The Design, Installation, and Maintenance of a Village-Sized Solar Power System in Uganda

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ABSTRACT

Power production and distribution in the developing world is a significant challenge for local and national governments. The high cost of distribution and the low reliability of production result in intermittent availability of electricity which hampers economic development. One means of alleviating this intermittency is through local production, storage and distribution that would avoid reliance upon a national grid system.

There are many potential energy sources that can be used for small-scale, localized electrical production including wind, hydro, solar, and biomass as examples. The selection of energy depends on the local geography and must be suited for the specific situation.

In this project, a small-scale solar power system was designed to electrify a village in a remote region of Uganda. The system was designed to provide lighting to approximately 50 homes, one school, and one pharmacy. In addition, four electrical outlets were included to allow charging of cellular phones and other small electrical devices. The success of the project demonstrates that similar small-scale solar-powered systems can be implemented in the developing world where grid-connected power is unavailable.

Keywords: solar power, rural electrification, developing world, sustainable energy

1 INTRODUCTION

Power production for civilian use in the developing world continues to be a challenge for governments who hope to stimulate economic growth and improve living standards. In some situations, no electricity is available. In other cases, electricity is made available but is primarily restricted to industrial utilization.

A consequence of this situation is that many citizens in developing nations are left with little to no electrical supply. On the other hand, small amounts of electrical power have the potential to make significant impacts on the quality of life. Electricity can provide lighting in the early morning and late afternoon times which lengthens the commercial day, it allows students to study, and it provides security. Additionally, with the penetration of cellular communications into these regions of the world, electrification allows the charging of mobile communication devices.

Numerous studies have shown a close relationship between power availability and poverty rates [1-3]. An understanding of the inter-relationships between power availability and societal health is important in nations such as Uganda where approximately 5% of the population has access to electricity [4]. In fact, the geovernment of Uganda recognizes this connection and, in cooperation with the World Bank, has developed a rural electrification plan. That plan focuses on increasing electrifical investment in rural Uganda [5].

In support of these endeavors, our research team embarked on a project to provide a sustained source of solar power for a small remote village in Western Uganda. The project involved the design, assembly, installation, and testing of a system that was suited for the target environment. The team worked extensively with local inhabitants to ensure the proper maintenance of the system would continue long after the final installation.

The success of the project demosntrates that small-scale solar-power systems are capable of providing electricity to regions of the world that are otherwise off-grid.

2 SYSTEM DESIGN

The village is dispersed along a dirt roadway; the linear length of the village is approximately 300 meters. The total electrical load of the village was constituted by 93 seven-Watt light bulbs and four outlets. The duration of power usage is controlled by a mechanical switch that allows morning and evening lighting. It is anticipated that during the morning, up to 700 W-hours of energy will be drawn while during the evening, at most 3300 W-hours will be used. The basis for these estimates is provided in Eqs. (1) and (2).

Morning energy requirements

$$50bulbs \cdot 7\,W \cdot 2\,hrs = 700W \cdot hrs \qquad (1)$$

Evening energy requirements

$$95bulbs \cdot 7\,W \cdot 5\,hrs = 3325W \cdot hrs \qquad (2)$$

It is further anticipated that approximately 1000W-hrs would be used each day for charging mobile communication devices. Therefore, our design goal required the supply of approximately 5000W-hrs of energy each day.

In order to increase reliability and robustness, our system was designed in a modular fashion with two parallel, independent energy sources and distribution systems. Each system had identical power-production capacity. The modularity in the design provides some safeguard so that if one portion of the system malfunctions, the entire system would not be disabled.

Each of the systems contained a number of key components: (1) four 175W solar panels, (2) a Maximum Power Point Tracking system (MPPT), (3) two 12-Volt lead-acid batteries, (4) an inverter, and (5) a mechanical switch to control the operating hours of the system.

The MPPT increased the efficiency of the charging operation so that lost energy would be minimized. The total energy generated daily by the solar panels is estimated to be approximately 10,000Watt-hrs which is in excess of the expected requirements for the village.

A schematic diagram showing the relative positions of the components in the solar charging system is provided in Figure 1.

