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# Fabrication and Testing of Hybrid Electric Vehicle

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**ABSTRACT - Better fuel economy and reducing the toxic emissions are achieved by running the vehicle with two sources of energy, such as an electric motor and an IC engine. Hybrid vehicles are designed to reduce emissions rather than minimize petroleum consumption. In the present work, two batteries with a capacity of 24 volts each are used to run the electric motor, which is fitted in the front wheel. A wind turbine is fitted in front of the vehicle to generate electrical power which is stored in the batteries. A DC charge controller is fitted in the vehicle to control charging and discharging the batteries as also control the speed of the motor. The performance of the vehicle is tested by three different modes of operation for three different loads on the engine, and the test results show that the electric mode gives better cost-effective operation and the hybrid mode gives better performance compared to other modes of operation.**

**Key Words: Hybrid vehicle, Electric vehicle, Hybrid mode, Electric mode, Battery powered vehicle**

## I. INTRODUCTION

The most commonly adapted hybrid electric vehicle (HEV) combines the propulsion sources of an electric motor and an I.C. engine. The power supply to the electric motor comes from onboard batteries. In a HEV, the I.C. engine cooperates with an electric motor, which leads to a more optimal use of the engine. Driving in city traffic involves frequent starts and stops of the vehicle. During idling, the engine consumes more fuel without producing useful work, thus contributing to higher fuel consumption, less efficiency, and unnecessary emissions from the exhaust.

The HEV solves the problem by switching to power transmission through the motor and shutting off the engine. This way, no fuel will be consumed during idling with no exhaust emissions. Another advantage of HEVs is that when the fuel tank gets empty while driving the engine, the vehicle can be driven on electric power within its maximum range. The major challenges for HEV design are managing multiple energy sources, being highly dependent on driving cycles, battery sizing, and battery management. HEVs take advantage of electric drive to compensate for the inherent weakness of I.C.engines, namely avoiding idling, increasing fuel efficiency, and reducing emissions during starting and speeding operations, and using regenerative braking instead of mechanical braking during deceleration and down slope driving.

Manoj et al. (2010) have implemented a smart boost converter to enable an electric bicycle to be powered by a battery/super capacitor hybrid combination. A front hub motor was retrofitted onto a normal geared bike powered by a lithium-ion phosphate battery pack. Based on the implemented system, experimental results show an improvement in the up-hill acceleration of the bicycle as a direct result of the boost converter being responsive enough to harvest the extra current from the high-power complementary super capacitor module, avoiding deep discharges from the battery. Kartik et al. (2016) have designed and developed a solar hybrid bicycle. This solar bicycle is an electric vehicle that provides that alternative by harnessing solar energy to charge the battery and thus provide the required voltage to run the motor. A hybrid bicycle combines the use of solar energy as well as the dynamo that runs through the pedal to charge the battery to run the bicycle. Thus, solar hybrid bicycles can become a very alternative to fueled automobiles. The result analysis of this setup is more effective than fuel.

Prashant Kadi and Shrirang Kulkarni (2016) have done a study on the hybrid powered electric bicycle. In this system, there are three different ways of charging a battery: solar power, dynamo, and AC wall charge. The power from these three modes is used to charge an electric permanent magnet DC motor running a bicycle. The hybrid powered bicycle is designed in such a way that the rider can have two modes of operating the bicycle, that whether he chooses to drive to drive it completely with the electric PMDC motor or manually by himself. The driver is choosing from various sources in a suitable climate. This design reduces fuel consumption and produces more power.

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John Kuria et al. (2012) have designed a hybrid conversion kit that can be implemented on factory made motorcycles to improve their efficiency and performance. In this kit, they have included a brushless DC motor, which can be fitted inside the front wheel. The user has to select the modes of operation, which are: engine only, motor only or both the motor and engine (hybrid). The microcontroller allows the user to obtain all the characteristics of both the electric motor and the internal-combustion engine. The power output and efficiency of the vehicle can be increased. Both sources are applicable in this kit, and more power is required.

