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Coin-Operated Wireless Mobile Charging Station

B Priyanka
Assistant Professor, Department of Electronics and Communication Engineering,
Sengunthar Engineering College (Autonomous), Tiruchengode, India
bpriyanka.ece@scteng.co.in
https://orcid.org/0009-0007-6213-5858
A Lokeshwaran, K Sharan Raj, M Pranesh
UG Scholars, Department of Electronics and Communication Engineering,
Sengunthar Engineering College (Autonomous), Tiruchengode, India

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Abstract: The project focuses on designing a solar-powered mobile charging system that operates using a coin insertion mechanism with intelligent monitoring and maintenance features. The system converts solar energy into electrical energy, which is stored in a battery for later use. Users can charge their mobile devices by inserting a coin, which activates the charging process through wired or wireless charging options for a limited duration. To improve system reliability, solar panel voltage is continuously monitored using a NodeMCU-based IoT system, and real-time status such as panel condition, battery voltage, and pump operation is displayed through a mobile application. When a drop in solar panel efficiency is detected due to dust accumulation, an automatic water pump cleaning mechanism is activated to restore panel performance. This setup provides a simple, sustainable, and intelligent solution for public charging stations by combining renewable energy, automation, and remote monitoring.Engineering knowledge, Problem analysis, Design & development of solutions, Use of modern tools, Environment & sustainability, Life-long learning. Apply electronics & communication concepts to design systems, Use modern embedded tools & techniques for real-world applications. Affordable & Clean Energy (because the system utilizes solar power), Industry, Innovation & Infrastructure (because the design integrates IoT, automation, and supports smart public infrastructure).
Keywords: Solar Energy, Coin Operated Charging Station, Wireless Mobile Charging, Arduino UNO, NodeMCU (ESP8266), IoT Monitoring, Renewable Energy, Mobile Charging System.

1. INTRODUCTION

In the modern world, mobile phones have become an essential part of daily life for communication, education, navigation, and many other activities. Due to the continuous usage of smartphones, the demand for easily accessible mobile charging facilities in public places has increased significantly. Locations such as bus stands, railway stations, parks, campuses, and public waiting areas often require reliable charging solutions. However, providing charging infrastructure in such places can be challenging due to limited access to continuous electrical power and uncontrolled usage of charging facilities. To address these challenges, renewable energy–based charging systems have gained importance. Solar energy is one of the most widely available and environmentally friendly energy sources that can be used to power small electronic systems. By using solar power, mobile charging stations can operate independently without relying completely on conventional electricity supply. In addition, controlled access mechanisms can be used to ensure fair usage of the charging facility. This project presents the design and implementation of a solar-powered coin-operated wireless mobile charging station. The system allows users to charge their mobile devices by inserting a coin into the charging unit. Once a coin is inserted, the charging circuit is activated for a fixed time duration, enabling users to charge their devices through wired or wireless charging interfaces. The system uses an Arduino microcontroller to manage coin detection, control charging activation, and display system status through an LCD interface. The charging station is powered using a solar panel that converts sunlight into electrical energy, which is stored in a rechargeable battery. This stored energy is then used to provide a regulated power supply for mobile charging. In order to support reliable operation, the system also includes basic monitoring and maintenance features that help maintain the efficiency of the solar panel and provide system status information through an IoT platform. The proposed system aims to provide a simple, cost-effective, and sustainable solution for public mobile charging infrastructure. By combining solar energy utilization, coin-based access control, and wireless charging technology, the system offers a convenient charging facility while promoting efficient use of renewable energy.

2. LITERATURE SURVEY

[1]Arun Kumar, S., & Vivek, R. (2025) – Solar Coin-Based Wireless Mobile Charging Station with IoT Monitoring. The authors developed a solar-powered mobile charging station that activates wireless charging through coin insertion. The system includes battery storage and IoT monitoring to track solar panel output and charging status. It improves public charging convenience while ensuring renewable energy usage and remote maintenance.

[2]Bharath, K., & Nandhini, S. (2025) – Smart Wireless Charging Kiosk with Solar Power and Automated Panel Cleaning. This work presents a solar-powered wireless charging kiosk with a built-in automated cleaning mechanism to maintain panel efficiency. A water pump system removes dust and improves energy generation. The design enhances longterm reliability and reduces manual maintenance requirements.

