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# Fuzzy Logic-Based Novel Hybrid Fuel Framework for Modern Vehicles

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**ABSTRACT** The transport sector has proven to be the largest contributor to global  $CO_2$  emissions. To reduce  $CO_2$  emissions and improve mileage, the existing research has proposed different fuel models for vehicles such as Plug-in Hybrid Electric Vehicles (PHEVs), Electric Vehicles (EVs), solar and hydrogen Vehicles. However, these vehicles suffer from a range of issues and solutions are required to increase range, and improve charging. In this context, we propose A Novel Hybrid Fuel Framework for Modern Vehicles, to reduce  $CO_2$  emissions and increase vehicle mileage, by managing energy resources efficiently through the application of Fuzzy Logic. It considers three different energy sources i.e., gasoline, solar and electric power, to charge a vehicle, and suggest a modification in the architecture of EVs is made for the availability of all these energy resources. We use Visual Studio to implement fuzzy logic based algorithm designed to simulate the proposed system and added a small gasoline engine to the existing architecture of EVs to provide energy resources that overcome charging issues during long-range travel. We use the Statistical Package for Social Sciences (SPSS) tool to evaluate the performance of the proposed framework for  $CO_2$  emissions and fuel efficiency. The proposed framework achieves the best mileage of 57.6 Kilometers per liter (Km/l) with a 660 Cubic Centimeter (CC) gasoline engine which is 111.11% more efficient than existing frameworks. Moreover,  $CO_2$  emissions through our proposed framework are 41.52 Grams per Kilometer (G/Km) which are 53% lower than current frameworks. The proposed framework also improves the charging duration of batteries i.e., a 10 Kilowatt-Hour (KwH) battery can be charged in 1 hour and 15 minutes.

**INDEX TERMS** Fuzzy Logic, hybrid vehicle, electric vehicle,  $CO_2$  emissions, fuel efficiency.

## I. INTRODUCTION

The transportation sector is one of the largest contributors to global greenhouse gas (GHG) emissions and energy consumption [1]. In 2015, the transport sector was responsible for around 24% of the global emissions of GHG [2]. In Norway, for example, the transport sector accounted for 31% of total

national GHG emissions and passenger cars were responsible for a third of this [3]. According to the statistical report of International Energy Agency (IEA), the world's oil consumption per day is 93 million barrel which makes an emissions of  $CO_2$  approximately 330 million tons of  $CO_2$  emissions globally in 2017, rising to 334 million tons in 2018 [4]. Today there are over 900 million vehicles are on the road and this is expected to increase to 1.1 billion by the end of 2020 [5]. Even though there are multiple sources of energy as shown

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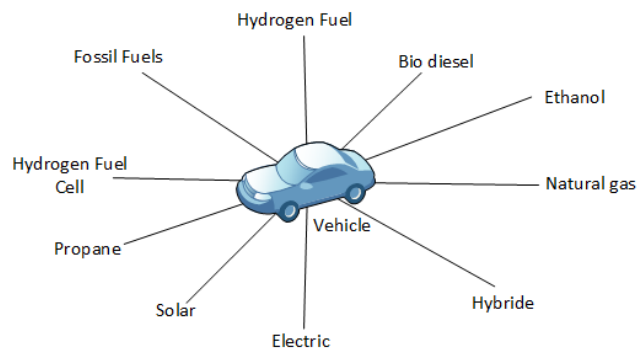


FIGURE 1. Energy sources of modern vehicles.

in Figure 1, it is reported that people who are more concerned about fuel-efficient vehicles are more likely to own a PHEVs rather than a gasoline power vehicle [3]. Charging these electric or PHEVs depends on electricity production plants, which run on gasoline, and are hence another contributor to GHG emission. Hydrogen is used as a fuel but production cost of this fuel has a large impact on the utilization rate [6]–[9] and electricity cost [6]–[11] which make it a sensitive point of analysis.

Solar energy is emission-free and is being widely used in industries and homes that charge battery packs for electricity use. In many countries, fuel consumption is much higher than production, such as the case in Pakistan [13]. Consequently, the required demand is not fulfilled by the power production companies. Policymakers suggest developing hybrid vehicle policies that will encourage people to shift to hybrid vehicles. Due to the increase in economic activity, the demand in the transport sector has also increased [12]. This ultimately elevated the demand for energy for the transport sector. In 2030 there is expected to an increase of more than 1% in gasoline and oil consumption and production. However, Pakistan cannot produce enough to fulfill demand [12]. Hence, Pakistan will be importing gasoline and will increase the cost of fuel. Large vehicles consume more energy during their whole life cycle from production to mobility whereas compact vehicles consume less [13]. In countries where electricity and fuel prices are high, a vehicle that utilises a combination of electric, engine, and solar can be used as an energy-efficient and cost-effective means of transportation.

This paper introduces a framework to solve the transportation problem that requires increases vehicle mileage and reductions in  $CO_2$  emission. In this work, A Fuzzy Logic Based Hybrid Fuel Framework for Modern Vehicles is introduced. The proposed framework offers real-time power distribution and management system to charge vehicle's batteries using multiple sources i.e., electric, engine, and solar power. A change in the architecture of EVs helps in the reduction of  $CO_2$  emission. For this purpose, a small gasoline engine is added to the existing architecture of EVs. Finally, the proposed framework is evaluated and compared with the existing frameworks and results are presented.

