Design and Development of an IoT-Enabled Smart Photovoltaic Inverter With MPPT

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April 05, 2024

Abstract

We are designing and implementing a solar inverter system that generates green power from solar energy and reduces air pollution and other environmental impacts. Our system uses a pure sine wave inverter that produces a sine wave virtually identical to the utility grid. The IoT-based MPPT solar charge controller ensures that the maximum amount of power is transferred from the solar panels to the battery bank and monitors the system in real-time. We also use a solar tracker with a single-axis rotation that orients the panels toward the sun in two directions. Our solar inverter system can handle a maximum load of 300 watts.
Abstract—We are designing and implementing a solar inverter system that generates green power from solar energy and reduces air pollution and other environmental impacts. Our system uses a pure sine wave inverter that produces a sine wave virtually identical to the utility grid. The IoT-based MPPT solar charge controller ensures that the maximum amount of power is transferred from the solar panels to the battery bank and monitors the system in real-time. We also use a solar tracker with a single-axis rotation that orients the panels toward the sun in two directions. Our solar inverter system can handle a maximum load of 300 watts.

Index Terms—IoT, SPWM, PWM, MPPT, SDG, P&O, PWM, PV, PCB, LDR.

I. INTRODUCTION

Renewable energy sources significantly reduce air pollution and other environmental impacts compared to conventional energy sources. Renewable energy sources do not cause harmful emissions when consumed, whereas fossil fuels release greenhouse gases and other pollutants when burned. Therefore, we have decided to help the green energy community by designing a solar inverter. We will develop a smart photovoltaic inverter with an MPPT solar charge controller and a solar tracker as our FYP.

A. Basic Concept

A power inverter is a device used to convert Direct Current (DC) into Alternating Current (AC). Power inverters are essential to many renewable energy systems, such as solar and wind, since they enable us to store surplus power and use it when needed. They may also be used to power essential systems during a power outage, such as medical equipment or communications systems, ensuring that these services function even when the grid is down. Hence, we are designing and developing a power inverter, an MPPT solar charge controller, and a solar tracker as our FYP.

B. Features of a Power Inverter

“Inverters have a broad range of uses, spanning from small switching power supplies in computing to extensive applications for transferring high power” [1]. Our inverter is based on a driver module named EGS002. It is a combination of features that are important for a device. We have implemented different types of protection for it. Voltage, current, and temperature protection are implemented on our power inverter. The maximum capacity of the inverter is 300 watts. A pure sinusoidal inverter generates an output signal similar to the utility grid. We have also implemented a voltage feedback control that limits the output voltage below a dangerous value.

C. Features of the MPPT Solar Charge Controller

“MPPT battery charger that enhances the efficiency of PV panels using the P&O MPPT algorithm to track the MPP. At the same time, a Pulse Width Modulation (PWM) signal is sent to a Buck converter to adjust the voltage and measure power. The P&O method steadily tracks the MPP and determines the operating point that produces the maximum power for the battery” [2]. Our MPPT solar charge controller has many valuable and unique features, the most important being Wi-Fi connectivity. It allows anyone to easily monitor critical parameters of the MPPT solar charge controller, such as panel voltage, panel current, and panel power, as well as battery voltage, battery current, and battery power, on a smartphone or any other device. These parameters are also displayed on the 16x2 LCD attached to the MPPT solar charge controller. It can charge different types of batteries,
including flooded, gel, and AGM batteries. The MPPT solar charge controller can handle an input voltage of 12 volts and a current of up to 40 amperes.

D. Features of the Solar Tracker

“A tracking mechanism is integrated into the solar power system, redirecting the solar panel toward higher solar radiation intensity areas. It enhances the efficiency of the solar panel in absorbing solar energy, leading to a boost of at least 15% in its performance”[3]. Our solar tracker mechanism has a single axis that orients toward the sun in only two directions. We use a stepper motor, LDRs, a tiny battery, and other components like an Arduino Uno to control its movement.

E. Block Diagram of the Project

The block diagram of “Design and Development of an IoT-Enabled Smart Photovoltaic Inverter With MPPT” is shown in Figure 1. It includes a solar tracker, solar panel, MPPT solar charge controller, battery, and ESP8266 Wi-Fi module. In short, the project is divided into two different parts.

1) The first part consists of a pure sine wave inverter and a solar tracker, which will be further developed after FYP-I.

2) The second part consists of an MPPT solar charge controller with IoT, making our project a smart solar inverter that will be developed in FYP-II.

