Fabrication of Hybrid Bicycle for Minimizing Pollutant Emissions

Tanuj Joshi¹, Ravikant Sharma², Vinod Kumar Mittal³, Vikas Gupta⁴, Om Parkash⁵

¹Department of Mechanical Engineering, Amity University Haryana, India
²Department of Mechanical Engineering, Amity University Haryana, India
³Department of Mechanical Engineering, NIT Kurukshetra, Haryana, India
⁴Department of Mechanical Engineering, CDLSIET, Panniwala Mota, Haryana, India
⁵Department of Mechanical Engineering, Amity University Haryana, India

Abstract. Hybrid power framework dependent on sustainable power sources i.e. particularly regenerative and solar energy. They are a successful choice to take care of the power-supply issue for motor. This paper exhibits an examination and plan of a hybrid bicycle framework for every day needs of little separation travel. The Hybrid Bicycle Framework utilizes two sustainable power hotspots for enhancing the framework effectiveness. The two sustainable power sources are Dynamo and sunlight based solar energy. Power produces by these two sources utilizes for charging the battery. Alternative Current (AC) adopter can likewise be used for charging the battery. A motor that drives the back-tyre fits over it and powered by the battery. This paper worries over the similar investigation of over three charging strategies. In present work we studied the battery charging timing at Ideal condition and at practical running conditions and presented with the help of the table and graph. In future work, further innovation is still required for enhancing and expanding the efficiency of charging.

Keywords: Hybrid, RFID, Relay, Accelerometer.

1. Introduction

Hybrid word implies the blend between various advancements to create Power. Hybrid can be utilizing in exceptionally immense sense in engineering. Hybrid Electric Vehicle (HEV) is the vehicles with in excess of two vitality sources are available. It uses the various vitality sources [1,2,3]. The HEVs arranged into two fundamental sorts’ series and parallel. The gapping between present petroleum derivative technology and zero emanation hybrid vehicles can be crossed over by hybrid technology [4]. The internal combustion engine is the greatest invention of human mankind. In any case, they have causes difficult issues for poor efficiency, environmental contamination and human life [5,6]. Petro Engines are not exceptionally effective engine and the last normal efficiency is 12-15% to 250% of its fuel content and the most part of energy are waste as a heat and drive train losses [7,8]. During the burning procedure of the fuel the discharge of toxic gasses creates i.e. Carbon Dioxide (CO2), Carbon Mono Oxide (CO) and Nitrogen Oxides (NOX).

A few political, financial and natural variables are adding to expanding enthusiasm for hybrid elective vehicle innovations. These components join rising overall enthusiasm for oil, comparing additions in fuel costs and anthropogenic ecological change [9]. Criticalness to wipe out (GHG) substance from all sources. GHG emission from the transportation part are increasing more quickly than from some other
monetary division and represented 28% of all out US GHG emission in 2004 [10]. The research demonstrates that 25% of CO2 generation originating from the US, and 33% of US CO2 originating from oil. Transportation shows that 28% of US energy use 70% of oil [11]. Greenhouse gases outflow from the transportation part is increasing more quickly than from other economic sector and INDIA is represented 5.7% of total GHG emanations in 2010 [12]. When the human and motor are arranged in series, then it is said to be series hybrid [13].

The exhaust gas from the engine causes the greenhouse effect and global warming. Because of these challenges, world is looking for hybrid technology sector [14]. Advancement in the hybrid bicycle has a massive development potential. Individuals attempt to move towards "clean and green" energy technology [15]. These assurances among other will create a base towards the hybrid bicycle industry on the most noteworthy purpose of the innovation. Hybrid bicycle consolidate human power with electric power [16].

The concept of Hybrid Bicycle consists a battery arrangement, which provide the power with the assistance of the motor and gearing mechanism to the rare tyre of the bicycle [17]. In addition, for charging of batteries there are three possible solutions, which are AC adopter (converts AC to DC), Dynamo (convert the rotational mechanical power to the electric power) and solar panel (utilize the solar energy to charge batteries) [18]. Bicycles with additional electric motor framework have a place with the hybrid vehicles, which are wholeheartedly fitting for standard regular customers. In face of steady environment talks and traffic issues, electric bikes/bicycles have the capacity of handling such task and making a more energy eco-friendly. So, it turns out to be exceptionally important to produce the electric cycles so efficiently that the ordinary citizens on the planet nation can bear to purchase it [19,20]. The most basic component of this bicycle is that it doesn't use huge non-sustainable power sources subsequently saving the money. It is eco-friendly and emission free and it is silent process [21]. People are effectively fit to convey the varying power 75 to 200 Watt through paddling over hours. That much power is adequate to run a cycle at steady speeds higher than 15 km/h in flat rods. However, against crosswind, on slopes, and especially in stop-and-go traffic power levels of up to several hundred watts non-athletic humans can deliver power above 200-watt levels only up to some minutes.

