Implementation of a Solar Test Laboratory in Sub-Sahara Africa

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Abstract

Penetration of decentralized power supply for households and commercial enterprises is low in Sub-Sahara Africa. Solar Home Systems (SHS), despite their widespread use in other continents have failed to attain much success in Africa. One of the reasons is the high rate of failure of existing implementations. Data shows earlier failure rates of 50 [1]. This is largely attributed to poor quality of products used, inefficient installation, mismanagement and lack of maintenance. To address this problem, the Centre for Research in Energy and Energy Conservation (CREEC) has set up a Solar PV test laboratory in Uganda. This paper describes the process used and how to sustain the laboratory after implementation. The lab is intended to provide a forum for training, research and consultancy under CREEC. It is intended as a tool to implement the triple helix and clusters procedure in the PV industry. This paper offers detail covering the current situation of the energy sector in Uganda and how the lab helps capacity building in the University to support the upcoming demand.

Keywords: Solar Home System; Renewable Energy; PV training; Clusters; Rural Development; PV market.

Introduction

Uganda is endowed with good insolation levels practically the whole year round raging from 4000 to 6000 Wp/m^2/day. The national grid covers less than 10% of the urban population and less than 3% of the rural one. Despite of this scenario, Photovoltaics (PV) technology has not managed to penetrate and the PV industry is small and financially weak in the country.

The Government is making an effort to further its dissemination but the results are rather meagre. The Ministry of Energy and Mineral Development (MEMD), Rural Electrification Agency (REA), Private Sector Foundation Uganda (PSFU) are the units receiving funds from the World Bank under the Energy for Rural Transformation (ERT) project phase II to tackle the problem.

Development agencies such as Sida, GTZ, and NORAD have also availed extra funds to strengthen the PV industry under the Renewable Energy Agenda.

The Private Sector has been improving steadily though on a small scale and of late has organised itself under the Uganda National Renewable Energy Association (UNREA). Leading academia's efforts, CREEC of the Faculty of Technology, Makerere University is creating capacity at technical, degree, masters and PhD levels. With the support of the above-mentioned development agencies, CREEC has established a Masters in Renewable Energy degree with four specializations: bio-energy, micro-hydro, PV and Energy Efficiency in the building environment supported by NORAD. Sida alone has provided close to US$10 million in a five years project to build capacity at PhD level with a total of 30 plus candidates. Four of them are conducting research in renewable energy. GTZ has sponsored quite a number of PV related projects and with the support of German private companies has provided CREEC with three PV systems for demonstration and training (sunny island 1050 Wp, power boy 330 Wp and a DC fridge system 185 Wp). It is within this framework that Sida availed USD 150,000 for the setting up a Solar PV laboratory.

CREEC

The Centre for Research in Energy and Energy Conservation is a research, consultancy and training organisation based at the Faculty of Technology, Makerere University. CREEC was founded in 2001 with the goal of developing into a centre of excellence in energy for Uganda and the entire East African Region.

Its goal is to create capacity in all fields related to energy with a special focus on the following areas:

- Energy management
- Hydropower

• Solar photovoltaic (PV)
• Bio-energy

Its aim is to develop technologies and systems that have a direct, positive impact on people's everyday lives. Along these lines, CREEC promotes technology transfer from researchers to society through pilot project implementation, training programmes and public awareness initiatives. This is done in order to bridge the missing link between researchers, the business community, funding agencies and the general public.

CREEC has a threefold mission:

Research – access to experts in the various fields of energy at PhD level. It participates in regional and international research initiatives, such as joint Master and PhD projects with renowned universities abroad.

Training –The centre coordinates the MSc Degree Programme in Renewable Energy in cooperation with the Norwegian University of Science and Technology (NTNU). CREEC plans to offer training courses to professionals who wish to improve their practical knowledge in photovoltaic installation, pico-hydro systems and energy management.

Consultancy – Apart from energy auditing, experienced staff offers expertise on energy policy, small-scale energy project implementation, rural electrification programs and others.

