Energy management System for Hybrid Electrical Vehicle using Soft Computing

[1]Ajay Landge, [2]Prof. H. V. Takpire

[1]Student, [2]Assistant Professor
Department of EPS
G.H Raisoni University, Amravati
Maharashtra, India

***Abstract*: Because of their great efficiency, low cost, and pollution-free properties, hybrid electric vehicles (HEVs) are becoming more popular. Long-distance driving necessitates the use of hybrid power sources. In electric vehicles that use hybrid power sources, energy management is a crucial issue. Artificial intelligence-based algorithms have made a substantial contribution to hybrid electric car energy management systems. In a hybrid electric car that uses fuel cells, batteries, and internal combustion engines as power sources, this article provides a Fuzzy logic-based energy management strategy. Based on the present battery state of charge, varying vehicle characteristics, and driving situations, the suggested method allows efficient regulation of power flow in HEVs. The proposed fuzzy management technique demonstrates reliability, easiness in implementation and robustness.**

***Keywords*: Hybrid Electrical Vehicle, Fuzzy Logic, Energy Management, Battery Management**

I. INTRODUCTION

The massive changes in world population and rising lifestyles in developing countries has caused a spike in the number of automotive vehicles. Traditional diesel/petrol vehicles, on the other hand, have become less efficient and less popular as a result of the scarcity of fossil fuels and the rise in air pollution caused by the release of dangerous gases. CO2 is emitted by classic inter combustion engine-based cars, which is the primary cause of global warming and air pollution. Because of their pollution-free nature, lower cost, and efficiency, electric vehicles have seen a recent surge in popularity. Despite this, the adoption of a fully electric car is difficult due to its restricted range.

The current electric car's range is limited to 150-200 kilometres per charge, limiting the vehicle's long-distance capacity. Hybrid electric cars use a combination of ICE and electrical power sources to improve HEV performance in challenging conditions. Researchers have worked on allied tiny power sources for HEV in addition to batteries because battery size and number are a major barrier in HEV [1-3].

Several projects involving fuel cells and their application have been undertaken in recent years in the quest for a clean car that saves the environment. The use of hydrogen as a possible alternative to gasoline and other conventional energy sources in vehicles is gaining traction. The fuel cell, which is powered by hydrogen, a renewable energy source, emits no emissions and has a high energy efficiency [4-5]. The fuel cell has a high energy efficiency and produces no pollutants [4-5]. It runs on hydrogen, which is a renewable energy source. As a result, it can be considered a renewable and sustainable energy source that helps to reduce greenhouse gas emissions.

The goal of reducing harmful CO2 and greenhouse gas emissions has prompted the development of electric and hybrid vehicles, particularly fuel cells that are fueled by non-polluting sources. Fuel cells are currently widely employed in electric vehicles due to their high energy density, low temperature, and, most importantly, high efficiency [6]. However, because of their slow dynamic, fuel cells are not always capable of responding to quick variations in the power supply when utilised as the principal source of electricity. Given the vehicle's energy behaviour and the fuel cell's dynamic features, it will be essential to integrate at least two sources of energy: one primary and one secondary [7-9].

This research presents a cost-effective energy management strategy for hybrid electric vehicles that uses a Fuzzy logic algorithm to select the most appropriate power source.

The following is how the rest of the article is structured: Section II describes the suggested energy management method for a hybrid electric vehicle. Section III deals with the investigative data and remarks. Part IV concludes with a discussion of the findings and their implications for the future.

2. PROPOSED METHODOLOGY

The suggested system manages the fuel cell for the electric vehicle based on the battery state of charge and load power profile. When computing the load power profile, various driving and environmental factors are taken into account, such as the vehicle's mass, airspeed, road inclination, ICE characteristics, and so on. SOC, upload, and Pfc are only a few of the input and output elements that are taken into account for HEV energy management, as shown in Table 1-2. As indicated in Table 3, a total of twenty rules for developing control actions for fuzzy logic-based energy management of HEVs have been created.

