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Name Kuladeep Mohapatra Sub EV

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ELECTRIC VEHICLE

1.1 Introduction.
1.2 Need for electric vehicle.
1.3 Problems of electric vehicles - (Range and batteries, charging, lack of performance, purchase price, safety and reliability)
1.4 Advantage of electric vehicle
1.5 Disadvantage of electric vehicle
1.6 Major component of electric vehicle - (motor, battery, charger, controller, DC converter, energy management system).

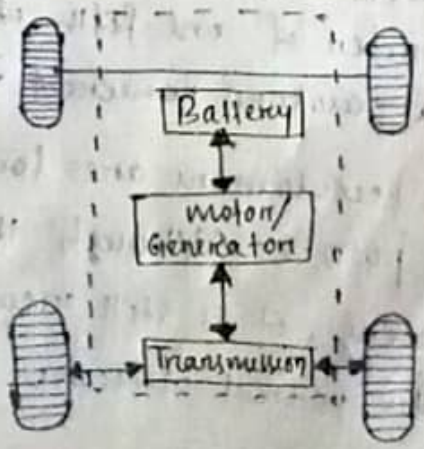
1.1 Introduction :-

→ Electric vehicles are defined as vehicles which use an electric motor for propulsion.

→ Electric vehicle is propelled by one or more electric motors, receiving power from an onboard source of electricity such as batteries, fuel cell, ultracapacitor, flywheel etc.

→ The electrical energy from the onboard source of electricity is used to power an electric motor, which then turns the wheels and provides propulsion.

→ EVs include a large range of vehicles from electric two wheelers, three wheelers (rickshaws), cars, and electric buses and trucks.



(Layout of an EV)

1.2 Need for electric vehicle :-

→ The main reasons for the need of electric vehicles are :-

(a) Depletion of oil reserves
(b) stringent emission standards
(c) Noise pollution

→ There would be no exhaust emissions emitted from electric drives. This zero emission vehicles are almost noiseless and can be charged at home or work place.

→ EVs are easier to service and maintain due to the absence of spark plugs, clutch and gears.

1.3 Problems of Electric vehicles :-

→ The major concerns regarding EVs today is their driving range, charging time and efficiency of batteries.

→ Much development is needed to find a higher energy, longer lasting battery and to bring down costs if EVs are to compete successfully with conventional vehicles.

Range and batteries :-

→ The main problem with electric vehicles, is the batteries used for energy storage. The current battery technology limits the distance an electric car can travell before its battery must be recharged.

→ The present electric vehicle have a limited range of only 80 to 160 Km, on the order of one-fifth of what can be easily realized with a gasoline powered vehicle.

→ In this case the customers are forced to rely on the public charging points. Although the number of charging station is increasing, it is still incomparable with the convenience of the petrol stations and their density.

→ And accessories, such as air conditioning or music system drain the battery even more quickly.

→ Batteries have about 1% of the energy per unit mass of a typical automotive fuel and a life span of about 2-3 yrs.

→ Batteries typically account for one-third or more of the vehicle weight. High capital cost of batteries is also a drawback.

Ex.

EV model	Approx. range on full charge
Tesla model S	500 km
Nissan leaf	151 km
BMW i3	190 km

Charging :

→ A majority of EV owners (95%) usually charge their car's batteries during the night, when they are not using the car.

→ Charging at night when consumption is low, allows for efficient use of electricity.

→ Anyway not all the members of the population have the facility of parking in a garage.

→ To charge the battery fully it takes about 6-7 hrs. The charging time is another issue, as charging time on the stations compared to refuelling diesel/petrol is high.

Lack of performance :

→ Electric cars are not able to accelerate, cruise and climb fast enough when compared to gasoline powered cars.

Purchase price :

→ The purchase price of any electric car is generally much higher than any other conventional vehicle from given class and quality segment.

→ The main reasons for electric cars being so expensive is mainly their battery price.

Safety and reliability :

→ The general perception among people is that EVs are not safe as they did not have ABS and many more safety features.

Fear of running out of charge in the middle of the road :

→ Many customers have this fear that without proper warning the car will run out of charge leaving them stranded.

1.4. Advantages of Electric vehicle :

Followings are the advantages of electric vehicle :

(1) Mechanically simpler.
(2) Running cost is 40 paise per kilometer.
(3) Zero emission vehicle, Also reducing green-house emission.
(4) They are very quiet in operation. While running it does not produce noise and vibrations.
(5) As there are no gears and clutch in these vehicles, they are extreamly reliable, safe and easy to drive and manoeuvre in the congested cities.
(6) Minimum maintenance and service as EVs have fewer moving parts.
(7) Ideal for stop-start conditions.
(8) More durable than gasoline powered cars.
(9) More energy efficient than gasoline engines.
(10) Reduce dependency on imported energy sources.
(11) Power regenerations.

1.5. Disadvantages of electric vehicle:-

There are some disadvantages in an electric vehicle -

(1) Vehicle range is limited on one charge. The vehicle can run 80 - 160 km on a single charge.

(2) Top speed is limited.

(3) It is heavy and bulky.

(4) Limited public charging stations.

1.6 Major components of Electric vehicle:-

→ An electric vehicle consists of a battery that provides energy, an electric motor that drives the wheels and a controller that regulates the energy flow to the motor.

→ There are no gearbox and clutch in these vehicles.

(a) MOTOR:-

→ The prime mover in electric vehicle is the high torque electric motor. The motor converts the energy stored in the power pack in to mechanical motion.

→ The high torque electric motor ensures a quick acceleration.

→ The power from the motor is delivered to the wheels directly or through the transaxle that propels the vehicle. While breaking, the motor acts like a generator (regenerative breaking) and recharges the batteries.

→ There are several choices of the type of drive motor. The basic choice is between an AC and a DC motor. The AC motor offers many control advantages but requires the DC produced by the batteries to be converted using inverter.

→ A DC shunt wound motor rated at about 50 kW is a popular choice for the smaller vehicles but AC motors are likely to become the most popular.

(b) POWER PACK (BATTERY)

→ Automobile manufacturers use three types of rechargeable battery electric car use. Those types are lead-acid batteries, nickel metal hydride (NiMH) batteries and lithium ion batteries.

→ The space occupied by these heavy batteries is large.

→ operational problems include the limited range of the vehicle and its comparatively low maximum speed.

→ Currently the main advantage of lead-acid batteries is the existing motive technology, which is accepted by the motor industry.

(c) CHARGER :

→ EVs have an on-board charger, which converts AC in to DC power to charge the power pack. The charger is computer controlled with an in-built stabilizer and auto shut-off mechanism.

→ The smart charger's output is connected to the power pack and ensures that optimum current and voltage is maintained at all times.

(d) CONTROLLER :

→ EV also have a computerised motor controller. This regulates the flow of energy from the power pack to the motor in direct relation to pressure applied on the accelerator.

→ It ensures perfect speed control and optimum use of energy in both forward and reverse directions. Speed controllers are rated according to the voltage and amperage ranges.

(e) DC/DC CONVERTER :

→ A 12V auxiliary battery is normally used in an electric car to power all 12V accessories such as lights, horn and so on. There is no alternator in EVs to keep this battery charged.

→ EVs use a DC/DC converter which taps the full battery pack voltage and cuts it down to a regulated 13.5 V output, similar to an alternator.

→ It is not advisable to eliminate the auxiliary battery completely, for safety reasons. If the DC/DC converter fails at night or the battery pack falls below the low voltage shut off of the converter, the auxiliary battery will have enough charge to bring the car home.

(f) ENERGY MANAGEMENT SYSTEM (EMS)

→ The brain of EVs is the energy management system (EMS) that monitors and controls all required functions.

→ The EMS is a computer based system that optimises charging and energy output of batteries to maximise operating range and improve performance.

→ The EMS increases the electric vehicle range by 10-15%. and battery life by 25% - 30%.

→ The system also predicts available range for a given state of battery charge. The EMS also maintains an electronic log of the vehicle performance, enables service personel to run diagnostic checks on the car to give service information about the car.

→ 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, an intelligent energy management system (EMS) needs to be adopted.

→ Making use of sensory inputs from various EV subsystems, including sensors for temperatures of outside and inside air current and voltage of the energy source during charging and discharging, current and voltage of the electric motor, vehicle speed and acceleration as well as external climate and environment, the EMS can realise the following functions:

(8)

(a) To optimize the system energy flow.

(b) To predict the remaining available energy and hence the residual driving range.

(c) To suggest more efficient driving behaviour.

(d) To direct regenerative energy from braking to receptive energy sources such as batteries.

(e) To modulate temperature control in response to external climate.

(f) To adjust lighting brightness in response to external environment.

(g) To propose a suitable battery charging algorithm.

(h) To analyse the operation history of the energy source, especially the battery.

(i) To diagnose any incorrect operation or defective components of the energy source.

