Design of Solar/Electric Powered Hybrid Vehicle (SEPHV) System with Charge Pattern Optimization for Energy Cost

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Abstract— **This paper proposes a Solar Electric Powered Hybrid Vehicle (SEPHV) system which solves the major problems of fuel and pollution. An electric vehicle usually uses a battery which has been charged by external electrical power supply. All recent electric vehicles present a drive on AC power supplied motor. An inverter set is required to be connected with the battery through which AC power is converted to DC power. During this conversion many losses take place and also the maintenance cost of the AC System is very high. The proposed topology has the most feasible solar/electric power generation system mounted on the vehicle to charge the battery during all durations. With a view of providing ignited us to develop this "Solar/Electric Powered Hybrid Vehicle" [SEPHV].This multi charging vehicle can charge itself from both solar and electric power. The vehicle is altered out of a Maruti Omni vehicle by replacing its engine with a 1.2HP, 24V Permanent Magnet DC [PMDC] Motor. The Supply to the motor is obtained from a battery set of 12V, 150AH. The household electric supply of 230V is reduced with a step-down transformer to 48V and then it is converted to the DC with a rectifying unit to charge the battery. Two solar panels each with a rating of 230watts are attached to the top of the Vehicle to grab the solar energy and is controlled with a help of charge controller. The SEPHV can be driven by 1.2 HP PMDC motor consisting of two 230 watts PV panel in the voltage rating of 24 V. The power which is absorbed by the PV panel is stored into the four 150 AH 12 V batteries. When there is no presence of sun, electric power supply act as an auxiliary energy source. For controlling speed of the motor, a switch is designed with four tapping, provided with different values of resistance at each tapping. It acts as a speed control switch for Solar/Electric Powered Hybrid Vehicle. This type of technique is to reduce the running cost and increasing the running efficiency of the vehicle. The performance of the SEPHV was found to be satisfactory for the load of four people with the average speed of 45km/hr. The integrated system consisting of Solar module, Charge Controller, Batteries, Boost Converter, Step-down Transformer, Diode Rectifier and PMDC motor which are required for the vehicle. Experimental results are presented to confirm the theoretical analysis.**

Keyword- Solar module, Batteries, PMDC motor, Charge Controller, Step-down Transformer Diode Rectifier.

I. INTRODUCTION

The fossil fuel such as petrol and diesel are very expensive way to be extracted and used. The use of fossil fuel based vehicles is one of the major reasons that has accelerated the extraction of these non-renewable resources in an unsustainable way. Further, transportation of these fuel to rural areas itself has become a problem. The major problem is green house effect caused due to this burning of fossil fuel where large amount of CO_2 will be emitted which causes lots of problem. Solar vehicles depend on PV cells to convert sunlight into electricity to drive the PMDC motors. Unlike solar thermal energy which converts solar energy to heat, PV cells directly convert sunlight into electricity. According to recent surveys the fossil fuels are depleting at a fast rate where in and around 50 years the whole fossil fuel in the world must be completely depleted. Therefore it is the need of the time to make a new exploration of natural resources of energy and power among the natural resources available sunlight is the most promising one. Sunlight is considered to be a source of energy which is implemented in various day to day applications.

The Solar/Electric Powered Hybrid Vehicle (SEPHV) contains the solar panel, Permanent Magnet DC (PMDC) motor, charge controller, batteries, solenoid control, step down transformer, additional brushes and diode rectifier unit. Diode Rectifier can be used to charge the batteries in normal AC supply during sunless conditions. A zero emission solar/electric vehicle is powered by Photovoltaic/Electric Supply energy by means of solar panels and AC supply with storage of electric energy in batteries [1].The PV array has a particular

operating point that can supply the maximum power to the load which is generally called Maximum Power Point (MPP). The maximum power point has a non linear locus where it varies according to the solar irradiance and the cell temperature. To boost the efficiency of the PV system, the MPP has to be tracked and followed by regulating the PV panel to operate at MPP operating voltage point, thus optimizing the production of the electricity [2]. One of the most important points is the construction of the vehicle is that, it is closely related to the chassis design, with the purpose of achieving a structural optimized work. So, in order to make the vehicle move under low power consumption and the redesign of chassis has to be done. The design was conceived from point of view of a high efficiency, light weight and stable transport with reduced costs and zero emission in its operation and in the obtaining of the energy [3].Solar Energy is being used to produce electricity with the help of these technology our aim to make solar energy powered Vehicle in our paper. Main disadvantages of solar energy is such that it is not a constant source of power and the amount of solar energy available keeps on varying throughout the day and at night time it is completely unavailable. So to power our vehicle during the absence of solar energy we designed as alternative method of obtaining power to run the vehicle from the Electric supply.

Solar/Electric Powered Hybrid Vehicle (SEPHV) can charge itself from both solar and electric power. The vehicle is altered out of a 'Maruti Omni' by replacing its engine with a 1.2HP, 24V Permanent Magnet DC [PMDC] motor. The electric supply to the motor is obtained from a battery set of 12v, 150AH. Two solar panels each with a rating of 230Watts are attached to the top of the vehicle to grab the solar energy and then it is controlled with the help of charge controller. This is used as a main source of energy to charge the battery. The household electric supply of 230V is reduced with a step down transformer to 24V and then it is converted it to DC with a rectifying unit to charge the battery. This is used as a backup source or auxiliary of energy to charge the battery. The Vehicle can be controlled and can matchup a speed of 45km/hr. The PV/Electric Powered Hybrid Vehicle [SEPHV] is thus a boom to the present world by providing us with fuel free mode of transport.

The paper is organized as follows. The system configuration and overview are discussed in section II. The PMDC Motor and characteristics are discussed in section III. Section IV discusses the overall design procedure of Solar/Electric Powered Hybrid Vehicle [SEPHV]. Section V gives the overall hardware implementation of proposed Solar/Electric Powered Hybrid Vehicle [SEPHV]. Section VI concludes the paper.

