DESIGN AND IMPLEMENTATION OF A MPPT MICROCONTROLLER BASED SOLAR CHARGE CONTROLLER FOR PHOTOVOLTAIC APPLICATION

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Abstract

Nigeria being an over-populated country needs to produce a huge amount of energy to meet its people's demands. On the other hand, it is quiet impossible to provide the large population with adequate energy with the conventional way of producing energy. About only 65% of our people have the privilege of using electricity. So apart from finding cost effective ways to harness energy, it is required to use the produced energy efficiently. This paper aim to find away to reduce the pressure on grid energy by using solar panels for electricity supply system. In this regard, it also focuses on having a charge controller circuit for [redacted] *ensuring battery longevity. Here AT89852microcontroller has been used to sense different voltage levels and make decisions according to them.*

KEYWORDS:
Photovoltaic (PV), Boost converter, MOSFET switching, Battery, Microcontroller.

Introduction

Solar energy is one of the most important renewable energy sources that have been gaining increased attention in recent years. Solar energy is plentiful; it has the greatest availability compared to other energy sources. The amount of energy supplied to the earth in one day by the sun is sufficient to power the total energy needs of the earth for one year. Solar energy is clean and free of emissions, since it does not produce pollutants or by-products harmful to nature. The conversion of solar energy into electrical energy has many application fields. Solar to electrical energy conversion can be done in two ways: solar thermal and solar photovoltaic. Solar thermal is similar to conventional AC electricity generation by steam turbine excepting that instead of fossil fuel; heat extracted from concentrated solar ray is used to produce steam and apart is stored in thermally insulated tanks for using during intermittency of sunshine or night time. Solar photovoltaic use cells made of silicon or certain types of semiconductor materials which convert the light energy absorbed from incident sunshine into DC electricity (Sathya and Natarajan, R., 2013). To make up for intermittency and night time storage of the generated electricity into battery is needed.

An important aspect of the solar electricity setup is the charge controller. It is inevitable when mentioning solar electricity as it forms an integral part of the solar electricity family. A charge controller limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and protect against overvoltage, which can reduce battery performance or lifespan and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life (Çınar and Akarslan, 2012). Because the intensity of sunlight fluctuates throughout the day, the output voltage of a solar panel fluctuates as well. In addition, because of this fluctuation, a solar panel is padded with more cells to compensate for times when the intensity of sunlight is low (Vani, 2015). For example, a solar panel rated 12V may actually be constructed with solar cells that will deliver 20V. This ensures that when there is low sunlight, the output of the solar panel will still be above the rated 12V. Since one of the primary job of a solar panel is to charge the battery, it creates a need for regulation of the voltage to make sure it does not get too high to damage the battery. This is essentially the job of a solar charge controller. The solar charge controller takes in the fluctuating input from the solar panel and stabilize it to safely charge of the inverter battery . A solar charge controller can also prevent reverse current. At night when there is no sunlight, the voltage from the battery will be higher than that of the solar panel. This will cause current to flow back from the battery to the solar panel. A good solar charge controller will prevent this from happening (Vani, 2015).

In this paper we have presented the photovoltaic solar panel's operation. The foremost way to increase the efficiency of a solar panel is to use a Maximum Power point Tracker (MPPT), a power electronic device that significantly increases the system efficiency. By using it the system operates at the Maximum Power Point (MPP) and produces its maximum power output. Thus, an MPPT maximizes the array efficiency, thereby reducing the overall system cost.

MATERIALS AND METHODS

Hardware design

The system design is based on the block diagram shown in figure 1. The sensors provide analog data as an output. This analog data is given to analog pins ATMega89852 microcontroller which can work on voltage up to 5V, so using an ATMega89852 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 ATMega89852 microcontroller and the A/D conversion is completed by using software program.

