

Solar Wireless EV Charging Station with RFID Authentication

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Abstract

The Solar-Powered Wireless Electric Vehicle (EV) Charging Station with RFID Authentication offers a secure, efficient, and sustainable solution for EV charging. Utilizing renewable energy, the system integrates a solar panel, Arduino Uno, RC522 RFID module, IR sensor, LCD display, L298 wireless charging coil, receiving coil, LED indicator, and a battery management system (BMS). User access is controlled through RFID authentication, ensuring only authorized vehicles can initiate charging. Once authenticated, the IR sensor detects vehicle presence in the designated slot. If properly positioned, the system activates wireless power transfer from the solar-powered source to the EV's receiving coil. Excess solar energy is stored for use during periods of low sunlight, enhancing system reliability. Real-time information on authentication status, charging progress, and battery levels is displayed via an LCD, while an LED indicator confirms charging initiation. By combining wireless charging with solar energy, the system eliminates the need for physical connectors and supports the advancement of sustainable and smart transportation infrastructure. Potential applications include public charging stations, smart cities, and renewable energy-based mobility solutions.

Keywords: *Arduino-Based Control, Wireless Power Transfer, Contactless Charging System, Battery Management System (BMS), Smart Charging Infrastructure.*

I. INTRODUCTION

The global transition towards electric vehicles (EVs) is driven by the urgent need to reduce greenhouse gas emissions and dependence on fossil fuels [1], [2]. As EV adoption increases, there is a corresponding demand for accessible, efficient, and environmentally sustainable charging solutions [3]. Traditional plug-in EV charging systems often face challenges such as wear and tear of connectors, safety risks in adverse weather, and limited user convenience [4]. In response to these challenges, wireless power transfer (WPT) technologies have emerged as a promising alternative, offering contactless energy delivery with improved user experience and reliability [5], [6]. Wireless EV charging, based on inductive coupling, eliminates the need for physical cables and enables automated energy

transfer between a ground-based transmitter and an onboard receiver coil [7]. When integrated with smart control systems, this approach enhances charging efficiency and user safety [8]. Moreover, the convergence of wireless charging with renewable energy sources, particularly solar power, has gained traction in recent years due to its potential for zero-emission energy delivery and grid independence [9], [10]. Solar-powered EV charging not only reduces carbon footprints but also supports decentralized energy infrastructure in smart cities [11].

Security and access control are critical in public charging environments to prevent unauthorized usage and ensure fair resource allocation [12]. Radio Frequency Identification (RFID) technology, widely used for authentication in embedded systems, provides a low-cost and effective means of verifying user identity before initiating the charging process [13]. RFID-based authentication, when combined with microcontroller platforms such as Arduino, enables real-time control, monitoring, and data display in intelligent charging systems [14], [15]. Recent studies have demonstrated the feasibility of integrating solar panels, WPT modules, battery management systems (BMS), and RFID authentication to develop secure and efficient EV charging stations [16]–[18]. Advanced battery management and energy storage mechanisms ensure uninterrupted service during cloudy conditions or nighttime [19]. User-friendly interfaces such as LCD displays and LED indicators further improve system transparency and usability [20].

The proposed system builds upon these innovations by combining solar energy harvesting, wireless charging, RFID authentication, and embedded system control into a single, self-contained platform. Such a system addresses key challenges in modern EV infrastructure—namely sustainability, user authentication, and maintenance reduction—while contributing to the realization of smart, autonomous urban mobility [21]–[24].

II. Problem Identification

The global transition toward electric mobility has created a pressing need for robust, secure, and sustainable charging infrastructure. However, existing electric vehicle (EV) charging systems continue to exhibit several limitations that hinder their scalability and user adoption. First, the dependence on wired charging mechanisms introduces practical challenges, including wear and tear of connectors, frequent maintenance, and user inconvenience—especially in public or high-usage environments. These issues not only impact system reliability but also reduce operational efficiency.

