Women's Cooperative supported the project by organising and funding the construction of the concrete foundation, and arranging for the cable trench to be dug and the battery plinth to be extended. In addition, Ms Eleanor Earl's input into the concrete foundation design is greatly appreciated. As previously, the School of Engineering has generously supported the project by funding travel and accommodation costs for the Engineering team, thanks especially to Prof Karen Holford.

A Wiring schematic

B Equipment



TITLE:	SHIYALA PV SUPPLY
DRAWN BY:	RHYS ROBERTS
DATE:	16/08/14
VERSION:	1.0

Item	Qty. or length in meters	Manufacturer	Model	Notes	Supplier	Supplier part number	Cost each / per meter	Total cost EX.VAT	Line cost IN.VAT
Combiner box								0	0
Enclosure	1	SCAME	686.409	JUNCTION BOX	EDMUNSON	686.409	22.5	22.5	27
Enclosure	1	ELDON	MAS0302515R5	300X250X155mm	EDMUNSON	MAS0302515R5	38.86	38.86	46.632
DIN RAIL 1M	1	IMO	DRO1C	1 METRE SLOTTED DIN-RAIL	EDMUNSON	DRO1C	4.13	4.13	4.956
Plastic cable gland kit	1		CW20		EDMUNSON	CW20	2.65	2.65	3.18
8-way earth block	1	SWA	8TB		EDMUNSON	8TB	4.24	4.24	5.088
STRIP CONNECTORS	2			15A	EDMUNSON	K0061 CS15NT-PE 814	0.4	0.8	0.96
								0	0
								0	0
Earthing								0	0
Earth rod	1	GREENBROOK	NR384E	~4ft long - INTENDED FOR PANEL ARRAY BUT NOT INSTALLED	EDMUNSON	NC38E	2	2	2.4
Earth rod clamp	1	GREENBROOK	NC38E		EDMUNSON		1.05	1.05	1.26
Earth wire	10				EDMUNSON		0.5	5	6
Earth tag	2							0	0
								0	0
								0	0
Cable								0	0
SOLAR CABLE 4MM	100				EDMUNSON		0.65		0
6 mm XLPE-SWA-PVC Armoured Cable 4 core	60		6944XLH		EDMUNSON		2.5	150	180
0,75MM 3 CORE FLEX WHITE CABLE	100		3183Y		EDMUNSON	3183Y	0.32	32	38.4
1.0MM T&E GREY	50		6242YH		EDMUNSON		0.285	14.25	17.1
0.75MM	50	CABLE	3183Y	WHITE	EDMUNSON		0.32	16	19.2
								0	0
Accessories								0	0
GLAND AND LOCKNUT	30	WISKA	10100611	Plastic cable gland for 18.7mm diameter SWA cable	EDMUNSON		0.61	18.3	21.96
CT1 SEALANT	1	C-TEC	535706		EDMUNSON		9.5	9.5	11.4
CABLE BAND	1	SWA	ARB12/P3/BL	BAND 12MMX3M	EDMUNSON		4.5	4.5	5.4
Wall screws	200		3719417	8 X 11/2'', COUNTERSUNK	EDMUNSON		0.0085	1.7	2.04
Wall plugs	100	THORSMAN	1090720	TPA2 RED	EDMUNSON		0.003	0.3	0.36
NYLON TELECLEAT	50	PRYSMIAN	385AA04		EDMUNSON		0.2347	11.735	14.082
Oval Conduit 16mm x 2m	10							0	0
Large cable clips for armourec cable	50							0	0
Electrical tape (red, black, green/yellow)	3			19X33 PVC	EDMUNSON		0.66	1.98	2.376
DANGER OF DEATH LABELS	1	SES	LFT23YB	PACK OF 5 (NOT SELF ADHESIVE)	EDMUNSON		4.5	4.5	5.4
Underground electrical warning tape 365metres	1				EDMUNSON		12.5	12.5	15
CABLE CLIP FOR 1-1.5MM T&E	400	THORSMAN	TCA5X8	For twin and earth cable	EDMUNSON		0.01568	6.272	7.5264
CABLE CLIP	100	THORSMAN	TCA7-10	WHITE ROUND CLIP	EDMUNSON		0.02227	2.227	2.6724
CIRCUITBREAKERS	4	GE	G102B10		EDMUNSON		21.81	87.24	104.688
Cable ties pack of 100 (300x4.8 mm)	1		CT300-4.8B	black, heat resistant nylon	EDMUNSON	CT300-4.8B	1.66	1.66	1.992
CONNECTOR BLOCK	2	GREENBROOK	CB3	100A SP BLOCK BETWEEN BATTERIES AND DIST. BOARD	EDMUNSON		4.43	8.86	10.632
CONNECTOR BLOCK	1			100A 2X5 WAY 35MM CONNECTOR BLOCK DP	SCREWFIX	21791	8.99		8.99
1 GANG 16MM	1			1 GANG 16MM	SCREWFIX	30573	0.46		0.46
LAP 13A SWD FCU NEON	1				SCREWFIX	79474	3.91		3.91
ADAPTABLE BOX	1			IP65 80X80X52MM	SCREWFIX	14556	4.26		4.26
RED WALLPLUG PK100	1				SCREWFIX	13209	0.45		0.45
EARPLUGS 10PAIRS	1	STANLEY		DISPOSABLE	SCREWFIX		1.24		1.24
20A 4TERMINAL STANDARD JUCTION BOX	3				SCREWFIX	1200D	0.85		2.55

