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Design and Development of Solar Charge Controller with Sun Tracking

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Abstract: This paper proposes the design and development of Arduino based solar charge controller with sun tracking using PWM technique. This PWM technique is employed using ATmega328P on Arduino board. The Arduino is used to charge a 12V battery using 10W solar panel. The main feature of this charge controller is to control the load. During day time when load is not connected the battery gets charged from solar panel. When battery reaches peak value of 14.7V charging current & further charging is interrupted by Arduino. An inbuilt analogue to digital converter is used to determine voltage of battery, solar panel and current drawn by the load. A solar tracking system is also implemented such that panel is always kept at right angle to incident radiation.
Keywords: photovoltaic (PV), Arduino Nano, LDR, Battery, Light Emitting Diode.

I. INTRODUCTION

As the conventional are depleted day by day the world is moving towards alternative sources, energy like solar energy, wind energy etc. Solar energy can be used to generate power in two-ways; solar thermal conversion and solar electrical conversion. Solar thermal is employed to heat fluids in order to produce steam to derive turbines while solar electric (photovoltaic) is the direct conversion of sunlight into electricity through photocells. Photovoltaic (PV) production becomes double every two years [2]. For this reason, it has become the world's fastest growing energy technology all around the world [4-10].

A charge controller is an essential part of nearly all power systems in which batteries are used to store generated power, whether the power source is PV, wind e.tc [3]. A PV system consists a number of solar cells which converts sunlight directly into electrical energy. A charge controller is one of the important components of PV system. The main function of a charge controller in a PV system is to keep batteries properly charged and safe for the long term, and to protect it from deep discharging [3], without which the battery will overcharge. Absence of charge controller in PV system results in high maintenance cost and frequent battery replacement. Hence, a charge controller is important to prevent battery overcharging excessively, over discharging, reverse current flow at night and to prolong the life of the batteries in a PV system [3]. Voltage change in LDR where combination of voltage and tracking position is implemented with the use of artificial intelligence algorithm which results in a single axis tracking strategy along with charge controller

When a lead acid battery is charged, its voltage rises. When the charge current is first turned on, the internal resistance of the battery resists the current, and the voltage immediately rises above the open circuit voltage. Towards the end of charge, the voltage rises sharply as the battery begins to "gas". "Gassing" is the decomposition of the liquid water into hydrogen and oxygen gasses which is also known as "electrolysis" [1]. If gassing is left to continue for a long period of time, the battery is overcharged, resulting in accelerated corrosion of the battery plates, loss of electrolyte, and physical damage of the plates.

The aim of this paper is to design and construct an Arduino based charge controller for PV application along with sun tracking system, capable of charging a 12V battery using 10W solar panel. The hardware design is adopted.

II. MATERIALS AND METHODS

A. Hardware design

The system design is based on the block diagram shown in figure 1. The LDR sensors provide analog data as an output. This analog data is given to analog pins ATMega328P microcontroller which can work on voltage up to 5V, so using an ATMega328P is an added advantage since reduces the cost of separate A/D converters IC. The analog output of sensors is connected to ADC pins of ATMega328P microcontroller and the A/D conversion is completed by using software program.

