Electric Load Management On Solar Power Plant System

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Abstract - Heightened electricity consumption inversely proportional to the thin fuel supply. Once the sun does not shine optimally during rainy season effecting the output of solar power generation. It been so long on every occasion if solar power unable to supply fully, State Electricity Company (PLN) will take over. This research focuses on designing a device to maximize the usage of solar power when unable to cover full load demand by utilizing Microcontroller Atmega 16. The results obtained to get the voltage according to the standards applicable to load 1 requires a minimum of 600 Watt / m² irradiation with a voltage of 217.69 VAC, 2 minimum irradiation loads 800 Watt / m² with a voltage of 217.48 VAC, and a minimum load 3 irradiation 1000 Watt / m² with a voltage of 217.27 VAC. State Electricity Company (PLN) will supply three loads when the solar panel receives irradiation from 100 - 500 Watt / m². When the solar panel receives irradiation from 600-700 Watt / m², load 1 is supplied by the solar power and load 2 and load 3 are supplied by State Electricity Company (PLN). Meanwhile the solar panel receives irradiation 800-900 Watt / m² load 1 and load 2 is supplied by the solar power, and load 3 is supplied by State Electricity Company (PLN). While Irradiation of 1000 Watts / m² all three loads are fully supplied by the solar power.

Key words: solar power, irradiation, microcontroller, Atmega 16

I. INTRODUCTION

Constructions of power plants in our country Indonesia are still focused on non-renewable energy from fossil fuel such as coal and it is used for Steam Power Plants. Related to Indonesian National Energy Policy it is targeted in 2025 the role of renewable energy reaches at least 23% of total national energy usage [1]. Consequently, many people would rather to choose the renewable energy and enviromentally friendly. Solar Power Plant is one of power plants applies renewable energy derived from solar energy. This solar power plant proceeds by directly changing solar irradiation into electricities [2][3]. Indonesia is geographically located on the equator and it gets advantage and also disadvantage. The advantage is the sun's energy can shine throughout the dry season and disadvantage is during the rainy season the sun's energy cannot shine optimally affecting output solar power [4].

This research focuses on electric load management on solar power generation system in collaboration with State Elctricity Company (PLN) that has purpose to maximize the output of electric power generated by solar power plants [5]. Electric load management divides the load into different load groups, so that when the electric power produced by a solar power plant cannot supply the load fully, it will be able to be utilized for supply loads that have lower power. The shortage of power supply at this load will be supplied by the State Electricity Company (PLN).

II. HARDWARE DEVELOPMENT

Electric load management design consists of several circuits, namely: solar modules, relays, LCD & LED indicators, chargers, irradiation sensors, and resources from Solar Power Plants and State Electricity Companies, microcontroller circuits, relay drivers, and modeling of Generators Solar Electricity. [6][7]

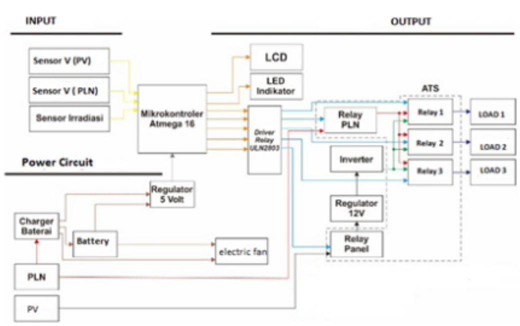

Fig. 1. Block diagram

A. Solar Module Design

The solar module thau is used for data collection consists of one solar panel, halogen lamp, DC fan, test box, and AC regulator. DC fans as coolers, AC regulators to regulate irradiation irradiation lights, and halogen lamps as solar simulations because they have almost the same spectrum [8][9][10]

