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# Integration of Automatic Transmission Towards Converted Electric Vehicle : A GT-Suite Approach

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## ABSTRACT

The growing adoption of electric vehicles (EVs) in Southeast Asia, particularly in Indonesia and Malaysia, is driven by policy incentives such as road tax exemptions and relaxed traffic restrictions. This study investigates the feasibility and performance impact of integrating a stock automatic transmission into a converted internal combustion engine (ICE) vehicle, replacing the commonly used single gear or manual transmissions in typical EV conversions. Using GT-Suite simulation software, a detailed model of a converted Toyota Avanza was developed to evaluate key performance metrics including acceleration, top speed, driving range, and energy consumption. Simulation results indicate that integrating an automatic transmission improves acceleration performance, reducing the 0–100 km/h time by 0.7 seconds compared to a single-gear configuration. Although the top speed is mechanically limited by the transmission's maximum input speed, the vehicle achieved a marginally higher top speed (191.3 km/h) and reached it 1.8 seconds faster. During range simulations under the New European Driving Cycle (NEDC) and constant highway driving at 100 km/h, the automatic transmission variant demonstrated a longer driving range—up to 7% farther—while also improving energy consumption from 8.55 km/kWh to 8.77 km/kWh.

**Keywords** : Automatic Transmission; Conversion; Electric Vehicle; GT-Suite; Simulation;

## ABSTRAK

Penerapan kendaraan listrik (*EV*) yang semakin berkembang di Asia Tenggara, khususnya di Indonesia dan Malaysia, didorong oleh insentif kebijakan seperti pembebasan pajak jalan dan pelonggaran pembatasan lalu lintas. Penelitian ini menyelidiki kelayakan dan kinerja dari pengintegrasian transmisi otomatis yang berasal dari manufaktur asal ke dalam kendaraan konversi mesin pembakaran dalam (ICE), menggantikan transmisi satu gigi atau transmisi manual yang umum digunakan dalam konversi EV pada umumnya. Menggunakan perangkat lunak simulasi GT-Suite, model rinci dari Toyota Avanza yang telah dikonversi dikembangkan untuk mengevaluasi parameter utama, termasuk akselerasi, kecepatan tertinggi yang dapat diraih, jarak tempuh maksimum, dan konsumsi energi. Hasil simulasi menunjukkan bahwa pengintegrasian transmisi otomatis meningkatkan akselerasi, mengurangi waktu akselerasi dari 0–100 km/jam sebesar 0,7 detik dibandingkan dengan konfigurasi satu gigi. Meskipun kecepatan tertinggi dibatasi secara mekanis oleh kecepatan input maksimum transmisi, kendaraan mencapai kecepatan tertinggi yang sedikit lebih tinggi (191,3 km/jam) dan mencapai kecepatan tertinggi 1,8 detik lebih cepat. Selama simulasi jarak dengan siklus *New European Driving Cycle* (NEDC) dan pengendaraan di jalan bebas hambatan dengan kecepatan konstan 100 km/jam, varian transmisi otomatis menunjukkan jarak tempuh yang lebih jauh hingga 7% serta meningkatkan efisiensi konsumsi energi dari 8,55 km/kWh menjadi 8,77 km/kWh.

**Kata Kunci :** Transmisi Otomatis; Konversi; Kendaraan Listrik; Simulasi; GT-Suite

## 1. INTRODUCTION

Sales of electric vehicles (EV's) in the world keep on increasing every year [1]. This upward trend has been largely driven by the 2016 Paris Agreement on climate change [2], which aims to limit the global temperature rise to 1.5°C above pre-industrial levels by the end of the 21st century. The growth in EV adoption has been further substantiated by Schub, et al. [3]. As illustrated in **Figure 1**, EV sales have shown significant variation among European countries, including the United Kingdom, France, and Germany.

The increased uptake of electrified vehicles—comprising hybrid, plug-in hybrid, and battery electric vehicles (BEVs)—can be attributed to government regulations and initiatives. For example, the implementation of Ultra Low Emission Zones (ULEZ) in the United Kingdom has incentivised the adoption of low-emission transport solutions [4]. Furthermore, UK government policies have set ambitious targets, including a ban on the sale of new petrol and diesel vehicles by 2030. By 2035, only vehicles with zero tailpipe emissions, such as BEVs and fuel cell electric vehicles (FCEVs), will be permitted for sale [4].

