A SOLUTION FOR CONVERTING THE PROPULSION SYSTEM OF LIGHT TRUCK

Minh Duc Le*, Van Nam Tran, Van Phuc Nguyen, Cong Tin Le, Quang Trung Nguyen

The University of Danang - University of Science and Technology, Vietnam

*Corresponding author: minhducle@dut.udn.vn

(Received: December 16, 2024; Revised: June 14, 2025; Accepted: June 16, 2025)

DOI: 10.31130/ud-jst.2025.23(6A).539E

Abstract – This study presents a powertrain conversion solution based on the Thaco Frontier light truck. The electric hybrid architecture includes series HEV, parallel HEV, and series-parallel HEV. The analyzed results show that the series HEV model is the best option to meet environmental and energy goals. It also meets the current technical requirements and resource limits of the Thaco Frontier truck. The KIA Frontier powertrain was converted into a series HEV powertrain for 4 basic operating modes, i.e., Battery-operated mode, Battery charging mode, and Hybrid driving mode. The electric motor is 80 kW. It matches the powertrain and the traction capacity of the original vehicle. The energy storage capacity is 67.5 kWh, which is suitable for a travel distance of 175 km.

Key words – Powertrain; HEVs Architecture; Serial Hybrid Energy; Environment.

1. Introduction

Nowadays, the rapid increase in greenhouse gas emissions in recent decades has harmed the environment and climate. The result is the warming of the atmosphere, land, cryosphere, and ocean. The current extreme weather, like heavy rains and frequent heat, is clear evidence. According to the latest research data published in the journal Earth System Science Data, the amount of greenhouse gases emitted each year is a record, equivalent to 54 billion tons of carbon dioxide (CO_2) released into the atmosphere. This leads to a rapid increase in the temperature of the Earth's surface. From 2013 to 2022, data showed a 0.2°C rise in average temperature every 10 years. It predicted global warming will hit 1.5°C by 2050 [1-2]. Countries face a major challenge: energy security. There are several issues. First, fossil energy use is rising. Second, fuel costs are high. Third, natural resources are depleted. Fourth, many countries depend on a few resource-rich nations for supplies. Finally, environmental impacts are causing global warming.

In particular, transport contributes a large part to the total amount of CO_2 emitted globally, equivalent to 24%. Transport is the leading cause of increased air pollution in large cities. It contributes up to 70% of the dust and emissions in the air [3]. The use of internal combustion engines is considered one of the main causes of environmental pollution and climate change. The Transport sector must quickly shift to sustainable practices to reduce greenhouse gases by 2050. This includes changing how we move, using low CO_2 fuels, improving engine efficiency, and combining energy sources in vehicles. There is also a trend to electrify transport vehicles.

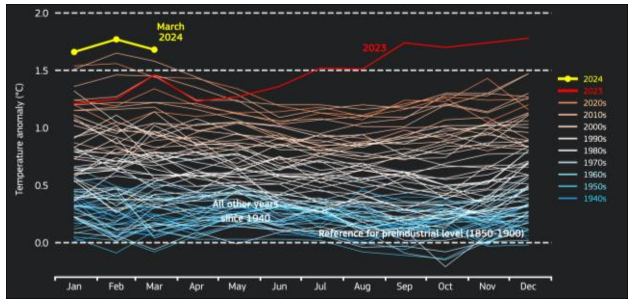

Figure 1. *Global surface air temperature [1]*

In Vietnam, the transport sector has made remarkable progress over the past 25 years. Freight demand grew at 11% per year. So, the volume of goods transported in the country rose from 32 billion in 2000 to 111 billion in 2016. This is a 340% increase. The rapid growth of transport has boosted the Vietnamese economy. But, it has harmed the environment and energy. To join the global fight against climate change and ensure energy security, Vietnam has committed to cut greenhouse gas emissions by 9% by 2030 under the Paris Agreement. It will also promote solutions to reduce reliance on fossil fuels. The Prime Minister of Vietnam committed to net zero emissions by 2050 at the COP26 Leaders' Summit [3].

To achieve that goal, the Prime Minister issued Decision No. 687/QD-TTg, dated July 6, 2022, and approved the Circular Economy Development Project in Vietnam. Its main goal is to reduce greenhouse gas emissions per GDP by 15% by 2030, compared to 2014. It aims for net "0" emissions by 2050 [3]. In recent decades, scientists and businesses in Transport have worked with the government. They have researched and applied solutions to reduce greenhouse gas emissions and dependence on fossil fuels in transport. Typical studies include research on fuels with lower CO_2 emissions to replace traditional fossil fuels. They also look at: 1) increasing public transport use instead of personal vehicles, 2) partially electrifying transport by combining electric energy with traditional vehicles, and 3) encouraging electric and hybrid vehicles.

