Solar panel installation in Kisenyi

An alternative energy supply to the existing water treatment project

A pilot project in Cooperation with Scan-Water, Naps and Fontes, partly funded by Innovation Norway, and supported by Eiksmarka Rotary Club

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1 Executive Summary

Scan Water together with Fontes initiated the installation of solar panel for the village of Kisenyi, southwestern Uganda, as the power supply for the pumps of the water treatment system. Partly funded by Innovation Norway and with support from NAPS the project was realized.

Photovoltaic solar panels used for pumping water is getting more and more common, especially because the prices have dropped significantly in the last years, but still is a fairly new technology and, especially, experience on operation and maintenance is limited.

Even though the operation and maintenance costs are low compared to other power sources like running a generator with diesel, other issues arise. A generator can be locked into a pump house, while the panels have to be exposed in the open in order to produce energy. This means that they are an easy target for theft and, therefore, security is a big issue. Even though fuel has not to be bought any more for pumping water, at most places the panels need to be guarded at night. The water committee from Kisenyi has now signed an agreement with the local authorities so that the police guard them for about half the cost of what they used on fuel earlier. But in other situations, the guarding might even get more expensive than the cost of fuel, a consideration which is highly important in planning of further installations. In addition, even though the panels themselves can last for many years, some fees for the investment and some maintenance costs have to be covered by the water price to guarantee sustainability in terms of replacement of panels after theft or damage.

During the technical part of the installation almost any type of complicating issues was experienced. The challenges which came up could mostly have been avoided if better documentation on the products would have been available.

The system has now been running for about two months and is performing well. The panels have delivered enough power for pumping except for two occasions, when it was raining all day, when they had to use the generator.

Valentin Koestler having been responsible for the installation of the solar system is doing electrical connections in the control box for the solar panels.

2 Considerations and recommendations

The solar panel power supply is an improvement of the existing water treatment set up in Kisenyi in terms of providing energy from a renewable source. This pilot was implemented with a clear focus on the investigation of sustainable solutions for surface water treatment in areas where surface water is the common source for drinking water although heavily polluted by human and animal activities. It has to be kept in mind that our water projects aim to provide safe and clean water within very short time, meaning a few days after any installation starts.

The installed solar panel array will provide in optimum conditions some 1500 watts to either pump water from the nearby river into the settlement tank for flocculation or to push water through the sand and activated carbon filters into the drinking water storage some hundred meters up in the village. Based only on the experience of some few weeks, we see that the power supply is sufficient to provide water to the Kisenyi population of about 1000 people. Only on some days with heavy rain or continuous clouding the stand-by generator has been used.

To install batteries, to provide power during days of insufficient sunshine was never a an option because batteries are very expensive, need careful maintenance and a lot of energy is wasted while charging, while also usually lasting only a limited time period. Therefore, a solution where a generator is installed to complement water treatment at times of limited sunshine is to be preferred. The only way to store energy in this context would mean to store enough water for several days in a water tower for periods of limited sunshine. This is only partly achieved in Kisenyi with having about 1.5 day's water consumption in storage capacity.

The question about cost effectiveness of investing some USD 25'000 for replacing diesel engine driven water treatment with an array of solar panels is actually closely related to security of the solar panels. Usually in this area of Uganda you have to use about USD 60 to 90 per month to a guard for securing the system. This is about equal to what is used to run the system with the diesel generator for a whole month. Because of the established contacts of Fontes and quite some negotiations it was possible to reduce this expenditure to about one third, which gives a real reduction in cost per month. This makes the installation in this specific case to a substantial improvement towards sustainability. Because of the issue of security it has, in other locations, been decided to set up the solar panel directly next to the police station, thereby reducing the cost of a guard. This might affect the technical design of the system and, therefore, has to be considered at an early stage of the project planning.

Although it is obvious that solar power supplied water treatment units are an important step in the direction of providing a sustainable concept for remote rural villages, the aspects of securing the highly attractive solar panels can outrange the cost of diesel.

Again, observations from a couple of more months are needed to better evaluate all different aspects, including operation, maintenance and cost effectiveness, of this solar driven water treatment system in Kisenyi.

