Electrical and Electronic Engineering 2017, 7(2): 24-27
DOI: 10.5923/j.eee.20170702.03

Concept of Solar and Pedal Powered Electric Bicycle

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Abstract Global warming and scarcity of traditional resources are becoming major problems in the current scenario. Due to the economic challenges India is facing in the automotive sector, the hybrid bicycle market has a huge growth potential. The main objective is that it can be used in remote or rural places, where the energy generated by pedaling is utilized to motor the cycle during commute. It makes use of the abundantly available solar energy which makes it a viable means to travel as well as a means to light up houses. The proposed model consists of a Solar panel, PMDC machine and a detachable battery. The motor is connected to the bicycle through suitable chain drive system. An electronic controller assists the control of the vehicle speed, charge output of the panel and prevents battery discharge when not in use. It inherits protection logic for voltage and current fluctuations and prevention of overcharging of battery during generation. It can also be charged using an AC supply when not in use. This project simplifies riding with minimal effort on flat paths as well as gradients. In addition to this, solar energy utilization and hybrid economy ensures a cleaner and more economical solution to the energy crisis. Boost converter raises the generator output of 6V to13V as input to the battery with 80% duty cycle.

Keywords PV Panel, Buck-Boost Converter, DC Motor

1. Introduction

The current trend in the power sector is to change societies dependent on fossil fuels, to a world opting for alternate renewable resources, for their energy requirements, so as to conserve the natural energy [1, 2]. Soon the world is going to be depleted of all - nonrenewable resources, like oil and gas reserves, if the world's demand for energy from fossil fuels continues at the present rate.

This idea is an example of replacing conventional vehicles used for transportation, which are dependent on fuel, with a more cost effective and environment friendly system, dependent on electricity, since it is the most efficient non-polluting source of energy known to man-kind today.

2. Materials and Methods

Cycle: A normal gearless cycle is required to generate the power; it is being used as a prime mover, and also as the means of transportation [3, 4].

DC machine: A 200W DC machine is used to convert electrical energy to mechanical energy and vice-versa. The power from the rotation of the pedal is fed to the battery through this DC machine. And it rotates the wheel during motoring.

Solar Panel: This 30W 12V Panel converts solar energy to electrical energy and supplies it to the battery. It is equipped with a charge controller which prevents battery from overcharging.

Battery: The 12V battery stores the energy in electrical form, it is supplied charge from the solar panel and DC machine working as generator. Since it is detachable, we can use the charge in it for non-transportation purposes also. Sprocket-chain gear assembly: This mechanism allows us to run the shaft of the generator at rated speed of 1500rpm from the normal riding speed of the bicycle; and vice-versa.

Mechanical Switching: There is a DPDT switch, which enables the rider to go to motoring mode when there is charge in the battery and also allows the system to trip the battery while the charge is below specified limits. Acceleration control is optional.

The AC step-down Rectifier circuit at power frequency is used to charge the battery to full capacity (12V) while parked near AC mains plug point. The step-down transformer brings down the value of voltage from 230V to 12V, while the rectifier circuit converts it into regulated and filtered DC 12V. It is then fed into the battery through the power electronic protection circuit. The circuit prevents the battery from overcharging by tripping the supply once it is fully charged, and also gives an indication. Now the bicycle is ready to be motored. On travelling, the motor can be switched on, by the user, whenever its assistance for riding is required and the power electronic circuit supplies the charge of the battery to the motor. There is a decrease in charge when motoring takes place. Now in case the rider is going down-hill or speeding up in a level road, he can switch over to generation by pedaling action by using the circuit buttons provided. Now the DC machine can act as a generator,

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Published online at http://journal.sapub.org/eee

supplying the lost charge back to the battery during commute. This action also happens only until battery reaches full charge.In case the battery is fully discharged on commuting, using the motoring action for a long time, the circuit prevents it from motoring further until sufficient charge is built-up in the battery again.

The solar panels also charge the battery through the charge controller whenever sufficient light intensity falls on it. This action can happen when the cycle is parked under direct sunlight. The charge controller is used to regulate the output of the panel which keeps varying, so that the battery is charged uniformly by the panel, until full-charge.

