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Effortless Hybrid Bicycle with PMDC Motor and Solar Assembly

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***Abstract*—An increasing demand for non-polluting mechanized transportation has increased the interest in the use of electrical power for personal transportation. A low cost alternative to an automobile is a bicycle. The rate of improvements in technology is at an exponential level despite that, the electric bicycle is a concept that has been very feasible for years but has not been fully explored yet. The electric bicycle is designed to provide electromagnetic propulsions to a bicycle thereby relieving the user from having to produce the energy required to run the bicycle. The system design is based on mechanically coupled dc motor which is used as the primary power source to drive the bicycle and electrically wiring the motor together with a rechargeable dc battery. In a PMDC brushed motor, the machine can also run as a generator while pedalling. This energy can be used to charge the battery and can be for either run-time energy needs like phone-charging or either motoring. For more efficient and better charging of the battery, solar panel assembly is provided such that the run-time charging duration is reduced. The term hybrid usually implies that more than one energy source is used to power all or part of a vehicle's propulsion. Rechargeable battery with long life is used for charging. DC electric motor is used in this project. The hybrid bicycle is a project that can promote both cleaner technologies as well as reduce the dependence on oil. It runs on clean electric power with rechargable ability, it runs on the power from the pedals of the bicycle and also through the solar energy.**

***Index Terms*— Hybrid; Regeneration; Solar.**

I. INTRODUCTION

Global warming and scarcity of traditional resources are becoming a major concern in the current scenario. Hybrid bicycle market has a huge growth potential; it has the power to boost the automobile industry in India. People now are trying to move towards cleaner energy sources.

Bicycles with supporting electric engine belong to a set of innovative vehicles, which are wholeheartedly suitable for everyday life. In the face of continuous climate discussions and permanent traffic jams, electric bikes have the potential of solving such issues and making a more energy efficient and environment friendly mobility possible. Electric cycles can be a game changer in this scenario, not only will it be a cleaner transportation method but will also improve the health of the masses. It becomes very important to manufacture the electric cycles cheaply and in a cost effective manner such that the common people in our country can afford to buy it. The currently existing electric scooters are far costlier and an average middle class person cannot afford such a locomotive at his place. Along with the development of technologies the theory must be also implemented to design and manufacture a product that can be sold off in large numbers,

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it should also have low production cost and should be of good quality. In order to implement all the above ideas, we planned to make the design and product in such a manner that it can be competed with the existing e-Bikes in the market.

II. SYSTEM DESIGN

The Hybrid Bicycle System is a project that incorporates three different ways of charging a lead acid VLRA battery: the 220VAC wall outlet, regeneration, and solar power; which is used to power an electric motor running a bicycle. In this electric hybrid bicycle, the backwheel has a compact PMDC motor. It will have a regenerative charging system and solar panels, which will enable long distance power assist cycling by regenerating power from pedaling energy (human energy) & solar energy ,then storing it in the battery.
The detailed block diadram representation of the Effortless Hybrid Bicycle as a system is represented in the figure shown below. The complete process of generation , using both pedals of the bicycle and the solar assembly , motoring and charging of the battery units are depicted in the diagram. The charging of battery from a charger circuitry is also shown .
The motor control and gear system is an optional add ons for the increased efficiency and reliability of the system as a whole. A control unit may be used to vary the speed of the motor using a throttle valve which is also an option to increase the versatality of the hybrid system.

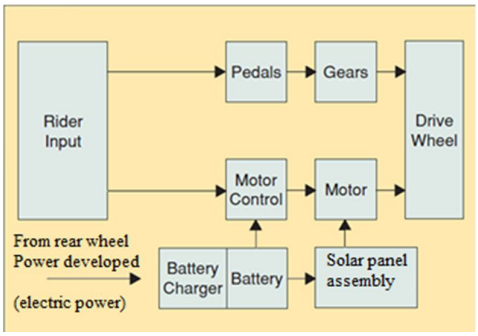


Fig. 1 Block diagram representation

A. DC motor

Detailed in a DC motor, an armature rotates inside a magnetic field. The working principle of DC motor is based on the fact that whenever a current carrying conductor is placed inside a magnetic field, there will be mechanical force experienced by that conductor. All kinds of DC motors work in this principle . Hence for constructing a DC motor it is essential to establish a magnetic field. The magnetic field is obviously established by the means of a magnet. The magnet can be of any type i.e. it may be electromagnet or it can be permanent magnet. When permanent magnet is used to create magnetic field in a DC motor, the motor is referred as permanent magnet DC motor or PMDC motor.