II. Literature Review

Non-renewable resources, such as coal, natural gas, and oil, are gradually depleting. The increased demand for energy has led to a rise in the combustion of these fossil fuels. They have contributed to the pollution of the atmosphere and the release of greenhouse gases. As a result, we are developing a complete solar energy system that will not pollute the environment or emit hazardous gases. It comprises a power inverter, a solar tracker, and an IoT-based MPPT solar charge controller. To create such a system, we reviewed the related research in the papers and identified gaps.

A. Related Works and Gaps

“The Arduino Uno is paired with a Node MCU that operates on the ESP8266 Wi-Fi module and can implement the IoT-enabled smart solar inverter. A solar tracking circuit can increase the output power from solar panels by absorbing maximum sunlight”[4]. The gap in the above paper is that they have designed a square wave inverter, which is not efficient and reliable for some electrical appliances. Therefore, we are developing a pure sine wave inverter for the project.

“The inverter operates on solar energy and integrates Wi-Fi technology for two-way communication with the user. It provides real-time updates of the inverter’s battery voltage and the user-selected loads’ running time”[5]. The gap in the above paper is that they have not designed a solar tracker, which would increase the efficiency of solar panels by at least 15 percent.

“Electricity is generated by utilizing solar energy, and wireless communication is utilized to monitor the solar power inverter. The solar-powered inverter, combined with the IoT-connected level indicator circuit, helps determine the remaining charge and time consumption based on the load usage”[1]. The gap in the above paper is that they have not designed an MPPT solar charge controller to increase a solar energy system’s reliability, stability, and efficiency.

“Real-time updates regarding the battery SOC, electrolyte level, and load run-time are conveyed to the user. A mobile application can wirelessly control the connected load”[6]. The gap in the above paper is that they have not designed a solar tracker and an MPPT solar charge controller that will boost the inverter’s efficiency and stability of the solar energy system.

“Solar panels are positioned to receive maximum radiation by tracking the sun’s direction to optimize sunlight exposure. These panels are responsible for converting light energy into electrical energy. Meanwhile, an inverter is an electrical device that converts DC to AC”[7]. The gap in the above paper is that they have not designed a sine wave inverter, which is not efficient and reliable. They also have not implemented an IoT-based inverter on the solar energy system.

“The efficiency and reliability of a solar power system can be improved by utilizing a microcontroller and cascade
H bridge topology to create a pulse width modulator inverter" [8]. The gap in the above paper is that they have designed a PWM-based solar charge controller, which is inefficient. Therefore, we are developing an MPPT solar charge controller to increase the system’s efficiency.

“With a low-cost inverter that utilizes Wi-Fi for two-way communication with the client, it is possible to monitor the battery voltage and running time of the hundreds of tests the client selects to conduct” [9]. The gap in the above paper is that it only focuses on making the inverter smart. We are working to make the inverter efficient by applying different tweaks and designing an additional solar tracker mechanism to keep the solar panel directed toward the sun.

“A comprehensive study of a solar inverter’s design, production, and performance analysis includes a detailed description of its theoretical and practical aspects. Accurate calculations and simulation results, such as VI charts, are presented to correctly demonstrate the inverter’s operation and conversion outcomes” [10]. This article will help us understand the basics of solar inverters for our project. The gap in the above paper is that it only focuses on the mathematical output values of the inverter and not on the components used to design it.

“Designing a reliable solar inverter that is flexible, has maximum efficiency, and is smart enough to minimize component costs. The fundamental goal of increasing efficiency is to reduce total harmonic distortion, which improves drive performance, ultimately reducing noise and extending system life” [11]. The gap in the above paper is that IC4047 has been used for pulse width modulation. In contrast, we are using the EGS002 driver module, which will give us a pure sine wave output, the option to switch output frequency between 50 and 60 Hz, and an additional LCD to display parameters like current, voltage, frequency, and temperature.

“Solar energy is becoming increasingly popular due to the depletion of non-renewable sources, but its output depends on weather conditions. Batteries are used as a secondary source to counter it, but the excess voltage can damage them. MPPT charge controllers help extract full power and protect batteries from overcharging” [12]. This paper emphasizes the significance of MPPT charge controllers and DC energy meters in harnessing solar energy, highlighting the gap in their implementation. We are using the P&O MPPT algorithm to enhance the efficiency of PV panels. MPPT charge controllers extract the most power while protecting batteries, and DC energy meters measure solar panel output. These technologies are critical for the efficient and secure utilization of solar energy.

“A standard MPPT control algorithm’s perturbation period may be chosen in a single-stage PV-fed buck converter’s design to enhance tracking performance” [13]. This paper proposes a small-signal model and control design for a single-stage PV panel-fed buck converter used as a charge controller, considering the effects of parasitic elements, cables, and PV modules.