[3]Chaitanya, P., & Praveena, M. (2025) – IoT-Enabled Coin Operated Wireless Charging System Using Renewable Energy.The proposed system integrates solar power, coin validation, and wireless charging technology for controlled public usage. IoT connectivity allows realtime monitoring of battery levels and charging sessions. The design ensures efficient energy utilization and improves operational transparency.

[4]Dinesh Kumar, V., & Akila, R. (2025) – Solar Powered Wireless Charging Station with Automatic Maintenance Module.This project introduces a solar-powered wireless charger equipped with automatic maintenance support for consistent performance. The system monitors panel efficiency and charging conditions continuously. It aims to increase charging reliability in outdoor installations.

[5]Elango, M., & Kavitha, P. (2025) – Renewable Energy-Based Coin Wireless Charger with Mobile Application Monitoring.The system uses solar panels and battery storage to power a wireless mobile charging station activated by coin input. IoT mobile applications provide system health information such as battery capacity and charging status. The design focuses on sustainable and user-friendly public charging.

[6]Farhan, A., & Nisha, S. (2025) – Public Wireless Charging System Using Solar Energy and Smart Control.A smart public charging station using renewable solar energy is proposed to support wireless charging access. The system manages charging duration using control logic to ensure fair usage. Monitoring features improve operational safety and energy efficiency.

[7]Goutham, R., & Dharani, S. (2025) – Smart Solar Wireless Charging Unit with Dust Cleaning Mechanism.This research presents a solar-powered wireless charger integrated with a dust-cleaning water mechanism. The cleaning system activates when solar efficiency drops below a threshold. The solution enhances panel performance and increases renewable power utilization.

[8]Harish, V., & Deepika, K. (2025) – IoT-Based Solar Coin Charging Station with Wireless Power Transfer.The charging station uses solar energy and battery backup with coin-based access control. Wireless charging technology eliminates cable dependency while IoT monitoring tracks energy consumption. The system improves safety, efficiency, and remote maintenance capability.

[9]Ishaan, P., & Kiran, T. (2025) – Automatic Solar Panel Cleaning System Integrated with Charging Stations.This work focuses on improving solar charging efficiency through automated panel cleaning triggered by performance changes. Sensors detect reduced output and activate a cleaning mechanism. The design ensures consistent energy generation and reduced manual effort.

[10]Jaya, R., & Manoj, S. (2025) – Coin Operated Wireless Power Bank Station for Public Areas.A wireless power bank charging station activated through coin insertion is proposed for public environments. The system provides time-limited charging sessions to manage fair usage. Renewable energy integration supports sustainable operation.

[11]Karthik, S., & Renu, V. (2025) – Solar Wireless Charging Kiosk with Smart Monitoring and Maintenance.The project integrates solar wireless charging with IoT dashboards displaying battery and panel performance. Maintenance alerts notify users about system conditions. The kiosk design ensures continuous service in outdoor public spaces.

[12]Lokesh, P., & Ananya, R. (2025) – Renewable Wireless Charging Station with Automated Solar Cleaning Robot.This system uses a robotic cleaning mechanism to maintain solar panel efficiency in wireless charging stations. Automatic cleaning activates during reduced sunlight absorption. The approach enhances system lifespan and renewable energy output.

[13]Mahesh, R., & Sneha, P. (2025) – Smart Coin Wireless Charging Station Using Arduino and IoT.A microcontroller-based system detects coins and activates wireless charging for a preset duration. IoT integration provides real-time information on battery condition and charging performance. The design supports cost-effective and automated public charging.

[14]Naveen, S., & Haritha, M. (2025) – Solar Powered IoT Mobile Charging Booth with Real-Time Monitoring.This charging booth uses solar panels and battery storage to provide wireless and wired charging options. IoT applications display system voltage, battery percentage, and charging status. The system improves reliability and user accessibility.

[15]Omkar, A., & Preethi, R. (2025) – Sustainable Wireless Charging Station with Self-Cleaning Solar Panels.The work integrates self-cleaning technology into a solar wireless charging system to maintain energy efficiency. Automated water spraying removes dust and debris. The design supports sustainable and long-term renewable charging infrastructure.

[16]Prakash, D., & Keerthana, V. (2025) – Smart Public Charging Station Using Coin Mechanism and Solar Power.The system combines solar panels, coin validation, and wireless charging to create a controlled public charging unit. Monitoring systems track energy usage and battery status. The design promotes eco-friendly and revenue-based charging services.

[17]Qureshi, A., & Meera, S. (2025) – Wireless Charging Infrastructure Powered by Renewable Energy with Maintenance Automation.A renewable-powered wireless charging infrastructure with automated maintenance features is proposed.

