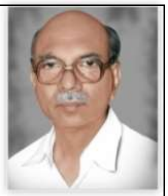


ELECTRIC VECHICLES

UNIT-I

INTRODUCTION TO EV SYSTEMS AND PARAMETERS

Past, present and future EV:

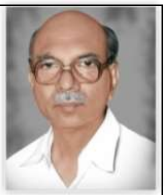
A) Past 30 years development: -

Energy and environment issues have pushed the development of EV's.In 1834, Robert Anderson of Aberdeen, Scotland built the first EV. From 1860-1924 it was golden age of EV. But from 1924-1960 due to the domination of gasoline cars, EV's have disappeared. In the early 1970s due to energy crisis i.e., petrol prices increased, electric vehicles once again grew in popularity. This created the second generation of electric cars. "A new technology started to emerge batteries improve and started making electric vehicles.

B) Present major issues: -

The major factors that make affordable are the range and cost. To tackle the range, the development of advanced batteries such as the Nickle-metal hydride (NiMH), Zinc air and lithium are in progress. The development of fuel cells for has taken on an accelerated pace in recent years. Meanwhile, the development of commercial hybrid electric vehicle (HEV, s) is also going on rapidly. HEVs improve the range performance of EVs at higher complexity and cost because of the additional energy, source, engine and other accessories.

To tackle the cost, efforts are being made to improve various EV sub systems, such as electric motors, power converters, electronic controllers, energy management units, battery chargers, batteries and other EV auxiliaries, as well as EV system level integration and optimization.



C) Future trends: -

In the next 30 years, it is anticipated that both EVs and HEVs will be commercialized, and they will have their market shares. EVs will be well accepted by some nice markets, namely the users for community transportation, the places where electricity is cheap and ease of access, and the cites with zero emission mandate. On the other hand, HEVs will have a nice market for those users desiring long driving ranges. The ultimate penetration of EVs and HEVs will mainly, depend on their respective cost, particularly the commercialization of fuel cell EVs will be accelerated in the next two decades, since they have the greatest potential to deliver some range and performance as are ICEVs. Our ultimate goal is the use of clean, efficient and intelligent. energy to achieve sustainable transportation system. The development trends of EVs & HEVs are illustrated in the figure.

EV concept:

The modern EV concept is summarized as follows:

1.The EV is road vehicle based on modern electric propulsion which consist of the electric motor, power converters and energy source and it has its own distinct characteristics.

2. The EV is not just a car but a new system for our society, clean and efficient road transportation.

3.The EV system is an intelligent system which can readily be integrated with modern transportation networks

4.EV design involves the integration of art and engineering

5.EV operating conditions and duty cycles must be newly defined

6. EV users' expectations must be studied; hence appropriate education must be conducted.

The EV system architecture consists of mechanical sub -systems, electrical and electronics sub systems, and information sub systems.

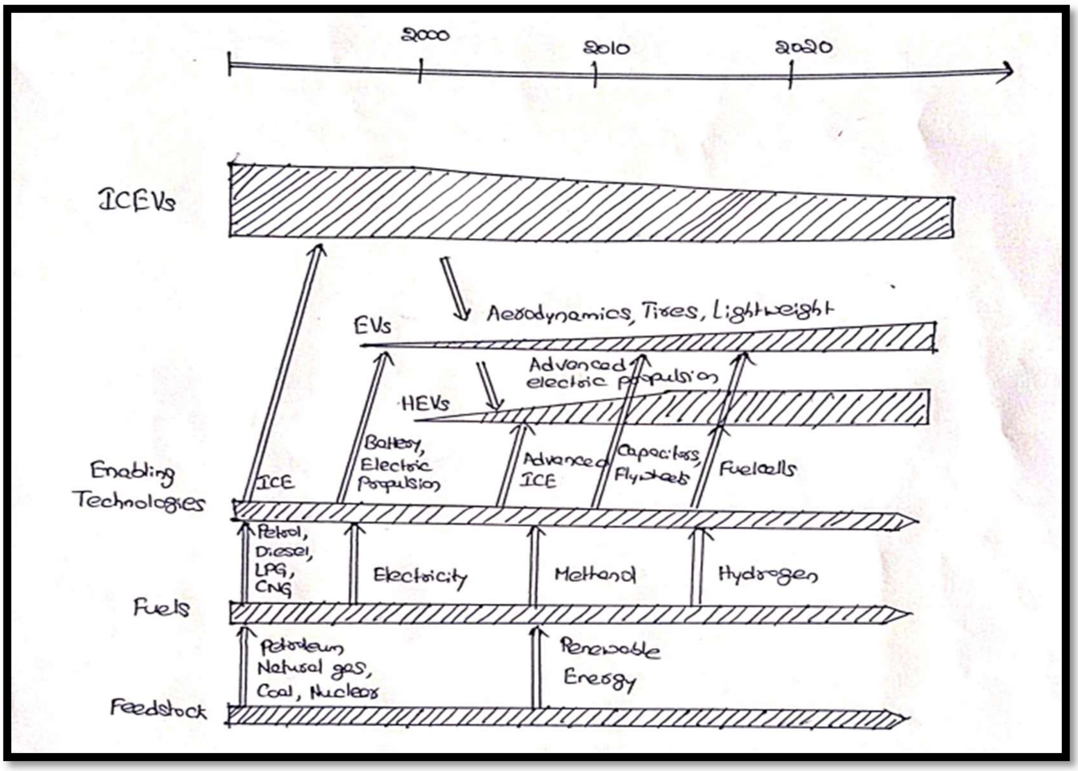


Fig: Development trends of EVs and HEVs

EV Technologies

The key technologies of EVs include automobile technology, electrical technology, electronic technology, information technology and chemical technology. Although the energy source is the most crucial area, body design, electric propulsion, energy management and system optimization are equally important. the integration of all these areas is the key to success.

Body design: -

There are two basic approaches for producing EVs

1.Conversion type EV

2. Purpose-built EV

Conversion type EV:

For the conversion type EV, the engine and associated equipment of an existing ICEV are replaced by the electric motor, power converter and battery.

EV Technologies: -

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1. Body Design-

There are two basic approaches for producing EVs

a) Conversion type EV

b) Purpose built EV

a) Conversion type EV: For the conversion type EV, the engine and associated equipment of an existing ICEV are replaced by the electric motor, Power converter and battery.

b) Purpose built EV: - The purpose-built EV takes the definite advantage over the Conversion one because it allows, He engineers having the flexibility to Coordinate and integrate various EV subsystems so that they can work together efficiently. There are some design concepts for purpose built EVs so that the overall performances such as range, gradeability, acceleration and top speed can be improved. These concepts include He consistent weight-saving design, low drag coefficient body design, and low rolling resistance concept.

2) Electric Propulsion: -

The electric propulsion system of EVs is responsible for converting electrical energy to mechanical energy in such a way that, the vehicle is propelled to overcome aerodynamic drag, rolling resistance drag and Kinetic resistance. The electric, propulsion system consists of the motor drive, transmission device and wheels.

