Design and Build a Battery Charging Station for Electric Vehicles

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Abstract Battery is a medium used to store electrical energy. Currently often found cases about the use of batteries that do not last long. This is because we often forget to turn off the device for charging when charging is complete. So that happens is that charging will continue to work even in an over current or over voltage state. In this system used battery type accu. The input voltage from the system charging is voltage PLN which is lowered by the transformer then rectified by the Uncontrolled Full Wave Rectifier and lowered again by Buck Converter. Method used is constant current constant voltage using PI control for the set point of current and output voltage of Buck Converter. The system used STM32F4 microcontrolleras the central control system. When battery is full the relay will work to stop the process charging then SMS gateway will send a notification that the charging is complete. From the test was found that the relay can disconnect when the input voltage of the buck converter is not according to the design and the relay is also able to disconnect when the battery output current is below 0.34 A to overcome overcharge. The implementation on hardware is in accordance with the plan so that the device can be used for charging with the method constant current constant voltage by maintaining acurrent charging of 1.049 A during the initial process charging and voltage charging of 13.8 V at the end of charging so as to prevent overcharge.

***Index Terms*— Accu, Battery, Buck Converter, PLN Grid, Uncontrolled Full Wave Rectifier.**

I. INTRODUCTION

PRIVATE vehicle is a mandatory requirement that must be owned by everyone. Along with the development of the age of vehicles that can or cause harm to the environment are abandoned. Because if left continuously will cause excessive pollution, disturbed health, and others - others. To overcome this, a solution emerged, namely vehicles that use electrical energy. In vehicles that use electrical energy, there is minimal pollution to the environment. This is because the energy used is electrical energy stored in the battery. Accu is a type of battery that is very commonly used in various motorized vehicles such as cars, motorcycles, and electric bicycles. Accu is the main choice because it can produce large amounts of electrical energy and can be refilled. However, if the battery is refilled with an improper charging process, the life of the battery will not last long. This is because we often forget to turn off thedevice battery charging when the battery is fully charged. So if there is an overcharge, thedevice charging will still work.

Based on these problems, an idea emerged to solve the problem, namely by designing asystem charging originating from the PLN grid. Because the voltage on the PLN grid is an alternating voltage and is very large, it is first lowered by atransformer stepdown which will then be rectified by an uncontrolled full wave rectifier. Then it is lowered by Buck Converter withmethod constant current constant voltage which can reduce the potential for overcharge. In theprocess, charging PI control is used to adjust the PWM on the Buck Converter. Then there is also protection when the voltage during theprocess is charging not appropriate and when the charging is complete. And when the charging is complete, the SMS Gateway will send a notification that the charging is complete.

II. THEORI

A. Accumulator (Accu)

The accumulator or often called the battery is one type of battery that is usually used to supply electricity for electric vehicles, lighting, etc. Accu serves to store electrical energy in the form of chemical energy. Capacitors and batteries are examples of accumulators. In everyday life, accumulators are usually used in private vehicles, namely motorbikes or cars. The accumulator itself is a secondary cell because the battery can generate an electric current and can be charged with an electric current again. The battery itself consists of an anode and a cathode, namely Pb and PbO2 electrodes with H2SO4 electrolyte. The battery also has a capacity when used per hour which is usually called Ah (Ampere Hour). The following table 2.1. which contains the state of charge of the battery.

TABLE 1
STATE OF CHARGE BATTERY

Charge	Vopen circuit 6-V battery	Vopen Circuit 12-V battery	VOpen Circuit 24-V battery	VOpen Circuit 48-V battery
100%	6.37	12.73	25.46	50.92
90%	6.31	12.62	25.24	50.48
80%	6.25	12.5	25	50
70%	6.19	12.37	24.74	49.48
60%	6.12	12.24	24.48	48.96
50%	6.05	12.1	24.2	48.4
40%	5.98	11.96	23.92	47.84
30%	5.91	11.81	23.62	47.24
20%	5.83	11.66	23.32	46.64
10%	5.75	11.51	23.02	46.04

The voltage charge on the accumulator generally ranges from 110% - 115% of rating thevoltage accumulator. Then for the ideal current when charging the accumulator it ranges from 10% - 40% of the rating currenton the accumulator. The battery charging time itself depends on the current and voltage used during the charging process. Ideally the accumulator is said to be full when the charging reaches 80%.

