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CONTROLLING TECHNIQUES OF HYBRID ELECTRIC VEHICLES

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ABSTRACT:

A number of control systems for hybrid electric vehicles have been developed in the literature. The goal of this research is to match the driver's power demands, improve the vehicle's overall efficiency, and recover as much braking energy as feasible. Using Regenerative braking system and electrically assisted turbo charger optimal control is possible. Control of hybrid electric vehicles with minimum fuel consumption and emission is possible with dynamic programming. This Paper also demonstrates the optimality of the equivalent consumption minimization strategy (ECMS) results from the close relation of ECMS to control theoretic concept of pmp. The results obtained with this control techniques show that the fuel economy that can be achieved. From electrically assisted turbo charger the robustness of this modeling approach has verified. The potential fuel economy improvement has been shown by fuzzy logic which increase the efficiency of the engine.

Keywords: Hybrid electric vehicle. Pontryagins minimum principle, dynamic programming, regenerative braking, turbocharger, fuzzy logic control, equivalent consumption minimization strategy.

INTRODUCTION:

A hybrid vehicle, often known as a HEV, is one that is powered by both an internal combustion engine (ICE) and an electric motor [1]. To help or assist a gasoline engine, most hybrids combine a high-voltage battery pack and a combination electric motor and generator. The ICE used in a hybrid vehicle can be either gasoline or diesel, although only gasoline powered engines are currently used in hybrid vehicles. An electric motor is used to help propel The vehicle, and in some designs, capable of propelling the vehicle alone without having to start The internal combustion engine [2].

The presence of an electric power train is designed to deliver either better fuel economy or better performance than a traditional car. HEVs come in a variety of shapes and sizes, and their ability to function as electric vehicles varies as well [3]. The hybrid electric automobile is the most prevalent type of HEV, however hybrid electric trucks (pickups and tractors) and buses are also available. Modern HEVs make use of efficiency- improving technologies such as regenerative braking, Which converts the vehicle’s kinetic energy into electric energy to charge the battery, rather Than wasting it as heat energy as conventional brakes do [4]. Some varieties of HEVs use their Internal combustion engine to generate

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3233-3242
electricity by spinning an electrical generator (this Combination is known as a motor- generator), to either recharge their batteries or to directly

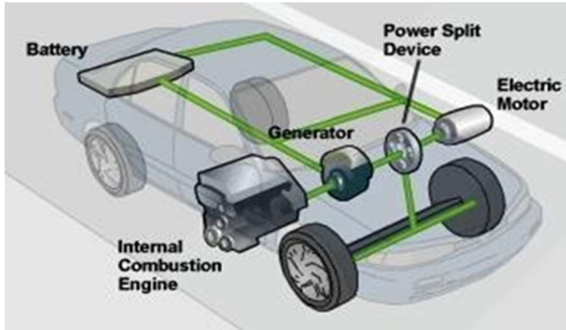


Fig 1.1 Components of Hybrid electric vehicle

the electric drive motors. Many HEVs reduce idle emissions by shutting down the ICE At idle and restarting it when needed; this is known as a start- stop system. A hybrid- electric Produces less emissions from its ICE than a comparably-sized gasoline car, since an HEV's Gasoline engine is usually smaller than a comparably-sized pure gasoline- burning vehicle(natural gas and propane fuels produce lower emissions) and if not used to directly drive the Car, can be geared to run at maximum efficiency, further improving fuel economy [5]. By turning off the ICE, many HEVs cut idle emissions. A start-stop system is one that shuts down the computer when it's not in use and then restarts it when it's needed. A hybrid-electric vehicle because a HEV's gasoline engine is usually smaller than a comparable-sized pure gasoline-burning vehicle (natural gas and propane fuels produce lower emissions), it produces fewer emissions from its ICE than a comparable- sized gasoline engine.

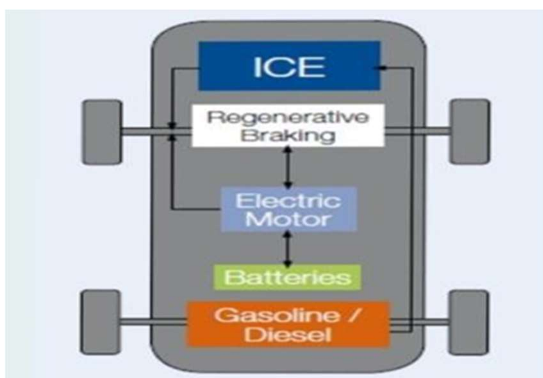


Fig 1.2 Block diagram of HEV

LITERATURE REVIEW:

Many researches have proposed various techniques that eliminate the risks caused by the Control of hybrid electric vehicles[6]. A conventional mode of controlling where Regenerative Braking system is reduces the emission of the vehicle and it improved the fuel consumption by 33% was introduced. Regenerative braking technology that has the potential to improving the Fuel economy of the vehicle is introduced[7]. Furthermore, with Regenerative braking it is Possible to meet the power demand of the drive. The different methods to control an EV are Equivalent consumption minimization strategy (ECMS) and Electrical assisted Turbochargers used for the controlling the vehicle with optimal efficiency are introduced[8].

