BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 316 (January 2022)

Power Electronics Laboratory

Final Project Report

Section: A1 Group: 06

MPPT Solar Charge Controller

Course Instructors:

Ramit Dutta, Lecturer
Md. Jawad Ul Islam, Part-Time Lecturer

Signature of Instructor: ____

Academic Honesty Statement:

IMPORTANT! Please carefully read and sign the Academic Honesty Statement, below. Type the student ID and name, and put your signature. ***You will not receive credit for this project experiment unless this statement is signed in the presence of your lab instructor.***

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

Signature: ______________________ **Full Name: Rowatul Zannat Rafi** **Student ID: 1906016**	**Signature:** ______________________ **Full Name: Tareq Mahmud Rakib** **Student ID: 1906024**
Signature: ______________________ **Full Name: Progna Dipta Saha** **Student ID: 1906027**	**Signature:** ______________________ **Full Name: Mithon Rahman** **Student ID: 1906028**

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1 Abstract

In this project Maximum power point tracker battery charger is proposed for extracting maximum power from a photovoltaic panel to charge the battery. The output power of the PV system continuously varies with change in irradiance and temperature. It is very important to improve the efficiency of charger.

2 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.

In this project 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.

In addition, we attempt to design the MPPT by using the algorithm of a selected MPPT method which is "Perturb and Observe" and implement it by using a DC- DC Converter. We have found various types of DC-DC converter. Among them we have selected the most suitable converter which is "Sepic" converter, for our design. PV generation systems generally use a microcontroller-based charge controller connected to a battery and the load. 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. Whereas microcontroller-based designs are able to provide more intelligent control and thus increases the efficiency of the system.

3 Design

3.1 Problem Formulation (PO(b))

3.1.1 Identification of Scope

In our country, most of the time we experience summer-hot. Photovoltaic (PV) energy is highly promising because of its renewable, green, and environment-friendly nature. In this project, the design and analysis of an PV system using a Sepic converter with perturb and observe based maximum power point tracking (MPPT) algorithm is presented.

3.1.2 Literature Review

4 **Introduction:** Maximum Power Point Tracking (MPPT) is a critical technology in solar energy systems that enhances energy harvest from photovoltaic panels. This literature review explores recent advancements, key principles, and applications of MPPT solar charge controllers.

5 **MPPT Principles:** MPPT controllers operate by continuously tracking the Maximum Power Point (MPP) of solar panels, ensuring they operate efficiently under varying conditions.

6 **Efficiency and Performance:** We have evaluated various MPPT algorithms, including Perturb and Observe (P&O) and Incremental Conductance (IncCond), highlighting their impact on controller efficiency. P&O offers simplicity, while IncCond is effective in rapid-changing conditions.

7 **Emerging Technologies:** Recent research by Chen et al. (2021) explores hybrid MPPT techniques, combining traditional algorithms with advanced control strategies, such as fractional-order controllers, to achieve improved efficiency in grid-connected systems.

8 **Integration with Battery Systems:** MPPT controllers play a pivotal role in charging batteries efficiently. Gupta et al. (2018) discuss integrated MPPT controllers in hybrid solar-wind energy systems, emphasizing the need for adaptive control to maximize battery lifespan.

9 **Environmental Adaptability:** Research by Mahmoud et al. (2019) addresses MPPT controllers' adaptability to various environmental factors like shading and temperature fluctuations. They suggest integrating sensor data for real-time adjustments, enhancing controller robustness.

10 **Market Trends and Challenges:** A review of the market trends, as discussed by Shafiullah et al. (2020), highlights increased adoption of MPPT controllers in both off-grid and grid-tied systems. However, challenges such as cost-effectiveness, compatibility with emerging PV technologies, and cybersecurity are also identified.

11 **Conclusion:** MPPT solar charge controllers continue to evolve, driven by advancements in control algorithms, integration with energy storage, and adaptability to diverse environmental conditions. Researchers are addressing efficiency improvements and emerging technologies, making MPPT controllers a pivotal component in maximizing solar energy system performance.

This literature review demonstrates the importance of ongoing research and development in MPPT technology, reflecting its critical role in enhancing the efficiency and viability of solar power systems in the transition towards sustainable energy solutions.

11.1.1 Formulation of Problem

To get maximum power from PV solar array, we need such a converter which's knowledge has been emerged from our power electronics course. Here some problems like choosing necessary values of inductor, capacitor and resistor arises to implement this solar charge controller. The P&O algorithm we promised to run this project with better efficiency is also a challenging task which needs necessary Arduino coding to be accomplished.

