HYBRID BIKE USING BATTERY PACK

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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INTERNAL EXAMINER	**EXTERNAL EXAMINER**

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ABSTRACT

As the emission norms are becoming stricter and loss of renewable fuels, the automotive manufacturers are facing several challenges in controlling the pollution and production of vehicles.Currently, there are tons of technologies emerging in batteries and charging infrastructure we can proceed safely into the EV (Electric Vehicles) environment. Indian manufacturers like Tata, Mahindra, Ather are looking into the battery chemistry of NMC (Nickel Magnesium & Cobalt) and Lithium ion which will eventually reduce the cost of the batteries.Our work is to merge the traditional IC engine and futuristic EV to create a hybrid between the two. So, we can introduce the new technology in the market and there by reduce the pollution and fear of EV amongst the people. Electric scooters are plug-in electric vehicles with two wheels that can be recharged from any external source of electricity, and the electricity is stored in a rechargeable battery, which provides power to one or more electric motors to attain movement. Electric scooter, as differentiated from scooters, do not have a step-through frame. The electricity generated from an external source helps in acceleration of the motorcycle. The speed of this cycle is limited (45km/h). The electricity is stored using a battery and the locomotion and movement of the vehicle is hence propelled using an electric hub motor The electric scooter are not using an engine, becomes an effective way of road transport as it causes no pollution. It is eco-friendly and it definitely reduces human effort. In this project report, work concerning product design and manufacturing process making of an electric scooter is described, which was the outcome of a collaborative project for new product development. The final product was satisfactory, and was designed according to the aesthetic principle of golden section proportion, and subsequently outer housings were produced with carbon fiber. Not only the product appearance was created, but an electric scooter was also built using various traditional modeling and engineering techniques.

TABLE OF CONTENT

CONTENTS **PAGE**

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

1. INTRODUCTION

In recent years, environmental problems caused by fuel vehicles and fuel economy become more and more serious. The vehicles of new energy, which is green, environmentally friendly and economical, is an important goal for economic and social development of many countries, but also the future development direction of the vehicle. HEV is a vehicle with zero pollution emissions, mileage and fuel vehicles can be mutually comparable electric vehicles. Being an e-scooter the electric system plays a promising role in its designing and creation. The electric system consists of battery, motor, motor controller and other electronic equipment. The most important thing that electric system does is that it gives power to the motor which helps in the running of the scooter. This energy in form of chemical or electric energy is stored in the battery which is used by a hub motor, thus the electric or chemical energy converted to mechanical energy. A proper electric system is important to ensure driver and vehicle safety in case of collision. The brushless DC (BLDC) motor is fixed to hub of rear wheel of e- scooter. The reason for choosing BLDC motor is its compactness and noiseless operation. So our main Objectives to design or development an e-scooter are as following and the type of electric scooter are

- Hybrid Electric Vehicle (HEV)
- Full Electric Vehicle (FEV)
- Plug-in Hybrid Electric Vehicles (PHEVs)
- Hybrid Electric Vehicles (HEVs) and Plug-in HEVs (PHEVs)

1.1 TYPES OF ELECTRIC VEHICLES

1.1.1 Hybrid Electric Vehicle (HEV)

Within the drive train, it combines an ICE with an electric motor. The electric motor mostly assists the ICE in terms of fuel economy and/or performance. The vehicle is then propelled either by a combustion engine or by an electric drive. A Plug-in Hybrid Electric Vehicle (PHEV) is a vehicle that, in general, has a larger battery than HEVs and can be recharged via household outlets or charging stations. While most vehicles can be propelled by both the electric drive and the ICE, certain vehicles only use the electric drive. In this case, the ICE can either replenish or directly power the battery.

1.1.2 Full Electric Vehicle (FEV)

It is entirely powered by electricity. Their batteries, like those of PHEVs, are huge and can be recharged at charging stations or at home. Because no pollutants are released while driving, these vehicles are frequently promoted as zero-emission automobiles. Naturally, this is not quite correct terminology, because charging the batteries will generate emissions depending on the actual emissions of the country's power generation. Because many power plants are located in less populous areas, the use of FEVs has a positive effect on emissions in population centers. Such vehicles could be thought of as filters that convert filthy energy into clean energy. 4

1.1.3 Plug-in Hybrid Electric Vehicles (PHEVs)

Plug-in hybrid electric vehicles (PHEVs) combine the benefits of an electric car with those of a combustion engine vehicle. Concerns regarding action range limitation are alleviated by the addition of an internal combustion engine (ICE), which can take over the power supply of the power train if the battery system runs out of power. Plug-in hybrids are currently the subject of political debate in approach to the issue of rapidly rising gasoline costs. PHEVs are most commonly utilised in delivery vans, which may be recharged at regular intervals throughout their daily route, as well as passenger cars, particularly those used for daily commuting. Similar to a pure electric vehicle (EV), a PHEV may use power from the grid. The quantity of carbon dioxide saved will be determined by the power mix, which includes a mix of fossil energy, nuclear energy, and renewable energy.

1.1.4 Hybrid Electric Vehicles (HEVs) and Plug-in HEVs (PHEVs)

The battery energy rating ranges from 5 to 50 kWh in these cases. While the machine's current limit is determined by its ability to dissipate heat, the voltage limit is determined by the dc-link voltage level. Using a dc-dc boost converter effectively extends the constant torque area. The current density of the 1200V SiC-MOSFET is comparable to the current density of the lower voltage 600V SiIGBT due to the improved current density characteristics of the SiC-MOSFET compared to the SiIGBT. This advantage results in a two-fold reduction in semiconductor chip area thanks to the use of high-voltage motors and SiCMOSFETs. 5 Furthermore, the reduced current peak at a higher voltage leads to smaller peak losses by a factor of four . Since power loss translates directly into cooling system capacity, a significant reduction in cooling system size and weight, as well as an improvement in EV range, can be achieved. Vehicle Type Electric Vehicles (EV) GasolinePowered (IC) Plug-In Hybrid (PHEV) Hybrid Vehicle (HV) Energy Source Electric only Gasoline only Main: Electric Sub: Gasoline Main: Gasoline Sub: Electric Propulsion Mechanism Motors Engine Motor & Engine Motor & Engine CO2 Emissions None Yes Fuel Facility Locations Charging stations Gas stations Gas stations,

Chargers Gas stations Tax Liability Low High Low Cruising Distance Short Long

Table 1.1 Distinguishing features of different vehicle technologies

CHAPTER 2

LITERATURE REVIEW

The damiano lanzoroto has studied and analyzed the main HEV architectures are presented in this paper and the focus is on medium size car (1450 kg). Different fuel consumption data available in the scientific literature, regarding these HEV architectures, were analyzed. The results show that the parallel CVT powertrain is not the most efficient solution, although it is the most common architecture one can find on the market. Two innovative technologies are then presented (supercapacitors and SiC components) which have a great impact on the HEV development. In particular, series architectures, which are disadvantaged by batteries, thanks to these innovations become the best practice in term of energy efficiency. Hence, electrical innovations by allowing the optimal management of power flows and ICE power generation (at the cost of low electrical losses), can make one reconsider the entire HEV design process.

J ia YingYing, et. al.,[1] has done a deep analysis of three-phase inverter systemlevel simulation model based on SVPWM algorithm and shown us from the simulation model that this control algorithm has good dynamic performance, when doing current control, according to the tracked current vector selecting optimized voltage vector to conduct PWM current tracking control. They also showed that SVPWM control has a lower switching frequency, which can effectively reduce the switching loss of the power switch and is more suitable for high power load applications.

Reda Cherif, et. al.,[2] suggested that if the electric car were to take over road transportation, one would expect an increase in demand for electricity to be quite substantial. However, renewables are growing rapidly enough to provide the increasing demand for electricity and potentially replace existing fossil energy sources. Examining the potential increase in demand for electricity because of a significant rise in electric vehicles, we note it would have been only a fraction of electricity consumption in an advanced economy in 2015. They also cautioned that a transition to EVs would also disrupt the auto industry, both in production and maintenance, with much shorter value chains and more reliable vehicles. The production of EVs requires a much smaller number of parts and much less maintenance in comparison to motor vehicles, and the possibility of onshoring into advanced economies would be likely to be done in the future.

Yantao Song and Bingsen Wang,[3] proposed a reliability prediction model for electric vehicles. In comparison to the existing part-count method that determines the reliability of a system solely based on the types and numbers of components used in the system, the model presented in this paper not only considers the thermal and electrical stresses, but also includes the effects of load variations related to driving behaviours and road conditions since the model is based on the standard driving cycles. Both the simulation and experimental results shown in that paper have verified that the proposed methods are effective in reducing losses of the HEV powertrain and improving the reliability.

Ms. Dolly Reney [4] compares sine pulse width modulation and space vector pulse width modulation. The simulation results from this paper clearly shows us that the SVPWM technique utilizes dc bus voltage more efficiently. The maximum output voltage based on the space vector technique is $2/\sqrt{3} = 1.155$ times as large as the convectional sinusoidal modulation. In addition to this, it also generates less harmonic distortion in a three-phase voltage source inverter.

Bo Dong, et. al.,[5] has found a way to get rid of the limitation of slow equalization speed in battery charge equalizers. This paper presented a new architecture for battery equalization in a series-string. Operating principles of this new architecture have been investigated, analysed, and compared in this paper. From simulations and experiments, it is proved that the new architecture has a faster equalization speed and shorter equalization time compared to the traditional architecture. This method will allow significant improvements in the performance of energy storage systems.

8 Hua Chen, et. al.,[6] has cautioned that the electrified automotive powertrain is a thermally limited. To overcome the limitations of the previous approaches, this paper proposes a composite boost converter. This approach employs a dc transformer module to process most of the indirect power in a more efficient way and combines several smaller converter modules into a composite system. Each module processes a fraction of the total system power, with higher efficiency. At a given operating point, one or more of the converter modules operate either in shut down or in pass through mode, reducing the ac power loss. This paper also shows that this greater complexity can lead to substantial benefits of nonincremental reductions in system loss and in film capacitor size.