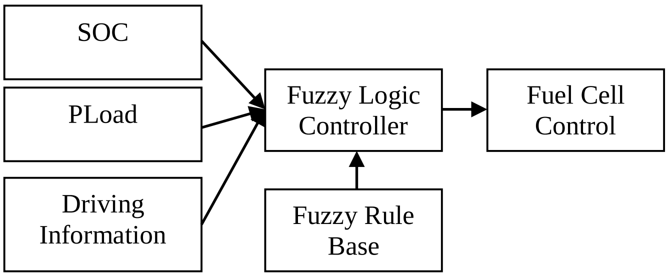


Fig. 1 Schematic of the proposed EMS system

TABLE 1. INPUT VARIABLES FOR FUZZY BASED EMS FOR HEV

Input Variable	Level	Range (%)
SOC	Very Low (VL)	0-40
	Low (L)	30-60
	Medium (M)	50-80
	High (H)	70-100
Pload	No Load (NL)	-1000-0
	Very Low (VL)	0-500
	Low (L)	400-1000
	Medium (M)	900-1500
	High (H)	1400-2000

Equations 1-4 describe the membership equations for the battery SOC. With a trapezoidal membership function, the SOC is divided into several variables such as very low (VL), low (L), medium (M), and high (H).

$$SOC_{VL}(x) = \begin{cases} 1 & 0 \le x \le 30 \\ \frac{40-x}{10} & 30 < x \le 40 \end{cases} \quad (1)$$

$$SOC_{L}(x) = \begin{cases} \frac{x-30}{15} & 30 \le x45 \\ \frac{60-x}{10} & 50 \le x \le 60 \\ 1 & 45 \le x \le 50 \end{cases} \quad (2)$$

$$SOC_{M}(x) = \begin{cases} \frac{x-50}{10} & 50 \le x \le 60 \\ 1 & 60 \le x \le 70 \\ \frac{80-x}{10} & 70 \le x \le 80 \end{cases} \quad (3)$$

$$SOC_{H}(x) = \begin{cases} \frac{x-70}{10} & 70 \le x \le 80 \\ 1 & 80 \le x \le 100 \end{cases} \quad (4)$$

The membership equations for the Load demand are explained in Equations 5-9. (PLoad). The upload is separated into distinct variables using a trapezoidal membership function, such as no-load (N), very low (VL), Low (L), medium (M), and high (H).

$$PLoad_{N}(x) = \begin{cases} 1 & -1000 \le x \le 0 \\ \frac{50-x}{50} & 0 \le x \le 50 \end{cases} \quad (5)$$

$$\text{PLoad}_{VL}(x) = \begin{cases} \frac{x-50}{50} & 0 < x \le 50 \\ 1 & 50 \le x \le 400 \\ \frac{500-x}{100} & 400 \le x \le 500 \end{cases} \quad (6)$$

$$\text{PLoad}_{L}(x) = \begin{cases} \frac{x-450}{50} & 450 < x \le 500 \\ 1 & 500 \le x \le 800 \\ \frac{1000-x}{200} & 800 \le x \le 1000 \end{cases} \quad (7)$$

$$\text{PLoad}_M(x) = \begin{cases} \dfrac{x-900}{1000} & 900 < x \leq 1000 \\ 1 & 1000 \leq x \leq 1400 \\ \dfrac{1500-x}{100} & 1400 \leq x \leq 1500 \end{cases} \quad (8)$$

$$\text{PLoad}_H(x) = \begin{cases} \dfrac{x-1400}{100} & 1400 < x \leq 1500 \\ 1 & 1500 \leq x \leq 2000 \end{cases} \quad (9)$$

TABLE 2. OUTPUT VARIABLES FOR FUZZY BASED EMS FOR HEV

Output Variable	**Level**	**Range (%)**
Pfc	Zero (Z)	0-100
	Low (L)	50-300
	Medium (M)	250-500
	High (H)	450-650

Equations 10-13 show the membership equations for the fuel cell power control variable (PFC). With a trapezoidal membership function, the upload is divided into multiple variables such as zero (Z), low (L), medium (M), and high (H).

$$PFC_Z(x) = \begin{cases} 1 & 0 \leq x \leq 50 \\ \dfrac{80-x}{30} & 50 \leq x \leq 80 \end{cases} \quad (10)$$

$$PFC_L(x) = \begin{cases} \dfrac{x-50}{50} & 50 < x \leq 100 \\ 1 & 100 \leq x \leq 200 \\ \dfrac{300-x}{50} & 250 \leq x \leq 300 \end{cases} \quad (11)$$

$$PFC_M(x) = \begin{cases} \dfrac{x-250}{50} & 250 < x \leq 300 \\ 1 & 300 \leq x \leq 450 \\ \dfrac{500-x}{50} & 450 \leq x \leq 500 \end{cases} \quad (12)$$

$$PFC_H(x) = \begin{cases} \dfrac{x-400}{100} & 400 < x \leq 500 \\ 1 & 500 \leq x \leq 650 \end{cases} \quad (13)$$

