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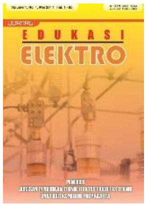

Characteristics of LiFePo4 and Li-Ion Batteries during the Process of Charging and Discharging for Recommendation Solar Power Energy Storage

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Abstract— One of the advantages of using electric vehicle batteries to store electrical energy is an appropriate technology that supports zero emission. Hence, this research tries to compare based on each type of Lithium to be seen in terms of capacity and total energy obtained during charging and discharging conditions. The aim of this study is to compare the performance characteristics of Lithium Iron Phosphate (LiFePO4) and Lithium-ion (Li-Ion) batteries in terms of their capacity and total energy output during charging and discharging conditions. Based on the results of testing the conditions when charging from both of them, it was found that the capacity of the LiFePo4 battery was 22.93Ah while the Li-Ion was 2.65 Ah. for a total LiFePo4 energy of 79.84 Wh and Li-Ion of 10.28 Wh. Meanwhile, when testing the Discharging conditions, the LiFePo4 battery capacity based on the test results was 22.76 Ah and Li-Ion 2.60 Ah. Meanwhile, the measured total energy from LiFePo4 is 69.45 Wh, and Li-Ion is 9.44 Wh. Hence, if viewed from the advantages and disadvantages, Lithium Iron Phosphate batteries are suitable for accumulators or electric car batteries and energy storage for solar power plants.

Keywords: characteristic of battery, charging condition, discharging condition, LiFePo4, Li-Ion

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1 Introduction

The use of electric vehicle batteries is currently increasing. From an economic point of view, this also has advantages for users. One of the advantages of using electric vehicle batteries to store electrical energy is an appropriate technology that supports zero emission. The storm that is generally used in electric vehicles is the Lithium type. Lithium has many kinds, including LiFePo4 and Li-Ion. The two batteries have different characteristics.

The reduction of the second use of the battery based on [1][2][3][4][5] mentions that there is a decrease of used electric vehicle battery usage of about 70-80% of its original capacity, and it is considered as the end of the first battery life, with a typical battery capacity of around 5-24 kWh [Mild Hybrid Electric Vehicle (MHEV) 5 kWh– Electric Vehicle Battery (BEV) 18–24 kWh] where the estimated battery life for a typical user is about ten years, with 40 minutes of battery use per day with [Depth of Discharge (DoD)] 35% with 200 annual charging. Based on [6][7] The Lithium-Ion battery type is most widely used because it is rechargeable. Its advantages are high energy, power capacity, self-contained low discharge, and a long life cycle.

On the other hand, Li-ion batteries lose capacity due to charge/discharge cycles. This capacity decreases, or degradation occurs due to various failure mechanisms, including formation and growth of the Solid Electrolyte Interface (SEI) layer, cracking of electrode particles, electrolyte decomposition, and lithium deposition. Therefore, life cycle testing consisting of multiple charge/discharge cycles is performed to determine the number of cycles to the End of Life (EOL), often identified as a 20% reduction in initial or rated capacity. Some manufacturers may have application-based failure criteria and test batteries for shorter or longer durations than necessary for a 20% capacity reduction [5][7]. Table 1 below describes some comparisons of each battery [8].

Table 1. Characteristic and specifications of commonly used rechargeable batteries

