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https://doi.org/10.5109/7172252

出版情報：Evergreen. 11 (1), pp.156-177, 2024-03. 九州大学グリーンテクノロジー研究教育センター
バージョン：

EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 11, Issue 01, pp156-177, March 2024

Methods of Implementation in an Electric Vehicle Conversion and Vehicle Controller: A Review

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(Received December 29, 2023; Revised October 13, 2024; Accepted March 16, 2024)

Abstract: The modern trends in converting a gasoline-powered vehicle (Diesel, Petrol, or CNG) into an electric vehicle requires an appropriate redesign in the placement of new electrical components. These new trends of approaches are often applied to vehicles that are manufactured for the sole purpose of operating a fully electric vehicle without any gasoline components. However, in the case of retrofitting a gasoline-powered vehicle into a battery-powered electric vehicle (EV), different approaches are used in an already running vehicle that can be converted into a fully functioning Electric Vehicle. This results in better recycling, environment-friendly usage of old vehicles, and a massive improvement in air pollution levels. A minimum amount of maintenance while owning an Electric Vehicle is a key factor where the automobile industry gains attention for buyers or customers. The conversion of traditional or conventional vehicles into fully functioning Electric Vehicles has gained preference in recent years. However, the components used in an Electric vehicle are to be discussed to fully assess the working of an EV in the process of this conversion. In this paper, we shall focus particularly on the implementation of such conversions and controlling of the electric vehicle through different types of Electric Vehicle Control. The functions of each component in an Electric Vehicle Controller or just a controller in general, show different approaches to communicating with each other to achieve an efficient range and performance of the particular electric vehicle. The relations between these components inside of an EV controller can be studied by their energy flow, circuitry, and their functions. Control Area Network (CAN) is also considered as a topology to determine the aforementioned working of each component. Fault diagnosis, charging status, and battery capacity status are some of the many factors that are applicable after installing a controller within the Electric Vehicle.

Keywords: EV, Conversion, Implementation, vehicle control system, control strategy, Controller, driving controller, motor controller

1. Introduction

The conversion of conventional vehicles into Electric Vehicles has been steadily increasing in recent years. One motor powering either wheels or a combination of motors adapting to the transmission is observed in recent years. Brush-less DC motors are most suitable for an economical conversion of vehicles. The idea of recycling old or idle conventional vehicles into an EV is economically viable instead of creating or designing new EVs in the present. Although the gap is challenging, to successfully retrofit electric components in a gasoline-powered vehicle, it was precisely designed to operate with mechanical components in the past. Hence, the conversion gives rise to various challenges. The drivetrain, power source, and control systems of a conventional vehicle must all be significantly altered in order to transform it into an electric vehicle (EV). Depending on the type of conventional vehicle being converted, the precise conversion procedure may change. Whether a car has front-wheel drive (FWD), rear-wheel drive (RWD), or all-wheel drive (AWD) is the main difference. Adaptation and thorough study of the safety of these conversions are to be focused on in order to meet the requirements of this conversion. An FWD test vehicle "Maruti Suzuki Wagon R" is proposed for the aforementioned conversion in this project. A normal car can be converted into an electric car (EV) through a complicated procedure that requires several parts working together to make the car run on electricity.

Examples include the electric motor, battery pack, motor controller, thermal management system, battery management system, transmission/gearbox, charger, and charging system, as well as mounting and structural alterations.

In the modern period, the development of the electric vehicle is based on modern technology like motor drive technology, energy storage technology, power electronics technology, automotive technology, etc[1,2]. As we all know the vehicle control unit is the most important component in the control system of an electric vehicle. Two aspects of the vehicle technology are; firstly, to effectively increase driving distance or range, the body weight of the car should be reduced, and secondly, to improve the vehicle performance, reduce cost, the arrangements and coordination of the electric controllers should be reasonable in electric vehicle[3]. The two kinds of electric vehicle controllers are: centralized control and distributed control. Control system distributes based on CAN bus, the process of controlling the electric vehicle controller for ECU by CAN bus communication and control[3,4] The EV is based on 6 functions where the electric vehicle operates. Due to environmental pollution and using a renewable source of energy, the EV or Hybrid market attracted customers significantly in the recent years.

The article proposes the fuzzy controller in which speed and pedal opening rate is taken as input and compensation torque is taken as output, by which the fuzzy controller is designed[3].

The vehicle control unit collects the signal of parts of the vehicle like the acceleration pedal signal, motor control system signal, the pedal signal, etc[5]. which analyse the intention of the driver and make analogical judgment. The motor output torque and parameters are calculated to protect the driving of the electric vehicles and coordinate the movements of power components[6]. For vibration mitigation, a new approach investigated is based on dynamic vehicle absorbing structure for a pure electric vehicle which is uses in-wheel switched reluctant motors. The completions of power control and energy, also monitor lower-level components' actions of the controller and provide functions of driving of electric vehicle for the battery energy, network management, vehicle status monitoring, fault diagnosis, and braking energy feedback. A recognition model by training a deep neural network estimates the distance.

2. Electric Vehicle: History

Before the beginning of the production of EVs, primary cells were first invented in 1832-1839. In 1835, Thomas Davenport invented the first working EV as a locomotive. The first successful EV was built by William Morrison in the USA. In 1893, a Chicago auto expo was observed with various brands (Henry Ford being one of them) displaying different models of EV. EV's in the past were surprisingly quick to grow before rising in trend of high-precision and high-tech gasoline engine vehicles. EV usage was at its peak in the 1900s, one-third of all cars were powered by electricity in the USA. By the 1920s, the supply of gasoline or crude oil increased proportionally to the demand of gasoline ICE vehicles. Consumers demanded vehicles covering long distances which also provided more power. Since then, the downfall of EVs has started. In 1972, the first pure hybrid EV was invented by Victor Wouk with minor support from General Motors automobile company (G.M) USA. In 1997, Toyota came up with its first full-hybrid Toyota Prius. Other automobile industries followed as well. By the end of 2000, All-electric (Pure Battery-powered EV's) came into production. In July 2008, Crude oil prices sky-rocketed. However, this made the automobile industries focus more on fuel-efficient vehicles rather than shifting towards Pure EVs altogether[7]

The current trend of turning gasoline-powered vehicles into electric ones entails rearranging the location of electrical components. This makes it possible to use older vehicles in a manner that is friendlier to the environment and more efficient. Because it requires less upkeep and has a smaller influence on the surrounding environment, the retrofitting procedure is becoming an increasingly appealing choice in the automotive sector. In this work, we investigate the implementation of these conversions and the numerous control systems that are utilised in electric car controllers. More specifically, we focus on the energy flow, circuitry, and functions of these controllers. In addition, the essay places an emphasis on the significance of safety and adaptability in the process of transforming conventional vehicles into electric ones. In particular, the paper addresses problems pertaining to drivetrains, power sources, and control systems. For this conversion, the usage of brushless DC motors is recommended because they are the more cost-effective option. The management of energy, the regulation of power, and environmental concerns are just some of the topics that are covered in this article. Additionally, the article delves into the role of the vehicle control unit and its essential tasks in the operation of electric vehicles. In conclusion, the paper discusses the implementation of a fuzzy controller for the purpose of enhancing the performance of electric vehicles. This serves to illustrate how the combination of a variety of technologies contributes to the expansion of the market for electric vehicles.

3. Electric Vehicle consumer analysis (EV)

Battery Electric Vehicles (purely battery-powered vehicles), Hybrid EV's in all types of configurations come under the term Electric Vehicles[8]. Since the rise in EV consumers has been on a steady increase, EV production gained support in the form of subsidies from various governments around the world. EV transport conversion reduces CO2 emissions and footprint[9]. However, the use of renewable energy sources for the use of these battery-operated vehicles such as photovoltaics power production can significantly improve the use of these vehicles[10,11]. The Hybrid EV and Battery EV (BEV) roadmap aims to reach 50% of the vehicle sales around the world by the year 2050[12,13]. Plug-in HEVs created an impact initially with over half a million PHEV (plug-in) sales around the world from 2011-to 2015. The Electric Vehicle Initiative (EVI), set a target goal to reach production of 20 million fuel-cell vehicles and EVs by the year 2020 worldwide[14]. The expected goal can grow further if the growth rates continue to rise[15].

4. Hybrid Electric Vehicle scenario comparison (HEV)

As 2016 ended, the worldwide inventory of EVs for customers reached 2 million units. Battery Electric Vehicles (BEV) and Hybrid Electric Vehicle (HEV) are two of the top technologies in Electric Vehicles[16,17]. HEVs use internal combustion engine paired with one or more electric motors that are powered by batteries[18]. Although HEVs are significantly more expensive than conventional ICE vehicles, HEVs were introduced to obtain cost saving benefits along with the power and range of a conventional vehicle. The fuel efficiency is improved to a massive 40%-45% when compared to real-world driving scenarios[19,20]. Battery Electric Vehicles have larger storage of batteries as compared to HEVs. An EV in general has only one source of energy to power the vehicle whereas HEVs use two or more for the same. HEVs can use various sources or combination of energy such as fuel cell, petrol, etc.