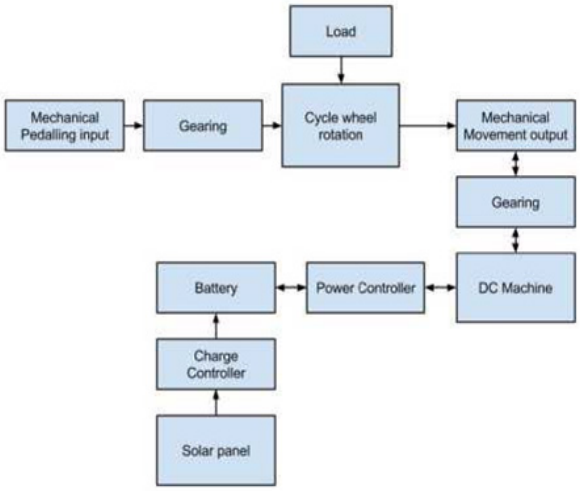

Figure 1. Block Diagram of the solar and pedal powered bicycle

This product can also be used as a generator, by supplying the charge to an empty battery during commute and through solar panels, and then removing the detachable battery with its circuit we can supply the charge to household equipment like bulbs and fans. Figure 1 and figure 2 shows block diagram of the proposed method and model of solar and pedal powered electric bicycle respectively.

Figure 2. Model of Solar and Pedal Powered Electric Bicycle

Once the battery attains full charge, we can see a rated voltage of 12V at its output terminals. The battery will be able to run for a longer time if its Ah rating is more. For example, in case a battery of 24Ah is used, it can run for 24 hours when a current of 1A load is drawn from it. For the 12V, 1500rpm, permanent magnet DC motor, the average current required for commute in a level road may be around 5-13A, in this case we are using 32 Ah battery so it is expected to last for 2 hours on continuous operation.

The cycle can be motored at a speed of 15kmph using the 200W motor alone, and if pedal power is also supplied, then the load on the motor decreases, and hence the speed or the discharge time can be increased.

Also the load increases when the cycle travels up the slope, and hence there is overload protection for the battery. The rider will have to assist the motor or vice-versa, but the motor alone will not be able to run the cycle. And during this, the battery is discharged at a faster rate.

Once the battery discharges below the minimum level with which it can motor, the mode is changed from motoring to generation, by boosting the output at the machine terminals using boost convertor circuit using MOSFET IRFZ44, then power gets fed back to the battery, otherwise there is no action. The solar panel also supplies the charge when sunlight falls on it.

The solar panel output voltage is seen to vary and hence its charge controller plays a vital role in regulating the voltage supplied to the battery. The panel is rated at 30 W, hence a current of around 1A is supplied from its terminals, which is usually less than that. It helps in charging the battery in the presence of sun light. The panel can only be utilized efficiently on a sunny day and is a major reform of utilization of renewable source of energy in this project.

3. Results and Discussions

Various tests were conducted on the DC machine, and experimental results were tabulated before and after mounting the circuitry on the bicycle. The following are the graphs and their explanation showing the various characteristics of the machine.

DC Motor Characteristics:

Brake test on the DC machine by applying varied load on the shaft of the motor gave the results as tabulated below. It was inferred that there is a decrease in the terminal voltage of the machine as the current through the motor increases owing to the resistance of the winding. Fig. 3 depicts the characteristics for two different trials.

By connecting the motor shaft to the cycle wheel and mounting it on the stationary stand, pedal assist support was provided to the motor to decrease the load on the machine by sharing the effort required to rotate the wheel. It was observed that the load current in the motor windings reduced and the terminal voltage increased as the pedaling support increased. Fig.4 shows the above mentioned observation.