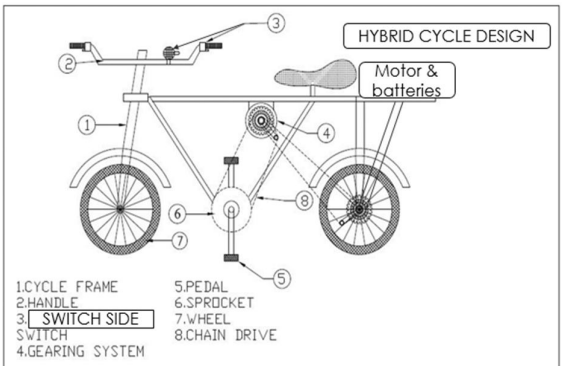


Fig. 2 Design layout with PMDC Motor and Batteries

Working Principle of Permanent Magnet DC Motor or PMDC Motor

The working principle of PMDC motor is similar to the general working principle of a DC motor. That is when a current carrying conductor comes inside a magnetic field, a mechanical force will be experienced by the conductor and the direction of this force is governed by Fleming's left hand rule. As in a permanent magnet DC motor, the armature is placed inside the magnetic field of permanent magnet; the armature rotates in the direction of the generated force. Here each conductor of the armature experiences the mechanical force F = B x I x L Newton where, B is the magnetic field strength in Tesla (weber / m2), I is the current in Ampere flowing through the conductor and L is the length of the conductor in metre. Each conductor of the armature experiences a force and the compilation of those forces produces a torque, which tends to rotate the armature.

Advantages of Permanent Magnet DC Motor or PMDC Motor

PMDC motor has some advantages as compared to other types of DC motors. They are:

- No need of field excitation arrangement.
- No input power is consumed for excitation which improves the efficiency of DC motor.
- No field coil hence space for field coil is saved which reduces the overall size of the motor.
- Cheaper and economical for fractional kW rated applications.

B. VRLA Battery

A VRLA battery stands for (alve-regulated lead-acid battery, more commonly known as a sealed lead-acid (SLA), gel cell, or maintenance free battery, is a type of rechargeable lead-acid battery. Due to their construction, the Gel and Absorbed Glass Mat (AGM) types of VRLA can be mounted in any orientation, and does not require constant maintenance. The term maintenance free is a bit misleading since VRLA batteries still require cleaning and regular functional testing. They are widely used in large portable electrical devices, off-grid power systems and similar roles, where large amounts of storage are needed at a lower cost than other low-maintenance technologies like lithium-ion.

Construction

VRLA cells can be made of flat plates similar to a conventional flooded lead acid battery, or may be made in a spiral roll form to make cylindrical cells.VRLA batteries have a pressure relief valve which will activate when the battery starts building pressure of hydrogen gas, generally a result of being recharged. Valve activation allows some of the gas or electrolyte to escape, thus decreasing the overall capacity of the battery. Rectangular cells may have valves set to operate as low as 1 or 2 psi; round spiral cells, with metal external containers, can have valves set as high as 40 psi.

The cell covers have gas diffuses built into them that allows the safe dispersal of any excess hydrogen that may be formed during overcharge. They are not permanently sealed, but are designated to be maintenance free. They can be oriented in any manner, unlike normal lead acid batteries, which must be kept upright to avoid acid spills. Cells may be operated with the plates horizontal (pancake style), which may improve cycle life.

At high overcharge currents, electrolysis of water occurs, expelling hydrogen and oxygen gas through the battery's valves. Special care must be taken to prevent short circuits and rapid charging. Constant-voltage charging is the usual, most efficient and fastest charging method for VRLA batteries, although other methods can be used.VRLA batteries may be continually float charged at around 2.35 volts per cell at 25 °C. Some designs can be fast charged (1 hour) at higher rates. Sustained charging at 2.7 V per cell will damage the cells. Constant-current overcharging at high rates (rates faster than restoring the rated capacity in three hours) will exceed the capacity of the cell to recombine hydrogen and oxygen and will damage these cells.