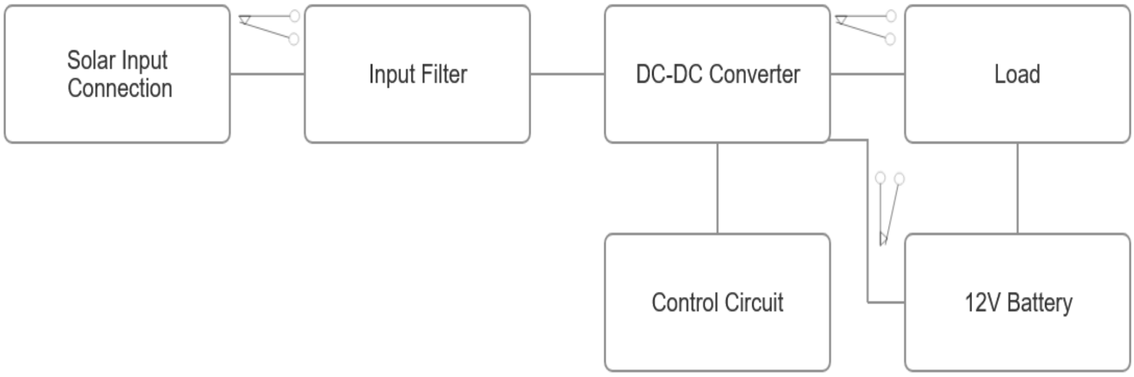
11.1.2 Analysis

To implement the project, analysis has been done for both of the hardware and software sections. At first, the hardware control circuit can be enough to get the proper gate pulse which is none other than a single signal generator of about 1kHz and a mosfet gate driver. Here mosfet has been employed as a switching device and the converter configuration has been chosen empirically buck, Cuk and Sepic in some respects.

In software section the microcontroller plays the role of sending the signals to operate the circuit with maximum power point and higher efficiency.

11.2 Design Method (PO(a))

From design perspective, to get a sustained and reliable DC power both the load and the lead-acid battery are connected to the converter. Load and battery will get power simultaneously in daylight. At night or dimmed weather, the relays connected between load and converter as well as battery and converter will be disconnected.



Solar Input Connection: It comprises with the Solar Panel, input terminal, relay, current sensor, TVS diode, resistors for voltage division.

Input filter: Here the LC filter is chosen.

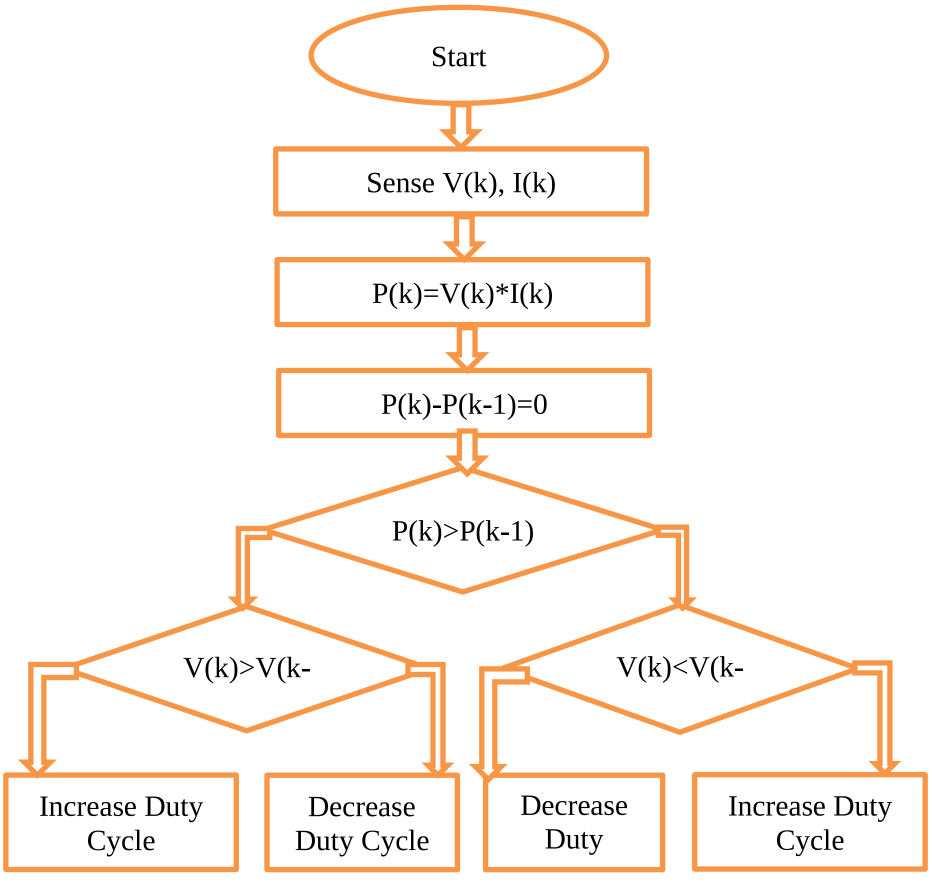
DC-DC Converter: A Sepic(Single-Ended Primary-Inductor Converter) is used after testing three more configurations. Each faces some problems whereas Sepic is good enough.