R. Erickson, D. Maksimovic, et. al.,[7] in designed a remarkable 98% efficient Si composite boost converter system switching at 20 KHz (boost and buck modules) and 33 kHz (DCX module) at a voltage operating point of 650 V, and with a wide range of output power. This remarkable efficiency characteristic leads to significant and non-incremental reductions in total loss over standard drive cycles, which can lead to reduced temperature rise and increased MTTF over the lifetime of the vehicle. They also proposed a system control algorithms, which leads to a stable and reliable operation with mode switching, current limiting, reversal of power flow, and damping of module resonances.

CHAPTER 3

EXISTING SYSTEM

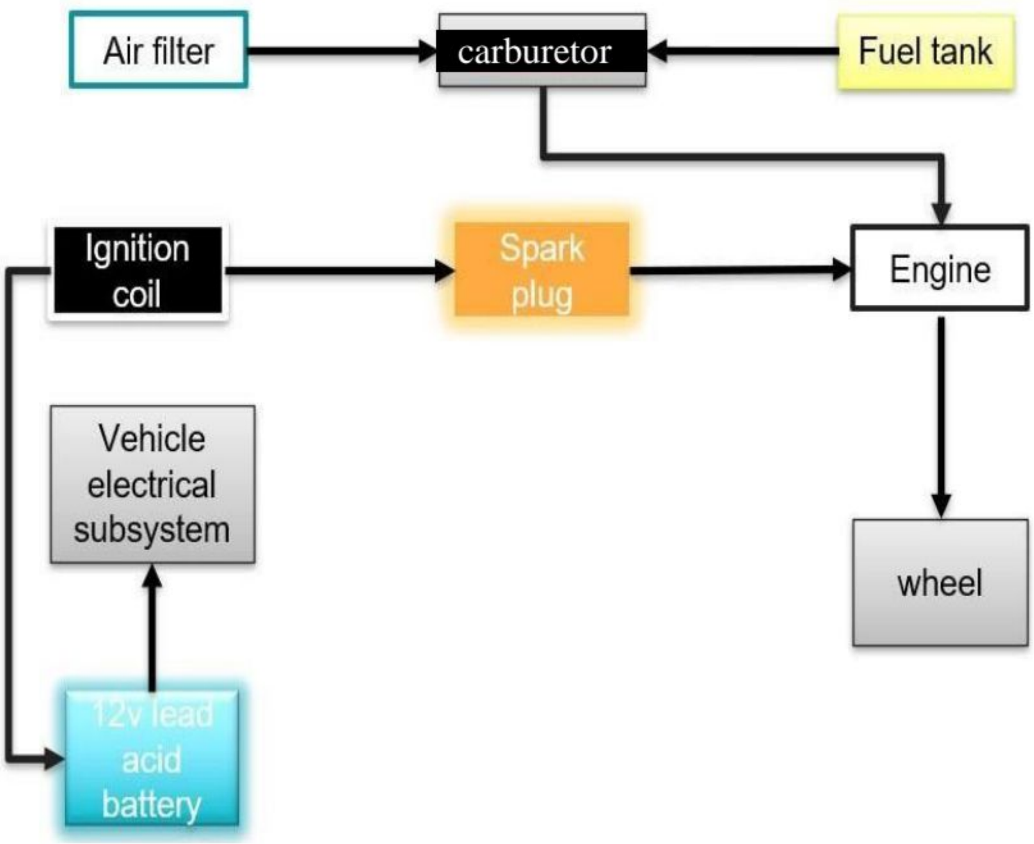

Fig :1. block diagram of petrol vehicle

Working principle

Combustion, also known as burning, is the basic chemical process of releasing energy from a fuel and air mixture. In an internal combustion engine (ICE), the ignition and combustion of the fuel occurs within the engine itself. The engine then partially converts the energy from the combustion to work. The engine consists of a fixed cylinder and a moving piston. The expanding combustion gases push the piston, which in turn rotates the crankshaft. Ultimately, through a system of gears in the powertrain, this motion drives the vehicle's wheels.There are two kinds of internal combustion engines currently in production: the spark ignition gasoline engine and the compression ignition diesel engine. Most of these are four-stroke cycle engines, meaning four piston strokes are needed to complete a cycle. The cycle includes four distinct processes: intake, compression, combustion and power stroke, and exhaust.Spark ignition gasoline and compression ignition diesel engines differ in how they supply and ignite the fuel. In a spark ignition engine, the fuel is mixed with air and then inducted into the cylinder during the intake process. After the piston compresses the fuel-air mixture, the spark ignites it, causing combustion. The expansion of the combustion gases pushes the piston during the power stroke. In a diesel engine, only air is inducted into the engine and then compressed. Diesel engines then spray the fuel into the hot compressed air at a suitable, measured rate, causing it to ignite.

CHAPTER 4

PROPOSED SYSTEM

4.1 Block diagram

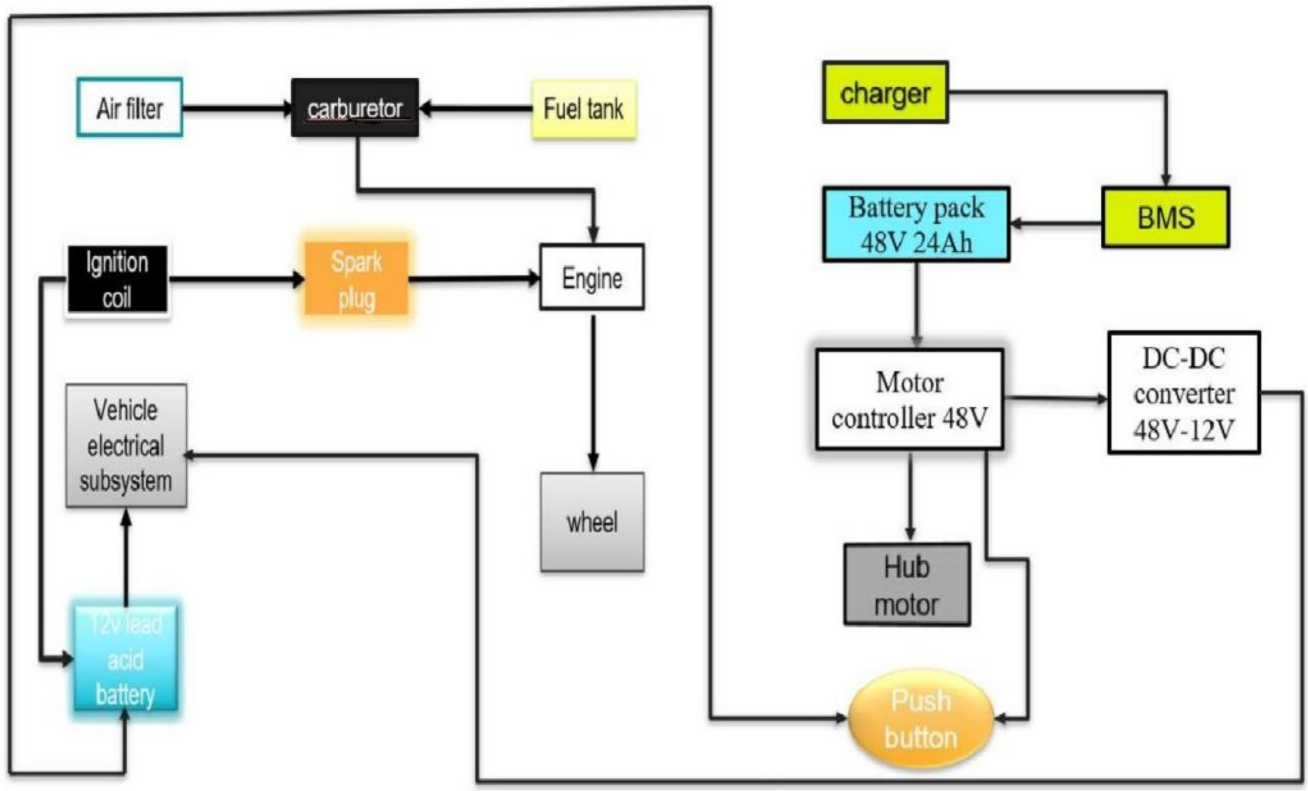

Fig .2. Block diagram of hybrid electric vehicle

4.2 LITHIUM-ION BATTERY

A lithium-ion battery or Li-ion battery is a type of rechargeable battery composed of cells in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge and back when charging. Liion cells use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. Li-ion batteries have a high energy density, no memory effect (other than LFP cells) and low selfdischarge. Cells can be manufactured to prioritize either energy or power density. They can however be a safety hazard since they contain flammable electrolytes and if damaged or incorrectly charged can lead to explosions and fires.

A prototype Li-ion battery was developed by Akira Yoshino in 1985, based on earlier research by John Goodenough, M. Stanley Whittingham, Rachid Yazami and Koichi Mizushima during the 1970s–1980s, and then a commercial Li-ion battery was developed by a Sony and Asahi Kasei team led by Yoshio Nishi in 1991. Lithium-ion batteries are commonly used for portable electronics and electric vehicles and are growing in popularity for military and aerospace applications.

Chemistry, performance, cost and safety characteristics vary across types of lithiumion batteries. Handheld electronics mostly use lithium polymer batteries (with a polymer gel as electrolyte), a lithium cobalt oxide ($LiCoO_2$) cathode material, and a graphite anode, which together offer a high energy density. Lithium iron phosphate ($LiFePO_4$), lithium manganese oxide ($LiMn_2O_4$ spinel, or Li_2MnO_3-based lithium rich layered materials, LMR-NMC), and lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$ or NMC) may offer longer lives and may have better rate capability. Such batteries are widely used for electric tools, medical equipment, and other roles.