The rest of the paper is organized as follows: related studies are presented in Section II. The system model and mathematical formulations along with the proposed methodology are demonstrated in Section III. Section IV describes the experiments and results of our proposed schemes. Finally, Section V concludes the paper.

## II. RELATED WORK

Increased demand for fuel-efficient vehicles has led to research into more efficient vehicles. In [14], the authors explain how China is trying to make a more efficient gasoline engine where other countries are trying to move fully towards electric vehicles. It can be argued that solely electric vehicles are not the only solution and merging multiple energy sources is better than relying on one. With the passage of time the customer's demand of having fuel-efficient vehicles is increasing. Motor companies such as Honda, Toyota and Nissan have among the best gasoline consumption vehicles, although their technology is not good enough to convert fuel optimally. However, alternatives to gasoline such as bio-fuels and hydrogen fuel are also in use. Hydrogen is a synthetic energy carrier [15] so can be used as an alternative to gasoline and EVs.

Modern hybrid vehicles use machine learning based systems to manage power consumption. In [16], a review is presented about how automotive software has been replacing the mechanical vehicle parts in today's EVs. It reduces manufacturing costs and also aims to reduce the number of Electric Circuit Units (ECUs) which leads to faster development with reduced cost.

The authors of [17] and [18] present a fuzzy logic control system to smartly charge EVs on a charging network and a fuzzy logic-based power control and energy management system to make PHEVs more fuel efficiently. An energy management strategy to manage power split between battery and capacitor is presented in [19]. In [20], an adaptive control approach with Fuzzy Logic Parameter Tuning (AFLPT) for the energy management of electric vehicles is proposed and it uses fuel cell based battery hybrid systems. The controller is adaptive to different driving conditions including normal, regenerative, and overload. Specifically, the power flow between the Fuel Cell (FC) and the Li-ion battery is controlled in real-time to maintain the battery's State of Charge (SOC).

In [21], a Real-Time Energy Management Strategy (R-EMS) is proposed that not only maintains the SOC but also saves fuel consumption as compared to the rule-based Energy Management Strategy (EMS).

Table 1, shows the number of vehicles in Pakistan is 23588268 [22], China is 327000000 [23], and Great Britain is 38200000 [24]. The majority of vehicles in these countries are low power as people in these countries prefer fuel-efficient vehicles. These countries also prefer PHEVs and EVs. As such their gasoline usage may be decreased and carbon dioxide ( $CO_2$ ) emissions may also be controlled. In such countries, the most efficient hybrid vehicle is much needed.

