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ANALYSIS OF THE PERFORMANCE EFFICIENCY OF THE ELECTRIC SHUTTLE BUS DRIVE SYSTEM RESULTING FROM CONVERSION

Rahma Yunia Adini[1], Ramdhani [2], Sriyono[3], Tatang Permana[4]
[1,2,3,4] Universitas Pendidikan Indonesia, Indonesia
[2]ramdhani@upi.edu

Abstract
This research aims to analyze the performance of the electric drive system in electric shuttle busses converted from internal combustion engine (ICE) vehicles to battery-based electric vehicles. The focus of the study is directed toward evaluating the technical characteristics of the electric motor, battery capacity and endurance, range estimation, power requirements, and the efficiency of the vehicle's drive system. The research method used is a quantitative descriptive method, literature study, and mathematical modeling based on the vehicle's technical specifications, including vehicle mass, battery capacity, power and torque of the electric motor, as well as vehicle resistance parameters such as rolling resistance and aerodynamic drag. The analysis results show that 2 lithium iron phosphate ($LiFePO_4$) batteries with a capacity of 15.84 kWh can support an operating time of approximately 6.46 hours with an estimated range of 323 km at a speed of 50 km/h. The motor power calculation shows that the electric motor has a maximum power of 96.33 kW, while the actual power requirement of the vehicle on flat roads is only about 4.8 kW. These results indicate that the electric drive system has sufficient power reserves and is technically feasible for use in the converted electric shuttle bus.

Keywords: *Electric shuttle bus; Vehicle conversion; Performance efficiency; Drive system; LiFePO4 battery*

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Introduction

Electric vehicles are a transportation system that utilizes electrical energy as the main power source, replacing the role of internal combustion engines in conventional vehicles. (Subekti, et al., 2014) stated that "Electric vehicles are vehicles that use electric motors as their drive, thus not requiring fuel like conventional motor vehicles" (Subekti, et al., 2014). Battery Electric Vehicles (BEVs) offer various advantages that the government considered in the Presidential Regulation of the Republic of Indonesia Number 55 of 2019 concerning the Acceleration of the Battery Electric Vehicle Program for Road Transportation, namely "for improving energy efficiency, energy resilience, and energy conservation in the transportation sector, and achieving clean energy, clean air quality, and an environmentally friendly commitment, as well as Indonesia's commitment to reducing greenhouse gas emissions" (Indonesia Patent No. 55, 2019). The advantages offered by electric vehicles have become a breath of fresh air for the global community, making the development of electric vehicles a current trend.

The development of electric vehicles is an effort to reduce dependence on fossil fuels and decrease exhaust emissions from the transportation sector. The development of electric vehicles is one of the most promising approaches to reducing petroleum-based energy consumption and greenhouse gas emissions in the long term. Electric vehicles have lower CO_2 emissions compared to internal combustion engine vehicles. Franzo and Nasca revealed that "Results show that CO_2 emissions over the Electric Vehicle's life cycle are lower than the ones associated to a comparable Internal Combustion Engine Vehicle in all the scenarios analyzed" (Franzo & Nasca, 2008).

The acceleration of the electric motor vehicle program has been implemented by the government since 2019 with the Presidential Regulation of the Republic of Indonesia Number 55 of 2019. The Indonesian government stipulates that the acceleration of electric vehicle development is not solely carried out thru the procurement of new electric vehicles but also thru the conversion of ICE motor vehicles into battery-based electric vehicles. Article 2 Paragraph (1a) states that "Battery-Based Electric Vehicles in new condition; and/or Battery-Based Electric Vehicles resulting from Conversion carried out by Conversion Workshops." (Indonesia Patent No. 79, 2023). The conversion of ICE vehicles to electric vehicles is an important research opportunity in supporting the development of sustainable transportation. This research focuses on the performance analysis of electric shuttle busses, by reviewing the technical characteristics of the applied electric drive system.

This research aims to analyze the performance of the electric drive system in passenger vehicles converted from Internal Combustion Engine (ICE) to battery-based electric vehicles. The research object is a unit of an electric shuttle bus that uses an electric motor as the main drive and is supported by a high-voltage lithium battery system with integrated battery management. The analysis focuses on the power characteristics and the role of the electric motor in replacing the conventional drive system. The results of the analysis are expected to provide a quantitative picture of the effectiveness and feasibility of the electric drive system in converted vehicles.