Sharada Prasad and Nataraj (2014) have studied the two independent propulsions: I.C. engines (ICE) and electric motors, which are independently operated for combined effort derivation in the total propulsion of the vehicle. The results of the study show that the ICE will be active in initial pickup, and the electric motor acts as a supportive propulsion driver. Adinarayana et al. (2014) have fabricated the hybrid petro-electric they explained the hybrid technology in the two wheeler sector and its feasibility on the road. This paper deals with an attempt to make a hybrid with electric start and petrol run.

Arun Eldho Alias et al. (2015) have bridged the hybrid technology with the gap between the current fossil fuel technology and zero emission. The hybrid bike system, the power is delivered both via an internal combustion engine and an electric motor. The electrical power is used to achieve either better fuel economy than a conventional vehicle, better performance and less pollution.

Kishore and Sanketh (2015) have fabricated a two wheeler hybrid vehicle. They have discussed the problems of air pollution, such as the problem of lost energy, as well as the need to reduce carbon emissions and dangerous pollutants. A lot of these technologies, whether it be turbo-chargers to improve fuel efficiency, catalytic converters that can remove dangerous gases, or drive train technologies that address problems of wasted energy.

Sathya Prakash (2016) has fabricated a self-charging electric vehicle. The motor uses the electric energy from the battery, and the battery can receive electric energy from the dynamo; this energy is stored in the battery. This e-bike's running cost is very low when compared to other sources of energy. Today, available e-bike use batteries. Then these batteries are charged by the dynamo. So electric supply costs were also reduced.

Ramesh Babu et al. (2011) have studied the fabrication of dual power vehicle management and research. Hybrid vehicle increases twice the existing and also reduces the emission to half. They like to explore hybrid technology in the two wheeler sector and its feasibility on the road.

The objective of the present work is to design and modify a two wheeler by hybrid electric vehicle powered by either an IC engine or a battery and also by both. The combination of both powers makes the vehicle dynamic by nature. It provides fuel economy and reduces environmental impact over conventional automobiles. Hybrid electric vehicles combine an electric motor, battery, and power system with an internal combustion engine to achieve better fuel economy and reduce toxic emissions.

To achieve the above stated objectives, the following methodology is used:

- A vehicle model is analyzed, and the required power and energy are evaluated.
- A conventional two wheeler bike is converted into a hybrid electric two wheeler by retrofitting the BLDC hub motor on the front wheel.
- An experiment will be carried out on the engine and hub motor to estimate torque and power requirements for various conditions.

## II. MODELING OF A HYBRID ELECTRIC VEHICLE

Figure 1 depicts a schematic of a hybrid electric vehicle drawn in AutoCad. The throttle is fixed on the left side of the vehicle. The front wheel of the vehicle is replaced with the hub motor. The batteries are placed under the seat. The DC controller is fixed in the middle of the vehicle. The generator is fixed at the front of the vehicle.

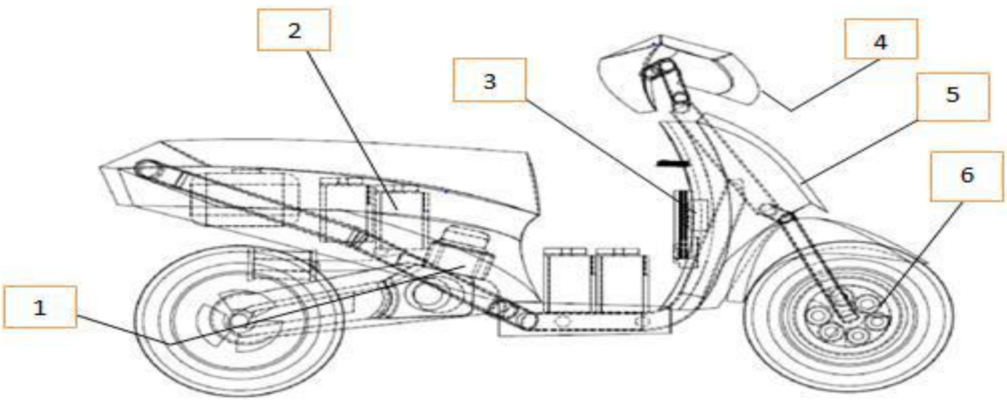


**Figure 1: Schematic of a Hybrid Electric Vehicle**

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1. IC Engine
2. Batteries
3. DC Controller
4. Throttle (accelerator)
5. Generator
6. Hub Motor

## III. COMPONENTS OF A HYBRID ELECTRIC VEHICLE

An IC engine is a device that transforms one form of energy into another, and if an engine converts thermal energy into mechanical work, it is called a heat engine. A heat engine converts the stored chemical energy of the fuels to thermal energy, and finally, this thermal energy is converted to mechanical work. Specifications for the IC engine are given in Table 1.

