Analysis of LiFePO4 Battery Size, Capacity, and Charging in Electric Vehicles with BLDC Motor Drive

Arwadi Sinuraya[1], Denny Haryanto Sinaga[2], Yoakim Simamora[3]

{arwadisinuraya@unimed.ac.id[1], denny.sinaga@unimed.ac.id[2], yoakimsimamora@unimed.ac.id[3]}

Department of Electrical Engineering, Universitas Negeri Medan,

Jl. Willem Iskandar Pasar V, Medan, North Sumatera, Indonesia

Abstract. The availability of fossil fuels such as oil, natural gas, and coal is dwindling day by day, while the human need for energy in the form of fuel is increasing. One of the efforts to utilize alternative energy is the use of battery-based electric vehicles. The battery is one of the most important components in an electric car. Batteries are used as an energy source for the entire electrical system and as a place to store electrical energy during the charging process. The battery serves to supply electric current so that the engine can be turned on, lights, and other electrical components. This study aims to design the size of an electric car battery according to its specifications. In addition, an analysis is also carried out on the calculation of the battery capacity that will be used and the process of recharging it.

Keyword : Electric Vehicle, LiFePO4, Battery Size, Battery Capacity, Charging, BLDC Motor

1 Introduction

In its development, vehicle technology has placed electric cars as one of the solutions in anticipating the impact of the energy crisis. By using an electric car, of course, it will also be able to create environmentally friendly technology because air pollution will be reduced [1]. Electric vehicles (EV) may reduce costs, greenhouse gas (GHG) emissions, and petroleum consumption. An electric car is defined as a car that uses a driving source from an electric motor instead of a gasoline engine. The electric motor gets energy from the battery through a controller that regulates the amount of power generated based on the use of the gas pedal from the car driver.

Brushless DC (BLDC) electric motors are now commonly used as electric vehicle propulsion. This motorhas a rotor in the form of permanent magnets and a stator in the form of windings to produce a magnetic field. BLDC motors have good efficiency, are more reliable, have a longer

ICIESC 2022, October 11, Medan, Indonesia

DOI 10.4108/eai.11-10-2022.2325395

life but are quite expensive in terms of price. A hall-effect sensor and a rotary encoder are used to electronically change the polarity of the BLDC motor [2].

One of the most important components of an electric car is the battery. Batteries are used as an energy source for the entire electrical system and as a place to store electrical energy during the charging process. In addition, the battery is used to supply electric current to run the drive, lights and other electrical components [3]. The cost of batteries is a significant barrier to implementing electric vehicles. For many electric vehicles, the battery is the most expensive component of the vehicle [4].

The use of electric vehicles is still constrained in terms of energy storage. this is due to limitations in battery capacity and the unavailability of electric charging stations such as gas stations for conventional vehicles.In addition, the battery capacity cannot be utilized optimally because of the depth of discharge value from the battery.

Because the use of batteries as energy storage needed by electric cars is very important, further calculations are carried out on the battery capacity that will be used to drive electric vehicles, store energy and recharge so that electric vehicles can be used sustainably with high energy reliability.

2 Method

The method in this study is to consider the weight of the vehicle according to the needs of the motor. Then from the electric motor data, the size of the battery will be determined according to the power requirements.After that, the estimated power that can be used and the length of the process of using and charging the battery is carried out. This is done to apply a 48 V BLDC motor drive to electric vehicles with a power of 1000 Watts. The design of the electric vehicle to be analyzed can be seen in Figure 1.

Fig 1. Electric vehicle

2.1 Electric Vehicle

An electric vehicle is a car that uses electrical energy as its energy source, using an electric motor as the main driver. In determining vehicle dimensions, there are various factors to consider such as interior ergonomics, layout and packaging of mechanical components, aerodynamic considerations, production and material considerations, formal form and industrial design aesthetics, and others. [5]. This electric vehicle uses a brushless DC 48V motor with a power of 1000 W. The technical specifications of this vehicle design are shown in table 1.

Table 1. Electric Vehicle Specifications

Vehicle Specifications	Value
Passenger capacity	2 Person
Vehicle Length	250 cm
Vehicle Width	120 cm
Vehicle Heigh	200 cm
Roof top Length	230 cm
Maximum Weight	800 kg

2.2 Motor *Brushless DC* (BLDC)

Brushless DC motor (BLDC) is a type of DC motor that does not have a brush. With the removal of the brush and commutator parts, this motor has advantages such as increased efficiency, reduced noise generated whenrotating, cheaper maintenance, and can rotate at high speeds due to reduced friction with the brush. While the disadvantages of this motorbike are that it is more complicated to control and is more expensive.