Research Method

The research method used in this study is a quantitative descriptive approach. The quantitative descriptive method systematically and objectively describes the phenomena being studied based on numerical data obtained in the field. According to (Listiani, 2014) in (Sulistyawati, et al., 2022), quantitative descriptive research is to describe, investigate, and explain something studied as it is, and draw conclusions from observable phenomena using numbers. This approach was chosen because this research aims to describe the conditions, characteristics, and performance achievements of the system being studied based on quantitative calculations and analyzes, and is not intended to test hypotheses or seek causal relationships between variables.

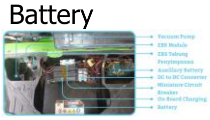
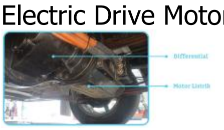
This type of research includes non-experimental research with a quantitative descriptive design. (Sulistyawati, et al., 2022) also revealed that quantitative descriptive research only describes the content of a variable in the study, not intended to test a specific hypothesis. Non-experimental research was chosen because the researcher does not provide a specific treatment to the research object, but rather conducts observation, measurement, and analysis of the available data. The research object is focused on the main technical parameters relevant to the research objectives, while the research subjects consist of technical data and supporting documents directly related to the study object.

Data collection techniques were carried out thru documentation studies and literature reviews. Documentation studies were used to obtain technical specifications and supporting information related to the research object, while literature reviews aimed to strengthen the theoretical and methodological foundations, particularly concerning the descriptive quantitative approach and the analysis techniques used. Data analysis techniques employed quantitative descriptive analysis, which involved processing numerical data thru mathematical calculations that represent the relationship between vehicle resistive force, electric motor power requirements, battery energy capacity, and the estimated duration of use and range of electric vehicles under specific operating conditions. The results of the analysis are presented in the form of tables and descriptive explanations to provide an objective overview of the condition and performance of the research object.

A. Data Collection

1. Specifications of the Shuttle Bus Electric Vehicle (EV)

Table 1. Specifications of the Shuttle Bus Electric Vehicle (EV)

No	Component	Specifications	Brand
1.	Battery 	LiFePo4 Prismatic Smart BMS 24S 500A 72V 220Ah	Hidtech EV Garage
2.	Electric Drive Motor 	*Permanent Magnet Synchronous Motor* (PMSM) 20 kW Average current 154 A Pole Pairs 4 Nominal Voltage 144 V Rate Speed 4000 RPM Peak Torque 230 N.m	
3.	Vehicle Control Unit	*Permanent Magnet SynchronousMotor* (PMSM) Rated Power 20 kW 144 V	

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2. Battery capacity calculation

The main function of a battery is as a medium for storing electrical energy. The estimated energy capacity of a battery is determined thru the calculation between its nominal voltage and charge capacity. The unit Watt-hour (Wh) is used to represent the power consumption of electrical energy used over one hour. The stored electrical energy is calculated using the basic electrical energy equation, which is the calculation between voltage (V) and battery capacity in Ampere-hour (Ah). This approach is a standard methodology in the analysis of electric vehicles and energy storage systems, as stated by (Larminie & Lowry, 2012) and (Husain, 2021). The battery capacity can be calculated with the specifications available, namely:

$$Energy\ (Wh) = Voltage\ (V) \times Capacity\ (Ah)$$

To simplify the calculation process in the subsequent analysis, the battery energy unit originally expressed in watt-hour (Wh) is converted to kilowatt-hour (kWh) by dividing the energy value in Wh by 1,000, resulting in the equation:

$$Energy\ (kWh) = \frac{Energy\ (\mathrm{Wh})}{1000}$$

3. Battery life calculation

Battery endurance greatly affects the performance of electric vehicles, as it serves as a reference for operational time when the battery will run out and needs to be recharged to maintain the continuity of the electric motor's operation. The battery used in this shuttle bus is of the Lithium Iron Phosphate (LiFePO4) type, chosen for its stable cycle and high energy efficiency when charged and discharged using the CC/CV (constant current / constant voltage) method. For estimating practical operating time, the percentage value of battery energy efficiency, battery capacity, and the current used by the motor are required, leading to the following formulation:

$$\text{Battery Life} = \frac{\text{Energi (kWh)}}{\text{Daya Motor} \times Efisiensi}$$