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### DC Controller

A DC controller is an electrical device that is used to control the generator and electric motor in between power circuits. The DC controller is used to control the brake light, electrical brake, headlight, and throttle, and it helps charge and discharge the batteries.

**Table 1: Engine Specifications**

| Specifications | Range |
|---|---|
| Type of Ignition | Spark Ignition |
| Engine Displacement | 59.90cc |
| Engine Type | Single Cylinder, 2 stroke |
| Cooling type | Forced air cooled |
| Starting | Kick start – Electric start |
| Mileage | 45 kmpl |
| Max power | 3.5 bhp@5500rpm |
| Max torque | 4.5 Nm@5000 rpm |
| Top speed | 60 kmph |

The controller connects the power source to the motor. It controls speed and direction of rotation and optimizes energy conversion. The specification of the DC controller is given in Table 2. The DC controller is fixed in front of the vehicle, just below the handle, as shown in Figure 2. The red and black wires of the controller are connected to the power input of the battery, and the yellow, blue, and green wires are connected to the hub motor. The red, green, and black wires are connected in the throttle to regulate the speed.

**Table: 2 Specifications of the DC Controller**

| Description | Specifications Range |
|---|---|
| Rated Voltage | 24 V |
| Rated Power | 500 W |
| Rated Current | 30 A |
| Voltage protection | 20+ -0.5 V |
| Current limited | 30+ -0.5 A |
| Consumption | 1.5 W |

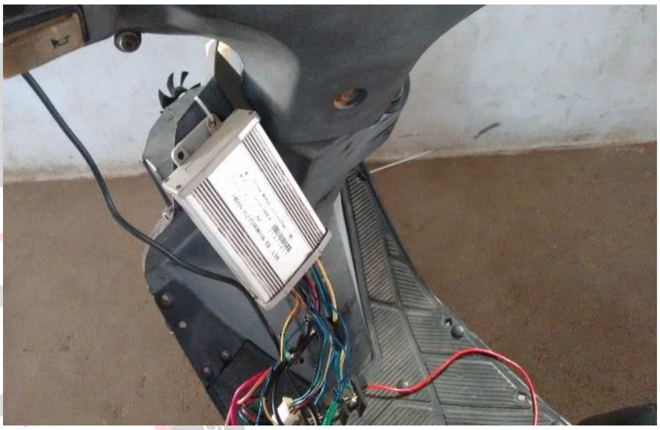

**Figure 2: Photographic view of the DC Controller Battery**

Batteries are devices that consist of electrochemical cells and provide electrical energy converted from stored chemical energy. The batteries are kept under the seat in the luggage compartment of the vehicle, as shown in Figure 3, and all the batteries are connected in series. The specifications of the battery are given in Table 3.

**Figure 3: Photographic view of the batteries located in the two wheeler**

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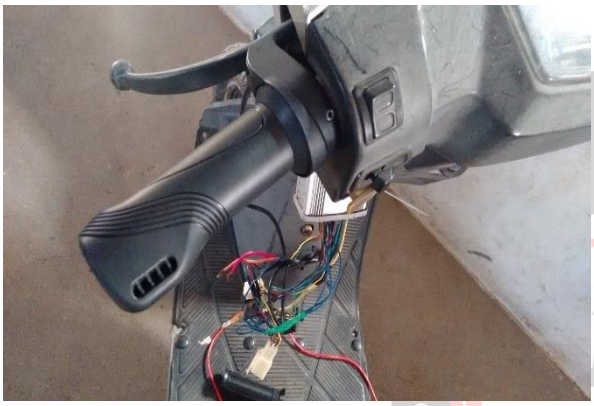
**Table 3: Specifications of the Battery**

| Specification | Range |
|---|---|
| Number of batteries | 2 |
| Voltage | 48 V |
| Battery Current | 26 Ah |
| Battery Weight | 36 Kg |