Control Circuit: This section consists of the microcontroller, mosfet gate driver.

Load: For load We have used

Batter: A 12V lead acid battery was suggested to charge.

Perturb and Observe Method for MPPT



11.3 Circuit Diagram

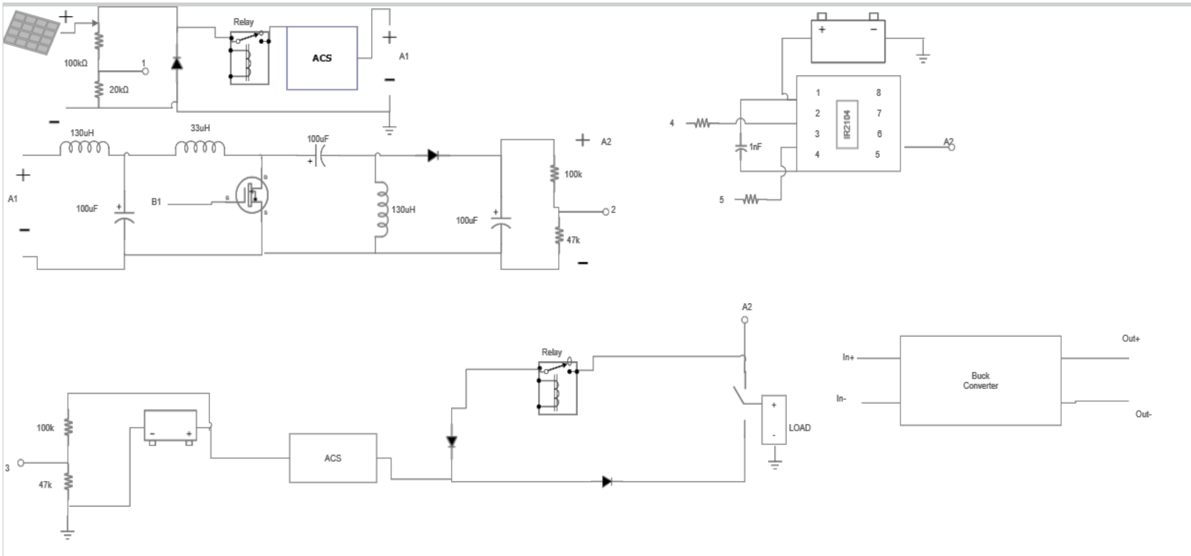


Fig. Circuit Diagram

Pin Planner:

1- **Solar Output Voltage**

2- **Sepic Output Voltage**

3- **Battery Voltage**

4- **PWM**

5- **Shut down**

6- **Vin**

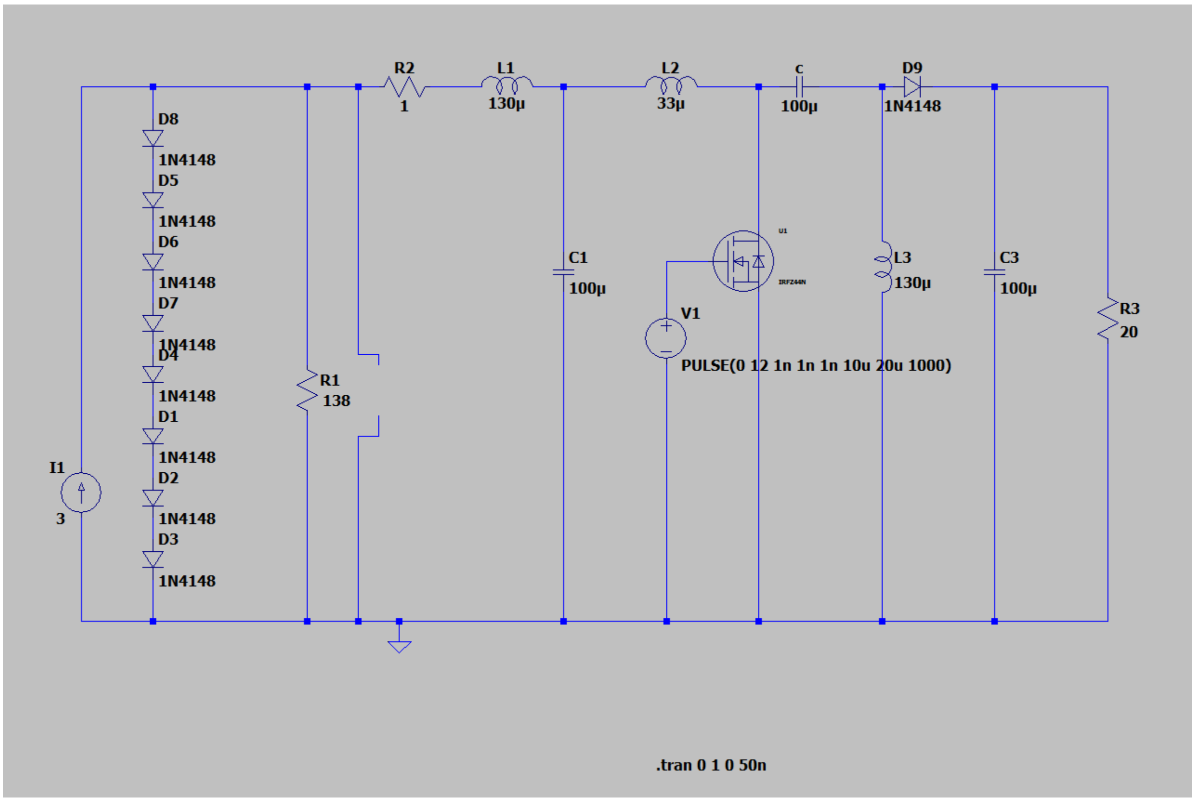
7- **Buck-out**

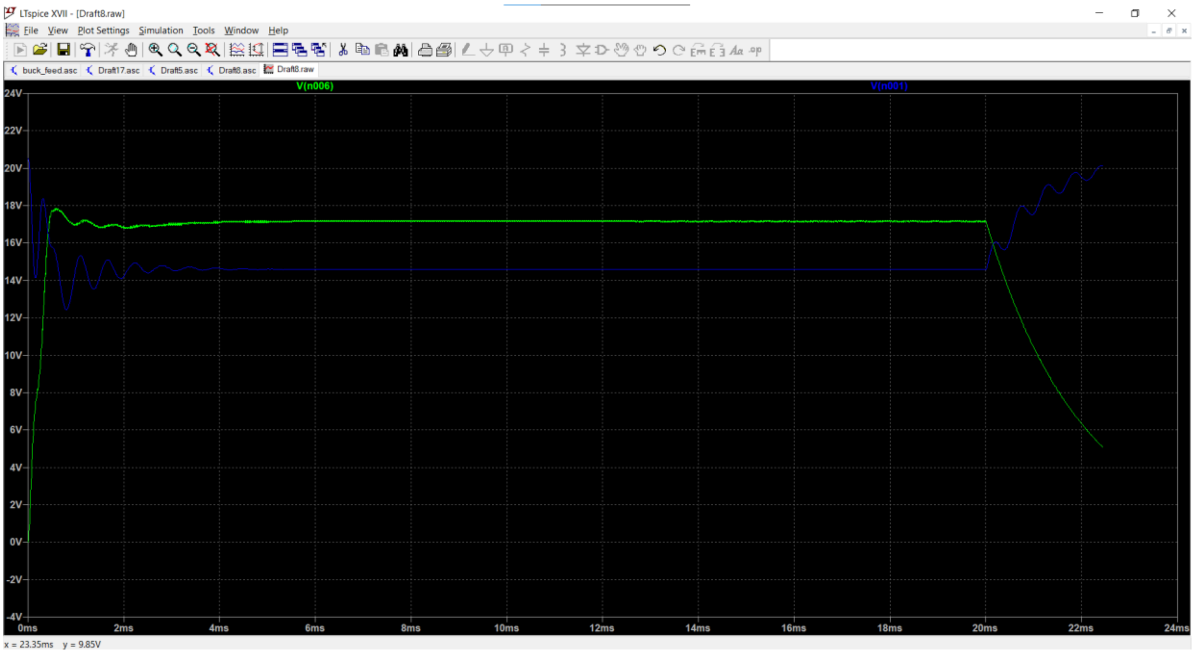
8- **Buck-out**

9- **GND, 10- GND**

11.4 Simulation Model

Here we are presenting a LTspice model:

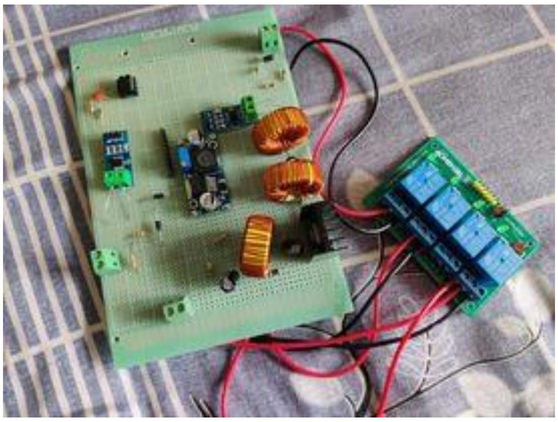




Here with 50 percent duty cycle, the output of the Sepic converter almost follows the input. The equivalent circuit of the PV solar array is designed by the Ltspice.

11.5 CAD/Hardware Design

Circuitry is built on a 16cm*18cm one-sided dotted veroboard. The components have been placed on it without the relay modules, lcd display, Arduino, Solar Panel and the battery.



12 Implementation

In this project we have divided the whole task into four segments to implement. First is, building Sepic Converter. Then constructed Solar input connection and input filter. After that we have attached the control circuit. Finally, Output is taken through the terminal of the load and the Battery. So, the necessary circuitry required for all the blocks mentioned above has been implemented individually by each person of the group.

Selecting the frequency: The switching frequency is inversely proportional to the size of the inductor and capacitor and directly proportional to the switching losses in MOSFETs. So higher the frequency, lower the size of the inductor and capacitor but higher switching losses. So, a mutual trade-off between the cost of the components and efficiency is needed to select the appropriate switching frequency.

Keeping these constraints into consideration the selected frequency is 50KHz.

Assume

We are designing for a 20W solar panel and 12V battery

Input voltage (Vin) =15V

Output Voltage (Vout)=12V

Output current (Iout) =20W/12V = 1.67A = 2A (approx)

Switching Frequency (Fsw)=50 KHz

Duty Cycle (D) =Vout/Vin= 12/15 =0.8 or 80%

Inductor Selection

L= Vin x D x 1/Fsw x 1/ dI

Where dI is Ripple current

For a good design typical value of ripple current is in between 30 to 40 % of load current.

Let dI =40% of rated current

dI=35% of 1.67=0.35 x 1.67 =0.5845A

So L= (15.0) x 0.8 x (1/50k) x (1/0.5845) = 41 uH (approx)

Inductor peak current =Iout+dI/2 = 1.67+(0.5845/2) = 1.96225A = 2A (approx)

So we have made a toroid inductor of 33uH and 2A.

So 33uH is enough for our design.

Capacitor Selection:

The capacitor, C1=C2= D / (R x Fsw x (dV/Vout))

Where dV is ripple voltage

Let voltage ripple(dV) = 1%*12V=24mV

Cout= 0.8/(20*50k*.01)= 80 uF

By taking some margin, I select 100uF 50V electrolytic capacitor.

Input Filter Selection:

For filter design, no certain formula hasn't been followed, rather than we take the values by simulating in Ltspice empirically.

L=130uH , C=100uF

Mosfet Selection:

The vital component of a buck converter is MOSFET. Choosing the right MOSFET from the variety of it available in the market is quite a challenging task.

These are a few basic parameters for selecting the right MOSFET.

1.Voltage Rating: Vds of MOSFET should be greater than 20% or more than the rated voltage.

2.Current Rating: Ids of MOSFET should be greater than 20% or more than the rated current.

3.ON Resistance (Rds on): Select a MOSFET with low ON Resistance (Ron)

4.**Conduction Loss:** It depends on Rds(ON) and duty cycle. Keep the conduction loss minimum.

5.**Switching Loss:** Switching loss occurs during the transition phase. It depends on switching frequency, voltage, current, etc. Try to keep it a minimum.

In our design, the maximum voltage is solar panel open-circuit voltage(Voc) which is nearly 21V and the maximum load current is 2A.I have chosen the **IRFZ44N** MOSFET. Current rating 49A, Voltage rating 55V, drain to source resistance 17milli ohm.