In the early stages, domestic researchers were interested in "cleaner" alternative fuels. They saw great potential in them. They hoped to reduce emissions and ensure energy security. Specifically, energy carriers such as CNG, LPG, Biogas, Ethanol, and Butanol started to be studied early in the early 1990s. Now, research is shifting to electric and hybrid power systems. Their CO_2 emissions are much lower than current levels. The goal is to improve vehicle fuel efficiency for a safe, sustainable transport future. Vietnam sees great potential in electric vehicles. So, it aims for 30% of two-wheeled electric vehicles by 2030. It also targets a 5% market share for electric vehicles by 2025, and 30% by 2030. Lastly, it aims for electric buses to make up 10% of total bus sales from 2020 to 2030. Also, stricter emission regulations are being implemented to reduce vehicles' environmental impact. In that context, large domestic auto manufacturers have begun to adjust their car development strategies. They are following a suitable roadmap. It aims to apply advanced technologies to reduce gasoline and oil use. They must also increase the number of electric, hybrid, and clean-energy cars. This is to meet strict emissions regulations and build a sustainable, safe, and friendly transport industry [4-6].

KIA Frontier light trucks are one of the light truck lines manufactured and assembled at Thaco with a high density of use in transporting goods. Thaco's stats show KIA Frontier truck sales in Vietnam hit nearly 6,000 a year. This is almost 30% of the light truck market [7]. However, KIA Frontier vehicles use traditional internal combustion engines. They are greatly contributing to CO_2 emissions that pollute the environment. Given Vietnam's emissions goals, we must convert the current vehicles. Switching from a traditional power system with an internal combustion engine to a hybrid one improves Frontier trucks. It helps the environment and boosts their performance and fuel economy. Also, with the Hybrid power system, Frontier trucks can operate more efficiently in urban traffic, where they stop and start frequently. The current power system is suitable for the economy. It uses the Enterprise's available resources.

2. Analysis and selection of powertrain

To achieve the dual goal of reducing emissions and ensuring energy security, the most feasible solution at present is to electrify transportation. Full electrification is characterized by pure electric vehicles (BEV), or fuel cell vehicles (PEV); partial electrification is characterized by hybrid vehicles between traditional internal combustion engines and electric motors (HEV). The rate of full or partial electrification depends on many factors, of which the ability to respond to infrastructure, and the ability to apply modern technology and internal resources are decisive factors [8-10].

BEVs are the most promising in terms of reducing emissions at the point of use. With that advantage, and at the same time convenient for short-distance travel, small BEV passenger cars have been on the rise in recent years. The basic limitation of BEV vehicles is the battery. Low energy density, and charging time do not meet transportation requirements and high initial investment costs, so the application of pure electric vehicles to high-load and long-distance vehicles is still limited. Charging infrastructure is currently a difficult barrier to access at present for vehicles with larger loads such as the KIA Frontier light truck. FCEVs have the potential to reduce emissions at the point of use similar to BEV vehicles. However, FCEV vehicles are currently not highly mature in terms of technology, especially the technology of converting energy carriers into hydrogen. The underdeveloped fueling system is a challenge for the implementation of FCEV vehicle applications. Therefore, it is difficult to ensure the effectiveness of research and feasibility of application after the study of FCEV powertrain conversion on the KIA Frontier light truck [10].

Hybrid powertrains are considered suitable for the current context, ensuring the dual goals of emission reduction and energy security while solving the basic disadvantages related to infrastructure, technology, cost, and travel distance of BEV and FCEV powertrains. Hybrid powertrains are a combination of internal combustion engine and electric motor power sources. The advantage of converting from a traditional powertrain to a Hybrid powertrain is that only part of the powertrain architecture is changed. Vehicles with Hybrid powertrains have low operating costs, little change in driving habits, and have become popular, above all, Hybrid has been accepted as an effective solution to urgent problems related to energy and the environment. There are three hybrid powertrain architectures including Series Hybrid, Parallel Hybrid, and Series-Parallel Hybrid.

2.1. Characteristics of Series hybrid powertrains

The series hybrid combines the best attributes of the ICE and BEV, aiming to extend the range of the BEV, and can be considered a pure electric drive architecture with an additional power path from the ICE. The HEV structure consists of an ICE, a generator, and an electric motor. The electric motor is responsible for transmitting torque to the vehicle's driving wheels, while the smaller ICE acts as a generator to generate electricity to charge the battery or supply the electric motor [10]. In which, only the electric motor needs to have a capacity that meets the maximum capacity of the vehicle. The HEV structure is described in Figure 2. The generated current is divided into two parts, one to charge the battery and one to run the electric motor.

