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RESEARCH ARTICLE

# Conversion and performance evaluation of an ICE Go-Kart to an electric vehicle: Electrical and energy performance analysis

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**Abstract:** The conversion of existing internal combustion engine (ICE) vehicles to electric propulsion offers a practical approach to extending vehicle service life while reducing direct exhaust emissions and dependence on conventional fuel-based drivetrains. This study presents the systematic conversion and experimental performance evaluation of an inoperable ICE go-kart into a fully electric vehicle (EV), with particular emphasis on drivetrain design, dynamic performance, electrical behaviour, thermal response, and speed-dependent specific energy consumption. The electric drivetrain was theoretically sized based on aerodynamic drag, rolling resistance, drivetrain efficiency, and battery-energy requirements to achieve a target maximum speed of 50–60 km/h and a minimum operational range of 40 km. The converted system incorporated a brushless direct current (BLDC) motor, a 72 V, 40 Ah lithium-ion battery pack, a motor controller, a Battery Management System (BMS), and a Hall-effect throttle. Replacement of the ICE components with the EV drivetrain resulted in a net component mass reduction of 15 kg. Experimental testing demonstrated a maximum speed of 59 km/h, an acceleration time of 6.9 s from rest to the maximum attainable speed, and an operational range of 46 km per charge, thereby satisfying the predefined design targets. During acceleration, the battery current reached a peak of 65.1 A, while the motor surface temperature increased from approximately 34.2°C to a maximum of 40.7°C during the three-minute full-power test. Speed-dependent measurements from 20 to 59 km/h showed that battery current increased from 15 to 51 A and battery-side electrical power from 1.050 to 3.519 kW, while specific energy consumption increased from 50 to 88 Wh/km. Pearson correlation analysis revealed a strong positive relationship between vehicle speed and energy consumption ($r = 0.978$, $p = 0.004$), while linear regression showed a strong association between the two variables ($R^2 = 0.956$). The results demonstrate that ICE-to-EV retrofitting can provide a technically viable small-scale mobility platform while highlighting the strong association between operating speed and battery energy demand. The integrated theoretical and experimental framework developed in this study provides useful guidance for the design, performance assessment, and optimisation of low-cost electric retrofit platforms.

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## 1. Introduction

The global effort to reduce greenhouse gas emissions and dependence on fossil fuels has accelerated the transition from conventional internal combustion engine (ICE) vehicles towards more sustainable transportation technologies [1]. Battery electric vehicles (BEVs) have emerged as an important alternative to conventional ICE vehicles as transportation systems move towards electrification. In addition to the development of new BEVs, the conversion of existing ICE-powered vehicles to electric propulsion provides another pathway for vehicle electrification by retaining and repurposing an existing vehicle platform [2], [3]. Such retrofitting can extend the functional use of an existing vehicle platform while reducing the need for complete vehicle replacement [2]. Small-scale vehicles such as go-karts provide a useful platform for investigating electric propulsion systems because of their relatively simple mechanical configuration and adaptability for experimental purposes. Previous studies have demonstrated the application of electric drivetrains in go-karts, including drivetrain design and performance analysis based on vehicle resistance, motor power requirements, and target operating speed [4], [5]. Battery-system design is also an important consideration because the selected battery and associated management system must satisfy the electrical and energy requirements of the propulsion system [6]. Electric go-karts can additionally serve as practical platforms for engineering education and experimental investigation of electric drivetrain behaviour [7].

Despite the growing interest in vehicle electrification, the conversion of an existing ICE platform into an electric vehicle involves more than simply replacing the combustion engine with an electric motor. Appropriate selection and integration of the motor, battery pack, controller, and associated electrical components are required to ensure that the converted vehicle satisfies its intended dynamic and energy-performance requirements. The required motor power must account for vehicle resistance, particularly aerodynamic drag and rolling resistance, while battery capacity must provide sufficient energy to achieve the desired operational range. Furthermore, experimentally measured electrical demand may differ from theoretical predictions because of drivetrain losses, transient acceleration, operating conditions, and other real-world effects.

