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DEVELOPMENT AND ANALYSIS OF PEM FUEL CELL FOR HYBRID ELECTRIC FUEL CELL VEHICLE

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Abstract - *In This paper we are Investigating a Hybridizing a fuel cell system with an energy storage system offers an opportunity to improve the fuel economy of a vehicle through regenerative braking and possibly to increase the specific power and decrease the cost of combined energy conversion and storage system ,we use Proton Exchange Membrane fuel cell (PEMFC) as the source of power ,for the system Hydrogen is an alternative attractive transportation fuel. It is least polluting fuel that can be used in internal combustion engine (ICE) and it is widely available. Hydrogen used in a fuel cell which convert chemical energy of hydrogen into electricity, (NOx) emission are eliminated. The investigation was carried out on a fuel cell car model by implementing polymer electrolyte membrane (PEM) types of fuel cell as the source of power to propel the prototype car. This PEMFC has capability to propel the electric motor by converting chemical energy stored in hydrogen gas into useful electrical energy. PEM fuel cell is used as the power source for the electric motor with the aid of other power source such as battery associated with it. Experimental investigations were carried out to investigate the characteristics of fuel cell used and the performance of the fuel cell car and Investigated parameters such as power it develops, voltage, current and speed it produces under different load conditions.*

1. INTRODUCTION

The increase in energy use and related emission was generated by a higher demand for heat from the residential and commercial sector and road transport demand; consequently, road transport greenhouse gas emissions increased for the second subsequent year, continuing the upward trend in emission that started in 2014. The electrification of mobility is an essential element in a wider strategy for achieving reduced greenhouse gas emission. During the previous century, the automotive industry transformed society, bringing new technologies to the market that enhanced their internal combustion engine vehicles, such as global electric vehicles, which are known as one of the most powerful alternative for lowering transport sector carbon dioxide emission. An electric vehicle is a road vehicle that includes electric propulsion. With this definition in mind EVs may include battery electric vehicle (BEV), hybrid electric vehicle (HEV), and fuel cell electric vehicles. As sustainable products, FCEVs bring hope for solving several mobility related problems, as they have no local emission. One of the most promising way to achieve an ideal zero emission replacement is to use clearly produced electricity from non Fossil fuels, such as hydrogen, using fuel- cell technology. Although FCEVs are promising ways to avoid emission , both technologies are far from being profitable for car manufacturers. Here electric vehicle policy focused mainly on technology optimization and market development, setting future challenges concerning battery and super capacitor durability, and charging infrastructure, among other. Direct combustion fuel for transportation account for over half of greenhouse gas emissions and a significant fraction of air pollutant emissions Because of growing demand, especially in developing countries, emission of greenhouse and air pollutants from fuels will grow over the next century even with improving of technology efficiency. Most issues are associated with the conventional engines, Internal combustion engine which primarily depend on hydrocarbon fuels. In this contest, different low-polluting vehicles and fuel have been proposed to improve environmental situation. Some vehicle technologies include advanced internal combustion engine, spark ignition or compression ignition engine, hybrid electric vehicle, battery powered electric vehicle and fuel cell vehicle. Fuel cell vehicles, using hydrogen, can potentially offer lower emission than other alternative and possibility to use different primary fuel option. A fuel cell vehicle fed by pure hydrogen are a ‘zero emission vehicle' in fact the only local emission are water vapour. But in this case it is important to consider the fuel cell cycle or ‘well to wheels' emission, (fuel production, transport and delivery emission). Primary source for hydrogen production is crucial for the environmental performance of vehicle hydrogen produce from renewable energy i.e. wind or solar power connected with electrolysis process and used in fuel cells can reduce significantly emission recent studies. Fuel cells have been used in various kind of vehicle including forklift, especially in indoor applications where their clean emission are important to air quality, and in space application. The first commercially produced hydrogen fuel cell automobile, the Hyundai Tucson FCEV, was introduced in 2013, Toyota Maria, followed in 2015 and the Honda entered the market in 2013. Fuel cell are being developed and tested in truck, buses, boats, motorcycle and bicycles, among other kinds of vehicles. This paper presents the technological trend of industrial development, mainly led in this case by the automobile industry, in order to establish, among others, who led the research and development. All this is done in order to draw the FCEV technology knowledge map, to discuss it with the result of other scientific- technical research studies, and therefore, to be able to predict the future paths of research trends and foreseeable scenario.

FUEL CELL, ITS COMPONENTS AND TYPES OF FUEL CELL

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel and an oxidizing agent into electricity through a pair of redox reactions. Fuel cell works like batteries but they do not need recharging. They produced heat and electricity as long as there is fuel. It is a proposed alternative of producing energy in a safer and ecological way. Fuel cell is having a variety of usage in the field of industrial, transport and residential sector.

