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Designing of Micro Controller based Charge Controller for SPV Powered Electric Vehicle

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Abstract— **This paper presents the design and implementation of SPV based Charge Controller for electric vehicle. The proposed charge controller is a smart Charge Controller as it automatically charge or discharge the battery bank based on the status of battery voltage of electric vehicle. Switching logic for Charge Controller is designed in such a way that battery is protected against over voltage and deep discharging. The performance analysis is carried out to test the prototype by charging and discharging test. Mahindra MAINI Electric Vehicle, procured by Basaveshwar Engineering College, Bagalkot is considered for test. It is observed from the experimental result that, proposed controller connects the battery bank to 1440W PV panel for charging upto 50V and discharges to 43V. In this manner, charge controller protects the batteries from overvoltage and deep discharging.**

Keywords-Smart Charge Controller, over voltage, deep discharge, PV panel.

I. INTRODUCTION

An electric vehicle is an automobile that is propelled by one or more electric motors, using electrical energy stored in rechargeable batteries or another energy storage device. Electric Vehicles are becoming popular today as they are pollutant free and maintenance free. A solar powered electric vehicle is an electric vehicle powered completely or significantly by direct solar energy. The Electric Vehicle used in this work is a Mahindra MAINI vehicle. The preliminary study [4] is performed on this vehicle and it is observed that, it consumes nearly 2190 units of energy per year for one time charging per day. This costs nearly ₹ 12045.00 annually. This is costly and uneconomical. In view of economic operation, it is proposed to design SPV source for charging the battery bank of the electrical vehicle. The specification of the electric vehicle consider in the work is as shown in Table-1.

In an electric vehicle, heavy and expensive batteries are used as energy storage device. When charging the battery bank of electric vehicle directly from SPV source, the battery may leads to overcharging.

Table-1: Specification of the electric vehicle

Sl No.	Particulars	Ratings
1	Total capacity	6 seaters
2	Total batteries	6
3	System voltage	48V, 150Ah
4	Battery weight	186 kg
5	Vehicle weight	470 kg
6	AC motor	4.6HP

Similarly while discharging, the battery bank may leads to deep discharging. Due to this life of the batteries reduces drastically. Advances in power electronics have helped to design effective charge controller, which controls charging and discharging of batteries. Proposed solar based smart charge controller is a small circuit consisting of voltage sensors for sensing panel voltage and battery voltage, MOSFET switches for switching application and PIC controller consider for monitoring the charging and discharging in a safe manner. Proposed controller connects battery bank to the panel for charging. When battery is at full charge (50V), the charging current becomes pulsed interrupted by PIC16F877A controller. Battery starts to discharge through the load till battery voltage falls to 43V and connects to panel for charging again. In this way, charging and discharging takes place through proposed controller without leads to overcharging and deep discharging.

II. EXCISTING CHARGE CONTROLLERS

There are different types [1] of Charge Controllers can be used in the circuits involving batteries. They are,

1. Series type Charge Controller
2. Shunt type Charge Controller
3. DC-DC Charge Controller
4. MPPT type Charge Controller

MPPT type of Charge Controllers are the latest type and more efficient controllers. But they require complex circuit, difficult algorithm. They are not economical [2]. DC-DC Converter type of Charge Controllers are also costlier when compare to the Series and Shunt Charge Controllers. Series and Shunt charge controllers pump maximum power from the panel. This paper describes the designing and performance analysis of Series Charge Controller Circuit. This circuit is also efficient controller and diverts excess electricity to the load connected. This helps during driving condition of the vehicle. Another advantage is that, they are economical when compare to other charge controllers. Therefore series ON-OFF charge controller has been designed and practically implemented.

III. BLOCK DIAGRAM OF THE PROPOSED CHARGE CONTROLLER

The block diagram of the proposed system consists of 1440W Solar panel for powering the circuit, MOSFET switches for switching application, PIC micro controller for controlling the charging and discharging rate of battery bank of the vehicle, resistors for scale down the panel voltage and battery voltage suitable for micro controller. The block diagram of the Proposed Charge Controller is shown in Fig-1.