3 Introduction

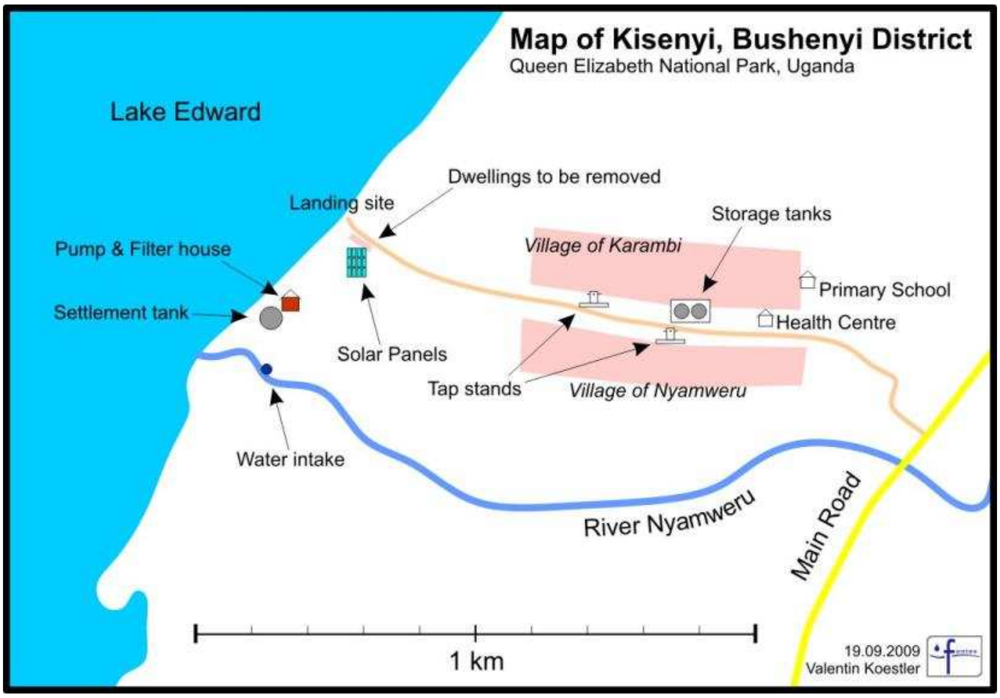
During the last few years, Scandinavian Water Technologies (Scan Water in Norway) has installed water treatment plants in Ugandan villages based on concepts originally developed for emergency response. All these installations are driven by diesel pumps always depending on the availability and the prices for diesel. Fontes installed similar water treatment plants in three villages, but has chosen to run the treatment process with electrical pumps driven by a diesel generator. Also these installations are depending on changing diesel prices and the often difficult availability of it in remote villages.

As a pilot project, Scan Water together with Fontes initiated the installation of solar panels for one of the villages as the power supply for water treatment and pumping. Innovation Norway, a governmental institution to support innovative approaches which can result in business development, was approached with an application. In addition, NAPS, a Finnish supplier for solar panels through its Norwegian agent was also approached with the invitation to participate in this pilot project. The financial burden of Fontes was partly covered by a donation from Eiksmarka Rotary Club.