Previous studies involving electric go-karts have demonstrated their feasibility for electric propulsion, drivetrain design, control, and engineering applications [4], [5], [7], [8]. However, within the literature considered in this study,

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limited attention has been given to an integrated retrofit framework that directly links theoretical drivetrain sizing with experimental validation of dynamic, electrical, thermal, and speed-dependent energy performance. In particular, quantitative evaluation of how battery current, electrical power, and specific energy consumption vary with vehicle speed is important for characterising the electrical and energy performance of the converted drivetrain [9]. Therefore, this study presents the systematic conversion and experimental evaluation of an existing ICE-powered go-kart into a fully electric vehicle. The electric drivetrain was initially sized using theoretical calculations incorporating aerodynamic drag, rolling resistance, drivetrain efficiency, power requirement, and battery-energy demand. A brushless direct current (BLDC) motor, lithium-ion battery pack, motor controller, and associated control components were subsequently integrated into the existing chassis. The converted vehicle was experimentally evaluated in terms of maximum speed, acceleration, operational range, battery electrical behaviour, and motor thermal performance. In addition, battery voltage, current, calculated electrical power, and specific energy consumption were evaluated at vehicle speeds ranging from 20 to 59 km/h.

The principal contribution of this study is the integration of theoretical drivetrain sizing, practical ICE-to-EV conversion, and quantitative experimental performance assessment within a single small-scale retrofit platform. Unlike an assessment based solely on successful vehicle conversion or maximum-speed testing, the present study examines the relationship between vehicle operating speed and battery energy demand using correlation and regression analyses. This approach enables the theoretical drivetrain requirements to be compared with actual vehicle performance while providing quantitative insight into the speed–energy trade-off of the converted electric go-kart. The findings provide an experimentally evaluated basis for the design and performance assessment of low-cost EV retrofit platforms for small-scale mobility and engineering applications.

### 1.1 Motor and Battery Calculation

To meet the performance objectives of achieving a target maximum speed of 50–60 km/h and a minimum operational range of 40 km, theoretical calculations were performed to estimate the required motor power and battery-energy capacity. Following the vehicle-resistance-based approach commonly applied in electric go-kart drivetrain sizing [5], the analysis considered aerodynamic drag, rolling resistance, and drivetrain efficiency under steady-state operating conditions. The design parameters used in the theoretical analysis are summarised in Table 1.

Table 1. Design parameters for theoretical power analysis at the target top speed

| Parameter | Unit | Value |
|---|---|---|
| Top speed | v | 60 km/h (16.67 m/s) |
| Total mass (go-kart + driver) | m | 150 kg |
| Frontal area | A | 0.6 $m^2$ |
| Drag coefficient | $C_d$ | 0.7 |
| Rolling resistance coefficient | $C_{rr}$ | 0.015 |
| Air density | ρ | 1.225 $kg/m^3$ |
| Gravity | g | 9.81 $m/s^2$ |
| Efficiency of drivetrain | η | 85% |

The frontal area, drag coefficient, rolling resistance coefficient, and drivetrain efficiency were adopted as design assumptions for the theoretical sizing analysis.

Power required to overcome aerodynamic drag:

$$P_{aero} = \frac{1}{2} . \rho . Cd . A . v^3 \quad (1)$$

$P_{aero}$ = (0.5) (1.225) (0.7) (0.6) $(16.67)^3$ =1191.7 W

Power to overcome rolling resistance:

$$P_{roll} = C_{rr} . m . g . v \quad (2)$$

$P_{roll}$ = (0.015) (150) (9.81) (16.67) = 368 W

The total mechanical power required at the target speed was therefore:

$$P_{total} = P_{aero} + P_{roll} \quad (3)$$

$$P_{total} = 1191.7 + 368 = 1560\ W$$

Considering drivetrain efficiency, $P_{input}$:

$$P_{input} = \frac{p_{total}}{\eta} \quad (4)$$

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$P_{input} = \frac{1560W}{0.85} \approx 1835.3\text{W}$

Based on the estimated steady-state input-power requirement of approximately 1.835 kW, a motor rated at ≥2.0 kW was considered suitable for the initial drivetrain sizing.

