Journal of Transportation Technologies, 2024, 14, 31-52
https://www.scirp.org/journal/jtts
ISSN Online: 2160-0481
ISSN Print: 2160-0473

Design and Analysis of Power and Transmission System of Downhole Pure Electric Command Vehicle

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How to cite this paper: Alam, J., Sujan, S., Tapu, Md.A.I. and Howlader, J. (2024) Design and Analysis of Power and Transmission System of Downhole Pure Electric Command Vehicle. *Journal of Transportation Technologies*, **14**, 31-52.
https://doi.org/10.4236/jtts.2024.141003

Received: October 14, 2023
Accepted: December 18, 2023
Published: December 21, 2023

Abstract

Electric vehicles use electric motors, which turn electrical energy into mechanical energy. As electric motors are conventionally used in all the industry, it is an established development site. It's a mature technology with ideal power and torque curves for vehicular operation. Conventional vehicles use oil and gas as fuel or energy storage. Although they also have an excellent economic impact, the continuous use of oil and gas threatened the world's reservation of total oil and gas. Also, they emit carbon dioxide and some toxic ingredients through the vehicle's tailpipe, which causes the greenhouse effect and seriously impacts the environment. So, as an alternative, electric car refers to a green technology of decarbonization with zero emission of greenhouse gases through the tailpipe. So, they can remove the problem of greenhouse gas emissions and solve the world's remaining non-renewable energy storage problem. Pure electric vehicles (PEV) can be applied in all spheres, but their special implementation can only be seen in downhole operations. They are used for low noise and less pollution in the downhole process. In this study, the basic structure of the pure electric command vehicle is studied, the main components of the command vehicle power system, namely the selection of the drive motor and the power battery, are analyzed, and the main parameters of the drive motor and the power battery are designed and calculated. The checking calculation results show that the power and transmission system developed in this paper meets the design requirements, and the design scheme is feasible and reasonable.

Keywords

Pure Electric Vehicles, Transmission, Gears, Electronic Differential,

Control Algorithms

1. Introduction

Pure electric vehicle (PEV) aims to save the existing natural resources and keep the environment neat, clean, and safe. These vehicles are less noisy, polluting, efficient, and more straightforward than internal combustion vehicles. These vehicles offer some great features using an electric motor, like a constant power supply during extensive speed range and high torque at lower motor rotations. High-speed motors are a great option to run an electric vehicle. They are very efficient with low weight and low cost. The major challenge lies in integrating a high-speed motor and a relevant gearbox to design a pure electric vehicle. However, due to motor characteristics, single-speed transmissions suit these pure electric vehicles whereas conventional internal combustion vehicles consist of the attributes of multi-speed communications. Downhole pure electric vehicles are particular kinds of electric vehicles which are used for underground applications. They are used for their less noisiness, simple and more efficient characteristics. Their structure is the same as the pure electric vehicles, but their purpose differs.

Although China's coal production ranks first globally, it consumes the most crucial amount globally. The most energy used includes coal, which is exceptionally hooked into coal; therefore, coal mining appears vital. However, the gas explosion that has plagued coal companies still exists for an extended time. Therefore, some relevant country departments require coal mining companies to be equipped with special underground explosion-proof command vehicles to stop unexpected needs. Because the driving environment of the car is mainly confidential, the lower the vehicle's peak is required, the better the friction sparks cannot be formed when the mechanical parts are moving. Therefore, the adaptability to varied roads is robust. Because explosions are susceptible to occur underground, the exhaust gas temperature is also required. The lower, the higher. Due to the stringent requirements of this series and the country's backward automobile research and development technology, most of the prototype cars produced by enterprises are challenging to implement. The foremost foreign underground vehicle brands include Caterpillar, Atlas Copco, and DUX [1]. The country's mine command vehicles mainly use explosion-proof diesel locomotives. Although these vehicles can work well in downholes, they're more flexible and have a high ratio, but there are many problems, like severe pollution and bangs. Explosion-proof diesel has low efficiency and low dust blown up by exhaust gas. The pure electric underground command vehicle has zero-emission characteristics, low noise, high efficiency, and explosion-proof, which conjures for these problems. Therefore, the pure electric command vehicle must be the long-term development direction. The facility and gear mechanism of the present pure electric command vehicle are insufficient in terms of power and economy. This study analyzes the facility and gear mechanism of the underground pure electric command vehicle to enhance the energy transmission efficiency of the car and improve confidential work protection and reliability.

The literature presented seeks to explain and explain the benefits of electric vehicles over conventional ones, with a focus on the environmental aspects. Additionally, a technical study on the design and selection of power system components for a command vehicle that operates entirely on electricity is covered, with an emphasis on the design's viability.

1.1. Development of Underground Pure Electric Vehicles Domestic and Abroad

1.1.1. Foreign Development

American technology is at the forefront of the globe among the electrical vehicles utilized in underground coal mining operations. At the same time, the quantity of underground electric vehicles in use is the largest in the world, and they are employed in all links of underground mines, followed by Australia and South Africa. Because the structure of lithium batteries is comparatively complicated and troublesome, resulting in increased production costs, and since heavy vehicles need counterweights, underground battery vehicles generally use lead-acid batteries for power supply. But now, lithium battery technology is continually breaking through, and its cost has declined, so lithium batteries are increasingly being loaded on pure electric vehicles.

To guard the body and mind of underground workers and the environment, most of the coal mines within us use electric trackless vehicles equipped with special explosion-proof lead-acid batteries, and their absolute number is far over that of explosion-proof diesel locomotives. Various manufacturers use an explosion-proof battery forklift [2] with a front and rear-hinged structure. The body is incredibly similar, equipped with a D.C. motor and an accumulator. **Figure 1** shows the explosion-proof particular lead-acid battery forklift.

Also, to the production of this battery forklift in the United States, some companies mass-produce a variety of light-duty battery vehicles for mining, including electric passenger and passenger-cargo vehicles and MAC-12 underground passenger vehicles [2] This is the structure, and this model has the most considerable load of this model. It can seat 13 people at the same time. The maximum load is 3.4 t. The top speed can reach 19.2 km/h. Lead-acid batteries are used to provide energy. A.C. traction motors are used to drive the vehicle. The vehicle adopts front and rear fully enclosed wet disc brakes to reduce the spark of friction and reduce the car's weight. The body is close to the ground, the centre of gravity is low, and the body's height is negligible. The driver can generally drive in a quiet space. The match is very high. **Figure 2** shows the US MAC-12 type explosion-proof underground mancarrier.

