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A Technical Survey of Hybrid Vehicle feature set with Multiple Energy Sources

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ABSTRACT: In this paper, I have undertaken an in depth study on Hybrid Electrical Vehicles (HEVs) to cover the technical aspects like- HEV sales projections, need & relevance of HEV Research, Environmental Concerns, Hybrid Vehicle – Basic structure & other requirements, performance, maintenance issues, Efficiency Factors, challenges, advantages & disadvantages, open research issues, Energy Aggregator systems, Motor- generator pair etc., as a part of my ongoing research work.

KEYWORDS: Hybrid Electric Vehicles (HEV), Regenerative braking, Energy aggregator, Motor-Generator pair.

I. INTRODUCTION

HYBRID CAR DEFINITIONS

A hybrid vehicle is a vehicle that uses two or more distinct power sources to move the vehicle. Hybrid electric vehicles (HEVs) include both a combustion engine as well as an electric motor. A hybrid electric vehicle (HEV) is a type of hybrid vehicle and electric vehicle which combines a conventional internal combustion engine (ICE) propulsion system with an electric propulsion system. [1]

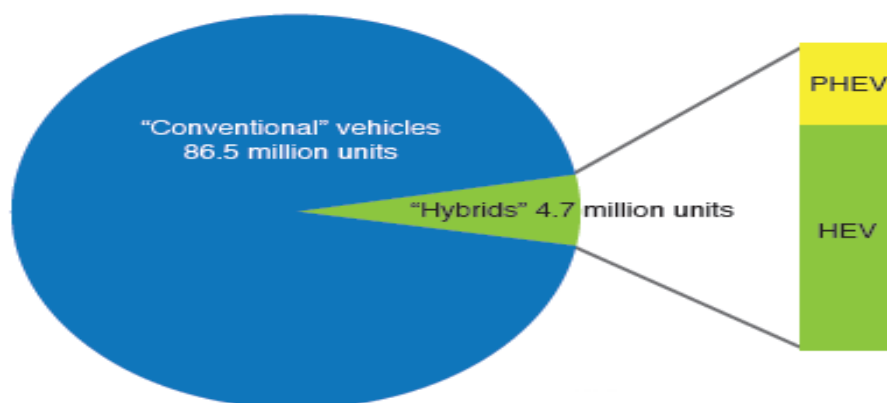


Fig.1 Projected Worldwide Passenger Vehicle Sales 2017

Any car that uses two power sources to move along is classified as a hybrid car. Most hybrid cars consist of a gasoline engine, and a secondary electric motor system accompanied by a pack of rechargeable batteries. The whole concept of hybridization is to save on fuel, and that's true with lots of sedans and compacts. However, the upscale hybrid cars focus more on enhancing power and performance without compromising fuel efficiency[2].

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As much as the storage of energy for electric motor is readily availed by the battery, this engine generates its own power with the help of gasoline in the fuel tank. Hybrid cars combine the best features of combustion engine and electric cars. The above combination allows the electric motor to use gasoline engine more efficiently and cut down on the fuel usage [3].

Relevance of HEV Research

HEV sales projections:

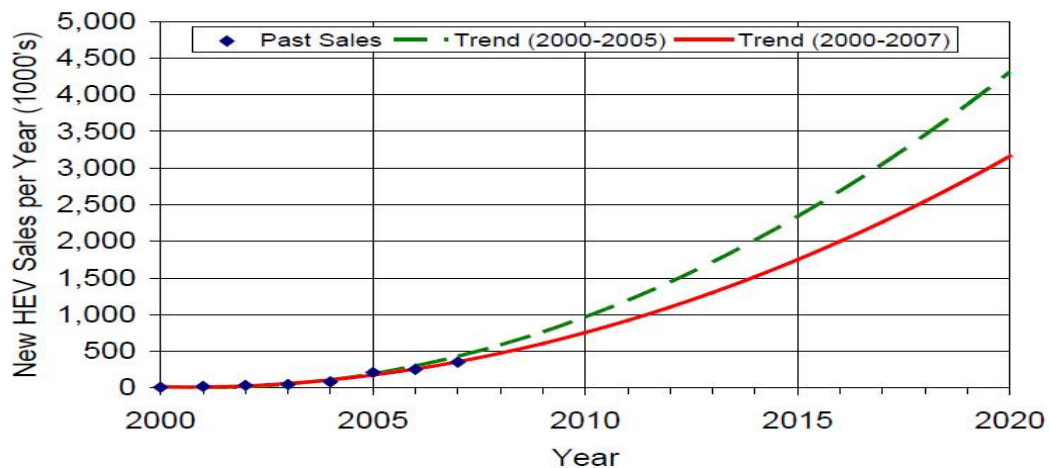


Fig.2 20 years HEV sales trends (2000 to 2020) [4]

The figure shows an estimate of future sales of HEVs per year. It compares the forecasts to a trend line based on HEV sales from 2000 through 2005. This trend is shown in below figure by the green dashed line. It also shows the sales trend, including sales data from 2006 and 2007, which is indicated by the solid red line. The fact to be noted is that the initial projections of HEV sales is a bit sluggish & below the predicted projections or trends.

II. RELATED WORK

Pavan [5] et.al has surveyed history and evolution, types of hybrid vehicles engine configuration, technology used like regenerative braking, benefits of HEV in terms of fuel consumption, emission reduction, noise and pollution.

Ning Ding, K Prasad, T.T Lie[6] et.al in their paper have extensively surveyed about electric vehicles with respect to classification of EV and have compared EVs into three categories like PEV, HEV, FCEV and have compared their features and tabulated them. The authors have analyzed energy diversification of electric vehicles in terms of energy resource, energy carrier and vehicle type. They have also reviewed various types of HEVs in terms of conventional. Micro and mild, full and dual, grid-able (PHEV). They have also discussed the battery, fuel cell and photovoltaic model of energy storage including super capacitor.

M A Hannan, Mohammed Azad, Fazid Arafat[7] et al, have covered various aspects of HEV, battery model, fuel cell, solar cell. The most interesting aspect of this paper to my research is vehicle load versus distance against energy used characterization is plotted. The authors have also surveyed power demand of vehicle as against state of charge (SOC) with respect to EMS operation. They have also analyzed various current challenges and problems of HEV like system stability, dynamic resource allocation, power quality, uninterruptible power availability.

M A Hannan, Mohammed Azad, Fazid Arafat [8] et al, have covered various challenge with respect to performance of battery, super capacitor and solar energy and also they have analyzed battery life cycle reduction in terms due to SOC recharge i.e., battery life reduces due to repeated charging and discharging. The major finding is that if the charge discharge threshold is below 50% then the life cycle of battery is reduced. This results in use of fossil fuels for short

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distance drive and battery fuel for long distance drive. Example: for city use (short distance) under heavy traffic condition fossil fuels are better when compared to battery operated systems.

Hofman [9] et al have covered drive function enhancement with respect to fuel consumption, emissions, comfort, drivability (performance), Safety. They have also analyzed conversion components EC and energy exchange system with design specification storage power, energy storage level, energy storage - and energy converter efficiency, the type of vehicle class, the type of engine, driving behaviour, climate - and geographical influences, additional electrical (accessory) loads, functional constraints on the EES. They have undertaken various energy management design and algorithm for various classes of vehicles like multipurpose vehicle, mini compact vehicle. The criticality of their research was to analyze significant difference in power request during vehicle launch and energy recovery gain during braking.

Daniel F. Opila, Xiaoyong Wang, Ryan McGee, Jeffrey A. Cook, and J.W. Grizzle et al, have covered HV energy management. They have analyzed vehicle architecture model, control model and have evolved vehicle simulation model with drivability constraints.

Need of hybrid vehicles

- Declining fuel reserves & dependency on fossils fuels can be decreased
- Increasing Demand on conventional fuel sources & increasing fuel price
- Reduce emission & to prevent Environmental Degradation
- Minimize propulsion system cost to keep affordable & provide Sustainable development
- Hybrids can be run on alternative fuels as well
- Reduce Global warming & Work towards Greener Earth
- To increase fuel economy
- New materials as vehicular fuel can be implemented
- Maintain acceptable performance with a reasonable cost
- Reduce the conventional car weight

Environmental Concerns:

- Current use of heat-combustion engine is a major source of air pollution and may be a cause of global warming.