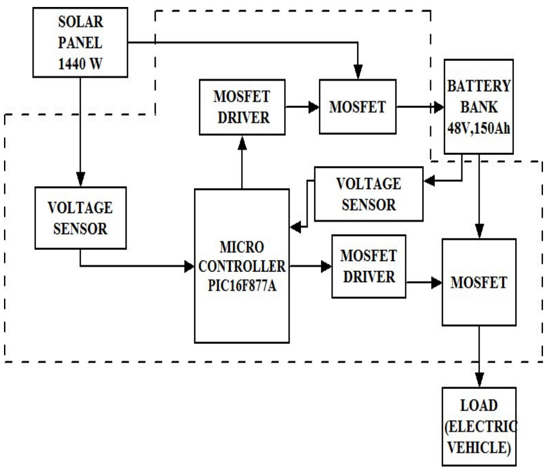

Fig-1: Block diagram of the proposed system

IV. DESIGN METHODOLOGY

1. Sizing of the Solar Panel

Sizing of the solar panel always done according to the storage device or battery. Battery used in the vehicle is of 48V, 150Ah rating.

Current required from the panel for charging the battery is given in equation (1).

Current required for charging = $\frac{1}{10}$. Battery Ah value (1)

$$= \frac{1}{10} \cdot 150Ah$$

= 15Ampere

Required voltage from the panel to charge the battery = 80V

Required voltage is taken slightly higher than battery voltage rating which is 48V.

Therefore required wattage = 15*80

= 1200W

Required solar panel = $\frac{1200W}{\text{Rating of the solar panel}}$

For, 180W panel = $\frac{1200}{180}$

= 7 panels required.

But in this work 8, 180W panels are used for charging purpose.

2. Designing of Voltage Divider circuit

Voltage Dividers are the voltage sensors required to measure the panel and battery voltage continuously. The circuit diagram of the Voltage Divider is shown in the Fig-2.

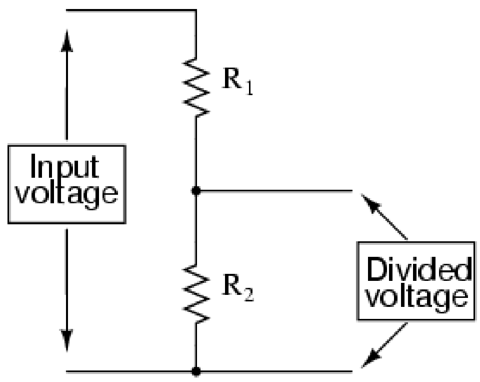

Fig-2: Circuit diagram of the Voltage Divider

a) Voltage divider for measuring the Panel voltage

The formula for finding the Voltage Divider resistor is given by equation (2).

$$Vo = \frac{R_2}{(R_1 + R_2)} \cdot Vin \quad (2)$$

Where, V_O = maximum voltage available from the panel

= 80V

V_{IN} = Input voltage to the controller = 5V

R_1 and R_2 = voltage divider resistors

Here R_1 is assumed as 10KΩ.

Substituting these values in equation (2), it is found to be

R_2 = 1KΩ

Therefore, voltage divider for measuring the panel voltage
consists of 10KΩ and 1KΩ resistors.

Fig-3: Circuit diagram of Charge Controller **Battery voltage**

Here V_O in equation (2) is considered as output voltage from the battery and it is taken as 50V.

Here also V_{IN} and R_1 is taken as 5V and 10KΩ respectively. Substituting the values in equation (2) it is found to be,

R_2 = 1KΩ.

Therefore, voltage divider for measuring the Battery voltage consists of 10KΩ and 1KΩ resistors.

V. WORKING OF THE PROPOSED SYSTEM

The specification of solar panel used for charging the battery bank of electric vehicle is as shown in Table-2.

Table-2: Specification of SPV Panel

Particulars	Ratings
V_{OC}	80V
I_{SC}	20A
V_M	63V
I_M	16A
Wattage	1440W

The circuit diagram [3] of the micro controller based Charge Controller is shown in the Fig-3.