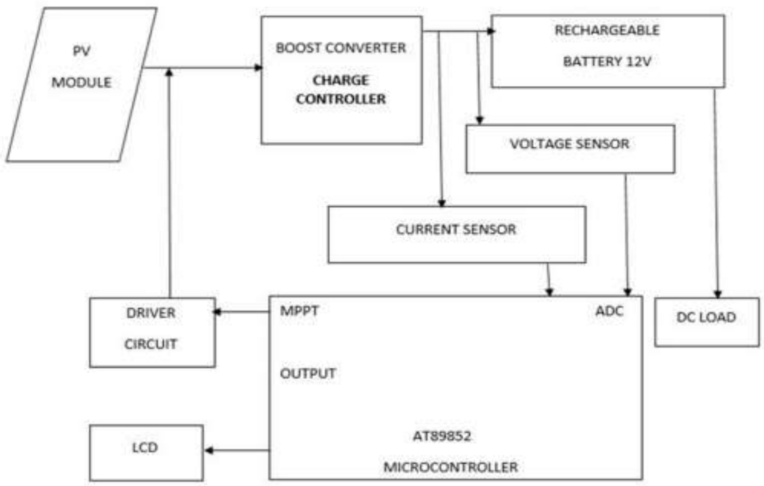

Figure 1: Blocks Diagram of MPPT Charge controller

Maximum Power Point Tracker

The maximum power point tracker (MPPT) is now prevalent in grid-tied PV power system and is becoming more popular in stand-alone systems. MPPT is a power electronic device interconnecting a PV power source and a load, maximizes the power output from a PV module or array with varying operating conditions, and therefore maximizes the system efficiency. MPPT is made up with a switch-mode DC-DC converter and a controller. For grid-tied systems, a switch-mode inverter sometimes fills the role of MPPT. Otherwise, it is combined with a DC-DC converter that performs the MPPT function (John, 2012).

This paper, therefore, chooses a method Perturb and Observe algorithm for digital control for MPPT. The design and simulations of MPPT will be done on the premise that is going to be built with a microcontroller.

DC-DC Converter

DC-DC converters are power electronic circuits that convert a dc voltage to a different dc voltage level, often providing a regulated output. The key ingredient of MPPT hardware is a switch-mode DC-DC converter. It is widely used in DC power supplies and DC motor drives for the purpose of converting unregulated DC input into a controlled DC output at a desired voltage level (Sathya and Natarajan,2013). MPPT uses the same converter for a different purpose, regulating the input voltage at the PV MPP and providing load matching for the maximum power transfer. There are a number of different topologies for DC-DC converters. In this design we are using DC-DC converter as it is obtained by using the duality principle on the circuit of a boost converter (Sathya and Natarajan,2013).

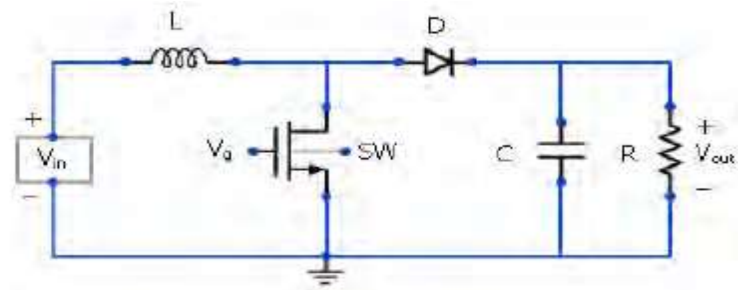

Figure 2: Block DC-DC Boost Converter.

Microcontroller and Voltage Regulator

The microcontroller that will be used in this system is AT89852. It is a 28 pin IC. It has a memory of 368 bytes and external programmable memory (EEPROM) of 256 bytes. The microcontroller senses both the panel and battery voltages and takes decisions to activatedifferent components of the circuits such as, transistors, relays and LED indicators. It is powered up by the lead-acid battery connected to it through a voltage regulator (LM7805) which converts the 12V into 5V and is connected to a RESET (pin 1). The microcontroller is also powered by a 5V supply at pin 20 and ground at pin 8 and 19.

Analog to Digital Conversion (ADC):

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.

Current sensor

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

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.

Rechargeable battery

The rechargeable battery used in this PV charge controller is 12V Genus Sealed Lead Acid battery which stores electrical energy in chemical form to operate dc load at night or bad weather and also requires lower maintenances, has longer life and gives better performance compared to normal battery.

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 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.

DESIGN FUNCTION

When the program is run on the microcontroller, the ADC ports of the microcontroller divides the analog inputs into 1024 quantized levels and display

the different voltages on a 16x2 LCD. In this way, voltage sensing of the panel and battery is achieved. The current supplied by the PV module, a shunt resistor is placed in series with an ADC input. The shunt resistor gives a voltage that is proportional to the current, e.g.: if 1A gives 5mV, 10A gives 50mV. This voltage output is then connected to another ADC port, AN2 via an Op- Amp and run in the algorithm as an input. If the battery is in need of charging, the PWM ports are activated. The battery is only charged if the panel voltage is greater than 10V and less than 12V. The panel voltage and current flows to the converter which is activated by a MOSFET connected to the PWM pin.
During discharging, the panel voltage and current flows to the converter which is activated by a MOSFET connected to the PWM pin. The switching mode of the converter matches the impedance of the battery to the optimal impedance of the panel. The point of intersection of the P-V curve of the panel and the battery gives the Maximum Power Point (MPP), John, 2012).