Practical Concerns:

- Current conventional cars use a quickly decreasing source of fossil fuel. Although no one knows exactly how long the world's supply of oil will last, most agree that it isn't too far in the future that our current supply will be used up[2].
- An electric-powered car cannot go more than 100 miles (161 km) between recharging, is difficult to re-charge and doesn't drive beyond 60 mph, although it emits little pollution
- Regenerative braking actually makes city driving more economical than on the highway. Hence, Hybrid Vehicles increases drive train efficiency by approximately 30-40%

Requirements of hybrid cars:

- It must drive at least 300 miles before re-fueling.
- It must be refueled quickly and easily.
- It must keep up with the other traffic on the road.

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Hybrid performance

- The key for the hybrid car is its ability to use a smaller engine
- A conventional engine is sized for peak power requirement, when a study shows that most drivers reach this less than 1% of our driving time.
- The hybrid engine is sized for running at the average power not the peak. But when it does reach that point that it needs help up a hill or to pass someone, it draws extra power from the batteries and the electric motor to get the job done [10].

Hybrid efficiency

- Recovers energy and stores it into the battery
- Regenerative braking
- Sometimes it will shut the engine off
- Reduces aerodynamic drag
- Low rolling resistance tires
- Stiffer and inflated more
- 1/2 the drag on the road
- Lightweight Materials
 - Carbon fiber
 - Metals
 - Aluminum
 - Magnesium [10]

Hybrid maintenance

- Warranties
- The average warranty for a hybrid now is around either 8 yr/ 100,000 miles or even 10 year/ 150,000 miles
- Brake pads
- Regenerative braking
- Batteries
- \$6800 for new Toyota and Honda hybrid
- But batteries tested to go for 180,000 miles and more [10].

Basic structure of hybrid vehicle

The batteries in a hybrid car are the energy storage device for the electric motor. Unlike the gasoline in the fuel tank, which can only power the gasoline engine, the electric motor on a hybrid car can put energy into the batteries as well as draw energy from them.

Parts to a Hybrid Car

- Gasoline Engine - Atkinson Cycle Engine
- Fuel Tank
- Electric Motor- Permanent Magnet motor
- Generator
- Batteries- Nickel-Metal Hydride/Lithium-Ion battery
- TransmissionMicro-converter and micro-inverter

HEV Efficiency Factors:

- Idle off - Engine Stop/Start when vehicle at standstill
- Regenerative Braking to charge batteries

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- Smaller engine size and reduced emissions
- Vehicle weight and aerodynamic design
- Using low rolling resistance tires
- Power Assist
- Electric Only drive

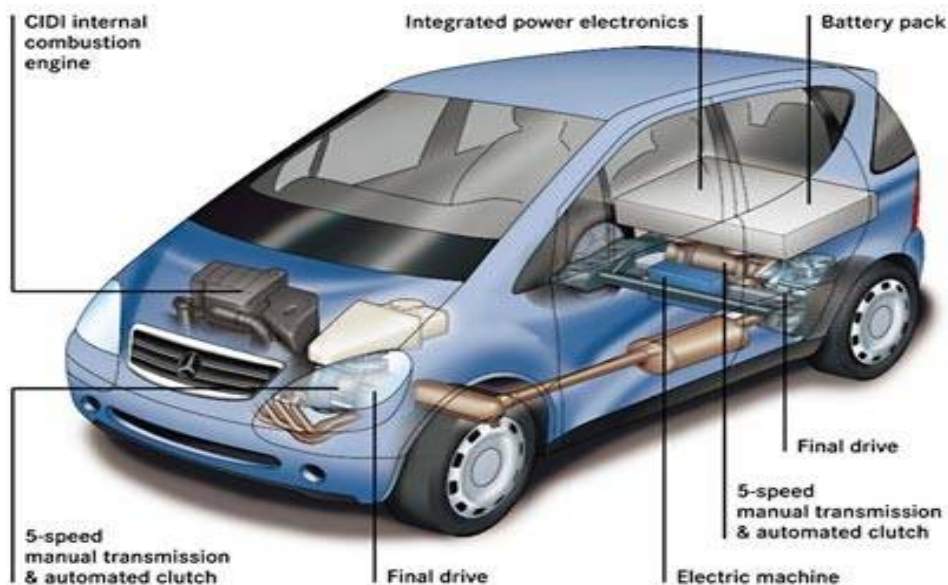


Fig.3 Hybrid vehicle [9]

