A Promising Off-Grid Solar-Powered Water Pumping System for Indonesian Rural House

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***Abstract*— People who live in rural area may have problem on providing water when their house is not connected with the city grid. This paper discuss the potency of photovoltaic water pump system to provide water in Indonesian rural area. The designed system use 70L/m water pump, 100 wp solar panel and 33A/12V battery. The designed system could be used to supply water for two houses during 2 operating hours.**

***Keywords*— photovoltaic, water pump, rural area**

I. Introduction

Urban people may not be worried about water due to the city water systems. The water-supply system will manage the water quality and flow from the raw water collection point to the customer faucet. People only need to pay their monthly bill to keep the water running.

On the other hands, people living in a remote area may face difficulties on providing their water needs. They usually depend on their traditionally operated private wells. For ones who do not have their own wheel, getting sufficient water for supplying their daily needs may become really difficult. Therefore, owning an electric water-pump is both a considerable convenience or a necessity.

In fact, sustain electricity networks may not reach all remote areas. Approximately 1.6 to two billions developing country civilian live without electricity in their dark homes [1]. The lack of power may become their major reason of not using an electric water-pump to supply their daily water needs.

An off-grid photovoltaic (PV) power system may answer water problems in lack electricity area. Solar is selected as energy source since it may produce clean energy [2]–[5]. Therefore, this paper promotes a design of a solar-powered water system to supply water for Indonesian villagers who live in remote areas. The next following sections details the potency of solar energy in Indonesia, the photovoltaic system and the design of solar powered water pumping system.

II. Potency of Solar Power in Indonesia

Earth atmospheres repel 80% of [6] average solar energy density. Only 20% (560 W/m^2 of 1,2 kW/m2) of it density is absorbed by earth [7].

Studies of using solar energy for electricity has been conducted in many Asian developing countries such as India [3], Nepal [1] and Bangladesh [8]. In Bangladesh, for instance, two millions installed solar home systems (SHSs) generates 94 MW power including 47.3 kWp of solar irrigation pumps. The growth rate of SHSs here is higher than other countries in the world; 58% in December 2012.

Based on solar insulation mapping, Indonesia has 4.5 kW/m^2/day of average solar energy density. Thus, Indonesia which has ±2 million km^2 [7], may produce 5.10^8 MW solar power. The power is used for paddy seed dryer [9], water heater [10] and photovoltaic (PV) power-generation system [6], [7], [11], [12]. The power systems are expected to produce 800 MW with 40 MW growth per year [6].

III. PV Power Systems

Photovoltaic power systems mainly consist of three types: on-grid and off-grid system [11] and hybrid system. The first type is the off-grid system. The system does not connect with the utility lines and only depends on solar rays to produce electricity. The characteristic of this stand-alone system makes it suitable for supplying electricity in a remote area.

The second type, on-grid system, connect the PV power system with the city grid networks. This PV system maintains the power sustainability of its users. The system replaces the electrical grid during a power outage. The produced power could reduce the consumer electricity bill. Hybrid PV system combines solar power system with another power-generation system. One example, the hybrid system integrates the PV system with wind turbines [12]. Integration of a hybrid system with the local grid is also possible, for instance, connects a solar-wind-hydro system with the city power grid [2].

The main components of a PV systems are solar module, solar charge controller, and battery [11]. The solar module converts solar ray directly into direct current (DC) electricity. The solar charge controller keeps the produced voltage steady, protects the battery from overcharging. Battery is used for electricity storage. While alternating current (AC) is needed, a converter should be added. It converts DC output into AC for supplying AC electrical devices.

The main factors that influence power generation is sunlight intensity [9], [13], solar module temperature [13], and shading [4], [6], [14]. Those factors may reduce the produced voltage as well as power generation efficiency.

TABLE I. FLOW RATE ESTIMATION

Item	Water Volume (G)	Operational time (h)	Flow (Gph)	Flow (Gpm)
Min	160	2	80.00	1.33
Max	200	2	100.00	1.67
Mean	180	2	90.00	1.50

IV. THE DESIGN OF SOLAR-POWERED WATER PUMPING SYSTEM

If the average of water consumption in a family is 160G to 240 per day in each month, depends on the need and the season [14]. Water average daily needs can reach 200 G. If we use the solar-powered pump system the flow rate needed is estimated in Table 1.

From the flow Rate estimation results, it can be assumed that the pump can only be operated 2h per day. As the results, the pump should have 2Gpm flow rate to fill 240g of water for 2 hours. From the Table 1, it can be seen the minimum, maximum and mean of water volume per day.

Here, the pump must be able to lift water from 3m to 5m height (hv), and transport those water to the tank which is located (ht) 100m to 150m from the pump. The more clear picturing of this condition can be seen in Figure 1 of pump installation plan. Then, it needs to account on some details about the system specifications.

A. *Total dynamic head (TDH)*

TDH pump is reached 105,58m or equivalent to 12,81psi, as shown to Table 2. TDH is shifted from 105m to 105,58m, as the effect of losses on the transmission of water (valves, fittings and pipes horizontal pressure).