Second, unauthorized access and lack of security protocols in traditional EV charging stations pose risks such as energy theft, resource misuse, and financial loss, particularly in open or unattended installations. Furthermore, the reliance on grid-based electricity, which is not always sourced from renewable energy, diminishes the environmental advantages associated with EV adoption and contributes to carbon emissions.

Additionally, most current systems lack intelligent automation, requiring manual intervention for user authentication, payment processing, and connection initiation. This

manual dependency leads to inefficiencies and limits the potential for seamless integration into smart city infrastructure.

In light of these challenges, there is a critical need for an automated, secure, and renewable energy-powered EV charging solution. This research addresses the problem by proposing a solar-powered wireless EV charging station integrated with RFID-based user authentication. The system aims to eliminate physical connectors, enhance operational security, utilize clean energy, and enable automated user access and charging initiation—contributing toward a more intelligent and sustainable transportation ecosystem.

Drawbacks of Existing Methods include:

- Wired EV Charging Susceptible to cable wear and tear, requires manual connection, and depends on grid electricity that may not be renewable.
- RFID Authentication without Wireless Charging Improves access control but still necessitates physical cable connection.
- Solar-Powered Charging without Wireless requires direct vehicle connection, retaining cable-related issues.
- Wireless Charging without Solar Integration often relies on fossil-fuel-based grid power and lacks secure user authentication, risking unauthorized usage.

Thus to address the above issues ,the primary objectives of this project are to:

1. To design a secure and automated wireless EV charging station with RFID authentication and vehicle detection for controlled and efficient charging access.
2. To integrate solar energy as a renewable power source, combined with wireless charging technology, to enable sustainable and cable-free EV charging.
3. To provide real-time user feedback through LCD and LED indicators while minimizing maintenance and reducing reliance on grid electricity.

III. PROPOSED SYSTEM

The proposed solution combines RFID-based user authentication, solar energy harvesting, and wireless charging technology to deliver a secure and efficient electric vehicle charging system. The design includes:

- User verification through an RFID module to restrict charging access to authorized vehicles only.
- Vehicle detection using an infrared sensor positioned in the parking space to trigger the charging process.
- Electricity generation from solar panels that supply power to the charging station and store surplus energy in a battery for later use.

- Wireless energy transfer facilitated by an L298 transmitter coil and a receiving coil installed in the vehicle.
- Real-time status updates presented on an LCD screen, along with LED indicators to signal charging progress.

This approach removes the reliance on physical cables, improves security measures, and encourages the adoption of sustainable energy sources.

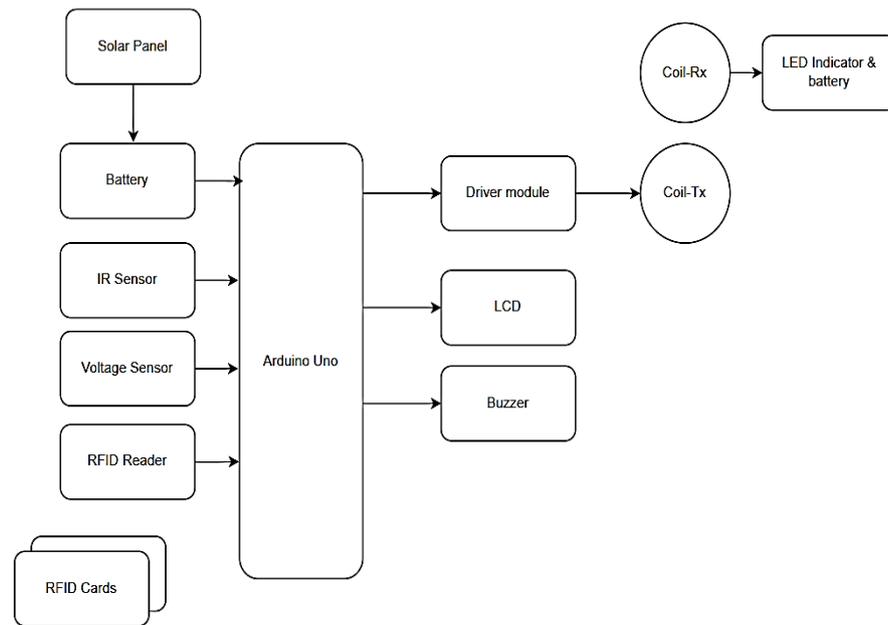


Figure 1: Block Diagram of the proposed system

A. Work Flow

The working flow of the system follows these key steps:

User Authentication : The user taps an RFID card on the RC522 module. The Arduino Uno verifies the card against stored data. If the user is authorized, the system proceeds; otherwise, access is denied.

