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THE ANALYSIS OF ELECTRIC,HYBRID AND FUEL CELL VEHICLES

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ABSTRACT:

Electric,hybrid,andfuelcellvehicleshaveattractedmuchinterestfromautomobileindustries, governments, and customers as a result of higher emissions and fuel economyrequirements, global warming, and energy resource restrictions. Innovative designs, low-costsystems,andareliablehybridelectricpowertrainhavebeenthefocusofresearchanddevelopment. Hybrid vehicles are expected to grow in popularity in the nextyears due totheir greater fuel economy and performance. Hybrid electric vehicles (HEVs) are more fuelefficient than conventional vehicles because the engine functioning is optimized and kineticenergy is recovered during braking. The current situation of electric, hybrid, and fuel cellautomobiles is highlighted in this study. The enabling technologies as well as the topologiesforeach categoryarediscussed.

1.1 INTRODUCTION:

Hybrid electric vehicles (HEVs) are more fuel efficient than conventional vehicles since theengine operation is improved and kinetic energy is recovered during braking. The car can bedriven on electric-only modes for a driving range of up to 30–60 km with the plug-in option(PHEV). The PHEVs are charged overnight from the electric power grid, which can bepowered by renewable energy sources including wind and solar energy, as well as nuclearpower. Fuel cell vehicles (FCVs) use hydrogen as a fuel to generate power, therefore theyrelease no emissions. The FCV can provide electricity for emergency power backup during apower loss when linked to the electric power grid (V2G). FCVs are currently unavailable tothe general population due to hydrogen production, storage, and technical limitations of fuelcells. In the coming years, HEVs are going to dominate advanced propulsion. Almost allsources of energy and engines can benefit from hybrid technologies. As a result, it is not atechnologyin transition.

More electrical components, such as electric machines, power electronic converters, batteries,ultracapacitors,sensors,andmicrocontrollers,areemployedinHEVsandFCVs.Conventionalinternalcombustionengines(ICE),aswellasmechanicalandhydraulicsystems, may still be included in addition to these electrification components or subsystems.Advancedpowertraincomponentsdesign,suchaspowerelectronicconverters,electricmachines, and energy storage, are among the challenges posed by these advanced propulsionsystems, as are power management, modelling and simulation of the powertrain system,hybridcontrol theory, and vehiclecontrol optimization.

An electric vehicle (EV) is propelled by Electric motors and uses electrical energy stores inbatteries. Unlike vehicles with combustion engines they do not produce exhaust gasesduringoperation.Thisalonemakeselectricvehiclesmoreenvironmentalfriendlythan vehicles with conventional technologies. However, the electrical energy for charging thevehicle does have to be produced from renewable sources like wind, solar etc. By combingdifferentdrivetypes,theoverallefficiencyofthevehiclecanbeimprovedandfuelconsumptioncan bereduced

1.2 HISTORYOFEV'S:

Introduced more than 100 years ago, electric cars are seeing a rise in popularity today formanyof thesamereasons theywere first popular.

Whetherit'sahybrid,plug-inhybridorall-electric,thedemandforelectricdrivevehicles will continue to climb as prices drop andconsumers look for ways to save money at thepump. Currently more than 3 percent of new vehicle sales, electric vehicles sales could togrow to nearly 7 percent-- or 6.6 million peryear-- worldwide by 2020, according to areport byNavigant research

With this growing interest in electric vehicles, we are taking a look at where this technologyhas been and where it's going. Travel back in time with us as we explore the history of theelectric car.

It is hard to pin point the invention of electric car to one inventor or on country, instead it wasseries of breakthroughs from battery to electric motors in 1880's that led to the first electricvehicleon the road.

Intheearlypartofthecentury,innovatorsinHungary,theNetherlandsandtheUnitedStates -- including a blacksmith from Vermont-- began toying with the concept of a battery-powered vehicle and created some of the first small-scale electric cars. And while RobertAnderson,aBritishinventor,developedthefirstcrudeelectriccarriagearoundthissame time,itwasn'tuntilthesecondhalfofthe19thcenturythatFrenchandEnglishinventorsbuiltsomeof thefirst practical electriccars.