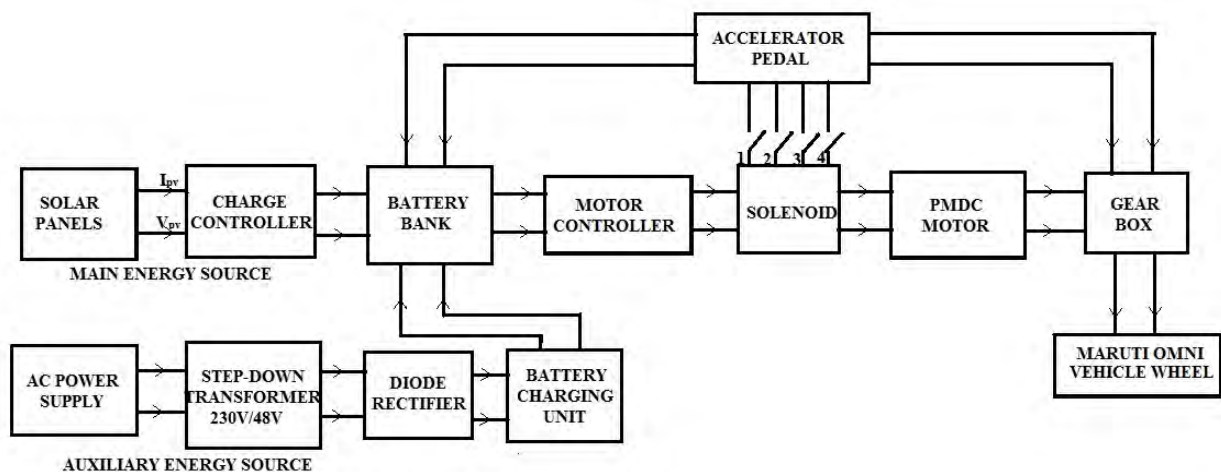## II.   SYSTEM CONFIGURATION AND OVERVIEW

Fig.1. Overall View of the SEPHV

The Fig.1. represents an overall view of the Solar/Electric Powered Hybrid Vehicle (SEPHV) sun is the main source of energy for the vehicle and electric power supply is the auxiliary source of energy for the vehicle.

In this paper the configuration of the Solar/Electric Powered Hybrid Vehicle (SEPHV) system are composed by solar panels, charge controller, battery bank, PMDC motor, step down transformer, battery charging unit and altered 'Maruti Omni' vehicle. Hybrid vehicle carries the energy from the both the solar and normal ac supply. The output power from the solar panel is varied depending up on the light irradiation on the atmosphere conditions. Discrete power from the solar panel is connected to the charge controller circuit and fed to the battery bank circuit. At the same time the continuous power from the ac supply is connected to the step-down transformer (230V/48V) and battery charging unit to battery bank. The electric energy thus formed is being fed to the battery bank. The Vehicle combines the use of electric energy from the three different sources [4]:

      a)   Photovoltaic solar energy
      b)   Rectified power supply
      c)   Batteries

The Solar cell collects a portion of Sun's energy and stores it in the batteries. Before that the charge controller convert the energy collected from the solar array to the proper system voltage. So, that the batteries and the motor can use it. Once the energy is utilized by the motor and the battery, an additional charging unit is implemented on the SEPHV to drive.

The additional charging unit is a rectifying unit of which will step down the 230V of normal electric AC Supply to 48V using a step-down Transformer and rectify it to DC supply to charge the batteries. The rotor shaft of the motor is directly coupled through the solenoid control a gear system. Solenoid control acts as a speed control switch. A Switch is designed with a 4 tapping, giving different values of resistance at each tapping, hence limiting the current that flows in the motor. The performance of the vehicle was found satisfactory for the load of four people with an average speed of 45km/hr.

The block diagram represents the overall representation of SEPHV. We altered a Maruti Omni Vehicle into Solar/Electric Powered Hybrid Vehicle (SEPHV) by first replacing its engine with a Permanent Magnet DC Motor [PMDC]. The Motor is made to run from a battery set which is charged from two methods. In the first method a series of Solar Panels are kept at the top of the SEPHV which produces a DC Voltage from the availability of solar radiation. The amount of DC Voltage developed is controlled using a charge controller.

In the second method the normal AC Supply is stepped down and rectified to produce a DC Voltage. These two methods are combined to charge the batteries. The charge controller controls the depth of discharge (DOD) of the battery in order to maintain the life of the battery. The motor controller can be used to control both the speed and its electrical braking. Solar charging controllers are designed to prevent solar/electric hybrid vehicle (SEPHV) from overcharging and excessive discharging, therefore to protect our investment and extend the battery life[4]. The electrical energy thus formed is being fed to the batteries that get charged and is used to run 24V PMDC motor. The shaft of the motor is connected to the gear box of the vehicle. The batteries are initially fully charged and thereafter they are charged by PV panels and electric supply.

The batteries are directly connected to the motor through a Solenoid control circuit. The Solenoids are acting as the speed control switch. Initially, First accelerator contact is pressed where the solenoid-I activates and the single battery is connected to the motor. When the second accelerator contact is pressed, solenoid-II activates and the two set of batteries are connected to the motor. When the third accelerator contact is pressed , solenoid-III activates and the three set of batteries are connected to the motor. When the fourth accelerator contact is pressed solenoid-IV activates and the four set of batteries are connected to the motor. In this method it acts as a voltage control method.

III. PMDC MOTOR AND CHARACTERISTICS

The stator is the fixed part of the motor, in which the rotor turns. The stator consists of a pair of permanent magnets aligned so that poles of opposite polarities forces each other. Thus one magnet has its North (N) pole close to the armature, while the other magnet has its South(S) pole close to the armature. Therefore, lines of magnetic field pass from one permanent magnet to other through the metallic armature. The rotor is the rotating part of the motor. It consists of a wire loop mounted on a rotary metallic armature [5]. The ends of the wire loop are connected to terminals located on the stator of the motor, via a commutator and a pair of brushes. The commutator has two segments isolated from one another.