Canadian companies' underground pure electric vehicles are mainly light-duty vans with a median mass of about 2 t. When fully loaded, the complete vehicle weight can reach 4 t [3], and it's equipped with a 40 kW·h lithium iron phosphate battery pack for power supply. To cut back the standard of the complete vehicle, the vehicle adopts a steel tube truss structure, which has strong resistance to deformation and impact but includes a low safety factor. After being fully charged, it can travel up to 80 km at a time. **Figure 3** shows the truss-type underground explosion-proof light passenger vehicle.

Figure 1. First explosion-proof particular lead-acid battery forklift.

Figure 2. US MAC-12 type explosion-proof underground man carrier.

Figure 3. The truss-type underground explosion-proof light passenger vehicle.

1.1.2. Domestic Development

Domestically, it had been relatively late to develop explosion-proof battery trackless vehicles independently. Within the 1980s, only some imported electric mining vehicles for underground personnel and material transportation were imported from abroad. The research and production of its products started after 2004, mainly CLX3 explosion-proof battery forklift [4]. The figure is shown in **Figure 4**.

The CLX3-type explosion-proof battery forklift has absorbed the structural characteristics of the front and rear-hinged joints of the American MAC-12 underground transport vehicle. Also, it adopts related technologies like explosion-proof unique lead-acid accumulator power technology. The rated load quality is 5 t. Electric motors drive the front and rear axles. Realize the entire vehicle operation. The car incorporates a compact structure, and the body is near the bottom, with high transmission efficiency, flexible steering, easeof use, and high convenience for maintenance.

Our country's first new variety of underground coalpit explosion-proof command vehicles was successfully developed in Shiyan Rongma Automobile Special Transmission Co., Ltd. 2008 [5]. The explosion-proof command vehicle adopts the looks of an off-road vehicle, and therefore, the interior is modified on the idea of it. Its internal structure is different from ordinary cars. The vehicle adopts bridgeless automobile chassis technology and uses an "eight-shaped" transmission mode. High-through capacity non-locking anti-skid differential transfer device technology. It chooses a suspension with a crankshaft-type rod structure, so when it works in various harsh environments, the wheels can always be kept in a line during movement, and therefore the driving is stable. The vehicle uses a whole set of special explosion-proof equipment. **Figure 5** shows the particular explosion-proof command vehicle for the coal mine.

Jizhong Equipment Group Stone Coal Machinery Company has also been developing underground battery electric vehicles to ensure the security of undercover coalpit production operations. In 2015, it finally developed the primary WLR-5 mine explosion-proof lithium-ion pure electric trackless electric vehicle 2015. The rubber-wheeled command vehicle [6] is safe and reliable after trial and is fully adapted to underground road conditions. The electric vehicle imitates the structure of a general automobile, uses a strengthened ground vehicle

Figure 4. Domestic CLX3 type explosion-proof battery forklift.

Figure 5. Explosion-proof command vehicle for coal mine.

chassis, and selects lithium batteries as the driving power source. It's utilized in mine safety production supervision and other situations. It has the characteristics of excellent manoeuvrability, flexible operation, stable operation, energy saving and environmental protection. As an underground command vehicle, this mine-used explosion-proof lithium-ion battery trackless rubber wheel command vehicle can carry up to five people, the fastest speed can reach 40 kilometres per hour, the most climb isn't but 14˚, and it can travel the farthest after being fully charged above 70 km. The noise is low, and there is less pollution.

1.2. Development Prospects

Because of the reliable performance and high-efficiency driving ability of the underground pure electric command vehicle, the mine's assembly speed and production quality are improved. Also, the safety isn't susceptible to accidents, and the economic benefits are high. Therefore, it's widely employed in advanced coal mining countries like us and Canada. The underground coalpit command vehicles operated in China are explosion-proof diesel locomotives. Although it can even meet the requirements of undercover work well, some practical problems are inevitable: serious oil consumption, significant exhaust gas emissions, severe noise, environmental pollution, and high harm to the health of underground operators. The undercover pure electric command vehicle has the subsequent advantages which form up for the shortcomings of diesel locomotives:

1) Pure electric vehicles use a good range of electrical energy sources, which might be obtained from renewable energy sources like solar power, wind energy, and tidal energy [7], and aren't obsessed with petroleum.

2) The air isn't easy to circulate within the well, and automobile exhaust isn't easy to dissipate. It'll accumulate in the atmosphere within the well and seriously endanger the health of the staff. An influence battery drives the pure electric vehicle. Therefore, the carcanhave low or no emissions during the driving process, which makes up for the shortcomings of diesel vehicles that emit exhaust gas.

3) Additionally, to the exhaust gas pollution within the well, sound pollution

warrants attention. In this reasonably semi-enclosed environment, the sound is amplified a lot. Since pure electric vehicles don't have an engine, they'll not make the noise of a standard car, and therefore, the vibration is much smaller, which cannot cause discomfort.

4) Most parts of the facility gear mechanism of electric vehicles are connected by wires, which significantly reduces the possibility of sparks generated by mechanical transmission, improves the protection of underground work, and the installation of every department will be flexibly arranged in step with the chosen transmission structure. This will further reduce the vehicle's weight. Moreover, electrical car parts aren't easy to wreck and don't need frequent maintenance. Therefore, replacing damaged parts is additionally straightforward [8], which reduces the workload and improves safety.

5) Pure electric vehicles use electric energy because of the power source. Since the present is a smaller amount than the energy loss of mechanical transmission, the energy utilization rate of pure electric vehicles is above that of traditional burning engine vehicles. Even during this case, the ultimate energy conversion rate is twice as high as that of conventional burning engine vehicles [9].

Therefore, it's essential to market the event of underground pure electric command vehicles. **Figure 6** shows the step of the configuration of pure electric command vehicle. Moreover, the pure electric command vehicle doesn't have to operate for long distances underground, which makes up for the shortcomings of the present pure electric command vehicle's short practice range on one charge. Still, the pure electric command is inevitably tested at this point.

