Low Cost, Novel PV Powered Water Delivery Project in Rural Ethiopia

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The paper describes the process which led to the success of a renewable energy project consisting of a solar powered water delivery system in Komboltcha, rural Ethiopia. The potable water delivery system serves a few thousand inhabitants of the rural community. The project benefited from the cooperation between the University of the District of Columbia, the Faculty of Technology of Addis Ababa University and a local nongovernmental organization, Hope2020, which signed a memorandum of understanding for the implementation of the project. The project includes a low cost, novel approach to water delivery to the local community, including a double reservoir system at different elevations. The project includes an indigenous design of a pole mounted PV panel support structure as well as the design of an inverter for possible expansion of the project for other applications such as lighting. In addition, the paper describes the data collection apparatus and proposes schemes for project sustainability.

Keywords: PV module, Stand-alone PV System, Inverter,

1 INTRODUCTION

The project described in this paper consists of a water delivery system using solar power for activating a submersible water pump. The project is located in the Chancho Kebena Kebele, Jeldu District, in the West Showa Zone of the Oromia Regional State, in the Federal Democratic Republic of Ethiopia.

A similar project was undertaken in the same Oromia regional State, two years ago [1]. Some of the challenges encountered and lessons learned during this initial project have been instrumental in the realization of this project. The phase I of the project was completed during the year 2010 and inaugurated in March 2010. The phase II, which is now under design and construction, is expected to be completed in 2011. The novel aspect of the project is that it only utilizes DC voltage for activating the pump. The water level is purposely selected to be of shallow nature, i.e. not exceeding 100 m, in order to satisfy the specifications of the DC/AC submersible pump to function a DC only mode. In most similar projects, when the water head exceeds 100 m, an AC system needs to be used due to the lack on the market of DC submersible pumps able to operate at that depth.

In the phase II of the project, water will be pumped out of a reservoir built during the phase I. The altitude of the second reservoir is selected to be within the range of the capability of a DC pump, similar to the one used in phase I. The water which will be stored in the second reservoir benefits from a higher gravity for providing more water points to the local community.

2 LOCAL PREPARATIONS

2.1 Solar Panel support design

The frame design was entirely accomplished with local talent and local craftsmanship. The frame is designed to support six (6) BP3170 [2], 170W modules. It is depicted in Fig.1.

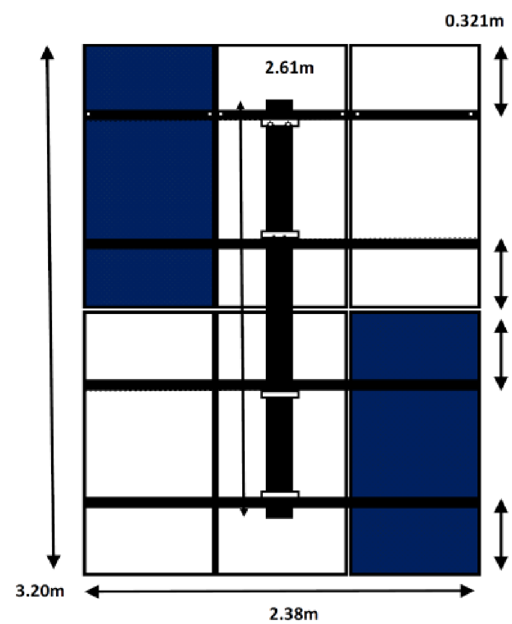

Figure 1 Frame design for supporting 6 BP370 modules

The center of the frame sits on a can like structure which serves as an adaptor to a pole structure. The can which supports the entire frame is screwed to the pole but can easily pivot on the pole for manual sun tracking. To allow for manual sun tracking during the various seasons, a tilt angle adjustment apparatus is provided at the can frame connection, as depicted in Fig. 4.

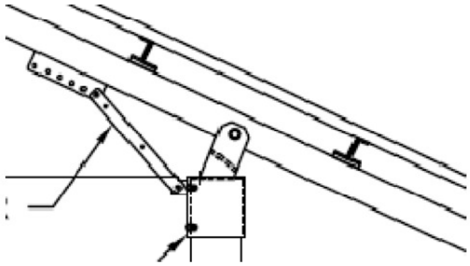

Figure 4 Manual sun tracking adjustment scheme.