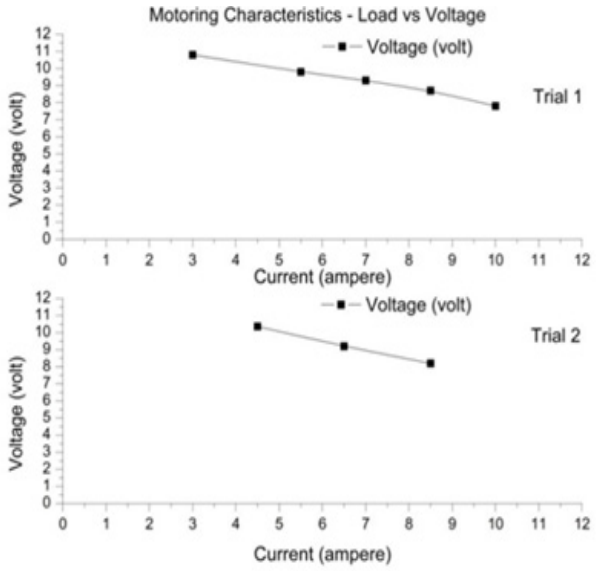

Figure 3. Motoring characteristics

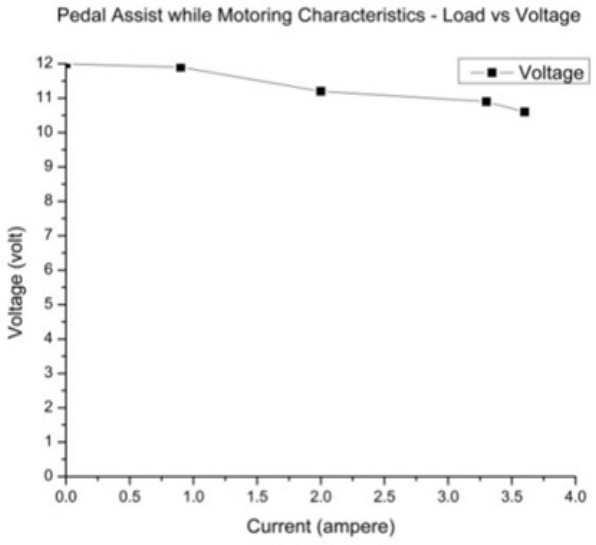

Figure 4. Pedal assist while Motoring Characteristics

DC Generation characteristics:

The motor was connected to the wheels of the bicycle and Open circuit voltages for different speeds were tabulated. As the speed of cranking the generator increased, the voltage at its terminals increased linearly. The mechanical energy of the rotation was converted to electrical energy by means of Electromagnetic induction between the permanent magnets. Fig.5 portrays the generation characteristics of the DC machine.

When the rheostatic load was connected across the terminals of the DC generator, it was observed that for constant current, the generator voltage increased with speed of rotation. The test was conducted at various loads. And figure 6 shows generated voltage vs. speed at different load currents corresponding to the panel characteristics, which matched closely to the manufacturer's specifications.

