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

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Power Electronics Laboratory

Final Project Report

Section: A1 Group: 03

Solar based UPS with Voltage Level Control, Battery Level Indicator and Auto Cut-off

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Signature of Instructor: ______________________________

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"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."

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1 Abstract

This project report explores the design, development and implementation of our designated project - a Solar based Uninterruptible Power Supply (UPS) system equipped with advanced features, including Voltage Level Control, Battery Level Indicator and Auto Cut-off. It aims to provide a sustainable solution for uninterrupted power supply in Bangladesh at the times of load-shedding while addressing voltage fluctuations, monitoring battery status and enhancing system efficiency. This report presents a comprehensive overview of the theoretical framework, software simulation, hardware design and experimental results along with other impacts of this project.

2 Introduction

Solar based UPS is an independent electrical system designed to supply power to a connected load. This system stands out as a great solution because of its eco-friendliness, cost-effectiveness and minimal maintenance requirements. Traditional UPS systems provide backup power when the grid fails but they rely on grid power which aren't very eco-friendly. But our solar-based UPS is a significant improvement in that case as it only uses solar panel to harness renewable energy source, Sun, reducing the need for grid power and lowering carbon emissions. Additionally, the system is smartly built with unique attributes like voltage level control, battery level indicator, and an auto cut-off mechanism, which collectively optimize energy usage, battery health, and system reliability.

In the subsequent sections of this report, we will explore the functionalities of the solar-based UPS system, discuss the design methodologies implemented in its construction, present the experimental findings concluding with its real-world applications and potential impact.

3 Design

3.1 Problem Formulation

From the beginning, our project aimed to create an independent electrical system capable of providing continuous power to a load without relying on the grid. In order to materialize it-

- Choosing a sustainable energy source as our main power generation method was essential.
- Identifying the process for transforming this energy source into a consistent DC input was crucial.
- Controlling the voltage accordance to necessity was a concern too.
- Indicating battery level and implementing auto cut-off.
- Establishing a dependable system design was necessary to convert DC power into AC power.

Through group discussions, we made decisions on each of these key aspects.

3.2 Design Method

As we had several key points to consider while designing our UPS, we took decision step by step which are-

- As sunlight is abundant and a renewable energy source, we chose to use solar panels for power generation. However, solar panels generate direct current (DC) voltage, which can fluctuate due to factors like sunlight intensity, temperature and humidity. To tackle this issue, we decided to connect a solar charge controller to the solar panel system which would not only monitor the battery level but also regulate it.

- We created a battery pack with a Battery Management System (BMS) module to ensure a stable DC power supply to the main circuitry, adjusting it based on the battery level and automatically cutting off power when necessary. This setup allowed precise control of voltage levels.

- In the main circuitry, we decided to build a clock pulse generator using a 555 timer and generated inverted clock pulse signal using optocoupler.

- Next, we addressed the need to convert DC to AC power by building an inverter circuit. After much discussion and setbacks, we decided to build a Push-pull inverter circuit and in its transformer end, we figured that we would connect the load. As push-pull inverter has a common ground nature, optocoupler didn't need isolated ground. Push-pull inverter converts DC into AC by using two MOSFETs that work in coordination with one transistor pushing the current while the other pulls it. This alternating push-pull action generates an AC output waveform which we used across the load.

3.3 Circuit Diagram

Firstly, a circuit was designed to implement our project purpose. Here is the planned circuitry designed in PROTEUS:

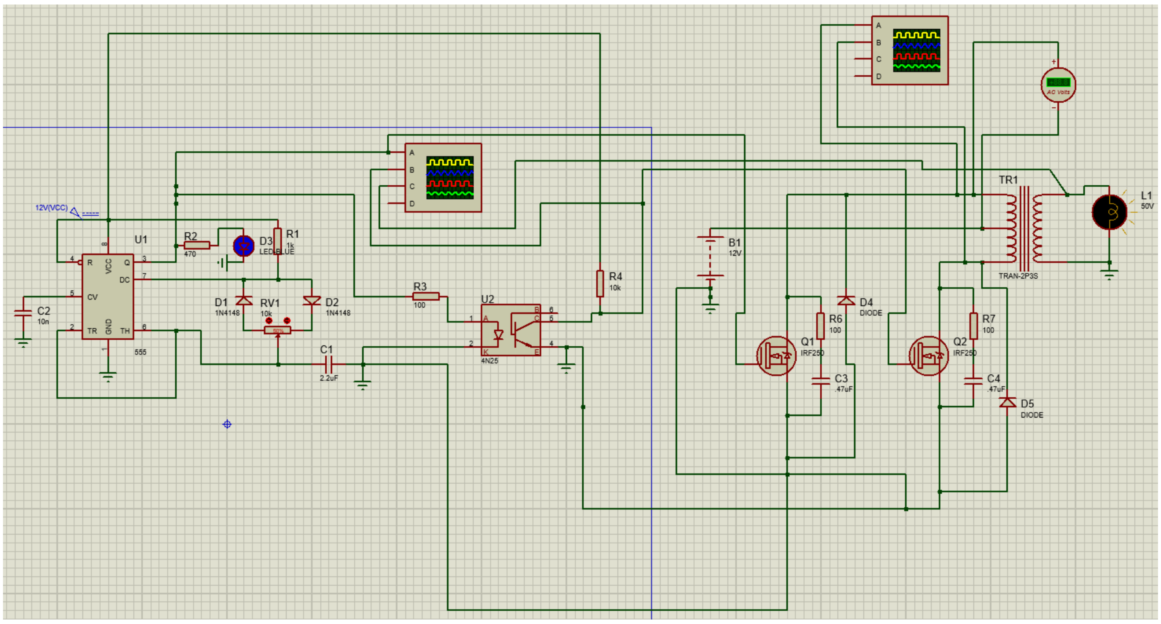


Figure 1: Main Circuit Schematic in Proteus

We aimed to generate gate pulse and inverted gate pulse from this portion using 555 timer and optocoupler:

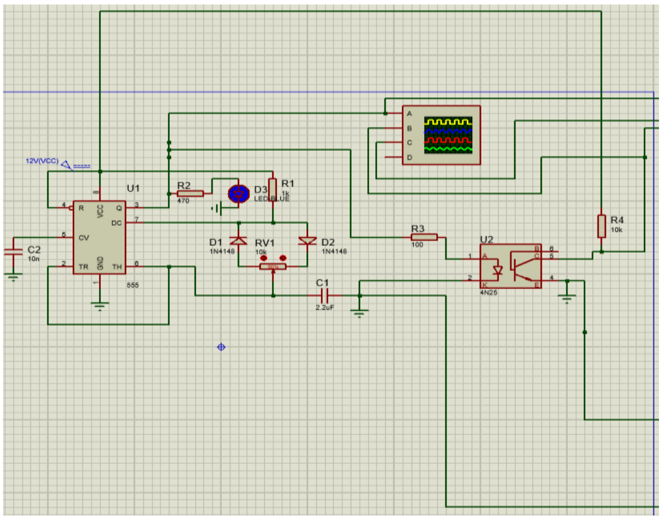


Figure 2: Gate Pulse Generator Circuit Using 555 Timer and Optocoupler

The push-pull inverter circuit configuration is designed as below:

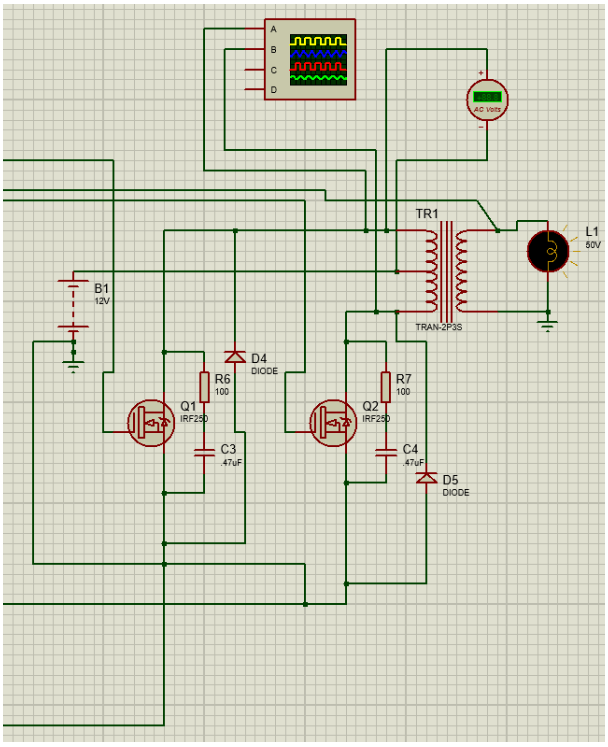


Figure 3: Push-pull Inverter

3.4 Simulation Model

Here is the simulation result of gate pulse generator portion where the above graph indicates the gate pulse generated from 555 timer and the below graph indicates the inverted gate pulse output from optocoupler. The pulse width is 50% and the frequency is 50 Hz.