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Sensors monitor solar efficiency and trigger maintenance actions when necessary. The system enhances operational sustainability.

[18]Rahul, M., & Yamini, T. (2025) – IoT Controlled Solar Charging Station with Wireless Output.This project proposes a wireless charging station powered by solar energy and monitored through IoT technology. Remote monitoring improves maintenance and system reliability. The design ensures uninterrupted charging performance.

[19]Sanjay, K., & Divya, L. (2025) – Automated Solar Panel Cleaning with Charging System Integration.An automated water-based cleaning system is integrated into solar charging infrastructure. The cleaning process is triggered when panel efficiency decreases. The solution ensures maximum sunlight absorption and consistent power generation.

[20]Tejas, R., & Nirmala, S. (2025) – Coin-Based Smart Wireless Charger with Solar Backup.A solar-powered wireless charging station with coin-based access control is proposed. Battery backup ensures charging continuity during low sunlight conditions. The system offers safe and convenient public charging access.

[21]Uday, V., & Lakshmi, K. (2025) – Smart Solar Charging Station with IoT and Wireless Energy Transfer.This research integrates IoT monitoring with wireless energy transfer to create a smart solar charging station. Real-time system data such as voltage and battery level are displayed remotely. The design enhances energy management and maintenance.

[22]Varun, P., & Aishwarya, M. (2026) – Intelligent Solar Charging Unit with IoT-Based Performance Tracking.An intelligent charging system is designed with IoT-based tracking for monitoring solar panel output and battery health. The wireless charging feature improves user convenience. Performance analysis helps optimize system efficiency.

[23]Waseem, S., & Kavya, R. (2026) – IoT-Enabled Coin Wireless Charging Kiosk for Public Places.The kiosk integrates solar panels, coin validation, and wireless charging technology with IoT monitoring. System alerts notify administrators about voltage drops or maintenance needs. The design supports reliable public charging infrastructure.

[24]Xavior, J., & Harini, S. (2026) – Self-Maintaining Solar Charging System with Automatic Water Cleaning.The solar panel cleaning system uses a motorized water mechanism to maintain energy output. Automatic activation occurs when performance drops below a threshold. The system reduces manual cleaning efforts and improves charging efficiency.

[25]Yashika, P., & Manoj, R. (2026) – Smart Renewable Wireless Charging Station with Maintenance Alerts.This project presents a smart wireless charging station powered by renewable energy with IoT-based maintenance alerts. The system monitors battery health, panel output, and charging activity. It enhances system safety and long-term sustainability.

3. PROPOSED SYSTEM

The proposed system presents the design and implementation of a solar-powered coin-operated wireless mobile charging station intended for use in public locations. With the increasing dependence on smartphones for communication, navigation, and digital services, the need for easily accessible mobile charging facilities has become very important. Public places such as bus stands, railway stations, parks, and college campuses often require convenient charging points for users who may run out of battery power during travel or daily activities. Traditional charging stations usually depend on grid electricity, which may not always be available in outdoor locations. In addition, free charging facilities can sometimes lead to misuse or excessive power consumption.