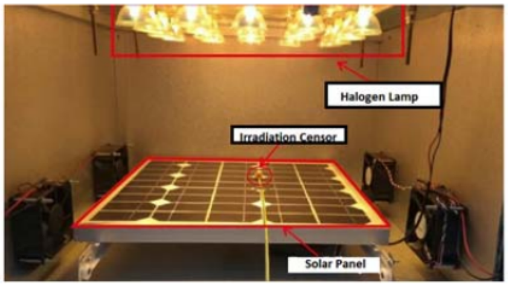

Fig. 2. Modul look inside

B. *Driver Relay Design*

The relay driver is used in this study because it has function as microcontroller and also be able to provide current and voltage to activate the 12 VDC relay. This relay driver uses IC ULN 2803. [11][12]

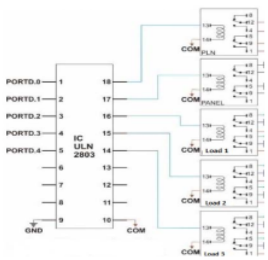

Fig.3 Relay driver circuit

C. *Design Of Battery Charger Circuit*

To create the charger circuit, this study uses IC LM317. LM 317 is a variable voltage regulator IC chip for positive DC voltage. The amount of output voltage depends on the variation of the resistor value used.[13]

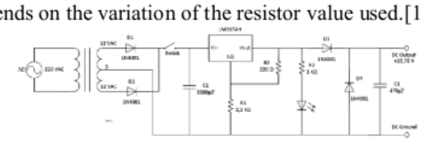

Fig. 4. Charger circuit *using IC LM317*

From *datasheet IC*LM317 obtained the following equation 1

$$V_o = 1{,}25\,V\left(1+\frac{R_2}{R_1}\right)+I_{ADJ}R_2 \qquad (1)$$

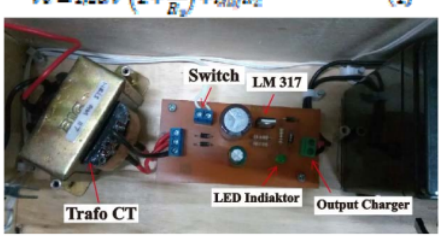

Fig. 5. Realization of Battery Charger Circuit using IC LM217

By combining the 220 ohm and 2.2k ohm resistor values and Iadj 46.10-6A obtained from the datasheet, a Vout of:

$$V_o = 13{,}78$$

D. Modeling Design For Solar Power Plants

The design of this modeling serves to convert the DC voltage generated by solar panels into 220 VAC voltage to supply the load.[14][15]

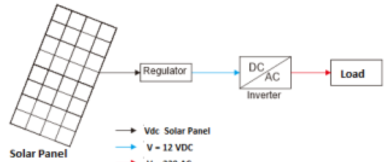

Fig. 6. Solar Power Plants Block Diagram

Voltage generated by solar panels in the form of voltage which is fluctuating, so it must be entered into the regulator (UBEC). The regulator output becomes a voltage of 12 VDC and it is connected to the inverter then converted to a voltage of 220 VAC. After a voltage of 220 VAC, continue to connect on resitor rock.

E. Design Of Irradiation Sensor Circuit

Irradiation sensor is used to detect the amount of irradiation value. Irradiation sensors use a photocell sensor with a voltage divider circuit using a 470 Ohm resistor as shown in Figure 7.[6][7]

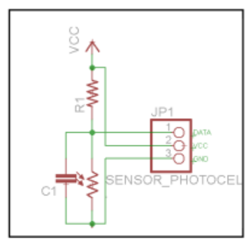

Fig. 7. Irradiation sensor circuit

Irradiation sensor interpreting on the microcontroller that is by changing the received analog voltage value to digital, then the data is converted to an irradiation value using Equations 2 and 3

$$Y = mx + c\ Y \qquad (2)$$

Where to get the values of m and c, use the equation:

$$m = \frac{(N \times xy_{sum}) - (x_{sum} \times y_{sum})}{(N \times x_{soua\,resum}) - (x_{sum} \times x_{sum})} \qquad (3)$$