Among many smaller projects, CREEC is currently implementing two large renewable energy projects:

Dissemination of energy efficient stoves:
CREEC won a grant from the World Bank's Bio-Energy Initiative for Africa (BEIA) to develop, produce and disseminate energy efficient stoves. In collaboration with Prof. Paul Anderson from the U.S [name of the institution that he represents??????]. CREEC will improve the existing TopLit UpDraft (TLUD) stove, which will be produced locally and disseminated in rural Uganda. Supported by GTZ, a facility called Centre for Research in Bio-energy has been established that is well equipped to conduct biomass research. CREEC owns the only Particles Emission Measurement System (PEMS) in Africa; this is being used to test and design stoves suitable to the African environment.

Millennium Science Initiative (MSI):
CREEC's Director, Dr. Izael Pereira Da Silva is the Principal Investigator of the interdisciplinary research project "Rural Electrification in Uganda Increasing Access to Modern Types of Energy" which is sponsored by the Uganda National Council for Science and Technology (UNCST). This research project focuses on the implementation of renewable energy systems, GIS mapping and business modelling.

Because CREEC is linked to the University and thus has at its disposal a large number of lecturers, undergraduate and graduate students it can develop the role of knowledge management and capacity building to strengthen the renewable energy sector not only in Uganda but also in the whole of East Africa.

The Ugandan Government

The Ministry of Energy and Mineral Development (MEMD) is very supportive of initiatives that foster the use of renewable energy. It has published the Energy Policy [2] in 2002 and the Renewable Energy Policy [3] in 2007.
With the support of the World Bank it has established the Rural Electrification Agency – REA to manage funds, implement and supervise activities aiming at provision of energy to rural areas.
The Private Sector Foundation Uganda (PSFU) is also playing a very important role as a government organ with the function of supporting the private sector. They have received support from the World Bank under the project ERT and have availed the business community with grants up to 50% to cover consultancy and market survey to provide a smooth start to business. Currently CREEC has a MoU with PSFU to work in three areas, namely: solar PV, small hydro-power and energy efficiency. Under this last one CREEC is expected to do Verification and Evaluation of the creation of a 10 MVA Virtual Power Station – VPS made up of savings from energy efficient projects from at least 50 industries.
Finally the Uganda National Bureau of Standards (UNBS) is also working on setting up standards to help curb the proliferation of poor quality PV equipment in the market.

The Private Sector

Uganda's GDP ranks amongst the smallest in the whole world but even when compared with other African countries it does not fare any better. More than half of the population lives under the poverty level on less than one dollar a day. Recently, Uganda and four neighbouring countries (Kenya, Tanzania, Rwanda and Burundi) joined the East African Community, allowing free movement of people and goods. This brings some hope to the PV industry as the over 130 million people [133.5 million (June 2010 est.)] in these five countries can make competitive importation of PV equipment from Europe and the USA more affordable.

UNREA

The Uganda National Renewable Energy Agency Limited (UNREA) is a confederation / association of Ugandan private companies dealing in distribution of Solar Photovoltaic (PV) and other renewable energy technologies in Uganda. It was incorporated in 2009 and has as members, the 10 most reliable PV dealers in Uganda:

1. Energy Systems Limited.
2. Power & Communications Systems Limited.
3. Solar Energy Uganda Limited.
4. Incafex Solar Power Systems Limited.
5. Konserve Consult Limited.
6. Ultra Tec Uganda Limited
7. Power Options Limited
8. Solar Energy For Africa Limited
9. Battery Masters Limited
10. Mark Impex (U) Limited

Its mission and work is defined as: "…an autonomous private sector based stakeholder and participant in the general energy sector pursuing realistic promotion, development, and deployment of sustainable clean renewable energy solutions by promoting, coordinating, demonstrating, financing, disseminating and influencing energy delivery policies, protect energy consumers, promoting private sector sustaining investment in energy delivery services in Uganda".

The core work of UNREA is to play a leading role in pursuing balanced rural electrification based on sustainable utilization of solar energy and other renewable energy resources in Uganda. UNREA is the strategic all-round working interface for the renewable energy sector. [4]

Triple Helix

Despite the reliability of the PV technology, the support of the Government via the above mentioned institutions, the willingness and good will of the private sector and the ability of the academia to handle applied research in this field, PV power as a percentage of total power consumed in Uganda is practically negligible at less that 1%.