The HEV consists of 6 powertrain configurations that can be used to operate the vehicle. Namely:

i. Series Hybrid Electric Vehicle (SHEV)
ii. Parallel Hybrid Electric Vehicle (PHEV)
iii. Series-Parallel Hybrid Electric Vehicle (PHEV)
iv. Complex Hybrids Electric Vehicle (CHEV)
v. Fuel Cell Hybrids Electric Vehicle (FCHEV)
vi. Plug-in Hybrid Electric Vehicles (PHEV)

4.1 Series Hybrid Electric Vehicle (SHEV)

This type of hybrid EV is powered by an Internal Combustion Engine (Conventional ICE) in addition to a generator, battery pack, and Electric Motor[21]. The ICE is not necessarily attached to the transmission of the vehicle as to the generator within the S-HEV continuously charges the energy storage unit or the battery pack. The electric motor draws power from this energy storage and hence the vehicle propagates in the form of an EV[22]. Since the ICE is not directly attached to the transmission or the differential, it produces optimal frequency when measured in heavy traffic in the cities. Parallel HEVs are given more preference over SHEVs as Electric Motors require larger size when driving inter-city or long highway-based routes. The reason is, that automobile consumers drive faster or at higher speeds on the highways to cover larger distances in a short period of time[23,24].

4.2 Parallel Hybrid Electric Vehicle (PHEV)

The engine (ICE) and the electric motor (EM) are connected in parallel to move the vehicle through the transmission. The ICE in PHEVs has a comparatively larger engine (in Litres/cc)[25]. PHEV's are preferably suited in long-distance routes and less preferred in urban cities where the energy-storing process is comparatively less[14]. Here, the ICE can be used to power the wheels in the vehicle including the EM. The ICE can also be used to store energy similar to what we have seen in SHEVs. A modification can be obtained by using Through-the Road (TtR) HEV that merges the two sources of propagation. The ICE powers the front wheels similar to a Front Wheel Drive (FWD) and the EM powers the rear wheels similar to what we see in a Rear Wheel Drive (FWD)[25,26]. PHEV can be recognized in two power train configurations

1. Pre-Transmission configuration
2. Post-Transmission configuration

4.3 Series-Parallel Hybrid Electric Vehicle (SHEV)

PHEV combines both series and parallel hybrid types into a single configuration. Also called power-split HEVs as SPHEV can operate on both SHEV PHEV or both at the same instant. It can achieve the advantage of operating the vehicle on a smaller size ICE including the reduction in demand of energy storage. Since SHEVs are preferred in urban traffic, where the speed is less and PHEVs are preferred in long routes, where the running average or speed is significantly higher, SPHEVs can overcome the drawbacks of both configurations as a consumer of hybrid vehicles[27,28]. Planetary gear is required to pair both the ICE and EM into a Continuously Varying transmission (CVT) automatic gearbox. Hence, the SPHEV can be operated in both SHEV and PHEV modes depending on what mode of operation the consumer uses. Engine heavy (ICE preferred) mode and Electric heavy modes (EM preferred) mode are some sorts of mode of operation[29].

4.4 Complex Hybrid Electric Vehicle (CHEV)

CHEV's are similar to SPHEV's, they use complex configurations that use more than one EM or generator. The motor power flow in these hybrid vehicles is bi-directional in nature whereas a unidirectional power flow is observed in the Series-Parallel HEV[30]. Ford motors (USA) have manufactured complex hybrid vehicles such as 'Ford Escape' that can be taken as an example.

4.5 Fuel-Cell Hybrid Electric Vehicle (FCHEV)

These hybrids obtain 0% greenhouse gas emissions, in the aspects of 'refuelling' the vehicle or recharge the vehicle, fuel cells can be a faster alternative when compared to fully electric vehicles and also have a better range in one cycle of refuelling[31)]. FCHEV operation is based on the principle of reverse electrolysis where oxygen and hydrogen gases come together to generate power through by-products of water and heat[32)]. The battery is the energy storage system and the fuel cell is the energy conversion system. Supercapacitors are also known to be used as an energy storage system[13)].

4.6 Plug-in Hybrid Electric Vehicle (Plug-in HEV)

PHEV are full hybrid vehicles that run on a large storage of energy and significantly larger EM as compared to other HEV's. They use a smaller ICE and are more focused on recharging their storage of energy/batteries through a plug-in type charging method. The charging can be achieved by grid power and other means. PHEV's have a shorter driving range compared to fully electric vehicles and a longer driving range when compared with other HEV's mentioned above.

Since PHEV's are recharged from the grid itself, they help the system to obtain a stable power grid level and reduce power ripples[33)].

Further, in order to maximize efficiency, we use the battery to provide grid regulation services via peak power shaving when the vehicle is idle at a location and not in use at an instant[34)]. Vehicle to grid (V2G) power transfer makes use of the economic relationship between the PHEV consumer and the grid facility, which is often called vehicle to building (V2B), which hence generates revenue to offset the battery cost[35)].

5. Case studies

5.1 Electric Ford Mustang "Lithium":

This project entailed the conversion of a 1968 Ford Mustang into an electric-powered, high-performance automobile.

The conversion process entailed the removal of the conventional V8 engine and its substitution with an electric motor that derives its power from a substantial battery pack. The electric Mustang has been meticulously designed to generate substantial levels of horsepower and torque.

Significance: The present case study serves to illustrate that the scope of EV conversions extends beyond the realm of tiny or compact vehicles. This demonstration highlights the potential for transforming traditional muscle cars into electric vehicles that possess both robust performance capabilities and a reduced environmental impact.

5.2 Converted Classic Porsche 911 by Singer:

The collaboration between Singer Vehicle Design and Williams Advanced Engineering resulted in the conversion of vintage Porsche 911 sports cars into electric vehicles.

The conversion process entailed the integration of an electric motor and modern battery technology into the renowned Porsche 911 architecture. The outcome is a high-performing electric sports vehicle that maintains the allure of its predecessor.

Importance: The present case study exemplifies the meticulous execution and meticulous attention to detail involved in EV conversions, resulting in a seamless integration of traditional aesthetics and contemporary advancements in technology.

5.3 The Zelectric Bug:

The Zelectric Bug is a project that involves transforming classic Volkswagen Beetles, more often referred to as "Bugs," into electric vehicles.

During the process of conversion, the conventional internal combustion engine will be swapped out for an electric motor together with a battery pack. These adaptations are well-known for retaining the iconic appearance of the Volkswagen Beetle while bringing its powertrain into the modern day.

Importance: The Zelectric Bug project is significant because it demonstrates how electric vehicle conversions may give historic automobiles a new lease of life by making them more environmentally friendly and energy efficient without sacrificing their iconic designs.

6. Methods of implementation

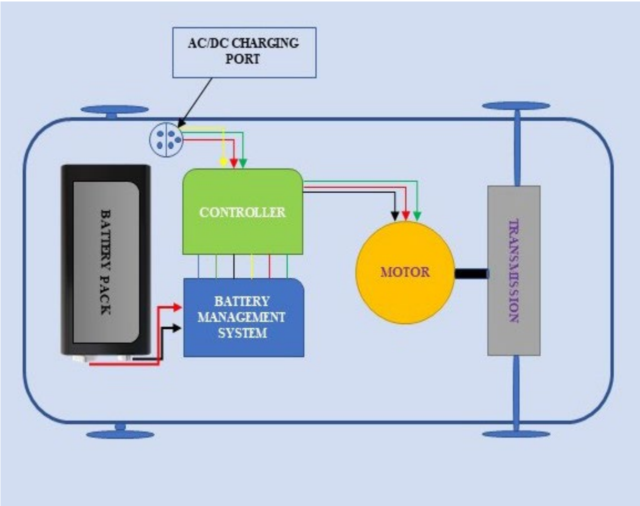

Fig.1: Basic components required in an EV

Figure 1 depicts the basic arrangement of pure EV's or Battery Electric Vehicles (BEV). The Motor, the Controller, Battery Management System (BMS), charging port(s) and battery pack are some of the key components in EVs. The transmission is paired with the AC or DC motor (subjective) in order to apply power to the transmission and move the vehicle.

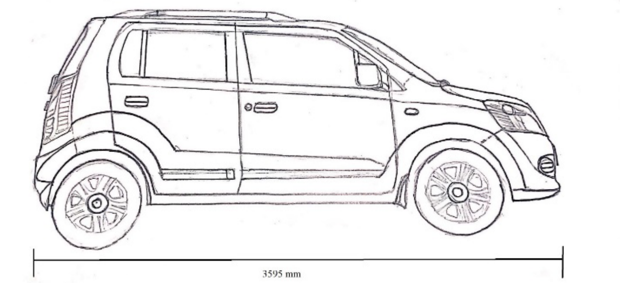

Fig. 2: Top view of test vehicle 'Maruti Suzuki Wagon R'

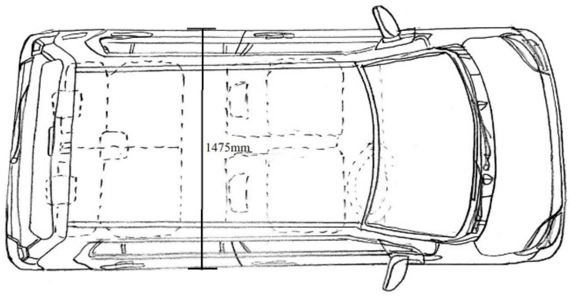

Fig. 3: Side view of test vehicle 'Maruti Suzuki Wagon R'

6.1 Test Vehicle specification

To determine the different approaches of converting or retrofitting a Vehicle into an Electric Vehicle, Maruti Suzuki Wagon R forward-wheel drive (FWD) with a manual 5 speed transmission as a test vehicle has been considered, which weighs about 800kgs. This particular car for retrofitting has been chosen for its light weight and compact design. The light weight may assist in the efficient performance with sufficient running range of the vehicle. The compact design does not limit the placement of electrical components within the FWD test vehicle, However, even after the right placement of these components, the test vehicle will still obtain a slight variation in the centre of gravity or even the balancing while operating or testing the vehicle on turns and slopes. Building the EV with inadequate knowledge of the parameters within the system could possibly lead to the failure of the design. The possibility of compromising on reliability and/or safety might arise during the conversion of the test vehicle due to the fact that the vehicle has been converted into an EV which was previously designed, engineered and intended to operate on conventional gasoline engine characteristics[36)]. Hence, rectifying these issues is required in every aspect of reliability and/or safety. The Electronic Control Unit (ECU) is an essential component of the engine management system, paired with drive by wire (DBW) components, the ECU is discussed later in the controlling section of the study[37)].

