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Design and Build Mppt Solar Charge Controller Using Buck Converter On Photovoltaic Based Microcontroller Pic

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Abstract **– Photovoltaic (PV) is a component for converting solar energy into electrical energy. On the other hand, the characteristics of PV performance are fluctuating, additional circuits are needed to maximize PV performance. This research discusses the maximum power point tracker (MPPT) in a solar charge controller system using PIC microcontroller as a solution to maximize PV performance. The MPPT algorithm used is perturb and observe (P&O) with PV power parameters because this algorithm is often used and has good efficiency. This research system was tested using a voltage scale of 15 V, 16V, 17 V, 18.1 V, 19 V, 20 V, 21 V, 22 V, 23.1 V, 24.1 V, and 25 V with the lowest average error value of 3.01447379% and highest 4.312288%. Testing the working characteristics of the 120WP solar panel shows that the solar panel will work optimally when the conditions are sunny and the temperature is not high. The results of testing solar panels with the highest average output voltage of 22.1 V. From testing the system on solar panels shows the value of the ADC output voltage with an average of 12.603V in sunny conditions, 12.372V in sunny cloudy conditions, 12.23V in cloudy conditions, 12.5 V in an obstructed condition. In testing system efficiency using the P&O algorithm with an average result of 80.4818%.**

Keywords: MPPT, photovoltaic, PIC Microcontroller,, perturb and observe (P&O).

I. Introduction

Indonesia is one of the tropical countries that has a huge potential for solar energy with a solar energy potential of 207,898 MW [1]. Photovoltaic is an equipment used to convert renewable energy from sunlight into electrical energy [2]. The power of photovoltaic itself in absorbing sunlight energy is affected by temperature factors and the intensity of sunlight radiation. The change of both non-linear factors is one of the main reasons photovoltaic cannot maximize photovoltaic performance [3]. Therefore, to maximize the power produced from photovoltaic is very necessary, so that the optimal point of the solar panel where the maximum power can be taken for each load given, one of which is by using the maximum power point tracker (MPPT)[7]. So far, many MPPT techniques have been used, ranging from perturb and observe, fuzzy logic algorithms, adaptive neuro fuzzy inference system (ANFIS)[7], to artificial neural networks. Of the several MPPT techniques, peturb and observe is the most popular algorithm and also has a high level of efficiency[6],[8],[9], but there is still voltage oscillation in the initial condition of the change in the output voltage value of the solar panel. The research conducted is still simulated.

This study discusses a solar charge controller system using MPPT with perturb and observe (P&O) techniques as a solution to photovoltaic problems. Modeling of the solar charge controller system using a buck converter as a voltage reduction circuit (DC-DC converter step down) has been carried out in [2],[4]. However, the research is still only limited to simulation, so direct testing has not been carried out so that the resulting efficiency has not been verified. In this study, planning and testing will be carried out directly the implementation of the perturb and observe (P&O) algorithm on the PIC microcontroller-based buck converter as an MPPT device in solar power plants. In this study, photovoltaic (PV) is used which is a tool to convert solar energy to electricity using components from semiconductors. Silicon in PV has two layers, namely positive charge and negative charge. Then there is a gate in the layer, the gate will open this is because the photovoltaic cell is made of a semiconductor material that can release electrons when solar radiation shines on the PV cell, then causes current to flow between two oppositely charged layers [5].

Solar charge controller is a series of systems used to control battery charging using a series of buck converters. The buck converter itself is a circuit used to lower the voltage of direct current or it can be called a DC-DC converter step down. The output voltage depends on the duty cycle and includes important parameters such as current ripples, voltage ripples and minimum and maximum currents through the inductor also depend on the duty cycle [6].

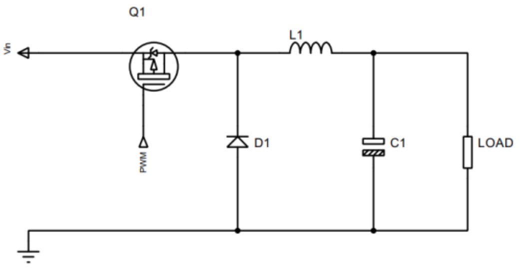


Figure 1. Network Buck Converter.