CALCULATIONS OF SOLAR CHARGE CONTROLLER

Calculations for voltage sensing section

$R1=100K\Omega$, $R2=20K\Omega$

5V=1024 ADC count

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

$Vout= Vin \times R2/ (R1+R2)$

$Vin= Vout \times (R1+R2)/R2$

$Vin= ADC\ Count \times (0.00488) \times (120K\Omega/20K\Omega)$ Volts

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

$Vin=2.5+ (0.100 \times i)$

$ADC\ Count= 512+(20.48 \times i)$

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

Software design

The microcontroller 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 3 and4. Based on these flowcharts the program was written in C language.

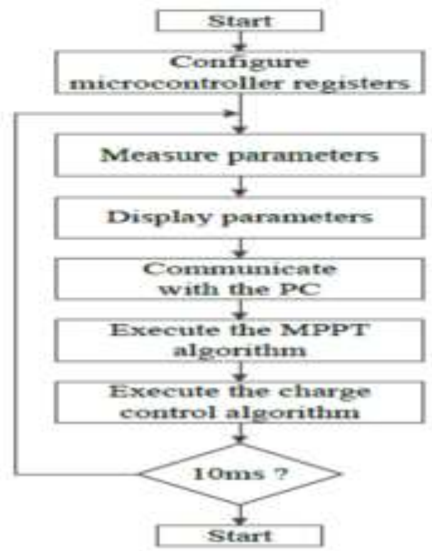

Fig 3: Flowchart of microcontroller program.

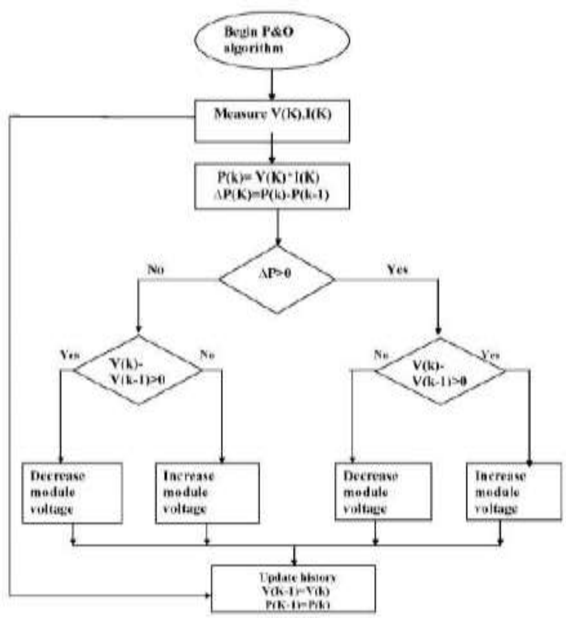

Figure 4: Perturb and Observer algorithm flow chart.

Special register of microcontroller are adjusted as a first step. Then the parameters are measured by ADC converter unit. After this procedure, measured parameters are displayed in LCD module. Following the displaying procedure, the PC communication subroutine is operated by USB interface unit. Finally, the MPPT

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and charge control algorithm are executed. All of these processes are operated in 10ms intervals

TEST RESULTS AND DISCUSION

Simulation Study: Charging Test

The test was conducted in Octorber 4, 2019 from 9:30AM to 5:30PM. A 100W 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 (V1)	Battery Voltage (V2)	Load Status	Battery Status
9:30AM	14.2V	11.5V	Off	Bulk Charging
11:30AM	14.65V	12.3V	Off	Bulk Charging
1:30PM	14.8V	12.7V	Off	Bulk Charging
3:30PM	14.9V	12.9V	Off	Bulk Charging
5:30PM	15.2V	13.8V	Off	Bulk Charging

Discharging Test

The voltages for discharging test was recorded for an interval of three hour. The parameters recorded are Battery voltage and load Status.

Table 2: Discharging test result

Time	Battery Voltage	Load Status
8:00PM	13.9V	On
11:00PM	12.7V	on
2:00PM	12.07V	On
5:00PM	11.6	Off

SYSTEM SIMULATION

The whole system is simulated in proteus ISIS v6 as shown in figure 5.