The permanent magnet dc motor having four brushes, but in this paper we have added additional four brushes. For the increasing the efficiency of the running time of the vehicle. The brush Permanent Magnet DC motors have four general characteristics.

    a)   Desirable torque versus speed
    b)   Simple control of torque and speed
    c)   High electromagnetic power supply
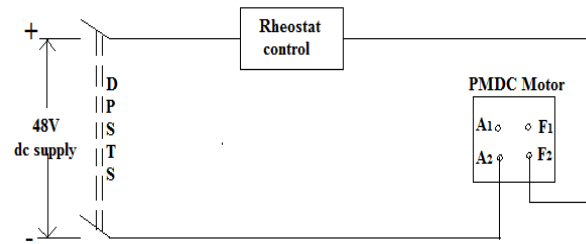   d)   Inverter set are not required.

Forward connection:

Fig.2. Circuit diagram for the movement of the vehicle – Forward Connection
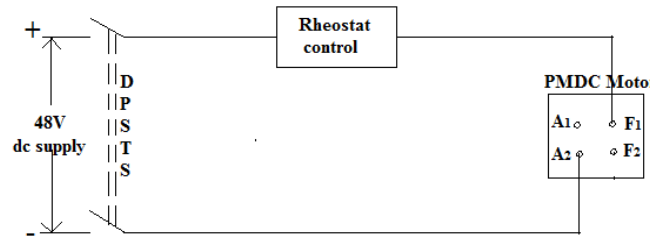
Reverse Connection:

Fig.3. Circuit diagram for the movement of the vehicle - Reverse Connection
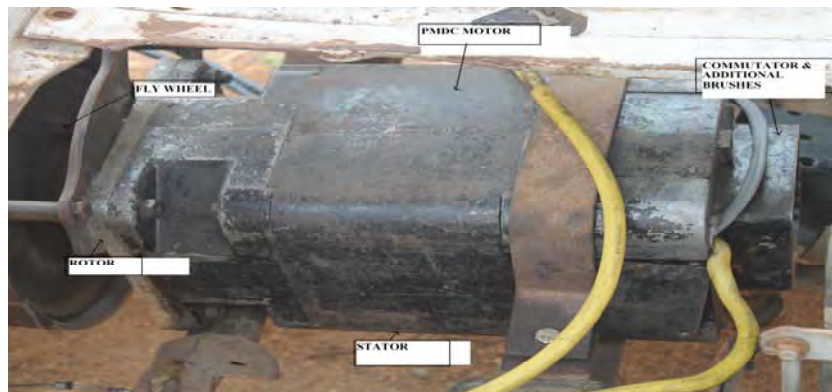

Fig.4. Hardware Setup of PMDC Motor

The Specification of PMDC Motor used in this paper are represented in TABLE I.

TABLE I
PMDC MOTOR SPECIFICATIONS

S.No.	Specifications	Range
1	Power	895Watts
2	Rated voltage	48V(it can be reduced to 24V with the help of solenoid control)
3	Rated current	12A
4	Rated speed	3000rpm
5	Rated torque	7.7NM(or)1090 oz-in (Ounce-force inch)
6	No load current	1.6A

The Fig.2.& Fig.3. Shown below represents the connections of the motor for forward and backward direction motions. There are four terminals on the motor, namely A_1, A_2, F_1, F_2 as A_1, A_2 are the armature terminals and they are internally shorted. All the connections are made keeping the DPDT switch at the centre. The either connections on DPDT switch are made for forward direction motion of motor and the next side of DPDT switch is made for reverse direction of the motor. The A_2 is directly taken from battery to the positive side of DPDT switch and F_2 is taken via controller unit to the negative terminal of the switch.

For the DPDT the centre terminals are given the upper side as positive from the battery and lower as the negative from the battery. Now the A_1, A_2 are the internally shorted terminals of the motor. Thus either of the one is the main and another one is the dummy. In case of our motor the A_1 terminal is dummy and A_2 is the main terminal. Thus all connections are made keeping A_2 as the main terminal. In the switch the A_2 and F_1 are

the terminals that are responsible for the reverse motion of motor. All are connected directly to the switch, A_2 is connected to the positive and F_1 is connected to the negative of the switch.

IV. Design Procedure of Solar/Electric Powered Hybrid Vehicle (SEPHV)

Design of the proposed SEPHV system involves the design of the altered PMDC motor and altered Maruti Omni vehicle.

a) Solar panel specifications

Solar cells are solid state semiconductor devices which convert light energy directly into electrical energy. A solar cell contains a low voltage typically about 0.45 volts per cell; cells are connected in series to increase voltage [8].

The model of solar cell can be categorized as P-N semiconductor junction, when exposed to light, the DC current is generated. The generated current depends on the solar irradiance, temperature and load current. The typical equivalent circuit of PV cell is shown in Fig.5. The energy produced by solar panel obtained from two types of energy contribution as shown in equation 1 and equation 2

i) Energy during driving time(E_{dt})

The energy produced during a running period of a vehicle is calculated by the following expression.

$$E_{dt} = \eta_{pv}*A_{pv}*e_{sun} *[(SE_{sun} - SE_{PT})/ SE_{sun}]*[(BA_{ct} - BA_{dt})/BA_{ct}] \qquad ------(1)$$

ii) Energy during Parking Time (E_{pt})

The energy produced captured during the parking period of vehicle is calculated by the following expression.

$$E_{pt} = EL_{DT} + \eta_{pv}*A_{pv}*e_{sun} *[(SE_{sun} - SE_{PT})/ SE_{sun}]*[(BA_{ct} - BA_{dt})/BA_{ct}] \qquad ------(2)$$

Where,

η_{pv} –   PV Panel efficiency

A_{pv}-   PV Surface Area

e_{sun} –   Average energy enough by solar panel captured.

