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Onboard Auxiliary Hydrogen Production In Automobiles Using Wind Energy

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ABSTRACT:
It is well known that now global warming has reached staggering proportions. The crude oil supply will run out in about forty years and the earth needs a different type of energy resource that can last indefinitely. The need to search for renewable, alternate and non-polluting sources of energy assumes top priority for self-reliance in the regional energy supply. In the wake of this crisis, is born a new technology. Hydrogen Fuel Cell Vehicles(HFCVs) which are driven by electrical power generated from hydrogen fuel. They are becoming predominant in the automotive industry and promise to be a feasible alternative for the fossil fuels. 'Hydrogen era' is expected to begin in the 2020's, and the biggest market for hydrogen fuel cells will certainly be the auto industry at that time.
As clean and efficient electrical power sources, hydrogen fuel cells have a range of vehicular applications and have been considered as promising elements for renewable electrical power utilization in automotive applications. This paper presents a novel systemized integration of an electrolyser and fuel cell to recover energy from oncoming wind due to acceleration, producing hydrogen to augment onboard stores, increasing efficiency and vehicle range. Our work is an investigation of the feasibility of a generic on-board hydrogen production and storage system for hydrogen fuel cell vehicles is carried out. A dynamic model of an onboard hydrogen production employing electrolysis energized by electricity recovered from the vehicle's onboard wind turbine system, is implemented in simulations using the software MATLAB and integrated with a fuel cell vehicle model.

INTRODUCTION:
The main purpose of this project is to develop a unit in automobiles that uses wind energy to produce hydrogen from water by electrolysis which in turn is used up by fuel cells to generate electricity thereby increasing the efficiency of the vehicle and vehicle range. To meet this requirement we have designed a unit consisting of various entities that can not only serve the purpose but also do it without much a change in ergonomics and vehicular design. The unit consists of wind turbines, generators, batteries, electrodes, storage tanks, pressure boosters and fuel cells. This system has to produce hydrogen and at the same time it must not occupy much of a space. Taking this into mind we have chosen simple components that make up a circuit which produces the desirable amount of hydrogen at a lower cost and smaller size.

The block diagram shown below gives a clear picture of the circuit.

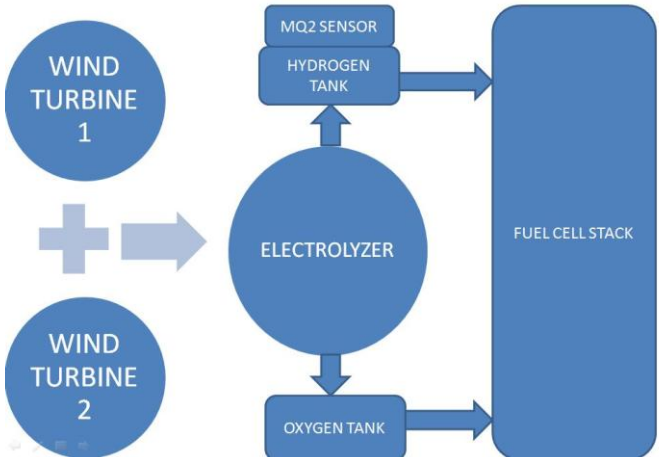

Figure 1: Block diagram.

LITERATURE REVIEW:
1) A.B. Kanase-Patil et., al provided information regarding the area consumption of the wind turbines, distribution of wind and the axis of rotation.
2) AkieUehara et., al provided the information regarding feasibility of wind and its power generation.
3) Belgin Emre Turkay et., al provided information regarding hybrid power system, its advantages and applications.
4) C Wang et., al provided information regarding the control measures and power management along with its efficiency.
5) Chunhua Liu et., al provided information regarding power generation using wind/photovoltaic cells and its technologies.
6) Dheeraj Kumar Khatod et., al provided information regarding the super relative analytical technologies which include feasible power generation using solar and wind energy sources.
7) Dong Chen et., al provided information regarding the power extraction using grid connected inverter and the necessary conditional frequencies.

