STUDY OF HYBIRD ELECTRIC VEHICLES (HEVs)

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By

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I hereby recommend that the thesis prepared by Abdulhadi Al-ghadri entitled "**Study of Hybrid Electric Vehicles (HEVs)"** has been accepted as fulfilling the part of the requirement for degree of Bachelor of Science in technical educational and mechanics engineering (BSc TE).

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DECLARATION

This is to certify that the work presented in this thesis is the outcome of the investigation carried out by **ABDULHADI MOHAMMED** under the supervision of **assistant Prof. Dr. A.R.M. Harunur Rashid**

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ABSTRACT

STUDY OF HYBIRD ELECTRIC VEHICLES (HEVs)

Alternative vehicles, such as plug-in hybrid electric vehicles, are becoming more popular. The batteries of these plug-in hybrid electric vehicles are to be charged at home from a standard outlet or on a corporate car park. These extra electrical loads have an impact on the distribution grid which is analyzed in terms of power losses and voltage deviations. These vehicles are charged instantaneously when they are plugged in or after a fixed start delay. This uncoordinated power consumption on a local scale can lead to grid problems. Therefore, coordinated charging is proposed to minimize the power losses and to maximize the main grid load factor. The optimal charging profile of the plug-in hybrid electric vehicles is computed by minimizing the power losses.

Modern HEVs make use of efficiency-improving technologies such as regenerative braking, which converts the vehicle's kinetic energy into battery-replenishing electric energy, rather than wasting it as heat energy as conventional brakes do. Some varieties of HEVs use their internal combustion engine to generate electricity by spinning an electrical generator (this combination is known as a motor-generator), to either recharge their batteries or to directly power the electric drive motors.

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FIGURE

CHAPTER I

1.1 A brief history of (HEVs)

In early 1889 William H. Patton filed a patent application for a gasoline-electric hybrid rail-car propulsion system and for a similar hybrid boat propulsion system in mid-1889. He went on to test and market the Patton Motor Car, a gas-electric hybrid system used to drive tram cars and small locomotives. A gasoline engine drove a generator that served to charge a lead acid battery in parallel with the traction motors.

In 1905, Henri-Pieper of Germany/Belgium introduced a hybrid vehicle with an electric motor/generator, batteries, and a small gasoline engine. It used the electric motor to charge its batteries at cruise speed and used both motors to accelerate or climb a hill.

In 1931 Erich Gaichen invented and drove from Altenburg to Berlin a 1/2 horsepower electric car containing features later incorporated into hybrid cars. The car battery was re-charged by the motor when the car went downhill. Additional power to charge the battery was provided by a cylinder of compressed air which was re-charged by small air pumps activated by vibrations of the chassis and the brakes and by igniting oxy hydrogen gas. No production beyond the prototype was reported.

Automotive hybrid technology became widespread beginning in the late 1990s. The first mass-produced hybrid vehicle was the Toyota Prius, launched in Japan in 1997, and followed by the Honda Insight, launched in 1999 in the United States and Japan.The Prius was launched in Europe, North America and the rest of the world in 2000.

In 2009 The Hyundai Elantra LPI Hybrid was unveiled in Seoul Motor Show, The Elantra LPI (Liquefied Petroleum Injected) is the world's first hybrid vehicle to be powered by an internal combustion engine built to run on liquefied petroleum gas (LPG) as a fuel. The Elantra PLI is a mild hybrid and the first hybrid to adopt advanced lithium polymer (Li–Poly) batteries.

Other gasoline-electric hybrids released in the U.S. in 2011 were the Lexus CT 200h, the Infiniti M35 Hybrid, the Hyundai Sonata Hybrid and its sibling the Kia Optima Hybrid.

The redesigned and more efficient fourth generation Prius was released for retail customers in Japan in December 2015. The launch in North American market is scheduled for January 2016, and February in Europe.

1.2 Introduction

A hybrid vehicle combines any two power (energy) sources. Possible combinations include diesel/electric, gasoline/fly wheel, and fuel cell (FC)/battery. Typically, one energy source is storage, and the other is conversion of a fuel to energy. The combination of two power sources may support two separate propulsion systems. Thus to be a True hybrid, the vehicle must have at least two modes of propulsion. These two power sources may be paired in series, meaning that the gas engine charges the batteries of an electric motor that powers the car, or in parallel, with both mechanisms driving the car directly. This type of vehicle is considered to have better performance and fuel economy compared to a conventional one. As With the increasing demand for environmentally friendlier and higher fuel economy vehicles, automotive companies are focusing on electric vehicles, hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and fuel-cell vehicles. These vehicles would also enable meeting the demands for electrical power due to the increasing use of the electronic features to improve vehicle performance, fuel economy, emissions, passenger comfort, and safety. In electric vehicles, HEVs, PHEVs, and fuel-cell vehicles, the challenges are to achieve high efficiency, ruggedness, small sizes, and low costs in power converters and electric machines, as well as in associated electronics.

Consistent with the definition of hybrid above, the hybrid electric vehicle combines a gasoline engine with an electric motor. An alternate arrangement is a diesel engine and an electric motor.