The transfer function of a buck converter is as follows.

$$\frac{Y(S)}{U(S)} = \frac{V_s}{LCS^2+\frac{L}{R}S+1} \quad (1)$$

In the solar charge controller system, a maximum power point tracker (MPPT) is used to track the highest value of the power generated by the PV. The tracking algorithm used in the MPPT technique is pertube and observe (P&O). Where the pertube and observe (P&O) algorithm is used to analyze the output power of the solar cell is also called the hill climbing algorithm, then by controlling the duty cycle with the STEP ΔI (current) of the buck converter circuit to track where the maximum power point location (MPP) is [7]. The constant step P&O algorithm can accurately track the maximum power of the solar cell under normal conditions. But there are also times when the ΔI step is unstable in the output power of the photovoltaic system and the tracking speed, then the maximum power output of the solar cell will fluctuate [8][9]. This can be solved by setting error limit parameters in the algorithm (P&O) [10].

The system is controlled using PWM signals from the PIC microcontroller. Where the parameters used to control the duty cycle use the power parameters produced from photovoltaic. To find out this value, the ACS 712 current sensor and the voltage sensor.

The ACS712 current sensor is a sensor used to measure AC or DC current with a single 5.0 V power supply operation and an output sensitivity of 66-185 mV. DC voltage sensor circuits use voltage divider circuits. Because in the PIC the maximum working voltage is 5 volts, it means that the voltage read should not give the VCC voltage to the circuit, because if the output of the voltage sensor circuit exceeds 5 volts that occurs, it will cause the PIC to be damaged. For the determination of the voltage divisor value using the following formula:

$$Vout = VCC\ x\ \frac{R2}{(R1+R2)} \quad (2)$$

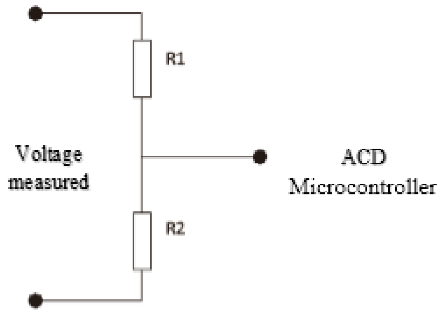


Figure 2. DC Voltage Divider Circuit

II. METHODS

The stages of the system completion method used in completing this article can be seen in Figure 3.

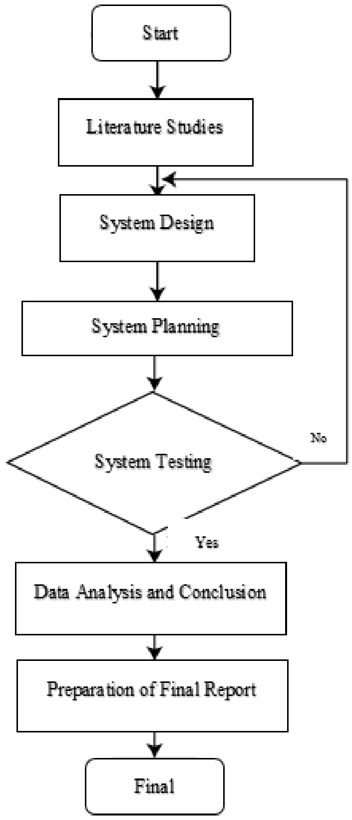


Figure 3. Research Flow Diagram

Literature study is a series of activities related to the collection of literature literature, making observations by reading and taking notes, and managing them as research materials. The method of collecting literature data obtained from journals, books, theses, theses and others. At this stage, create a system design scheme to be created

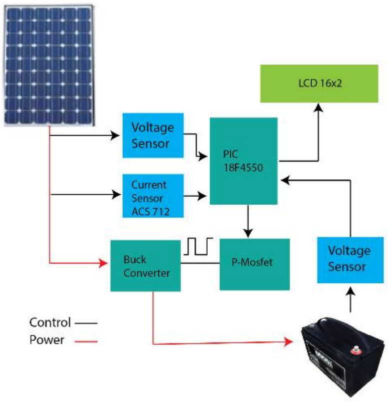


Figure 4. Schematic of solar charge controller system

The schematic system of the MPPT solar charge controller design is as shown in Figure 4 where there are two system lines, namely the control line and the power line. The working system of the design is that every output from the power path that passes through the buck converter will be controlled regarding the output from the solar panel before it goes to the load. The control on the output of the buck converter is controlled using pulse width modulation in the form of duty cycle values where each duty cycle value uses parameters from voltage sensors and current sensors. The process of completing the system design where the flow is as follows

