HYBRID ELECTRIC POWERED BICYCLE WITH TRI SOURCE CHARGING

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Abstract -*Electric vehicle is inevitably the future of powered vehicles, but the cost of the present-day electric vehicles are very high. Hence converting a normal bicycle to a electric powered vehicle which can be charged using multiple sources is a very practical idea. In this project the primary source of power is the ac wall charging. India being a country which receives abundant solar radiation, one of the sources can be solar power. The inherent regenerative property of BLDC motors can also be used as another source for power. The power can be stored in an onboard lead acid battery. Hybrid cycle is hence a very practical idea for short distance transportation in developing countries.*

Key Words: Electric bicycle, Tri-source, DC-DC boost Converter, Inverter, BLDC motor, Regeneration, Solar charging

1.INTRODUCTION

With the ever-increasing price of petroleum fuels and the its negative environmental impact, the governments around the world has being giving a thrust for electric vehicles. Latest statistics shows that the fossil fuel reserve of the world would get completely depleted before this century. Further the harmful gases released by the vehicles running on petroleum-based fuels are causing severe problems to both the environment as well as the humans. Therefore, the shift towards alternative sources of power is the need of the hour. With some basic knowledge in electrical and electronic aspects and with the help of a mechanic for doing some mechanical modifications, we can convert a conventional bicycle to a electrically powered bicycle.

1.1 Motor Used

The motor we have selected for powering the cycle is a BLDC motor. The cycle has three sources for charging, one primary and two secondary sources. The primary source is the ac wall charging. The secondary sources are solar power and regeneration of the BLDC motor. Electric bicycles are not used very commonly, but they have a very good scope of increasing in popularity as it can help us battle many scenarios we face nowadays like pollution from exhaust of conventional vehicles and also the increasing prize of fuels.

1.2 Solar Panel

The photovoltaic solar panels used here convert the solar radiation falling on them to electricity through the principle of photovoltaic conversion. Conventional solar panel has an efficiency of about 11 to15 percentage. With the ever improving field of renewable energies solar panels of greater efficiency can be incorporated.

1.3 Storage Unit

Electric powered vehicle normally uses lead acid battery or lithium ion battery for storing the energy. Conventional electric powered vehicles use lithium ion batteries as they are very efficient and at the same time has more energy to weight ratio than lead acid batteries. Here in this project we would be using a lead acid battery mainly due to financial constraints. The other advantages provided by lead acid battery over lithium ion battery in particular for this project will be dealt with later on.

1.4 Design

This hybrid cycle will incorporate a battery box over the rear tyre, and the solar panels will be included over it in a foldable manner. The cycle would be run with the BLDC motor using a chain drive system. The BLDC motor will be provided over the pedaling section and will drive the bicycle using a drive mechanism attached to the rear sprockets.

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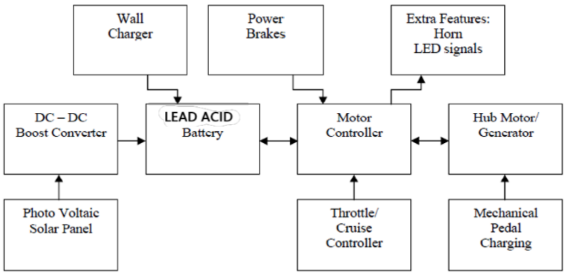

Fig-1 Basic block diagram

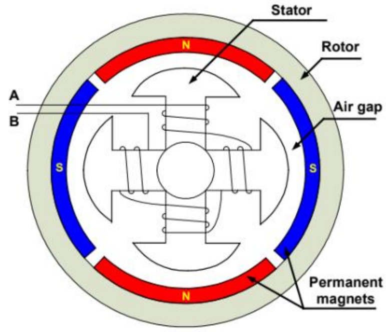

Fig-2 BLDC stator

2.BLDC MOTOR

BLDC stands for Brushless DC Motor. It is similar to a synchronous DC motor and is powered by a DC current via an inverter mechanism or SMPS which converts the DC to AC. The motor used in this project uses a inverter to convert the DC to AC. The construction of a BLDC motor is similar to permanent magnet synchronous motor (PMSM), switched reluctance motor, or an induction motor.