B. Uncontrolled Full Wave Rectifier

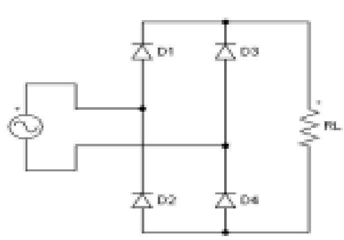

Fig. 1. Full Wave Rectifier Circuit

The working principle of thecircuit fullwave rectifier above is that when it gets a positive cycle of alternating current flowing in the circuit, then diodes 1 and 3 will be on because they are in acondition forward bias while diode 2 and diode 4 will be off because they are experiencing reverse bias conditions. Then when it gets a negative cycle from alternating current, diodes 2 and 4 will be on because they are experiencing acondition forward bias while diodes 1 and 3 will be off because they are experiencing acondition reverse bias. Then the following formula is used to determine the percentage error between the output voltage in theory and practice.

C. Buck Converter

Buck Converter is a DC-DC converter which is used as a DC voltage reducer. The components of the buck converter circuit consist of a diode, capacitor, inductor, and mosfet. There are 2 switch conditions on the buck converter, namely:

1. Closed Switch

When the switch is closed, the diode is reverse biased as shown in Fig. 2 below

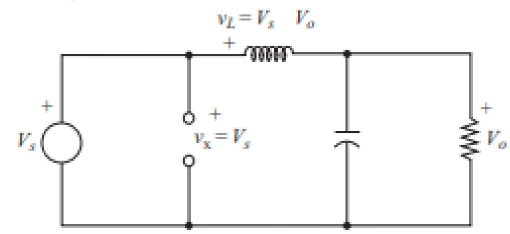

Fig. 2. Buck Converter Circuit When Closed Switch

2. Open Switch

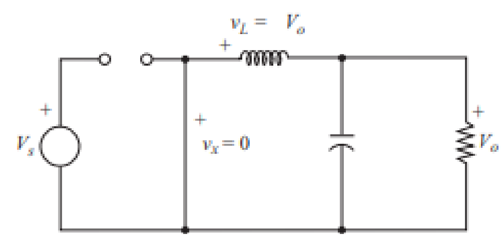

Fig. 3. Buck Converter Circuit When Open Switch

III. METHODS

The methods that used in this research are conducting literature study, perform partial tool test, integration tool test, and characteristic data analysis from testing.

A. Diagram Block

The following block diagram of the planning of the battery charging station system for electric vehicles is shown in Fig. 4.

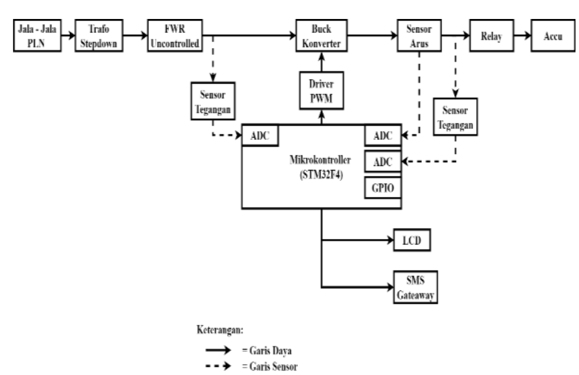

Fig. 4. Diagram Block System

System to be designed uses a source from the PLN grid, then the voltage from the PLN grid is stepped down through atransformer stepdown and then rectified by the Uncontrolled FWR. Then the output voltage from the Uncontrolled FWR will later become the Input Voltage from the Buck Converter. The method used in the Buck Converter is themethod constant current constant voltage using a PI control to adjust the set point of theoutput current and voltage Buck Converter.method Constant current and constant voltage can reduce the potential overcharge the battery(batteries).Then in this final project there are voltage sensors and current sensors, these sensors are used to send the output current conditions and input and output voltages when charging the battery (accu) to the STM32F4 microcontroller as a control center on the Buck Converter. Voltage when charging The will be displayed through the LCD then when the battery is full the relay will work automatically to stop the process charging so that there is no overcharge and the user gets a notification that theprocess is charging complete from the SMS Gateway. The following Fig. 5 is a flowchart system.If you want to submit your file with one column electronically, please do the following:

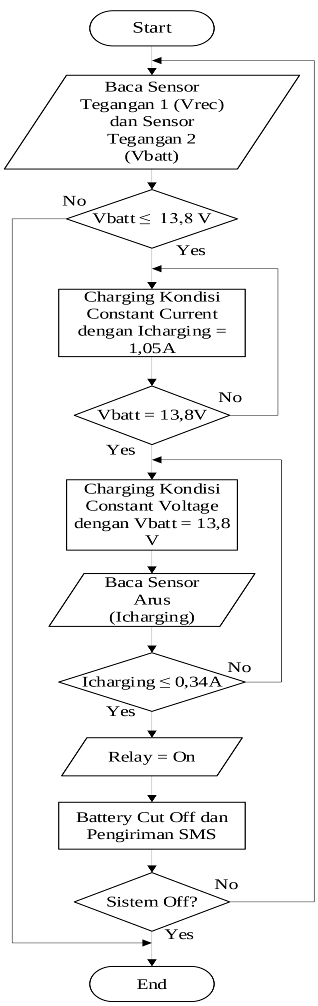

Fig. 5. Flowchart System

A. Accu Planning

The used for this final project is battery a 12V 7Ah battery. So that the charging current and voltage for the battery can be calculated as follows:

Icharging = 15% x 7 = 1,05 A

Vcharging = 115% x 12 = 13.8 V

B. Modelling of Uncontrolled Full Wave Rectifier

In this final project, an Uncontrolled Full Wave Rectifier is designed to rectify the voltage from the PLN grid which has been lowered by a step down transformer, namely from 20 Vac to 28.27 Vdc. The following is the calculation of the Uncontrolled Full Wave Rectifier which will be used for the Buck Converter input voltage:

$$Vo(dc) = Vm - (\Delta Vo / 2)$$

ΔVo that allowed is $0{,}1\% Vo$, so :

$$\Delta Vo = 0{,}028V$$

$$Vdc = 28{,}28 - (0{,}028 / 2)$$

$$Vdc = 28{,}28 - 0{,}014$$

$$Vdc = 28{,}27V$$

If :

$$Vin = 20Vac$$

$$Vo = 28{,}27Vdc$$

$$R = 1k\Omega$$

So :

$$C = \frac{Vm}{2x\Delta Vox fx R}$$

$$C = \frac{28{,}27}{2x0{,}028x50x1000} = 10mF$$

C. Modelling of Buck Converter

The buck converter circuit is used to lower the voltage to a voltage that suits the needs of the battery. In this buck converter circuit there are several components, namely diodes, inductors, capacitors, resistors and Mosfet. In designing a good buck converter, parameters are needed to obtain the right component values in order to produce a good output. To determine the component value of the buck converter, it is done by calculating

$$Vin = 28{,}27V$$

$$Fswitching = 40kHz$$

$$Io = 1.05A$$

$$Vo = 13.8V$$

$$\Delta i = 20\%$$

$$\Delta Vo = 0.1\%$$

$$D = 0.49$$

$$R = 13.14\Omega$$

$$L = 0.838mH$$

$$C = 47.5\mu F$$

D. Modelling of Control PI

For the design of the PI control, we must know the results of the simulation wave in the opencondition loop to find out the existing parameters as shown in Figures 3.5 and 3.6.