NMC and its derivatives are widely used in the electrification of transport, one of the main technologies (combined with renewable energy) for reducing greenhouse gas emissions from vehicles.[18][19] Improperly recycled batteries can create toxic waste, especially from toxic metals and are at risk of fire. Moreover, both lithium and other key strategic minerals used in batteries have significant issues at extraction, with lithium being water intensive in often arid regions and other minerals often being conflict minerals such as cobalt. Both environmental issues have encouraged some researchers to improve mineral efficiency and alternatives such as iron-air batteries.

Research areas for lithium-ion batteries include extending lifetime, increasing energy density, improving safety, reducing cost, and increasing charging speed, among others. Research has been under way in the area of non-flammable electrolytes as a pathway to increased safety based on the flammability and volatility of the organic solvents used in the typical electrolyte. Strategies include aqueous lithium-ion batteries, ceramic solid electrolytes, polymer electrolytes, ionic liquids, and heavily fluorinated systems.

4.2.1 Design

Fig.3. Cylindrical Panasonic 18650 lithium-ion cell before closing**.**

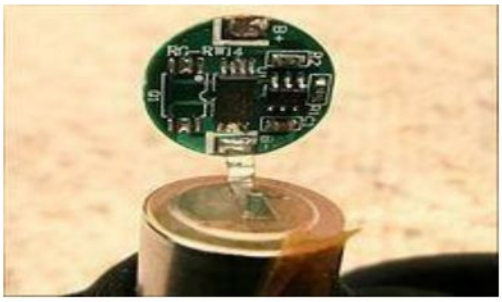

Fig.4.Lithium-ion battery monitoring electronics (over-charge and deep-discharge protection)

Fig.5.lithium ion battery

- An 18650 size lithium ion cell, with an alkaline AA for scale. 18650 are used for example in notebooks or HHEVs
- Generally, the negative electrode of a conventional lithium-ion cell is made from carbon. The positive electrode is typically a metal oxide. The electrolyte is a lithium salt in an organic solvent. The electrochemical roles of the electrodes reverse between anode and cathode, depending on the direction of current flow through the cell.
- The most common commercially used anode (negative electrode) is graphite, which in its fully lithiated state of LiC_6 correlates to a maximal capacity of 1339 C/g (372 mAh/g). The positive electrode is generally one of three materials: a layered oxide (such as lithium cobalt oxide), a polyanion (such as lithium iron phosphate) or a spinel (such as lithium manganese oxide). More experimental materials include graphene-containing electrodes, although these remain far from commercially viable due to their high cost.
- Lithium reacts vigorously with water to form lithium hydroxide (LiOH) and hydrogen gas. Thus, a non-aqueous electrolyte is typically used, and a sealed container rigidly excludes moisture from the battery pack. The non-aqueous electrolyte is typically a mixture of organic carbonates such as ethylene carbonate or diethyl carbonate containing complexes of lithium ions. The salt is almost always lithium hexafluorophosphate ($LiPF_6$), which combines good ionic conductivity with

chemical and electrochemical stability. Other salts like lithium perchlorate ($LiClO_4$), lithium tetrafluoroborate ($LiBF_4$), and lithium bis(trifluoromethanesulfonyl)imide ($LiC_2F_6NO_4S_2$) are frequently used in research for reasons of cost or convenience but are not usable in commercial cells.

- Depending on materials choices, the voltage, energy density, life, and safety of a lithium-ion cell can change dramatically. Current effort has been exploring the use of novel architectures using nanotechnology to improve performance. Areas of interest include nano-scale electrode materials and alternative electrode structures.
- The increasing demand for batteries has led vendors and academics to focus on improving the energy density, operating temperature, safety, durability, charging time, output power, elimination of cobalt requirements, and cost of lithium-ion battery technology.

4.2.2 Electrochemistry

The reactants in the electrochemical reactions in a lithium-ion cell are materials of anode and cathode, both of which are compounds containing lithium atoms. During discharge, an oxidation half-reaction at the anode produces positively charged lithium ions and negatively charged electrons. The oxidation halfreaction may also produce uncharged material that remains at the anode. Lithium ions move through the electrolyte, electrons move through the external circuit, and then they recombine at the cathode (together with the cathode material) in a reduction half-reaction. The electrolyte and external circuit provide conductive media for lithium ions and electrons, respectively, but do not partake in the electrochemical reaction. During discharge, electrons flow from the negative electrode (anode) towards the positive electrode (cathode) through the external circuit. The reactions during discharge lower the chemical potential of the cell, so discharging transfers energy from the cell to wherHHEVer the electric current dissipates its energy, mostly in the external circuit. During charging these reactions and transports go in the opposite direction: electrons move from the positive electrode to the negative electrode through the external circuit.

To charge the cell the external circuit has to provide electric energy. This energy is then stored as chemical energy in the cell (with some loss, e. g. due to coulombic efficiency lower than 1).

Both electrodes allow lithium ions to move in and out of their structures with a process called *insertion* (*intercalation*) or *extraction* (*deintercalation*), respectively.

As the lithium ions "rock" back and forth between the two electrodes, these batteries are also known as "rocking-chair batteries" or "swing batteries" (a term given by some European industries).

The following equations exemplify the chemistry.

The positive electrode (cathode) half-reaction in the lithium-doped cobalt oxide substrate is

$$\mathrm{CoO_2 + Li^+ + e^- \rightleftharpoons LiCoO_2}$$

The negative electrode (anode) half-reaction for the graphite is

$$\mathrm{LiC_6 \rightleftharpoons C_6 + Li^+ + e^-}$$

The full reaction (left to right: discharging, right to left: charging) being

$$\mathrm{LiC_6 + CoO_2 \rightleftharpoons C_6 + LiCoO_2}$$

The overall reaction has its limits. Over discharging supersaturates lithium cobalt oxide, leading to the production of lithium oxide, possibly by the following irreversible reaction:

$$\mathrm{Li^+ + e^- + LiCoO_2 \longrightarrow Li_2O + CoO}$$

Overcharging up to 5.2 volts leads to the synthesis of cobalt (IV) oxide, as Evidenced by x-ray diffraction:

$$LiCoO_2 \longrightarrow Li^+ + CoO_2 + e^-$$

In a lithium-ion cell, the lithium ions are transported to and from the positive or negative electrodes by oxidizing the transition metal, cobalt (Co), in $Li_{1-x}CoO_2$ from Co^{3+} to Co^{4+} during charge, and reducing from Co^{4+} to Co^{3+} during discharge. The cobalt electrode reaction is *only* reversible for $x < 0.5$ (x in mole units), limiting the depth of discharge allowable. This chemistry was used in the Li-ion cells developed by Sony in 1990.

The cell's energy is equal to the voltage times the charge. Each gram of lithium represents Faraday's constant/6.941, or 13,901 coulombs. At 3 V, this gives 41.7 kJ per gram of lithium, or 11.6 kWh per kilogram of lithium. This is a bit more than the heat of combustion of gasoline but does not consider the other materials that go into a lithium battery and that make lithium batteries many times heavier per unit of energy.

The cell voltages given in the Electrochemistry section are larger than the potential at which aqueous solutions will electrolyze.

Liquid electrolytes in lithium-ion batteries consist of lithium salts, such as $LiPF_6$, $LiBF_4$ or $LiClO_4$ in an organic solvent, such as ethylene carbonate, dimethyl carbonate, and diethyl carbonate.A liquid electrolyte acts as a conductive pathway for the movement of cations passing from the negative to the positive electrodes during discharge. Typical conductivities of liquid electrolyte at room temperature (20 °C (68 °F)) are in the range of 10 mS/cm, increasing by approximately 30–40% at 40 °C (104 °F) and decreasing slightly at 0 °C (32 °F). The combination of linear and cyclic carbonates (e.g., ethylene carbonate (EC) and dimethyl carbonate (DMC)) offers high conductivity and solid electrolyte interphase (SEI)-forming ability. Organic solvents easily decompose on the negative electrodes during charge. When appropriate organic solvents are used as the electrolyte, the solvent decomposes on initial charging and forms a solid layer called the solid electrolyte interphase, which is electrically insulating, yet provides significant ionic conductivity. The interphase prHHEVents further decomposition of the electrolyte after the second charge. For example, ethylene carbonate is decomposed at a relatively high voltage, 0.7 V vs. lithium, and forms a dense and stable interface. Composite electrolytes based on POE (poly(oxyethylene)) provide a relatively stable interface.[58][59] It can be either solid (high molecular weight) and be applied in dry Li-polymer cells, or liquid (low molecular weight) and be applied in regular Li-ion cells. Room-temperature ionic liquids (RTILs) are another approach to limiting the flammability and volatility of organic electrolytes.

Recent advances in battery technology involve using a solid as the electrolyte material. The most promising of these are ceramics. Solid ceramic electrolytes are mostly lithium metal oxides, which allow lithium-ion transport through the solid more readily due to the intrinsic lithium. The main benefit of solid electrolytes is that there is no risk of leaks, which is a serious safety issue for batteries with liquid electrolytes. Solid ceramic electrolytes can be further broken down into two main categories: ceramic and glassy. Ceramic solid electrolytes are highly ordered compounds with crystal structures that usually have ion transport channels. Common ceramic electrolytes are lithium super ion conductors (LISICON) and perovskites. Glassy solid electrolytes are amorphous atomic structures made up of similar elements to ceramic solid electrolytes but have higher conductivities overall due to higher conductivity at grain boundaries. Both glassy and ceramic electrolytes can be made more ionically conductive by substituting sulfur for oxygen. The larger radius of sulfur and its higher ability to be polarized allow higher conductivity of lithium. This contributes to conductivities of solid electrolytes are nearing parity with their liquid counterparts, with most on the order of 0.1 mS/cm and the best at 10 mS/cm. An efficient and economic way to tune targeted electrolytes properties is by adding a third component in small concentrations, known as an additive. By adding the additive in small amounts, the bulk properties of the electrolyte system will not be affected whilst the targeted property can be significantly improved. The numerous additives that have been tested can be divided into the following three distinct categories: (1) those used for SEI chemistry modifications; (2) those used for enhancing the ion conduction properties; (3) those used for improving the safety of the cell (e.g. prHHEVent overcharging).

