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Research

Hybrid Electric Vehicles (HEVs) Technologies and Reinforcement Look ahead Energy Management

Muhammad Yousaf Iqbal [1*], Wang Tie[1], Guoxing Li[1], Dongdong Chen[1], Ji Zhiyong[1]
[1*]College of Mechanical Engineering, Taiyuan University of Science and Technology, China
College of Mechanical Engineering, Taiyuan University of Science and Technology, China

[*]***Corresponding author***
Yousaf@link.tyut.edu.cn
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***Abstract:** This paper presents a predictive energy management strategy for a parallel hybrid electric vehicle (HEV) based on velocity prediction and reinforcement learning (RL). The design procedure starts with modeling the parallel HEV as a systematic control-oriented model and defining a cost function. Fuzzy encoding and nearest neighbor approaches are proposed to achieve velocity prediction, and a finite-state Markov chain is exploited to learn transition probabilities of power demand. The significant motivators for shifting to EVs are reducing polluting engine emissions and reducing dependence on costly oil fuels. By the end of 2019, the global stock of EVs crossed the ten million mark. The growing acceptance of EVs is the outcome of several factors: technological advancements, rising storage capacity of traction batteries coupled with their falling cost, increased public charging facilities and Govt. incentives. The two EV technologies currently remain at the top are the battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEV). This paper gives an overview of various EV technologies, their features, limitations and challenges in their bulk deployment as a replacement to conventional vehicles.*

***Keywords:** Traction Batteries, Hybrid Electric Vehicles, Bulk deployment.*

1.1 Introduction:

The energy management strategy (EMS) is a key to reduce the equivalent hydrogen consumption and slow down fuel cell performance degradation of the plug-in fuel cell hybrid electric vehicles. The development of automobiles powered by internal combustion engines (ICE) was one of the most outstanding engineering achievements towards the end of the nineteenth century. The availability of low-cost fuels, ease of use, increased reliability and extended driving range boosted the acceptance of these vehicles. However, vehicles propelled by heat engines are inferior in fuel efficiency (~ 20-25%), besides the combustion of hydrocarbon fuels in these vehicles releases many toxic gases [1- 3]. Today, the automotive industry and many cars worldwide are causing serious concerns for the public and the environment [4]. HEVs are powered by an internal combustion engine (ICE) and an electric motor that uses energy stored in a battery. The extra power provided by the electric motor allows for a smaller engine without sacrificing performance; the battery also powers auxiliary loads like audio systems and headlights and can reduce engine idling when the vehicle is stopped. Some HEVs can drive short distances at low speeds on electrical power alone [5]. These capabilities typically result in better fuel economy and lower emissions than comparable conventional vehicles [6]. HEVs cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the ICE Regenerative braking allows HEVs to capture energy usually lost during braking using the electric motor as a generator and storing that captured energy in the battery [7]. A common feature of all-electric vehicles is the capability for Regenerative Braking is a process by which kinetic energy (KE) of the moving vehicle is converted into electricity by reversing the operation of the motor into a generator. Conversion of KE into electricity slows the vehicle, which otherwise would have lost as heat by friction in the mechanical brakes. In a report by Xiao et al. [8], a fuel cell–battery hybrid electric vehicle EMS is applied fuzzy logic with four operational modes. The vehicle was modeled and simulated using which the vehicle was modeled based on 25 kW [9-12] fuel cell, 12 V battery and 75 kW motor. With DC voltage 308 V, performed 88.5 km/h acceleration speed. Unfortunately, the EMS was not described thoroughly.

1.2 Hybrid Structure:

You can combine the two power sources found in a hybrid car in different ways. One way, known as a parallel hybrid, has a fuel tank, which supplies gasoline to the engine [13-14]. But it also has a set of batteries that provides power to an electric motor. Both the engine and the electric motor can turn the transmission simultaneously, and the transmission then turns the wheels.

An electric motor is all about magnets and magnetism: A motor uses magnets to create motion. We know the fundamental law of all magnets: Opposites attract and likes repel. So if you have two bar magnets with their ends marked "north" and "south," then the north end of one magnet will attract the south end of the other. On the other hand, the north end of one magnet will repel the north end of the other (and similarly, south will repel south). Inside an electric motor, these attracting and repelling forces create rotational motion.