2.1 Battery electric vehicle (BEV) - (advantage, disadvantage, applicat°)
2.2 Hybrid electric vehicle (HEV) - (advantage, disadvantage, applicat°)
2.3 Plug in hybrid electric vehicle (PHEV) - (advantage, disadvantage application)
2.4 Energy sources (Battery, cells, capacitors, flywheels, fuel cells)
2.5 Requirements of EVs energy sources
2.6 Battery - requirement of EV batteries, selection of battery, deep cycle battery.
2.7 Types of battery for EVs (lead-acid battery, lithium-ion battery) and their advantages and disadvantages
2.8 Ultra capacitor and its working principle
2.9 flywheel and its advantages and disadvantages.

CLASSIFICATION of EVs :-

→ EVs can be classified on the basis of their attributes such as (i) charging time
(ii) Driving Range
(iii) the maximum load it can carry.

(i) CHARGING TIME :- (i.e the time required to fully charge the battery)
→ A measure of the time taken to charge the battery from 0% to 100% .
→ charging time depends upon the input power characteristics (i.e input voltage and current), battery type and battery capacity.

(ii) DRIVING RANGE :- (i.e the maximum distance an EV can roam when fully charged)
→ A measure of the distance electric vehicles can cover on a single charge of battery.

(iii) PAY LOAD CAPACITY :

→ A measure of the maximum load (weight) a vehicle can carry.

CLASSIFICATION :

→ There are 3 types of electric vehicle :-

(A) Battery Electric Vehicle (BEV)

(B) Hybrid Electric Vehicle (HEV)

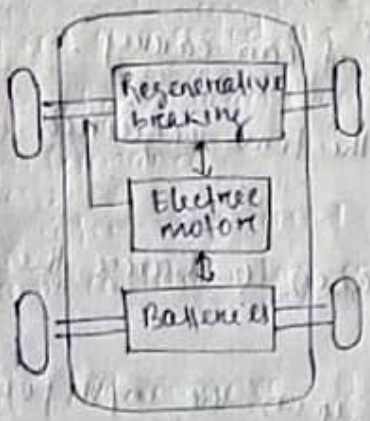
(C) Plugin Hybrid Electric Vehicle (PHEV)

2.1

(a) BATTERY ELECTRIC VEHICLE :

→ A BEV runs entirely using an electric motor and battery without the support of a traditional internal combustion engine and must be plugged in to external source of electricity to recharge its battery.

→ Like all electric vehicles, BEVs can also recharge their batteries through a process known as regenerative braking, which uses the vehicle's electric motor to assist in slowing the vehicle and to recover some of the energy normally converted to heat by the brakes.



→ BEVs have to rely solely on the energy stored on their battery packs, therefore the range of such vehicles depends directly on the battery capacity.

→ Typically they can cover 100km - 250 km on one charge whereas the top-tier models can go a lot further, from 300km to 500km.

→ These ranges depend on driving condition and style, vehicle configurations, road conditions, climate, battery type and age.

ADVANTAGES :

(a) No emissions while reenning
(b) Silent
(c) No gas or oil changes
(d) Ability to conveniently charge at home.
(e) Fast and smooth acceleration
(f) Low cost of operation
(g) Instant and high torques, even at low speeds.

DISADVANTAGES :

(a) Shorter ranges than gasoline vehicles although most people drive well with in the range of today's BEV and could rent a hybrid for the rare long treps
(b) Slightly more expensive then their gasoline equivalent although the gasoline savings pay off the differences in typically 2-3 years.

APPLICATION :

→ Nissan leaf and Teslas are some, fresh selling BEVs these days, along with some chinese vehicle.

2.2

(b) HYBRID ELECTRIC VEHICLE (HEV)

→ HEVs produce supplemental fuel source to produce electricity on-board. HEVs have two complementary drive systems a gasoline engine with a fuel tank and an electric motor with a battery.
→ Both the engine and electric motor can turn the transmission at the same time, and transmission then turns the wheels.
→ HEVs can not be recharged from the electricity grid, all their energy comes from gasoline and from regenerative braking.

(14)

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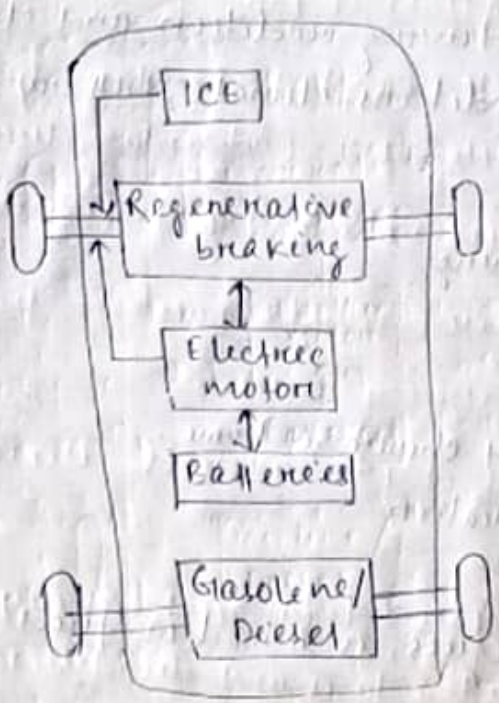


→ An HEV uses the electric propulsion system when the power demand is low. It is a great advantage in low speed conditions like urban areas.

→ It also reduces the fuel consumption as the engine stays totally off during idling periods for example traffic jam.

→ This features also reduces the greenhouse gas emissions.

→ When higher speed is needed, the HEV switches to the engine mode. The two drive trains can also work together to improve the performance.

→ Hybrid power systems are used extensively to reduce or to completely remove turbo lag in turbo charged cars, like Accura NSX.

→ It also enhances performance by filling the gaps between gear shifts and providing speed boosts when required.

→ The internal combustion engine can charge up the batteries, HEVs can also retrieve energy by means of regenerative braking.

→ Therefore HEVs are primarily engine driven cars that use an electrical drive train to improve mileage or for

performance enhancement.

→ A typical hybrid EV is fuelled by gasoline and uses a battery powered motor to improve efficiency, thus is not considered a plug in electric vehicle.

→ The battery in a gasoline hybrid is never plugged in to an electrical outlet, but instead is powered by a combination of gasoline engine and regenerative breaking.

ADVANTAGES :

1. Low exhaust emission levels than internal combustion engines.
2. Increased range compared to EVs.
3. Engines can be down sized to accomodate average load, not peak load, which reduces the engine's weight.
4. Fuel efficiency is greatly increased.
5. Emissions are greatly decreased.

DISADVANTAGES :

1. Bulky and heavy
2. Requires very complicated control system
3. Cost is very high

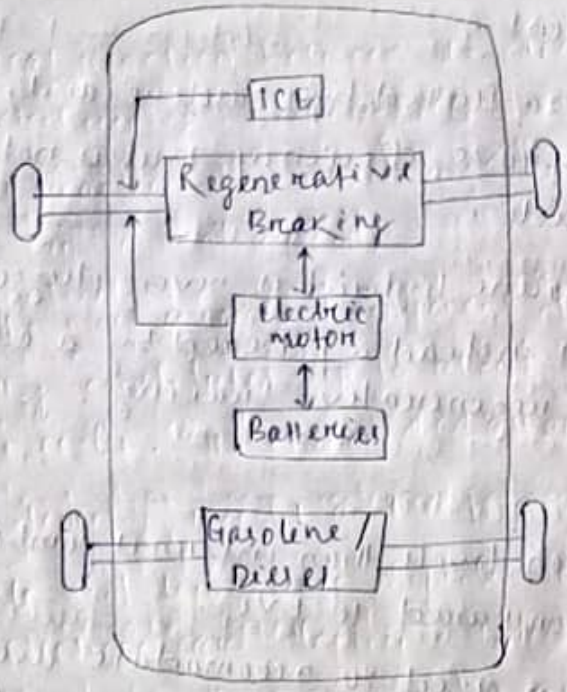
APPLICATION :

The most well known hybrid vehicle is the Toyota Prius.

2.3

(c) PLUG-IN HYBRID ELECTRIC VEHICLE : (PHEV)

→ PHEVs use an electric motor and battery that can be plugged in to the power grid to charge the battery, but also have the support of an internal combustion engine that may be used to recharge the vehicle's battery and/or to replace the electric motor when the battery is low. Because plug in hybrids use electricity from the power grid, they often realise more savings in fuel costs than traditional hybrid electric vehicles.



→ The vehicles generally rely on the electric motor until the battery is depleted, at which point the engine can kick in extending the car's range.

ADVANTAGES :-

* Longer range than BEV
* Less gas consumption than gas only vehicle
* Fewer emissions
* Very simple mechanics, less to go wrong

DISADVANTAGES :-

* Produces tailpipe emissions
* Needs gas and oil changes
* More expensive to operate than BEV but less than traditional HEV.

APPLICATION :-

→ An example of plug-in hybrid is the chevrolet volt.