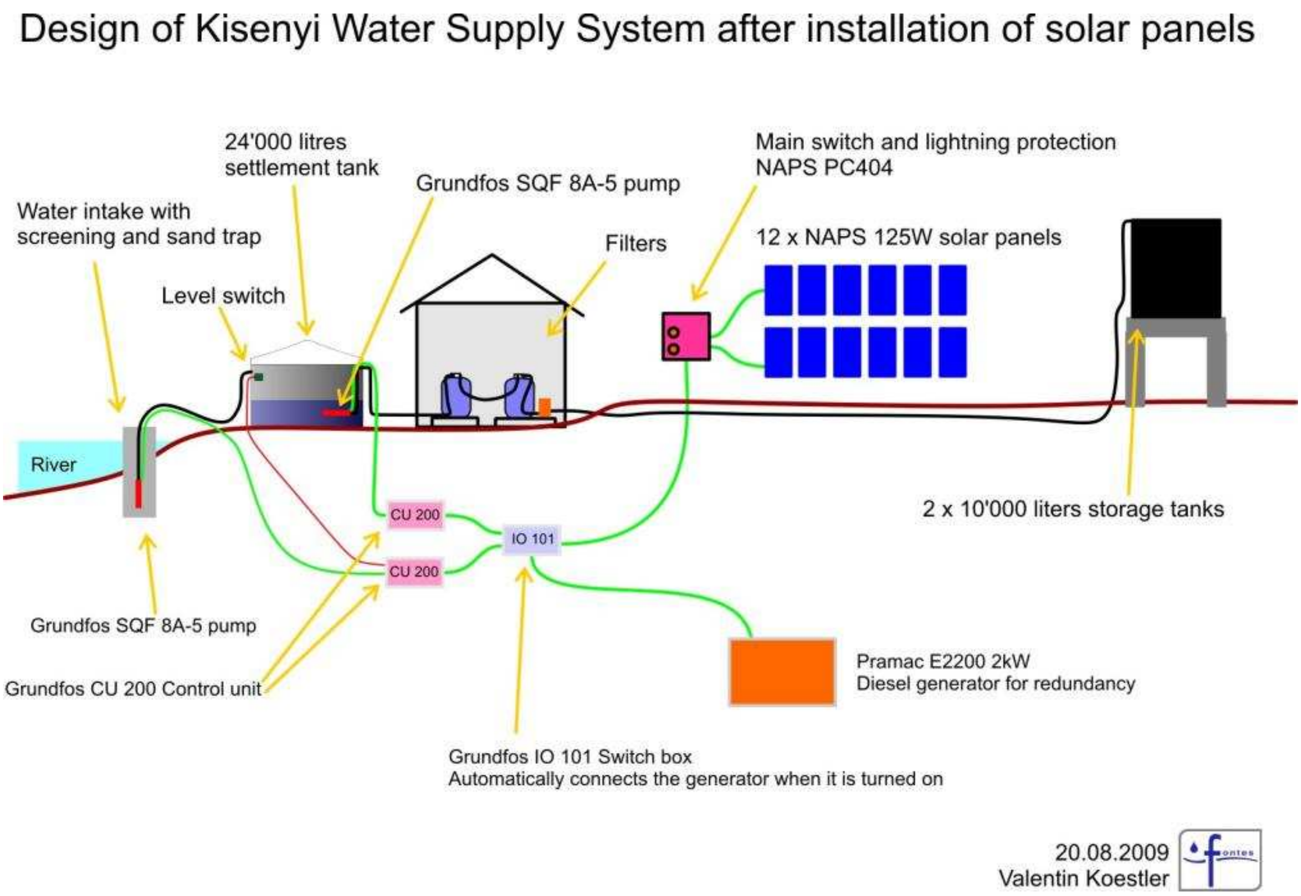
Continued support from the Uganda Wildlife Authorities and the Bushenyi Local Government and the people of the village of Kisenyi was essential for the project to be accomplished.

4 General information about the water treatment system in Kisenyi

The Kisenyi water treatment system was implemented by Fontes in fall 2007 with funds from Eiksmarka Rotary Club from Norway. The system takes water from the nearby Nyamweru River and treats it before distribution to two tap stands. Due to high turbidity, aluminum sulphate is added to the water before filling it into a settlement tank, where it settles for some hours. Afterwards, the water is pumped through a high pressure sand filter and an activated carbon filter before it is chlorinated and conveyed into the storage tanks, some hundred meters away.



The water project is managed by a democratically elected water committee, which hires 2-4 technicians to run the system on a daily basis. They also supervise one caretaker for each tap stand, who receives money and keeps the tap stands clean. The committees need support in how to manage the system on a financially sustainable basis, how to set a price that is accepted by the community but still gives enough income to cover the expenses, and how to supervise the work of the technicians and caretakers. The technicians need support and technical training; they are all local community members with mostly little technical experience. After the technical installation is complete, most of the time spent on follow up goes to management issues. *(Adapted from Fontes Newsletter 2008-09)*



5 Placement

5.1 Location

Initially the idea was to place the solar panels close to the control house and settlement tank so that they could stand together in one fenced compound. The people said it would not be secure in that place because it is too far from where there are people most of the day and especially during the nights. Ideally, the panels should have been placed in the middle of the village, but this was not feasible because it was too far away and the energy losses in the cables would have become far too big. We decided to place the solar array close to the landing site at the lake, because there many more people are around most of the time. Currently there are people sleeping in houses around the landing site, but these houses are to be moved up to the village because the Uganda Wildlife Authorities do not allow dwellings close to the lake shore. There is a guard at the landing site guarding the fishing boats during the night.