Brushless dc motor is included in the type of synchronous motor. This means that the magnetic field generated by the stator and the magnetic field generated by the rotor rotate at the same frequency. BLDC motors do not experience slipping as occurs in ordinary induction motors. This type of motor has permanent magnets on the rotor and electromagnets on the stator [6], [7].

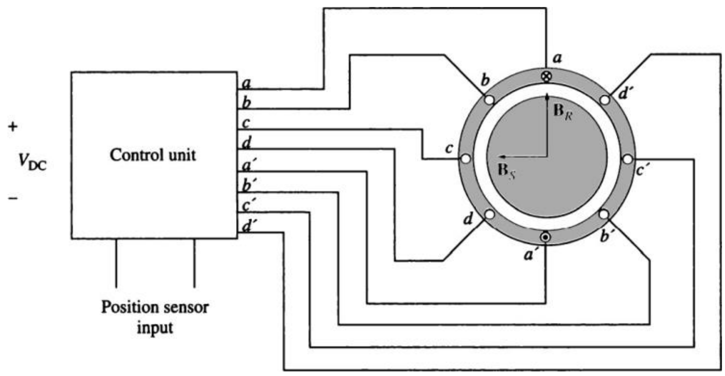

Fig 3. A simple brushless dc motor and its associated control unit [7].

This electric vehicle uses a 48V BLDC motor with a single line transmission as the rear wheel drive. Inthis electric vehicle, the motor gears are connected directly to the gears that are connected to the wheels using a chain. The technical specifications of the BLDC motor are shown in table 2.

Table 2. Brushless DC Motor Specifications

BLDC Motor Spesification	Value
Voltage	48 V
Power Watt	1000 W
Over Power Watt	> 1000 W
Current	16 – 18 A
Over Current Max	> 35 A
Torque Without Gear Reduction	5 Nm
Torque With Gear Reduction	25 Nm
Speed Without Reduction Gear	2750 Rpm
Speed With Reduction Gear	580 Rpm

2.3 LiFePO4 Battery

Batteries are important storage devices for storing electrical energy in the maximum utilization of intermittent renewable resources [8]. LiFePO4 battery is a secondary battery type, this battery is one type with Lithium Ion battery, this type of battery has a cell voltage of 3.3v/cell with an energy density of 220Wh/L. This battery has a stable reactivity and thermodynamics. This battery has a long life cycle, high energy density, and high work voltage.

Lithium Iron Phosphate (LiFePO4) battery capacity is greater than other types of batteries, this is because the energy density in this type of battery is very tight. [5]. The battery will carry out the charging process when the condition of the electrical energy generated from the chemical reaction is below the specified terminal level and when the energy is fully charged the battery will send electrical energy. This process is also known as discharging [9]. In this study, the battery used is a LiFePO4 type battery with a voltage of 48 V and a capacity of 100 Ah.

Table 3. LiFePO4 Battery Specifications

Battery Specifications	Value
Nominal Voltage	48 V
Charge Voltage Range	52.5 - 54.0 V
Typical Capacity	100 Ah
Typical Energy	4800 Wh
Max.Permanent Charge Current	100 A
Max. Permanent Discharge Current	100 A
Dimension (LxWxH)	440 mm x 440 mm x 133 mm

3 Results

3.1 Battery size

This electric vehicle uses a bldc motor drive with a voltage of 48 V and a power of 1000 W. therefore weneed a battery with the appropriate capacity to get the required voltage. The number of battery series requiredto match the working voltage can be calculated by the equation:

$$\text{Number of battery series} = \frac{\text{System Working Voltage}}{\text{Battery Voltage}} = \frac{48\text{ v}}{48\text{ v}} = 1\text{ series}$$

The required battery capacity in this electric vehicle system is [10]:

$$\text{Battery capacity} = \frac{\text{Daily Energy}}{\text{Battery Voltage}} = \frac{1000\text{ wh}}{48\text{ v}} = 20{,}8\text{ Ah}$$

However, there is a 20% loss of energy during charging and discharging. so the approximate battery capacity is as follows

$$\text{Battery capacity} = \frac{20{,}8}{0{,}8} = 26{,}04\text{ Ah}$$

The battery in this study uses a type of Lithium Iron Phosphate (LiFePO4). In this study we consider the battery depth of discharge to extend battery life. DOD is assumed to be 80% for the LiFePO4 type. the minimum battery capacity used is 100 Ah as shown in the following calculation:

$$\text{Battery capacity} = \frac{26{,}04}{0{,}8} = 32{,}55\text{Ah}$$

In this study, a battery with a minimum capacity of 32.55 Ah will be used. To increase battery capacity andincrease vehicle mileage, we will use a battery with a voltage of 48 V and a capacity of 100 Ah.