### Throttle (Accelerator)

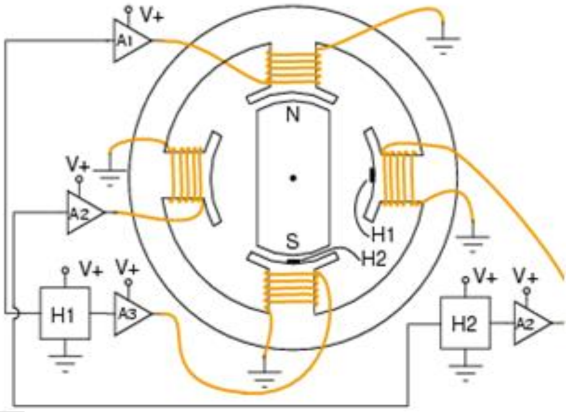
The throttle is replaced on the left side of the handle. The throttle is used to control the speed of the hub motor under different load conditions. It is easy to handle, and it is also more flexible for the driver to adjust the speed. The photographic view of the throttle is shown in Figure 4.



| Specifications | Range |
|---|---|
| Voltage | 48V |
| Power | 250 W |
| Speed | 250 to 900 rpm |
| Torque | 3 to 7 N-m |
| Load carrying capacity | 220 kg |
| Efficiency | > 85 % |
| Noise | < 50 DB |
| Speed | 30 – 40 km / hr. (max) |

**Figure 4: Photographic view of the Throttle**

The hub motor is fixed to the front wheel of the vehicle, and this hub motor is a closed-loop synchronous motor. Offer the benefits of hub motors, such as compactness, noiseless operation, and high efficiency, for electric vehicles. These motors have stators fixed at the axle, with the permanent magnet rotor embedded in the wheel. The electric power is supplied by the magnet, which is energized to run the vehicle in a counterclockwise direction. The main reason for choosing a hub motor is that it does not require a transmission system. Therefore, it helps reduce transmission losses. It has greater traction control. The back emf created by the BLDC motor can easily be stored in the batteries, and it has a high load carrying capacity. The circuit diagram of the hub motor is shown in Figure 5 (a), and a photographic view of the hub motor located on the front wheel of the vehicle is shown in Figure 5 (b). The detailed specification of the hub motor is given in Table 4.




**5 (a) Circuit diagram of Hub motor**

**5 (b) Photographic view of Hub motor**

**Table 4: Specifications of the hub motor**

### Generator

The generator is fixed in front of the vehicle. The principle of the generator is that the rotational force or mechanical energy is converted into electrical energy, and the energy is stored in the batteries. The output voltage of the generator varies from 6 V to 38 V, and the range of speed is 240 rpm to 900 rpm. The photographic view of the generator is shown in Figure 6.


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**Figure 6: Photographic view of the generator**

Photographic View of the fabricated hybrid electric vehicle is shown in Figure 7.

**Figure 7: Photographic View of a Hybrid Electric Vehicle**

## IV. MODES OF OPERATION OF HYBRID ELECTRIC VEHICLES

There are four different modes of operation for the vehicles. They are:

### Mode 1: Operates on an internal combustion engine alone

The vehicle is run by IC Engine alone. The accelerator is used to vary the speed of the vehicle by using the clutch plate. Here, the electric power is idle.

IC Engine → Clutch Plate → Transmission link → Wheel

### Mode 2: Operates on an Electric motor alone

Batteries release the electric energy to pass through the motor by using power electronics. The electric power is used to actuate the motor, and it rotates the wheel. The throttle is used to vary the speed of the motor under different load conditions. The different loads are applied by using power electronics, and the speed of the vehicle is measured by using a tachometer.

Batteries → Power Electronics → Motor → Wheel

### Mode 3: Hybrid Mode: Operates on both the Internal combustion engine and the electric motor

The hybrid mode is a dual energy source applied to the vehicle. Fuel energy is used to actuate the engine, and at the same time, electric power is used to actuate the motor. The different loads are applied to the vehicle, and the speed of the vehicle is observed with respect to the various loads.