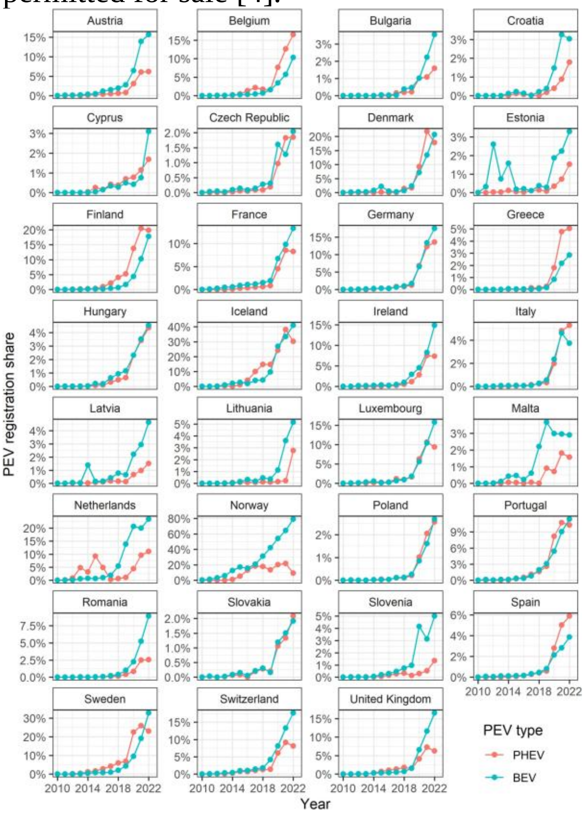


**Figure 1.** Sales registration share for PEV and BEV in European countries [3].

Nevertheless, despite the global rise in BEV sales, the rate of adoption remains relatively slow [5]. A study by Logan, et al. [5], dentified cost as the primary barrier preventing widespread consumer adoption in the UK. Many prospective buyers perceive BEVs as prohibitively expensive when compared to internal combustion engine (ICE) vehicles of similar class or segment.

Study by Pedrosa, et al. [6], shown that compared to developing and buy a new BEV, it is cheaper to convert an ICE car to fully electric or BEV. Trend of converting or retrofit an ICE car to EV is increasing around the globe as price of the parts are becoming cheaper and cheaper every year. In most of European countries and United States (US), most of the people will not buy a new BEV then, converting a car from ICE to EV is getting popular nowadays especially if the price converting an ICE to EV is cheaper than today [4, 7].

In countries such as Malaysia and Indonesia, owning an electric vehicle (EV) provides several advantages compared to other types of vehicles. For instance, road tax for electric vehicles is exempted in both Malaysia and Indonesia. In the United Kingdom, all electric vehicles are permitted to enter Ultra-Low Emission Vehicle (ULEV) and Super Ultra-Low Emission Vehicle (SULEV) zones [4, 8]. Additionally, in Indonesia, EV owners are allowed to enter areas governed by the odd-even traffic restriction system regardless of their vehicle's number plate, further incentivising EV adoption. These policies also extend their benefits to individuals who convert internal combustion engine (ICE) vehicles to electric.

The process of converting or retrofitting an ICE vehicle to an EV typically begins with the removal of ICE-related components, including the engine, fuel tank, air-conditioning compressor, and fuel lines. These components are replaced with an electric drivetrain comprising an electric motor, battery pack, and other power electronics [9]. In most conversion projects, a single-gear transmission is utilised. Manual transmissions are also commonly retained due to their ease of installation and the ability to fix the gear ratio. For example, in a simulation study by Yosua Setiawan [10] , a Toyota Avanza was retrofitted with an electric powertrain using its original factory-installed manual transmission. Even though manual transmission was used, author only use single gear ratio since it is hard to rev match if the gear was change on the fly.

Although retrofitting an ICE car equipped with an automatic transmission is generally more challenging, most modern vehicles are now equipped with automatic transmissions rather than manual ones. While some manufacturers still offer both transmission options for specific models, this practice is becoming increasingly uncommon [11]. If the vehicle's original automatic transmission can be reused during the conversion process, it could significantly reduce the cost, as there would be no need to source and install a manual transmission. Moreover, utilising the stock transmission contributes to a lower carbon footprint by eliminating the need to manufacture or purchase additional transmission components.