Essential Hybrid Operations

- Engine Downsize : Performance is retained by supplementing the power of the IC engine with the electric motor
- Regenerative Braking:Recharges the batteries thus recovering energy that would otherwise be lost as heat
- Electric Launch & Drive:Propels the vehicle without turning on the IC engine

Benefits of EV's and HEV's compared with conventional vehicles

- The electric motor is far more efficient (70%-85% efficiency) than the heat engine (need some numbers).
- EV's can use regenerative stopping (regain 30% of energy used, theoretically).
- As mentioned already, HEV's are more environmentally friendly and the oil supplies for conventional vehicles are being depleted.
- Regenerative Braking
- Reduction in engine and vehicle weight
- Fuel efficiency is increased
- Emissions are decreased
- Cut emissions of global warming pollutants by 1/3 or 1/2
- Reduce the dependency on fossil fuels
- Some states offer incentives with owning an HEV
- 2 times more efficient than conventional engines

HEV challenges

- Energy storage devices with high power-to-energy ratios
- Frequent shut down and start up of the HEV

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- Reduce the size, weight, and cost
- Higher efficiency in the conversion of fuel to useful power
- Advanced configurations for the propulsion system components

HEV advantages	HEV disadvantages
Environment Friendly	expensive –high maintenance cost
Fuel Efficient	Different drive experience – heavier car
Reduced Noise	Less Power
Better Performance	Low fuel mileage on highway
Financial Benefits – Govt. aid [11]	Disposal of Hybrid car battery [11]
Less emission, particularly pollutants such as carbon monoxide that are leading to global warming	Safety -risk of exposure to high voltage wires in case of crash
Less dependence on Fossil Fuels	Slower than gas-powered cars
Regenerative Braking System[12]	Poorer Handling[12]
Further range on a single tank of gas.	Long waiting line to get a hybrid car
Quieter	Parts can be very expensive to repair
Built from Light Materials	Sometimes they can be pretty ugly
Higher Resale Value[13]	Presence of High Voltage in Batteries [13]

Open issues needing further Research relating to Hybrid Vehicles:

- Increasing maximizing the efficiency
- Reduce Mass
- Decrease material and manufacturing costs.
- Improving the Hardware.
- Battery – alternatives to/maximizing the nickel-metal hydride currently in use.

Key Hybrid vehicle requirements:

- A three-fold improvement in vehicle fuel economy to 35 kmpl [83mpg]
- A vehicle range of 612 km (380 miles) per refuel
- Acceleration from 0-97 km/h in 12 seconds (0-60 mph in 12 seconds).
- Attain a maximum speed of 137 kmph (85mph).
- Climb a 6.5% grade at 89 km/h (55 mph) for 20 minutes.
- Achieve drive away power in 5 seconds and full power in 2 minutes.
- Must meet FMVSS safety requirements and EPA Tier II emissions standards.
- Purchase price equivalent to today's family sedan
- Generate a maximum Power 60 to 70KW @ 3000 to 6000RPM
- Generate maximum torque of 100 to 200Nm @ 3000 to 4500RPM

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III. METHODOLOGY

Energy Aggregator [$ET = E1 + E2 + E3$ & so on]



Fig.4 Power/Energy Aggregator for hybrid vehicle system [14]