TABLE 3. RULES FOR FUZZY BASED EMS FOR HEV

Fuzzy Rule Base		
Input		***Output***
SOC	***Pload***	***Pfc***
VL	N	Z
VL	VL	L
VL	L	M
VL	M	H
VL	H	H
L	N	Z
L	VL	L
L	L	M
L	M	M
L	H	H
M	N	Z
M	VL	Z
M	L	L
M	M	L
M	H	M

H	N	Z
H	VL	Z
H	L	Z
H	M	L
H	H	L

II. SIMULATION RESULTS AND DISCUSSIONS

The proposed system is implemented using MATLAB /Simulink software on personal computer. Fig 2. shows the schematic of the proposed fuzzy logic based EMS.

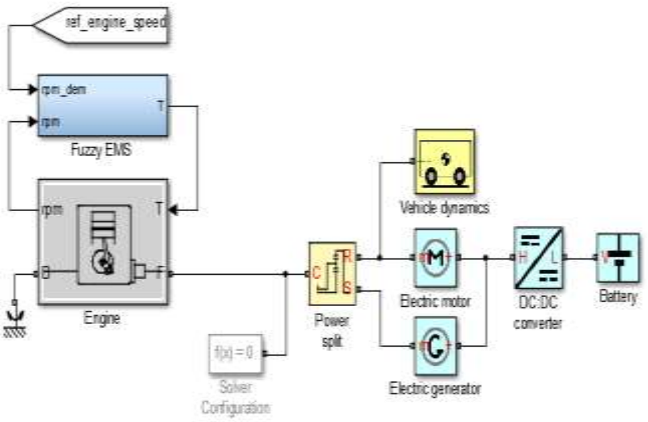
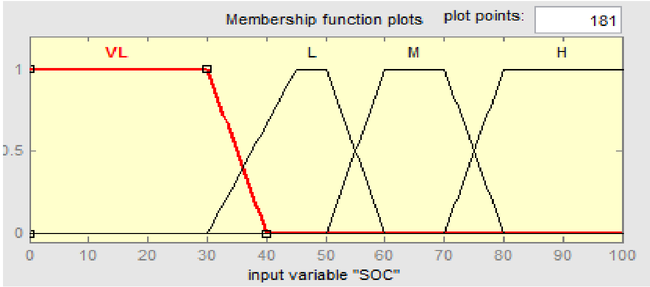


Fig. 2 Simulink design of proposed EMS

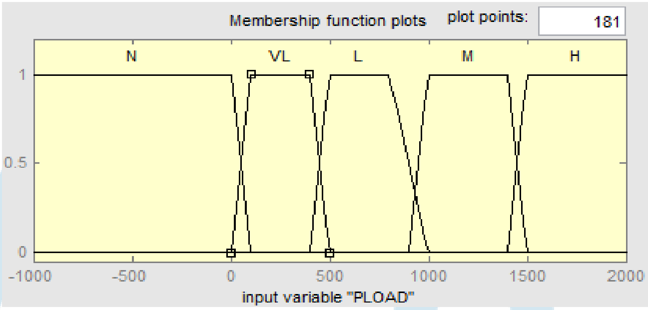
Table 4 gives a comprehensive explanation of the numerous electrical and vehicle dynamics utilized for the simulation.

Table 4: Vehicle and power drive parameters

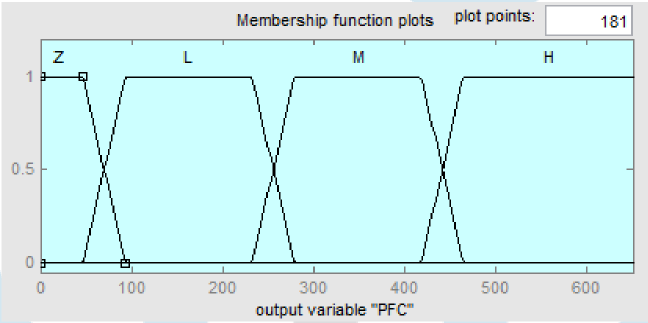
Parameter	Value	Unit
Battery Capacity	20	Ah
Motor Efficiency	94	%
Converter Output Voltage	500	V
Motor Maximum Power	100	kW
Maximum Motor Torque	450	Nm
Tire radius	0.25	m
Vehicle mass	1000	Kg
ICE Maximum Power	100	kW
Battery Nominal Voltage	300	V



a)



b)



c)