2.1 Advantages

Brushless dc motor has many advantages over brushed motors, they are:

- Higher efficiency and more reliability
- Lower noise
- Comparatively smaller and lighter
- Better speed vs torque characteristics
- Higher speed range
- Longer life
- Better suitable for explosive environments

2.2 Stator

The rotor has permanent magnets to form two magnetic pole pairs and it surrounds the stator, which has the windings. Figure-2 shows the cross-sectional diagram of a single phase dc motor.

A single-phase motor has one stator windings, wound in clockwise or anticlockwise directions. The stator windings can be different type based on the shape of the back emf signal. They are trapezoidal and sinusoidal. They are determined by the coil interconnections and the air gap. The sinusoidal motor produces a smoother torque than the trapezoidal one. But they have a higher cost due to the extra copper. The BLDC motor uses a trapezoidal stator winding.

2.3 Rotor

The rotor uses a permanent magnet arranged to form between two to eight pole pairs. There are mainly three type of magnet arrangement in the rotor. They are (a)surface mounted, (b) embedded and (c)inserted type. The cross section is as shown in the figure below.

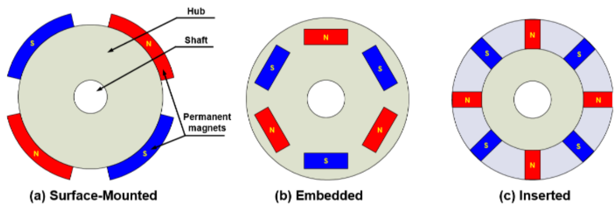

Fig-3 BLDC rotor types

2.4 PRINCIPLE OF OPERATION

The operation of BLDC motor is based on the attraction and repulsion between the magnetic poles. The stator windings are energized by giving a dc supply. The operation based on the interaction between the permanent magnet and the electro magnet. The process starts when current flows through the stator windings. A magnetic pole are created which is attracted to the nearest opposite permanent magnet pole. As soon as the corresponding attracting pole reaches near it, the polarity of the electro magnet is reversed and it gets repelled, or attracted to the next pole. This change of polarity once it reaches the nearest attracting pole which causes repulsion and attraction to the next pole causes the motor to rotate

3. BATTERY SYSTEM

The storage system used in the project is lead acid battery. The rating of the battery used is 24V, 12Ah. These are the most commonly used type battery. Lead acid batteries provide many advantages. They are very cheap comparatively. It is also very reliable as it has over a decade of development. It has a robust construction and is tolerable to overcharging. It can also deliver very high

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current. It also can be left on float charging for a very long time. It is available in a wide range of size and capacities. It is also the largest recycled type of battery in the world.

The battery system is arranged in a battery container specially build for holding it. It is arranged on the carrier over the rear tyre. It is designed such that the batteries are protected from the environmental conditions.

4. CHARGING MODES

There are 3 main modes of charging in this project. The primary mode of charging is the AC wall charging. There are two secondary modes of charging. They are photovoltaic charging via the solar panels fixed behind the cycle.

4.1 AC Wall Charging

Ac wall charging is the primary source of power in the project. This is as in conventional electric vehicles where a charging plug is provided. The ac power is stepped down from available 230V to 30V using a step down transformer. This 30V AC is then rectified and converted to 30V DC to charge the battery.

4.2 Solar Powered Charging

Solar cells convert the solar energy obtained from the sun directly to electrical energy using photovoltaic effect. This process involves the creation of a voltage when these photovoltaic materials are exposed to electromagnetic waves. Multiple solar cells are connected together and encapsulated as one to form a solar panel. They are provided with glass covering over them to protect them and at the same time allow solar radiation to irradiate them. Solar panels are connected in series to obtain the desired peak DC voltage and they are connected in parallel to obtain the desired DC current level.