Battery Calculation

The theoretical battery-energy requirement was estimated based on the required drivetrain power and target operating range. This approach is consistent with electric go-kart power-supply design studies in which battery-system requirements are determined from the energy demand of the propulsion system under specified operating conditions [6].

$$t = \frac{d}{v} \tag{5}$$

Time, $t = \frac{40}{60} = 0.667\ h = 2400\ s$

The theoretical energy requirement was calculated as:

$$E = P_{input} \cdot t \tag{6}$$

$$E = (1835)(2400) = 4400400\ \text{J}$$

Converting to watt-hours,

$$E_{kWh} = \frac{E}{3600} = \frac{4400400\ \text{J}}{3600} \approx 1223.5\ Wh \approx 1.223\ kWh$$

The theoretical minimum energy requirement was estimated at approximately 1.223 kWh under the assumed steady-state operating condition. However, the battery was not selected solely on the basis of this minimum theoretical value. An additional energy reserve was considered to accommodate real-world drivetrain losses, usable battery capacity, variations in operating conditions, and potential battery performance degradation. Consequently, a 72 V, 40 Ah lithium-ion battery pack with a nominal energy capacity of 2.88 kWh was selected, providing a substantial capacity margin above the theoretical minimum requirement.

## 2. Methods and Materials

This section describes the systematic methodology adopted to convert an ICE-powered go-kart into a fully electric vehicle. The conversion process involved dismantling the existing ICE components, fabricating custom mounting brackets, integrating the electric drivetrain components, and experimentally evaluating the completed vehicle under field operating conditions. The methodology was designed to ensure secure mechanical integration, reliable electrical operation, and systematic evaluation of the dynamic, thermal, and energy performance of the converted go-kart.

### 2.1 Dismantling of the existing ICE components

The conversion began with the removal of the existing ICE-related components, including the engine, fuel tank, exhaust system, fuel line, carburettor, and associated mounting brackets. During disassembly, care was taken to avoid damage to the main chassis structure and to preserve its structural integrity for subsequent EV component integration. The removed components were documented and individually weighed to establish the baseline ICE component mass and enable comparison with the subsequently installed EV components.

### 2.2 Custom Mounting and EV Component Integration

Following the removal of the ICE components, the electric drivetrain components were integrated into the existing go-kart chassis. Custom mounting brackets were fabricated to securely accommodate the BLDC motor and battery pack within the existing chassis while considering structural integrity, component accessibility, and mass distribution. The motor controller was subsequently installed and configured to regulate motor operation, including current limiting and throttle response. A Hall-effect sensor-based throttle was integrated with the controller to provide proportional acceleration control.

### 2.3 Selection, Configuration, and Performance Testing of the Electric Propulsion System

The electric propulsion system was selected based on the theoretical power and energy requirements established in Section 2, together with considerations of electrical compatibility, safety, and project constraints. The theoretical input-power requirement at the target maximum speed was estimated at approximately 1.835 kW. Accordingly, a 3 kW BLDC motor with a nominal voltage rating of 48 V was selected, providing a power margin above the theoretical steady-state requirement.

The theoretical energy requirement for the targeted 40 km range was estimated at 1.223 kWh. However, the battery was selected with additional capacity to provide an energy reserve for real-world operating conditions. Accordingly, a 72 V, 40 Ah lithium-ion battery pack, corresponding to a nominal energy capacity of 2.88 kWh, was selected. The use of a battery pack together with a Battery Management System (BMS) is consistent with established electric go-kart power-

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supply architectures, in which battery-system parameters are selected according to the energy and power requirements of the propulsion system [6].

Although the selected 3 kW BLDC motor has a nominal voltage rating of 48 V, the motor controller was configured to interface with the 72 V battery pack and regulate the electrical power delivered to the motor using pulse-width modulation (PWM). The controller was configured with a continuous current limit of 100 A and a peak current limit of 150 A to restrict excessive current demand during high-load operation. The battery pack was equipped with a BMS to monitor and protect the battery cells against abnormal operating conditions, including overcharge, over-discharge, and excessive current.

Dynamic performance testing was conducted in three repeated trials under comparable operating conditions. Maximum vehicle speed was measured using a GPS tracker, while the acceleration time from rest to the maximum attainable speed was recorded for each trial. The reported maximum speed and acceleration time represent the mean values obtained from the three trials. The operational range was evaluated by operating the go-kart from a fully charged battery condition until the predetermined minimum battery operating limit was reached, with the travelled distance recorded using the GPS tracker.

