UNIT-4

ENERGY MANAGEMENT STRATEGIES

Different Energy Management Strategies

➢ **Introduction**

An energy management strategy (EMS) is important for hybridelectric vehicles (HEVs) since it plays a decisive role on theperformance of the vehicle. However, the variation of future drivingconditions deeply influences the effectiveness of the EMS . Most existing EMS methods simply follow predefined rules that are notadaptive to different driving conditions online. Therefore, it is useful that the EMS can learn from the environment or driving cycle. Anenergy management strategy (EMS) is one of the key technologiesfor hybrid electric vehicles (HEVs) due to its decisive effect on theperformance of the vehicle. The EMS for HEVs has been a very activeresearch field during the past decades. However, how to design ahighly- efficient and adaptive EMS is still a challenging task due to thecomplex structure of HEVs and the uncertain driving cycle.

➢ **The existing EMS methods can be generally classified into the following four categories:**

Rule-based EMS
Optimization-based EMS
Learning-based EMS
Deep reinforced learning

1. **Rule-based EMS**

Thermostatic strategy
Load following strategy
Electric assist strategy

➢ **Importance**

These methods rely heavily on the results of extensive experimental trials and human expertise without the a priori knowledge of the driving conditions.

➢ **Other related control strategies employ**

Heuristic control strategy
Fuzzy rules

➢ **Implementation**

Rule-based strategies are effective and can be easily **implemented**, their optimality and flexibility are critically limited by working conditions and, consequently, are not adaptive to different driving cycles.

2. **Optimization based EMS**

➢ **Importance**

some optimization methods employed in control strategy are either based on the known driving cycles or predicted future driving conditions.

- **Strategies.**
  Dynamic programming (dp)
  Sequential quadratic programming (sqp)
  Genetic algorithms (ga)
  The pontryagin minimum principle (pmp)

  1) Usually, these algorithms can manage to determine the optimal power split between the engine and the motor for a particular driving cycle.
  2) However, the obtained optimal power-split solutions are only optimal with respect to a specific driving cycle.
  3) In general, it is neither optimal nor charge-sustaining for other cycles.

- **Implementation**
  Unless future driving conditions can be predicted during real-time operation, there is no way to imply these control laws directly. Moreover, these methods suffer from the "curse of dimensionality" problem, which prevents their wide adoption in real-time applications.

Another type

- **Model predictive control (mpc)**
  The optimal control problem in the finite domain is solved at each sampling instant and control actions are obtained based on online rolling optimization. This method has the advantages of good control effect and strong robustness.

- **Advantages**
  Good Control Effect
  Strong Robustness

3. **Learning Based EMS**
   Traffic information
   Cloud computing in intelligent transportation systEMS (itss) \

- **Importance**
  It can enhance HEV energy management since vehicles obtain real-time data via intelligent infrastructures or connected vehicles .these EMS methods also need complex control models and professional knowledge from experts. these EMS methods are not end-to-end control methods.

Another type

- **Reinforced learning based EMS**
  Reinforcement learning must be able to learn from a scalar reward signal that is frequently sparse, noisy, and delayed. Additionally, the sequence of highly-correlated states is also a large problem of reinforcement learning.

- **Problem.**
  Data distribution changes
  The algorithm learns new behaviours in reinforcement learning.

The learning-based EMS is an emerging and promising method because of its potential ability of self-adaption according to different driving conditions, even if there are still some problEMS.

In addition to

Neural dynamic programming
Fuzzy q-learning.
These strategies do not rely on prior information related to future driving conditions and can self-tune the parameters of the algorithms.

4. **Deep reinforced learning.**

➢ **Importance**

The DRL method is a powerful algorithm to solve complex control problEMS and handle large state spaces by establishing a deep neural network to relate the value estimation and associated state-action pairs.

➢ **Applications**

robotics
building HVAC control
ramp metering
other fields.

➢ **In automotive:-**

lane keeping assist
autonomous braking system
autonomous vehicles

➢ **Implementation**

However, motion control of autonomous vehicles needs very high precision from our perspective. The mechanism of DRL has not been explained very deeply and may not meet this high requirement. DRL is a powerful technique that can be used in HEV EMS in this research as it concerns the fuel economy compared to the control precision. A DRL-based EMS has been designed for plug-in hybrid electric vehicles (PHEVs) .

Comparison Of Different Energy Management Strategies

1. **Rule-Based Energy Management Strategy**

➢ **Importance**

These methods rely heavily on the results of extensive experimental trials and human expertise without the a priori knowledge of the driving conditions.

➢ **Strategies**

Heuristic control strategy:- A heuristic technique is any approach to problem solving or self-discovery that employs A practical method that is not guaranteed to be optimal, perfect or rational, but instead sufficient for reaching an immediate goals.

Fuzzy rules:- Extra high voltage (EHV) transmission system is the vital links between the generating units and the transmission substations. Transmission of power to the utilities located over long distances through extra high voltage (EHV) transmission is efficient and cost effective.

- **Implementation**
  Rule-based strategies are effective and can be easily implemented, their optimality and flexibility are critically limited by working conditions and, consequently, are not adaptive to different driving cycles.

2. **Optimization Based Energy Management Strategy**

- **Importance**
  some optimization methods employed in control strategy are either based on the known driving cycles or predicted future driving conditions.

- **Strategies**
  Dynamic Programming (Dp):- Dynamic programming (DP) is one of the optimization-based control strategies presenting outstanding fuel economy performance .
  Sequential Quadratic Programming (Sqp):- Sequential quadratic programming (SQP) is an iterative method for constrained nonlinear optimization. SQP methods are used on mathematical problEMS for which the objective function and the constraints are twice continuously differentiable
  Genetic Algorithms (Ga):- A genetic algorithm (GA) is A search algorithm based on the mechanism of natural selection and natural genetics.
  The Pontryagin Minimum Principle (Pmp):-The optimal cost-to-go and the optimal policy for all time and for all possible states.

- **Implementation**
  Unless future driving conditions can be predicted during real-time operation, there is no way to imply these control laws directly. Moreover, these methods suffer from the “curse of dimensionality” problem, which prevents their wide adoption in real-time applications.

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Deep Reinforced Learning Energy Management Strategy

- **Importance**

  The DRL method is a powerful algorithm to solve complex control problEMS and handle large state spaces by establishing a deep neural network to relate the value estimation and associated state-action pairs.

- **Applications**

  Robotics
  Building Hvac Control
  Ramp Metering
  Otherfields.

- **In Automotive**

  Lane Keeping Assist
  Autonomous Braking System
  Autonomous Vehicles

- **Implementation**

  However, motion control of autonomous vehicles needs very high precision from our perspective. The mechanism of DRL has not been explained very deeply and may not meet this high requirement.
  DRL is a powerful technique that can be used in hev EMS in this research as it concerns the fuel economy compared to the control precision.
  A DRL-based EMS has been designed for plug-in hybrid electric vehicles (phevs).

