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Design & Development of a Microcontroller Based High-Efficient Smart Solar Charge Controller for Standalone Solar Photovoltaic Systems

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Abstract

In this work a 120A, 24V charge controller has been designed and developed. As the solar energy is costly, measured has been taken to minimize the loss of the controller. PIC16F72 microcontroller has been used as the main controlling unit of the system. To minimize the loss, four 60A relays have been used. The battery status has been sensed by the ADC unit of the microcontroller. The high voltage regulation point and the PV reconnect point can be set any voltage level by adjusting two presets. Hence, the hysteresis can be controlled. The system is capable of displaying the battery voltage status on LED level meter or on LCD display. The controlling program of the system has been developed using FlowCode software. The controller is being tested in a solar PV system and it is found that the total loss of the controller is only 3Watt while it can control a system of 2880Watt.

Keywords: Photovoltaic (PV), Microcontroller, Electric Hysteresis.

1. INTRODUCTION

The human population of the earth has now passed 6 billion, and all of these inhabitants want the energy necessary to sustain their lives. Exactly how much energy is required to meet these needs and exactly what sources of energy will meet these needs will be questioned by the present and by future generations.

Photovoltaic power systems, a promising source of energy for the future, are actually solar panels are referred to by the industry as solar electric modules or PV modules. The modules can be wired as series or parallel arrays to produce higher voltages and currents. In general, a standalone PV system also known as a off grid system consists of a PV array which converts sunlight to direct-current electricity, a control system which regulates battery charging, discharging and operation of the load , energy storage in the form of secondary batteries and loads or appliances.

A charge controller is one of functional major components in PV systems. A charge controller is used to maintain the proper charging voltage on the batteries. As the input voltage from the solar array, the charge controller regulates the charge to the batteries preventing any overcharging. So a good, solid and reliable PV charge controller is a key component of any PV battery charging system to achieve systems maximum efficiency. Simple relay-operated charge controllers allow relatively coarse adjustment of the current flow and seldom meet the exact requirements of PV systems (Preiser et al. 1995). Whereas microcontroller based designs are able to provide more intelligent control and thus increases the efficiency of the system.

The efficiency of the charge controller depends mainly on the selection of switch. If semiconductor switches are used in a series controller power will be lost in these series switch. On the other hand if they are used in shunt controller, power will be lost in the series diode. In this point of view, relays have been used in this controller to minimize the loss.

The main problem of the relays in the high ampere controller is their low lasting period. Generally, relays are connected in parallel to increase the current capacity. But, mechanical relays cannot become ON or OFF at the same time. The relay that will become ON first, the full load or charging current passes through that relay and it burns out. In this work, the system has been made modular. The PV modules will be wired in four groups and each group will be controlled by one relay. Since, the high watt PV systems are generally AC, the charge controller need not to control the load. This is done by the inverter.

2. DESCRIPTION OF THE SYSTEM

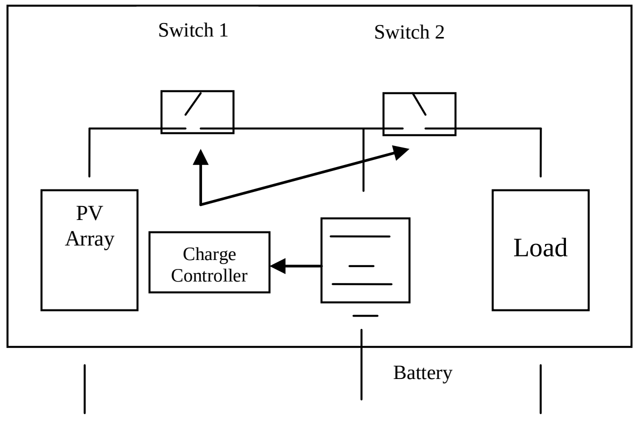


Figure 1: A Typical stand alone system showing a solar charge controller.

Figure 1 shows a typical stand alone PV system. The first switch is connect/disconnect the PV array and the second switch connect/disconnect the load. Now when the first switch connects, the battery starts charging. When the 2nd switch connects, the battery starts discharging. When both the switch is connected the system is the in the charging & discharging state. To eliminate overcharge & over discharge, resulting from the oscillatory process hysteresis has been introduced into the circuit as shown in Figure 2, so that the array will not reconnect to the batteries until the batteries have discharged somewhat or load will not reconnect to the batteries until the batteries have some prescribed voltage left.