Specifications	**Types**					
	Lead Acid	**NiCd**	**NiMH**	**Li-Ion**		
				Cobalt	**Manganese**	**Phospate**
Specific Energy (Wh/kg)	30-50	45-80	60-120	150-250	100-150	90-120
Internal Resistance	Very Low	Very Low	Low	Moderate	Low	Very Low
Cycle Life (80% DoD)	200-300	1,000	300-500	500-1,000	500-1,000	1,000-2,000
Change Time	8-16h	1-2h	2-4h	2-4h	1-2h	1-2h
Overcharge Tolerance	High	Moderate	Low	Low. No Trickle Charge		
Self-Discharge/Month (room temp)	5%	20%	30%	<5% Protection Circuit Consumes 3%/month		
Cell Voltage (nominal)	2V	1.2V	1.2V	3.6V	3.7	3.2-3.3 V
Charge Cut-off Voltage (V/Cell)	2.40 Float 2.25	Full Charge Detection by Voltage Signature		4.2 typical Some go to higher V		3.6
Discharge Cut-off Voltage (V/Cell, 1C)	1.75V	1.00V		2.50-3.00V		2.50V
Peak Load Current (Best Result)	5C 0.2C	20C 1C	5C 0.5C	2C <1C	>30C <10C	>30C <10C
Charge Temperature	20 to 50C (-4 to 122 F)	20 to 50C (-4 to 122 F)		20 to 50C (-4 to 122 F)		
Discharge Temperature	20 to 50C (-4 to 122 F)	20 to 50C (-4 to 122 F)		20 to 50C (-4 to 122 F)		
Maintenance Requirement	3-6 month (topping chg)	Full Discharge every 90 Days when in full use		Maintenance-Free		
Safety Requirements	Thermal stable	Thermally stable, fuse protection		Protection Circuit Mandatory		
In Use Since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very High	Very High	Low	Low		
Coulombic Efficiency	~90%	~70% slow charge ~90% fast charge		99%		
Cost	Low	Moderate		High		

This study uses two batteries, LiFePo4 and Li-Ion, by comparing the conditions when charging and discharging based on a specifications table. Research [9][10][11] has been proven for the second time to use Li-Ion batteries as energy storage on a small scale. The aim from this study to understanding the performance differences between LiFePO4 and Li-Ion batteries is crucial for optimizing the selection of energy storage solutions in applications such as electric vehicles and solar power plants, leading to enhanced efficiency and sustainability. One of the main objectives of this research is to reduce battery waste from electric vehicles, namely by processing battery waste for electrical energy storage, which is then used as electrical energy storage.

2 Methods

This study uses the experimental method by conducting direct testing for both batteries. Figure 1. is a research flowchart showing the stages for carrying out a comparative test of the characteristics of LiFePo4 and Li-Ion Batteries, to be seen from the results of the voltage and current characteristics and capacity, which have many advantages so that they can be used as battery comparisons.

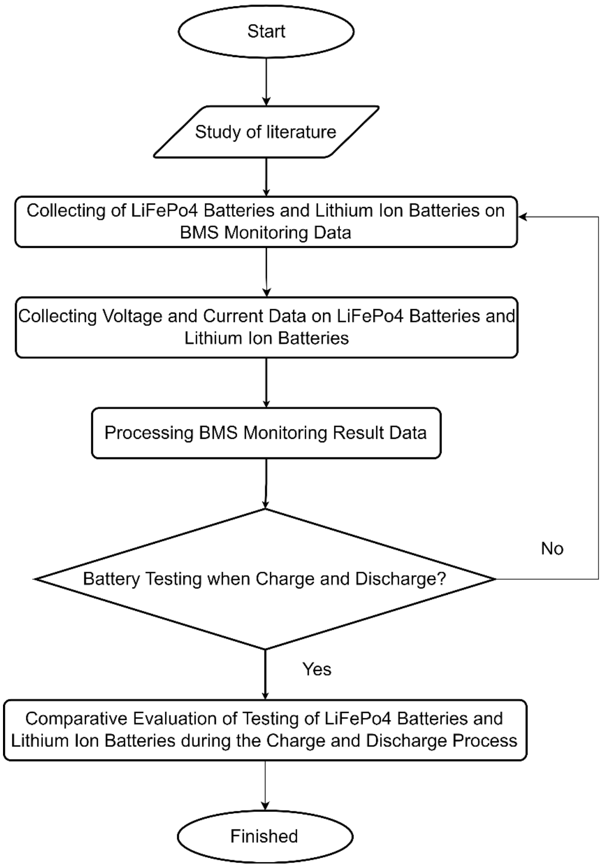


Fig. 1. Research flow chart

The pictures are based o average ratings of commercial batteries at publication. Meanwhile, the specifications for LiFePo4 and Li-Ion Batteries to be used are in Tables 2 and 3 below.