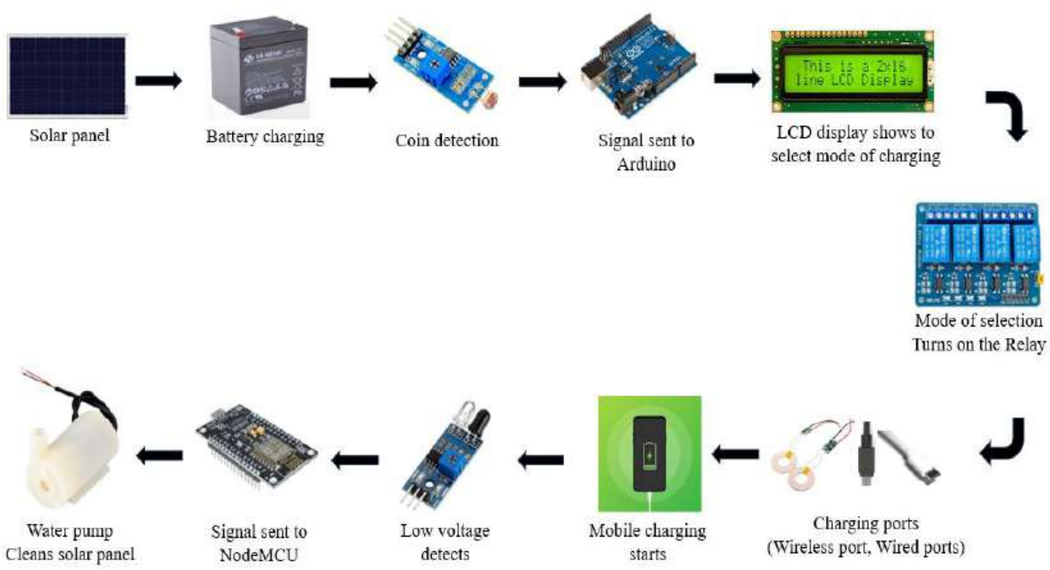

Figure 3.1. Block Diagram of Proposed System.

To address these challenges, the proposed system utilizes solar energy as the primary power source and incorporates a coin-based charging mechanism to regulate access to the charging service. In this system, a solar panel converts sunlight into electrical energy. The generated energy is stored in a rechargeable battery through a charge controller. This stored energy is then used to power the mobile charging system. Users can activate the charging service by inserting a coin into the coin detection module. Once the coin is detected, the Arduino microcontroller activates the charging circuit for a predefined time duration. During this period, the user can charge their mobile device using the provided charging interface.

3.1 Working Principle:

The working principle of the system is based on solar energy generation and coin-based activation of the mobile charging service. During normal operation, the solar panel converts sunlight into electrical energy and charges the rechargeable battery through a charge controller. The battery acts as an energy storage unit and provides power to the mobile charging system whenever required.When a user inserts a coin into the coin sensor module, the sensor detects the coin and sends a signal to the Arduino microcontroller. After receiving this signal, the Arduino activates the charging module for a predefined time period. During this time, the user can connect their mobile device to the charging port or place the device on the wireless charging pad to start charging. The Arduino controller also displays system messages on the LCD display to inform the user about system status such as coin detection, charging start, and charging completion. Once the preset charging time expires, the Arduino automatically deactivates the charging circuit, ensuring controlled usage of the charging station. At the same time, the voltage sensing module continuously measures the solar panel output voltage. These readings are transmitted to the NodeMCU module for monitoring purposes. The NodeMCU can send system information such as voltage levels and operational status to a mobile application through IoT connectivity. If the solar panel performance decreases due to dust accumulation, the relay driver circuit can activate the water pump to clean the panel surface. After cleaning, the system resumes normal operation and continues to provide charging services.

3.2 System Architecture:

The system architecture is mainly designed around solar power generation and coin-controlled mobile charging.

- The Solar Panel converts sunlight into electrical energy.
- The Battery Storage Unit stores the generated energy for later use.
- The Coin Sensor Module detects coin insertion by the user.
- The Arduino Controller controls the charging operation and system functions.
- The Charging Interface provides wired and wireless charging for mobile devices.
- The Voltage Sensor measures solar panel output voltage.
- The NodeMCU Module provides basic monitoring and IoT communication.
- The Relay Driver Circuit acts as a switching device for the pump.
- The Water Pump assists in maintaining solar panel cleanliness when required.
- The Regulated Power Supply ensures stable voltage for electronic components.

This architecture ensures proper coordination between energy generation, charging control, and system monitoring.

3.3. System Operation:

The operation of the system follows these steps:

- Energy Generation: The solar panel converts sunlight into electrical energy and stores it in the rechargeable battery.
- Charging Activation: When a user inserts a coin, the coin sensor detects the coin and sends a signal to the Arduino controller. The controller activates the charging circuit for a predefined duration.
- Mobile Charging: The user can charge the mobile device using the available charging port or wireless charging module during the activated time.
- System Monitoring: The voltage sensor measures solar panel output and sends information to the NodeMCU module for monitoring purposes.
- Maintenance Support: If necessary, the relay-controlled pump can be activated to maintain solar panel performance.
- IoT Status Update: System parameters such as voltage level and operational status can be viewed through the mobile application.

This process ensures reliable and controlled operation of the solar-powered coin-operated mobile charging station.

3.4. Objectives of the Proposed System:

The main objectives of the proposed system are:

- To design a solar-powered mobile charging station for public use.
- To implement a coin-based mechanism for controlled access to the charging facility.
- To provide both wired and wireless charging options for mobile devices.
- To utilize renewable solar energy for sustainable power generation.
- To ensure safe and regulated power output for mobile device charging.
- To incorporate basic monitoring features for observing system performance.

To improve reliability of the solar power unit through simple maintenance support.