This is mostly because there is not a coordinated effort by the three players namely Government, Private Sector and Academia to put their specific gifts to work in a concerted manner to achieve the goal of widespread use of solar energy in Uganda. The solution for this problem could perhaps be the implementation of the so called "triple helix" or clusters initiative.

To understand better the triple helix concept we list below three citations:

At the moment, one unsatisfactory element in the European system has been that the linkages between university and industry, research and business world are not strong enough. Moving towards the knowledge-based society, however, also means that boundaries between public and private, science and technology, university and industry are blurring as the distribution of research locations becomes a key factor of economic growth in a knowledge-based economy. Knowledge has become in growing extent a potential product that can be exploited on the market, which means the industrialisation of the production of scientific knowledge (e.g. Jacob 1997; Ziman 1994). [5]

Universities and firms are in growing extent assuming each other's tasks, and, as the university crosses traditional boundaries in developing new linkages to industry, it has to devise the connections between research, teaching, and economic development. Within industry, questions are raised about what should be located inside the firm, between firms, or among firms, universities, and government institutions. Are the firms willing to support basic research or is better to leave this task to the universities? What is the role of government given the need for technological innovation in international, national and regional development? (Etzkowitz & Leydesdorff 1995). [6]

This mode of thinking - referred as 'triple helix' - is beneficial especially for the 'hard sciences', in which basic and applied research can be organised according to the triple helix model. However, in the field of humanities and social sciences, anything comparable to the technology centres has not yet been established, even though there are some efforts to that direction. Today the life sciences are a good example of a field where the co-operation between state, universities and a specific industrial cluster is a prerequisite for generating innovations. Universities are needed for the basic research, and they collaborate in R&D with the enterprises for the development of practical applications in specially designed environments (science parks etc.) funded largely by national governments but extracting also a lot of other funding. These installations have the capacity to employ a large amount of experts with postgraduate qualifications in different disciplines. [7]

An example of a successful triple helix implementation is Silicon Valley, where Government has provided land, financing mechanisms, tax holidays and suitable policies to allow the private sector thrive - in this specific case on the IT industry.
On its side, the private sector (Dell, HP, Oracle, Intel, Microsoft, etc) do what they know best which is production of reliable computers and software produced in a sustainable and efficient manner.
The very needs of the industry, powered by the created market, makes the need for the academia which in this case comprises of ICT professionals who are given all facilities to do R&D and product development to further boost the industry.
Government, Industry and Academia all profit as taxes are collected on sales of goods, revenue is generated and knowledge is developed within a suitable research environment.
Nevertheless, this is not the whole story. The greatest beneficiaries of this cluster program are the consumers who can buy good and reliable computers - tools to empower them as individuals and provides a platform for them to play a meaningful role in society.

CREEC's PV Laboratory

Many solar laboratories have been built in Africa but most of them have failed because technicians were not familiar with equipment and/or because income generating activities were not defined as a critical output of the laboratories. In order to avoid this, CREEC plans to establish cooperation with Government and PV Dealers to create business for the lab. This is done on the spirit of collaboration mentioned above. The four possible ways to sustain the lab are:

– Cooperation with the Uganda National Bureau of Standard (UNBS) to set up standards to be met by solar products entering the country. Use the laboratory to do labelling on their behalf.
– Charging for Independent PV testing and consultancy from importers who wish to test prototypes/samples of equipment they plan to sell to the Ugandan market.
– Offering our practical expertise to train engineers at undergraduate and graduate levels to satisfy the market need.
– Train technicians from the private sector in all matters pertaining PV design, installation and maintenance.
– Ensure the quality label of Lighting Africa by using Lighting Africa's test procedures and standards to test solar lanterns (pico-PV products).

Besides the above CREEC will be able to pay for services rendered by the laboratory when it is used to provide tests to projects such as the one sponsored by the World Bank and the Uganda National Council for Science and Technology.

