South Sudan Rural Electrification Project

The Hybrid Mini-grid & PBK Project

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Abstract— **Village Help for South Sudan in collaboration with IEEE's Community Solutions Initiative (CSI) and private donors are striving to create a sustainable business model for rural electrification in South Sudan, one of Africa's least developed countries. The pilot project is a combination of Mini-grid PV system with Portable Battery Kits (PBKs) as a means of delivering electricity to remote regions. The 4.2 Kilowatt PV system will have a Mini-grid to connect customers living within range; it will also be used as a charging station for PBKs that are used by customers not able to connect to the grid. The Mini-grid, which is most commonly used to bring electricity to remote areas does have drawbacks in its limited capability and reach beyond a few hundred meters. The PBK model developed by IEEE's CSI has the advantage of its great portability, allowing customers to charge their portable batteries at the main station and take them to light their home and charge small electronics such as cell phones and radios. A single PBK, however, has very limited power reserve and does not deliver any AC Power often required to power many electronics. The goal of this pilot is to test the effectiveness, scalability, and business sustainability of delivering electricity to remote regions of the world using the hybrid model of Mini-grid and PBKs.**

I. Background and Introduction

Energy poverty in the world, in spite of the fact that it was common knowledge to most, had been shunned up until now. Last year, the United States government passed the "Electrify Africa Act" which attempts to direct aid specifically to energy sectors in the sub Saharan Africa. According to the International Energy Agency (IEA), "Globally, over 1.3 billion people are without access to electricity and more than 95% of these people are either in sub-Saharan Africa or developing Asia and 84% are in rural areas." In the sub Saharan Africa alone, 589 million or 68% of the population, are without access to electricity according to the U.S. government's Electrify Africa Act of 2013. South Sudan is one of the Africa's most impoverished countries, certainly one of the toughest to access. The country has been involved in many prolonged civil wars since Sudan's independence in 1956, and currently still rages in three of the country's ten states. This has frustrated any attempts to build basic infrastructure to initiate development. This also means that the country has had no opportunity to develop critical institutions to foster the provision of basic electricity, even to its main cities. The only grid is located in the country's capital, Juba, and only runs for 8 to 12 hours a day. The rural population, hence, has no reasonable hope of connecting to the grid anytime in the next twenty years. Village Help for South Sudan in collaboration with IEEE's Community Solutions Initiative (CSI) and private donors are attempting to create a sustainable business model for rural electrification in South Sudan, one of Africa's least developed countries. We are incorporating the ideas of professional engineers from the Institute of Electrical and Electronic Engineers (IEEE), the entrepreneurs, and the villagers themselves to come up with a solution that makes rural electrification practical both from a business and customer perspective. The pilot project is a hybrid Mini-grid Photovoltaic (PV) system with that of the Portable Battery Kits (PBKs) as a means of delivering electricity to the remote villages in South Sudan.

II. The Problem

The mini-grid, which has been widely used and lauded as one of the best methods to bring electricity to remote areas, does also have its disadvantages. To clearly define what scope we are talking about when we say "the mini-grid," we are talking about systems sized anywhere between 1 and 50 Kilowatts. In addition to that, we are only using photovoltaic panels as our power supply source. The mini-grid is certainly great for remote locations for it can be designed to fit the exact need anywhere. The problem is that there is always a "but" in there, and that refers to their high cost. The issue behind these mini-grids has been the difficulty to put together a rational business plan to attract a large scale investment. Another obstacle for mini-grids is that although small in scale, they require considerable skill to install and maintain, necessitating leadership by the local talent. In South Sudan and much of sub Saharan Africa, this is hard to find as technical training in electrical power industry has not be prioritized. South Sudan, for example, has no technical training institutions and Electrical Engineering is taught by just one higher learning institution. The PBK model developed by IEEE's CSI has the advantage of its great portability, where customers can simply charge their portable battery at the main station and take it to light their home and charge small electronics such as cell phones; and this they can use no matter how far away they live from the station. With this proven model, millions of rural villagers can have their homes lighted within a few years. It does not, however, deliver any form of AC Power that is often required to power many electronics. It also has very limited

power reserve and hence is unable to adequately power large electronics such as televisions, Computers, and fans.