6.1.1 Dimensions

The dimensions of this test vehicle have been given below.

6.1.2 Specifications

The test vehicle consists of a FWD 3-cylinder engine with a capacity of 1.0 L (998cc displacement).

Dimensions and Capacity
- Length: 3595mm
- Width: 1475mm
- Height:1700mm
- Seating Capacity: 5
- Ground clearance: 165mm
- Wheelbase: 2400mm
- Kerb Weight: 870kg
- Gross Weight: 1350kg
- Tyre Size: 145/80 R13

Engine and Transmission
- Type: K Series Petrol Engine
- Displacement: 998cc
- Max. Torque: 90Nm@ 3500rpm
- Max. Power: 67bhp @ 6200rpm
- No. of valves per cylinder: 4
- No. of cylinder: 3
- Transmission: Manual FWD
- Gearbox: 5 Speed

Suspension and Steering
- Front: McPherson Strut with coil spring
- Rear: Isolated Trailing Link with coil spring
- Steering: Power
- Turning Radius: 4.6m

6.2 Ideal component implementation for EV conversion

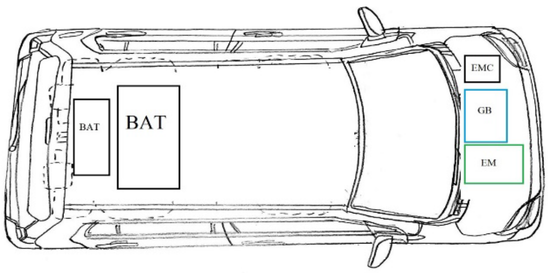

Fig. 4: Schematic placement of components (EMC - electric motor controller, EM - electric motor, BAT – batteries, G - gearbox) [34]

The petrol-powered engine in this test vehicle in particular, weighs about 150kgs, whereas the radiator weighs about 4kgs. These components including the alternator are extracted and removed from the vehicle (including the undesired components not required for this conversion). During the conversion, the gearbox is detached from the engine and is mechanically attached to the Brush-Less DC Motor (BLDC) which is powered by Lithium-ion batteries, and connected in series.[38] In the process of conversion, the procedure of connecting the BLDC motor with the gearbox requires a modification in order for the combination to be adaptable. The BLDC motor is a widely used alternative to giving traction to the vehicle as it significantly performs better in the feasible conversion scenario as compared to other types of motors[39].

6.3 Placement of components

6.3.1 Methodology 1

In order to retain the centre of gravity and other various measures, the placement of components with respect to their weight is taken into consideration. Since the transmission part of the test vehicle is left as it is, the engine and other components to be removed are replaced with the electrical components that mimic the weight of such components as mentioned above. A

3 KW BLDC Motor weighs about 9Kgs, the motor, controller, batteries and other such components can be placed in a similar manner in order to mirror or mimic the weight of the test vehicle that was previously engineered for a conventional ICE engine as shown in Fig 4.

6.3.2 Flywheel

Flywheels are bulky discs made of metal, cast iron or even aluminium. This disc is placed in the transmission of a conventional ICE vehicles, used for storing energy. Flywheels assist in obtaining mass for rotational inertia, which in turn keeps the engine running. The kinetic energy of the spinning disc is released when the flywheel slows down[40]. The edges of the flywheel consist of rows of gear teeth. The flywheel is a crucial part of the transmission which is attached to the crankshaft of the vehicle. It gives an ample amount of balance to the engine.

6.3.3 Transmission Conversion

In case of the achieving a conversion by changing the transmission from a 4-speed manual gear into an automatic transmission, The BLDC motor is attached to an adaptive plate with equal number of holes as the gearbox. Further, this system is attached to the flywheel and clutch assembly in order to provide an ample amount of torque.

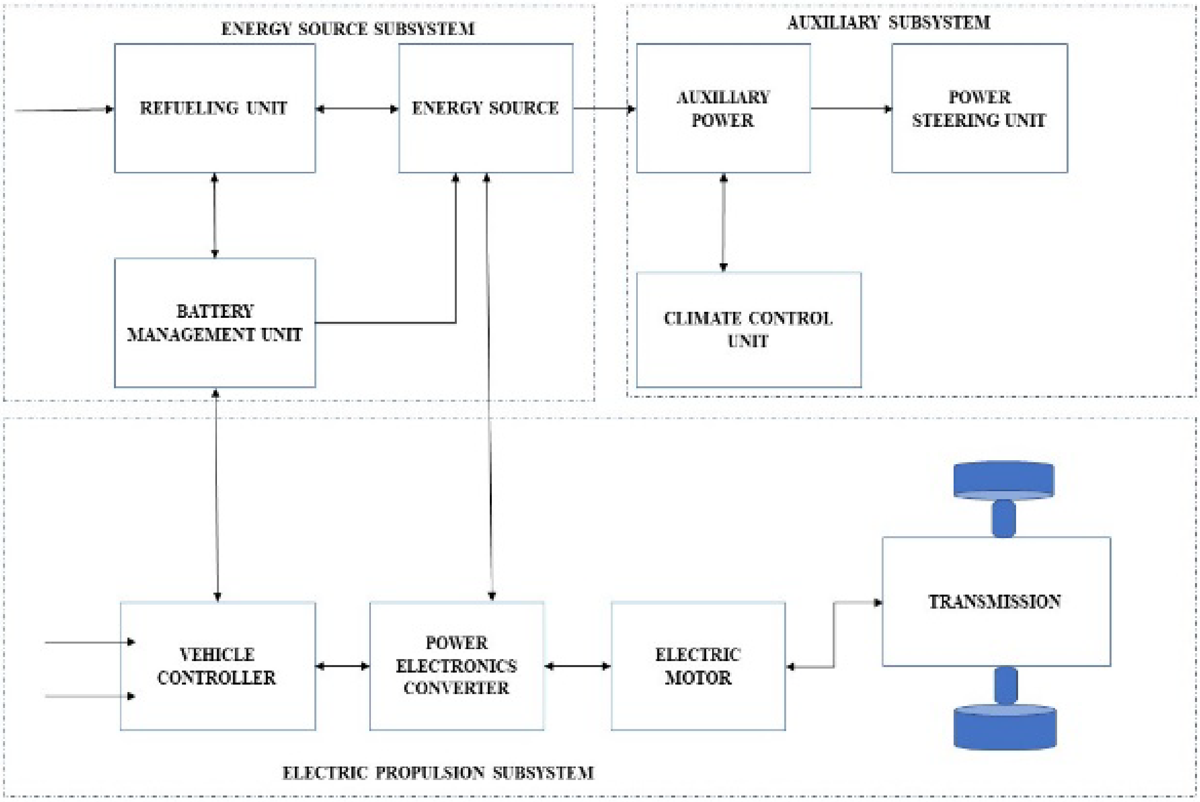

Fig. 5: Basic arrangement of EV components[13]

As stated in Ref.[41] "The transmission matches the rotational speed of the flywheel to the wheels, the flywheel giving out energy as it decelerates. Whether mechanical or electrical, the system can also be used to recover kinetic energy when braking. The flywheel can be accelerated, turning the kinetic energy of the vehicle into stored kinetic energy in the flywheel, and acting as a highly efficient regenerative brake.

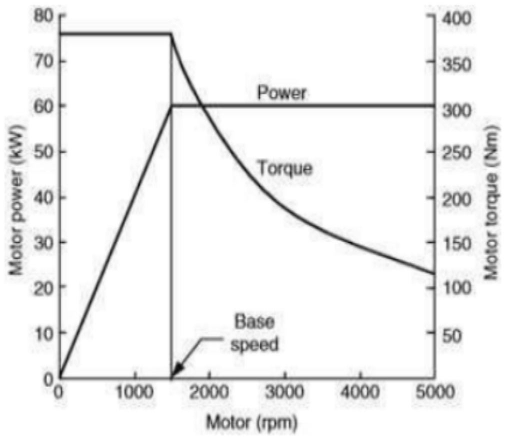

Fig. 6: Types of Electric Motor characters[36]

If we opt for an already existing 4-speed manual transmission, we shall study the performance of the test vehicle in each gear. The gears in this particular test vehicle consist of 4 gears forward and 1 gear in reverse.

6.3.4 Methodology 2

Another alternative to the methodology, is to remove the pistons of the engine while keeping the engine block. The BLDC Motor is mounted on top of a plate covering the engine block and is then coupled directly to the timing belt of the engine, which powers the crankshaft and hence powers the vehicle Electrically. Although, this approach/methodology gives rise to loss of power which in turn leads to the rapid decrease in efficiency and performance of the converted EV when compared to the previously mentioned approach.

The drawbacks in adapting to timing belts is the weak design which usually absorbs significant amount of vibration in the engine. The conversion of EV where the timing belt powers the crankshaft via pulley, demands high maintenance, reduces efficiency and performance of the EV as mentioned above. In order to fully support the environmental aspects of converting a traditional vehicle into an EV, we must opt for a motor that directly powers the vehicle when coupled with the transmission in order to retain the capacity of the Li-ion batteries and hence, improve the range of the electric vehicle considering it charged to its maximum capacity in one cycle.