Vehicle Detection : An IR sensor detects whether a vehicle is parked in the charging slot. If a vehicle is present, the system moves to the next step.

Solar Power Management: The solar panel generates power and charges a battery. The stored power is supplied to the wireless charging coil.

Wireless Charging Activation : The L298 wireless charging coil transmits power to the receiving coil in the EV. An LED indicator glows to show charging status.

Monitoring and Display : The LCD screen displays authentication status, charging progress, and battery levels. The system stops charging automatically when the battery is full or the RFID card is tapped again to end the session.

B. Methodology

The system is developed using an Arduino-based embedded control system with IoT integration for real-time monitoring. The methodology follows:

- ❖ System Design and Hardware Selection
 - Identifying required components (Arduino Uno, RFID module, wireless charging circuit, solar panel, IR sensor, LCD display, battery, LED indicators).
- ❖ Circuit Design and Integration
 - Connecting the RFID module for user authentication. Implementing the IR sensor for vehicle detection. Integrating the solar panel and battery management system. Designing the wireless charging circuit using L298 coil technology.
- ❖ Software Development
 - Writing Arduino code to handle RFID authentication, sensor input, and charging control. Programming the LCD display for real-time status updates.
- ❖ Prototype Implementation and Testing
 - Assembling hardware components. Testing power transfer efficiency and authentication accuracy.

C. System Design and Hardware Selection

The following is the component description of different types of hardware components used in the proposed system.

LCD Display:

A 16×2 LCD has two registers like data register and command register. The RS (register select) is mainly used to change from one register to another. When the register set is '0', it is referred to as the command register. Likewise, a register set that has a value of 1 is referred to as a data register.

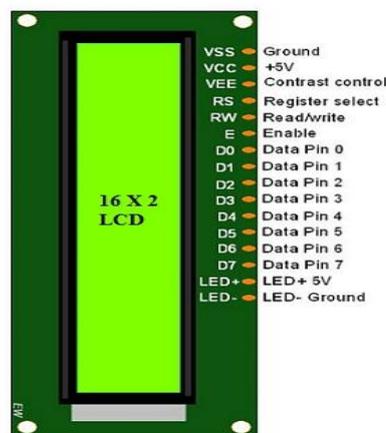


Figure 2 : LCD Display

Command Register : The main function of the command register is to hold the command instructions that are transmitted to the display. in order to perform predefined tasks including cursor positioning, screen cleaning, display control, and initialization. Here, commands can be processed using the register.

Data Register : The main function of the data register is to hold the data that will be shown on the LCD panel. In this instance, the ASCII value of the character will be the data shown on the LCD screen. Data is sent to the data register, where the process starts, each time we supply it to the LCD. When register set = 1, the data register will be selected.

16×2 LCD Commands:

The LCD 16X2 has the following commands.

The LCD command for Hex Code-01 will be displayed on the clear LCD panel.

Hex Code-02's LCD command will be returning home.

The decrement cursor will be the LCD instruction for Hex Code-04.

The increment cursor will be the LCD command for Hex Code-06.

Shift display to the right will be the LCD command for Hex Code-05.

The LCD command for Hex Code-07 is to shift the display to the left.

Hex Code-08 will use the LCD command "Display off, cursor off."

Hex Code-0A's LCD instruction will turn the cursor on and the display off.

For Hex Code-0C, the LCD command will turn the display on, but for Hex Code-0E, it will blink.

