ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

Peer Reviewed
2016 Solar Research Conference

2016

Xiaowei Shen

Photovoltaics for Basic Health and Communication Services in Post-Cyclone Vanuatu

Xiaowei Shen[1], Richard Corkish[1]

[1] *School of Photovoltaic and Renewable Energy Engineering, University of New South Wales, Sydney, 2052 Australia*

E-mail: xiaowei.shen@unsw.edu.au

Abstract

Both the local health and communication services on the Island of Tanna, Vanuatu suffered from the damage caused by Cyclone Pam in 2015 and most of the island also suffers from lack of affordable energy services. Application of stand-alone PV systems in the local villages can contribute to more reliable health and communication services and, consequently, better health, educational opportunities and reduction of poverty.

This paper describes a contribution of photovoltaics to the recovery of Vanuatu from Cyclone Pam — the design and implementation of stand-alone photovoltaic systems (SAPS) for remote dispensaries on Tanna. It describes system sizing and design, including load estimation, simulation, practice and implementation in village dispensaries, and comments on social impact and provides discussion and recommendations for future directions. The paper also provides a taste of the logistical challenges provided by inter-island shipping and unavailability and misunderstanding of standards and guidelines.

The implementation of the designed system was conducted and completed in April 2016 during an 18-day trip to Vanuatu. Following the upgrade of an established PV system in one village, a stand-alone PV system was installed in the village of Ikuaramanu, providing an average annual energy output of 263kWh/year, allowing LED lamps usage and cell phone charging at the regional dispensary. A user manual was provided and a payment program (for phone charging) was designed, for long-term reliable operation.

This grass-roots approach addressed basic needs that were not being satisfied by conventional services and needed a direct and community-centered approach. The same approach will also guide another student trip in January 2017 to reinstate vaccine fridges, solar lights and phone charging in remote Tanna communities.

1. Introduction

1.1. Background

Severe tropical Cyclone Pam was the strongest tropical cyclone in the southern hemisphere in 2015 and it is considered one of the worst natural disasters in the history of Vanuatu (Robertson, 2015).

According to United Nations Children's Fund, at least 132,000 people in Vanuatu have been affected by tropical Cyclone Pam and around one third of them are children. Cyclone Pam has resulted in the communication paralysis across Vanuatu and there was only one cellular tower remaining operation in Port Vila (ReliefWeb, 2015). Approximately 60 inhabited islands became cut-off from the outside world due to this cyclone (BBC News, 2015). The electrical grid system in Vanuatu was also destroyed and officials estimated that repairs could be long delayed. In Vanuatu, as many as 90% of the buildings were affected. Hospitals, schools and water sources were also destroyed or compromised.

On the island of Tanna, most concrete buildings held up during the cyclone but lost their roofs. A pilot who flew to the island reported that all the infrastructure was damaged to some extent (Robertson, 2015). According to the United Nations Educational, Scientific and Cultural Organization, up to US$268.4 million is needed for recovery and rehabilitation of Vanuatu (Preventionweb.net, 2015).

Ongoing communication with Jacob Kapere, chief of the village of Imaki, on the island of Tanna identified that many villages in the island of Tanna have still been suffering due to lack of electricity and damage to previous energy services caused by Clone Pam.

1.2. Objectives and Motivation

The basic and primary objectives of this project are to design and install appropriate and reliable energy services supplying necessary loads for the dispensaries on the Island of Tanna. The energy service should also be renewable, clean, and suit the local culture and circumstances, especially for emergency situations. Meanwhile, the loads should satisfy routine local basic needs to the maximum possible extent.

The dominant motivations of design and implementation of reliable energy services are to take action to mitigate damage caused by Cyclone Pam, thus improving the life quality for local people through application of photovoltaics engineering.

1.3. Location

The village of Imaki and Ikuaramanu were chosen as target sites due to suggestion from a local community leader.