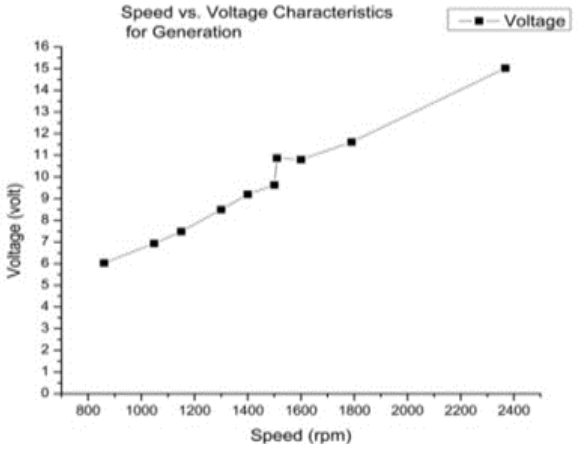

Figure 5. Generation characteristic

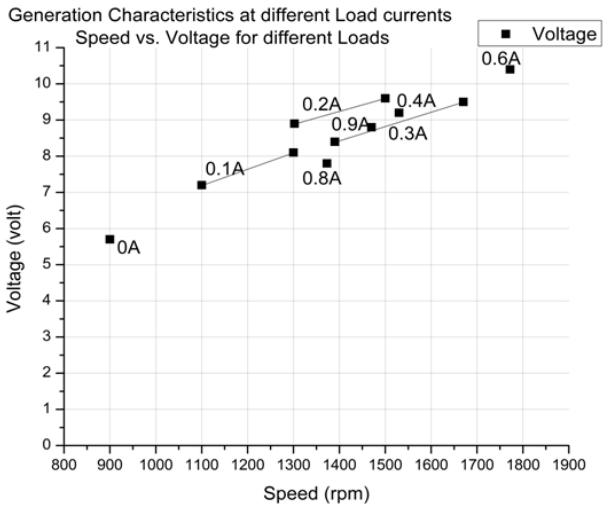

Figure 6. Generated voltage vs. speed at different load currents

Solar Panel Output characteristics:

The solar panel was connected with an ammeter and rheostat load across its terminals and voltage across the panel was also measured for varied load at constant intensity of radiation. As the Load increased, the terminal voltage reduced from rated value of above 18V down to 13V-14V at maximum current of 1A output from it. This meant that the Solar Panel was capable of charging the battery at times when there is sufficient sunlight falling on it. Figure 7 shows the graph corresponding to the panel characteristics, which matched closely to the manufacturer's specifications.

On road tests:

Once the circuitry and connections were made, the bicycle was taken out to the roads, and it motored well on level road, pulling a current of 5A to 9A on average and up to 12A during mechanical braking transients. In case pedal support was provided, the same current reduced even down to 3A to 5A. Up the gradient the pedaling effort was noticeably eased by the motor that the rider could sit and ride the heavy bicycle which was otherwise very difficult. On travelling down the gradient, the DC machine was put to generation

mode and current of 1A to 3A was achieved. Also noticeable braking effect was provided by the machine to the cycle movement. Generation by pedaling on stationary stand provided the same charging current with more effort required by the user, which could also be adjusted using the PWM input.

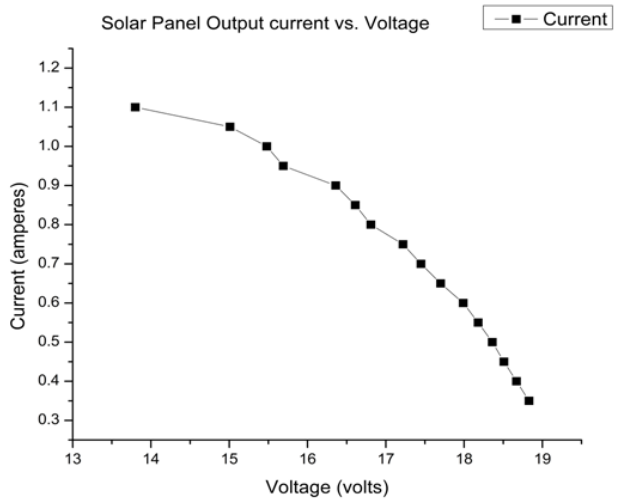

Figure 7. Solar panel output current vs. voltage

4. Conclusions

The pedal and solar powered electric bicycle was tested on level, inclined and drooping roadways of Vamanjoor with satisfactory results. The innovative component of the developed model is the use of regenerative braking and use of solar panel to ride an electrically motorized bicycle. Under motoring mode and level road conditions, the DC machine mounted on the bicycle exhibits an overall conversion efficiency of 85% for a single rider with a top speed of 15kmph without pedal power in use. This higher conversion efficiency is attributed to the fact that the permanent magnet DC motor was used which eliminated the field copper losses. In generating mode, the bicycle was able to generate 35 watts of power going downhill and the solar panel gives a variable output in the range of 12 Watts (dawn) to 17 Watts (midday) which continuously charges the battery.

The product could incorporate monitoring and display devices which could help the rider to change from generation to motoring modes and vice versa. It is possible to use a hub motor instead of a permanent magnet DC motor as it does not need extra gear sprocket arrangement. This reduces the overall weight of the system. A small wind energy generator can be incorporated as an auxiliary system into the bicycle mainframe so that it can add up with the main generating system to charge the battery.

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