The motor drive, comprising of the electric motor, power converter and electronic controller. The main requirements for propulsion motors are roughness, greater torque to inertia ratio, high torque density, wide speed range, low noise, low or maintenance, ease to control and low cost.

Various types of electric machine technologies are being used for automotive propulsion. These include Induction, switched Reluctance, Permanent Magnet (PM) and axial gap machines. Most of the vehicles use either Induction of PM motors for propulsion.

For transmission devices, conventional gearing can no longer satisfy the needs of EVs. Recently, planetary gearing has been accepted as the transmission device of the latest EVs.

3. Energy Sources:

At present, the main obstacles of EVs are the high initial cost and short driving range. The EV energy source has been identified to be the major cause of these problems. The main parameters in the selection of a battery for EV applications are: - power density, Energy density, weight, Volume, cost and life cycle.

Currently, there is no sole EV energy source that can fully satisfy all of Hese parameters. When batteries are selected, here are Various Compromises among Here criteria. Rather Hon based on and energy source, the use of multiple energy sources, so called hybridization of energy sources, can eliminate the compromise between the parameters.

4) Energy Management: -

Compared with Internal combustion Engine Vehicles (ICEVs), EVs offer a relatively short driving range. Thus, in order to maximize the utilization of on-board stored energy, and system (EMS) needs to be adopted." intelligent energy management (EMS) need to be adopted.

The EMS can realise the following functions:

1.To suggest more efficient driving behaviours.

2.To redirect regenerative energy from broking to receptive energy

Sources such as batteries.

3.To modulate temperature control in response to external climate.

4.To adjust lighting brightness in response to external environment.

5.To propose a suitable battery charging algorithm.

When the EMS is coupled with a navigation system, it can efficient routes, locate charging facilities for extended plan ere trips etc. In summary, the EMS has He distinct features of integrated multi-functions, flexibility and adaptability such that the limited on-board. energy can be used wisely.

5) System optimization: -

The EV System has a complex architecture that contains multi- disciplinary technologies, Since the EV performance can be affected by many multidisciplinary interrelated factors, computer simulation is the most important technology to carry out the optimization for performance improvement and Cost reduction.

The system-level simulation and optimization of EVs should consider

The following issues:

1.As the interactions among various subsystems greatly affect the performance

of EVs, the significance of Hose interactions should be analysed and taken into account.

2.Matel usability, trade-offs among the accuracy, complexity and usability.

as well as simulation time should be considered.

3.Motor dove voltage and current ratings, acceleration performance, driving range and safety should be optimized on the level. System

4.Multiple energy sources combination and hybridization ratio should be optimized on the basis of Ho vehicle performance and cost.

5.Since EVs generally adopt fixed gearing, the gear ratio can greatly affect the vehicle performance and driveability. An optimal ratio should be determined though iterative optimization under different driving profiles.

STATE-OF-THE-ART EVS:

Besides the commercialization of EV_2, He development has been. focused on the advancement of their technologies. Examples of this are the use of advanced Induction motors 06 Permanent magnet brushless motors to improve electric propulsion system, the employment of advanced to batteries, fuel cells, to improve the on-board energy source, and the adoption of Inductive charging or variable temperature seats to improve the EV auxiliaries. The most advanced propulsion Systems are showcased below.

1.GM EV2-

- General Motors developed the EV1 electric car as the world first specially designed production electric vehicle in 1997.
- The GM EV-1 is a rechargeable battery powered two-seater car. It had a front-wheel drive which adopted 1.02 kk 3-phase Induction motor and a single-speed transaxle with dual-reduction of 10.946: 1.

- It contained 26-module 312V Valve -regulated lead-acid (VRLA) batteries. Which were inductively charged a 6.6 kw off-board charger or and l2kw on board charger.
- It can achieve a top-speed of 128 km/h and an acceleration from 0 to 96 km/h in less than 9 sec. For city driving, it could provide a range of 110km per charge;
- Whereas on highway operation, it offered 144 km per charge. In 1999 the EV1 adopted nickel-metal hydride (NiMH) batteries, hence reaching 220km per charge.

2.Nissan Altra EV:

- In 1997, four-seater Altra EV has been developed by Nissan. It used a 62kW permanent-magnet synchronous motor which weighed only 39 kg, the highest power-to-weight ratio (1.6 KH/kg) for any EV motos available.
- Making use of maximum efficiency control, the total efficiency of the propulsion system was more than 89%. Power came from the cobalt-based lithium-ion batteries which had a specific energy of 90 Whing, a specific power of 300 w/kg and a long cycle life of about 1200 recharges.
- This battery pack could be charged up by an on-board inductive charging system within Sh. It could achieve a top speed of 100 km/h and a range of 192km for city driving. In 1999, the Altra adopted the manganese-based lithium-ion batteries to further increase both specific energy, and specific power to 91 Wh/kg and 350 w/kg respectively.

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3) Ford P2000: -

- Ford P2000 is four-door sedan which was launched in the year 2000 by food. It was powered by the Ford's Think fuel cell system, namely the proton-exchange-membrane (PEM) fuel cells,
- Which was fuelled by compressed hydrogen gas stored at 25MPa and oxygen gas simply from the air. It adopted a three-phase Induction Motor offering a peak power of 67KW a peak torque of 190 Nm and peak efficiency of 91%. It could achieve a top speed of 128 km/h and a driving range of 160 km per charge

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4) NECAR 3: -

- Daimler-Bent, now Daimler Chryster, presented its first methanol felled fuel cell EV in 1997 the NECAR 3. It used proton exchange. membrane (PEM) fuel cells to generate a power of 50 KW for propulsion.
- The hydrogen fuel was directly extracted from methanol via a mini reformer, thus bypassing the problem of having compressed gas canisters on board the vehicles
- The fuel cells were stored beneath the floor, while the reformer, methanol tank and control systems were located in the boot.
- The NECAR 5 launched in 2000 was the technological successor of the NECAR 3, while reducing the Size of the drive system by half and the weight of the vehicle by 300 kg. It also boasted up the power to 75 kk to reach speeds over 150 km/h.

5) Reva EV-

- The Reva EV is a two-door hatchback EV, which was touched in the Year 2001 and would be India's first moss-produced EV.
- It adopted a separately excited dc motor and a 48V tubular lead-acid battery pack. Its on-board charger (220 V, 2.2kW) Could provide 80% charge within 3h and 100% within 6h. with the curb weight of 650 kg, the Reva EV could achieve a top-speed of 65 km/h and a range of 80 km per charge.
- The most attractive feature was its incredibly low initial and running costs!

EV Configuration: -

Composed to Internal Combustion Engine Vehicle (ICEV), the Configuration of EV is flexible. The reasons for this flexibility are: -

i) The energy flow in EV is mainly via flexible electrical wires better than bolted flanges or rigid shafts. Hence, distributed subsystems in the EV are really achievable.