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8) F Valenciaga et., al provided information regarding the control of hybrid energy using techniques enhanced to the development of power.
9) G Mahesh Manivanna et., al provided information regarding the seven level inverter system and its analysis using simulation.
10) J Carrasco et., al provided information regarding the power systems, its application, the field of renewable energy, its advantages and growth in years and its applications.
11) P. Alotto et., al provided information regarding the batteries, fuel cells and the redox power for storage of renewable energy.
12) S. Karellas et., al provided information regarding the hydrogen and it power in connection to its compression under storage systems.

COMPONENTS USED:

- Fans (3).
- 12V Dynamos (3).
- Connecting wires.
- Stainless Steel 406 plates (10).
- Acrylic tubes (4).
- PVC fittings (4).
- Gas sensor (MQ 2).
- Non-return valve.
- Swivel elbow (4).
- Backup battery 12V 7Ah.

WORKING PRINCIPLE:

The working principle of this project is to develop an auxiliary unit in automobiles to produce hydrogen from electrolysis of water. The unit consists of wind turbines, generators, batteries, electrodes, storage tanks, pressure boosters and fuel cells. This system has to produce hydrogen and at the same time it must not occupy much of a space. Taking this into mind we have chosen simple components that make up a circuit which produces the desirable amount of hydrogen at a lower cost and smaller size. Wind turbine generators are placed in the path of the wind (usually in the front portion of the vehicle) and the incoming wind is converted into electrical energy by the action of the generators. This electrical energy is sent to a reservoir containing water. The water tank has electrodes made up of stainless steel 304 plates immersed in water completely. When electricity is produced by the wind turbine generator circuit, the electricity is passed on to the two ends of the plates(cathode and anode) with the help of connecting wires.
Electricity causes electrolysis of water to take place and thus occurs the splitting up of water molecules into hydrogen and oxygen. The hydrogen is formed in form of the bubbles on the plates surface near the cathode while the oxygen is formed near the anode. The separator is kept between the anode and cathode to prevent hydrogen and oxygen from mixing and turning back into water. With continuous production of hydrogen and oxygen, the gases escape the tank to their respective storage tanks and they are ready to be sent to the fuel cells where hydrolysis occurs to produce the power required to propel the vehicle.

Figure [2]: Views of the unit.

CALCULATIONS:

Step 1: Calculation of power produced from wind:

$$P = \frac{1}{2} * \ell * A * V^3$$

where,
ℓ is air density (1.225kg/m^3).
A is area swept by the wind turbine in m^2.
V is velocity of wind in m/s.

Putting all constant values we determined power produced at the following wind speeds,

Wind speed(m/s)	Power Output(kW)	Energy (kWhr)
5	0.004	0.014
10	0.034	0.122
20	0.264	0.955
30	0.891	3.24
50	4.125	14.85

Step-2: Calculation of amount of hydrogen produced:

Since electrolysis is used to split water into hydrogen, we can use the electrolysis equation to determine the amount of hydrogen produced for a given amount of electricity provided to the electrolyzer.

$$\mathbf{2H_2O2H_2 + O_2}$$

1 litre of water weighs 1 kg and when electrolyzed will produce hydrogen and oxygen as described by the above equation. The proportion of the amount produced is in terms of the atomic weights of hydrogen and oxygen. If there were 36.0012kg of water, electrolysis would separate it into 4.0032kg of hydrogen and 31.998kg of oxygen.
Considering our case where we are splitting 1kg of water,
Amount of H_2 = 4.0032/ 36.0012 = 111.19gms.
Amount of O_2 = 31.998/ 36.0012 = 888.81gms.
Thus when electrolysis is done on 1kg of water, 111.19gms of hydrogen and 888.81gms of oxygen are formed.