The LCD command will cause the pointer to flash when Hex Code-0F is displayed. The LCD instructions for the Hex Code-10 display will turn on if you move the cursor to the left.

The LCD instruction for Hex Code-14 can be found by moving the cursor to the right.

The LCD command for Hex Code-18 is to move the entire display to the left.

The LCD command for Hex Code-1C is to move the entire display to the right.

Hex Code-80's LCD instruction will be to push the cursor to the first line.

Force cursor to begin (second line) will be the LCD command for Hex Code-C0.

Hex Code-38's LCD instruction will be a two-line, 5x7 matrix.

IR(Infrared) Proximity Sensor

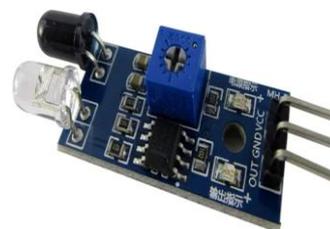
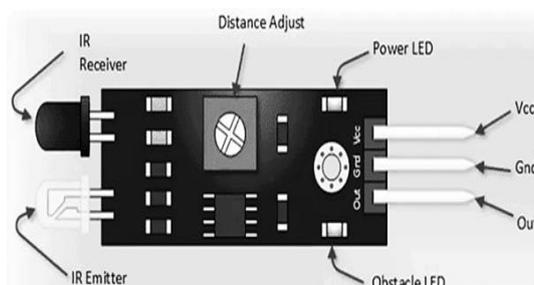


Figure 3 : Proximity Sensor

The purpose of this proximity sensor is to identify obstacles and things in front of it. When an object approaches, the sensor continues to emit infrared light and is recognized by sensors that track the object's reflecting light. RPM can be used to rotate objects like automatic doors, parking aids, security alarm systems, or fan blades without the need for a tachometer.

Table 2 : Pin description of proximity sensor

Pin Name	Description
VCC	Power Supply Input
GND	Power Supply Ground
OUT	Active High Output

VOLTAGE SENSOR

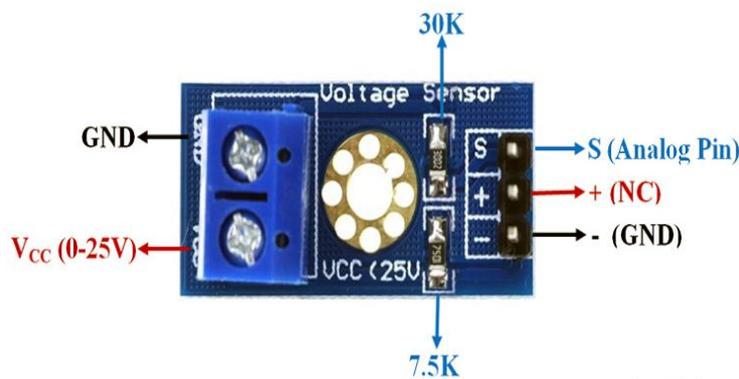


Figure 4: Voltage Sensor

Table 3 : Pin description of Voltage sensor

Pin Name	Description
VCC	Positive terminal of the External voltage source (0-25V)
GND	Negative terminal of the External voltage source
S	Analog pin connected to Analog pin of Arduino
+	Not Connected
-	Ground Pin connected to GND of Arduino

The straightforward and incredibly helpful Voltage Detection Sensor Module reduces any input voltage by a factor of five using a potential divider. This enables us to monitor voltages higher than what a microcontroller can sense via its analog input pin. For instance, you can measure a voltage up to 25V using an analog input range of 0V to 5V. Additionally, this module has

handy screw terminals for quick and safe wire connections. The internal circuit of the Voltage Sensor Module consists of divider circuit of two resistors in which R1 is 30K and R2 is 7.5K.