4.3 Regeneration

Regenerative braking is a method incorporated to conserve energy. According to the law of conservation of energy, energy can neither be created nor be destroyed, but can only be converted from one form to another. Regenerative braking converts the kinetic energy of the vehicle slowing down to electrical energy instead of the energy being lost as heat. The percentage of braking energy to tractional energy is more than 40% for a drive cycle. This recovery of energy helps in increasing the energy efficiency. In regenerative braking, the direction of power flow is reversed. When torque of the electric machine is in opposite direction of the system speed, machine receives mechanical power from the load and the kinetic energy is converted to electrical energy and is stored in the battery for further use. The power converter applies less voltage than the machine has developed due to kinetic energy of the vehicle and allows the power flow from machine to the battery which reduces the speed of the vehicle.

5. CHARGING CIRCUIT

The charging circuit uses a relay to control the charging of the battery. Figure-4 shows the charging circuit. The circuit is designed in such a way that the relay stops the charging of the battery when the voltage across the battery reaches 28V. The highlighted part of the figure represents the input to the circuit from the three sources of power. It is given to the common of the relay. During charging the relay directs the flow to the battery through the normally closed terminal. A diode ensures unidirectional flow. A variable resistor is provided which is adjusted in such a manner so that when the voltage across the battery exceeds 28V the voltage drop across the Zener diode is 6.2V at which the Zener diode starts conducting and the current reaches the base of the transistor BC547. The two resistors, one at the base of BC547 and the other at the collector of BC557 decides the other threshold of the relay changeover, meaning the full charge cutoff threshold of the battery. Here the values are arbitrarily selected. For accurate results these values will need to be optimized with trial and error method. As a 6.2v flows to the base of the transistor BC547 it is switched ON. The collector of T1 is of positive polarity and its emitter is grounded. When it is switched ON emitter to collector becomes negative and it flows to the second transistor T2 i.e.; BC557. The two stages of transistor is required for the current amplification process. This current is sent to the coil of the relay which attracts the switch to normally open terminal and cuts off the charging of the battery. As soon as the charge across the battery drops below 28V this process stops and the switch goes back to normally closed terminal and recharges the battery.

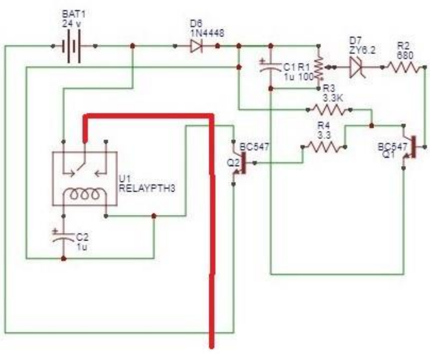


Fig-4 Charging Circuit

5.1 Overall Circuit

The three sources of power are integrated into the circuit. Figure-5 shows the charging circuit along with its power sources. The ac wall charger is set after stepping down using a step down transformer. Solar power has a DC DC boost converter along with it to increase the value to a desired level. The circuitry of BLDC motor regeneration is inside the motor controller which includes the three phase inverter.

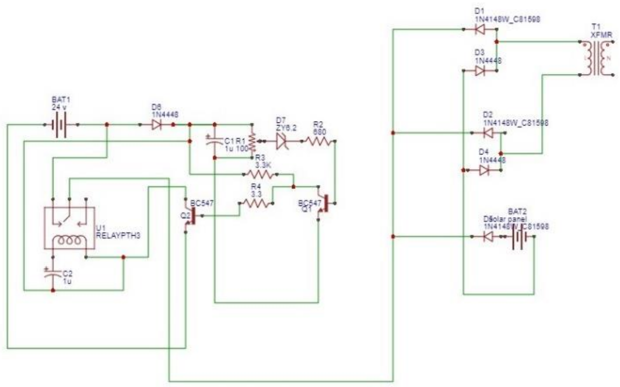


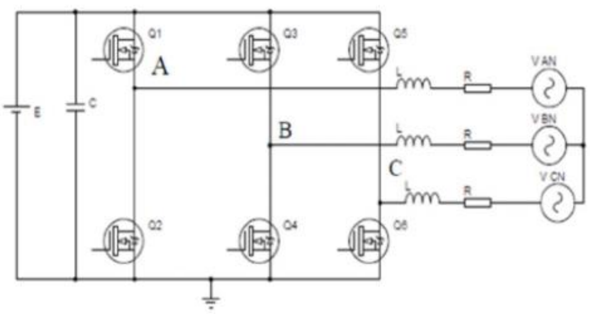
Fig-5 Overall Charging Circuit

6. AUXILLARY CIRCUITS INVOLVED

The main auxiliary circuits involved are three phase inverter for the operation of the BLDC motor which is inside the motor controller and the DC DC boost converter for the solar charging.