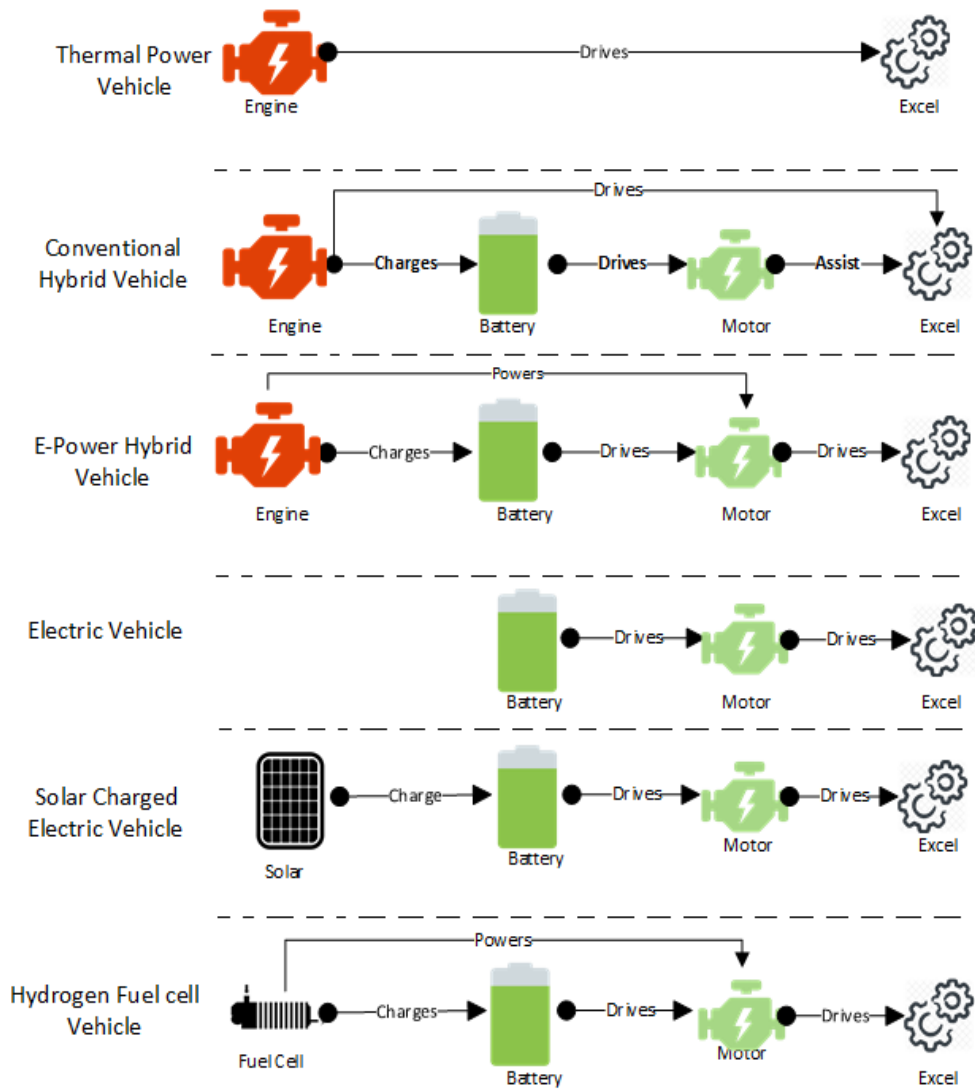


FIGURE 2. Comparison of different vehicular Energy Sources.

TABLE 1. No of Vehicles in Pakistan, China and Great Britain by 2018.

Country	Number of Vehicles
Pakistan	23588268
China	327000000
Great Britain	38200000

### A. GASOLINE POWER VEHICLE

In gasoline vehicles, most fuel waste in heat dissipation but these vehicles are cheap as their technology is not that much expansive. Figure 2, shows the working of conventional gasoline power engine vehicles. Gasoline power vehicles are widely used whereas Hydrogen Fuel, biodiesel, ethanol, natural gas, and propane are alternative fuels. Table 2 shows the limitations of gasoline as an energy source. In the light-duty sector advanced gasoline technologies continue to push the efficiency limits for conventional power trains, while electrification at various levels is being pursued and will play an increasing role in the future.

TABLE 2. Gasoline power vehicles.

Pros	Cons
Low production cost	Fossil fuel
Easily available fuel	High CO <sub>2</sub> emissions
Low operational cost	Low energy efficiency
No rang issues	No regenerative braking benefits
Gas station infrastructure	No cleaner energy
-	Bad torque
-	Noise pollution

### B. ELECTRIC VEHICLES

China has a broad industrial policy to decrease dependency on imported petroleum and lead the world in electric vehicles [13]. Tesla, Audi and Nissan are attempting to convert people from conventional gasoline vehicles to electric vehicles. Most companies are working on light duty (LD) electric vehicles, though some are exploring heavy duty (HD) electric vehicles [13]. Norway is trying to convert all vehicles to hybrid and

TABLE 3. Electric vehicles.

Pros	Cons
Cleaner Electric energy	Higher initial cost
Zero CO <sub>2</sub> emissions	Long range issue
Regenerative braking system captures energy and reuses it	Long Charging time
Low fuel and operational cost	Availability of a charging infrastructure
Silent operation of vehicle	Battery pack replacement issues
Maximum torque at 0 RPM	Battery technology need improvement

TABLE 4. Hybrid vehicles.

Pros	Cons
Optimized performance	Higher Initial cost
Refuel cost is less	Complex power trains
Less CO <sub>2</sub> emissions and re-fuel cost	Cost of replacement of the battery, power trains
Regenerative braking system captures energy and reuses it	Availability of battery and power trains
Zero emissions capability	Added weight
Gas station infrastructure	Bigger engine
Cleaner electric energy	-

electric vehicles and they found that these electric vehicles do not cost-efficient to buy. Many people there are still not convinced of the reliability and cost savings of purely electric cars [3], which might also be a barrier for adoption. Table 3, explains the pros and cons of electric vehicles [25] and Figure 2, presents the major building blocks of an electric vehicle engine. Only electric motor assists the power train and an inverter is used to manage the electric power between motor and battery. Alternative Current (AC) motors are generally used in modern vehicles, due to their resilience and simple construction. It will provide better performance than others as mentioned in [26].

C. CONVENTIONAL HYBRID VEHICLE

Due to the limitations of gasoline power vehicles some companies, such as Toyota, are trying to develop the best hybrid vehicles by combining the benefits of electric and gasoline engines. So far, Prius Prime is the best hybrid car in the hybrid car category. It can achieve up to 54 miles per gallon (mpg), 133 mpg when the vehicle is fully charged and the electric driving range is 25 miles only [27], [28]. Figure 2, shows the components used in a conventional hybrid vehicle and how they are connected to each other, while table 4 explains the benefits and limitations of this energy source.

D. E-POWER HYBRID VEHICLE

A new technology that is closer to electric, Nissan has aimed to improve conventional hybrid systems to E-Power technology. Its technology has both high fuel efficiency and high power generation efficiency than conventional hybrid technology. The engine is used to charge the battery and assist the motor only during uphill [29]. Figure 2, shows the configuration of vehicle components. An inverter is used only to manage the electric power between the battery engine, and

TABLE 5. E-Powered hybrid vehicle.

Pros	Cons
Optimized performance	Higher Initial cost
Refuel cost is less	Bigger engine as it needs to run continuously to charge
Less CO <sub>2</sub> emissions and re-fuel cost	Cost of replacement of battery, power trains
Regenerative braking system captures energy and reuses it	Availability of battery and power trains
Gas station infrastructure	Added weight
Use more powerful motor than a conventional hybrid	Small battery pack

TABLE 6. Solar power vehicle.