DC series motor used in a hybrid electric vehicle is a versatile and flexible machine. It can satisfy the demands of load recurring high starting, accelerating and retarding torques [15-20]. A DC machine is also easily adaptable for drives with a wide range of speed control and fast reversals. In the diagram shown below, we can see two magnets in the motor: The armature (or rotor) is an electromagnet, while the field magnet is a permanent magnet. Using the concept of hybridization of cars results in better efficiency and saves a lot of fuel in today's fuel deficit world. Though the idea has been put into maximum utilization by Honda & Toyota, it is a vital research avenue for other car manufacturing units. A hybrid gives a solution to all the problems to some extent. If proper research and development is done in this field, the hybrid vehicle promises a practical, efficient, low pollution vehicle for the coming era. One can indeed conclude that this concept and the similar ones to follow with even better efficiency & conservation rate are very much on the anvil in today's energy deficit world.

1.3 Hybrid Efficiency:

Besides a smaller, more efficient engine, today's hybrids use many other tricks to increase fuel efficiency. Some of those tricks will help any type of the car get better mileage, and some only apply to a hybrid.

1.3.1 Recover energy and store it in the battery:

Whenever you step on the brake pedal in your car, you are removing energy from the vehicle. The faster a vehicle is going, the more kinetic energy it has. The brakes of a vehicle release this energy and dissipate it in the form of heat. A hybrid vehicle can capture some of this energy and store it in the battery to use later. It does this by using "regenerative braking." Instead of just using the brakes to stop the car, the electric motor that drives the hybrid can also slow the vehicle. In this mode, the electric motor acts as a generator and charges the batteries while the car is slowing down.

1.3.2 Sometimes shut off the engine:

A hybrid car does not need to rely on the gasoline engine all of the time because it has an alternate power source -- the electric motor and batteries. So the hybrid car can sometimes turn off the gasoline engine, for example, when the vehicle is stopped at a red light.

1.3.2 Use low-rolling-resistance tires:

The tires on most cars are optimized to give a smooth ride, minimize noise, and provide good traction in various weather conditions. But they are rarely optimized for efficiency. The tires cause a surprising amount of drag while you are driving. Hybrid cars use special tires that are both stiffer and inflated to a higher pressure than conventional tires. The result is that they cause about half the drag of regular tires.

2.1 Electric-Drive Vehicles at a Glance:

HEVs: HEVs are powered by an ICE and an electric motor that uses energy stored in a battery. The battery is charged through regenerative braking and by the ICE. The vehicle cannot be plugged in to charge. PHEVs: PHEVs are powered by an ICE and an electric motor that uses energy stored in a battery. The battery can be charged by plugging into an electric power source, through regenerative braking and I.C.E. EVs: EVs are powered by an electric motor that uses energy stored in a battery. EV batteries are charged by plugging the vehicle into an electric power source and through regenerative braking.

2.2 Vehicle Safety:

HEVs, PHEVs, and EVs undergo the same rigorous safety testing as conventional vehicles sold in the United States and must meet Federal Motor Vehicle Safety Standards. Their battery packs meet testing standards that subject batteries to conditions such as overcharge, vibration, extreme temperatures, short circuit, humidity, fire, collision, and water immersion. When they detect a collision or short circuit, manufacturers design vehicles with insulated high-voltage lines and safety features that deactivate electric systems.

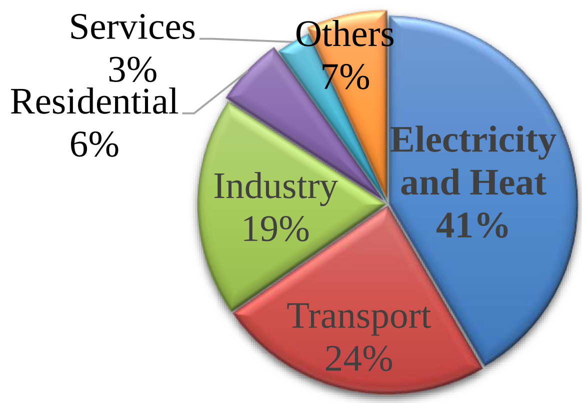


Figure 1 World CO_2 Emissions from Fuel Combustion by sector (IEA report 2018).