Fig. 3 Visualization of Fuzzy membership functions for input and output variables a) SoC b) PLoad c) Pfc

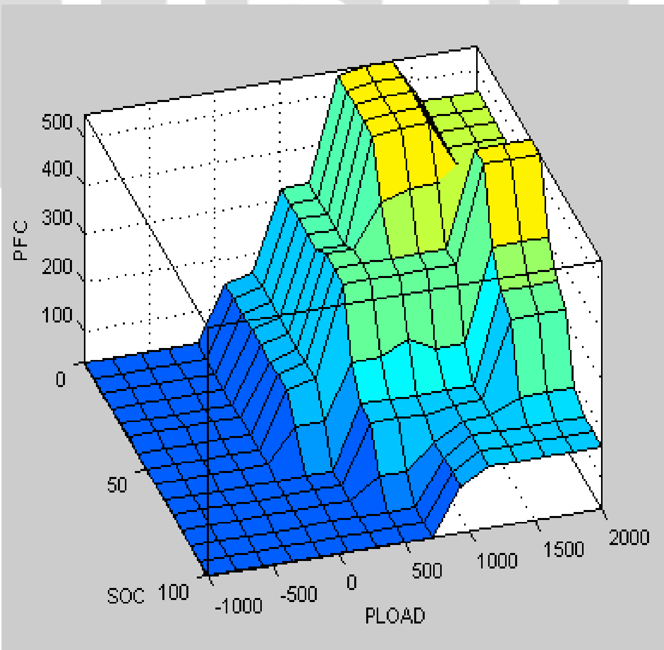


Fig. 4. Surface plot for SOC vs PFC vs PLoad

The surface map illustrates that the fuel cell must be turned on when the load is higher and the battery SOC is lower. The fuel cell is ready to be turned off when the plod is lower and the SOC is higher. The system's performance is calculated using a 96.00% accuracy under various random SOC and PLoad scenarios. The sample control conditions for various input conditions are shown in Figures 5-6.

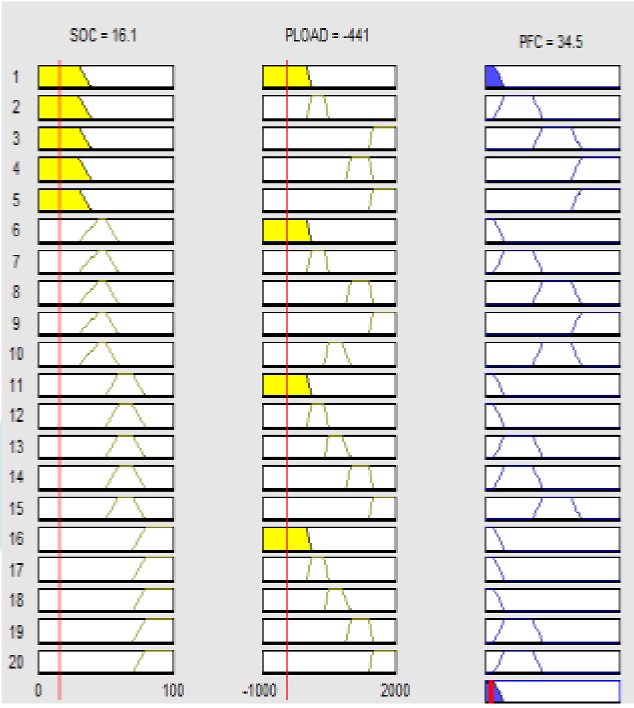


Fig. 5. Fuzzy rule viewer for very low PFC (34.5) for input variables SOC=16.1% and Pload=-441