The village of Imaki is located on the southeast of Tanna which is the second southerly island among the archipelago of Vanuatu and the island lies between latitude 19°S and 20°S and longitude 167°E and 168°E, while the village of Ikuaramanu is located on the east of Tanna, close to the active volcano, Mt. Yasur.

2. Design and Sizing

2.1. Design Criteria

For reliable and effective long-term running of stand-alone photovoltaic systems (SAPS) in Imaki and Ikuaramanu, it is vital to confirm suitable design criteria to meet the social, geographical and cultural environment before carrying out needs assessment, load estimation and component sizing.

- Oversizing

Unfortunately, no preliminary site visit was possible for this project, leading to the lack of basic information needed for the design of SAPS, such as electrical load, shading problem, indoor layout among other things. In addition, the design capacity of SAPS should take incremental growth in demand for electricity into consideration.

- Interaction

Another criterion is that the user or the villagers can observe the performance parameters, such as energy production, load consumption, SOC of battery.

- Reliability

Reliability is the most important design criteria of SAPS due to the remote, rural area and limited local expertise. Even though the village committees take responsibility of the operation and management of SAPS, there tends to be insufficient local expertise so reliability of the components and materials is paramount.

Moreover, the lifetime of components has a great impact on the reliability. Especially, the battery lifetime should be emphasized as it is a relatively unreliable component of SAPS in remote areas (Hankins, 2009), if inverters are avoided. Additionally, the lack of funds for long-term maintenance is another challenge.

2.2. Load Assessment and Determination

The primary need identified for the dispensary in the village is to provide electricity for lighting under emergency situations, such as the occurrence of tropical cyclone, in case of the need for injury responses. Additionally, cyanosis lamps, which can detect cyanosis—the bluish discoloration in the skin, indicating that oxygen levels in the blood are dangerously depleted, are to be included and applied in this project, It is desirable to provide the function of phone charging, for communication in case of emergencies. In order to benefit as many stakeholders as possible, laptop charging is also to be provided for the resident nurse in each dispensary.

Basic needs, in terms of lighting and the cell phones, were estimated from discussions with Jacob Kapere and Daniel Samson from the Tanna branch of the National Disaster Management Office.

The load assessment followed the procedure indicated in AS/NZS 4509.2. Energy efficiency principles, such as the application of LED lamps rather than compact fluorescent lamps have been applied to reduce the estimated energy demand. A generous load estimate was made, since there was no chance to undertake site visit and reliability was important. The oversizing also guards against failure of the designed SAPS if the local people increase their energy demands.

2.3. System Design

As it is determined that the load consists of lighting, phone and laptop charging and they could be powered either through DC or AC voltage by converter or transformer. The cost of an inverter is fairly high and it is less reliable compared to other components (Bower, 2000). Meanwhile, the introduction of AC high voltage can result in the danger to local people, which is the main consideration. However, for extra low voltage DC systems, transmission should be emphasized in the design, to prevent excessive voltage drop and consequent high energy loss.

The system design followed AS/NZS 4509.2 including component sizing and specification, circuit protection and transmission regulation. The electric schematic for the designed SAPS is shown below (Fig. 1).

