A Portable Photovoltaic Powerplant for Emergency Electrical Power Supply in Disaster Affected Areas

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***Abstract* — We propose a novel portable photo voltaic electric generator capable of tracking sunlight in all directions essential for disaster areas. Such occurrence often results in disruptions of public services especially power grids. The system prototype consists of a 10W solar panels capable of two axes motion of 120° horizontal and 360° azimuth driven by ATMega8535 micro controller. Two-axis movement is based on two types of sensors capable of 360° directional movements based on the HMC5883 compass sensor. This compass sensor panel is also configured to always directs towards the sun so that if the direction of the base plate was changed, it will automatically direct the panel to the direction of the sun; while 120° vertical movement based on three pieces of LDR (Light Dependent Resistor) as sun sensors. Thus the amount of light received and hence the power output are maximized.**

Keywords - photovoltaic panel; portable power generator; disaster affected area; emergency power generation; solar tracker; microcontroller.

I. Introduction

The use of alternative energy as a power plant is becoming much discussed lately, it is due to the increasing amount of electrical energy needs. One of the most explored about alternative energy is sunlight. Utilization of sunlight as electrical energy is done by utilizing the so-called solar cell or solar panel. The use of solar panels has been widely used as, for example, street lighting, but the installation of solar panels mostly is made static so that when the sun is not perpendicular to the surface of the panel then the generated power is also less than maximum.

Another potential use of small sized photovoltaic power plant is in a disaster struck area, where severe natural disaster occurrence often leads to shutdown of power grids, either intentionally due to safety reasons or because the grid itself was damaged or destroyed. Example for the former is during Jakarta Great Flood in 2012, where 30% of the city’s electricity grid is shut down for fear of causing electrocution due to contact with water. Another example is during major earthquakes such as in Yogyakarta (2006), Tohoku (2011), and Kumamoto (2016) where electricity power lines is severed due to collapsed poles.

II. Literature Review

Apparent movement of the sun makes the installation of solar panels began to be equipped with a mechanical tracking system, but the movement of the system is in one axis [1,2], so the placement of this system must always be under the path of the sun's rotation. While others also experimented with two axis movement, most if not all is still designed for fixed location such as in India [3,4], and Iran [5]. Current studies about tracking system is mostly done outside the equatorial zone, therefore, most installation has the panels facing south for Northern Hemisphere, and vice versa. Equatorial zone tends to have the sun also appears moving north to south and vice versa and adds another requirement for a second-axis system. This paper presents a development of the emergency power supply [6] with the design aims to complement the mechanical movement of the solar panels into two axes: 120° in vertical axis and 360° in azimuth which also developed for Green Kamal community project with simpler fixed panel and single axis movement [7]. The movement of the system can be simulated as a hemispherical shape. It is intended that the sunlight is always perpendicular to the surface of the photovoltaic panel.

III. System Design

The proposed design is using microcontroller ATMega8535 as the main controller system, two DC motor as the mechanical panel adjuster, compass sensor as directional sensor and LDR sensor panels as the vertical axis movement sensor. After the system start-up, the microcontroller will read through the position of the horizontal axis compass sensor to check if the system is already aligned to the direction of the sun or not. If the position is not aligned, then the microcontroller commands the horizontal axis motor to rotate the panels so it is facing to the east. When the east-facing position is achieved, then the microcontroller will read the ADC value from the three LDR light sensors to determine the incident angle of sunlight. The photovoltaic (PV) panel will be tilted at 60° from horizontal and facing to the east if the value of the East LDR is larger than the Center and West LDRs, the PV panel will be tilted

30° towards the west if the ADC value of West LDR is greater than the value of the other two LDRs. The position of the panel will be facing halfway up (30° angle from horizontal) facing east if the value of the East and Center LDRs is greater than the West LDR and halfway down (30°) when Center and West LDRs greater than East LDR. Figure 1 shows the light sensor circuitry.

After panel angle has been achieved, microcontroller will read battery voltage through Zener diode sensor. This circuit uses a relay as the main switch when the battery is fully charged; when the battery is not full then the relay will be off or be in a position normally closed. Sensor for the battery charge is a 12V Zener D1, so when the battery was full the Zener diode will switch the base of the transistor Q2. Q2 is used as an electrical switch that will function to switch ground current from R2, which will light up the LED indicator and will read a logic 0 on microcontroller's C.7 pin. When C.7 pin in the microcontroller receives logic 0 then the microcontroller will turn on the rightmost relay 1 to be opened up to D1, which normally do not receive the voltage of over 12V. If the battery in full condition then the microcontroller will switch on the inverter so in this case the load will also be controlled by reading the value of the load, when the load exceeds the inverter output, microcontroller will disconnect the system temporarily to prevent excessive usage. The battery charging system is shown in Figure 2.