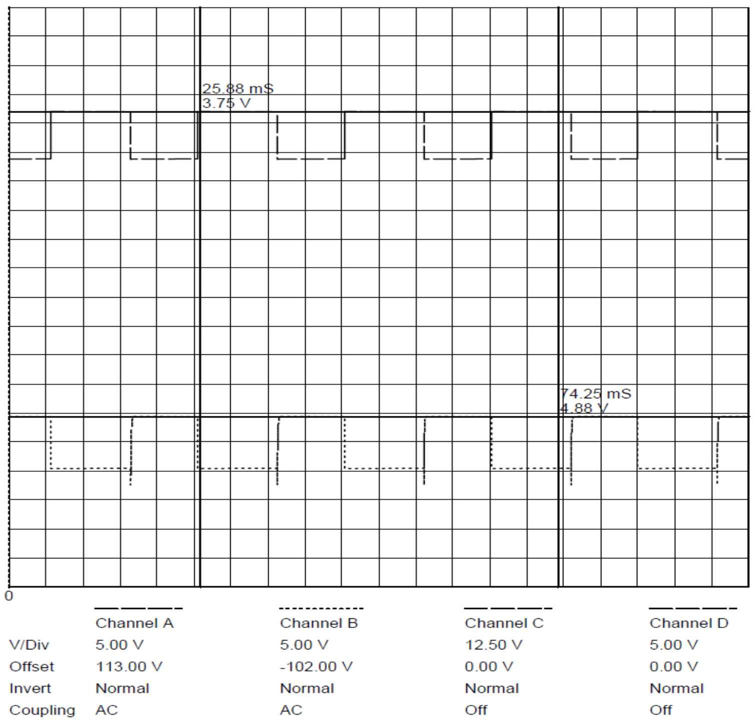


Figure 4: Gate Pulse from 555 Timer(above), Inverted Gate Pulse from Optocoupler(below)

The center tap transformer output and input of the push-pull inverter circuit is given below:

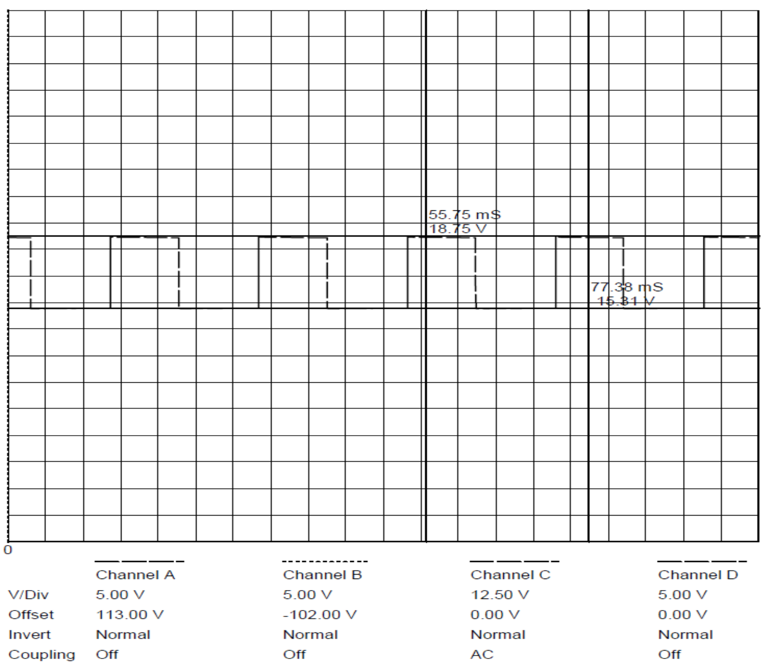


Figure 5: Transformer output

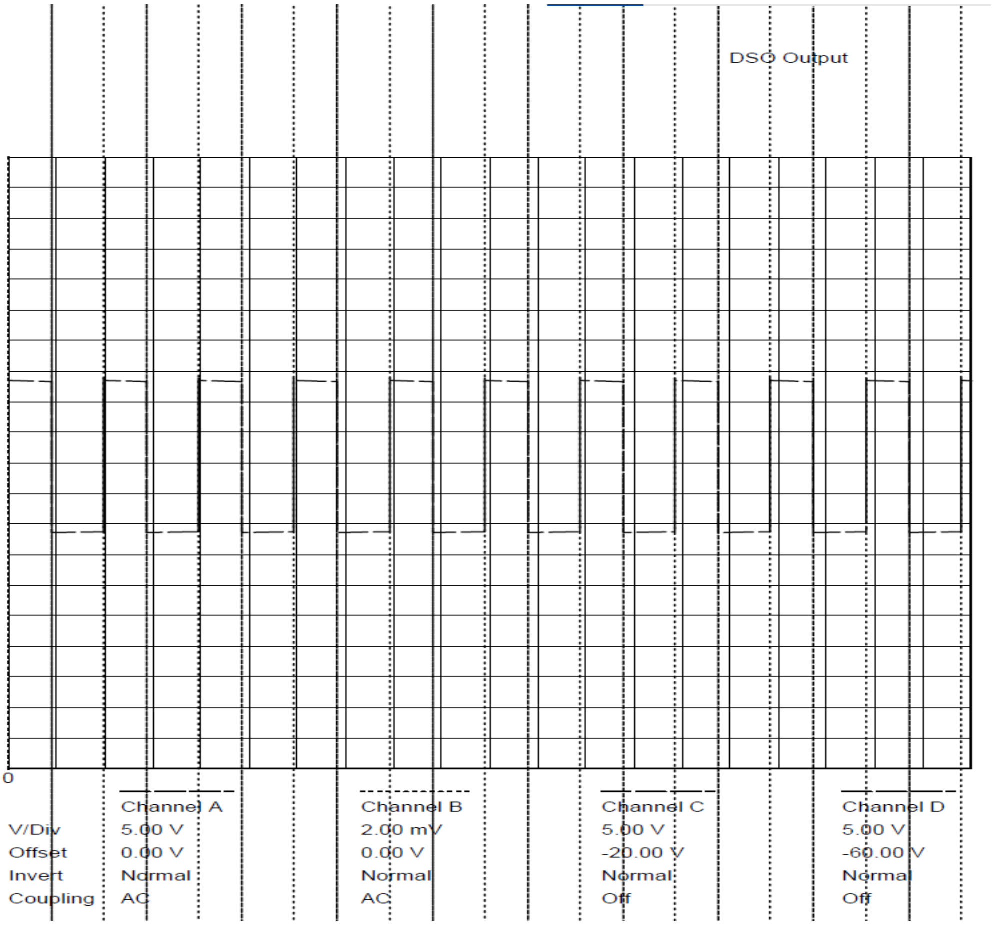


Figure 6: Transformer Input

3.5 Hardware Design

Here are the final hardware design of our project and the section-wise photos of relevant parts:

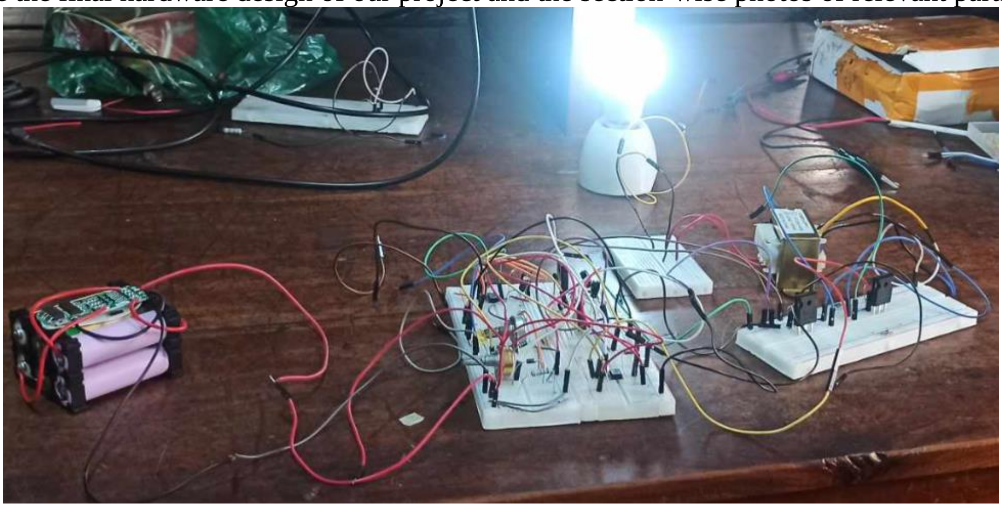


Figure 7:Overall Circuitry (Solar panel not shown)