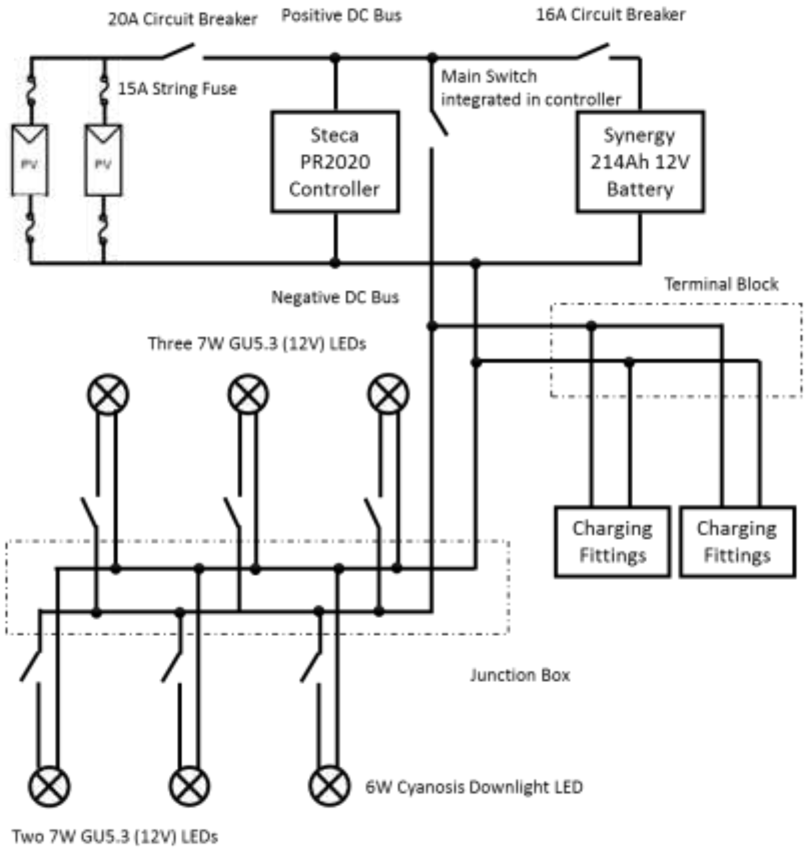

Figure 1. Final electric schematic for installed SAPS in dispensary of Ikuaramanu.

2.4. Simulation & Modelling

Unfortunately, there is no ground measured solar irradiance data for the target site. Thus, satellite based data from NASA SSE was used for this project, in spite of the consequent lower accuracy.

Simulation for designed SAPS was conducted through PVSyst 6.3.0 in order to check the performance of the designed system before implementation and to allow improvement based on the feedback from the simulation. The simulation results, including energy collection and system loss, unused energy and energy supplied to users, are shown in Figure 2, assuming constant monthly energy consumption (PVSyst, 2016). Moreover, the unused energy can be regarded as an allowance for future load growth.