Active Passive Buzzer

Table 4 : Buzzer Pin Configuration

Pin Number	Pin Name	Description
1	Positive	Identified by (+) symbol or longer terminal lead. Can be powered by 6V DC
2	Negative	Identified by short terminal lead. Typically connected to the ground of the circuit

Features and Specifications:-

rated voltage : 6V DC

Voltage Range for Operation: 4-8V DC

rated current : <30mA

Type of Sound: Constant Beep; Resonant Frequency: about 2300 Hz

A little, well-sealed package

Perf board and breadboard compatible

ARDUINO UNO:

The Arduino Uno microcontroller board (datasheet) is built on top of the ATmega328. There are 14 digital input/output pins (six of which can be used as PWM outputs), six analog inputs, a reset button, an ICSP header, a USB connector, a power jack, and a 16 MHz crystal oscillator. Everything needed to support the microcontroller is included; all you need to do is plug it into a computer using a USB wire or power it using an AC-to-DC adapter or battery.

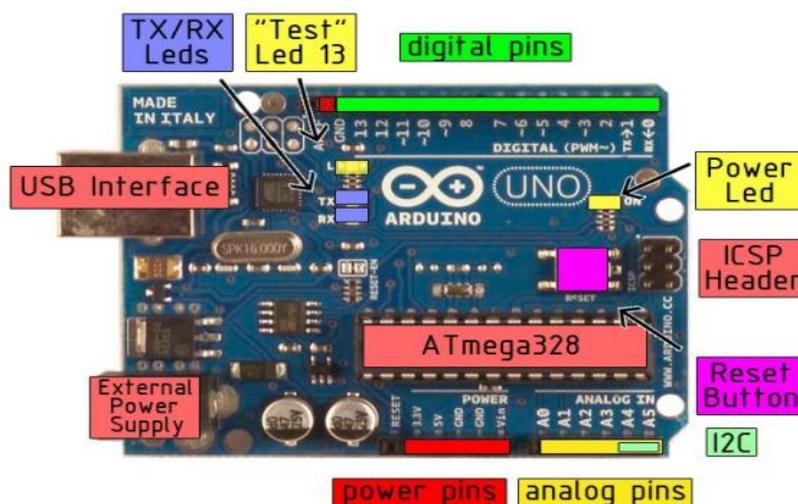


Figure 5: Arduino Uno PCB pin indication

There are several ways to connect the Arduino Uno to a computer, another Arduino, or other microcontrollers. On digital pins 0 (RX) and 1 (TX), the ATmega328 offers UART TTL (5V) serial connection. The board's ATmega8U2 routes this serial communication via USB and shows up to PC software as a virtual com port. The '8U2 firmware does not require an extra driver; it uses the regular USB COM drivers. But on Windows, you need a *.inf file.

D. Circuit design and integration:

The RFID module is connected to Arduino for authentication. The IR sensor detects vehicle presence and activates charging. The solar panel charges the battery, which supplies power to the wireless charging coil. The L298 coil wirelessly transfers energy to the receiving coil in the EV. An LCD screen and LED indicators provide user feedback.

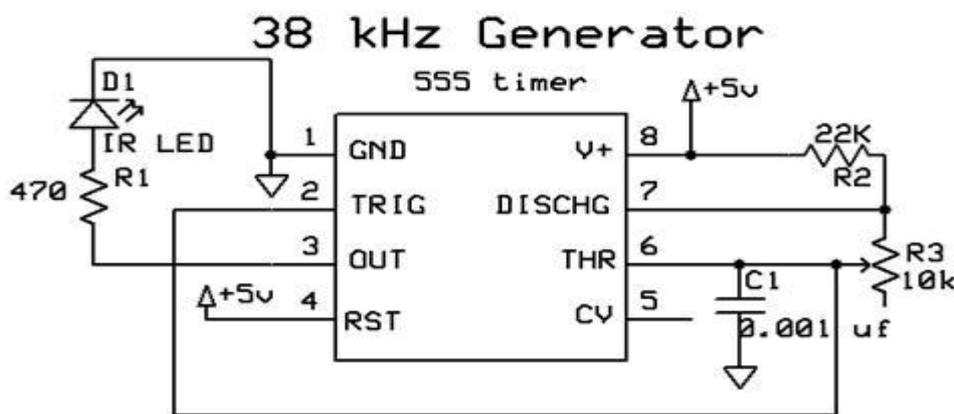


Figure 6 : Pulse generator

A 555 timer IC, 470 and 22K resistors, a 10K variable resistor, a 0.001 μ f capacitor, and one infrared LED are needed for the circuit above. Thus, choose the parts from the Proteus software's library. In the library menu bar, select the device or symbol. The window that is displayed below will then open. The components might be chosen in a different method. There is a toolbar on the left side of the workspace. Either select from the library or click the component mode option in that toolbar.