SE_{sun} – Solar energy captured during a sun at (7 AM to 6 PM)

SE_{PT} –   Solar energy during a parking time.

BA_{ct} -   Battery Charging time.

BA_{dt} -   Battery Discharging time.

EL_{DT} -   Energy loss during driving time.

During sunless conditions, battery will be charged with the help of electric power supply (230V, AC). It can be stepped down and can be rectified into DC with the help of Diode Rectifier.

$$E_{bat} = \eta_{ac}*[(BA_{ct} - BA_{dt})/BA_{ct}] \qquad ------(3)$$

E_{bat} – Energy stored in battery due to power supply

η_{ac} – Power supply efficiency

Total power = Driving time + Parking time
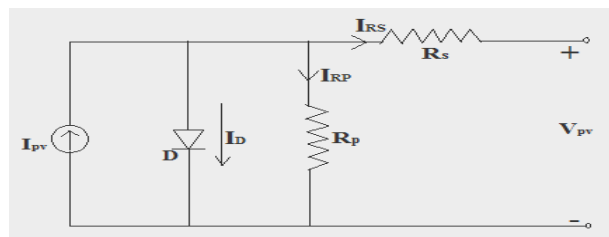
$$E=E_{dt}+E_{pt} \qquad ----- (4)$$

Fig.5. Equivalent Circuit of PV Cell

I_{pv} – PV Current in Amps.

V_{pv} – PV Voltage in Volts.
I_D - Diode current in Amps.
I_{RP} – Parallel Resistance current in Amps.
I_{RS} – Series Resistance current in Amps.

The Solar Module mounted on the top of vehicle is used to charge the batteries via charge controller. The upper frame of this solar module is converted with thick glass to avoid breakage of the solar panel. For the vehicle designed, we have mounted the solar panel in south-east direction during the time 7AM to 11AM and the solar panel is moved towards in the direction of south-west during the time 11AM to 6PM with the help of hybrid stepper motor. After that the electric supply are stepped down with the help of step down transformer and rectified with the help of diode rectifier and connected to the lead-acid batteries.Fig.6. shows the current and the voltage waveform of 230Watts Solar Module.

The specification of solar module used in this paper are represented in TABLE II

TABLE II
SOLAR PANEL SPECIFICATIONS

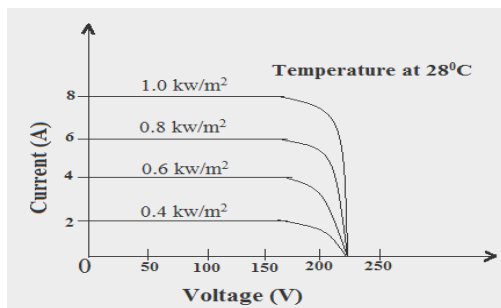| S.No.	Specifications	Range
1	Maximum Power (P_{max})	230 watts
2	Maximum Power Voltage (V_{pm})	24volts
3	Maximum Power Current (I_{pm})	5.10A
4	Open Circuit Voltage (V_{oc})	37.20A
5	Short Circuit Current(I_{sc})	8.55A
6	No load current	24.2%

Fig.6. V-I Curve of the 230 watts Solar Module

b) Charge controller and battery specifications

Charge controller limits the rate at which electric current is added to or drawn from the electric batteries. The prime purpose of using the charge controller is to prevent against overcharging and deep charging of a battery [6]. In the SEPHV design we will be taking a depth of discharge to be 85%.Temperature correction is needed because at low temperature battery efficiency decreases.

Charge controller consists of a circuitry that controls the DOD of the battery. The DOD and the battery life have inverse relationship. The battery that is discharged more has lesser life than that which is discharged less. The charge controller prevents the battery to be overcharged (or) over discharged.
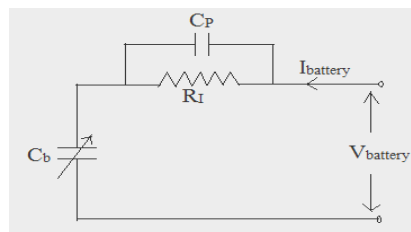

Fig. 7. Equivalent Circuit of Battery

C_P – Polarization Capacitor in Farad

C_b – Variable battery Capacitor in Farad

R_I – Internal Resistor in Ohms

$V_{battery}$ – Battery Voltage in volts

$I_{battery}$ – Battery Current in Amps

The correct dimensions of battery establish the Solar/Electric Powered Hybrid Vehicle. The goal is to search for a suitable relation among weight, volume, life time, cost, energy density and environmental impact. These factors must be expressed in the lowest possible weight and volume of the SEPHV.

For the 24V/150AH battery bank, 24V/12A solar charge controller is an ideal choice. Charge controller is connected between the solar modules and the batteries. In Fig.7. represents equivalent circuit of battery model. It includes the internal Resistor and Polarization capacitor (Cp) [12].

The specifications of batteries used in this paper are represented in TABLE III.