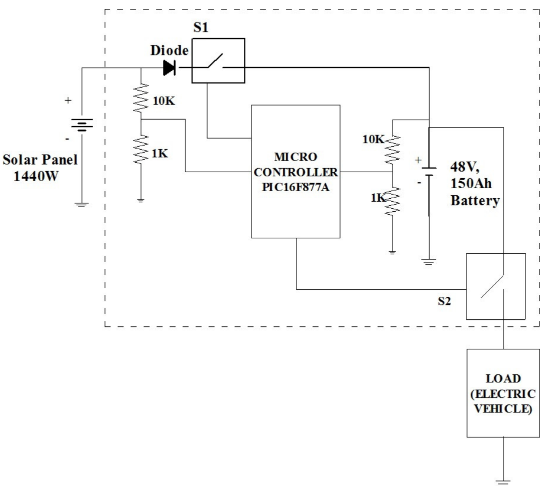

Fig-3: Circuit diagram of the Proposed Charge Controller

The designed charge controller circuit is placed between 750W solar panel and battery bank of the electric vehicle. Initially micro controller reads the panel voltage and battery voltage. If the panel voltage is greater than battery voltage then microcontroller sends signal to the switch S_1 to close so that battery charges from the panel voltage till battery reaches 50V. During the mean time panel charges the battery with 100% duty cycle. This is observed in CRO as shown in Fig-4.

When battery reaches 50V, duty cycle becomes zero through switch S_1 by the Micro Controller as 50V is set as high voltage
disconnect point. Now, battery disconnect from the solar panel. This is observed in CRO as shown in the Fig-5.

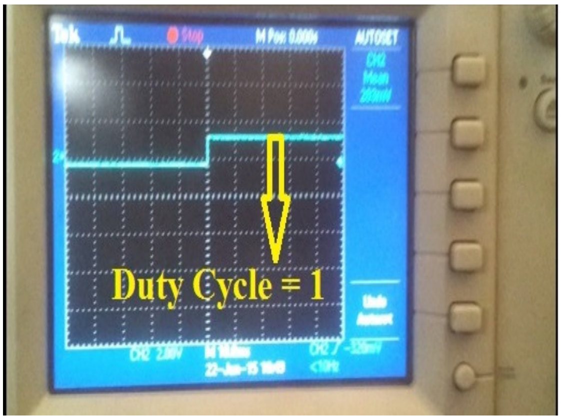

Fig-4: Battery charges with 100% duty cycle

Then controller closes switch S_2 to connect load to the battery for discharging. The battery discharges till it reaches 43V. As soon battery reaches 43V, controller disconnects load from the
battery by opening switch S_2. When battery is full and panel voltage is sufficient to drive the load then controller connects load to the panel directly till panel voltage falls down.

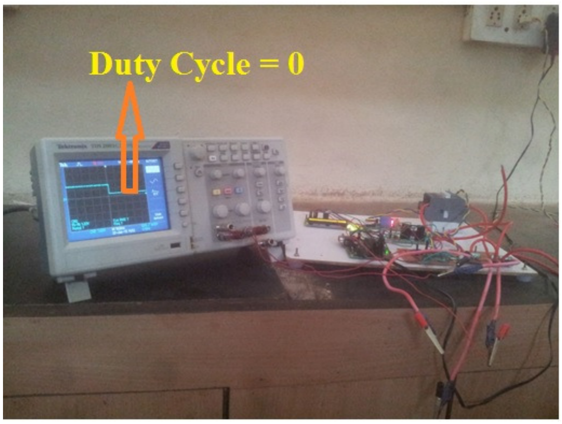

Fig-5: Battery disconnect from the panel

During the time both switches S_1 and S_2 are closed. In this way, controller protects the battery from the overcharging and deep discharging. The switching operation is shown in the Table-3.

Table-3: switching operation of the proposed Charge Controller

S_1	S_2	Operation
0	0	Battery neither charges nor discharges
0	1	Battery discharges - Load ON
1	0	Battery charges - Load OFF
1	1	Battery Charges and Load ON

The flowchart of working methodology of the proposed charge controller circuit is as shown in the Fig-6.