For thermal evaluation, the go-kart was operated under full-power conditions for three minutes, during which the motor surface temperature was recorded at fixed time intervals. The thermal test was repeated three times, with sufficient cooling time allowed between successive trials. This experimental approach complements previous electric go-kart studies in which vehicle speed, electrical parameters, and motor performance were evaluated under field operating conditions [11].

### 2.4 Electrical and Energy Performance Data Analysis

The electrical and energy performance of the converted EV go-kart was evaluated over five test runs corresponding to target speed levels of 20, 30, 40, 50, and 59 km/h. These speed levels represent the target speeds attained during each test run rather than the average speed maintained throughout the entire test duration. At each target speed level, battery voltage (V), battery current (A), operating time, and distance travelled were recorded. The average battery voltage and current measured over each test run were used to determine the corresponding battery-side electrical power.

The battery-side electrical power was calculated as:

$$P = \frac{VI}{1000} \tag{7}$$

where $P$ is the electrical power (kW), $V$ is the battery voltage (V), and $I$ is the battery current (A). The electrical energy consumed during each test was calculated as:

$$E = VIt \tag{8}$$

where E is the electrical energy consumed (Wh) and t is the duration of the test run (h). The specific energy consumption was subsequently determined by normalising the electrical energy consumed by the actual distance travelled:

$$EC = \frac{E}{d} = \frac{V_{avg} I_{avg} t}{d} \tag{9}$$

where $EC$ is the specific energy consumption (Wh/km) and $d$ is the actual distance travelled (km).

Because the specified speed levels represent target speeds attained during the respective test runs rather than constant average speeds, specific energy consumption was determined from the measured energy use and actual distance travelled and was not calculated directly from the ratio of electrical power to the target vehicle speed. The resulting data were analysed quantitatively to characterise the relationship between target vehicle speed and battery electrical demand. Descriptive statistics, including the mean and standard deviation, were calculated for battery voltage, current, battery-side electrical power, and specific energy consumption across the five investigated target-speed levels. Pearson correlation analysis was performed to assess the strength and direction of the relationship between target vehicle speed and specific energy consumption. Simple linear regression was subsequently applied to characterise the observed speed–energy relationship, with the coefficient of determination ($R^2$) used to describe the proportion of variation in specific energy consumption associated with target vehicle speed. Statistical significance was evaluated at $p < 0.05$.

Given the limited number of target-speed levels (n=5), the correlation and regression analyses were used as exploratory assessments to characterise the observed speed–energy relationship rather than to provide definitive statistical validation.

## 3. Results and Discussion

This section presents and discusses the experimental results obtained from the converted EV go-kart. The evaluation covers component mass changes, electrical system performance, motor thermal behaviour, dynamic performance, operational range, and speed-dependent specific energy consumption. The experimental findings are also compared with the theoretical design requirements and relevant findings from previous studies to assess the overall performance of the converted vehicle.

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### 3.1 Component Mass Changes Following ICE-to-EV Conversion

The removed ICE components had a total mass of 29.0 kg, as shown in Figure 1, comprising the engine, fuel tank, exhaust system, fuel line and carburettor, and associated mounting brackets. In comparison, the installed EV components had a total mass of 14.0 kg, including the BLDC motor, lithium-ion battery pack, motor controller, wiring and connectors, throttle interface, and custom mounting brackets, as shown in Figure 2. Consequently, the conversion resulted in a net component mass reduction of 15.0 kg. The EV components were positioned within the available chassis space with consideration given to component accessibility, structural integration, and mass distribution. The lower total mass of the installed EV components relative to the removed ICE components demonstrates that the conversion was achieved without introducing an additional component-mass penalty to the original platform.