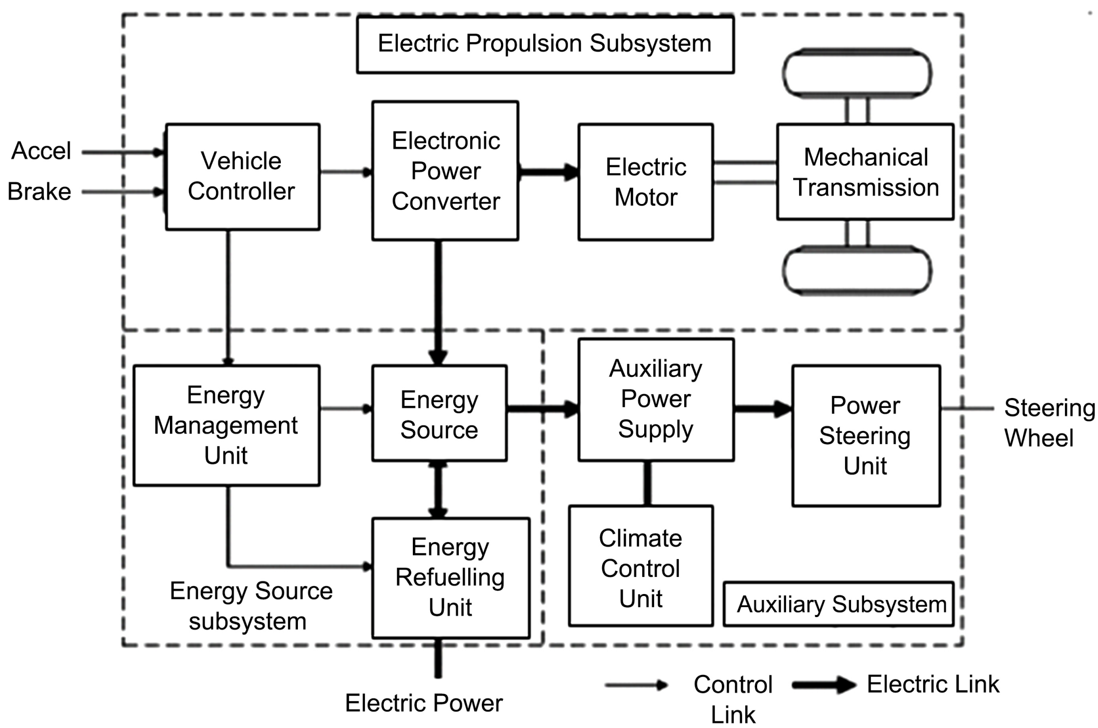

Figure 6. Steps of the configuration of pure electric command vehicle.

Among them, the ability to match electric vehicles and the choice of gear are two critical factors affecting the facility and economy of pure electric vehicles [10]. To realize the planning goals of pure electric command vehicles, the facility system should be a Reasonable design analysis, so consider the transmission closely associated with the performance of electric cars. The look of the gear will directly affect the operation of the motor. A superb gear mechanism can maximize the engine's performance and make it often add the most efficient range. Therefore, planning the facility and transmission of the pure electric command vehicle is essential.

1.3. Design Steps and Content

Here, the power and transmission system of a pure electric vehicle for downhole operation is studied, and the steps of the study are shown below.

The specific research content is as follows:

1) This text introduces the fundamental structure of the pure electric command vehicle. It selects the parameters of the car in line with the info given by the topic and the partners' requirements.

2) Design and analysis of the most components of the facility system of the pure electric command vehicle: The performance indicators of assorted drive motors and power batteries currently employed in electric vehicles are compared and analyzed, and therefore, the performance of the pure electric command vehicle is analyzed in keeping with the vehicle parameters. Most parameters of the drive motor and power battery are designed and analyzed.

3) The assorted structural sorts of the gear mechanism of pure electric vehicles were compared and analyzed, and a structure was selected for the specific design of its main components: the layout of the instrument was designed, and also the essential components within the transmission system: Design analysis of reducer and half shaft.

4) After inspecting most components of the pure electric command vehicle gear mechanism, perform corresponding mathematical modelling supported by CATIA.

2. Design and Analysis of the Power System of Downhole Electric Command Vehicle

A drive motor, a battery, a power converter and other components combined comprise the power system of the downhole pure electric command vehicle. The main principle of analyzing the power system is converting the electrical energy into mechanical energy and delivering the output energy to the wheels. The motor drive and the power battery are two main parts of an electric vehicle. This chapter introduces the fundamental structure of the pure electric command vehicle and compares and analyzes the characteristics of varied drive motors and power batteries. Per the necessities given by the topic, most parameters of the drive motor and power battery of the underground pure electric command vehicle are analyzed inexpensively.

2.1. The Basic Structure of a Pure Electric Command Vehicle

Electric vehicle architecture or configuration refers to the layout of the energy source. Therefore, the drive train components of an electrical vehicle, an architecture of the E.V. is flexible when compared with conventional combustion engine powered cars because of the absence of complex engine setup, no clutch, zero requirement of manual gear, no condition of piping, etc. [11] [12] [13] [14] [15]. Flexible electrical wires with no mechanical linkage make the energy flow in electric vehicles; electric vehicle motor driving systems have different system architectures, and energy sources have different characteristics and charging systems. Battery electric vehicles powered by one or more electric engines have the foremost undemanding architecture because the motor can acquire the specified power. The detailed foundation of an electrical vehicle system and its interconnection with different components is shown in **Figure 7**. The essential fundamental elements of an electrical vehicle system are the motor, controller, power source, and transmission system.

Here, the electric drive subsystem is usually composed of 5 parts, of which two factors play a significant role, namely the electronic controller and, therefore, the motor. After the motive force uses the pedal to input braking or acceleration signals to the electronic controller, the electronic controller sends out corresponding commands to manage the facility converter. But if the treadle and pedal are depressed simultaneously, the electronic controller will prioritize responding

