FEASIBILITY STUDY OF A SOLAR WATER PUMPING SYSTEM

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ABSTRACT

Solar photovoltaic (SPV) water pumping systems have the potential to provide clean drinking water to millions of unserved people around the world . The abundant solar energy resource and groundwater availability in the Pacific Island Countries (PICs) can be combined to make much needed potable water available to remote island communities in these countries. This paper looks at the feasibility of using a SPV pumping system in one of the villages in the Fiji islands.

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1.0 Introduction

Access to clean drinking water is a basic human right and one of the eight Millennium Development Goals as adopted by the United Nations in 2000 [1]. According to a WHO report, 6.7 million Pacific Islanders suffer from acute diarrhoea annually resulting in 2800 deaths, mostly children under 5 [2]. Recent cases of cholera in Papua New Guinea and typhoid in Fiji are some of the examples of the challenges faced by the islanders. In 2004, only 43% of urban population and 51% of rural population had access to safe drinking water in Fiji [3].

In most of the islands fresh water resources are: rainwater (collected from artificial or natural surfaces), surface water and groundwater [4]. Groundwater is one of the most important sources of drinking water in almost all PICs and for some islands the only source of fresh water [5]. For example, in Tonga, there are no large surface water supplies and all domestic, industrial, and agricultural water comes from wells, that tap water from a lens positioned above seawater [6]. In Fiji too, majority of the people depend on water sourced from borewells. Almost all borewell pumps are operated using electricity from diesel generators. The dependence of PICs on diesel for the electricity needs is well documented. For example, in 2006, fossil fuels accounted for 85% of regional energy supply [7]. In a recent UNDP study, Fiji, Solomon Islands, Samoa and Vanuatu were found to be highly vulnerable to oil price increases [8].

Renewable energy technologies can play a significant role in increasing access to clean water without increasing the fuel bill. There is tremendous global interest in using Solar Photo voltaic (SPV) technology for water pumping. However, almost 90% of the SPV systems are concentrated in the developed nations like Japan, USA, and the Europe [9]. There are a number of reasons for this with the upfront costs and awareness being the main barriers. For example, India has had a long-term plan since 1993 to install 50,000 SPV pumping systems but until 2004, only 6,780 were installed [10]. However, development of the right impetus and appropriate policies by the national governments, there is no reason why SPV based systems are not widespread throughout the developing world.

The PICs are blessed with abundant solar energy supply throughout the year and SPV systems could provide an economically attractive and sustainable alternative to diesel operated water pumping.

In this work, we have studied the feasibility of a SPV based water pumping system for a rural location in Fiji Islands.

2.0 Methodology

We have used PVSYST 5 [11] to simulate a SPV system that can provide clean water to a rural community in the Fiji Islands. The following sections describe the simulation procedures.

2.1 Location of the project

The community is located in Wailevu, Cakaudrove province, on the second largest island (Vanua Levu) in the Fiji group. This community of about 400 people has experienced serious outbreaks of typhoid in recent years due to contaminated water [12]. The water requirements are estimated to be 26 m^3 per day. The simulated system will have two days of autonomy with 5% accepted loss of load. The most important parameter for SPV applications is obviously solar radiation. The nearest weather station is Labasa and for this simulation, values for Labasa (latitude 16.26 ^{0} South, longitude 178.27 ^{0} East) were used. Fig. 1 shows the global irradiation values for this location with a monthly average of 1873.2 kWh/m^2 on a horizontal surface.