4.2.3 Charging And Discharging

During discharge, lithium ions (Li^+) carry the current within the battery cell from the negative to the positive electrode, through the non-aqueous electrolyte and separator diaphragm.

During charging, an external electrical power source (the charging circuit) applies an over-voltage (a higher voltage than the battery produces, of the same polarity), forcing a charging current to flow within each cell from the positive to the negative electrode, i.e., in the reverse direction of a discharge current under normal conditions. The lithium ions then migrate from the positive to the negative electrode, where they become embedded in the porous electrode material in a process known as intercalation.

Energy losses arising from electrical contact resistance at interfaces between electrode layers and at contacts with current collectors can be as high as 20% of the entire energy flow of batteries under typical operating conditions.

The charging procedures for single Li-ion cells, and complete Li-ion batteries, are slightly different:

A single Li-ion cell is charged in two stages:

1. Constant current (CC).
2. Constant voltage (CV).

A Li-ion battery (a set of Li-ion cells in series) is charged in three stages:

1. Constant current.
2. Balance (not required once a battery is balanced).
3. Constant voltage.

During the constant current phase, the charger applies a constant current to the battery at a steadily increasing voltage, until the voltage limit per cell is reached.

During the balance phase, the charger reduces the charging current (or cycles the charging on and off to reduce the average current) while the state of charge of individual cells is brought to the same level by a balancing circuit, until the battery is balanced. Some fast chargers skip this stage. Some chargers accomplish the balance by charging each cell independently.

During the *constant voltage* phase, the charger applies a voltage equal to the maximum cell voltage times the number of cells in series to the battery, as the current gradually declines towards 0, until the current is below a set threshold of about 3% of initial constant charge current.

Periodic topping charge about once per 500 hours. Top charging is recommended to be initiated when voltage goes below 4.05 V/cell

Failure to follow current and voltage limitations can result in an explosion.

Charging temperature limits for Li-ion are stricter than the operating limits. Lithium-ion chemistry performs well at elevated temperatures but prolonged exposure to heat reduces battery life. Li-ion batteries offer good charging performance at cooler temperatures and may haven allow 'fast-charging' within a temperature range of 5 to 45 °C (41 to 113 °F). Charging should be performed within this temperature range. At temperatures from 0 to 5 °C charging is possible, but the charge current should be reduced. During a low-temperature charge, the slight temperature rise above ambient due to the internal cell resistance is beneficial. High temperatures during charging may lead to battery degradation and charging at temperatures above 45 °C will degrade battery performance, whereas at lower temperatures the internal resistance of the battery may increase, resulting in slower charging and thus longer charging times. Consumer-grade lithium-ion batteries should not be charged at temperatures below 0 °C (32 °F). Although a battery pack may appear to be charging normally, electroplating of metallic lithium can occur at the negative electrode during a subfreezing charge, and may not be removable haven by repeated cycling. Most devices equipped with Li-ion batteries do not allow charging outside of 0–45 °C for safety reasons, except for mobile phones that may allow some degree of charging when they detect an emergency call in progress.

Fig.6. lithium power bank battery

A lithium-ion battery from a laptop computer (176 kJ)

Batteries gradually self-discharge Haven if not connected and delivering current. Liion rechargeable batteries have a self-discharge rate typically stated by manufacturers to be 1.5–2% per month.

The rate increases with temperature and state of charge. A 2004 study found that for most cycling conditions self-discharge was primarily time-dependent; however, after several months of stand on open circuit or float charge, state-ofcharge dependent losses became significant. The self-discharge rate did not increase monotonically with state-of-charge, but dropped somewhat at intermediate states of charge. Self-discharge rates may increase as batteries age. In 1999, self-discharge per month was measured at 8% at 21 °C, 15% at 40 °C, 31% at 60 °C, By 2007, monthly self-discharge rate was estimated at 2% to 3%, and 2–3% by 2016. By comparison, the self-discharge rate for NiMH batteries dropped, as of 2017, from up to 30% per month for previously common cells to about 0.08–0.33% per month for low self-discharge NiMH batteries, and is about 10% per month in NiCd batteries.

• CATHODE

Cathode materials are generally constructed from $LiCoO_2$ or $LiMn_2O_4$. The cobaltbased material develops a pseudo tetrahedral structure that allows for twodimensional lithium-ion diffusion. The cobalt-based cathodes are ideal due to their high theoretical specific heat capacity, high volumetric capacity, low selfdischarge, high discharge voltage, and good cycling performance. Limitations include the high cost of the material, and low thermal stability. The manganese based materials adopt a cubic crystal lattice system, which allows for threedimensional lithium-ion diffusion. Manganese cathodes are attractive because manganese is cheaper and because it could theoretically be used to make a more efficient, longer-lasting battery if its limitations could be overcome. Limitations include the tendency for manganese to dissolve into the electrolyte during cycling leading to poor cycling stability for the cathode. Cobalt-based cathodes are the most common, however other materials are being researched with the goal of lowering costs and improving cell life.

As of 2017, $LiFePO_4$ is a candidate for large-scale production of lithium-ion batteries such as hybrid electric vehicle applications due to its low cost, excellent safety, and high cycle durability. For example, Sony Foreloin batteries have retained 74% of their capacity after 8000 cycles with 100% discharge. A carbon conductive agent is required to overcome its low electrical conductivity.

Positive electrode

Technology	Company	Target application	Benefit
Lithium Nickel Manganese Cobalt Oxide **NMC**, $LiNi_xMn_yCo_zO_2$	Imara Corporation, Nissan Motor,[91][92] Microvast Inc., LG Chem,[93] Northvolt[94]	Electric vehicles, power tools, grid energy storage	good specific energy and specific power density
Lithium Nickel Cobalt Aluminium Oxide **NCA**, $LiNiCoAlO_2$	Panasonic,[93] Saft Groupe S.A.[95] Samsung[96]	Electric vehicles	High specific energy, good life span
Lithium Manganese Oxide **LMO**, $LiMn_2O_4$	LG Chem,[97] NEC, Samsung,[98] Hitachi,[99] Nissan/AESC,[100] EnerDel[101]	Hybrid electric vehicle, cell phone, laptop	
Lithium Iron Phosphate **LFP**, $LiFePO_4$	University of Texas/Hydro-Québec,[102] Phostech Lithium Inc., Valence Technology, A123Systems/MIT[103][104]	Segway Personal Transporter, power tools, aviation products, automotive hybrid systems, PHEV conversions	moderate density (2 A·h outputs 70 amperes) High safety compared to Cobalt / Manganese systems. Operating temperature >60 °C (140 °F)
Lithium Cobalt Oxide **LCO**, $LiCoO_2$	Sony first commercial production[105][53]	broad use, laptop	High specific energy

Anode

Negative electrode materials are traditionally constructed from graphite and other carbon materials, although newer silicon-based materials are being increasingly used (see Nanowire battery). These materials are used because they are abundant and are electrically conducting and can intercalate lithium ions to store electrical charge with modest volume expansion (~10%). Graphite is the dominant material because of its low voltage and excellent performance. Various materials have been introduced, but their higher voltage reduces low energy density. Low voltage is the key requirement; otherwise, the excess capacity is useless in terms of energy density.

Negative electrode

Technology	Density	Durability	Company	Target application	Comments
Graphite	Weight: 260 wh/kg		Tesla	The dominant negative electrode material used in lithium ion batteries, limited to a capacity of 372 mAh/g.[39]	Low cost and good energy density. Graphite anodes can accommodate one lithium atom for every six carbon atoms. Charging rate is governed by the shape of the long, thin graphene sheets. While charging, the lithium ions must travel to the outer edges of the graphene sheet before coming to rest (intercalating) between the sheets. The circuitous route takes so long that they encounter congestion around those edges.[108]
Lithium Titanate **LTO**, $Li_4Ti_5O_{12}$			Toshiba, Altairnano	Automotive (Phoenix Motorcars), electrical grid (PJM Interconnection Regional Transmission Organization control area,[109] United States Department of Defense[110]), bus (Proterra)	Improved output, charging time, durability (safety, operating temperature −50–70 °C (−58–158 °F)).[111]
Hard Carbon			Energ2[112]	Home electronics	Greater storage capacity.
Tin/Cobalt Alloy			Sony	Consumer electronics (Sony Nexelion battery)	Larger capacity than a cell with graphite (3.5 Ah 18650-type cell).
Silicon/Carbon	Volumetric: 730 W·h/l Weight: 450 W-h/kg		Amprius[113]	Smartphones, providing 5000 mA·h capacity	Uses < 10% wt Silicon nanowires combined with graphite and binders. Energy density: ~74 mAh/g. Another approach used carbon-coated 15 nm thick crystal silicon flakes. The tested half-cell achieved 1.2 Ah/g over 800 cycles.[114]

As graphite is limited to a maximum capacity of 372 mAh/g much research has been dedicated to the development of materials that exhibit higher theoretical capacities, and overcoming the technical challenges that presently encumber their implementation. The extensive 2007 Review Article by Kasavajjula et al. summarizes early research on silicon-based anodes for lithium-ion secondary cells. In particular, Hong Li et al. showed in 2000 that the electrochemical insertion of lithium ions in silicon nanoparticles and silicon nanowires leads to the formation of an amorphous Li-Si alloy. The same year, Bo Gao and his doctoral advisor, Professor Otto Zhou described the cycling of electrochemical cells with anodes comprising silicon nanowires, with a reversible capacity ranging from at least approximately 900 to 1500 mAh/g.

To improve stability of the lithium anode, several approaches of installing a protective layer have been suggested. Silicon is beginning to be looked at as an anode material because it can accommodate significantly more lithium ions, storing up to 10 times the electric charge, however this alloying between lithium and silicon results in significant volume expansion (ca. 400%), which causes catastrophic failure for the cell. Silicon has been used as an anode material but the insertion and extraction of can create cracks in the material. These cracks expose the Si surface to an electrolyte, causing decomposition and the formation of a solid electrolyte interphase (SEI) on the new Si surface (crumpled graphene encapsulated Nanoparticles). This SEI will continue to grow thicker, deplete the available , and degrade the capacity and cycling stability of the anode.

