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Design and Development of MPPT Solar Charge Controller for Efficiency Enhancement in Solar PV System

Abstract: - Maximum power point tracking charge controller simulation is done in in proteus 8 professional software and validate using development of hardware model of MPPT solar charge controller for battery. Solar panel does not generate enough voltage all time.Panel can generate 12V to 21V according to solar radiation and environmental condition. For charging of 12V battery minimum required voltage is 14.6V. So, the Maximum power point tracking controller will give extra voltage into usable current, so battery can charge in short period.Development of MPPT Solar Charge Controller is done using ardunionano controller board, ACS 712 current sensor, mosfet driver IR2102, dc-dc buck converter using mosfet, inductor, capacitor and wifi module for data collection, LCD display,LED indication for battery status of charging. Battery charge using three state charging say buck, absorption and float mode. Performance analysis done using simulation model using LCD display status, where first column of display shows PV voltage, PV current and PV power. Second column of display reads battery voltage, status of battery. Third column reads pwm duty cycle in percentage and load status. Voltage level is shown by LED. Yellow LED indicates a fully charged battery, green indicates a regular voltage, and red indicates a low voltage. Performance study was done and the model was validated using a hardware model. All parameters and functionalities for measured solar panel voltage, current, power, battery voltage, charger state, SOC, PWM duty cycle, and load status are shown in real-time on the hardware display. Three-step battery charging algorithms are utilized, specifically the buck stage, absorption stage, and float stage. The battery peak charges to 90% SOC and the battery current is almost steady during the buck stage. In the buck stage, the battery voltage rises to a peak of 14.4V. Absorption occurs in the second phase when the battery's voltage remains constant and its current decreases. Battery current will be very low in the final phase, almost like trickle current.

Keywords: BUCK,DC-DC,PWM,SOC,MPPT

1. INTRODUCTION

Battery life and performance are mainly dependent on charging methods of battery. Various methods used for protecting battery from undercharge or overcharge. There are two types of charge controller are used : PWM charge controller and MPPT charge controller.PWM charge controllers have same voltage at battery and PV panel. MPPT charge controller can operate at higher voltage than battery. Synchronous buck converter is used in design, which decreases the voltage of PV panel for charging of battery at 12V.Ardunio controller is used to maximize the panel power by operating at peak voltage and use maximum available power from solar panel. The maximum power point tracking mechanism uses algorithm and electronic circuitry based on principle of impedance matching between load and PV panel, maximum power transfer takes place between source and load which ensures that maximum power is extracted form PV panel.

2. MATERIALS AND METHODS

Peak Power Outage By optimizing the quantity of solar energy stored in the battery, a tracking charge controller is an electronic device that controls the charging of batteries from panels. It accomplishes this by continuously modifying the panel's voltage and current to match the battery's charging voltage. This can boost a solar system's total power output and enable the battery to charge more swiftly and effectively.

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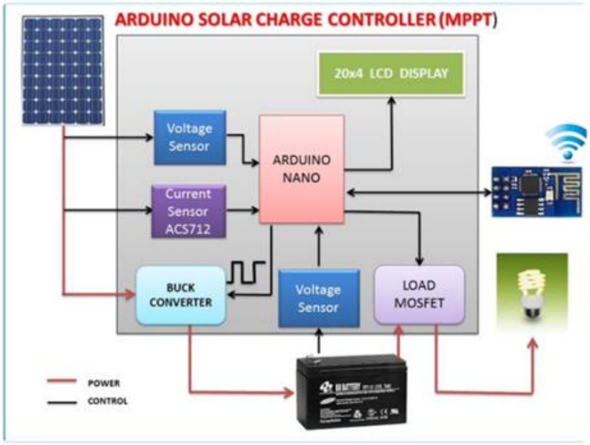


Fig.1 Block schematic

Specification:

- Based on maximum power point tracking algorithm
- SOC indication by LED
- 20×4 character display.Battery voltage, solar panel voltage, current, power, charger state, SOC, PWM duty cycle, and load status
- Overload and Reverse Polarity protection
- 12V voltage (rated)
- 5A current (Max)
- Input from solar 12 to 25V
- Solar panel power = 30W, 12V
- Maximum power (Pmax)-30Wp
- Maximum voltage (Vmp)-18.57V
- Maximum current (Imp)-1.61A
- Open circuit voltage- 22.50V
- Short circuit current-1.77A
- battery specification: 12V,7Ah

Schematic and circuit diagram

Generated voltage of panel depends on several factors such as the amount of sunshine, the connected load, and the panel's temperature. Complete schematic of the MPPT solar charge controller is shown in Fig.2 As the The amount of solar radiation varies during the day. As a result, the voltage that the solar panel produces will fluctuate continuously. It is the fluctuating voltage that causes the fluctuating current.