2.2 Battery Electric Vehicles (BEVs)

BEVs are fully electric vehicles, meaning they are powered by electricity and do not have a petrol engine, fuel tank or exhaust pipe. BEVs are also known as ‘plug-in’ EVs as they use an external electrical charging outlet to charge the battery. BEVs can also recharge their batteries through regenerative braking. Models available in Australia include the BMW i3 and the Nissan Leaf, producing zero CO_2 exhaust emissions1.

3.1 Materials and methods

3.1.1 Working Principle

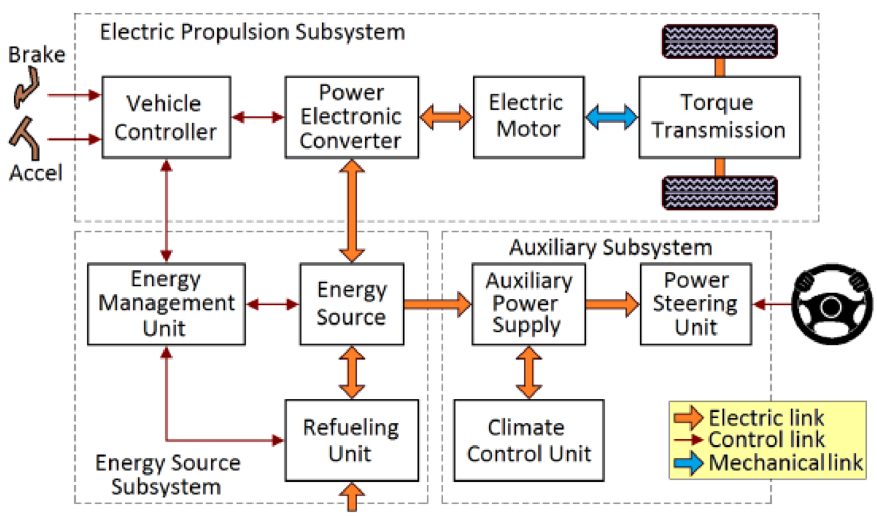


Figure 2 Basic Arrangement of an EV drive

The drive train of an EV (Fig. 2) consists of three major subsystems: motor propulsion, energy source and auxiliary. The propulsion system consists of the controller, power electronic converter, motor, torque transmission and wheels. The energy source section includes the energy source, energy management unit and the energy refilling unit. The auxiliary subsystem consists of power steering unit, climate control unit, and auxiliary supply unit .

3.2 THE DRIVE SYSTEM AND GETTING IT ALL TO FIT IN YOUR CAR

HEV drive systems are very complex and vary significantly from vehicle to vehicle. The batteries are generally balanced - they are either centered or distributed between the front and rear of the vehicle, because they are heavy and take up many volumes. All other components are arranged for maximum efficiency and convenience (in many different configurations). The number of electric motors varies, as does the non- electric torque source. The presence of two power sources makes a switching mechanism necessary. Most HEV systems also allow both the ICE (and other non- electric engines) and the electric motors to work simultaneously.