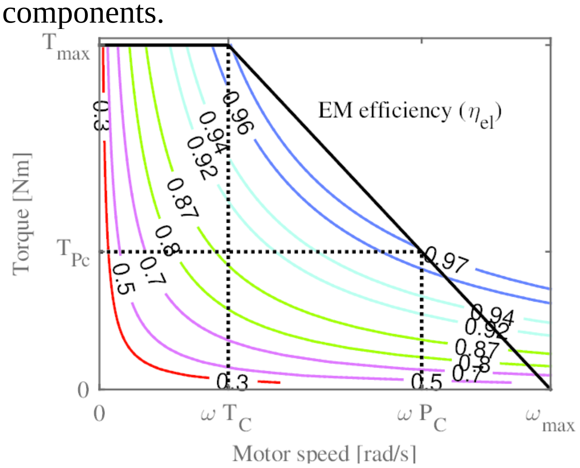


**Figure 2.** Typical electric motor efficiency across its rotational speed [14].

The use of an automatic or multi-speed transmission in electric vehicles may also enhance overall efficiency. This is primarily because the electric motor can be maintained within its optimal efficiency range. Figure 2 illustrates a typical electric motor efficiency map across various rotational speeds. When the motor operates beyond its peak efficiency range, its overall efficiency begins to decline. For this reason, Porsche has adopted a dual-speed transmission in its electric vehicle, the Porsche Taycan [12]. The manufacturer claims that the dual-speed system improves efficiency and enhances both acceleration and top-speed performance. Furthermore, a study by Wei [13], demonstrated that employing a continuously variable transmission (CVT) design in EVs could reduce total cost of ownership by 5.7%, and may also enable the use of smaller motors due to the wider range of gear ratios available in a CVT gearbox.

## 2. RESEARCH METHODOLOGY

This research was based on author previous work on converted ICE to EV using Toyota Avanza as based model for this research. The Toyota Avanza was chosen as the base vehicle for ICE to EV conversion because of its popularity and availability in Indonesia. The specific/based model used featured a 1.3-liter engine with an automatic transmission, originally delivering 93 horsepower and 120 Nm of torque. To replicate its performance in electric form, a suitable electric motor had to be selected. A Synchronous AC motor was used for the conversion, offering a peak power of 60 kW, a rated power of 33 kW, and an efficiency of 95%. This motor delivers 220 Nm of torque and can reach up to 12,000 rpm. The specifications of the converted vehicle, including details of the electric motor and battery pack setup, are shown in **Error! Not a valid bookmark self-reference.**.

**Table 1.** Toyota Avanza converted car specifications

| Vehicle Parameter | Values | Unit |
|---|---|---|
| Vehicle Gross Weight | 1250 | $kg$ |
| Aerodynamic drag coefficient | 0.3 [15] | |
| Frontal Area | 2.23 [15] | $m^2$ |
| Final Drive Gear Ratio | 5.125 | |
| Motor Voltage | 260-410 | $V$ |
| Max Torque | 220 | $Nm$ |
| Peak Power | 60 | $kW$ |
| Battery Pack Rated Voltage | 268.8 | $V$ |
| Battery Pack | 40.32 | $kWh$ |

Capacity

**Using the specifications provided in**

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Table 1, a detailed vehicle model was created in GT-Suite. The resulting model is illustrated in Figure 3. The simulation was conducted using GT-Suite's built-in electric vehicle template, which served as the foundational framework. However, several parameters were customised to accurately represent the characteristics of the converted electric vehicle. For instance, the final drive ratio was adjusted to match the stock differential of the original vehicle.

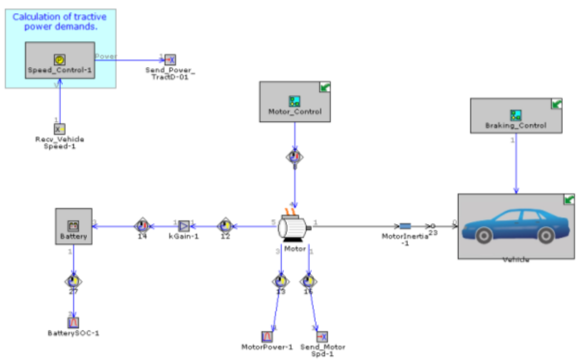


**Figure 3.** Map of Toyota Avanza in GT-Suite.

When integrating an automatic transmission into the model, the gear ratio specifications for each gear must be known in order to implement them accurately within the transmission module in GT-Suite. The gear ratio details used in this study are presented in Table 2. Once the specifications for the automatic transmission were obtained, a transmission module was added to the electric vehicle system using the Transmission template in GT-Suite. Figure 4 shows the transmission module template used in the simulation.