TABLE III
BATTERY SPECIFICATIONS

Voltage	12V
Maximum Current	6A
No. of Cells	6 Cells
Ampere Hours	150AH

c) Integration setup observations of SEPHV

The Complete integrated setup consists of the solar panel, solar charge controller, batteries, step down transformer, charging circuit, PMDC motor and altered Maruti Omni vehicle. The complete integration setup of solar/electric powered hybrid vehicle is shown as in Fig.8.
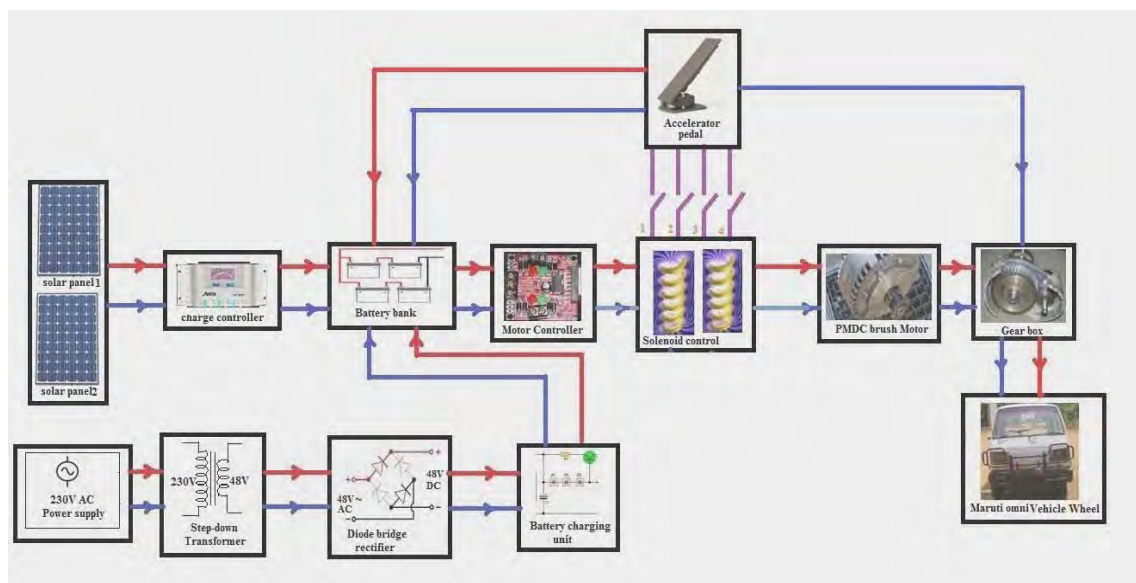

Fig.8. Integration setup of SEPHV

The specifications of entire SEPHV system in this paper are represented in TABLE IV

TABLE IV
INTEGRATION SETUP OF SEPHV

Solar module		Battery		PMDC motor		Charge controller		Diode rectifier		Step down transformer	
V (V)	I (A)	V (V)	I (A)	V (V)	I (A)	V (V)	I (A)	i/p (V)	o/p (V)	i/p (V)	o/p (V)
24	8.10	12	6	24	12	48	24	48V AC	48V DC	230V AC	48V AC

The hybrid vehicle different modes of operation are represented as shown in TABLE V

TABLE V
MODES OF OPERATION

Mode	Energy Source	Type of Energy Source	Storage Device
Mode -1	Solar energy-230Watts	Main energy source	Battery bank
Mode -2	Plug in energy source (with step down transformer &diode rectifier)	Auxiliary energy source	Battery bank

In mode 1, solar energy source acts as the main energy source. The battery is charged from the main energy source and the controller circuit controls the power supply to the motor and directly controls the translation speed of the vehicle.Fig.9.shows the mode 1 operation of the vehicle with energy storage.
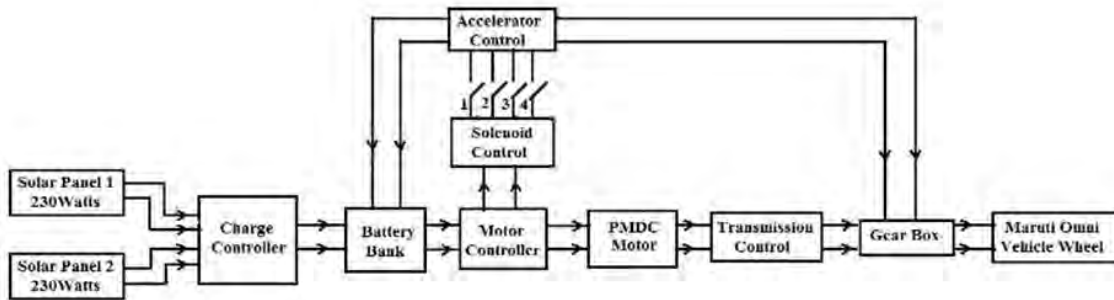
Fig.9. Mode 1 Operation of SEPHV

In the mode 2, plug-in power supply acts as the back up energy source. The battery is charged from the Auxiliary energy source and the controller circuit controls the power supply of the motor and directly controls the translation speed of the vehicle. Fig.10. shows the mode 3 operation of vehicle with energy storage.
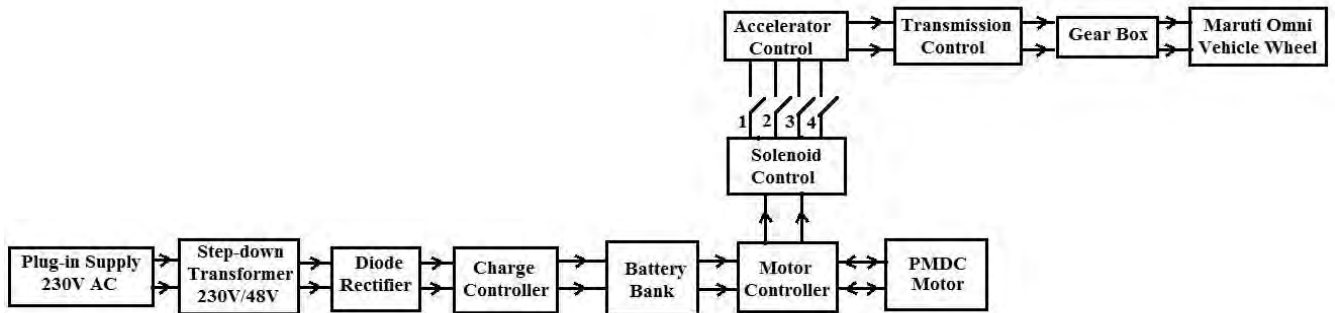

Fig.10. Mode 2 Operation of SEPHV

In Fig.11 shows control algorithm flowchart for Solar/Electric Powered Hybrid Vehicle (SEPHV). Solenoid control circuit is act as the speed control switch and it can be used to increase the efficiency of the running time. In TABLE VI shows the modes of operation of speed control switch. In Table VI shows the modes of operation of speed control switch.