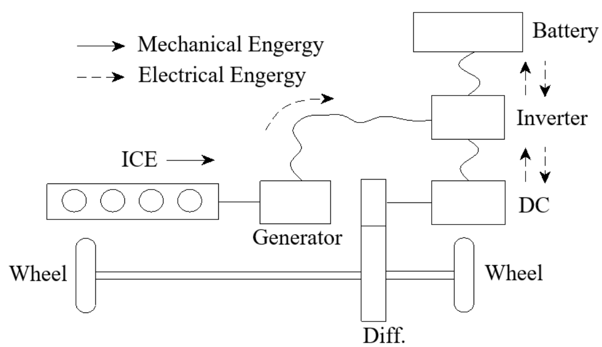

Figure 2. *Powertrain of a series hybrid*

As shown in Figure 2, the internal combustion engine is designed to be independent of the vehicle's operating mode, easily implementing control of the operating point to optimize energy and emissions. Therefore, the operating efficiency of the ICE engine can be up to 30% to 40%. On the other hand, the ICE engine only operates if the car travels a distance exceeding the specified distance for the battery. In addition, the mechanical connection between the ICE engine and the driving shaft is eliminated, so theoretically the gearbox in this case can be eliminated.

However, the series combination requires a battery with a larger storage capacity than the parallel and hybrid HEV architecture, which increases the mass and is not optimal for the layout space.

2.2. Characteristics of Parallel hybrid powertrains

In Parallel Hybrid, the energy flow to the driving wheels is a combination of the internal combustion engine and the electric motor or an independent operating state between the two power sources. The combined mode is controlled depending on the different operating modes of the vehicle, bringing significant benefits in terms of useful energy coordination. This architecture provides additional degrees of freedom in meeting the vehicle's energy requirements, optimizing the power distribution path between the two power paths brings great efficiency in the goal of fuel economy and reducing greenhouse gas emissions, usually, the ICE engine plays a major role in the stable operating mode of the vehicle, the electric motor plays a supporting role in high load modes such as acceleration or climbing slopes.

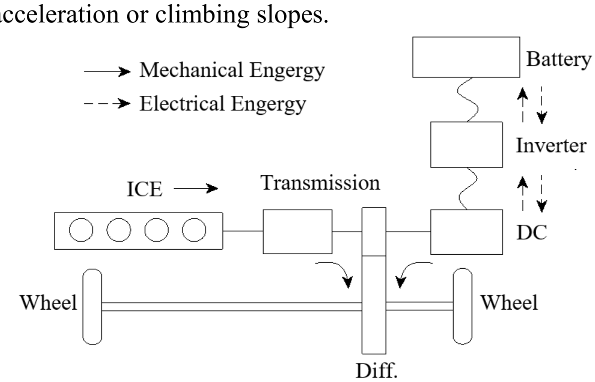

Figure 3. *Powertrain of a parallel hybrid*

In this hybrid system, the electric motor is designed to have dual-purpose commutation, meaning that it has both the function of an electric motor and the function of a generator, thus significantly increasing the efficiency of the power transmission line. In principle, the required power of the vehicle is equal to the total power of the electric motor and the internal combustion engine, which contributes to making the structure compact and reducing the amount of electricity stored in the battery, thereby contributing to reducing the vehicle's weight. This is considered an outstanding advantage of parallel HEV compared to other architectures. However, the coordination of two energy sources is relatively complicated. The components in the architectural system such as the electric motor (electric machine) as well as the electric motor control unit have a complex structure and are expensive. The ICE engine must be designed with a larger capacity than the series hybrid type. Environmental pollution as well as fuel economy are not high.

2.3. Characteristics of Series-Parallel powertrains

The hybrid HEV architecture is an intermediate configuration between the series HEV and parallel HEV systems to maximize the benefits generated. This hybrid system has a component called a "power split device" that transfers a continuously variable ratio of the power of the heat engine and the electric motor to the driving wheels. Therefore, the control of the power split is a challenge in hybrid HEV. This type of hybrid is depicted in Figure 4.

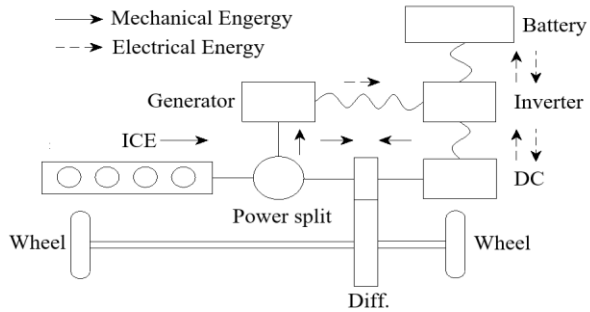

Figure 4. *Powertrain of a Series-Parallel hybrid*

3. Evaluation and solutions

3.1. Conversion methods

Over the past decades, our knowledge of HEV architecture has grown from a small seed to a mature tree with many branches. Since its inception in 1899, HEV technology has made great progress and proven its effectiveness in bringing many practical benefits to the environment and energy. Today, the focus of HEVs research on the interconnected architecture and control solutions for ICE engine operating modes is attracting increasing attention from scientists. Scientists in the fields of motors, electricity, and electronic control are deeply involved in developing control solutions for ICE engine operating modes and developing optimal control algorithms for the combination of ICE and electric motors. With previous research achievements and practical production results, we can draw clear conclusions about the advantages and limitations of HEVs architectures and the specific applications of each HEVs architecture [10].