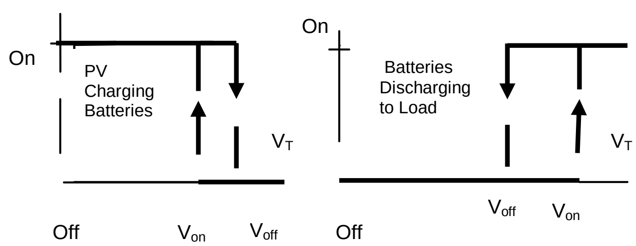


Figure 2: Hysteresis loops in charge controller

3. MICROCONTROLLER BASED CHARGE CONTROLLER

charge controller is divided into three main portions, which are a) voltage sensing circuit & hysteresis Microcontroller based charge controller design is feasible for performing complex task efficiently and accurately. PIC16F72 microcontroller used in this charge controller is the central of coordinating all systems activity. It is a 28 pin,8 bit “RISC CPU” which implements the Harvard architecture. This solar hysteresis control, b) control section and c) switching section.

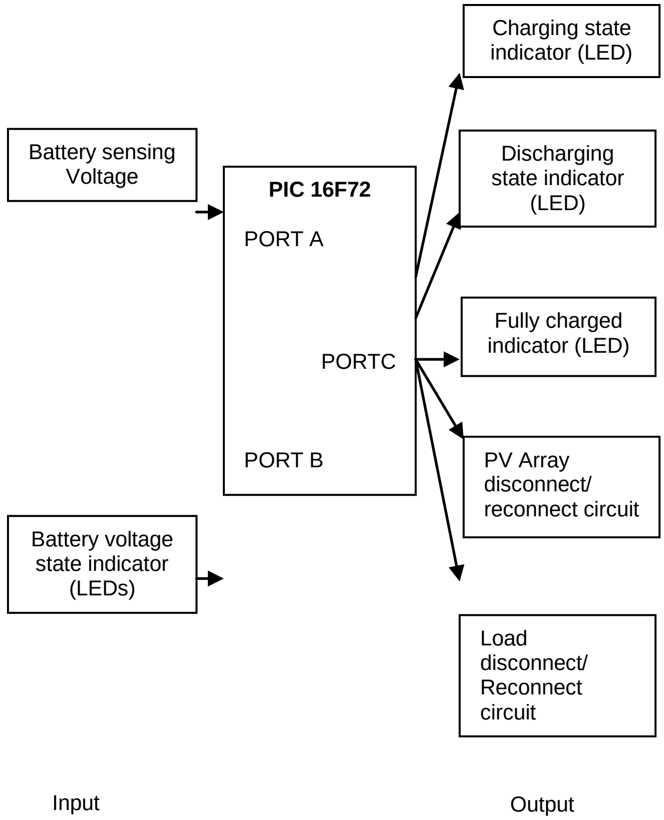


Figure 3: Block diagram of Microcontroller based smart solar charge controller.