C. Chain Drive with Sprockets

All Chain drive is used to transmit mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles. Most often, the power is conveyed by a roller chain, known as the drive chain or transmission chain, passing over a sprocket gear, with the teeth of the gear meshing with the holes in the links of the chain. When the gear is turned this pulls the chain putting mechanical force into the system.

Fig. 3 Chain and Sprocket

Sometimes the power is output by simply rotating the chain, which can be used to lift or drag objects. We can also use a second gear, the power is recovered by attaching shafts or hubs to this gear. Though drive chains are often simple oval loops, they can also go around corners by placing more than two gears along the chain; gears that do not put power into the system or transmit it out are generally known as idler-wheels. By varying the diameter of the input and output gears with respect to each other, the gear ratio can be altered. For example - when the bicycle pedals gear rotate once, it causes the gear that drives the wheels to rotate more than one revolution.

D. Diode

A diode is a device which allows only unidirectional flow of current if operated within a rated specified voltage level. A diode only blocks current in the reverse direction while the reverse voltage is within a limited range otherwise reverse barrier breaks and the voltage at which this breakdown occurs is called reverse breakdown voltage. The diode acts as a valve in the electronic and electrical circuit. A P-N junction is the simplest form of the diode which behaves as ideally short circuit when it is in forward biased mode and behaves as ideally open circuit when it is in the reverse biased mode. Beside simple PN junction diodes, there are different types of diodes but their fundamental principles are more or less same. A particular arrangement of diodes can convert AC to pulsating DC, and hence, it is sometimes also called as a rectifier. The name diode is derived from di-ode which means a device having two electrodes.

E. Boost Converter

Switched mode supplies can be used for many purposes including DC to DC converters. Often, although a DC supply, such as a battery may be available, its available voltage is not suitable for the system being supplied. For example, the motors used in driving electric automobiles require much higher voltages, in the region of 500V, than could be supplied by a battery alone. Even if banks of batteries were used, the extra weight and space taken up would be too great to be practical. The answer to this problem is to use fewer batteries and to boost the available DC voltage to the required level by using a boost converter. Another problem with batteries, large or small, is that their output voltage varies as the available charge is used up, and at some point the battery voltage becomes too low to power the circuit being supplied. However, if this low output level can be boosted back up to a useful level again, by using a boost converter, the life of the battery can be extended.

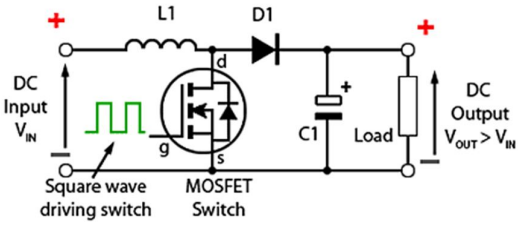


Fig. 4 Circuit Diagram for Boost Converter

The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos and DC generators. The boost converter is different to the Buck Converter in that it's output voltage is equal to, or greater than its input voltage. However it is important to remember that, as power (P) = voltage (V) x current (I), if the output voltage is increased, the available output current must decrease.

TABLE I. LIST OF MATERIALS AND PARTS

no:	ITEM	SPECIFICATION	QTY	AMOUNT
1	Cycle	Gearless cycle- HERO	1	1000
2	Motor	PMDC Brushed 24Volt , 250W 2000rpm	1	3500
3	Battery	12V ,7.2Ah Li-ion Battery	2	2000
4	Chain	3/8 inch pitch large and small	1 each	200
5	Gear Sprockets	12.2mm pitch,3mm width,18 teeth both large and small	2	400
6	Diodes	5 amps max	2	50
7	Switch and wires	10A Push button switch with NC as motoring and NO as generation	1	100

III. CALCULATIONS AND OBSERVATIONS

A. Motoring

As24V, 250W, 1500 rpm, permanent magnet direct current motor is used. PMDC is used because it can act as motor and generator. This makes the regenerative aspect much simpler.

$$\text{Torquedelivered} = \frac{P*60}{2*3.14*N}$$

$$= \frac{250*60}{2*3.14*1500}$$

$$= 1.59\text{Nm}$$

Two 12V batteries are connected in series to achieve 24V potential to supply PMDC which is rated at 24V. Using this machine initial torque or starting torque cannot be delivered. For an example during starting of bicycle with an overall load of 100kg required torque will be 49Nm which much bigger value than the delivered value.150cc bike produces only 12.5Nm but starting is managed by gear system. Motor is used as pedal assist during running normal parallel road.