Implementation issues of energy management strategies

Ans. When energy use is deliberately monitored, controlled, and conserved, decreases in utility consumption and overall costs can be realized without sacrificing facilities operations. Such energy management techniques can take on many shapes and sizes. Following are strategies facility management executives can use to IMPLEMENT efficiency while overcoming potential costly challenges.

- **Actively manage real-time energy use.**

Proactive, real-time data management can expose a wide range of unknown challenges associated with occupancy, building use, and peaks in utility usage. For example, my firm, Southland Energy, installed a comprehensive metering system for a data center customer, monitoring everything from air and water flows, to very specific details of the data center.

The real-time data allowed the building operators to identify potential issues instantaneously, implement corrective actions to prevent critical shutdowns, and manage loads before they affected the entire system.

- **Actively manage what is measureable.**

  Use advanced metering and energy management system (EMS) to capture real-time data, ensure its accuracy and, in turn, address specific issues. For example, a K-12 school installed an energy dashboard that managed the overall facility while actively engaging faculty and students.

  The customer could view how the system were operating and how much they were saving based on their actions and system improvements. In instances where building owners have utility monitoring equipment but no collection or processing software, the meters or monitoring equipment become stranded assets.

  This is because millions of data points have to be gathered and processed manually, multiple times during the year. A sophisticated metering system equipped with the proper EMS software will automatically collect, process, and format these data points in real time, if not hourly. The ability to process these useful data points into an easy to use format improves the overall system effectiveness and functionality.

- **Actively manage energy consumption**.

  Use collected data to build a strategy that manages costs and consumption on a daily, weekly, monthly, and annual basis. Southland Energy worked with an industrial customer to evaluate multiple peak demand reduction strategies. Load shifting and demand limiting systems were implemented to limit customer loads during peak hours and reduce costs.

  Limiting peak demand consumption offers additional benefits that are not always easy to identify or claim. For example, during peak hours, utilities run "peaker plants" to meet demands from the grid. However, these plants are often older and less efficient electricity generation plants, with the sole purpose to run periodically to meet demand. Reducing peak demand during summer months saves electricity costs and overall greenhouse gas emissions per kW.

  Managing consumption allows for early detection of improper set points, schedule misalignments, and equipment/system failures. Analyzing trends of metered points over days, weeks, months, and years helps to pinpoint irregularities, leaks, and excessive run times. The proper system can flag leaks, changes in occupancy, occupant set point changes, and energy and water waste.

- **Have a holistic plan.**

  Without clear direction and an action plan, it is difficult to make a meaningful impact beyond the "low hanging fruit." A holistic plan is critical to leverage overall savings and provide a mix of improvements for substantial results.

Facility leaders often benefit from a holistic plan that bundles low hanging fruit such as lighting and building automation measures with longer paybacks such as renewable energy. This evaluates all possible savings including water, waste, energy, and system/facility reliability to package the appropriate measures for the facility's goals and financial requirements.

- **Secure leadership buy-in and support.**
  Real, holistic changes will not be attainable without direct involvement and support from leadership. It is critical to engage leadership and key decision makers that impact the financials of facility operations.

- **Negotiate.**
  Negotiate supply contracts with third-party marketers to reduce energy costs. Southland Energy has worked with several customers on energy specific solutions and identified opportunities to help them negotiate utility rates efficiently. The firm worked with a condominium high-rise customer and was able to negotiate a 5% reduction of utility rates, while also evaluating improvement measures. These results can be achieved when we know historical consumption and have accurate projections for consumption; take advantage of available curtailment, arbitrage, and/or demand response programs; and issue pricing RFPs to multiple suppliers to ensure best market value.

- **Take risks.**
  Major changes that drastically reduce consumption can require difficult steps and decisions, but reward outweighs risk if changes are properly managed. The ability of a trusted advisor to leverage in-house capabilities coupled with a strong commitment to change helps alleviate the burden.

- **Take action but don't "over study."**
  While energy studies and audits are useful and provide direction, in most cases data is already available and can be used to take action sooner rather than delaying it. Develop a plan for action with available information.
  Many facility executives complete several energy audits but do not act on a path forward. Southland Energy has performed such studies and audits, while also leveraging customers' existing studies and audits to implement their suggestions. From simple lighting retrofits to complicated central utility plants and renewable energy systems, customers have turned improvement ideas into a reality.

- **Partner with those who can supplement in-house knowledge.**
  Relationship building and partnering are keys to building an effective energy management strategy. This can involve partnering with other facility management and energy management leaders; energy services companies (ESCOs); industry subject matter experts, such as the U.S. Department of Energy or consultants; utilities; and other knowledge centres, such as the Association of Energy Engineers (AEE).

- **Establish an occupant behavioural awareness program.**
  Technology implementation and building retrofits are only part of the equation. Occupants have a big impact on a building's efficiency and investments made.

Education is key to the behavioural process, and empowering occupants with knowledge and resources will help increase energy savings as they can realize the impact through efficiency or financial gain.

UNIT-4

CASE STUDIES

A CASE STUDY ON DESIGN OF HYBRID ELECTRIC VEHICLE

- **Abstract**

  With the advancement in 21st Century, there has been increase in usage of Oil and Gas leading to problems like Global Warming, climate change, shortage of crude oil, etc. Due to these reasons Automobile Companies have started doing research for making Hybrid Techonolgy usable into the daily life.

  The Paper starts from brief history about Hybrid Technology and also some brief introduction on it. Paper will also discuss the technologies used in the making of Hybrid Cars such as “Hybrid Solar Vehicle”, “Hybrid Electric Vehicle” and “Plug In hybrid electric vehicles”.

  Our Paper is based on the explanation of such technologies, their function, drawback of this technology, efficiency of Hybrid Cars, Case studies on the present commercial hybrid cars such as Toyota Prius series, Astrolab etc and the fuels and raw materials used in the Hybrid Cars. Paper concludes on the advantages and dis-advantages of Hybrid Cars and how this technology will take over the world in future and would become the alternative for Petrol and Diesel Cars.

- **Introduction**

  With the invention of Internal Combustion Engine by Nicolas Otto, there was revolution in Automobile field. Later on, Petrol and Diesel became the main source of fuel for these vehicles. This technology made Human Efforts very easy through commercializing in the market. As, the world went through 20th Century, there happened many advancements for making this technology efficient and cost-effective. Due, to which it became the commercial success and its use in the day to day period increased.

  People could reach thousands of kilometres/miles in hours with the help of this technology. As we know everything has its own positive and negative side. The rate of Carbon Monoxide (CO) and Carbon Dioxide (CO2) suddenly increased at the dangerous level in the beginning of 21st Century which made a negative impact on Ecosystem, reason for Global Warming, Health related issues, etc. This forced Scientist, Researchers and Policymakers to focus or made them start thinking for Green Technology or the technology which can stop the adverse effect happening on Nature.