Figure 8: Solar Panel with Solar Charge Controller and Battery Pack

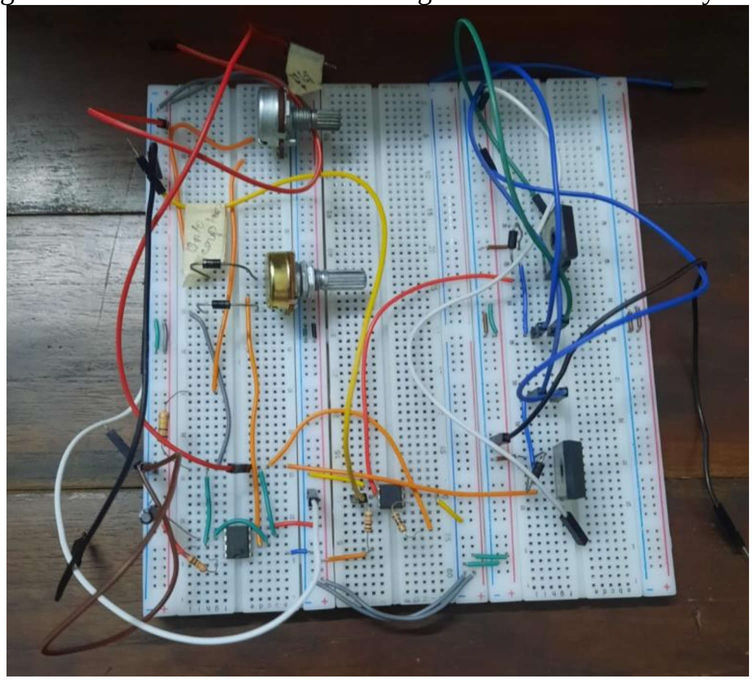


Figure 9: Clock Pulse Generator and Push-Pull Inverter Circuit

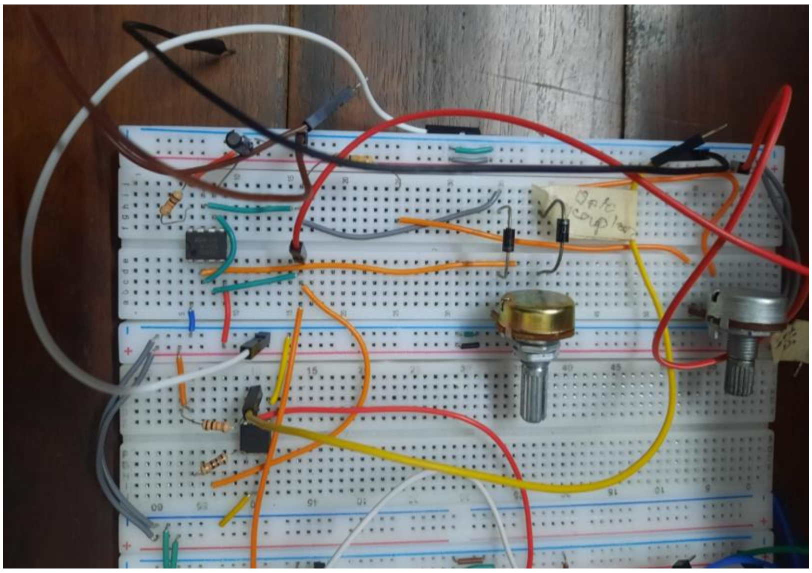


Figure 10: Clock Pulse Generator Circuit with 555 Timer and Optocoupler

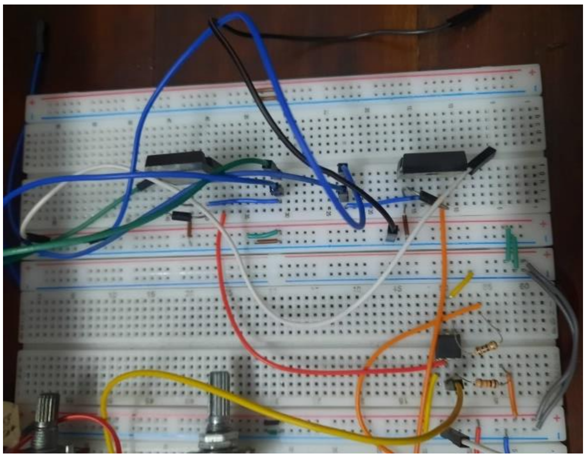


Figure 11: Center Tap Transformer

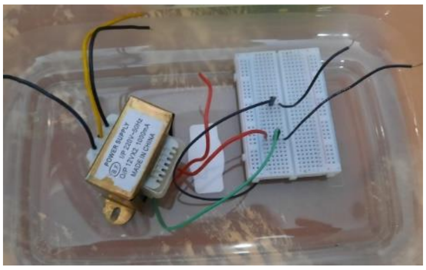


Figure 12: Push-Pull Inverter Circuit

4 Implementation

4.1 Description

Block diagram:

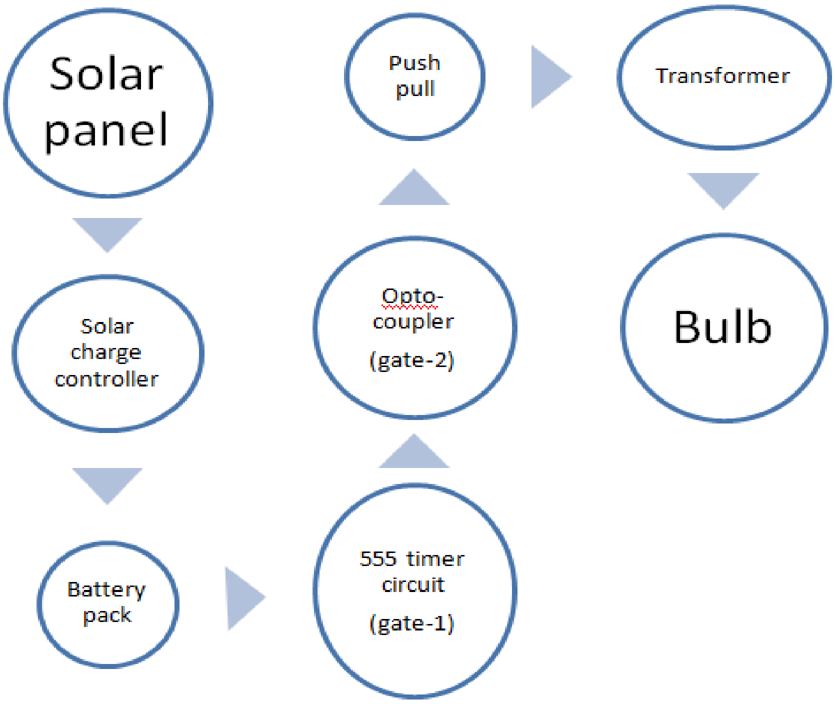


Figure 13: Block diagram

Following the block diagram, firstly our solar panel will charge our battery pack. We controlled the charging path using solar charge controller.

Our solar panel:

Figure 14: Solar Panel

The rating of our solar panel:
Maximum power-30W
Tolerance-0-3%
Rated voltage-18.7V
Rated current-1.6A

Solar charge controller:

Figure 15: Battery is being charged by solar panel

A solar charge controller is a vital component in solar power systems, responsible for regulating the flow of electricity from solar panels to batteries. Its core functions include managing the voltage and current from the solar panels to match the battery's requirements, preventing overcharging and over-discharging to safeguard battery health, and optimizing the charging process through multi-stage algorithms.
We used digital solar charge controller. In our project, we were told to make battery level indicator. By using this controller, we indicated whether the battery is being charged or not.

Battery pack:

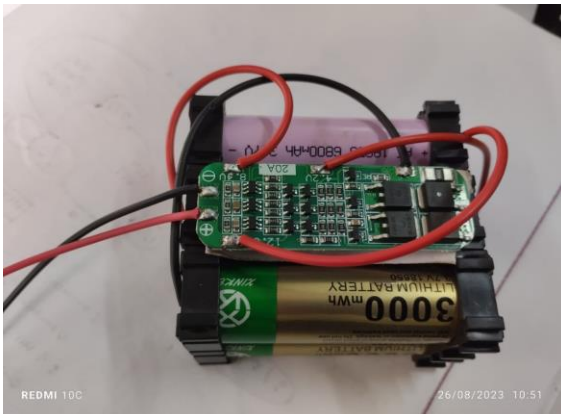


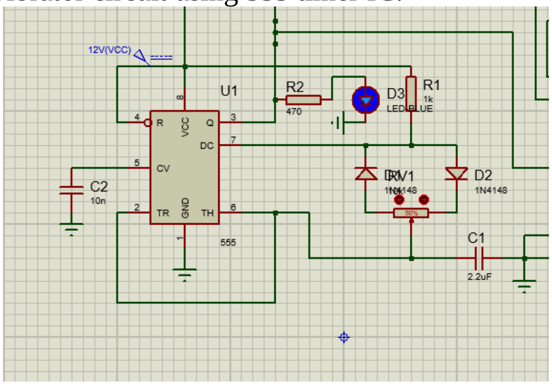
Figure 16: BMS

We used total 6 Li ion batteries to make this battery pack. We used two 3.7V, 6800mAh and four 3.7V,3000mWh Li ion batteries.
Then the rating of our battery pack-
Rated voltage=$3.7 \times 3 = 11.$
But after adding BMS the maximum charging voltage of our battery is 12.6V.
Rated $mAh = \frac{((3000\times2+25160)\times2)}{3.7\times3} = 5614.41\ mAH$

BMS (Battery Management System):
We used 3s 12.6V Li ion battery management system. We have connected a BMS module in our battery pack. A Battery Management System (BMS) plays a critical role in an auto cutoff system by safeguarding the battery's health and ensuring safety. It monitors essential parameters like voltage, current, and temperature, taking action to prevent overcharging, over-discharging, or overheating, which can harm the battery. The BMS also balances individual cells in multi-cell battery packs, maximizing overall capacity and performance. Furthermore, it estimates the battery's state of charge (SOC), helping determine when to initiate an auto cutoff to prevent over-discharge. Communication interfaces in the BMS facilitate interaction with other system components, enabling timely responses and actions to maintain user safety and extend battery life. Additionally, it detects faults and initiates cutoffs when necessary, contributing to overall system reliability and longevity.