4. Calculation of travel distance

The determination of the distance calculation is carried out to measure the operational range of the vehicle based on battery endurance. This calculation also aims to validate whether the available battery capacity aligns with the target travel distance. Ehsani, Gao, Gay, & Emadi in 2005 revealed that the range of electric vehicles is determined by the energy capacity stored in the energy storage system and the power consumption rate of the vehicle during operation. The formula for calculating the range is an adaptation of the basic kinematic equation, which becomes:

$$distance\ traveled = Velocity \times Battery\ Life$$

5. Battery charging calculation

One of the most important aspects of electric vehicles is their battery charging mechanism. Considering that time efficiency is a priority for users, the choice of charging method—whether standard or fast charging—becomes very important. The calculation of battery charging time refers to the basic relationship between charge capacity and electric current derived from fundamental electrical laws. Linden & Reddy (2002) revealed that the battery charging time is determined by the relationship between the electric charge that must be returned to the battery and the charging current provided, taking into account the charging efficiency. Here are the calculation parameters used:

$$\text{Charging Time} = \frac{\text{Efficiency} \times \text{Battery capacity}}{\text{Current}}$$

6. Calculation of Electric Motor Power

The calculation of motor power serves as a parameter to evaluate the compatibility between the specifications of the drive components and the mechanical needs of the converted vehicle. This step is very important to ensure that the electric motor has sufficient capacity to overcome the total drag force and can provide optimal work efficiency according to the system design plan. Montanha (2009) revealed the basic formula for rotational speed that requires the following data:

$$\text{Velocity } (rpm) = \frac{2\pi}{60} rad/s$$

After understanding the basic formula for rotational speed, then:

$$\text{Power (kW)} = \frac{\text{Torque (Nm)} \times \text{Rotational speed (rpm)}}{9.550}$$

7. 7. Calculation of Engine Power Against Vehicle Capability and Efficiency

The calculation of motor power in relation to the vehicle's capability and efficiency is determined by calculating the drag force at a speed of υ = 50 km/h (13.88 m/s). The total drag force is explained in the book Fundamentals of Vehicle Dynamics by Thomas D. Gillespie: "Tractive effort is the total force that must be available in the vehicle's drive system at the wheels to overcome all resistances" (Gillespie, 1992). Therefore, the formula for the total drag force is as follows:

$$Fte = Frr + Fad + Fhc + Fla$$

- *Frr (Rolling Resistance)*:
- *Fad (Aerodynamic Drag)*:
- *Fhc (Hill Climbing)*:
- *Fla (Linear Acceleration)*:

Yunus A. Çengel and John M. Cimbala state that the aerodynamic drag coefficient (Cd) for land vehicles is influenced by shape, level of streamlining, and flow conditions at high Reynolds numbers, where the value of Cd tends to be constant (Çengel & Cimbala, 2018).

Table 2. Motor Power Calculation Parameters Against Vehicle Capability and Efficiency

Parameter	Symbol	Value	Unit
Vehicle Mass	m	1500	kg
Gravitational Acceleration	g	9,81	m/s²
Rolling Resistance	frr	0,015	-
Aerodynamic Drag Coefficient	Cd	0,35	-
Cross-sectional area	gA	2,2	m²
Air Density	ρ	1,225	kg/m³
Drivetrain Efficiency	ηd	0,9	-

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The total drag force required to obtain the effective power value on the EV shuttle bus is the total constant drag force, which is:

$$Ftotal = Frr + Fad$$
$$Ftotal = (Frr = m \cdot g \cdot frr) + (Fad = \frac{1}{2} \cdot \rho \cdot A \cdot Cd \cdot \upsilon^2)$$