2.4 ENERGY SOURCES :-

→ EVs can get the energy required to run from different sources.
→ EVs use different types of energy storage to store their power.
→ They include (a) Batteries
(b) Ultracapacitors
(c) Flywheels
(d) Fuel cells

2.5 REQUIREMENT OF EVs ENERGY SOURCES :-

→ The criteria such sources have to satisfy are
1. High specific energy and energy density
2. High specific power and power density
3. Fast charging and deep discharging capabilities
4. Long cycle and service lives
5. Low self discharging rate and high charging efficiency.
6. Safety and cost effectiveness
7. Maintenance free
8. Environmental sound and recyclable

→ High specific energy is required from source to provide a long driving range where as high specific power helps to increase the acceleration
→ The other characteristics that make a perfect energy source are fast charging, long service and cycle life, less cost and maintenance.

2.6 BATTERY :-

→ Batteries have been the major energy source for EVs for a long time. The battery converts stored chemical energy into electric energy.

→ The chemical reaction between the electrodes and electrolytes generates electricity. Rechargeable batteries can reverse the chemical reaction by reversing the current. This way the battery can be recharged.

→ Battery is the most important component of an electric vehicle and typically constitutes up to about half of the vehicle cost and weight. The choice of batteries depends on the energy density, weight and costs.

→ Electric cycle and low range mopeds have simple battery units while electric cars deploy a large number of batteries.

REQUIREMENT OF EV BATTERIES :

→ The batteries should have

1. A suitable voltage output over a good depth of discharge.
2. High energy capacity for the given battery weight and size.
3. High peak power output per unit mass and volume.
4. High energy efficiency.
5. Able to function with wide ranges of operating temperature.
6. Good charge retention on open circuit stand
7. Ability to accept fast recharge.
8. Ability to withstand overcharge and overdischarge.
9. Reliable in operation.
10. Maintenance free.
11. Rugged and resistant to abuse.
12. Safe both in use and accidental conditions.
13. Made of readily available and inexpensive materials with environmental friendliness.
14. Efficient reclamation of materials at the end of service life.

SELECTION OF BATTERY :

→ This depends on mainly the voltage. The higher the voltage, the better the acceleration and a higher top speed can be achieved.

→ A normal sized EV using a voltage system of 96-120V with 6 deep cycle batteries will give more amphere hours and weigh more.

→ Therefore, it will have a fairly high range but poor performance.

→ The same vehicle using a voltage system of 96-120V with 12V batteries will give high performance but lower range.

→ That is because the battery pack will be lighter and in turn the vehicle will be lighter.

DEEP CYCLE BATTERIES :

→ Deep cycle batteries are normally available in three voltage sizes 6, 8 and 12 V. For range 6V batteries are used because of their high specific energy.

→ For performance 12V batteries are used. The 8V battery packs offer a good balance between the range of 6V battery and the acceleration capabilities of the 12V battery.

2.7 TYPES OF BATTERY FOR EVs :

→ The following four types of batteries are commonly used today in EVs

1. Lead-acid battery
2. Nickel-cadmium (Ni Cd)
3. Nickel metal hydride (Ni MH)
4. Lithium ion (Li ion)

→ Traditionally most electric vehicles have used lead-acid batteries due to their mature technology, easy availability and low cost.

LEAD-ACID BATTERY :

→ The first generation of EV batteries are likely to include advance lead acid battery. Traditional liquid electrolyte lead-acid batteries have been use in many EV conversions, although they have numerous disadvantages for this application.

→ Lead content has been reduced over time since they are heavy and have low energy densities, require frequent watering, generate gases when recharging and contain liquid electrolyte that can be hazardous if spilled in a collision.

→ They have short life times (24000 to 40000 km) and they can be damaged if they are allowed to discharge to too low charge often. Advanced lead acid batteries are commercially developed and available.

→ These batteries are lighter and maintenance free, have higher energy and power densities, can recharge much faster than conventional lead-acid batteries and are sealed so that the gases generated during recharging recombine with chemicals in the batteries.

→ However, they are expensive, highly toxic, and the amount cadmium reserves available to make them batteries may not be sufficient to supply a large demand in the EV market.

→ It is called lead-acid battery because its active ingredients are the metal lead and sulphuric acid.

→ The difference in voltage between the positive plate (lead peroxide) and the negative plate (spongy lead)

is 2.13 V when a sulphuric acid solution of 1.265 - 1.280 specific gravity is added, and the temperature is 68°F - 80°F.

→ Lead peroxide and spongy lead are used in the automotive battery today because no other materials have a greater voltage difference.

(1) Chemical reaction when discharging

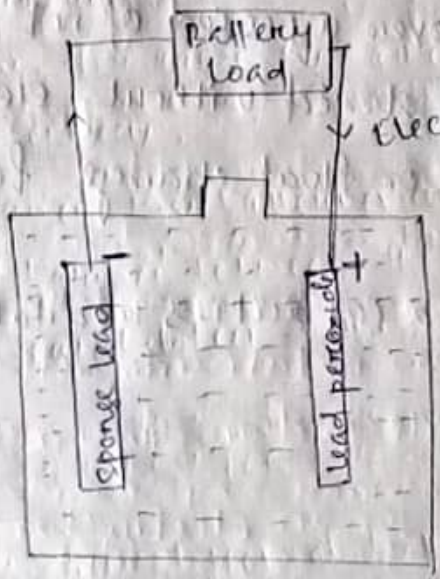
$$PbO_2 + 2H_2SO_4 + Pb \longrightarrow PbSO_4 + 2H_2O + PbSO_4$$

(+ plate) (electrolyte) (- plate) (+ plate) (water) (- plate)

(2) Chemical reaction when charging

$$PbSO_4 + 2H_2O + PbSO_4 \longrightarrow PbO_2 + 2H_2SO_4 + Pb$$

(+ plate) (water) (- plate) (+ plate) (electrolyte) (- plate)



Discharge :-

During discharge, the lead peroxide (positive plate) and lead (negative plate) react with the electrolyte of sulphuric acid to create lead sulphurate, water and energy.

CHARGE :-

During charging, the cycle is reversed : the lead sulphate and water are electro-chemically converted to lead, lead peroxide & sulphuric acid by an external electrical charging source.

ADVANTAGES :-

1- Reliable
2- Robust
3- Range
4- Rapid recharge
5- Tolerant to overcharging
6- Low internal impedance
7- Can deliver very high currents
8- Ability to hold charge over a period of not being used.
9- Indefinite shelf life if stored without electrolyte.
10- Can be left on trickle or float charge for prolonged periods
11- Wide range of sizes & capacities available.

DISADVANTAGES :-

1- Heavy & bulky
2- Very low specific energy
3- Danger of overheating during charging
4- Not suitable for fast charging
5- Typical cycle life 300 to 500 cycles
6- Must be stored in a charged state once the electrolyte has been introduced to avoid deterioration of the active chemicals
7- Acid fumes and corrosion - Results in decreased battery life
8- Loss of voltage over discharge.

LITHIUM-ION BATTERY

→ Lithium-ion batteries have higher specific energy relative to the other battery types. Advanced lithium batteries, including lithium-ion and lithium polymer batteries offer advantages of higher energy & power-densities, with longer life on-board the vehicle as they can withstand over 1000 charge-discharge cycles.

⇒ They are much lighter than lead-acid (three times or more the energy density of an equal weight) and promise a higher level of consumer safety, since lithium is non-toxic.

⇒ The use of lithium batteries in cars, motorcycles, heavy vehicles and off-road equipment is increasing rapidly.

→ Lead acid batteries are being replaced by lithium batteries to improve charge/discharge performance, save weight, save space, increase lifetime & avoid Pb (lead) in the environment.

→ This battery is now used primarily for electric vehicles, as they are much lighter which provides a more fuel efficient vehicle.

→ The Porsche 911 2010 model uses the lithium ion battery for starting.

→ These are very expensive batteries and starting costs for cars are about Rs 60,000.