III. Solutions

A. The Mini-grid

The mini-grid will be installed in market areas mostly in rural areas. In a market survey we conducted in 2013 to get a general picture of the need for electricity in small marketplaces, it was found that virtually 100% of the shopkeepers' desired electricity. The survey indicates that they are willing to pay an average of $35.14 a month, a much higher pledge than indicated by the survey in the surrounding residential areas. This is reasonable because the shopkeepers would benefit from longer hours of operation with the additional ability to sell refrigerated goods at premium prices. This system will be mounted on poles next to the iron-sheet frame construction to house sensitive electronics and the battery bank.

- System

This is a 48 VDC system. Its designed output is 4.2 Kilowatts with a 900 Ah battery bank and a 6 Kilowatt inverter. It employs two charge controllers both rated at 150 VDC, 80 A.

- Panels

Twenty four 175-Watt monocrystalline solar panels, able to provide 4.2 Kilowatts of power

- Controllers

Since one charge controller rated at 150 VDC and 80 A cannot handle the entire array, two of them are used as pictured in figure 1 below.

- Inverter

Outback Power FlexPower Two. This is an integrated system containing two inverters, each rated at 3 Kilowatts, bringing the system's inversion capability to 6 Kilowatts.

Figure 1: Outback Power's Flexpower TWO

- Battery Bank

The system will use sixteen Rolls/Surette S600 batteries. These are 450 Ah (20hr), 6 volt deep-cycle batteries. Eight of them are wired in series to get a 48 volt system and two strings in parallel to get a 900 amp-hour capacity.

- Transmission Line

The mini-grid power will be distributed via a 150 meter, single phase, household gauged conductor. The main conductor will be an 8 AWG and the line to customer conductors will be a 12 AWG.

IV. The Portable Battery Kits

Portable Battery Kits are a set of small 12 volt deep cycle batteries. They are normally encased in a box to enable connection of LED bulbs and Universal Serial port (USB) outlets for charging of small electronics. A single PBK comes with two or three 2-watt LED lamps, wires, and switches. Rated at about 200 watt-hours and a discharge limit of 50% governed by an integrated low voltage disconnect switch, the batteries will give typical customers about 20 hours or four days of usage, assuming they keep the lights on for four to five hours each day. There are several vendors of these PBKs, including BBOXX, whose brand will be used in this pilot project. The specific brand is BB17 kit as shown in figure 2 below

Figure 2: BBOXX's BB17 Kit

V. The Business Model

The business plan of the hybrid system is separated into the two respective energy delivery services, the mini-grid and the Portable Battery Kits. Meters will not be utilized in the mini-grid system, however, customers will be charged based on the number of electrical devices they use, as is the norm in the country. The number of customers expected is between 35 and 45. Since customers use electrical devices varying anywhere from a single light bulb up to two refrigerators and TVs, estimated revenue is based on a range rather than a squared expectation. Below is a summary of the devices the customers said they would be using during the survey and the estimated revenue.

Device (s) used by customer	Unit Price	Quantity	Estimated MonthlyRevenue
Single Light bulb	$5	15	$75
Two Light bulbs	$5	10	$100
Three light bulbs	$5	5	$75
Refrigerators	$62.5	5	$312.5
Cell Phone charging stations	$75	4	$300
Televisions	$65	1	$65
Total			**$927.5**

The business model for the portable battery kits is such that the customer pays a monthly fee of $10. Since 80 PBKs will be in operation, that puts the monthly revenue at $800. The

combined total revenue for the hybrid system comes to $1,727.5 a month or $20,730 a year.

VI. Conclusion

The goal of this pilot is to test the effectiveness and scalability of delivering electricity to remote regions of the world using the hybrid model of mini-grid and Portable Battery Kits. The mini-grid PV system will have a short transmission line to connect shopkeepers in the market and residents living within close range. The station will also be used as a charging hub for Portable Batteries that are used by customers not able to connect to the grid and those living in the far away villages. By combining the two solutions most often used for rural electrification, it is calculated that this will produce a more sustainable way to bring energy to those living in the rural area. The success of this project means the creation of a sustainable business plan that will be easily scalable to other remote regions. With this hybrid system, rural villagers in South Sudan and elsewhere have a new hope of receiving life changing electricity in their homes.

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