  Hence, the 21st Century will become the Century for Evolution in various technologies with the main focus in Automobile Sector. The technologies which will change the face of Automobile Sector would be “Hybrid Electric Vehicle”, “Hybrid Solar Vehicle”, “Hydrogen Fuel Cell”, etc. From all this Hybrid Electric Vehicle is considered as the most industrially matured technology and has efficiency more than cars running on Petrol/Diesel/CNG while Hybrid Solar Vehicle has lower efficiency than vehicle running on Petrol/Diesel/CNG.

  So, this technology is for drivers who want to cover less distance. To overcome this constraint, “Plug-In Hybrid Electric Vehicle” came into existence. “Toyota Prius Series” is an example of Hybrid Electric Vehicle technology, “Astrolab” is an example of Hybrid Solar Vehicle and “Chevrolet Volt” is an example of Plug-In Hybrid Electric Vehicle.**Fig.1**

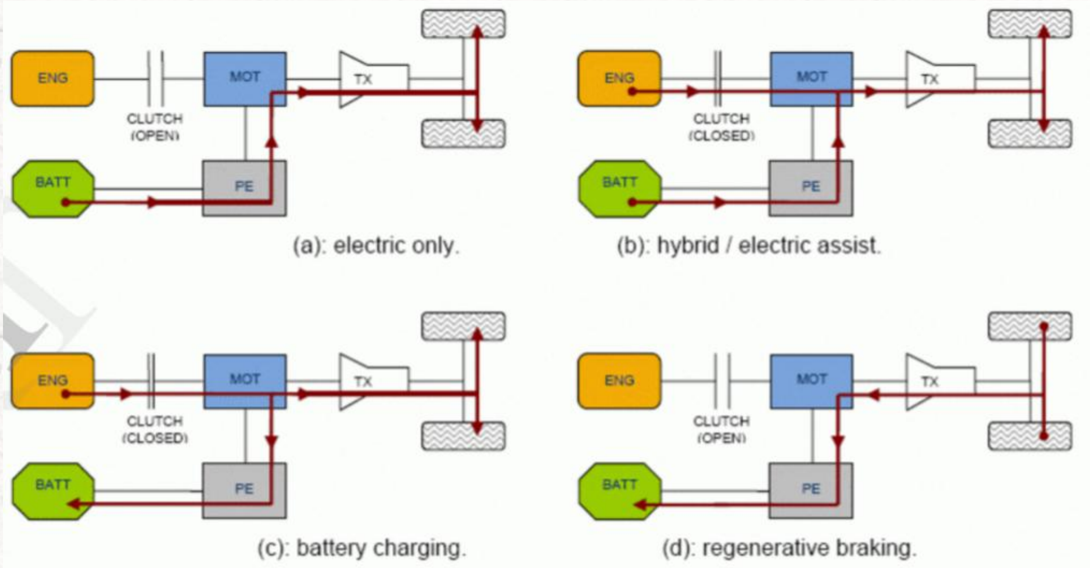


Fig. 1: Working Principle of Hybrid Vehicle

Regenerative braking is an energy recovery mechanism which slows down a vehicle by converting its kinetic energy into another form, normally into electrical energy, which can be used immediately or stored until needed in high voltage batteries.

The electric motor is operated in reverse during braking or coasting, acting as generator. The rotors of electric traction motor are coupled with wheels, they experience opposing torque as current is induced in the motor coils. The wheels transfer kinetic energy via drive train to generator.

At the same time, generator resistance produced from the electricity created, slows the vehicle. When more braking torque is required than the generator alone can provide, additional braking is accomplished by friction brakes.

- **Types Of Hybrid Vehicle**

Hybrid Electric Vehicle (HEV) A hybrid electric vehicle is a type of hybrid vehicle which combines a conventional internal combustion engine propulsion system with an electric propulsion system. Or in a technical way, a Hybrid Electric Vehicle is a type of technology which indulges both mechanical drive train and electric vehicle. International Journal of Engineering Research & Technology (IJERT)drive consists of the Fuel tank (containing conventional fuels like petrol/diesel/CNG), the Combustion Engine, the gear box and transmission to the wheels **in Fig. 2.**

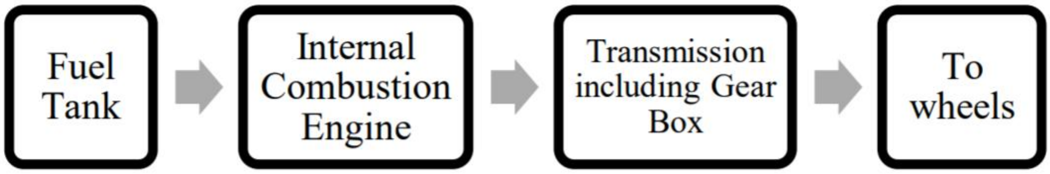


Fig. 2: Flow of energy within a mechanical drive train [10]

An electric drive consists of the Battery, an electric motor and Power Electronics for control as shown**in Fig. 3.**

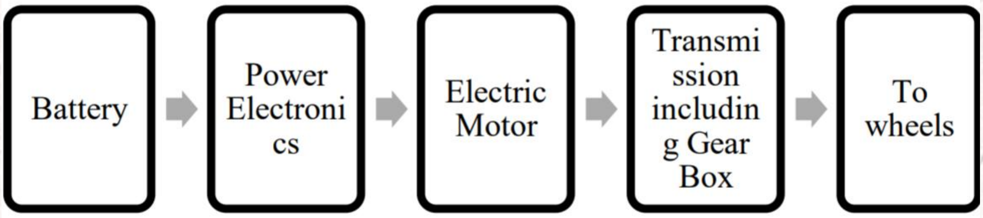


Fig. 3: Flow of energy within a electric drive train [10]

The use of Ultracapacitors has a high potential in the Hybrid Electric Vehicles. They have the advantage of being a more robust power device when compared to batteries (Lithium Ion and Nickel Metal Hydride), as an example during regenerative braking which is considered as a high powered event.

- ➢ **Classification of Hybrid Electric Vehicle: -**
- ➢ **Series Hybrid:**

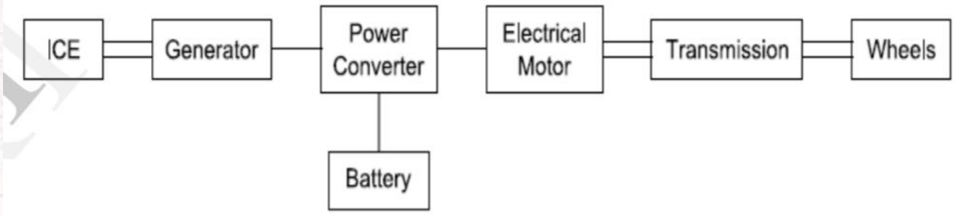


Fig. 4: Series Hybrid Structure

The traction power is delivered by the electric motor, while the internal combustion engine, via a generator, produces electric power to drive the electric motor. The excess power is then stored in the battery pack. The Internal Combustion Engine is decoupled from the driven wheels and can be operated mostly in the maximum efficiency region. The major shortcomings of the series hybrid drive train configurations are the high power installed in each component and the request of a generator. In fact the energy from the Internal Combustion Engine is converted twice before to drive the wheels. Thus the system is more expensive than the parallel one.