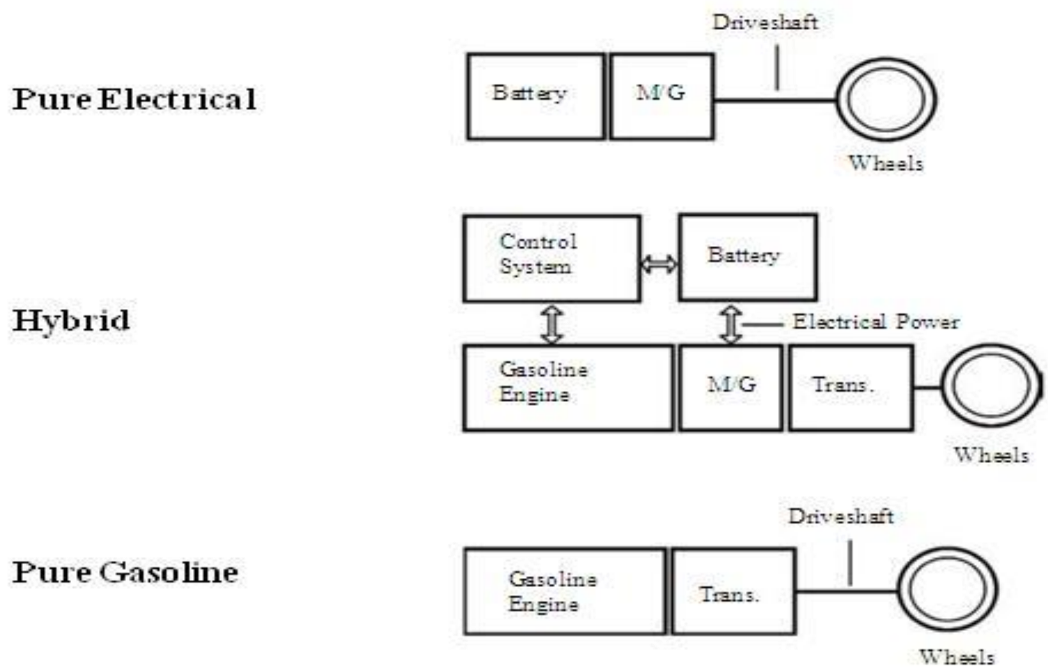

Figure 1: Components of a hybrid Vehicle that combines a pure gasoline with a pure EV.**(**15/09/2017**)**

As shown in Figure 1, a HEV is formed by merging components from a pure electrical vehicle and a pure gasoline vehicle. The Electric Vehicle (EV) has an M/G which allows regenerative braking for an EV; the M/G installed in the HEV enables regenerative braking. For the HEV, the M/G is tucked directly behind the engine. In Honda hybrids, the M/G is connected directly to the engine. The transmission appears next in line. This arrangement has two torque producers; the M/G in motor mode, M-mode, and the gasoline engine. The battery and M/G are connected electrically.

1.3 Objectives of the project

- ✓ To cut down on fossil fuels while maintaining excellent performance and saving the money.
- ✓ To combine a gas engine and an electric motor that assists the engine when accelerating.
- ✓ To save the natural fuel sources from wastage.

1.5problem statement

The major problem with the Hybrid cars are that they generate less power and are twin powered engine. The gasoline engine which is primary source of power is much smaller as compared to what you get in single engine powered car and electric motor is low power. The combined power of both is often less than that of gas powered engine. It is therefore suited for city driving and not for speed and acceleration. And the other problem is poor handling that a hybrid car houses a gasoline powered engine, a lighter electric engine and a pack of powerful batteries. This adds weight and eats up the extra space in the car. Extra weight results in fuel inefficiency and manufacturers cut down weight which has resulted in motor and battery downsizing and less support in the suspension and body. Even economically and financially they have Higher Maintenance Costs that the presence of dual engine, continuous improvement in technology, and higher maintenance cost can make it difficult for mechanics to repair the car. It is also difficult to find a mechanic with such an expertise. And finally, Presence of High Voltage in Batteries, In case of an accident, the high voltage present inside the batteries can prove lethal for you. There is a high chance of you getting electrocuted in such cases which can also make the task difficult for rescuers to get other passengers and driver out of the car.

CHAPTER II

LITRATURE REVIEW

By following the history and as we know before many years ago there was no vehicle and they was using camel and donkey for carrying their tools. But gradually by the time the people tried to decrease the cost and the power by creating first car

In 1768 the first car was working by the steam created by Nicolas-Joseph.

Figure 2: fardier à vapeur. (15/09/2017)

In 1808 François Isaac designed the first car powered by an internal combustion engine fueled by hydrogen.

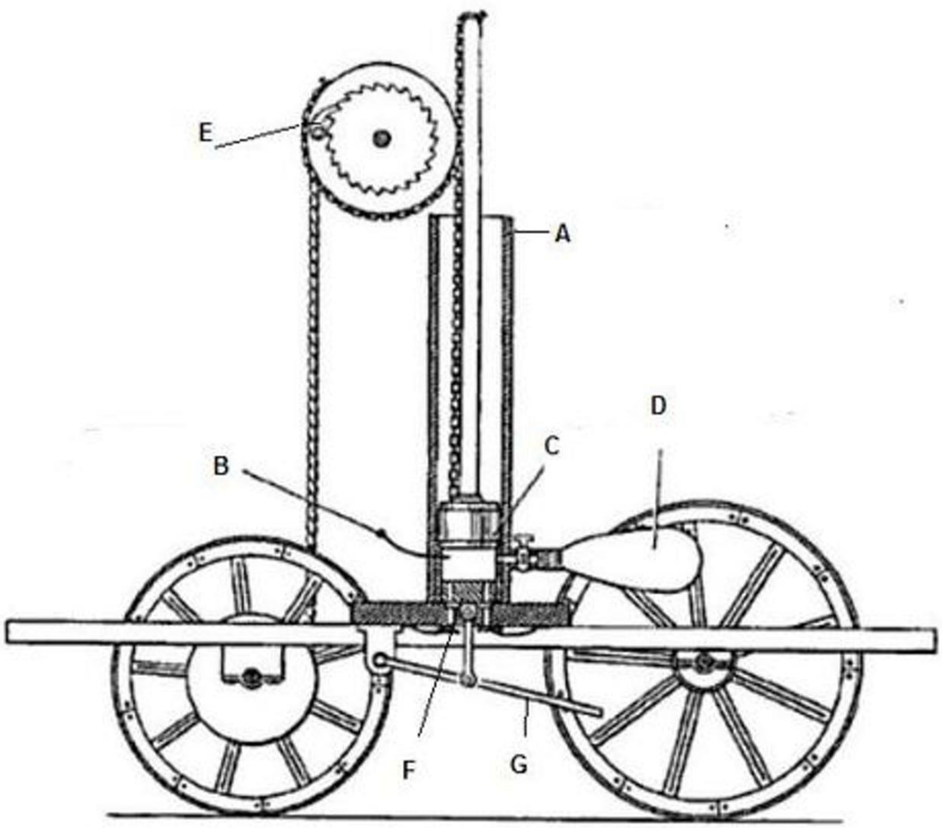

Figure 3: François Isaac de Rivaz hydrogen powered engine (15/09/2017)

The first gasoline (petrol) powered engine came in 1870, when Siegfried Marcus placed his two-cycle combustion engine on a pushcart. He even developed cars with steering, a clutch system and brakes.