Mosfet Gate Driver Selection:

For this design, We are using an IR2104 Half-Bridge driver. The IC takes the incoming PWM signal from the microcontroller and then drives two outputs for a High and a Low Side MOSFET.

12.1 Description

This is the description for the design

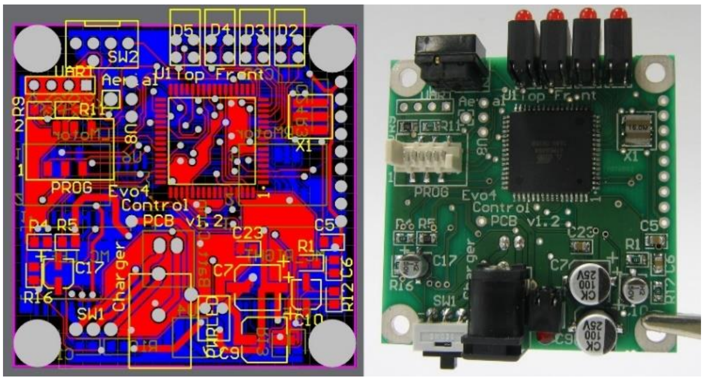


Figure 2: (Left) PCB Layout and (Right) Implementation of Design

This project offers maximum power extraction from solar panel. Here we used a SEPIC converter which can boost or step-down voltage with the demand of the input voltage so that maximum power of solar can be taken. This operation is controlled by the P&O algorithm coded into the Arduino nano.
The most important part is mosfet's switching which occurs by the gate driver. The driver is able to

take low input logic signal and can deliver high current output to the mosfet gate. Mosfet gate can switch very fast by this.

Later part of the project is to install a load and a battery. The battery will be connected in daylight and will be cutoff in low irradiance so that the battery charging procedure will get off and the supply from the battery is going on.

12.2 Experiment and Data Collection

Open Circuit Voltage = 19.1V

With 10ohm load, Solar Oputput Volatge = 14V

With control circuit-

Duty Cycle-67%

Battery Volatage-13.1V

Solar Output-12V

Solar Output Current-0.5A

Load Voltage-220ohm

Load Current-0.9A

Effeciency- 78.1%

Callibration:

Arduino can read from ACS712 in 0 to 4096 range. From calibration, we got 100 analog values is equivalent to 1A.

ACS scaling constant = 100/4096 = 0.024414

ACS offset value = 2048

As the Solar input voltage, battery voltage and load output voltage is sampled to show in display the scaling factors:

Solar input Voltage Scaling = (120/20)*(5/4096) = 0.007324

Battery and load output voltage Scaling = (147/47)*(5/4096) = 0.0038179

12.3 Data Analysis

12.4 Results

The experimental results of battery charging using the P&O MPPT algorithm are divided in two separated tests. First test, using one PV panel with Pmax=20 W, Vmp=19.6 V, Imp=0.56 A, under standard temperature condition and one lead-acid battery with V = 12 V and Imax = 5Ah, that consists, first, the PV panel is connected directly to the battery. From first test it can be seen that charging the 12V battery with the P&O algorithm, the absorbed power from the PV panel is around 7.35W with charging current of 0.592 A in Constant Current mode.

In the Second test, the PV panel is connected to the battery using the developed MPP tracker board running the MPPT algorithm. From first test it can be seen that charging the 12V battery with the P&O algorithm, the absorbed power from the PV panel is around 12.5W with charging current of 1.04 A. The experimental setup with the MPPT has provided always more delivered energy to the battery than the direct connection. The MPPT has increased the PV panel capacity of supply energy in 87% using a 12V battery.

12.5 Github Link

https://github.com/rowatulrafi

12.6 YouTube Link

13 Design Analysis and Evaluation

13.1 Novelty

13.2 Design Considerations (PO(c))

After considering buck, cuk and sepic converters, we finally realized that it is best to use the sepic converter due to proper rated current on continuous conduction mode and also there's no issue with voltage polarity like cuk. We also programmed our Arduino so that it is very readable and easy to work with.

13.2.1 Considerations to public health and safety

a. *Electrical Safety:* Ensuring that the system complies with electrical safety standards and regulations to prevent electrical hazards, such as electric shock and fire. Proper grounding, circuit protection, and insulation are also critical.

b. *Fire Safety*: Implementing fire prevention measures. Include fire detection and suppression systems where necessary.

c. *Structural Safety:* Ensuring the structural integrity of the solar panels and mounting systems to prevent accidents like falling panels. Wind and snow loads should be considered in the design.

d. *Maintenance Safety:* Designing the system for ease of maintenance, including safe access to panels and other components. Provide guidelines for routine inspections and maintenance tasks.