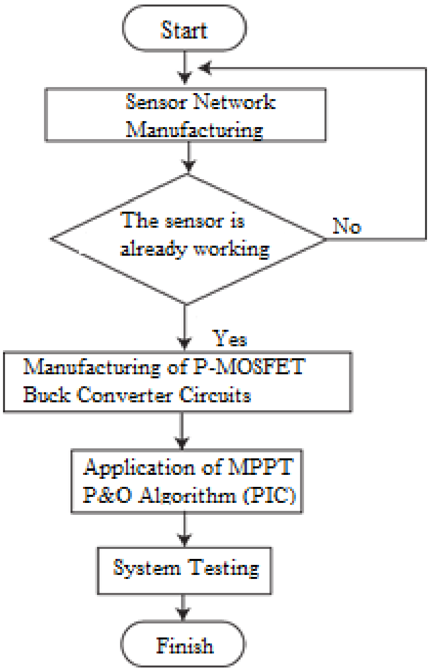


Figure 5. System Design.

System design begins with the creation of a series of sensors and sensor calibration. Then if successful, it will be continued with the design of the manufacture of the pertube and observe algorithm which will be implemented in the P-MOSFET buck converter series. The algorithm is created as follows.

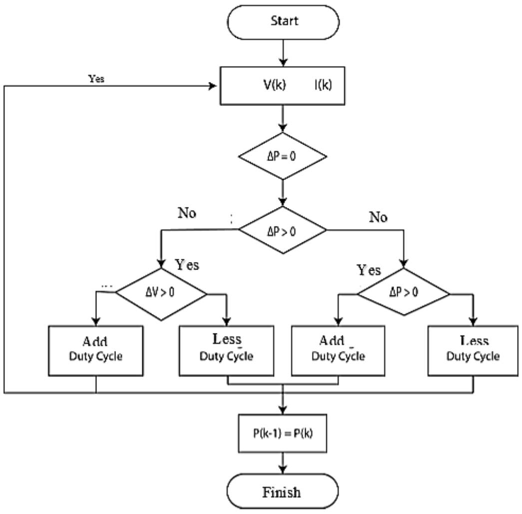
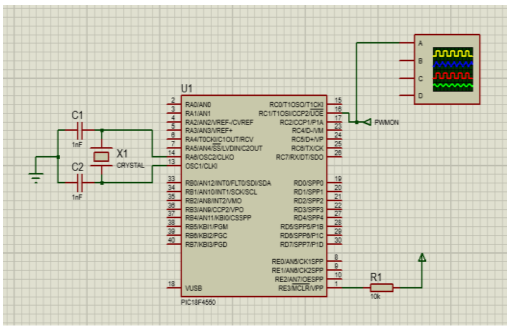


Figure 6. Pertube and observe algorithm.

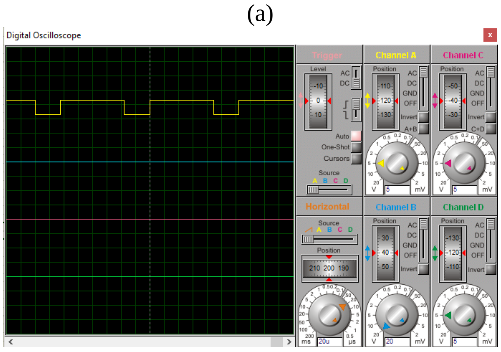
The system test on this research flow diagram is a test of the system design and system design that has been made. For this reason, at this level it will be tested whether the system is in good and stable condition, if yes, it will proceed to the next stage, and if not, it will be returned to the system design stage to be analyzed again until the system becomes good and good. Testing is carried out in two stages, namely hardware and software testing.

III. Results and Discussion

PWM program testing on PIC 18F4550 using MPLAB software and proteus simulation.