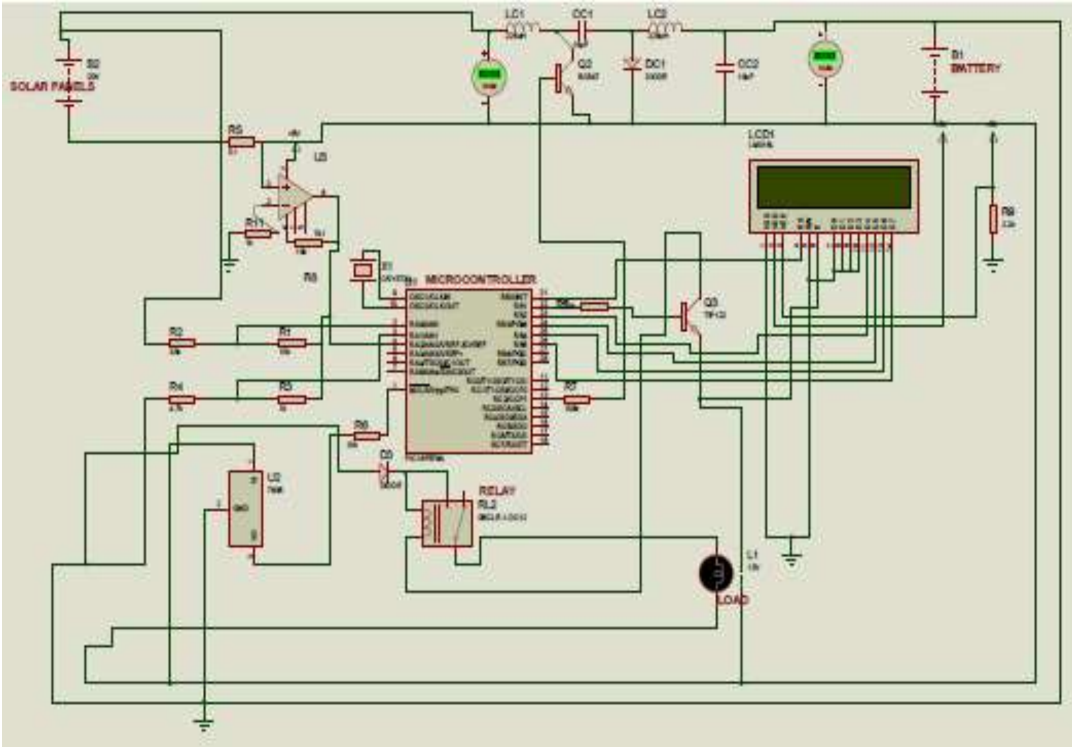

Figure 5: MPPT Charge Controller Circuit Diagram

In this Circuit Diagram, PORTA and PORTC of the microcontroller are used as input and output port respectively. Two pins of PORTA (RA1, RA2) are programmed as ADC module. These RA1 and RA2 pins are used to sense battery voltages and voltages from the light intensity circuit, respectively. In these two cases, voltage divider circuit is used as microcontroller cannot take more than 5 volts as input. The connection of the battery with the solar panel is controlled by relay which is connected to the output pin of microcontrollerRC0 through transistor. Intensity of the lights is controlled by MPPT technique. Intensity of load will vary according to light intensity of environment.

Boost Converter DC-DC Simulation

Figure 6 and Figure 7 shows the circuit diagram used for PROTEUS simulation of Boost Converter and Interfacing of ATMEL microprocessor (AT89852). The purpose of this circuits is to measure output voltage and current waveform.