5.2.2 Considerations to Environment:

a. *Site Selection*: Choose installation locations that minimize environmental impact. Avoid sensitive ecosystems, wildlife habitats, and protected areas.

b. *Ecosystem Impact*: Assess the potential impact of the solar installation on local flora and fauna. Implement measures to protect and mitigate harm to wildlife, such as bird deterrents or wildlife corridors.

c. *Resource Use*: Optimize the use of materials and resources during system construction and maintenance. Consider recycling and disposal of components at the end of their life cycle.

d. *Land Use and Erosion Control:* Implement land-use practices that prevent soil erosion and promote the restoration of natural vegetation. Use erosion control measures like vegetation buffers and permeable surfaces.

13.2.2 Considerations to cultural and societal needs

a. *Cultural Respect :* Consult with local communities and indigenous groups to understand their cultural and historical ties to the land. Respect sacred sites and heritage areas.

b. *Aesthetic Impact:* Consider the visual impact of the solar installation on the surrounding landscape and communities. Implement design elements that blend harmoniously with the environment or local architectural styles.

c. *Community Engagement:* Engage with the local community to gather input, address concerns, and provide information about the project. Foster positive relationships through open communication.

d. *Job Creation:* Explore opportunities to provide employment and training for local residents, contributing to the economic development of the area.

13.3 Investigations (PO(d))

13.3.1 Literature Review

13.3.2 Experiment Design

13.3.3 Data Analysis and Interpretation

13.4 Limitations of Tools (PO(e))

Resistors through which voltage is sampled to send the analog signal to the Arduino have some tolerances. These tolerances can occur some errors. Moreover, the current limit of the variable power supply we have used during experiment can provide maximum 2.28A and the voltage fluctuates with some extent. Again, Arduino nano is 12-bit controller which is pretty precise to read the values but the calibration of the current sensor ACS-712 went a little bit harder. The high side of the IR2104 gate driver can't operate according to the low side simultaneously. So, it needs to take one LO side to drive the mosfet. Synchronous buck converter here is not working for this reason.

13.5 Impact Assessment (PO(f))

This section is mandatory to write if the course outcomes address PO(f) Read the PO Statement in the website first, before writing this section ([Program Outcomes and Program Educational Objectives | Department of EEE, BUET]*)*

13.5.1 Assessment of Societal and Cultural Issues

Due to high carbon pollution and shortage of natural fuels everywhere, we need alternatives sources of power. Renewable energy comes handy just then. Our project relies on the same vision which will improve societal condition.

13.5.2 Assessment of Health and Safety Issues

There's no health or safety issue upon using this project according to the manual.

13.5.3 Assessment of Legal Issues

There's no legal issues for this project. This holds no harm to anyone.

13.6 Sustainability and Environmental Impact Evaluation (PO(g))

Maximum Power Point Tracking (MPPT) solar chargers contribute positively to sustainability and have a relatively low environmental impact in the context of renewable energy technologies. Here's a concise note on their sustainability and environmental aspects:

1. Renewable Energy Source: MPPT solar chargers harness energy from the sun, a renewable resource, reducing reliance on fossil fuels and decreasing greenhouse gas emissions associated with energy generation. This promotes sustainability by reducing the carbon footprint of power production.

2. Energy Efficiency: MPPT technology maximizes the energy harvested from solar panels, improving the overall efficiency of solar power systems. This means fewer solar panels are needed to generate the same amount of energy, reducing resource consumption and minimizing environmental impact.

3. Extended Battery Life: MPPT controllers optimize battery charging, preventing overcharging and extending battery lifespan. This reduces the frequency of battery replacements, which can involve environmentally harmful materials and processes.

4. Sustainable Manufacturing: Many MPPT solar chargers are designed for durability and reliability, leading to longer product lifespans. Sustainable manufacturing practices, such as the use of recyclable materials and energy-efficient production methods, are becoming more common in the solar industry.

5. Reduced E-Waste: Longer-lasting MPPT chargers, coupled with their recyclable components, contribute to reduced electronic waste (e-waste). Proper disposal and recycling of electronic components help mitigate environmental harm.

6. Low Maintenance: MPPT solar chargers often require minimal maintenance, which reduces the environmental impact associated with servicing and replacement parts.

7. Energy Independence: MPPT controllers can be used in off-grid and remote areas, promoting energy independence and reducing the need for extensive infrastructure development, which can have negative environmental consequences.