4.2.4 Performance

Specific energy density	00 to 250 W.h/kg (360 to 900 kJ/kg)
Volumetric energy density	50 to 680 W·h/L (900 to 2230 J/cm^3)
Specific power density	00 to 1500 W/kg (at 20 seconds and 285 W·h/L)

Because lithium-ion batteries can have a variety of positive and negative electrode materials, the energy density and voltage vary accordingly.

The open-circuit voltage is higher than in aqueous batteries (such as lead–acid, nickel–metal hydride and nickel-cadmium). Internal resistance increases with both cycling and age, although this depends strongly on the voltage and temperature the batteries are stored at. Rising internal resistance causes the voltage at the terminals to drop under load, which reduces the maximum current draw. HHEVentually, increasing resistance will leave the battery in a state such that it can no longer support the normal discharge currents requested of it without unacceptable voltage drop or overheating.

Batteries with a lithium iron phosphate positive and graphite negative electrodes have a nominal open-circuit voltage of 3.2 V and a typical charging voltage of 3.6 V. Lithium nickel manganese cobalt (NMC) oxide positives with graphite negatives have a 3.7 V nominal voltage with a 4.2 V maximum while charging. The charging procedure is performed at constant voltage with current-limiting circuitry (i.e., charging with constant current until a voltage of 4.2 V is reached in the cell and continuing with a constant voltage applied until the current drops close to zero). Typically, the charge is terminated at 3% of the initial charge current. In the past, lithium-ion batteries could not be fast-charged and needed at least two hours to fully charge. Current-generation cells can be fully charged in 45 minutes or less. In 2015 researchers demonstrated a small 600 mAh capacity battery charged to 68 percent capacity in two minutes and a 3,000 mAh battery charged to 48 percent capacity in five minutes. The latter battery has an energy density of 620 W·h/L. The device employed heteroatoms bonded to graphite molecules in the anode.

Performance of manufactured batteries has improved over time. For example, from 1991 to 2005 the energy capacity per price of lithium ion batteries improved more than ten-fold, from 0.3 W·h per dollar to over 3 W·h per dollar. In the period from 2011 to 2017, progress has averaged 7.5% annually. Overall, between 1991 and 2018, prices for all types of lithium-ion cells (in dollars per kWh) fell approximately 97%. Over the same time period, energy density more than tripled. Efforts to increase energy density contributed significantly to cost reduction.

Differently sized cells with similar chemistry can also have different energy densities. The 21700 cell has 50% more energy than the 18650 cell, and the bigger size reduces heat transfer to its surroundings

4.3 BATTERY MANAGEMENT SYSTEM (BMS)

BMS is an electronic system that manages a rechargeable battery to ensure it operates safely and efficiently. BMS is designed to monitor the parameters associated with the battery pack and its individual cells, apply the collected data to eliminate safety risks and optimise the battery performance.

Img Source

Fig.7.img source

4.3 BATTERY MANAGEMENT SYSTEM

As you can see in the picture, the Battery Management System is an embedded system that has a number of electronic components on a circuit board. An embedded system comprises of purpose-built electronics along with purpose-built software to enable a specific application. We will elaborate further on the functionality of BMS in the subsequent sections.

4.3.1 Primary Functions Of The BMS For An HEV

1. **SAFETY**

Hybrid Electric vehicles run on high voltage Lithium-ion battery packs. Lithium-ion batteries have higher energy density (i.e., 100-265 Wh/kg) than other battery chemistries. These batteries come with a risk of catching fire under unusual circumstances. It is imperative to operate the HHEV batteries in pre- defined safe limits to ensure the safety of the user as well as the vehicle. The Battery Management System continuously monitors parameters such as temperature, voltage and current in and out of the pack to ensure it is being operated in safe conditions the entire time. BMS is responsible for thermal management of the battery and monitors its temperature continuously. If required, BMS can adjust cooling and trigger other safety mechanisms to cease operations and minimize the risk. e.g. in Hyundai Kona Electric, if overheating of the battery pack is detected by the BMS, the vehicle's power output is automatically limited and the car is put in fail-safe mode.

Overcharging of lithium-ion cells can also lead to thermal runaway and potentially an explosion. BMS continuously monitors the voltage of the pack as well as individual battery cells and controls the supply of the current to avoid overcharging. BMS can enforce the limits of maximum charge or discharge current according to temperature. Sensing electrical isolation — The BMS also checks that the vehicle chassis is completely isolated from the high voltage battery pack at all times to prevent the user from getting an electric shock.

2. PERFORMANCE OPTIMIZATION

BMS is responsible for optimising the performance of the battery pack. Lithium-ion batteries perform best when their State of Charge (SOC) is maintained between the minimum and maximum charge limits defined in the battery profile. Overcharging as well as deep discharging degrades the capacity of the battery, thereby shortening its life. At the time of charging, BMS determines how much current can safely go in and communicates the same to the HHEVSE (Hybrid electric vehicleSupply Equipment or the Charger). During discharge of the battery, BMS would communicate with the motor controller to avoid the cell voltages reaching too low. The vehicles can show a corresponding alert to the user to charge the battery pack. The BMS also controls the recharging of the battery pack by energy generated through regenerative braking. Individual cells in the battery pack can develop differences in capacity with time, which amplify with each charge/discharge cycle. This imbalance limits the amount of energy that can be derived from the battery, and also how much the battery pack can be charged. Cell Balancing is needed to maintain the cells at equal voltage levels and maximise the capacity utilization of the battery pack Measurement of individual cell voltages by BMS indicates their relative balance and acts as a pointer to how much charge equalization is required. The BMS performs cell balancing by draining excess energy from cells that are more charged than others, through active or passive balancing techniques.

CHAPTER 5

5.MOTOR

5.1 BRUSHLESS DC MOTOR:

A brushless DC electric motor (BLDC motor or BL motor), also known as an electronically commutated motor (ECM or EC motor) or synchronous DC motor, is a synchronous motor using a direct current (DC) electric power supply. It uses an electronic controller to switch DC currents to the motor windings producing magnetic fields which effectively rotate in space and which the permanent magnet rotor follows. The controller adjusts the phase and amplitude of the DC current pulses to control the speed and torque of the motor. This control system is an alternative to the mechanical commutator (brushes) used in many conventional electric motors.

The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor. They may also use neodymium magnets and be outrunners (the stator is surrounded by the rotor), inrunners (the rotor is surrounded by the stator), or axial (the rotor and stator are flat and parallel).

The advantages of a brushless motor over brushed motors are high power-toweight ratio, high speed, nearly instantaneous control of speed (rpm) and torque, high efficiency, and low maintenance. Brushless motors find applications in such places as computer peripherals (disk drives, printers), hand-held power tools, and vehicles ranging from model aircraft to automobiles. In modern washing machines, brushless DC motors have allowed replacement of rubber belts and gearboxes by a directdrive design.

5.1.1 Brush commutator

In brushed motors this is done with a rotary switch on the motor's shaft called a commutator. It consists of a rotating cylinder divided into multiple metal contact segments on the rotor. The segments are connected to conductor windings on the rotor. Two or more stationary contacts called *brushes*, made of a soft conductor such as graphite, press against the commutator, making sliding electrical contact with successive segments as the rotor turns. The brushes selectively provide electric current to the windings. As the rotor rotates, the commutator selects different windings and the directional current is applied to a given winding such that the rotor's magnetic field remains misaligned with the stator and creates a torque in one direction.

5.1.2 Disadvantages of commutator

The commutator has disadvantages that has led to a decline in use of brushed motors. These disadvantages are:

- The friction of the brushes sliding along the rotating commutator segments causes power losses that can be significant in a low power motor.
- The soft brush material wears down due to friction, creating dust, and Eventually the brushes must be replaced. This makes commutated motors unsuitable for low particulate or sealed applications like hard disk motors, and for applications that require maintenance-free operation.
- The electrical resistance of the sliding brush contact causes a voltage drop in the motor circuit called brush drop which consumes energy.
- The repeated abrupt switching of the current through the inductance of the windings causes sparks at the commutator contacts, which is a fire hazard in explosive atmospheres and a source of electronic noise, which can cause electromagnetic interference in nearby microelectronic circuits.

During the last hundred years, high-power DC brushed motors, once the mainstay of industry, were replaced by alternating current (AC) synchronous motors. Today, brushed motors are only used in low power applications or where only DC is available, but the above drawbacks limit their use even in these applications.

5.1.3 Brushless solution

In brushless DC motors, an electronic servo system replaces the mechanical commutator contacts. An electronic sensor detects the angle of the rotor and controls semiconductor switches such as transistors which switch current through the windings, either reversing the direction of the current or, in some motors turning it off, at the correct angle so the electromagnets create torque in one direction. The elimination of the sliding contact allows brushless motors to have less friction and longer life; their working life is only limited by the lifetime of their bearings.

Brushed DC motors develop a maximum torque when stationary, linearly decreasing as velocity increases.[7] Some limitations of brushed motors can be overcome by brushless motors; they include higher efficiency and lower susceptibility to mechanical wear. These benefits come at the cost of potentially less rugged, more complex, and more expensive control electronics.

A typical brushless motor has permanent magnets that rotate around a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solidstate circuit rather than the commutator system.

Brushless motors offer several advantages over brushed DC motors, including high torque to weight ratio, increased efficiency producing more torque per watt, increased reliability, reduced noise, longer lifetime by eliminating brush and commutator erosion, elimination of ionizing sparks from the commutator, and an overall reduction of electromagnetic interference (EMI). With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling. This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter.

Brushless motor commutation can be implemented in software using a microcontroller, or may alternatively be implemented using analog or digital circuits. Commutation with electronics instead of brushes allows for greater flexibility and capabilities not available with brushed DC motors, including speed limiting, micro stepping operation for slow and fine motion control, and a holding torque when stationary. Controller software can be customized to the specific motor being used in the application, resulting in greater commutation efficiency.