(a)



(b)

Figure 7. (a) PWM test circuit, and (b) PWM signal display

This PWM program test uses Timer 2 and activates the CCP2 pin on the microcontroller pin and the generated wave as shown in figure 7. To activate PWM on the PIC, it is necessary to perform a PWM period calculation, with a frequency of 8Khz:

PWM priode = $(PR2 + 1) * 4 * Fosc * Prescaler$ (3)

1/F = $(PR2 + 1) * 4 * Fosc * Prescaler$

$$\frac{1}{8KHz} = (PR2 + 1) * 4 * (\frac{1}{20MHZ}) * 16$$

$$PR2 + 1 = 39.06$$

$$PR2 = 38.06 \approx 38$$

$38 = 26\ hex$ PR2 = 0x26;

Then for the duty_cycle value, for the activated CCPR2L, it must be calculated in advance how much duty_cycle is desired, for example 80%, then the calculation is as follows:

$$CCPR2L = \frac{PWM}{Tosc} * Prescale \quad (4)$$

$$CCPR2L = \frac{(\frac{1}{8KHz})}{(\frac{1}{20MHz})} * 16$$

$$CCPR2L = 156.25 \approx 156$$

Elimination

$$156 = 100\%$$

$$x = 80\%$$

$$X = \frac{12480}{100} = 124.8 = 124 = 0001111100$$

Then the 2 binary values from the front are removed then 0001111100 = 00011111 so the hexa value generated to get duty_cycle = 80% i.e. 1F then the program written CCPR2L = 0x1F.

Testing of 16x2 LCD programs on PIC 18F4550 using MPLAB software and proteus simulation.

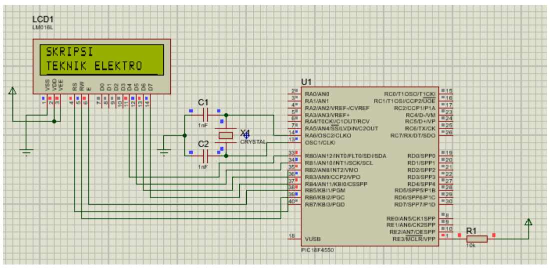


Figure 8. Test results of the 16x2 LCD program.

The test in figure 8 is a series of test results displaying characters on a 16x2 LCD with a 18F4550 microcontroller. This 16x2 LCD program test uses PORTB for E pin using PORTB4 and activating LATB4 and TRISB4 registers, RS pin using PORTB5 and activating LATB5 and TRISB5 registers, RW pin using PORTB6 and activating LATB6 and TRISB6 registers while D4-D7 uses PORTB0-PORTB3.

Testing of the ADC program on PIC 18F4550 using MPLAB software and proteus simulation by testing voltage values.

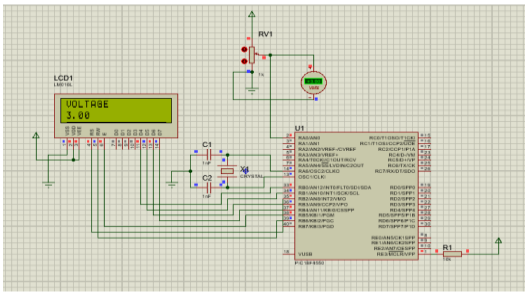


Figure 9. ADC program test results.

Figure 9 shows the ADC test circuit on the PIC 18F4550 using a PORT as an analog input port on the microcontroller. This ADC program test uses PORTA1 as the input pin where the input analog pin on the PIC microcontroller has a maximum reference voltage limit of 5V and uses a value scale of 0-1023.

Testing of MPPT solar charge controller using a buck converter with a lithium battery load of 16,500mAh input reference voltage of 15 V, 16V, 17 V, 18.1 V, 19 V, 20 V, 21 V, 22 V, 23.1 V, 24.1 V, 25 V, then testing using a 120 WP solar panel with a 12 V LED load and a 16,500mAh lithium battery.

Figure 10. Tool Testing.

This test is carried out to determine the accuracy of the work of the system can be seen in the following equation:

$$error = \left|\frac{\text{Measurement results of measuring systems}}{\text{Measuring Instruments}}\right| x100\% \quad (5)$$

This test was carried out by taking 10 experimental samples of each input voltage reference. From the tests carried out, the average result of each reference voltage produced is as shown in table 1.

