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Hybrid Solar and Muscle Powered Solution for Rural Electrification

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ABSTRACT: In today's world, energy is becoming a precious resource. Life without electrical energy seems like a faraway nightmare. Yet, people in many rural areas live with no electricity at all. A small device which traps solar energy or which stores energy converted from mechanical forces can come a long way in electrifying these areas. Even just a single light bulb capable of glowing through the night can make a difference in their lives. Thus here is a hybrid solar and muscle powered solution. This report shows one such prototype built and the improvements and modifications which can be made in it.

KEYWORDS: solar; muscle; chain drive;

I. INTRODUCTION

Rural electrification can be considered to be one of the main challenges India faces today. The problem of low power availability is aggravated by the fact that, some rural areas are almost inaccessible except on foot. Micro-grids can be set up after overcoming a lot of challenges, but these micro-grids usually powered by solar or wind energy sources are not always reliable. Especially on cloudy days, the energy generated is too low for even day to day purposes of all the residents. There is an alternate solution to this problem. A small hybrid solar and muscle powered unit built with easily available parts (for example the parts of a cycle to run the dynamo) can go a long way in ensuring that the residents have a least basic lighting.

The hybrid unit contains a dynamo and a solar panel. A battery is charged either by using the dynamo or the solar panel. During cloudy days or in the night time when energy due to solar energy is not sufficient, the dynamo can be run either by hand or by feet. The dynamo shaft is coupled to a handle through gears and a chain drive to make this possible. This way, there is an alternate energy source available.

The success of the device rests on the fact that the components in the device are easily available even in the rural areas such as the dynamo and the chain drive which runs the dynamo.

II. LITERATURE SURVEY

The availability of hybrid systems which combine solar and wind energy are abundant. These systems have improved in complexity and efficiency. These systems work to maximize the efficiency considering the erratic nature of wind energy. The basic components which go into both these systems are about the same. The lack of human and solar hybrid in the market is evident.

Muscle powered solution are available abundantly in the market today. They are mostly sold in the form of small battery powered torches whose batteries can be charged by driving the handle provided. This can become tedious and tiring and the power which can be generated is very limited.

Solar powered toys to cookers are readily available, but suffer the drawback of being unusable on days which are not sunny. There are a lot of applications of solar energy and there are a lot of applications of human muscle energy. There are a few systems which combine these two systems which are available in the market. One such unit tends to agricultural needs[8] while another was used along with a bicycle to run the dynamo and a small motor which would drive the bicycle when the user is tired of encounters an uphill climb.

The unit which is reported here is different from these other hybrid units in the sense that it is essentially made for rural application. It is made of parts which would easily be available even in rural areas.

III. REQUIREMENTS

There are two parts to the project, the hardware part and the software part. The hardware components used are, bicycle dynamo, chain, sprocket, freewheel, battery, charge controller, ATmega16 microcontroller and current sensor. The software used for this project are, AVR Studio 4, Usbasp driver for programmer, hyper terminal for serial communication and eXtreme burner to dump the code.

A. Bicycle Dynamo

A bicycle hub dynamo was used for this project. It was chosen because it is easily available even in rural areas. The hub dynamo, a dynamo integrated into the hub of the wheel, has long since been popular with riders who rely a lot on their generator. It used to be expensive, but it was reliable and virtually service-free. In recent years, more manufacturers offered hub dynamos, competition increased, prices dropped. Today, a very acceptable hub dynamo is no longer more expensive than a high quality bottle dynamo and it's quite common that touring bikes come with a stock hub dynamo. It is rated at 3W (6V, 0.5A). This dynamo gives a sinusoidal output. The below figure shows the cycle dynamo and a freewheel welded to the end of its shaft.

Figure 1: Freewheel attached to the shaft of the dynamo

B. Chain Drive

The chain drive consists of the sprocket, the chain and the freewheel. The entire set-up rests on a stand, so as to give the user space to rotate the handle of the sprocket. The components of this chain drive are parts of a standard bicycle. Thus malfunction of any part of this ensemble can be conveniently dealt with. The below figure shows the chain drive system.

Figure 2: Chain drive along with the stand for the entire setup

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C. Battery and Chain Drive

A 12V maintenance free battery is used in the device. The battery is charged through a charge controller. Greater efficiency can be achieved if impulses waveforms can be absorbed and stored. These impulses are caused due to sudden jerks made by the user in running the dynamo. In order to assimilate the energy produced due to these jerks supercapacitors can be used.

The charge controller must stop flow of current in the backward direction. It must also protect the battery against overcharging.

D. Software used

Software was used to record the actual values output by the dynamo or the solar charge controller. ATmega16 has a built in ADC which was used to convert the analog values output into digital values. Serial communication was used to view the output on the computer in hyperterminal; AVR studio was used code and eXtreme Burner to dump code on to the microcontroller.

IV. DETAILED DESIGN

The components used for the project have already been elucidated. In the process of completion of the project there are some things which have to be tended to.

A. Method of Charging the Battery

1) Charge Controller Circuit

The charge controller circuit is shown in the circuit diagram below.