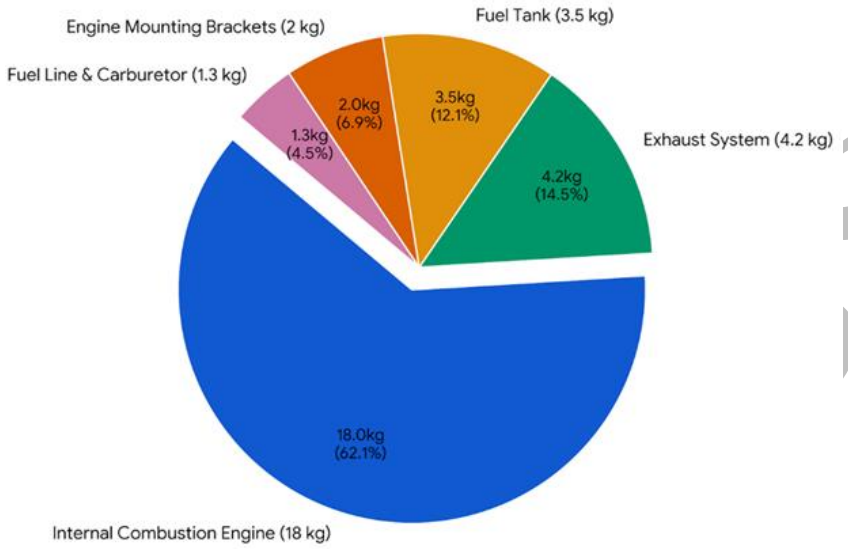



Figure 1. Mass of the ICE components removed during dismantling

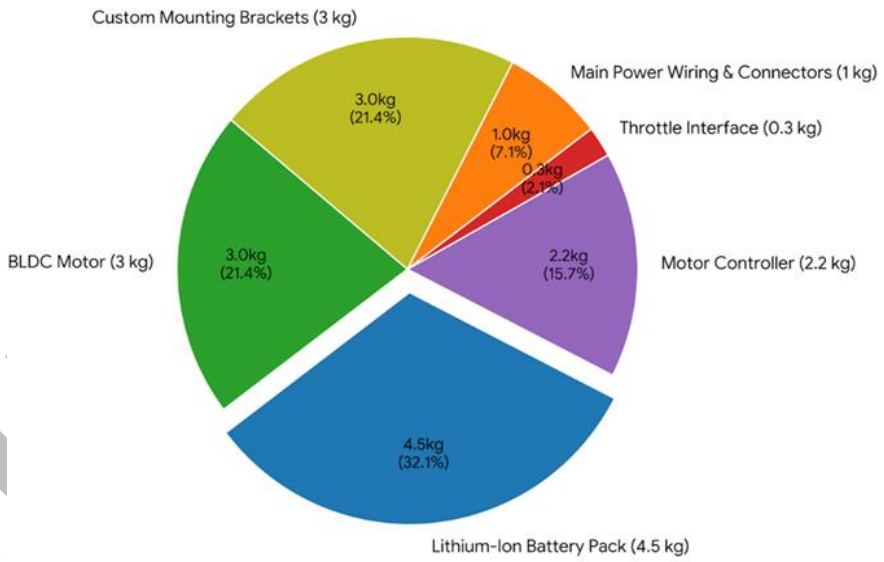



Figure 2. Mass of the EV components installed during conversion

### 3.2 EV Component Integration and Electrical Configuration

Figures 3 and 4 illustrate the electrical configuration and physical integration of the converted EV go-kart, respectively. Figure 3 shows the electrical connections between the 72 V battery pack, motor controller, 48 V BLDC motor, BMS, and throttle sensor, while Figure 4 identifies the main components installed on the converted vehicle. The motor controller served as the electrical interface between the 72 V, 40 Ah lithium-ion battery pack and the nominally rated 48 V BLDC motor. The controller accepted the 72 V battery input and regulated the electrical power delivered to the motor using pulse-width modulation (PWM) according to the operating demand. The controller was configured with a continuous current limit of 100 A and a peak current limit of 150 A to restrict excessive current demand during high-load operation. The maximum battery current recorded during acceleration was 65.1 A, which remained below both configured controller current limits.

The BMS provided an additional protection and monitoring layer for the 72 V battery pack. Its primary role was to monitor battery operating conditions and protect the cells against abnormal conditions such as overcharge, over-discharge, and excessive current.