Figure 4: Siegfried Marcus Petrol Car 1875. (15/09/2017)

the contribution of Karl Benz Starting in 1885, he developed a single cylinder two-stroke gasoline (petrol) powered engine, which was used in what is widely considered to be the first "production" vehicle ever built.

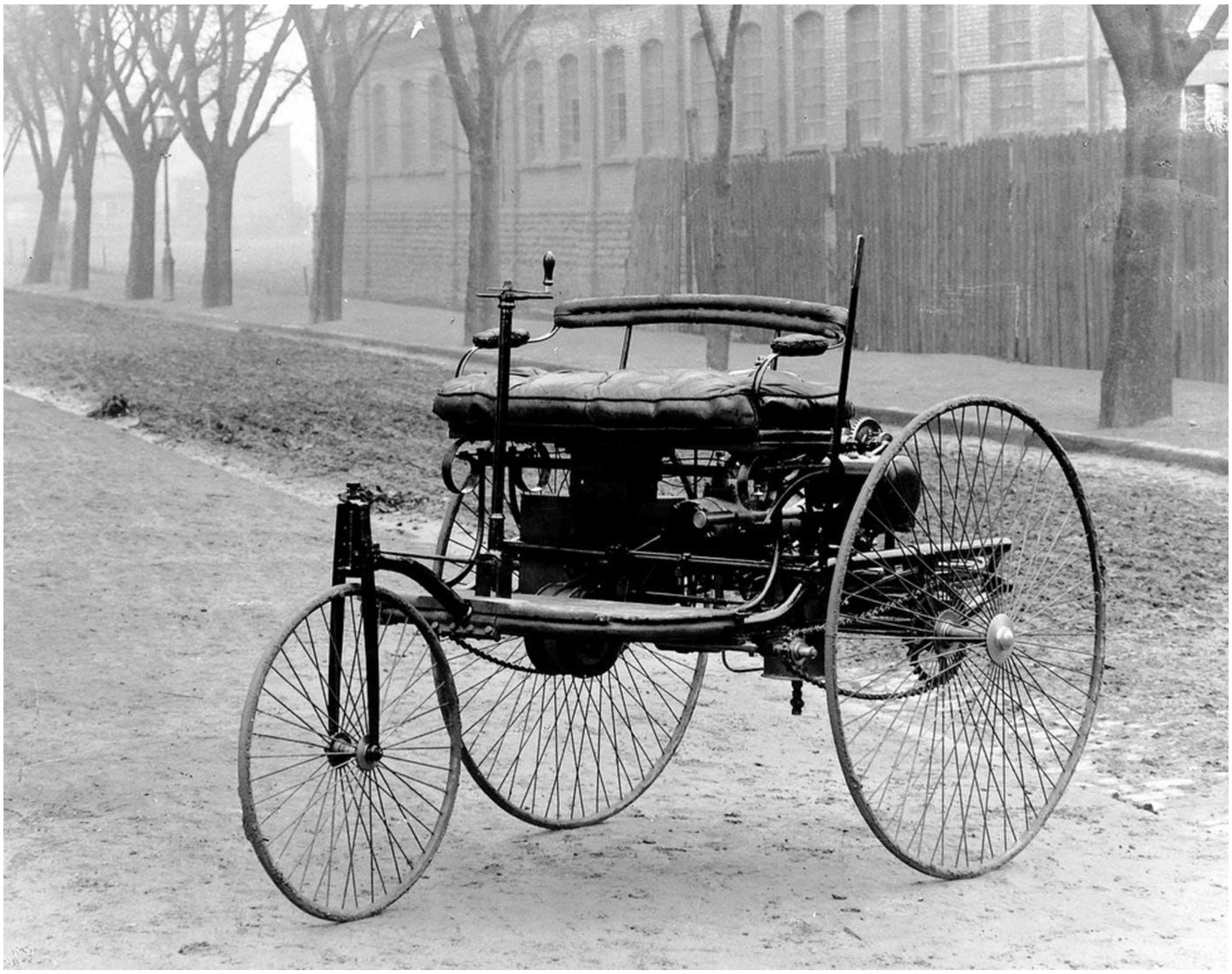

Figure 5: 1885 Benz Patent Motorwagen (20/09/2017)

2.1 Modeling and simulation

Karen et al (1999) presented a simulation and modeling package developed at Texas A&M University, V-Elph 2.01. V-Elph was written in the Matlab/Simulink graphical simulation language and is portable to most computer platforms. They also discussed the methodology for designing vehicle drivetrains using the V-Elph package. An EV, a series HEV, a parallel HEV and a conventional internal combustion engine driven drivetrain have been designed using the simulation package. Simulation results such as fuel consumption, vehicle emissions, and complexity are compared and discussed for each vehicle.

Cuddy and Keith (2007) performed a parallel and series configured Hybrid vehicles likely feasible in next decade are defined and evaluated using a flexible Advanced Vehicle Simulator (ADVISOR). Fuel economies of two diesel powered hybrid vehicles are compared to a comparable technology diesel powered internal combustion engine vehicle. The fuel economy of the parallel hybrid defined is 24% better than the internal combustion engine.