Table 1. Interpreting ADC value on irradiation sensor

Irradiation Value (Watt/m²)	ADC Value 1	ADC Value 2	ADC Value 3	average ADC
100	63	65	59	62
200	123	118	111	117
300	171	173	174	173
400	231	238	234	234
500	281	271	295	282
600	388	326	327	330
700	397	391	392	393
800	467	423	424	438

900	503	472	471	482
1000	594	471	495	520

To calculate the value of irradiation, you can use Equation 2 and Equation 3, where Y is the irradiation value of the measuring instrument, and X is the average value of the ADC.

calculation 1

searching X_{sum} :

$X_{sum} = 62+117+173+234+282+330+393+438+482+520$

$X_{sum} = 3033$

calculation 2

searching X_{sum} :

$Y_{sum} = 100+200+300+400+500+600+700+800+900+1000$

$Y_{sum} = 5500$

calculation 3

searching XY_{sum} or the sum of the multiplications of the measuring instrument irradiation and the average value of the ADC

Table 2. Multiplication of irradiation value on measuring instrument with average value of the ADC

Irradiation Value (Watt/m²)	average ADC	XY
100	62	6233,33
200	117	23466,66
300	173	51800
400	234	93733,33
500	282	141166,66
600	330	198200
700	393	275333
800	438	350400
900	482	433800
1000	520	520000

* XY = the result of multiplying irradiation value on measuring instrument with average value of the ADC

Based on Table 2, the value XY_{sum} can be obtained by adding up the multiplication results of X and Y.

$XYsum = 6233,33+23466,66+51800+93733,33+141166,66+198200+275333+350400+433800+520000$

$XYsum = 2094133,33$

calculation 4

searching $X_{squaresum}$ or the sum of X^2

$X_{squaresum} = 3885,44+13767,11+29813,78+54912,11+79712,11+109120,1+154711,1+191844+232324+270400$

$X_{squaresum} = 1140489,77$

calculation 5

searching $Y_{squaresum}$ or the sum of Y^2

$Y_{squaresum} = 10000+40000+90000+160000+250000+360000+490000+640000+810000+1000000$

$Y_{squaresum} = 3850000$

calculation 6

searching value m or the regression coefficient using Equation 2

$$m = \frac{(N \times XY_{sum}) - (X_{sum} \times Y_{sum})}{(N \times X_{squaresum}) - (X_{sum} \times X_{sum})}$$

$$m = \frac{(10 \times 2094133,33) - (3033 \times 5500)}{(10 \times 1140489,77) - (3033 \times 5500)}$$

$$m = 1,93025069$$

calculation 7

searching value c or error values using Equation 3

$$c = \frac{(X_{squaresum} \times Y_{sum}) - (X_{sum} \times XY_{sum})}{(N \times X_{squaresum}) - (X_{sum} \times X_{sum})}$$

$$c = \frac{(1140489,77 \times 5500) - (3033 \times 2094133,33)}{(10 \times 1140489,77) - (3033 \times 3033)}$$

$$c = -7,447 \times 10^{-7}$$

From calculation 6 dan 7 can be ontained value $m = 1,93025069$ and value $c = -7,447 \times 10^{-7}$, so the value

$$Y = 1,93025069x - 7,447 \times 10^{-7}$$

F. Determining Set Point.

To determine the set point value, data collection can be done with three variations of the load and variations in irradiation. The voltage at the load must be according to PLN standards of 220 VAC + 5% and -10% [9]. At set point 1 determine the minimum value of irradiation to supply 1 load.[16]

Table 3 Experimental data on irradiation with 1 load

Irradiasi (Watt/m²)	(V)
100	23,35
200	60,47
300	95,12
400	107,25
500	136,51
600	217,69
700	217,69
800	217,69
900	217,7
1000	217,7

Based on the standard PLN voltage of 220 VAC + 5% and -10% [9], the set point value for one load is obtained at 600 Watt / m² irradiation with a voltage value of 217.69 V, in the same way a set point value for two the load is obtained at irradiation 800 Watt / m² with a voltage value of 217.48 V and the set point value for three loads is obtained at irradiation of 1000 Watt/m² with a voltage value of 217.27 V

III. TESTING AND ANALYSIS

A. *Testing On Irradiation Sensor.*

Irradiation sensor testing is done by measuring the irradiation produced by halogen lamps with an iradiance meter then measuring the irradiation with an irradiation sensor. This test aims to determine the performance of the irradiation sensor that has been made. Irradiation sensor testing is shown in Figure 8.