Here inthe U.S.,the first successful electric car made its debutaround 1890 thanks toWilliam Morrison, a chemist who lived in Des Moines, Iowa. His six-passenger vehiclecapable of a top speed of 14 miles per hour was little more than an electrified wagon, but ithelpedspark interest in electric vehicles.

Over the next few years, electric vehicles from different automakers began popping up acrossthe U.S. New York City even had a fleet of more than 60 electric taxis. By 1900, electric carswereattheirheyday,accountingforaroundathirdofallvehiclesontheroad.Duringthenext10years, theycontinued to show strongsales.

Newbeginningforelectriccars:

While all the starts and stops of the electric vehicle industry in the second half of the 20thcentury helped show the world the promise of the technology, the true revival of the electricvehicle didn't happen until around the start of the 21st century. Depending on whom you ask,it was oneof two events that sparked the interest weseetodayin electricvehicles

Thefirstturningpointmanyhavesuggestedwastheintroductionofthe ToyotaPrius.Released in Japan in 1997, the Prius became the world's first mass-produced hybrid electricvehicle. In 2000, the Prius was released worldwide, and it became an instant success withcelebrities, helping to raise the profile of the car. To make the Prius a reality, Toyota used anickel metal hydride battery -- a technology that was supported by the Energy Department'sresearch. Since then, rising gasoline prices and growing concern about carbon pollution havehelpedmakethe Prius thebest-sellinghybridworldwide duringthe past decade.

The other event that helped reshape electric vehicles was the announcement in 2006 that asmall Silicon Valley startup, Tesla Motors, would start producing a luxury electric sports carthat could go more than 200 miles on a single charge. In 2010, Tesla received at $465 millionloan fromtheDepartmentofEnergy'sLoanProgramsOffice–aloanthatTeslarepaidafull nine years early-- to establish a manufacturing facility in California. In the short timesincethen, Tesla has won wideacclaim forits cars andhas becomethelargest auto employerinCalifornia.

Tesla's announcement and subsequent success spurred many big automakers to acceleratework on their own electric vehicles. In late 2010, the Chevy Volt and the Nissan LEAF wererereleased in the U.S. market. The first commercially available plug-in hybrid, the Volt has agasoline engine that supplements its electric drive once the battery is depleted, allowingconsumers to drive on electric for most trips and gasoline to extend the vehicle's range. Incomparison, the LEAF is an all electric vehicle (often called a battery-electric vehicle, anelectric vehicleor just anEV forshort), meaningit is onlypowered byan electric motor.

Consumers now have more choices than ever when it comes to buying an electric vehicle.Today, there are 23 plug-in electric and 36 hybrid models available in a variety of sizes --from the two-passenger Smart ED to the midsized Ford C-Max Energi to the BMW i3 luxurySUV. As gasoline prices continue to rise and the prices on electric vehicles continue to drop,electric vehicles are gaining in popularity -- with more than 234,000 plug-in electric vehiclesand3.3 million hybrids on the roadin theU.S. today.

1.3 ARCHITECTUREOFEV:

EV architecture gives an idea of the complete cycle of the working, arrangement of thecomponentshouldbeplacedinasequenceandwhiledesigningavehicle,balanceinperformance and cost must be achieved therefore the selected architecture plays an importantrole.

Electricvehiclearchitecturepowertrains:

TheElectricvehiclearchitectureconsistsof5importantcomponentsandthroughthiscomponent powertrain is completed in EV, such as the Electric motor, Battery pack, andInverter,Charger, DC-DC converter,etc.

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ElectricMotor

Electric motors provide torque to thevehicleby utilizing electromagnetic fields,energysupplied bythebattery, and the torqueis controlled byvaryingthe current flow.