B. Generation

Generation from Pedals

Today dynamo equipped bicycles are common which power the headlights during night. But in the case of hybrid bicycle a permanent magnet dc motor is used for power generation.

Then the generated power can be stored in a battery. This article focus on how the power is generated from a bicycle pedals. The permanent magnet dc motor is connected to the back tyre through gear drives, so during pedaling the bicycle moves forward by the rotation of back tyre. When tyre rotates the shaft of the permanent magnet dc motor also rotates then it acts as a generator and generates electricity. The generated power is then stored by using a battery. The amount of electricity generated depends upon the speed of the tyre. 250W, 24V, 1500 rpm PMDC motor is used, so two 12V, 7.2Ah lead-acid batteries are used for charging.

Generation from Solar Panels

Hybrid bicycle uses solar panels for electricity generation. The lead acid battery is charged with voltage generated due to solar energy with the help of a photovoltaic cell. Solar cells convert the solar energy directly into electricity using photovoltaic effect. The photovoltaic effect involves conversion of light into electricity.

Solar cells are made of semiconductor material called silicon. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current-that is, electricity. Solar cells are connected electrically and manufactured as a module with a sheet of glass on top to allow light to pass and protect the semiconductor from the weather. To obtain the voltage of 24 V two panels of 12V each are connected in series.

C. Solar Panel Rating Calculation

Power (in watts) = voltage * current That is 250 = 24*I

Therefore, total current load,

I = 250/24
= 10.41A

Specification of battery be,
Total load (in watts) * hours of back up required / 24

$$= \frac{250}{24} * 1 = 10.41AH$$

Requires 10.41AH in order meet, 2 batteries of 7.2AH is installed. Charging Current of Batter = 1/10th of its Total AH

$$\frac{1}{10} * 14.4$$

= 1.44 Amps

Power required to charge battery = 26*1.44
(voltage * charging current of battery)
= 37.44 W

Solar panel used should deliver 40W

D. Regeneration

A regenerative brake is an energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. This is in contrast with the conventional braking system, where the excess kinetic energy is converted to unwanted energy and is wasted as friction in brake, this energy is dispersed in the form of heat. The most common form of regenerative brake involves an electric motor as an electric generator. Electric motors, when used in reverse, function as generators and convert mechanical energy into electrical energy. Vehicles propelled by electric motors use them as generators while when using regenerative braking, while breaking it transfers mechanical energy from the wheels to an electrical load. Regenerative braking has been in extensive use on railways for many decades and is now used in formula one car as KERS-Kinetic energy recovery system.

Regeneration is also possible in bicycle here in our project when the supply is drawn from the battery the machine act as motor, during the pedaling action the machine act as generator, if we want to slow down or if the we are riding through a inclined surface we have to apply resistance brakes (for cycle it might be disc brakes or rubber brakes reassembles drum brakes) to slow down or stop the cycle. In order to stop immediately, resistance braking is the best option, but if we want just slow down gradually, using resistance braking is a loss instead of this we can use regenerative braking by reverse functioning of motor as generator, by this method we are applying a load through which mechanical energy is converted back into electrical energy and then to chemical energy (to battery). Slowing down of bicycle is achieved by generating a useful energy without loss of energy in the form of heat, wear and tear etc.

Regenerative braking has a similar energy equation to the equation for the mechanical flywheel. Regenerative braking is a two-step process involving the motor/generator and the battery. The initial kinetic

energy is transformed into electrical energy by the generator and is then converted into chemical energy and stores in a battery. But this process is less efficient than the flywheel. The efficiency of the generator can be represented by:

$$\eta_{gen} = \frac{w_{out}}{w_{in}}$$

Where:

- w_{in} is the work into the generator
- w_{out} is the work produced by the generator

The only work into the generator is the initial kinetic energy of the car and the only work produced by the generator is the electrical energy. Rearranging this equation to solve for the power produced by the generator gives the equation: -

$$P_{gen} = \frac{\eta_{gen} m v^2}{2\Delta t}$$

Where:

- Δt Is the amount of time the car brakes.
- m is the mass of the car.
- v is the initial velocity of the bicycle just before braking.