Engine → Transmission Link → Motor → Wheel
↑
Battery → Charge Controller

### Mode 4: Operation of Battery Charging

A small fan is running when the vehicle is running on the road. The fan is directly connected with the shaft of the generator. The generator converts the rotational (mechanical) energy into electrical energy, and this power is stored in batteries through a charge controller.

Generator → Charge Controller → Batteries

## V. CALCULATION OF TORQUE

**Specification (Electric mode)**

Battery voltage = 48 V

Battery current = 26 Ah

Generator voltage = 36 V

Generator current = 8 Ah

Hub motor power capacity = 250 W

Battery capacity

= (battery voltage) × (Battery current)

Generator capacity

= (Generator voltage) × (generator current)

**1. Battery Charging Time**

= (Battery capacity) / (Generator capacity)

= (48×26) / (36×8)

= 4.30 hours (without fluctuation)

**2. Battery Discharging Time** $T_d$

= (Battery capacity) / (Hub motor capacity)

= (26×48) / 250 = 4.9 hours (without loss)

$T_d = (5 \times 40) / 100$

= 2 hours (with 40% loss)

**3. Torque calculation for electric motor**

Torque (T) = $(P\times60) / (2\pi N)$

Hub motor power (P) = 250 W

Speed (N) = 335, 237, 118 rpm

Torque at 335 rpm

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= (250×60) / (2× $\pi$×335)

= 6.72 Nm

Torque at 237 rpm

= (250×60) / (2× $\pi$ ×237)

= 10.07 Nm

Torque at 118 rpm

= (250×60) / (2× $\pi$ ×118)

= 20.23 Nm

## VI. RESULTS AND DISCUSSION

Tests are conducted on the vehicle by varying the load and the test results are explained in this section.

### Electric mode

Figure 8 shows the variation of speed with respect to load on the vehicle run by electric motor alone. When the load on the vehicle increases, the corresponding speed of the vehicle is decreases. When the load on the vehicle is 60 kg, the corresponding speed is 335 rpm. The load on the vehicle is increased to 70 kg, and the corresponding speed is 237 rpm. The load on the vehicle is increased to 80 kg, and the corresponding speed is 118 rpm. The corresponding speed-load ratios are 5.58, 3.38, and 1.475. The ratios are gradually decreasing.

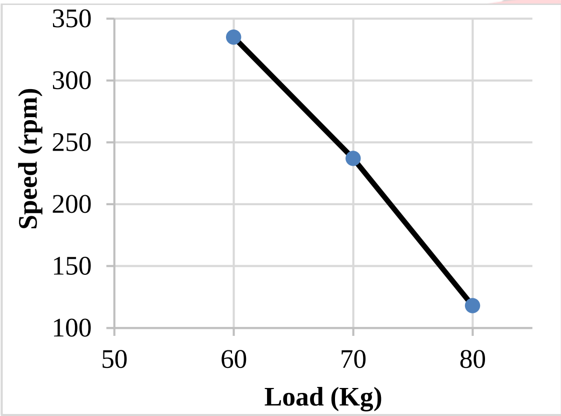


**Figure 8: Variation of speed with respect to load on the vehicle run by electric motor**

Figure 9 shows the variation of speed with respect to torque of the vehicle run by electric motor alone. It is seen from the figure that when the load on the vehicle is 60 kg, the corresponding speed and torque are 335 rpm and 6.72 Nm; when the load is increased to 70 kg, the corresponding speed and torque are 237 rpm and 10.07 Nm; and when the load is increased to 80 kg, the corresponding speed and torque are 118 rpm and 20.23 Nm. It is construed from the above graph that as the load on the vehicle increases, the corresponding torques of the vehicle are increased, and at the same time, the speed of the vehicle decreases. The corresponding speeds to torque ratios are 49.82, 23.53, and 5.83. The ratios are gradually decreasing.