The electric motor gives more than 90% efficiency as compared to ICE, it provides torquewith zero speed so it allows the vehicle with a single gear ratio between motor tire rather thanmultiplespeed transmission.

BatteryPack

The battery pack is the energy storing device, it must both accept and provide current to theelectric machine. Battery packs provide direct current (DC) at their output terminals. Electricmachinesarecontrolledbyvarying an alternatingcurrent (AC) waveform.

Invertor

The motor inverter provides this conversion between DC and AC and the torque controlfunctionality.

DC-DCConverter

A DC/DC converter is used to convert power from battery pack voltage down to 12 volts.(E.g.wipers, infotainment system, mirrorcontrol)

On-boardcharger

Thechargerperformsthreefunctions:

- RectificationofACvoltage fromthe gridtoDCvoltage.
- Controlsthecurrentflowingintothebatterypackbycontrollingthe DCoutputvoltage.
- Communicateswiththe vehicle,off-vehicle equipment.

BatteryManagementSystemComponents

BMS is used to monitor the state of the battery and is responsible to take the necessarymeasurements i.e. SOC, SOH. Battery management system performs cell balancing to deliverthebestefficiencyoutputfromabattery pack,andasmallECUisusedinthisforcommunicationwith other components.

Apart from these important components, there are multiple hardware and software used in EVpowertrain architecture.There are small monitoring ECUs placed for the specific functionandcommunication is donebyCAN protocol.

CHAPTER2:METHODOLOGY

TYPESOFEV:

- Batteryelectricvehicle(BEV)

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- Hybridelectricvehicle(HEV)
- Plug-inHybridelectricvehicle(PHEV)
- Fuelcellelectricvehicle

2.1 BATTERYELECTRICVEHICLE:

Basicsof BEV:

Although people start communicating more about HEVs, which have grown very popular,their underlying mechanism is difficult due to the fact that they have two propulsion sources.ApureEVissimplerbecauseitjusthas onesourceofenergy,whichisabattery.Similarly,its propulsion is provided by an electric motor, eliminating the requirement for an ICE.If theICEisremoved,thevehicleswillnolongerrequirefuelinjectors,variouscomplexengine controllers, and all of the other engine and gearbox peripherals. It will also be more reliablewithfewer parts andasimplersystem

2.2 HYBRIDELECTRICVEHICLES:

A **hybridelectricvehicle** (**HEV**)isatypeof hybridvehicle thatcombinesaconventional internalcombustionengine(ICE)systemwith anelectric propulsionsystem(hybrid vehicle drivetrain) . The presence of the electric powertrain is intended toachieve either better fueleconomy than a conventional vehicle or better performance. Thereis a variety of HEV types and the degree to which each function as an electric vehicle (EV)alsovaries.ThemostcommonformofHEVisthehybridelectriccar,althoughhybridelectrictrucks (pickups and tractors),buses,boatsand aircraft alsoexist.

Differenttopologies:

- SeriesHEV
- ParallelHEV
- Series-parallelHEV

2.2.1. Series HEV:

The series–parallel HEV shown in Figure incorporates the features of both series andparallel HEVs. Therefore, it can be operated as a series or parallel HEV. In comparison toa series HEV, the series–parallel HEV adds a mechanical link between the engine and thefinaldrive,sotheenginecandrivethewheelsdirectly.WhencomparedtoaparallelHEV, the series–parallel HEV adds a second electric motor that serves primarily as agenerator. Because a series–parallel HEV can operate in both parallel and series modes,the fuel efficiency and drivability can be optimized based on the vehicle’s operatingcondition. The increased degree of freedom in control makes the series–parallel HEV apopular choice. However, due to increased components and complexity, it is generallymoreexpensive than series or parallel HEVs.

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2.1 PLUG-INHYBRIDELECTRICVEHICLE:

Plug-in hybrid electric vehicles (PHEVs) use batteries to power an electric motor, as well asanother fuel, such as gasoline or diesel, to power an internal combustion engine or otherpropulsionsource.PHEVscanchargetheirbatteriesthroughchargingequipmentandregenerative braking. Using electricity from the grid to run the vehicle some or all of the timereduces operating costs and fuel use, relative to conventional vehicles. PHEVs may alsoproduce lower levels of emissions, depending on the electricity source and how often thevehicleis operated in all-electric mode.