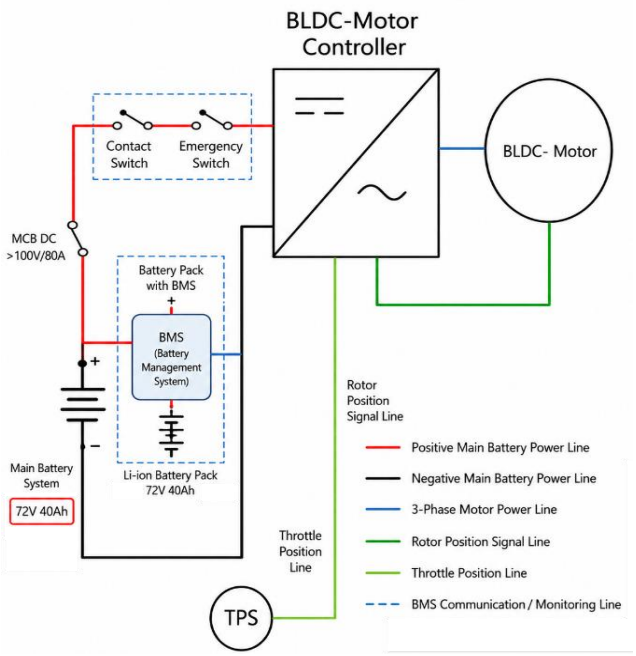



Figure 3. EV Go-Kart wiring diagram

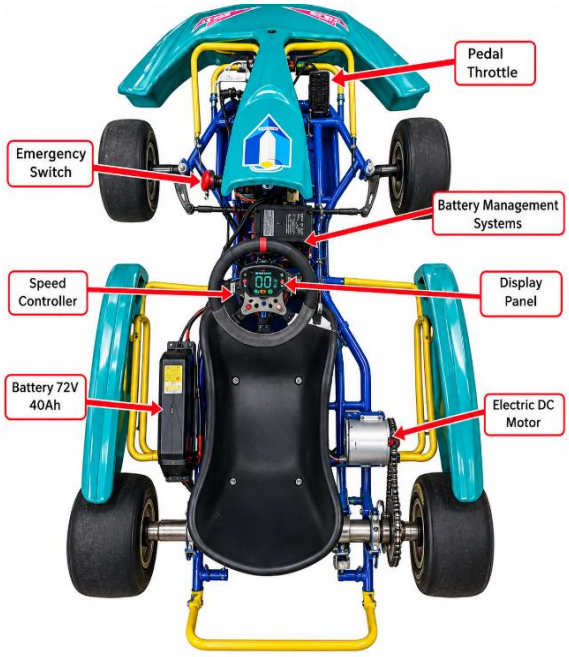



Figure 4. EV go-kart with labelled components

### 3.3 BLDC Motor, Battery, and Dynamic Performance

The motor controller was configured with a continuous current limit of 100 A and a peak current limit of 150 A to restrict excessive current demand during high-load operation. The controller voltage limits were set at 48 V for the lower cut-off and 90 V for the upper limit. The thermal response of the BLDC motor was evaluated during a three-minute full-power test. As shown in Figure 5, the motor surface temperature increased gradually from approximately 34.2°C to a maximum of 40.7°C during the 180s test period. The limited temperature rise indicates that no excessive surface-temperature increase occurred under the tested short-duration full-power condition. However, the three-minute test does not represent prolonged thermal loading, and longer-duration testing would be required to evaluate sustained thermal performance.