Table 1. Average test results of each reference voltage with 10 experimental samples.

Vin (V)	Vs (V)	Ein (%)	Vout (V)	Vo (V)	Eo (%)	D (%)
15	14.5	3.16	12.56	12.28	3.25	61.2
16	14.3	3.83	12.70	12.64	3.38	65.6
17	16.5	3.11	12.65	12.68	3.26	71.1
18.1	17.4	3.82	12.95	12.54	3.85	72.0
19	18.4	3.05	12.76	12.47	2.74	73.9
20	19.4	3.01	12.71	12.68	3.01	75.6
21	20.4	3.01	12.90	12.34	4.31	76.2
22	21.4	2.88	12.74	12.82	4.18	77.8
23.1	22.3	3.53	12.86	12.40	3.55	79.2
24.1	23.3	3.52	12.74	12.50	4.31	80.8
25	24.2	3.06	12.81	12.39	4.08	80.8

Based on the data in Table 2, where the ADC reading results were tested by measuring 10 experimental samples of each reference voltage used, it can be seen that the ADC reading produced a fairly good level of accuracy with the highest reading error value of 4.31% and the lowest of 2.74% where the average error value of 11 samples was 3.61%.

The test of the 120 WP solar panel is carried out using the working condition parameters on the solar panel as a result of the irradiation conditions that hit the solar panel.

Figure 11. Solar panel testing.

Based on the data in Table 2, it can be seen that in sunny conditions the panel produces maximum voltage, but when the temperature increases, the panel experiences a decrease in output voltage, this indicates a decrease in the performance of the solar panel. From the recorded average, the highest output voltage of solar panels was obtained when the conditions were sunny and the temperature was not hot, which was in the range of 30 oC with an output voltage of 22.1 V

Table 2. Test results

Solar Conditions	Temperature (^{o}C)	Output (V)
Bright	29	21.2
Bright	30	22.1
Bright	35	19.6
Sunny Cloudy	32	20.6
Sunny Cloudy	29	20.6
Shadowed	30	18.7
Shadowed	30	18.5

Efficiency Testing with Pertube and Observe Algorithm System with Lithinum Battery Load. Testing this system using lithinum battery load, by taking sample data as many as 20 times sampling.

Based on the data in Table 3, the results of the system efficiency test using the P&O algorithm have an average input power recorded of 4.38975 W, then for the average system output power of 3.53294 W with an average efficiency in the system is 80.5804%. The efficiency generated in this test is quite good because the system can maximize the input power with an average efficiency of 80.4818 %.

Table 3. Results of system efficiency testing with P&O algorithm

Vs (V)	Is (A)	Ws (W)	Vout (V)	Iout (A)	Wout (W)	Efisiensi %
21.84	0.2	4.368	12.82	0.3	3.846	88.04
21.79	0.2	4.358	12.92	0.28	3.6176	83.01
20.84	0.18	3.751	12.87	0.28	3.6036	96.06
21.64	0.18	3.895	12.92	0.28	3.6176	92.87
21.79	0.18	3.922	12.97	0.128	1.6601	42.32
21.84	0.2	4.368	12.97	0.12	1.6601	38.00
21.79	0.17	3.704	12.97	0.12	1.6601	44.81
21.79	0.17	3.704	12.92	0.3	3.876	104.6
20.84	0.2	4.168	12.97	0.3	3.891	93.35
21.64	0.18	3.895	13.12	0.28	3.6736	94.31
21.79	0.18	3.922	12.97	0.28	3.6316	92.59
20.84	0.18	3.751	12.93	0.28	3.6204	96.51
21.64	0.3	6.492	12.87	0.28	3.6036	55.50
21.64	0.3	6.492	12.97	0.28	3.6316	55.93
21.84	0.2	4.368	12.93	0.3	3.879	88.80
21.84	0.2	4.368	12.87	0.3	3.861	88.39
21.79	0.2	4.358	12.87	0.3	3.861	88.59
21.64	0.3	6.492	12.92	0.48	6.2016	95.52
21.84	0.17	3.712	12.97	0.28	3.6316	97.81
21.79	0.17	3.704	12.97	0.28	3.6316	98.03
21.62	0.20	4.389	12.93	0.27	3.5329	80.48

Testing Systems with Solar Panels and Lithinum Battery loads. Testing of this system uses 120 WP solar panels with lithinum battery load with some irradiation condition parameters as shown in table 4-7

Table 4. Test results in Sunny conditions.