Pros	Cons
Cleaner Electric energy	Higher initial cost
Zero CO <sub>2</sub> emission	Long-range issue
Regenerative braking system captures energy and reuses it	Long Charging time
Low operational cost	Availability of a charging infrastructure
Silent operation of vehicle	Battery pack replacement issues
Solar energy used	Battery technology need improvement
Maximum torque at 0 RPM	Solar cells cost
-	Solar cells availability and replacement

motor. This technology also has limitations that are explained in Table 5.

E. SOLAR POWER VEHICLE

Light Year is a company that has created a vehicle fully powered by solar cells so its batteries can be fully charged using solar power mounted over with the bonnet, roof, and boot lid with 5 meter square (m<sup>2</sup>) or 54 square feet of solar panels. Through fast charging, this car can charge up to 570Km worth of energy in one hour and with a 230V charging socket it is possible to charge up to 230Km worth of energy overnight [30]. The maximum achievable range of this vehicle is 735Km. The solar cell used in this vehicle can charge up to 12 Kilometer per Hour (Km/H) during sunny days [30]. And 83 Watt Hour per Kilometer (Wh/Km) of energy is used by the motor. Figure 2 shows all the components used in a solar power vehicle. Including all the benefits this technology also has limitations which are explained in Table 6.

F. HYDROGEN FUEL CELL VEHICLE

Hydrogen fuel cell electric vehicles are alternative to gasoline vehicles. Fuel cells use hydrogen (H) and oxygen (O) to generate electricity. As hydrogen reacts with oxygen rapidly and creates water. In fuel cell technology hydrogen is on a negative electrode of catalyst and oxygen is on a positive electrode of catalyst and then hydrogen passes through Polymer Electrolyte Membrane to make the reaction happen, so the water has formed that make it beneficial as explained in table 7. Figure 2, shows the abstract working of fuel cell vehicles.

TABLE 7. Hydrogen fuel cell vehicle.

Pros	Cons
Zero CO <sub>2</sub> Emission	Increase Cost of production
Higher energy efficiency that gasoline power engine	Increase cost of mobility
Regenerative braking system captures energy and reuses it	Consumer Education
No dependence on fossil fuel	Standard Development
Maximum torque at 0 RPM	Availability and affordability of hydrogen Fuel
-	Radiation
-	Hydrogen container needs to be tougher
-	High burning temperature

Issues like high production cost [31] and burning temperature up to 500°C high make it riskier [15].

All the above-mentioned sources of energy for vehicles have their pros and cons, like how it affects the fuel efficiency and cost from production to operational, as presented in this section. In the next section, we proposed a framework in which we attempt to achieve the benefits seen in the pros of these different energy resources. For example, the benefits of EVs like zero emissions and maximum torque at zero round per minute (RPM) can be achieved using an electric motor to drive the vehicle. The long-range problem can be removed, by adding a small 660 CC gasoline engine to charge the battery pack. We propose Solar panels mounted on the roof to also help charge the vehicle, and to reduce the emissions produced by gasoline engine while charging.

### III. A NOVEL HYBRID FRAMEWORK FOR MODERN VEHICLES

This section will provide a brief overview of the proposed framework of presenting the requirements of each component and configuration details about their attachment.

#### A. OVERVIEW

Our framework will improve fuel efficiency and reduce CO<sub>2</sub> emissions of future vehicles. Figure 3, expresses how to combine all three energy sources - electric, gasoline and solar power - to make one better technology that is less expensive and also have the benefits of all three sources. First, the vehicle can be charged using a 240 Volt (V) charging socket. We use a small engine (660 CC) to run a power generator to charge the vehicle. Further, a solar roof will also help to charge it so that the low cost of charging can be achieved. It will help to charge a 10 kWh battery pack. When the vehicle decelerates, energy is captured and stored in the battery pack with the help of the regenerative braking system. In countries like Pakistan sunlight can be used to charge the vehicle minimum of 8 hours daily. In our scenario, 8 hours of sunshine can charge up to 76.8Km daily. It is enough for the daily use of an in city driven vehicle. An inverter used to manage the heterogeneity ways of charging this battery pack. In this way, the cells of these battery packs will be saved from overcharging. Each Component is explained below.

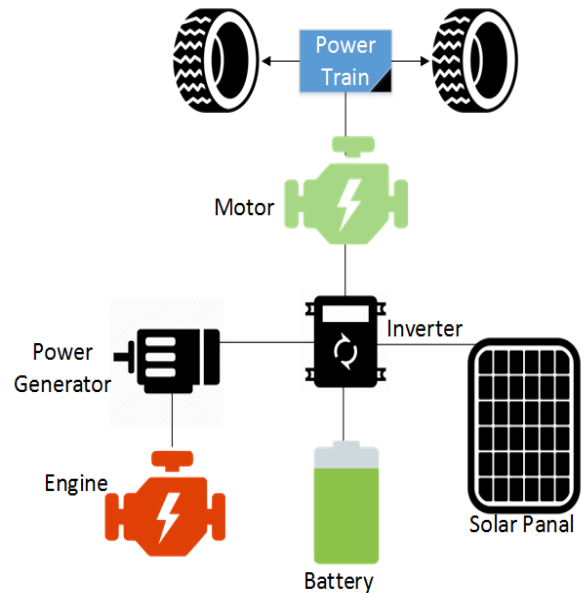


FIGURE 3. The proposed hybrid framework for modern vehicles.