“A microcontroller-based battery charge controller with a MPPT has been designed to improve the efficiency of photovoltaic (PV) systems. The MPPT controller utilizes the P&O technique to track the MPP of the PV panel under different conditions” [14]. The gap in the above is that they have not implemented the IoT, where we can monitor the parameters of the solar panel and battery. This paper proposes the design of a microcontroller-based solar charge controller with a MPPT to improve the efficiency of photovoltaic (PV) systems and increase the battery’s lifespan.

“For remote monitoring and control, a novel MPPT solar charge controller employs IoT-based sensors to communicate data to the cloud. The system uses a PIC16F877A controller, a P&O technique, and a buck-boost converter that is specifically designed to monitor the PV system’s peak power point” [15]. The gap in this paper is that we have designed the P&O MPPT algorithm and buck converter used to regulate and enhance the efficiency of the battery’s charging and boost the PV panels using the microcontroller Arduino Nano and ESP8266 ESP-01 Wi-Fi module.

B. Problem Statement and SDGs

We have determined our problem statement by doing long-term research that will help the community by reducing environmental pollution. The problem statement is as follows:

Can we design an efficient and reliable power inverter for a solar energy system with an IoT-enabled solar charge controller and solar tracker for the photovoltaic panels?

Yes, we can design such a solar energy system by employing some tweaks and using reliable components for the project. The project objective is as follows:

To design and integrate a low-cost solar inverter system that consists of an MPPT solar charge controller, a solar tracker, a pure sine wave inverter, and an IoT-enabled smart monitoring system, which will enhance the efficiency, reliability, and ease of use of solar energy.

Our project also meets the Sustainable Development Goals (SDGs). It meets the three goals of SDGs:
1) Affordable and clean energy (Goal 7)
2) Industry, Innovation, and Infrastructure (Goal 9)
3) Responsible consumption and production (Goal 12)
III. Methodology

We are designing a power inverter that will take 12 V DC energy from the battery and convert it into 220 V AC with a pure sine wave output. We are also developing an MPPT solar charge controller, which will increase the efficiency of the solar panels and protect the battery by regulating the voltages as per the battery’s needs. The MPPT solar charge controller is interfaced with the IoT system, which can monitor the parameters remotely through phones or laptops. Additionally, we are developing a solar tracker mechanism to increase the overall efficiency of our inverter.

A. Required Components

Before building our project, we must have the correct and efficient components for it. Therefore, we have gathered the required elements for the power inverter, MPPT solar charge controller, and solar tracker. We picked a long list of components for our three devices.

1) Components of a Power Inverter: EGS002 SPWM driver module, LCD for EGS002, 8x IRF3025 MOSFETs, 500W high power 7.5 V to 220 V Transformer, 8x TO-220 Isolation set, 8x 1N4007 Diodes, TIP31C NPN Transistor, LM7805 Regulator, 10 KΩ NTC Thermistor, 10 Ω Multiturn Trimmer Resistor, 4x 10 Ω Resistors, 2.2 KΩ Resistor, 4x 10 KΩ Resistors, 2x 100 KΩ Resistors, 470 nF 25 V Capacitor, 2.2 µF 350 V Capacitor, 2.2 µF 25 V Capacitor, 10 µF 2 5V Capacitor, 100 µF 25 V Capacitor, Double Layer PCB, Etchant (Ferric Chloride), Cooling Fan 12 V, and 2x Heatsinks as shown in Figure 2.

2) Components of the MPPT Solar Charge Controller: Arduino Nano, ESP8266 ESP-01 Wi-Fi Module, 16x2 LCD, 12C LCD Module, ACS712 30A 2x, Push Buttons 3x, MC34063 IC, PC817 Optocoupler, MOSFETs IRF3710 4x, MBR20100CT Diode, 1N5819 Diode, 100 µH Inductor, 330 µH Inductor, 1 nF Capacitor , 100 µF 50 V Capacitor, 1000 µF 100 V Capacitor 4x, 5 kΩ Trimpot 3x, 100 kΩ Resistor, 1 kΩ Resistor, 47 kΩ Resistor 3x, 10 kΩ Resistor 3x, 3.3 kΩ Resistor, 1 Ω Resistor, 2 Pin Screw Terminal 2x, and Heatsink as shown in Figure 3.

3) Components of the Solar Tracker: Arduino Uno, LDR 5 Ω 2x, SG90 Micro-servo motor, Rocker Switch, SPST, Battery Holder 18650, Cells 3.7 V 2x, 100 kΩ Resistor, Solar Panel 10 Watts, and Wooden Frame as shown in Figure 4.