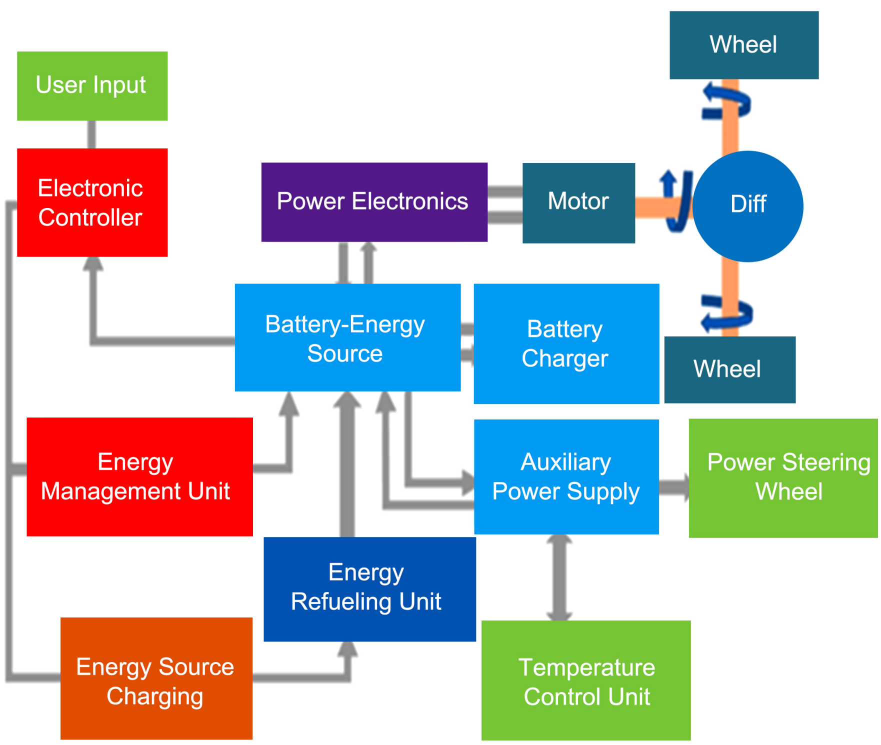

Figure 7. The basic structure of electric vehicles.

to the brake signal for safety [16]. The function of the facility converter is to regulate the energy matching between the motor and the energy source. When the pure electric vehicle starts or accelerates, it converts the power stored within the battery into the energy of the motor rotation, and when the car decelerates, or brakes, the wheel's energy generated by the process is converted into power and stored within the battery. Electric motors have two functions in electric vehicles: electric and power generation. They convert fuel into energy during everyday driving and voltage when decelerating or coasting. The function of the mechanical transmission device is to transfer the torque from the electrical motor to the half shaft of the vehicle to rotate the wheels when the car is running. Because the engine's speed is straightforward to regulate, and its excellent speed regulation characteristics, its mechanism incorporates many components but traditional diesel locomotives. It always uses a set speed reducer to amplify the motor torque. Because the electrical motor can quickly reverse to attain the aim of changing, the reverse gear within the traditional gearbox will be eliminated, further reducing the vehicle's weight and energy consumption and increasing the cruising range.

The energy subsystem comprises the power supply, energy management, and charging system. Its primary function is to supply the drive motor's current, monitor the battery pack's employment, and control the engine to charge the facility battery pack when decelerating or braking. The structure of the energy management system is analogous to the electronic controller. It takes the control unit ECU because of the core. The energy management system uses sensors to watch various battery parameters to create the battery charge and discharge and ensure efficient and stable performance when the vehicle is running. Do analysis and processing and energy distribution, and manage the power of varied functional components when working so that point is often accustomed to the most extent, extending the vehicle's mileage. Improper use of the battery will shorten its life, like the voltage mismatch and overcharging of the components when the electric car is running. To optimize the energy flow of the storm, increase its use time to the maximum amount possible, and improve the protection and reliability of driving, it's necessary to conduct real-time detection of state parameters like battery temperature, battery voltage, battery remaining power and current size, and Display the relevant parameters and transmit an alarm when the info is abnormal. The signal of the energy subsystem should flow to the auxiliary module's driver's cab display console so the motive force can grasp and cooperate with its operation at any time and timely charge the battery or perform maintenance as required [17].

The auxiliary control subsystem is designed to enhance the comfort of the motive force and the vehicle's convenience. It also consists of three parts: the auxiliary power supply unit, the facility steering unit and the temperature control unit. The subsystem additional power supply unit's role is to provide power to other electrical systems like the facility mechanism, the lamp system, and the window system. Electric vehicles have three crucial signal input sources: the accelerator, foot lever and handwheel. The ability mechanism receives a spatial relation signal from the wheel and controls the vehicle's steering. It relies on the driver's physical strength and cooperation with other powers because of the steering energy. To take into consideration the portability of low-speed steering and also the enhanced road feel at high-speed, modern cars are generally equipped with electronically controlled power-assisted steering EPS driven by a motor alone, which may automatically control the force of turning the wheel in step with the driving speed and improve driving safety.

2.2. Power System Structure and the Main Parameters of the Pure Electric Command Vehicle

A drive motor, a battery, a power converter and other components combined comprise the power system of the downhole pure electric command vehicle. The main principle of analyzing the power system is converting the electrical energy into mechanical energy and delivering the output energy to the wheels. The motor drive and the power battery are two main parts of an electric vehicle. To increase the transmission efficiency and reduce the mechanical transmission from the system, the traditional clutch can be removed from the power system of the pure electrical vehicle model. In this study, the pure electrical vehicle system consists of the motor, battery, control system and mechanical driving device. The power structure of a pure electrical vehicle is shown in Figure 8.

In this study, power battery parameters and the drive motor are related mainly according to the design requirements of the vehicle. The vehicle's basic parameters are shown in Table 1.

Performance Indicators of pure electric command vehicles are shown in Table 2.

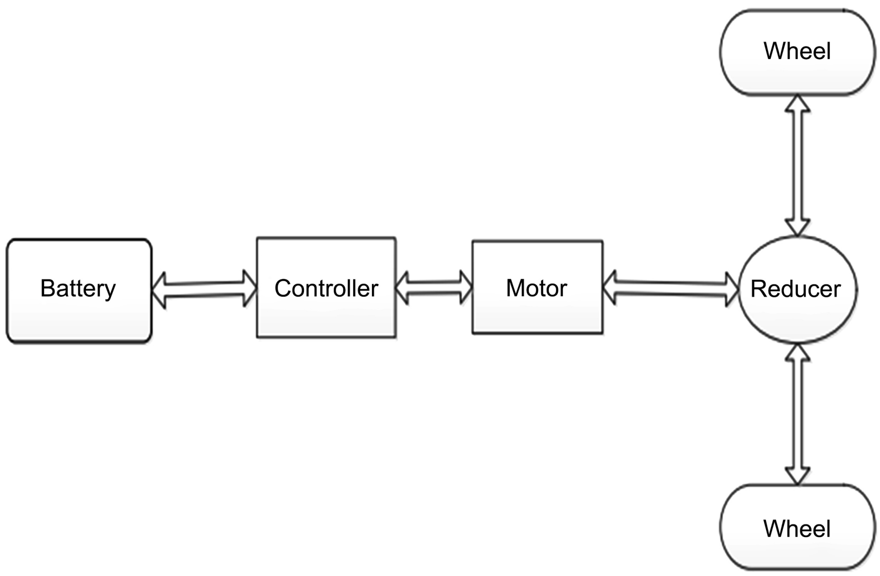

Figure 8. Power system structure of pure electrical vehicle.