The maximum power that can be applied to a brushless motor is limited almost exclusively by heat;[citation needed] too much heat weakens the magnets and will damage the windings' insulation.

When converting electricity into mechanical power, brushless motors are more efficient than brushed motors primarily due to the absence of brushes, which reduces mechanical energy loss due to friction. The enhanced efficiency is greatest in the no-load and low-load regions of the motor's performance curve.

Environments and requirements in which manufacturers use brushless-type DC motors include maintenance-free operation, high speeds, and operation where sparking is hazardous (i.e. explosive environments) or could affect electronically sensitive equipment.

The construction of a brushless motor resembles a stepper motor, but the motors have important differences due to differences in implementation and operation. While stepper motors are frequently stopped with the rotor in a defined angular position, a brushless motor is usually intended to produce continuous rotation. Both motor types may have a rotor position sensor for internal feedback. Both a stepper motor and a well-designed brushless motor can hold finite torque at zero RPM.

5.1.4 Controller implementations

The controller implements the traditional brushes' functionality it needs to know the rotor's orientation relative to the stator coils. This is automatic in a brushed motor due to the fixed geometry of the rotor shaft and brushes. Some designs use Hall effect sensors or a rotary encoder to directly measure the rotor's position. Others measure the back-EMF in the undriven coils to infer the rotor position, eliminating the need for separate Hall effect sensors. These are therefore often called sensorless controllers that sense rotor position based on back-EMF have extra challenges in initiating motion because no back-EMF is produced when the rotor is stationary. This is usually accomplished by beginning rotation from an arbitrary phase, and then skipping to the correct phase if it is found to be wrong. This can cause the motor to run backwards briefly, adding even more complexity to the startup sequence. Other sensorless controllers are capable of measuring winding saturation caused by the position of the magnets to infer the rotor position. A typical controller contains three polarity-reversible outputs controlled by a logic circuit. Simple controllers employ comparators working from the orientation sensors to determine when the output phase should be advanced. More advanced controllers employ a microcontroller to manage acceleration, control motor speed and fine-tune efficiency.Two key performance parameters of brushless DC motors are the motor constants (torque constant) and (back-EMF constant, also known as speed constant

5.1.5 Application

Brushless motors fulfil many functions originally performed by brushed DC motors, but cost and control complexity prevents brushless motors from replacing brushed motors completely in the lowest-cost areas. Nevertheless, brushless motors have come to dominate many applications, particularly devices such as computer hard drives and CD/DVD players. Small cooling fans in electronic equipment are powered exclusively by brushless motors. They can be found in cordless power tools where the increased efficiency of the motor leads to longer periods of use before the battery needs to be charged. Low speed, low power brushless motors are used in direct-drive turntables for gramophone records.

5.2 HUB MOTOR

Fig.8. Hub Motor

Most electric-powered vehicles (electric cars, electric bicycles, and wheelchairs) use onboard batteries and a single, fairly ordinary electric motor to power either two or four wheels. But some of the latest electric cars and electric bicycles work a different way. Instead of having one motor powering all the wheels using gears or chains, they build a motor directly into the hub of each wheel so the motors and wheels are one and the same thing. That's what we mean by a hub motor.Photo: Left: The hub motor of an electric bike. Right: Take it apart and what you'll see is a bit like this brushless motor from a PC cooling fan. Note the thick copper coils of wire that convert electric power from the battery into the movement that pushes you along.

Fig .9.hub motor with hall effect sensor

5.2.1 Working

Ordinary electric motors use a mechanical device called a commutator and two contacts called carbon brushes to reverse the electric current periodically and ensure the axle keeps turning in the same direction.

Hub motors are typically brushless motors (sometimes called brushless direct current motors or BLDCs), which replace the commutator and brushes with halfadozen or more separate coils and an electronic circuit. The circuit switches the power on and off in the coils in turn creating forces in each one that make the motor spin. Since the brushes press against the axle of a normal motor, they introduce friction, slow it down, make a certain amount of noise, and waste energy. That's why brushless motors are often more efficient, especially at low speeds. Getting rid of the brushes also saves having to replace them Very so often when friction wears them down.

Here are some photos of a typical brushless DC motor. First, look at the fully assembled motor shown in the top picture. In a normal motor, you'd expect the inner coil to rotate (it's called the rotor) and the outer magnet to stay static (that's called the stator). But in this motor, the roles are reversed: the inner part with the coils is static and the gray magnet spins around it. Now look inside and you can see exactly how it works: the electronic circuit sends power round the nine copper coils in turn, making the gray outer case (which is a magnet split into a number of sections, bent round into a circle) spin around the copper coils and circuit board (which remain static).

How does the circuit know which of the nine coils to switch on and off—and when? You can't really see in this photo, but there are several tiny magnetic field sensors (known as Hall-effect sensors) positioned between some of the coils. As the permanent magnets on the outer rotor sweep past them, the Hall-effect sensors figure out where the north and south magnetic poles of the rotor are and which coils to activate to make it keep spinning. The trouble with this is that it means the motor does need an electronic circuit to operate it, which is something you don't need for an ordinary DC motor.

5.2.2 Advantages

It depends whether you're talking about an electric bicycle or an electric car. Adding a hub motor and batteries to a bicycle is a mixture of pro and con: you increase the bicycle's weight quite considerably but, in return, you get a pleasant and effortless ride whenever you don't feel like pedaling. Where electric cars are concerned, the benefits are more obvious. The weight of the metal in a typical car (including the engine, gearbox, and chassis) is perhaps 10 times the weight of its occupants, which is one reason why cars are so very inefficient. Swap the heavy engine and gearbox for hub motors and batteries and you have a lighter car that uses energy far more efficiently. Getting rid of the engine compartment also frees up a huge amount of space for passengers and their luggage—you can just stow the batteries behind the back seat.

Vehicles powered by hub motors are a whole lot simpler (mechanically less complex) than normal ones. Suppose you want to reverse. Instead of using elaborate arrangements of gears, all you have to do is reverse the electric current. The motor spins backward and back you go! What about four wheel drive? That's quite an expensive option on a lot of vehicles—you need more gears and complicated driveshafts—but it's very easy to sort out with hub motors. If you have a hub motor in each of a car's four wheels, you get four-wheel drive automatically. In theory, it's easy enough to make the four motors turn at slightly different speeds (to help with cornering and steering) or torque (to move you through muddy or uneven terrain).

5.3 MID DRIVE MOTOR

As the name suggests, it's a motor placed in the back of the bike. More accurately on the axis of the back wheel. It's a big enclosed cylindrical case that sits in the middle of the wheel. There are some e-bikes with a front-hub motor, but they are much rarer and, in my humble opinion, have barely any advantages over the rear hub motor.

A mid-drive motor (MDM), as the name suggests, is a motor located in the middle of the bike, right between the pedals. Unlike the RHM, this type of motor only helps you with pedalling and can't operate on its own. It amplifies your efforts and transfers them to the rear wheel via the chain.

5.3.1 Mid Drive Motor Gear Power

Probably the biggest advantage of the mid-drive motor is its gear ratio. It allows its use on any terrain and helps you climb otherwise impossible steep hills. On a lower gear, you can have a boost start. More importantly, it amplifies your efforts, so it can make you climb faster compared to a RHM. However, it's good to remember that it's not a stand-alone system, and it requires your input, so being completely out of shape and taking on Alpe d'Huez with a mid-drive motor is definitely not a great idea.

5.3.2 Mid Drive Motors Weight And Balance

Although it will put some additional weight on your bike, it'll still weigh less than an RHM. There are some mid-drive motors that are as light as 2.5 kilograms.

Usually, a good cross-country bike with an MDM is around 21-23 kilograms, which is pretty light compared to the alternative. However, that's not the main advantage here. Being at the centre of the bike, the MDM balances the bike, and the weight is directly under the central axis. This helps immensely with the control when it comes to off-road and downhill riding and makes the bike easier to control on swirling trails, pump tracks, during jumps and all other features.

Furthermore, MDMs are much smaller and thus are practically invisible at first glance. This makes the bikes look much better and more picture-friendly. They look tight and sporty, definitely not like a motorbike.

5.4 Hall effect sensor

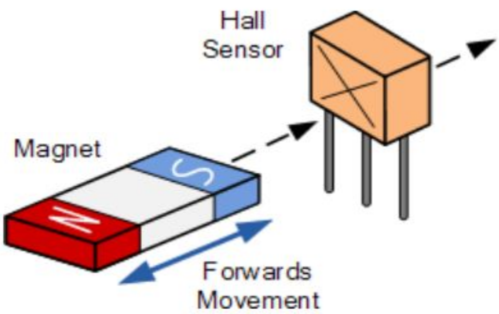

Fig .10. HALL SENSOR

We could not end this discussion on magnetism without a mention about magnetic sensors and especially the very commonly used hall effect sensor.

Magnetic sensors convert magnetic or magnetically encoded information into electrical signals for processing by electronic circuits, and in the sensors and transducers tutorials we looked at inductive proximity sensors and the ldvt as well as solenoid and relay output actuators.

Magnetic sensors are solid state devices that are becoming more and more popular because they can be used in many different types of application such as sensing position, velocity or directional movement.

5.4.1 Principles

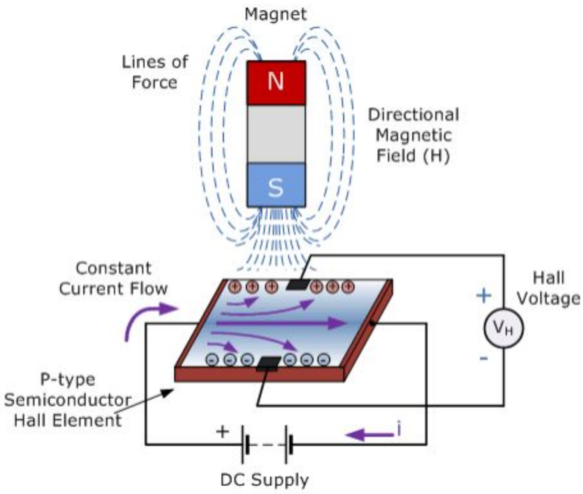

Fig.11.hall effect principle

Hall Effect Sensors consist basically of a thin piece of rectangular p-type semiconductor material such as gallium arsenide (GaAs), indium antimonide (InSb) or indium arsenide (InAs) passing a continuous current through itself.