The battery discharges very soon because of its low current density. A smart microcontroller-based boost converter is utilized with 36V, 250W front centre hub motor that retrofitted onto an ordinary outfitted bicycle with lithium ion phosphate battery pack having a supercapacitor of 16.2V and 58F. The uphill acceleration is improved by a boost converter [22].

A research shows that if the total torque obtained by the ICE and electric motor synchronized for respective road gradient by varying suitably so with this type of arrangement, can enhance and improve mileage performance efficiently by 25% [23].

It is said to be regenerative because at one condition the motor works as a generator itself and provide the power [24]. The on-board efficiency of the electric drive vehicle is about 80%. However, with the assistance of the range extended electric vehicle innovation REEV with the distinctive driving cycles the energy effectiveness can achieve 33%, the extensive efficiency of the generator and rectifier can reach above 90% [25].

Purdue tracer is the new plan of approach for building up the light obligation hydraulic driven hybrid vehicle. Purdue tracer disposes of the exemplary chain-sprocket mechanical transmission from hybrid power transmission with electronic controls [26].

The simulation results and experimental outcomes demonstrated that the controller has effectively controlled the bike torque relying on the contribution from the pedal torque sensor [27]. Investigation of plug in hybrid electric vehicle demonstrates that, outflow of CO2 diminishes. It is the headway of the HEV [28,29].

Most car manufacturers are at present creating PHEVs and a few including GM, Toyota and Ford have reported plans to put up them for sale to the public inside the following two years [30].
2. Components Required

Table 1. Components requires for making hybrid bicycle

| Sr. No. | Components          |
|---------|---------------------|
| 1       | Dynamometer         |
| 2       | Solar Panel         |
| 3       | DC motor            |
| 4       | RFID System         |
| 5       | RFID Antenna        |
| 6       | RFID Tag            |
| 7       | LCD (16x2)          |
| 8       | Relay               |
| 9       | Accelerometer       |
| 10      | Gearbox             |
| 11      | Battery             |
| 12      | Voltage Regulator   |
| 13      | Wires and Switch    |

2.1. Dynamometer

A measuring device (dynamometer), or "dyno" for brief, may be a device for mensuration force, power and torque. They are of two types AC and DC dynamos [31]. Dynamo works on the principle of electromagnetic induction. When a conductor moves in an exceedingly force field, current is produced in it [32]. The direction is set by Fleming’s rule. Strength of the current relies upon:

- Magnet strength
- No. of turns of wire in coil

2.2. Solar Panel

Polycrystalline Solar Panels absorb solar radiation as a source of energy to generate electricity. This plate has a connect assembly of typically 4x6 photovoltaic solar cells. This framework generates and supplies solar power as wanted. Every module appraised by its DC output power below standard test conditions. A solitary solar module can deliver just a restricted power, for more power different modules required. An electrical photovoltaic framework for the most part incorporates an array of electrical photovoltaic modules, an electrical converter, and a battery pack for energy depot, interconnection wiring and a solar tracking system.

2.3. DC Motor

A DC motor might be a rotating electrical machine, which convert a form of energy electrical to mechanical output. The current conveying conductor set in the magnetic field; it experiences the mechanical force. This force produces the power. DC motor's speed might be controlled over a decent differ, either a variable give voltage or by dynamical the quality of current in its field windings.

2.4. RFID System

Figure 1. RFID system
Radio frequency Identification (RFID) is a programmed identification strategy where data put away on RFID labels or transponders, which remotely retrieved. It comprises of a reception apparatus or antenna, a transceiver handset (with decoder) and an electronically programmed transponder (RF tag) for special data. There are various distinctive types of RFID systems inside the market. These arranged on the basic of frequency range. Commonly, utilized RFID packs are low frequency (30-500 kHz), mid frequency (900 KHz - 1500MHz) and high frequency (2.4-2.5GHz) [33].

