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Renewable Source of Mobility:A Future Prospect

Ayush Goel[1], Rajveer Mittal[2], Ruchika[3], S S Deswal[4]

Department of Electrical and Electronics Engineering, Maharaja Agrasen Institute of Technology, Delhi, India

ABSTRACT: In present scenario, the world is facing shortage of fossil fuels and hike in their prices due to ever increasing demand. Henceforth, it has become imperative to revolutionize our way of living by initiating green revolution in automobile industry. The biggest concern for the world population today is to breathe fresh air and thus combat related health issues. This paper focuses on hardware development of Hybrid Electric vehicle to address this severe situation and has been coupled with green technologies: solar and regenerative braking, which not only offer an alternative to Internal Combustion driven Vehicles but can also help us take a leap forward in achieving sustainable global development by reducing air pollution and ever increasing temperature of the earth. Hybrid electric vehicle's setup essentially consists of motor controller, hub motor and battery bank with Electric brake paddle attached to chassis of the vehicle which can be used by the commuter to develop desired level of regenerative power using VaReB technology. It is further accompanied by solar module, set up on the top of the vehicle controlled by a charge controller to charge the battery bank.

KEYWORDS: Hybrid Electric Vehicle, Charge controller, Hub motor, VaReb, Regenerative braking, Solar panel

I. INTRODUCTION

Hybrid vehicle is one that combines two energy sources. A hybrid electric vehicle can combine diesel/electric, battery/flywheel, fuel cell/battery sources to generate power. In the paper [1] author states" A hybrid car is a vehicle that uses two or more distinct power sources to move the car. The term most commonly refers to hybrid electric vehicle (HEVs) which combines solar energy and electrical energy." The hybrid electric vehicle is driven by an electric motor, whose performance is governed by a motor controller, which further gets its power from battery packs which can be charged through a battery charger.

As stated by author in paper [2], electric vehicles on single charge range is significantly less than the motor car, lack of serious impact on the development and popularization of electric vehicle, included in the design of electric vehicle's energy recovery system is the effective way to solve this problem. Hence, using technologies such as regenerative braking and solar powered electric vehicle, the limitations of convention electric vehicle can be diminished to an extent as author in paper [5] tells us Hybrid electric vehicles were designed to overcome the disadvantages of gasoline powered d battery electric vehicles. HEVs combine the conventional ICE driven mechanical drivetrain with a motor propelled electric drivetrain. Electric power to the motor in a hybrid vehicle is usually provided by a chemical battery.

This paper discusses the Regenerative Braking and solar technology put in use to eliminate limitations of the Electric Vehicle. It further discusses the types of charge controller used to control current from solar panel to battery and their relative merits and demerits. The idea has been demonstrated by Hardware Implementation and detailed research has been done to evaluate techno-commercial benefits of green technology assisted vehicle as compared to fuel driven vehicles.

As stated in the paper [7], HEV technology for both light and heavy duty applications is commercially available today and demonstrates substantial reductions in tail-pipe emissions and fuel consumption, even when compared to other available low emission technologies. HEVs are particularly effective for urban travel, significantly lowering pollutant emissions and providing cost-effective CO_2 reductions in personal mobility. Encouraging hybridization of vehicle fleets through enabling policies and incentive structures can serve to lower both conventional and CO_2 emission, thus improving public health, energy security, and reducing fuel costs.

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II. SOLAR POWERED ELECTRIC VEHICLE

The most abundant source of power in nature is the solar power which if properly harnessed can help us reduce our dependence on non-conventional energy sources for power. The amount of irradiation incident per unit area of the earth's surface is 2.88 kwh/day. For an electric vehicle this solar power can be harnessed by employing solar panel on the roof of the vehicle and a suitable charge controller between solar panel and battery pack.

A. Solar Cell/Panels and Principle

Solar cell is a device which can convert solar light into electricity using photovoltaic effect and its efficiency is given by fraction of incident sunlight converted into electricity.