The effective power produced is the calculation of the motor power minus the total constant force and the Estimated Power Requirement needed by the wheels and the motor output power, namely:

$$P_{motor} = \frac{(Pwheel = \text{Ftotal} \times \upsilon)}{nd}$$

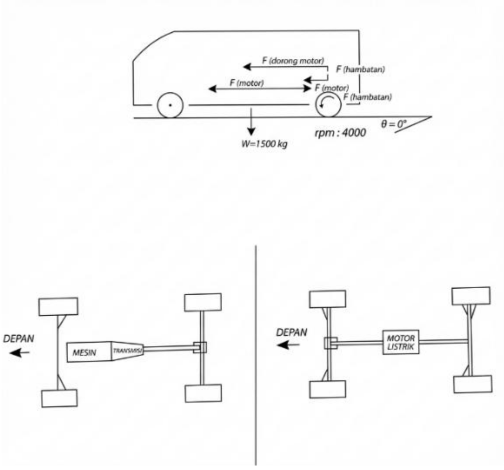

Figure 1. Calculation of motor power against vehicle capability and efficiency

Results and Discussion

The analysis focuses on examining the main technical parameters that affect the performance of electric vehicles, including battery characteristics, electric motors, and the resistive forces acting during vehicle operation. The approach used is analytical-descriptive, referring to the technical specifications of the vehicle and assuming certain operating conditions, such as constant speed and flat road conditions. The stages of analysis are carried out systematically, starting from the identification of the function of each main component, determining the relevant magnitudes, to the formulation of the calculation model used as the basis for evaluation.

1. Battery Capacity Calculation

   It is determined that a battery with a voltage specification of 72V and a battery capacity of 220Ah is used. Therefore, the calculation results based on the battery specifications used are as follows:

   $$Energy\ (Wh) = Voltage\ (V) \times Capacity\ (Ah)$$
   $$Energy\ (Wh) = 72V \times 220Ah$$
   $$Energy\ (Wh) = 15.840Wh$$

   The unit of battery energy, originally expressed in watt-hours (Wh), is converted to kilowatt-hours (kWh) by dividing the energy value in Wh by 1,000, resulting in the equation:

   $$Energy\ (kWh) = \frac{15.840Wh}{1.000}$$
   $$Energy\ (kWh) = 15.84kWh$$

   Battery capacity = 15.84kWh

   The batteries used are two in number, so the battery capacity becomes:

   Battery capacity = 15.84 kWh × 2 = 31.68 kWh

The calculation results show that the battery capacity of the converted EV Shuttle Bus is 31.68 kWh. A battery capacity of 31.68 kWh falls into the medium capacity category for electric vehicles ranging from city cars to MVPs. (Doulgeris, et al., 2023) revealed that modern urban electric busses use batteries with capacities between 350–400 kWh to support long-distance operations and intensive daily use. A battery modeling study on electric busses conducted by (Duangsrikaew, et al., 2019) indicates that battery capacity can be optimized based on the vehicle's energy needs, so it does not always require a very large capacity like long-distance urban busses. The 31.68 kWh battery capacity in this study can still be considered adequate if used in shuttle vehicles with short routes and limited operational speeds.

2. Battery Life Calculation

LiFePO4 batteries were chosen as the main power source due to their performance efficiency reaching 98%. The calculation results of the efficiency figure for battery endurance are as follows.

$$\text{Battery Life} = \frac{\text{Energy (kWh)}}{\text{Motor Power} \times Efficency}$$

$$\text{Battery Life} = \frac{31.68\ kWh}{4{,}8\ kW \times\ 98\%}$$

$$\text{Battery Life} = 6{,}46\text{h}$$

The calculation results show that the battery endurance of the converted EV shuttle bus can operate for 6.46 hours under certain usage conditions. The duration of electric vehicle battery usage is greatly influenced by the available energy capacity and the power consumption level during vehicle operation. The battery life of each vehicle varies in specific situations, according to (Klaproth, et al., 2025) the duration of operation of urban electric bus fleets depends on energy consumption and average speed during the usage cycle, where the battery can support vehicle operation for several hours in one charging cycle.