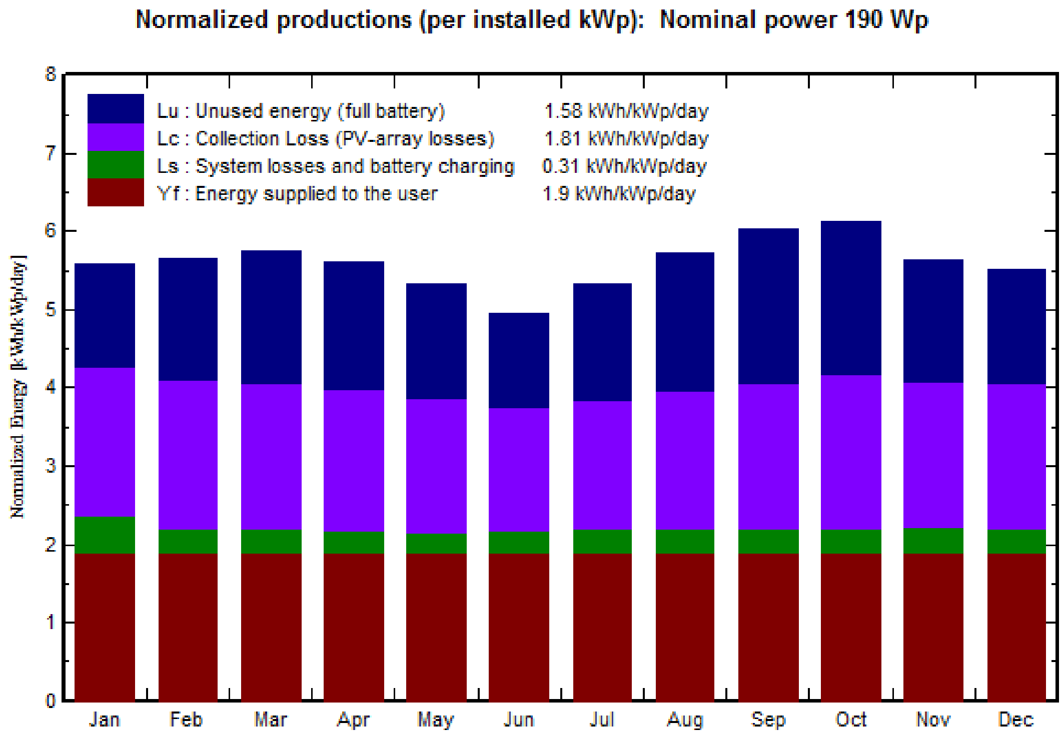

Figure 2. Monthly normalised production of designed SAPS

2.5. Implementation

The designed SAPS was not installed in the village of Imaki as it was found that there had been two existing SAPS working for the dispensary of Imaki, one designed for a vaccine fridge and the other for lighting and charging. Thus, assessment of existing SAPS (for lighting and charging) was undertaken and consequent improvement was carried out, resulting in decision and action to move the existing PV modules away from Winter shading sources, including trees, a flag pole and the dispensary building.

Fortunately, implementation of designed SAPS was successful and smooth in the village of Ikuaramanu, leading to energy availability for illumination and charging, fulfilling the initial objectives.

Modules are planned to be removed and protected in case of future cyclones for both villages.

3. Barriers

3.1. Financial Barrier

- Financial support

There was insufficient funding for a preliminary site visit, leaving just one chance to finish the implementation in Vanuatu.

- Currency exchange

One intention of this project was to support the local renewable energy industry. Photovoltaic modules, batteries, and cables were ordered and purchased through local suppliers in Port

Vila, the capital of Vanuatu. However, payment for the purchase could not be easily processed from Australia as they only accepted the bank transfer in local currency or cash.

- Higher cost of components in Vanuatu

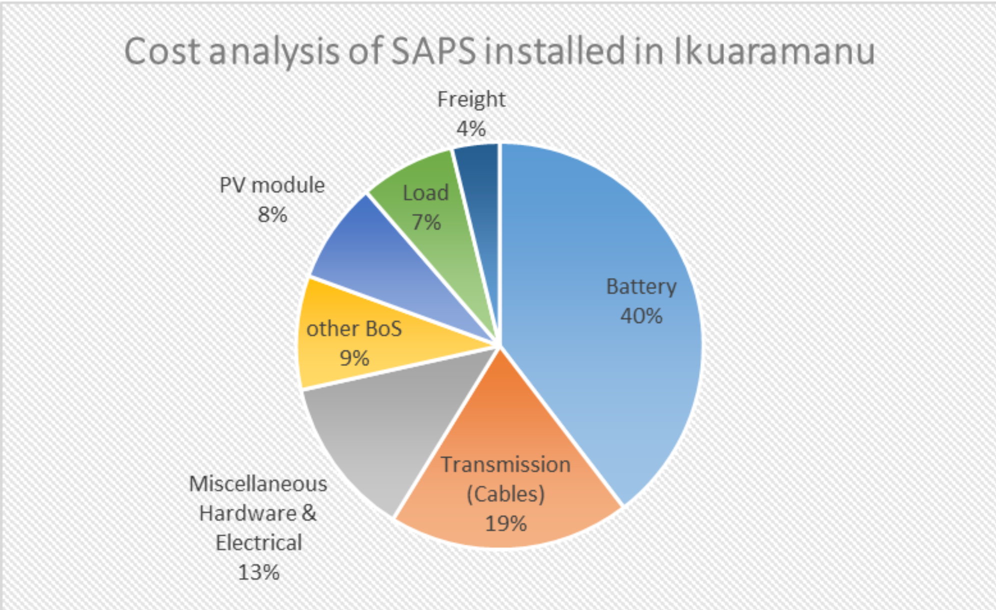

Figure 3. Cost analysis of SAPS installed in Ikuaramanu

As almost all the components purchased in Vanuatu were imported from overseas such as Fiji and New Zealand, the import duty of around 40% was charged. These included the heavy and bulky components, such as batteries and cables, which dominated the cost (Fig. 3). Meanwhile, 12.5% of commercial tax was also applied which means around half of the price was paid for taxation and duty charged by government for most components, which significantly raised total cost of the system. For future projects in Vanuatu, waivers for such kinds of taxation and duty could be sought, due to the purpose of support and aid rather than commercial application.