Mathematically, efficiency of a solar cell can be given by:

$$N = (V \times I \times FF) / P_{in} \qquad (1)$$

where,
V : Open circuit voltage
I : Short circuit current
FF : Fill Factor
N : Efficiency
P_{in}: Input power

Solar cells utilize photovoltaic effect which is a phenomenon to generate an emf due to absorption of ionizing radiation.

As solar cells are prone to mechanical damage, several solar cells are highly interconnected and encapsulated into single stable unit called solar module which increases their lifetime to 20 years.

TABLE I: SOLAR MODULE PARAMETERS OF THE PANEL CONNECTED ON THE TOP OF THE VEHICLE

I_{sc} / I_{mp} [A]	3.805/ 3.571
V_{oc} / V_{mp} [V]	22.22/ 18.17
P_{mp} [W]	64.9 (PASS)
F.F	0.767
Cell Efficiency [%]	16.16
Module Efficiency[%]	13.60
Module Area [m^2]	0.477225
Cells serial	36
Cells parallel	1

B. Solar Panel to Battery Connections

To connect a battery bank to a solar panel is relatively easy and we need to connect the positive end of the battery bank to the positive terminal of the solar panel and negative end of the battery bank to negative terminal of solar panel. We cannot connect the battery bank directly to the solar panel as during night electricity can leak back into the panel which will slowly discharge the battery. This potential problem can be solved by incorporating a charge controller in the line.

C. Charge Controller

As discussed in previous section solar charge controller provides a one way path for electric current and restricts its flow from solar panel to battery. It moreover ensures that the battery gets the voltage they need and that they don't get overcharged. There are mainly two type of charge controller:

(a) PWM Charge Controller

This type of controller restricts the output voltage of the panel to near that of battery. It is a sophisticated voltage regulator that takes incoming voltage from your panel and changes it to what your battery need. It is a small and inexpensive controller and is ideally suited for small PV systems with one or two panels but it is a 30 Amp controller and

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thus has limited power handling capability. Therefore, if panels are connected in series we need to move to MPPT charge controller as voltage increases when panels are connected in series. PWM controller is connected to one solar panel of rating 12V, 60 W and is placed inside the bike.

(b) MPPT Charge Controller

In this controller power transmission is far more efficient and we can use thinner, cheaper wire. Hence, you can save enough in the wire while mounting panel 60 feet (say) away from the controller and moreover, we gain efficiency. The MPPT charge controller can charge the batteries nearly the entire time the sun is out while PWM controller has to wait till the voltage necessary to charge the batteries is generated.

The selection between the two controllers should be based on the system requirements and should be carefully selected as cost increase exponentially from PWM to MPPT controller.

D. Circuit Diagram for Charge Controller

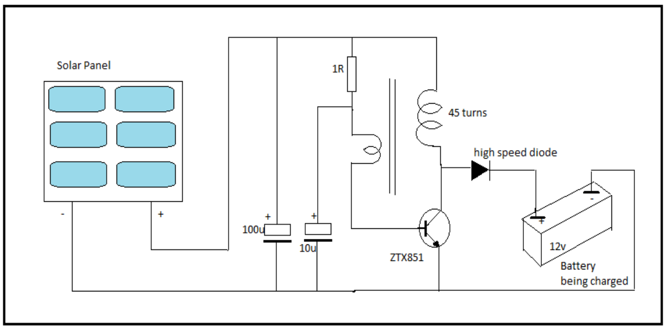

Fig.1. Circuit diagram of solar charge controller

E. Hub Motor

In the electric vehicle the brushless dc motor is installed owing to its various advantages such as light weight, less noisy operation, increased reliability and no sparking. Rotor of this motor has permanent magnet and stator is fitted with coils. B y applying dc power to coil, the coils are energized and become an electromagnet. The operation of a BLDC is based on force interaction between electromagnet and permanent magnet. The rotor rotates as the current shifts from one coil to another in a 3-phase motor as shown in the diagram:

III. REGENERATIVE BRAKING

In a conventional braking system, kinetic energy is lost as heat energy in airstream while braking via mechanical friction brakes. Thus, a lot of energy is wasted every time we apply brake. Regenerative braking is a process wherein this kinetic energy is stored in a short term storage system such as battery and utilized later for accelerating the vehicle.