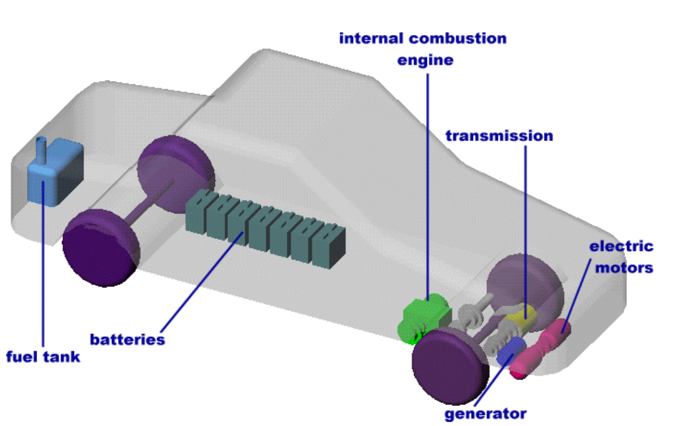


Figure 3 Way Cool Transparent View of

Table 1 COMPARISON OF ENGINE VEHICLES VS. ELECTRIC VEHICLES

IC Engine (ICE) Vehicles	Electric Vehicles (EV)
Powertrain: IC engine	Powertrain: Motor (+ engine)
High specific energy of fuel	Low specific energy of battery
Power density: High	Power density: Low
Emits greenhouse gases	No tailpipe emissions
Travels > 300 miles / fill	Travels < 100 miles / charge
Short refilling time (< 5 min.)	Long charging time (0.5-8 hr.)
Fuel tank takes less space	Battery takes large space

4.1 Key Components of a Hybrid Electric Car

Battery (auxiliary): In an electric drive vehicle, the auxiliary battery provides electricity to start the car before the traction battery is engaged and powers vehicle accessories. DC/DC converter: This device converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed to run vehicle accessories and recharge the auxiliary battery. Electric generator: Generates electricity from the rotating wheels while braking, transferring that energy back to the traction battery pack. Some vehicles use motor generators that perform both the drive and regeneration functions. Electric traction motor: Using power from the traction battery pack, this motor drives the vehicle's wheels. Some vehicles use motor generators that perform both the drive and regeneration functions. Exhaust system: The exhaust system channels the exhaust gases from the engine out through the tailpipe. Fuel filler: This is a filler or "nozzle" used to add fuel to the tank. Fuel tank (gasoline): This tank stores gasoline on board the vehicle until it needs it. Internal combustion engine (spark-ignited): In this configuration, fuel is injected into either the intake manifold or the combustion chamber. It is combined with air, and the spark from a spark plug ignites the air/fuel mix. Power electronics controller: This unit manages the flow of electrical energy delivered by the traction battery, controlling the speed of the electric traction motor and the torque it produces. The thermal system (cooling) maintains an acceptable operating temperature range of the engine, electric motor, power electronics, and other components. The concept of a hybrid vehicle drive train and the possible power flow routes are shown in Fig. 4. There are five unique features standard in hybrid EVs: idle-off, regenerative breaking, power assist, electric-only drive, and extended battery-electric range.

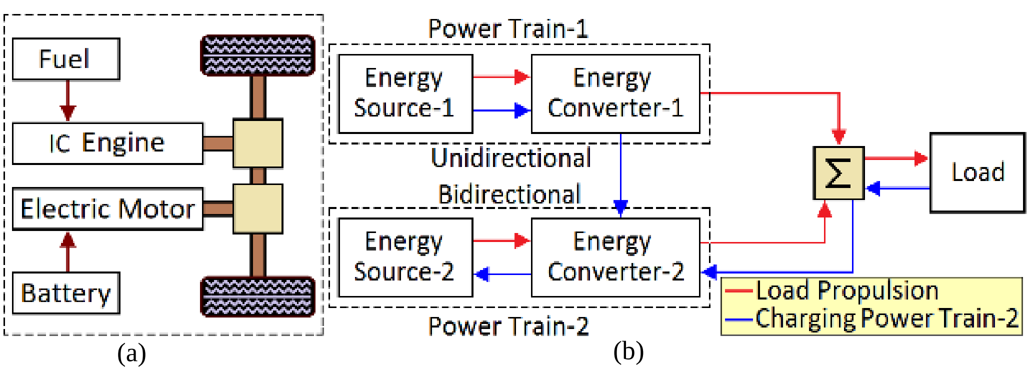


Figure 4 (a) and (b) Arrangement of an HEV with power flow paths

To represent how much is the share of electric power in an HEV in comparison with the overall power, a hybridization factor (HF) is defined as

$$\textbf{\textit{HF}} = \frac{\text{Sum of Power of Electric Motors}}{Sum\ of\ Motor\ Power\ +Engine\ Power} \tag{1}$$