3. Distance Calculation

Distance calculations use an estimated maximum speed in residential areas and campus areas, which is 50 km/h. Determining the alignment between the stored energy capacity and the planned travel distance for daily operations is detailed in the following distance calculations:

$$distance\ traveled = Velocity \times Battery\ Life$$

$$distance\ traveled = 50km/h \times 6{,}46h$$

$$distance\ traveled = 323km$$

The calculation results show that the converted electric shuttle bus has a travel distance of 323 km at a constant speed of 50 km/h with a battery capacity of 31.68 kWh and a battery endurance of 6.46 hours. According to (Nasution, et al., 2025), electric vehicles show a clear relationship between battery capacity and the maximum distance that can be traveled. Vehicles with larger battery capacities are generally more capable of covering greater distances, whether on flat, uphill, or downhill roads. A study on the development of electric vehicles in Indonesia mentions that some electric vehicles currently in circulation are capable of covering distances of up to 300–400 km on a single battery charge, depending on the battery capacity and the vehicle's energy efficiency (Ahmad, et al., 2022). Based on that comparison, the estimated range of 323 km for the converted EV shuttle bus can efficiently support the operational needs of electric shuttle busses for use in limited operational vehicles such as campus area shuttles, tourism, or residential areas.

4. Battery Charging Calculation

Measurement of charging effectiveness using level one charging standards with a current output of 12A. Level one charging standards can be performed independently with flexibility in carrying out the charging. Based on the current specifications used, the battery charging duration is as follows:

$$\text{Charging time} = \frac{Efficiency \times Battery\ capacity}{Current}$$

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$$\text{Charging time} = \frac{98\% \times 31.68kWh}{12\text{A}}$$

$$\text{Charging time} = 2{,}58h$$

The calculation results show that the charging time for the converted electric shuttle bus battery with a standard household alternating current (AC) charging of 12 A takes about 2.58 hours to fully charge the battery. The charging time for electric vehicles is greatly influenced by the battery capacity and the type of charging system used. (Priyono, et al., 2025) revealed that the charging method using an alternating current (AC charging) charger or household charging generally takes between 6 to 16 hours depending on the battery capacity (Indonesia Patent No. 55, 2019) and charging efficiency.

The battery charging time of 2.58 hours for the converted EV shuttle bus can be categorized as quite efficient and still falls within the normal charging range for electric vehicles. This charging duration is faster compared to the standard household charging for some electric vehicles, which can take more than 6 hours, and is close to the medium charging characteristics commonly used in MVP electric vehicles.

5. Power Calculation

The motor produces a torque of 230 Nm with a maximum rotational speed limit of 4,000 rpm. The power formula according to the specifications will be obtained with the following calculation details:

$$Power\ (kW) = \frac{Torque\ (Nm) \times rotational\ speed\ (rpm)}{9.550}$$

$$Power\ (kW) = \frac{230Nm \times 4000rpm}{9.550}$$

$$Power\ (kW) = \frac{920.000}{9.550}$$

$$Power\ (kW) = 96.33kW$$

The calculation results show that the electric motor on the converted shuttle bus is capable of producing a maximum power of 96.33 kW. This power value is obtained from calculations based on the motor's maximum torque of 230 Nm and a maximum rotational speed of 4,000 rpm. It is known that the actual power requirement of the vehicle is relatively small compared to the maximum power of the motor. (Rahman, et al., 2024) state that the motor power in electric vehicles is generally designed to be greater than the average power requirement of the vehicle. The goal is to anticipate dynamic load conditions such as initial acceleration, uphill climbs, and changes in vehicle load during operation.

6. Calculation of Engine Power in Relation to Vehicle Capability and Efficiency

Calculation of drag force at a speed of υ = 50km/h (13.88 m/s) with total drag force on the horizontal force is

- *Frr* (Rolling Resistance):
  $Frr = m \cdot g \cdot frr = 1500 \times 9{,}81 \times 0{,}015 = 220{,}7N$
- *Fad* (Aerodynamic Drag)::
  $Fad = \frac{1}{2} \cdot \rho \cdot A \cdot Cd \cdot \upsilon^2 = 0{,}5 \times 1{,}225 \times 2{,}2 \times 0{,}35 \times (13{,}88)^2 \approx 90{,}86$ N
- Constant Total Force:
  $Ftotal = Frr + Fad = 220{,}7 + 90{,}86 = 311{,}5$ N

The estimated power requirements for the wheel (P_{wheel}) and the required motor output power (P_{motor}) are as follows:

- Wheel Power:
  $P_{wheel} = Ftotal \times \upsilon = 311{,}5 \times 13{,}88 = 4.324.4528$ Watt $\approx 4{,}32$kW
- Motor Power (considering efficiency):
  $P_{motor} = \frac{Pwheel}{nd} = \frac{4{,}32}{0{,}9} \approx 4{,}8$ kW

The calculation results show that the total drag force on the electric shuttle bus at an operating speed of 50 km/h (13.88 m/s) is 311.5 N, consisting of a rolling resistance of 220.7 N and an aerodynamic drag of 90.86 N. Based on this total drag force, the wheel power requirement is 4.32 kW. Considering a drivetrain efficiency of 90%, the electric motor power requirement to maintain a constant speed is approximately 4.8 kW. (Martini, et al., 2025) explain that the power consumption of electric vehicles is directly influenced by several factors, including rolling resistance, aerodynamic drag, and the vehicle's gravitational force.

The comparison between the maximum motor power of 96.33 kW and the actual power requirement of the vehicle at around 4.8 kW indicates that the system operates under high efficiency conditions. (Lee, et al., 2024) reveal that the efficiency of electric vehicles is influenced by the distribution of motor energy, battery, and drivetrain efficiency, where the actual power requirement of the vehicle is generally much smaller than the maximum motor capacity.

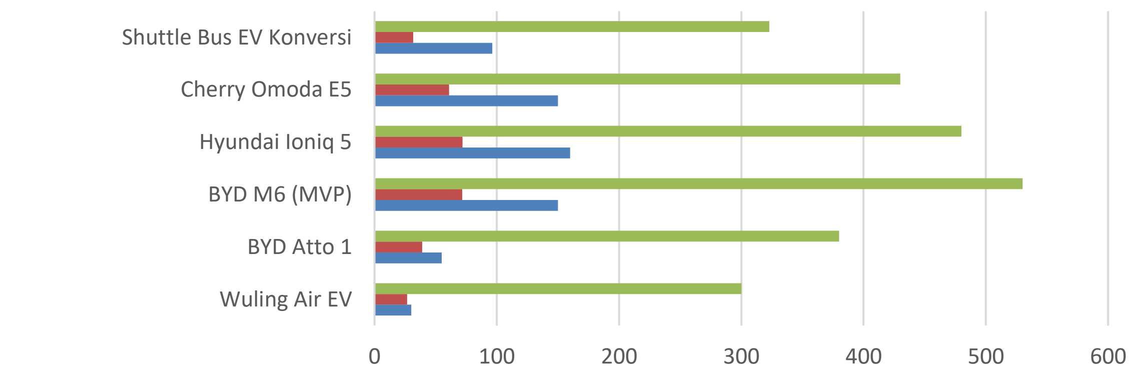
7. Comparison of Electric Shuttle Bus Specifications with Standard Industry Electric Vehicles

Based on the calculations in this study, the converted electric shuttle bus has a battery capacity of 31.68 kWh, a maximum motor power of 96.33 kW, and an estimated range of 323 km at a constant speed of 50 km/h. (Doulgeris, et al., 2023) revealed that 12-meter urban electric busses generally use batteries with a capacity of 350–400 kWh and high-power electric motors to support long-distance operations and heavy loads. Urban electric busses are designed for long routes, large passenger loads, and are used throughout the day for operation.

Table 3. Specifications of Urban Electric Busses in Doulgeris Research

	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5
Battery Capacity (kWh)	350	400	350	350	350
Motor Power (kW)	350	300	300	200	240
Distance Estimation (km)	942	2087	1141	1030	950

The specification graph shows the performance position of the converted electric shuttle bus compared to several industrially produced electric vehicles, namely vehicles in the city car to SUV/MPV category. The parameters compared include estimated range, battery capacity, and electric motor power.