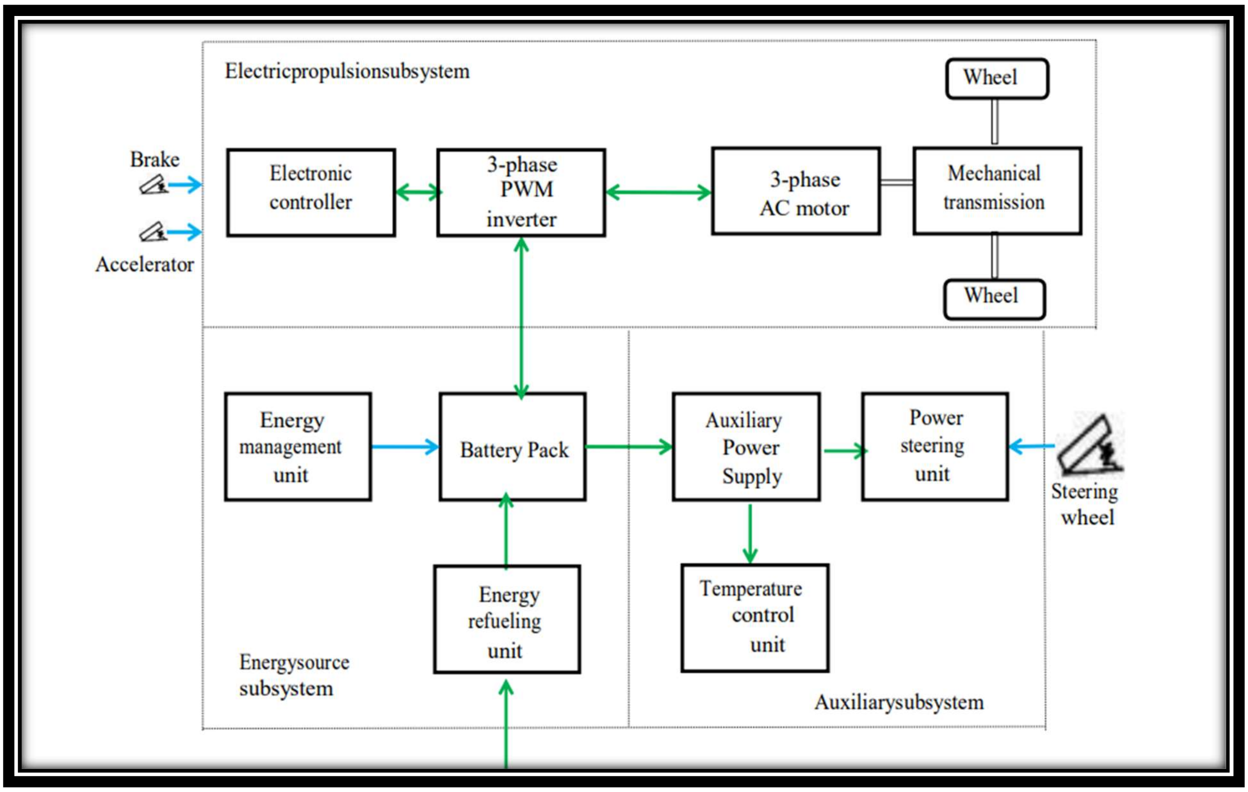
ii) The EVs allow different propulsion arrangements such as independent four wheels and in wheel drives.

The general configuration of the EV is shown in the figure. The EV has three major subsystems:

i) Electric Propulsion.

ii) Energy Source.

iii) Auxiliary system.



- The Electric propulsion subsystem comprises of The Electronic Controller, Power converter, Electric Motor (EM), Mechanical transmission Driving Wheels.
- The energy source subsystem consists of The Energy source, Energy Management Unit, Energy Refuelling Unit.
- The Auxiliary subsystem consists of Power steering unit, Temperature, Control Unit, Auxiliary power supply.
- In the figure, a mechanical link is represented by a double line, an electrical link by a thick line and a control link by a thin line. The arrow on each line denotes the direction of electrical power flow or control information.
- Based communication. the control inputs from the brake and accelerator pedals, the electronic controller provides proper Control signals to switch ON or OFF

- The power Converter which in turn regulates the power flow between the electric motor and the energy source. The backward power flow is due to regenerative booking of the EV and this regenerative energy can be stored.
- The energy management unit cooperates with the electronic controller to control regenerative braking and its energy recovery. It also works with the energy refuelling unit to control refuelling and to monitor usability of the energy Source.
- The auxiliary power supply provides the necessary powers with different voltage levels for all EV auxiliaries, especially the temperature Control and power steering units.
- Besides the brake and accelerator, the steering wheel is another Key control input of the EV. Based on its angular position, the power steering unit can determine how sharply the vehicle should turn. **(Sub systems are contd in page no, 19)**

Fixed and Variable Gearing.

Fixed gearing means that there is a fixed ratio between the gear propulsion device (ICE or electric motos) to the driving wheels.

Variable gearing involves shifting between different gear ratios, this can be accomplished by using a combination of clutch and gearbox.

The purpose of variable gearing is to provide multiple-speed transmission.

ICEVS use variable gearing as the ICE cannot offer the desired torque-speed characteristics such as high torque for hill climbing and high speed for cruising without multiple-speed transmission.

Using The typical force-speed characteristics of an ICE with five- speed transmission is shown below. Also, the force-speed characteristics of EV with fixed gearing is shown below.