The friction factor is calculated by Equation depending on the ranges of Reynolds number

$$f = \frac{64}{Re} \qquad Re < 2000 \tag{2}$$

$$f = f_{La} + \frac{f_{Tu} - f_{La}}{Re_{Tu} - Re_{La}} (Re - Re_L) \qquad 2000 < Re < 400 \tag{3}$$

$$\frac{1}{\sqrt{f}} \cong -1.8log\left[\frac{6.9}{Re} + \left(\frac{\frac{\tau}{d}}{3.7}\right)^{1.11}\right] \qquad Re > 2000 \tag{4}$$

The flow rates in each pipe are determined where the head losses in each pipe are balanced as

$$f_1 \frac{L_1}{d_1} \frac{Q_1^2}{2gA_1^2} = f_2 \frac{L_2}{d_2} \frac{Q_2^2}{2gA_2^2} \tag{5}$$

The effectiveness of the cross flow type heat exchanger with louvered-fin is calculated as

$$\varepsilon = 1 - exp\left\{\frac{NTU^{0.22}}{c}[\exp(-cNTU^{0.78}) - 1]\right\} \tag{6}$$

The temperature of a component is calculated from the balance of the heat generation, heat transfer to coolant, and heat transfer to the environment.

$$M.Cp_{comp}.\frac{d}{dt}T_{comp}\ \dot{Q}_{comp} \tag{7}$$

$$-h.A.(T_{comp} - T_{cool}) - h_{nat}\ .A.(T_{comp} - T_{cool}) \tag{8}$$

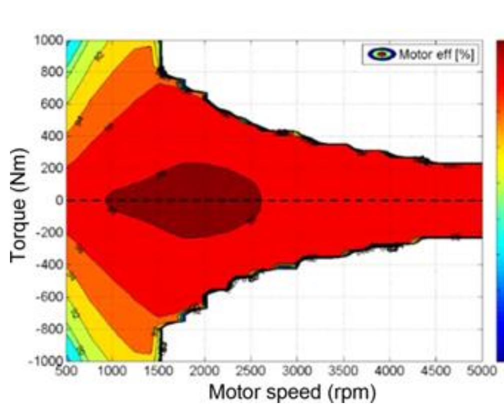
Coolent temperature is calculated

$$T_{cool,o} = T_{cool,i} + \frac{h.A.(T_{comp} - T_{cool})}{\dot{m}\ Cp_{cool}} \tag{9}$$

Based on the degree of hybridization, hybrid electric vehicles can be classified as (i) Micro Hybrid, (ii) Mild Hybrid and (iii) Full Hybrid Micro Hybrid (μHV): Micro hybrid is the least electrified type of HEV. It is a conventional ICE vehicle with an oversized starter motor of about 3 to 5 kW at 12 V to assist the starting of IC engine. The motor cannot propel the vehicle, but can help accessories such as power steering and air conditioning. This type EV is generally used for frequent idle stop or stop-start mode operations. During idling of a μHV, the engine is shut down and during regenerative braking, the motor works as a generator to charge the battery. Regenerative braking, however, may not be a standard feature in all μHVs. Micro hybrids usually have a hybridization factor of 5%-10% with an energy savings of about 3%-10% in city driving. μHV design is traditionally found in light vehicles and is most suited for urban applications. Example: Mercedes Smart. Mild Hybrid (MHV): This hybrid uses a motor of 7-15 kW at 60-200 V. Motor does not alone propel the vehicle but only supports the starting of the engine, regen-braking, and also provides extra torque when peak power is needed during acceleration. In MHV, the IC engine will always be running, unless the vehicle has stopped or the speed is deficient as it is coming to a complete stop. The hybridization factor of mild hybrids is about 10%-30%. The battery size is larger than the micro-hybrid. Energy savings in city driving is about 20%-30%. Example: Honda Civic and Honda Insight. Full Hybrid (FHV): A hybrid EV that can move by electricity alone is a full hybrid. Since a FHV can run in only electric mode, it needs a large capacity motor, about 30-50 kW at 200-600 V. Energy saving is of the order of 30%-50%.

The PEM fuel cell system operated in a relatively steady state. The output current and voltage varied in the ranges of [98 A, 117 A] and [347 V, 370 V], respectively [8]. The output power of the PEM fuel cell stack and DC converter fluctuated slightly between 36 kW and 40 kW, and 32 kW and 36 kW, respectively.