3.2 Battery Usage Time

Electric power consumption on the motor can be calculated using the battery for a BLDC motor at maximum speed with a working voltage of 48 V and a motor working current of 18 A obtained :

$$\text{Battery usage time} = \frac{\text{Battery Capacity}}{\text{Motor Working Current}} = \frac{100\text{ Ah}}{18\text{ A}} = 5{,}55\text{ h}$$

Considering the battery efficiency of 80%, the usage time will be:

$$5{,}55 \text{ x } \frac{80}{100} = 4{,}44\text{ h}$$

So the duration of battery usage is 4,44 hours.

Table 4. Battery Usage Time

Motor Working Current	Efficiency 80 %	Usage Time (hours)
34	0,59	2,35
30	0,67	2,67
26	0,77	3,08
22	0,91	3,64
18	1,11	4,44
14	1,43	5,71
10	2,00	8,00
6	3,33	13,33
2	10,00	40,00

3.3 Battery Charging Time

The length of time to charge the battery depends on the amount of current the battery has and how the charging method is carried out. In addition, the voltage for charging the battery also requires a voltage that is higher than the battery voltage, the goal is that there is a potential difference between the charging device and the battery to be charged [3]. When there is a potential difference, electric current can flow from high voltage to low voltage. For charging batteries with a working voltage of 48 V generally use a voltage of 52.5 V to 54 V. Battery charging time can be calculated using the following equation [6]

$$\text{Battery Charging Time (hour)} = \frac{\text{Battery Capacity}}{\text{Charging Current}} + \left(20\%\ \frac{\text{Battery Capacity}}{\text{Charging Current}}\right)$$

There are two methods of charging the battery. those methods are slow charging and fast charging. The slow charging method requires a charging current of at least 10% of the current capacity of the electric car battery [3]. The charging time of a battery with a capacity of 100 Ah using this method is:

$$\text{Slow Charging Time (hour)} = \frac{100}{10} + \left(20\%\ \frac{100}{10}\right) = 10 + (0{,}2 \text{ x } 10) = 12 \text{ hours}$$

With a battery capacity of 100 Ah, it takes 12 hours of charging time using the slow charging method.

The fast charging method requires a maximum current of 40% of the battery capacity used. With the fast charging current method, the time it takes to charge a battery with a capacity of 100Ah is:

$$\text{Fast Charging Time (hour)} = \frac{100}{40} + \left(20\%\ \frac{100}{40}\right) = 2{,}5 + (0{,}2 \text{ x } 25) = 3 \text{ hours}$$

With a battery capacity of 100 Ah, it takes 3 hours of charging time using the fast charging method.

Table 5. Battery Charging Time

Charging Current (Ampere)	Battery Efficiency 80 %	Charging Time (hour)
40	0,5	3,0
38	0,5	3,2
36	0,6	3,3
34	0,6	3,5
32	0,6	3,8
30	0,7	4,0
28	0,7	4,3
26	0,8	4,6
24	0,8	5,0
22	0,9	5,5
20	1,0	6,0
18	1,1	6,7
16	1,3	7,5
14	1,4	8,6
12	1,7	10,0
10	2,0	12,0

4 Discussion

From the results obtained, we can see that the specified battery size is a LiFePO4 type battery with a voltage of 48 V and a capacity of 100 Ah based on the power requirements of the BLDC motor used. The length of time for charging the battery depends on the amount of current that is the source of energy to charge the 100 Ah 48 V LiFePO4 battery, Table 5 shows that charging the battery with the fast charging method requires a charging current of 34 A to 40 A with a charging time of three hours, while the slow charging method takes 7 to 10 hours.