4. SYSTEM OPERATION

4.1 Hardware Requirements:

The development and implementation of the proposed solar powered coin-operated wireless mobile charging station require a combination of appropriate hardware and software resources. System requirements define the components and tools necessary to design, develop, and operate the system efficiently. These requirements play an important role in ensuring that the system performs its intended functions such as solar energy utilization, controlled mobile charging, automated operation, and system monitoring. In this project, both hardware requirements and software requirements are essential for achieving proper system functionality. Hardware components are responsible for performing the physical operations of the system, while software tools are used to program, control, and manage the system behavior.

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1. Solar Panel

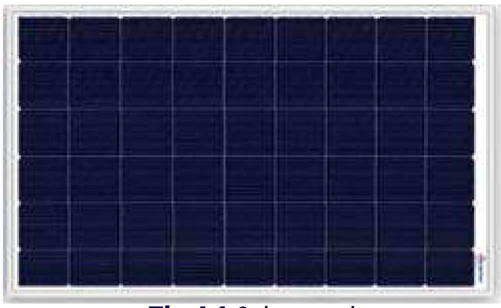

Fig 4.1 Solar panel

A solar panel is a renewable energy device that converts sunlight into electrical energy using photovoltaic (PV) cells. These PV cells are typically made from semiconductor materials such as silicon, which generate electrical current when exposed to sunlight. Solar panels are widely used in standalone energy systems because they provide a clean and sustainable power source without producing pollution. In this project, the solar panel acts as the primary power generation unit for the entire charging station. The use of a solar panel makes the charging station energy efficient and environmentally friendly. It allows the system to operate independently in outdoor locations where grid electricity may not be easily available. In addition, solar energy reduces operational costs and promotes the use of renewable energy technologies.

2. Battery

Fig 4.2 Battery

A rechargeable battery is an energy storage device that stores electrical energy and supplies it to the system whenever required. Batteries play an important role in solar-powered systems because solar panels generate electricity only when sunlight is available. Therefore, the battery stores the energy produced during the day so that it can be used later when sunlight is not available or when the demand for power increases. The battery also helps maintain a stable voltage supply for the electronic components. Solar panels may produce fluctuating voltage depending on sunlight intensity, temperature, and environmental conditions. By storing the energy in the battery, the system can deliver a consistent and reliable power output for mobile charging. This ensures that connected devices receive stable power without sudden interruptions.

3. Arduino Uno

Fig 4.3 Arduino UNO

Arduino UNO is a widely used microcontroller development board designed for building embedded systems and automation applications. It is based on the ATmega328P microcontroller, which contains programmable memory, input/output pins, and processing capability required to control electronic devices. The Arduino platform is popular among engineers and students because it provides an easy programming environment and supports a wide range of sensors and electronic modules.

4. IR Sensor (Coin Detection)

An Infrared (IR) sensor is an electronic sensing device that detects objects using infrared radiation. It typically consists of an IR transmitter that emits infrared light and an IR receiver that detects the reflected or interrupted light signal. IR sensors are commonly used in automation systems for object detection, obstacle detection, and counting applications. In this project, the IR sensor is used to detect coin insertion in the charging system. When a user inserts a coin into the coin slot, the coin passes through the infrared beam generated by the IR transmitter.

This interrupts the beam reaching the IR receiver. The sensor detects this interruption and generates a digital output signal. This signal is then sent to the Arduino controller as an indication that a coin has been inserted.

Fig 4.4 IR Sensor

5. LDR (Light Dependent Resistor)

Fig 4.5 LDR Sensor

A Light Dependent Resistor (LDR) is a type of electronic sensor whose resistance varies depending on the intensity of light falling on its surface. When light intensity increases, the resistance of the LDR decreases. Conversely, when the light intensity decreases, the resistance increases. Because of this property, LDR sensors are widely used in light detection and brightness monitoring applications. In this project, the LDR sensor is used to detect the availability of sunlight around the solar panel. By monitoring the light intensity, the system can determine whether the solar panel is operating under sufficient sunlight conditions. This information helps in analyzing the performance of the solar power system and ensuring efficient operation of the charging station.

6. LCD Display

Fig 4.6 LCD display

A Liquid Crystal Display (LCD) is an electronic display module used to present text and numerical information. The 16×2 LCD display is capable of displaying two lines of characters, with each line containing up to sixteen characters. LCD displays are commonly used in embedded systems because they provide a simple and effective way to communicate system information to users. The LCD display improves the user experience by providing clear and understandable information about the system operation.