2.5. **RFID Antenna**

![RFID antenna](image)

The reception apparatus (antenna) transmits radio signs to actuate the tag & read/write informative data in it. It is the channel among the tag and transceiver, which controls the framework's information acquisition and for communication. Principally receiving wire packaged with decoder and transceiver to go about as a reader. The reader transmits radio waves from 2.5 cm to 30 meters or extra, contingent on its power capacity and frequency used. In our project maximum scope of radio waves are 4.5 cm.

2.6. **RFID Tag**

It incorporates a microchip containing perceiving information about the thing and a receiving wire used for transmitting data to the user. Most elementarily, the chip contains a sequential image or enlistment number, which unambiguously perceives that thing (like standard identifications i.e. bar codes).

2.7. **LCD (16×2)**

![LCD display (16x2)](image)

A Liquid Crystal Display (LCD) could be a flat board display, electronic visual screen, or video display unit, which utilizes daylight regulating liquid crystal property. 16x2 LCD has two even line which including a space of 16 showing digits/character.

2.8. **Relay**

![Relay](image)
A relay is a switch, which electrically worked. Relays are a unit which is utilized when directing a circuit by various low control signals, or wherever numerous circuits can confine by one signal. Magnetic power relay utilized in this venture. Magnetic latching relays will have either single or twin coils.

2.9. GY-61 3-Axis ±3g Accelerometer Sensor: ADXL335

![Figure 5. GY-61 3-Axis ±3g accelerometer sensor](image)

Module could be a three-axis measuring system (accelerometer sensor) detector module supported ADXL335 integrated circuit. The ADXL335 has a three-axis measuring system having very low noise and power intake and sensor having sensing range, which varies from +/-3g. It used to measure static acceleration because of gravity in tilt-sensing applications.

| Table 2. Accelerometer parameters |
|-----------------------------------|
| Parameters                     | Description         |
| Operating Voltage               | 1.8~5 V             |
| Range                           |                     |
| Supply Current                  | 350μA               |
| Interfaces                      | Analog              |
| Operating Temperature           | -40°~ 85°           |
| Dimension                       | 20.3mm×15.7mm×11.6mm|

2.10. Gearbox

The speed and torque of any automobile vehicle can achieve with the help of the gearbox at load or no-load condition. The gearbox, which used in this project, has simple gear ratios, which meet the requirement and having sufficient torque. Spur gear arrangement used for the gearbox. Gearbox powered by the DC motor and used to drive the rear wheel of bicycle with the help of chain.

2.11. Battery

A 12-volt Lead Acid DC battery utilized for the charging reason. This battery act as a source which intensity the cycle. In spite of having a less energy to-weight quantitative ratio and minor energy to-volume quantitative ratio, its capacity to deliver high surge currents implies the cells and has a relatively enormous power to-weight quantitative ratio. That is why we choose DC battery over other possibilities.

2.12. Voltage Regulator

Voltage regulator introduces in a solar bike and is commonly associated between the solar panels and battery. This is because that the power of the solar board is not constantly consistent and thus such a framework cannot be associating with battery directly.
3. Methodology

3.1. Working Method

- The working principle of the cycle is extremely basic an individual peddled the cycle and cycle will push to forward direction at simple condition.
- After certain time interim, when an individual worn out the speed of the cycle is diminished.
- For giving the additional power, the RFID Tag detected by the RFID Sensor. RFID sensor code contains the 16 digits. The system will on when initial 4 and last 4 digits are coordinated with the system.
- Then switch on, and battery offer power to the DC motor that drive the gearbox and the chain drive the back wheel.
- Hence, the cycle will accelerate.
- Because of the rotation of the tyre with the dynamo, this will create the power.
- The (+) ive and (−) ive terminals of dynamo are associated with the battery terminal which is utilized to charge the battery.
- The second technique is by the solar panel.
- Within the sight of the solar radiation, the solar panel will absorb the radiation power and convert the solar power to the electrical energy.
- The (+) ive and (−) ive terminals of solar panel are associated with the battery terminal which is utilized to charge the battery.
• The third strategy to charge the battery is by the AC adopter.
• Voltage regulator is utilizing in this cycle between solar panel and battery and between dynamo and battery. This is because the power output of the solar panel is not constantly steady.
• When solar and the dynamo both are associated with the battery terminal, the higher wattage framework will charge the battery, because power streams from higher to lower side.

