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Dual power sources with photovoltaic and small water turbine for generating electric supported flood mitigation

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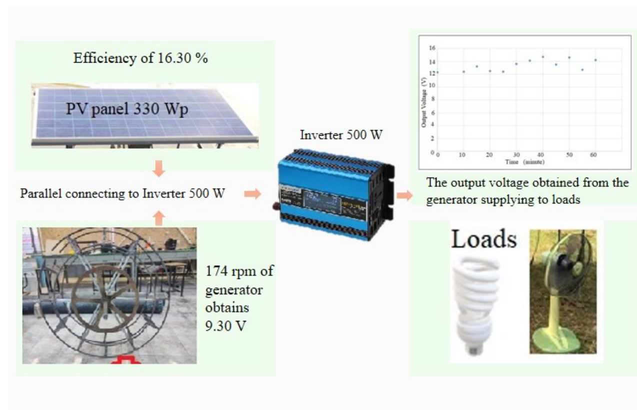
Abstract



This study aims to investigate the electric generation systems used for flood relief by integrated photovoltaic with a small water turbine. Solar panel type of polycrystalline by size of 330 Wp and area of 2 m^2 was parallel connected to the small water turbine with dimension of 1.24 m width and 2 m length. The Bankie wheel turbine has 1 m diameter with 12 blades. The flat blades has area of 0.30 m^2 constructing on the floating tubes. The floating tubes fabricated across the wheel turbine dues to protect the turbine from flooding debris and it control the turbulent stream to be the laminar stream. The solar panel fabricated as the roof of the water turbine on the iron structure dimension of 1 m width, 2 m length and 1.40 m height. The photovoltaic was tested under the conditions of solar intensity ranged from 976.63 W m^{-2} to 1,139 W m^{-2} and ambient temperature of 29 ^{o}C. In standard conditions of solar intensity, the efficiency of photovoltaic obtained by 16.30% and fill factor of 0.96. Deep cycle battery 45 Ah and DC/AC inverter 12 V 500 Wp were connected to the generating system. The gearing ratio of wheel turbine to generator's axle was 1:7 to generate electric from water stream. The relationship of turbine rotation and the generator rotation was performed in laboratory experiment that found to be linear. The voltage obtained by 9.30 V at the generator rotation of 174 rpm. The power producing from photovoltaic and small water turbine obtained total load by 350 W for lamps, fans, and mobile chargers. The dual power sources can be used for producing electrical supply whenever people islanding in flood disaster.

Keywords: Photovoltaic; Water turbine; Flood; Integrated system

1. Introduction

Thailand locates in hot humid zone effected from tropical monsoon climate every year during rainy season. Department of Disaster Prevention and Mitigation, Ministry of Interior indicated flooding in yearly report damaging not only infrastructures but also life, agricultural areas, and assets. A number of natural disaster cases with flooding are high in months at the end of year affecting to the troubled people around country [1]. An economic damage from flooding in 2011 by 23.84 billion Baht and back 5 years by average of 0.47 billion Baht (counted until 2019) [2]. In emergency case of who islanding from flood, electricity needs to shut down for safety reason. Troubled people are needed food and some necessities such as electric lighting, mobile charging and fans that are required power source supplying. The flood stream is normally high flowrate for a day to weeks. A small water turbine is considered appropriately for electrical supply in case of flood emergency. The wheel turbine needs to design shallow drowning and construct easily with a little maintenance. A small water wheel turbine was designed for producing electric power in the low stream velocity by Paengteerasukkamai [3] obtaining output power enough for some loads of lighting. The bigger blade area can be driven water wheel faster and produced higher output power. While, the shape of blade in concave facing to water stream was designed by Yamakupt [4] with water momentum of waterway obtaining high water flowrate. The blade dimension of 0.50 m width and 1.20 m length for 12 blades fabricated in a wheel turbine diameter of 2 m. The wheel turbine supplied electricity for lighting system as an energy benefit for energy saving.

This study designed and construct a small water turbine to generate electricity in case of flooding when electrical grid is shutting off for safety reason. The photovoltaic system including battery were connected to the turbine. This system increases output power supply in clear sky condition. The electrical power from dual power sources is enough for living in home requirement.