In regenerative braking system, electric motor that normally runs the vehicle start rotating in reverse direction during braking and act as a generator thus, producing electricity. Hence, the same motor, instead of consuming power from batteries, start charging the batteries.

In the paper [4] the author states “Regenerative Braking concept can be used to store energy by use of following techniques-

A. Alternator Coupled Braking Mechanism
B. Kinetic energy Recovery system
C. Solid state Regenerative Braking

Regenerative braking offers various advantages such as overall efficiency of vehicle and life span of friction braking system increases. It can be implemented in locomotives such as metro and electric vehicles.

Regenerative braking module is a 3-phase rectifier circuit acting as a converter employed to get DC voltage from trapezoidal back emf of BLDC Hub motor. The DC voltage in the range 28-48V is obtained and is used as a power source for headlights in the electric vehicle. VaReb Technology has been employed to implement the regenerative

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braking in electric vehicle which involves varying the intensity of braking and extraction of energy from the back EMF to get optimal energy even when momentum of vehicle is varying.

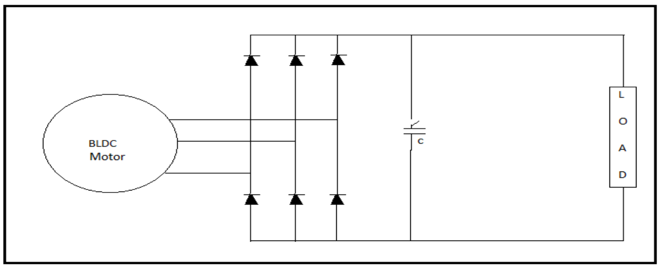

Fig.2. Circuit of RB Module

The circuit employs four capacitors which can be connected to rectifier circuit according to requirement and get included in the circuit in increasing order of their capacitive reactance.

The four sets of capacitances as stated in paper [4] are as follows:

1) C1= 100 µF 2) C2= 433 µF
3) C3= 1433 µF 4) C4= 3433 µF

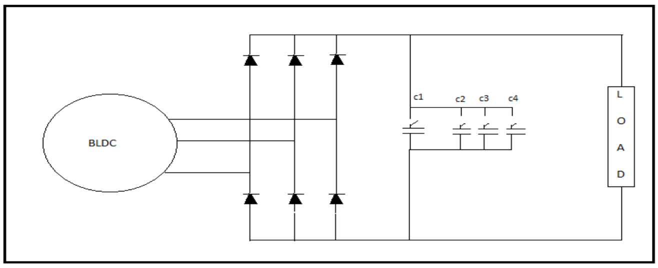

Fig.3. VaReB Circuit Diagram

IV. BLOCK DIAGRAM OF SOLAR HYBRID ELECTRIC VEHICLE

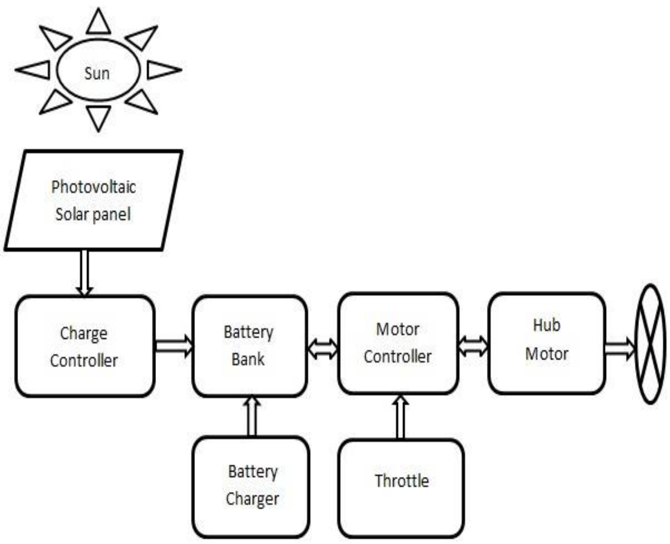

Fig.4. Block Diagram

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V. RESULTS

The idea of green technology that is, solar technology was implemented on Hardware and a 12v battery was charged using one solar panel of 12V, 60W. Moreover, regenerative braking system utilized lost electric power during frictional braking to illuminate the electric vehicle for short period of time.

Fig.5(a). Solar Hybrid Electric Vehicle

The electric vehicle gave maximum speed of 25km/hr (run on a smooth road).

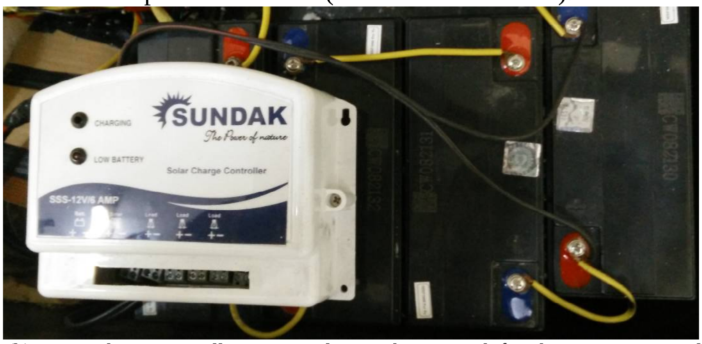

Fig.5(b). PWM charge controller connected to one battery with four batteries connected in series

Four batteries were connected in series to get higher output voltage of 48V to meet the BLDC motor requirements(48V, 500W)

Fig.5(c).One solar panel (12V, 60W) connected to battery

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Fig.5(d). Illumination of bike employing Regenerative power

A board consisting of LED light was connected to the regenerative circuit to provide illumination for a short period of time for the bike.

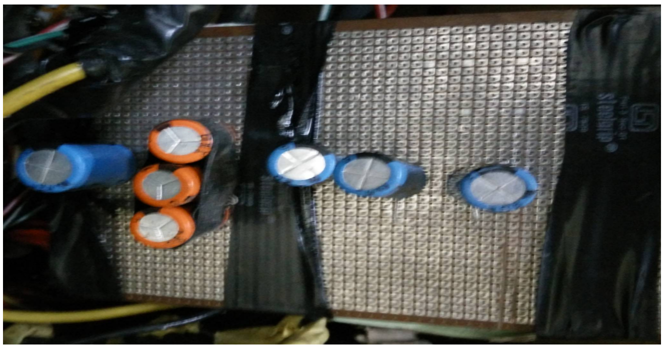

Fig.5(e). Capacitors in regenerative circuit

In the VaReB circuit diagram, the capacitance of different values is connected to rectifier circuit in order of their increasing capacitive reactance.

A. THEORITICAL CALCULATIONS:

A solar panel of 12V, 60W gives about 70% of the power that is 42W and hence current can be obtained as:

Current from solar panel =

Power of module/ Voltage of module

Current from solar panel = 42/12 = 3.5A

1 Battery of 24Ah is discharged maximum up to 70% which makes it 16.8Ah

Time taken to charge 1 battery completely via solar panel =

16.8/3.5 = 4.8 hours approximately.

B. PRACTICAL OBSERVATION AND DISSCUSION:

It was observed that it took 5.5 hours to charge 1 battery from solar panel when vehicle was stood under the sun for 5 straight hours without using it for transportation purpose and hence the result was quite close to expected theoretical result.