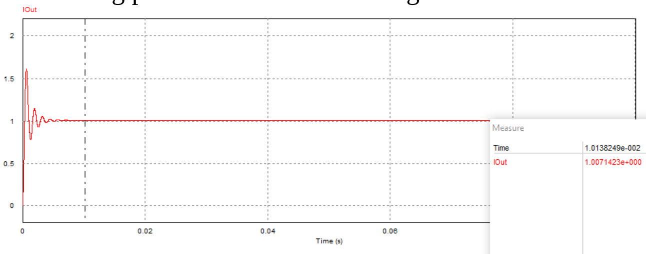

Fig. 6. Current Wave Uncontrolled

In this system, theis used PI control to adjust the output current from the converter to be constant at 1.05 A. The following is the calculation for PI control

Steady State Time (ts) = 10 ms
Steady State Voltage (Yss) = 1 A
Target Voltage (Xss) = 1.05 A

OLTF

$$K = \frac{Yss}{Xss} = \frac{1}{1.05} = 0.952$$

$$\tau = \frac{ts}{5} = \frac{10ms}{5} = 2ms$$

$$OLTF = \frac{K}{\tau + 1} = \frac{0.952}{2s + 1}$$

CLTF

$$ts' = s\tau$$

$$\tau' = \frac{1}{5}ts = \frac{1}{5}.2 = 0.4ms$$

$$CLTF = \frac{1}{\tau' + 1} = \frac{1}{0.4s + 1}$$

Kp and Ki Value

$$Kp = \frac{\tau}{K\tau'} = \frac{2}{0.952x0.4} = 5.25$$

$$Ki = \frac{Kp}{\tau} = \frac{5.25}{2} = 2.625$$

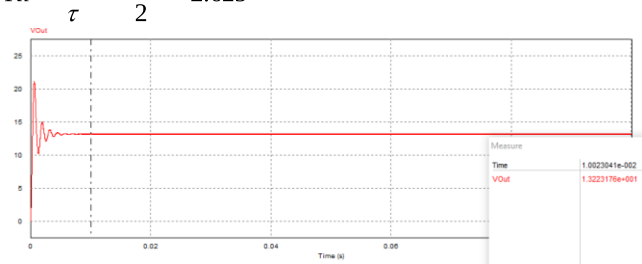

Fig. 7. Voltage Wave Uncontrolled

In this system, theis used PI control to adjust the output voltage from the converter to be constant at 13.8 V. The following is the calculation for PI control

Steady State Time (ts) = 10 ms
Steady State Voltage (Yss) = 13.23 V
Target Voltage (Xss) = 13.8 V

OLTF

$$K = \frac{Yss}{Xss} = \frac{13.23}{13.8} = 0.958$$

$$\tau = \frac{ts}{5} = \frac{10ms}{5} = 2ms$$

$$OLTF = \frac{K}{\tau + 1} = \frac{0.958}{2s + 1}$$

CLTF

$$ts' = s\tau$$

$$\tau' = \frac{1}{5}ts = \frac{1}{5}.2 = 0.4ms$$

$$CLTF = \frac{1}{\tau' + 1} = \frac{1}{0.4s + 1}$$

Kp and Ki Value

$$Kp = \frac{\tau}{K\tau'} = \frac{2}{0.958x0.4} = 5.21$$

$$Ki = \frac{Kp}{\tau} = \frac{5.21}{2} = 2.605$$

E. SMS Gateway Planning

At the end of the project, SMS Gateway serves to send notifications to the user that the charging process has been completed. When the relay has stopped the charging process because the current is approaching 0 then a gateway sms will be sent to the user to notify that the battery is full.

IV. RESULT AND DISCUSSION

A. Buck Converter Test

In the buck converter test, the aim is to get buck converter data starting from the input voltage to the efficiency of the buck converter that has been made. In the test used a load resistor of 13.14 Ohm. Then the input voltage is set at 28.27 volts with a duty cycle of 10% - 50% with a 5% step.