There are several light-duty PHEVs commercially available , and medium-duty vehicles arenow entering the market. Medium- and heavy-duty vehicles can also be converted to PHEVs.AlthoughPHEVsaregenerallymoreexpensivethansimilarconventionalandhybridvehicles, somecost canbe recoveredthrough fuel savings, a federal taxcredit , or stateincentives.

The above figure shows the configuration of a series HEV. In this HEV, the ICE is themain energy converter that converts the original energy in gasoline to mechanical power.The mechanical output of the ICE is then converted to electricity using a generator. Theelectricmotormovesthefinaldriveusingelectricitygeneratedbythegeneratororelectricity stored in the battery. The electric motor can receive electricity directly from theengine,orfromthebattery,orboth.Sincetheengineisdecoupledfromthewheels,the engine speed can be controlled independently of vehicle speed. This not only simplifiesthe control of the engine, but, most importantly, can allow operation of the engine at itsoptimum speed to achieve the best fuel economy.It alsoprovides flexibility in locatingtheengineonthevehicle.Thereisnoneedforthetraditionalmechanicaltransmissionina series HEV. Based on the vehicle operating conditions, the propulsion components on aseriesHEVcan operatewith different combinations:

- **Batteryalone**:Whenthebatteryhassufficientenergy,andthevehiclepowerdemand is low, the I/G set is turned off, and the vehicle is powered by the batteryonly
- **Combined power**: At high power demands, the I/G set is turned on and the batteryalsosupplies power to theelectricmotor.
- **Engine alone**: During highway cruising

and at moderately high power demands, theI/G set is turned on. The battery is neither charged nor discharged. This is mostly dueto the fact that the battery's state of charge (SOC) is already at a high level but thepower demand of the vehicle prevents the engine from turning, or it may not beefficientto turn theengine off.

- **Power split**: When the I/G is turned on, the vehicle power demand is below the I/Goptimum power, and the battery SOC is low, then a portion of the I/G power is usedtochargethe battery.

2.2.2. PARALLELHEV:

The above figure shows the configuration of a parallel hybrid. In this configuration, theICE and the electric motor can both deliver power in parallel to the wheels. The ICE andthe electric motor are coupled to the final drive through a mechanism such as a clutch,belts, pulleys, and gears. Both the ICE and the motor can deliver power to the final drive,eitherincombinedmode,oreachseparately.Theelectricmotorcanbeusedasagenerator torecover the kinetic energy during braking or absorbing a portion of powerfrom the ICE. The parallel hybrid needs only two propulsion devices, the ICE and theelectricmotor, which canbeusedin thefollowingmode:

- **Motor-alone mode**: When the battery has sufficient energy, and the vehiclepower demand is low, then the engine is turned off, and the vehicle is powered bythemotor and batteryonly.
- **Combined power mode**: At high power demand, the engine is turned on and themotoralso supplies power to thewheels.
- **Engine-alone mode**: During highway cruising and at moderately high powerdemands, the engine provides all the power needed to drive the vehicle. Themotor remains idle. This is mostly due to the fact that the battery SOC is alreadyat a high level but the power demand of the vehicle prevents the engine fromturningoff, orit maynot be efficient to turn the engine off.
- **Power split mode**: When the engine is on, but the vehicle power demand is lowand the battery SOC is also low, then a portion of the engine power is convertedto electricitybythe motor to chargethe battery.

2.2.3. SERIES-PARALLELHEV'S:

KeycomponentsofPlug-inHybridElectricVehicle:

Battery (auxiliary): In an electric drive vehicle, the low-voltage auxiliary battery provideselectricity tostartthe car before thetractionbattery isengaged;italsopowers vehicleaccessories.