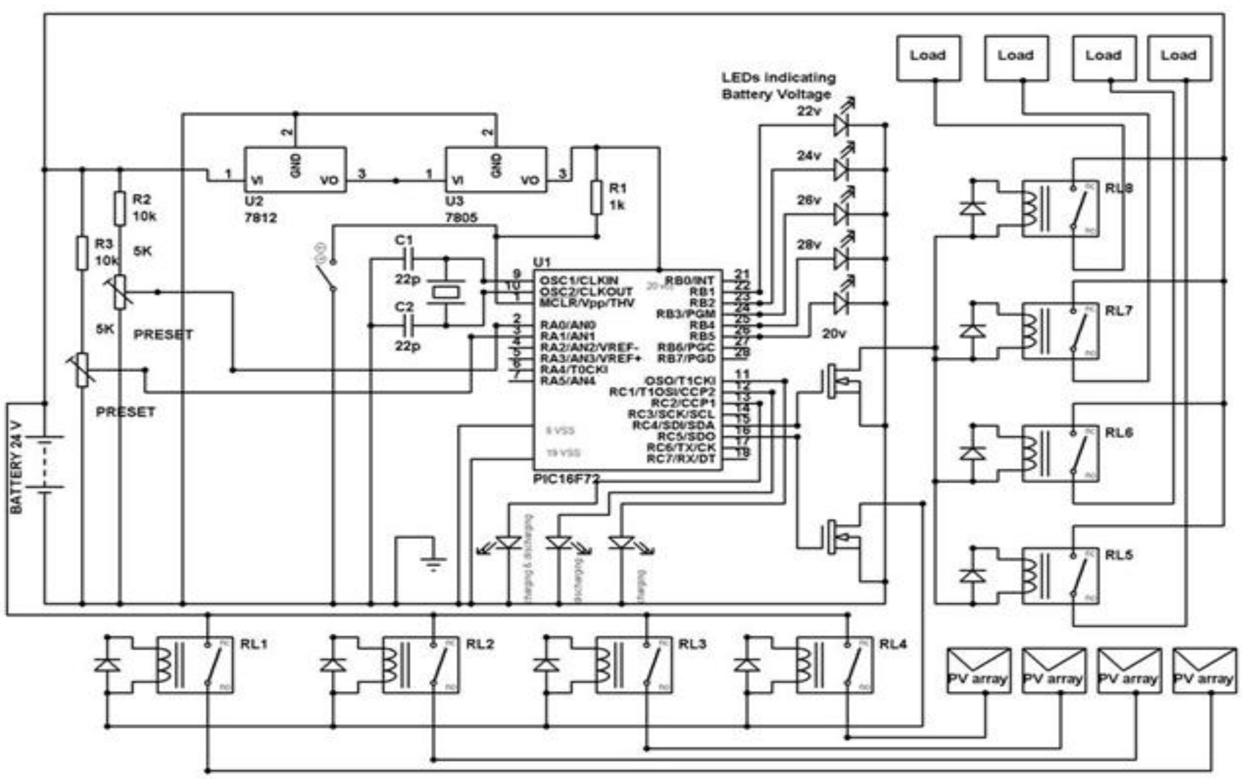


Figure 4: Charge controller schematic diagram.

A) VOLTAGE SENSING CIRCUIT AND HYSTERESIS CONTROL

The input parts for the charge controller are voltage sensing circuit and hysteresis control. To sense the battery voltage two preset resistors have been used.

One is to start charging and the other is to stop charging. Thus adjusting these presets the panel reconnect point and the high voltage regulation point can be changed. In this way hysteresis of any value can be introduced and reduce the relay chattering. Normally the hysteresis of the locally available charge controller cannot be changed by the user. If the LOAD hysteresis is too small, the load may cycle on and off rapidly between load reconncect voltage (LRV) & low voltage load disconnect (LVD), possibly damaging the load and/or controller. If the LOAD hysteresis is too large, the load may remain off for extended periods until the array fully recharges the battery. With a large LOAD hysteresis, battery health may be improved due to reduced battery cycling, but with a reduction in load availability. The proper LOAD hysteresis selection for a given system will depend on the battery chemistry and size, and PV and load currents. But still with simple hysteretic control there is a disadvantage that is, the frequency variation is very large under load variations; hence this charge controller is designed to avoid such large variations in the frequency by controlling the LOAD hysteresis.

B) SWITCHING SECTION

For the output part, it consist the switching section, whose job is to connect/ disconnect panel-battery and load. Relay switches are used to operate the switching. There is no loss due to the relay switch, because each relay is connected to a separate PV panel. If the entire relay were connected in parallel to control a single PV panel then the relays would have burned out. Because, if the relays were placed in parallel, a single relay may become ON earlier than the others. Hence, the full current from the PV panel will pass through single relay. One relay will not be able to withstand high amp (in case of this system 120 Amp). The charge controller is designed such a way that it can handle large current (Up to 120 Amp). Each relay can withstand a current of 30 A maximum, so a total of 120 A is easily getable by the four relays used in the system. Here two power MOSFETs (IRFZ44) are also used to drive the 24v relays. Most ICs (chips) cannot provide required current to the relays so MOSFET is usually used to amplify the small IC current to the larger value required for the relay coil. The use of MOSFET reduces the loss of driving circuit of the relays. In case of shunt type controller there would be a drop of 0.7V in the series diode. Hence for a 120A system 84Watt power will be lost in the series diode. On the other hand, in case of a MOSFET-based series charge controller, 0.5V will be dropped in the MOSFET and a total switching loss will be 60Watt. To avoid this loss of solar energy, relays have been used in this system.