➢ **Parallel Hybrid:**

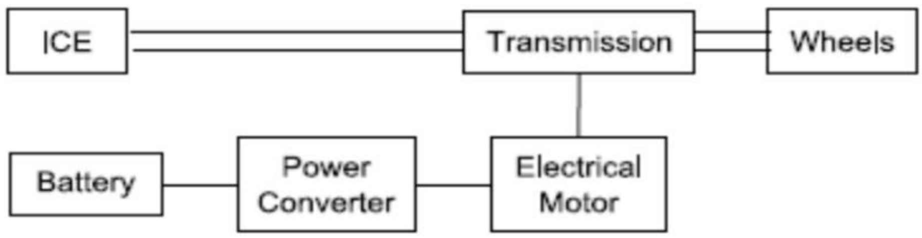


Fig. 5: Parallel Hybrid Structure

There is direct mechanical connection between the hybrid power unit and the wheels. In addition, this layout has an electric traction motor that drives the wheels and can recuperate a share of the braking energy, in order to charge the batteries (regenerative braking) or help Internal Combustion Engine during acceleration conditions.

In fact, Internal Combustion Engine and electric motor are coupled by a mechanical device. Then the electrical machine can be designed with a reduced capability, i.e. cost and volume.

There are several configurations depending on the structure of the mechanical combination between the Internal Combustion Engine and the electrical motor. There can be a torque-coupling with a single shaft or two shaft configuration, a speed-coupling with planetary gear unit, a merge of both previous coupling.

➢ **Series-Parallel Hybrid:**

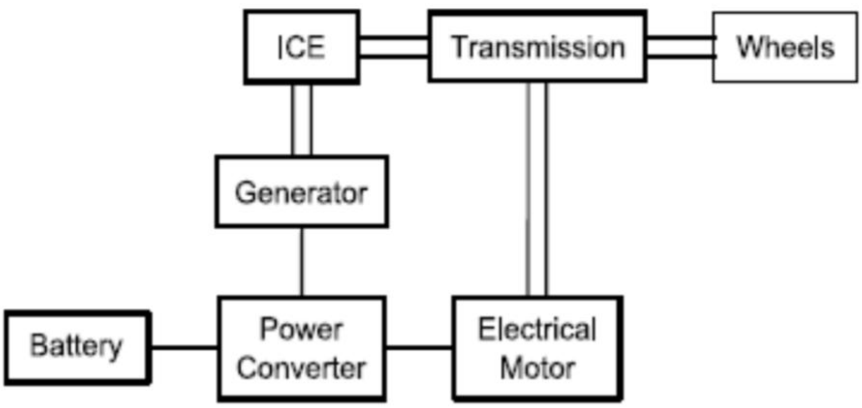


Fig. 6: Series-Parallel Hybrid Structure

The series layout and the parallel layout are merged together in order to have both advantages. In particular the ICE is able to supply the electrical motor or charge the battery thanks to a generator.

➢ **Complex Hybrid**:

There are two separate mechanical links obtaining a light transmission system and a flexible mounting. As an example, the front wheels are powered by hybrid propulsion, while the rear wheels have a pure electric system. There is a wideflexibility on the power flux managing.

➢ **Hybrid Solar Vehicle (HSV)**

This technology is an integration of Vehicle and Photovoltaic Panels. Normally, photovoltaic panels are mounted on the roof-tops of the vehicles. It is also classified into four types: - Series Hybrid, Parallel Hybrid, Series-Parallel Hybrid and Complex Hybrid. Out of which,

Series Hybrid technology is very efficient and more research is going on this type as shown

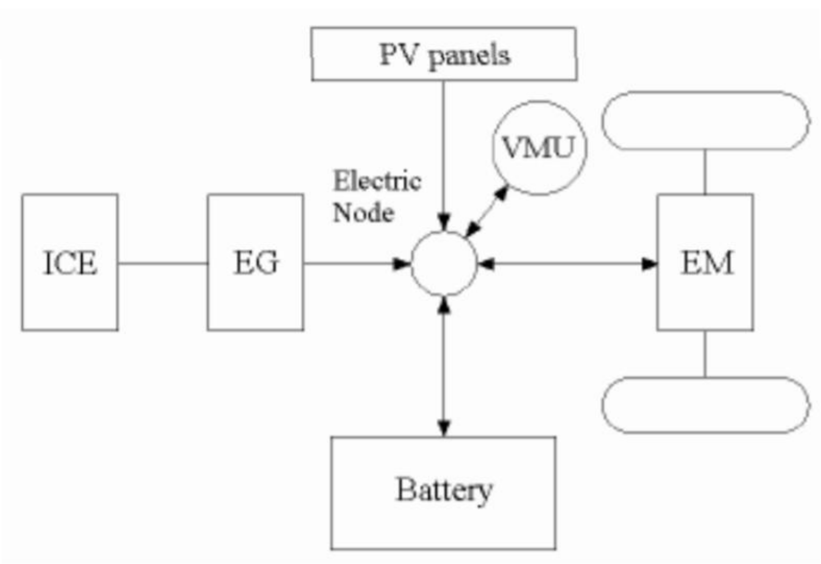


Fig. 7: Basic Diagram of series Hybrid Solar Vehicle [6]

➢ **Plug-In Hybrid Electric Vehicle (PHEV)**

A plug-in hybrid electric vehicle is similar to the hybrid electric vehicles (HEVs) on the market today, but it has a larger battery that is charged both by the vehicle's gasoline engine and from plugging into a standard 110 V/230V electrical outlet for a few hours each day.

➢ **Classifications of Plug-In Hybrid Electric Vehicle**

➢ **Series Plug-In Hybrids:**

Also called as Extended Range Electric Vehicles (EREVs). Only the electric motor turns the wheels; the gasoline engine is only used to generate electricity. Series plug-ins can run solely on electricity until the battery needs to be recharged. The gasoline engine then generates electricity to power the electric motor. For shorter trips, these vehicles might use no gasoline at all.

- **Parallel Or Blended Plug-In Hybrids:**

  Both the engine and electric motor are mechanically connected to the wheels, and both propel the vehicle under most driving conditions. Electric-only operation usually occurs only at low speeds. III.

- **Case Study**

  Toyota Prius Series A.1. First Generation: THS (Toyota Hybrid System) The first generation consisted of two hatchback models the "NHW10" and the "NHW11".

- **Challenges:-**

  Longevity of the battery (7-10 years)
  Need for a hybrid system
  High performance of engine for charging the battery.