No	Weather Conditions	Solar Panels (V)	Vout Voltmeter (V)	Vout Sensor (V)
1	Bright	20	11.6	12.55
2	Bright	19.6	11.8	13.18
3	Bright	19.6	13.1	12.55
4	Bright	20	11.2	12.7
5	Bright	20.1	13.3	13
6	Bright	20	13	13.3
7	Bright	19.8	11.8	12.4
8	Bright	19.6	12.3	12.2
9	Bright	20	11.7	12.1
10	Bright	21.8	12.2	12.05
Average		20.05	12.2	12.603

Table 5. Test results in cloudy conditions.

No	Weather Conditions	Solar Panels (V)	Vout Voltmeter (V)	Vout Sensor (V)
1	Cloudy	17.4	11.8	12.05
2	Cloudy	18.2	12.3	12.23
3	Cloudy	18.4	11.7	12.74
4	Cloudy	18.4	12.2	13.3
5	Cloudy	18.8	12.8	13.3
6	Cloudy	19	13.6	12.4
7	Cloudy	18.1	12.6	12.2
8	Cloudy	18.8	12.4	12.1
9	Cloudy	17.8	12.4	12.05
10	Cloudy	18.1	12.5	12.23
Average		18.3	12.43	12.46

Table 6. Test results in sunny cloudy conditions.

No	Weather Conditions	Solar Panels (V)	Vout Voltmeter (V)	Vout Sensor (V)
1	sunny cloudy	20	12.4	12.4
2	sunny cloudy	20.1	12.5	12.2
3	sunny cloudy	20	11.5	12.1
4	sunny cloudy	20	12.8	12.05
5	sunny cloudy	19.72	13.6	12.23
6	sunny cloudy	19.72	12.6	12.74
7	sunny cloudy	20.6	12.4	13.3
8	sunny cloudy	20	12.4	12.4
9	sunny cloudy	19.72	12.5	12.2
10	sunny cloudy	20.6	11.5	12.1
Average		19.98	12.42	12.372

Table 7. Results of the shadow closed condition test.

No	Weather Conditions	Solar Panels (V)	Vout Voltmeter (V)	Vout Sensor (V)
1	shadow closed	18.1	12.5	12.23
2	shadow closed	18.8	11.5	12.74
3	shadow closed	17.8	12.8	13.3
4	shadow closed	18.8	12.3	12.23
5	shadow closed	19	11.7	12.74
6	shadow closed	18.8	12.2	13.3
7	shadow closed	18.8	12.8	12.4
8	shadow closed	18.2	13.6	12.2
9	shadow closed	18.4	12.6	12.1
10	shadow closed	17.4	12.4	12.05
Average		18.41	12.44	12.56

Based on the data of the system test results in Table 4-7, the MPPT output voltage data with the P&Q algorithm in sunny, cloudy, cloudy, and shaded conditions are 12,603V, 12.46V, 12,372V, and 12.56V, respectively. This shows that MPPT with P&O algorithm can work well to keep the output voltage of the MPPT stable in some operating conditions of the power plant with changes in the output voltage of the panel.

IV. Conclusion

Based on the design and testing of MPPT that has been carried out, the application of the P&O algorithm on MPPT can work well in maintaining the stability of the output voltage of the solar panel in several test conditions, the output and input conditions of the MPPT are monitored using ADC facilities, where the percentage of ADC reading error is relatively small, which is an average of 3.3%. The results of the panel output voltage test obtained the highest output voltage from the panel of 22.1 V and the lowest voltage of 18.5V, with the variation of the output voltage that has been realized MPPT is able to maintain an average output voltage of 12,603V in sunny and cloudy conditions, 12.23V in cloudy sunny conditions, and 12.5 V in shadowy conditions, with an average efficiency of 80.4818%.

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