Charging Reactions :-

Cathode reaction: $LiCoO_2 \longrightarrow Li_{1-x}CoO_2 + xLi + xe^-$

Anode reaction: $C + xLi^+ + xe^- \longrightarrow CLi_x$

Battery as a whole: $LiCoO_2 + C \longrightarrow Li_{1-x}CoO_2 + CLi_x$

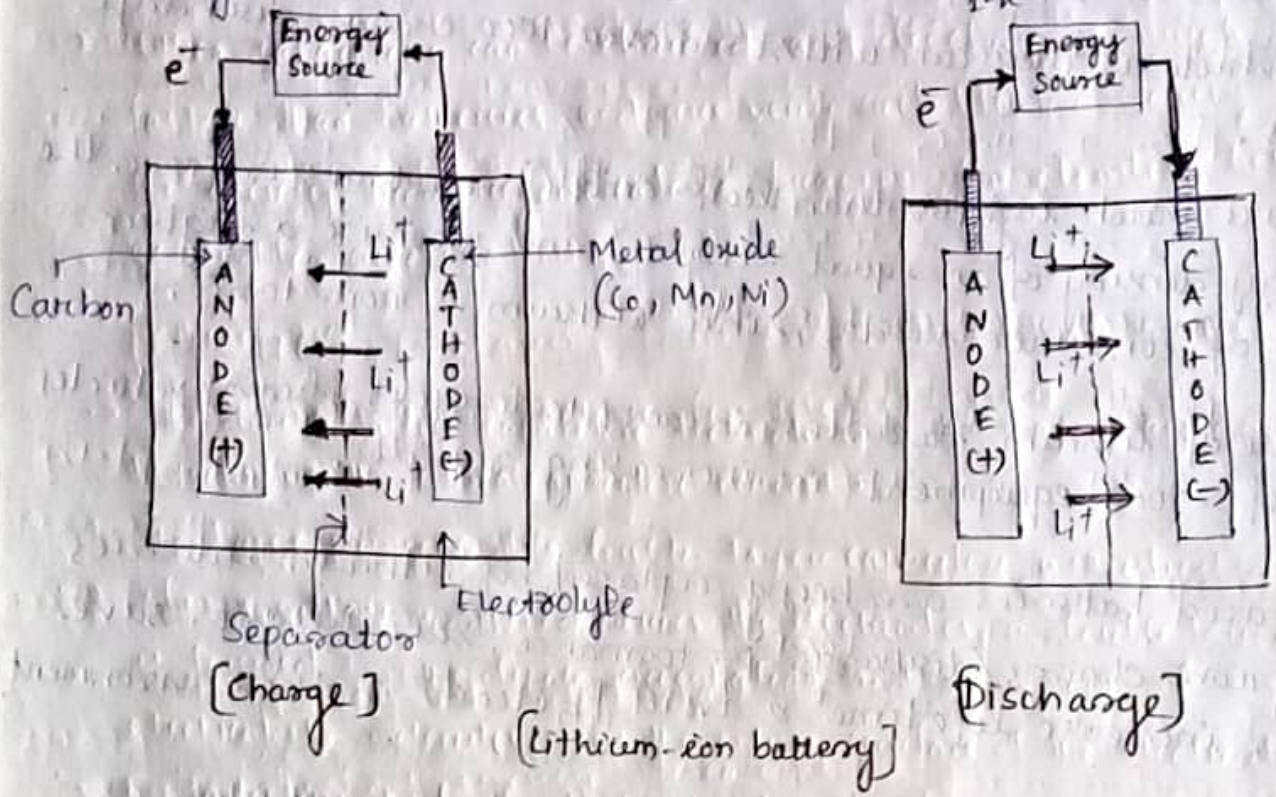
(24)

Discharging Reactions :-

Cathode Reaction : $LiCoO_2 \longleftarrow Li_{1-x}CoO_2 + xLi^+ + xe^-$

Anode reaction : $C + xLi^+ + xe^- \longleftarrow CLi_x$

Battery as a whole : $LiCoO_2 + C \longleftarrow Li_{1-x} + CoO_2 + CLi_x$



[Lithium-ion battery]

⇒ Lithium-ion cells, in their most common form consist of a graphite anode, a lithium metaloxide cathode and an electrolyte a lithium salt and an organic solvent.

⇒ Lithium is a good choice for an electrochemical cell due to its large standard electrode potential (3.04V) resulting in a high operating voltage (which helps both power & energy and the fact that it is the metal with the lowest density (which reduces weight).

⇒ In an automotive application a lithium-ion battery consists of a few to thousands of individual cells packaged together to provide the required voltage, power and energy.

Advantages Over Conventional Batteries :-

1- Higher specific energy
2- Higher specific power
3- Power to weight, upto 80% weight saving
4- Charge and discharge at high currents
5- Low self-discharge
6- Offer phenomenal starting power and massive deep cycle reserve power. They are capable of providing engine cranking pulses of 2250 amps for 10 seconds.
7- Longer life span with a minimum of 5 years service life, up to 10 years depending on use.
8. No harmful emission
9. Less of voltage over discharge

Disadvantages :-

1. Heat
2. Higher initial cost

28 ULTRA CAPACITOR :-

→ Ultra capacitors otherwise known as super capacitors or electrochemical capacitors, are different from batteries as batteries store their energy chemically where an ultra capacitor stores it physically.

→ A capacitor is a device for storing electrical energy in a dielectric placed between two conducting plates. Small volume capacitors are used frequently in numerous types of electric circuits.

→ Their capacity is directly proportional to the area of the conducting plates. Thus if large area capacitors used, they gain a high storage potential.

→ If the capacity per unit weight is same or greater than the secondary battery it becomes possible to use it as an EV battery.

→ Alternatively using a material whose surface has numerous small holes in it would reduce the size of the capacitors.

→ In an electric car, an ultra capacitors can provide the power needed for acceleration, while a battery provides range and recharges the ultracapacitors between surges.

→ Ultra capacitors can be charged and discharged much faster than batteries and are very suitable for storing the energy from regenerative braking, for climbing hills or sudden acceleration.

PRINCIPLE :

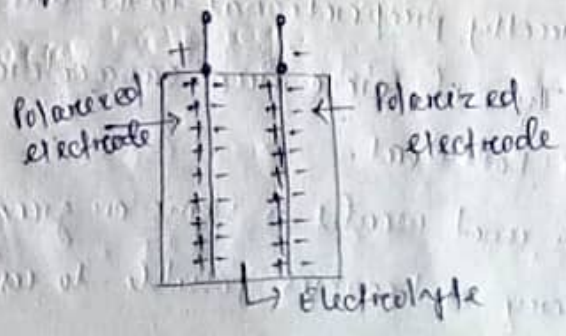
→ The double layer capacitor technology is the major approach to achieve the ultra capacitor concept.

→ The basic principle of a double-layer capacitor is illustrated.

→ When a voltage is applied across the electrodes, a double layer is formed by the dipole orientation and alignment of electrolyte molecules over the entire surface of the electrodes.

→ By adopting high-dielectric materials, short separation distance and large electrode surface areas, the capacitance can be greatly increased.

→ At the present status of ultra capacitor technology, the corresponding electrode materials may be carbon/metal fibre composites, doped conducting polymer films on carbon cloth or mixed metal oxide coatings on metal foil, while the electrolyte materials may be aqueous/organic solutions or solid polymer.



2.9 FLYWHEEL:

→ The flywheel is an energy storage device, similar to battery, but instead of storing the energy chemically, it is stored in kinetic form in a rotating disc.

→ Typically the rotor is accelerated by an electric motor (charging process) and decelerated when the motor is switched to generative operation (discharging).

→ This flywheel energy storage system (FESS) composed of composite rotors spinning at thousands of rpm on frictionless magnetic bearings, which can drive a generator to provide power for EVs.

→ Energy stored in flywheels increases quadratically with rotational speed of the rotors. An energy is used up, the rotor slows.

→ The importance of energy storage with flywheel is to reduce the loss of mechanical energy, namely the loss of kinetic energy that consists of air friction resistance and rotary resistance.

→ According to different means for the reduction of energy loss FESS can be devided into low speed flywheel system and high speed flywheel system.

→ The first reduces air friction by increasing the mass of flywheel while the second is to reduce the air pressure of operating environment of flywheel.

→ The high speed flywheel system benefits from the use of high strength composite material. It has characteristics of small mass low volume and high speed. Thus it is fit for vehicle usage.

→ The high speed flywheel system consists mainly of a flywheel, a motor and a generator. It is connected with exterior electrical systems through input or output electronic equipments and the power transported from exterior systems is converted

from electric energy into mechanical energy by raising rotary speed of flywheel. When it is needed to output power, mechanical energy is converted back into electric energy through generator and meantime the rotary speed of flywheel is reduced.

→ The motor and generator are usually integrated together and magnetic suspension bearings adopted by flywheel system, through the supports of which the flywheel is fixed in a vacuume container.

ADVANTAGES :-

→ There are primarily four properties that make the flywheel attractive for use as energy storage.

1. High power density
2. Long cycle life
3. No degradation over time
4. Easily estimated state of charge
5. Highest energy storage density
6. Shortest charging time
7. Easiest maintenance
8. No pollution

DISADVANTAGES :-

→ Excessive high cost its cost is about 1.5 times that of ultra-capacitors and is about 6 ~ 7 times that of chemical battery.

3.1 Electric motor
3.2 Requirements of EV motor
3.3 Brushed D.C motor
3.4 Brushless D.C motor
3.5 Switched reluctance motor
3.6 AC induction motor
3.7 Indian electric vehicle (4 wheeler, 3 wheeler, 2 wheeler)

3.1 ELECTRIC MOTOR

→ Electric motors convert electrical energy into mechanical energy.

→ Two types of electric motors are used in electric vehicles to provide power to the wheels: the direct current (DC) motor and the alternating current (AC) motor.

→ DC motors are larger and more complicated than AC motors, and it is difficult to make them highly efficient.

→ On the benefit side, however, is that the DC motor's controller can be easily made. As a result, most of the EVs use DC motors.