The efficiency of the battery can be described as:

$$\eta_{batt} = \frac{P_{out}}{P_{in}}$$

Where:

$*P_{in} = P_{gen}$

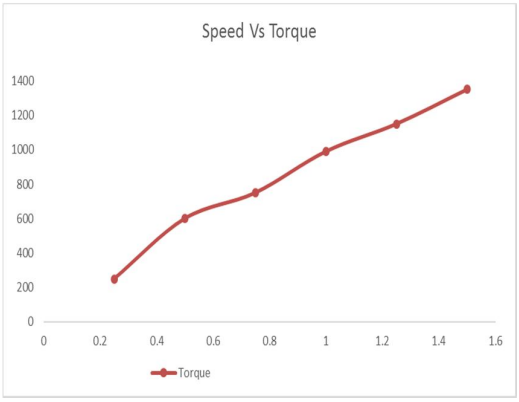
$*P_{out} = \frac{W_{out}}{\Delta t}$

The work out of the battery represents the amount of energy produced by the regenerative brakes. This can be represented by:

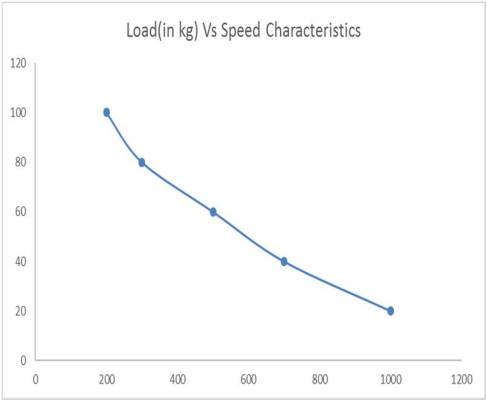
$$W_{out} = \frac{\eta_{batt}\, \eta_{gen} m v^2}{2}$$

IV. Test Results

The hybrid cycle was tested in the laboratory for different characteristics of the vehicle. Load test was the major one among them. The cycle was given DC supply from a rectifier source which was variable. The speed of the machine gradually increased from zero to the rated speed on no load condition.
The speed versus torque graph of the cycle at no load is shown below: -
The rated speed of the machine is 1500 rpm and this was achieved under no load at rated speed. As the machine was lightly loaded with the chain drives that connected the machine with the rear wheel of the cycle, the load increased decreasing the speed of the machine.
The cycle was then made to undergo the load test. This was done using a pully arrangement coupled to the compound drive which was intermediate between the machine and the cycle rear wheel.



The cycle was uplifted and attached to a double pole structure for the convenience of the test. Initially the load was only due to the chain weight and the tension between the sprockets.
The machine was loaded with weight blocks of 10 to 60kg and the machine operation was observed
The Load versus Speed graph is shown below : -



Graph showing the variation in speed as the load is varied

V. Conclusion

The issues associated with electric bicycles may be addressed by custom-designed drives that are most efficient over a given operating cycle. These include city bicycles, hill bicycles, distance bicycles, and speedy bicycles. The results of the studies listed here can serve as a platform to improve electric bicycle performance if new drive systems are designed around key parameters that will result in improvement of the system performance.
Furthermore, they can be used for comparison of existing drives in a systematical, comprehensive, and technical way.

VI. Future Research And Development

The Battery
Further investigation is needed to examine how Improved battery technology could improve the performance of electric bicycles. Further investigation on the importance and Influence of battery density and charging time on electric bicycles is needed.

Drive
The motor should be designed to be most efficient over the operating cycle. Further investigation is needed on the assets and drawbacks of different motor types and controllers.

Regenerative Braking

Regenerative braking will be more useful in hilly areas or when braking is used often, as in city rides. Future work needs to identify the percentage recoverable energy, the impact on efficiency, cost, and the reduction of dependence on battery technology.

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