B. Calculations

Before designing the inverter, we must do the required calculations, which help us understand what we will do. We did a detailed analysis to get a rough idea of the number of PV panels required, the size of the inverter, battery, MPPT solar charge controller, and the time needed to charge the battery, which is shown below:

Load Information:

Following is the information for the load we are using:

- 1 X 25 W lamp is used for 1 hour a day.
- 1 X 60 W fan is used for 1 hour a day.

Total Power Consumption:

The total power consumption can be calculated as:

\[(1 \times 25) + (1 \times 60) = 85 \text{ Wh/day}\]

The correction factor is 1.3. So,

\[\text{PV size} = 1.3 \times 85 = 110.5 \text{ Wh/day}\]

PV Panels Needed:

The number of panels needed can be calculated as:

If we select a 110 W panel,

\[\frac{110.5}{110} = 1 \text{ panel needed}\]

If we select a 10 W panel,

\[\frac{110.5}{10} = 11 \text{ panels needed}\]

Inverter Sizing:
The size of the inverter can be calculated as:
\[(1 \times 25) + (1 \times 60) = 85 \text{ W}\]
The safety factor is 1.5,
Inverter size = \(1.5 \times 85 = 127.5 \text{ W}\)

**Battery Sizing:**

The size of the battery required can be calculated as:
\[\text{Total appliances} = (1 \times 25) + (1 \times 60) = 85 \text{ W}\]
Nominal voltage = 12 V
Days of autonomy = 1
\[I_m = 6.6 \text{ A}\]
\[I_{sc} = 7.5 \text{ A}\]
Capacity = \[\frac{\text{Total Load} \times \text{Days of autonomy}}{\text{Battery Loss} \times \text{DOD} \times \text{Nominal voltage}}\]
Capacity = \[\frac{85 \times 1}{0.85 \times 0.6 \times 12} = 13.89 \text{ Ah}\]
Capacity = 14 Ah

**Charge Controller Sizing:**

The size of the charge controller required can be calculated as:
If we select a 10 W panel,
\[= \frac{\text{No. of Modules} \times I_{sc} \times \text{Correction Factor}}{85 \times 0.6} = 97.5 \text{ A}\]
Charge Controller = 100 A at 12 V Output
If we select a 110 W panel,
\[= \frac{\text{No. of Modules} \times I_{sc} \times \text{Correction Factor}}{85 \times 0.6} = 9.75 \text{ A}\]
Charge Controller = 10 A at 12 V Output

**Charging Time:**

The time required to completely charge the battery can be calculated as:
The 10W panel supplying 1 A at output and the battery capacity is 14 Ah,
\[\text{Time Required} = \frac{14}{1} = 14 \text{ Hours}\]
The 110W panel supplying 10 A at output and the battery capacity is 14 Ah,
\[\text{Time Required} = \frac{14}{10} = 1.4 \text{ Hours}\]

**Summary of Calculations:**

Comparison between 110 W Panel and 10 W Panel is shown in the Table [1]

**C. Working of the Power Inverter**

In the workings of our pure sine wave inverter, the EGS002 SPWM board plays a vital role in regulating the output voltage and frequency of the inverter circuit to generate a stable and clean pure sine wave output. The inverter circuit and transformer collaborate to convert the DC input power into a high-quality AC output appropriate for powering various loads and devices. The inverter circuit consists of MOSFETs and a transformer that transforms the DC voltage into a AC voltage. The MOSFETs switch on and off at a high frequency of 23.4 kHz, producing an alternating current (AC) wave output. Generally, the output voltage of the inverter is 7.5 volts AC. To step it up to 220V, a step-up transformer is used. The trimmer resistor in our inverter is used to set the output voltage according to our needs. A filter capacitor of 2.2 µF is connected in parallel to our load to remove any noise and distortion from the inverter’s output voltage. A feedback circuit is also connected to our inverter to maintain and regulate the output voltage, providing a stable and consistent output. This feedback circuit is also responsible for providing values of frequency, voltage, current, temperature, etc., to the inverter, which is displayed on the LCD as well.

The most crucial part is the MOSFET, which aims to convert DC to AC. These MOSFETs are connected in parallel; the more MOSFETs are connected in parallel, the higher the output power of the converter. In our project, we use eight MOSFETs, providing an output power of approximately 300W. Then we use the EGS002 driver board, which will provide Sinusoidal Pulse Width Modulation (SPWM) for our power inverter. This board will also integrate voltage, current, and temperature protection functions, an LED indicator, and temperature fan control. A small LCD connected to this board shows the values of the inverter’s current, voltage, frequency, and temperature. This board also allows us to switch the output frequency between 50 Hz and 60 Hz, which can be done by adjusting jumper pins on the board. Finally, during manufacturing, we obtain a distortion-free and noise-free pure sine wave output of 220 volts (AC) at 50 Hz, which can power any home appliance.