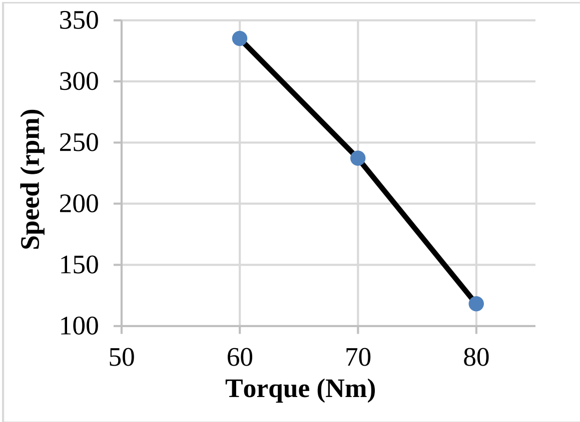


**Figure 9: Variation in speed with respect to torque of the vehicle is run by an electric motor**

### Hybrid Mode

Figure 10 shows the variation of speed with respect to the load on the vehicle run by both IC engine and electric motor. When the load on the vehicle is 60 kg, the corresponding speed is 620 rpm. The load on the vehicle is increased to 70 kg, and the corresponding speed is 523 rpm. The load on the vehicle is increased to 80 kg, and the corresponding speed is 335 rpm. The corresponding speed and load ratios are 10.33, 7.47, and 4.17. The ratios are gradually decreasing.

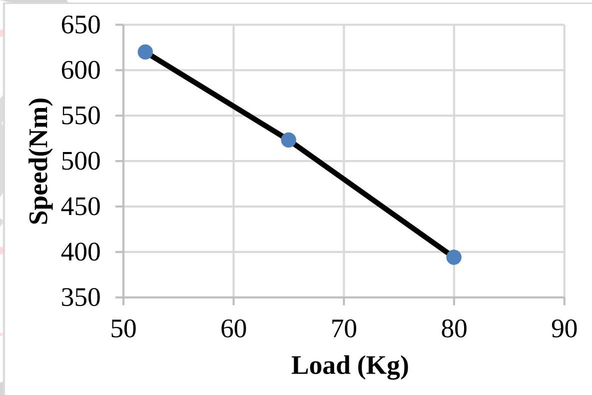


**Figure 10: Variation of speed with respect to load on the vehicle run by both an IC engine and an electric motor**

Figure 11 shows the variation of speed with respect to torque of the vehicle run by both IC engine and electric motor. When the torque increases, the speed of the vehicle decreases. When the load on the vehicle is 60 kg, the corresponding speed and torque are 620 rpm and 43.9 Nm. The load on the vehicle is increased to 70 kg, and the corresponding speed and torque are 523 rpm and 52 Nm. The load on the vehicle is increased to 80 kg, and the corresponding speed and torque are 394 rpm and 69.72 Nm. It is construed from the above figure that as the torque of the vehicle increases, the speed of the vehicle decreases. The corresponding speed and torque ratios are 14.12, 10.05, and 5.65. The ratios are gradually decreasing.

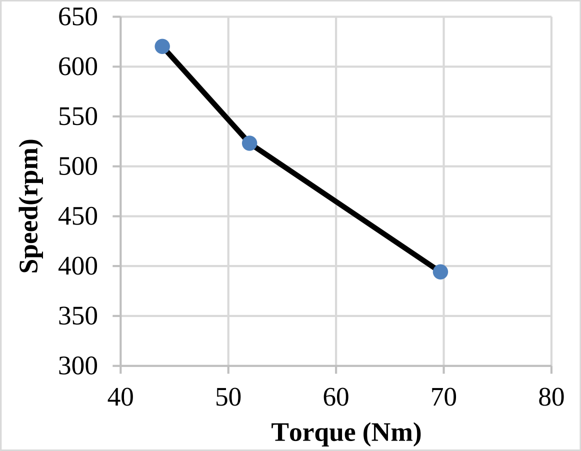


**Figure 11: Variation of speed with respect to torque of the vehicle run by both the IC engine and electric motor**

It is observed from Figures 8 to 11 that for the same load on the engine hybrid mode, gives better torque and speed compared to electric mode. It is construed that the hybrid mode produces torque 3.5 to 6.5 times that of the electric mode. It is suggested that when the vehicle is climbing up the hill and for better torque, the vehicle is run in hybrid mode.