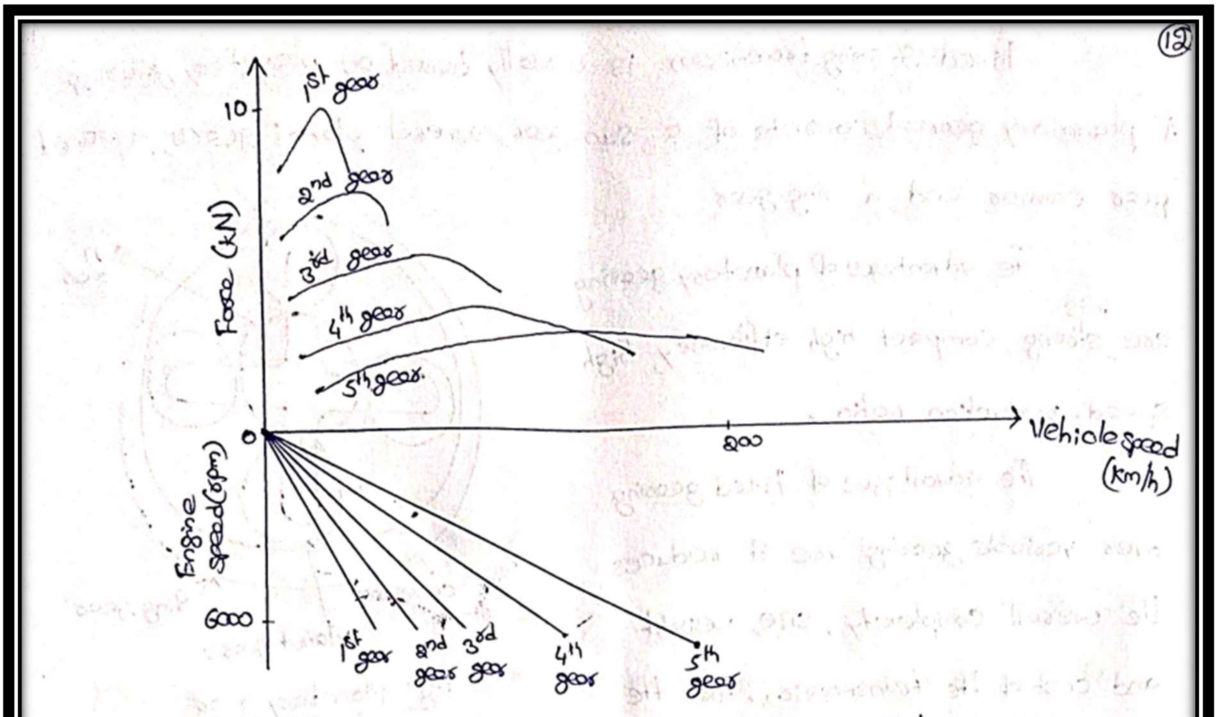


Fig:- ICEV force-speed characteristics with five-speed transmission

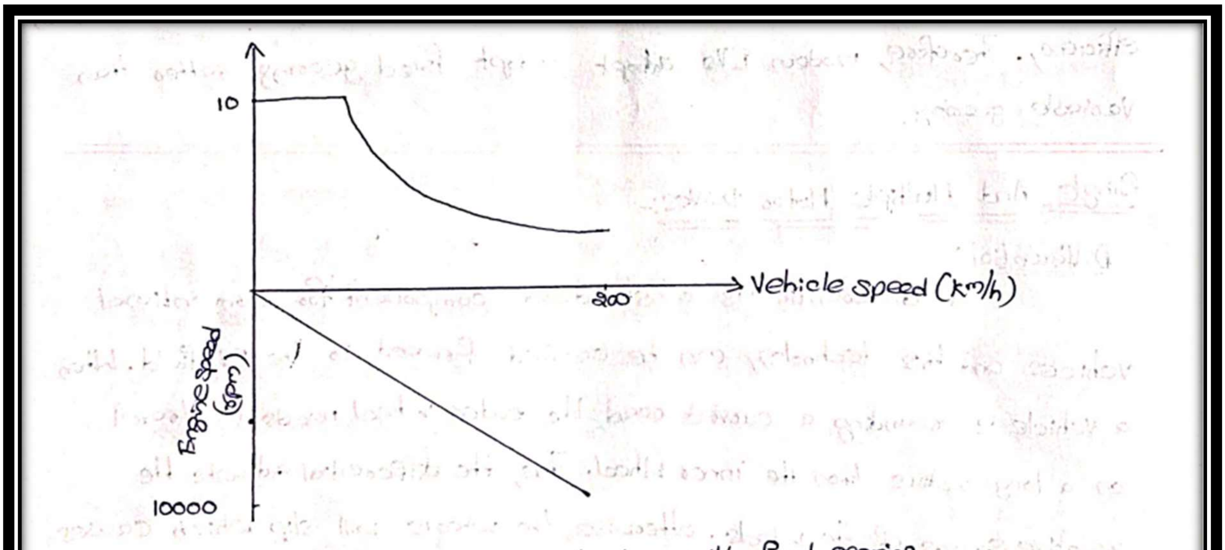


Fig:- EV force-speed characteristics with fixed gearing

The advantages of variable gearing are it can enhance the electric motor achieving regenerative braking and high efficiency operation over a wide speed range.

Fixed-gearing

Fixed-gearing transmission is usually based on planetary gearing. A planetary gearset consists of a sun-gear, several planet gears, a planet gear Carrier and a ring gear

The advantages of planetary gearing are it is strong, compact, high efficiency, high Speed-reduction ratio.

The advantages of Fixed gearing over variable gearing are it reduces the overall complexity, size, weight and cost of the transmission. Also, He Ring gear planet gears

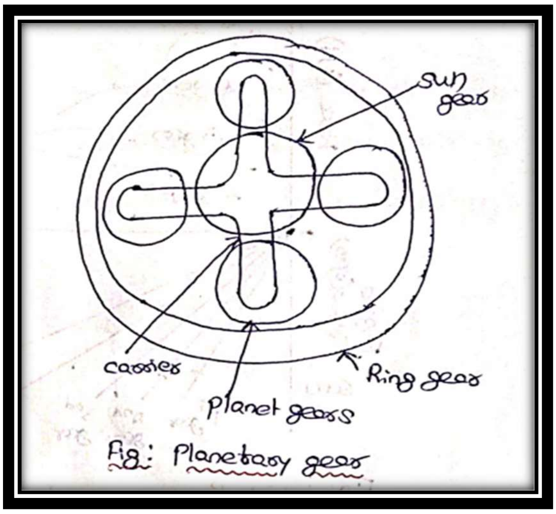


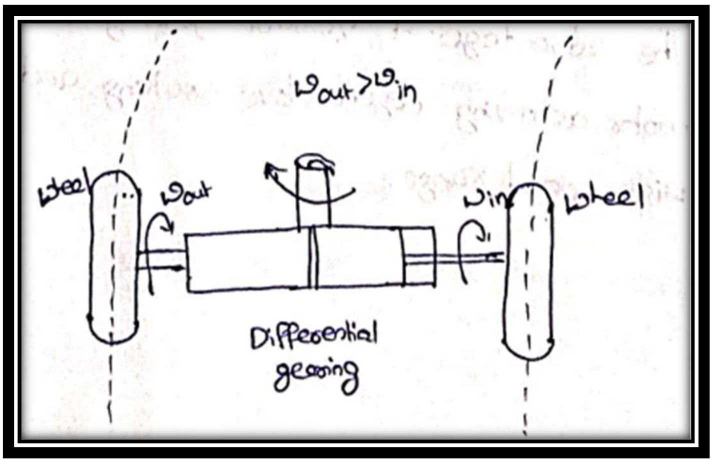
Fig: Planetary gear

Absence of gear changing can greatly enhance smooth driving and transmission efficiency. Therefore, modern EVs adopt fixed gearing rather than Variable gearing.

Single and Multiple Motor Drives: -

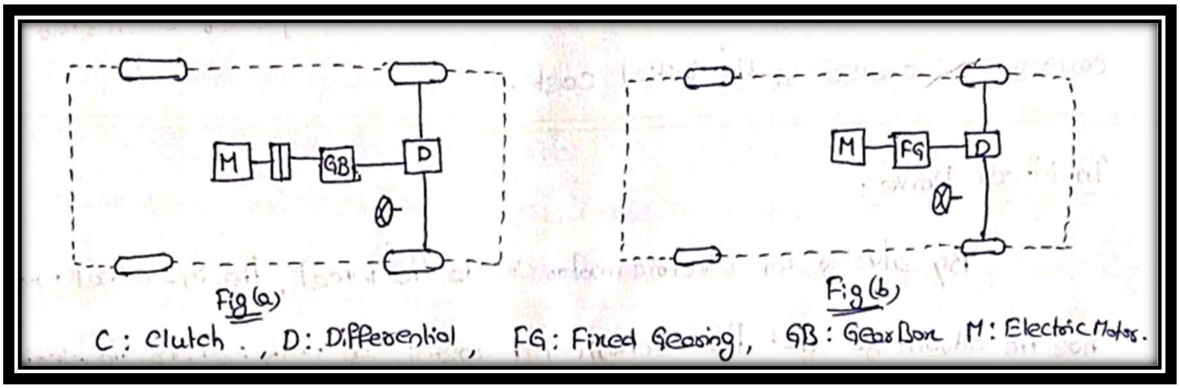
Differential:

A differential is a standard component for Conventional vehicles and this technology can be carried forward to the EV field. When a vehicle is rounding a curved road, the outer wheel needs to travel on a long radius than the inner wheel. Thus, the differential adjusts the relative speeds of the wheels, otherwise, the wheels will slip which causes tire wear, steering difficulties and poor road holding. For all ICEVs a differential is mandatory.