#### 1) ENGINE

Gasoline engines are used in hybrid and E-Power vehicles. Petrol engines are used for LD vehicles as they are more efficient and reliable; diesel engines are used for HD vehicles. A petrol engine of 660 CC is cheap and easy to maintain, making it particularly attractive to developing countries. Further, many developing countries have low custom duty on engines that are smaller than one liter. Four-cylinder engines are more stable than a 3-cylinder, and turbocharged engines can be used to increase horsepower. However, both the four-cylinder and turbocharged engine are larger than a three-cylinder engine and consume more fuel. So that it can easily charge the battery pack. Here, we use a three cylinder 660 CC Daihatsu Dynamic Variable Valve Timing-intelligent (DVVT-i) [32] engine of 64 (Break Horsepower) BHp is used to run power generation which is of only 47 Kilogram (Kg) and will produce 64BHp and 47 Kilowatt (Kw) at 6400 RPM [28] whereas only 4Kw of energy is needed from the engine to charge the battery pack. 4Kw is equal to 5.4BHp which can be achieved with an additional 600RPM. It makes the vehicle so fuel-efficient engine that will only consume 1.67 liters of fuel per hour with the lowest CO<sub>2</sub> emissions vehicle with 41.52 G/Km.

Why do we choose a small engine? Because it is lightweight and waste less energy to maintain its working stability whereas big engines waste more energy due to its heavy power train(crunk).

#### 2) MOTOR

There is a choice of an AC or DC (direct current) motor. Each type has its benefits and limitations. AC motors are solid, cheap, reliable, and easy to maintain. AC motors are generally used in modern vehicles, because of their effortlessness, tough development, unwavering quality, and simple construction [33]. In the proposed system a three-phase

**TABLE 8.** Mapping and Combination of if/then Rules.

Rule No.	Condition	Action
1	IF actualCharging= Small AND target = Medium THEN	Large
2	IF actualCharging = Large AND target = Medium THEN	Small
3	IF actualCharging= Very Large AND target= Medium THEN	Very Small
4	IF actualCharging = Very Small AND target = Very Large THEN	Very Large
5	IF actualCharging =Medium AND target = Medium THEN	No Change

induction motor will be used to drive the vehicle. It will provide better performance than others as is analysed in [33]. Electric vehicles require higher power motors (perhaps 300 to 400 bhp) [33] than hybrid vehicles (which require 40 to 70 bhp) [27], [29]. Our proposal delivers 54bhp.

### 3) BATTERY

Electric vehicles, such as those from Tesla, use 60KWh to 100KWh battery pack. However, it is usually too expensive and difficult to replace if any damage occurs to their cells. Manufacturing of such a large battery pack would emit 74% more  $CO_2$  that manufacturing a gasoline vehicle [34]. The charging system of Tesla battery packs is innovative, that it charges each cell individually so cells will not damage by overcharging and heating. Water coolant will also be used to cool down the battery pack. 10KWh lightweight, compact, and the high-performance lithium-ion battery is used for our vehicle so it can easily be charged and maintained. Charging at 230V with 3.7KWh charging power can fully charge it under 3 hours.

### 4) INVERTER

Inverters are used to manage the power between the battery pack and the power supply. Inverters used by different companies such as Toyota can manage all other power supplies to charge the battery pack but for solar charging new components are required. Light year used the inverter to charge vehicle battery packs using solar cells as these cells provide DC voltages. Combining both techniques solved the problem of charging. It also manages the heterogeneous way of charging this battery pack and also converts DC and AC to manage electric power between the battery and electric motor. In this way, all the power will be managed by a single component. It is a Fuzzy Logic based algorithm to make the charging more efficient and fast.

The management system computes and assigns fast charging to battery pack based on three fuzzy inputs i.e., solar, engine, and 240V AC. Proposed scheduling algorithm 1 is used for the assignment of fast charging to the battery pack. The purpose of the proposed algorithm is to charge the Vehicle rapidly when multiple sources provide charging at the same time. Table 8, shows the knowledge base rules for our proposed algorithm. In algorithm 1, first **if** condition com-

### Algorithm 1 Multi-Source Charging Algorithm

**Fuzzy Logic:** The actual charging value  $aC$  of vehicle is computed by fuzzy logic system.

**Input :**  $Psolar$ ,  $engine$  and  $AC240$

**Output:**  $actualCharging$

**while** ( $Charging=true$ ) **do**

**if** ( $engine=true$  and  $AC240=true$  and  $Psolar=true$ )

**then**

Find the charging power coming from solar combine it with  $engineCharging$  and  $AC240$  to compute  $actualCharging$ .

**if** ( $engine=true$  and  $Psolar=true$ ) **then**

Find the charging power coming from solar combine it with  $engineCharging$  to compute  $actualCharging$ .