Then from the block diagram, we can see that we generate gate pulse of MOSFET-1 using 555 timer IC. We used DC supply from solar charge controller to conduct the circuit. We used push-pull inverter. So, we need two inverted gate pulses to operate two MOSFETs one after another. We used opto-coupler to invert the gate pulse of MOSFET-1. The whole process is described below:

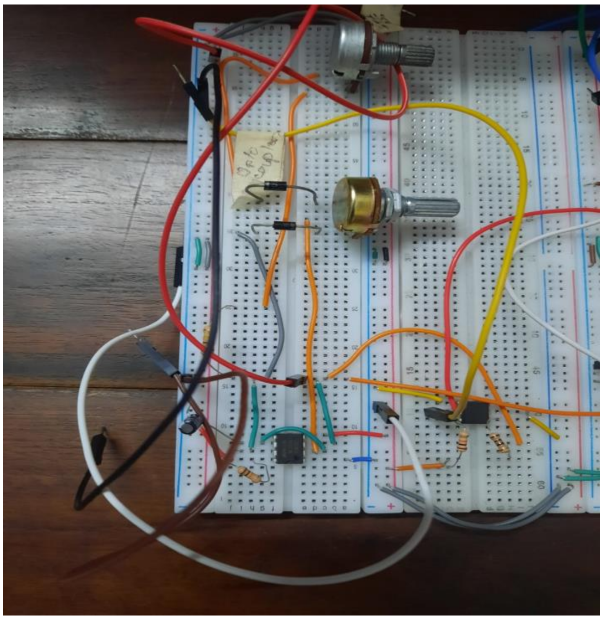
Generating gate pulse using 555 timer IC:
We designed astable multivibrator circuit using 555 timer IC.



In this circuit charging and discharging of capacitor C1(connected with pin6) generates gate pulse. There is a flip flop inside 555 timer IC. Flip flop helps to make pulse signal. Here changing the pot(pot1) value, we can control the pulse width.

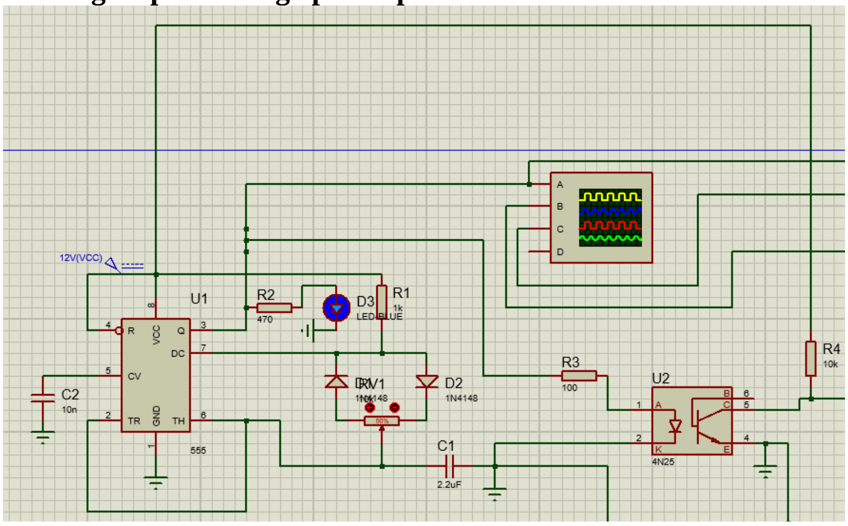
Practical Implementation:

Circuit:



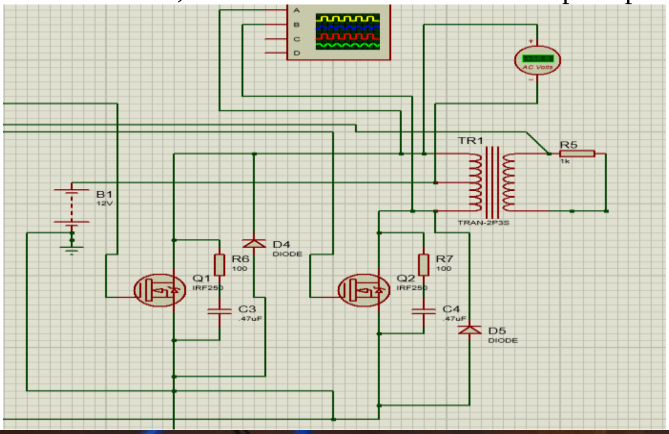
But when we practically implemented the circuit, we kept an extra option which is varying frequency. By varying R2(a resistor between two diodes) with a pot(pot2) we vary the frequency.
The formulas of gate pulses are:
$T_{on} = 0.693 \times (R_1 + R_x) \times C_1$ [Rx is the left side resistance of pot1]
$T_{off} = 0.693 \times (R_2 + R_y) \times C_1$ [Ry is the left side resistance of pot2]
$T = 0.693C_1(R_1 + R_2 + R_x + R_y)$ [where Rx and Ry are adjusted according to our need]
So, we can see that varying R2 can control frequency.

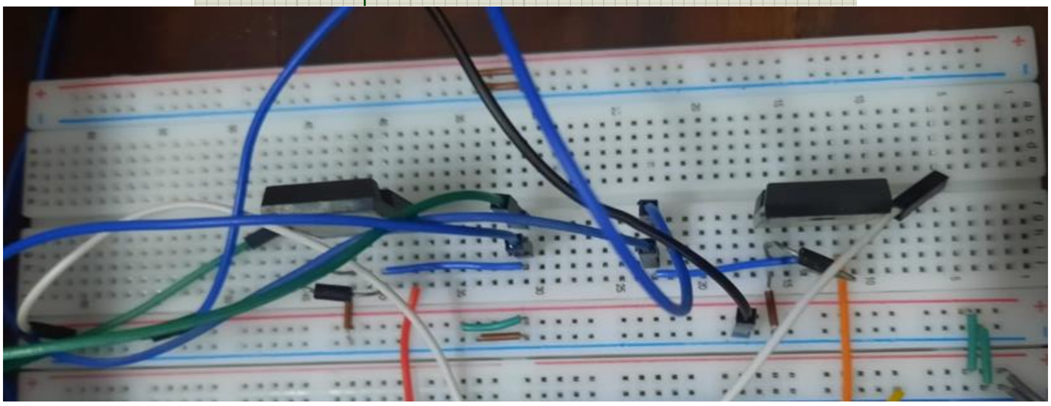
Generating inverted gate pulse using optocoupler:



Here inside optocoupler there is a LED which converts the electric signal into light signal. The photosensitive transistor converts the light signal to electric signal. Thus, when the transistor is on $V_{out}=0$ and when it is off $V_{out}=V_{in}$. Thus, optocoupler inverts the gate signal by this way.

Push-pull inverter:
With the gate pulses described above, we drive the two MOSFETs of push pull inverter.

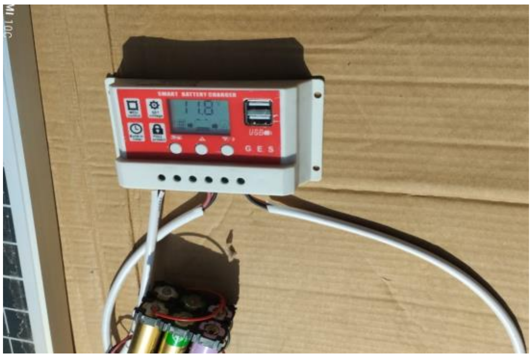




The output of the push pull inverter is not pure square wave due to inductive current flowing through the freewheeling diodes. In a push-pull inverter circuit using two MOSFETs, the operation involves efficient conversion of DC power into AC. Two MOSFETs, typically two N-Channel MOSFETs, are used. A control circuit generates switching signals that alternate the states of these MOSFETs. When Q1 is turned on, it provides a low-resistance path for current from the DC input through a transformer's primary winding, generating a magnetic field and inducing AC voltage in the secondary winding. This AC output is then rectified and filtered to achieve a cleaner and more sinusoidal waveform. The control circuit periodically switches between Q1 and Q2 to create the alternating polarity required for AC power generation. The output frequency is determined by the switching frequency of the MOSFETs, making this configuration valuable for various applications requiring controlled and stable AC power sources, such as motor drives and power inverters.