- **Solutions:-**

  The battery pack is always charged between 40%-60% for maximum efficiency.
  The introduction to the "Toyota Hybrid System".
  Introduction of the Double Overhead Cam-Shaft (DOHC) engine.

- **Benefits**

  The introduction of the DOHC engine allowed the engine to have four valves per cylinder. By having four valves in the cylinder instead of two, a larger portion of the area could be used to let air in and exhaust out.
  The engine made more power if more air entered the cylinder, and it wasted less power and it was easier to pump the exhaust out of the cylinder. At higher engine speeds, the engine pumped a lot of air though the cylinders.
  Having four valves per cylinder allowed the engine to pump enough air to run and make useful power at these higher speeds. Hence the general problem of low speed was overcome.

- **Working of Toyota Hybrid System**

  The Toyota Hybrid system consists a petrol engine along with two motor generators (MG1 and MG2) a power control unit and a battery. When the car is started it runs solely on the electric motor (MG2) .
  Later when the car achieves a higher speed the petrol engine kicks in and the car runs both on the motor and the petrol engine. Moreover the engine also operates a generator with the help of a power split device which in turn drives the electric motor (MG2 (288 V)). This power splitting is controlled by the power control unit which manages the power for the maximum efficiency.
  During braking the motor acts as a generator and the energy recovered is stored in the battery. The battery doesn‟tneed any external charging. If the battery is drained, the car is run on the petrol engine in "stand mode" which charges the battery.

➢ **Drawbacks**

The backing of the car at steeps was difficult.

The ride was jerky at times Overall, the mileage for the First Generation Prius was 5.6 L/100 km in city driving, 5.7 L/100 km for highway driving and 5.7 L/100 km for combined driving

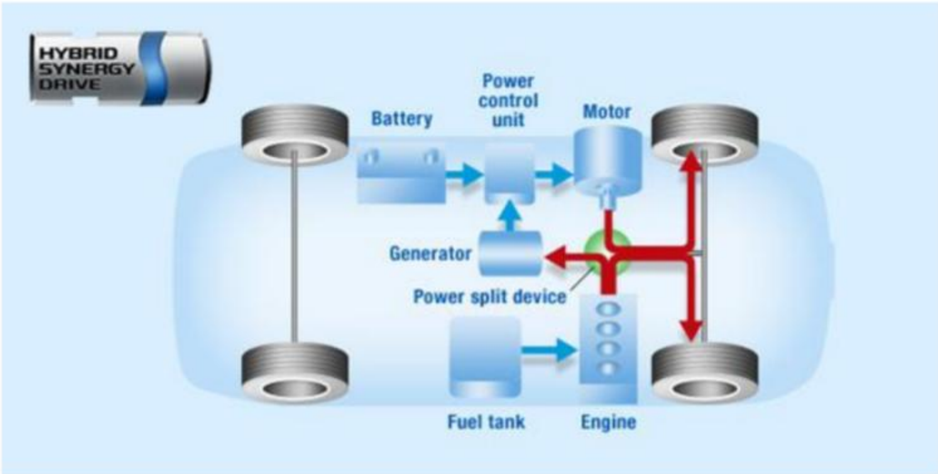


Fig. 8: Diagram of Toyota Hybrid System

The Hybrid Synergy Drive adds a DC to DC converter boosting the potential of the battery to 500 V or more. This allows smaller battery packs to be used, and more powerful motors. This removes the need to continuously run the engine when cabin cooling is required. In addition, the Motor (MG2) is linked to the front wheel transaxle by means of a second planetary gear set, thereby making it possible to increase the power density of the motor. Moreover the power control unit (PCU) uses indirect cooling.

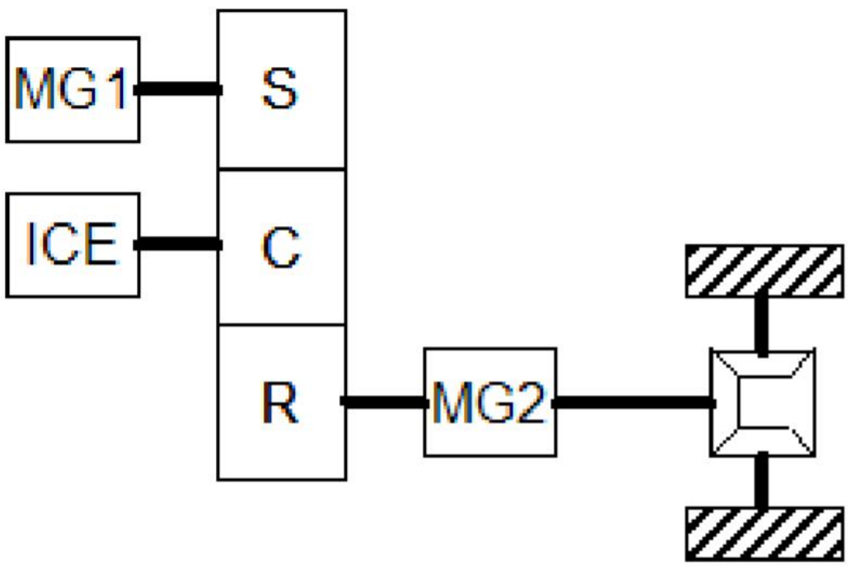


Fig. 9: Hybrid Synergy Drive mechanism

Fig. 9: Hybrid Synergy Drive mechanism The original Prius used shrink-wrapped 1.2 volt D cells. The Toyota Hybrid System relies on the voltage of the battery pack — between 276 and 28 V

- **The Prius II with HSD has the following improvements compared to the Prius I:**

  Superior power: ICE + 8% and electrical MGs +50% (up to 500 V)
  Torque electrical motor + 14 %
  Inferior electrical losses
  Improved charge capacity of the generator
  New HV battery with superior power density and charge/discharge capacity, and 14% weight reduction. However both these generations use the 1.5 litre 14 DOHC engines. Overall, the mileage for the Second Generation Prius was 4.9 L/100 km in city driving, 5.2 L/100 km for highway driving and 5.1 L/100 km for combined driving.
- **Third Generation:**

  Hybrid Synergy Drive The new Prius III (2009) has a re-engineered Hybrid Synergy Drive system. It brings significant reductions in weight and size, contributing to the overall improvements in fuel economy:
  The internal combustion engine is a new 1.8-litre VVT-i Atkinson cycle petrol engine with cooled Exhaust Gas Recirculation. It is more powerful (90 hp vs 70 hp).
  The electric motor MG2 is 20% more powerful (60kW vs 50 kW) and 33% smaller.
  The Ni-MH battery power has been increased to a maximum 27kW (+2kW), and has reduced size.
  The new inverter(PCU) is 36% lighter , faster switching for improved efficiency and now converts the battery"s DC into a higher, 650V (+150V) voltage to drive the electric motor. It also involves direct cooling hence making it 37%compact and much faster
  Fuel economy is improved by 14% (4 litre /100 km); CO_2 emissions are reduced to 89g/km
  The third generation Prius also has a gear set called the „motor speed gear reduction" (which is a planetary gear set) for the MG1.