Parallel HEVs offer significant benefits in terms of energy loss and can operate at zero emission. However, in terms of powertrain layout, the ICE engine is larger than that of series HEVs with the same driving power required, and power flow control needs to be considered appropriately in driving modes. In terms of application, parallel HEVs are often considered for vehicles that rarely operate at stops. Hybrid HEVs are a combination of series HEVs and parallel HEVs. Therefore, this architecture is still complex in terms of powertrain control features and high design costs, making it difficult to meet the conversion requirements for existing vehicles. Power flow control is considered a major obstacle. Hybrid HEVs are often applied to passenger cars and light vehicles.

With serial HEVs, the reduction of the direct driveline from the internal combustion engine allows for a smaller internal combustion engine design. The life of the internal combustion engine and the entire powertrain is significantly increased, and the internal combustion engine can be operated at zero emissions. The powertrain layout space is simpler than other HEV architectures, which is a prominent advantage when considering the use of the powertrain transition step. At the same time, serial HEVs use additional energy from the battery directly based on the internal combustion engine, which can allow the vehicle to operate continuously, without changing current driving habits. Serial

HEVs have also been considered for application on large vehicles such as large buses and trucks.

To convert a traditional powertrain on a vehicle carrying a load and operating at high frequency, many aspects and different levels of efficiency need to be considered. The choice of the powertrain architecture should be based on the transport task, load, terrain, and frequency of operation. Technological factors and corresponding hybrid components including energy storage systems, batteries, and energy converters are considered when selecting the architecture. The objective function of converting the powertrain on a vehicle includes environmental and energy efficiency while meeting the technological factors of the manufacturing plant and being suitable for the mass production stage. Therefore, the overall efficiency of the conversion on a micro level is a problem combining technological factors, human resources, and social impacts (including environment and energy). To do that, it is necessary to analyze, select, and be precise in the design process, taking into account the characteristics of each locality and operating conditions. Therefore, the serial HEVs architecture is a suitable approach for the KIA Frontier light truck in the current phase to deliver the desired environmental and energy benefits while being consistent with the internal technology and resources.

With the series HEVs architecture designed for conversion on the Frontier truck, the ICE engine and the battery are connected by electrical paths. The battery output voltage is supplied to the electric motor. The overall layout of the series HEVs powertrain architecture is shown in Figure 5.

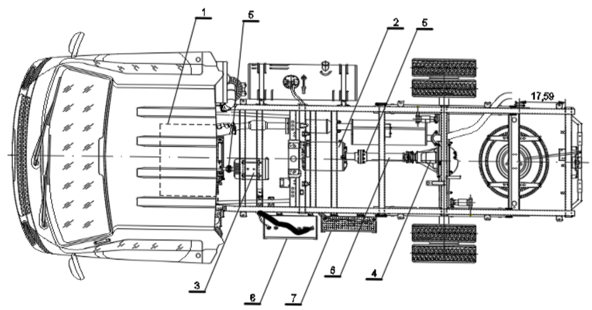

Figure 5. *The general layout of a designed powertrain system 1. ICE; 2. Electric motor; 3. Generator; 4. Axes; 5. Joint; 6. Cardan; 7. Battery pack; 8. Original battery*

3.2. Strategies for operation

The design of converting the traditional powertrain into a series HEVs powertrain for the KIA Frontier vehicle has 4 basic operating modes as follows:

***Battery-operated mode*:** When the battery is fully charged, this mode is considered a pure electric, zero-emission driving mode, as shown in Figure 6.

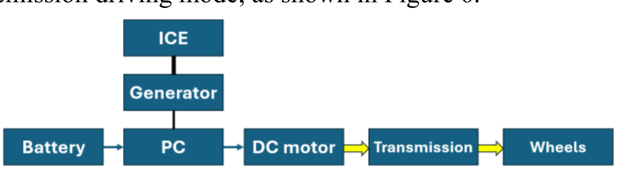

Figure 6. *Description of battery operation mode on KIA Frontier vehicle after powertrain conversion*

Battery charging mode: When the battery charge level is very low, the internal combustion engine is activated (the operation of the internal combustion engine is set at the operating point with maximum efficiency). The power generated by the difference between the internal combustion engine power and the power at the link is used to charge the battery via the generator; Such a combination of charging and discharging the battery represents cyclic operation, which is a characteristic mode of serial hybrid vehicles, as shown in Figure 7.

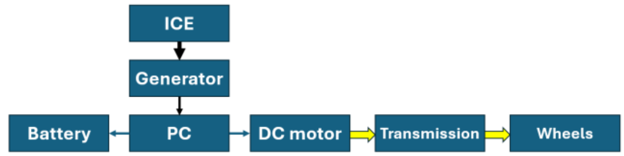

Figure 7. *Description of battery charging mode on KIA Frontier vehicle after powertrain conversion*

Hybrid drive mode: When the internal combustion engine power (at the fuel optimum point) is lower than the power at the link, the missing power is supplied by the battery, as shown in Figure 8.