4.2 Experiment and Data Collection

Charging our battery:
At 2:55pm:



Battery voltage level indicates 11.8V

At 4:47pm:

Battery voltage level indicates 12.21V

Calculation:

The rated power of our solar panel is 30W.The rated voltage of our battery is 12.6V and current rating is 5614.41mAH. So, to properly charge battery we have to charge battery for at least $\frac{5.61441 \times 12.6}{30} = 2\ hr\ and\ 21\ min$

Measurement of Current after charging:

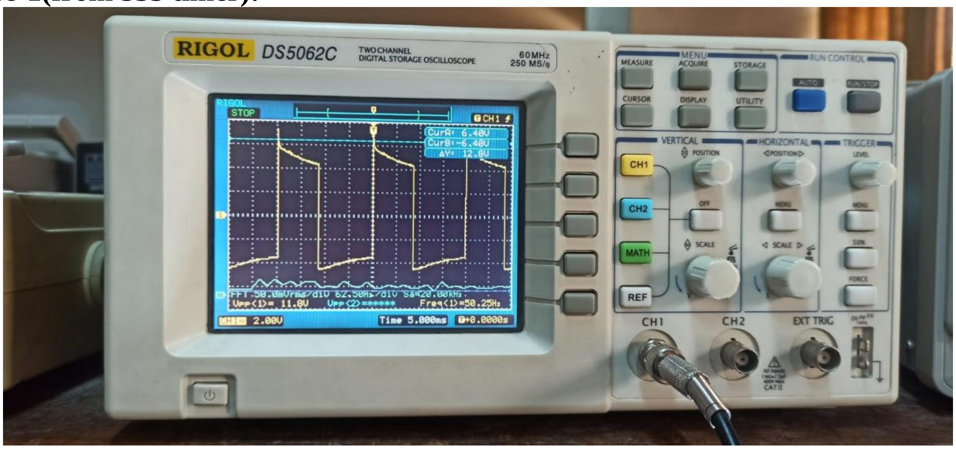
Current and voltage from solar panel during charging	0.092A	12.69V
Current from battery	0.46A	12.31V
Current from load terminal	0.161A	12.30V

Calculation:

P (solar panel) =$12.69 \times 0.092 = 1.17W$

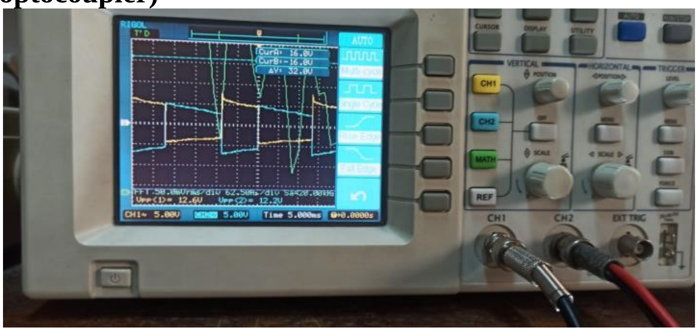
P(battery)= $12.31 \times 0.46 = 5.66W$

Gate pulse-1(from 555 timer):



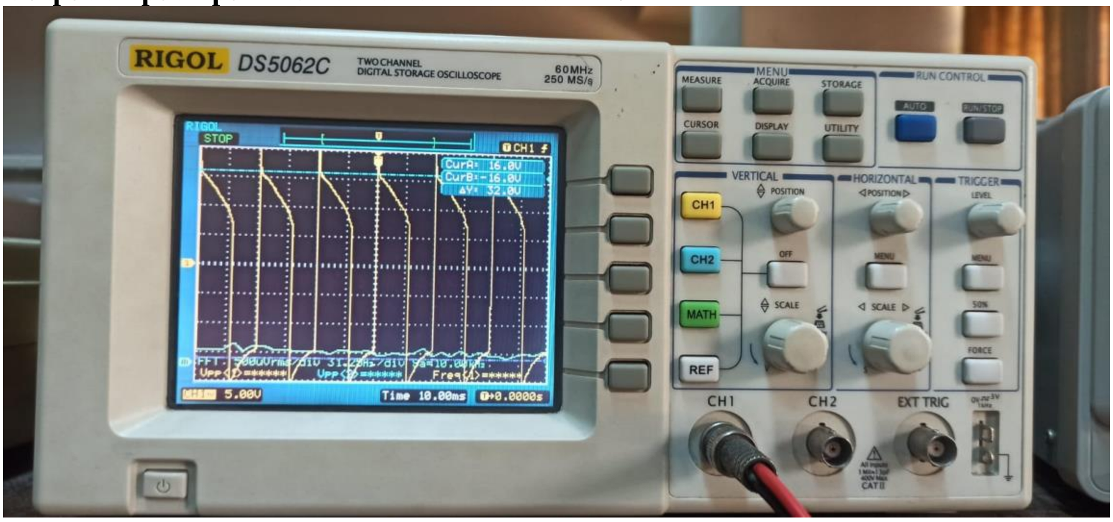
Here the peak-to-peak voltage of the gate pulse from 555 timer Vpp=11.8V and frequency=50.25Hz

Gate pulse-2 (from optocoupler)



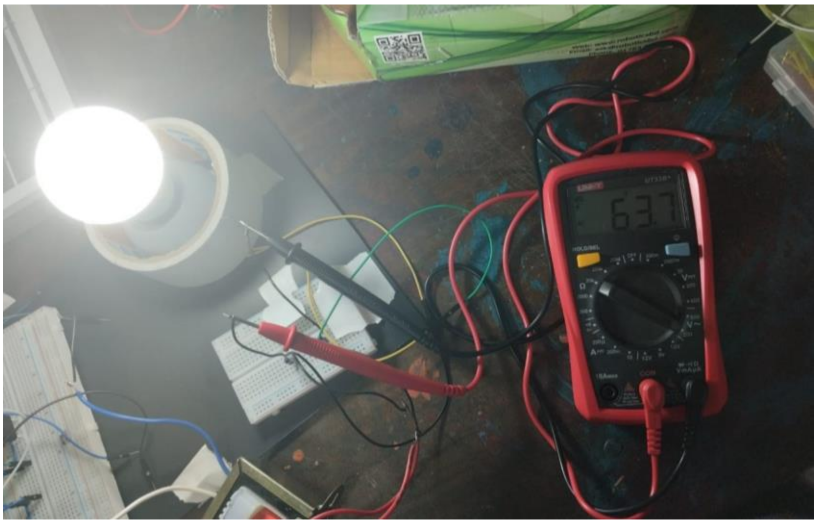
Here peak-to-peak voltage of the inverted gate pulse from optocoupler Vpp=12.6V and frequency remains same.

Output of push-pull inverter before transformer:



Here peak-to-peak voltage Vpp=35V and frequency=50.25Hz.

Output voltage across load:



Vrms=63.7V across the light bulb

Without light bulb:

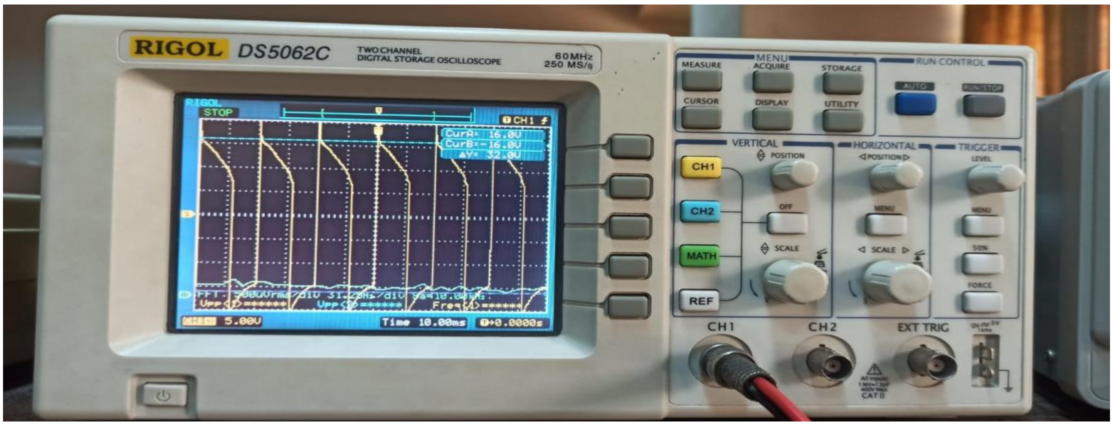
Without light bulb the rms voltage Vrms=181.5V

4.3 Data Analysis

Time of charging batteries: We charged the battery pack under sunlight for straight 2 hours. That's why it is not fully charged.