Table 1. Main parameters of the vehicle.

CURB weight (Kg)	1050	Frontal Area (m^2)	1.97
Gross weight (Kg)	1350	Transmission Efficiency	0.9
Wheelbase (mm)	2467	Drag Coefficient	0.284
Wheel Rolling Radius (mm)	279	Rolling Resistance Coefficient	0.018

Table 2. Performance Indicators of the pure electric command vehicle.

Power Performance	Maximum Speed (km/h)	≥120
	(0 - 50 km/h) Acceleration Time (S)	≤10
	Maximum Climbable Gradient (%)	≥15
Economy	Endurance Mileage (km)	≥100

2.3. Design of Drive Motor of Pure Electric Command Vehicle

Type Selection of Drive Motor

Electrical energy converts to mechanical energy by using Electrical machines and vice versa. In pure electrical vehicles, torque and power are provided to the transaxle for propulsion through electrical devices. Compared with an internal combustion engine, energy conversion efficiency is higher in an electrical machine, typically between 80% - 95% [18] [19]. High torque and highpower density are provided by an electric motor with better torque characteristics at a lower speed, and the power lies between two or three times the rated capacity of the engine [20]. The electric motor works as a generator while the electric machine processes the power in the backward direction. The braking mode can be known as regenerative braking.

Electric vehicles use different electric machines and drives compared to industrial ones [21] [22]. In a pure electric vehicle system, the electric propulsion system is called the heart of the system, where electrical machines and drives are the core of the system and by which system electrical energy is directly converted to mechanical energy, which gives the linear motion of the vehicle. A single-speed reducer is used in most electric cars where transmission systems are kept optional to drive the wheel of the pure electric vehicle. Every electric motor has two parts known as the stator, which is the stationary part and the rotor, which is the rotating part. These two parts also play an essential role in the pure electric vehicle system [23] [24].

Three variables define the selection of the motor and the motor drives in a pure electric vehicle. They are vehicle requirements, restrictions and power sources [25]. **Figure 9** shows the three variables. The drive cycle schedule is known as the vehicle requirement. Type of vehicle, payload, vehicle weight, battery weight, etc, develop the vehicle restrictions. Lastly, considering all these variables, a motor can be chosen for the pure electric vehicle.

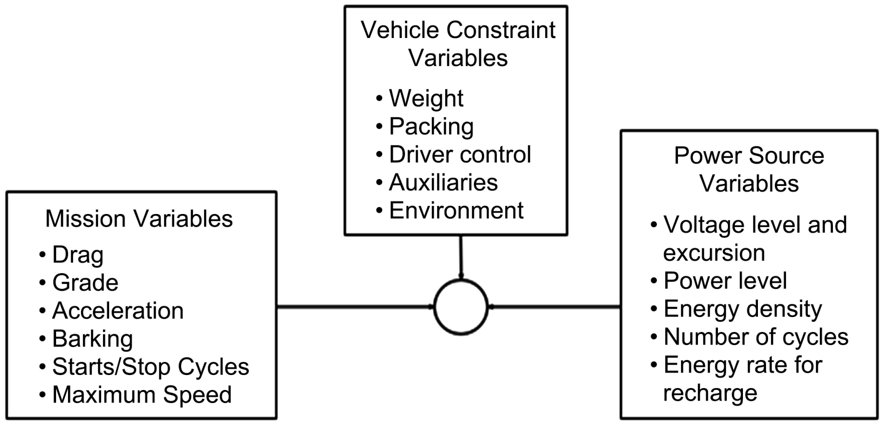

Figure 9. Variables of the pure electric vehicle system.

There are different types of motors. **Figure 10** shows the classification of engines. Two main types of motors are referred to as Direct Current (D.C.) motors and Alternating Current (A.C.) motors. Higher torque, high power, higher efficiency, affordability, higher reliability, variable range of speed, etc., define the requirement for an engine to be used in a pure electric vehicle. Initially, DC motors were used in these cars, but their unreliability and inefficiency made them less unpopular to use in these vehicles [26]. Recently, permanent magnet (PM) and induction types of motors have generally been used in PEV for their developed power electronics system [27]

Four to five kinds of motors are used in pure electric vehicles. They are stated as follows:

Brushed DC Motor

The propulsion system of a pure electric vehicle (PEV) primarily uses the D.C. motor and D.C. motor drives. They were initially chosen for their control simplicity and industrial maturity. They have stators with permanent magnets (PM), and their rotors have brushes. The DC motor receives higher power density for the E.V. propulsion system, spins up nearly 5000 rpm, and uses a fixed gear system for stepping down up to 1000 rpm. The bulky, complicated, inefficient reverse gear system is removed using reverse rotation [28] [29]. The motor controller, single-speed reducer differential, and driving wheels gearbox are some of the motor drive system subsystems shown in **Figure 11**. The basic setup of the D.C. motor drive is shown in **Figure 11**, which controls the armature current and output torque.