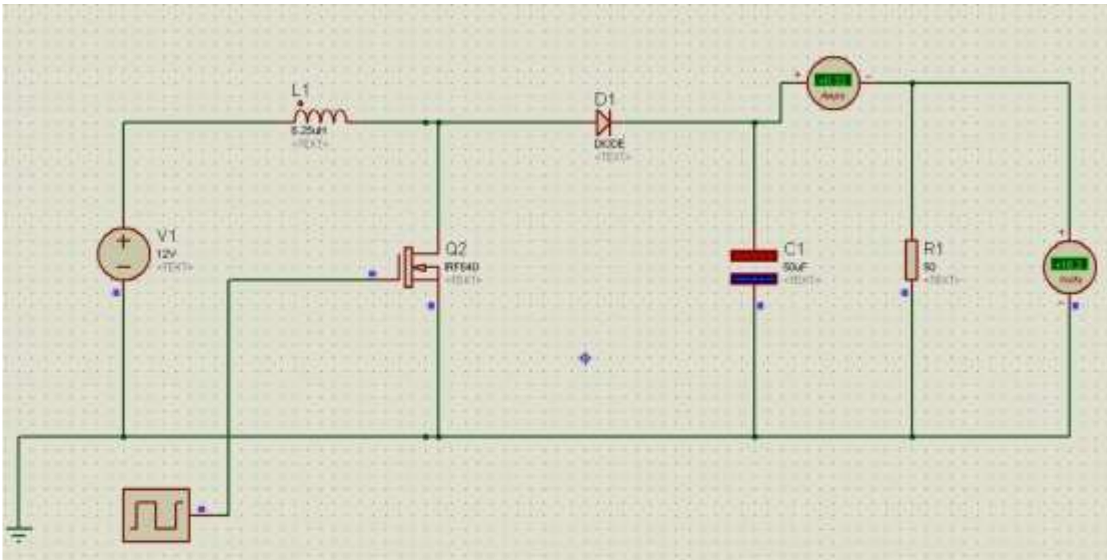

Figure 6: Simulated diagram of Boost Converter in Proteus ISIS v6

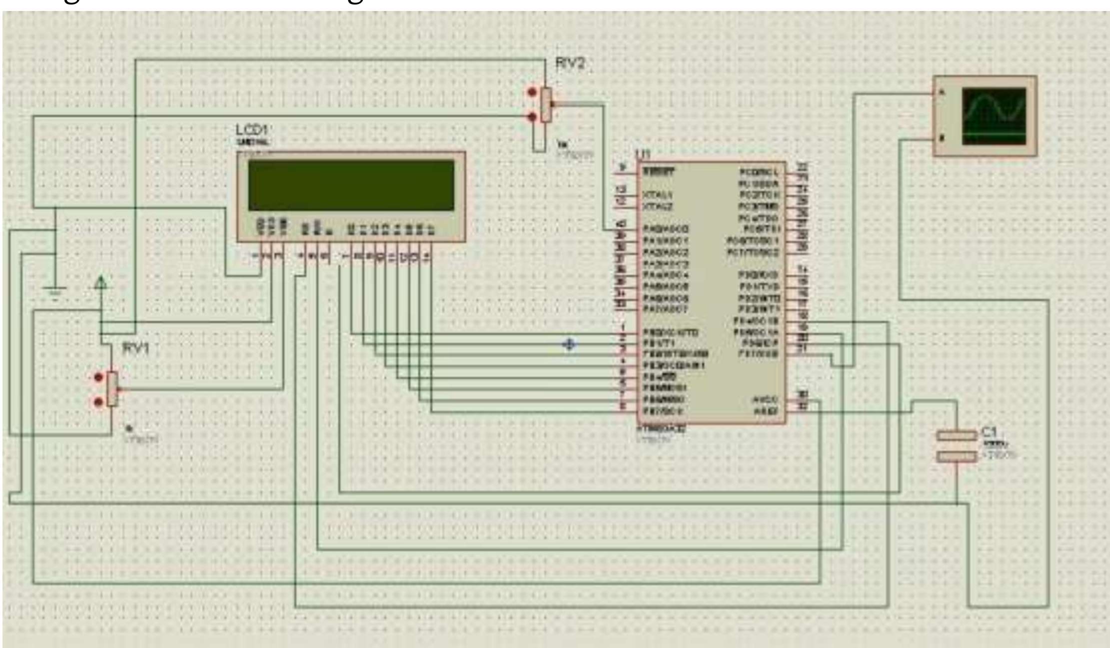

Figure 7: Schematic diagram of interfacing of ATMEL microprocessor (AT89852) in Proteus ISIS v6.

TEST RESULTS

The results were presented in modules and at the end of the whole modules tests, all the modules were assembled together to produce the desired system results.

After the whole system design was done, it was lastly tested to ensure that the overall results meet their expected specifications and objectives.

Testing the boost converter circuit

Solar panel output is given to the boost converter. Output of the MOSFET driver is given as input to the switch of the boost converter. For smooth and quick switching MOSFET driver is used in between microcontroller and the boost converter. Output of the boost converter is taken as a feedback and a voltage divider is used to reduce the voltage to a prescribed level and given as one of the inputs to the microcontroller.