7. Relays

Fig 4.7 Relay modules

A relay is an electrically controlled switch that allows low-power electronic circuits to control high-power electrical devices. It operates using an electromagnetic coil that opens or closes electrical contacts when a control signal is applied. Relays are commonly used in automation systems where microcontrollers need to control devices that require higher current or voltage. In this project, 5V relay modules are used to control the water pump used for solar panel cleaning. The relay acts as an interface between the NodeMCU controller and the pump motor. When the NodeMCU sends a control signal, the relay switches ON the pump, allowing water to flow over the solar panel surface.

8. Charging Points

Charging ports are electrical interfaces that allow electronic devices such as smartphones, tablets, and portable gadgets to receive electrical power for battery charging. In modern electronic systems, Universal Serial Bus (USB) connectors are widely used because they provide a standardized method for both power delivery and data communication.

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USB charging interfaces are designed to provide regulated voltage and current suitable for charging various electronic devices safely and efficiently.

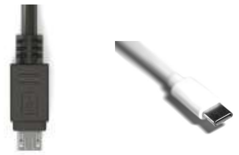

Fig 4.8 Charging ports (B-type, C-Type)

In this project, USB Type-C and USB Type-B charging ports are used as wired charging interfaces for mobile devices. These charging ports are connected to the regulated power supply derived from the battery storage unit. The coin detection mechanism sends a signal to the Arduino controller. The Arduino then activates the charging circuit for a predefined time duration. During this time, power from the battery is supplied to the USB charging ports, allowing users to connect their mobile devices and charge them.

9. Wireless Charging Coil

Fig 4.9 Wireless Coil

Wireless charging technology allows electronic devices to charge their batteries without the need for physical cables or connectors. This technology operates based on the principle of electromagnetic induction, where electrical energy is transferred between two coils through a magnetic field. One coil acts as a transmitter connected to the power source, while the other coil acts as a receiver located inside the mobile device. In this project, a wireless charging module is included to provide an additional and convenient charging option for users. The module consists of a transmitter circuit and a transmitter coil. When the charging system is activated after coin insertion, electrical power from the battery is supplied to the wireless charging transmitter. The transmitter coil generates an alternating magnetic field that transfers energy to the receiver coil present in compatible smartphones.

10. WATER PUMP

Fig 4.10 Water Pump

A DC water pump is a small electrically powered mechanical device used to move or circulate water using direct current (DC) electrical energy. DC pumps are widely used in small automation systems, irrigation systems, fountains, and cooling systems because they are compact, efficient, and easy to control using microcontrollers. In this project, a mini DC water pump is used as part of the solar panel maintenance mechanism. Solar panels installed in outdoor environments are often exposed to dust, dirt, and environmental particles. Over time, these particles accumulate on the surface of the panel and reduce the amount of sunlight reaching the photovoltaic cells. This reduces the overall efficiency of solar power generation.

11. NodeMCU

NodeMCU is an open-source Internet of Things (IoT) development board based on the ESP8266 Wi-Fi microcontroller chip. It is widely used in IoT applications because it provides built-in wireless communication capability and can easily connect to Wi-Fi networks. The NodeMCU board includes a microcontroller, memory, input/output pins, and a USB interface for programming.

Fig 4.11 NodeMCU ESP8266

In this project, the NodeMCU is used to implement the IoT monitoring functionality of the solar-powered mobile charging station.

The module is responsible for collecting system data such as solar panel voltage and operational status and transmitting this information to the Blynk IoT mobile application through Wi-Fi connectivity.The NodeMCU communicates with the voltage sensing module to measure the output voltage of the solar panel. These voltage readings help determine the performance of the solar power system. The collected data is then transmitted to the Blynk cloud server, where it can be accessed through the Blynk mobile application interface.

4.2 Software Requirements:

In this project, software is used to implement the control logic of the solar powered coin-operated wireless mobile charging system. The microcontrollers used in the system require appropriate programming tools and development platforms to write, compile, and upload the program code. These software tools help in developing the firmware that controls the charging process, sensor inputs, relay operations, and system display functions. Therefore, the software requirements for this project include development environments, programming languages, and IoT platforms that support the design and implementation of the system. These tools allow developers to write embedded programs, test system functionality, and monitor the operation of the hardware components effectively.