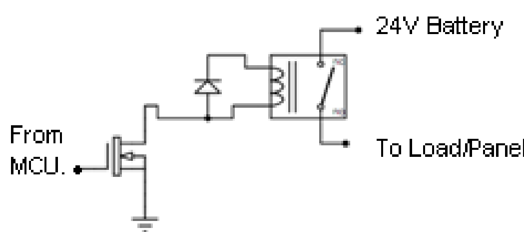


Figure 5: Implementation of relay switching.

C) Control Section

The purpose of this section is to control the whole hardware. A microcontroller (PIC16F72) has been used to control the system. PIC16F72 contains 3 I/O ports. Port A is used to perform the analog to digital conversion at the input stage to sense the battery voltage and to control hysteresis level. Prescaled output (V1) of the preset-1 is fed to PORTA (pin-2) of the microcontroller. Similarly, output of preset-2 is fed to PORTA (pin-3). Hence, PORTA is configured as input port. Whereas PORTC controls disconnect or reconnect operations for PV panel or load and PORTB is used to provide the information of battery charging status. RC0, RC1 & RC2 indicates low battery, fully charged battery & normal condition respectively. Where normal condition refers to both charging & discharging of battery simultaneously. PORT B is used to show different battery voltage level indicated by LEDs. The five pins (RB1, RB2, RB3, RB4, and RB5) in PORTB are used to indicate battery voltage condition. The battery SOC (state of charge) is displayed on LED level indicator. LED level indicator has been used here to minimize cost. But an LCD display can also be connected with the system to display SOC. The successful control is achieved by loading a program to the program memory of the microcontroller. Block diagram of smart solar charge controller is shown in Figure 3.

4. CONSTRUCTION OF THE SMART SOLAR CHARGE CONTROLLER

To construct a smart solar charge controller, one needs to do the following task.

4.1. Voltage Control Algorithm

Microcontroller analyzes data and will operate according to the program written inside its memory. To construct a charge controller, the first thing that needs to be done is to write a program for the MCU. The main objective of the program is to give instruction, control and coordinate the PIC16F72 to execute various tasks, such as to control battery voltage. For writing the program for MCU, FLOWCODE software is used. FLOWCODE is a graphical high level programming language also it provides more efficient and intelligent control. Control program has been developed according to the algorithm shown in Figure 6.