→ The features of the AC motors are just the opposite. Advances of semiconductor field can be used to make the DC-AC converter for the AC motor's controller highly efficient and small in size.

→ The combination of motor and controller is making the AC motor gradually superior in terms of the efficiency, price and size.

→ However with the advent of better and less expensive electronics a large number of today's electric vehicles are using AC motor controller systems because of their improved motor efficiency and lighter weight.

3.2 REQUIREMENTS OF EV MOTOR :-

→ The mayor components of EV motor drive are summerized as follows :-

1. High instant power and high power density.
2. High torque at low speeds for starting and climbing as well as high speed at low torques for cruising.
3. Very wide speed range including constant - torque and constant power regions.
4. Fast torque response
5. High efficiency over wide speed and torque ranges.
6. High efficiency for regenerative breaking.
7. High reliability and robustness for various vehicle operating condition.
8. Reasonable cost.

3.3 BRUSHED D.C MOTOR :-

→ The simplest motor that can be used in automotive applications is the brushed DC motor. This motor is used in all sorts of domestic electric appliances like hairdryers and fans.

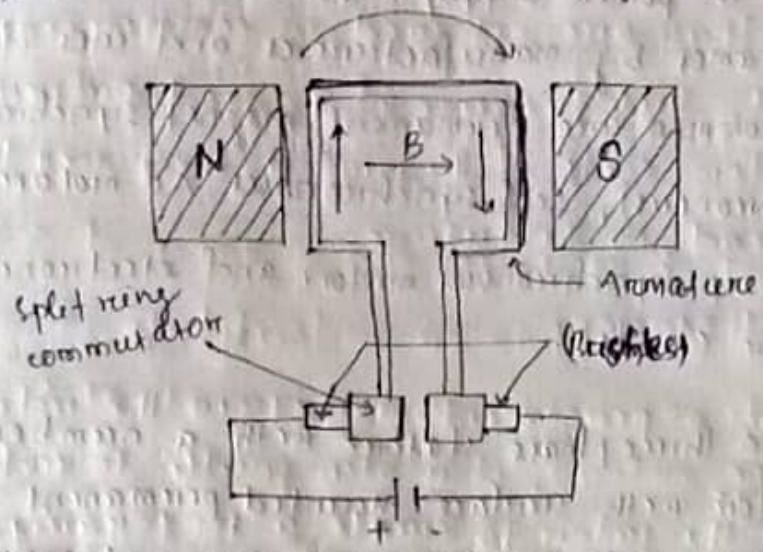
→ A two-pole brushed DC motor is shown with one coil.

→ The motor consists of a stator with two permanent magnets and brushes and a rotor (coil) with commutators and windings.

→ The force on the left side is upwards where the force on the right side is downwards, causing the coil to turn clockwise.

→ when the wires of the coil with the commutator are clear of the magnets momentum carries the rotor halfway around until it connect with the brushes again.

→ The commutator is constantly changing the direction of the current to ensure that the forces are pushing the coil clockwise.



→ A real DC motor however is using a rotor with multiple coils and a stator with more than one pair of magnets but the principles remain the same.

→ There are three basic brushed DC motors, a parallel, series and separately excited brushed DC motor for use in electric vehicles the one that can be used is the separately excited motor.

→ The required torque can be controlled at any angular speed giving the motor great flexibility. Due to the brushes making physical contact with the commutator, sparking is a common issue with brushed motors.

→ They are causing friction, limit the speed range and regular maintenance.

3.4 BRUSHLESS DC MOTOR :

→ A brushless DC (BLDC) motor actually is not DC but AC motor.

→ The motor needs an alternating current but must have variable frequency. Therefore the current have to be derived from a DC power supply. The BLDC motor is given different names by manufacturers and user of which the most common are permanent magnet synchronous motor (PM synchronous), self synchronous AC motor, variable frequency synchronous motor and electronically commuted motor (ECM).

→ The motor has a three phase stator with a number of coils and a rotor with surface mounted permanent magnets. The stator and the rotor are reversed compared to the Brushed DC motor where the permanent magnet are mounted on the stator.

→ The way a BLDC motor works is that the poles on the stator are alternating in such a way that the rotor is turning clockwise.

→ The pole on the stator pulls the pole on the rotor clockwise and when the poles are in line with each other the current is switched off.

→ Momentum then carries the rotor further and the current is reversed, changing the magnetic field and the poles in the stator.

→ To make sure the motor keeps on turning sensors are needed to determine the position of the rotor. This is often done using Hall effect sensors.

→ BLDC motors are very efficient. Torque is high under low speeds and goes down as the speed goes up. A drawback of this type of motor is the price compared to the other possible EV motors.

→ A BLDC motor needs a strong permanent magnet that can influence the total price of the motor.

3.5 SWITCHED RELUCTANCE MOTORS

→ The switched reluctance (SR) motor is a simple motor with an iron rotor and stator. The stator is magnetised and attracts the rotor.

→ When the rotor is aligned with the stator (magnetic field is symmetrical) the current is switched off and momentum carries the rotor further and the current is switched on again.

→ The stator and control electronics of a SR motor are similar to those of a BLDC and induction motor. The rotor of a SR motor however is much simpler, making it cheaper and more rugged than the BLDC and induction rotor.

→ The SR motor does not create back EMF because it has no permanent magnets. It therefore can reach higher speeds.

→ Back EMF is the voltage that is generated when an electric motor with permanent magnets is spinning.

→ The speed of BLDC motor is limited because of this back EMF.

→ Also the current in the coil of a SR motor does not need to alternate. It needs an advanced control systems and sensors to adjust the speed and make sure the current is switched on and off on time.

→ Another drawback of the motor is that it is a bit noisy. SR motors are not used in commercial EVs and HEVs yet, but because of the good properties and possible low costs of the motor they will become more widespread in the future.

3.6 AC INDUCTION MOTOR

→ Instead of using a permanent magnet in the rotor (as in the BLDC motor), it is also possible to induce a current in the rotor to create a temporary magnet.

→ This is done in an AC induction motor. The rotor type that is most common in induction motor (IM) is the "squirrel cage". The rotor consists of a stack of steel laminations with evenly spaced conductors bars around the shaft.

→ The conductor bars are forming a kind of cage. The conductor bars are electronically ~~kind~~ linked with end rings.

→ The rotor of an IM consists of a number of coil with the windings displaced by 120°. When 3 phase AC is supplied to the rotor a current is induced in the conductor bars of the rotor.

→ It will turn clockwise 'chasing' the magnetic field that is going anticlockwise. The angular speed of the rotor is lower than the magnetic field.

→ This is so called 'slip' velocity is the relative velocity between the rotor speed and magnetic field.

→ The technology of the IM is very mature and is used in all sorts of appliances like washing machines, pumps and industrial machines. Therefore it is a popular choice and most used in EVs and HEVs of today.

→ The think city electric vehicle and the Tesla roadster which are already on the market uses a 3-phase AC induction motor. BEVs that are coming on to the market next years also uses other electric motors.

→ The Mitsubishi i-MiEV for example and the e6 from BYD are supplied with a BLDC motor or permanent magnet synchronous motor as the car manufacturers names the motor.

8.7 INDIAN ELECTRIC VEHICLES

→ India is well suited for the introduction of EVs today with the existing technologies available, making EVs cost effective.

→ India stands out for its mechanical hardware availability and low manufacturing cost. Other advantages for India are its low labour cost, low production start up cost, availability of R and D facilities in electrical, electronics and auto industries coupled with large infrastructure of auto components, less present investment in internal combustion engine capacity and the potential of large domestic markets.

→ Information technology and electronics facilities further enhances its EV manufacturing potential. With the largest EV potential market in the world, the chance of reducing the production of EV cost in the near future is highest in India.

4-wheelers :-

(a) REVA :-

→ The first electric car in India was launched by Bangalore based company REVA in early 2000's.

→ REVA is a stylish, fully automatic (no clutch, no gears) compact two door hatch back that carries two adults and two children on a payload of 227 kg.

→ It has a top speed of 65 km/h and a range of 80 km.

→ REVA has an onboard charger to facilitate charging by plugging in to a 220 V, 15 amp socket at home or at work place.

→ The auto cut off mechanism prevents overcharging.

→ The charge time is 5-6 hours though 80% of full charge can be attained in 2.5 hours, good enough for 65 km.

→ A full charge consumes just about 9 ~~mo~~ units of electricity.

(b) MAHINDRA ELECTRIC :-

→ Mahindra electric mobility limited is formerly known as Reva electric car company, involved in designing and manufacturing of compact electric vehicles.

→ Mahindra electric started their journey in to the EV space in 2011 by launching Mahindra Reva, India's 1st electric car.

→ They subsequently launched Mahindra E20, the current version on roads in India.

→ Powered with Lithium ion batteries, the new model allows for a top speed of 80 KM/hr and a driving range of 100 KM with a single charge. With a charging time of 5 hours, it is marketed to provide significant cost savings over a conventional car.