Figure 8 and Figure 9 Shows simulated diagram MPPT Charge controller test result at full voltage and high voltage.

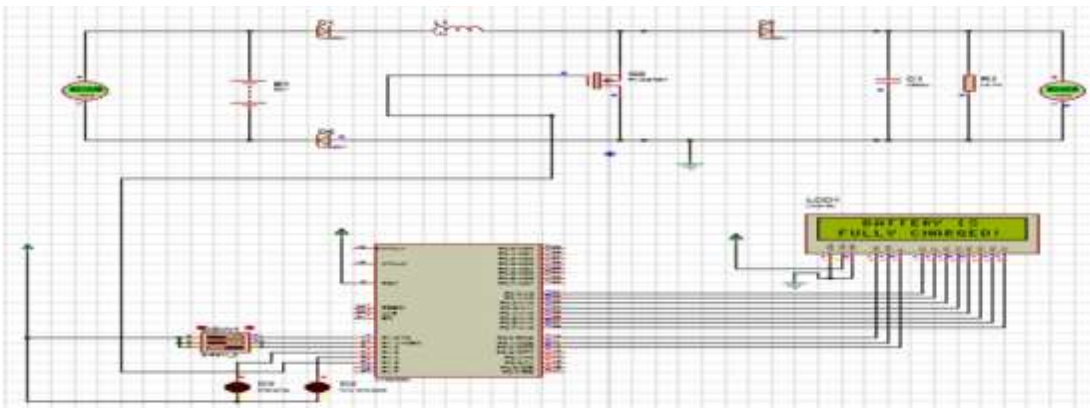

Figure 8: Simulated diagram of MPPT Charge Controller showing test result at full voltage.

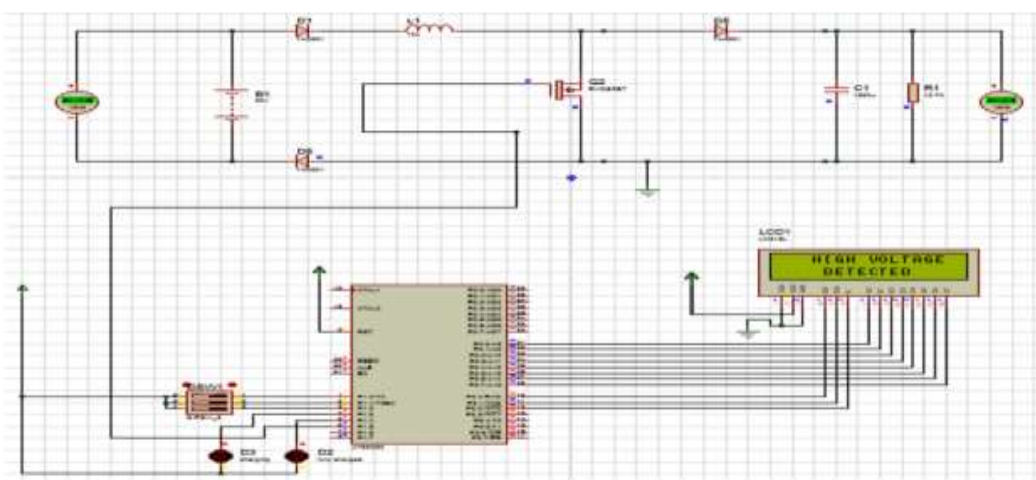

Figure 9: Simulated diagram of MPPT charge controller showing test result at high voltage.