Charge port: The charge port allows the vehicle to connect to an external power supply inorderto chargethe traction batterypack.

DC/DC converter: This device converts higher-voltage DC power from the traction batterypack to the lower-voltage DC power needed to run vehicle accessories and recharge theauxiliarybattery.

Electric generator: Generates electricity from the rotating wheels while braking, transferringthatenergybacktothetractionbatterypack.Somevehiclesusemotorgeneratorsthatperformboth the driveand regeneration functions.

Electric traction motor: Using power from the traction battery pack, this motor drives thevehicle's wheels. Some vehicles use motor generators that perform both the drive andregenerationfunctions.

Exhaustsystem: Theexhaustsystemchannelstheexhaustgasesfromthe engineoutthroughthe tailpipe. A three-way catalyst is designed to reduce engine-out emissions within theexhaustsystem.

Fuelfiller: Anozzlefromafueldispenser attaches tothereceptacleonthevehicletofill thetank.

Fuel tank (gasoline): This tank stores gasoline on board the vehicle until it's needed by theengine.

Internal combustion engine (spark-ignited): In this configuration, fuel is injected intoeithertheintakemanifoldor thecombustionchamber, whereit iscombinedwith air,and theair/fuelmixtureis ignited bythe spark fromasparkplug.

Onboard charger: Takes the incoming AC electricity supplied via the charge port andconverts it to DC power for charging the traction battery. It also communicates with thecharging equipment and monitors battery characteristics such as voltage, current,temperature,and state ofcharge while chargingthe pack.

Power electronics controller: This unit manages the flow of electrical energy delivered bythe traction battery, controlling the speed of the electric traction motor and the torque itproduces.

Thermal system (cooling): This system maintains a proper operating temperature range oftheengine, electric motor, powerelectronics, andothercomponents.

Tractionbatterypack: Storeselectricityfor usebytheelectrictraction motor.

Transmission: The transmission transfers mechanical power from the engine and/or electrictractionmotorto drivethe wheels.

2.4 BATTERY

One of the key elements of an electric vehicle is battery. Energy densityis a measure of howmuch energy a battery can hold. The higher energy density ,the longer it will last before needtobe charged.

Power is the rate at which energy is used. Power density is a measure of how much batterycandeliver on demand; thatis,how quicklyitcanreleaseit's energy.

TYPESOFBATTERY:

- Lead acid battery
- Nickel-metal-Hydride
- Li-Ion
- Lithiumpolymer
- Lithiumphosphate

Someimportantbatteryterms:

Stateofcharge(SOC)

-Battery capacity, expressed as percentage

of maximum capacity.Depthof discharge

-The percentage of discharge capacity that

has been discharged.Capacity

-ThetotalAmp-hours(Amp-hr)availablewhenthebatteryisdischargedata specificcurrent(specified as C-rate)from 100%SOC.

Energy

-

ThetotalWatthour(Wh)availablewhenthebatteryisdischarged ataspecificcurrent(specified as C-

Specificenergy

-The total watt hours per unit

mass.Specificpower

-

Maximumpower(watts)thatthebatterycanprovideperunitmass,functionofinternalresistanceof battery.

2.4. FUELCELLVEHICLE:

How doFuelCell ElectricVehiclesworkusingHydrogen?

Likeall electric vehicles, fuel cell electric vehicles (FCEVs) use electricity to power anelectric motor. In contrast to other electric vehicles, FCEVs produce electricity using a fuelcell powered by hydrogen, rather than drawing electricity from only a battery. During thevehicle design process, the vehicle manufacturer defines the power of the vehicle by the sizeof the electric motor(s) that receives electric power from the appropriately sized fuel cell andbattery combination. Although automakers could design an FCEV with plug-in capabilities tocharge the battery, most FCEVs today use the battery for recapturing braking energy,providingextrapowerduringshortaccelerationevents, andtosmooth outthe powerdelivered from the fuel cell with the option to idle or turn off the fuel cell during low powerneeds. The amount of energy stored onboard is determined by the size of the hydrogen fueltank. This is different from an all-electric vehicle, where the amount of power and energyavailableareboth closelyrelated to thebattery's size.