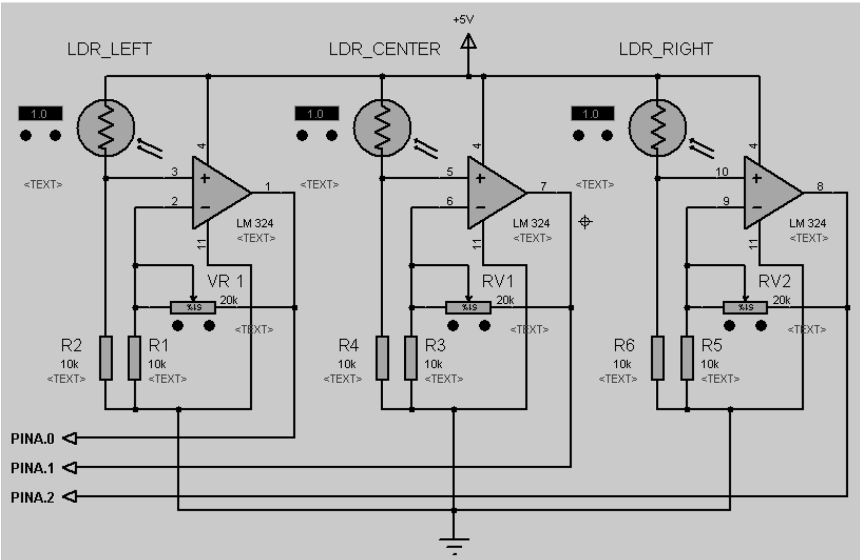

Figure 1. Light sensor circuit.

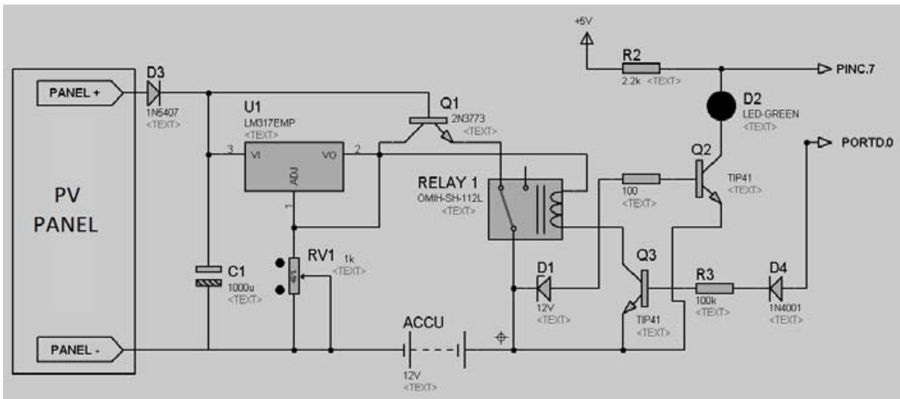

Figure 2. Battery charging.

Inverters used here is a 4047 IC, MOSFET transistors, 5A transformer, and relays. IC 4047 is used as a square wave generator which will switch the MOSFET transistor IRF540N to perform the push pull transformer, using the MOSFET type transistor inverter is expected to be able to bear loads up to 150 watts. Relay on the inverter is used as switch when battery condition has not yet reached the minimum charge or fully charged the inverter cannot be switched on. Figure 3 shows the inverter's schematics. The source select switch is used to select the power source to the load, whether from battery or from public grid. Figure 4 shows the source select switch scheme.

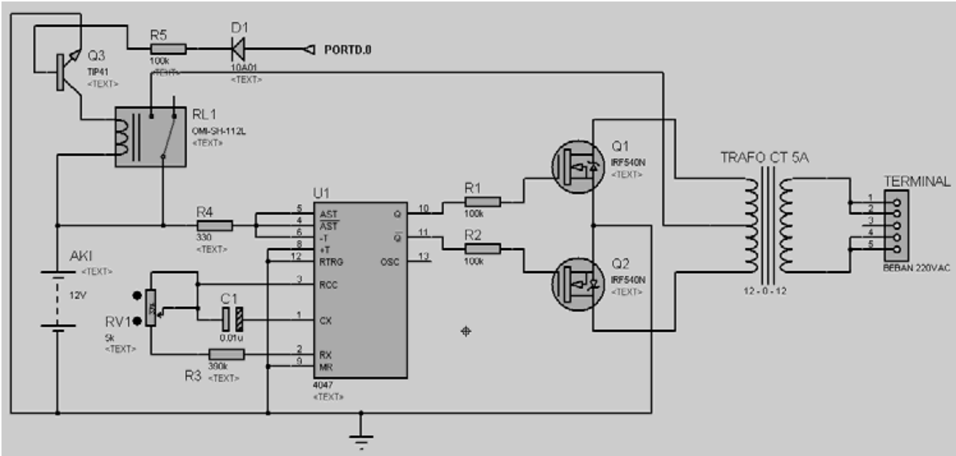

Figure 3. Inverter system of the EPS.