4. Charging Methods
Three types of charging methods used which are following
• AC Adopter Charging Method
• Solar Charging
• Dynamometer Charging

4.1. AC Adopter Charging Method
It is a charging system in which the common house power is used to charge the battery. The lead acid battery uses the steady current steady voltage charge framework. A controlled current raises the terminal voltage until the higher charge voltage limit is come to close, at that reason this drop occurs. With the help of greater charge current and multi-stage charge systems, the charge time reduced to 8-10 hours.

![Figure 8. Charge stages of a lead acid battery [34]](image)

4.2. Solar Charging
Polycrystalline solar panel utilizes in this project. Polycrystalline photovoltaic solar panel absorbs daylight as a source to produce electrical power [35]. In great conditions, the efficiency of crystalline panel is higher, and it is physically littler than amorphous of a similar wattage [36].

Solar battery charger follows the principle that the charge feedback loop can create the consistent voltage. The charging current permits to voltage controller for utilizing the diode. The o/p current and voltage are constrained by changing the adjust pin of the voltage regulator. The charging of the battery will be finished by exploitation a comparable current.
4.3. **Dynamometer Charging**

A magnet generator (also referred to as PMA, generator or magneto) depends on the magnetic flux generated by a magnet to convert energy into wattage.

5. **Calculations and Result**

5.1. **Calculations**

- **At Ideal condition – No loss condition.**
  
  **For Solar Panel**
  
  Solar panel rating = 2W  
  Output Voltage = 5V  
  Power (P) = Voltage (V) x Current (I)  
  2W = 5V x I  
  I = 2/5  
  I = 0.5A = 500mA/Sec  
  Total Actual Terminal Current = 7.2 Amp/Sec  
  Total time required to charge the battery = \( \frac{7.2}{0.5} = 14.4 \text{ Hours} \)

  **For Dynamometer**
  
  Power (P) = Voltage (V) x Current (I)  
  Output current from Dynamometer = 100mAmp  
  Total Actual Terminal Current = 7.2 Amp/Sec  
  Total time required to charge the battery = \( \frac{7.2}{0.12} = 60 \text{ Hours} \)

At Ideal condition, the single solar panel and dynamometer will take 14.40 Hours and 60 Hours respectively to complete charge the battery.

- **At Actual Condition – Losses are considered**

  Experimental result shows that the percentage loss is about 20% in the actual current value.

  **For Solar Panel**
  
  20% reduction in current value i.e. 0.4 Amp  
  Time required to charge the battery = \( \frac{7.2}{0.4} = 18 \text{ Hours} \)

  **For Dynamometer**
  
  20% reduction in the current value i.e. 0.104 Amp  
  Time required to charge the battery = \( \frac{7.2}{0.104} = 69 \text{ Hours} \)
5.2. Results

Table 3. Current available from different methods at different conditions

| Methods    | Ideal Condition | Actual Condition |
|------------|-----------------|------------------|
| AC Adopter | 1.5             | 1.2              |
| Solar      | 0.5             | 0.4              |
| Dynamo     | 0.130           | 0.104            |

Table 4. Charging time for different conditions (hours)

| Method    | Ideal Condition | Actual Condition |
|-----------|-----------------|------------------|
| AC Adopter| 4.8             | 6                |
| Solar     | 14.4            | 18               |
| Dynamo    | 60              | 69               |

From the above table we can see that the different methods and respected time taken by them to charge the batteries. AC Adopter charging method take’s 6 hours to charge, from the second method by solar panel 18 hours are required for charging completely the battery. Single dynamometer will take 69 hours for charging. As the increment of the dynamos proportionally in, series so the charging time proportionally reduced.