6.1 Three Phase Inverter Circuit

The equivalent circuit of a BLDC motor with 3 phase inverter is shown in figure 6. L and R are the motor inductance and resistance respectively. Van, Vbn and Vcn represents the back emf of the BLDC motor. E and C represents the battery and the capacitor of the inverter. **F**



ig- 6 Three phase inverter based BLDC drive

Q1 to Q6 represents the switches of the inverter. A, B and C are the three phase outputs. Figure-7 shows the desired switching needed to run the BLDC motor. At first Q1 and Q4 are turned ON which causes the current to flow from battery to the motor as shown by the bold red line. During this cycle the motor inductor stores energy and in the next cycle Q1 is turned OFF and Q4 remains ON. The inductor releases the energy via Q4 and the diode Q2 as shown by the dotted green line. This process is for one state which is 60 degree. Similarly there is a total of 6 states. In the above explained process Q1 is operated with PWM. BLDC operation is based on the rotor position sensed by the hall sensors. Switching is based on these signals. There are three hall sensors which are placed with a phase difference of 120 degree. Figure-8 shows the response of the hall sensors and back emf during an electrical cycle. Figure-9 shows the pattern in which the 6 switches of the inverter must be operated to run the motor properly. Figure-10 shows the desired line to line voltage. The output voltage shows a phase difference of 120 degree.