When the deviceis placed within a magnetic field, the magnetic flux lines exert a force on the semiconductor material which deflects the charge carriers, electrons and holes, to either side of the semiconductor slab. This movement of charge carriers is a result of the magnetic force they experience passing through the semiconductor material.

As these electrons and holes move side wards a potential difference is produced between the two sides of the semiconductor material by the build-up of these charge carriers. Then the movement of electrons through the semiconductor material is affected by the presence of an external magnetic field which is at right angles to it and this effect is greater in a flat rectangular shaped material.

The effect of generating a measurable voltage by using a magnetic field is called the **Hall Effect** after Edwin Hall who discovered it back in the 1870's with the basic physical principle underlying the Hall effect being Lorentz force. To generate a potential difference across the device the magnetic flux lines must be perpendicular, (90^o) to the flow of current and be of the correct polarity, generally a south pole.

5.4.2 Applications

Hall effect sensors are activated by a magnetic field and in many applications the device can be operated by a single permanent magnet attached to a moving shaft or device. There are many different types of magnet movements, such as Head-on, Sideways, Push-pull or Push-push etc sensing movements.

Which THE Very type of configuration is used, to ensure maximum sensitivity the magnetic lines of flux must always be perpendicular to the sensing area of the device and must be of the correct polarity.

5.5 ELECTRONIC THROTTLE CONTROL

Electronic throttle control (**ETC**) is an automobile technology which electronically "connects" the accelerator pedal to the throttle, replacing a mechanical linkage.[1] A typical ETC system consists of three major components: (i) an accelerator pedal module (ideally with two or more independent sensors), (ii) a throttle valve that can be opened and closed by an electric motor (sometimes referred to as an electric or electronic throttle body (ETB)), and (iii) a powertrain or engine control module (PCM or ECM).[2] The ECM is a type of electronic control unit (ECU), which is an embedded system that employs software to determine the required throttle position by calculations from data measured by other sensors, including the accelerator pedal position sensors, engine speed sensor, vehicle speed sensor, and cruise control switches. The electric motor is then used to open the throttle valve to the desired angle via a closed-loop control algorithm within the ECM.

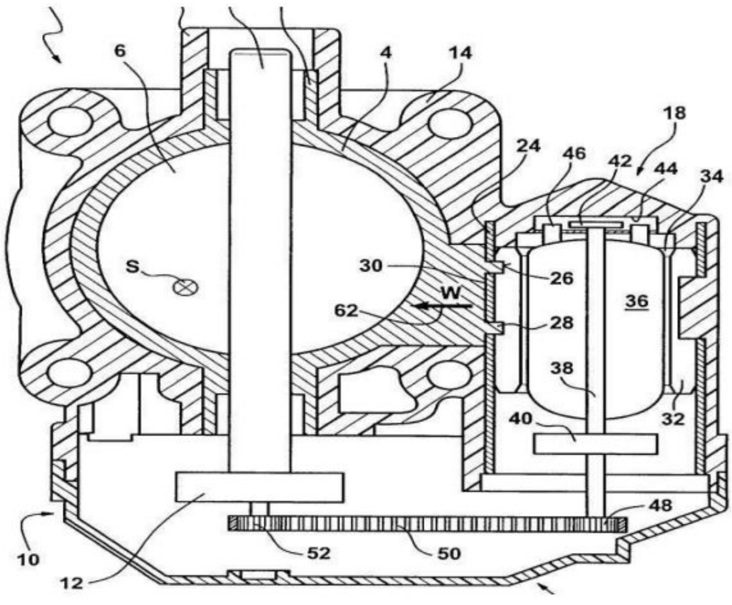

Fig .12. throttle control

The benefits of electronic throttle control are largely unnoticed by most drivers because the aim is to make the vehicle power-train characteristics seamlessly consistent irrespective of prevailing conditions, such as engine temperature, altitude, and accessory loads. Electronic throttle control is also working 'behind the scenes' to dramatically improve the ease with which the driver can execute gear changes and deal with the dramatic torque changes associated with rapid accelerations and decelerations.

Electronic throttle control facilitates the integration of features such as cruise control, traction control, stability control, and precrash systems and others that require torque management, since the throttle can be moved irrespective of the position of the driver's accelerator pedal.

ETC provides some benefit in areas such as air-fuel ratio control, exhaust emissions and fuel consumption reduction, and also works in concert with other technologies such as gasoline direct injection.

Failure modes

There is no mechanical linkage between the accelerator pedal and the throttle valve with electronic throttle control. Instead, the position of the throttle valve (i.e., the amount of air in the engine) is fully controlled by the ETC software via the electric motor. But just opening or closing the throttle valve by sending a new signal to the electric motor is an open loop condition and leads to inaccurate control. Thus, most if not all current ETC systems use closed loop feedback systems, such as PID control, whereby the ECU tells the throttle to open or close a certain amount. The throttle position sensor(s) are continually read and then the software makes appropriate adjustments to reach the desired amount of engine power.

5.6 FORWARD / REVERSE CONTROL (DIR) OF BLDC MOTOR

The motor's running direction can be controlled by controlling the on and off of the terminals DIR and COM. Terminal "DIR" internal resistance to pull up to +12Ω, can be used with passive contact switch, but also with the collector open PLC and other control units. When "DIR" and terminal "COM" are not connected, the motor runs clockwise (facing the motor shaft), otherwise, it runs counter clockwise. In order to avoid the damage of brushless dc controller, when changing the BLDC motor steering, the motor should be stopped before the operation of changing the steering, to avoid the motor running direction control.

Speed Signal Output (SPEED) of BLDC Motor

The brushless DC controller provides the user with a pulse signal proportional to the brushless DC motor speed via the terminals SPEED~COM. Pulse per revolution =6 * motor pole logarithm, SPEED frequency (Hz) = pulse per revolution * SPEED (RPM) divided by 60. Example: 4-pole motor, 24 pulses per revolution, when the motor SPEED is 500 revolutions/min, the output frequency of terminal SPEED is 200Hz.

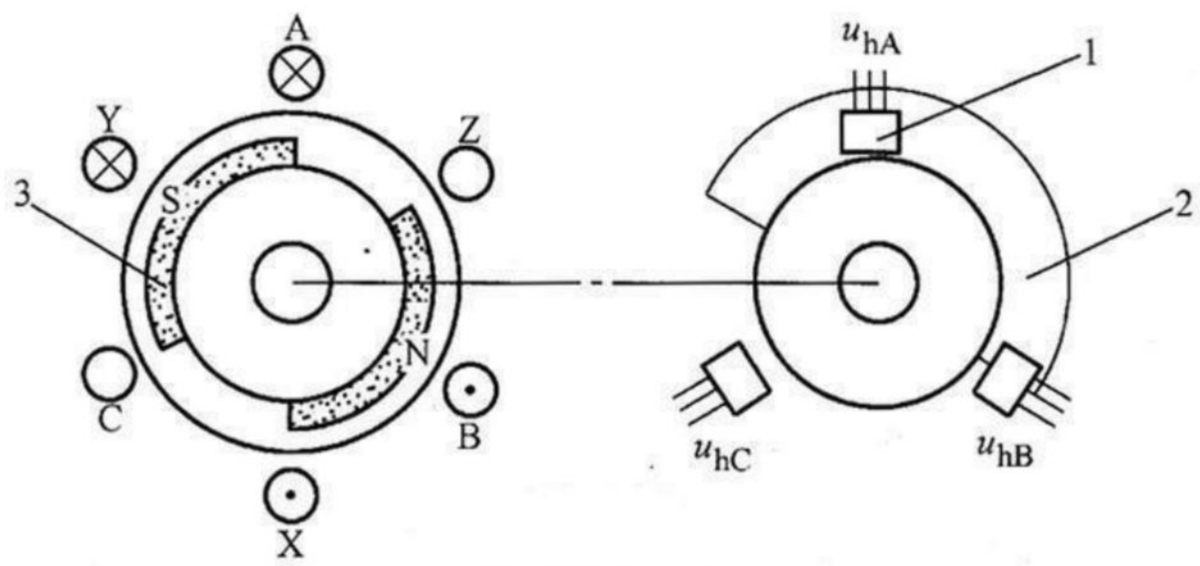

Fig.13. FORWARD / REVERSE CONTROL (DIR) OF BLDC MOTOR

5.7 REGENERATIVE BRAKING:

Ebike DC's controller system is capable of Regen-braking, however our geared motors freewheel when not energized. So normally when you squeeze the brake it signals for cut-off only. If the motor rotor is forced to spin on both directions together with hub by locking up mechanically the clutch, this signal activates the Regenerative (Regen) mode. The side disk in the picture showing a 500W geared hub motor internal parts is the clutch. You need to lock up the motor internal clutch to force the rotor spin back ward or generate negative torque. This option is available by modification or customization of the hub motor.

In regen mode the hub motor convert the mechanical torque to electrical back current to battery and recharge the battery while braking or going down hill while dragging the bike or decelerating. It can generate about the same amount of torque as full throttle but in the reverse direction. This braking can decelerate to about 5km/h speed but cannot fully stop the bike, so the disk or rim brakes on the other wheel should complete the job.