Single Motor Drive-

A single motor dove is a system that includes only one motor to control the speed of all the wheels. The schematics of single motor drive are shown below.

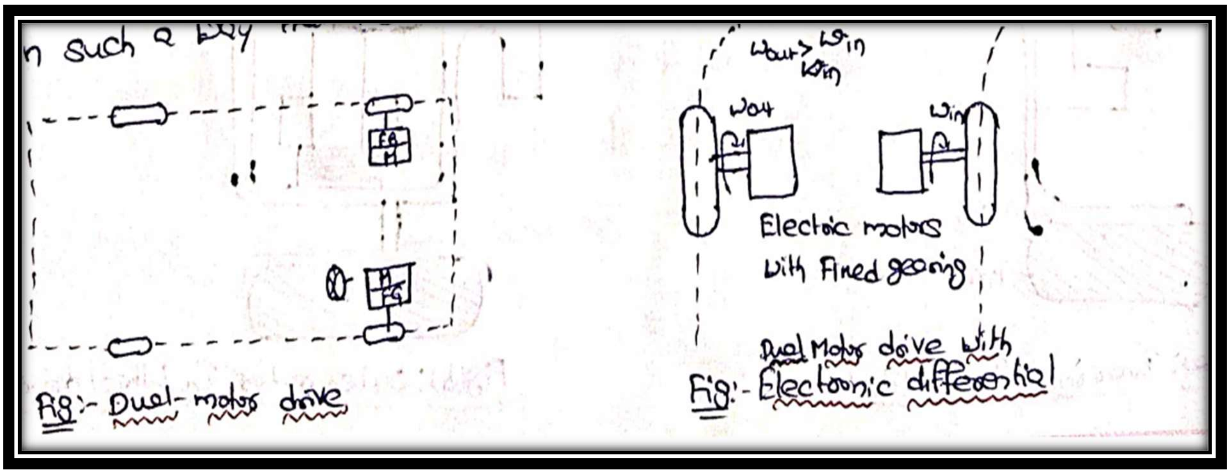


- In Fig a), it shows the first alternative which is a direct extension of the existing ICEV adopting longitudinal from engine, front-wheel drive.
- It consists of an electric motor, a clutch, a gearbox and a differential. The clutch is a mechanical device which is used to connect as disconnect power flow from the electric motors to the wheels.
- The gearbox is another mechanical device which consists of a set of gears with different gear ratios.
- In fig(b), it shows the arrangement which consists of an electric motor, fixed gearing and a differential.

- By replacing the gearbox with fixed gearing and hence removing the clutch, both the weight and size of the mechanical transmission can be greatly reduced.

Multiple Motor Drives:

A Multiple motor drive includes two or even four electric motors to the driving wheels. The speed of each wheel can be independently controlled in such a way that the differential action can be electronically achieved.



The above figures show a dual motor with an electronic differential

Advantage:

1.This arrangement is smaller and lighter than the mechanical differential

Disadvantage:

1.The use of additional electric motor and power converter causes an increase in the initial cost

In Wheel Drives:

In Wheel Drives By placing an electric motor inside the wheel, the in-wheel motor has the advantage that the mechanical transmission path between the electric motor and the wheel can be minimized. Two possible configurations for in wheel drives are:

• When a high-speed inner-rotor motor is used (Figure 6a) then a fixed speedreduction gear becomes necessary to attain a realistic wheel speed. In general, speed reduction is achieved using a planetary gear set. This planetary gear is mounted between the motor shaft and the wheel rim. Usually, this motor is designed to operate up to 1000 rpm so as to give high power density.

• In case outer rotor motor is used (Figure 6b), then the transmission can be totally removed and the outer rotor acts as the wheel rim and the motor speed is equivalent to the wheel speed and no gears are required.

The trade-offs of the high-speed inner rotor motor are:

• It has the advantage of smaller size, lighter weight and lower cost

• Needs additional planetary gearset

The trade-offs of outer-rotor motor are

• Low speed and hence does not need additional gears

• The drawbacks are larger size, weight and cost because of the low-speed design.

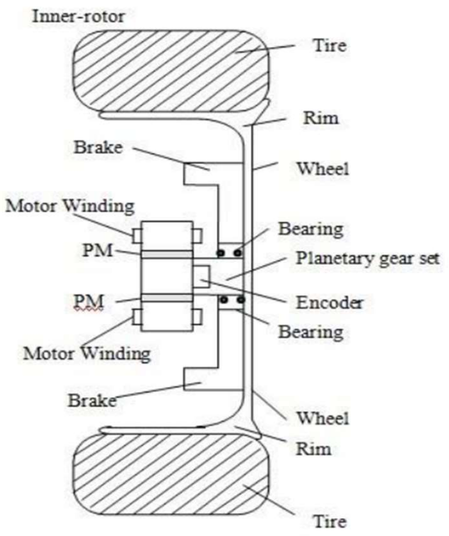


Figure 6a: Inner rotor *In Wheel* drive [1]

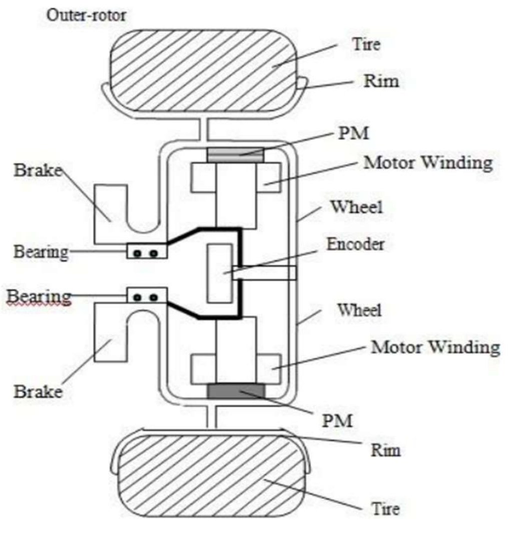


Figure 6b: Outer rotor *In Wheel* drive [1]

EV Parameters:

1) Weight and Size parameters:

Vehicle weights are key parameters in EV's because they seriously affect the driving range and vehicle performance. Their definitions are listed below

a) Curb weight: The weight excluding payload.

b) Gross Weight: - The weight including payload.

c) Payload: The weight of passengers and cargo

d) Inertia weight: The curb weight plus a standard payload

e) Maximum weight: The maximum gross weight for safety operation.

f) Drivetrain weight: - The weight of the whole drivetrain in the EV.

g) Battery weight: - The weight of the whole battery pack in the EV.