We must develop a Buck Converter to handle the load of a 12V lead-acid battery for a 30W solar panel. A DC-DC converter known as a "buck converter" consistently produces an output voltage that is either lower than or equal to the input voltage.

The input voltage is supplied by the solar panel voltage. The synchronous MOSFET Q4 and Q5, as well as the energy storage devices inductor L1 and capacitors C4 and C9, were used in the design of the buck converter. The output voltage and switching current are both smoothed by the inductor. Snubber networks, such as capacitor C3 and resistor R4, are employed to lessen the inductor's ripple. The reverse power flow from battery to panel is stopped by the MOSFET Q3.

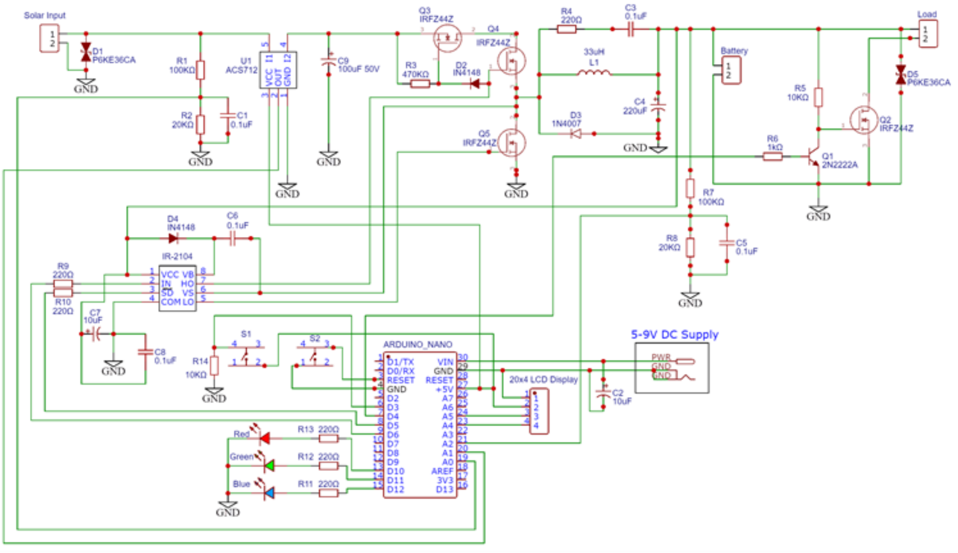


Fig.2 Schematic circuit diagram

The MOSFETS, capacitor, and inductor make up the Buck converter. The size of the inductor and capacitor are inversely correlated with the switching frequency, but the switching losses in MOSFETs are directly correlated. With these limitations in mind, 50 KHz was chosen as the chosen frequency.

Inductor Calculation:

We are designing board for panel ranges from 30W to 80W and 12V battery.

The board can manage a maximum current of 5A and a voltage of 21V when considering the highest wattage panel. The greatest voltage that the battery can output (Vout) is 13V. Output current (Iout) = 105W/13V = 8.07A (considering maximum wattage). Fsw (Switching Frequency)50kHz Duty Cycle (D)= 13/21 = 0.6190 or 61.90% = Vout/Vin

$$L = \frac{(V_{in} - V_o) \times D}{f_{sw} \times d_I}$$

Where $d_I$is ripple current.Ripple current is 30 to 40% load current. Let d_I =35% of rated current =0.35 X 8.07A = 2.82A

So, inductor of 33uH, 5A

Capacitor Calculation:

To reduce the voltage overshoot and output ripple, output capacitance is required in buck converter. For ripple specification of buck converter circuit output capacitor should be high capacitance and low ESR.

$C_{out} = \frac{d_I}{(8 X f_{sw} X d_V)}$where$d_V$is ripple voltage let it 50mV

So available capacitor is 220uf electrolytic capacitor

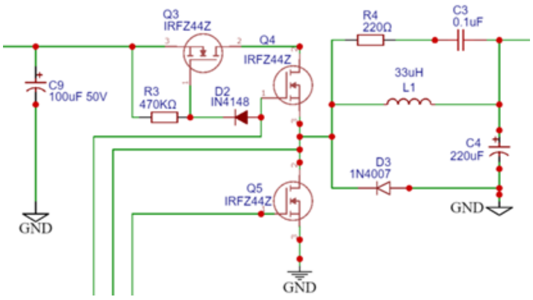


Fig. 3 Buck converter with MOSFET

MOSFET selection:

1. Voltage Rating: Vds higher than 20% of the voltage that is rated.

2. Rating for Current: IDs exceeding 20% of the rated current

3.Rds on (ON Resistance): low OFF Resistance (Ron)

4.Minimum Conduction Loss

5.Switching Loss: Because IRFZ44N MOSFET is readily available, we used it for the MOSFET portion. There is sufficient margin and a low Rds(On) value in the IRFZ44N MOSFET Vds and Ids values. incredibly little switching loss.