Figure 10 shows Simulated Output Voltage from DC-DC Boost Converter

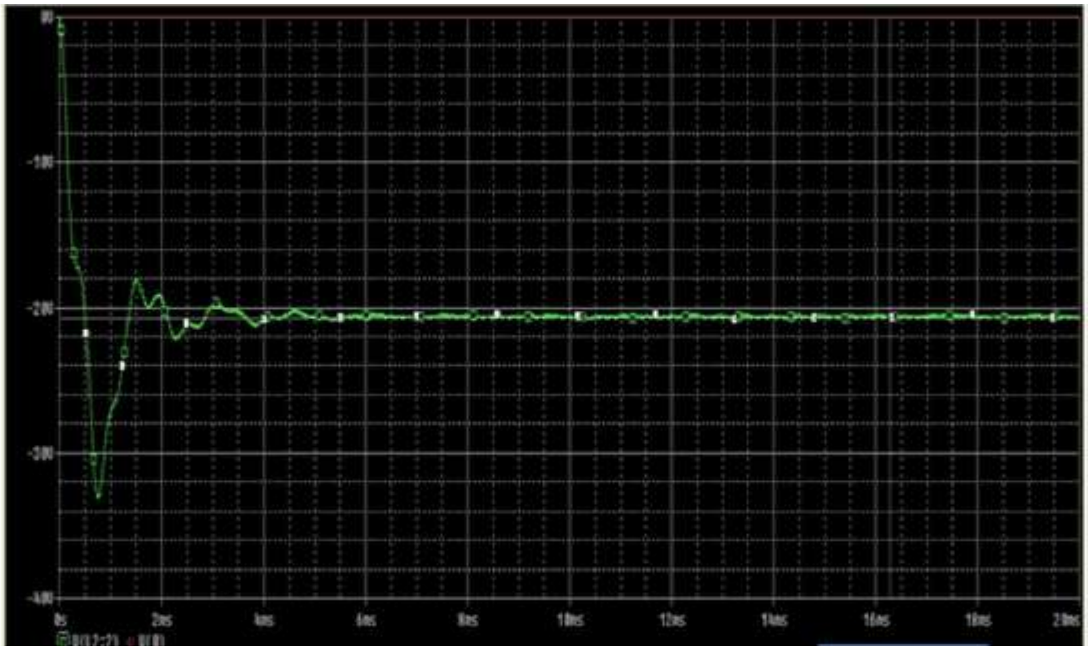

Figure 10: Simulated output voltage of Boost Converter

Testing the complete PV/MPPT circuit

Fig 11 shows a typical 75W PV Module Power/Voltage/Current the Standard Test Conditions (John, 2012).

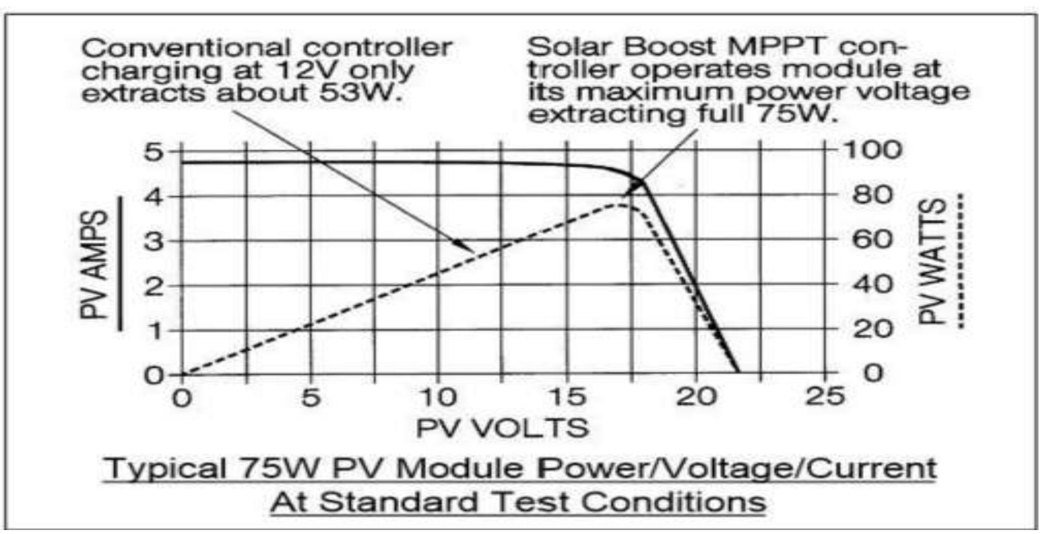

Figure 11: Power/Voltage/Current Plot of an MPPT

Figure 12: Demonstrates a graphical point regarding the output of MPPT technology

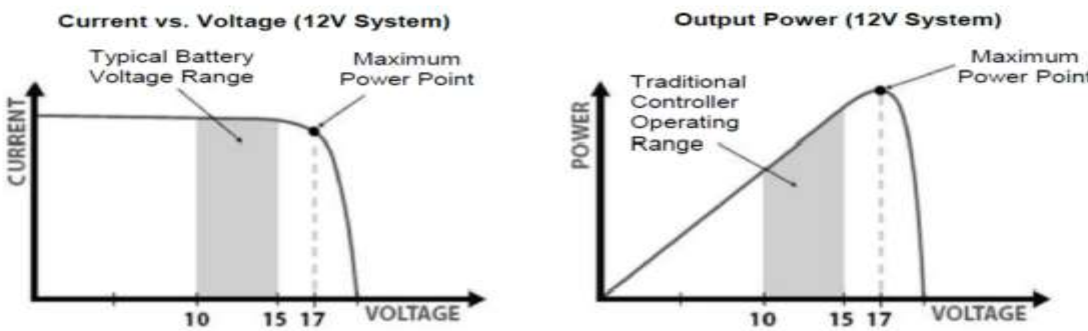

Fig 12: Current-Voltage characteristics of MPPT Tracker (John, 2012).