Components of fuel cell:

Fuel cell stack: It is the combination of hundreds of fuel cell. It generates power in the form of dc current from chemical reactions inside the fuel cell.

Fuel processor: The fuel processor converts fuel into a form that can be used by the fuel cell. If hydrogen is fed to system, processor may not be required or it may be required to filter impurities out of hydrogen gas.

Current inverters and conditioner: It adapt the electrical current from fuel cell to suit the electrical needs according to the application.

Heat recovery system: Fuel cell operating at high temperature generate large amount of heat, this excess energy can be converted to electricity by gas turbine or other technology.

TYPES OF FUEL CELL

Proton Exchange Membrane Fuel Cell (PEMFC) are most widely used in the field of FCVs (Fuel Cell Vehicles).PEMFC is an open system i.e., it continues taking fuel from external source. Other types of fuel cells include: SOFC (SOLID OXIDE FUEL CELL), AFC (ALKALINE FUEL CELL), DMFC(DIRECT METHANOL FUEL CELL),PAFC(PHOSPHORIC ACID FUEL CELL),MCFC(MOLTEN CARBONATE FUEL CELL).PEMFC is widely used as it has higher power density ,occupies less space and has a working temperature of 70degrees thus allowing a rapid startup. The efficiency is about 40-60% and the output power can be changed as per demand.

A PEMFC transforms the chemical energy liberated during electrochemical reaction between hydrogen and oxygen to electrical energy. In PEMFC, At the anode a platinum catalyst causes the H2 fuel to split into positive charged hydrogen ions and negatively charged electrons. PEM allows the entry of only the positively charged hydrogen ions to pass through it to the cathode. The negatively charged electrons thus must travel along an external circuit to the cathode, creating an electrical current, and water is thrown out as an end product. Reactions for the process is as follows:

H_2 (gas) → $2H^+ + 2e^-$

½O_2 (gas) + $2H^+$ + $2e^-$ → H_2O

H_2 (gas) + ½O_2 (gas) → H_2O

The other fuel cell is SOFC (solid oxide fuel cell), the operating temperature for this fuel cell is 800-1000 °C and efficiency of this fuel is 40%.SOFC are particularly used for Auxilary Power Unit(APU) such as heating ,air conditioning etc.,

Another fuel cell is the AFC (Alkaline Fuel Cell), it has an operating temperature of 90-100 °C, and its efficiency is 50-60%. The advantage of using this fuel cell is that it has low cost components.

DMFC (Direct Methanol Fuel Cell) is used for portable applications and in niche transport sectors such as marine, motorbikes and APU. The operating temperature of this fuel cell is 60-130°C, and its efficiency is 40%.

In coming few years there is vast applicability of the PEM fuel cells that hold much promise in Automobile sector and is important in reducing the air pollution.

INTRODUCTION TO BRAKING

A brake is a device by means of which artificial frictional resistance is applied to a moving machine member, in order to retard or stop the motion of machine. Brakes are generally applied to rotating axles or wheels but may also take other forms such as surface of a moving fluid (flaps developed into water or air).Some vehicles used combination of braking mechanism, such as drag racing car's with both wheel brakes and a parachute, or airplanes with both wheel brakes and drag flaps rise into the air during landing. Most brakes commonly use friction between two surfaces press together to convert the kinetic energy of the moving object into heat, through other methods of energy conversion may be employed.

Goals:-

To design a braking system that is simple and ensures safety of the driver. To design a braking system which takes least time to bring the vehicle to stop.

Selection of brakes:-

We are using disc brake tata tigor (electric) for both front wheels and rear wheel considering the respective advantages, availability, and their limitations. The following reasons support the selection of disc brakes for the front and rear wheels. Disk brake contributes for reduction in overall weight of the vehicle. More braking torque needs to be generated by the rear brake even after weight transfer, because the single brake has to manage the braking torque requirement of the entire rear driveshaft. Brake Caliper: achieving a better braking efficiency and to improve the for vehicle braking effect we have opted to use double calipers for rear wheel.