Zhou and Chang (2008) established powertrain dynamic simulation model of an integrated starter/generator (ISG) hybrid electric vehicle (HEV) using Simulink. The parallel electric assist control strategy (PEACS) was researched and designed. The analysis of dynamics performance and fuel economy of the model was carried out under the FTP drive cycle, which can provide a design reference for the setup of the powertrain test bench. The results show that the fuel consumption can be effectively reduced by using the designed PEACS with the state-of-charge of the battery maintaining in a certain scope.

2.2 Control system

The effectiveness of fuel consumption depends not only on vehicle design but also on the control strategy used. The control strategy provides a dynamic control of the vehicle to ensure the best utilization of the onboard energy resources for the given operating conditions. So, the energy management strategy is extremely important to decide how and when energy will be provided by various sources of PHEV.

In 1999, AVL Company proposed a hybrid system that used a 50 cc

Carbureted lean-burn two-stroke engine with a 0.75 kW electric motor mounted on the engine crankshaft mainly to provide increased torque during acceleration.

Su-Hau et al (2004) focused on the highly efficient energy usage of the battery energy and proposed an integrated management system for electric motor. This integrated management system includes the power-saving controller, energy management subsystem and some hardware protection strategies. The energy management system acts as a supervisor to manage all the events about the battery energy, including the residual capacity estimation and regenerative braking operation.

Wenguang et al (2005) presented an approach to control powertrain of series hybrid electric vehicles. A formulation of the system equations and controller design procedure were proposed by them. They also proposed a new switching algorithm for the power converter for motor torque and motor flux control. The sliding mode method is applied to excitation winding control in synchronous generator to achieve the desired current distribution in Powertrain.

Yimin and Mehrdad (2006) introduced a speed and torque coupling hybrid drivetrain. In this drivetrain, a planetary gear unit and a

Generator/motor decouples the engine speed from the vehicle wheel speed. Also, another shaft-fixed gear unit and traction motor decouple the engine torque from the vehicle wheel torque. Thus, the engine can operate within its optimal speed and torque region, and at the same time, can directly deliver its torque to the driven wheels. They also discussed the fundamentals architecture, design, control, and simulation of the drivetrain. Simulations show that the fuel economy in urban and highway driving cycles can be greatly improved.

Markel and Simpson (2007) discussed the battery power and energy requirements for grid-charged parallel hybrid electric vehicles with different operating strategies. First, they considered the traditional all-electric range based operating concept and shown that this strategy can require a larger, more expensive battery due to the simultaneous requirement for high energy and power. They then proposed an alternative electric-assist operating concept for grid-charged HEVs to enable the use of a smaller, less costly battery. However, this strategy is expected to reduce the vehicle efficiency during both charge-depleting and charge-sustaining operation.

Emadi et al (2008) focused more on power electronics as an enabling technology for the development of plug-in hybrid electric vehicles and implementing the advanced electrical architectures to meet the demands for increased electric loads. A brief review of the current trends and future vehicle strategies and the function of power electronic subsystems are described. The requirements of power electronic components and electric motor drives for the successful development of these vehicles are also presented.

2.3 Electric propulsion and energy storage device

In the area of propulsion motor and other motor control technologies, methods to eliminate speed/position sensors, inverter current sensors, etc., have been under investigation for several years. The technological challenges for the electric motors will be light weight, wide speed range, high efficiency, maximum torque and long life. Most hybrid hardware subsystems and components with exception of energy storage devices have been matured to an acceptable level efficiency performance and reliability. As per the studies, the energy stored in the HEV storage unit is much smaller than that in the EV unit. It is also clear that the power capability of the batteries designed for HEVs is much higher than those designed for EVs. However, batteries for plug-in hybrid electric vehicles require both high energy density and high-power capability based on the driving requirements. The other significant technical challenges include higher initial cost, cost of battery replacement, added weight and volume, performance and durability.

2.4 Performance testing and emission analysis

In the present economic crises, many people want low powered small vehicles with fuel economy and the automakers are shifting their production to more fuel efficient and environmental friendly vehicles to satisfy customer demands. The automakers are working to promote hybrid vehicles because their fuel efficiency and low emissions make them the ideal solution to the current state of the world. Plug-in hybrids are making their way into the spotlight, making electric vehicles a serious possibility**.**

2.5 Economic analysis

Karl (2005) developed a methodological approach to combine a technology assessment of the major subsystems of a personal electric vehicle with a technical model of vehicle performance in order to estimate the cost and mass of a vehicle for a given set of functional requirements. Personal electric vehicles offer several potential benefits to consumers and to society including lower transportation costs, reduced trip times and lower environmental impact. Personal electric vehicles are technically feasible now. However, suppliers have not yet arrived at a set of practical vehicles that best match technical feasibility and consumer demand. Part of the challenge is to understand the relative trade-offs among cost, weight, range and other dimensions of vehicle performance. His article estimates the technological frontier defined by these trade-offs. This frontier illustrates what is likely to be technically possible. The question of what is commercially feasible remains. However this question will be answered by suppliers and consumers in the marketplace in the coming years.

2.6 Related patents

Fields and Metzner (1982) developed a car which has, in combination, a heat engine driving a set of front wheels, storage batteries and an electric motor driving a set of rear wheels. It also has a system for selecting electric or heat engine drive either manually or automatically and a single accelerator for controlling either mode of drive. Battery charging power is derived from the electric motors acting as generators driven by the rear wheels while the vehicle is in heat engine drive and the battery charging rate is selected by the operator. Changeover from electric drive to heat engine drive is simplified by a changeover system and excessive loading of the heat engine by the battery charging system is eliminated on hills and during acceleration by a hill and acceleration sensing system. The car is designed for low speed and stops and goes driving powered by the electric motors while the heat engine may be used for high speed and long distance travel.