TABLE 2
DATA OF BUCK CONVERTER TEST

Vin (V)	Iin (A)	Duty (%)	Vo Prak (V)	Io (A)	Vo Teo (V)	Eror (%)
28,27	0,022	10	2,23	0,23	2,827	21,117
28,27	0,05	15	3,5	0,342	4,240	17,462
28,27	0,084	20	4,8	0,43	5,654	15,104
28,27	0,14	25	6,27	0,53	7,067	11,284
28,27	0,24	30	7,6	0,68	8,481	10,387
28,27	0,275	35	9,1	0,75	9,894	8,029
28,27	0,41	40	10,5	0,92	11,308	7,145

28,27	0,53	45	11,9	1,03	12,721	6,457
28,27	0,61	50	13,3	1,15	14,135	5,907

TABLE 3
EFFISIENCY OF BUCK CONVERTER

Duty (%)	Pin (W)	Pout (W)	Efisiensi (%)
10	0,621	0,512	82,467
15	1,413	1,197	84,683
20	2,374	2,064	86,916
25	3,957	3,323	83,963
30	6,011	5,767	85
35	7,774	6,825	87,789
40	11,590	9,66	83,342
45	14,983	12,257	81,805
50	17,244	15,295	88,693
Effisiensi rerata			85,022

B. Rectifier Test

In this project, the rectifier test aims to ensure that the input and output voltages of the rectifier are in accordance with the design because the rectifier plays a role in the input voltage of the buck converter that has been designed. There is a slight difference in value between the results of the calculation of the rectifier theory at this time as shown in table 4 and there is a physical form and testing of the rectifier as shown in Fig. 8.

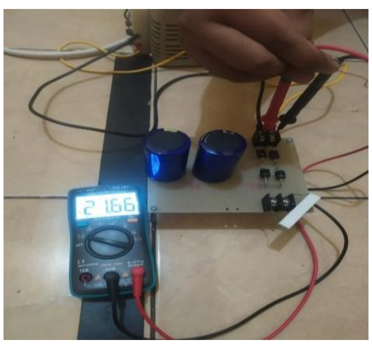

Fig. 8. Rectifier Test

TABLE 4
DATA OF RECTIFIER TEST

Vin Teori (V)	Vin Praktek (V)	Vo Teori (V)	Vo Praktek (V)	Eror Vin (%)	Eror Vo (%)
20	21,6	28,27	28,4	8	0,45
19	20,5	26,85	27	7,89	0,55
18	19,3	25,44	25,6	7,22	0,62
Error rerata				7,7	0,54

C. Battery Test

In this project, the Kijo 12 V 7 AH battery is used. To find out the characteristics of the battery used, a battery testing process is needed. In this test, 2 loads are used, namely 5 Watt dc lamps and 12 Watt dc lamps. Table 5 and Table 6 are battery testing and Fig. 9 is a battery test image.

TABLE 5
DATA OF DISCHARGE TEST WITH LOAD DC LAMP 5 WATT

Jam	Tegangan (V)	Arus (A)
12.22	12,78	0,3
13.22	12,68	0,28
14.22	12,66	0,26
15.22	12,62	0,25

TABLE 6
DATA OF DISCHARGE TEST WITH LOAD DC LAMP 5 WATT

Jam	Tegangan (V)	Arus (A)
16.05	12,6	0,43
17.05	12,49	0,42
18.05	12,42	0,41
19.05	12,36	0,4
20.05	12,29	0,39

It can be seen in table 5 that the longer the voltage and current values will decrease because the test carried out is a discharge test. Then in table 6 it can also be seen that the longer the voltage and current values will also decrease because the test carried out is a discharge test.

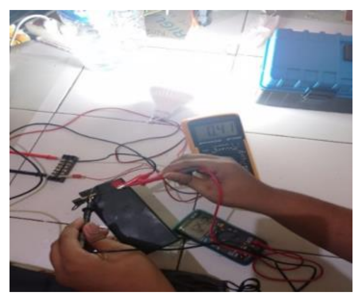

Fig. 9. Battery Test

D. SMS Gateway Test

In this final project, the SMS gateway is used to notify when the charging is complete, by sending an SMS when the battery is full. As Fig. 10 and 11.