Table 2. Characteristics and spesifications LiFePo4

Specification		
Capacity	Typical	2600mAh
Call Voltage	Nominal	3,6V
	Charge	34,2V
	Discharge	2,5 V
Charge Current	Standard	2,6A
	Maximum	6.0A
Charge Time	Standard	1.5h
Discharge Current	Maximum	35A
Ambient Temperature	Charge	0°C ~ 60°C
	Discharge	-40°C ~ 60°C

Based on Table 2, this battery can charge with high efficiency, and when the discharge process occurs, the charge loss is very small, and charging is fast when compared to other types of batteries; the capacity of Lithium Iron Phosphate (LiFePO4) batteries is greater than different types of batteries. Another thing is that the energy density of this type of battery is very tight.

Table 3. Characteristic and specifications Li-Ion INR 18650-26E

Specification		
Capacity	Typical	2500mAh
Call Voltage	Nominal	3,6V
	Charge	3,65V
	Discharge	2,0 V
Charge Current	Standard	5A
	Maximum	25A
Charge Time	Standard	3h
Discharge Current	Maximum	0°C ~ 40°C
Ambient Temperature	Charge	0°C ~ 40°C
	Discharge	-20°C ~ 60°C

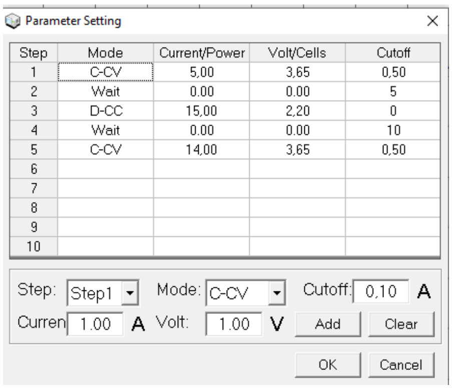
Based on Table 3, the Li-Ion battery, for type 18650 Lithium battery voltage, reaches 3.6-3.7V DC. Lithium battery charging with a charger can accept 4.2V DC voltage. An ordinary battery has a 1.5V DC output (battery disposal or battery exhausted and thrown away). Rechargeable batteries such as NiMH or NiCD batteries have a 1.2V DC output (rechargeable).

This study used the Battery Tester Electronic Load tool and monitored it through the EB Tester Software. The following is a comparison process carried out:

a. Turn on the Battery Tester by pressing the power button on the back.
b. Connect the red probe to the positive terminal and the black probe to the battery's negative terminal. Simultaneously look at the Battery Tester screen. The battery voltage will be displayed and if the battery voltage is not readable or below the minimum battery voltage limit. Caused by the Battery Tester tool has a minimum voltage on the battery that will be charged or discharged using the device Battery Charger dan Discharger IMAX B6AC.
c. Before opening the application, the step must be to connect the Universal Serial Bus (USB) to the laptop. This is done if the application is opened first before joining the Universal Serial Bus (USB), then COM on the computer will not be detected.
d. After the application is open, we can immediately select COM and click connect. Then on the Battery Tester screen the words PC will appear. This indicates that the Battery Tester and the laptop are connected. Figure 2 shows the monitoring of the battery tester connected to the laptop.

Fig.2. Battery tester LCD display

e. Next step is to enter the parameter settings by means of a cycle test – setting – step 1 enters the appropriate parameters – Add – after all the steps are filled click OK.



Step	Mode	Current/Power	Volt/Cells	Cutoff
1	C-CV	5,00	3,65	0,50
2	Wait	0.00	0.00	5
3	D-CC	15,00	2,20	0
4	Wait	0.00	0.00	10
5	C-CV	14,00	3,65	0,50
6				
7				
8				
9				
10				

Fig. 3. Parameter setting

f. In the next step, enter the parameter settings according to the battery used based on Figure 3. Figure 4 for the LiFePo4 battery and Li-Ion batteries.