2. Materials and Methods

There are 2 types of hydropower turbine including reaction turbine and impulse turbine. The reaction turbines such as Kaplan, Deriaz and Francis use for the low water head to drive the wheel, while the impulse turbines such as Pelton, Turgo and Bankie need high water head. The higher power producing requires the higher water head. For example, Khwanphet [5] installed Turgo turbine for 5 kW with water head by 30 m. So that the water pressure hits the blades of turbine by momentum transfer depending upon the water mass flowrate. According to the water stream of flooding is normally turbulent, the water turbine and the floating need to strength and stable. The water head of flooding is also low but the stream running is high velocity. The cross-flow water turbine is suited for driving the generator wheel. A small wheel turbine was designed in 1 m diameter with 12 blades using Bankie turbine dues to simple design and construction. The flat blade has dimension of 0.15 m width and 0.20 m length made from iron steel. The iron casing dimension of 1.24 m width by 2 m length fabricated a floating tube side by side diameter of 0.20 m and 2 m length. The wheel is in the water by 0.35 m depth. The rotation ratio of wheel turbine and generator axle was 1:7 rpm. The rotation ratio affects to the electrical yield of the generator [3]. A solar panel was installed as solar rooftop with dimension of 1 m width and 2 m length using poly crystalline by 330 Wp (Fig. 1). The poly crystalline panel obtained annual energy yield higher than mono crystalline and amorphous panels in hot humid climate as Thailand [6]. The generator power of 500 W at 750 rpm and 12 V DC were used and connected to DC/AC inverter power of 500 W. A deep cycle 45 Ah battery was also connected to the system for energy storage.

The solar panel efficiency was tested in outdoor conditions of solar irradiant of 976.63 W m^{-2} to 1193 W m^{-2} and ambient temperature of 29 ºC. Pyranometer CMP-3 was used for measuring solar intensity (I) while, electrical multi-meters and thermocouple were used for measuring open circuit voltage (V_{oc}), short circuit current (I_{sc}) and ambient temperature respectively.

Fig. 1 A small water turbine integrated with a solar panel 330 Wp type of poly crystalline.

The solar panel efficiency determined by the ratio of power output ($V_{oc}\ I_{sc}$) obtained to power input supplied from solar intensity (I) falling onto solar panel area (A). So, the solar panel efficiency is calculated by eq. (1):

$$\eta = \frac{V_{oc} I_{sc}}{IA} \times 100 \quad (\%) \tag{1}$$

Fill factor of solar panel (FF), representing an actual power in real conditions comparing to the maximum power that calculated from the maximum voltage (V_{mp}) and maximum current (I_{mp}) in theory obtained dividing with actual power output, is written by eq. (2):

$$FF = \frac{V_{mp} I_{mp}}{V_{oc} I_{sc}} \quad \text{(decimal)} \tag{2}$$

The rotation ratio of generator to voltage output was performed in laboratory using motor as the driving power for rotating the generator. The motor rotation was adjudged by variable voltage transformer (VARIAC). The voltage output and generator's rotation frequency were measured for determining the ratio of generator rotation to voltage output at the minimum rotation.

The experiments performed in the hypothetical situation of flooding likely by water pumping in a pond at 1.50 m water deep. The water stream of flooding was simulated. Water pump of 3 hp (2.24 kW) was used for producing water flowing rate and controlled water velocity by water pump valve. The water velocity through the blades was measured. According to momentum conservation, the mass of water flow with any velocity hits the blade of the wheel driving the generator. The water flowrate (Q) in volume per second was determined from the cross-section area of the blade area (A) and the water velocity (v) given by eq. (3):

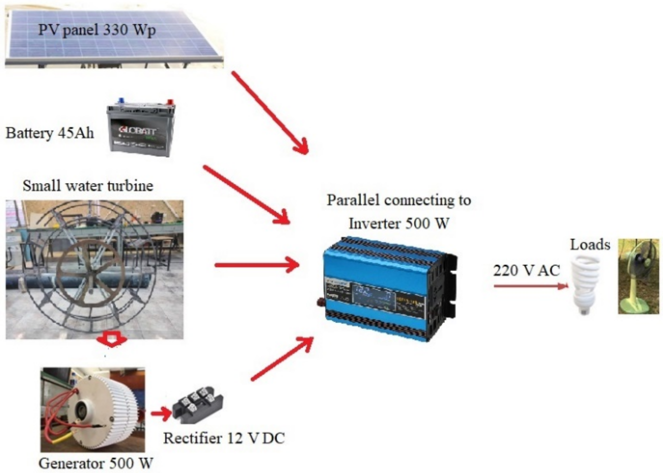
$$Q = Av \ (m^3\ s^{-1}) \tag{3}$$

The electrical circuit of PV connected parallel to water turbine and battery storage, the next connected to DC/AC inverter (Fig. 2). The separated power input from those suppliers were tested for inverter working measured by multi-meter. The output power to loads can be read from the inverter's monitor in watt.