3.2. Information Gathering and Communication

Since a preliminary visit was not possible, many parts in the design were based on estimation and oversizing to allow for the possible variation. Moreover, inefficient and ineffective communication was another constraint as the project relied on local people to provide sufficient necessary information and it was mainly conducted through email as international calls are too expensive for local people.

3.3. Immature Infrastructure and Industry

- Transportation Industry and Infrastructure

Transportation by inter-island shipping of some materials and tools was delayed for around 8 days, which threatened the whole project. The local shipping companies in Port Vila provide relatively uncertain schedules and there were no precise times for departures. Meanwhile, the trips could be postponed due to the bad weather or incomplete cargoes. For smaller shipping business, the deal was just agreed orally and the departure date cannot be confirmed in advance.

- Renewable Energy Industry

First of all, it was difficult to have internet access to the local suppliers, which was the first barrier. As initially, it was fairly difficult to find a supplier. Moreover, most of local suppliers offered cheap products based on the sacrifice of quality as many local customers have a low level of understanding of quality measures and accreditations. Such phenomenon can restrict of high quality components and smear the image of renewable energy services. On the other hand, it was discovered during this project that high quality components and services are also available in Port Vila.

3.4. Education

Lack of relevant knowledge was a serious problem for such kind of projects, especially for their long term reliable performance. Firstly, maintenance of SAPS needs expertise and qualified staff. However, most communities or villages lacked access to a qualified electrician. Moreover, a concern was raised about applying additional loads to the installed SAPS after the installation team realized a local community had extended a cable from the dispensary to the staff house for phone charging and occasional entertainment. It could not be concluded that such action was damaging as the system had been designed and installed by others but estimation and calculations should be undertaken before such extensions to ensure the safety of the system, especially the battery.

4. Future direction

4.1. Future Projects

The installation trip in April 2016 was also regarded as a site visit for future projects. Further new energy systems for remote dispensaries on Tanna Island as well as some maintenance and improvement projects have already been begun. New projects are being prepared and an installation trip is going to be conducted in January 2017.

4.2. Interaction with local community

An effective and efficient interface and communication between authors and local community can contribute to better performance in terms of maintenance, fault detection, components replacement and potential load growth. Additionally, authors communicated with local community through phone regarding solutions to situation that two installed LED lights did not operate, post departure of the installation team, but other load remained working. It was repaired by the local people following guidance.

Interaction between system and local community is also fairly vital as the smart charge controller can provide abundant parameters regarding the operation of designed SAPS. Local community can refine the energy usage behaviour according to daily generation and usage coupled with battery SOC. However, the basic understanding of the system remains a problem and thus it is recommended that basic education in terms of SAPS could be involved in future projects.

4.3. Cooperation of Vanuatu Government

Based on experience learnt during the installation trip, closer cooperation with Vanuatu Government should be considered. Firstly, anecdotally, the Health Department has funding for application and installation of SAPS for dispensaries in remote areas (Kapere, 2016). Such student projects of School of Photovoltaics and Renewable Energy Engineering, UNSW could be fairly attractive to the Vanuatu Government as there would be no consideration for cost of labour. Moreover, due to the purpose of aid rather than business, import duty and taxation on the solar components, whether purchased in Vanuatu or shipped from Australia, could be waived, reducing the capital expenditure on components by approximately 50%.

5. Discussion and Conclusion

This project of recovery from Cyclone Pam for Vanuatu was initiated to help the local population recover after occurrence of disaster. The main objectives, to provide reliable energy services with lighting and charging systems for dispensaries on the island of Tanna, were successfully achieved in April 2016.