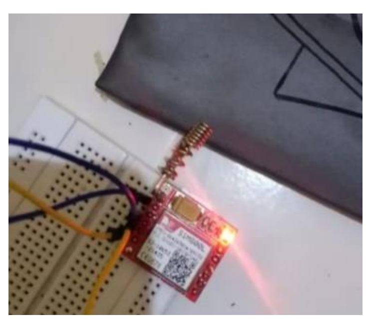

Fig. 10. Module SMS Respond

It can be seen in Figure 10 that the response of the SMS module can send a message if there is a light that lights up slowly which indicates the module is getting a signal to send an SMS.

Fig. 11. Notification Test

Fig. 11 is a test image of the notification from the sms gateway which indicates that the sms gateway module can send messages because the module has received a signal so that the message can be sent according to what we designed.

E. Charging Open Loop Test

In this project, theprocess is carried out battery charging using a buck converter in ancondition open loop. At this time theparameter is charging carried out when the battery has reached thevoltage battery of 12.44 V, this is done with ancondition open loop or without control. The following table 7 data and figure 4.20testing process battery charging.

TABLE 7
BATTERY CHARGING TEST

Menit	Vin (V)	Vo (V)	Iin (A)	Io (A)	Pin (W)	Po (W)	Eff (%)
0	28,2	13	0,39	0,611	10,998	7,943	72,222
10	28,2	13,08	0,31	0,57	8,742	7,455	85,284
20	28,2	13,08	0,31	0,561	8,742	7,337	83,938
30	28,2	13,09	0,301	0,541	8,488	7,081	83,429
40	28,2	13,12	0,296	0,541	8,347	7,097	85,033
50	28,2	13,14	0,293	0,541	8,262	7,108	86,035
60	28,2	13,15	0,281	0,519	7,924	6,824	86,126
70	28,13	13,17	0,28	0,512	7,876	6,743	85,610
80	28,2	13,22	0,273	0,502	7,698	6,636	86,203
90	28,1	13,25	0,27	0,49	7,587	6,492	85,574
100	28,15	13,27	0,268	0,483	7,544	6,409	84,958
110	28,2	13,3	0,268	0,481	7,557	6,397	84,647
120	28,2	13,34	0,258	0,47	7,275	6,269	86,175
130	28,2	13,41	0,253	0,451	7,134	6,047	84,768
140	28,21	13,45	0,25	0,433	7,052	5,823	82,578
160	28,2	13,47	0,243	0,42	6,852	5,657	82,558
170	28,22	13,49	0,241	0,42	6,801	5,665	83,308
180	28,2	13,54	0,23	0,401	6,486	5,429	83,711
Efisiensi rerata							84

It can be seen from table 7 that the longer the charging process, the higher the battery voltage, while the battery current (Io) will decrease. For 180 minutes, it can be seen that the battery voltage (Vo) which was originally 12.44 increased to 13 V then the average efficiency was 84%.

F. Relay Test

In this project there is a relay that functions as a cut off for charging the battery with a current parameter of 0.34 A. The following Fig. 12 test for cut off relay.

TABLE 8
DATA OF RELAY TEST

Kondisi	Relay
Ibatt < 0,34 A	On
Ibatt > 0,34 A	Off

G. Charging Close Loop Test

This test is carried out using software, namely Matlab. In this Matlab software, a charging process for the battery is designed using a buck converter with a close loop circuit. The following Fig. 12 is a series of simulations and table 4.22 is the test data.