Summary

The high fuel consumption and emission contribution of two-wheelers in urban areas needs to receive more attention in order to improve the near term sustainability of energy and urban air quality in the future. Therefore, the implementation of plug-in hybrid technology for two-wheelers will result in reduction of greenhouse gas emission and petroleum oil independency to a large extent. The plug-in concept is implemented in certain concept cars and two-wheelers in the market in a limited way. Following are the important conclusions drawn from the above literature review:

- ✓ Modeling, simulation, sizing and selection of powertrain components for the plug-in hybrid electric two-wheeler are based on all-electric range, driving style and battery type.
- ✓ There is a need for development of optimum control strategy for plug-in hybrid electric two-wheeler to manage the energy and power between hub motor with battery pack and IC engine.
- ✓ Estimation of correct battery type, battery energy capacity and its mass for different all-electric range may vary based on driving cycle.
- ✓ Economic and emission reduction analysis will help the commercialization of plug-in hybrid electric two-wheelers.

The above factors from the literature survey clearly show the available scope for the present work.

CHAPTER III

METHODOLOGY AND PROCEDURE

Nowadays, fuel economy and pollutant emissions are keenly felt topics and hybrid electric vehicles (HEVs) represent the best opportunity to respond to this problem in the short term. Hybrid electric vehicles meet the high-efficiency of electric motors, with the high reliability of the internal combustion engines, granting optimal results both in terms of emissions and fuel economy. The vehicle and path features highly affect the architecture choice. A parallel architecture, having a more flexible layout and providing a higher drive power, is more suitable for long paths and higher speeds, while the series one better adapts to urban cycles, as can be switched to a pure electric mode. At the same time, parallel-series architecture is in general a good choice. Another crucial point is the definition of a control strategy suitable for the mission the car is expected to accomplish, that must properly control both the load partitioning, between engine and motors, and the regenerative braking. According to all these considerations, the aim is to lay the basis of a comprehensive methodology, which can allow to simply define an optimized powertrain layout, i.e. architecture and devices size, and an efficient control strategy.

3.1 Hybrid-Enabling Technologies

Hybrids share an overlapping set of technologies to make their systems work. Their basic goal is to maximize the use of the electric portion of the drivetrain because electric motors are more efficient and produce no emissions. Hybrids have been called a “bridge” toward pure electric vehicles. In other words, they are a compromise, so another qualifier is they can be considered good, better, and best compromises.

All gas-electric hybrids utilize some size of battery pack and electric motor. Engineers have come up with various ways to keep the battery charged short of plugging the car in. An exception is – as you might have guessed – the plug-in hybrid which can partially recharge on the road, but needs to be plugged in because its battery is too large for the car to efficiently recharge it on the go. An exception in turn here is the Porsche Panamers S E-Hybrid which is able to fully recharge while driving.

Figure: Prius battery pack. (25/09/2017)

The smaller batteries in regular "full" or "mild" hybrids – or even purported "micro hybrids" – are replenished through a couple of ways. One is by the motor/generator which alternately helps propel the car, or upon deceleration, generates power back to the pack. This is what "regenerative braking" involves. The motor essentially reverses and works to create energy when the car is slowing down. It thus converts kinetic energy and is an elegant solution.

Another way is by allowing the engine to turn the motor/generator in certain portions of the drive cycle where it can most efficiently do so. Of course this would be impossible without fairly advanced computer controls which monitor these and a few other tricks. Other tricks include "stop-start" technology, also known as "idle-off," which shuts down the engine when the car comes to a stop, and these come in a variety of types.

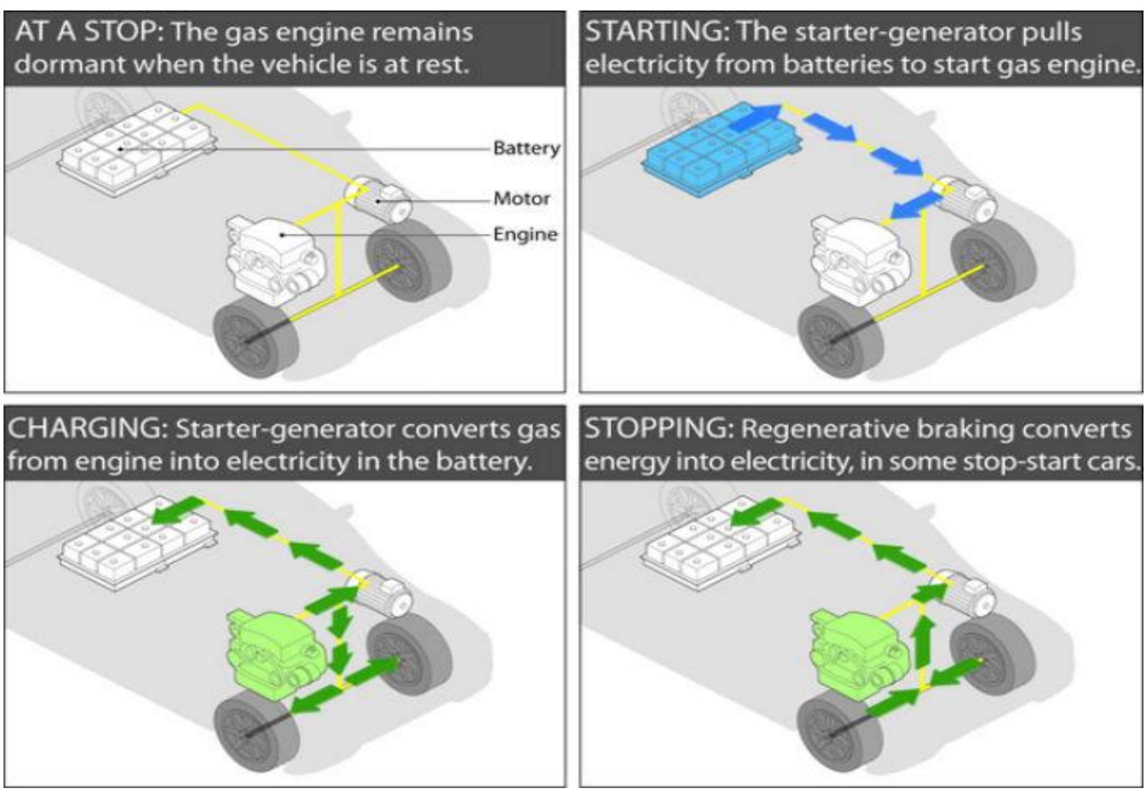

Figure: Stop-start technology. (1/10/2017)

In common to all, is releasing the brake lets the engine restart instantly – and it is engineered for this, so there's no concern with lack of oil pressure or friction from frequent starts as there might be if you simply turned a regular car off, and started it with the key (or start button).