The charge controllers used in the design was the MPPT type due to its reputable efficiency characteristics when compared to the conventional charge controllers. The MPPT type was chosen over the other charge controllers because of the fact that it is by far, the most efficient type especially when designing small scale PV systems like ours.

Perturb and Observe Algorithms

Figure 13 is a flowchart which summarizes this behavior i.e. the relation between the maximum power and the algorithm. Maximum power is initialized to a certain value and actual value is computed using the measured values of current and voltage. If the change in power comes out to be more than the limit set, the value of maximum power is perturbed and this keeps happening till the actual power becomes equal to the maximum power point on the graph.

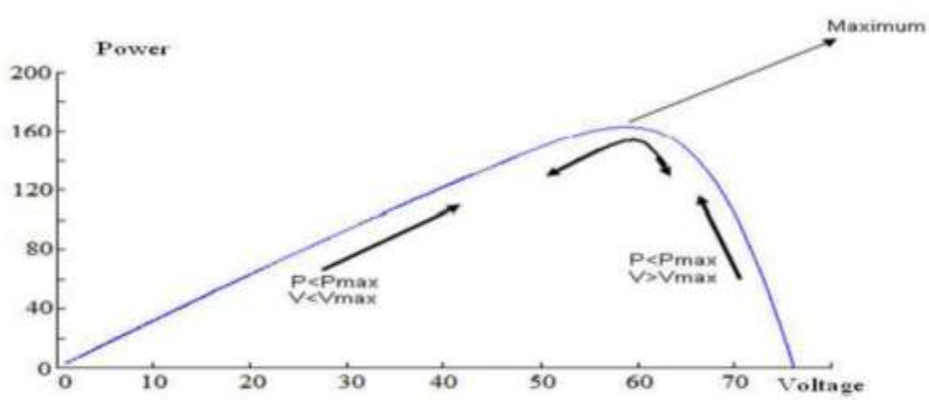

Figure 13: Graph Output power using P&O algorithm

Discussion

The results of the tests that were carried out throughout the whole design were all gotten through systematic checks and observations, and using the appropriate test tools and equipment where necessary. The major tests that were carried out all met the expected specifications with negligible deviation or tolerance. One thing was peculiar about the results; each of the tests that were carried out in each of the subsystems that make up the PV system was done in relation to the next subsystem that was connected to it. The outputs from the PV system installation were all as expected as shown by the final results. When the final installation was made, the system was tested by gradually loading it to see that it responds to the load increase as expected; and after the load test we observed that batteries voltage dropped slightly due to the loading effect and that was normal.

Conclusion

This study presents a simple but efficient photovoltaic system with maximum power point tracker. Description of each component like Solar Panel, DC-DC Converter and Charge controller is presented here. As, our aim was to design a system which can extract maximum output power, so we explained about maximum power point (MPP) and maximum power point tracker (MPPT). While we implemented in hardware we found that the results matched with the simulation. We designed the whole circuit using Atmel ATMega89852 microcontroller to have efficient system and much longer battery lifetime. Our analysis of the algorithm and understanding of the different functions shows that by ADC of the voltages and current and PWM of the boost converter, we will be able to attain the MPP. From the overall analysis presented, it can be concluded that our proposed MPPT charge controller can be commercially used to optimize the energy crisis in the rural areas.

Recommendations

Research should be encouraged in solar electric technology to help improve the output capacity of solar micro grid power system. Research in new material, cell designs and novel approaches to solar material and product development is still continuing. The price of photovoltaic power will be competitive with traditional sources of electricity within 10 years and we will soon be able to see the use of solar energy as a common scenario in everyday life.

It is my view to say that it is now visible that advancements in research and development is the only way to bring this latest technology to bear putting in mind the ravaging effects of the use of fossil fuels and hydrocarbons on the environment. The future is bright for solar power.

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