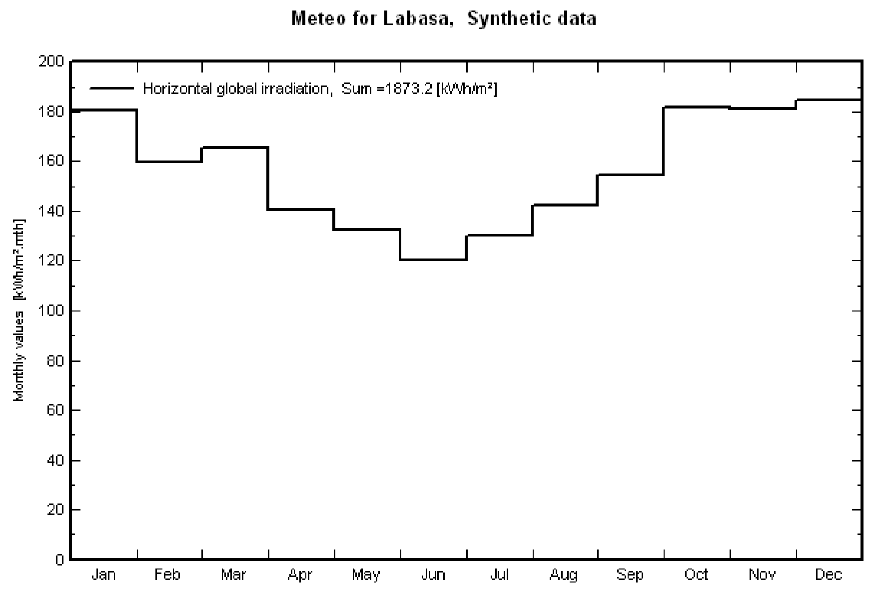

Fig. 1. Solar radiation data for Labasa

2.2 SPV system design

The main design parameters are shown in table 1 below:

Water requirement	26 m^3 /day, two days autonomy
Head	100 m
Pipe length	112 m with 3 elbows + other friction factor of 10
Water storage	50 m^3 , bottom alimentation
Borehole diameter	15 cm
Pump type	Grundfos, multistage centrifugal, 1500 W Model: SP 2A-15 120V
Solar panels	Suntech, 160 W, 29 V, Mono-Si Model: STP 160S-24/Ac
Tilt	Horizontal-optimized for the whole year.
Azimuth	180^0
Power conditioning	MPPT to AC-inverter

Table 1: SPV system input parameters

It was assumed that the solar panels are always unshaded with a free horizon. The calculations were performed on a yearly basis. We have chosen a submersible multistage centrifugal AC pump which is one of the most common pumps used for village power supply [Practical Action].

3.0 Results

3.1 SPV system: technical details

The main results of the simulation are shown in table 2:

PV size	6.4 kW_p, 40 modules: 5 strings of 8 modules in series.
Pump power	3 KW (2 pumps in series electrically)
Water pumped (annual)	9095 m^3 with 4.2% loss of load
Pump efficiency	48.5 %
System efficiency	78%
Average water pumped	24.92 m^3/day , least amount 22.37 m^3 /day in June.
Loss of load (maximum)	13.97 % in June

Table 2: Main simulation results

As can be seen from table 2, the simulated system of forty 160 W solar modules and two 1500 W AC centrifugal pumps will be able to provide about 96% of the water needs for the community. During the month of June, there is a significantly (~14%) reduced supply due to lower solar irradiation.

Figure 2 shows the energy balance of the proposed SPV system. Since the system is designed based on annual needs, there is a considerable excess energy available (tank full) for at least 6 months in a year, which could be used for some other productive use like battery charging.