After the site was selected, it was arranged that a letter was made stating that this land could be used for the solar panels to avoid future conflicts. The letter was signed by the Sub County chairman (LC3), Parish chairman (LC2), both Nyamuweru and Karambi village chairpersons (LC1) and some other people.

5.2 Security

Because solar panels are expensive equipment and there is high demand for them on the black market, the security of the panels is a severe issue. In addition, the panels have to be installed in the open in order to receive sunshine, so it is difficult to physically protect them.

The issue of security was discussed with the local community in a security meeting with most of the water committee, local leaders (LCs) and security officers present. Everybody was concerned about the security of the panels. They said they would preferably need two policemen to guard the panels at night. Currently the expenses for fuel have been around 130 000 UGX (approx 65 USD) every month. They said it would normally cost around 90 000 UGX (45 USD) for one guard for a month, this means the guards would become more expensive than the fuel. The Sub County chairman (LC3) agreed to look into the issue and sent a request to the District Headquarters of Bushenyi. The police agreed to guard the panels even though an proper agreement was not yet made. An agreement has later been signed between the Water Committee and Bushenyi Local Government, in which the police guard the panels for 60 000 UGX/month (approx 32 USD).

They proposed that an alarm or a security light could be installed for improved security. There is currently no provision for this. In addition, to make this working at night you would need a battery. As installed now, it is difficult to connect a battery charger directly to the current solar array because of the high voltage (240V DC), so a small solar panel would also have been required for the alarm purpose. Using a motion detector sensor is not feasible because it will be triggered by people walking by and wildlife, which means some kind of alarm which triggers if the panels are removed would be the best option. If the baboons climbing over the fence turn out to be a big problem, it should be considered to install an electrified fence like the ones used for cattle etc.

Also a shelter is wanted for the security guards at night.

5.3 Fencing

A fence covering 7 by 7 meters was put up in order to protect the solar panels from both people and wildlife. The poles were dug approximately 40cm into the ground and anchored with concrete. First a 6 feet tall wired netting was put up, and then three rounds with barbed wire on the top.

Some poles have already been broken because a hippopotamus scratching its back against it. Sharp rocks will be put up around the fence so that hippos will not destroy it again, because hippos don't like walking on hard and sharp ground.

The fenced compound for the solar panels being constructed.

5.4 Orientation of solar panels

Usually solar panels are tilted towards the south in the northern hemisphere and to the north in the southern hemisphere. Since the village of Kisenyi is situated only slightly, approx 35km, south of the equator, the panels should ideally have been mounted flat to get the best efficiency. This is not feasible, though, because the panels have to be mounted at minimum angle of 10-15 degrees, in order to let water drain when it rains. If the panels would have been tilted either to the south or the north, the seasonal fluctuations in power generated would have become quite large.

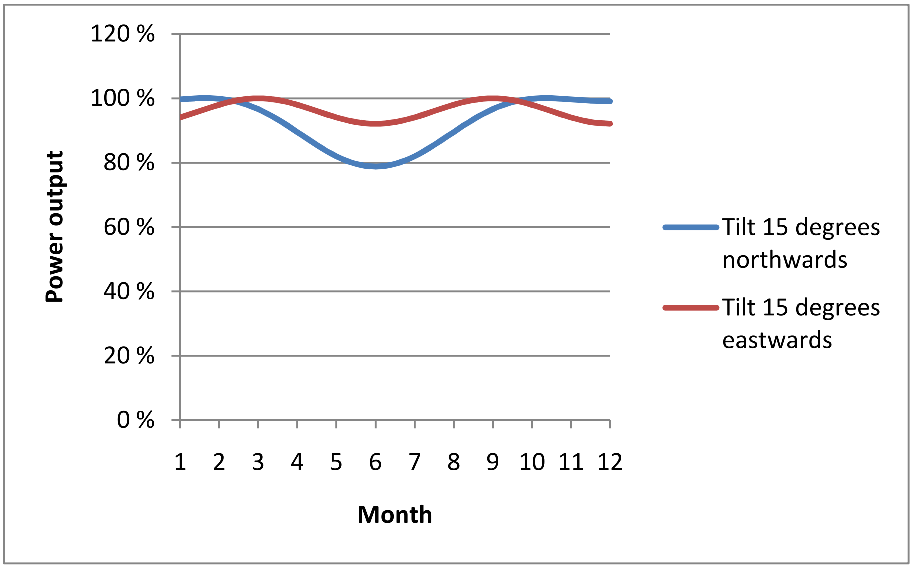


Diagram showing that the seasonal fluctuations in power output are bigger when the panels are tilted northwards, which would be the traditional orientation.