Flowchart:

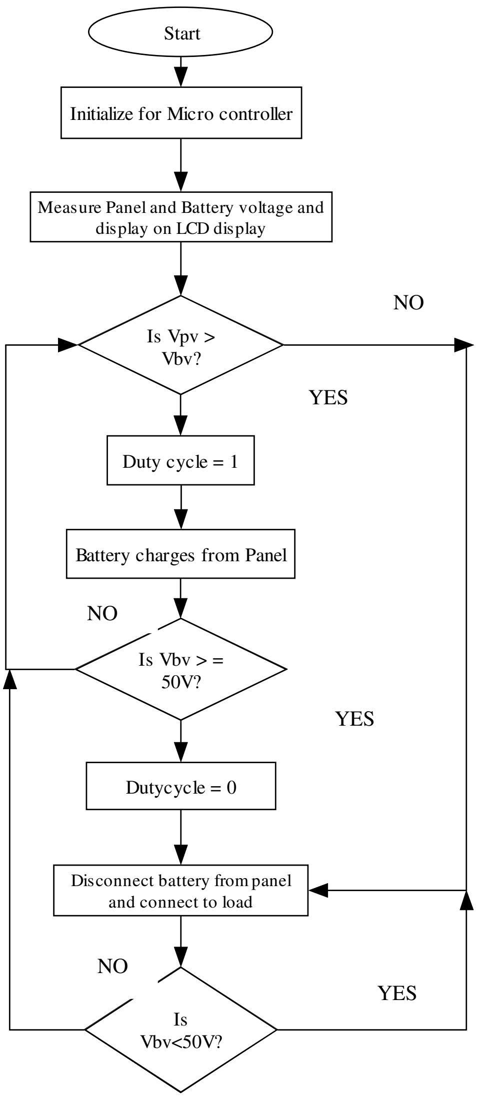

Fig-6: Flowchart of the working of proposed Charge Controller

VI. PERFORMANCE ANALYSIS OF PROPOSED CHARGE CONTROLLER

Performance analysis is conducted to test the proposed charge controller. It is carried out on 13/05/2015 by conducting charging test on battery bank of Mahindra MAINI electric vehicle. During the test variation of panel voltage, battery voltage, battery charging current and solar radiation with respect to time is recorded as shown in Table-4 and results are interpreted.

Table-4: Charging Test result conducted on 13/05/2015

Time (in min)	Current (amp)	Battery voltage (Volts)	Panel voltage (Volts)	Solar radiation (W/m^2)	Battery Status
10.30am	14.8	43.92	60	864.75	Battery charging
10.45am	15.1	44.32	61	915	Battery charging
11.00am	15.2	44.81	61	936.3333	Battery charging
11.15am	15.3	45.02	62	963	Battery charging
11.30am	15.4	45.83	62	966.6667	Battery charging
11.45am	15.7	46.01	62	982.3333	Battery charging
12.00pm	15.3	46.85	62	963.3333	Battery charging
12.15pm	15.6	47.03	62.5	978.6667	Battery charging
12.30pm	15.5	47.38	62.5	976.6667	Battery charging
12.45pm	15.8	47.82	62.5	989	Battery charging
01.00pm	16	48.01	63	1001.667	Battery charging
1.15pm	16	48.34	63	1002.667	Battery charging
1.30pm	15.5	48.8	62	972.3333	Battery charging
1.45pm	13	48.89	61	681.3333	Battery charging
02.00pm	15.1	49.2	62	913.3333	Battery charging
02.15pm	13.5	49.27	60	694	Battery charging
02.30pm	14.7	49.41	61	840.6667	Battery charging
02.45pm	14.4	49.76	60	794.6667	Battery charging
03.00pm	14.3	49.87	60	756.6667	Battery charging
03.15pm	14.1	49.96	60	705.3333	Battery charging
03.30pm	13.2	50	60	650.3333	Battery full

The increasing of battery voltage with respect to time is as shown in the Fig-7. The graph shows the linear increase in the voltage with the time.

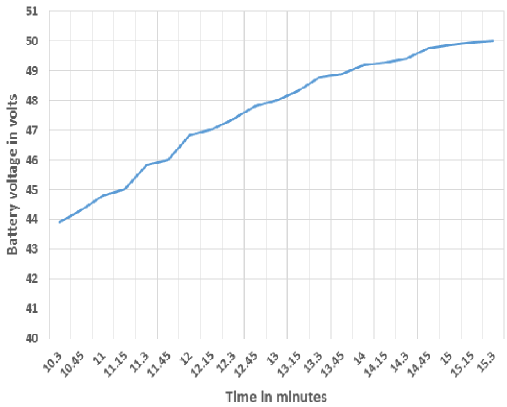

Fig-7: Increasing of Battery Voltage with respect to Time

Fig-7 shows the variation of battery voltage with respect to time. Nature of curve is almost linearly increasing and is stops at 50V as it is high voltage disconnect point.