	Wuling Air EV	BYD Atto 1	BYD M6 (MVP)	Hyundai Ioniq 5	Cherry Omoda E5	Shuttle Bus EV Konversi
Estimated Distance Traveled (km)	300	380	530	480	430	323
Battery Capacity (kWh)	26.7	38.88	71.8	72	61	31.68
Motor Power (kW)	30	55	150	160	150	96.33

Estimated Distance Traveled (km) Battery Capacity (kWh) Motor Power (kW)

Figure 2. Specifications of Electric Shuttle Bus with Industry Standard Electric Vehicles

The battery capacity is designed proportionally to the vehicle's weight and target range. The battery capacity of the converted EV shuttle bus is larger than that of electric vehicles in the city car category like the Wuling Air EV (26.7 kWh), but smaller than that of SUV and MPV electric vehicles like the BYD M6 (71.8 kWh) and the Hyundai Ioniq 5 (72 kWh). (Syamaidzar, et al., 2024) explains that the battery capacity of electric vehicles generally ranges from 20–40 kWh for city cars and 50–80 kWh for passenger vehicles. The 31.68 kWh capacity in the converted shuttle bus is still considered adequate for short-distance operational vehicles such as campus area shuttles, tourism, or limited areas, although it is not yet equivalent to long-distance passenger vehicles.

The converted EV shuttle bus has a power output of 96.33 kW, higher than the Wuling Air EV (30 kW) and BYD Atto 1 (55 kW), but still below the Hyundai Ioniq 5 and Cherry Omoda E5, which reach 150–160 kW. The power specifications of electric vehicle motors are adjusted according to the mass and performance requirements of the vehicle, so the motor power does not always have to be the largest, but sufficient to meet operational needs. (Rahman, et al., 2024) explains that electric vehicle motors are generally designed with oversizing power (power greater than the average requirement) to maintain dynamic performance and system efficiency. The actual power requirement of the Shuttle bus EV is only around 4.8 kW, far below the maximum power of 96.33 kW, so it can be concluded that the system has a very adequate power reserve and operates in a high-efficiency zone.

Range, the converted EV shuttle bus can reach 323 km, surpassing the Wuling Air EV (300 km), approaching the BYD Atto 1 (380 km), but far below the BYD M6 MVP electric vehicle which reaches 530 km. (Ehsani, et al., 2005) state that driving range is a direct function of energy storage capacity and vehicle energy consumption. The EV shuttle bus has a smaller battery capacity compared to SUVs/MPVs, and the achievement of 323 km in the converted shuttle bus indicates good energy efficiency, especially since the vehicle operates at low constant speeds and on short routes as it only operates within the campus area.

Conclusion

This research aims to analyze the performance of the drive system in electric shuttle busses converted from internal combustion engine (ICE) vehicles to battery-based electric vehicles. The approach used is a quantitative descriptive method with analysis based on technical specification data and mathematical modeling, so that the research results can provide a quantitative picture of the technical feasibility of the applied electric drive system.

Based on the battery capacity analysis results, it is known that the lithium iron phosphate ($LiFePO_4$) battery with a voltage of 72 V and a capacity of 220 Ah has an energy capacity of 15.84 kWh per unit. With the use of two battery units, the total available energy capacity reaches 31.68 kWh. This capacity is considered sufficient to support the operation of the electric shuttle bus under the planned usage scenario. Battery endurance calculations indicate that the system can operate for approximately 6.46 hours, resulting in an estimated range of up to 323 km at a constant speed of 50 km/h. These results demonstrate that the battery energy capacity is well-suited to the vehicle's operational needs.

Analysis of the battery charging system shows that with a standard charging current of 12 A, the battery charging time is around 2.58 hours. This duration is considered efficient to support operational flexibility, especially in the use of shuttle busses in limited environments such as campus areas or residential neighborhoods.

The results of the electric motor calculations show that a motor with a maximum torque of 230 Nm and a rotational speed of up to 4,000 rpm can produce a maximum power of 96.33 kW. Based on the calculation of vehicle drag on flat road conditions at a speed of 50 km/h, the actual power requirement of the vehicle is only about 4.8 kW. This comparison indicates that the electric motor has a very adequate power reserve to overcome vehicle resistance and support stable and efficient performance.

Overall, the results of this study indicate that the electric drive system on the converted shuttle bus is technically feasible to operate. The combination of battery capacity, motor power, and drive system efficiency indicates that converting ICE vehicles to electric vehicles can be an effective and sustainable solution in supporting the development of environmentally friendly transportation.

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