TABLE VI
MODES OF OPERATION

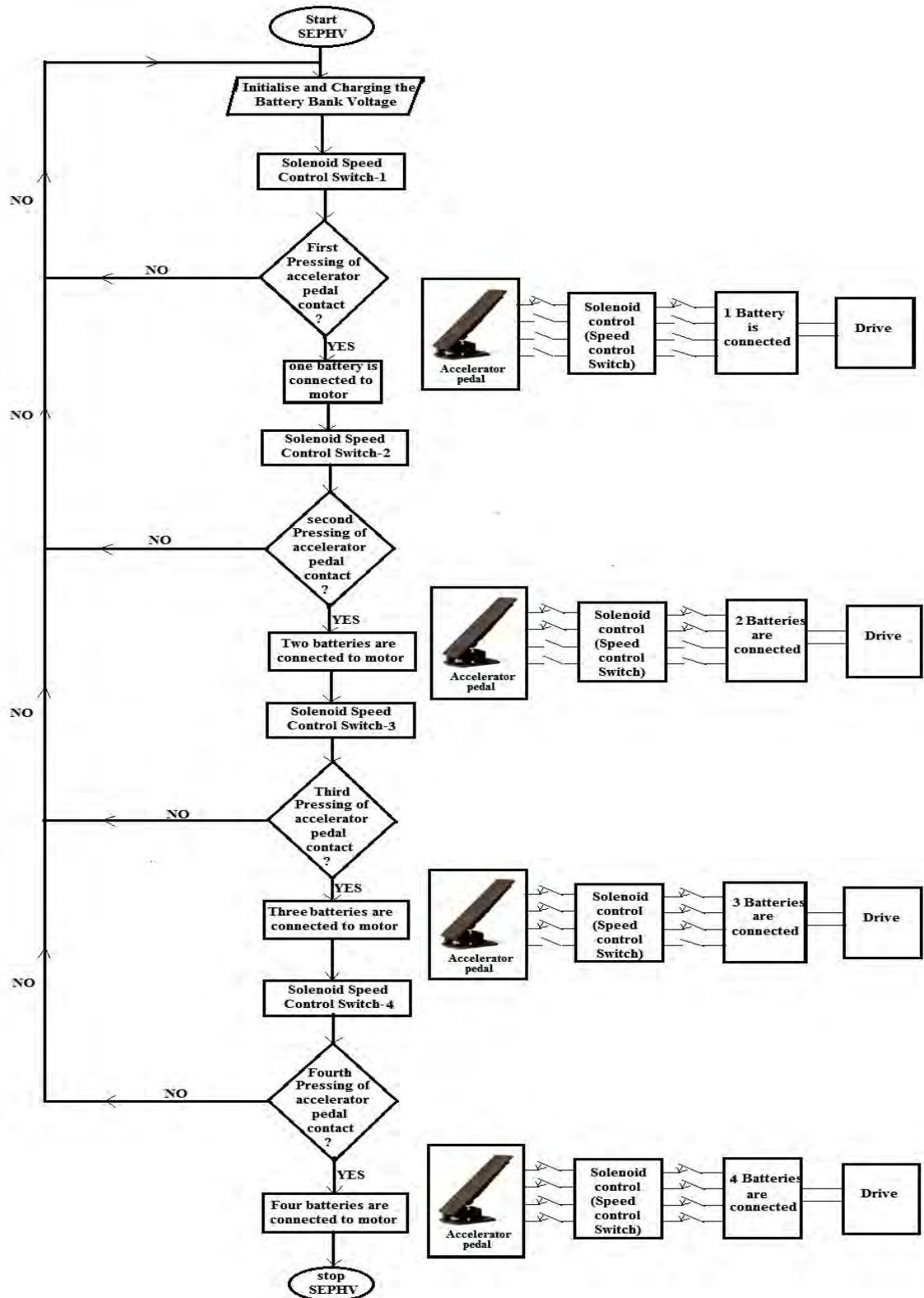| Mode No.	Accelerator Contact	Battery Level	Speed in KM/hr
Mode I	Ist Contact	One battery is connected	10 km/hr
Mode II	IInd Contact	Two batteries are connected	20 km/hr
Mode III	IIIrd Contact	Three batteries are connected	30 km/hr
Mode IV	IVth Contact	Four batteries are	45 km/hr

Fig.11. Control algorithm Flow chart for SEPHV

V.   HARDWARE IMPLEMENTATION OF PROPOSED SOLAR/ELECTRIC POWERED HYBRID VEHICLE (SEPHV)

Electric vehicles are divided into two general categories: Battery-electric vehicles and Hybrid-Electric vehicles [7]. A Vehicle needs high torque and acceleration. An electric motor develops maximum torque at low rpm, then torque declines with speed, mostly in step with a vehicle's natural demand [16].

In this paper, Maruti Omni vehicle engine, Fuel tank and other unwanted mechanical parts of the vehicle are removed and slightly rearranged. Replacing the engine and fuel tank with solar panels and batteries are added to the Maruti Omni vehicle. Power from solar array is limited by the size of the vehicle and area that can be exposed to sunlight. While energy can be accumulated in batteries to lower peak demand on the array and provide operation in sunless conditions. SEPHV is combined technology of solar and electric power. Solar vehicle depends on PV cells to convert sunlight into electricity to drive electric motors. The specifications of SEPHV are represented in TABLE VII.