Another thing enabled by hybridization is reduction of the engine displacement and often number of cylinders. Because the electric motor shares the load, a gasoline engine can be optimally sized for fuel efficiency and clean burning.

Most full hybrids also incorporate the Atkinson Cycle. This shortens the intake and compression stroke of a four-cycle engine to increase efficiency at the expense of some horsepower and torque. Again, with the addition of electric motor to fill in the gaps, the driver does not perceive an underpowered vehicle.

3.2 Materials for Electric Vehicle Technology

Materials play an ever more important role to help reduce carbon emissions and dependence on petroleum. DuPont Automotive has the broadest range of high-performance materials, polymer science capabilities, and application knowledge to help automakers quickly develop more efficient, safer, lighter hybrid and electric vehicles. And the benefits of using DuPont materials in electric vehicle technology can be listed as bellow:

Safety

- Help provide stability at high temperatures with DuPont™ Energain™ battery separators for high-performance lithium ion batteries.
- Protect batteries with new materials that offer higher voltage performance, reduced flammability electrolyte technology, high-

temperature-stability separators, and electrode materials to reduce battery heating.

- Improve battery pack performance with flame-retardant and thermoplastic materials.
- Prevent electrical arcs and sparks in connectors with USCAR-rated thermoplastic materials that meet 650-volt system requirements.

Energy Density and Power

- Help boost kilowatt-per-hour and power capabilities with improved battery chemistries and materials for critical binders, and with DuPont™ Energain™ battery separators.
- Prevent electrical discharge with improved insulation systems that draw from the broadest array of material choices.

Weight and Packaging

- Reduce weight up to 40% using plastics instead of aluminum and steel.
- Use high-performance polymers and elastomers to integrate components and functions — this miniaturization reduces space and improves packaging.

3.2 Usages of DuPont Materials in Electric Vehicle Technology

Battery Pack Cells

- DuPont Energain battery separators for high-performance lithium ion batteries can help boost power by 15%–30% and provide stability at high temperatures, so drivers may reach their desired speed more quickly and safely, and drive longer on a single charge.

Battery Pack Structures

- Our flame-retardant plastics help meet emerging safety requirements.
- Our dimensionally stable and impact-resistant resins can improve crashworthiness.
- For liquid-cooled pack systems, DuPont plastics provide excellent coolant resistance.

Electric Motors

- Materials designed specifically for automotive traction applications include paper made with DuPont Nomex fiber, DuPont Kapton polyimide films, DuPont Voltatex VS wire enamels and DuPont Voltatex resins and varnishes.
- Our unmatched portfolio for electrical insulation includes resins, paper laminates and polyimide films which carefully isolate wires and components and increase protection inside a harsh vehicle operating environment.

Thermal Management Systems

- Our high-performance plastics provide excellent heat aging, coolant and ATF resistance to optimize operating temperatures while reducing mass up to 40%.
-

Connectors and Cable Jacketing

- Our "electrically friendly" resins are flame-retardant, V-0, U- rated nylon/PPA products with CTI above 600 volts.
- Our PBTs are hydrolysis- resistant and USCAR Class IV-capable.
- DuPont Vamac AEM elastomer is designed for high-energy cable insulation.

Working with DuPont's global development team to identify the right electric vehicle technology materials for their designs, automakers can build hybrid and electric vehicles that meet consumer and environmental needs.

Note: **du Pont de Nemours and Company**, commonly referred to as **DuPont**, was an American conglomerate that was founded in July 1802 as a gunpowder mill by American chemist and industrialist Éleuthère Irénée du Pont

3.3 Types of hybrid electric vehicles (HEVs)

Hybrids can basically be divided into three main types: These are: full hybrids, mild hybrids, and plug-in hybrids. Then again, you have variations, such as so-called “muscle hybrids” and “micro hybrids” – for which arguments could be made that these are sub-types.

3.3.1 Full Hybrids

Among “regular” hybrids – not including the plug-in variety – full hybrids are the most fuel efficient. And they are the most thoroughly engineered solutions. The classic example of a full hybrid is the Toyota Prius, or any of Toyota’s Hybrid Synergy Drive vehicles, but today many automakers now offer full hybrids. Full hybrids are also more efficient – and so defined – because they can automatically choose to operate in series mode, parallel mode, or all-electric mode.

