Faculty of Engineering, Environment and Computing

A Project Proposal Report of

7160CEM - MTech Automotive Software Engineering Project - 2223AAA

By

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List of Abbreviations

Abbreviations	Description
ICE	Internal Combustion Engine
FC-HEV	Fuel Cell Hybrid Electric Vehicle
EMS	Energy Management Strategy
EM	Electric Motor
DC	Direct Current
SOC	State of Charge

Research Question, Problem Statement or Topic for Investigation

Investigation on Energy performance of Fuel Cell Hybrid Electric Vehicle

The Environmental problems faced in a conventional vehicle with Internal Combustion Engine (ICE) is widespread as harmful gases are being released into the atmosphere. Another problem is related with fossil fuel availability which is reducing drastically due to high power demands all over the world. Looking for an Environmentally friendly solution is best alternative to cater to these problems and thus Electric Vehicle is the way forward for the future of transportation **(Jiageng et al., 2021, p. 1)**. There are different types of electric vehicle technologies currently available like Battery electric vehicle, Fuel Cell based vehicle technologies. Here, FC-HEV shall be used for this research work which considers battery as well as FC as sources. In the present chain of vehicles in this segment, multiple problem persists with respect to energy consumptions and uncertainty in meeting the required power demands. A lot of researchers have worked in this area by developing a control strategy to work on this Energy Management aspect. The use of traditional Energy Management Strategy (EMS) techniques is not solving all problems like optimal energy usage, and optimal use of FC and batteries to meet maximum range in vehicles. Still work needs to be done in this area as in most of the papers referred, they have not considered developing an optimum control strategy which aims at effective utilization of multiple energy sources (battery, fuel-cell) without over-compensating on the constraint limits specified for individual sources. Therefore, in this project, a novel energy management strategy using Fuzzy Logic based optimization will be used in order to mitigate the need for excess energy and to reduce the over-usage of an individual source. The advantages of using this EMS are improvement of fuel cell economy, reducing the Fuel Cell degradation and improving the overall Efficiency of the system **(Di Shen et al., 2020, p. 1)**. Finally, a detailed Simulation study using MATLAB/ Simulink will showcase the effectiveness of the proposed energy management strategy over conventional one.

Intended user or group of users and their requirements.

In the currently existing Fuel Cell Vehicles, it is difficult to meet peak power requirements generally during hill climbing scenarios, high acceleration conditions. So, the traditionally available fuel cell mechanism is replaced by adding an addition power storage device (Battery) to help address the above issues **(Silvia C et al., 2020, p. 1)**. Also, the Range travelled by the normal fuel cell vehicle is less which can be improved comparatively by using this concept. It can also reduce the cost incurred on hydrogen gas re-fueling by applying proper energy management principles thus benefitting the End User.

Systems requirements, project deliverables and final project outcome

System Requirements-

The Proposed Fuel Cell Hybrid Electric Vehicle (FC-HEV) can be seen as per block diagram mentioned below (Figure 1), a combination of Fuel Cell and Battery as it is a hybrid configuration. Battery is charged by FC whenever required through converter and it can work as a supplement to FC whenever excess power is requested by Electric Motor (EM).