Power from solar panel:
Current=0.092A
Voltage=12.69V
So, power=1.16W

Our input voltage is 12.00V dc voltage
Output of Gate pulse-1:
The peak-to-peak voltage of gate pulse-1 Vpp=11.8V and the frequency=50.25Hz. We fixed the frequency by varying the potentiometer(pot-2). The amplitude of the square wave is 5.9V which is enough to turn on MOSFET-1
Output of inverted Gate pulse-2:
The peak-to-peak voltage of gate pulse-2 Vpp=12.6V and the frequency=50.25Hz. The amplitude of the square wave is 6.3V which will turn on MOSFET-2.
Output of push-pull inverter circuit:
The peak-to-peak voltage of the output of the push pull inverter circuit is 35V and frequency=50.25Hz. The amplitude of the output waveform=$\frac{35}{2}$V=17.5V



The output is not pure square wave. It is because of the inductance of transformer.
It could be improved if we used a LC filter after the output. But from above we can see that the rms output voltage is 181.5V which is very high voltage. We did not have any inductor or capacitor which is compatible with high voltage.
We tried a different approach before. We used half bridge inverter instead of push-pull. We tried to filter the square waveform into sinusoidal waveform by using different filters. We used both passive and active filter. But when the shape of the waveform improved, the gain of the filter decreased and vice versa. We gave input of the filtered output (a non-sinusoidal waveform) to the transformer but it could not step up the output. That's why, we tried push pull inverter at last.
Output voltage (without load):
The rms value of the output voltage=181.5V
Output voltage (across load):
The rms value of the output voltage=63.7V
Cause:
Voltage Regulation:
Transformers are designed with a specific turn ratio between the primary and secondary coils. The turns ratio determines how much the voltage is stepped up or stepped down. However, transformers are not perfect, and they may have some inherent voltage regulation. This means that the voltage can vary slightly depending on the load. When you connect a load, the transformer may not be able to maintain the exact same output voltage as when it was unloaded, and it drops to 64V due to this

regulation.
Load Characteristics: The load connected to the secondary coil can also affect the output voltage. If the load is drawing a significant amount of current, it can cause a voltage drop due to the internal resistance of the transformer and the resistance of the winding. Transformers have a rated load capacity, and if the connected load exceeds this capacity, it can lead to a significant voltage drop.

4.4 Results

Our goal of the project was to convert DC to a pure sinusoidal AC wave and conduct a load(bulb). It's already discussed how we tried to convert sine from square when we used half bridge inverter. But due to low quality of filtering our plan failed and we made a push-pull inverter.
The output results of our project are discussed below:

I)
The input power from solar panel):
The output power across load:
Efficiency=
Ii)
Transformer nominal voltage=181.5V
Assuming the bulb we connected is our transformer maximum load capacity-
Transformer full load voltage=63.7V
So, voltage regulation= $\frac{181.5-63.7}{63.7} = 1.84$
Iii)
For push pull inverter-
$V_o = \frac{N_s}{N_p} V_1$
Here V_1=8.75V
and V_o(rms)=181.5V or 256.67V
From rating of transformer $\frac{N_s}{N_p} = \frac{220}{12}$ =18.33
So, V_o=18.33×8.75=160.4V
So, the practical result is huge different from ideal result.

5 Design Analysis and Evaluation

5.1 Novelty

I)Variable frequency: Generally, UPS are designed to conduct at 50Hz frequency. But in our project we can vary frequency. In Bangladesh frequency gets fluctuated between 48Hz to 52Hz.We can tune our ups according to the frequency we needed.

II)We can use our project in different fields-

Here are some electrical components or devices that can be conducted by square wave power or modified sine wave power, as long as the waveform and voltage levels are within acceptable tolerances:

1. Induction Motors: Some types of single-phase and three-phase induction motors can operate on square wave or modified sine wave power, although it may affect their efficiency and performance compared to pure sine wave power.

2. Switching Power Supplies: Many modern switching power supplies and DC-DC converters are designed to handle non-sinusoidal input waveforms, including square waves. They often incorporate rectification and filtering stages to convert the input waveform into a stable DC voltage.

3. Universal Motors: Universal motors, commonly used in appliances like blenders and power tools, can operate on square wave or modified sine wave power sources with some limitations. The waveform may affect their speed control and efficiency.

4. Electronic Devices with Power Supplies: Some electronic devices, like laptop chargers and phone chargers, contain internal power supplies that can tolerate non-sinusoidal input waveforms to a certain extent. However, it's essential to check the manufacturer's specifications for compatibility.

5. Incandescent Bulbs: Incandescent light bulbs can generally operate on square wave or modified sine wave power sources, as they are not sensitive to the waveform of the input voltage.

6. Resistive Heaters: Devices that use resistive heating elements, such as electric heaters, can typically operate on square wave or modified sine wave power without issues, as long as the voltage levels are appropriate.

7. Some Audio Equipment: Certain audio equipment and amplifiers may work with square wave or modified sine wave power, but the quality of the output audio may be affected.

5.2 Design Consideration

5.2.1 Consideration to public health and safety

Our instruments are not harmful for public health. We used rechargeable battery (Li ion battery 18650) instead of lead acid battery considering public health.

5.2.2 Consideration to environment

- We used solar panel to reduce waste of solar energy. Averaged over a year, approximately 342W of solar energy fall upon every square meter of earth. This is a huge amount of energy (44 quadrillion). But a huge amount of this solar energy is being wasted just because of lack of utilization.
- Also we used rechargeable battery to prevent battery from soil pollution
- There is no Carbon emission

5.2.3 Consideration to Culture and Social Needs

- The cost of our project is affordable for middle class people. But to make this project affordable to general people, we need further research and mass production.
- As Bangladesh is at north of the equator, we are blessed to have sunlight for every month. Our project is solely based on solar power. Thus, our project can be very useful for the people of our country.

5.3 Investigations (PO(d)):

5.3.1 Literature Review:

We did not follow any research paper based on solar ups.We tried to complete our project following what we have learned in our laboratory

5.3.2 Experiment Design:

We have discussed the design of our project in 3.2(Design method)

5.3.3. Data analysis and Interpretation:

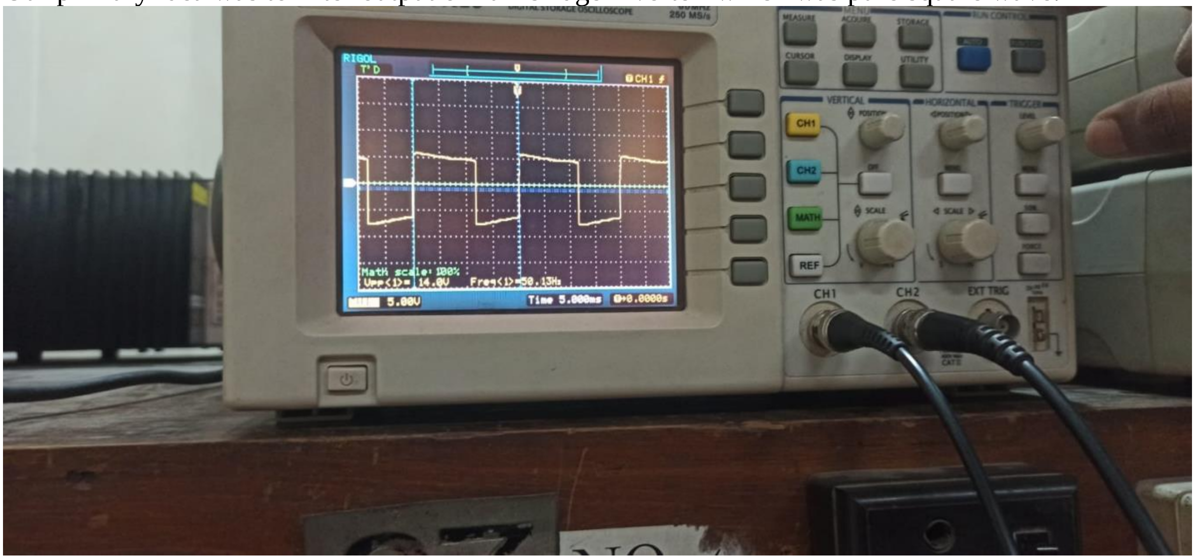
We discussed data analysis in 4.3

5.4 Limitation of Tools(PO(e)):

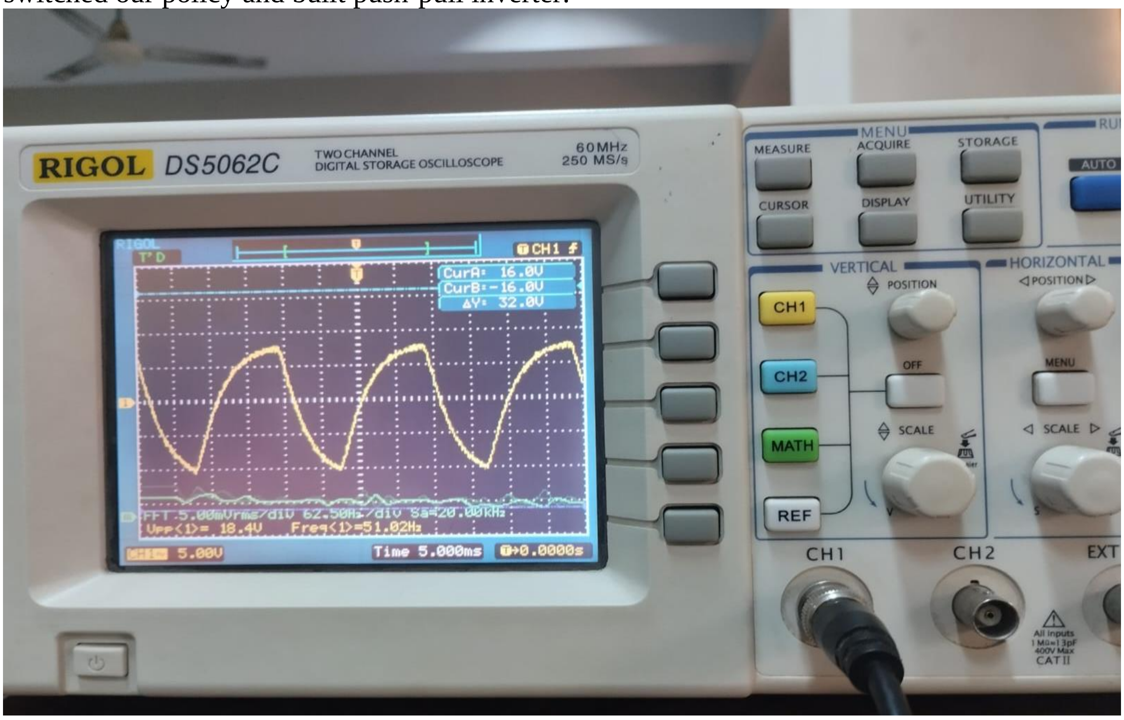
1. High voltage tolerable resistance, capacitance: The output of our inverter circuit is not pure sinusoidal. So, we needed to filter the output waveform. To do that we needed such resistor, capacitor, inductor that could tolerate high voltage and current. We did not have any of these.