DUST MASK	2			PK2	SCREWFIX		1.79		3.58
CABLE GLANDS	2			PK10	SCREWFIX	17058	6.04		12.08
STRIP TERMINAL	3			PK10	SCREWFIX	51536	3.31		9.93
								0	
Lighting								0	
FloodLight 10Watt LED 220 VAC with PIR	15	CHANNEL	E/FLOOD/LED/10W/PIR		EDMUNSON		25.5	382.5	459
Junction box	4	HAGER	J301	20 Ampere 4 terminal standard surface mount	EDMUNSON		0.8	3.2	3.84
JUNCTION BOX	15	WISKA	308/5	85X85X51MM IP66 BOX 60401	EDMUNSON		3.22	48.3	57.96
1G Switch faceplate	4	MK (electric)	K4870 WHI	SWITCH 1GANG 2WAY SP 10A	EDMUNSON		2.98	11.92	14.304
1G Surface mounted box	4	MK (electric)	K2140WHI	BOX 1GANG 30MM SURFACE	EDMUNSON		2.24	8.96	10.752
EMERGENCY LIGHTING IN MATERNITY WARD	1	CHANNEL	GR/NM3/LED	TWIN DIRECTIONAL LIGHT WITH BACKUP LI-ION BATTERY	EDMUNSON		45	45	54
EMERGENCY LIGHT IN CONSULTING ROOM	1	CHANNEL	ME/M3/LED	3HRM BULKHEAD 8W	EDMUNSON		15	15	18
TWIN SOCKET								0	0
TWIN SOCKET	1	ROBUS	RCDWS-24	175X80X115MM	EDMUNSON		14	14	16.8
								0	
TOOLS								0	
DRILL BIT	5	BOSCH		SDS-PLUS3 6X100X160MM	SCREWFIX	83037	2.45		12.25
DRILL BIT	5	BOSCH		SDS-PLUS-3 10X100X160MM	SCREWFIX	52276	3.13		15.65
MASONRY BIT	1	DEWALT		10X160MM	SCREWFIX	34514	4.29		4.29
KNIFEBLADES PK10	1				SCREWFIX		0.99		0.99
MASONRY BIT	1	DEWALT		6X160MM	SCREWFIX		2.99		2.99
MASONRY BIT	1	ERBAUER		22X450MM	SCREWFIX		15.49		15.49
MASONRY BIT	1	TITAN		25X400MM (AKA 'THE BEAST')	SCREWFIX	93167	9.19		9.19
CONCRETE BIT	1	BOSCH		16X100X160MM	SCREWFIX	29095	11.99		11.99
CONCRETE BIT	1			6X90X150MM	SCREWFIX	38027	3.13		3.13
FORGE STEEL FIBREGLASS TAPE	1	FORGE STEEL		50M	SCREWFIX	56093	14.99		14.99
CHALKLINE SET	1	STANLEY			SCREWFIX	43718	9.59		9.59
BOX LEVEL	1	FORGE STEEL			SCREWFIX	99153	9.99		9.99
MASONRY BOLSTER	1	ROUGHNECK		2.75 X 8.5INCH	SCREWFIX	81206	7.99		7.99
MASONRY BIT	1	IRWIN	IRW10501847	10X160MM	SCREWFIX		3.62		3.62
								TOTAL COST:	1361.9608