TATA MOTORS :-

→ Tata motors have launched a car - Tigor EV and have recently delivered their first set of cars to energy efficiency services Ltd from their sanand plant in Gujarat.

→ The Tigor Electric will be able to do about 120 - 150 kilometers on a full battery charge.

→ The Nano EV could be the first electric car that the automaker launches in India, followed by the Tigor and Tiago electric vehicles.

→ Electric car charging infrastructure is at its infancy in India, and the government is fast stepping up its efforts to roll out charging stations.

3 - WHEELERS :-

→ More recently, electric rickshaws are gaining popularity as a good substitute for conventional three wheelers and paddle - rickshaws as public and goods transportation over short - to - medium distances.

→ Scooters India Ltd and Mahindra and Mahindra Ltd. have brought out battery operated three wheelers, which are already running in several cities in India. Bajaj, TVS and Ashok Layland are working on hybrid and pure electric vehicles.

→ E-rickshaws must be registered and the drivers are required to have driving licenses. The challenges for using e-rickshaws are

1. Use of lead acid batteries, which need to be replaced with in 7-8 months.
2. Current design of e-rickshaws does not possess the required vehicle strength and often fail on safety standards.
3. Un availability of fixed e-rickshaws stands and charging points.

2- WHEELERS :-

→ 2-wheelers is the largest segment in the Indian automotive industry representing ~80% of Indian automotive sales.

→ Around the year 2000, only a couple of two-wheelers were available in the Indian market. However the market has expanded and over two dozen different two wheelers are available in the market at present.

→ These include low speed vehicles with a maximum speed of 25 km/hr to high speed vehicles capable of achieving speeds of up to 65 km/hr. The driving range varies from 20 km to 100 km.

→ The following aspects would help drive e-mobility in this segment.

(1) Over 2 million petrol run delivery bikes with a long daily run engaged in courier and food delivery services.

(2) Extra city travels (maximum around 100-150 km a day)

(3) Ease of charging : can be easily charged on a standard residential/ workplace plug point.

CHAPTER-4
HYBRID VEHICLES

4.1 HYBRID ELECTRIC VEHICLE (HEV)

4.2 ADVANTAGES AND DISADVANTAGES OF HEV

4.3 COMPONENTS OF HEV

4.4 WORKING OF HYBRID VEHICLE

4.5 HYBRIDIZATION (MICRO HYBRID, MILD HYBRID, FULL HYBRID)

4.6 FUEL CELL ELECTRIC VEHICLE (FCEV) WORKING PRINCIPLE, ADVANTAGES AND DISADVANTAGES

4.1 HYBRID ELECTRIC VEHICLE (HEV)

→ A Hybrid electric vehicle (HEV) is a type of vehicle that uses both an electric motors and a conventional internal combustion engine (petrol or diesel engine).

→ This type vehicle is considered to have better performance (increased torque and power), fuel economy and reduced emissions compared to a conventional one of the same size, performance and comfort.

→ Hybrid vehicle has a small battery which drives the vehicle over a short distance before switching to engine.

→ A hybrid electric vehicle can not be plugged in for charging. Instead, the battery is charged through regenerative braking and by the internal combustion engine.

→ Hybrid electric vehicles (HEVs) incorporate a small internal combustion engine with an electric motor and storage batteries.

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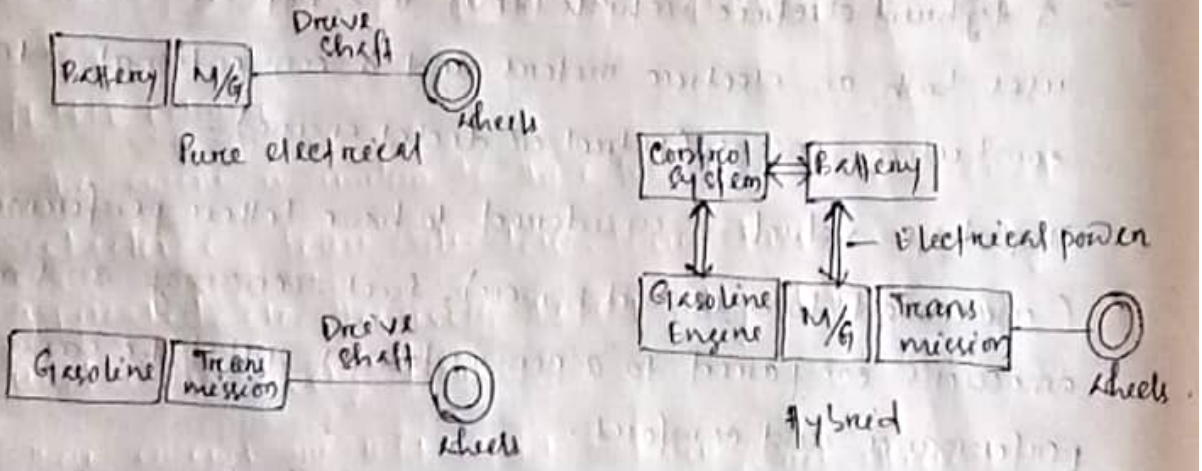
→ They eliminate the basic weaknesses of electric vehicles (limited range, bulky and heavy, more time for recharge) and internal combustion engines (Harmful emissions, higher fuel consumption, etc)

→ A hybrid electric vehicle has more promise than an electric vehicle, since the HEV has an internal combustion engine to provide the energy to meet vehicle range requirements.

→ The battery then provides the additional power needed for acceleration and climbing hills. The fuels used in the HEV engines in current production include gasoline, diesel and natural gas.



→ Internal combustion engines produce dangerous emission and have poor efficiency at part load. IC engine cars are both light weight and can cover excessive distances before they need to refill the fuel tank.

→ Refilling the fuel tank is very rapid compared with the time taken to recharge batteries. The dis advantages of the IC engines are harsh emissions and harsh fuel consumptions when compared to electric power.

→ Electric drives produce no emissions but have a limited range

→ The solution is to combine the best aspects of both IC engine and electric drives.

→ A hybrid car combines the low emissions and low fuel consumption of an electric vehicle and provides a high weight vehicle that can travel a long distance. Depending up on how the hybrid system is designed, the engine simply functions as a means of driving a generator.

→ The generator then charges the battery that power the electric motors which provide power to the vehicle transmission.

→ This type of vehicle can use the electric drive in slow traffic and towns and use the IC engine on the high way. An efficient control system allows even better usage such that under certain conditions both the motor and the engine can be used.

→ HEVs usually have the following properties.

Auto start/Auto shut-down :- To avoid wasting energy during idle time, the engine of a hybrid electric vehicle automatically shut down and starts as soon as the accelerator is touched.

Regenerative Braking :- Considered one of the salient features of HEVs, the energy wasted during braking and coasting is converted and stored in the battery, which is then used by the electric motor.

Electric motor assist :- By helping the engine during passing accelerating or moving up a hill, the electric motor allows the engine to be made smaller and more efficient in nature.

4.2 ADVANTAGES :

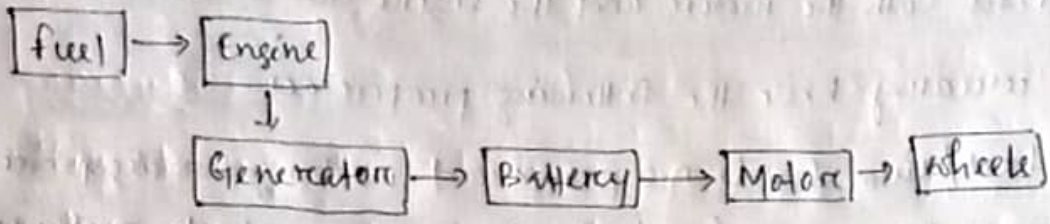
1. Low exhaust emission levels.
2. Longer range than BEV.
3. Engines can be down sized to accomodate average load, not peak load, which reduces the engine's weight.
4. Fuel efficiency is greatly increased.
5. Low maintenance cost.

DISADVANTAGES:-

1. Bulky and Heavy.
2. Require very complicated control systems.
3. Still produces emissions.
4. Expensive to operate (8-10 times more expensive than BEV) but less than traditional gasolene vehicle.
5. No ability to conveniently charge at home.

4.3 COMPONENTS OF HEV:-

→ A typical hybrid car contains the following components.



PETROL ENGINE:-

→ The engine is similar to those fitted to conventional vehicles e.g four cylinders, four stroke normally aspirated, etc. However, the capacity of the engine used is relatively small.

→ These engines are light weight and very fuel efficient. They typically produce approximately 70 brake horsepower which is supplemented with a electric motor rated typically at approximately 50 horse power.

ELECTRIC MOTOR:-

→ The electric motor is used to propel the car, however with the use of electronic technology, the motor can also function as a generator to recharge the batteries.

ELECTRIC GENERATOR :-

→ Electric generation generates electricity from the rotating wheels while braking, transferring that energy back to the traction battery pack.