2. Limited slew rate and bandwidth of LM741:

Our primary idea was to filter output of half bridge inverter which was pure square wave.

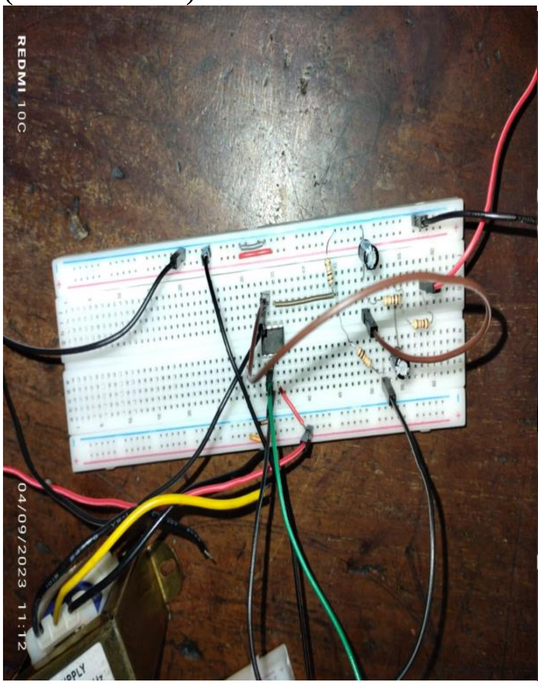


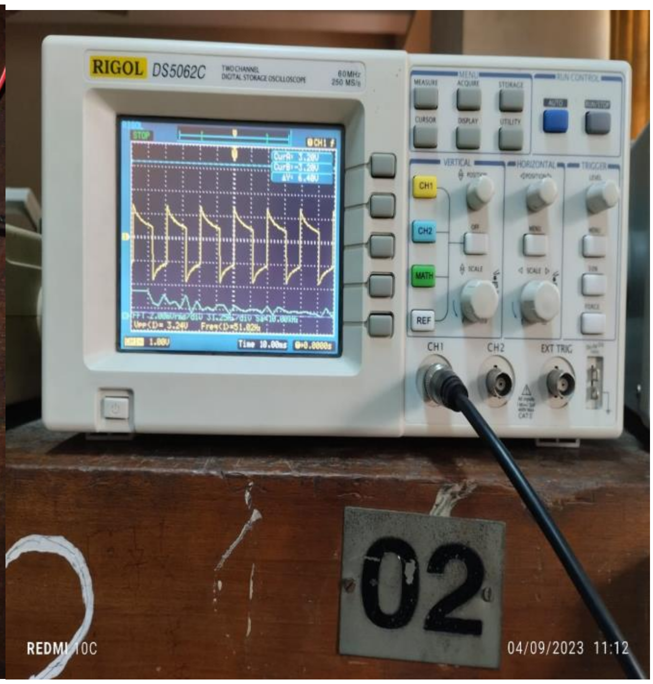
We used three stage RC filter. But if we improved the quality of the filtered output, then the gain decreased and vice versa. This non sinusoidal waveform could not be conduct by transformer. So, we switched our policy and built push-pull inverter.



To improve voltage, we even tried full bridge inverter. According to our theory we should get at least

double peak to peak of output voltage but the output of our half bridge inverter and full bridge inverter were identical.
Then we used active 2nd order filter using LM-741.But the worst happened. The filtered output remained square with decreased amplitude. This is because we used LM741 which has limited bandwidth and slew rate. It is not compatible with higher frequency waveform and a square wave contains higher frequency sine waves. We did not use op-amp of higher slew rate and wider bandwidth (such as TL072) due to lack of time.





3.Low voltage after connecting load: The reason behind this problem has been discussed above.

5.5 Impact Assessment (PO(f))

5.5.1 Assessment of Societal and Cultural Issues

Solar powered UPS system can reduce the reliance on fossil fuels and decrease carbon emissions, aiding in creating a greener society. It also promotes renewable energy usage and innovation in this sector thus motivating further education and research into this field as consumers reap more benefits from such systems and become aware of its various advantages. Widespread usage of solar powered UPS systems especially in rural regions can make households and businesses self-sufficient in terms of power and also promote social equity. Such systems reduce the energy cost of societies as a whole and thus enabling more budget to be allocated for improving the standard of life of people. Moreover, such systems can allow the society to be more resilient to disasters and power outages as they can provide energy without main grid power supply. Finally, a cultural impetus towards a greener energy system can be seen within people if such systems are used more and more, setting the social trend and also affecting the policies of the government.

5.5.2 Assessment of Health and Safety Issues

Solar-based uninterruptible power supply (UPS) systems are generally considered safe when properly designed, installed, and maintained. However, like any electrical system, they come with certain health and safety considerations that should be addressed. Here are some health and safety issues to keep in mind when dealing with solar-based UPS systems:

- **Electrical Safety:**
  Solar UPS systems involve electrical components, so there's a risk of electric shock if not handled correctly. Installers and maintenance personnel should be trained in electrical safety procedures and use appropriate personal protective equipment (PPE). Moreover, faulty wiring or equipment can lead to short circuits, posing fire and electrical hazards. Regular inspections and quality installations are essential to prevent such issues.

- **Fire Safety:**
  Solar panels and batteries can generate heat. Ensure that adequate ventilation and cooling mechanisms are in place to prevent overheating, which can lead to fires. Furthermore, batteries in a UPS system, especially if improperly charged or maintained, can be a fire hazard. Battery enclosures and fire-resistant materials can mitigate this risk.

- **Chemical Hazards:**
  Lead-acid and lithium-ion batteries, commonly used in UPS systems, contain chemicals that can be hazardous if handled improperly. Spills, leaks, or damage to batteries can release toxic substances. Proper storage and maintenance procedures are crucial.

- **Fall Hazards:**
  Workers involved in the installation and maintenance of solar panels may be exposed to fall hazards, especially when working at heights. Safety harnesses, guardrails, and proper training can reduce the risk of falls.

- **Environmental Impact:**
  Solar UPS systems may contain components that require special disposal procedures, such as batteries. Improper disposal can harm the environment and human health. Ensure that old batteries and other components are disposed of according to local regulations.

- **Electromagnetic Fields (EMF):**
  Solar inverters and electrical components can generate electromagnetic fields. While the exposure to EMF from typical solar UPS systems is generally low and not considered harmful, it's essential to follow established safety guidelines.

By addressing these health and safety issues, solar-based UPS systems can be deployed and operated safely, minimizing risks to people and property while harnessing the benefits of renewable energy and uninterrupted power supply.

5.5.3 Assessment of Legal Issues

When dealing with solar-powered uninterruptible power supply (UPS) systems, there are several legal issues and considerations that may come into play. These issues can vary by jurisdiction and can involve regulations, permits, contracts, and liability concerns. Here are some common legal issues associated with solar-powered UPS systems:

- **Regulatory Compliance:**
  Depending on the location, one may need permits or approvals from local authorities or utility companies to install solar panels and UPS systems. Compliance with building codes and zoning regulations is essential.

- **Grid Connection and Net Metering:**

  If you plan to connect your solar system to the electrical grid or participate in net metering programs, you may need to sign interconnection agreements with your utility company. These agreements can involve legal obligations and compensation structures.

- **Environmental Regulations:**

  In some cases, large-scale solar installations may require environmental impact assessments and compliance with environmental regulations.

- **Tax and Incentive Programs:**

  It is necessary to research and understand any available tax credits, rebates, or incentives for solar installations in the region. Compliance or non-compliance with these programs may have legal implications.

- **Property Rights and Easements:**

  While installing solar panels, one should be aware of property rights and easements that may affect the installation and maintenance of solar panels, especially if the system is on shared or communal property.

Navigating these legal issues and considerations can be complex, and it's advisable to consult with legal professionals experienced in renewable energy and local regulations to ensure compliance and protect one’s interests when installing and operating a solar-powered UPS system.