Therefore, it was decided to tilt the panels eastwards, because then the output will become more stable throughout the year. Eastwards was chosen opposed to westwards, because normally thunderstorms build up in the afternoon and, therefore, there is more sunshine during morning hours.

In order to align the solar panels quite exactly eastwards the following method was used: The compound of the fence which is a 7m by 7m square was put up aligned to the other houses around. A GPS was used to make two waypoints on the extended line of one of the sides of the square about 100m apart. Using these waypoints, it was determined that the side of the square had a heading of 113 degrees, since 90 degrees is straight east, the solar panels need to be 23 degrees rotated from the fenced area.

Since the sides of the fenced square are known and the angle is also known, trigonometry (tan) was used to find the offset of the panels and a piece of string was put up to mark this. Thereafter the foundation was aligned along this string.

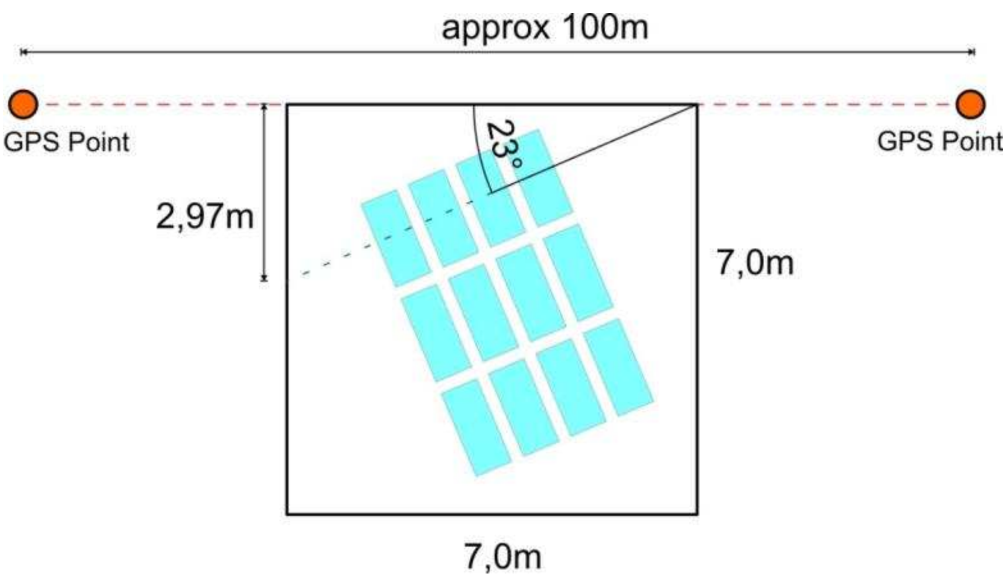


Illustration showing how the solar panels were aligned to become properly oriented to the east.

6 Mountings

6.1 Foundation

As a foundation for the solar panels it was chosen to use steel angle irons of 60x60x6mm. Because this was faster too assemble, such a construction was used instead of a concrete foundation. In earlier constructions making accurate structures with good strength concrete basis have also proved to be difficult. It was chosen to bolt the angle irons together instead of welding as there was neither a welding machine nor the required skill nearby.

Drilling of holes in the angle irons.

The angle iron was bolted together into a rectangular frame with six legs, 400cm long, 210cm wide and 150cm long legs. Each joint had two bolts. Due to transport limitation the long sides of the rectangle were joined from two pieces. The legs were dug about 50cm into the ground and concrete was poured around them. To add traction between the legs and the concrete, slits were cut into the legs and binding wire was put around. Concrete has also to protect the legs from rusting.

The frame being aligned within the compound and concrete was poured around the legs.