A local metal worker was commissioned to build the structure, including the adaptor can, with steel purchased on the local market. The cost of the frame was almost an order of magnitude lower than the one used in the Ambo project [1], which was purchased from a company in the US. The locally built structure and the adaptor can are shown in Figs. 2 and 3 respectively.

Figure 2. Panel support frame structure with steel

Figure 3. Adaptor Can built with steel (held by the author)

The final frame assembly with the angle adjuster and can adaptor is depicted in Fig. 5.

Figure 5. Panel support frame assembly.

2.2 Panel support pole design.

The support pole was designed to withstand local wind conditions and storm winds up to 100m/s. Six feet underground and six feet above ground were considered to be the most suitable dimensions for the desired specifications. The pole was built with steel reinforced concrete, using local talent and is depicted in Fig. 6

Figure 6. Frame support concrete pole

The final pole-mounted module support structure, including the control box, IO101 from Grundfos for pump ON/OFF and for monitoring the delivered electric voltage from the modules is shown in Fig. 7.

Figure 7. Final pole-mounted module support structure with I200 control box.

In addition, the NGO, Hope2020 made all the necessary arrangements with the local community for securing land for the installation of the PV modules and for obtaining permission for the taping the spring water.

3 SPRING BOX and RESERVOIR for phase I

The reservoir and spring box were built simultaneously while the solar module support structure was being completed, all using local talent.

3.1 Spring box and capping

In phase I of the project, a 5.5 m long spring box and a 10 m^3 collection chamber were built. Figures 8, 9, 10 and 11 show the spring box, the collection chamber, the spring box access and the finished, capped spring box, respectively.

Figure 8. Construction of the spring box

Figure 9. Construction of the collection chamber

Figure 10. Access to the spring box

Figure 11. Capped spring box

3.2 Reservoir for phase I

A 15 m^3 reservoir was constructed at about 1,200 m on a higher ground (about 65m) from the collection chamber. The reservoir has 8 built-in water taps to accommodate eight villagers at a time.

Figure 12. A 15 m^3 reservoir for phase I

4. Water points and distribution system

4.1 Distribution

A 2,500m water distribution HDPE pipe system was laid connecting the water chamber at the spring level to the reservoir and back to two water points. The soil excavation for installing the pipes and the back filling was entirely done with the help of the local volunteer villagers.

4.2 Water points

Two water points with six faucets each were installed at a convenient location for easy access by the local villagers. The faucets have been a major source of excitement and socialization for the locals, as depicted by Fig 13.

Figure 13. Water point with six faucets

The water was inspected and tested for potability by the Pasteur Institute in Addis Ababa.
The phase I was inaugurated on March 3, 2010 as shown in Fig. 14

Figure 14. Inauguration of phase I

4 PROPOSED PHASE II

4.1 Proposed scheme

The phase II of the project is intended to provide:

- More water points to the local villagers at a longer distance from the first village;
- Electricity supply to the villagers for minimal use such as lighting and mobile phone charging etc…

The phase II of the project, which is shown in Fig. 15, will comprise the following:

- A pole-mounted solar module panel positioned next to the reservoir of phase I;
- A submersible DC pump to be installed inside the reservoir of phase I;
- A 50 to 70 m^3 second reservoir at an altitude of about 60 m from the first reservoir;
- A battery bank with a charge controller; and
- A locally built inverter for providing 220V/50Hz AC voltage to the villagers.

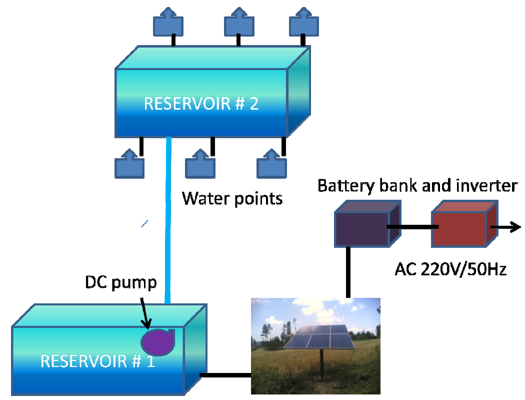

Figure 15 Proposed phase II scheme

4.2 Inverter design

The proposed inverter is designed with inexpensive and simple components, such as insulated gate transistors and elementary logic circuit devices. The power supply for the gate driver circuitry is taped from the DC voltage generated by the solar panels. The 3-phase inverter is shown in Fig. 15 with its corresponding timing diagram of the three voltages, $V_{T,S,R}$ available at the load.