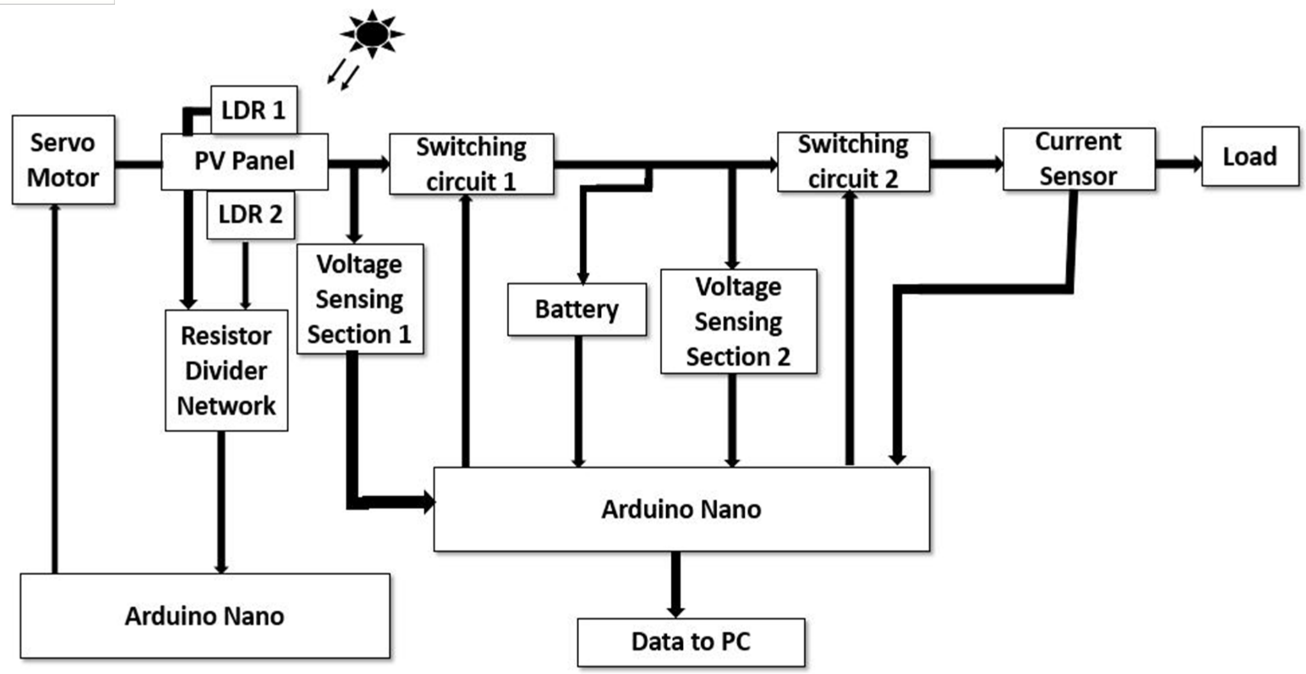

Figure 1: Block diagram of the system

B. Voltage sensing section

Voltage divider network is used as voltage sensor for the controller. The resistance values chosen are 20KΩ and 100KΩ such that maximum input voltage to A/D converter is 5V.

C. Current sensor

The current sensor is used for measuring load current. Here in this project we used Hall-effect sensor as a current sensor.

D. Switching Circuit

MOSFET is used as a switching device because it has fast switching speed and low voltage drop. MOSFET is a voltage-controlled device. It operates in two modes-enhanced mode and depletion mode. IRF9540 MOSFET is used as a switch because it is easy to use and has faster switching speed. In the hardware circuit transistor is used to switch the mosfet from microcontroller. A MOSFET and transistor combination is used for the switching purpose between solar panel and battery.

E. Battery

Battery capacity is expressed in Amp-hours or mA-hours. Battery charge and discharge currents are expressed in terms of “C-Rate”. The solar energy is converted into electrical energy and stored in a 12V battery. The efficiency of battery charging system is to store the energy from solar panel. The main two types of batteries are rechargeable and disposable. The most popular types of rechargeable batteries in use today are the Sealed-Lead-Acid (SLA), Nickel-Cadmium (NiCd), Nickel-Metal-Hydride (NiMH), and Lithium-Ion (Li-Ion). Weight, capacity, and cost are the primary consideration in battery equipment. Lead-acid battery is used in this system because it is inexpensive and high capacitated. The 12V of lead-acid battery has 6 cells. It is safe to charge most of lead-acid batteries by current up to 0.1C rate, where C is the battery capacity in Ah. Overcharging battery can cause reduce life span of battery.

F. PV panel

The solar panel is used to convert solar energy to electrical energy. Solar energy is being used around the world. Solar panel is connected in either series or parallel to achieve the desire output voltage and current. Three types of solar panels are Monocrystalline (single silicon), Polycrystalline (Multi-silicon), and amorphous thin-film. Crystalline solar cells are wired in series to produce solar panels. Monocrystalline solar panels are more efficient than polycrystalline but also the most expensive. The

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efficiency of amorphous solar panel is not as high as crystalline solar panel. The solar panel is used to charge a 12V battery. The peak output voltage of solar panel is 20V. A typical 12V panel will contain 36 cells. Photovoltaic cells combine to make solar panel, solar module or PV array. Photovoltaic solar panel is used to absorb current and voltage depends on light intensity.