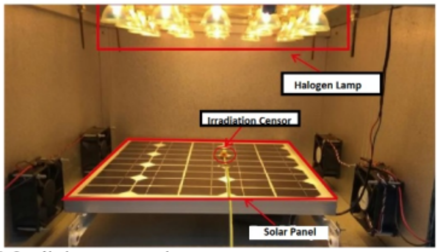

Fig. 8. Irradiation sensor testing

Testing is completed by comparing the irradiation value on measuring instrument with irradiation value displayed by the microcontroller, then get an error from the reading difference value. Irradiation sensor testing is completed with 10 variations of irradiation. The measurement scale is between 0 Watt / m² to a maximum of 1000 Watt / m². So the error obtained is the difference between the irradiation of the irradiance meter with the irradiation value measured by the irradiation sensor then multiplied by 100%. Data from the results of the experiment can be seen in Figure 9

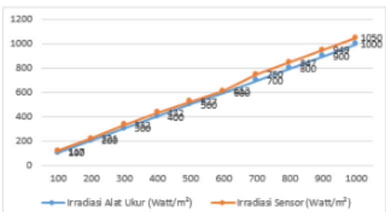

Fig. 9. Comparison graph of irradiation values on measuring instruments and sensors

Based on the graph in Figure 9, the average error interpreting of irradiation sensor is 6% because the value of irradiation sensor consists of a resistor that has a tolerance on value which indicated on the resistor ring of 5% and rounding the calculation. Calculation of rounding constant value and analog to digital conversion value on a microcontroller that lacks on precision causes the greater the measurement voltage value, the greater the sensor reading value is the difference

B. *Modeling Testing On Solar Power Generation*

Testing is conducted with load test and measured on the value of the short circuit voltage (V_{sc}) at the output of the inverter, and the value of irradiation that goes to the solar panel. The second measured is on short circuit current (I_{sc}) on inverter output, and the irradiation value that goes to the solar panel. Multiplication result (V_{sc}) and (I_{sc}) is called maximum power (P_m). Maximum power is extreme power that can be released by the solar panel after going through an inverter under certain irradiation conditions. Measurement using SANWA PC5000 digital multimeter, with a variation of 1 load, 2 loads, and 3 loads. Measurement of voltage and current data is carried out at an irradiation value of 100-1000Watt / m², with a difference of 100Watt / m² each increme

C. Testing With Irradiation 100-1000watt / M² 3 Load

Testing with 3 load conditions, voltage and current measurements with irradiation variations from 100 Watt / m² to 1000 Watt / m². Data can be seen in Table 4.

Table 4 Testing with irradiation of 100Watt / m² to 1000Watt / m² with 3 loads

Irradiasi (Watt/m²)	Inverter (V)	I Inverter (mA)	Output Inverter (W)
100	0,37	0,017	0,000
200	29,2	1,41	0,041
300	40,2	1,9	0,076
400	49,5	2,38	0,118
500	57,4	2,73	0,157
600	64,7	3,27	0,212
700	83,48	4,03	0,336
800	93,18	4,42	0,412
900	181,14	9,15	1,657
1000	217,27	10,99	2,388

Table 4 shows an increasing inverter output voltage at irradiation value of 100 Watt / m² to 1000 Watt / m². That is due to an increase in inverter input voltage. At the irradiation value of 100 Watt / m² to 900 Watt / m² the value of the output voltage on inverter is still not in accordance with the specifications of inverter and PLN standard of 230VAC + 5% and -10% because the input voltage on the inverter still does not match the minimum voltage of inverter. Whereas at the irradiation value of 1000 Watt / m², the voltage value is in accordance with the PLN standard of 217.27 VAC