6.2 Support structure *Naps G4*

The support structure of the panels consisted of one long girder to mount the panels on, a selection of short girders for installing the panels at different angles and angle irons for mounting the girders to the foundation. The support structure was bolted onto the foundation with M8 bolts.

The installation of the support structure was straight forward, except that the main girders have two sets of holes for solar panels with a slightly different spacing: on one side the spacing is 60cm and on the other 62,3cm. This was not mentioned in the documentation of the support structure and was at first not noticed.

The solar panels were easily mounted to the support structures with four bolts for each panel.

The slightly offset holes in the support girders.

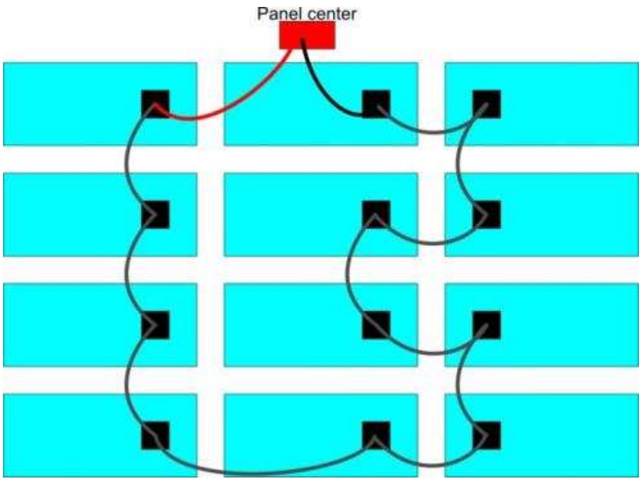
Installation of solar panels

7 Electrical connections

7.1 Solar Panels *Naps NP125GK*

It was chosen to connect all the 12 panels into one series because the cable span at around 190m to the pump house is fairly long and the voltage losses would have become significant large at a lower voltage. In addition the connection boxes from Grundfos are not designed for a current of more than 7 Amps which is the short circuit current of these panels.

The panels were very easy to connect together because of the Huber & Suhner Solar S4R100 connectors. Where the panels are close together, though, the cables are too long and they had to be wound around the support structure for them to not hang down too much. The fast connectors have the advantage that it is very easy to disconnect the panels when working on the system so there was no need to cover the panels. The locals feared that the baboons would play with the cables and disconnect them.



How the panels were connected in series to allow for a minimum use of transfer cable.

The solar panels from below. The panel control was bolted to the metal frame.

7.2 Earth rod

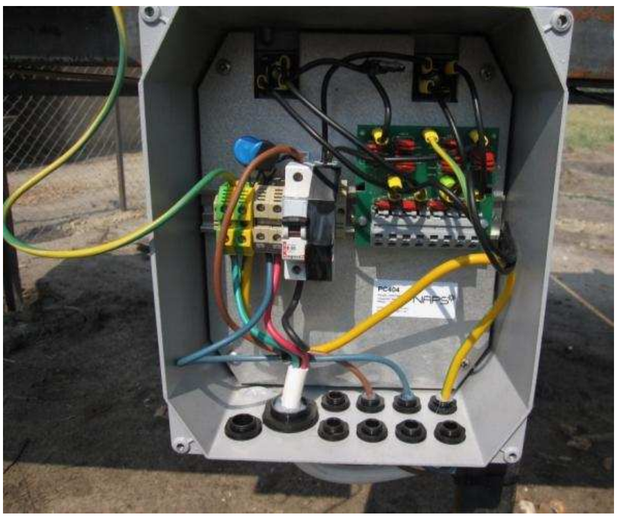
A six feet copper covered steel earth rod was supplied. The rod was forced into the ground just besides the panel control. There was no clamp supplied to attach the earth wire to the rod, so a clamp was made locally. Since the soils are wet a resistance of less than 1 Ohm was measured between the support structure of the panels and the earth rod.

The earth rod with an improvised clamp, it was forced into the ground so that it is no longer visible.

7.3 Panel Control *Naps PC404*

The panel control was fixed to the metal frame with three bolts. When doing this it was noticed that the bolts holding the rectifier diodes used to separate different solar circuits (not in use in this installation) in place are extending slightly from the back plate of the panel control which makes it difficult to bolt it onto a flat surface. The earth, panels and the cable to the pumps were connected to it.