Another study on a comparatively heavier test vehicle based on this conversion, used a 3-phase AC motor in order to determine the gear ratios. Gears are components which help transfer power to the wheels of the vehicle. When a number of gears are considered, there are two components influencing the propagation of the vehicle. The gear attached to the drive is known as the input gear or driver gear and the gear attached to the wheel is called the output gear or driven gear. The gear that is situated between the driver gear and the driven gear is called the idler gear. [54] Gear ratio in this scenario, is the ratio of the number of teeth in the output gear to the number of teeth in the input gear. The gear ratio is the description of the ratio of the output torque to the input torque.[55]

As concluded in Ref.[42]: Selection of the transmission ratio that is very suitable for use in two-speed transmissions, is the transmission ratio 1.96 for 2nd gear and 1.25 transmission ratio for 3rd gear based on calculations and from the results. The most optimized result is the combination between the 2nd and 3rd gears. The value of torque and power to speed

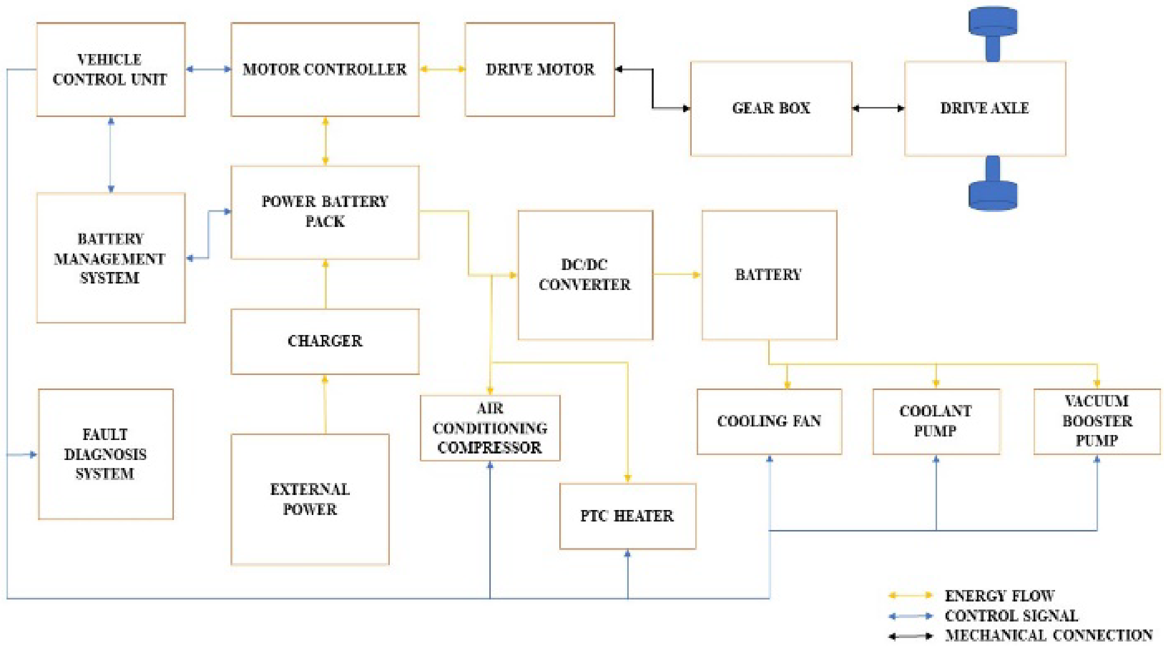

Fig.7: Electric vehicle dynamic control vehicle structure [2]

optimization has the highest value so the vehicle is only capable of traveling at 65.30 km / h at two speeds and the vehicle is also capable of traveling at 49.98 km / h in second gear.

6.4 Objectives

In our case of attaching a brush-less DC Motor (BLDC Motor), the test vehicle in this project is further:

1. Tested on a dyno to determine peak performance from the BLDC Motor.
2. Tested for its range and capacity of Lithium-ion batteries including the charging time.
3. Tested for its peak performance with gearing from 1 to 4
4. Determined for its efficiency as a 2-speed transmission system.
5. Balancing of test vehicle with regards to the appropriate centre of gravity.
6. Examined for safety of components and driveability within the EV

7. Construction of electric vehicle control system

Controller consists of a block wiring that consists of 3 connectors that supply the motor and another 2 connectors which supply the voltage. The controller also consists of Throttle connection, Hall sensor connection, Back-off, Switch, Meter connection, Low Level brake, High level brake, and various other microprocessor-based tasks that assist the controller in achieving various operations.

Vehicle controller is the most important part of the electric vehicles and as the electric control unit through this we collect the real time parameters of the dynamic parts of the controlled object and feedback. Through the controller area network (CAN) bus is passed to the vehicle controller for analysis and operation and then to coordination of the specific performance of the electronic control unit (ECU) we use the vehicle control unit (VCU) to the electronic control unit (ECU) control instruction.

8. Cognition of the function of the electric vehicle controller

It has two parts:
1.Centeralized control
2.Distributed control

8.1 Centralized control

To finish the signal processing, energy data and word distribution is by the core processor. And the advantage of centralized control is it is low in cost, gives response faster, high implementation and deals with concentration. The disadvantage is bad heat dissipation.

8.2 Distributed control

The core controller through the field bus and communication electronic control unit for each is the method of control. And the advantage of distributed control is that it is flexible, and has low complexity, modularity and configuration. And the disadvantage is that it is high in cost and has a complicated structure.
On the basis of the modular structure, it improves the relation between each subsystem of the electric vehicle. Systems are divided into two layers: -
1.Whole car controller
2.Secondary controller
The whole care controller is as we can say vehicle

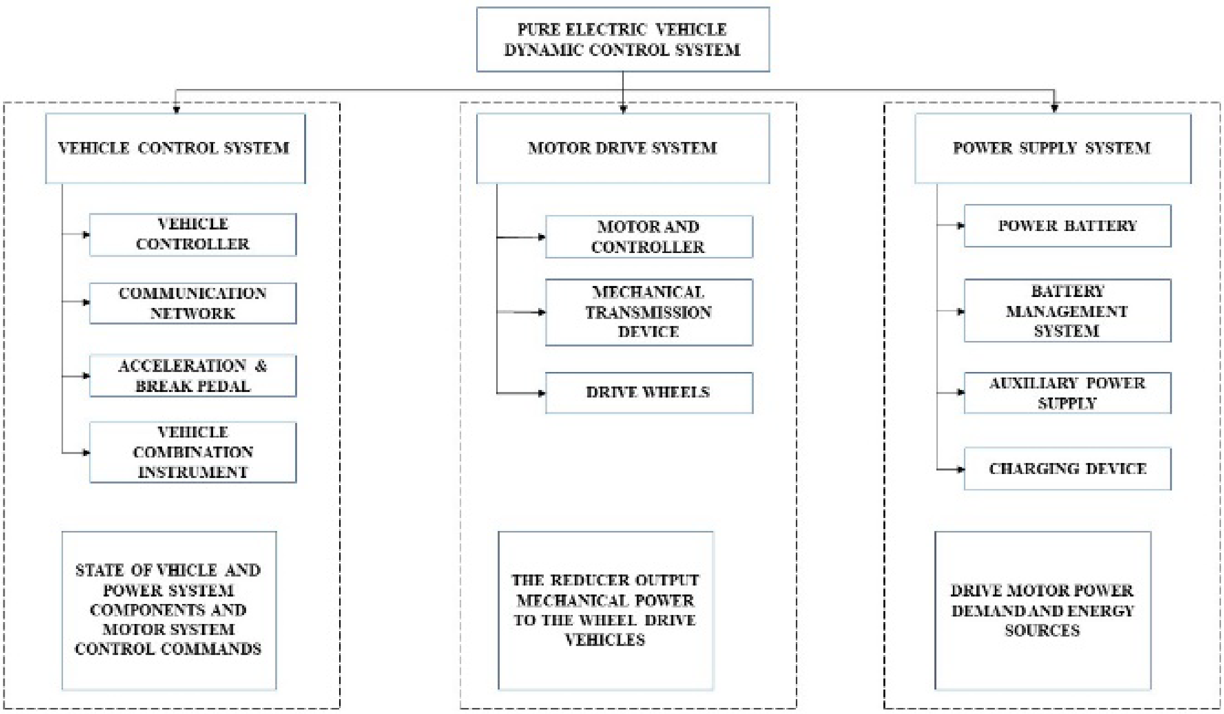

Fig. 8: structure of the vehicle control system

control unit (VCU) gives the information which is processed and unfolds the instruction.

The secondary controller works as a motor controller, electric vehicle combination instrument and battery management system and monitors the controlled object.

9. Vehicle control system structure: -

Vehicle control system consist of vehicle controller, power battery, motor controller, power battery management system, auxiliary system, gearbox, fault diagnosis management system, main reducer and other components. Battery provides the power to all the equipment of the vehicle and it is power source of the whole electric vehicle. The auxiliary system includes air conditioning motor, steering motor and its controller, DC/DC, braking system and so on. Through the vehicle controller the driver achieves overall control of the electric vehicle[43].