Step	Mode	Set1	Set2	Cutoff
1	C-CV	15,00	3,60	0,50
2	Wait	0.00	0.00	5
3	D-CC	15,00	2,20	0
4	Wait	0.00	0.00	10
5	C-CV	15,00	3,60	0,50

(a)

Step	Mode	Set1	Set2	Cutoff
1	C-CV	1,50	4,20	0,10
2	Wait	0.00	0.00	5
3	D-CC	1,50	2,50	0
4	Wait	0.00	0.00	10
5	Wait	0.00	0.00	1

(b)

Fig.4. Parameter setting batteries LiFePO4 (a) and Li-Ion (b)

g. After the parameter settings are complete, click start and wait for the Charge and Discharge process to complete. The following Figure 5 Taking when testing LiFePo4 and Li-Ion batteries, respectively.

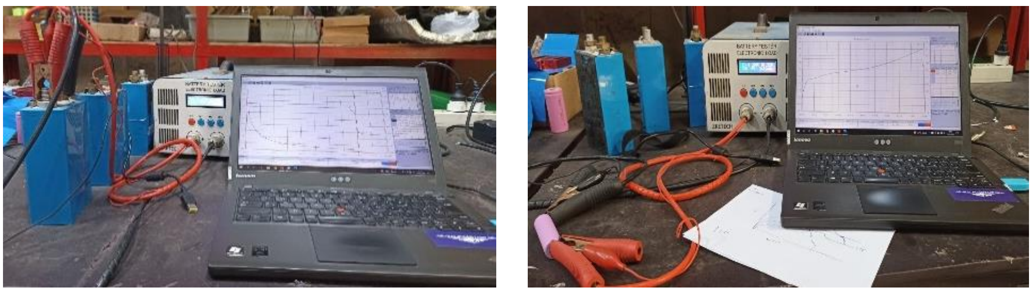


Fig.5. Battery testing

3 Result and Discussion

The following results are obtained based on test data using the Electronic Load Battery Tester and monitoring through the EB Tester Software. The test was carried out in 2 conditions with 2 types of batteries.

3.1. Charging Conditions

Charging the LiFePO4 battery takes 2 hours. In carrying out this battery test, data readings are carried out every 2 seconds. It can be seen in the graph that when the voltage on the battery reaches its maximum voltage, the current will decrease. The battery runs at maximum voltage after charging, lasting 1 hour and 35 minutes. The maximum voltage on a LiFePO4 battery is 3.65V. Reducing the current value is intended so the charged battery does not experience overcharge. The following graphs show the current and voltage resulting from the Charge process using a current of 15A. It shown on Figure 6 and 7 shows the testing process during charging, respectively.

In testing from Figure 7, the 18650 Lithium-ion battery charge lasted 2 hours and 4 minutes. In carrying out this battery test, data readings are carried out every 2 seconds. It can be seen in the graph that when the voltage on the battery reaches the maximum voltage, then the current will decrease. The battery reaches the maximum voltage after charging and lasts 1 hour and 30 minutes. Charging a Lithium-ion battery with a charger can accept a voltage of 4.2V. This decrease in current is intended so that the battery in Charge does not experience Overcharge. The following is a graph of the current and voltage resulting from the Charge process using a current of 1.5A. Meanwhile, Table 4 displays the data from the test results when charging.