The transmission module includes configurations for forward gears, neutral gear, reverse gear, and thermal behaviour settings, all of which must be defined for the module to function correctly. The forward gears were configured using the gear ratios of the Toyota Avanza automatic transmission, as listed in Table 2. However, the neutral gear, reverse gear, and thermal behaviour were set to be ignored in this simulation. Neutral and reverse gears were excluded as they were not relevant to the driving scenarios simulated, while thermal behaviour was disregarded to simplify the overall simulation process.

**Table 2.** Gear ratio specification of Toyota Avanza

| Gear Number | Gear Ratio |
|---|---|
| 1st Gear | 2.731 |
| 2nd Gear | 1.526 |
| 3rd Gear | 1 |
| 4th Gear | 0.696 |

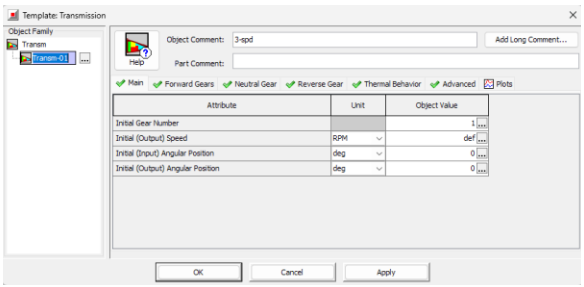


**Figure 4.** Transmission template in GT-Suite.

To implement the transmission shift strategy, a shift control system needed to be incorporated into the model. This required the addition of a Transmission Control Module (TCM) within the GT-Suite simulation environment. Figure 5 shows the template used to control the transmission shifts in GT-Suite. Within the TransControl template, there is a transmission shift strategy object that must be configured. This shift strategy governs gear selection based on specific vehicle speeds and loads.

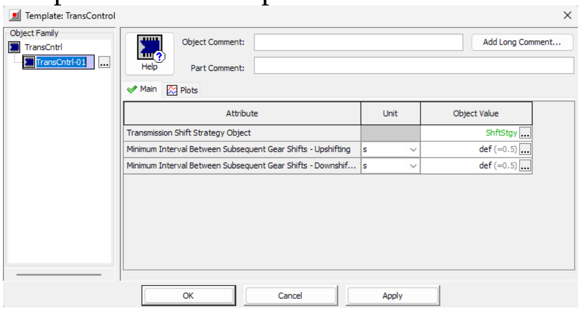


**Figure 5.** TransControl template in GT-Suite.

In this study, for the purpose of simplifying the simulation, the transmission shift strategy was based solely on vehicle speed. Gear shifts were triggered once the vehicle reached predefined speed thresholds. For instance, the transmission would shift from 1st to 2nd gear when the vehicle reached 25 km/h. The complete shift strategy parameters for each gear are presented in Table 3.

**Table 3.** Shift strategy speed of automatic transmission of Toyota Avanza.

| Gear No. | Vehicle Speed at Gear Up-Shift | Vehicle Speed at Gear Down-Shift | Unit |
|---|---|---|---|
| 1st Gear | 25 | ign | km/h |
| 2nd Gear | 45 | 18 | km/h |
| 3rd Gear | 65 | 35 | km/h |
| 4th Gear | ign | 58 | km/h |

In this research, a comparison was carried out to evaluate several key aspects between a single-gear transmission and an automatic transmission. The comparison was based on the author's previous work involving the simulation of electric powertrain integration into a converted internal combustion engine (ICE) vehicle. The primary focus of the study was on acceleration, top speed, and driving range. In contrast, motor efficiency and motor rotational speed (rpm) were considered as supplementary aspects.