From the driver the operation information gives to the vehicle controller such as the brake pedal, the shaft lever signals, the acceleration pedal. Based on this information, the corresponding operation and drivers' intention are determined. The vehicle output torque and the vehicle status are sent to the vehicle controller during the running state of vehicle. The high and low voltage is controlled to turn on and off in sequence while the vehicle is started and stopped. And high and low voltage power is supplied by the external equipment. By the CAN network the vehicle controller communicated with other units, to coordinate the working state of the vehicle

10. Electric vehicles controlling functions:

Main functions are-

10.1 Drive torque control

The basic and the most important function of the vehicle controller is driving control. Through information gathering, the pedal works and then it reveals the intention of operation to the pilot to realize the transformation of the motor output torque. By this process the driver manipulates the brake pedal to consider signal input.

10.2 Optimization control in braking energy

The difference between electrical vehicles and traditional energy vehicles is breaking energy recovery. Only power output is the motor and two functions of motor and generator are first when the driver suddenly press down on the accelerator pedal of a vehicle, function of the motor is equivalent; second when the driver press down the brake pedal to slow down the vehicle when driving function of the motor is equivalent to the generator, and also take advantage of the electric car power breaking and storage of the electric power storage device. To increase energy efficiency, increase range, and lessen wear on the braking system, electric vehicles (EVs) must optimize braking energy. To effectively capture and use braking energy in EVs, however, might present a number of obstacles. Examples include the effectiveness of regenerative braking, battery state of charge (SoC), thermal control, switching from regenerative to friction

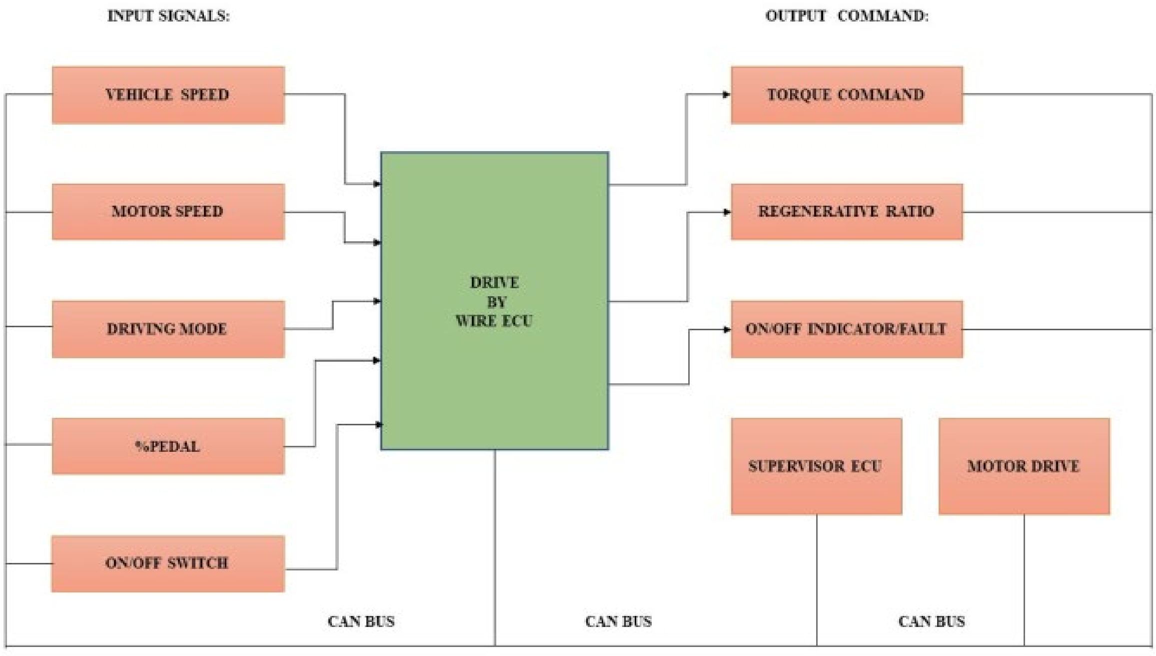

Fig. 9: Input and output signal flow of the drive-by-wire ECU with CAN bus interface[40]

braking, driver expectations and behavior, adverse road conditions, vehicle weight and inertia, hardware and software integration, cost considerations, and safety standards.

10.3 Energy Management of the electrical vehicle

To increase electric vehicle (EV) efficiency, increase range, and lower running costs, energy management must be improved. Energy management in EVs can be improved by a number of techniques and technology. such as Thermal Management, Optimizing Regenerative Braking, Battery Management System (BMS) Efficient Powertrains, Energy Recovery, Aerodynamic Design, Battery Pack Weight Reduction, etc. In this process, the only supply of energy is the electric supply system and also to drive the system and also to the air conditioning, same as the motor and other power supply in the electronic control unit. To extend the limit of electric vehicles, the optimization of energy can be reasonable by the vehicle controller. In low battery power, vehicle controllers send off part of the subsidiary electric control instructions, thus improving the utilization of ratio of energy to confirm the safety of electricity which is used in the vehicle.

10.4 CAN:

The management and maintenance of the network- In communication network the vehicle controller is the master node, which also operates the vehicle network, communication network, which has a number of master slave-node, real-time vehicle state regulation.

10.5 Processing and fault evaluation

Vehicle controller can monitor the Continuity of the real-time of vehicle running state, together with the parts EUD working condition, when the rejection of the electronic control unit firstly alarm timely, at the same time security measures, the fault diagnosis send the error code and store, which provide the future maintenance and car inspection routinely. At the end the problem of processing of fault classification and for those who do not affect the operation of the vehicle glitches to maintain the movement of the vehicle.

10.6 Monitor the vehicle conditions

To display the operation state in real-time of the vehicle information the vehicle controller based on on-board instrumentation control, to make the knowledge of the driver of the vehicle state. On CAN bus communication the vehicle condition monitoring technology is based on. And CAN bus communication, which is for motor speed, battery remaining power, running state parameters, and above data through the cluster display, improved the car interactivity between vehicles and drivers, and at same time the driver acknowledged the condition of the operations of the vehicle to provide suitable conditions.

11. Electronic Control Unit paired with CAN Bus interface

The Electronic Control Unit (ECU) can be depicted by a flow chart to observe the essential components in an input along with the output[44]. The Controller Area Network bus assists the whole system through nodes that linearly sends signal to output commands. The ECU precisely calculates and forms output based on the input signals. i.e., the output is changed variably.

12. Control strategy: -

In the MATLAB/Simulink the control strategies of the vehicle are modelled. The single-mode control strategy can aggregate in the condition of single driving, while the condition of urban roads is diversified. According to the road condition the control strategy should be designed.

In the acceleration pedal opening, only the driver's demand power is not reflected unless the driver's demand power is related to the change rate of pedal opening. For torque, the more essential the driver's demand is, the faster the change in pedal opening rate. During the motor testing map generated, map is a data curve, in different speeds and torques map declares the distribution of motor efficiency[45].

13. Torque compensation: -

By proper correction the driver's operation can be improved for sensitivity of torque output. In the condition where the driver needs urgently acceleration the great change rate occurs in the speed of accelerator pedal. Excepts driver control the vehicle by judging the vehicles speed. That is why for the fuzzy controller as the input variable two independent variables can be chosen, they are the speed of the accelerated pedal opening and the speed of the vehicle. To improve the sensitivity of the operation the torque map curve is added in the integrated mode. For the better achievement of the driver’s intention this article proposed to take the compensation torque as output, speed and pedal opening rate as input and then fuzzy controller designed[46].

14. Driving characteristics of electric vehicles: -

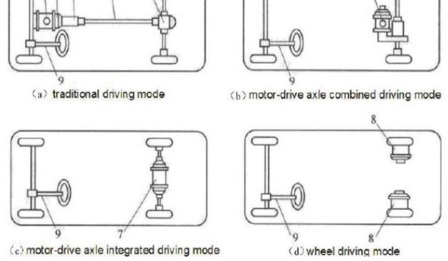

Fig. 10: Drive mode of electric vehicle drive system

The basic requirement for driving control system: -

1. Power should be high. Usually, maximum power reaches (1-1.25) kW/kg.
2. Motor Speed should be a large range. Maximum speed usually reaches 20%-100%. For maximum speed of the electric vehicle and highway Patrol of the vehicle, the performance may have permanent power and small torque.
3. Adaptability of the environment should be good.
4. Torque response should be fast. In all ranges of speed, the driving control system can control the braking torque and driving torque mildly and quickly.
5. Motor should have maximum controllability, dynamic characteristics, and a good steady state.
6. Efficiency should have good characteristics.
7. Starting torque should be sufficient to satisfy the demand of fast starting, climbing, accelerating, and sudden start/stop[47,48)].

15. Driving control of the electric vehicle: -

Electric vehicles have a much more flexible structure than fuel vehicles, in fuel vehicles, power is transmitted by coupling and shaft, and in electric vehicles, the power is transmitted by flexible wire. In an electric vehicle, choosing parts and positioning the parts are flexible. The first consideration of the traditional vehicle is what kind of transmission box is chosen, and it is also an essential part of the traditional vehicle. But in an electric vehicle, the electric controller controls the torque and speed of the motor. That is why we have many choices in transmission systems during design.

In the electric vehicle driving motor many types of motor can be applied, such as AC motor, wheel motor and DC motor. Electric vehicles are very flexible. In an electric vehicle's weight, volume, and length is affected by different types of energy storage such as fuel cell, battery, high-speed wheels, and super capacities and, by all this the performance is affected also. With these different choices, the electric vehicle is designed in a much more flexible way and the best guidelines are produced. The traditional driving mode, wheel driving mode, and motor drive axle integrated driving mode are included in electric vehicle driving mode including combined driving mode.

15.1 The traditional driving control: -

In present trends, EV uses traditional driving modes which is traditional clutch transmission shaft drive axle wheel driving mode.