The fundamental component phase voltage generated by the inverter is expressed by equation 1 below; where $\boldsymbol{V_d}$ is the DC voltage from the solar panels or battery.

$$V_p = \frac{2V_{dc}}{\pi}\sin(100\pi t) \qquad (1)$$

The root-mean-square phase voltage, $\boldsymbol{V_{rms}}$, is given by $V_{rms} = 0.45V_{dc}$. In order to obtain ***RMS*** line voltage of 380 volts and phase voltage of 220 volts, the DC voltage from solar panels should be around 500 V. However, during switching, the voltage across the switching devices is normally above this value due to the high rate of change of the current.

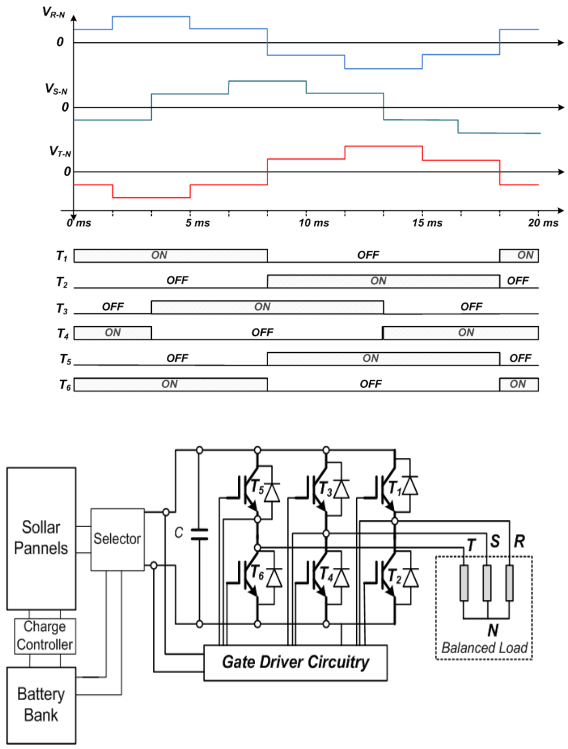

Figure 15 Inverter circuit and corresponding timing diagram.

The inverter is intended to supply AC power to be used by the villagers for lighting of homes or public buildings and

6. ENHANCEMENTS

The following enhancements will be considered:

a. Remote access of the system for monitoring the power as proposed in the project realized at the Farsi Senkele site in 2008 [3];
b. Water delivery to a latrine and public shower area; and
c. Imposition of a minimal water usage fee on the community in order to provide sustainability.

5 COMPARATIVE CHART

The comparison between the main features of the phase I and the proposed phase II of the project is summarized in table I.

Description	Phase I	Phase II (proposed)
Water source	Spring	Reservoir
Discharge rate	1.2 L/s	TBD
Water collection chamber	10 m^3	None
Reservoir	15 m^3	50-75 m^3
Reservoir altitude (head)	65 m from spring	50m from reservoir
Water faucets on reservoir	8	8
Water points	2	6
Water faucets at water points	6	6
Distribution pipe length	2,500m	7,800 m
Solar panels	6 BP 3170	50 BP185
Population served	1,500	3,700
Pump	DC/AC Grundfos	DC/AC Grundfos
Controller box	IO101 Grundfos	IO101 Grundfos
Battery bank	None	Size TBD
Inverter	None	3-Phase Local built
Cost	USD 35K	USD 75 K

Table I: Comparative chart between phase I and phase II

7. Acknowledgements and Conclusion

The support of BP Solar, through its module donation program [4] has been very useful for the realization of the program. A private “anonymous” donor from Northern Virginia, in the US has donated USD15K and his contribution is greatly appreciated. The US Scholar Fulbright Program has partially supported the author, Dr. Samuel Lakeou during the implementation of the project.
It is believed that the phase II of the project will materialize during the course of 2011.

8. References

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