A. Required Calculations:-

Where height of centre of gravity=1.01746m
h=0.08824m
Let us assume the static weight distribution ratio be 40:60
Static weight on front axle = (0.4xvehicle weight) =0.4x1516
=606.4N
Static weight on rear axle = (0.6x vehicle weight) = (0.6x1516)
=909.6N
Let us take stopping distance as 2m.
From Newton's laws of motion $V^2 - u^2 = 2as$
Where v is velocity after braking = 0m/s2 u is velocity before braking = 21.11m/s2
(i.e., the maximum velocity of the vehicle)
Deceleration = $((v^2 - u^2)/2s) = ((0)^2 - (21.11)^2)/(2x2)$ = -111.408m/s2
As we know = u + at
Where t is the stopping time t = ((v-u)/a) = (0-21.11) / (-111.408) = 0.1893s
Stopping time is 0.1893 seconds.
Dynamic weight transfer =(h x wt x Deceleration)/ (l.01746x9.81)
= (0.0884x1516x111.408)/(1.0174x9.81)
=1495.916N-m
Dynamic weight on front axle = (static front weight + dynamic weight transfer)
=606.4+1495.916
=2102.316N-m
Dynamic weight on one front wheel = (Dynamic weight on front axle /2)
= 2102.316/2=1051.158N-m
Dynamic weight on rear axle = static rear weight + dynamic weight transfer
=909.6+1495.916
=2405.516N-m
Frictional force at each front wheel: = (0.4xDynamic weight on one front wheel)
=0.4x1051.158
=420.4632N
Frictional force at each rear wheel = (0.6xDynamic weight on rear axle)
=0.6x2405.516
= 1443.3096N
Required braking torque at front wheel = (Frictional force at wheel x Front wheel rolling radius) = $420.4632x355.6x10^{-3}$
= 149.516N-m.
REQUIRED VALUES:-
Maximum Velocity:-76kmph
Pedal Effort:-178N
Adhesion Factor of Road:-0.4
Coefficient of friction between brake pads and rotor:-0.4
Stopping Distance:-2m
Stopping Time:-0.1893sec
Required braking torque at rear wheel = (Frictional force at wheel x Rear wheel rolling radius)
= $(1443.3096x355.6x10^{-3})$
=513.241N-m
Effective rolling radius of front wheel =355.6mm
Braking force acting on single front tire = (Torque/ effective rolling radius)
=123.34N
Area of piston in the calipers=$24600mm^2$
Pressure acting in the master cylinder = Pressure in the calipers.
Force acting on calipers =Pressure x area =8994.44x24600 =$221.2N/m^2$
Clamping force generated on disc=$221.2N/m^2$
Coefficient of friction between pad and rotor=0.4
Friction force between disc and pad =clamping force x coefficient of friction
=221.2x0.4
=$88.48N/m^2$

The idea behind this braking system is that to get minimum stopping distance .As the design component of the paper, various, mathematical formula was derived from the fundamental to calculate the various parameters needed under assumption of some basic values of the vehicle.

WORKING

A hybrid electric vehicle (HEV) augments an electric vehicle (EV) with a second source of power referred to as the alternative power unit (APU).

Pure electric vehicles currently do not have adequate range when powered by batteries alone, and since recharging requires several hours, the vehicles are viewed as impractical for driving extended distances. If air conditioning or heating is used, the vehicle's range is further reduced. Accordingly, the hybrid concept, where the alternative power unit is used as a second source of energy, is gaining acceptance and is overcoming some of the problems of pure electric vehicles.

Series Hybrid:-
A series hybrid is similar to an electric vehicle with an on-board generator. The vehicle runs on battery power like a pure electric vehicles until the batteries reach predetermined discharged levels. At that point APU turns on and begins recharging the battery. The APU operates until the batteries are charged to a predetermined levels.

Parallel Hybrids:-
In the parallel hybrid configuration, an APU capable of producing motive force is mechanically linked to the drive train. This approach eliminates the generator of the series approach. When the APU is on, the controller divides energy between the drive train (propulsion) and the batteries (energy storage). The amount of energy divided between the two is determined by the speed and driving pattern.

When the APU is off, the parallel hybrid runs like an electric vehicle. The batteries provide electricity to the electric motor where it is converted to mechanical energy to power the vehicle. The batteries also provide additional power to the drive train when the APU is not producing enough and to power auxiliary systems such as the air conditioner and heater.

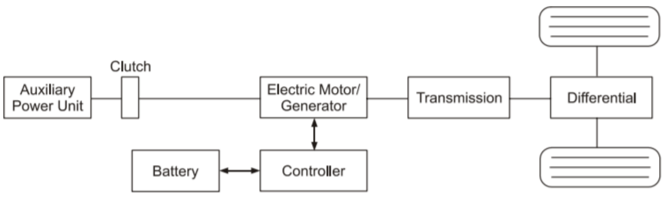

Fig.1:BLOCK DIAGRAM OF ELECTRIC VEHICLE

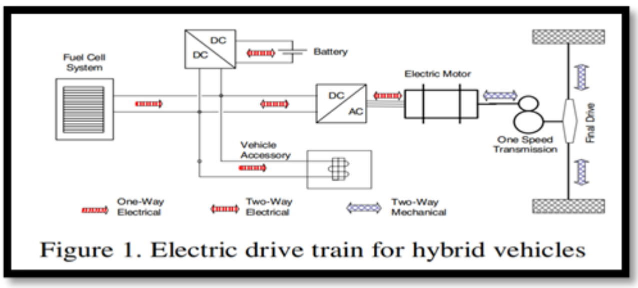

Figure 1. Electric drive train for hybrid vehicles

FIG.2: BLOCK DIAGRAM OF HYBRID ELECTRIC FUEL CELL VEHICLE

Economy of Fuel Cell

Using the highest projected value for the specific energy of advanced lithium ion battery systems

the battery-system weights for BEV ranges of 100 and 300 miles amount to 110 and 330 kg, respectively. Here it should be noted that the gain in vehicle weight would be larger than the estimated battery weight increase due to the need for additional structural reinforcements and the effect of larger weight on energy consumption per mile.