1. Arduino IDE

Arduino Integrated Development Environment (IDE) is an open-source software platform used for writing, compiling, and uploading programs to Arduino microcontroller boards. It provides a user-friendly graphical interface where developers can easily create program code, compile it, and transfer the compiled program to the microcontroller through a USB connection. The Arduino IDE supports programming using Embedded C/C++ language, which makes it suitable for developing embedded system applications. The software also includes a built-in text editor, compiler, and serial communication interface that helps developers test and debug their programs effectively. In this project, the Arduino IDE is used to develop and upload the control program for the Arduino UNO microcontroller, which manages the main operations of the coin-operated solar mobile charging station. The program written in the Arduino IDE controls the charging process by processing signals received from the IR coin detection sensor. When a coin is detected, the microcontroller activates the charging circuit and allows power to be supplied to the mobile charging ports for a predefined time duration.

Key Features of Arduino IDE

- Open-source and easy-to-use software environment
- Supports programming using Embedded C/C++ language
- Built-in libraries for sensors, displays, and communication modules
- Serial monitor for debugging and testing system operation
- Cross-platform support for Windows, Linux, and macOS.

2. Embedded C Programming

Embedded C is a specialized programming language used for developing software for microcontroller-based embedded systems. It is an extension of the standard C programming language that includes additional features for direct interaction with hardware components. Embedded C allows programmers to control hardware devices such as sensors, motors, displays, communication modules, and relays through software instructions executed by a microcontroller. In this project, Embedded C programming is used to implement the core control logic of the solar-powered coin-operated mobile charging station. The program defines how the system should respond when a user inserts a coin into the charging station. When the IR coin detection sensor detects the presence of a coin, the signal is sent to the Arduino microcontroller. The Embedded C program processes this signal and activates the charging circuit through a relay module. Embedded C programming ensures that all hardware components in the project operate in a coordinated and reliable manner. Because it directly interacts with microcontroller registers and hardware peripherals, it provides high execution speed, efficient memory usage, and stable system performance.

Advantages of Embedded C Programming

- Efficient control of microcontroller hardware resources
- High execution speed and low memory consumption
- Direct interaction with sensors and electronic components
- Reliable operation in real-time embedded systems
- Widely used for developing firmware in industrial and IoT devices

3. Blynk IoT Platform

Blynk is a cloud-based Internet of Things (IoT) platform designed to simplify the development of connected electronic systems. It provides an easy way to create mobile applications that can communicate with hardware devices through the internet. The Blynk platform includes three main components: the Blynk mobile application, the Blynk cloud server, and the hardware device such as a microcontroller with internet connectivity. In this project, the Blynk IoT platform is used for remote monitoring of the solar-powered mobile charging station. The NodeMCU microcontroller connects to a Wi-Fi network and communicates with the Blynk cloud server. The NodeMCU collects system information such as solar panel voltage and operational status and sends this data to the Blynk server through the internet.The Blynk mobile application retrieves this data from the cloud server and displays it in real time through a graphical interface. This allows users or system administrators to monitor important parameters such as solar panel voltage, charging system status, and pump operation status directly from their smartphones.

4. NodeMCU ESP8266 Development Environment

The NodeMCU module used in this project is programmed using the Arduino IDE with ESP8266 board support packages. This development environment allows developers to write firmware programs for the NodeMCU using Embedded C language. The ESP8266 board libraries provide functions for Wi-Fi connectivity, sensor communication, and IoT data transmission. In this project, the NodeMCU program reads voltage values from the voltage sensing module and processes the data to determine the operating condition of the solar panel. The microcontroller then transmits this information to the Blynk platform through wireless communication. The NodeMCU can also control the relay module that activates the water pump used for cleaning the solar panel surface.

5. Libraries Used in the Project

Libraries are pre-written software modules that provide ready-made functions for interacting with hardware components and communication protocols. Using libraries simplifies programming and reduces development time by providing built-in functions for common tasks.

Several libraries are used in this project to support different hardware modules and communication processes.

- Liquid Crystal Library
- ESP8266WiFi Library
- Blynk Library
- Wire Library

These libraries simplify hardware interaction and help in efficient implementation of the system.

6. Serial Monitor and Debugging Tools

The Arduino IDE includes a built-in serial monitor that helps developers observe system behavior during program execution. It allows the microcontroller to send debugging messages, sensor readings, and status information to the computer through a USB connection. In this project, the serial monitor is used during testing and development to verify the working of sensors, monitor voltage readings, and check communication between the Arduino and NodeMCU modules. Debugging through the serial monitor helps identify programming errors and ensures that the system operates correctly before final implementation.