→ Some vehicles use motor generators that perform both the drive and regeneration functions.

CONTROLLER :-

→ Regardless of the energy source, an electric vehicle needs a controller, which is connected to the accelerator pedal, for directing the flow of electricity from the energy source to the motor.

DC/DC CONVERTER :

→ This device converts higher voltage DC power from the traction battery pack to the lower voltage DC power needed to run vehicle accessories and recharge the auxiliary battery.

TRANSMISSION :

→ The transmission transfers mechanical power from the engine and/or electric traction motor to drive the wheels. The transmission can be either manual or automatic.

FUEL TANK :-

→ The fuel tank is used to store petrol for the petrol engine.

Batteries :

→ The batteries provide the energy source for the electric motor, either recharged by an external power source or recharged by the generator or electric motor when it is functioning as a generator.

→ Most electric cars use lead-acid batteries, but new types of batteries, including zinc chlorine, nickel metal-hydride and

Sodium-sulphur, are becoming more common.

BATTERY (AUXILARY):

→ In an electric drive vehicle, the auxiliary battery provides electricity to start the car before the traction battery is engaged and also powers vehicle accessories.

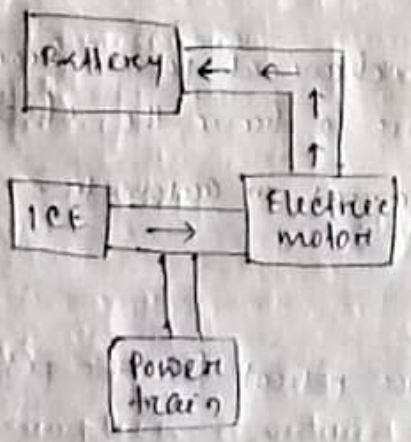
TRACTION BATTERY PACK:

→ Traction battery pack stores electricity for use by the electric traction motor.

4.4 WORKING OF HYBRID VEHICLES:

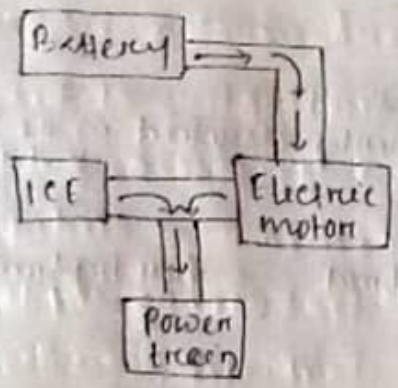
STARTING:

→ While starting the vehicle, the IC engine may, need the motor as a generator to produce some power and, store it in the battery.



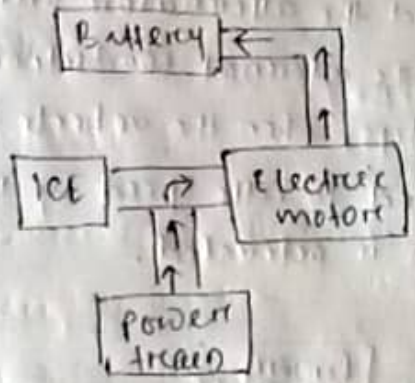
PASSING:

→ Passing needs a boost in speed, therefore the IC engine and the motor both drives the power train.



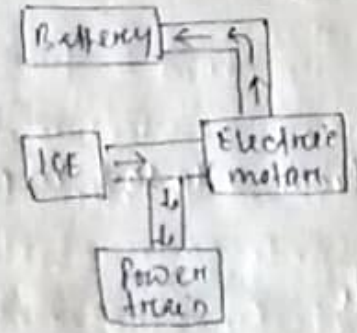
BRAKING :-

→ During braking the power train reverse the motor as generator to charge the battery by regenerative braking



CRUISING :-

→ While cruising, the engine runs both the vehicle and the motor as generator, which charges the battery. The power flow is stopped once the vehicle stops.



4.5 HYBRIDISATION :

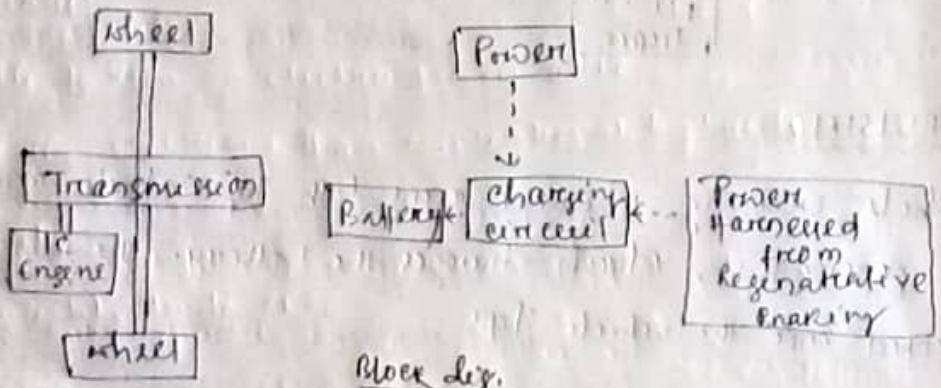
→ Hybrid cars are most commonly classified in the following 3 categories :-

1. Micro Hybrid 2. Mild hybrid 3. Full hybrid.

1. MICRO HYBRID :

→ Micro hybrid technology is the lowest level of vehicle hybridisation. It contains mainly start-stop technology. Here energy stored in an auxiliary battery is used to quickly start a vehicle at the traffic signal.

→ In this system the starter and the alternator are replaced with an electrical machine. The internal combustion engine switched off when the vehicle stops, when the vehicle sets off again it is quickly accelerated to idle speed by the electrical machine and then the ignition is activated.



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ADVANTAGES :

1. Fuel consumption is reduced from 5 to 10% in city driving
2. CO_2 emission is reduced.
3. Engine restarts in milliseconds.
4. Noise and vibrations are suppressed.
5. Implementation cost is not very high.

DISADVANTAGE :-

1. High maintenance cost
2. Some vehicle functions (air conditioner, etc.) may not work when engine is off.

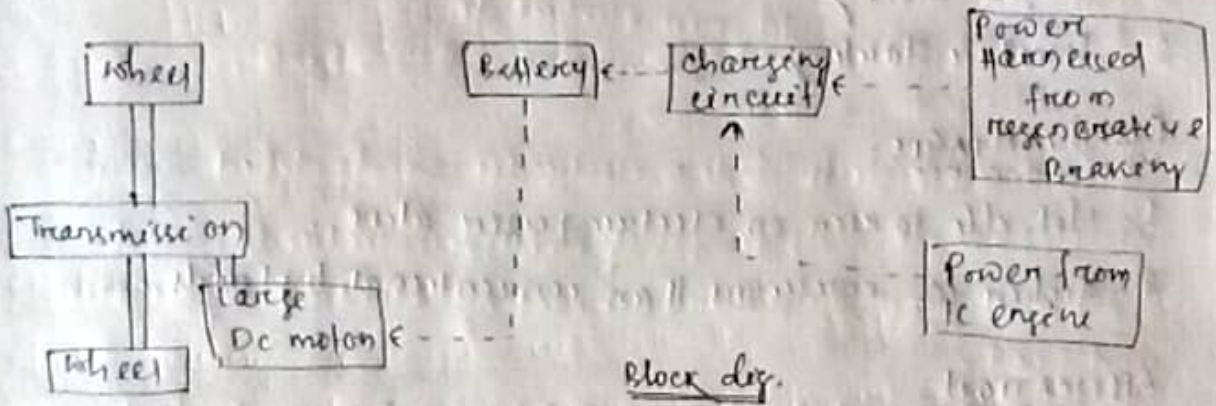
APPLICATION :

→ In India, a common example of micro hybrid is the Mahindra scorpio. Tata motors introduced this technologies in Tata ACE, BMW, fiat, Honda, Volkswagon and many other automobile manufacturers use this technology.

2. MILD HYBRID :

→ The next level of hybridisation is the mild hybrid where electrical energy is used for start-stop and also for driving vehicle for short distance at low speed or to aid in acceleration

→ A mild hybrid motor is only able to assist the engine ; it is not potent enough to drive the car independently, hence the word 'mild'



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→ Mild hybrid cars spend most of their time powered by their combustion engine, with a small motor/generator usually taking the place of conventional alternator - the device that normally charges the battery in a regular combustion engined car.

→ The electric motor can be directly flanged to the crank shaft in a mild hybrid. In mild hybrids, additional electrical energy of up to 20 KW is provided by the electric traction accumulators (battery). Unlike a full hybrid system the electric motor of a mild hybrid system never propels the

car on its own, with the motor/generator only delivering power for starting off and accelerating at low engine rpm.

→ As well as providing a boost to the engine, mild hybrids cuts the ignition when engine power is not needed such as when stationary, rolling on when braking - a system more commonly known as engine start-stop.

→ Some also capture energy using regenerative braking, which converts the car's kinetic energy when decelerating and stores it as electrical energy in the batteries.