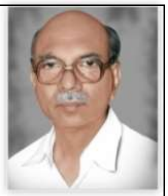
VEHICLE SIZE PARAMETERS DEFINITIONS ARE LISTED BELOW:

a) Vehicle dimensions: - The length, width, height and ground clearance.

b) Frontal area: - The equivalent frontal area affecting the vehicle aero-dynamic drag.

c)Seating capacity: - The number of passengers, sometimes adult or child is also specified.

d) cargo capacity: - The volume of cargo.

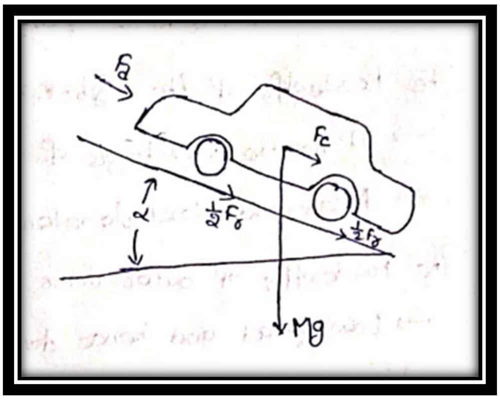


2) Force Parameters: -

The force that a vehicle must overcame to travel is known as

Road Load. As shown in the figure, this Road Load Fl consists of three mains

Components-



1) Aerodynamic drag force Fd

2) Rolling resistance Force Fr.

3) Climbing force Fc

Fl = Fd+Fr+Fc

a) Aerodynamic drag force Fd is due to the dong upon the vehicle body When moving through the air. The aerodynamic force can be expressed as

$$F_d = \frac{1}{2} \rho C_d A (v+v_0)^2$$

where C_d is the aerodynamic drag coefficient (dimensionless)

ρ is the air density in kg/m^3.

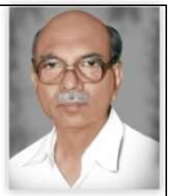
A is the frontal area in m^2.

v is the vehicle velocity in m/sec.

v_0 is the head wind velocity in m/sec.

b) The rolling resistance force is due to the work of deformation on the Wheel and road surface. Factors that affect the rolling resistance are tire types, tire pressure, tire temperature vehicle speed, tried thickness The rolling resistance force is expressed as:

Fr = Mg Cr



Here Mg is the Vehicle moss in kg.

g is the gravitational acceleration (9.81m/sec^2)

Cr is the rolling resistance coefficient (dimensionless)

c) The climbing force fc is the climbing resistance or downward force for a vehicle to climb up an incline. This force is given by:

Fc= Mg Sinα.

Where **α** is the angle of incline in radians or degree.

3) Energy parameters

The energy parameter of ICEVs can also be expressed as the per • unit volume of fuel, so called the fuel economy. The Corresponding SI unit is km/litre. Also, it is expressed as the miles per gallon (mpg) of fuel.

For battery powered EVs, the fuel economy is expressed in km/kwh.

The energy efficiency $\boldsymbol{\eta_e}$ is the ratio of energy output to energy input while the power efficiency $\boldsymbol{\eta_p}$ is the ratio of power output to power input.

$$\eta_e = \frac{E_{out}}{E_{in}}$$

$$\eta_p = \frac{P_{out}}{P_{in}}$$

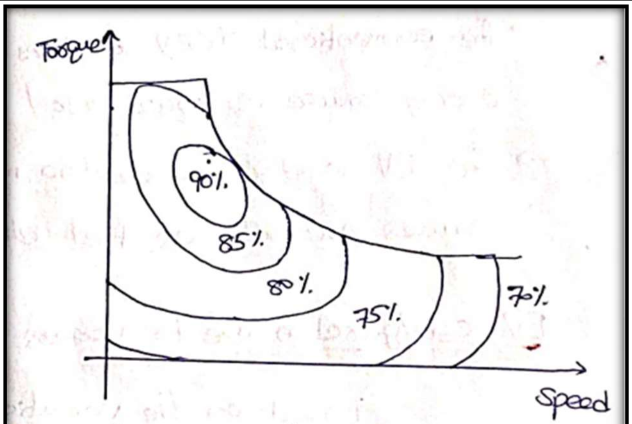


Fig :- Power efficiency map of an EV Induction motor

Instead of using a particular operating point (such as rated power at rated torque and rated speed) to describe the power efficiency of a vehicle sub-system or component, an efficiency map is generally adopted. The efficiency map of a three-phase Induction motor for propelling an EV. Hence, the energy efficiency can be derived by summing powers over a given time period.

Regenerative braking:

Regenerative braking is a definite advantage of EVs over ICEVs. During braking ,the motor operates in the regenerative mode which converts the kinetic energy during braking into electrical energy, hence recharging the batteries.

Performance parameters:

The performance parameters for EVs are listed below

i) Range per charge: The driving range in km of an EV that has been fully charged up. It can also be extended to describe the range per refuelling for those EVs adopting other energy sources such as fuel cells.

ii) Acceleration rate: -It is usually expressed as the minimum time required to accelerate the vehicle from zero to specified speed such as 40, 60 or 80 km/h.

Maximum speed: - It is the quoted maximum safe speed in km/h. that a Vehicle can attain.

EV System: -

1.The conventional ICEV employs energy source is liquid petrol a combustion or diesel. engine for propulsion. Its

2.The EV employs an electric motor and the corresponding energy sources are batteries, fuel cells, capacitors and/or flywheels. Contd in last page...