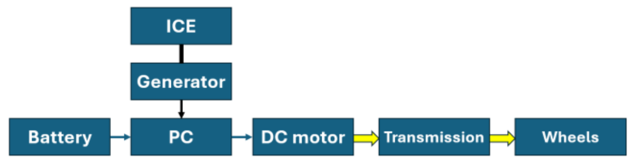

Figure 8. *Description of the combined operating mode on the KIA Frontier vehicle after powertrain conversion.*

Energy recovery mode: During braking and deceleration, energy is recovered by the electric motor, as shown in Figure 9.

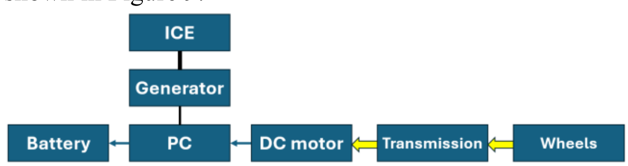

Figure 9. *Description of energy recovery mode on KIA Frontier vehicle after powertrain conversion.*

3.3. Basic parameters of Hybrid powertrain

In the basic understanding, it is recognized that the hardware of an HEVs structure consists of three main parts, including the ICE engine, the electric motor, and the energy storage device. In the powertrain conversion solution, the internal combustion engine is an available component, and in the serial HEV architecture, the internal combustion engine only needs to have a power smaller than the required power of the vehicle. Therefore, the existing internal combustion engine already meets the technical requirements well. In the basic parameter calculation, we perform the electric motor selection calculation, then confirm the suitability of the electric motor calculation parameters, and at the same time, add the calculation related to the energy storage system. Fuel consumption and emission levels are considered to evaluate the effectiveness of the conversion solution.

a. Electric motor selection

The operating conditions of the KIA FRONTIER truck were surveyed by the research team with measurements of mass, size, speed, and operating condition indicators. Some of the main input parameters of the vehicle are described in Table 1.

Table 1. *Specifications of Thaco Frontier K200S*

Parameter	Unit	Value
Vehicle weight (no load)	Kg	1430
Payload	Kg	1490
Full load weight	Kg	3600
Overall dimensions (L×W×H)	mm	4730 x 1750 x 2000
Wheelbase	mm	2415
Wheel radius (R_w)	mm	3210
Maximum speed	km/h	110
Ground clearance	mm	185
Hill-climbing capability	%	≥ 39.14

The vehicle powertrain generates mechanical energy that is stored instantly in the vehicle. The driving resistance forces are assumed to be used to dissipate energy from the stored energy. The energy in the vehicle is stored in the form of kinetic energy when the vehicle accelerates and potential energy when the vehicle is at a high altitude. The mechanical energy stored in the vehicle is intended to meet the regular operating modes of a vehicle, and the energy is dissipated through the loss force components including aerodynamic resistance, rolling resistance, and braking energy loss. For the KIA Frontier truck, the case of the vehicle going uphill with the largest load is analyzed to calculate the required traction parameters. The scheme of the vehicle longitudinal dynamics is described in Figure 10.

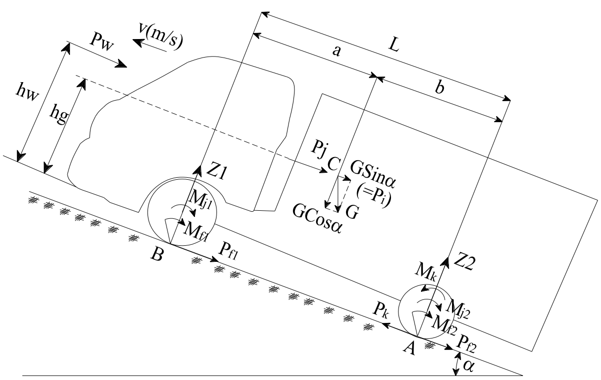

Figure 10. *Scheme of the vehicle longitudinal dynamics*

The required power of the engine must overcome the resistance during movement, including road resistance, P_f, uphill resistance, P_i, air resistance, P_w, and inertia force when accelerating, P_j.

Total resistance force when the truck is moving is described as follows [11-13]:

$$P_c = P_f + P_w + P_i + P_j \quad (1)$$

However, in actual operating conditions, the truck is not operated in a mode where all four resistance forces occurred at the same time. When the vehicle is going uphill, we only allow the vehicle to run at a steady speed and low speed, so the inertia force and wind resistance are ignored (i.e., Case 1). When the vehicle is running at maximum speed, the uphill resistance force and inertia force are omitted (i.e., Case 2). Thus, the required force of the electric motor in these two cases is recalculated, respectively, as follows:

$$\text{Case 1: } Pc_1 = 504 + 7{,}200 = 7704 \text{ [N]} \quad (2)$$

$$\text{Case 2: } Pc_2 = 504 + 1845 = 2349 \text{ [N]} \quad (3)$$

Both of these cases have a lower overall resistance than the general case and are consistent with the actual operating mode of the vehicle. In this study, the case of the vehicle climbing a slope is considered to determine the required torque at the wheel and running at maximum speed to determine the power balance for the electric motor.