Although this value can considerably change depending upon various factors such as

A. Weather pattern during the day
B. Day hours in which the vehicle is run
C. Direction of sun over the day
D. Amount of usage of battery while charging the same

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The way the technology discussed can help in revolutionize our way of living can be seen by evaluating techno-economic benefits for fuel driven vehicles and solar hybrid electric vehicle by taking a scenario as shown below:

TABLE II: COST ESTIMATION OF CONVENTIONAL FUEL BASED VEHICLE

S. No.	Parameter	Conventional Fuel Based
1.	Bike speed [km/hr]	20
2.	Bike running [km] in one day[say]	40
3.	Bike running days in 1yr[say]	312
4.	No. of km run by bike in 1yr	12480
5.	Bike running [km] in 1L petrol	80
6.	Amount of petrol [L] required	156
7.	Cost of 1L of petrol [Rs]	61.2
8.	Total cost of bike running on petrol in 1yr [Rs]	9547

TABLE III: COST ESTIMATION OF PROPOSED HYBRID VEHICLE

S. No.	Parameter	Proposed Hybrid Based
1.	Battery + charger costs [Rs] [4 no.12v 24Ah]	9000
2.	Battery life [years]	3
3.	Battery cost per year	3000
4.	Solar kit cost[Rs] [4 no. 12v 60w panel + charge controller]	32000
5.	Solar panel/kit life[years]	20
6.	Solar panel/kit cost per year	1600
7.	Bike motor [500w 48v] drawing current[A]	10.4
8.	Battery supplying current[A] capacity in 1hr	24
9.	If bike is fully charged by battery charger at start it will run for [hr]	2[approx.]
10.	Bike speed [km/hr]	20
11.	If battery is fully charged by battery charger at start it will run for [km]	40
12.	Battery gets discharged in 2hr after bike operation but as battery[24Ah] can get discharged maximum up to 70% net balance[Ah]	7.2
13.	Net balance [Ah] to be charged by solar panel	16.8
14.	Solar panel current capacity[A] [48V, 168W]	3.5
15.	Time taken by the solar panel to charge the battery bank[hr]	4.8
16.	Battery charger specification	Input- 220V,

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		1A Output-59V, 2.7A
17.	To charge a discharged battery [7.2 to 24Ah] time taken [hr] by battery charger	6
18.	Battery charger wattage[W]	220
19.	Power consumed by charger in 6 hrs[W]	1220
20.	Power unit consumed by charger per day[no.]	1.22
21.	Cost of 1 Power unit [Rs]	6.5
22.	Cost of charging per annum [312 days][Rs]	2474
23.	Total cost of running the bike on Battery+ Solar [Battery cost per year + Solar panel/kit cost per year + Cost of charging the battery] [Rs]	7074

As it is evident from the table, solar technology will not only help us to combat the problem of air pollution as no fuel is required for its working but also help us save [9547 – 7074 = 2473 in the scenario discussed] valuable money. When the solar technology is accompanied by the regenerative braking system it gives an edge over conventional fuel driven vehicles as regenerated power can be temporarily stored in the batteries which can be used later to accelerate the vehicle or the regenerated power can also be used to operate auxiliary equipment fitted in the vehicle.

Green technology assisted vehicle is pollution free, noise free; require less maintenance and fewer mechanical components in addition to being economical. It can be easily recharged by the battery charger and can be widely used for short distance travelling.

VI. CONCLUSION

The Hybrid Electric Vehicle combining the solar power technology and regenerative braking system is built and tested to provide pollution free alternative to Internal Combustion driven vehicles. PWM controller was used to charge one 12 V battery from one 12V, 60 W solar panel while MPPT controller can be used to charge four batteries in series (12 V each) from four such panels connected in series and achieve higher overall efficiency for the vehicle as compared to PWM. Regenerative braking using VaReb technology is employed to provide regenerative power for any other auxiliary equipment

During the development of Solar hybrid electric vehicle it was seen that some modifications such as using fan inside a wind tunnel fitted on top of the vehicle to harness wind energy.

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