Since all the panels are connected in series, the voltage is fairly high at around 240V DC. After connecting the panels to the panel control, the over-voltage protection varistors burned. It turned out that the control is only designed for 48 volts, and the varistors, of the type P100Z15 which are for the over-voltage protection can't handle more than about 100 volts. The entire over-voltage protection in the panel control was disconnected and new varistors from a household over-voltage protection were installed. This issue could have been avoided if proper manuals and information for the panel control would have been available.



The panel control after the wiring was in place. The circuit board on the right is entirely disconnected, replaced by new varistors (blue things on the top left).

All the electrical protection provided by the panel control is provided by varistors, which do not protect against lightning which is the major threat to a solar powered system. It should therefore be considered to install some proper lightning protection in the future.

The panel control box had a hole which was only covered by a sticker which had already fallen off. This hole was sealed with silicon. Because the main cable used was to thin for the biggest cable bushing, ants had made their way inside the box. Therefore all the holes and cable bushings were sealed with silicon.

The small uncovered hole in the panel control. In tropical areas it is highly important to avoid any small animals to enter electrical installations.

7.4 Cables

Because the panels were moved further away from the pumps than initially planned, an additional 110m of cable was acquired from Kampala. The cable which was supplied with the solar panels had solid conductors. With the thin cable of 2,5mm^2 for the level switch this was not an issue, but for the main cable with 6mm^2 cables it became very stiff and difficult to handle. Pliers had to be used to bend the cable inside the control box.

None of the cable joints was part of the kit, so the connections were made by soldering the leads together, insulating with heat-shrinkable tubing and then a small piece of hose was pulled over the connections for protection. The joint was then filled with silicon to make it waterproof.

One of the cable joints on the main power cable.

7.5 Switch box *Grundfos IO101*

The Grundfos IO101 switch box is located in the control and pump house. It has a built-in relay which automatically switches to generator power when it is turned on. This is practical in cases when there is not sufficient sunshine. In addition the box has a main switch.

Connecting this box was done without any difficulties.

Inside the Grundfos IO101 after the connections were in place. The white box on the left is the relay for automatic switching between solar and generator power.

7.6 Pump Controller *Grundfos CU200*

Both Grundfos IO100 switch boxes were replaced with the more advanced Grundfos CU200 pump controller. This controller communicates with the pump through the power cable and allows you to monitor the pump status. In addition, it has a small display showing how many watts the pump is consuming i.e. the solar array producing.

For the pump in the settlement tank the CU200 worked very well, but the CU200 failed to communicate with the pump at the river intake (F3 error). It states in the manual that the communication only works with cables up to 200m, but the cable in use is only 80m. Still the controller works as an on/off switch and for the level switch.

Replacing the old boxes was straightforward and Grundfos supplied plugs for the holes which are not in use which is quite convenient.

The control boxes while operating. The panels are currently producing 0.89 kW.

7.7 Level Switch (unknown brand, supplied by Grundfos)

A level switch was installed in the settlement tank so that the pumping automatically stops when the tank is full. It would have been preferred to also put level switches on the storage tanks up in the village, but this was not feasible because of too long distance.

The switch was mounted by drilling an 8mm hole into the settlement tank (PE), a little below the level when it is full, and the cable was pulled through this hole from the inside. Afterwards the cable was extended and connected to the CU200 pump controller.

The level switch (red) mounted inside the settlement tank.

8 Performance

The system only ran for one day while I still was there. Therefore, it was not possible to do extensive testing on the performance. The panels were connected for the first time around 15:00 and then they were producing about 880W. After pumping in the evening and the next morning the settlement tank of $20m^3$ was filled at 9:00. After waiting for the water to settle for two hours they started pumping water through the filter system and up to the storage tanks. At approx 13:00 they had filled 1 ½ storage tanks ($15m^3$). The weather on this day was like an average day; with sunshine in the morning hours, and thunderstorms building up in the afternoon. This shows that they can produce one batch ($20m^3$) of water during one day which is what the solar array was designed for to do. Currently they consume around 10 000 L of water every day, so they run the system every other day. This also means that there is sufficient capacity also for increased water consumption in the future.

While writing this report in October 2009, the system has now been operating for almost two months, and according to the scheme operators it is performing well. The panels have been giving enough power for water production except for two occasions when it was raining all day and the generator was used.