Charging of the battery depends on the solar radiation of the day. Therefore, variation of the solar radiation with respect to time is as shown in the Fig-8.

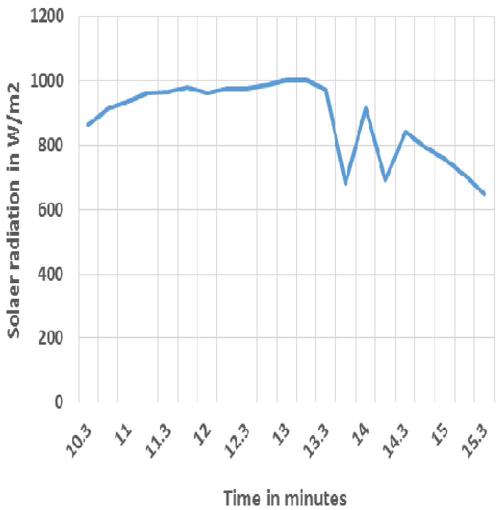

Fig-8: Graphical representation of solar radiation with time

The graph in the Fig-8 shows the variation of solar radiation with the time during charging test day. Solar radiation is maximum in the interval between 11.30am to 1.30pm in the noon. Then it decreases slowly.

The current produced from the solar panel also depends on the solar radiation of the day. Therefore variation of the current with solar radiation of the day is as shown in the Fig-9.

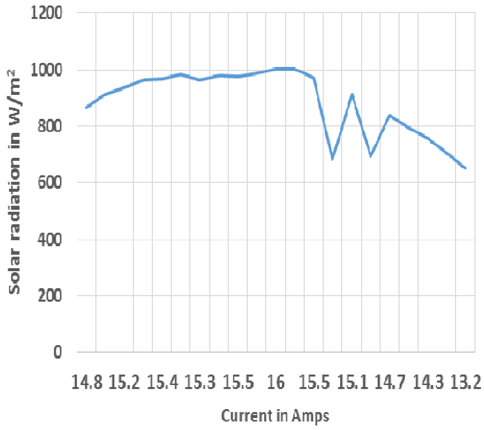

Fig-9: Graphical representation of Current with Solar radiation

The graph in Fig-9 shows that, initially current raises from 14.8A to 15.5A. It remains almost constant after 15.5A. Then variation occurs in current as there is a variation in solar radiation. Finally at the end current produced from the panel decreases as there is a reduction in solar radiation.

Result of the Performance Analysis

Duration of the Battery Charging = (Time at battery full) –

(Initial battery charging

time)

= 3.30PM – 10.30AM

= 5 Hours.

Duration of the Charging time may vary according to the weather condition of the charging day.

VII. DISCUSSION

Performance of the proposed charge controller is tested on 13/05/2015 by conducting charging test using electric vehicle. It is observed from the experimental result that, controller connects battery bank of vehicle to 1440W panel for charging to its high voltage (50V). Further it discharges battery through load to its low voltage (43V). During this experiment, the battery charging voltage, battery charging current, panel voltage are recorded as shown in Table-4 and results are graphically represented as shown in the Fig-7,8 and 9. Proposed controller pumps maximum power from the SPV panels for charging the battery without heating. This controller is a simplest and cheapest circuit compare to others as it uses only MOSFET for switching application. It is a preferred choice as it do not allow the battery to heat or overcharge and deep discharge which results in improving the life of batteries.

VIII. CONCLUSION

For 6 seater electric vehicle an ON-OFF Charge Controller has been designed to charge the 48V, 150Ah battery bank from the 1440W solar panel. The performance also has been analyzed by conducting charging test on the battery bank of electrical vehicle. From the performance analysis, it is concluded that charge controller stops charging the battery when it reaches high voltage (50V). Similarly while discharging, proposed system disconnects the load when battery reaches its low voltage (43V). By this way, Charge Controller charges and discharges the batteries within safe limits without leads to overcharging and deep discharging. Therefore Charge Controllers extends the life of the batteries.

IX. REFERENCES

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