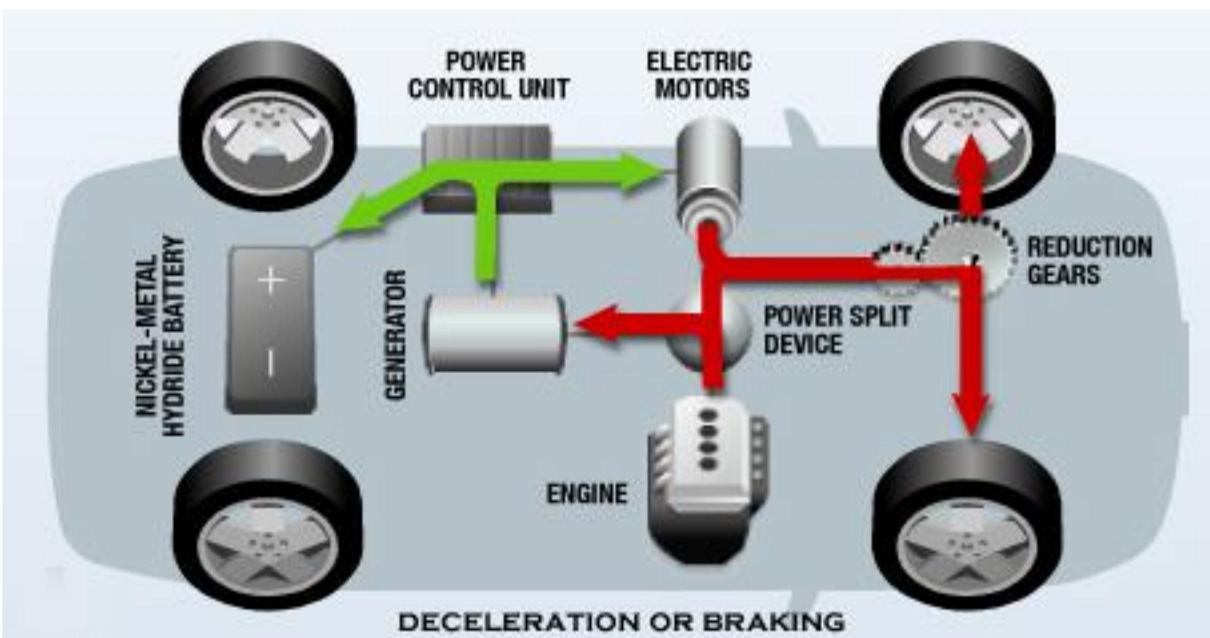

Figure: full hybrid declaration or braking. (2/10/2017)

In basic terms, a **Series Hybrid** is a powertrain that uses the electric motor to drive the wheels, and the gas engine to provide the power as an on-board generator. In other words, the gas engine never mechanically turns the drive wheels.

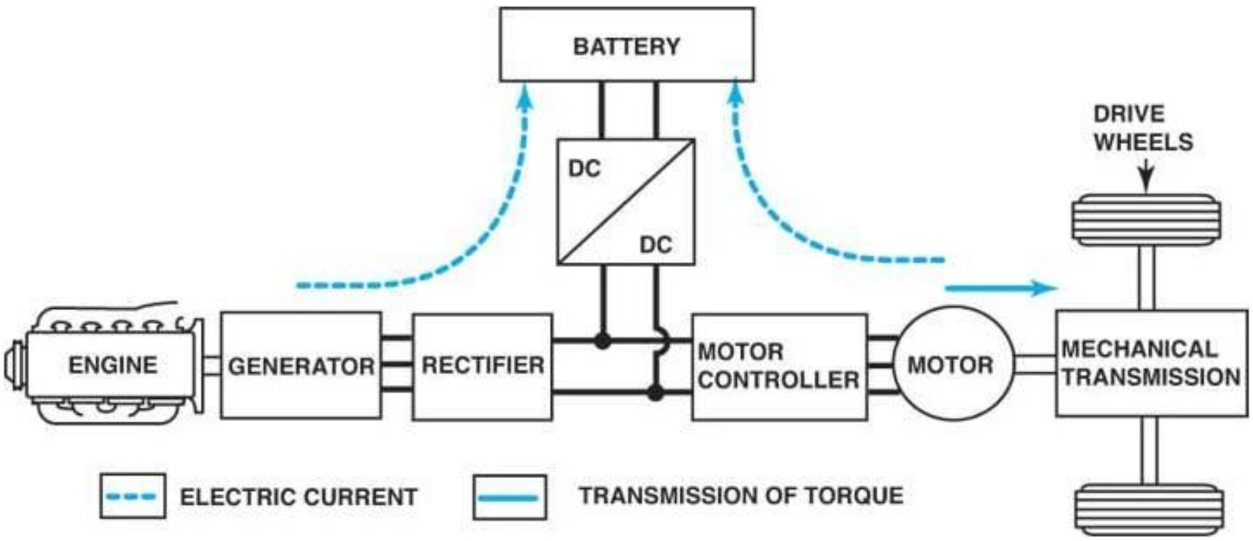

Figure: Components of a series hybrid EV

A diesel locomotive is actually a series hybrid. It’s really an electric-powered vehicle despite those great big chugging engines and the black smoke – that’s just how it generates its own electricity.

In **Parallel mode**, both the gas engine and electric motor contribute to driving the wheels.
A full hybrid may also operate for short durations in pure electric mode. Have you ever had your back turned and had a hybrid almost silently sneak up behind you? At low speeds – where energy usage is minimal – the small battery packs and electric traction motor can most effectively operate in pure electric mode.

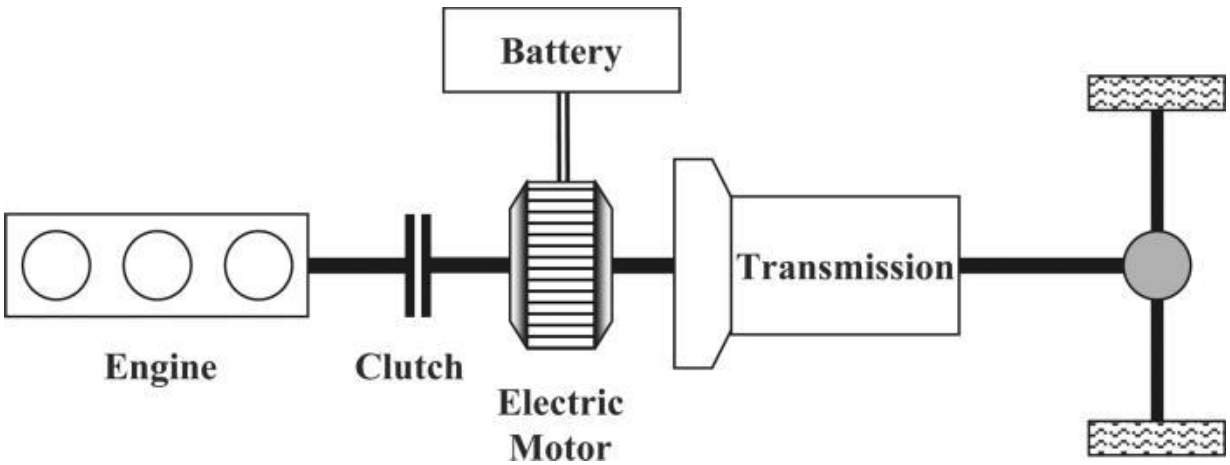

Figure: Supervisory Control of Parallel Hybrid Electric Vehicles for Fuel and Emission Reduction.