8. Environmental Considerations: While MPPT controllers themselves have a low environmental impact, it's crucial to consider the environmental impact of the entire solar power system, including solar panel production and end-of-life disposal. Sustainable practices throughout the lifecycle of the system are essential.

In summary, MPPT solar chargers play a key role in promoting sustainability and reducing the environmental impact of solar power systems. Their ability to maximize energy output, extend battery life, and contribute to renewable energy adoption aligns with the broader goals of reducing carbon emissions and mitigating environmental harm in the transition to cleaner energy sources.

13.7 Ethical Issued (PO(h))

We worked diligently together we pull out this project within deadline. We took help from various sources to get to know about the working principles our project. We didn’t directly copied from already done projects on the internet. We tried various things we get the best results out of our components. We kept integrity throughout the whole timeline.

14 Reflection on Individual and Team work (PO(i))

14.1 Individual Contribution of Each Member

Our project was maily divided in two parts, hardware and software. Id 1906024, Md Tareq Mahmud and id 1906028, Mithon Rahman was involved with the hardware part and id 1906016, Rowatul Rafi and 1906027, Progna Dipto Saha was involved with the software part. In the case of buying hardware and assembling parts, we all worked together.

14.2 Mode of TeamWork

Our Longest part of the project was to sort out the hardware and get proper output from the circuit. ID 1906028, 1906024 lead the way in hardware ID 1906016, 1906027 followed the procedures and worked together. Then after getting desired results from the circuit we moved to the MPPT programming and there ID 1906016, 1906027 lead the software part and 1906028,1906024 followed in testing and perfectioning.

14.3 Diversity Statement of Team

1906016: Committed hard worker , good at programming

1906024: Committed hard worker, helped at hardware

1906027: Committed hard worker, helped at improving code and logic.

1906028: Committed hard worker, leader in hardware.

14.4 Log Book of Project Implementation

Date	**Milestone achieved**	**Team Role**
Week 3	Planning	Everyone worked together
Week 7	Buying hardware and Implementation	Mainly roll 24,28
Week 10	Assembling and testing	Everyone worked together
Week 11	Programming and implementing	Mainly roll 16,27

Week 13	Finalizing and completion	Everyone Worked together

15 Communication (PO(j))

15.1 Executive Summary

A Maximum Power Point Tracking (MPPT) solar charge controller optimizes solar panel performance by continuously tracking and adjusting voltage and current to extract maximum power from changing environmental conditions. It enhances solar system efficiency by ensuring panels operate at their Maximum Power Point (MPP), increasing energy harvest. We can either run a load or charge a battery with it. And the battery can run the load when solar is disconnected. We kept a feature to automatically switch to battery mode when solar is off grid and vice versa.

15.2 User Manual

It is very easy to run this project. Connect the battery to the charger and it charges the battery given that there is enough power available from the solar panel and it will also show you in a lcd display the amount of power it is delivering to you by the MPPT method. You will also get to see the input current and voltage of solar panel and current battery voltage.

16 Project Management and Cost Analysis (PO(k))

16.1 Bill of Materials

16.2 Calculation of Per Unit Cost of Prototype

Item	Quantity	Unit Price	Price
Solar Panel	1	1200	1200
Lead Acid Battery	1	700	700
Inductor Core	3	20	60
Inductor Wire		200	200
Wire	3	50	150
TVS Diode	1	10	10
MOSFET IRFZ44N	1	45	45
Heat Sink	1	50	50
Relay Module	1	450	450
ACS 712	1	120	120
Diode(IN4007)	2	5	10
Capacitor (100uF)	3	20	60
Gate Driver IR2104	1	100	100
Buck Module	1	80	80
IC base(8 pin)	1	10	20
Male Header	11	5	5
Veroboard	1	175	175
Arduino Nano	1	452	452
LCD Display	1	418	418
Lead Acid Battery	1	700	700
Resistors(2pieces 10kohm,3 pieces 100k, 2pieces 47k)		50	50
Breadboard	1	1201	120
Total			5325

16.3 Calculation of Per Unit Cost of Mass-Produced Unit

16.4 Timeline of Project Implementation

Task Name	Week Wise Progress			
	Week5	Week7	Week10	Week12-13
Planning	Done			
Research		Done		
Design		Done	Done	
Implementation				Done
Follow up				

17 Future Work (PO(l))

There are many improvements that can be done on this project. First would be efficiency. Then we can also add parallel load control where the solar charger can directly provide power to the load simultaneously with the battery. We can also improve our code to implement complex algorithms to track MPPT points.

18 References

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