Hybrids and all electric vehicles create their own power for battery recharging through a Process known as regenerative braking. We have explained what regenerative braking is and How the process works in general terms, but many folks are interested in the deeper nuts and Bolts of electricity generation[9]. They understand that in a hybrid or all electric vehicle the word "regenerative" in terms of regenerative braking, means capturing the vehicle's momentum (kinetic energy) and turning it into electricity that recharges (regenerates) on board battery as The vehicle is slowing down and/or stopping. It is this charged battery that in turn powers the Vehicle's electric traction motor. In an all-electric vehicle, this motor is the sole source of Locomotives

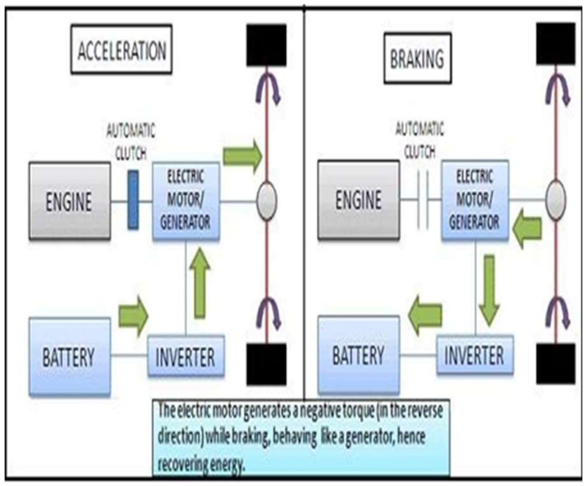


Fig 2.1 Braking modes of RB system.

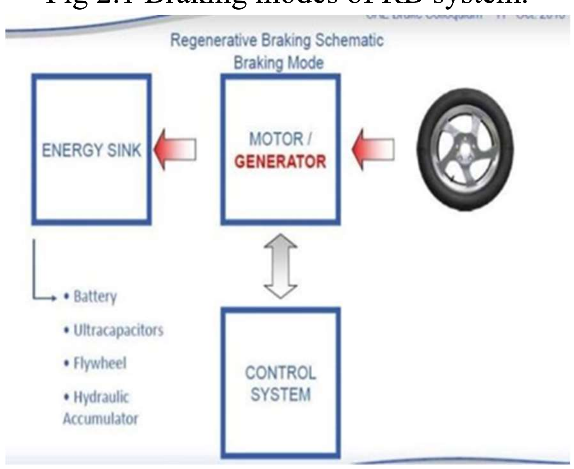


Fig 2.2: Braking mode

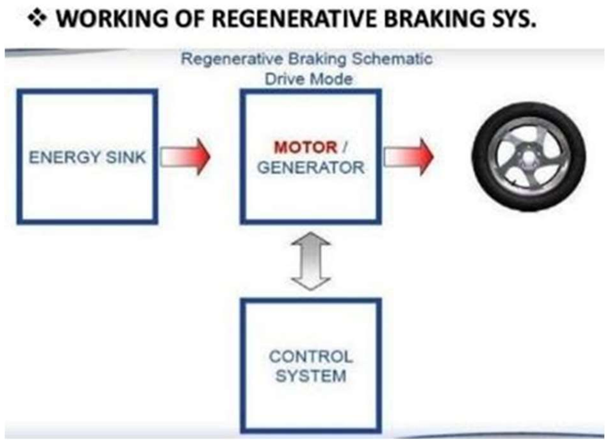


Fig 2.3: Regenerative morning mode

Most, if not all, hybrids and electrics use an electronic throttle control system. When The throttle pedal is pushed, a signal is sent to the on-board computer, which further activates a Relay in the controller that will send battery current through an inverter/converter to the Motor/generator causing the vehicle to move. The harder the pedal is pushed, the more current Flows under direction of a variable resistance controller and the faster the vehicle goes [10].
In a Depending Hybrid, depending upon load, battery state of charge and the design of the hybrid drive train, a Heavy throttle will also activate the internal combustion engine for more power. Conversely, Lifting slightly on the throttle will decrease current flow to the motor and the vehicle will slow Down. Lifting further or completely off the throttle will cause the current to switch direction Moving the motor/generator from motor mode to generator mode and begin the regenerative Braking process.