When the truck climbs a slope, the required torque at the wheel is calculated as:

$$M_{bx} = P_{c1} \text{ x } R_w = 7{,}704 \text{ x } 0.26 = 2003 \text{ [Nm]} \quad (4)$$

The power resistance when running at maximum speed is as:

$$N = P_c.v = 2349 \text{ x } 27.78 = 65255 \text{ [W]} \quad (5)$$

Then the engine power is as:

$$N_e = N/\eta = 65255/0.92 = 70929 \text{ [W]} \quad (6)$$

where η is the efficiency of the powertrain, $\eta = 0.92$.

Selection of the engine mounted on the vehicle corresponding to the overload capacity is as follows:

$$N_{emax} > 1.1 \times N_e > 1.1 \times 70929 = 78021 \text{ [W]}$$

This is the engine power required for the car to operate properly under the conditions selected above.

With the same capacity, if the voltage of the electric motor is increased, the current running in the circuit and the mass of the electric motor will decrease. However, the number of batteries will increase accordingly to ensure the necessary voltage and at the same time require better electrical safety. According to actual statistics, the mass of the battery is proportional to its capacity. Therefore, the total mass of the battery pack does not depend on the voltage of the system but only on the power required to supply.

From the above constraints, and based on the statistics of the voltage levels of the types of electric motors available on the market, the following DC motor was chosen, with its specifications as follows:

- Model: TZ-280-X-G-GA05;
- Engine power: 55/80 kW;
- Torque: 240 Nm;
- Maximum engine speed: 4400/6000rpm;
- Weight: 62 kg;
- Voltage: 350/750V;
- Dimensions (L x D): 357 cm x 280 cm;
- Weight: 61 kg.

b. DC motor

The characteristics of electric motors are usually obtained through experimental measurements. However, for the calculations at the initial design stage, a theoretical solution is considered [9]:

$$M_{DC} = \frac{N_{DCmax}}{\omega.(1+1.\lambda-1.\lambda^2)} \quad (7)$$

where: M_{DC}: DC torque (Nm); N_{DCmax}: DC motor power (kW); ω: angular speed (rad/s); λ = (0.1-1.0) [9].

A characteristic graph of the electric motor is shown in Figure 11, as follows:

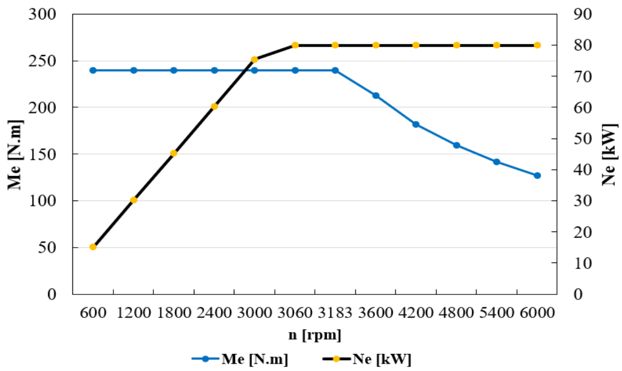

Figure 11. *Characteristic of DC motor*

c. Characteristics of ICE

To verify the calculated indexes of the electric motor, and evaluate the suitability of the electric motor designed for the current vehicle in terms of torque and power index, an analysis and comparison of the indexes of the electric motor and the internal combustion engine is necessary. to obtain the traction capacity of the available vehicle.

THACO FRONTIER is equipped with HYUNDAI 4-stroke diesel engine model D4CB-CRDi [11]. The basic technical parameters are shown in Table 2.

Table 2. *Specifications of D4CB Engine*

Parameter	Unit	Value
Maximum Power	kW	95.6
Engine speed @Maximum Engine Power	rpm	3800
Maximum Torque	N.m	255
Engine speed @Maximum Torque	rpm	1500÷3500

The empirical formula of S.R. Lay Decman has been proven to be valid in theoretical research to determine the torque and power of internal combustion engines [12-14]. The formula of S.R. Lay Decman is as follows:

$$N_e = N_{max}[a\frac{n_e}{n_N} + b\left(\frac{n_e}{n_N}\right)^2 - c\left(\frac{n_e}{n_N}\right)^3] \quad (8)$$

where:

N_e, n_e: Engine power (kW) and crankshaft revolutions (rpm);

N_{max}, n_N: Maximum power of the engine (kW) and the revolutions corresponding to the above power;

a, *b*, *c*: Experimental parameters.

The engine torque is then estimated as follows:

$$M_e = \frac{10^4 * N_e}{1,074 * n_e} \quad (9)$$

The characteristics of the ICE of the KIA frontier truck are shown in Figure 12.