ADVANTAGES:

1. Improve efficiency by up to 15%.
2. Weight saving
3. Smoother starting

DISADVANTAGES:

1. Not able to run on electric power alone.
2. Higher CO_2 emissions than conventional hybrids.

APPLICATION

→ Honda Insight, Honda CR-Z

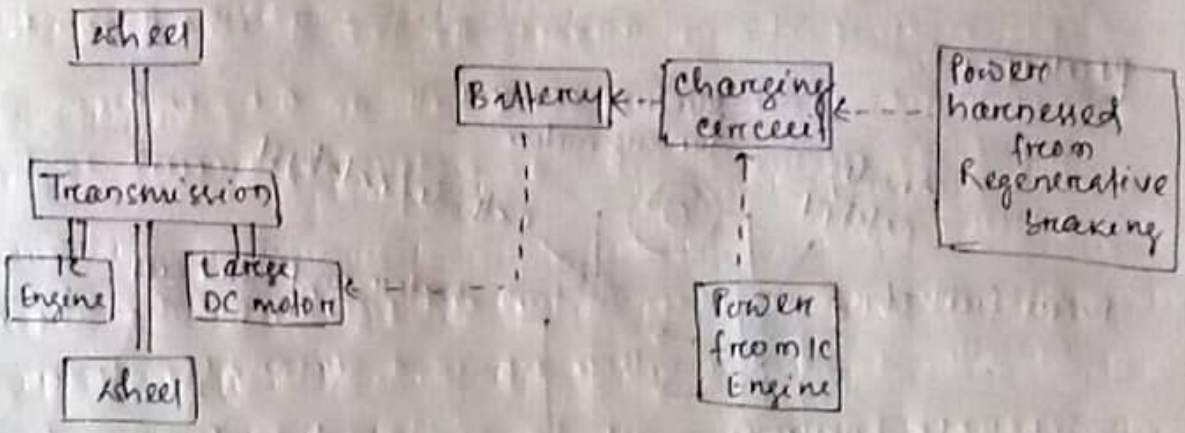
3. FULL HYBRID

→ A full hybrid (HEV), sometimes also called a strong hybrid is driven over longer distances with the electric drive alone.

→ The internal combustion engine does not function during electric driving. As strong hybrids can travel considerable distance using electric energy only, zero emission can be achieved.

→ The accumulator of these system is more powerful than those of the above mentioned micro-hybrid and mild hybrid variants.

→ The voltage of the traction electrical system on the battery usually ranges between 200 and 350V. It has a typical output of about 25 to 50 kW.



→ The full hybrid can be classified as a parallel hybrid or a series hybrid. The fuel savings of a full hybrid can be up to 30%.

Ex: Lexus CT200h

4.6 FUEL CELL ELECTRIC VEHICLE (FCEV)

→ The feasible alternatives to batteries for electric vehicles and hybrid electric vehicles are fuel cell and flywheels.

FUEL CELL:

→ A fuel cell is an electrochemical energy conversion device.

→ A fuel cell converts the chemicals hydrogen and oxygen into water and in the process it produces electricity (DC voltage) with water and heat as its by-product.

→ In principle, a fuel cell operates like a battery. Unlike battery a fuel cell does not run down or require recharging. It will produce electricity as long as fuel is supplied.

→ There are different types of fuel cells, each using a different chemistry. Fuel cells are usually classified by the type of electrolyte they use.

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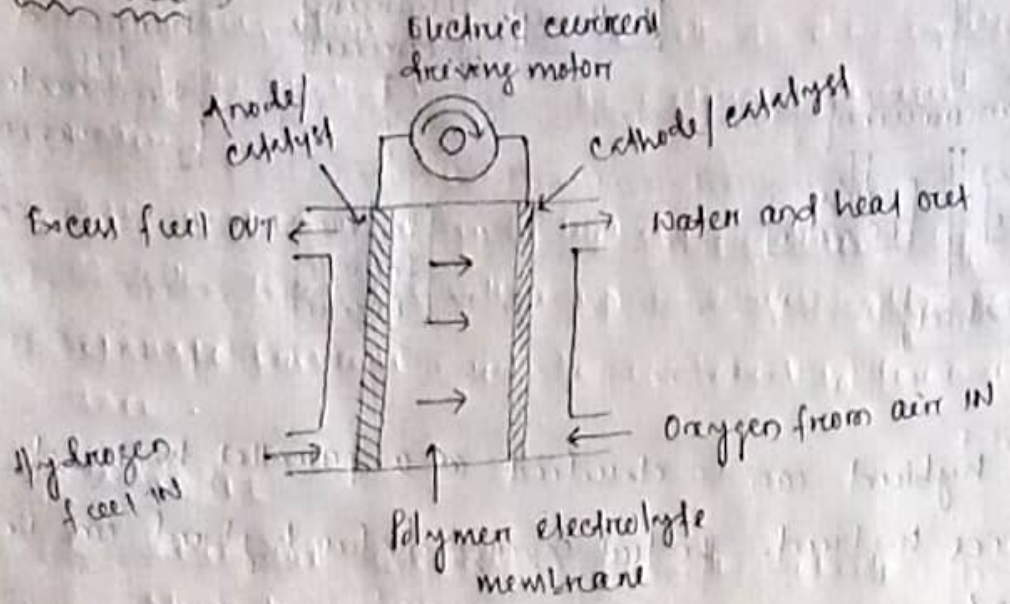
(a) Alkaline fuel cell
(b) Phosphoric fuel cell
(c) Solid oxide fuel cell
(d) Molten carbonate fuel cell.

PRINCIPLE :



→ A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water and heat.

→ The pressurised hydrogen gas (H_2) entering the fuel cell on the anode side, which is negative post of the fuel cell.

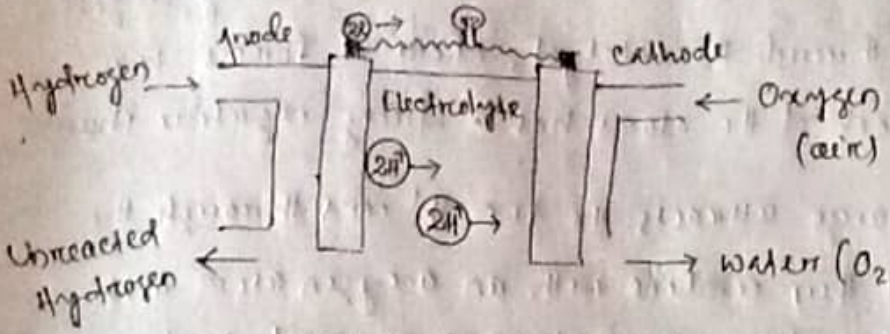
→ It conducts the electrons that are free from the hydrogen molecules so that they can be used in an external circuit.

→ It has channels etched onto it that disperse the hydrogen gas equally over the surface of the catalyst.

→ Oxygen (or air) enters through the cathode, which is the positive post of fuel cell. The cathode also channels etched into it that distribute the oxygen to the surface of the catalyst.

→ It also conducts the electrons back from the external circuit to the catalyst where they can combine with the hydrogen ions

and oxygen to form water.



$H_2 \rightarrow 2H^+ + 2e^-$ $\quad 2e^- + 2H^+ + \frac{1}{2}O_2 \rightarrow H_2O$

→ The electrolyte is the proton exchange membrane. The especially treated material only conducts positively charged ions. The membrane blocks electrons.

→ The catalyst is a special material that facilitates the reaction of oxygen and hydrogen. It is usually made platinum powder very thinly coated onto carbon paper or cloth.

→ The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen.

→ The platinum-coated side of the catalyst face the polymer electrolyte membrane (PEM).

→ The pressurized hydrogen gas (H_2) entering the fuel cell on the anode side. This gas is forced through the catalyst by the pressure

→ when a hydrogen molecule comes in contact with the platinum on the catalyst, it splits in to two H^+ ions and two electrons (e^-).

→ The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.

Anode side : $2H_2 \longrightarrow 4H^+ + 4e^-$

cathode side : $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Net reaction : $2H_2 + O_2 \rightarrow 2H_2O$

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→ Mean while on the cathode side of the fuel cell, Oxygen gas (O_2) is being forced through the catalyst, where it forms two Oxygen atoms. Each of the atoms has a strong negative charge.

→ This negative charge attracts the two H^+ ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form water.

→ This reaction in a single fuel cell produces only about 0.7 volts. To get this voltage up to a reasonable level, many separate fuel cells must be combined to form a fuel cell stack.

ADVANTAGES:-

1. There are no emissions from the vehicle.
2. Noise levels are very low.
3. Vehicle is vibration free.
4. Operating range is comparable to conventional vehicles.
5. Highly efficient.

DISADVANTAGES:-

1. Storage and handling with some primary fuels such as hydrogen and natural gas is difficult.
2. It is difficult to match the electrical output to fluctuating vehicle demand.
3. Complicated controls are needed.