COMPONENTS:

The followings are the parts of regenerative braking system

1. Alternator
2. Inverter
3. Convertor
4. Storage Battery
5. DC Motor

2.1 Alternator :

Principle:

A.C. generators or alternators (as they are usually called) operate on the same fundamental Principles of electromagnetic induction as D.C. generators. Alternating voltage may be generated by rotating a coil in the magnetic field or by rotating A magnetic field within a stationary coil. The value of the voltage generated depends on

1. The number of turns in the coil.
2. Strength of the field.

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3233-3242

3. The speed at which the coil or magnetic field rotate.

3.1 inverter :

An inverter is an electrical device that converts electricity derived from a DC (Direct Current) source to AC (Alternating Current) that can be used to drive an AC appliance. The Theory of operation is relatively simple. DC power, from a hybrid battery for example, is fed to The primary winding in a transformer within the inverter housing. Through an electronic switch (generally a set of semiconductor transistors), the direction of the flow of current is Continuously and regular broken (the electrical charge travels into the primary winding, then Abruptly reverses and flows back out). The in/out flow of electricity produces AC current in the transformer's secondary winding circuit. Ultimately, this induced alternating current electricity flows into and produces power in an AC load (for example an electric vehicles Electric traction motor). A rectifier is a similar device to an inverter except that it does the Opposite, converting AC power to DC power.

3.2 Convertor:

More properly called a voltage converter, this electrical device changes the voltage (either AC or DC) of an electrical power source. There are two types of voltage converters, one is step up (which increases voltage) and other is step down (which decreases voltage). The most common Use of a converter is to a take relatively low voltage source and step it up to high voltage for Heavy duty work in a high power consumption load, but they can also be used in reverse to Reduce voltage for a light load source.

TECHNIQUES/METHODS:

Controlling systems plays a crucial role in development of HEVs. As compared to Gasoline engine vehicles. Various controlling technologies that provide controlling and Increase the driving range are introduced. A number of control strategies can be used to control the drive Of the hybrid electric Vehicle

The control objectives of the hybrid electric are:

- To meet power demand of the driver
- To operate each component of the vehicle with optimal efficiency
- To recover braking energy as much as possible
- To maintain the state-of- charge (soc) of the battery.

Global optimization technique:

Global optimization techniques, such as Dynamic programming, serve mainly to Evaluate the potential fuel economy of a given powertrain configuration. Unless the Future driving conditions can be predicted During real time operation, these control Laws cannot be implemented directly, but The results obtained using this non causal Approach establish a benchmark for Evaluating the optimality of realizable Control strategies. From the optimal energy Management strategy, sophisticated control,

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3233-3242

Power split control, Dynamic model using Radar sensor and global optimization Technique gives the improvement in fuel Efficiency, reducing the pollution, and Speed of the vehicle measured.

Electrically Assisted Turbocharger:

An electrically assisted turbocharger in a hybrid electric vehicle (HEV) with a turbocharged engine, based on fuel economy and acceleration performance. This system has two electric machines, a traction motor and a boost motor coupled to the shaft of the turbocharger, and offers an additional control variable in the energy management problem i.e., the amount of electrical boost (e-boost) to reduce the turbo lag. This approach is used to analyses the effect of turbo lag on the fuel consumption and acceleration performance. The turbocharger is increasing the pressure of air entering into the engine. The variable geometry turbocharger is used for wide range of speeds. First, a control-oriented model of a parallel HEV with a turbocharged engine is derived Based on first principles. After a series of investigations, a suitable Method to model turbo lag is proposed. It is based on a predefined map for Permissible engine torque obtained through scattered interpolation of experimental measurements. The boost mechanism uses an electric Motor coupled to the shaft of the turbocharger.

Pontrygains minimum principle:

A PMP (Pontryagin's minimum principle) Algorithm to control hybrid vehicles in Optimality. The PMP algorithm can be used For Real-time optimal control because it is based on the instantaneous minimization of the Hamiltonian. We proved that the optimal Control based on PMP can be a global Optimal Control under the assumptions of the Battery, which are reasonable in a charge-Sustaining optimal control problem of HEVs. Based on the assumption, the cost ate Of PMP can be considered as a constant parameter; it simplifies the optimal control problem. The pontryagins minimum principle is used to design the vehicles with optimal and controls the power management. Power split system consists of 2 motors and 2 generators (Toyato hybrid system).