Based on the external characteristic curve of electric motors and internal combustion engines, some following observations are drawn: Trucks using internal combustion engine need a certain amount of time to achieve the maximum torque for acceleration. Meanwhile, as soon as the driver steps on the gas pedal, the entire traction of the electric motor is utilized to propel the truck forward. As a result, the acceleration when starting of electric vehicle (i.e., truck) will be better than that of a truck using internal combustion engines.

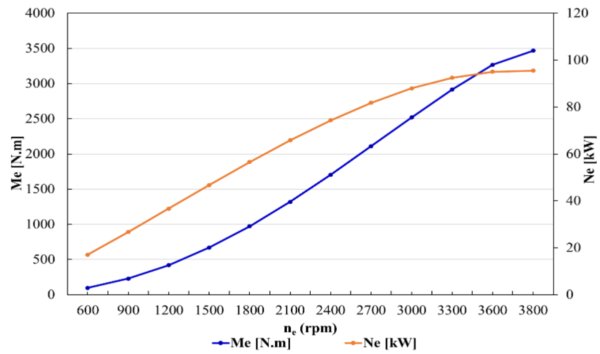

Figure 12. *Characteristics of ICE*

3.4. Battery selection

A battery is a component that converts chemical energy into electrical energy and vice versa, representing a reversible energy storage system [15-18]. The desirable properties of batteries in HEVs are high specific power, high specific energy, long cycle life, low initial and replacement costs, high durability, and reliability. Over the past decade, battery technology has advanced significantly, For instance, Li-ion batteries have an energy density of three to five times higher than lead-acid batteries (Figure 13).

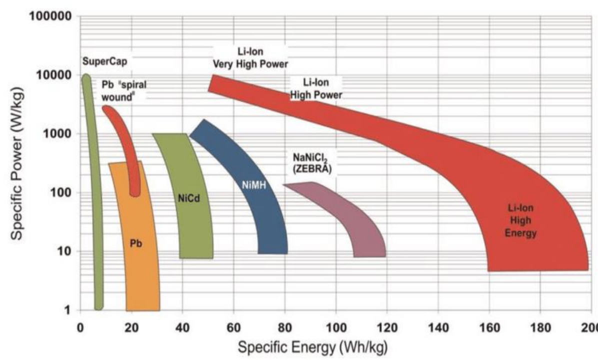

Figure 13. *Energy storage density of batteries [19]*

The choice of energy storage system is very important, it has a decisive factor in the technical and economic aspects of the vehicle. The choice of energy storage in HEVs depends on many factors. These include the charging rate, energy density, life, cost, weight, and size [16]. All loads on the vehicle use electricity from the battery available on the car, so the battery is only used for the electric motor. The battery capacity is standard. So, an 18650 LISHEN Li-ion battery was chosen. The technical parameters of a cell are given in Table 3.

Table 3. *Specifications of 18650 LISHEN Li-ion*

No.	Parameter	Unit	Value
1	Votage	V	3.6
2	Capacity	A.h	2.5
3	Weight	Kg	0.045
4	Length	m	0.065
5	Diameter	m	0.018

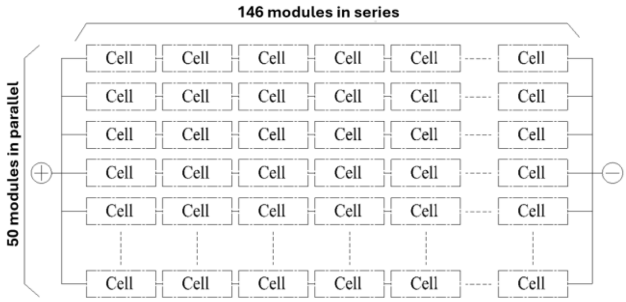

Figure 14. *Battery connection arrangement*

The battery specifications are shown in Table 4.

Table 4. *Battery specifications*

No.	Parameter	Unit	Value
1	Number of cells	Cell	7300
2	Number of modules connected in series	Module	146
3	Number of modules connected in parallel	Module	50
4	Voltage	V	540
5	Battery capacity	kWh	67.5
6	Maximum discharge current of the battery system	Ah	1250

4. Conclusions

In this study, we have analyzed the feasibility of converting the traditional powertrain on the KIA Frontier truck from an environmental and energy perspective, while also being used with the original engine and components of the manufacturer. The HEVs series powertrain is considered for conversion with the best response level in terms of technical and cost goals. The conversion plan implements the addition of an electric motor with a maximum capacity of 80 kW, which is responsible for creating traction for the original vehicle. The internal combustion engine now acts as an energy source, which is responsible for charging the energy storage system. The optimal operating mode in terms of energy and fuel is the outstanding advantage of the conversion. An energy storage system with a capacity of 67.5 kWh has been estimated theoretically. The response level meets the expectation of continuous travel for 175 km when fully charged.