Characteristics of traditional driving mode-

- Motor replaced the engines.
- Low efficiency and complex structure.
- Uses of the transmission system of engine vehicles, including shaft, clutch, driving axle and transmission, are still going on.
- Driving modes have different kinds like P-R, F-F.

15.2 Motor drive axle combined driving mode: -

Motor drive axle combined driving system is to install the speed differential gear and speed-reducing gears under the motor output's shell. Through the two half axes which are on the left and the right the power drives the wheel. The speed reducer, the driving axle, and the shells of the motor are joined together and their axis is reciprocally paralleled. Thus, the entire driving system has become more compact.

Characteristics of the motor drive axle combined driving mode-

- It has high transmission efficiency.
- It has easy installation and compact transmission.
- Driving modes have different kinds like P-R, F-F.

15.3 The motor drive axle integrated driving mode:

Motor drive axle integrated driving system is manufactured as a hollow shaft. It can be devised under the electric vehicle frame; it has a low volume and a compact structure.

During integrated driving mode can create an integrated driving axis transmission system with twin motors. In this figure, mechatronics is realized by removing the gear.

Characteristics of motor drive axle integrated driving mode-

- It has high efficiency and compact transmission.
- Easy installation.
- On the cover of the motor install the difference edge finder and gears.
- Driving modes have different kinds as R-R, F-F.

14.4 Wheel motor drive mode

From the traditional driving mode of fuel vehicles, the distributed driving system of the wheel motor is completely separated. In electric wheel driving the motors are installed in the wheels. It can exceed the space for transmission to set the parts of the vehicle and sprung mass can be reduced. Wheel motors can be deployed in the two rear wheels or four wheels, forming front-wheel driving mode, two front wheels, 4-wheel driving mode or rear-wheel driving mode.

Characteristics of the wheel motor driving mode-

- The mass of the whole vehicle has been reduced because of removing the transmission, clutch, shaft, differential and transmission system.
- On the 4-wheel pure electric vehicle if 4WS technology is applied then the performance of the steering will be realised. Even if the training radius is 0 then the training radius will be reduced, thus the flexibility of steering increased greatly.

- The connection among the power source and electric wheels is flexible cable, which uses small space
- For improvement of the energy usage the retrieve system of braking energy is applied on each wheel. The energy retrieved is more compared with a single motor driving vehicle.

Electrically driving vehicles have little mechanical and magnetic noises and also reduce the noise as compared to fuel vehicles. [48–50]

16. Electric vehicle controller design for different motors: -

The electric vehicle runs by the motor, which is supplied through the battery from the controlled power circuit. For auto electronics, there are is lot of auxiliary control other than the circuit for control of the motor. The control strategies are implemented in the microprocessor, like a Digital signal process. The control of electric vehicles is virtually the control of the motor. The different motors only replace the motor and its rising power circuit. Different control strategies of motors are used for different motors. Generally, for DC motor the PWM (Pulse width module) control is used, for induction motor direct torque control, field-oriented control, variable voltage variable frequency is used. Many modern technologies are used for electric vehicle control like as fuzzy control, adaptive control, and expert systems[51].

17. Motor Controller

The motor controller is a combination of embedded micro-computing elements powers were electronics to make efficient conversion of energy stored in an EV's battery to generate motion. Transferring energy from the battery to motorboating to acceleration for the vehicle. An embedded system is a combination of computer hardware along with electrical parts and system software to perform some specific tasks.

18. Parts of the motor controller:

Basic Motor the controller has two parts which are power unelectronic embedded micro-computing element. The microprocessors are the heart of the controller system. Micro Processor has an embedded firmware to realize all the functions the motor controller.

Power elements: Power elements is a part of power electronics in a controller which is a bi-directional power converter. Power element capability to transfer energy from battery to motor and vice versa.

Input connection: Input connection connected to the power element and input interfaces connection like as brake, forward, reverse, and throttle.

Communication Interfaces: Communication interfaces are connected to the microprocessor. Communication interfaces wireless or wired technologies are used to connect devices to the Internet, remote servers, etc.

Sensing/Protection: Sensing element measures all parameters of the system like battery voltage, current, motor speed control, voltage control, current control, etc. In an event of any faulty condition(s), the system will detect and trigger/activate self-protection.

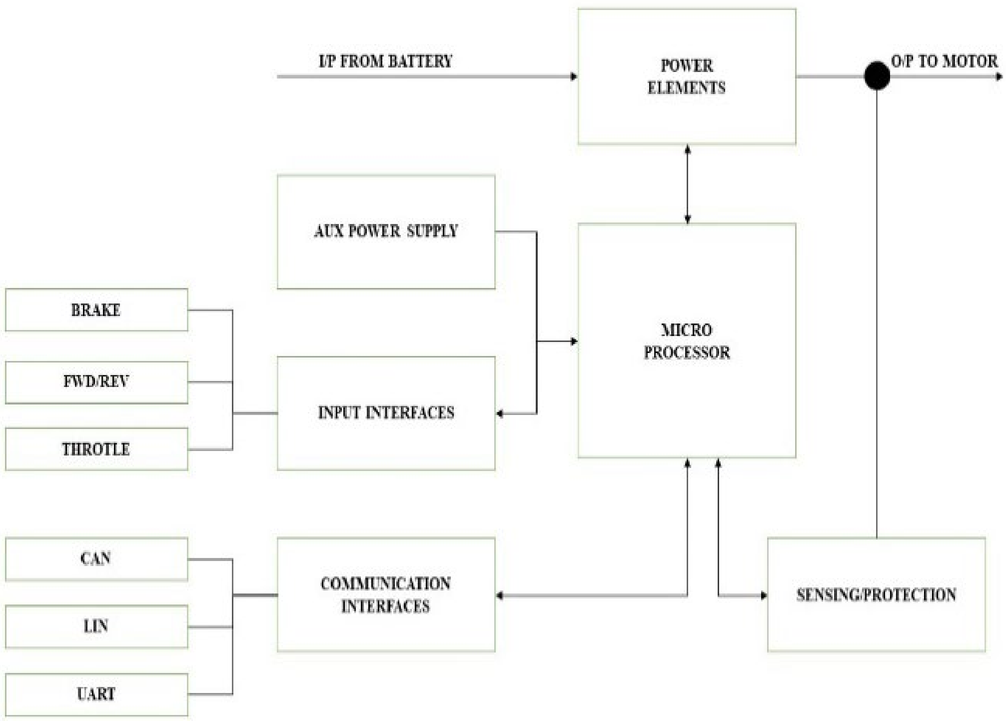

Fig. 11: Block diagram representation of motor controller parts

19. Types of motor development in the electric vehicles: -

Different types of electric motors, each with a unique combination of benefits and drawbacks, are used in electric vehicles (EVs). The selection of a motor type is influenced by a number of variables, including price, effectiveness, power output, and application. Here are some notable benefits of the primary motor types utilized in electric vehicles.

18.1 Classification of EV Traction Motor:

Mainly traction motors include direct current motors (DCMs), induction motors (IMs), permanent magnet motors (PMMs), and switched reluctance motors (SRMs). A permanent magnet motor is divided into permanent magnet direct current, permanent magnet synchronous motor, permanent magnet brushless direct current motor, and permanent magnet hybrid excitation motor[52)].

18.1.1 DC Motor:

Direct current motor is used as a traction motor in electric vehicles it is an old model from the 19th century and its performance is very poor. However simple speed regulation, low efficiency, large mass, and poor reliability. They are used only for low speed, such as conveyer of logistic cargo moving inside plants

18.1.2. Switched reluctance motor:

Switched reluctance motor rotor and stator are composed of silicon steel laminates and adopt a salient pole structure. On the stator, simply concentrated windings are installed and no-slip rings and windings on the rotor. In switched reluctance motor the rotor structure enables simple, low cost robust, and high-speed operation. The short circuit fault is prevented by its inverter's reliable structure[53)]. SRMs are able to produce tremendous power output for their size due to their high torque density. They have a reasonably straightforward design and don't use permanent magnets, which can save production costs and increase dependability. SRMs are appropriate for tough situations since they are less susceptible to changes in temperature and magnetic field.

18.1.3 Induction motor:

Induction motors (IMs) are more dependable and require less maintenance because they have fewer moving parts. They also endure wear and tear less frequently. Compared to PMSMs or other advanced motor types, IMs are frequently more affordable to build. They are appropriate for a variety of working settings since they can manage fluctuations in voltage and temperature better. With different power range induction, the motor can easily run at 15000 rpm high speed. Characteristics of an induction motor of having low-cost mall torque ripple, maintenance-free simple and strong structure, low noise, and high reliability. In electric vehicles widely-used motors are induction motors. In electric vehicles squirrel, cage induction motors are used widely[54)].

19.1.1 Permanent magnet motor:

1. Permanent magnet direct current motor- PM-DCM (permanent magnet direct current motor) is established by replacing magnetic poles and field windings of conventional DCMs (direct current motors) with PMs (permanent magnet). Due to the brush system and commutator PMDCM needs to exhibit low life and more maintenance and torque fluctuation and it shows a higher power efficiency and density.
2. Permanent magnet synchronous motor (PMSM): - The high efficiency of PMSMs, particularly at higher speeds, translates into superior overall energy efficiency and a greater driving range. PMSMs are suited for a range of vehicle sizes because they are often smaller and lighter than some other motor types. For optimum energy economy and a comfortable driving experience, they provide precise control of speed and torque. Regenerative braking, which enables the vehicle to collect energy while braking and enhance overall efficiency, is a good fit for PMSMs. In a permanent magnet synchronous motor its stator is similar to the sync heinous motor stator and the induction motor or stator has three phase winding. In traditional synchronous motor the excitation winding is replaced by the permanent magnet. The feature of well-designed interior permanent magnet is simple structure, low heat, high reluctance torque, small package, high power factor and low noise. Interior permanent magnet becomes dominant applications in traction motor with the development of power control strategies.
3. Permanent magnet brushless dc motor (BLDC): - Permanent magnet brushless dc motor is a special permanent magnet synchronous motor theoretically and structurally, but the waveshape of stator current is trapezoidal rather than sinusoidal in surface permanent magnet and it's winding are normally concentrated[55)] BLDC motors are appropriate for both low-speed and high-speed applications because they have good efficiency over a broad speed range. They last longer than conventional brushed DC motors because their brushes endure less wear and tear. Driving is usually quieter contributing to the silent operation of BLDC motors.