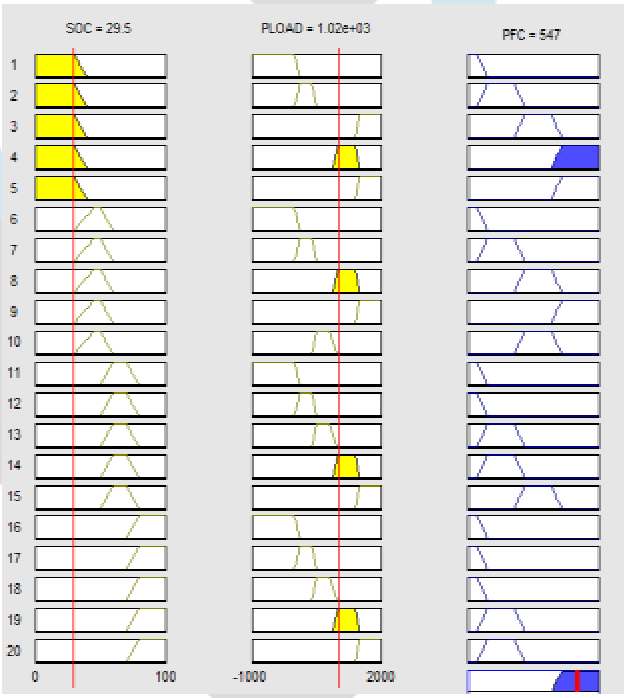


Fig. 6. Fuzzy rule viewer for very high PFC (547) for input variables SOC=29.5%, and Pload=1020

III. CONCLUSIONS AND FUTURE SCOPE

As a result, this research proposes a fuzzy logic-based energy management system for a hybrid electric automobile that is dependent on battery state of charge, vehicle dynamics, and driving scenarios. It enables precise fuel cell power control based on battery state of charge and load profile while accounting for a variety of vehicle parameters such as vehicle dynamics, atmospheric pressure, and so on. The fuzzy logic-based EMS efficiently and automatically controls the power flow in a HEV. The fuzzy logic-based energy management system is a simple rule-based energy management system that takes minimal computing labour and is straightforward to implement on the hardware platform. In a range of driving circumstances, it enables for multi-objective vehicle speed regulation. To charge the battery, a variety of renewable energy sources could be used in future.

REFERENCES

[1] Ostadian, R., Ramoul, J., Biswas, A., Emadi, A.: Intelligent Energy Management Systems for Electrified Vehicles: Current Status, Challenges, and Emerging Trends. IEEE Open Journal of Vehicular Technology, (2020).

[2] Nazari, S., Borrelli, F., & Stefanopoulou, A. (2020). Electric Vehicles for Smart Buildings: A Survey on Applications, Energy Management Methods, and Battery Degradation. *Proceedings of the IEEE*, *109*(6), 1128-1144.

[3] Tran, D. D., Vafaeipour, M., El Baghdadi, M., Barrero, R., Van Mierlo, J., & Hegazy, O. (2020). Thorough state-of-the-art analysis of electric and hybrid vehicle powertrains: Topologies and integrated energy management strategies. *Renewable and Sustainable Energy Reviews*, *119*, 109596.

[4] Zandi M, Payman A, Martin JP, Pierfederici S, Davat B. Energy management of a fuel cell/supercapacitor/battery power source for electric vehicular applications. IEEE Trans Veh Technol 2011;60(2):433–43.

[5] Zhou D, Al-Durra A, Gao F, Ravey A, Matraji I, Simões MG. Online energy management strategy of fuel cell hybrid electric vehicles based on data fusion approach. J Power Sources 2017;366:278–91.

[6] Hwang JJ, Chang WR. Life-cycle analysis of greenhouse gas emission and energy efficiency of hydrogen fuel cell scooters. Int J Hydrogen Energy 2010;35:11947–56.

[7] Payman A, Pierfederici S, Meibody-Tabar F. Energy control of supercapacitor/fuel cell hybrid power source. Energy Convers Manage 2008;49(6):1637–44.

[8] Kisacikoglu MC, Uzunoglu M, Alam MS. Fuzzy logic control of a fuel cell/battery/ ultracapacitor hybrid vehicular power system. In: Proc. IEEE vehicle power and propulsion conference, p. 591–96, 2007.

[9] Marzougui H, Amari M, Kadri A, Bacha F, Ghouili J. Energy management of fuel cell/ battery/ultracapacitor in an electric hybrid vehicle. Int J Hydrogen Energy March 2017;42:8857–69.