Permanent Magnet Brushless DC Motor

These motors have high-energy permanent magnets. Their lower volume confirms higher power density, which offers high efficiency because there is no copper loss. Heat dissipation and cooling system seems very good in these types of motor. They ensure higher reliability as they have fewer heating issues. Their primary material is the permanent magnets (PM). PM BLDC motors are PM AC machines where concentrated windings give the trapezoidal back-emf waveforms. As there is no winding in the rotor, no copper loss occurs here. This

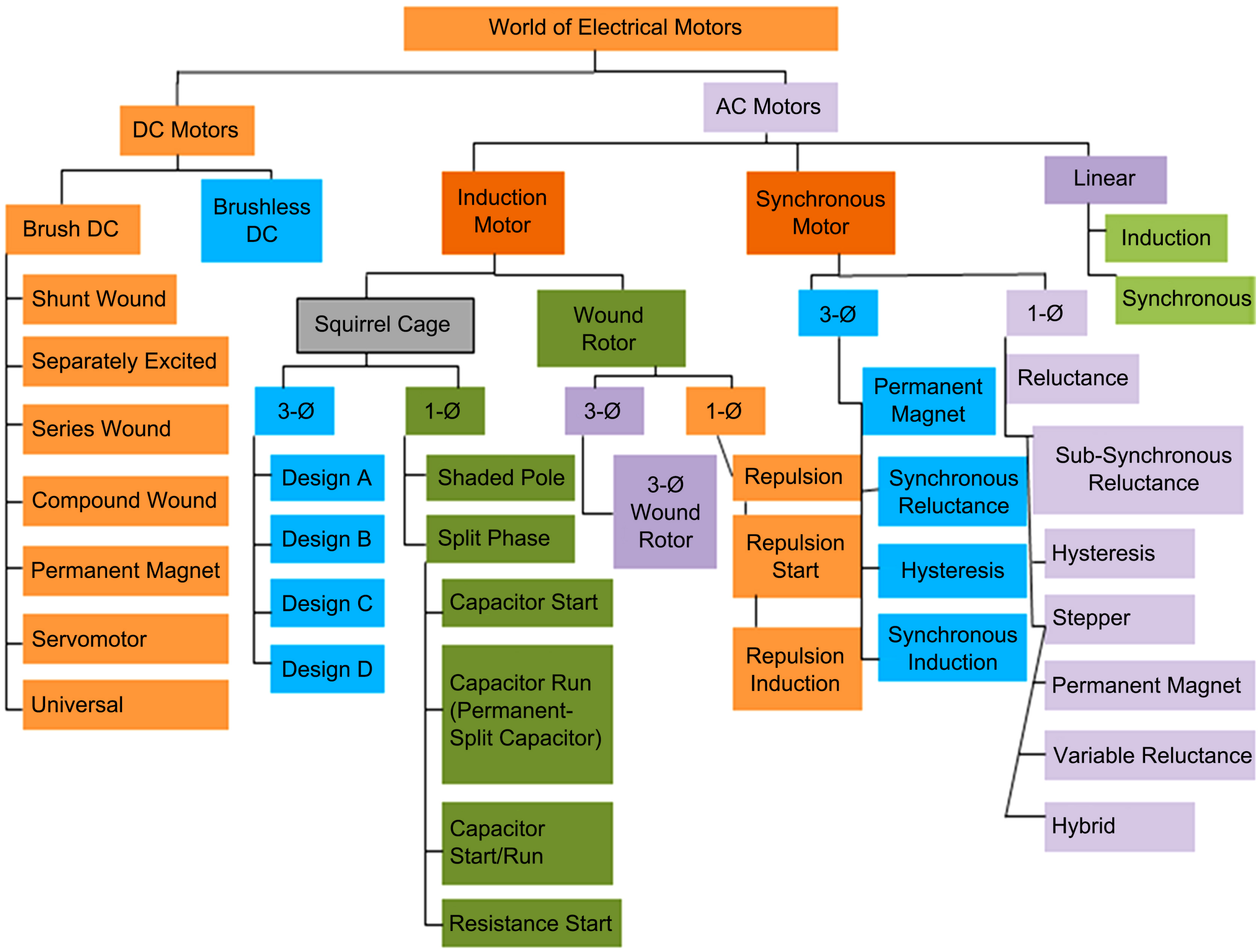

Figure 10. Classifications of electrical motors.

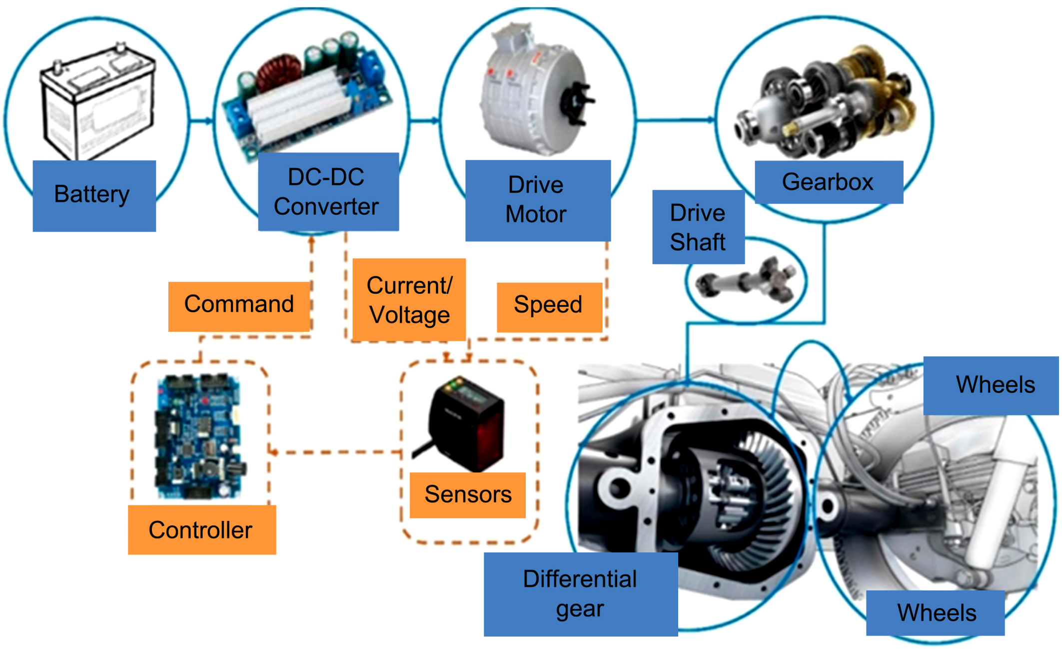

Figure 11. The basic setup of the D.C. motor driving system.

makes these types of motors more efficient than the induction motors. The PM BLDC motors ensure higher efficiency and reliability than the D.C. motors and are almost maintenance-free [30]-[35]. **Figure 12** shows the basic structure of the permanent magnet brushless D.C. motor.

Permanent Magnet Synchronous Motor

Permanent magnet synchronous motors may be divided into magnet brushless D.C. motors and static magnet A.C. synchronous motors. Fixed magnet motors generally adopt current control, with simple structure, convenient maintenance, and safety and reliability. Its small size, high efficiency, good overload capacity, and fast response are very matched with electric vehicles. However, it's challenging to make a high-power magnet motor smaller because of the troublesome manufacturing of static magnet materials to scale back the engine's standard, and therefore the cost is comparatively high.