1) **Simulation and PCB of a Power Inverter:** We have also designed the circuit of our power inverter on Proteus software for simulation to check its proper working, which turned out to be perfect. The simulation of our power inverter is shown in Figure [5]. To enhance the look of our project, we designed a PCB for our power inverter circuit using the home fabrication/etching method, which turned out to be perfect. Our PCB is a double-layer PCB, meaning it has circuit lines on both sides, i.e., a top layer, a bottom layer, and the filter capacitor PCB. We have created two different builds of the project, each with the exact specifications and features. The difference is that our new build has a more compact PCB size. The PCB of our first power inverter build is shown in Figure [6] and our second power inverter build is shown in Figure [7].

**D. Hardware of a Power Inverter**

In the design of the power inverter, we have created two different builds of the project, each with the same specifications and features. The difference is that our new build has a more compact PCB size. The hardware of our
### TABLE I. Comparison Between Panels

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of Parameters</th>
<th>110 W Panel</th>
<th>10 W Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PV Panels Needed</td>
<td>1 Panels Needed</td>
<td>10 Panels Needed</td>
</tr>
<tr>
<td>2</td>
<td>Charge Controller Size</td>
<td>9.75 A</td>
<td>97.5 A</td>
</tr>
<tr>
<td>3</td>
<td>Charging Time Required</td>
<td>1.4 Hours</td>
<td>14 Hours</td>
</tr>
</tbody>
</table>

first power inverter build is shown in Figure 8 and our second power inverter build is shown in Figure 9.

1) Waveforms of a Power Inverter: The waveforms of our power inverter for both simulation’s waveform and hardware on the oscilloscope’s waveform are shown in the figure 10.
E. Working of the MPPT Solar Charge Controller

The workings of the MPPT solar charge controller are straightforward. By controlling the voltage and current that the PV panels provide to the battery, this controller aims to prevent the battery from being overcharged. The MPPT solar charge controller continuously monitors the terminal voltage from the PV panel, measures it up to the battery voltage, and ensures that the maximum voltage from the solar panels is employed to recharge the battery. The optimal voltage can subsequently be generated using that maximum voltage to supply the battery with the greatest possible current. Each and every DC load coupled to the battery will also get power from it. It uses the Arduino Nano processor, and there are two pairs of voltage and current sensors, one for the input and one for the output. The buck converter steps up the input voltages to charge the battery. The PC817 optocoupler is used to remove noise and filter out any distortion. The IRFB4310 N-channel MOSFETs are used to regulate the charging current and voltage to the battery. The MBR2C100CT-1 Schottky diodes are used for fast switching. The 16x2 LCD displays different parameters such as voltage, current, power, frequency, battery percentage, etc. Three push buttons are used to set the parameters of the charge controller on a 16x2 LCD. Additionally, the ESP8266 ESP-01 Wi-Fi module is used to display the same parameters mentioned above on smartphone screens online through a web server.

1) Simulation and PCB of the MPPT Solar Charge Controller: We have also designed the circuit of our MPPT solar charge controller on Proteus software for simulation to check its proper working, which turned out to be perfect. The simulation is shown in Figure 11. To enhance the look of our project, we have designed our MPPT solar charge controller on a PCB that was first modeled on Proteus. Subsequently, we placed an order for the PCB design with a reputable Chinese PCB manufacturing website for our MPPT solar charge controller. Our PCB is a double-layer PCB, meaning it has circuit lines on both sides, i.e., a top layer and a bottom layer. The final output of our PCB is shown in Figure 12.

Fig. 11. Proteus Simulation of MPPT Solar Charge Controller

![Proteus Simulation of MPPT Solar Charge Controller](image1)

Fig. 12. PCB of MPPT Solar Charge Controller Front Layer, and Back Layer

![PCB of MPPT Solar Charge Controller](image2)

2) Hardware of the MPPT Solar Charge Controller: The hardware of our MPPT solar charge controller is shown in Figure 13. It includes a microcontroller, a Wi-Fi module, two current sensors, resistors, inductors, capacitors, MOSFETs, a heatsink, a PCB, and different ICs.

F. Solar Panel Specifications

The solar panel used for our complete project has specifications as shown in Figure 14.