3. Results and Discussion

The efficiency of photovoltaic system was analyzed by selecting data in conditions of solar intensity about 1,000 W m^{-2}, ambient air temperatures 28 – 29 °C obtaining by 16.30% and fill factor 0.96%. The Fig. 3 represented I-V curve with open circuit (V_{oc}) between 38.50 V and 40.10 V, and short current (I_{sc}) about 9.20 A. According to a new solar panel, the efficiency and fill factor obtained values nearly manufacturer data of 18% and 0.98 respectively.

The laboratory experiment for determining the generator rotation ratio to output voltage obtained linear relationship as in Fig. 4. Water turbine is normally generated electricity with linear model of water head, speed of generator and water angle of attack [5, 7].



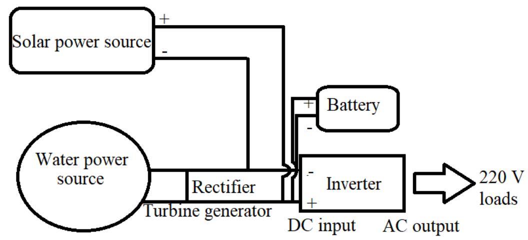


Fig. 2 The measuring diagram of photovoltaic and small water turbine generator power suppliers for energy loads.

The initial voltage of 9.30 V at the generator rotation of 174 rpm steps up to the final voltage of 58.40 V at the generator rotation of 1060 rpm. According to the gear ratio of wheel turbine and generator axle by 1:7, the output voltage of 12 V to 15 V needs the wheel turbine rotation by 30 rpm to 38 rpm respectively. The wheel turbine rotation is driven by water stream velocity at 0.17 m s^{-1} to 0.20 m s^{-1} or flowrate of 0.005 m^3 s^{-1} to 0.006 m^3 s^{-1} respectively. The stream velocity driving wheel turbine obtained comparing to Paengteerasukkamai [3] was the same by average of 0.20 m s^{-1}, though the blade this paper is smaller. That wheel turbine [3] has diameter of 1.40 m and 6 blades. The blade was designed with small water-resistant sizing of 0.90 m width and 1 m length. Earlier, Yamakupt [4] designed the bigger blade area and water facing with concave shape obtaining high rotation of wheel and high current by 15 A at 1,500 rpm. The big blade can be obtained high current with smaller driving flowrate dues to the larger water momentum hitting the wheel turbine [8]. The output voltage from the experiment for 60 minute represented in Fig. 5 and the power output supplied to loads represented in Table 1. The stream flowrate passing through the turbine affected to the output voltage fluctuated. The load devices include lamp, fans, mobile chargers, and computers totally 350 W. The power loading from fan (motor) consumed energy higher at starting so the load power is over 350 W.

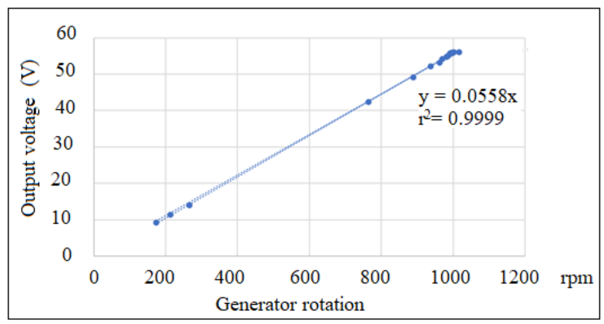


Fig. 4 The relationship of generator rotation and voltage output performed in the laboratory.