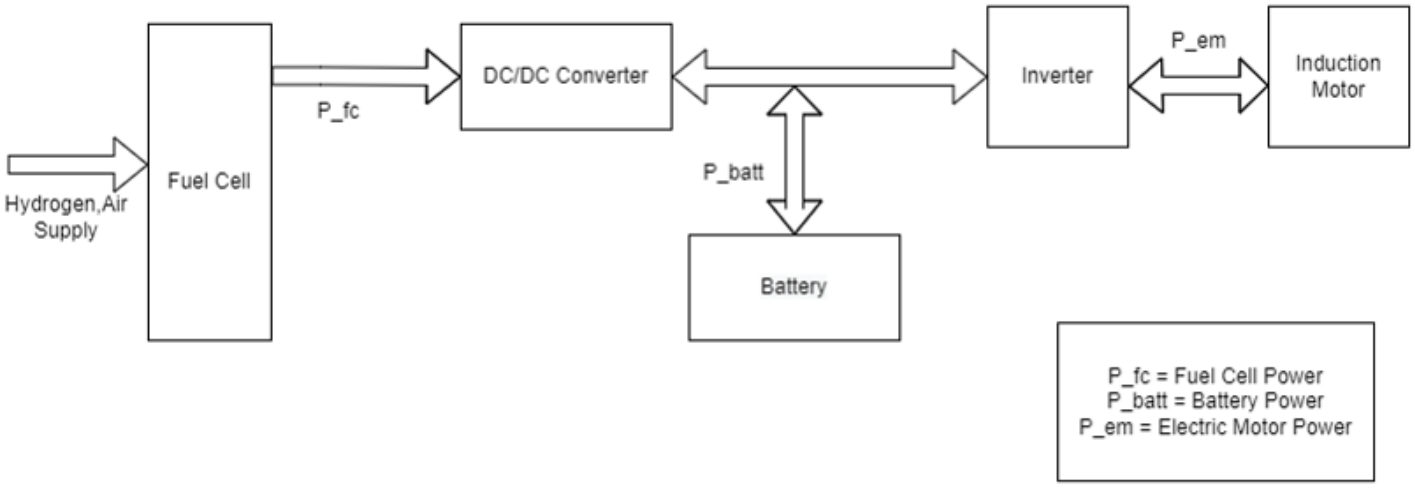

Figure 1 Block Diagram

Plant Model-

In the following system, the Battery can be charged with Fuel Cell using the DC/DC Boost Converter. The Fuel Cell current value is controlled by regulating the converter based on the power demand requirements **(Derick F et al., 2020, p. 2-3)**. The Power required by Electric Machine is met by using the Fuel Cell and Battery power excluding Power consumed by Auxiliary loads.

Controller-

The controller is developed to achieve an optimum set-point value of Fuel Cell current in order to meet the objectives specified in the below section. Based on the Power demand and SOC of the Battery the controller tries to maintain the amount of Energy drawn from the battery. The system also considers Fuel Cell voltage as an input for measuring the set-point **(Derick F et al., 2020, p. 2-3)**.

Project Deliverables-

A Simulation Model using Matlab Simulink software shall be developed for the following Fuel Cell Hybrid Vehicle architecture using the Powertrain Blockset. Also, it aims to develop a controller model for devising an optimal energy management strategy in order to increase the range of travel, minimize the cost incurred for the Fuel Cell recharging/replacement and increasing the battery lifetime **(Jiageng et al., 2021, p. 1)**.

To verify the effectiveness of the developed controller model, the aim is to use multiple drive cycles such as FTP75 etc. as an Input and, also measure/analyse the total energy, power data consumed/absorbed by the vehicle model at the output side by using a dashboard.

Final Project Outcome-

An optimum control mechanism will be proposed in this thesis in order to allocate required energy/power to the FC-HEV system. The below mentioned objectives shall be achieved at the end of this work.

a) Reduction in the consumption of Hydrogen in Fuel Cell -This will also reduce the degradation of the system and optimize the use of FC.
b) Increase in the Fuel Economy- By using proper control mechanism the fuel consumption is reduced and the Range/Distance travelled by the vehicle is increased.
c) To Prevent Excessive Discharge of Battery- By using current controlled mechanism of the Fuel Cell the SOC of the Battery can be maintained to not go below a certain percentage.
d) Excessive charging Prevention-As the battery is recharged with the help of Fuel Cell it needs to be monitored whether the battery does not get charged beyond a certain level **(Silvia C et al., 2020, p. 1)**.

Primary Research Plan-

1) Identifying the Purpose of Research -From the latest journal articles, it is observed that one of the major problems faced in the automotive industry is due to global warming. Due to the emission of harmful gases, it is necessary to switch to environmentally friendly options and thus Fuel Cell (FC) concept is considered.

2) Identifying the Objectives to be achieved by considering the FC Concept-Finding out the advantages of the new technology in aspects like performance, efficiency, user benefits etc are to be researched and defined.

3) Defining the research methodology – As per literatures available in database (like journals and conference papers), a primary research objective has been formed. Based on the initial literature review, the research gaps have been identified. After a thorough analysis, it was found out that Fuel cell plus Battery hybridization helps cater to higher/peak power demands of the system. But, apart from that there is also a need for optimal control strategy for Proper Energy Management to reduce losses and improve Efficiency.

4) Formulation of Research Objective - The Aim of the project will be to develop an Energy Management control strategy using Matlab/Simulink for a FC-HEV to work on the above-mentioned issues currently faced and understand what all benefits can be achieved from it.