This solar charge control combines multiple features into a single design: 1A current rating, low dropout voltage (LDO), range of voltage adjustment (accommodates 6 & 12V lead-acid batteries), reverse polarity protection, low parts cost and low parts count (14 components). High performance is attributed to the application of the op amp and adjustable shunt voltage regulator [6].

2) Circuit Operation

R1 biases D3, the voltage reference diode. The 2.5V reference from D3 is compared with voltage feedback from the resistor divider. The op amp does all within its power to keep these two voltages identical. The ratio of R3/R2 controls the proportional gain, and C1 is a compensation capacitor that blocks DC feedback, but responds to changes in output signal thus maintaining stability (prevents oscillation). Zener D2 prevents overvoltage at the gate of Q1—R4 limits op amp output current when D2 is conducting. C1 is the positive rail bypass capacitor. D1 prevents battery voltage from appearing across the solar panel and prevents unnecessary battery discharge when the solar cells are not generating power.

When the feedback voltage from the wiper of R6 drops below 2.5V; the output of U1A moves in the negative direction thus turning Q1 on. The increased current out of Q1 causes the battery voltage to increase and increases the voltage at the wiper of R6 until it is equal to the reference voltage [6].

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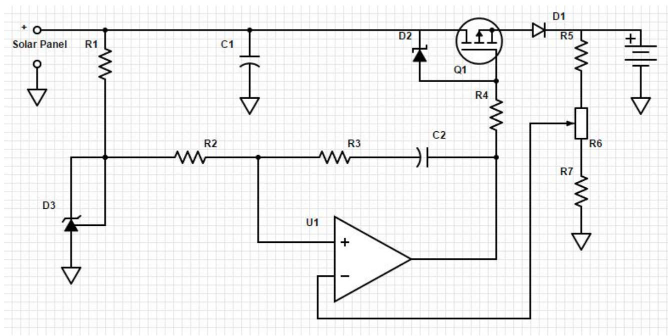

Figure 3: Solar charge controller circuit

3) Rectifier Circuit

A full wave bride rectifier should be used, as the output of the dynamo is alternating. A basic full wave bridge rectifier circuit along with capacitor to decrease the ripple voltage is shown below. In order to reduce the voltage drop, schottky diodes are used.

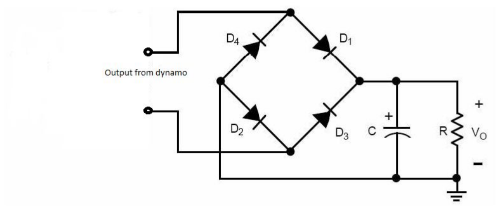

Figure 4: Full wave rectifier circuit

B. Mechanical System

1) Gear and Drive System

There a quite a few challenges which had to be overcome to solve the ploblem of mechanical coupling. There were a lot of options before us to couple the dynamo shaft and handle. Accoring to the problem statement, a rotational speed of 60-200 rpm had to be met. The following are the options available.

(i) Use meshing gears, one coupled to the dynamo while the other is connected to the handle.
Disadvantage:
- The weak shaft of the dynamo might noy be able to withstand the weight of the gear and may thus bend.

Advantage:
- Reliable method.

(ii) Use a belt drive
Disadvantage:
- Not reliable as the belt may slip; low efficiency

Advantage:
- Machinging involved to get the drive running is minimum.

(iii) Use a chain drive
Disadvantage:
- Precision involved is maximum. Even a slight misalignment may cause the chain drive to fail.
- Even though the chance of bending of reduced, it is still probable.

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Advantage:

- Use of cheap cycle parts which are easily available

2) Mechanical Structure

In the project a chain drive was used and to house the sprocket and the freewheel along witht the dynamo, a metallic structure was built. U shaped blots were used to fasten each onto the structure. The metallic structure built was fixed with no option for fine adjustments. Thus some madifications have to be made in order for the system to succeed.
Suggested Modifications

- Allowance for movement of dynamo and freewheel in the up-down direction.
- Allowance for moment of dynamo and freewheel in the right-left direction.

V. CONCLUSION

The unit developed was restricted to separately developed muscle powered drive and a solar charge controller circuit. The entire muscle powered drive was made using commonly available cycle parts. The freewheel of the bicycle was welded onto the dynamo. This was a difficult and ultimately fruitless affair because the diameters of the two did not match. A bearing was used and welded onto the outer covering of the dynamo. This proved to be a fatal flaw in the design as the shaft of the dynamo bent which made the freewheel wobble on the shaft. The use of a chain drive added fuel to the fire. It is a difficult affair to perfectly align a chain drive. The chain dive chosen was vertically oriented just like that in a bicycle. Due to the wobble in the shaft, the chain continuously failed, meaning fell off the drive and we were not able to achieve a high speed. Use of the sprocket and the freewheel itself does not give a very high mechanical advantage. When used for an actual application, the speed that one can achieve has to be pre-calculated.
The use of a supercapacitor bank to absorb the peaks of energy from the dynamo was thought of. But a solution to the problem of differential charging of the supercapacitors could not be achieved. This was partly due to the fact that dissipation of energy and the charging time were not optimal with any of the solutions.
The charge controller used dissipates some energy. The use of switched mode DC-DC converters should be considered for low power applications.

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