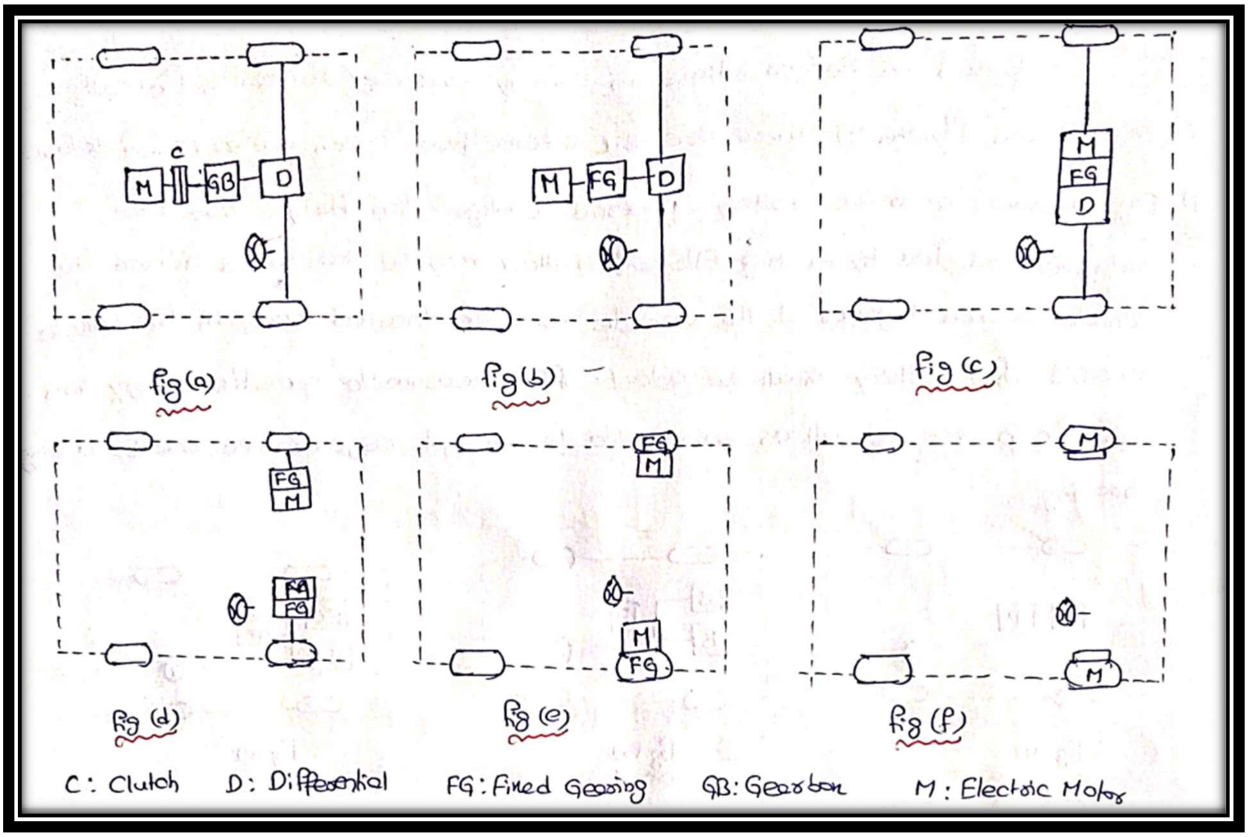
EV configuration due to various variations in electric propulsion: -

Based on the variations in electric propulsion, there are Sin alternatives which are explained below: -

i) The first alternative is a direct extension of the existing ICEV adopting longitudinal front-engine front-wheel drive. It consists of an electric motor, a clutch, a gearbox and a differential.

ii) In the second alternative the gearbox is replaced with fined. gearing. Hence removing the clutch, both the weight and size of the mechanical transmission can be greatly reduced. Fig (b) shows this arrangement which consists of an electric motor, fined gearing and a differential.

iii) In the third alternative the electric motor, fined gearing and differential are integrated into a single assembly, while both axles point at both driving wheels. Fig (c) shows this configuration.



C: Clutch D: Differential FG: Fixed Gearing M: Electric Motor GB: Gear box

iv) Besides the mechanical means, the differential action of an EV later, Concerning can be electronically provided by two electric motors operating at different Speeds. Fig (d) shows a dual motor configuration in which two electric motors separately drive the driving wheels via fixed gearing.

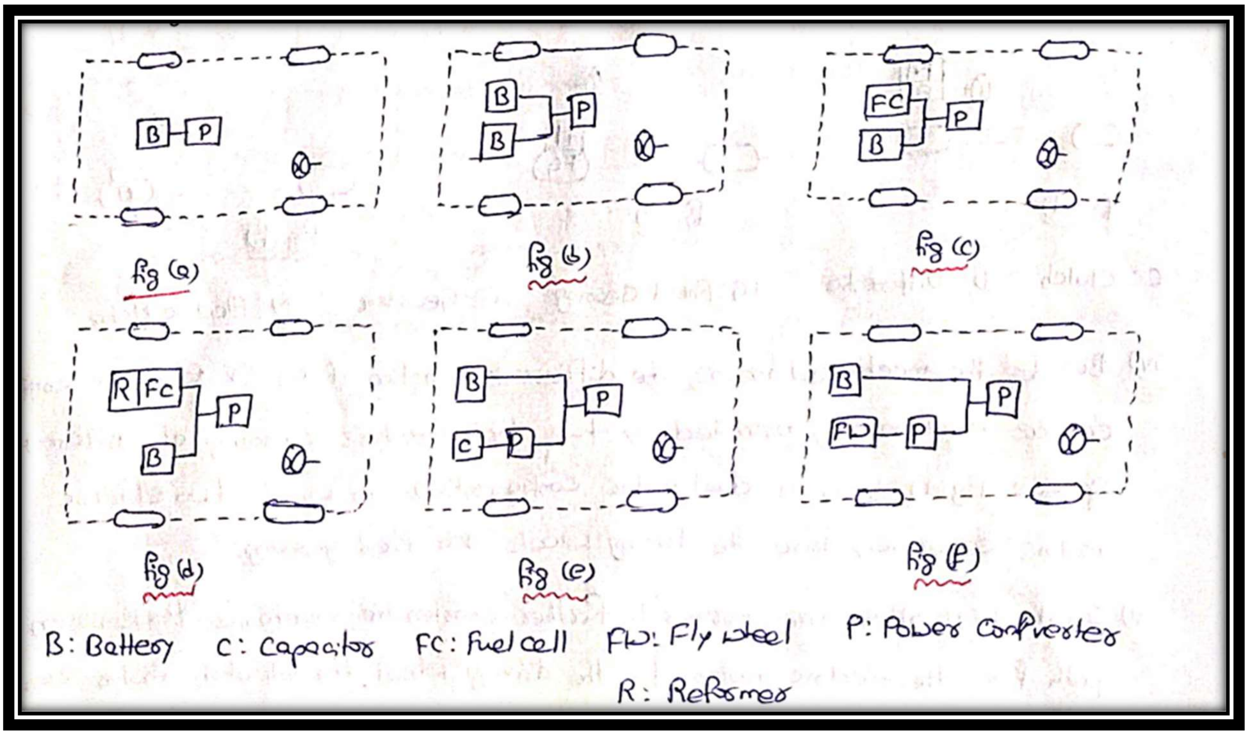
v) In the fifth alternative in order to further shorten the mechanical transmission = path from the electric motor to the driving wheel, the electric motor can be placed inside a wheel. This arrangement is the In-wheel drive. Fig e) Shows this configuration.

vi) In the sixth alternative, by fully abandoning any mechanical gearing, the in-wheel drive can be realized by installing low speed outer-rotor electric motor inside a wheel. Fig (f) shows this gearless arrangement in which the outer rotor is directly mounted on the Wheel rim. Thus, this speed Control of the electric motor is equivalent to the control of the wheel speed and hence the vehicle speed.

EV Configuration due to variations in energy sources: -

Based on the variations in energy sources (batteries, fuel cells, capacitors and flywheels), there are six alternatives which are explained debut-

i) Fig (a) shows a basic battery-powered configuration that is almost = exclusively adopted by existing EVA! The battery may be distributed around the vehicle, packed together at the vehicle back or located beneath the vehicle chassis. This battery should be able to offer seasonable specific energy and specific power as well as being able to accept regenerative energy during braking.