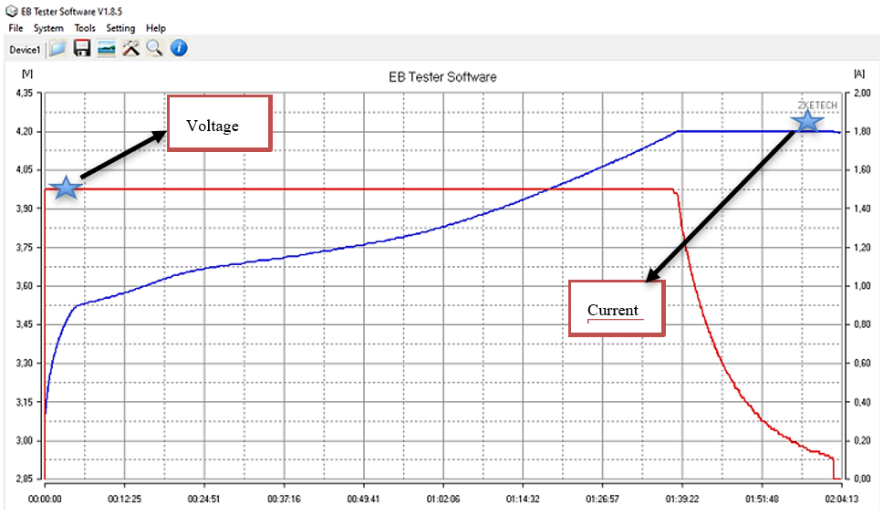


Fig. 6. LiFePO4 battery charge chart

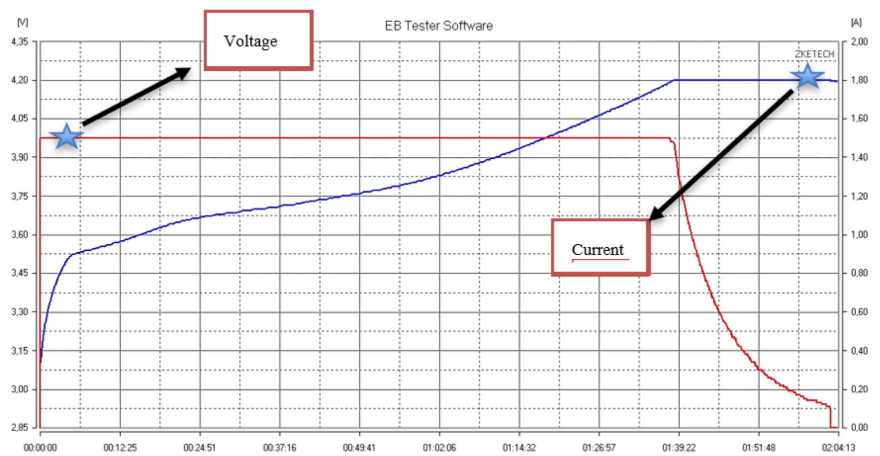


Fig. 7. Li-Ion battery charge chart

Table 4. Test result data during charging condition

Charging Condition		
Specification	**Number of Capacities**	
	LiFePo4	**Li-Ion 18650 26E**
Voltage	Begin volt: 2,7V	Begin volt: 3,01V
	Cutoff volt: 3,6V	Cutoff volt: 4,2V
	Avg volt: 3,48V	Avg volt: 3,87V
Capacity	22,93Ah	2,65Ah
Total Energy	79,84Wh	10,28Wh

3.2. Discharging Conditions

Emptying or discharging the LiFePO4 battery takes 1 hour 51 minutes. In this battery test, data readings are carried out every 2 seconds. In this test, the current is in a stable position of 15A. If you look at the voltage curve, the voltage will tend to fall. This is in accordance with the process being carried out, namely battery discharge. If the battery voltage during the discharge process exceeds the minimum voltage, the battery will be exposed to deep discharge, which can cause the battery cells to die. The minimum voltage of a LiFePO4 battery is 2.0V. Then the time taken in the Discharging process is similar to the Charging process. The following is a graph of the current and voltage generated from the Discharge process using a current of 15A. It shown from Figure 8.