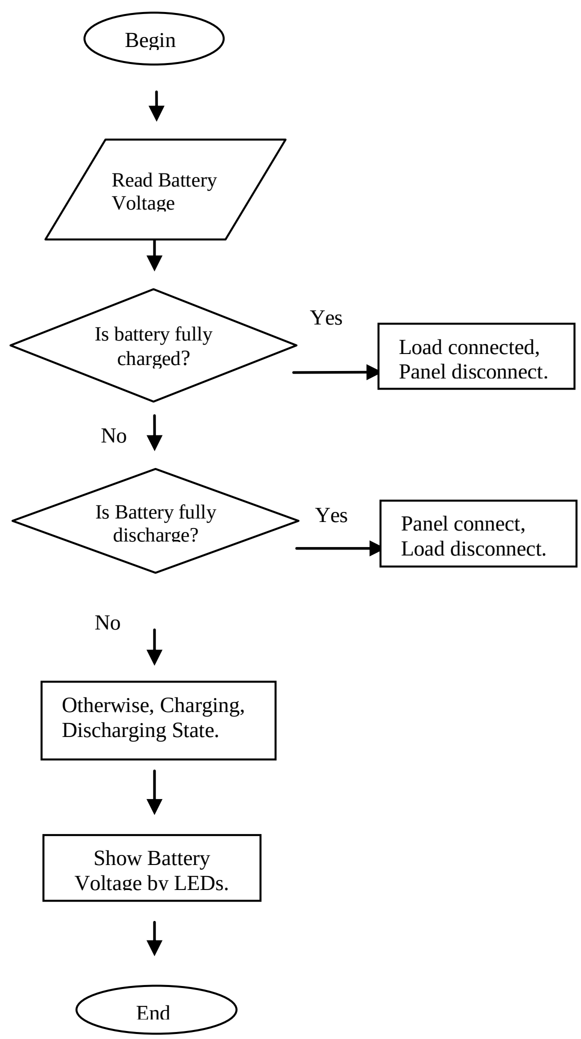
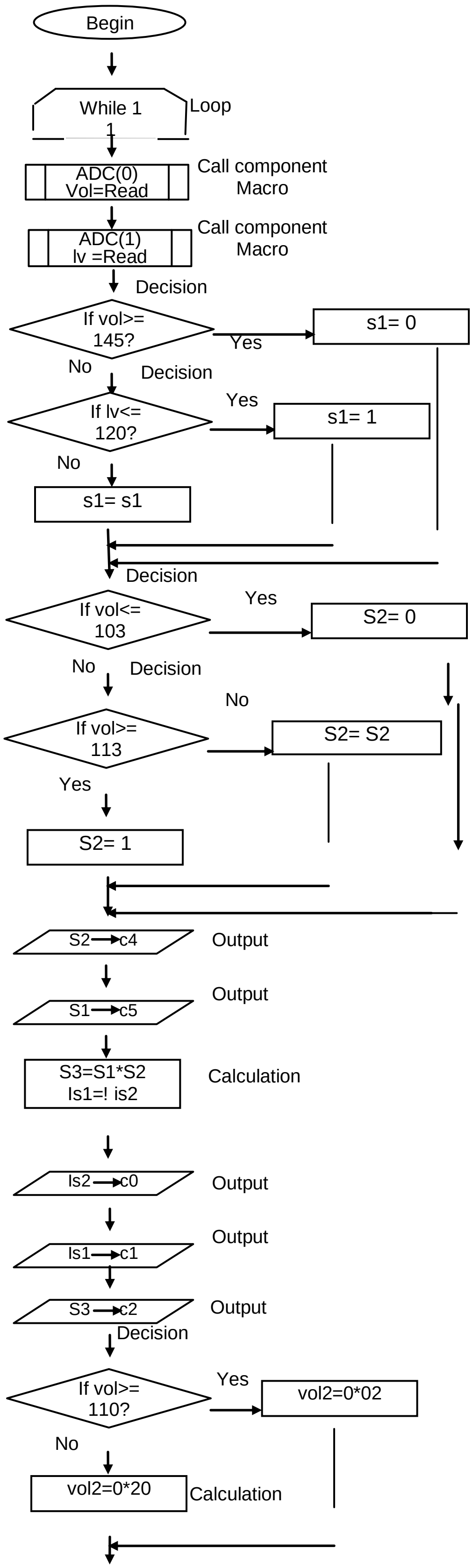


Figure 6: Simplified flowchart of charge controller.

With the help of the flow chart the Flowcode program has been written. The Flowcode program is shown in figure 5. Once the program is written it is compiled to HEX. file with help of Flowcode compiler. Then the HEX. file is burned to the microcontroller with the help of MCU burner.



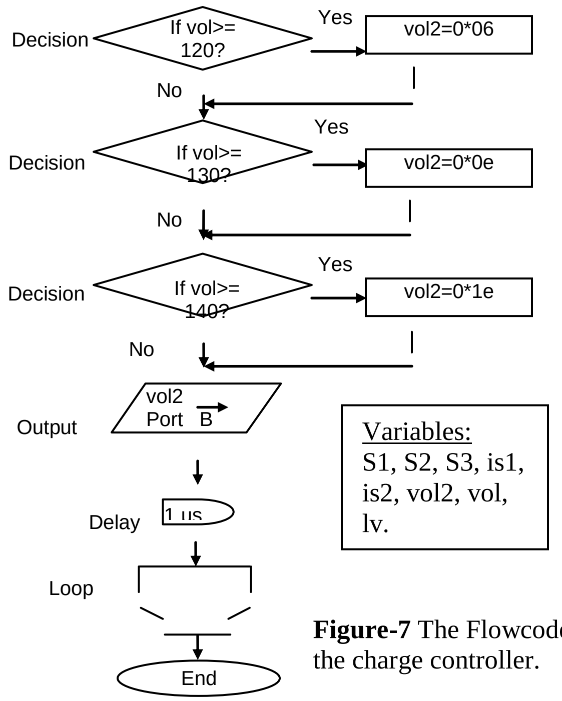


Figure-7 The Flowcode of the charge controller.