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

Solar-based uninterruptible power supply (UPS) systems have several sustainability and environmental benefits compared to traditional fossil fuel-based power generation and backup systems. Here's an overview of their positive impact:

- **Clean Energy Source:**

  Solar UPS systems harness energy from the sun, a clean and renewable source. They produce electricity without emitting greenhouse gases, thus significantly reducing carbon emissions and contributing to a cleaner environment.

- **Reduced Dependency on Fossil Fuels:**

  Solar-based UPS systems reduce the need for backup power generated from fossil fuels like diesel generators. This reduces the consumption of finite fossil fuel resources and associated pollution.

- **Energy Efficiency:**

  Solar panels and inverters used in these systems are highly efficient in converting sunlight into electricity. This efficiency reduces energy waste compared to traditional backup systems.

- **Minimal Environmental Impact:**

  Solar UPS systems have a minimal environmental impact during operation. They do not produce noise pollution or release harmful emissions, making them suitable for urban and sensitive environmental areas.

- **Energy Independence:**
  Solar UPS systems can operate independently of the grid during daylight hours, reducing strain on the grid during peak demand times and enhancing overall grid stability.

- **Battery Technology Advancements:**
  Advances in battery technology, such as lithium-ion batteries, have made energy storage more efficient and sustainable, further enhancing the environmental benefits of solar UPS systems.

- **Extended Lifespan:**
  Solar panels and inverters typically have long lifespans, often exceeding 20-25 years. This longevity reduces the need for frequent replacements and associated environmental impacts.

- **Reduced Noise Pollution:**
  Solar UPS systems operate silently, which contrasts with the noise pollution generated by diesel generators or other backup power sources.

- **Scalability:**
  Solar UPS systems are modular, allowing users to expand their capacity as needed without significant environmental disruption. Increasing the number or size of solar panels, increasing the battery size, voltage and power ratings and also changing battery type if needed, the Solar UPS system can be scaled up to provide for larger loads.

- **Grid Support and Grid Services:**
  Some solar UPS systems can provide grid support services, such as peak shaving and frequency regulation, which can contribute to a more stable and efficient electrical grid. Peak shaving is the strategy implemented in the management of energy systems during peak hour so that the load on the grid can be reduced.

- **Reduced Transmission Losses:**
  When solar UPS systems are installed close to the point of use, they can reduce transmission and distribution losses, as electricity generated on-site doesn't need to travel long distances.

- **Green Image and Sustainability Goals:**
  Organizations and individuals that adopt solar-based UPS systems demonstrate a commitment to sustainability, which can positively influence environmental awareness and actions in their communities. Solar powering has already been implemented in various parts of our country and although their contribution and usage is limited as of now, further scaling up the operations will allow it to provide for a larger chunk of the power grid.

While solar-based UPS systems offer numerous sustainability and environmental advantages, it's essential to consider factors like the manufacturing and disposal of solar panels, as well as the environmental impact of battery production. However, the overall environmental benefits typically outweigh these concerns, especially over the system's operational lifespan. As technology continues to improve and renewable energy adoption increases, the sustainability and environmental impact of solar UPS systems will likely become even more significant.

5.7 Ethical Issues (PO(h))

Ethical issues related to solar-based uninterruptible power supply (UPS) systems primarily revolve around responsible and sustainable practices in the production, installation, and use of these systems. The first issue would be the proper usage of the solar technology and also the energy produced using it so that it is not used to serve any purpose that harms others. Moreover, the various mineral elements and raw materials required for the production of solar panels and batteries like silicon, lithium etc. come from various parts of the world. Russia and China are main suppliers of silicon while Australia, China, Zimbabwe are some countries that supply lithium. Ethical issues might arise regarding the usage of products which contain materials from the countries which supply them, especially if some of the materials have been mined out by forced labor or other illegal means. The proper disposal and recycling of the solar panels, batteries after their lifespan with due regard to the safety of the citizens and those involved in the recycling and disposal process while extracting the most amount of recyclable material poses another ethical concern. Another ethical concern is the impact of the UPS system on the environment taking into account the toll on the environment while extracting the minerals for the production of the components of the system. Installation of large-scale solar panel projects might also harm the society and environment around the region especially if done on hill tract regions or other places by relocating the people there and removing the flora and fauna. Again, ensuring that people from different walks of life can access the technology, that is, maintaining social equity is also an ethical issue.

Addressing these ethical issues is essential to promote responsible and sustainable adoption of solar-based UPS systems while ensuring that the benefits are shared equitably and environmental concerns are minimized. Industry stakeholders, policymakers, and consumers should collaborate to establish ethical standards and practices that guide the development and deployment of renewable energy technologies.

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

6.1 Individual Contribution of Each Member

In this section, we outline the unique contributions made by each team member to the project:

<u>Roll 1906003:</u>
- Did simulation in proteus to see whether the project is implementable or not in our approach.
- Conducted testing using a full-bridge and push-pull inverter.
- Experimented with RC, RLC and LC filters to remove harmonics from the output.
- Constructed and updated necessary circuitry of boost converter and transformer to get desired output voltage.

<u>Roll 1906015:</u>
- Undertook the task of improving output waveform by eliminating harmonics through an active 2nd order filter.
- Constructed a half-bridge inverter, which was later replaced with a push-pull inverter for getting higher voltage.
- Constructed a full-bridge inverter for higher output voltage and better performance

<u>Roll 1906023 and 1906033:</u>
- Constructed the control circuit using 555 timer for generating pulse width modulated 50 Hz

frequency signal.
- Constructed the control circuit using SG3524 for generating pulse width modulated signal. But later the control circuit using 555 timer was used.
- Worked in selecting appropriate passive filter through necessary calculations.
- Collaborated on aspects related to solar panels and battery management systems (BMS).
- Worked in connecting and testing the transformer for getting desired output voltage.

Besides, All the members tried their best improving the circuit performance through testing, debugging and continuously updating the circuit. Again, all of them wrote certain parts of the project report.

6.2 Mode of Teamwork

We did the whole project as a team. For some part, we worked on individual tasks and then coordinated them together. Sometimes we had to sit together for a hands-on team effort. Discussions regarding ideas and problems were done in our chat group.
Our skills lie in different areas, but we all were aware of what others were doing. That helped us grow as team.

6.3 Diversity Statement of Team

Our team consisted of people of different type and backgrounds. Three of us were girls and one of us was a boy. All hailed from different parts of the country and from different institutional backgrounds before BUET. Each have their own areas of interest which may not share commonality. The common interest of this project, however, encouraged us to work as a team.

6.4 Log Book of Project Implementation

Date	Activity	Comments
26 June	Proteus done	Was successful
7 August	Constructed Control circuit using 555 timer	Didn’t work
8 August	Made Control circuit using SG 3524 Made half bridge inverter	Didn’t show desired output
14 August	Rebuilt Control circuit using 555 timer Built full bridge inverter Soldered battery pack	Control circuit Worked Full bridge inverter didn’t give our desired output voltage level
19 August	Worked with Control circuit with 555 timer, half bridge inverter and passive filter	Showed output but wasn’t sine wave
21 August	Added Solar panel, BMS	Worked
22 August	Added transformer	Didn’t work
28 August	Tested with Active filter Soldered boost converter	Still got distorted output
29 August	Added Boost converter	Improved output voltage
3 September	Tried to get desired output voltage through different modifications Added light bulb	Couldn’t reach our target that much
4 September	Replaced half bridge inverter with Push-pull inverter	Got better output voltage

8 September	Took final readings	Didn't get sine wave but could brighten an LED blub.

7 Communication (PO(j))

7.1 Executive Summary

Our goal was to build a solar based UPS. Solar panels are a renewable energy source, but their direct current (DC) voltage can fluctuate due to factors like sunlight intensity, temperature, and humidity. To address this, a solar charge controller was connected to the solar panel system, regulating the battery level. A battery pack with a Battery Management System (BMS) module ensured stable DC power supply, allowing precise control of voltage levels. A push-pull inverter circuit was built to convert DC to AC power, generating an AC output waveform.

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

8.1 Bill of Materials

Components	**Per unit cost**	**Total cost**
12 V 30 W solar panel	**1700**	**1700**
6 Li-ion battery bank with BMS		**1010**
SG 3524, 555 timer, MOSFET IRF 250, Optocoupler, Diode, Jumper, Capacitors, Resistors, Potentiometer		**1126**
Transformer	**180**	**180**
Multimeter	**900**	**900**
Bulb and socket	**150**	**150**
Solar charge controller	**715**	**715**
Total		**5781**

8.2 Calculation of Per Unit Cost of Prototype

4500

9 References

How to generate pulse using 555 timer-
https://www.youtube.com/watch?v=Q5tcf1pYZRc
How to make a battery pack with BMS-
https://www.youtube.com/watch?v=GcmcV763sX8&t=301s
Solar charge controller setup-
https://www.youtube.com/watch?v=WCZ1BxGRLwI
How inverter works-
https://youtu.be/GIsgjr0CU6Q?si=qKPWQlXxwWIxr-6r