KeycomponentsofHydrogenFuelCellElectricVehicle:

Battery (auxiliary): In an electric drive vehicle, the low-voltage auxiliary battery provideselectricity tostartthe carbefore the tractionbattery isengaged;italsopowers vehicleaccessories

Battery pack: This high-voltage battery stores energy generated from regenerative brakingandprovides supplemental power to theelectric traction motor.

DC/DC converter: This device converts higher-voltage DC power from the traction batterypack to the lower-voltage DC power needed to run vehicle accessories and recharge theauxiliarybattery

Electric traction motor: Using power from the fuel cell and the traction battery pack, thismotor drives the vehicle's wheels. Some vehicles use motor generators that perform both thedriveand regeneration functions.

Fuelcell stack: An assembly of individual membrane electrodes thatuse hydrogenandoxygento produceelectricity.

Fuel filler: A nozzle from a fuel dispenser attaches to the receptacle on the vehicle to fill thetank.

Fuel tank (hydrogen): Stores hydrogen gas onboard the vehicle until it's needed by the fuelcell.

Powerelectronicscontroller(FCEV): Thisunitmanagestheflowofelectricalenergy delivered by the fuel cell and the traction battery, controlling the speed of the electric tractionmotorand the torqueit produces

Thermal system (cooling) - (FCEV): This system maintains a proper operating temperaturerangeof thefuel cell,electric motor, power electronics, and othercomponents.

Transmission(electric): Thetransmissiontransfersmechanicalpower fromtheelectrictractionmotorto drivethe wheels.

CHAPTER-3:FUTURESCOPE

Thefutureof electricvehicles

It’s hard to tell where the future will take electric vehicles, but it’s clear they hold a lot ofpotentialforcreatingamoresustainablefuture.Ifwetransitionedallthelight-dutyvehiclesin the U.S. to hybrids or plug-in electric vehicles using our current technology mix, we couldreduce our dependence on foreign oil by 30-60 percent, while lowering the carbon pollutionfromthetransportation sector byas muchas 20 percent.

Tohelpreachtheseemissionssavings,in2012 PresidentObamalaunchedtheEVEverywhereGrandchallenge -- anEnergyDepartmentinitiativethatbringstogetherAmerica's best and brightest scientists, engineers and businesses to make plug-in electricvehicles more as affordable as today's gasoline-powered vehicles by 2022. On the batteryfront,theDepartment'sjointcenterfor EnergyStorageResearchatArgonneNational Laboratoryis working to overcome the biggest scientific and technical barriers that preventlarge-scaleimprovements of batteries.

And the Department's Advanced Research Projects Agency-Energy (ARPA-E) is advancinggame-changingtechnologiesthatcouldalterhowwe thinkofelectricvehicles.Frominvesting in new types of batteriesthat could go further on a single charge to cost effectivealternativestomaterialscriticaltoelectricmotors,ARPA-E'sprojectscouldtransformelectricvehicles.

CHAPTER-4:CONCLUSION

Nowadays, the use of fuel cars is experiencing exponential growth, resulting in greater airpollution. To control this, the usage of EV is required since it has unique benefits, such asbeing aneco-friendly product, being more suitable for city useas itmay minimize theemission of dangerous gases, and therefore eliminating atmospheric pollution. Due to thecontinuous increases in gasoline prices, the electrically charged vehicle is perceived to be theleastexpensive when compared to thetraditionalvehicle.

With ever-increasing energy resource restrictions and environmental concerns,HEVs will get increased interest from the automobile industry and consumers. Although themarket share is still modest today, it is projected that HEVs will progressively gain marketacceptance due to greater fuel economy and vehicle performance. Modeling and simulationwill be crucial to the growth of HEV design and development. Because control is the primaryessential technologyin HEVs, HEV control theoryshould beadvanced.

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