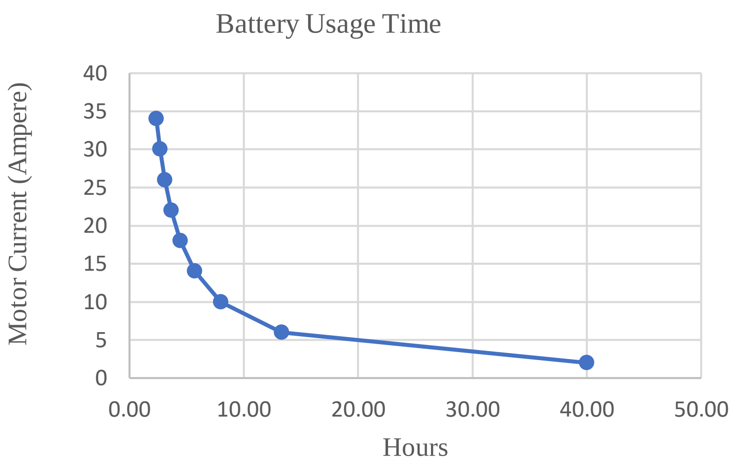

Fig 3. Battery usage time

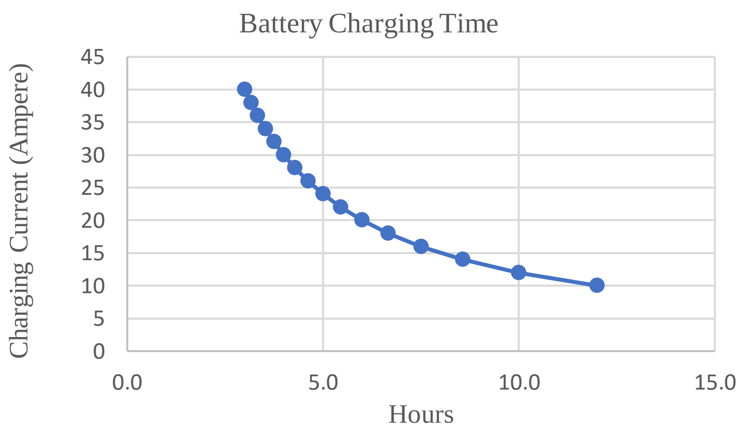

Fig 4. Battery charging time

From Figures 3 and 4 we can conclude that the higher the current used in the motor, the shorter the battery usage time will be. We can also see in Figure 4 that if the charging current in the battery is higher, it will have an impact on increasing the speed of battery charging time.

5 Conclusion

The energy storage used in this electric vehicle is a LiFePO4 type battery with a voltage of 48 V and a capacity of 100 Ah. This battery can be used to drive an electric motor for 4.4 hours with a motor current of 18 A. Through the charging process the battery will be fully charged for 3 hours through the fast charging method with a charging current of 40 A. LiFePO4 batteries have better quality and can provide greater electrical energy than a VRLA battery of the same capacity. This is associated with higher DOD values and efficiency. Batteries require periodic discharges to extend battery life, which is only about 10 percent of the total capacity. Full discharge of the battery is not recommended because it will reduce the battery life cycle.

References

[1] D. Beeton, *Electric Vehicle Business Models Global Perspectives*. Switzerland: Springer, 2014.

[2] A. N and M. R.K, “Permanent magnet brushless DC motor optimal design and determination of optimum PID controller parameters for the purpose of speed control by using the TLBO optimization algorithm,” *American Journal of Research Communication*, vol. 1, no. 1, pp. 294–313, 2013.

[3] I. Susanti, Rumiasih, C. R.S, and A. Firmansyah, “Analisa Penentuan Kapasitas Baterai Dan Pengisiannya Pada Mobil Listrik,” *Elektra*, vol. 4, no. 2, pp. 29–37, Jul. 2019.

[4] T. Yuksel, S. Litster, V. Viswanathan, and J. J. Michalek, “Plug-in hybrid electric vehicle LiFePO4 battery life implications of thermal management, driving conditions, and regional climate,” *Journal of Power Sources*, vol. 338, pp. 49–64, Jan. 2017, doi: 10.1016/j.jpowsour.2016.10.104.

[5] J. Fenton, *Handbook of Vehicle Design Analysis*. England: Mechanical Engineering Publications Limited, 1996.

[6] J. Larminie and J. Lowry, *Electric vehicle technology explained*, Second edition. Chichester, West Sussex, United Kingdom: Wiley, a John Wiley & Sons, Ltd., Publication, 2012.

[7] S. J. Chapman, *Electric Machinery Fundamentals*, 5th ed. United States: McGraw-Hill, 2012.

[8] P. Bajpai and V. Dash, “Hybrid renewable energy systems for power generation in stand-alone applications: A review,” *Renewable and Sustainable Energy Reviews*, vol. 16, no. 5, pp. 2926–2939, Jun. 2012, doi: 10.1016/j.rser.2012.02.009.

[9] P. F. Ribeiro, B. K. Johnson, M. L. Crow, A. Arsoy, and Y. Liu, “Energy storage systems for advanced power applications,” *Proceedings of the IEEE*, vol. 89, no. 12, pp. 1744–1756, 2001.