Regenerative braking system:

Regenerative Braking System is the way of slowing vehicle by using the motors as Brakes. Instead of the surplus energy of the vehicle being wasted as unwanted heat, the motors Act as generators and return some of it to the overhead wires as electricity. The vehicle is primarily powered from the electrical energy generated from the Generator, which burns gasoline. This energy is stored in a large battery, and used by an electric Motor that provides motive force to the wheels. The regenerative braking taking place on the Vehicle is a way to obtain more efficiency, instead of converting kinetic energy to thermal Energy through frictional braking, the vehicle can convert a good fraction of its kinetic energy back into charge in the battery, using the same principle as an alternator.

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3233-3242

Equivalent Consumption Minimization Strategy (ECMS):

The equivalent consumption minimization strategy heuristic method to address the optimal control. It provides the effective solution to HEV energy management problem. Equivalent fuel consumption is sum of the real fuel consumption of the Ic engine and equivalent Consumption of the electric motor. The ECMS reduces the fuel consumption up to 30%. The Equivalent specific fuel consumption as evaluated by ECMS.

Description of work in RBS:

The regenerative braking system delivers a number of significant advantages over a car that only has friction brakes. In low-speed, stop-and-go traffic where little deceleration is required, the regenerative braking system can provide the majority of the total braking force. This vastly improves fuel economy with a vehicle, and further enhances the attractiveness of Vehicles using regenerative braking for city driving. At higher speeds, too, regenerative braking has been shown to contribute to improved fuel economy by as much as 20%. Consider a heavy loaded truck having very few stops on the road. It is operated near maximum engine efficiency. The 80% of the energy produced is utilized to overcome the rolling and aerodynamic road Forces. The energy wasted in applying brake is about 2%. Also its brake specific fuel Consumption is 5%. Now consider a vehicle, which is operated in the main city where traffic Is a major problem here one has to apply brake frequently.

Elements of regenerative braking system:

Energy Storage Unit (ESU): The ESU performs two primary Functions

- To Recover & Store Braking Energy.
- To absorb excess engine energy during light load operation.

The Selection Criteria for an effective energy Storage includes.

- High specific energy storage density.
- High energy transfer rate.
- Small space requirement.

The Energy recaptured by regenerative braking might be stored in one of three devices an Electrochemical battery, a Flywheel, & a Hydraulic Accumulator

REGENERATIVE BRAKING WITH BATTERIES:

- Regenerative braking is used in vehicles that make use of electric motors, primarily fully Electric vehicles and hybrid electric vehicles.
- It’s run in one direction, it converts electrical energy into mechanical energy.
- When the motor is run in the opposite direction, a properly designed motor becomes an Electric generator, converting mechanical energy into electrical energy.
- This electrical energy can then be fed into a charging system for the car’s batteries.

REGENERATIVE BRAKING WITH FLYWHEELS:

- In this system, the translational energy of the vehicle is transferred into rotational energy in the flywheel, which stores the energy until it is needed to accelerate the vehicle.

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3233-3242

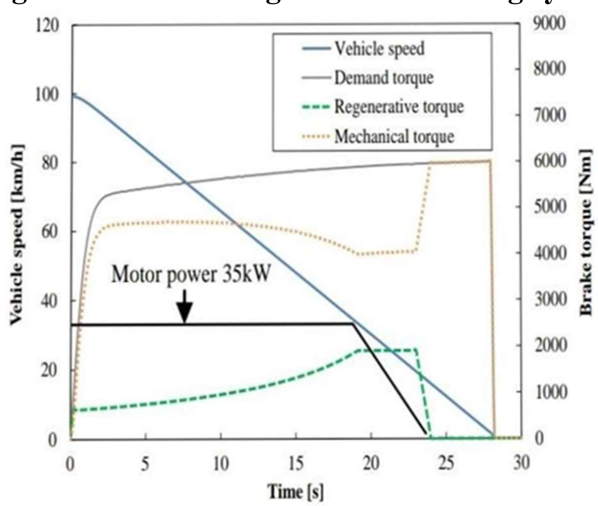
- The benefit of using flywheel technology is that more of the forward inertial energy of the Car can be engaged even during relatively short intervals of braking and acceleration. In the Case of the batteries, they are not able to accept charge at these rapid intervals, and thus more Energy is lost to friction.