The motor model is developed based on a performance map data. The unmanned military SHEV in this study is driven by six in-wheel motors. Figure 5 shows the efficiency map of a motor.



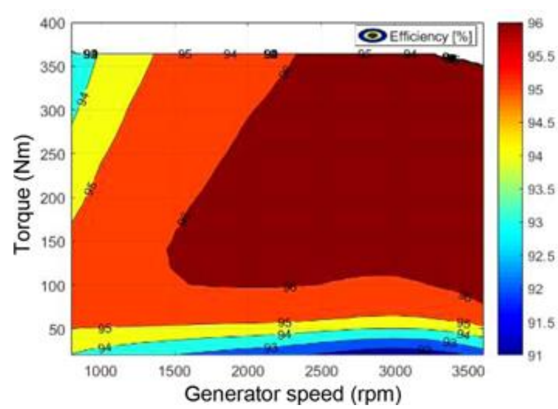


Figure 5 Efficiency map of motor (157 kW) **Figure 6 Efficiency map of the generator**

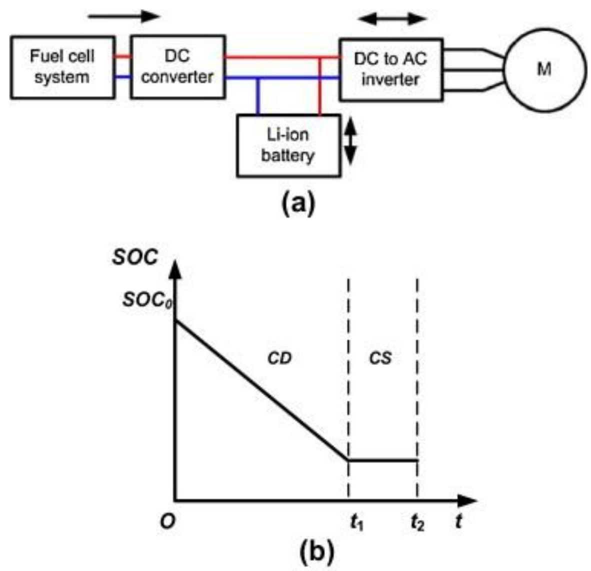


Figure 7 (a) Structure of the PEM fuel cell/Li-ion battery power-train. Lines with arrow(s) show the direction of energy flow (b) scheme of the CDCS strategy.

4.2 Charging Forward

One major problem with the electric car at its present stage of development is that the vehicle's batteries can hold only so much charge before needing to be plugged back in. The car can charge the batteries only so much on the gas motor itself while in use. Volvo hopes to overcome that limitation by developing and embedding an inductive charging system in the road surface itself. The concept works in much the same way that the inductive chargers from Energizer and others do, with electrical power being transferred from an inductive plate on the bottom of the car. Volvo warns motorists not to expect this breakthrough anytime soon though: As yet there is no standard for the technology. the heat generation at higher temperature is smaller than those at lower temperature condition due to lower internal resistance of the battery at higher temperature. Figure 7 shows the temperature history of powertrain components during driving cycle.

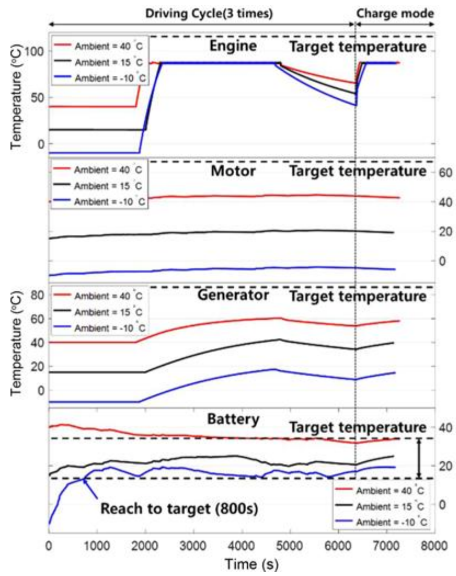


Figure 8 Results of components temperature at different ambient temperatures.