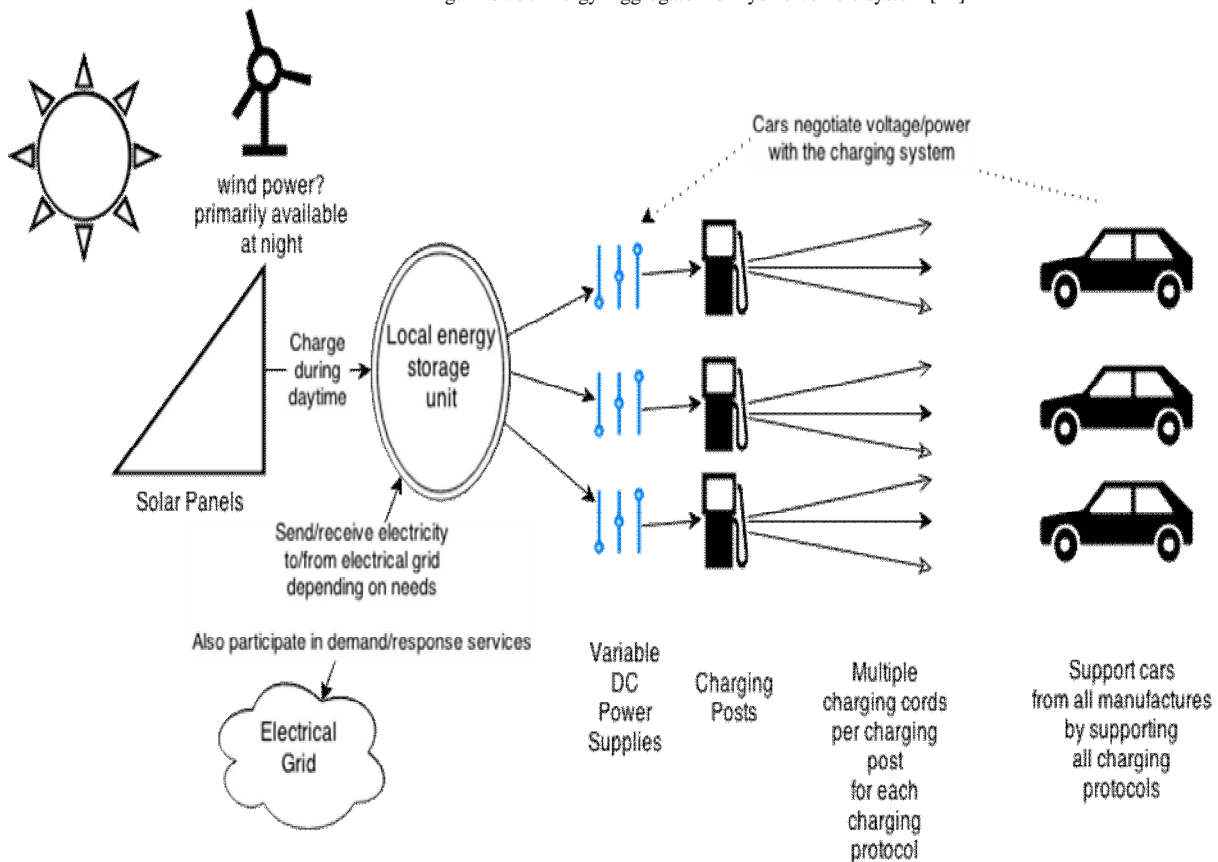


Fig.5 Energy Aggregator System with SOLAR & WIND Energy sources powering a HYBRID VEHICLE [15]

Motor – Generator pair

The below figure closed loop system containing a motor generator pair in our proposed hybrid vehicle is intended to work as follows:

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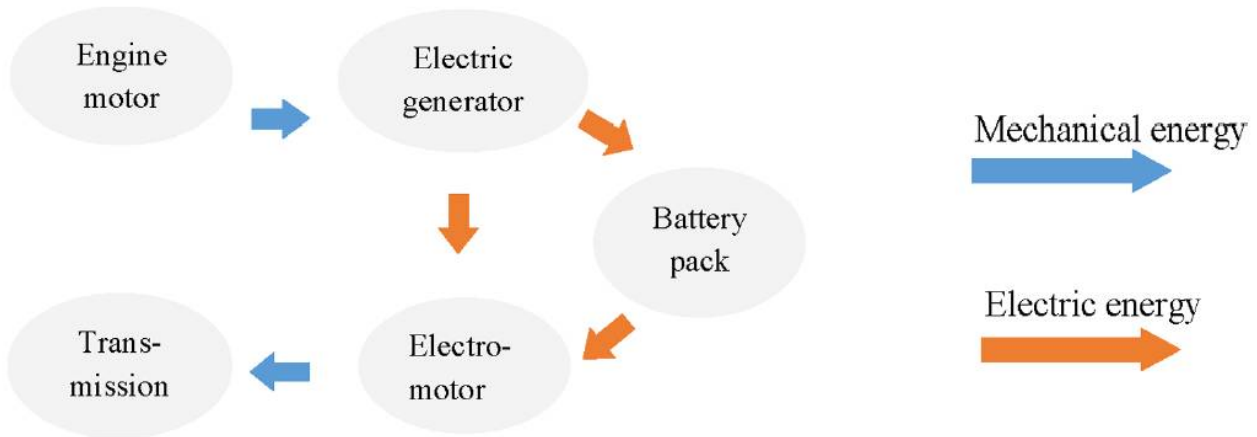


Fig.6 Motor Generator Pair in hybrid vehicle [6]

As shown in the figure above, a closed loop MOTOR GENERATOR PAIR charging a battery with energy indicators will be modelled, developed and tested.

IV.RESULTS

KEY FINDINGS OF SURVEY

After in-depth and exhaustive survey it can be inferred that fossil fuels like petrol, diesel etc are going to get exhausted in upcoming years. Hence there is a strong need to find out other alternative energy sources to act as vehicle fuels.

Fossil fuels have many advantages like

1. Abundant availability in the world
2. Good supply chain management like petrol/gasoline bunk available throughout the world.
3. High power output torque, acceleration, smooth drive.
4. No better high performance and efficient alternatives.
5. Ever increasing demand for fuel because of increased car/vehicle sale every year.

Example: A person with cycle will always aspire to buy a scooter/bike (2wheeler). The person owning a bike or 2wheeler will always like to buy an entry level car. A person owning an entry level car will always try to buy/upgrade a mid segment car likewise person owning a mid segment car will always upgrade/purchase high and luxury cars and so on. So these up gradation leads to increased sale of two wheelers, four wheelers and other vehicles.

6. Also with increasing population every year globally, there is enormous increase in public transport provided by both private and public agencies. Hence enormous increase of vehicle and proportional demand for vehicle fuel arises.
7. Fossil fuel also contribute to severe environment degradation due to carbon-di-oxide and carbon monoxide emissions which contribute to global warming and depletion of ozone protective cover to earth and its living organisms.

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8. Only electricity and electrical engines/vehicles are able to provide capable alternatives to fossil fuel engines. Example: we have electric locomotive engine (train) replacing traditional diesel engine.
9. As of date, only electrical engine can generate such enormous power, torque and drive a heavy load (tons) during traction.
10. Various other energy sources are researched and experimented like solar, wind, nuclear, bio fuels etc. But except nuclear none of the other energy sources provide high power output required for energy traction.
11. But nuclear energy is hazardous for commercial vehicle applications (uncontrolled chain reaction leads to massive explosions).
12. Energy storage, aggregation, harvesting and management is also another major challenge for arriving at alternatives to fossil fuels.
13. Battery technology, manufacturing, monitoring, measurement, servicing is also another major research domain.
14. Efficient motor generator pair also needs to be researched and experimented.
15. Tapping wind energy available in abundance during vehicle traction and linking it with energy storage is very interesting and useful research area.

V. CONCLUSION

As a part of my on-going Research, I will undertake Multi range power measurements; along with feasibility study on suitability of various renewable energy sources like Solar and Wind for Hybrid vehicle applications will be undertaken. Multiple Energy Aggregator with renewable energy sources [Gasoline, Electric, Solar & Wind] for Hybrid cars will be designed and a very serious attempt will be made to implement the above frame work to reduce vehicle consumption of fossil fuel & to cut vehicle emissions dangerous to environment.

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