5) Model Formulation, Results and Analysis- Simulink Model development and verification to check whether the set objectives and purpose of the project is achieved.

6) Conclusion and Future Scope- From the detailed study, an optimal energy management strategy shall be finalized. A MATLAB model will be built in order to support the above-mentioned statement. A thorough analysis will be done in order to prove the effectiveness of the optimal control strategy over the conventional one. Validation is Hardware prototype will be the future scope of the work.

7) Timelines for the multiple phases of the Project-

   Phase1 (Feb-March)- Understanding the System Requirements of the Project

   Input, Process and Output of the system needs to be Identified. Understanding and Developing the Block Diagram based on that requirements will be the next step. Another step will be to Identify the ratings of the different components which is being used in the work like capacity, power, current, voltage etc.

   Phase2 (Apr-May)- Theoretical Analysis and Performance measurement

   After understanding the system requirements, we need to perform some theoretical calculations and understand the system constraints to be set up for each device being used like Battery, Fuel Cell SOC and current limits to be set. Also, need to understand what maximum power is supplied individually by fuel cell and battery as per power demand, the maximum speed which can be achieved and the range which can be travelled.

   Phase3 (June-July)- Simulation Model Development and Verification

   The next step is to develop a model in Matlab/Simulink software. This includes developing a Plant Model for Vehicle Powertrain part and Controller model for the control strategy part. To validate the plant/controller specific set of Inputs such as Drive Cycle and vehicle dynamics (Environmental conditions) will be considered. Also, to measure the different parameter values calculated as per the driving cycle requirements, a dashboard model will be designed to verify the values obtained for different parameters at different time zones of the drive cycle.

Initial/Mini-Literature Review-

Hybrid Electric Vehicles are a promising solution to the environmental problems and emissions caused by the Internal Combustion Engine (ICE). Also, there is shortage of petroleum/fossil fuels which leads us to looking for an alternative energy supplement. Fuel Cell Electric vehicle is one of the best solution available as there is no emission of pollutant gases and on top of it, they also have a greater energy density **(Jiageng et al., 2021, p. 1)**. Hybridization of FC-EV is done so that vehicle can meet peak power demand when needed in drive cycle. Furthermore, it helps in improving the efficiency of the system and reducing the size of fuel cell component. In a FC-HEV, the driving range is longer and re-fuelling time is quite less.

In FC-HEV, the battery can be recharged by the FC component in the vehicle as it works in alignment with the State of Charge (SOC). The mechanism of charge sustaining is applied here as emphasis is on maintaining the battery SOC in the appropriate range **(Silvia C et al., 2020, p. 1)**.

Proton Exchange Membrane (PEM-FC) will be considered for this research work. It is one of the mostly used application since they are compact, have high power density, low operation temperature and low operating pressure in comparison with other FC technologies. The disadvantage which they possess is the high cost with respect to structure. In addition, the cost incurred in purchase of hydrogen gas is also higher than the normal Hybrid Electric Vehicle (HEV). Thus, to solve the relevant issues mentioned above a control strategy needs to be developed for optimized energy management of FC-HEV in order to make the system more efficient and economically advantageous **(Derick F et al., 2020, p. 1-2)**.

There are generally two different types of controllers available -one is Offline Controller and other one is Online. While using offline optimization techniques it considers a fixed path/track (Drive Cycle path) which is the basis for Public Transport and Racing Cars. In those scenarios where the driving path is uncertain as to what will happen in the future, Online Controllers are used.

Different papers have presented different control strategies to undergo energy management scenarios. Two different control methods mentioned are Heuristic method and optimal control theory method. Heuristic method uses Rule based strategies to control parameters. There are multiple ways in which this approach can be used like hysteresis band control (HBC), fuzzy logic controllers, maximum efficiency point tracking (MEPT), maximum power point tracking (MPPT), neural network modelling and extremum seeking method. The Problems faced in this type of methods are when the complexity of the model increases it will be very difficult to perform prioritization of multiple rules. Thus, it will not be able to exploit maximum performance of the vehicle. Whereas optimal controllers are considered advantageous as they have the capability to handle multiple system constraints simultaneously. One of the most commonly used method here is Model Predictive Control (MPC) **(Di Shen et al., 2020, p. 1-2)**.

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