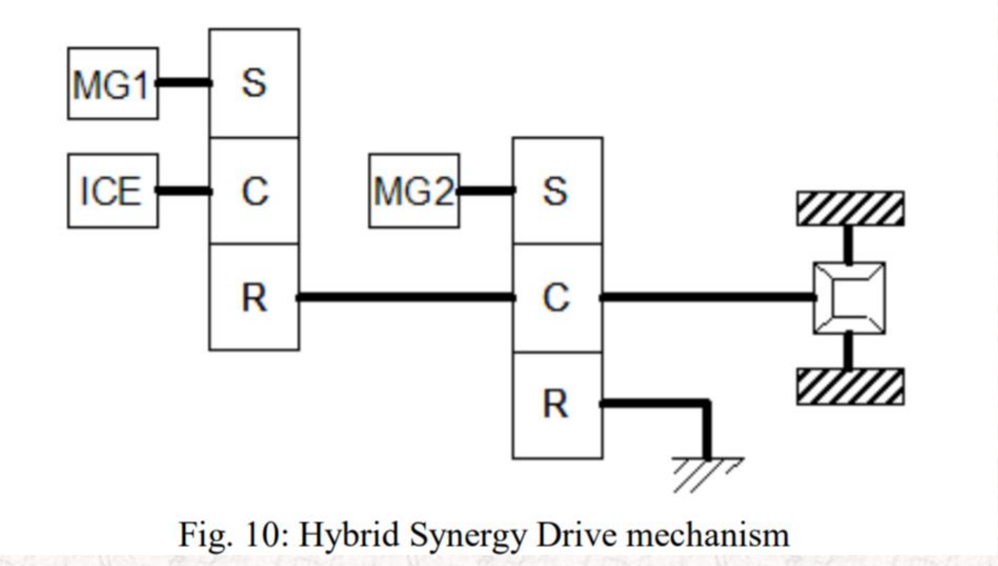


Fig. 10: Hybrid Synergy Drive mechanism

Hybrid Synergy Drive mechanism Overall, the mileage for the Second Generation Prius was 3.70 L/100 km in city driving, 3.90 L/100 km for highway driving and 3.90 L/100 km for combined driving.
Toyota Prius Solar A prototype of Solar Prius has also been recently developed by Solar Electric Vehicles, equipped with a PV panel of 16% nominal efficiency.
It has been estimated that the PV Prius can have a range based on solar power alone between 5 and 8 miles per day, and that it can consume between 17% and 29% less gasoline than the standard Prius. With the Solar Electric Vehicle (SEV) solar system, the Toyota Prius can operate up to 30 miles per day in electric mode thus improving fuel economy by up to 34-60% (depending on driving habits and conditions

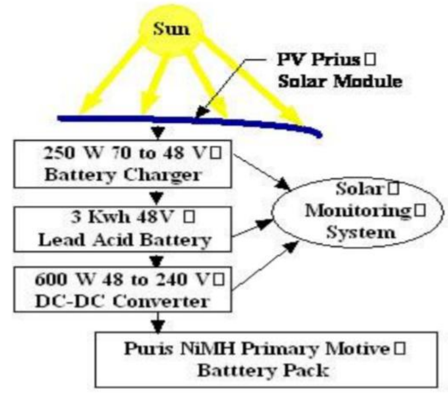


Fig. 11: Connection Diagram for Solar Components of the Photovoltaic (PV) Prius.

Fig. 11:Connection Diagram for Solar Components of the Photovoltaic (PV) Prius.

- **Toyota Prius Plug-In Hybrid**

This version of Prius came out in 2012 which involves a 4.4 kWh Lithium ion battery which allows an all electric range of 23 km. The lithium-ion battery pack can be charged in 180 minutes at 120 volts or in 90 minutes at 240 volts. According to Toyota the Prius plug-in is expected to release only 49g CO2 -emissions. Its mileage is same as the third generation Prius except for the fact that it has an all electric efficiency of 2.5L/100km. The main advantage is that the battery can be charges at any outlet.

- **Astrolab - Ventruri Automobiles**

Capable of running on very little energy (16kW motor) and of recharging with solar energy even when in motion, this vehicle of another era does not, however, need to be permanently exposed to the Sun in order to move. It‟s NiMH Venturi NIV-7 batteries liquid cooled in fact enable it to restitute stored energy, whether solar or from the electricity supply, making it the world‟s first electro-solar hybrid vehicle.
With a top speed of 120 km/hr. and a range of 110 kilometres, allow it for extensive trips on an everyday basis. This is the first vehicle to consume no fossil resources, with CO2 emissions that are necessary to its construction even set off by environmentally friendly actions. The Astrolab has opened up a new era for automobile architecture: light and high profiled, it offers the rays of the Sun for

3.6 m2 of the photovoltaic cells (for an overall vehicle length of fewer than 4 metres
Fig. 12: Picture of Astrolab car- Venturi Automobiles

Fig. 12: Picture of Astrolab car- Venturi Automobiles

- **Advantages And Disadvantages**

The reason for two motors is in the strengths and weaknesses of both types. Specifically, electric motors use no energy during idle - they turn off - and use less than gas motors at low speeds. Gas motors do better at high speeds and can deliver more power for a given motor weight.

That means during rush hour stop and go driving, the electric motor works great and, as an added benefit, does not produce any exhaust thus reducing smog levels. At higher speeds - above 40 km/hr - the gas motor kicks in and gives that peppy feel so many car owners look for when driving on the highway.

Another benefit of having the gas motor is it charges the batteries while it‟s running. Many an electric car owner has been stranded just out extension cord range of an outlet. Hybrid owners can forget about this annoyance; the gas motors starts automatically when the battery gets low and proceeds to charge the battery - a hybrid never needs to be plugged into an outlet.

Of course, if you forget to fill the tank. Still, you can carry a gas can a half mile while a tow truck is necessary in a straight electric car. Honda Insight, All this new technology comes at a price: a hybrid car is complex and expensive. It has two motors and all the ancillary systems to manage them plus a heavy battery and a regeneration system used to produce electricity during breaking.

All of these systems must work together, adding complexity. While cars and, just as importantly, the computers that control them, have become more reliable, they still suffer from failures. So owners of hybrids can expect more time in the shop and larger repairbills.

Hybrids are the most gasoline efficient of all cars - they typically get 20.4 to 25.51 kmpl (claimed). Not bad, but only about 20% to 35% better than a fuel efficient gasoline powered vehicle - like the Honda Civic, for example, that gets 15.3 kmpl. But, when comparing prices - hybrids cost from $19,000 to $25,000 and gas saver cars cost $14,000 to $17,000 - the justification to buy becomes less clear. Indeed, the difference in average annual fuel bills - $405 for a Honda Insight versus $635 for a Honda Civic - means you may never recoup the added initial cost of a hybrid.