## VII. COST ANALYSIS

A cost analysis was carried out to estimate the distance traveled per km of the vehicle for all three different modes of driving the vehicle. Table 5 shows the cost per km distance traveled by the vehicle for three different modes of operation. The cost per km is Rs 0.6, when the vehicle is run by an electric mode. If the vehicle is run by hybrid (both an IC engine and an electric motor) mode the cost per km is Rs 2.5, which is still lower than the cost per km if the vehicle is run in IC engine.

**Table 5: Cost Estimation per km of Distance Traveled by the Vehicle**

| Mode of operation of the vehicle | Load on the vehicle in kg | Cost in rupees | Distance travelled in km | Cost per km of distance travel in Rupees |
|---|---|---|---|---|
| Run by IC engine using petrol | 60 | 94 / liter | 40 | 1.9 |
| Run by electric motor using stored energy in the batteries | 60 | 18 / 1.25 W units of electrical charge | 30 | 0.6 |
| Run by both IC engine and electric motor | 60 | 94 / 1 liter petrol + 1.25 W unit of electrical charge | 70 | 2.5 |

## VIII. CONCLUSION

In the present work, the electric motor is fitted in the front wheel, and its accelerator is fixed in the handle (12V and 26A) for driving the vehicle in electric mode. Two 24V batteries are used for charging and discharging the electrical energy, and they are kept under the seat. A 250W DC controller is used to control the accelerator, motor, and battery. Also, a wind generator is fixed on the front side of the vehicle to generate the additional electrical energy needed to charge the battery. The vehicle is run in IC engine mode, electric motor mode, and both IC engine and electric motor modes. It is construed from the test results that when the vehicle is run in electric motor mode, the running cost is very low compared to the other two modes. It is also observed that the performance of the hybrid mode (run by IC engine and Electric motor) gives better results compared to other two modes.

## REFERENCES


[1] Manoj.E, Dino Isa, Roselina Arelhi, "Super capacitor/Battery hybrid Powered Electric Bicycle via a Smart Boost Converter", World Electric Vehicle Journal, Vol. 4, Nov 2010

[2] Kartik S Mishra. Shivprakash B Barve, "Design and Development of Solar Hybrid Bicycle" International Journal of Research in Engineering and Technology (IJRET) Vol.2,Sep 2016, pp. 377-381.

[3] Mr.Prashant Kadi, Mr.Shrirang Kulkarni, "Hybrid Powered Electric Bicycle", IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 05, 2016, pp. 1017-1020

[4] John P Kurian, Jithin George, Jibin A V, Muhammad Majas K M, "Performance Aiding of Motorcycles using Hybrid Technology" International Journal of Research in Engineering and Technology (IJRET), Vol. 3, Issue 5, PP. 655-657, 2014.

[5] Sharada prasad N, K R Nataraj, "Design and Development of Hybrid Electric Two Wheeler Suitable for Indian Road Conditions", International Journal of Electrical, Electronics and Data Communication, Volume-2, Issue-9, Sept.-2014.

[6] G. Adinarayana, Ashok Kumar, M. Ramakrishna, "Fabrication of Hybrid Petro Electric Vehicle", Journal of Engineering Research and Applications, Vol. 4, Issue 10 (Part - 6), pp. 59-62, 2014.

[7] Arun Eldho Alias, Geo Mathew, Manu G, Melvin Thomas, Praveen V Paul, "Energy Efficient Hybrid Electric Bike with Multi -Transmission System", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 4, Special Issue 1, pp. 103-109, 2015.

[8] Kishore H, Sanketh S, "Design & Fabrication of Two Wheeler Hybrid Vehicle", International Journal of Science and Research (IJSR), Volume 6, Issue 3, pp. 1595-1598, 2017.

[9] M.Sathya Prakash, "Design and Fabrication of Self Charging Electric Vehicle", International Journal of Power Control Signal and Computation (IJPCSC), Vol. 8, Jan-March 2016.

[10] P.Ramesh Babu, M.Anil Kumar D. Prathap Varma, "Fabrication of Dual Powered Vehicle" International Journal & Magazine of Engineering, Technology, Management and Research" Vol. 2, Issue 7, pp. 188-195, 2015.


 DOI : 10.35291/2454-9150.2024.0095 