MOSFET Driver:

The half-bridge MOSFET gate driver, IC IR2104. PWM signal from Arduino Pin D6 drives MOSFETs. The Arduino pin D5 provides a control signal to the IR2104 driver.

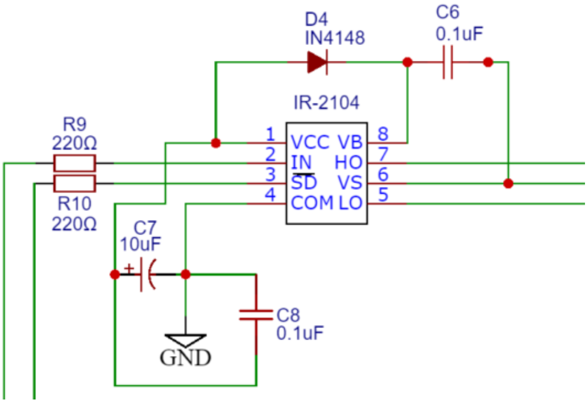


Fig.4 MOSFET driver circuit

Bootstrap circuit formed by D4 & C6.PWM duty cycle is never reach at 100% or fully on.

To measure the panel and battery, there are two voltage divider circuits (R1, R2, and R7, R8).

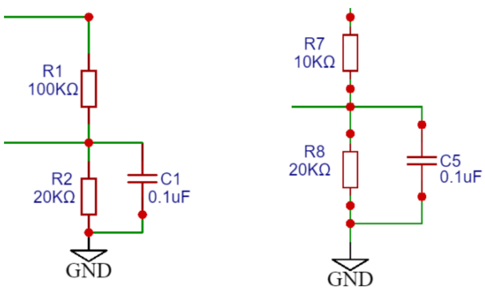


Fig.5 Voltage divider network (for solar input and battery)

Pins Ao and A2 on the Arduino are provided by the voltage divider output. A diode is used to increase the efficiency of a converter. D1 and D5 protect against overvoltage from both the load side and the PV panel. The load is managed by the MOSFET Q2. This MOSFET is driven by resistors R5, R6, and a 2N2222 transistor, Q1.ACS 712 detects the current and sends it to the Arduino's pin A1. The output LED indicates the charge level.

Simulation Model of MPPT solar charge controller:

Simulation Results:

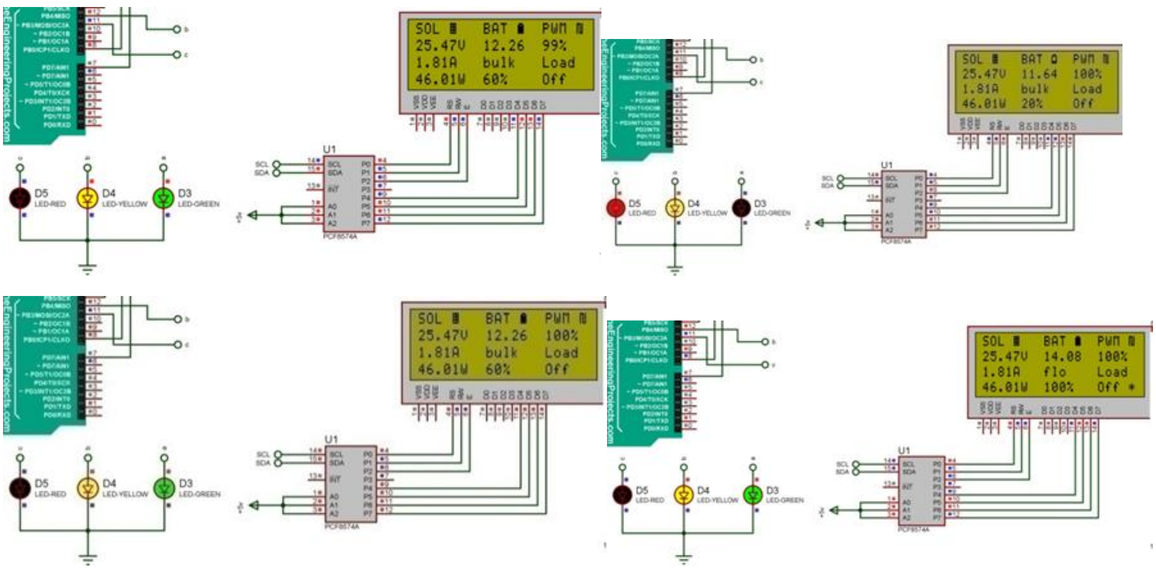
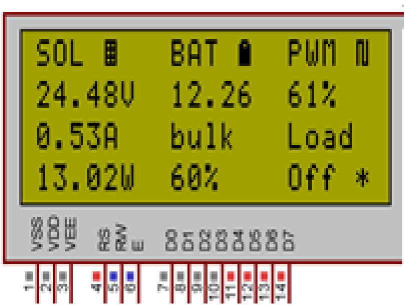
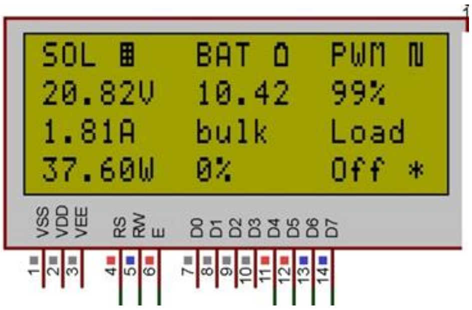