![Solar Panel Specifications](image3)

G. Working of the Solar Tracker

In addition to the power inverter, we are also designing a solar tracker. The solar tracker will be used to orient the solar panel towards areas of high sunlight intensity; in this way, the solar panel will absorb more energy, and hence the efficiency of our inverter will increase by at least 15%. The workings of a solar tracker are effortless. It comprises a few components: an Arduino UNO microcontroller, two LDR sensors, a solar panel, and a servo motor. The Arduino Uno serves as the brain and processing unit of the single-axis solar tracker. The two LDR sensors are used to detect light intensity and, therefore, change the resistance value. For instance, resistance decreases when light intensity
increases, while resistance increases when light intensity increases. The Arduino is programmed to keep the light intensity the same for both LDR sensors. When the light intensity changes for one of the LDRs, the resistance changes, and the LDR sends an analog resistance value to the Arduino Uno. After that, it sends a signal to the servo motor to rotate in the direction of the sun’s movement until the sunlight falling on both LDR sensors becomes equal. It is a continuous process that runs throughout the day. In conclusion, when the solar panel is always directed towards the sun, the maximum amount of sunlight falls on the solar panel’s photovoltaic (PV) cells, increasing energy production by the solar panels.

1) Simulation of a Solar Tracker: We have also designed the circuit of our solar tracker on Proteus software for simulation in order to check the proper working of our solar tracker, which turned out to be perfect. The simulation of our solar tracker is shown in Figure 15.

2) Hardware of the Solar Tracker: The hardware of our solar tracker is shown in Figure 16. It includes a microcontroller, two light sensors, a servo motor, a wooden frame, a PV panel, and a power source.

H. Results

We have successfully designed and developed a solar inverter system to harness the sun’s energy into electrical energy. We have developed a pure sine wave inverter that converts DC into AC power virtually identically to the grid sine wave and gets the 220 V. We also designed an MPPT solar charge controller that regulates and charges the battery in the protected range, extends the life of the battery, and enhances the efficiency of the solar panel through MPPT technology. It has improved the efficiency of the power inverters as the solar panel efficiency increased with the MPPT algorithm. We also developed a solar tracker that orients the PV panel along a single axis. The results of all three devices are shown in the following Figures. The power inverter is shown in Figures 17, 18, the MPPT solar charge controller is shown in Figure 20, 21, and solar tracker is shown in Figure 19.

I. Project Milestones

The project milestones of our FYP are as follows:

- Collecting relevant data (November 2022)
- Mathematical Calculation for inverter and solar charge controller sizing (1 Dec – 15 Dec 2022)
- Designing of simulation on software (16 Dec – 30 Dec 2022)
- Sourcing of required components (2 Jan – 10 Jan 2023)
- Complete designing of Inverter (10 Jan – 25 Jan 2023)
J. Work Division

The project team consisted of two members with distinct roles and responsibilities. The following section outlines the work performed by every team member:

1) Team Member 1: The name of team member 1 is Muhammad Nouman Hanif. The following responsibilities lead into the FYP:

- Researched for the project from recent year research papers.
- Gathered relevant information required for the project.
- Designed and implemented a simulation of a power inverter, MPPT solar charge controller and solar tracker on Proteus software.
- Mathematical calculations for sizing the power inverter, solar panels and MPPT solar charge controller.
- Designed the PCB layout for the power inverter and MPPT solar charge controller.
- Developed the code for the Arduino Uno used for a solar tracker, the Arduino Nano used for an MPPT solar charge controller, and the ESP8266 ESP-01 WiFi module used for an MPPT solar charge controller.
- The printed PCB of the MPPT solar charge controller double-layer PCB was ordered at the Chinese PCB Manufacturing Website.
- Made the proposal, report and IEEE research paper from LaTeX.

2) Team Member 2: The name of team member 2 is Haseeb Ahmed. The following responsibilities lead into the FYP:

- Fabricated and designed the pure sine wave inverter dual layer PCB.
- Assembling and soldering of all components of Inverter.

- Final evaluation and demonstration (18 May 2023)
Assembling and soldering of all the components of the solar charge controller.
Assembling of the frame and components of the solar tracker.
Testing of the output voltage and waveform of inverter on an oscilloscope.
Testing of proper working and battery charging from the solar charge controller.
Live testing of solar tracker in Sunlight.

K. FYP Costs

Our FYP aims to build a solar energy system with a power inverter, MPPT solar charge controller, and solar tracker. We aim to make the solar energy system cost-effective and efficient in powering homes or industries. The costs of each device are as follows:

L. Cost of a Power Inverter

- EGS002 Module with LCD (Rs. 1600)
- 7.5V to 220V Transformer 500W (Rs. 1800)
- MOSFETs x16 (Rs.960)
- Resistors, Capacitors, Inductor, trimmer resistor, Screw terminal (Rs. 500)
- TIP31C, LM7805, 1N4007 diodes x8, Isolation pad (Rs. 250)
- PCB, 12V DC fan, Heat Sink, (Rs. 600)

The total cost for a power inverter is Rs. 5710.