3.3.2 Mild Hybrid

A mild hybrid is not typically as efficient as a full hybrid because it is limited to parallel hybrid mode. Another simple way of looking at a mild hybrid is it has a battery and helper motor, but these operate while the gas engine is on, and never fully take over. They are not powerful enough to propel the car without the gas engine also doing some of the work. Mild hybrids may also make use of stop-start and regenerative braking but they tend not to return as high of EPA-rated mpg.

Figure: Buick LaCrosse assist, a mild hybrid. (2/10/2017)

3.3.3 Plug-In Hybrid

This is one step further along the "bridge" toward a pure electric vehicle. Most of these include all the technologies of a full hybrid, but have an extra trick – they have larger batteries. These can be plugged into the grid and their increased supply of on-board electricity allows them to run in all-electric mode from a low of maybe six to 14 miles for the Toyota Prius PHEV, to 38 miles for the Chevy Volt.

Figure: Ford C-Max Energi PHEV.(10/10/2017)

3.3.4 Micro and Muscle Hybrids

A micro hybrid is considered by some barely even a hybrid. It usually utilizes stop-start, and often may include a 48-volt battery to operate on-board electrical systems, and may improve economy 10-20 percent. Examples include the Chevy Malibu with stop-start, or Mazda's i-ELOOP system.

Figure: Micro and Muscle Hybrids(15/10/2017)

Micro hybrids are at best the lowest rung on the hybrid ladder, and there's no electric traction motor to actually drive the wheels. The system only saves the engine the extra work of powering subsystems.

A muscle hybrid is an approach that uses the electric motor as extra power, sort of like how a bolt-on turbocharger or supercharger would. Instead of cramming more fuel in, it gives more power without requiring more fuel.

Figure: Infiniti's Q50 Hybrid and BMW's ActiveHybrid3 (15/10/2017)

These tend to be full or even plug-in hybrids, and may save fuel as well, but the emphasis is weighted toward speed performance, more than efficiency performance – even though in all-electric mode, they may momentarily bask in the efficiency of a pure electric car.

3.4 Advantages of Hybrid Electric vehicles

Here are few of the top advantages of Hybrid Electric vehicles:

1. Environmentally Friendly: One of the biggest advantage of hybrid car over gasoline powered car is that it runs cleaner and has better gas mileage which makes it environmentally friendly. A hybrid vehicle runs on twin powered engine (gasoline engine and electric motor) that cuts fuel consumption and conserves energy.

2. Financial Benefits: Hybrid cars are supported by many credits and incentives that help to make them affordable. Lower annual tax bills and exemption from congestion charges comes in the form of less amount of money spent on the fuel.

3. Less Dependence on Fossil Fuels: A Hybrid car is much cleaner and requires less fuel to run which means less emissions and less dependence on fossil fuels. This in turn also helps to reduce the price of gasoline in domestic market.

4. Regenerative Braking System: Each time you apply brake while driving a hybrid vehicle helps you to recharge your battery a little. An internal mechanism kicks in that captures the energy released and uses it to charge the battery which in turn eliminates the amount of time and need for stopping to recharge the battery periodically.

5. Built from Light Materials: Hybrid vehicles are made up of lighter materials which mean less energy is required to run. The engine is also smaller and lighter which also saves much energy.

3.5 Disadvantages of Hybrid Electric vehicles

There are disadvantages to owning a hybrid car, but the disadvantages will depend on the type of hybrid fuel that your car uses.

Here are few of the disadvantages of a hybrid car:

1. Less Power: Hybrid cars are twin powered engine. The gasoline engine which is primary source of power is much smaller as compared to what you get in single engine powered car and electric motor is low power. The combined power of both is often less than that of gas powered engine. It is therefore suited for city driving and not for speed and acceleration.

2. Can be Expensive: The biggest drawback of having a hybrid car is that it can burn a hole in your pocket. Hybrid cars are comparatively expensive than a regular petrol car and can cost $5000 to $10000 more than a standard version. However, that extra amount can be offset with lower running cost and tax exemptions.

3. Poorer Handling: A hybrid car houses a gasoline powered engine, a lighter electric engine and a pack of powerful batteries. This adds weight and eats up the extra space in the car. Extra weight results in fuel inefficiency and manufacturers cut down weight which has resulted in motor and battery downsizing and less support in the suspension and body.

4. Higher Maintenance Costs: The presence of dual engine, continuous improvement in technology, and higher maintenance cost can make it difficult for mechanics to repair the car. It is also difficult to find a mechanic with such an expertise.

5. Presence of High Voltage in Batteries: In case of an accident, the high voltage present inside the batteries can prove lethal for you. There is a high chance of you getting electrocuted in such cases which can also make the task difficult for rescuers to get other passengers and driver out of the car.

CHAPTER V

CONCLUSION

Using the Hybrid Electric Vehicles can largely help in Environment protection and energy crisis management. Financially, HEVs can meet customers' need currently and will grow in faster rate. The main issue in HEVs is to optimize the multiple energy sources to obtain best fuel economy or low emission at lower cost.

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