BEVs targeting the mid-size car market/pricing are limited in range to 100 miles. Therefore, without radical changes in battery and/or vehicle technology, the production of BEVs with driving ranges of 200 miles might be challenging and for anywhere near 300 miles is likely not feasible for the mid-size car market due to battery weight and cost constraints.

Contrary to BEVs, driving ranges of 300 miles under real-road conditions have already been demonstrated for hydrogen-powered FCEVs using ≈5kg Hydrogen stored in high-pressure tanks (1 kg Hydrogen providing a range of ≈63 miles). Cost estimates, however, are probably even more uncertain for FCEVs than for BEVs, due to the very low production volumes. For a ≈100 mile range, BEVs most likely will have a cost advantage. Analogously, a BEV battery-system is predicted to have a lower weight compared to a fuel cell plus Hydrogen tank system at ≈100 mile range, but will have a weight disadvantage for a ≈300 mile range.

FUTURE OF FUEL CELLS

Platinum is used in Proton Exchange Membrane (PEM) of Fuel cell which is very expensive and it may get contaminated also.

The most widely employed strategy to increase mass activity is the dispersion of Pt nanoparticles on high-surface area carbon black. Platinum has long been known to be the most active metal for the electrochemical reduction of oxygen.

The most commonly and commercially used support is the High Surface Area Carbon Black which meets the criterion of performance and cost.

But in terms of durability, its performance is unsatisfactory under high temperature and humidity, low pH and strong oxidizing and reducing atmospheres. Its amorphous nature may cause the platinum to lose its catalytic activity and subsequent dissolution into the electrolyte.

So, carbon nanotubes (CNT) prove to be a much promising alternate as catalyst support.

CNT are impacting future science and technology since it is a highly potential material with unique structure, high crystallinity, conductivity, high accessible surface area and resistance to corrosion

CONCLUSION

Researches and project developed during the past years present different solution and approaches to the hybrid, fuel cells and hybrid technologies. Hence it is validated by means of computational simulation the functioning of the control system for the motor working as motor, generator and fuel cell treating all the aspects and subsystem of a hybrid electric vehicle carefully is a complex and time consuming task. Hybrid electric car are definitely more environmental friendly than Internal combustion vehicles. Batteries are being engineered to have long life. When the hybrid car become more widespread, battery recycling will become economically possible. Research into other energy sources such as fuel cell and renewable fuel make the future look brighter for hybrid cars. The future of the FCVs and EVs realise on their battery and fuel cell quality. If researches can produced or find the super battery or super fuel cell the future of this vehicle is promising.

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REFERENCES

[1] Direct hydrogen fuel cell system for hybrid vehicle......Author-Rajesh k AluwaliaM. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[2] Recent advance in hybrid fuel cell based power system....Author- Ankit Thakkar Harshit Mehta.

[3] Recent advance in hybrid fuel cell based power system....Author- Ankit Thakkar Harshit Mehta.

[4] PEM FUELL CELLS: DEMAND, DEVELOPMENT AND CHALLENGES, Department of Mining Engineering, I.I.T. (B.H.U.).

[5] V.B.BHANDARI.

[6] Electromobility: Batteries or Fuel Cells? (Published 2015) Oliver Groger, Hubert A. Gasteiger and Jens-Peter Suchsland Technical University of Munich, Germany.

[7] Processing of Pristine Carbon Nanotube supported Platinum as catalyst for PEM fuel cell. Paper by: Chanchal Gupta, Priyanka H Maheshwari, S Sasikala, R B Mathur.Published on: 14 August 2014.

[8] PEM fuel cell, Demand, Development, and Challenges.. author-Nikhil Jain.

[9] Investigation Of Fuel cell for Automotive use... EEA. Key Trends and Drivers in Greenhouse gas Emissions in the EU in 2015 and the Past 25 Years; EEA: Denmark, Copenhagen, 2017. Haneda, T.; Ono, Y.; Ikegami, T.; Akisawa, A.

[10] Technological assessment of residential fuel cells using hydrogen supply systems for fuel cell vehicles. Int. J. Hydrog. Energy 2017, 42, 26377–26388.