1) Cost of the MPPT Solar Charge Controller:

- Arduino Nano, ESP1 WIFI module (Rs. 2000)
- 16x2 LCD module, PCB, Heat sink, ACS current sensor, push button x2 (Rs. 1800)
- Resistors, Capacitors, Inductors, Screw Terminals, Jumper wires (Rs. 600)
- MC34063, PC817 Optocoupler, IRF3205 diode, 5K trim pot, MBR20100CT diode (Rs. 800)
- Dry Battery 12V, 7.2AH (Rs. 8000)

The total cost for the MPPT solar charge controller is Rs. 13200.

2) Cost of a Solar Tracker:

- Arduino UNO (Rs. 1200)
- Servo Motor (Rs. 400)
- Resistors, LDR, Jumper Wires, 9V battery, Rocker switch (Rs. 400)
- 10W Solar Panel (Rs. 2900)

The total cost for a solar tracker is Rs. 4900.

3) Miscellaneous Expenses:

- Casing of project (Rs. 2000)
- Extra, alternate components (Rs. 1000)
- Delivery charges, transport, duty fees (Rs. 1500)
- Printing of FYP Report Booklet (Rs. 5000)

The total cost for the miscellaneous expenses is Rs. 9500.

M. Total Cost of FYP

The total cost of our FYP will be = Rs.13200 + Rs.5710 + Rs.4900 + Rs.9500 = Rs.33,810 Only

IV. Conclusions

Our aim in this project is to develop a photovoltaic inverter system that generates green power from solar energy and reduces air pollution and other environmental impacts. Our system uses a true sine wave inverter that generates a sine wave virtually identical to the utility grid. The IoT-based MPPT solar charge controller ensures that the optimum power is transferred from the PV panels to the battery bank and monitors the system in real time. We also use a solar tracker with a single-axis rotation that orients the panels toward the sun in two directions. Our solar inverter system can handle a maximum load of 300 watts. The technologies used in our FYP are as follows:

- IoT Server
- C++
- Arduino IDE
- Arduino Uno
- Arduino Nano
- Wi-Fi Module

A. Conclusion of Power Inverter

This project aimed to design a power-efficient, low-cost power inverter that could produce a pure sine wave output. To achieve this, we first designed and simulated the circuit using Proteus software. Once we confirmed that the circuit produced the desired output, we moved on to designing the printed circuit board (PCB). We created the PCB layout on Proteus software, printed the layout, and fabricated the PCB using the home-etching method. The PCB output was excellent, and the circuit worked as intended.

Next, we soldered the main components of the inverter, such as MOSFETs, capacitors, resistors, and diodes, onto the PCB. We also designed and simulated the circuit for the solar tracker on Proteus software, which worked well. Inverters are essential components in solar energy systems, acting as the *CPU* of the system.

B. Conclusion of MPPT Solar Charge Controller

Our project aimed to design an MPPT solar charge controller that could efficiently charge our battery pack and protect it from overcharging while also providing real-time monitoring of important parameters such as panel voltage, panel current, battery voltage, battery current, total power, and remaining battery percentage. Our all-in-one MPPT solar charge controller was designed for a 500-watt solar system and utilized MPPT technology to feed the optimum amount of power from the PV panels to the battery.

To achieve our goal, we first designed a complex double-layer PCB layout and had it fabricated by Next PCB China. We then soldered all the components to the PCB, including the Arduino Nano brain of the controller and the WIFI module. Next, we connected the battery pack and solar panels to the controller. We confirmed proper
operation, including correct battery charging and displaying parameters on a smartphone screen via WIFI and an LCD screen.

We ultimately designed a 500W smart solar charge controller that matched the rating of our inverter. The development of an IoT-enabled smart 500W solar charge controller with MPPT technology provided an effective and efficient solution for managing our solar power system. By optimizing charging efficiency and providing real-time monitoring, the controller maximizes the overall energy output of the solar panel system and ensures reliable operation.

C. Conclusion of Solar Tracker

We incorporated a single-axis solar tracker system further to enhance the efficiency of our pure sine wave inverter. This arrangement spins around a single axis to absorb and collect the most sunlight and provide the most solar panel power to the battery pack.