Although previous practice in 1980s illustrates that free donation is not necessarily the best way to apply renewable energy services, as local committee may not cherish something donated (Gregory and McNelis, 1994), the installed stand-alone power system in Ikuaramanu is expected to produce an average annual energy of 263kWh per year without carbon emission and diesel consumption, which relives financial burden on local community. The energy production of PV array exceeds normal daily energy demand but meets the demand in worst cases such as occurrence of cyclones, allowing for potential growth of energy demand. A small market of electricity for phone charging has been suggested and a price of per charging is set so the local committee will be able to pay for future replacement of components and potential ongoing maintenance.

The designed stand-alone power system operating in the dispensary of Ikuaramanu has been providing valuable energy services, thus contributing to local electrification. Meanwhile, provision of solar energy improves local health and communication services, resulting in better quality of life. Furthermore, the project also provides a foundation for future directions and recommendations for developments of future renewable energy projects have been considered.

Figure 4. Villagers in front of dispensary with installed PV modules in Ikuaramanu

Acknowledgements

Authors would like to thanks for the generosity of following donors, UNSW Natural Disaster Recovery Initiative, St Marys Senior High School, SPREE and UNSW staff and their families, with whose financial support the project has been successful. Thanks also to Adam Kornhauser, the Commercial Manager Medical at Planet Lighting, which generously donated cyanosis lamps for the project.

Also, thanks to staff and students, Audrey Kaur and Felicity Yee, at Temasek Polytechnic in Singapore for their preliminary work and suggestion for application of cyanosis lamps. Thanks to Jieying (Elaine) Xue for her hard work on communication with local suppliers and purchase of travel essentials.

An enormous thankyou to the communities of Imaki and Ikuaramanu for their hard work and hospitality. Thanks to Noel for his guidance and willingness to finish off the job at Imaki. Thanks to Gibson's family and Dominic for their hospitality. Thanks also to Jacob, Jackson and Daniel for their support and arrangement.

References

BBC News, (2015). Cyclone Pam: Vanuatu islanders forced to drink saltwater - BBC News. [online] Available at: http://www.bbc.com/news/world-asia-31917913 [Accessed 2 Nov. 2016].

Bower, W. (2000). Inverters—critical photovoltaic balance-of-system components: status, issues, and new - millennium opportunities. Progress in Photovoltaics: Research and Applications, 8(1), pp.113-126.

Gregory, J. and McNelis, B. (1994). Nontechnical barriers to the commercialisation of PV in developing countries. Proceedings of 1994 IEEE 1st World Conference on Photovoltaic Energy Conversion - WCPEC.

Hankins, M. (2009). Stand-alone solar electric systems. Earthscan, London.

Kapere, J. (2016). pers. comm.

McGrath, C. (2009). The Design and Installation of a Remote Area Power Supply System in Vanuatu: Pico-hydro in a Development Application. Bachelor Thesis. UNSW.

Preventionweb.net, (2015). UNESCO supports recovery of Vanuatu's culture sector following Tropical Cyclone Pam - News - Professional Resources - PreventionWeb.net. [online] Available at: http://www.preventionweb.net/english/professional/news/v.php?id=44408 [Accessed 16 Sep. 2015].

PVSyst. (2014). PVSyst Software. Available at: www.pvsyst.com/ [Accessed 2 Nov. 2016]

ReliefWeb, (2015). Emergency - Cyclone Pam, Vanuatu. [online] Available at: http://reliefweb.int/report/vanuatu/emergency-cyclone-pam-vanuatu [Accessed 16 Sep. 2015].

Robertson, J. (2015). Cyclone Pam: aid agencies report widespread devastation in Vanuatu. [online] the Guardian. Available at: http://www.theguardian.com/world/2015/mar/15/cyclone-pam-vanuatu-more-deaths-water-shortages-storm [Accessed 2 Nov. 2016].

NASA SSE (2016). NASA Surface meteorology and Solar Energy. Available at: https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=skip@larc.nasa.gov [Accessed 2 Nov. 2016]