20. Motor Controller Technologies

Electric vehicle (EV) performance is significantly influenced by motor control technologies. These technologies affect variables like acceleration, energy usage, and the overall driving experience by determining how effectively and efficiently the electric motor transmits power to the wheels[56]. The exact motor type, vehicle design, economic concerns, and the desired balance between performance and energy efficiency all play a role in the decision of which motor control system to choose.

The Permanent Magnet Synchronous Motor (PMSM) control technology, among its other types include, variable-voltage-variable frequency (VVVF) control method. In this high-performance technology, three methods are used: The constant voltages-per-frequency (V/F=constant), field-orientation control (FOC) and direct torque control (DTC). Three motor method is following in table where 3 methods of controlling technology has been mentioned below[57]. Namely, V/F C, FOC and DTC.

20.1 Constant Voltage/Frequency Ratio Control (VF Control):

Control v/f ratio control is known as constant flux control. Constant v/f ratio control can receive the constant flux and it can guarantee that the stator voltage per frequency maintains ate constant. In an N-T coordination system the state feedback control was adopted and for PMSMs a new sensor less voltage per frequency control method was proposed[58]. The T-axis current is kept the system ate high stability in the low speed of the motor. A velocity stability loop is added to operate the motor stable at high and medium frequency. And for compensation an active power disturbance component is extracted[59]. It is used to operate the motor in stable condition at medium and high frequencies. Voltage/Frequency control is common method for induction-motor speed control. However, the robustness and starting performance is comparatively low among the other two technologies.

20.1.1 Field Orientation Control (FOC):

Field Orientation controlling technology (FOC) is used in alternating current (AC) synchronous and/or induction motor for controlling speed variably, similar to that of an unexcited DC Motor 50). FOC is significantly efficient in running as it generates maximum torque at almost zero speed, which results in the improvement of vehicle driving range. It also acquires less power and reduction in energy consumption Despite its complex structure, it provides quick acceleration and deceleration. In 1970s, field orientation control was proposed by Blanche. Under the constant rotor flux in the special coordinate system the stator current was decoupled within the magnetized and the torque component. An unexpected DC motor can be equivalent to the control of an alternative current AC motor. On the basis of the motor speed-torque-current diagram a vector control strategy is proposed[60]. The energy consumption and the power demand were effectively diminished, and the range of vehicle driving is extended. Because of an estimator with disturbance and the improved uncertainty a flux weakening control strategy is proposed. At the flux weakening the robustness is enhanced consequently.

20.1.2 Direct Torque Control (DTC):

DTC controlling technology influences the torque and flux which can be changed instantly by changing the references. The losses in this technology are reduced as transistors are switched only when the torque and flux is needed be within their hysteresis bands, Hence, the switching losses are minimized. Used to generate PWM modulation signals in a 2-phase static coordinate[61]. By Depenbrock, the direct torque control was proposed. In a two-phase coordination to generate PWM modulation signal the two-bit bang-bang control is used. Advantages of DTC are fast dynamic response, strong robustness, simple structure, and low sensitivity to parameter; accordingly, these advantages are suitable for application requiring wide speed regulation and rapid dynamic response. For optimal switch selection, the weighting factor adjustment was not required now. A voltage vector allocated strategy was proposed on the basis of the dual space vector (PWM) pulse width modulation control scheme. The accurate speed tracking, instantaneous torque response, and small torque ripple were achieved[62]. The harmonic current was suppressing by the final voltage vector of the stator was obtained; hence the performance is unchanged in the good steady performance and the fast-dynamic response. A novel multi-machine robust DTC scheme was proposed on the basis on the nonlinear model prediction method[63]. The harmonic voltage elimination methods (HVEM) and the quadratic estimation method (QEM) was proposed for improving control strategy[64]. Emphasizing on the reference value, the switching frequency of the transistors is not constant. Although, the average switching frequency can be kept almost at its reference value by controlling the width of the tolerance bands[65]. However, the torque and current ripples at low speeds is considered as a drawback in most cases[66].

20.1.3 Distributed control system (DCS)

A distributed control system (DCS) can improve the electric vehicle (EV) control network by offering a platform that is more adaptable, responsive, and reliable for managing many aspects of the vehicle's operation. A distributed control system improves the electric vehicle's control network by offering an adaptable, versatile, and networked platform that maximizes driving efficiency, user safety, and comfort. DCS will be crucial in enabling cutting-edge features and enhancing the general functionality of electric vehicles as EV technology continues to improve.

21. Mitigation of EV motor failures by changing control method

Adopting measures that improve motor dependability, longevity, and overall performance is necessary to mitigate electric vehicle (EV) motor failures through modifications to control mechanisms. There are some ways to mitigate motor failures by modifying control methods[67]:

21.1 Current Limiting and Overcurrent Protection:

To stop the motor from working at currents higher than those specified in the motor's design, implement current limiting and overcurrent protection in the motor control system. This reduces the risk of overheating and damage from too much current.

21.2 Thermal Management Control:

Create advanced thermal management control algorithms to track and manage the operational temperature of the motor. This ensures that the motor doesn't overheat or experience thermal deterioration by keeping it within safe temperature ranges.

21.3 Voltage and Torque Control:

In order to control the motor's performance under a variety of load scenarios, use precise voltage and torque control algorithms. By doing this, the motor will experience less strain and will endure less wear and tear.

21.4 Dynamic Load Balancing:

Implement dynamic load balancing algorithms that distribute load among multiple motors in multi-motor EVs. This prevents overloading of individual motors and extends their lifespan.

21.5 Advanced Feedback Control:

Utilize advanced feedback control systems, such as field-oriented control (FOC), which provide precise control over motor current, speed, and torque. FOC can optimize motor efficiency and reduce stress on motor components[68].

21.6 Vibration and Resonance Analysis:

Implement control methods that monitor and analyze motor vibrations and resonance frequencies. By avoiding operation at resonance frequencies, you can prevent mechanical stress and failures[69].

21.7 Predictive Maintenance Algorithms:

Develop predictive maintenance algorithms that monitor motor performance and provide early warnings of potential issues. This allows for proactive maintenance to address problems before they lead to motor failure.

21.8 Fault Detection and Diagnostics:

Implement fault detection and diagnostic algorithms that continuously monitor motor performance and identify abnormal behavior or degradation. Quick diagnosis can lead to timely repairs or replacements[70–72].

21.9 Dynamic Voltage Regulation:

Use dynamic voltage regulation to ensure that the motor receives the correct voltage, even under varying conditions. This prevents overvoltage or undervoltage scenarios that can damage the motor.

21.10 Integration with Battery Management System (BMS):

Integrate motor control with the BMS to optimize motor operation based on battery state of charge (SoC) and health. Adjusting motor parameters according to battery conditions can prolong both motor and battery life.

21.11 Driver Assistance Systems:

Incorporate driver assistance systems that help drivers operate the vehicle more efficiently. For instance, provide real-time feedback on acceleration and braking behavior to promote smoother driving and reduce stress on the motor.

21.12 Adaptive Control Algorithms:

Develop adaptive control algorithms that adjust motor control parameters based on real-time operating conditions, load, and environmental factors. This allows the motor to operate optimally in various situations.

21.13 Robustness Testing:

Subject control algorithms and motor systems to rigorous testing under extreme conditions to ensure their robustness and reliability[72]. Identify weaknesses and vulnerabilities in the control methods and address them.

21.14 Redundancy and Failover Systems:

Implement redundancy and failover systems for critical components, including motor controllers. This ensures that if one system fails, a backup system can take over to prevent motor failure and maintain vehicle operation.

By modifying control methods and implementing advanced control strategies, EV manufacturers and engineers can significantly reduce the risk of motor failures, enhance motor reliability, and extend the lifespan of EV motors. These strategies contribute to the overall durability and performance of electric vehicles.

22. Potential Limitations or Drawbacks of the EV conversion process

The transition from internal combustion engine (ICE) vehicles to electric vehicle (EV) vehicles offers a variety of benefits; however, it is essential to take into account the various restrictions and drawbacks involved in the process. The following are some important constraints that should be kept in mind:

22.1 The price of the conversion:

Converting a gas-powered car to one that runs on electricity can require a substantial initial financial investment. The price covers not only the materials necessary for the conversion, such as the electric motor, battery pack, and motor controller, but also the labour involved in the process. Over time, these expenditures can end up cancelling out any possible savings on fuel.

22.2 Labour and Expertise in Various Technical Fields:

The process of converting an internal combustion engine vehicle into an electric vehicle involves specialised knowledge and abilities, notably in the fields of electrical and mechanical engineering. This can restrict access to conversions to just those individuals who possess the appropriate skills or those individuals who are ready to pay for professional services.

Procedural Steps That Take A Lot Of Time: The conversion process might be time-consuming, which can result in the vehicle being out of service for a longer period of time.