CONTINUOUSLY VARIABLE TRANSMISSION:

- The Energy storage unit requires a transmission that can handle torque and speed demands in a steeples manner and smoothly control the energy flow to and from the vehicle wheels. For The flywheel the continuously variable transmission and vehicle because flywheel rotational Speed increase when vehicle speed decrease and vice versa.
- A continuously variable transmission is one of the most common forms of variator Mechanism, which varies the speed.
- The following types of CVT is used:

1. Hydrostatic CVT.
2. Electrical or Electromagnetic CVT.
3. Mechanical CVT

Fig: Flow chart of regenerative braking system



RESULTS & DISCUSSION:

In most of Hybrid electric vehicles there is at least regenerative braking system used. Electric Vehicles (EVs) and various Hybrid Electric Vehicles (HEVs) have been attracting a lot of Attention for environmental issues and energy crisis. One of advantages of using foregoing vehicles is Charging energy by the regenerative brake. The running distance by one electric charge is increased a lot by the regenerative brake. However, the absorbed capacity of the regenerative energy is limited because of the Motor capacity and the current limit of the battery. As a result not only the regenerative electric brake but also the mechanical brake must be used. This becomes serious issue in the heavy weight vehicle such as the Bus and the truck, the effectiveness of EV/HEV is not obtained. To increase the regenerative energy, the large motor and the battery are requested, however, it is very difficult because of the cost and the limit of the inverter capacity

Catalyst Research Volume 23, Issue 2, November 2023 Pp. 3233-3242

CONCLUSION:

A hybrid vehicle is a vehicle that uses two or more distinct power sources to move the Vehicle. The term most commonly refers to hybrid electric vehicles (HEVs), which combine an internal combustion engine and one or more electric motors. Modern HEVs make use of Efficiency-improving technologies such as regenerative braking, which converts the vehicle's Kinetic energy into electric energy to charge the battery, 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. Many HEVs reduce idle emissions by shutting down the ICE at idle and restarting it when needed; this is known as a start-stop system. A hybrid- electric produces less emissions from its ICE Than a comparably-sized gasoline car, since an HEV's gasoline engine is usually smaller than A comparably-sized pure gasoline-burning vehicle (natural gas and propane fuels produce lower Emissions) and if not used to directly drive the car, can be geared to run at maximum efficiency, Further improving fuel economy.

REFERENCES:

[1].Sciarretta Antonio, and Lino Guzzella. "Control of hybrid electric vehicles." IEEE Control Systems Magazine 27, no. 2 (2007): 60-70.

[2].Jain, Achin , Tobias Nueesch, Christian Naegele , Pedro Macri Lassus, and Christopher H. Onder. "Modeling and control of a hybrid electric vehicle with an electrically assisted turbocharger." IEEE Transactions on Vehicular Technology 65, no. 6 (2016): 4344-4358.

[3].Kim, Namwook, Sukwon Cha, and Hupei Peng. "Optimal control of hybrid electric vehicles based on Pontryagin's minimum principle." IEEE Transactions on control systems technology 19, no. 5 (2010): 1279-1287

[4].Xu, Qiwei, Fukang Wang, Xuefeng Zhang, and Shumei Cui. "Research on the Efficiency optimizationcontrol of the regenerative braking system of hybrid electrical Vehicle based on electrical variable transmission." IEEE Access 7 (2019): 116823-116834.

[5].Musardo, Cristian, Giorgio Rizzoni, Yann Guezennec, and Benedetto Staccia. "A- ECMS: An adaptive algorithm for hybrid electric vehicle energy Management."

[6]. Jāmiʻat Ṣafāqis. National Engineering School of Sfax. Laboratory of Sciences and Techniques of Automatic Control & Computer Engineering, IEEE-Tunisia Section., and Institute of Electrical and Electronics Engineers, Sixteenth International Conference on Sciences and Techniques of Automatic Control & Computer Engineering : STA'2015.

[7].M. Boujneh, N. Majdoub, T. Ladhari, and Sakly, "Optimal Control Strategy Parameters of Parallel Hybrid Electric Vehicles Based on Particle Swarm Optimization," in Proceedings - STA 2020: 2020 20th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering, Institute of Electrical and Electronics Engineers Inc., Dec. 2020, pp. 107–112. doi: 10.1109/STA50679.2020.9329308.

[8].Z. Shupeng, Z. Shifang, X. Pengyun, and L. Meng, "The Eighth International Conference on Electronic Measurement and Instruments Control Strategy and Simulation analysis of Hybrid Electric Vehicle 1 Instruction."

[9].IEEE Staff, 2017 25th Mediterranean Conference on Control and Automation (MED). IEEE, 2017.

[10]. University of Michigan--Dearborn., Vehicular Technology Society., IEEE Power Electronics Society., and Institute of Electrical and Electronics Engineers., 5th International IEEE Vehicle Power and Propulsion Conference : September 7-11, 2009, Dearborn, Michigan, USA.