G. Software design

The Arduino is operated according to the program written inside its memory. The main objective of this program is to control, coordinate and to execute various task such as to control battery voltage, controlling of load and to track position of sun. The program has been developed according to the flow chart shown in figure 2 and figure 3.Based on these flowcharts the program was written in Arduino IDE, debugged and then loaded into Arduino nano board.

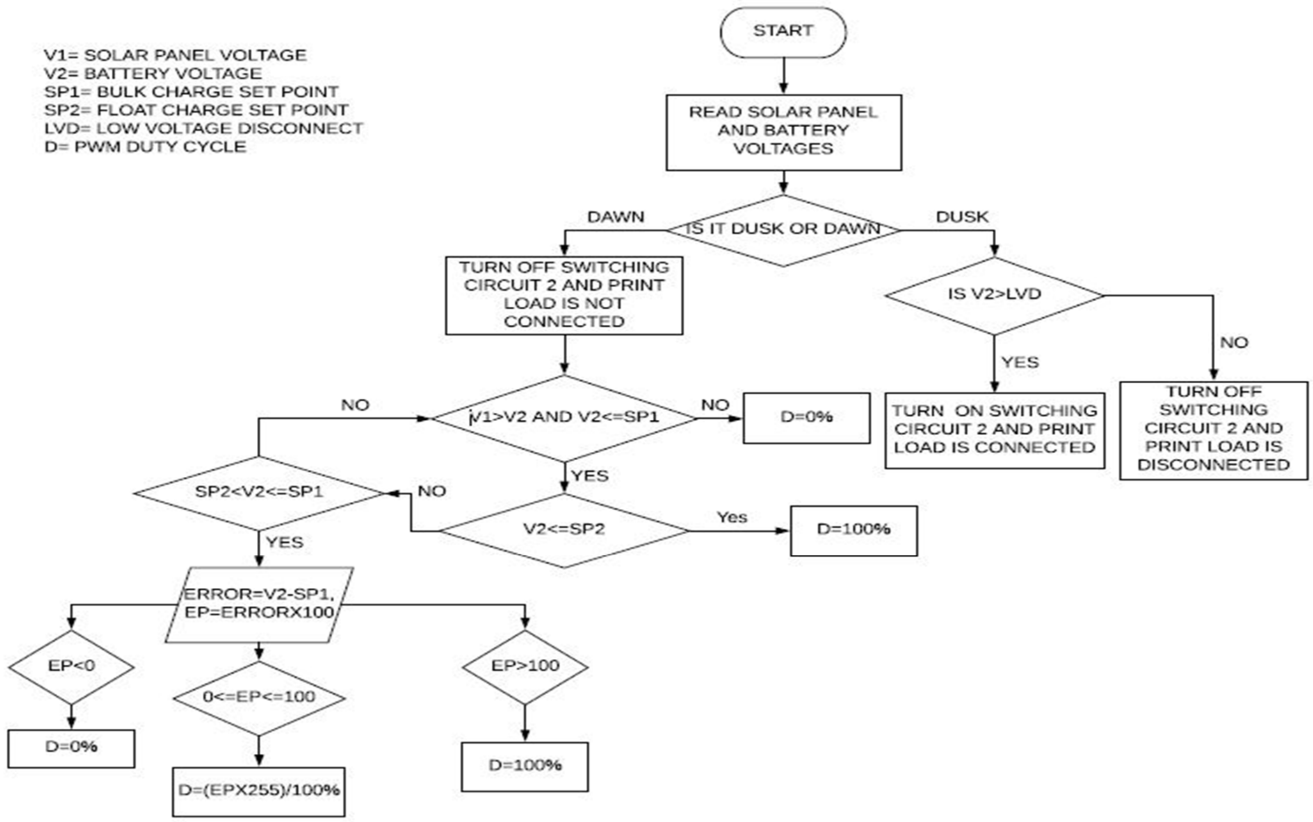

Figure 2: Charge controller program flow chart

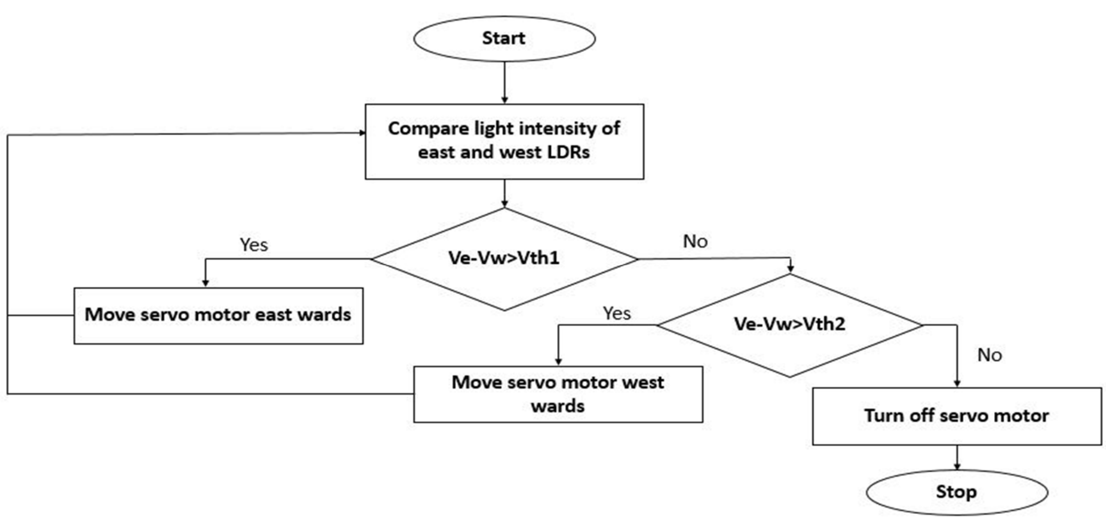

Figure 3: Sun tracking system program flow chart

H. System Modelling

The Arduino reads solar panel voltage and battery voltage with the help of inbuilt ADC and displays battery and load condition on PC monitor. The Arduino monitors input signal of ADC and activates battery and load switching circuit. When the solar panel voltage is greater than battery voltage, current flows from solar panel through diode. This diode prevents reverse current flowing battery to solar panel. The Arduino activates MOSFET 1 connecting battery and solar panel through transistor Q1. The battery continues to charge till it gets fully charged and once its gets fully charged the switching circuit 1 is turned off by Arduino. In the absent of solar radiation Arduino senses this through ADC and activate the load by switching on MOSFET 2 via a transistor Q3 and " load on" message as well as the battery's voltage are displayed. In this mode, the Arduino monitors for low battery. When the battery voltage drops below 10.4Volt the Arduino turns off MOSFET Q2 and "Battery low" message is displayed. Solar tracking is designed on the basis of Light dependent resistor (LDR) characteristics. We know that the resistance of LDR is changed according to the light intensity. Figure 4 shows how the resistance in the LDR varies in proportion to the light intensity falling upon its surface.