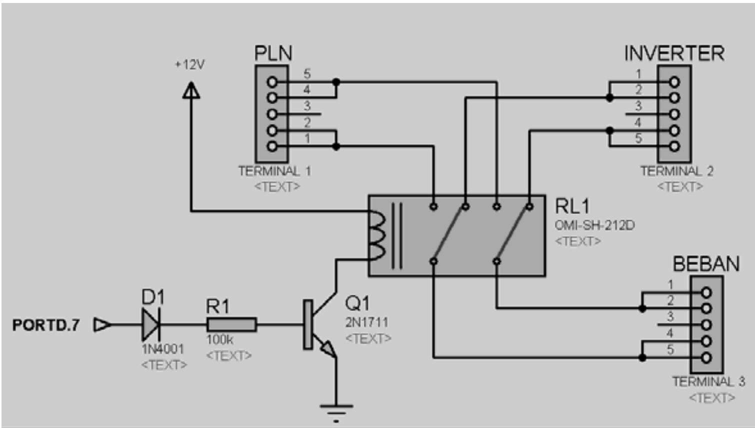

Figure 4. Source Select switch scheme.

The completed prototype with fully independent power source is shown in Figure 5, the two lamps represents the test loads equivalent to 46 Watts.

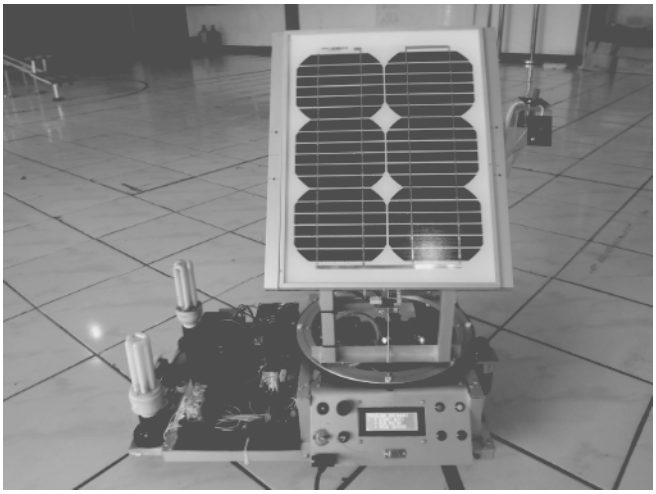

Figure 5. EPS Prototype

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IV. Testing and Analysis

A. LDR Light SensorTesting

Testing the sunlight sensor circuit using LDR is done by measuring the voltage at the output of the LM324 which will go into the microcontroller ADC PORT ATMega8535. The following Table 1 shows the LM324 output measurements test results.

TABLE I. LIGHT SENSOR TESTING RESULTS

Time	V_{out} LDR (volt)			V_{out} LM324 (volt)		
	East	Center	West	East	Center	West
09.00-15.00	5.3	4.93	4.98	4.47	4.5	4.3

B. Inverter Testing

DC to AC inverter testing is done by providing a50 Watt direct current voltage of +12 volts. In order for DC to AC inverter circuit of 150 watts to work, the voltage supplied +12 volts, and the output section connected by a digital voltmeter and digital ammeters. IC CD4074 is used as a generator. The following Table 2 shows the result of testing 150 Watt inverter using three light bulbs each at 20 watts' load.

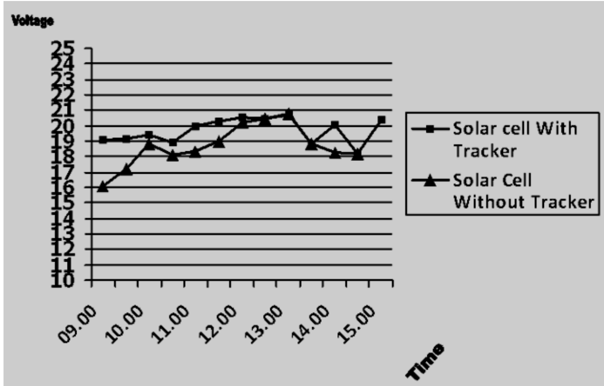
TABLE II. INVERTER TESTING RESULT

Battery status	Load Stats		
	Load 1	Load 2	Load 3
13,6 volt	ON	ON	ON
11.2 volt	ON	OFF	ON

C. Solar Cell Module Testing

Solar cell testing was conducted from 09.00 to 15.00 with direct measuring of the output voltage on the poles of the solar cell module with the results is in Table III.