TABLE VII
SPECIFICATIONS OF SEPHV

S.No.	Parts	Specifications
1	Altered Vehicle (with out engine, fuel tank & unwanted Mechanical Parts)	400 kg
2	Battery Bank	4X6 kg
3	Rider(4 persons)	270kg
4	Other parts	2kg
5	Solar panel	17.8X2kg
	Total Weight	729.6kg

Hardware implementation of proposed Solar/Electric Powered Hybrid Vehicle (SEPHV) is represented as shown in Fig. 12 (a,b,c,d).
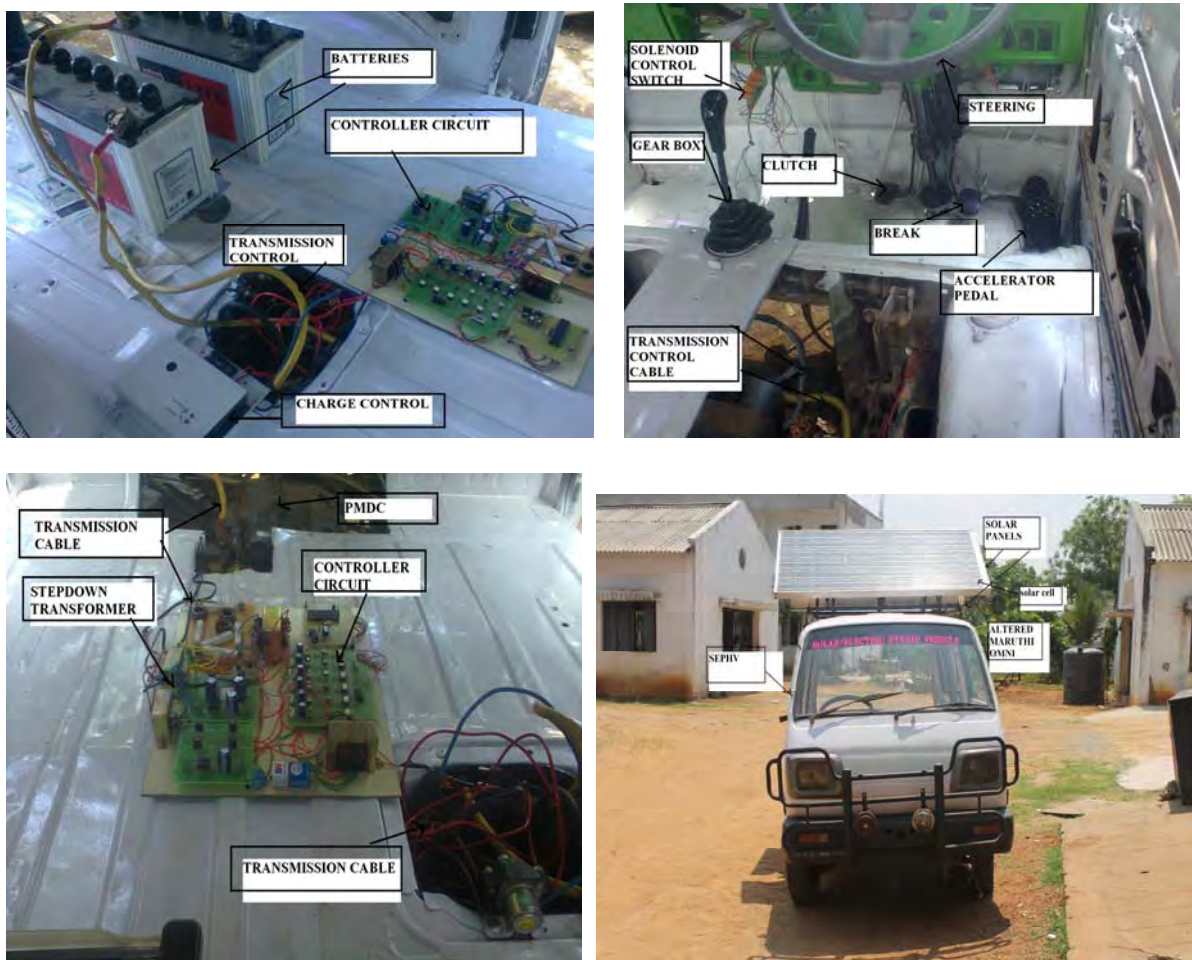

Fig. 12 (a,b,c,d) Hardware Implementation – SEPHV

Speed control switch are connected to the accelerator pedal. The speed control of the DC motor is the essential part of the Solar/Electric Powered Hybrid Vehicle (SEPHV). For controlling speed of the motor, a switch was designed with 4 tapping, giving different values of resistance at each tapping, hence limiting the current that flows in the motor. The switch uses pure nichrome wire for resistance. It uses a four tapping DC switches. The switch has been provided with two terminals; one for the motor connections and the other for the battery connections. The arrangement of the switch is more (or) less like a rheostat. The different tapping act as

resistance points. With each increase in tapping valve, the valve of resistance decrease, thus at the last tapping the motor will run at the highest speed as the limiting resistance will be minimum whereas the high torque condition of the motor will arise when the minimum tapping will be used. Since the limiting resistance will be maximum.
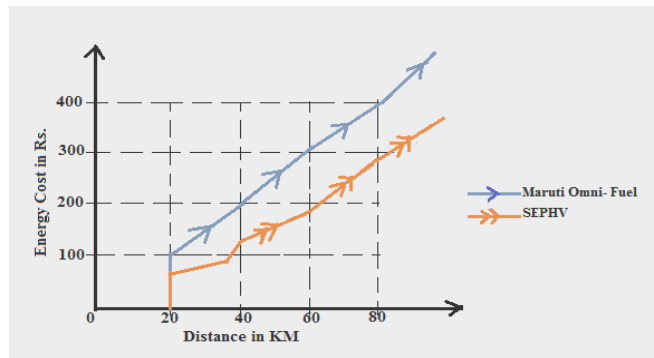

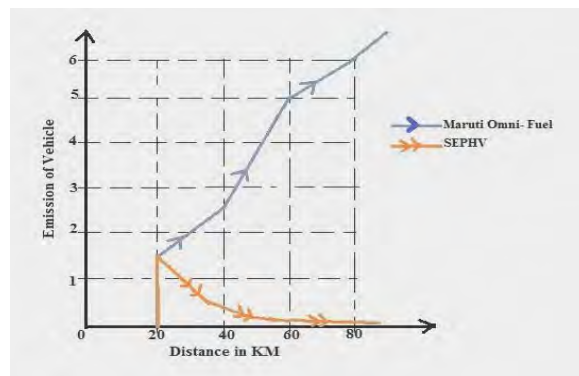Fig. 13. Comparison between the energy Consumption in Fuel Vehicle Over SEPHV