4. Conclusion

The dual power supplier from solar energy and water stream energy was investigated. The use of solar panel type of poly crystalline 330 Wp generates electricity with a small water turbine and battery for energy storage. Firstly, solar panel was determined the efficiency outdoor under the strong solar irradiant and ambient air temperatures 28 – 29 °C. The efficiency and fill factor were 16.30% and 0.96 respectively. The small water turbine with 12 flat blades worked in water stream at initial velocity of 0.16 m s^{-1} obtaining output voltage about 12 V. The output voltage was fluctuated depend upon stream velocity. The electrical producing by solar

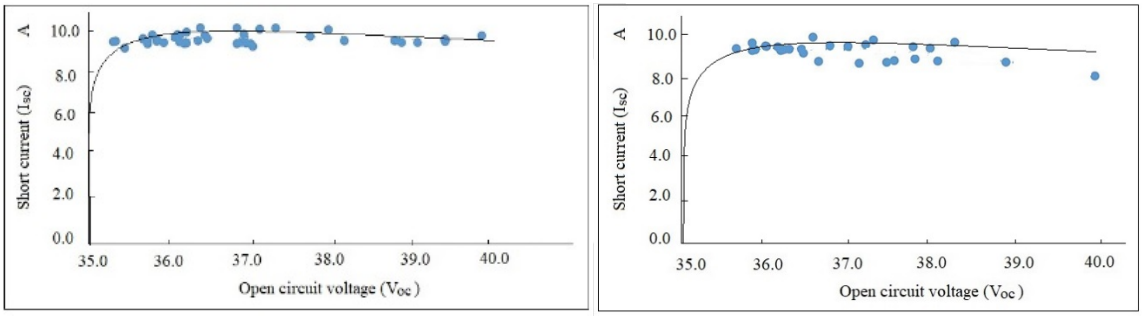


Fig. 3 The I-V curve from 2 experiments in solar intensity of 930.20 – 1,089 W m^{-2} ambient temperatures of 28 – 29 °C.

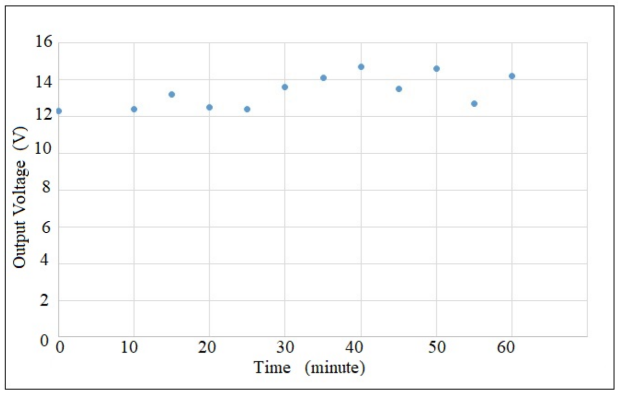


Fig. 5 The output voltage obtained from the generator supplying to loads.

Table 1 Power output from integrated power sources supplying to loads consumption under solar intensity range from 603.20 to 710.30 W m^{-2}.

Time/Source	Output voltage (V)			Load power (W)
	Solar panel	Water turbine	Battery	
5	14.80	12.30	12	360
10	15.10*	12.40	12	350
15	14.60	13.20	12	350
20	14.80	12.50	12	350
25	14.90	12.40	12	350
30	15	13.60	12	350
35	16.80*	14.10	12	320
40	16.30*	14.70	12	320
45	14.90	13.50	12	350
50	12.10	14.60	12	350
55	12.40	12.70	12	350
60	14	14.20	12	350

*Note: If the input voltage to DC/AC inverter over load, the beep warning do work. The line input from PV needs to switch off. Power source from water turbine and battery will supply to loads.

energy and water turbine can be supported to loads including lamp, fans, and mobile chargers totally 350 W. The power supply sources generated electricity for the troubled people whom needed the lighting, communication and a few convenient devices among flooding situation.

5. Suggestions

The higher power of inverter may use for the higher consumption more this experiment 1.50 times according to power supplies of PV, water turbine and battery storage, whenever the electrical load is totally 1 kW. The larger battery's capacity is good for the longer energy storage in cloudy sky condition. The electric power can be supplied from water turbine even if in the rain.

The water diffuser is the necessary device for converting turbulent flow to be laminar flow with optimal size and design. The water diffuser is also protected the small turbine and generator from flooding debris and it may decrease the water stream velocity.

The large blade increases the area contacting to water stream driving power increasing. The large blade area may need the lower water stream velocity.

6. Acknowledgement

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