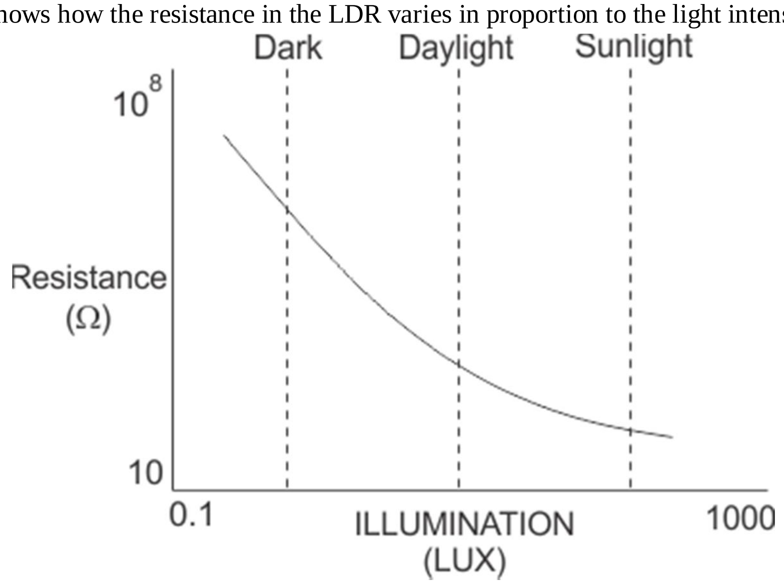

Figure 4: Characteristics curve of LDR

So the voltage will be changed across the resistor dividing network. Two LDRs are used to sense the appropriate solar position. LDR1 and LDR2 are used to track the solar module Left and Right respectively upon their light intensity imbalance. LDR3 is used to sense the morning sun position. When the difference of light intensity of LDR1 and LDR2crosses the threshold level then motor will rotate until their difference below the threshold level.

III. CALCULATIONS OF SOLAR CHARGE CONTROLLER

A. Calculations for voltage sensing section

R1=100KΩ, R2=20KΩ

5V=1024 ADC count

1 ADC count= (5/1024) Volt= 0.0048828 Volts

Vout= Vin x R2/ (R1+R2)

Vin= Vout x (R1+R2)/R2

Vin= ADC Count x (0.00488) x (120KΩ/20KΩ) Volts

B. Calculations For Current Sensor

Sensitivity of ACS 712 is 100mV/Amp= 0.100V/A

No test current through output voltage is Vcc/2= 2.5

ADC count =(1024/5) x Vin

Vin=2.5+ (0.100 x i)

ADC Count= 512+(20.48 x i)

I= (ADC count/20.48)-(512/20.48)

IV. SIMULATION STUDY

A. *Charging Test*

The test was conducted on March 1, 2018 from 10:00AM to 1:00PM. A 10W solar panel was used to provide charging voltage. A voltage sensor was used to measure voltage of solar panel and battery. Solar panel voltage and battery voltage was noted and recorded at the beginning of the charging experiment. All the values are tabulated until the battery is fully charged. The results obtained was tabulated in Table 1. The measured parameters include solar panel voltage (V1), battery voltage (V2), load status and battery status.

Table 1: Charging test result

Time	Solar Panel voltage	Battery voltage	Load status	Battery status
10:00 AM	14.4V	11.7V	Off	Bulk Charging
10:30 AM	14.7V	11.9V	Off	Bulk Charging
11:00 AM	14.72V	12.3V	Off	Bulk Charging
11:30 AM	14.73V	12.5V	Off	Bulk Charging
12:00 AM	14.83V	12.7V	Off	Bulk Charging
12:30 AM	14.9V	13.4V	Off	Float Charging
1:00 PM	14.9V	13.7V	Off	Charged

B. *Discharging Test*

The voltages for discharging test was recorded for an interval of an hour. The parameters recorded are Battery voltage and load status. The results are tabulated in Table 2.

Table 2: Discharging test result

Time	Battery voltage	Load status
7:00 PM	13.7V	On
8:00 PM	13.5V	On
9:00 PM	13.2V	On
10:00 PM	12.9V	On
11:00 PM	12.6V	On
12:00 AM	12.3V	On
1:00 AM	12.03V	On
2:00 PM	11.6V	Off

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V. CONCLUSION

In this paper The Arduino based solar charge controller with sun tracking has been presented and over charging of the battery is prevented. The switching circuit 1 connects the solar panel to the battery through a schottky diode. When the battery reaches fully charged the Arduino interrupts charging current. In the absence of solar radiation the Arduino activates switching circuit 2. When the battery voltage is below 11.7 V the Arduino turns off the load in order to prevent the battery from deep discharging. Solar tracking system is successfully implemented, such that maximum sun light is incident on the solar panel throughout the day which enhances the generation efficiency.

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