Figure 10. Final charging time from different charging methods

6. Conclusion and Future Scope

6.1. Conclusion

Hybrid vehicle frameworks controlled by sustainable power sources are imperative research enthusiasm of the scientists. Presently, couple of thoughts inside the world is concern in building up this innovation. Idea of this project is to giving straightforwardness to the rider when he is riding a bike and to save energy by every conceivable mean depicted into figure 6. At the point when the solar electrical bike is solid underneath light, then the sunrays charge the battery through the solar panel. The battery controls an electric motor and motor transfers power to the wheel. By minimizing, the resistance in paddling creates the smooth uphill travelling. At the point when there is no sunlight, the bike charged by mains power as shown in the figure 7. Dynamometer is tangentially associated with the back wheel (tyre), if bicycle is running more than 5km per hours, then with the help of dynamometer the cycle battery will charged. When we increment the no. of dynamometer, the time utilization will relatively reduce. From the above outcomes, we reasoned that for the charging purposes we utilize solar panel or dynamometer that is why the battery will charge while bicycle is running. It is running efficiently in both the procedure however in day condition, solar panel is more helpful than the dynamometer charging yet around evening time solar panel isn't charged because of inaccessibility of daylight. In this both solar panel and dynamometer will charge the battery however solar board is more efficient than the dynamometer.
because solar plate gives high power and take less time approx. 18 hours and 69 hours taken by dynamometer respectively resulted into figure 10. As the no. of dynamo increases and the solar plate of higher rating is utilized so the charging time will be reduced.

6.2. Future Scope

The futures in this paper both technologically and societal has been taken to a reasonable stage the future work manages discovering manners by which to charge battery naturally while not victimizing electricity. Today’s we have to think about the future reusable concept of the cycle to control the emission. The machines will be automatic by victimization Microcontroller.

- From the above procedure the extra power generated which utilized by the vehicle.
- The above mechanism used for charging the automobile batteries and it is very helpful for providing the continuous power to electrical charge rickshaw.
- Solar panel is the future idea, which utilized to charge the vehicle.
- Increase the charging rate through solar plate.
- Advance Solar plate will be suitable to charge the car.
- Advance dynamo will appropriate for charging car and truck batteries.
- Small wind turbines can be utilizing in convenient places.
- Bicycle can be more digitalize by using sensors.