Choose every component from the library that has been added to the list of devices. To adjust the device's angle, click on it and use the rotate buttons. The chosen component is then positioned in the work space after you click there. After arranging all of the devices in the workspace, position the cursor at the component pin end and use the pen symbol to draw the connections. Figure 2 displays the intended circuit after all the components have been connected in accordance with the circuit. Once the design is finished, debug it and save it with some name. Since this is a virtual simulation, we can use the software to virtually visualize the outcome without really building a circuit and to develop the PCB layout for the circuit we need.

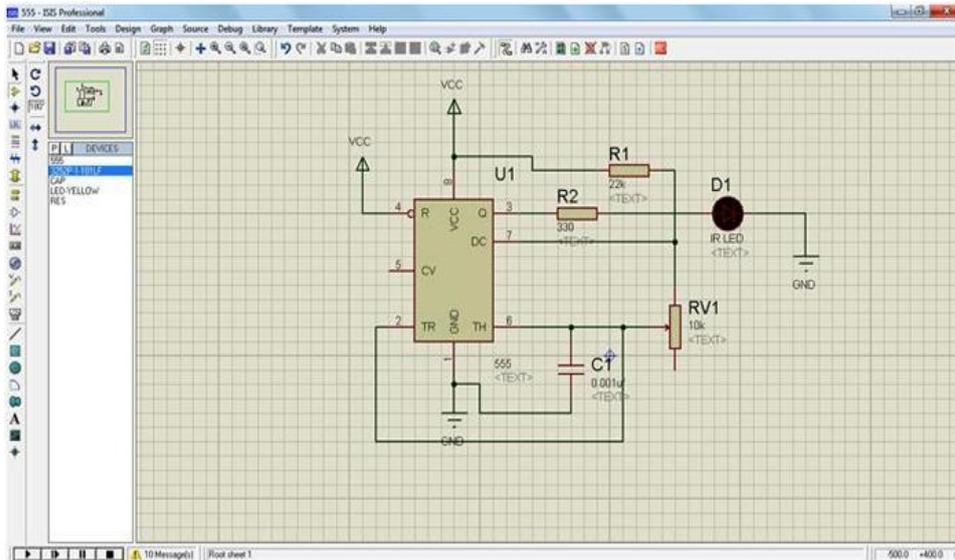


Figure 7: Designing circuit using proteus software

E. Software Implementation:

Arduino IDE is used for programming the microcontroller. The system logic includes RFID authentication, IR sensor detection, solar power control, and wireless charging activation. Real-time display updates on the LCD screen inform users about the charging status.

IV. RESULTS & DISCUSSION

The Hardware Tools and Specifications of the proposed system are as follows:

Table 1 : . Hardware Tools and Specifications

Component	Specification	Function
Arduino Uno	ATmega328P	Microcontroller to control all components
RC522 RFID Module	13.56 MHz	Reads RFID cards for authentication
LCD Display	16x2	Displays charging status and user authentication
Solar Panel	12V, 20W	Generates power for the charging station
IR Sensor	3.3V-5V	Detects vehicle presence in parking slot
L298 Wireless Charging Coil	5V-12V	Transfers power wirelessly to EV
Receiving Coil	5V-12V	Receives wireless power from the transmitter coil
Battery	12V, 7Ah	Stores excess solar energy for charging
LED Indicator	5V	Shows charging status
Receiving Coil	5V-12V	Receives wireless power from the transmitter coil
Battery	12V, 7Ah	Stores excess solar energy for charging
LED Indicator	5V	Shows charging status