22.3 Constrained Scope:

Converted electric vehicles typically have a shorter range than purpose-built electric vehicles because of the complexity of the conversion process. The restrictions of battery capacity and energy density can have an effect on the distance that can be driven between charges.

22.4 Both in Weight and in Space:

Increase in Weight: The incorporation of hefty battery packs and other electric components might lead to an increase in the total weight of the vehicle. This additional weight may have an effect on the performance, handling, and energy efficiency of the vehicle.

Place Restriction: Locating an appropriate place in which to install the battery pack in addition to the other components might be difficult, particularly in vehicles that are smaller or more compact.

22.5 Compliance with Regulations Regarding Safety:

Regulatory Compliance and Safety Standards All conversions are obligated to meet all applicable safety and regulatory compliance standards. It may be difficult and expensive to ensure that the converted vehicle conforms to all of the applicable local and national regulations.

22.6 The Warranty and Resale Value of the Product:

Voided Warranties: In many instances, conducting an EV conversion on a brand-new car might void the warranty that was originally purchased with the vehicle, leaving the owners responsible for any potential future repair costs.

Value at Resale There is a possibility that converted automobiles will have a lower resale value in comparison to their original ICE equivalents. This is due to the fact that prospective purchasers may have reservations about the quality of the conversion work.

22.7 Limited Capacity of Available Charging Infrastructure:

Infrastructure for Charging Vehicles The availability of charging infrastructure can be limited in some areas, making it difficult for owners of converted electric vehicles to find charging options that are convenient for them.

22.8 Outdated Automobiles:

Donor Vehicles that Are Appropriate In general, conversions are easier to accomplish with older vehicles. This is because retrofitting current automobiles can be difficult technically due to the complexity of their electronic systems.

22.9 Considerations Regarding the Environment:

The correct disposal and recycling of batteries that have been used in conversions is essential to reducing the amount of negative influence that is had on the environment. The disposal of batteries might be an environmental issue if it is not managed in a responsible manner.

22.10 The Variability of Performance:

Performance that is Not Consistent The quality and performance of conversions can differ depending on the components that are used as well as the experience of the team that is performing the conversion. There is a possibility that some conversions will not reach the same performance criteria as purpose-built electric vehicles.

22.11 Fear of Being Surrounded:

Limited Range Confidence: Drivers of converted electric vehicles may have "range anxiety," which is the fear of perhaps running out of battery charge while on a drive. This fear is exacerbated in regions that have a limited number of charging infrastructure options.

23. Conclusion

The components involved in the conversion of conventional vehicles into an electric vehicle in relation with their placements plays a significant role in achieving a successful conversion.

The placement of major components in general are determined in order to gain an efficient performance of EV among other factors contributing it. The objectives are obtained in order to achieve the successful conversion of the test vehicle. The gearbox ratios in different combinations are also to be focused upon including various tests and experimentation. Electric vehicle controller is an important component in the vehicle control system. The key role in controlling parts is in the moving car, driving moment control, braking control and optimisation, management of energy in vehicle, CAN network management and maintenance, fault diagnosis and treatment. In controlling part introduces the composition of electric vehicle control network and using distributed control system is determined, and then describe the construction of the control system of electric vehicle network and then finally put forward the main functions of the controlling of the electric vehicles. In which, there are 6 main functions of the controlling of electric vehicle controller; drive torque control, optimization of braking energy, energy management in vehicle, maintenance and management, fault diagnosis and processing, monitor the vehicle condition.

23.1 Future advancements in motor control technologies for electric vehicles (EVs)

23.1.1 Efficiency of the Motor Improved:

Innovative Motor Designs: The goal of ongoing research and development work in this field is to find ways to increase the energy efficiency of electric motors. In the quest to maximise power production while simultaneously minimising energy losses, advanced motor designs are being investigated. These designs include the use of innovative materials and magnet topologies.

23.1.2 Controllers for Intelligent Motors:

Integration of AI and Machine Learning: It is quite likely that artificial intelligence (AI) and machine learning algorithms will be integrated into future motor controllers. These systems are able to respond to changes in driving circumstances, thereby maximising fuel economy by enhancing power delivery and regenerative braking.

Predictive maintenance is a feature that may be included in motor controllers. This feature makes use of data analytics to predict and avoid problems with motors before they result in failures.

23.1.3 Configurations with Multiple Motors:

Individual Motors for Each Wheel: Multi-motor designs, in which each wheel is controlled by its own motor, can enable precise control over the vehicle's traction and stability. It is possible that this technology may become more common, particularly in electric vehicles with great performance.

Wireless motor control as well as wireless charging:

Wireless charging systems that can charge the car while it is moving (also known as "dynamic wireless charging") may become increasingly widespread in the future. It will be necessary to modify motor controllers so that they can simultaneously manage the flow of energy from the charging infrastructure and the battery.

23.1.4 Recovery and Generation of Lost Energy:

Advanced Regenerative Braking: The motor control systems of the future may be able to improve the effectiveness of regenerative braking by improving their ability to foresee driving circumstances and optimising energy recovery. This has the potential to further increase the driving range of electric vehicles.

23.1.5 Inverters with a High Frequency:

Technology Relating to High-Frequency Inverters High-frequency inverters have the potential to provide faster and more precise control of the electric motor, which in turn results in enhanced power delivery and lower energy losses.

23.1.6 The Integration of V2G:

Vehicle-to-Grid (V2G) Capabilities: Advanced motor control technologies will make it possible for electric vehicles to smoothly integrate with the electrical grid, not only for the purpose of charging, but also for the purpose of feeding extra energy back into the grid at times of peak demand. This will allow grid operators to give financial incentives to owners of electric vehicles.

23.2 Environmental Implications of EV Conversions

The widespread usage of electric vehicles (EVs) offers the possibility of lowering emissions of greenhouse gases and lessening the negative impact that the transportation industry has on the surrounding environment. Although electric cars (EVs) have many positive effects on the environment, such as no emissions from the tailpipe and less reliance on fossil fuels, it is vital to investigate the environmental repercussions that would result from switching conventional vehicles powered by internal combustion engines (ICE) to EVs.

23.2.1 Emissions of Greenhouse Gases That Are Lower:

Elimination of Tailpipe Emissions Eliminating emissions from the tailpipe is one of the most significant environmental benefits that can be gained from converting ICE vehicles to EVs. Because electric motors don't produce any direct emissions, they help reduce overall emissions of greenhouse gases, which is especially beneficial in metropolitan settings.

23.2.2 The Origin of Energy Is Important:

Impact of Electricity Generation The environmental impact of electric vehicles is heavily dependent on the type of electricity that is generated to power the vehicles' charging stations. The environmental advantages of electric vehicles are accentuated in areas of the country where the majority of the electricity generation comes from renewable sources such as solar, wind, and hydro.

23.2.3 Production of Batteries and Recycling of Used Batteries:

Raw Material Extraction The manufacturing of lithium-ion batteries, an essential component of electric vehicles, requires the removal of various minerals and metals from their natural environments. To reduce the amount of damage done to the environment, it is vital to obtain these resources in a responsible manner and to recycle them.

23.2.4 Recycling of Batteries:

The correct recycling and disposal of batteries is essential to the reduction of waste and recovery of valuable materials, which in turn helps to reduce the environmental impact of electric vehicles.

23.2.5 Utilisation of Energy and Efficiency:

Enhanced Energy Efficiency: Internal Combustion Engine (ICE) vehicles are often less fuel-efficient than Electric Vehicles (EVs). They are able to transfer a higher percentage of the energy from the source into movement for the vehicle, hence reducing the amount of energy that is consumed overall.

23.2.6 Pollution caused by Noise:

Reduction in Noise Pollution Because EVs are quieter than their internal combustion engine (ICE) equivalents, they can help contribute to a reduction in noise pollution, which can result in urban surroundings that are more pleasant.

23.2.7 Braking with Regenerative Energy:

Energy Recovery: Electric vehicles can recover energy by utilising regenerative braking systems, which allow for the recuperation of kinetic energy that is lost during deceleration and braking. This technique increases energy economy and decreases brake wear, which leads to a reduction in the amount of maintenance that must be performed.

23.2.8 Management of Batteries at Their End of Life:

Disposal with Responsibility It is essential to ensure that used electric vehicle batteries are disposed of in an appropriate manner in order to prevent pollution of the natural environment. Recycling and reusing old batteries can help cut down on the need for fresh raw materials to be mined and processed.

23.2.9 Impacts on the Environment That Are Not Direct:

Impact on a Larger Scale The expansion of the electric vehicle sector has wider-ranging repercussions for the environment, including shifts in the construction of new infrastructure, the establishment of networks of charging stations, and the possibility of grid integration and smart grid technologies that improve energy efficiency.

It is essential to recognise that although EV conversions have the potential to make a positive contribution to environmental sustainability, the extent of that contribution is contingent on a wide range of circumstances. These considerations include the sources of energy, the management of batteries, and the responsible practises employed throughout a vehicle's life cycle. It is vital to take a comprehensive strategy that takes into consideration the entire ecosystem in order to make the most of the environmental benefits that may be gained from EV conversions. This includes everything from the generation of electricity to its final disposal.

In addition, politicians, manufacturers, and individuals alike should make an effort to make environmentally conscious decisions when converting vehicles to electric power and driving them in a way that minimises energy consumption and emissions. This can be accomplished by making environmentally conscious choices when converting vehicles to electric power and by driving vehicles in a way that reduces emissions. As a result of this, EV conversions have the potential to be a strong weapon in the transition towards a transportation system that is cleaner and more sustainable.

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