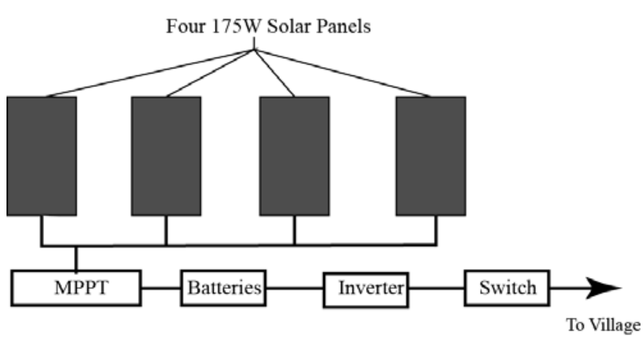

Figure 1: Wiring diagram of solar array.

2.1 The Installation Location

The targeted village for the installation was Kitembe, which is shown in an aerial view in Figure 2. This village contains approximately 50 one- or two-room mud houses in the Ntungamo district in Western Uganda.

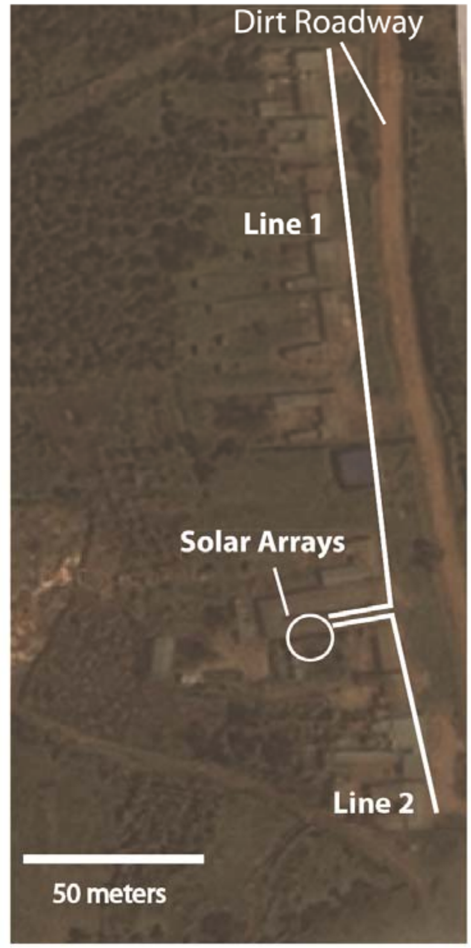

Figure 2: Aerial photograph of village and positioning of solar array and power lines.

The solar arrays were located on a private plot approximately 20 meters from the axis of the village. The two independent power lines are shown separately in the figure.

The solar arrays were housed in a small mud and brick structure that served a number of purposes. First, it reduced the daytime temperatures which is critical to the lifetime of the batteries. Second, the structure had a metallic frame which allowed the placement of the solar panels in an elevated and unobstructed location. Third, the shelter had internal shelving to protect against the potential threat of water. Finally, the structure and an exterior fencing that allowed a secure location for the arrays. A photograph showing the top of the structure with four visiable solar panels, razor wire, and a local rooftop in the backgroun is presented in Figure 3.

Figure 3: Photograph of the solar panels behind a wire fence.

2.2 Local Residences

The homes which populate the village are small, mud-walled dwellings with one or two rooms. The roofs are constructed by timbers laid horizontally to support corrugated sheet metal. A photograph showing the inside of a typical dwelling is provided in Figure 4. In that figure, installation of a single 7-watt bulb is occuring by hanging wiring from the supporting timber.

Figure 4: Photograph showing the installation of wiring within a dwelling.

3 RESULTS

The completion of the installation was followed by the electrification of the village and a series of instructional lectures given to the village population on the proper care of the solar system and disposal of the compact flourescent bulbs. A photograph showing lights along the outside of a number of hosues is provided in Figure 5.

Figure 5: Lit bulbs along the outsides of homes in the village.

The total cost of equipment was approximately $7000. The total cost of the project was $23000 and included ground and air transport for volunteers. It is believed that future projects which rely upon volunteer funded travel will be able to reduce the overall project costs to approximately $10000. More details of the project are presented in [6].

4 CONCLUDING REMARKS

This work has showcased a low-cost and successful installation of solar power electricity in a rural village in the developing world. The targeted country of Uganda currently experiences high rates of poverty and lack of electricity.

The design described here was a modular solar-power array capable of electrifying a small village

The success of the pilot project has encouraged our research team to explore opportunities for replicating the success at other locations within Uganda and the developing world. We are currently seeking external funding sources for the continuation of this project.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support of Xcel Energy and the University of St. Thomas, Office of the President.

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