## 3. RESULTS AND DISCUSSION

### 3.1. Acceleration and Top Speed

It is well established that electric vehicles (EVs) generally exhibit superior acceleration performance compared to internal combustion engine (ICE) vehicles. This advantage is primarily due to the unique characteristics of electric motors, which deliver immediate torque and smooth, linear acceleration. According to the author's previous work, the vehicle could accelerate from 0 to 100 km/h in 14 seconds using a single-gear configuration. However, based on simulation results conducted in GT-Suite, it was found that integrating an automatic transmission reduced the 0–100 km/h acceleration time to 13.3 seconds—an improvement of 0.7 seconds.

Figure 6 illustrates the difference in acceleration between the single-gear and automatic transmission configurations. It is evident that the vehicle using a single gear demonstrates a more linear acceleration profile, whereas the vehicle equipped with an automatic transmission exhibits significantly faster acceleration up to 70 km/h, after which the acceleration rate begins to taper off as it approaches 100 km/h.

The maximum acceleration rate recorded was 5.58 $m/s^2$ for the vehicle with an automatic transmission, compared to only 2.95 $m/s^2$ for the single-gear vehicle. On average, the acceleration rate was 5 $m/s^2$ for the first 1.8 seconds after launch. At that moment (1.8 seconds from a standstill), the vehicle with the automatic transmission reached a speed of 34.3 km/h, while the single-gear vehicle reached only 19.2 km/h.

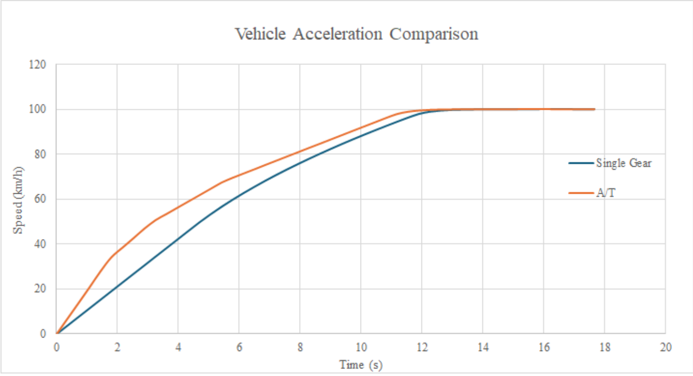


**Figure 6.** Vehicle acceleration comparison.

Acceleration performance was found to be superior with the automatic transmission, and a similar trend was observed for top speed. However, due to the transmission's maximum allowable input speed of approximately 6000 rpm, the top speed was limited by the transmission's capability to withstand high motor speeds. Simulation results indicated that the vehicle equipped with an automatic transmission achieved a maximum speed of 191.3 km/h, marginally higher than the 190 km/h attained with the single-gear configuration. The time required to reach maximum speed was 41.2 seconds for the automatic transmission and 43 seconds for the single-gear setup. Figure 7 presents a graph comparing the acceleration profiles of both transmission types as they approach their respective top speeds. It is evident that the rapid initial acceleration provided by the automatic transmission gives it an early advantage, allowing the vehicle to reach top speed 1.8 seconds faster. However, after reaching 100 km/h, both transmission types exhibited similar acceleration rates.

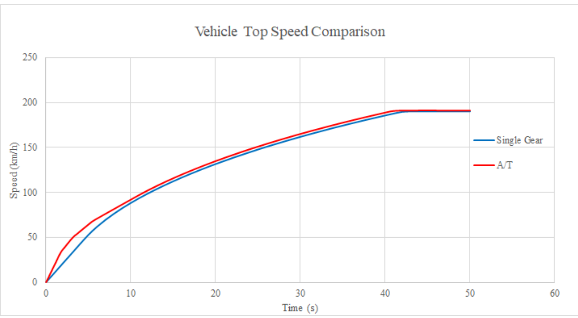


**Figure 7.** Vehicle top speed comparison graph.

## 3.2 Range of Electric Vehicle

One of the most widely recognised and commonly used driving cycles for automotive testing is the New European Driving Cycle (NEDC). This standardised test procedure enables a vehicle to reach a maximum speed of up to 120 km/h. The full NEDC cycle lasts for 1,180 seconds, offering a comprehensive assessment of vehicle performance under a range of speed and load conditions. NEDC was choosen because NEDC is more suitable with driving condition in Indonesian since it only have maximum speed of 120 km/h. In this study, the NEDC was employed to evaluate the vehicle's driving range, measuring the distance it could travel from a fully charged state until the battery was completely depleted.