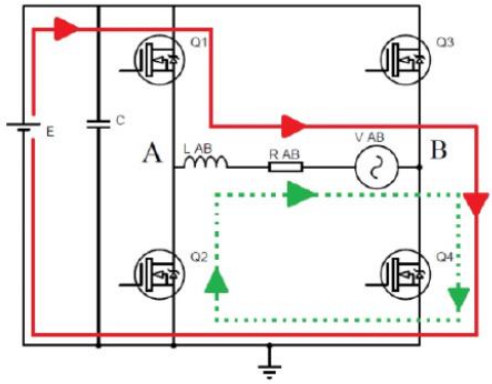


Fig-7 Motor operation

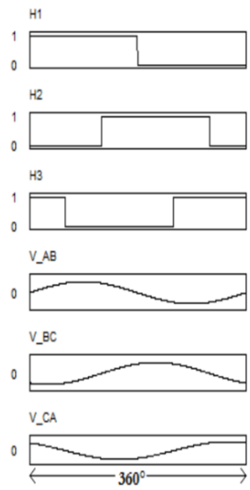


Fig-8 Hall signal and back emf

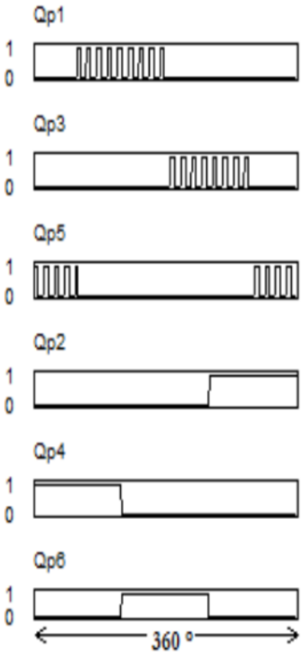


Fig-9 Desired switching for motor

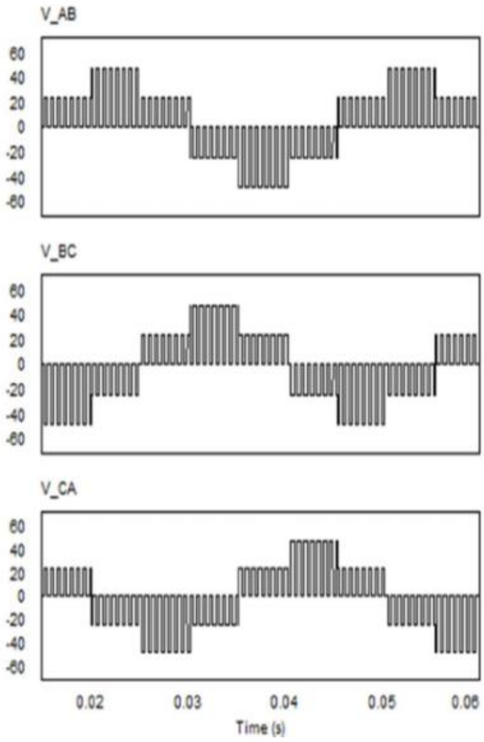


Fig-10 Line to line voltage

6.2 DC DC Boost Converter

Having a solar panel as a source of charging brings forth a problem. The output from the solar panel can have fluctuations due to a variety of factors like intensity of sunlight, angular changes of irradiation and many other environmental factors. A dc-dc boost converter is used to overcome this problem. The output of the solar panel is given as the input to the boost converter whose output is given to the battery for charging. The dc-dc boost converter, converts the fluctuating input voltage into a constant output voltage. A dc-dc boost converter is basically a step up power converter which accepts a dc voltage and produces a higher dc voltage at the output. The dc-dc boost converter used in our project is designed to have an input voltage range of 0V to 8V and to give an output constant voltage of 30V desirable for the charging of the battery. Its steps up the output voltage while stepping down the output current. It comes under the class of switched mode power supply (SMPS) having at least two semiconductors and atleast one energy storage element like a capacitor or an inductor or a combination of both. Capacitor filters are also used for smoothening the ripple in the voltage.

From the calculations done the various parameters are obtained as; L=1mH, C=33uF, D=.74

Figure-12 shows the output obtained from the simulated dc-dc boost converter showing a constant output voltage of 30V.

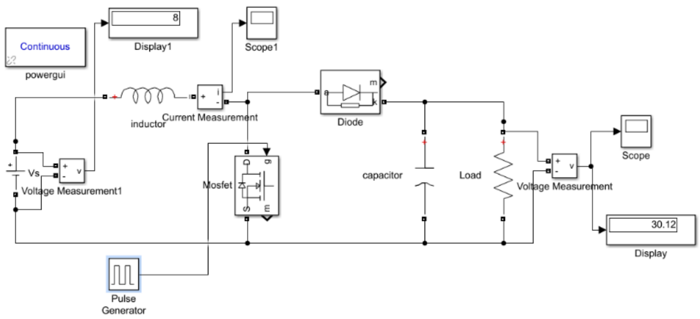


Fig-11 Simulated DC-DC boost converter

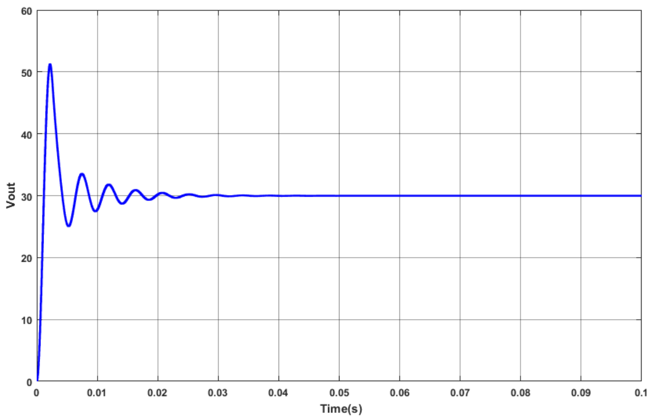


Fig-12 Simulated output of converter

7. CONCLUSION

A hybrid electric powered bicycle is practically designed and developed with an electrical efficiency greater than 80% and the maximum speed of this bicycle is 30 km/h, can be travelled up to 35 to 40 km with full charge of battery. It is suitable for both city and country roads, that are made of cement, asphalt, or mud. It can be used by any age group people and caters the need of economically poor class of society. It can be operated throughout the year free of cost. The most important feature of this bicycle is that it does not consume valuable fossil fuels thereby saving the money. It is eco-friendly and pollution free, as it does not have any emissions and also good weight of loads can be pulled using this design. The solar bicycle is also cost effective when compared to conventional bikes.

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