B: Battery C: Capacitor FC: Fuell Cell P: Power Converter R: Reformer

ii) Instead of using a Compromised battery design, two different batteries (one is optimized for high specific energy while another for high specific power) can be used simultaneously in an EV. Fig (b) shows the basic arrangement of this battery & battery hybrid energy source.

iii) Differing from the battery which is on energy storage device, the fuel cell is an energy generation device. The operating principle of fuel cells is reverse process of electrolysis - Combining hydrogen and oxygen gases to form. electricity and water. Hydrogen gas can be stored in an on-board tank.

Whereas the oxygen gas is simply extracted from air. Since the fuel cell can offer high specific energy but cannot accept regenerative energy, it is preferable to combine it with a battery with high specific power and high energy receptivity. Fig (c) shows this arrangement.

iv) Rather than storing it as a compressed gas, a liquid or a metal hydride, hydrogen can be on-board generated from ambient-temperature liquid fuels such as methanol or even petrol. As shown in fig (d), a mini reformer is installed in the EV to produce on line the necessary hydrogen gas for the fuel cell.

v) In contrast to the fuel cell & battery hybrid in which the battery is purposely selected to offer high specific power and high energy receptivity, the battery the battery & capacitor hybrid is aimed to have high specific energy. This is because a capacitor con inherently offers a much higher specific power and energy receptivity then a battery. Since the available capacitors for EV application usually termed as ultra capacitors, are of relatively low voltage level, an Additional dc-dc power Converter is needed to interface between the battery and capacitor terminals. Rig (e) shows this configuration.

vi) Similar to the capacitor, the flywheel is another emerging, energy storage device which can offer high specific power and high energy receptivity. This ultra-high-speed flywheel is incorporated into the motor of an electric machine which operates at motoring and generating modes when conventional Converting electrical energy to and from kinetic energy respectively. Fig (f) shows this configuration. Since this flywheel is preferable incorporated into an ac machine, an additional ac-dc Converter is needed to interface between the battery and flywheel terminals.

EV System:

-An EV system has the following two features: -

i) The energy source is portable and chemical or electromechanical in nature.

ii) Traction effort is supplied only by an electric motor.

An EV system driven by a portable energy source is shown below

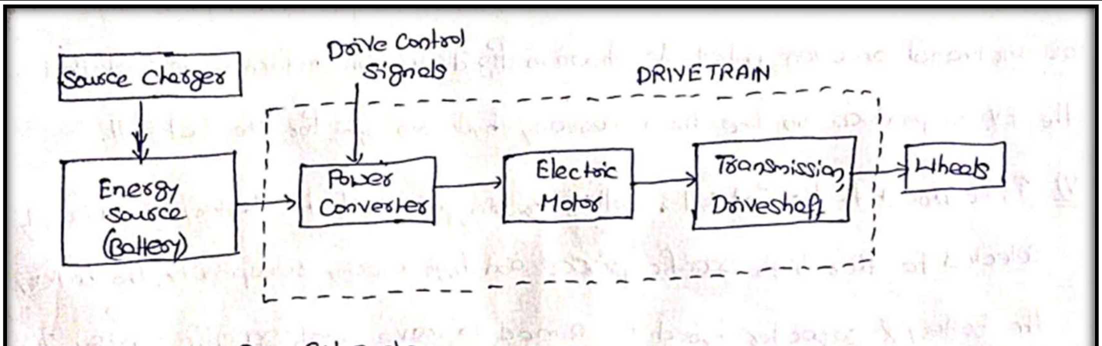


Fig:- EV system

1.The electromechanical energy conversion linkage system between the Vehicle energy source and the wheels is the drivetrain of the vehicle. The drivetrain has electrical as well as mechanical components.

2.The primary components of an EV system are the motor, controller, power source and transmission. The detailed structure of an EV system and the interaction among its various components are shown in the below figure.

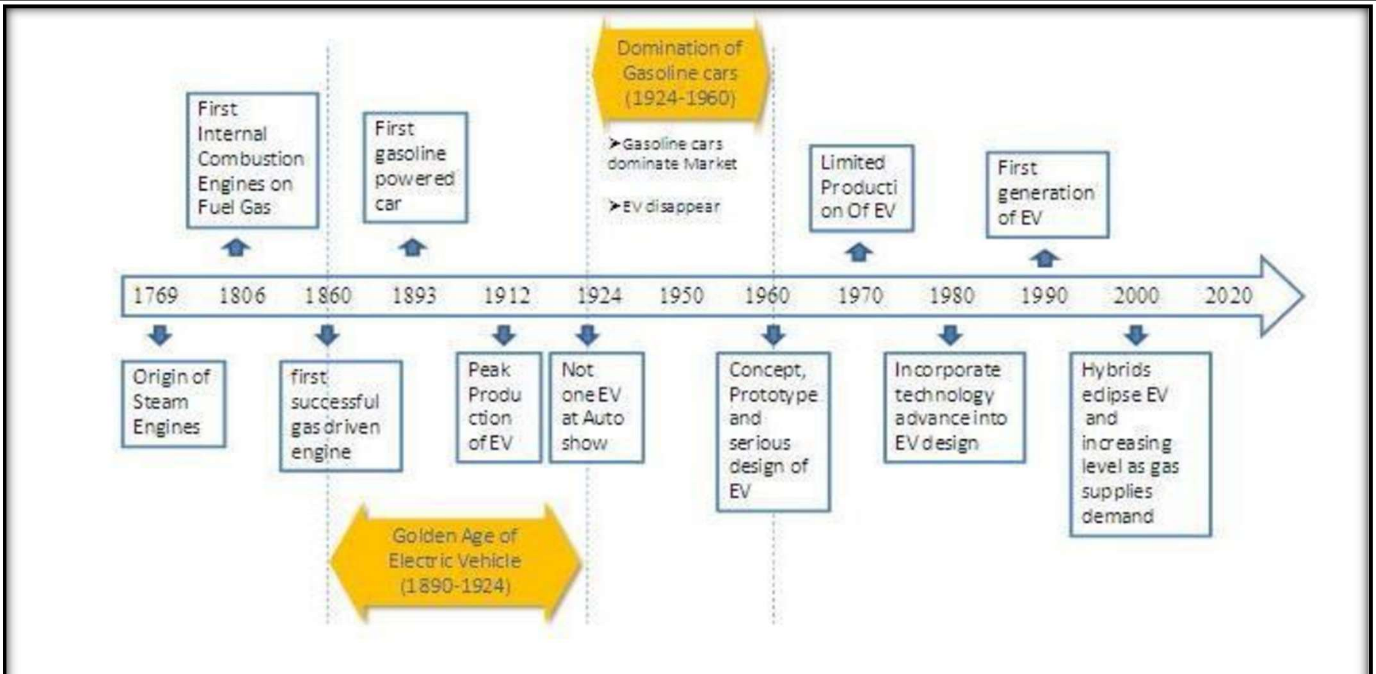


Figure 3: Historical development of automobile and development of interest and activity in the EV from 1890 to present day. Electric Vehicle merged into hybrid electric vehicle.