Fig. 14. Comparison between the Emission of Maruti Omni Over SEPHV

Fig.13. shows the waveforms of the comparison between the energy consumption in Maruti Omni fuel Vehicle over SEPHV. Fig.14. shows the waveforms of the Comparison between the Emission of Maruti Omni over SEPHV. Fig.15. Shows the Speed and time Characteristics of Solar/Electric Powered Hybrid Vehicle. Fig.16.shows the waveforms Experimental Results for Battery Voltage (Vs.) Speed on SEPHV. Fig.17. Shows the Speed and time Characteristics of Solar/Electric Powered Hybrid Vehicle.

Solar module mounted on the top of the vehicle is used to charge the batteries via charge controller. Two 230watts solar module is used to charging the batteries and start the load on the motor is nearly 730kg including the weight of four people driving and travelling it. The motor after starting acquires the maximum speed of 45kmph. The batteries get charged always from the solar panel and so it provides the power to run the vehicle. During the sunless conditions, electric supply are stepped down and converted to DC Power with help of diode rectifier and it is used to charging the battery. It provides the continuous run for the vehicle.
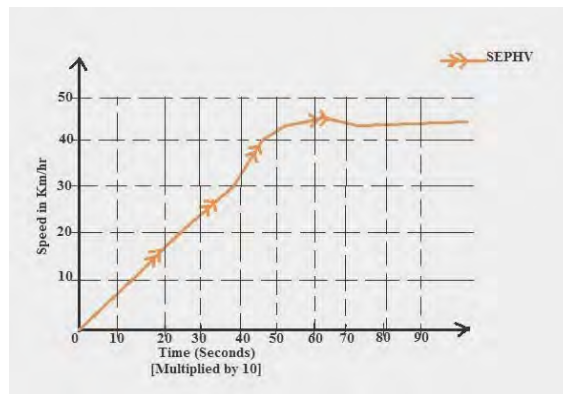

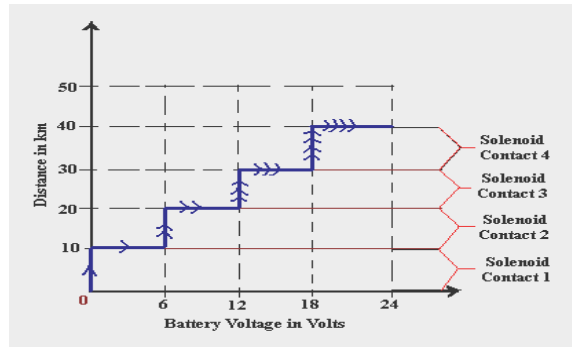Fig. 15. Comparison between Speed and time for SEPHV

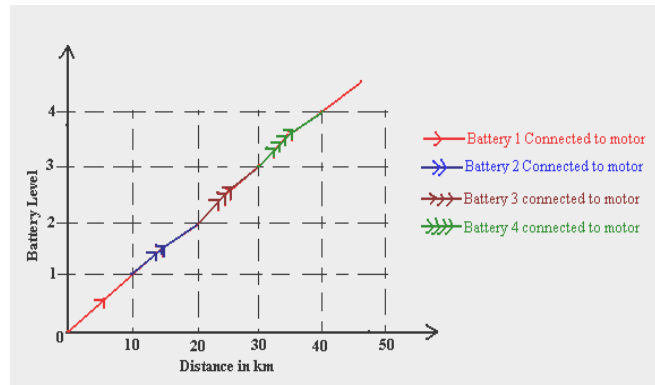Fig.16. Experimental Results for Battery Voltage (Vs) Speed on SEPHV.

Fig.17. Experimental Results for Battery Voltage (Vs.) Speed on SEPHV.

VI.   CONCLUSION

The Solar/Electric Powered Hybrid Vehicle (SEPHV) solves many problems related to the environment and is the best pollution free method. Solar vehicles do have some disadvantages like small speed range, continuous running depending upon the climatic conditions. But these disadvantages can be easily overcome by SEPHV. This multi charging vehicle can charge itself from both solar and electric power. During sunless condition, the household electric supply of 230V is reduced with a step-down transformer to 48V and then it is converted it to DC with a rectifying unit to charge the battery. This is the back-up source of energy to charge the battery. The batteries are directly connected to the motor through a Solenoid control circuit. The Solenoids are acting as the speed control switch. Initially, First accelerator contact is pressed, solenoid-I activates and single battery is connected to the motor. When the second accelerator contact is pressed, solenoid-II activates and the two set of batteries are connected to the motor. When the third accelerator contact is pressed, solenoid-III activates and the three set of batteries are connected to the motor. When the fourth accelerator contact is pressed, solenoid-IV activates and the four set of batteries are connected to the motor. In this method it acts as a voltage control method. The SEPHV has been satisfactorily completed the prototype that vehicle can run in normal surface with a total weight of 730kg. When the battery of the vehicle is fully charged it can run continuously at an average speed of 45km/h. If the price is compared to petrol driven Omni Vehicle, the cost per KM travelled will be Rs. 3.90. Here the distance covered by the SEPHV in a single day is 45 KM when the batteries are fully charged, then cost per KM travelled in a single day for 45 KM will be 50 paisa per KM. A good feature of the proposed configuration is making a Solar/Electric Powered Hybrid Vehicle (SEPHV) prototype as our research work and the Maruti Omni vehicle is running successfully on solar /electric power. The efficiency and running time of the Solar/Electric Powered Hybrid Vehicle [SEPHV] was verified by experimental results.

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