The initial set of equipment that the lab has acquired is listed below:

- Luxmeter
- Photometer box
- Integrating Sphere with photometer
- Set calibration lamps
- Spectrophotometer with optical fiber
- DC supplies
- Multimeter
- Datalogger
- Battery charging and analyzing device
- PV module analyzer

Using the procedures developed by Fraunhofer ISE during the lamp-test with GTZ and published under Lighting Africa and quoted in MICRO ENERGY international (www.microenergy-international.com) [8], the laboratory will be able to test the functions of SHS test facility:

- Demonstrate solar home systems
- Evaluate the quality of the whole SHS system configuration e.g. checking how many watts a panel actually delivers
- Unmask illegal imitation systems
- Confirm manufacturers stated specifications
- Design the systems configuration

Another goal for the laboratory is to set up a network with global test facilities such as Joint Research Centre in Ispra - Italy (JRC).

- Simulate different user's profiles

- Collect information about the long-term performance of SHS
- Compare the performances of different system configuration e.g. change the different load appliances, batteries, charge controllers, & solar panels, to compare their performance.
- Check the potential effects on the systems of some uncommon usage practices e.g. bridging the battery

The local test facilities have to have the following features:

- Should be built of robust components
- The set-up and the operation should be clear to local technicians
- It can be used for training local technicians
- Running costs should be covered by its activity (cost-recovery approach)
- Check the performance of the whole SHS system as well as separate components
- Data analysis should be adapted to the already used analysis programs
- Autonomous power supply to run the logging unit, especially to operate in the off-grid areas and the areas of unstable grid

An additional target of the laboratory is to involve electrical engineering students from the Faculty of Technology to work under the supervision of trained personnel in practical activities to enhance their training and awareness regarding renewable energy in general and solar PV technologies in particular.
This will definitely have a positive impact on the solar market in Uganda and is a typical win-win situation as students can work for small pay and thus help reducing the laboratory operational costs.
CREEC has an agreement with the Faculty of Technology through which the Faculty avails the centre with space, electricity, internet, water and security for free, further helping the lab to be self-sufficient.

First tests done by the laboratory

Village Energy Solar lamp Test
CREEC tested a solar system which was assembled in Uganda with as much local products as possible. These lights are meant to be sold in the rural and peri-urban areas and are designed to target the poor in those areas.

Those LED lamps are also designed to be assembled where there is no electricity so, for instance, the connections are made in such a way that they do not need soldering. A plastic bottle head forms the lampshade and works as the container for the electronic parts. The LEDs are inserted in a cushion covering the lamp.
This is a seemingly excellent idea of a product built by the poor for the poor without compromising quality. For this reason the CEO of Village Energy asked CREEC to test the prototype.

CREEC's test methodology focused on following measurements:
Battery Discharging Test *versus* Lumen Output
The discharging curves from the datasheet are verified by measuring the battery voltage drop over time while lamp is switched on. During this experiment, the battery voltage and the current were continuously measured by data loggers. The lamp was lit inside of a dark box within which was a light meter (luxmeter) to measure light intensity. The measurement started with fully charged batteries and lasted until the battery was fully discharged.

Charging Test
The battery voltage and the power provided by the PV panel during charge by sunlight were measured. The idea was to find out how long would it take for the battery to be fully charged under several insolation conditions.

Comparative Light Output Test
The light output of the lamp was measured and compared to the light output of a kerosene lamp and also a wax candle.

IP Rating Test
The degree of protection in accordance with EU standard DIN EN 60529 is used as a measure for the safety of the system.