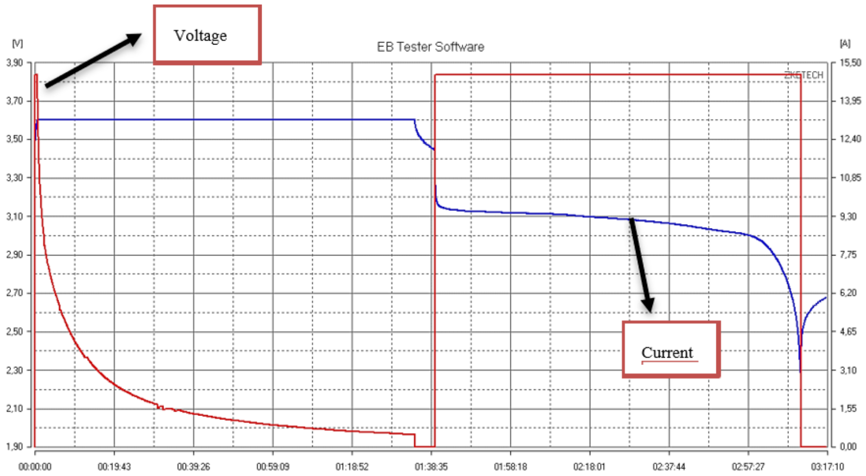


Fig. 8. LiFePO4 battery discharge chart

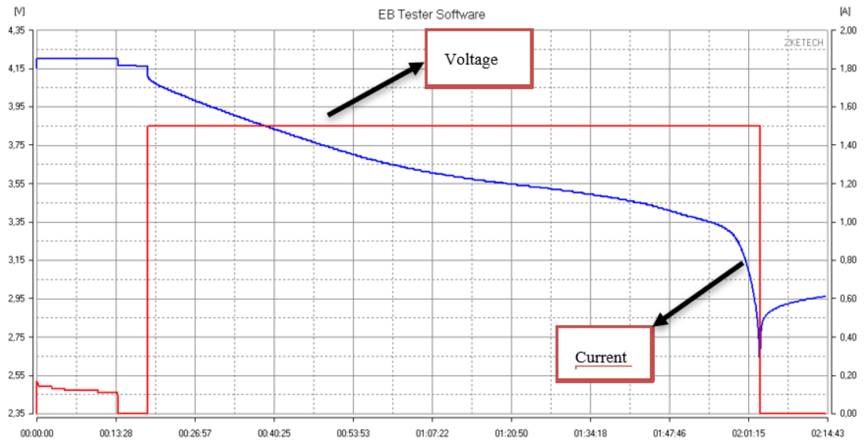


Fig. 9. Li-Ion battery discharge chart

The process of discharging or discharging the 18650 Lithium-ion battery from based on Figure 9, takes 1 hour 44 minutes. In this battery test, data readings are carried out every 2 seconds. In this test, the current is in a stable position of 1.5A. If you look at the voltage curve, the voltage will tend to fall by the process being carried out, namely battery discharge. If the battery voltage during the discharge process exceeds the minimum voltage, the battery will be exposed to deep discharge, which can cause the battery cells to die. The minimum voltage for a Lithium-ion battery is 2.5V. Then the time taken in the Discharging process is similar to the Charging process. The following is a graph of the current and voltage generated from the Discharge process using a current of 1.5A. Table 5 displays the data from the test results when discharging.

Table 5. Test result data during discharging condition

Charging Condition		
Specification	**Number of Capacities**	
	LiFePo4	**Li-Ion 18650 26E**
Voltage	Begin volt: 3,44V	Begin volt: 4,15V
	Cutoff volt: 2,2V	Cutoff volt: 2,5V
	Avg volt: 3,05V	Avg volt: 3,5V
Capacity	22,76Ah	2,60Ah
Total Energy	69,45Wh	9,44Wh

4 Conclusions

The results of the comparison of the characteristics of the two batteries show that Lithium Iron Phosphate batteries have better quality. Based on the results of testing the conditions when charging from both of them, it was found that the capacity of the LiFePo4 battery was 22.93Ah while the Li-Ion was 2.65 Ah. for a total LiFePo4 energy of 79.84 Wh and Li-Ion of 10.28 Wh. Meanwhile, when testing the Discharging conditions, the LiFePo4 battery capacity based on the test results was 22.76 Ah and Li-Ion 2.60 Ah. Meanwhile, the measured total energy from LiFePo4 is 69.45 Wh, and Li-Ion is 9.44 Wh. Hence, if viewed from the advantages and disadvantages, Lithium Iron Phosphate batteries are suitable for accumulators or electric car batteries and energy storage for solar power plants. In addition, do not rule out that Lithium-ion batteries can also be used to store electrical energy. However, suppose you look at the weather conditions in Indonesia, which has a tropical climate. In that case, this battery is very suitable because Lithium Iron Phosphate batteries are very safe, durable, stable at high temperatures, and economical.

5 Acknowledgment

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