Over a ten year period owning a hybrid will save you only $2,300 - less than the cost difference for comparably equipped cars. Much of the fuel efficiency comes from improvements in aero dynamics, weight reduction and, the biggest change: a smaller, less powerful gas engine. In fact, any car will get substantially better mileage just by reducing the engine size. The main reason this is not done has to do customer demand - they want the extra power and zippiness.

Divers find that real mileage from hybrids is actually about 10% less than claimed. When consulting manufactures web pages for mileage tips, they list the same ones that would give better fuel economy from any car: drive slow, no jack rabbit starts, etc. But hybrid cars offer more than just great fuel economy, they offer many green advantages as well.

Even a small increase in fuel economy makes a large difference in emissions over the life of the car. Also, in large cities where pollution is at its worst, they make an even larger difference since they produce very little emissions during low speed city driving and the inevitable traffic jams. While the US has just started producing hybrids, the Japanese are the recognized leaders.

Honda and Toyota are the two largest producers with the Insight and Prius. US car makers are well behind. In fact, during recent introduction of a new hybrid by GM - the Mercury Mariner, they admitted they had to license over 20 separate technologies from the Japanese. US car makers still specialize in SUVs and trucks - Ford has even introduced a hybrid version of its popular Escape SUV.

Industry analysts say US hybrids are just token models - not a serious attempt to get into the market. The reason for hybrid introduction has to do with Corporate Average Fuel Economy (CAFE) regulations. Current standards mandate that average mileage of the fleet of cars sold by an automaker should be 11.69 kmpl. This means that if an automaker sells one hybrid car that gets 25.51 kmpl, it can then sell four less efficient cars - like SUVs and trucks - that only get 8.5 kmpl.

- **Conclusion**

Hybrid Cars use no energy during idling state; they turn off and use less energy than petrol engines at low speeds. At lower speeds, no smog is emitted maintaining its sustainable advantage.

Till lower speed, the car runs on the electric motor and on cruising speed, it runs on IC engine. They offer greater mileage than conventional cars. Noise pollution and emission of CO2 is considerably reduced.

But, they are more expensive than conventional cars, are more complex in construction and working than IC engine cars, offer larger repair bills, capacity of batteries is not much advanced.

A CASE STUDY ON DESIGN OF BATTERY ELECTRIC VEHICLE

- **Abstract**

The growing environmental consciousness and seeing the adverse effects of climate change, the governments in India are supporting initiatives for development of eco-friendly mobility solutions including electric vehicles. To offset the disadvantages of electric vehicles regarding range, weight and charging time, efforts have to be made to orient the use of electric vehicles to niche situations and niche markets where these limitations can be leveraged by design. Confined spaces like airports, industrial campuses, gated communities lend themselves easily to vehicle electrification.

When the technology does not offer major physical constraints as in electric vehicles in comparison to the traditional vehicles, design criteria will have to be predominantly use oriented - psycho-physiological, cultural, contextual and environmental. The physiognomy / aesthetics of electric vehicles can be and should be quite different from what we see today in cars or hybrid vehicles to depict the uniqueness of this breed of products. In this presentation some design case studies based on the above would be discussed.

- **Policy**

With the growing environmental consciousness and seeing the adverse effects of climate change, the Government of India and the governments of various Indian states are supporting many initiatives for the development of ecofriendly technologies, which can reduce the carbon footprint emanating from India. Regulation has become one of the prime factors driving this change. Energy audits have been made mandatory in large consumer units from March 2007.

An energy-labelling programme for appliances was launched in 2006 and comparative star-based labelling has also been introduced. Recent signing of the agreement in Copenhagen on Climate Change, India is committed to pursue this policy aggressively. Programme of 'Urban Renewal' of the Government of India insists on energy efficiency, and incentives in the form of cheaper loans are offered to urban transport authorities.

The National Solar Mission would promote the use of solar energy for power generation and other applications. Even Indian industry has taken up these issues seriously. Energy efficiency has become the top most agenda for Indian companies as well. Big automobile companies are developing electric vehicle technologies and/ or buying smaller electric vehicle companies to prepare for the future. One good example is that Mahindra & Mahindra recently bought Reva Electric car company from Bangalore.

- **The Challenge**

Although first electricity driven car was driven in 1880s, it lost the race to gasoline-powered vehicles due to the deficiencies of range, weight and time of charging. Despite having made great strides in technology in more than hundred years, the electric vehicle suffers from same problems even now. What is however encouraging is that serious thought is being given to add value and make these vehicles viable 'somehow' and 'somewhere'.

The rising cost of crude oil is helping this movement. Advantage of this movement is that it is throwing challenges to various technology disciplines, and the persons working in these areas are doing their best to find solutions and attracting research investment. With these inputs, it is bound to yield positive results in due course.

- **Strategy**

As a strategy to make the electrical vehicles acceptable and usable, efforts can be made to design and orient the use of specialized electric vehicles to niche situations and markets, where these vehicles can have an edge over petrol driven conventional vehicles. This needs to be understood well. If the limitations of the electric driven vehicles is leveraged by design, special vehicles for special applications / special situations can become viable and common-place, thereby relieving the pressure on oil, environment (pollution), health & carbon footprint.

The limitation of range if understood, can let us identify areas where range of a vehicle is not important. One such example is airport. Airports have become an essential infrastructure of a city however small. Airports are highly traffic and surface vehicle intensive and therefore one of the most polluted area of a cityscape. If analysed, the airport can lend itself very easily to vehicle electrification.

It is now easy to think that all busses running in the airport for ferrying passengers to and from aircraft to the terminals could be electric vehicles. One can argue that aero-bridges obviate the need for such traffic. But then aero bridges in the context of developing countries like India are available only in a few large city airports. The rest are still dependent on gas guzzling, Carbon Dioxide fuming buses for ferrying millions of passengers across the airports all over the country. Although it seems so obvious that we should have ‘electric ferry busses’ on the airports, but I have not seen even one electric bus on any Indian airport, despite paying so much lip service to pollution and carbon footprint by government, media and civil society.

Not only busses, but all the vehicle at the airports could be electricity driven, which can include aircraft tow tractor, baggage and food trolley towing tractors, maintenance runabouts, crew vehicles etc. It could be a small but a very important beginning.

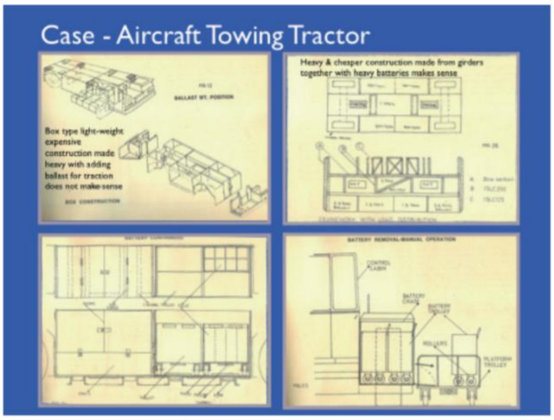
- **Case 1**

One case study was developed through a project for the ‘design of electric aircraft tow tractor’. An aircraft tow tractor tows the aircraft from runways to the tarmac or apron, and back. Presently it is highly fuel guzzling and polluting vehicle, as it has to have weight (added through ballast) for traction to tow the heavy aircraft.