Induction Motor System

A.C. induction motor doesn't have a D.C. motor commutator. Its simple structure, convenient manufacturing, easy maintenance, high limit speed, stable working performance, small size, fast response, large capacity, and its design and manufacturing process are mature and cost-effective low. There are currently twospeed control methods for A.C. induction motors: variable frequency speed and vector control. It has the characteristics of solid safety, long service life, low noise, wide speed range, and excellent dynamic performance. The most significant disadvantage of an A.C. induction motor is its complicated controller, high control cost, and superficial damage. At present, A.C. induction motors are widely utilized in electric drive systems of pure electric vehicles [36] [37] [38].

Switch Reluctance Motor

Switch reluctance motors are synchronous motors driven by a unipolar inverter-generated system. They are also known as doubly salient motors. They follow the working principle of the variable reluctance. SRM is needed in situations where high-speed operation is required without mechanical failure. They are preferable for driving PEVs as a wheel driving system because they have higher mechanical integrity. But they aren't preferable for some disadvantages like high torque ripple, larger acoustic noise, low torque density, etc. [39] [40] [41]. It has

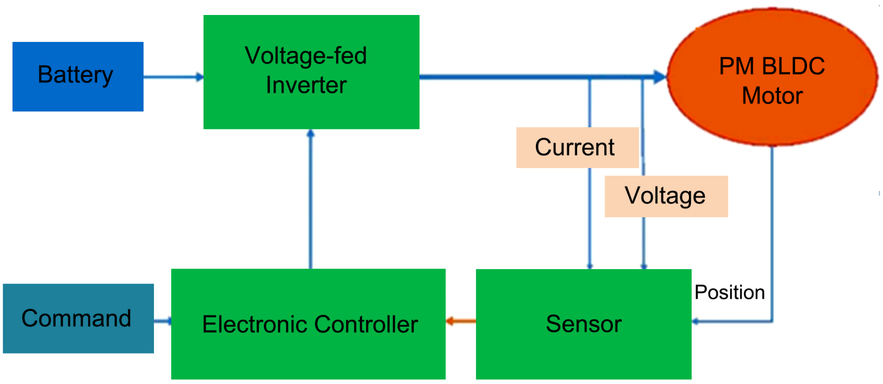

Figure 12. The basic structure of PM BLDC motor.

rapid acceleration and immensely high-speed generation due to its simple rotor structure that doesn't require windings, magnets, brushes and commutators. It makes the PEV propulsion suitable for the gearless operation [42] [43].

Table 3 Defines the motor and two motors-based transmission systems in detail.

Comparison of the PEV Drives

Considering the previous discussion, which drives are more suitable for pure electric vehicles can be found. The movements are discussed considering their parameters.

Now, the parameters are shown in **Table 4**. It is seen that the S.R. drive has the disadvantage of high acoustic noise. In contrast, induction motor drive gives the advantage of low-cost operation and PM brushless motor provides a super miracle of high-power density and higher efficiency. The discussion is about the failure of D.C. drive as they have lower efficiency and higher cost. So, it should be avoided while the PM BLDC and induction-type drive are the best options.

Table 5 shows the implementation of existing drives in battery electric vehicles (BEVs). In this implementation technique, the D.C. drive is undesirable, whereas the S.R. drive is rare, and there are massive implementations of induction and PM SM types of industries.

Table 3. One motor and two motors-based transmission system.

One Motor Based Transmission system	
Conventional Type	Here, the PEV propulsion system consists of a clutch, a differential (D), a gearbox (G.B.) and an electric motor (M). This can be replaced by an ICE vehicle with a rear-engine-front-wheel system. This system is nothing but a replacement of the ICE, where an electric motor replaces an internal combustion engine.
No Transmission Type: Rear-engine-Front-wheel (R.F.)	Here, fixed gearing is used instead of a clutch and gearbox. It is pretty similar to the conventional system.
No Transmission Type: Front-engine-Front-wheel (F.F.)	Here, the differential, fixed gearing and the electric motor are placed in front of the vehicle. It is nearly the same as ICE with Front-engine-Front-wheel drive.
Two Motors-Based Transmission System	
No differential Type	The differential is eliminated by two motors placed for two individual front wheels. Fixed gearing is applied with two engines attached with two front wheels.
In-wheel type with fixed gear (F.G.)	This type is similar to the no-differential type, but the location of the motors is random. Electric motors are embedded in-wheel type in the wheels.
In-wheel type without fixed gear (F.G.)	There is no mechanical gearbox in this system. The speed is directly proportional to the speed of the motor.

Table 4. Comparison of the existing PEV drives.

Factors	DC	Induction	SR	PMSM	PM BLDC
Power density	2	3	3.5	4.5	5
Efficiency	2	3	3.5	4.5	5
Controllability	5	4	3	4	4
Reliability	3	5	5	4	4
Maturity	5	5	4	5	4
Cost level	4	5	4	3	3
Noise level	3	5	2	5	5
Maintenance	1	5	5	5	5
Total	25	35	30	35	35

Table 5. Comparison of the existing PEV drives.

Type of the drives	Electric Vehicle Model
PMSM	KIA Soul E.V. and Niro, MG ZS EV, Hyundai-Kona and Ioniq, Citroen C-Zero, Nissan leaf, Peugeot iOn E.D. etc.
D.C.	Panda Elettra from FIat, Reva G-Wiz DC, three-wheeled tempos, Citroen Berlingo Electrique.
Induction	GM EV1, Tesla Roadster, Reva G-Wiz I, BMW Mini E, Mahindra Electric E-20 series etc.
PM BLDC	Bright for E.D. and some Chinese electric cars.
S.R.	Panda Elettra from Flat, Reva G-Wiz DC, three-wheeled tempos, etc.

2.4. Parameter Designing for Pure Electrical Vehicle

The matching of the drive motor is principally used to calculate rated power, rated speed and rated torque. Figure 13 shows the relationship of ratedspeed, torque and motorpower. The choice of motor parameters has a vital influence on the ability and economy of the vehicle.

If the chosen rated power is too low, the drive motor will work under overload for an extended time, reducing the service lifetime of the engine. At the same time, the ability is just too high; the motor will often work under insufficient load, leading to the typical working efficiency of the enginebeing relatively low, reducing the practice range of pure electric vehicles, thereby reducing the economic benefits of pure electric cars.