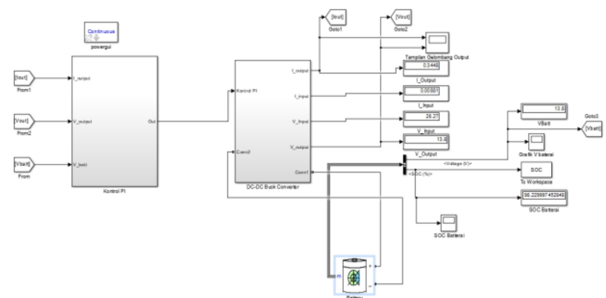

Fig. 12. Charging Battery Simulation Test

TABLE 9
DATA OF CHARGING BATTERY WITH CLOSE LOOP BUCK CONVERTER

SOC (%)	Vin (V)	Vo (V)	Io (A)
40	28,27	9,8	1,049
45	28,27	10,56	1,049
50	28,27	11,16	1,049
55	28,27	11,65	1,049
60	28,27	12,06	1,049
65	28,27	12,41	1,049
70	28,27	12,7	1,049
75	28,27	12,96	1,049
80	28,27	13,19	1,049
85	28,27	13,39	1,049
90	28,27	13,56	1,049
95	28,27	13,72	1,049
98	28,27	13,8	0,56
98,1	28,27	13,8	0,46
98,2	28,27	13,8	0,37
98,23	28,27	13,8	0,34

It can be seen in table 9 that when the 40% SOC of the battery reaches the set point voltage or 98% SOC, the constant current method is used with a constant current of 1.049 A then when it reaches 98% SOC it changes to a constant voltage of 13.8 V. Then the charging will be completed when the battery current is below 0.34 A. The following Fig. 13 and 14 illustrate the response of the output current and output voltage.

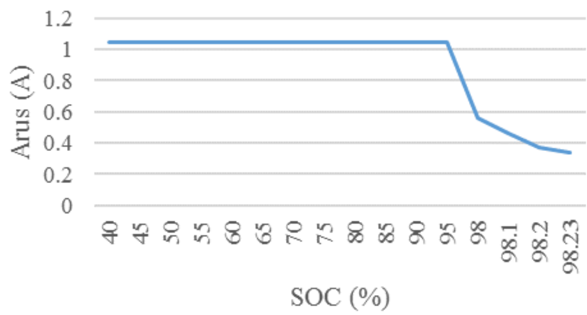

Fig. 13. Graph of Output Current Response when Constant Current

From Fig. 13 it can be seen that the output current response when SOC 40% - 95% the output current will be constant at 1.049 A then when the battery voltage has reached 13.8 V or SOC 98% the output current will decrease because it is already in a constant voltage condition.

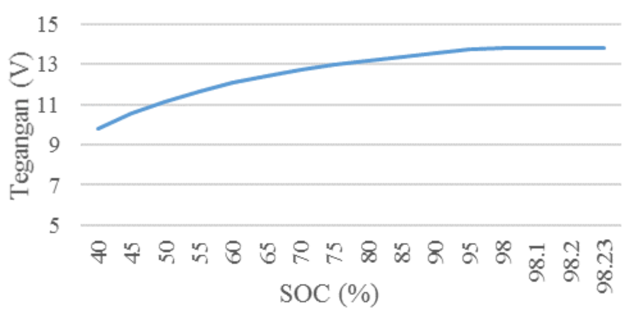

Fig. 14. Graph of Output Voltage Response when constant voltage

From Fig. 14 it can be seen that when SOC 40% - 95% the output voltage will continue to rise then when the output voltage has reached the charging set point value of 13.8 V (98% SOC) then the output voltage will continue to be constant until the charging process is complete.

V. CONCLUSION

After the planning process for testing and analysis and also comparing it with supporting theories, it can be concluded that:

1. The average efficiency of the Buck Converter at the time of the open loop is 80% while the efficiency at the time of the close loop at the time of Constant Current Constant Voltage in the large simulation is around 99% due to the application of the PI control itself.
2. Testing Buck Converter with PI control in the simulation by changing the voltage from 28.27 V - 23.27 V with 1V steps producesvoltage outputof a constant around 13.8 V according to the design in thecondition closed loop .
3. Testing Buck Converter with PI control in the simulation by changing the voltage from 28.27 V - 23.27 V with 1V steps producescurrent outputof a constant around 1.05 A according to the design in thecondition closed loop .
4. There are relays used for currents less than 0.34 A.
5. Thetest buck converter that uses PI control for charging battery has succeeded in using a constant current constant voltage with acurrent of charging 1,049 A and a voltage of 13.8 V.
6. Simulation test can be seen that the current which was initially constant at 1.049 A will continue to drop and is cut off at 0.34 current to prevent overcharge.

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