Making it electric, can offer many fold advantages, which will be elucidated in the case study presentation. The disadvantage of an electric vehicle is that it is heavy, which is a positive aspect for an aircraft tow tractor. Cheaper, heavier and dependable lead acid batteries can be used as their high weight can create an advantage.

The airport is a confined space; hence the range of the vehicle need not be large. Intermittent usage (as it is not used all the time) of such vehicle can allow it to move to the charging stations more often to get charged. The structure of this vehicle need not be efficient and expensive (as in monocoque vehicles), but inefficient, heavy, rugged and less expensive.

What we see here is that all the inherent disadvantages of an electric vehicle could be converted into advantage in this situation. Similar advantage can be created in varying degrees in industrial campuses, gated communities, small urban clusters and similarly identified situations, with vehicles for different usage and where short range is good enough.



- **Education & research**

  A new Masters and Doctoral level program was started from last year for education and research into 'mobility and vehicle design' issues at Industrial Design Centre, IIT Bombay, to create a body of specialist vehicle designers, who can address the problems of future mobility in the country, and also to develop the research culture in this discipline.

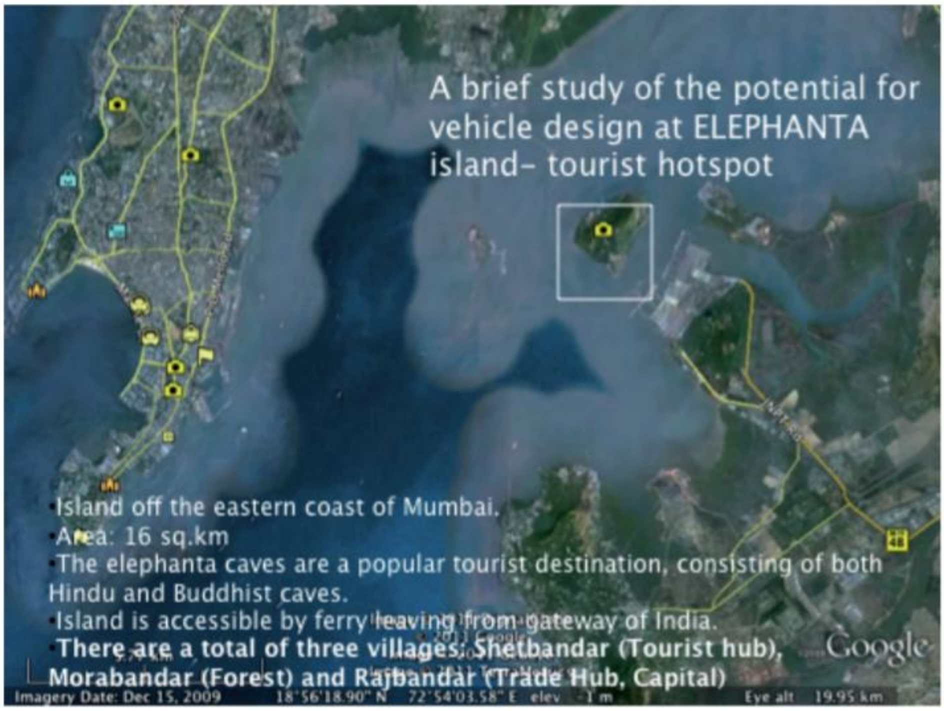
  Special emphasis is given to eco-friendly vehicle development and research. Light weighting is a very important criterion for electric vehicles, to make them run cheaper and longer. Initiatives to develop small electric vehicles are undertaken for situations like campuses, gated communities, industrial estates where heavier vehicle are not necessary for transport and smaller ones are adequate enough.

  Research is being conducted on light weighting of these vehicles to reduce the power consumption further. Integrated single unit reinforced plastic bodies for 2-wheelers and 3-wheelers are built and tested to achieve this objective. By designing 'single-seat mini electric scooter' and similar small vehicles, examples were created, and proto types were developed to prove the concepts. These concepts can be adopted and developed by 'research-shy' companies for manufacture and marketing.

- **Design Integration**

  Integrating computer and communication technologies with electric vehicle can become a big driver for development. One such example can be the development of autonomous road trains for small tourist destinations / archaeological locales, which are sensitive to pollution from high traffic during the season. Pollution free transport seems to be an imperative need.

A project is being undertaken at IIT Bombay to develop a mobility facility at Elephanta Island, a small tourist spot near Mumbai, for tourists who visit the ancient caves there. An autonomous mini road train running on battery bank charged through Solar panels and following a 'tour line' is being contemplated.
Besides being a facility for tourists, it offers an additional means of livelihood to the local community who are dependent on tourism. It is to be showcased as a prototype for mobility solution in small towns particularly the tourist towns.



Elephanta Island

- **Water in Pot Model**

Traditionally the form or physiognomy of a product is dictated by the size of the components, mechanical linkages and their physical interference or fit. The emerging technologies are fluid in character, and therefore physically pliable. There is very little or no physical constraint offered. Like water, usefulness of technology is dependent on the form of the container or 'pot' in which it is placed.
For example, if water is to be drunk, it has to be kept in a glass or tumbler, and if it has to be poured, it is kept in a jug with spout; and if it has to be carried, the pot takes the shape of 'narrow mouthed' vessel, so that it does not spill and so on. Besides the use factor the 'pot' has cultural connotations.
For example, a tea-cup is not suitable for drinking water, though it can be used. Modern technology, which is fluid, placed in suitable "container" performs better, if the shape of the "container" is designed to suit the situations. Human and contextual issues are the determining factors for design. Major design criteria therefore have to be psycho-physiological, cultural and environmental.

- **Unique Formal Language**

Electric vehicles do not need the space for voluminous internal combustion engines or bulky gear trains. The primemovers in electric cars are built into the wheels, the battery pack, particularly the newer polymer batteries are flexible and can be configured according to the availability of spaces and spread, and yet the electric vehicle simply looks like a sedan, or SUVs and even with ‘air vents’ in the front.

The physiognomy of electric vehicles can be and should be quite different from what we see today in cars or hybrid vehicles. Industrial Designers and stylists are struggling hard to invent a new formal language, which depicts the uniqueness of this breed of products. We have had similar difficulties in the past, when cars were made like horse buggies, and first TVs were made to look like radios.

With so much interest and so many people inspired to work in this area, discovery of a new identity / aesthetic breakthroughs for electric vehicles are not far off, as new conceptual breakthroughs are invariably driven by the development of new technologies which I believe have fairly matured and moved to ‘post failure’ stage. The attempts in this direction are worth watching.