Fig.6 simulation results





3. RESULTS AND DISCUSSION

Different observation of battery charging are recorded for different radiation condition during morning to evening. Battery charging voltage and current shows as battery state of charge (SOC) increases with decreasing charging current.

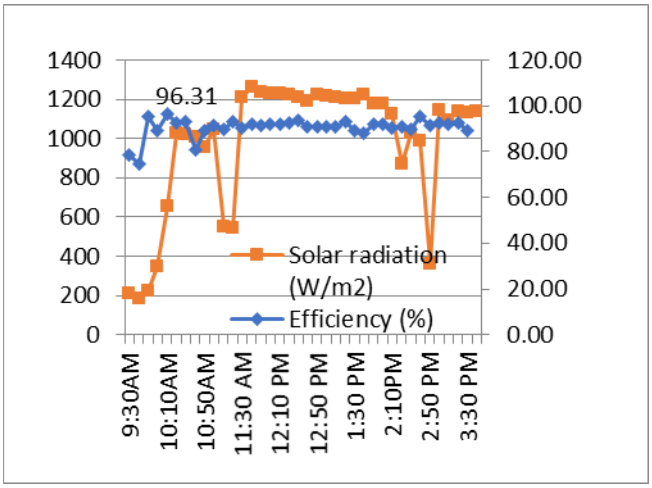


Fig.7 Solar radiation Vs efficiency

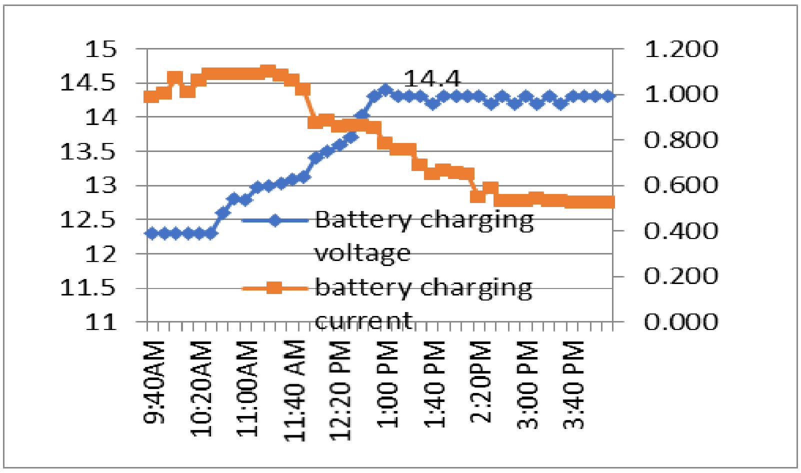


Fig.8 Battery charging voltage Vs battery charging current

MPPT charge controller efficiency where peak efficiency result is 96.31% with overall average efficiency achievement. Efficiency has been compared as below:

Sr.No.	Particulars	Achieved Efficiency	Comparative efficiency
1	Developed MPPT charge controller	96.31% For whole day Real time simulation	99.5% Ref [5] for 10s simulation
2	Developed MPPT charge controller	96.31%	94.8% Ref [6]
3	MATLAB simulink model for MPPT	98-99%	97.34% Ref[7]

4. CONCLUSION

With a 10W resistive load, the maximum power point tracking (MPPT) charge controller yields an average efficiency of 96.31%, whereas the pulse width modulation (PWM) charge controller yields an efficiency of 69.71%. In comparison to references [5,], [6], and [7], the developed maximum power point tracking (MPPT) charge controller and its MATLAB simulink model have a better efficiency (96.31%) with real-time readings for the entire day.

As well as MPPT controller tracks the solar radiation and tracks the peak power. So developed MPPT charge controller increase the efficiency of 26.60% more than PWM charge controller. Developed MPPT charge controller will charge the battery at peak voltage (14.12V) with less time (2hr 30mt) compared to PWM technique. So developed MPPT charge controller is best suited for battery charging and efficiency enhancement.

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