Step-3: Case study of a real time fuel cell vehicle:
In order to validate our proposed model, we must implement it into a real time situation. We aim to study the intended vehicle and study its performance after the installation of our project.In this case the Toyota Mirai is taken for the case study.
The Mirai's Fuel cell stack achieves a maximum output of 114 kW (153 hp). The fuel cells are arranged in a fine 3D lattice structure and enhance the dispersion of air (oxygen), thereby enabling uniform generation of electricity on cell surfaces. Each stack comprises 370 (single-line stacking) cells, with a cell thickness of 1.34 mm and weight of 102 g. The Mirai has a converter developed to boost power generated in the Toyota FC stack upto 650 volts.

Figure [3]: Real time fuel cell vehicle Toyota Mirai.

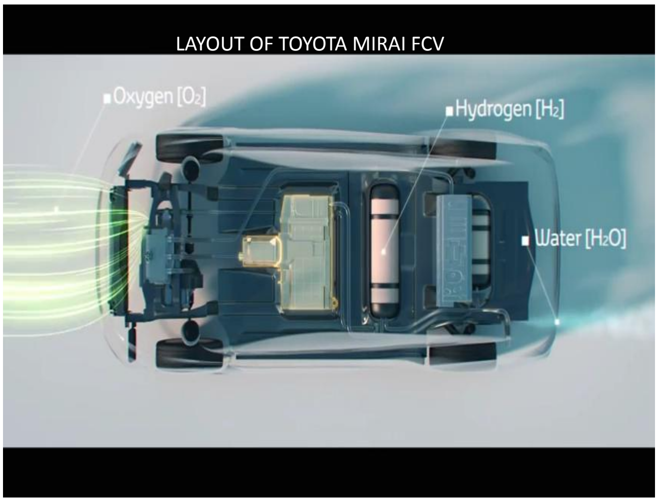

Figure [4]: Top view of Mirai assembly.

Step 4: Change in fuel economy with addition of this unit:
The fuel economy of the FCV Toyota Mirai is about 60mpg or 25km/l, which means the car runs 25km for every kg of hydrogen used up.
Since the tank capacity is about 5.64kg of hydrogen, for a single re-fuelling the car can run a maximum distance of about 141km.
Our unit consists of a water tank of capacity of approximately 7 litres. As we already saw in the previous step of calculations, electrolysis of 7 litres of water produces 0.778kg of hydrogen. Thus,

$$0.778kg * 25 = 19.45kms$$

So with the electrolysis of our unit producing hydrogen, we can produce hydrogen which will enable the vehicle to cover a maximum distance of 160.45km for a single re-fuelling of hydrogen (5.64kg) at the primary tank and a re-fuelling of water(7 litres) at the secondary tank.

SIMULATIONS:
In order to validate our work we did few simulations using Matlab-Simulink and this simulations was done in two stages.

Stage 1 - Simulations of wind turbine-generator circuit:
The first stage of simulations involved the determination of the amount of current and voltage produced by the circuit for a particular period of time for a constant wind speed. In this stage of simulation, we provide the input values such as number of dynamos used and their capacity, constant value of average wind speed and also the dimensions of the fans and air density.

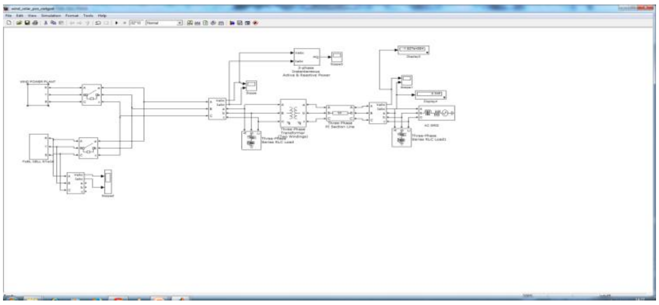

Figure [5]: Wind turbine-generator circuit.

Once these inputs are provided, the simulation is processed by the software giving the values of current and voltage for the given time period at the preset value of wind speed. The output is in the form of graphical representation with current and voltage in the y-axis and time always being the x-axis.