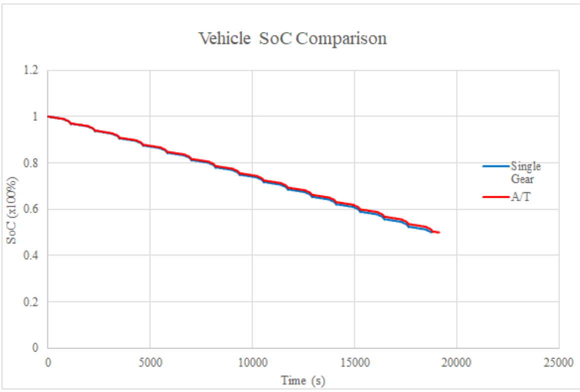


**Figure 8.** Vehicle SoC comparison from 100% to 50%.

Figure 8 hows the SoC graph from 100% to 50% for both transmissions. It is evident that the automatic transmission requires a longer time to reach 50% SoC, indicating that the vehicle equipped with an automatic transmission is more efficient than the one equipped with a single-gear transmission.

Simulation results also show that, from 100% to 50% SoC, the vehicle with an automatic transmission can travel 176.8 km, while the vehicle with a single-gear transmission can only cover 172.8 km. By doubling these distances, we can estimate the full range of the vehicle with a single charge. Based on this, a fully charged vehicle with an automatic transmission can travel 353.6 km, while the single-gear configuration can reach only 345.6 km.

Considering that manufacturers typically utilise only 90% of the total battery capacity to preserve battery health, the effective driving range becomes 318.2 km for the automatic transmission and 311 km for the single-gear transmission. These results show that using an automatic transmission allows the vehicle to travel 7.2 km farther, representing an improvement in efficiency of approximately 2.3% compared to the single-gear setup.

As outlined in the methodology, the total battery pack capacity of this converted EV is 40.32 kWh. By dividing the driving range by the battery capacity, the energy consumption was calculated to be 8.77 km/kWh for the vehicle with an automatic transmission and 8.55 km/kWh for the vehicle with a single-gear transmission.

Other than the NEDC, this research also simulated the vehicle from 100% state of charge (SoC) to 0% SoC, or until the battery was fully depleted, during operation at a constant highway speed of 100 km/h. This constant speed was chosen as it is the maximum legal speed on Indonesian highways. At this speed, the maximum distance that can be achieved is 459 km and 429 km for the automatic transmission and single-gear transmission, respectively. This represents the maximum theoretical range.

Normally, to preserve and protect the battery, only 90% of the total capacity is used. Based on this standard, the vehicle could travel up to 413 km and 386 km for the automatic and single-gear transmissions, respectively. This also means that the vehicle with an automatic transmission could travel 27 km farther than the one equipped with a single-gear transmission. In other words, the automatic transmission can extend the driving range by up to 7% compared to the single-gear configuration.

## CONCLUSION

With the completion of this study, it can be concluded that the integration of a stock automatic transmission into a converted electric vehicle is both feasible and offers several advantages, as outlined below:

- **Acceleration**: The use of an automatic transmission reduced the time required to accelerate from a standstill to 100 km/h by 0.7 seconds, representing an improvement of approximately 5% in acceleration performance.
- **Top Speed**: Although the top speed is mechanically limited to 191.3 km/h due to the transmission’s maximum input speed, the vehicle equipped with an automatic transmission reached this speed 1.8 seconds faster than the single-gear counterpart.
- **Driving Range (NEDC)**: Under the NEDC cycle, the vehicle with an automatic transmission demonstrated a 2.3% longer driving range, equating to an additional 7.2 km compared to the vehicle with a single-gear transmission.
- **Energy Consumption**: The energy consumption efficiency improved from 8.55 km/kWh to 8.77 km/kWh when using the automatic transmission.
- **Highway Driving Simulation**: During constant-speed highway driving simulations, the vehicle equipped with an automatic transmission achieved a 7% increase in driving range, or 27 km more, relative to the single-gear configuration.

However, further investigation is required to optimise the integration of a stock automatic transmission into converted electric vehicles. Comprehensive research is necessary to develop an efficient gear-shifting strategy that ensures optimal performance and accuracy in results.

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