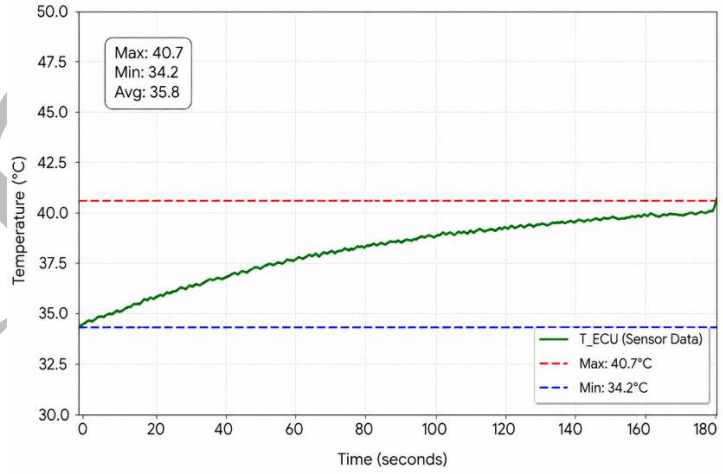



Figure 5. BLDC motor surface temperature during the full-power test

A clear difference in battery current demand was observed between acceleration and cruising conditions. As shown in Figure 6, the battery current reached a peak of 65.1 A during full acceleration, corresponding to approximately 4.3 kW of battery-side electrical power, whereas cruising at 25 km/h required approximately 14.7 A (0.9 kW). The acceleration peak remained below the configured continuous current limit of 100 A and peak limit of 150 A. These results demonstrate the substantially higher electrical demand associated with vehicle acceleration compared with steady cruising. For comparison, Ramasir et al. [10] reported an electric go-kart equipped with a 10 kW BLDC motor and a 50.4 V, 100 Ah second-life lithium-ion battery, achieving a maximum speed of 67 km/h. Their system exhibited a peak current of approximately 287 A during acceleration, accompanied by a battery voltage reduction from approximately 52 V to 41 V. In comparison, the present converted go-kart achieved a maximum speed of 59 km/h with a considerably lower peak

battery current of 65.1 A. The difference in current demand is consistent with the substantially different motor ratings, battery configurations, and intended performance levels of the two platforms.

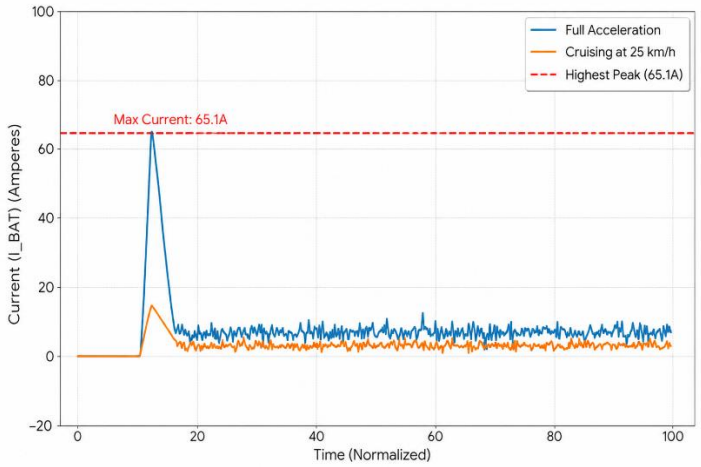



Figure 6. Battery current during full acceleration and cruising at 25 km/h

### 3.4 Speed-Dependent Electrical and Energy Performance

The speed-dependent electrical and energy performance of the converted EV go-kart was evaluated at five operating speeds ranging from 20 to 59 km/h, as presented in Table 2. Battery voltage remained relatively stable between 69 and 72 V across the investigated speed range. In contrast, battery current increased from 15 A at 20 km/h to 51 A at 59 km/h, resulting in an increase in battery-side electrical power from 1.050 to 3.519 kW. The experimental battery-side electrical power at the highest tested speed was substantially higher than the theoretical input-power requirement. The theoretical model predicted approximately 1.835 kW at 60 km/h, whereas the experimental battery-side power reached 3.519 kW at 59 km/h. Arshad et al. [5] similarly evaluated electric go-kart power requirements by considering major resistance forces, including rolling, aerodynamic, and gradient resistance. In the present study, the higher experimental power demand may reflect differences between the simplified steady-state theoretical model and actual operating conditions. Road gradient, ambient wind, tyre-pressure variation, battery state of charge, and variations in actual vehicle-plus-driver mass were not systematically incorporated into the theoretical analysis. Wind may also have contributed to the observed difference because the tests were conducted in a coastal environment; however, wind speed and direction were not measured during testing. Therefore, the theoretical value should be interpreted as a first-order steady-state design estimate rather than an exact prediction of battery-side electrical power under field operating conditions.

Across the five operating-speed points, the mean battery voltage, current, battery-side electrical power, and specific energy consumption were 70.60 ± 1.14 V, 30.20 ± 15.32 A, 2.126 ± 1.056 kW, and 66.00 ± 14.98 Wh/km, respectively. Specific energy consumption increased from 50 Wh/km at 20 km/h to 88 Wh/km at 59 km/h, corresponding to a 76% increase across the investigated speed range. Pearson correlation analysis showed a strong positive relationship between vehicle speed and specific energy consumption ($r$ = 0.978, $p$ = 0.004). Simple linear regression further indicated that vehicle speed was strongly associated with specific energy consumption across the investigated operating points, with $R^2$=0.956. The fitted regression model indicated an average increase of approximately 0.945 Wh/km in specific energy consumption for every 1 km/h increase in vehicle speed within the tested range. The observed increase in energy demand with vehicle speed is broadly consistent with Hermawati et al. [11], who reported that drivetrain efficiency varied significantly with vehicle speed and driver load in a 4 kW BLDC electric go-kart. Their highest reported efficiency was 95.45% at 40 km/h with a 55 kg driver, whereas the lowest was 62.49% at 60 km/h with a 75 kg driver. Although drivetrain efficiency and specific energy consumption represent different performance metrics, both studies indicate that operating conditions, particularly vehicle speed and load, can substantially influence electric go-kart energy performance.