**if** ( $AC240=true$  and  $Psolar=true$ ) **then**

Find the charging power coming from solar combine it with  $AC240$  to compute  $actualCharging$

**if** ( $AC240=true$ ) **then**

Select only  $AC240$  charging as  $actualCharging$

**if** ( $engine=true$ ) **then**

Select only  $engine$  charging as  $actualCharging$

**if** ( $Psolar=true$ ) **then**

Select only  $engine$  charging as  $actualCharging$

putes and combines three energy sources to enable efficient fast charging.

### 5) POWER GENERATOR

Power generators are used in hybrid and E-power vehicles to charge the battery pack. They are attached to the engine directly and give charging power to the inverter so the inverter will charge the battery pack. Nissan used a power generator in its Note E-power to charge the battery pack. A similar type of power generator is used to provide charging to the battery pack. Here a 4KWh power generator charges a 10KWh battery pack in 2.5 hours.

### 6) SOLAR CELLS

Nowadays energy driven and batteries are integrated into the energy source. Home appliances, mobile gadgets and electric vehicles use batteries. Batteries are energy limited and require recharging. For decades these batteries have used conventional ways of charging. But in the last decade companies have started developing multiple ways of charging such as using power generators and solar energy. Solar energy provides a free source of energy for charging battery packs. Light Year Company use solar cells to charge the battery of their vehicles so that they can reduce the load on conventional ways of charging a battery. Different types of solar cells are available in the market. Their prices are different with respect to their performance. A solar roof is used to charge the vehicle

**TABLE 9. Components of hybrid framework for modern vehicles and their capacity.**

Engine	Generator	Battery	Solar Roof	Solar Charging/day	Charging voltage	Charging Power	Motor consumption
660 CC	4 KwH	10KwH	.50 KwH	76.8Km	230V	3.7KwH	41.5 Wh/Km

**TABLE 10. The proposed hybrid vehicular framework.**

Pros	Cons
Cleaner Electric energy	High initial cost
Zero CO <sub>2</sub> emission	Solar cells cost
Regenerative braking system captures energy and reuses it	Battery technology need improvement
Low refuel and operational cost	Solar cells availability and replacement
Silent operation of vehicle	-
Maximum torque at 0 RPM	-
Cleaner Electric energy	-
Low operational cost	-
Gas station infrastructure	-
Solar energy used	-
Easily available fuel	-
No rang issues	-

battery pack. It can be easily mounted on the roof of vehicles and there is no need to change the shape and architecture of vehicles. The integrated design of Photovoltaics's (PV's) and the battery will serve as an energy-sufficient source that solves the energy storage concern of solar cells and the energy density concern of batteries [33]. In [33], a test was carried out to charge the battery and obtain nearly 100% electrical to battery charge efficiency on solar panels. As a light year one used a solar cell on the bonnet, roof, and boot lid that can provide 12Km/H range to battery [30] that is 96Km in 8 hour sunlight for an 80KwH motor. But if we only mount solar cells on the roof that will reduce the 50-60% charging capacity. Its charging capacity will be 500 Watt-hour (Wh). As our motor is 54BHp and its 41.5KwH, so on a sunny day, 8 hour of sunlight will charge it up to 76.8Km daily.

**IV. EXPERIMENTAL RESULTS**

Table 11, shows a table that compares these vehicle energy sources on the bases of some factors, mainly on engine BHp and CO<sub>2</sub> emissions G/Km. This table shows us that by combining the three energy sources solar, electrical and small gasoline power engines we can achieve the best fuel-efficient vehicle.

The CO<sub>2</sub> emissions of one liter combustion of diesel, gasoline, and kerosene combustion is 2.64, 2.36, and 2.53Kg respectively [35]. As 1 liter gasoline is equal to 750 G in which approximately 87% is carbon. In order to combust it requires 1740G of oxygen. So the equation of CO<sub>2</sub> per liter emissions for gasoline:

$$CO_2/L = 87\%of750_Ggasoline + 1740_GOxygen \quad (1)$$

And the equation to calculate the CO<sub>2</sub> per Km for gasoline:

$$CO_2/Km = \frac{liters/100Km \times CO_2/L}{100} \quad (2)$$

To convert power *P* from Kw to BHp:

$$P_{(Kw)} = 0.745699872 \times p_{(BHp)} \quad (3)$$

The equation to estimate maximum fuel consumed by gasoline engine per hour is:

$$GPH = \frac{SFC \times BHp}{FSW} \quad (4)$$

where *GPH* is a gallon per hour, *SFC* is specific fuel consumption and *FSW* is Fuel Specific Weight, this equation is applied when the engine is at maximum power and throttle. In our case, the engine will be at cruising speed that will help in consuming less fuel. For gasoline engines, the value used for *SFC* is .50 pounds per BHp and 6.1 pounds per gallon for *FSW*.

We compare different vehicle technologies to find the best match for low fuel consumption vehicles with maximum efficiency. 660 CC vehicles of 58 BHp with 41.5KwH motor and 10KwH battery give the best results with the most fuel-efficient hybrid vehicle.

Figure 5, shows the CO<sub>2</sub> emissions of vehicles with respect to their technology. As we all know, electric vehicle's CO<sub>2</sub> emissions is zero. Our proposed hybrid technology produced the lowest CO<sub>2</sub> emissions that is 41.52 G/Km which is better than any other hybrid technology available out there.