Reference

[1] Papazek P., Raidl G.R., Rainer-Harbach M., Hu B. (2013) A PILOT/VND/GRASP Hybrid for the Static Balancing of Public Bicycle Sharing Systems.
[2] Hannan M. A., Azidin F. A., Mohamed A. (2014). Hybrid electric vehicles and their challenges: A review. Renewable and Sustainable Energy Reviews, 135–150.
[3] Verma R., Sharma T., Vardhan A., Kumar Singh P., (2016) Designing and Fabrication of Hybrid Bicycle, International Journal of Engineering Science and Computing, 61(5).
[4] Adinarayana G., Kumar A., Ramakrishna M. (2014). Fabrication of Hybrid Petroelectric Vehicle, Int. Journal of Engineering Research and Applications, 4(10).
[5] Saplachidis C., Yxhage E., Lamm E., Sundgren M. (2015). Development of a future electrical bicycle for the ageing population, Chalmers University of Technology Gothenburg, Sweden (Master of Science Thesis).
[6] Bushell M., Poole B., Zegeer C., Rodriguez D.A., Costs for Pedestrian and Bicyclist Infrastructure Improvements (http://www.pedbikeinfo.org/cms/downloads/Countermeasure%20Costs_Report_Nov2013.pdf)
[7] Rony Argueta, A Technical Research Report: The Electric Vehicle, University of California Santa Barbara College of Engineering, March 11, 2010, (http://www.writing.ucsb.edu/faculty/holms/Writing_2E_EV_Technical_Research_Report.pdf)
[8] FuelEconomy.gov. (Accessed June 22, 2010). (www.fueleconomy.gov/fev/atv.shtml)
[9] Spagnol P., Corno M., Mura R., Savaresi S.M. (2013), Self-sustaining Strategy for a Hybrid Electric Bike, American Control Conference (ACC) Washington, DC, USA.
[10] Dowds J., Hines P., Farmer C., Watts R., Letendre S. (2010). Plug-in Hybrid Electric Vehicle Research Project: Phase II Report, UVM Transportation Research Center.
[11] Energy Information Administration Annual Energy Review 2008.US DOE/EIA-0384 (2008), 2009. (http://www.eia.doe.gov/aer)
[12] "History of Hybrid Vehicles". HybridCars.com. 2006-03-27 Archived from the original on 2009-02-08 Retrieved 2010-03-21
[13] Fuchs A. (2009). Principles of Human-Electric Hybrid Drives for Human Powered Vehicles, 6th European Seminar on Velomobile Design Copenhagen, October 16-17, 2009
[14] Prasad S., Nataraj K.R. (2014). Design and Development of Hybrid Electric Two-Wheeler Suitable for Indian Road Conditions, International Journal of Electrical, Electronics and Data Communication, 2(9).
[15] Pedalling Towards a Greener India, (http://www.teriin.org/eventdocs/files/Cycling_Report_LR.pdf)
[16] Elias B. P., Devassykutty D., George J., Akhila K. (2017), Hybrid Bicycle, IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), e-ISSN: 2278-1676
[17] Kothari D. G., Patel J. C., Panchal B. R. (2014). Hybrid Bicycle, International Journal of Engineering Development and Research, 2(1).
[18] Gohil P. B., Jadav D. P., Katakia C. N., Zala J. B. (2017). Solar Battery Charger, International Journal of Engineering Development and Research, 5(2)
[19] Prajapati D. R., Shinde K., Mhaske A., Prabhu A., Matey S. (2017). Design and Fabrication of Electric Bike, International Journal of Mechanical Engineering and Technology (IJMET), 8(3), March 2017, 245–25
[20] Electric Bicycles, Annette Muetze & Ying C. Tan, (http://www.site.uottawa.ca/~rhabash/Project-bicycles.pdf)
[21] Kadi P., Kulkarni S. (2016). Hybrid Powered Electric Bicycle, IJSRD - International Journal for Scientific Research & Development, 4(5).
[22] Manoj E., Isa D., Arelhi R. (2010), Supercapacitor/Battery hybrid Powered Electric Bicycle via a Smart Boost Converter, World Electric Vehicle Journal Vol. 4 - ISSN 2032-6653
[23] Prasad S., Nataraj K. R. (2014). Design and Development of Hybrid Electric Two-Wheeler With Solar Charging Methodology, International Journal of Scientific & Engineering Research, 5(11).
[24] Alias A.E., Mathew G., Manu G., Thomas M., Paul P. V. (2015). Energy Efficient Hybrid Electric Bike with Multi -Transmission System, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 4(1).
[25] Nikhil M. S., Pavan J. K., Ningaraja B. N., Gowtham K M, Hybrid Bike Using Range Extended Electric Vehicle (REEV) Technology, Project Reference No.: 39S_BE_0861
[26] Marinaro G., Xu Z., Chen Z., Li C., Mao Y., Vacca A. (2018). The PurdueTracer: An Energy-Efficient Human-Powered Hydraulic Bicycle with Flexible Operation and Software Aids, Energies.
[27] Indulal S., Ushakumari S., Nair P. S. (2018). Real time analysis of an intelligent torque controller for a hybrid cycle, International Journal of Engineering & Technology, 7(2.21).166-171.
[28] Alan Millner, Nicholas Judson, Bobby Ren, Ellen Johnson, William Ross, Enhanced Plug-in Hybrid Electric Vehicles, (http://www.ieeepesboston.org/files/2011/06/IEEE-Alan_Millner_584.pdf)
[29] Bradleya T. H., Frankb A. A. (2009). Design Demonstrations and Sustainability Impact Assessments for Plug-In Hybrid Electric Vehicles, Renewable and Sustainable Energy Reviews, 115–128.
[30] EPRI, Technology Primer: The Plugin Hybrid Electric Vehicle 2007, Electric Power Research Institute.
[31] Mohanty T., Subudhi B. (2013). Design of a Hybrid Electric Vehicle, Department of Electrical Engineering, National Institute of Technology, Rourkela, (B. Tech Thesis).
[32] Transchela R., Stirlingmannb J., Blattnerc M., Bille B., Thielec R., Kusterad F., Wegenera K. (2012). Effective Dynamometer for Measuring High Dynamic Process Force Signals in Micro Machining Operations, 5th CIRP Conference on High Performance Cutting.
[33] Domdouzis K., Kumar B., Anumba C. (2007). Radio-Frequency Identification (RFID) applications: A brief introduction, Advanced Engineering Informatics, 21(4), 350–355.
[34] Charging Lead Acid Battery (Dynamometer (https://batteryuniversity.com/learn/article/charging_the_lead_acid_battery)
[35] Thomas B., Paul A., Babu A., Anagha M. (2018). Hybrid Electric Vehicle with Solar Charging Assist, International Research Journal of Engineering and Technology (IRJET), 5(4).
[36] Chiou F. (2015). Solar Charging Station for Education and Research, 122nd ASEE Annual Conference & Exposition.
[37] Solar Battery Charger Circuit (https://www.electronicshub.org/solar-battery-charger-circuit/)