Software Tools used:

- ❖ Arduino IDE – For coding and uploading programs to the Arduino Uno.
- ❖ Embedded C/C++ – Programming language used to implement system logic.
- ❖ Proteus – For circuit simulation and testing.
- ❖ Fritzing/TinkerCAD – For PCB design and wiring diagrams

The Solar Wireless EV Charging Station with RFID Authentication was successfully implemented and tested. The system achieved the following outcomes:

The RC522 RFID module accurately authenticated authorized users. Unauthorized users were denied access, ensuring security. The IR sensor correctly identified the presence of a vehicle in the charging slot. If no vehicle was detected, charging did not start, preventing energy waste. The L298 wireless charging coil successfully transmitted power to the receiving coil in the EV. The system delivered stable power output with minimal energy loss. The solar panel efficiently generated power and stored excess energy in the battery. The system provided uninterrupted charging even during low sunlight conditions.

The LCD display provided real-time status updates, including:
Authentication success/failure, Charging progress, Battery status
The LED indicator visually represented the charging process.

Prototype and Testing:

The charging process was fully automated, requiring no manual intervention. Security was enhanced by using RFID-based authentication, preventing unauthorized access.

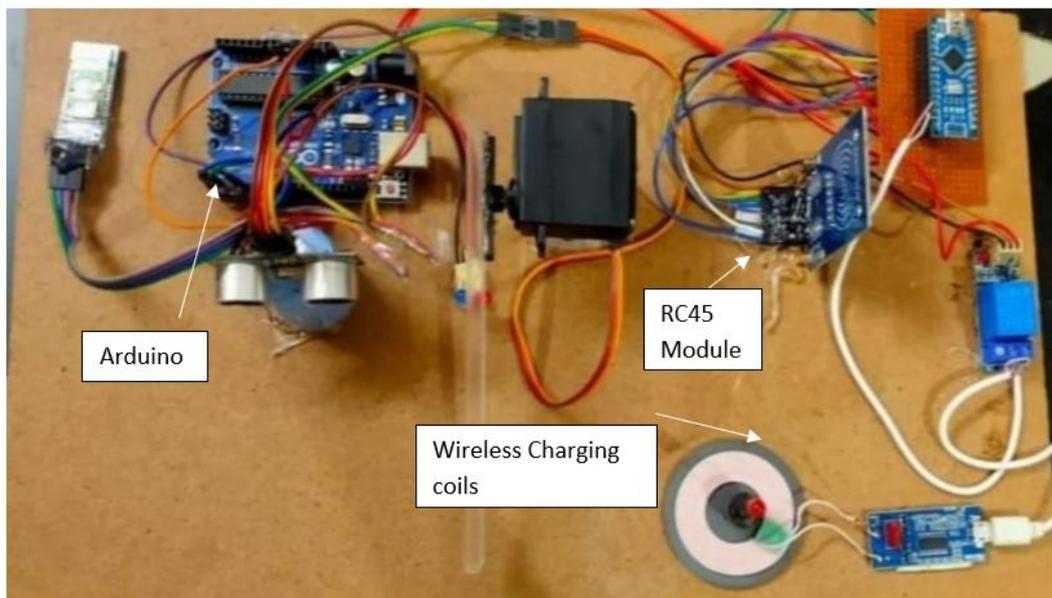


Figure 8: Hardware setup of proposed system

V. CONCLUSION

The proposed Solar Wireless Electric Vehicle (EV) Charging Station integrated with RFID authentication presents a secure, efficient, and environmentally sustainable alternative to conventional EV charging infrastructure. By harnessing solar energy, implementing wireless power transfer, and incorporating RFID-based user authentication, the system effectively addresses key limitations associated with traditional charging methods. This approach not only improves user convenience and system reliability but also contributes to the broader adoption of renewable energy technologies, thereby supporting the global shift toward sustainable and intelligent transportation systems.

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