There is an increasing on current value from 0.017 mA to 10.99 mA at irradiation of 100 Watt / m² to 1000 Watt / m². This is due to an increase in the value of voltage at the output of the inverter. This increasing is in accordance with the theory where with the same load, the current value is directly proportional to the voltage

In Table 4 there is an increasing on power at irradiation value of 100 Watt / m² to 1000 Watt / m². This is due to an increasing value of the inverter output current and voltage. At irradiation of 1000 Watt / m², the solar panel can supply a 20K Ohm load resistor which requires power of 2.36 Watt.

C. *Testing The Whole Devices*

All devices testing on electric load management design use ATmega 16 that is carried out with 3 variations, namely: testing with sources State Electricity Company, testing with sources from solar panels, and testing with sources of solar panels and State Electricity Company.

This test is carried out to test the response of the switching on device with sources from solar power generation and State Electricity Company (PLN), where the load is maintained to get a source both from solar panels and from PLN. This test carried out variations of irradiation from 100 Watt / m² to 1000 Watt / m² with multiples of 100 Watt / m².

Table 5 Testing device with sources from Solar Power Plants (PV) and State Electricity Company (PLN)

Irradi (Watt/m²)	VAC (V)			Source		
	Load 1	**Load 2**	**Load 3**	**Load 1**	**Load 2**	**Load 3**
100	233,73	233,73	233,73	PLN	PLN	PLN
200	233,71	233,72	233,71	PLN	PLN	PLN

300	233,72	233,73	233,70	PLN	PLN	PLN
400	233,69	233,72	233,70	PLN	PLN	PLN
500	233,73	233,71	233,71	PLN	PLN	PLN
600	217,63	233,69	233,71	PV	PLN	PLN
700	217,67	233,73	233,70	PV	PLN	PLN
800	217,30	217,32	233,72	PV	PV	PLN
900	217,34	217,35	233,69	PV	PV	PLN
1000	217,15	217,15	217,15	PV	PV	PV

Based on Table 5 acquires at irradiation of 100 Watt / m² to 500 Watt / m², the three loads supply from PLN proven by the average voltage flowing on the three loads of 233.71 VAC.

At irradiation 600 Watt / m² to 700 Watt / m² load 1 is supplied by Solar Power Plant proven on voltage flowing at load 1 of 217.67 VAC, and load 2.3 supplied by State Electricity Company (PLN) with proven voltage flowing at load 2 on average by 233.71 VAC and the average voltage flowing at load 3 is 233.71 VAC.

At irradiation of 800 Watt / m² to 900 Watt / m² the load 1.2 gets the supply from PV with proven average voltage flowing at load 1 of 217.32 VAC and at load 2 of 217.33 VAC. Whereas at load 3 it is supplied by PLN with proven voltage flowing at load 3 of 233.71 VAC.

At 1000 Watt / m² irradiation, the three loads get the supply from PV proven with voltage flowing at load 1 of 217.15 VAC, load 2 of 217.15 VAC, and load 3 of 217.15 VAC. The voltage is in accordance with the standards of PLN of 230 VAC + 5% and -10%.

IV. CONCLUSION

Based on the whole testing, it can be concluded that the design of the electric load management was successfully carried out. The system can run according to predetermined design. At irradiation 0 Watt / m² to 500 Watt / m², all three loads get the power supply from PLN. When irradiation 600 Watt / m² to 700 Watt / m² 1 load gets power supply from PV, and 2 loads get supply from PLN. At irradiation 800 Watt / m² to 900 Watt / m², 2 loads get power supply from PV and 1 load gets power supply from PLN. At an irradiation value of 1000 Watt / m², all three loads can be supplied from PV.

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