From an operational perspective, the results indicate that moderate vehicle speeds may provide more favourable energy utilisation, whereas operation near the maximum speed imposes greater battery energy demand. However, the statistical analysis was based on only five operating-speed points. Therefore, the correlation and regression results should be interpreted as exploratory rather than definitive statistical validation. Future work should incorporate repeated measurements at each operating speed under controlled conditions, including vehicle mass, road gradient, tyre pressure, battery state of charge, and ambient wind conditions, to quantify measurement variability and further validate the observed speed–energy relationship.

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Table 2. Electrical and energy performance of the EV Go-kart at different vehicle speeds

| Speed (km/h) | Voltage (V) | Current (A) | Calculated Power (kW) | Specific Energy Consumption (Wh/km) |
|---|---|---|---|---|
| 20 | 70 | 15 | 1.050 | 50 |
| 30 | 71 | 17 | 1.207 | 55 |
| 40 | 72 | 28 | 2.016 | 65 |
| 50 | 71 | 40 | 2.840 | 72 |
| 59 | 69 | 51 | 3.519 | 88 |

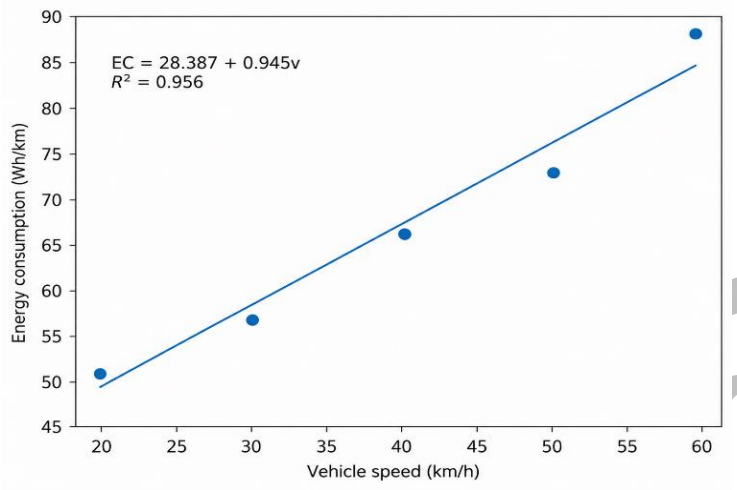



Figure 7. Relationship between vehicle speed and energy consumption of the EV Go-Kart

Table 3. Comparison between theoretical design and experimental performance

| Performance indicator | Theoretical target | Experimental result | Difference/assessment |
|---|---|---|---|
| Maximum speed | 50–60 km/h | 59 km/h | Target achieved |
| Minimum range | 40 km | 46 km | 15% above target |
| Required input power at 59 km/h | 1.835 kW | 3.519 kW at 59 km/h | Higher under actual operation |
| Energy requirement | 1.223 kWh | - | Experimental battery-energy total needed for direct comparison |
| Acceleration to maximum speed | - | 6.9 seconds | - |




Figure 8. The GPS tracker interface for dynamic testing displays

## 4. Conclusion

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**Ethics Statement**
This study involved engineering design, vehicle conversion, and experimental performance testing and did not involve animals or personally identifiable data; therefore, ethical approval was not required.

**Generative AI Disclosure**
During the preparation of this manuscript, generative AI was used solely to assist with language refinement and improvement of clarity and readability. All AI-assisted content was reviewed and edited by the authors, who take full responsibility for the final manuscript. Generative AI was not used to generate, fabricate, or alter the experimental data or results.

**Declaration of Competing Interests**
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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