This article is part of a series of works to convert light trucks to use batteries combined with diesel engines (i.e., hybrid series). Generally, in this project, the idea is to bring hybrid series vehicles back to the automobile market with a very special role: using the main energy source as batteries while the diesel engine plays the main role of charging the battery. In this current article, the authors present Part 1: The classifications of hybrid powertrain and choosing the most suitable method for light trucks, one of the types of freight vehicles that currently account for a very large market share in Vietnam. Part 2 of the project will focus on designing battery packs, simulating and evaluating battery pack cooling solutions. Part 3 of the project will be to design and modify the light truck chassis system to suit the arrangement of the hybrid series powertrain. Finally, Part 4 of the project will be to evaluate the working parameters of the diesel-battery hybrid series powertrain.

Acknowledgment: This research was funded by the Ministry of Education and Training, grant number B2024.DNA.14.

REFERENCES

[1] ERA5, "Copernicus: March 2024 is the tenth month in a row to be the hottest on record", *climate.copernicus.eu*, April 9, 2024. [Online]. Available: https://climate.copernicus.eu/copernicus-march-2024-tenth-month-row-be-hottest-record, [Accessed September 10, 2024].

[2] T. Duong, "Vietnam Circular Economy Forum 2024: Real-world application", *vneconomy.vn*, December 9, 2024. [Online]. Available: https://vneconomy.vn/vietnam-circular-economy-forum-2024-real-world-application.htm, [Accessed December 10, 2024].

[3] V. Khoa, "With 80.6 million vehicles on the roads, air pollution rate worsens", *Vietnamnet global*, August 11, 2024. [Online]. Available: https://vietnamnet.vn/en/with-80-6-million-vehicles-on-the-roads-air-pollution-rate-worsens-2338692.html, [Accessed December 5, 2024].

[4] NASA, "Global Warming", *earthobservatory.nasa.gov*, June 3, 2010. [Online]. Available: https://earthobservatory.nasa.gov/features/GlobalWarming/page2.php, [Accessed December 5, 2024].

[5] CPV, "Opportunities, challenges on pathway to Net Zero: experts", *dangcongsan.vn*, August 19, 2023. [Online]. Available: https://en.dangcongsan.vn/vietnam-today/opportunities-challenges-on-pathway-to-net-zero-experts-605805.html, [Accessed December 5, 2024].

[6] VNS, "THACO outlines strategies for green energy vehicle development", *vietnamnews.vn*, October 7, 2024. [Online]. Available: https://vietnamnews.vn/economy/1664447/thaco-outlines-strategies-for-green-energy-vehicle-development.html, [Accessed December 5, 2024].

[7] THACO, "KIA FRONTIER", *thacoauto.vn*, March 09, 2024. [Online]. Available: https://www.thacoauto.vn/en/thuong-hieu/kia-frontier, [Accessed December 5, 2024].

[8] P. X. Mai, P. V. Ha, T. T. M. Tien, and T. H. H. Nhan, "Design method of electric vehicle power system", *The University of Danang - Journal of Science and Technology*, vol. 20, no. 2, pp. 80-85, 2022. https://jst-ud.vn/jst-ud/article/view/7773

[9] T. Denton, *Electric and Hybrid Vehicles,* 2nd edition. London: Routledge, 2020. https://doi.org/10.1201/9780429296109

[10] T. Denton and H. Pells, *Electric and Hybrid Vehicles*, 3rd edition. London: Routledge, 2024. https://doi.org/10.1201/9781003431732

[11] THACO, "KIA FRONTIER K250", *thacotai.vn*, March 09, 2024. [Online]. Available: https://thacotai.vn/kia-frontier-k250, [Accessed December 5, 2024].

[12] G. Rill, *Road Vehicle Dynamics: Fundamentals and Modeling*, 1st edition. Boca Raton: CRC Press, 2011. https://doi.org/10.1201/9780429244476

[13] M. Ehsani, Y. Gao, S. E. Gay, and A. Emadi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design*, 1st edition. Boca Raton: CRC Press, 2004. https://doi.org/10.1201/9781420037739

[14] A. H. Wickens, *The Dynamics of Vehicles on Roads*, 1st edition. London: Routledge, 1982. https://doi.org/10.1201/9780203736876

[15] I. Husain, *Electric and hybrid vehicles: design fundamentals*. Boca Raton: CRC press, 2005. https://doi.org/10.1201/9780429490927

[16] A. Emadi, *Advandced electric drive vehicles*, 1st edition. Boca Raton: CRC Press, 2015. https://doi.org/10.1201/9781315215570

[17] A. Link, A. O'Connor, and T. Scott, *Battery Technology for Electric Vehicles: Public science and private innovation*, 1st edition. London: Routledge, 2015. https://doi.org/10.4324/9781315749303

[18] M. Ehsani, Y. Gao, S. Longo, and K. Ebrahimi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, 3rd edition. Boca Raton: CRC Press, 2018. https://doi.org/10.1201/9780429504884

[19] K. Werner, V. Stahl, and P. Vetter, "Thermal storage using metallic phase change materials for bus heating—state of the art of electric buses and requirements for the storage system", *Energies*, Vol. 13, no. 11, pp. 3023, 2020. https://doi.org/10.3390/en13113023