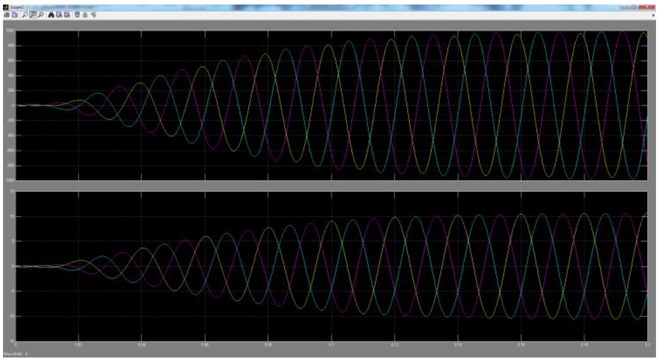

Figure [6]: Wind circuit output.

Stage 2 - Simulations of fuel cells circuit:
The second stage of simulations involve the determination of the amount of electricity produced by the fuel cells for a given amount of hydrogen and oxygen sent to the fuel cells. Based on the quantities, hydrolysis rate is calculated by the software and thus resulting electricity output of fuel cell is determined.

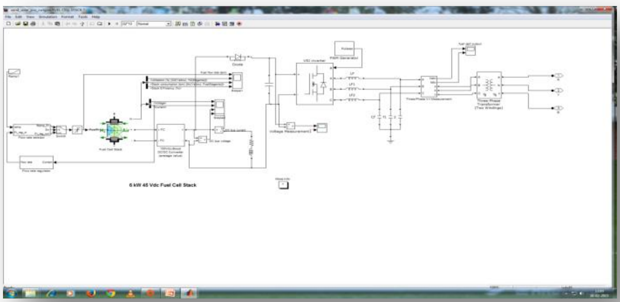

Figure [7]: Fuel cell circuit

This amount of electricity is expressed as graphical representations of current and voltages produced for a time period where the amount of hydrogen and oxygen produced remaining constant.

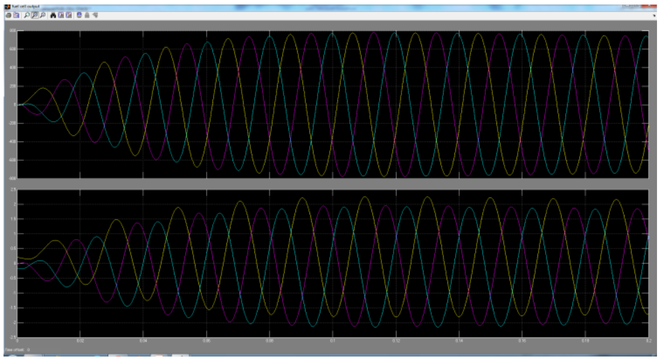

Figure [8]: Fuel cell output.

CONCLUSION AND FUTURE PROSPECTS:

With the condition of our environment deteriorating, focus on non-polluting sources of transport seems as an inevitable technology for the sustainable future of our species. With the advent of Hydrogen fuel cell technology the demand for new systems and optimization of existing systems is one of the foremost and crucial objectives in the field of engineering. Using hydrogen as a substitute for fossil fuels is a major revelation of our concern for reversing the damage caused to the environment by us. By implementing our project in the existing hydrogen fuel cell vehicle we hope to augment the fuel input by using wind energy to produce fuel on-board, thereby increasing the mileage and efficiency of the vehicle.
So far we have manufactured and simulated a rough model from our conceived idea. For this concept to manifest itself as an optimally working system, some modifications are in order. The first area of modification will most likely be the replacement to the miniature dynamos with a much larger dynamo with a large enough fan to capture the incoming wind energy and generate sufficient electricity for electrolysis without much trouble in overcoming starting torque. Next, with Copper being the most efficient metallic conductor, it can be used as electrode material so as to increase the efficiency. Then, the produced hydrogen can be supplied at high pressure to the primary hydrogen tank itself by the introduction of a gas pressure booster to the system. Next, the electrical circuit can be designed in such a way as to remain a closed circuit only when the accelerator in stepped on. This makes sure that no hydrogen is produced when the car is stationary and wind rotates the fan blades.

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