To implement the solar tracker, we designed a wooden frame with precise measurements to fit the size of the solar panel. We attached a servo motor and LDR sensors and connected them to an Arduino UNO microcontroller. We then designed and uploaded a sketch to the microcontroller to control the rotation of the servo motor and adjust the PV’s orientation in response to changes in the direction of sunlight during the day. Finally, we tested the system in different weather conditions and confirmed its proper operation.

In conclusion, our project aims to provide local consumers with ease, relaxation, and peace of mind during load shedding and power breakdowns. By offering clean and pollution-free backup power to run essential home appliances, we are addressing a critical need in our community. The applications of our FYP extend to various industrial and residential settings, including electricity generation, remote power systems, and grid-tied solar systems, as well as off-grid applications such as solar street lighting, solar water pumping for agriculture, rural electrification, and solar water heaters.

Our hardware and software methodologies and tools are intended to foster successful industrial innovation and infrastructure. We promote responsible power consumption and production by providing consumers with affordable and clean energy, ensuring a more sustainable future.

V. Recommendations for Future Work

There are many different ways in which we can improve our project. Some potential improvements include the incorporation of the following devices in future work:

A. Future Work For Power Inverter

We can improve our pure sine wave inverter in several ways. One significant improvement would be to increase its output power. Our inverter is designed to deliver 500W, which is suitable for many applications. However, there may be situations where we require more power. To achieve this, we would need to upgrade several components, including the transformer (to 1000W), MOSFETs (to 16), and capacitors (to a higher rating), to ensure that they can handle the increased load. Moreover, we can replace the inverter’s design with a single coil inductor, increasing its efficiency, reducing its form factor, and lowering its standby power consumption. The components used in the inverter could be mounted using surface-mount technology (SMT) to make the inverter circuit board smaller. As the source of the MOSFET driver gate is connected to Vcc and restricts the input voltage of the LM7805 regulator, the current panel in the inverter can only accept a 20-volt DC input. Therefore, the circuit could be reconfigured, and the LM7805 regulator could be replaced with an XL7005A switching regulator for separate rails on the inverter board to work with up to 80 V power sources (12 V, 24 V, 48 V, and 72 V). An app can be developed and interfaced with the power inverter to handle different loads connected to the power inverter; this will also help build home automation.

In addition to increasing the output power, we have also added an LCD module to display important parameters such as voltage, current, frequency, and temperature. To take things further, we could develop and integrate a mobile application to enable IoT functionality, allowing us to wirelessly monitor and control the inverter from our phones. With this app, we could add features such as a power on/off button and load management, making it even more convenient to operate the inverter remotely.

B. Future Work For MPPT Solar Charge Controller

There are several areas in which the MPPT solar charge controller can be improved. First, more research could be conducted to enhance its overall efficiency through either hardware changes or software updates. The output capacity of the controller can also be increased, allowing it to be used for larger solar systems in commercial and industrial settings. Additionally, a fault detection and diagnosis system could be integrated with the MPPT solar charge controller to detect and diagnose any issues that may arise in the solar system. An intelligent control algorithm could also be developed to optimize the efficiency of the MPPT solar charge controller, adapting to changing weather conditions and environmental factors to maximize the solar panel’s power output.

As renewable energy sources like solar power become increasingly common, the MPPT solar charge controller can be modified to communicate with the smart grid,
providing information on power output to enable more effective management and protection of the grid. Finally, designing a user-friendly interface for the MPPT solar charge controller could be another area for future work. It would involve developing a smartphone application that allows users to easily monitor the performance of their solar power system and make informed decisions about its operation.

C. Future Work For Solar Tracker

There are many areas in which the solar tracker can be improved. The solar tracker that we have designed is a single-axis tracker, which means it can only rotate clockwise and anticlockwise around a single axis. We can modify our solar tracker to design a dual-axis solar tracker that can rotate around the X and Y axes. It will allow the solar panel to track the sun at a 90° angle accurately. By keeping the solar panel always at an exact 90° angle from the sun, we can increase energy production compared to the single-axis solar tracker. Our solar tracker is currently limited to holding only small solar panels. However, we can improve its capacity by implementing an effective mechanism to accommodate larger solar panels.

We can also add more sensors to the solar tracker system, such as temperature, humidity, and wind speed sensors, to obtain more accurate environmental data. With these additional sensors, we can adjust the solar panel’s position for better performance and protection against unfavorable weather conditions. In addition, we can integrate IoT with our solar tracking system by developing an IoT platform, such as a smartphone application and integrating it with our system. It will enable remote monitoring and control of the system. The application will keep us updated with temperature, humidity, and wind speed values, providing more valuable data for more efficient system operation.

References