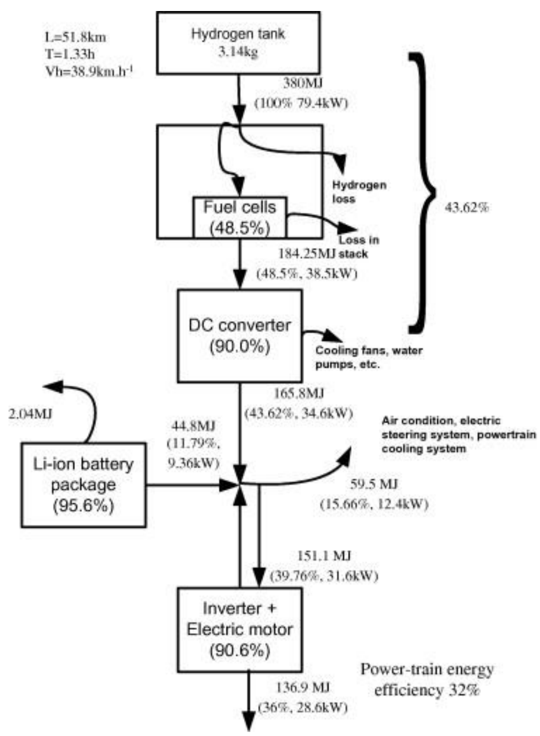


Figure 9 Energy flow diagram of the PEM fuel cell city bus in an on-road testing

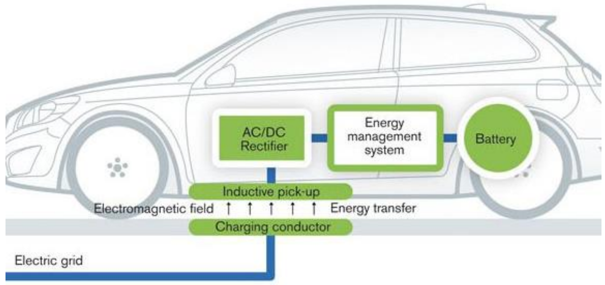


Figure 10 Charging Forward

4.3 Driver-Side Doctor Diagnostics

Asthmatic or allergy-prone, Diabetic, Have heart issues? Ford is working on technologies that will build health monitoring capabilities into its cars. The vehicle would display pollen counts through its Sync system when tethering to a smartphone, or to display glucose levels from a Bluetooth-enabled monitoring device. The carmaker is also working on technologies that build heart sensors into the driver's seat, giving the driver early warning of heart problems.

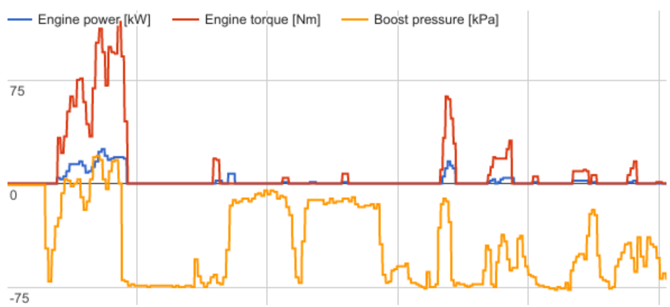


Figure 11 Doctor Diagnostic Figure 12 Engine Performance with Sensors Displaying results

5.1 Conclusion

In this paper, an integrated model of an SHEV powertrain system and VTMS for an unmanned military ground vehicle is developed and the integrated model is used for the validation of new VTMS architecture for an SHEV powertrain based on a military driving cycle. Using the hybridization of cars results in better efficiency and saves a lot of fuel in today's fuel deficit world. Though the idea has been put into maximum utilization by Honda & Toyota, it is a vital research avenue for other car manufacturing units. A hybrid gives a solution to all the problems to some extent. If proper research and development is done in this field, the hybrid vehicle promises a practical, efficient, low pollution vehicle for the coming era. One can indeed conclude that this concept and the similar ones to follow with even better efficiency & conservation rate are very much on the anvil in today's energy deficit world. This study aimed to comparatively analyze the fuel efficiency improvement between a powersplit HEV and an ICEV, according to each influencing factor.

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Muhammad Yousaf Iqbal , Pakistan, yousaf@link.tyut.edu.cn, +8615535174094

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Conflicts of Interest

There are no conflicts to declare.