Figure 6 shows that combining EV's technology with gasoline provided us the best fuel-efficient vehicles. As seen in the figure that a 660 CC vehicle with 58 BHp and 54 BHp motor can achieve 57.6Km/L in best conditions. No other technology can be so fuel-efficient. PHEVs are close to achieving this efficiency but its engine has more BHp that produces more CO<sub>2</sub> emissions as shown above in figure 5.

Table 12 gives the comparison of gasoline, hybrid and EVs with respect to torque, CO<sub>2</sub> emission, and maintenance cost/ Km. As EVs have maximum torque at 0 RPM that's why its torque is high. However, its CO<sub>2</sub> emissions is 0 which makes it the lowest CO<sub>2</sub> emissions vehicle as compared to other hybrid and gasoline vehicles. The maintenance cost of EVs is extremely low as there is no fluid used in them. Only water coolant is used to maintain the temperature in batteries and motor.

To enable efficient fast charging, we compute actual Charging *aC* for that we find the charging power in watts coming from solar *s* and combine it with engine Charging *eC*. As calculated in equation 5:

$$aC = eC + s \quad (5)$$

Similarly combining solar power with 240V AC can also charge vehicles quickly. For this we compute using the following equation:

$$aC = s + AC240 \quad (6)$$

where *s* is solar actual watt and AC240 is the voltage of home.

$$aC = s + AC240 + eC \quad (7)$$

**TABLE 11. Comparison of different vehicular technologies.**

Vehicles Technologies	Gasoline 1.8	Gasoline 1.0	Gasoline .660	E-power 1.2	PHEV 1.8	Electric Vehicle	Solar Electric Vehicle	Proposed .660	Proposed 1.0	Proposed 1.8
Engine Power BHp	139	69-72	64	80	95	-	-	58-64	69-72	139
Engine Type	1.8 litter 4 cylinder DOHC with VVT-i	1.0 liter 3 cylinder DOHC VVT	.660 liter 3 cylinder DOHC VVT	1.2 liter 3 cylinder	1.8 litter 4 cylinder DOHC with VVT-i	-	-	.660 liter 3cylinder DVVT	1.0 liter 3 cylinder DOHC VVT	1.8 litter 4 cylinder DOHC with VVT-i
Estimated Range Km/L	13.17-18	27.6	27	34	22-56.54	-	-	57.6	30	27.12
Real Range Km/L	11-15	18-22	20-22	26-30	20-50	-	-	TBC	TBC	TBC
Estimated l/h	-	-	-	-	-	-	-	1.67	1.67	3.55
Estimated Kw/h	-	-	-	-	-	-	-	4	4	8
EV Range Km	-	-	-	-	40	408-537	575-725	194-240	96-125	194.4-240
CO <sub>2</sub> emissions G/Km	128	84	88.57	62	112.46	0	0	41.52	79.73	88.20
CO <sub>2</sub> emissions g/l	2304	2318.4	2391.39	2108	2464	0	0	2319.39	2318.4	2304
Motor Power BHp/Kw	-	-	-	107/80	26/19	340/250-447/333	107/80	54/40	107/80	107/80
Motor Type	-	-	-	AC synchronous	Permanent magnet AC synchronous	Permanent magnet AC synchronous	In-wheel electric hub motor	AC synchronous	AC synchronous	AC synchronous
Battery Capacity KwH	-	-	-	1.5	8.8	50-75	60	10	10	20
AC Charging Time 240V hours: minutes	-	-	-	2:10	5:40-8:19 @ 32A 7:23-10:50 @ 48A	16:26-20:43 @15.21A	2:42 @15.41A	2:42 @15.41A	4:50 @15.41A	-
AC Charging 240V Km/H	-	-	-	-	19	48-70	35	90	45	45
Solar Charging Km/H	-	-	-	-	-	-	12	9.6	4.8	7.2
Solar Roof m <sup>2</sup>	-	-	-	-	-	-	5	2	2	3
SR Charging KwH	-	-	-	-	-	-	1.25	.50	.50	.75
Motor Wh/Km	-	-	-	83-104	15.534	102-211	83-104	41.5-52	83-104	83-104

We will use these equations to compute fast charging to charge vehicles more efficiently and in less time. Further, we have tried to combine all three energy sources to charge the vehicle in even lesser time.

Figure 4 shows the charging time of different energy sources like engine, solar, and AC 240V. Charging time is shown on X-axis whereas battery capacity is shown on Y-axis. We also simulate the charging time by combining these

**TABLE 12. Performance of EV, Gasoline and Hybrid vehicles.**

Energy Source	Torque	CO <sub>2</sub> Emission	Maintenance Cost /KM
gasoline	Low	High	High
Hybrid	Medium	Medium	Medium
EVs	High	Low(0)	Low

mediums to check fast charging times and we found that by combining all three energy sources we get the minimum time