CHAPTER 6

6. CONTROLLERS

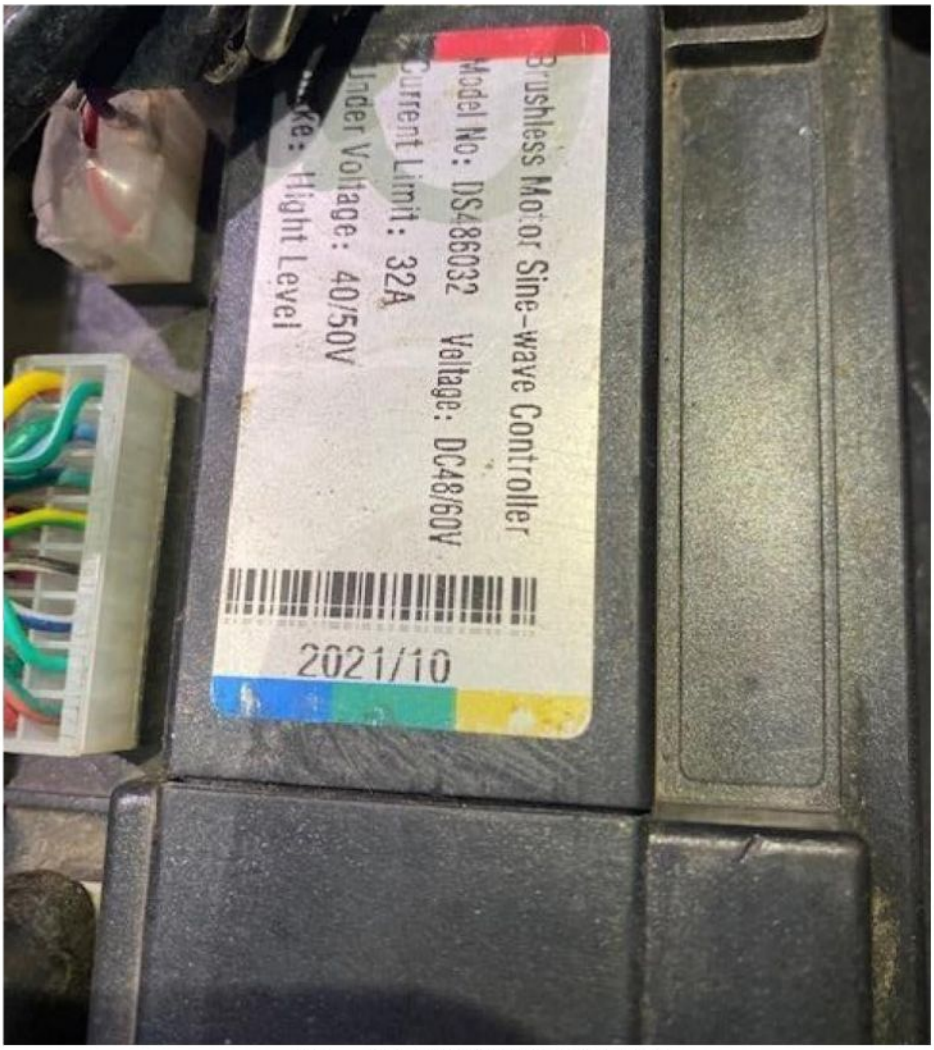

Fig .14. CONTROLLER

6.1. SINEWAVE CONTROLLER

Sine wave controllers produce sinusoidal waves which appear smooth and more formed. They are used with sinewave brushless DC (BLDC) motors with an approximately sinusoidal current and flux density distribution. The structure of a sinewave brushless DC motor is similar to that of a square BLDC motor, with surface-mounted permanent magnets on the rotor. This motor type achiHHEVes the required sinusoidal distribution of flux density by tapering the thickness of the permanent magnets towards the edges of the poles.

A sine wave/ FOC controller (Failed Oriented Control) on a sinewave BLDC motor essentially functions as an inverter with a sinusoidal output current waveform. Usually, the inverter output phase is locked to the rotor position by controlling the inverter from a position transducer such as an encoder or a resolver.

The rotor motion controls the inverter output frequency, as in the squarewave BLDC motor. The current phase is controlled such that the stator and rotor magnetic fields are at right angles.

6.1.1 Working

Sine wave controllers function like (simulate) a simple on/off switch in a room or a dimmer switch, letting in power to the motor at particular instances. They form a smooth curve on their peak lHHEVel and a smooth curve once they are back off.

To understand the functioning of a sinewave controller, you need first to understand the makeup of brushless DC motors in hybrid electric scooters. A brushless DC motor on an hybrid electric scooter consists of permanent magnets on the rotor (the part which rotates) and electromagnetic coils on the stator (the stationary parts).

These electromagnets are arranged in groups of three per phase- the reason brushless motors are often referred to as 3-phase motors. When you pass DC current through the coils, they become energised and transform into electromagnets. The operation of these motors is based on the simple force interaction between the electromagnets and the permanent magnet.

For the motor to revolve and consequently power up the wheels, the rotor and stator need to be energised and de-energised at different times. The stator electromagnets are arranged around the rim and energised differently. For instance, the stator electromagnets number 1, 4, 7, and 10 can be energised simultaneously, while the stator coils (electromagnets) 2, 5, 8, and 11 would be de-energised simultaneously.

In the next phase, the stator coils number 1, 4, 7, and 10 would be de-energised simultaneously, while stator coils 2, 5, 8, and 11 would be energised at a go.

The Field-Effect-Transistors (FETs) in the controllers are responsible for energising and de-energising the stator electromagnets, causing characteristic electric motor spins (motion). An FET essentially acts as a simple ON/OFF switch that energises and de-energises the stator electromagnets in an instance. An increase in the number of FETs in a controller means that the stator coils can be energised and de-energised concisely, enhancing its responsiveness.

In essence, the sine wave controller rotates the motor rotor by constantly altering the voltage of the stator coil sinusoidally per the rotor's rotation angle. The controllers are linked to sensors used to detect the position of the rotors HHEVery 60 degrees. The position of the rotor is estimated in real-time, and the controller releases a sinewave voltage based on the signal from the throttle.

6.1.2 Properties Of Sinusoidal Waves

As mentioned earlier, sine wave controllers produce sinusoidal waves, which have various distinguishing properties, including:

- Sinusoidal signals are smoothly varying, i.e., they don't have any sudden changes in amplitude.
- In sinusoidal waves, also referred to as sine waves, the rate of amplitude changes is not constant, i.e., slope. The slope varies dynamically.
- Sine wave signals occur in repeated cycles. The number of cycles that occur in one second is equal to the frequency of the signal, usually abbreviated in hertz(Hz) • The amplitudes of sinusoidal signals often vary with respect to time. In some instances, degrees rather than time are used to describe the horizontal progression of the signal. Completing one full cycle equals 360°, and the halfway point happens at 180°.

6.1.3 Advantages

- Sine wave controllers are usually dead-silent. They produce little noise facilitating a comfortable scooter riding experience. This is because they make pure sine waves, which have very low harmonic distortion causing the hybrid electric scooter to run quieter.
- Sine wave controllers deliver enormous starting torque producing faster scooter starting acceleration.
- In normal riding conditions, a sine wave e-scooter can achiHHEVe constant speed movement, better known as cruise speed, with outstanding ride comfort the whole way.
- A sine wave controller has a higher motor efficiency when climbing steep inclines or when carrying heavy loads.

Sine wave e-scooter controllers have more efficient and predictable control of all operations than their counterparts. They prevent crashes or glitches in the scooter components, which could cause serious malfunctions.

Sine wave e-scooter controllers are more efficient in terms of electricity consumption, thus offering greater range and prolonging battery life.

6.1.4 Disadvantages

Highly-priced

Only compatible with matched motors

6.2 SQUARE WAVE CONTROLLERS

Square wave controllers produce trapezoidal waves, which are rather juggled, not smooth. The transitions between each square wave cause harmonic losses (loss of energy through sound in square wave controllers), making them less efficient. These controllers also have minimal computational power needs, requiring only the 3 phase on/off signal to drive the motor in a time sequence.

Compared to sinewave controllers, square wave controllers are generally cheaper due to minimal computational power needs.

6.2.1 Properties Of Square Waves

A square wave is best described as a non-sinusoidal periodic waveform where the amplitude alternates at a steady frequency between fixed maximum and minimum values. The time between the minimum and maximum durations is almost similar. In a perfect square waveform, the maximum and minimum transitions are instantaneous. However, a perfect square wave is practically impossible to create, considering that the falling and rising edges are never instantaneous, plus the tops are never flat. A practical square wave(trapezoidal wave) usually has a non-zero rise time, and the tops are rarely flat.

Unlike sine waves with a smooth ascending and descending waveform with rounded edges at the negative and positive peaks, square waves have pretty steep, almost vertical negative and positive peaks. The top and bottom of the waveforms are usually flat, producing a waveform that matches its description, i.e., square.

6.2.2 Advantages

- Smooth performance
- Offer better control
- Less noisy
- Better performance at a lower speed

- More suited for uphill rides or carrying weight

6.2.3 Disadvantages

- Cost more
- Work with matching motors only
- Consume more power

CHAPTER 7

7. RESULTS AND DISCUSSION

Fig 15 components

Fig :16 development of hybrid vehicle

CHAPTER 8

CONCLUSION

Due to the many problems of congestion, pollution and urban mobility, new modes of transportation (hybrid electric scooter) transportation devices, increasingly seem to be an alternative to widespread automobile use. The ergonomic Evaluation also demonstrated that power scooter is easy to use in normal use situations, including situations involving obstacles, for a broad cross section of users. The devices also compare favourably with other types of vehicles, particularly in terms of stability, where they seem superior to other vehicles such as bicycles and mopeds. However, hybrid electric scooter is designed for a broader segment of the population and is meant to meet a wider variety of mobility requirements in urban transfers to alternative forms of mobility and use for short distances. The performance studies carried out in a closed environment also demonstrated that power scooter is easy to use in normal use situations as well as to get around obstacles. The survey results clearly show that a large majority of test participants found all scooter movements easy to perform. However, this hybrid electric scooter is targeted more for young people and seems primarily intended for recreational purposes. The Evaluation results suggest that electric power scooter use is appropriate in closed environments, such as major industrial complexes, hospitals, shopping centres and airports. The reliability and safety of this hybrid electric scooter when used in urban communities; Social acceptance of power scooters help to reduce traffic problem. In future we can use flexible sitting system. This scooter can be modified according to once interest.

Fig 16 developed HEV model

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