5. RESULTS &DISCUSSION

The experimental setup was designed to demonstrate the operation of a solar-powered coin-operated wireless mobile charging station. The system allows users to charge their mobile devices in a controlled manner by inserting a coin, which activates the charging process for a fixed duration. An Arduino microcontroller acts as the main controller to manage coin detection, control the charging ports, and display system messages on the LCD. The charging unit includes a solar panel ,charge controller, rechargeable battery, coin detection module, Arduino controller, LCD display, wireless charging module, and mobile charging ports.

Fig 5.1 Wireless Charging

The solar panel converts sunlight into electrical energy which is stored in the battery and later used to provide a regulated power supply for charging mobile devices. A NodeMCU module is additionally used for basic system monitoring and maintenance support. The complete setup was tested under different conditions such as direct sunlight and partial sunlight to evaluate charging stability, system response, and overall performance. The testing confirmed that the system operates reliably and provides stable charging for mobile devices.

5.1 Testing Procedures:

The testing of the developed system was carried out in a step-by-step manner to verify the proper operation of the coin-operated mobile charging station and the overall system performance. Initially, the solar panel was connected to the charge controller and rechargeable battery to ensure proper energy storage and power supply to the system. After completing the hardware connections, the system was powered ON and the Arduino controller was checked to confirm that the LCD displayed the standby message indicating that the charging station was ready for operation.

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The solar panel was then placed under sunlight and the output voltage was measured to verify proper solar power generation. A coin was inserted into the coin detection slot to test the coin-operated mechanism.

Fig 5.2 Wired Charging

Fig 5.3 IoT Monitoring

The Arduino controller successfully detected the coin and activated the mobile charging port for a fixed duration. A mobile device was connected to the charging port and the charging process was verified. The output voltage of the charging port was measured using a multimeter to confirm that a stable 5V supply was provided for safe mobile charging. After the preset charging time elapsed, the system automatically stopped the charging process as programmed. Further testing was performed to observe system monitoring and operational behavior. The system parameters such as voltage values and operational status were observed through the IoT dashboard. Additional tests were conducted under different sunlight conditions to evaluate charging stability and system response. These procedures confirmed that the complete system operates reliably and provides controlled mobile charging using solar energy.

5.2Performance Analysis:

The performance of the developed system was evaluated based on the stability of mobile charging, response of the coin detection mechanism, solar power utilization, and system monitoring capability. During testing, the Arduino controller successfully detected coin insertion using the IR sensor and activated the charging circuit for the predefined time duration. The charging ports provided a stable output voltage suitable for charging mobile devices. The solar panel generated electrical energy which was stored in the rechargeable battery and used to power the charging station. The system was able to provide continuous charging even when sunlight intensity changed due to environmental conditions. The wireless charging module also operated successfully for compatible mobile devices. The NodeMCU module monitored system parameters and transmitted voltage readings to the Blynk IoT platform. The mobile application displayed real-time system status, which helped observe the performance of the solar power system. The automatic cleaning mechanism helped maintain solar panel efficiency by removing dust from the panel surface when required. Overall, the system demonstrated stable charging performance, reliable coin detection, and efficient use of solar energy for powering the charging station.

5.3Limitations Observed:

- The system performance depends on the intensity of sunlight available for the solar panel.
- The charging duration is fixed for each coin and cannot be modified dynamically by the user.
- The system is designed for normal mobile charging and does not support high-power fast charging.
- The voltage threshold used for detecting panel efficiency reduction requires proper calibration for accurate operation.

The prototype system is designed for small-scale demonstration and may require higher capacity components for large public installations

6. CONCLUSION

The rapid growth in mobile device usage has increased the need for accessible charging facilities in public locations. In many areas, continuous electrical supply is not always available, making renewable energy–based solutions more practical. To address this need, the project developed a solar-powered coin-operated wireless mobile charging station that allows users to charge their mobile devices in a controlled and convenient manner. The system uses a coin detection mechanism to activate the charging process for a fixed duration, ensuring regulated access and efficient usage. An Arduino microcontroller manages the charging operation and maintains a stable output suitable for mobile devices. In addition to the charging functionality, the system includes basic monitoring and maintenance features to support reliable operation. A NodeMCU module enables voltage monitoring and IoT-based status updates through a mobile application, while an automated cleaning mechanism helps maintain solar panel performance.

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Experimental results showed that the system successfully provides stable charging, controlled access, and reliable operation under different conditions. The developed system demonstrates that a solar-powered coin-operated charging station can serve as an effective, sustainable, and practical solution for public charging infrastructure.

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