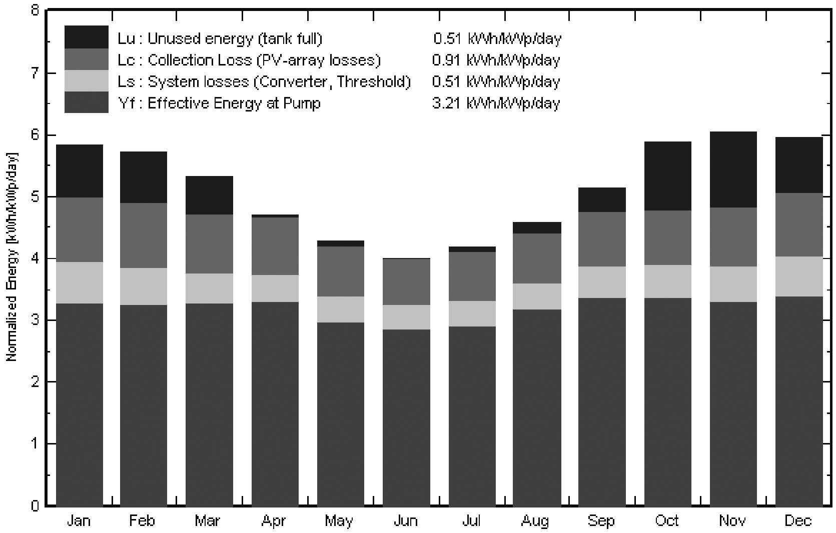

Fig. 2. Energy balance of the SPV system

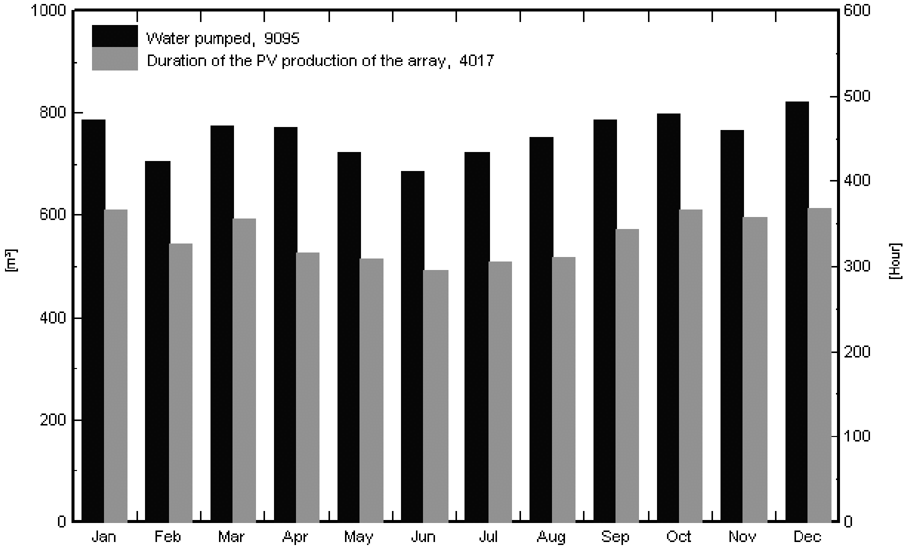

Fig. 3. System performance: Water pumped and PV production

Figure 3 shows the SPV system performance in terms duration of electricity generation and the amount of water pumped. The PV system produces electricity for a total of 4017 hours in a year for pumping 9095 m^3 water.

3.2 SPV system: Economic analysis

The PV system software also allows undertaking economic analysis of the simulated SPV system. For this, the following approximate values were considered:

Cost of PV module: Euro 900.00 per module, Total cost = Euro 36,000.00, life –20 years
Cost of Pumps: Euro 1,000 per pump, Total cost = Euro 2,000.00
Power conditioning: Euro 1,000.00
Wiring etc.: Euro 1,500.00
Running cost (including pump replacement in 5 years): Euro 400 .00
Net investment: Euro 40,500.00
Annuity: Euro 5502.65 per year assuming an annuity factor of 13.59% /year. Loan period 10 years, rate 6%.
Total annual costs: Euro 5902.65 per year

Based on above information, the water cost comes out to be Euro 0.65 per m^3 (approx. 1.64 F$ per 1000 litre). A number of studies have shown that SPV systems are more cost-effective than diesel based pumping especially in island countries. For Cook Islands, pumping costs using solar were estimated to be 30% lower than those with diesel based systems [13]. The O & M costs for the diesel systems are high and transportation of diesel to remote areas is always expensive. A SPV based pumping system is relatively maintenance –free with very low running costs.

3.3 Sustainability issues

While the usefulness of a SPV system is not very difficult to fathom, the long-term sustainability of these systems has always been a sticking point in making them widely available. It is imperative that village level (or nearby) technical skill is available to carry out routine operation and maintenance of the system. In order to assure sustainability, the villagers should assume 'ownership' of the system [14]. According to a study in rural Thailand 'lack of responsibility and village commitment ' resulted in 60% pump failures in [15]. A village water committee should be formed that oversees the operation of the SPV system and collects an agreed water charges from all the consumers. The PV modules can last for 20 years and with proper management by the committee, the SPV system should serve the community for at least that duration. The installation of a SPV system should be accompanied by community education in hygiene, health, and related issues.

4.0 Conclusions

In this work, a solar photovoltaic-based water pumping has been designed for a rural community in Fiji. The system is capable of providing a daily average of 24.9 m^3 water for 400 people in the village with two days autonomy. The water costs are approximately 0.65 Euros per 1000 litre. The system is designed for 20 years and assumes that the consumers will be able to pay for their water usage. The impacts of clean drinking water on the health and hygiene of the community cannot be overemphasized and SPV systems can play a significant role in achieving country's MDG targets.

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