First, analyze the utmost power required by the pure electric vehicle when running at the best speed on the road: At present, the car is running at a continuing speed at the best rate on a straight road, and therefore, the road has no

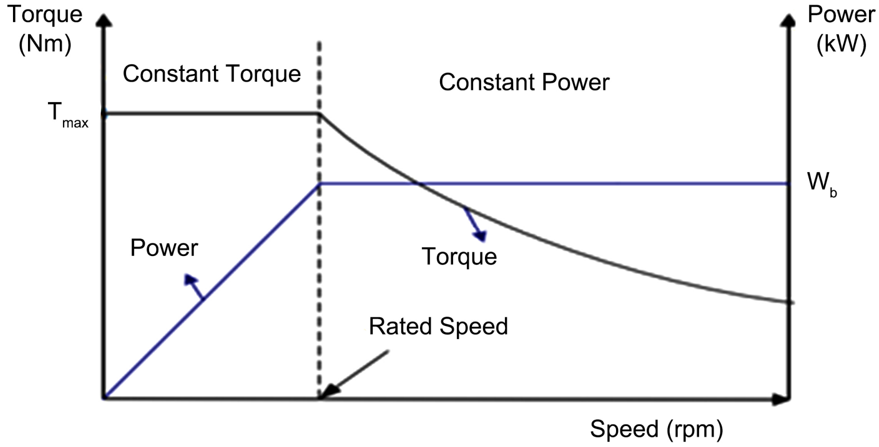

Figure 13. Motor drive torque characteristics.

slope, ignoring acceleration resistance, assuming that the wind speed is zero, we will get When the electric vehicle is running at the best rate, the ability consumed to beat the resistance is:

$$P_{\max 1} = \frac{v_{\max}}{3600\eta_T} \times \left(mgf + \frac{C_d A v_{\max}^2}{21 \cdot 15} \right) \tag{1}$$

where η_T is the transmission coefficient efficiency; m is the vehicle weight; C_d Is the drag coefficient, f is the rolling resistance coefficient, A is the formal Area; $v_{\max}$ It is maximum speed. Here, calculated $P_{\max1}$ = 22.9 KW, integer 23 KW.

Maximum gradient,

$$P_{\max 2} = \frac{v}{3600\eta_T} \times \left(mgf \cos a_{\max} + mg \sin a_{\max} + \frac{C_d, A \cdot v^2}{21 \cdot 15} \right) \tag{2}$$

Here, $a_{\max}$ Is maximum climbable gradient; speed while maximum climbable angle is v. Here, 21 K.W. is the result by calculation.

Lastly, at the time of the acceleration:

$$P_{\max 3} = \frac{1}{3600t\eta_T} \left(\delta_m \cdot \frac{V_m^2}{2\sqrt{t}} + mgf \frac{v_m}{1 \cdot 5} + \frac{C_d A V_m^3}{21.15 \times 2.5} t \right) \tag{3}$$

δ_m Is the rotating mass conversion coefficient; t is the acceleration time; acceleration terminal velocity is v_m. The result is $P_{\max3}$ = 35 K.W.

Now, Table 6 shows the parameter drives of the electrical machine.

3. Design and Analysis of the Transmission System of Downhole Electric Command Vehicle

The gear of the underground pure electric command vehicle includes a reducer, differential, half shaft and other components. The standard of the gear mechanism contains a decisive effect on the vehicle's ability, and the reducer is the most significant component within the gear. This chapter compares and selects the transmission structure of the pure electric command vehicle, and focuses on the planning and analysis of the reducer and half shaft.

Table 6. Parameters of machine drives.

No	Parameter name	Parameter value
1	Rated voltage	330 V
2	rated power	24 kw
3	Maximum power	60 kw
4	Rated torque	115 N·m
5	Maximum torque	290 N·m
6	Rated speed	2000 r/min
7	Maximum speed	4000 r/min

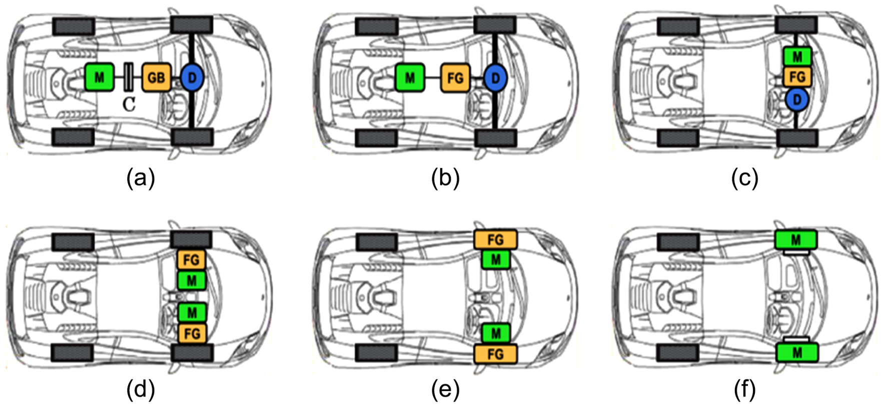

Figure 14. Configurations of the six types of transmission.

The Structure of the Transmission System

The transmission system of a PEV expresses the combination of electrical and mechanical subsystems. The electrical system gathers energy from the batteries and gives them to one or more motors using power electronics. Different types of converters and inverters stay in the section of power electronics. A transmission, a clutch and a differential are combined to form the mechanical system.

The transmission structure of the PEV is divided into two sections. They are one motor structure and two motor structures. It is shown in Figure 14.

4. Conclusion

The field of pure electric vehicle development is still not so rich. Although Tesla, Nissan Leaf and electric cars are sold, there are many ways to improve this site. The cost of analyzing the E.V. is the main reason for the lack of research in this field. Most of the research in this field is focused on improving the energy source and developing an efficient transmission system. The motors, differential, gearbox system, clutch, simulation and the configuration of the PEV also should be studied in depth. Due to the limited level and time, much work still needs to be done for further in-depth study and improvement. For the research work of this article, there are the following aspects that need to be further improved in the preliminary matching, and it is expected that more accurate algorithms will be used to evaluate the power requirements of the vehicle's acceleration performance. The algorithm that combines energy conservation and empirical methods used in this paper is relatively simple. When designing the specific parameters of the main components of the power system, the dynamic design should be carried out under various complex road conditions in the well.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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