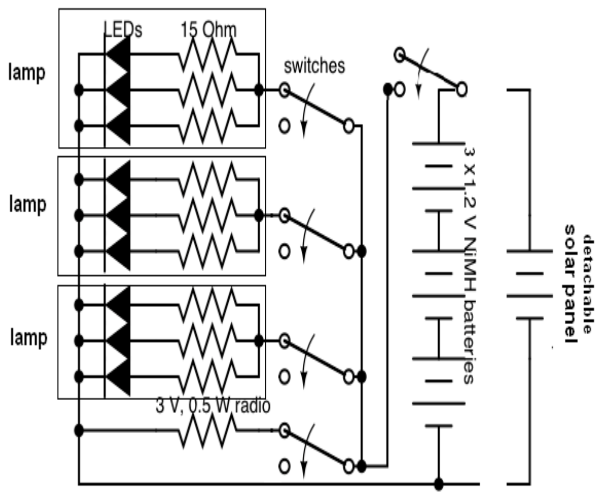

Figure 1: Wiring Diagram of the LED Lamp

Figure 2: Village energy Solar LED lamp

The results of CREEC's test were not very positive as the light output of the lamps was almost 3 times less than the one of a paraffin lamp. The recommendation to increase lumen output has obvious cost implications and thus affects the payback period of the product.
This example shows clearly how a laboratory in Africa can help private sector people to test they product not only as regards as the technical aspect but also to show them at prototype stages which measures to take to provide the market with a successful product. In the near future CREEC has plans to cooperate with the UNBS to be able to test and label PV equipment on behalf of their institution at a nominal fee.

Performance Test of Sunny Island PV System

CREEC was granted a Sunny Island PV system of 1050 Wp with a 600Ah 24V battery bank (14.4KWh). In January 2010 the control system for the Sunny Island (Sunny Webbox) was showing power available (SoC) at about 50% of the expected and the weather was sunny with almost no clouds.
The load attached to the system was way below its nominal size and there were no losses in cables or connections as the panels are at a maximum 5 meters from the battery bank which is about 5 meters from the load.
This became a puzzle which CREEC personnel took upon themselves to solve. Tests on each of the components were performed and it was found that the output from the 6 175 Wp panels were not the expected. A visual inspection of the panels showed no defective parts nor stains which could have accounted for the weak output.

One of the most conventional modes of installation of solar panels in Uganda is to secure them with an angle L shaped iron frame to avoid the so common event of thefts. Well, it so happens that in this case the frame was not tightly attached to the panels and thus was creating shadow on a whole set of cells of the panels. (See picture below).
A simple reduction of the size of the frame and a support placed under the panels resolved the problem totally. This is a typical issue which, left unchecked would make people in NGOs, users and even in Government to come to the wrong conclusion that PV systems do not work in our region.
Again, the presence of well trained personnel with a set of well suited tools such as the ones in CREEC made it possible to solve this problem. CREEC has since then tried to disseminate this information so that all stakeholders are aware of this possibility when installing PV systems.

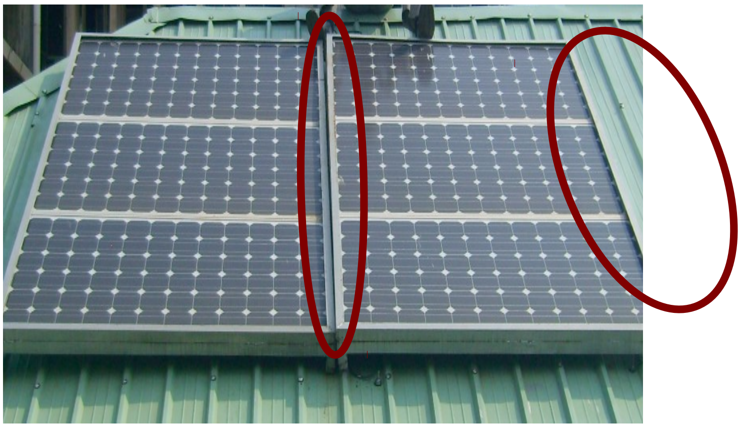

Figure 3: Shadow at 3 pm due to the unsuitable frame

Conclusions

As it can be seen by the two sample activities performed at CRECC's lab, the initiative can help all PV industry stakeholders. Government has created a position called DEO – District Energy Officer to handle matters pertaining especially renewable energy at district level. Currently there are close to 111 districts in Uganda. So, practical training in our facilities would go a long way to promote penetration of this technology into rural Uganda. For the private sector the lab can provide short term training to get technicians able to install reliable systems from SHSs to large institutional ones. And finally for the academia this is a perfect place to give engineers hands on experience which sometimes are lacking in many

high level training institutions in sub-Sahara Africa.
All these possible activities of the PV laboratory at CREEC have as their overall goal to support the growth of the solar market in Uganda and provide solutions for the energy-needs of people in rural areas using the concept of decentralized renewable energy power supply. Once fully installed the lab will play a relevant role in the setting up of a renewable energy cluster in Uganda and the East African region able to emulate the success of Silicon Valley example.

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