Solar Panel output shows that V_{out} is stable near maximum of 20 Volts, except for some drops due to cloud cover. Comparison of the output between static and tracker equipped Solar Panel is shown in Figure 6.



-Figure 6. Static and Tracker-equipped panel V_{out} comparison

TABLE III. SOLAR CELL MODULE V_{OUT} MEASUREMENT RESULT

Time	V_{Out} (Volts)	Sun Elevation (Degrees)	Panel Position
09.00	19.05	45°	East
09.30	19.20	52,5°	
10.00	19.40	60°	
10.30	18.89	57,5°	
11.00	19.97	75°	Center
11.30	20,3	82,5°	
12.00	20,52	90°	
12.30	20,5	97,5°	
13.00	20.72	105°	
13.30	18.85	112,5°	West
14.00	20.02	120°	
14.30	18.22	127,5°	
15.00	20.35	135°	

D. Mount Testing

Testing of the completely assembled component focused on the mount with the goals is:

- When the base plate's direction is changed, the panel mount should align itself to the east,
- The panel should trace the elevation of the sun,
- Inverter can support loads,
- Source select switch work properly during overload

From the testing, the base plate can align itself facing toward East direction by 5 degrees per second. Static panel output measured at 16 Volts in the morning compared to 19 Volts when equipped with tracker with both peaked at around 20 to 21 Volts during mid-noon, and then static panel starts to drop again after 13.00 while tracker equipped panel can maintain output voltage.

Load testing of the inverter and battery with loads of up to 46 Watts, simulated by a pair of 23W lamps, the stored energy can support the load for 4 hours. Theoretically, this can last for 5 hours to fully discharged, but the inverter itself also needs energy and will cease functioning when the voltage drops below 9 Volts. This is required to generate square wave for triggering the transistor to perform push-pull and convert DC output from the panel and battery to AC for the load.

V. Conclusion

After the test has been completed, conclusion can be drawn as follows:

- The solar tracker can track the position of sun in horizontal plane (azimuth) and in vertical plane (elevation)
- Tracker can maintain the output of solar panel by align it perpendicular to the direction of incident sunlight
- This tracker is especially designed to be lightweight for portable use on emergency units and may be useful for other mobile platforms
- Higher capacity and/or non-chemical-based electricity storage is considered to enable the generator fulfill its potential use in larger scale.

References

[1] Tudorache, T.. "Design of a Solar Tracker System for PV Power Plants," Acta Polytechnica Hungarica. Vol. 7, No. 1, 2010, pp.23-39.

[2] A. Balabel, A.A. Mahfouz, and F.A. Salem, "Design and Performance of Solar Tracking Photo-Voltaic System; Research and Education," Int. J. of Control, Automation and Systems, Vol. 1, No. 2, 2013, pp. 49-55.

[3] Deb, G., Roy, A.B.. "Use of Solar Tracking System for Extracting Solar Energy," Int. J. of Computer and Electrical Engineering, Vol.4, No.1, 2012, pp.42-46.

[4] Dhanabal, R., et al., "Comparison of Efficiencies of Solar Tracker systems with static panel Single-Axis Tracking System and Dual-Axis Tracking System with Fixed Mount," Int. J. of Engineering and Technology. Vol. 5, No. 2, 2013, pp.1925-1933.

[5] Bazyari, S., et al., "A Study on the Effects of Solar Tracking Systems on the Performance of Photovoltaic Power Plants," Journal of Power and Energy Engineering, Vol. 2 No. 2, 2014, pp.718-728.

[6] I. Riyanto, A. Octaviano, Suparmoko and K. Obara, "Portable Photovoltaic Powerplant with Solar Tracker for Disaster Affected Area Emergency Power Supply," Proc. The 7th Indonesia-Japan Joint Scientific Symposium, November 2016.

[7] P.W. Purnawan et al., "Green Kamal Project: Empowering the Least Developed Part of a Metropolitan City through PV Power Generators Installation," Proc. of the 5th IEEE Region 10 Humanitarian Technology Conference, December 2017.