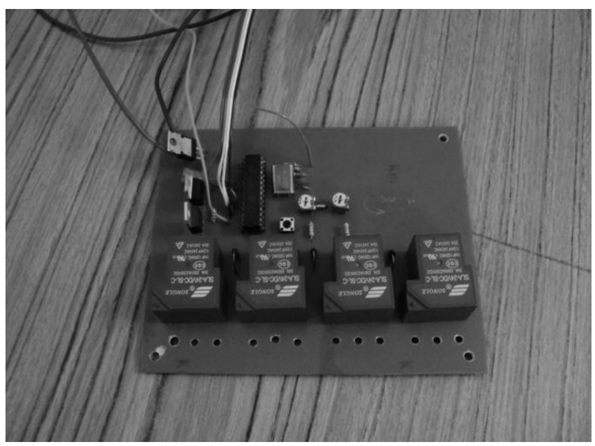


Figure 8: The complete Printed Circuit Assembly.

Once making of PCA is completed, it is fitted into a metal box and thus making of a smart solar charge controller is complete and ready for commercial use.

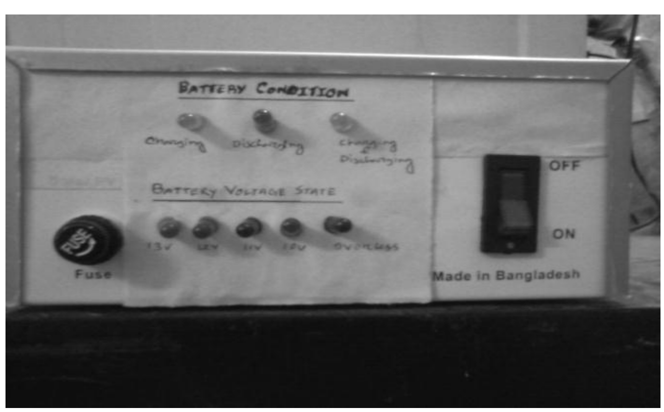


Figure-9: A complete Solar Charge Controller.

5. RESULTS

The charge controller is now attached with a solar panel to prove that the efficiency of the charge controller is high. The data was taken from 10 A.M to 3 P.M Bangladesh time.

Table-1

Time	Battery Current (A)	Battery Voltage (V)	Controlled Power (W)
10:00	7	22.4	156.8
10:30	9.2	25.5	234.6
11:00	12.3	25.7	316.11
11:30	11.6	26.1	302.76
12:00	12.5	26.2	327.5
12:30	13.2	26.5	349.8
1:00	13.5	27.0	364.5
1:30	12.1	27.3	330.33
2:00	11.2	27.4	306.88
2:30	8.1	27.6	223.56
3:00	7.8	27.8	216.84

Table-2

Time	Current (mA) across Charge Controller	Voltage (V) across Charge controller	Power Consumption (W)
10:00	160	22.4	3.584
10:30	161	25.5	4.1055
11:00	161	25.7	4.1377
11:30	160	16.1	2.576
12:00	161	26.2	4.2182
12:30	162	26.5	4.293
1:00	161	27.0	4.347
1:30	160	27.3	4.368
2:00	160	27.4	4.384
2:30	161	27.6	4.4436
3:00	161	27.8	4.4758

From table 1 & 2 it is seen that the efficiency of the charge controller is good. While taking the data, a solar panel of 1K watt is used. The solar panel being small, the current is less than the theoretical value shown in the table. It would suffice to say that the charge controller will operate smoothly & accurately if a solar panel of higher kilowatt is used.

CONCLUSION

Bangladesh being a least developed country, our emphasis on constructing the solar charge controller is to make it cheap and cost efficient. Also the algorithm used here is an improved one and hence it has enhanced the efficiency of the charge controller as well as simplifies the circuit of the charge controller. The charge controller also has hysteresis control and battery voltage indicator. Because LEDs are used the charge controller is a cost effective. Last but not the least, this charge controller, being a series charge controller, its efficiency is higher than the shunt charge controller. Therefore, this smart solar charge controller is good for commercial use.

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