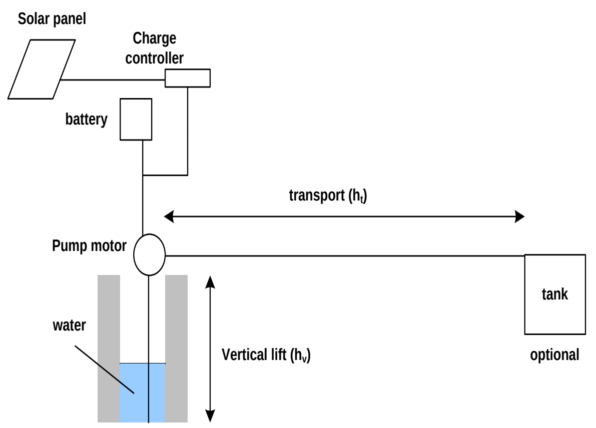

Fig. 1. Pump Installation Plan

TABLE II. TDH CALCULATION RESULTS

Total Dynamic Head (TDH)			Hydraulic pressure (Psi)	
I. Static head				
a. Lift	5.00	m	vertical loss	7.10
b. Slide (1/2" horizontal pipe)	100.00	m	horizontal loss	4.89
II. Dynamic Head				
a. valve & Fitting loss	0.58	m	valve & fitting	0.82
Total TDH	105.58	m	Total TDH (psi)	12.81

TABLE III. PUMP ENERGY OUTPUT OF 2 HOUR OPERATIONAL TIME

Hydrolyc Power (Po,pump)		Produced energy	
a. min	75.81 W	a. min	151.63 Wh
b. max	94.77 W	b. max	189.54 Wh
c. mean	85.29 W	c. mean	170.58Wh

B. *Hydraulic pump energy output (Eout_pump)*

To generate maximum 1,67 Gpm Flow rate (Table 1) and move the water with TDH 105,58m, it is needed 94,77W hydraulic power. As the result, the pump will consume out 189.54Wh of electric energy. Table 3 shows the calculaton of pump energy output (Eout_pump). Energy produced by PV panel

It should be noted that in designing a solar-powered water pump system, the capacity of the panel should be multiplied by 1.2 up to 1.3 (oversize factor) of the capacity of the hydraulic pump (x). The total energy to be generated by solar panels = Eout_pump x 1,3Wh/day = 246,40 Wh/day. While the size of the PV panels must be calculated as follows.

Solar Panel capacity needs= E_{Panel}/2,4. Wp = 246,40/2,4 ≅ 110 Wp. Solar Panel amount needs = 1x 110Wp. Thus, the solar panel with 110Wp is selected with the following details:

Maximum Power	: 110 Watt
Power Tolerance	: ±5%
Voltage at max power (Vmp)	: 17.2V
Current at max power (Imp)	: 6.40A
Open Circuit Voltage (Voc)	: 21.6V
Short Circuit Current (Isc)	: 6.32A
Operating Temperature	: -40°C- 85°C
Maximum System Voltage	: 1000V
Maximum Series Fuse Rating	: 8A

With the average of effective sun is 5,4h per day and the level of optimism is 0.76, this panel is capable to produce (5.6hx110Wpx0.76) = 468,16Wh energy per day. From the Aspect of Design, the capacity of electrical energy is enough to run the system optimally; even if the system is always operated with its maximum rating.

C. Pump Motor, Regulator (charge controller) and Battery

The selected Pump motor has 100W power rating, so it has 5.23W greater than the needed hydraulic power.

Water Pump : DPW69-12 DC 12V 8A 1000 GPH

Alternative : 1. DPW69-24 DC 24V 4.5A 1000GPH

2. 12V Shuflo motor

Motor : Brushless DC Motor

Power Output = 100W

Working Voltage = 12Vdc

Current input = 8A

Eff. Motor = 88%

Head = 7m max. lift

Volume = 69Lpm (equal to 18.22Gpm)

Dimension = 3.5" x5.7"

Weight = 740g

Pipe = ½ "

The Capacity of Regulator dc= 20-30% is larger than the total power load, so $P_{regulator}$= 125% x 100W = 125 W. Battery capacity = (E_{out_pump}x 3)/(0.85 x 0.6 x 12) = 49.01 Ah. Therefore, the selected battery should have the capacity of 12V, 50 Ah with 3 days of autonomy. Solar charge controller rating = (4 strings x 6.32 A) x 1.3 = 32.8 A rounded to 33A, while the working voltage is 12V.

V. CONCLUSION

The designed Solar-Powered Water Pumping System seems to be promising to encounter water problem in Indonesian rural area. Theoretically, the system may be potential to encounter water problem in rural area since the PV system may last for 30 years [2], [14].

In fact, the price of utility customers is still lower than present PV energy cost [5], [15]. Thus, the design should be implemented in particular period to observe the system efficiency. Application of maximum power poin tracker (MPPT) can be proposed to improve the energy conversion process [4], [13]. In the future, the speed of water pump can be controlled to increase suction power or reducing the power consumption.aa

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