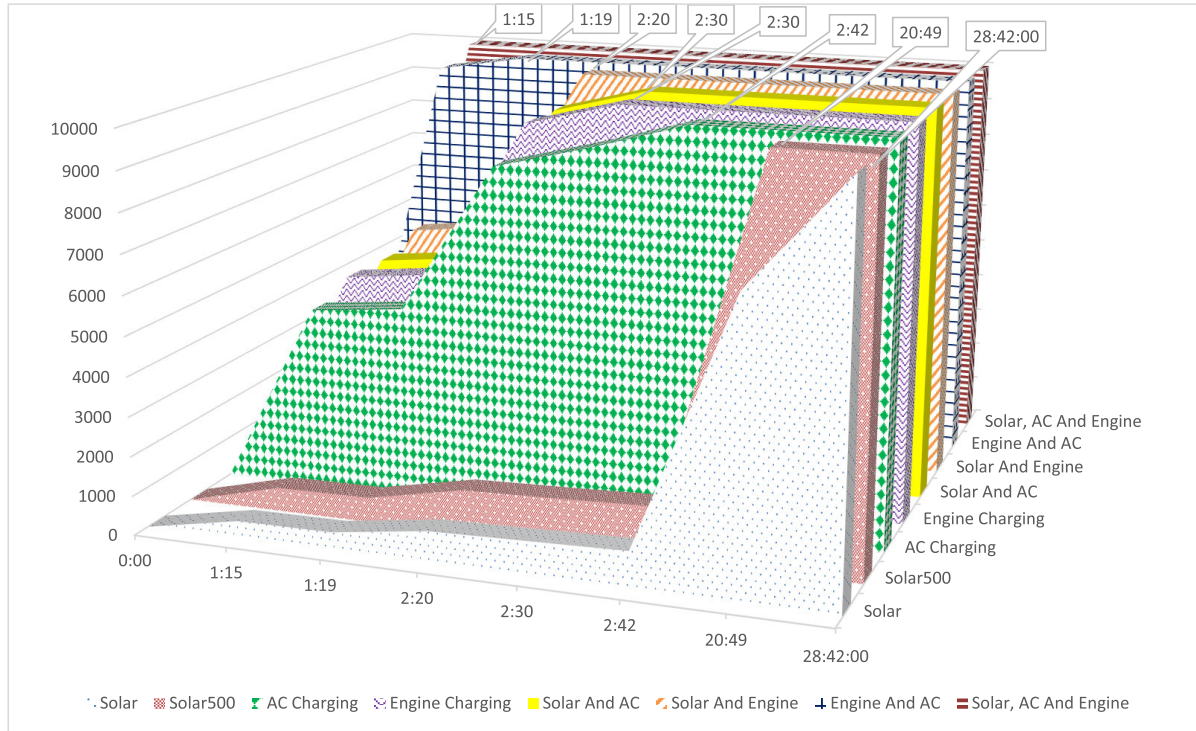


FIGURE 4. Charging time of different energy sources.

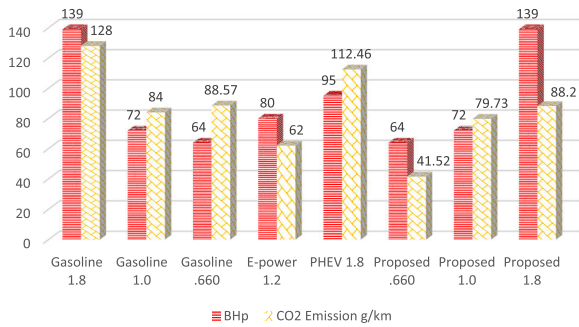


FIGURE 5. BHP vs CO<sub>2</sub> Emissions.

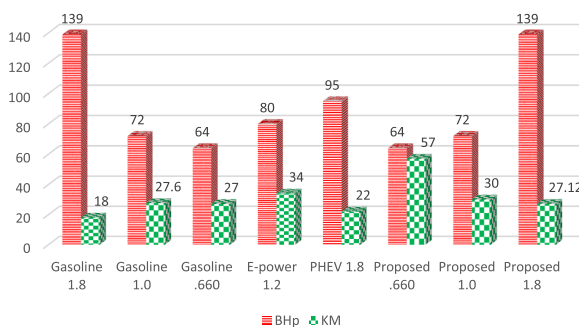


FIGURE 6. BHP vs km.

for charging 10Kwh battery pack of 1 hour and 15 minutes. Here we simulate charging time of this battery pack using

constant solar energy of 500 W and also random. As solar cells do not give constant energy so its charging time varies.

### V. CONCLUSION

In this paper, we proposed a framework to solve a major transportation problem regarding CO<sub>2</sub> emissions, vehicle mileage, and longer range. Our proposed system uses fuzzy logic to manage the energy resources i.e., electric, solar, and gasoline power, efficiently. A small change in EVs architecture made it possible to provide all these energy resources to the fuzzy logic system to solve the longer range and CO<sub>2</sub> emissions issues. We evaluated our proposed framework and found promising results i.e., our proposed framework provides 111% more mileage and 53% lesser CO<sub>2</sub> emissions than any existing solution does for a 660 CC gasoline engine. It has also reduced the charging time of the vehicle’s battery pack i.e., using three energy resources take 1 hour and 15 minutes to charge a 10Kwh battery pack. We used fuzzy logic to manage energy resources efficiently; however, we aim to use other Artificial Intelligence (AI) techniques in the future to improve the proposed system for further reduction in CO<sub>2</sub> emissions and efficient management of energy resources to achieve better mileage in the longer range under different driving conditions.

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