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Smart Solar Powered Wireless EV Charging Station with IoT Integration

[1]Mr. Chetan Kidile, [2]Mr. Deeyaansh Mandiye, [3]Mr. Yash Tembhurne, [4]Ms. Shailaja Ganeshkar,

[5]Ms. Pranali Godde,[6]Ms. Samiksha Bahadure, [7]Ms. Sakshi Nandanwar

[1]Assistant Professor, [2,3,4,5,6,7]Students
Department of Electrical Engineering,
G. H. Raisoni College of Engineering and Management, Nagpur, India

Abstract: This paper introduces a prototype for charging an EV wirelessly through renewable energy sources while also monitoring the battery status and show this information on the Internet through an online website and mobile application. In this way, this prototype focuses on improvising the EV charging experience for the user, while also enhancing safety and efficiency. The system utilizes energy generated by the Solar PV module while also being able to use energy from the battery and main grid if needed. This prototype uses DC power for demonstration purposes. The Output power of the sources is reduced from a 12V DC supply to a stable 5V DC with the help of a Buck converter. This energy is sent to the transmitter coils for wireless power transfer (WPT). After the receiver coil receives this power, it is sent to the battery for charging while the IoT circuit, consisting of microcontroller, sensors and transmitter, monitors the battery parameters while also uploading this data to the internet for the user to monitor.

IndexTerms: **Solar Energy**, **Electric Vehicle (EV)**, **Battery Parameters, Grid supply**, **Transmitter Coil**, **Receiver Coil**, **IoT circuit**, **Real-time monitoring**, **Charging Efficiency**, **Centralized grid**, **Online Website, Mobile Application, Wireless Power Transfer (WPT).**

I. INTRODUCTION: The market for EVs is growing, so better charging stations are needed. The current charging stations draw power from centralized sources like conventional thermal power plants which use fossil fuels thatZ pollute the environment. The cars are connected through a cable, which proves to be inconvenient and dangerous in certain situations. As communication technology advances, manual monitoring has also to be taken into account. This prototype covers all these parameters to improve the current EV charging technology.

This prototype utilizes solar energy as a primary source for electrical power. Under properconditions, it will produce sufficient power for wireless power transfer. In case of insufficient power generation, battery will provide power for mutual induction. In case of insufficient charge in battery, grid supply will be consumed. This power is converted in a suitable form of either AC or DC. In this prototype, a DC-DC buck converter is used to provide a stable 5V DC supply to the transmitter coils. In a real-life scenario, transformers or other converters can be used. After flux linkage, the receiver coils receive this power and provide it to the battery of the EV. ACS-712 Current sensor and DHT-11 Temperature sensors are connected to an Arduino UNO board that continuously monitor parameters like Current, Voltage, Temperature and Humidity & displays them on an LCD display for instant monitoring. An ESP8266 Wi-Fi module is also connected to transmit and display this data through an online website or mobile application. This allows the user to monitor these parameters from a remote location. Hence, this prototype enhances user experience with EV charging, increases charging efficiency and safety with real-time monitoring system while also leaving room for future development.

II. OBJECTIVES

1. To design a Smart Solar Powered Wireless EV charging station with IoT integration.
2. To implement Wireless Power Transfer for contactless and efficient EV charging using inductive or resonant coupling methods.
3. To integrate an IoT-based system for real-time monitoring, displaying data of battery parameters on website and mobile app.
4. To promote clean and user-friendly EV charging that is sustainable, safe, and convenient for urban and rural applications.

III. LITERATURE REVIEW:

1. **Shweta L. Tiwari, S.R. Gaigowal & Kiran Raut. “Design of wireless charging system for E-Vehicle.” AIP Advances Publishing, ISSN 2158-3226, 26th August 2024:**

This paper describes the design of a wireless ground to vehicle charging system powered by solar energy for EV charging. This study also shows that efficiency is increased when the distance between windings is kept to a minimum. Furthermore, as the distance between the coils increases, the induced voltage on the secondary side decreases.

2. **Sheeraz Iqbal, Nahar F. Alshammari, Mokhtar Shouran & Jabir Massoud. "Smart and Sustainable Wireless Electric Vehicle Charging Strategy with Renewable Energy and Internet of Things Integration." MDPI Journal, ISSN: 2071-1050, 17th March 2024:**
This research introduces a novel approach to EV charging by integrating Wireless Power Transfer (WPT), Renewable Energy Resources (RERs), and Internet of Things (IoT). It employs a mix of solar energy systems and battery storage solutions to facilitate a sustainable and efficient energy supply to EVs.

3. **Aravind Kumar, Yashaswini, Rudresha. S & Kiran Kumar. "Solar-Based Wireless Charging System for Electric Vehicles. Journals of Power Electronics & Devices." Volume:09, 15th September 2023:**
The techniques mentioned in this paper allows the charging of Electric Vehicles while moving along, not at a charging station. Hence the technology supports the feasibility of a wireless, road-integrated, solar powered EV charging system using Solar Panels, Batteries, Transformers, Converters, Copper Coils, Controller, Regulators & LCD.

IV. BLOCK DIAGRAM:

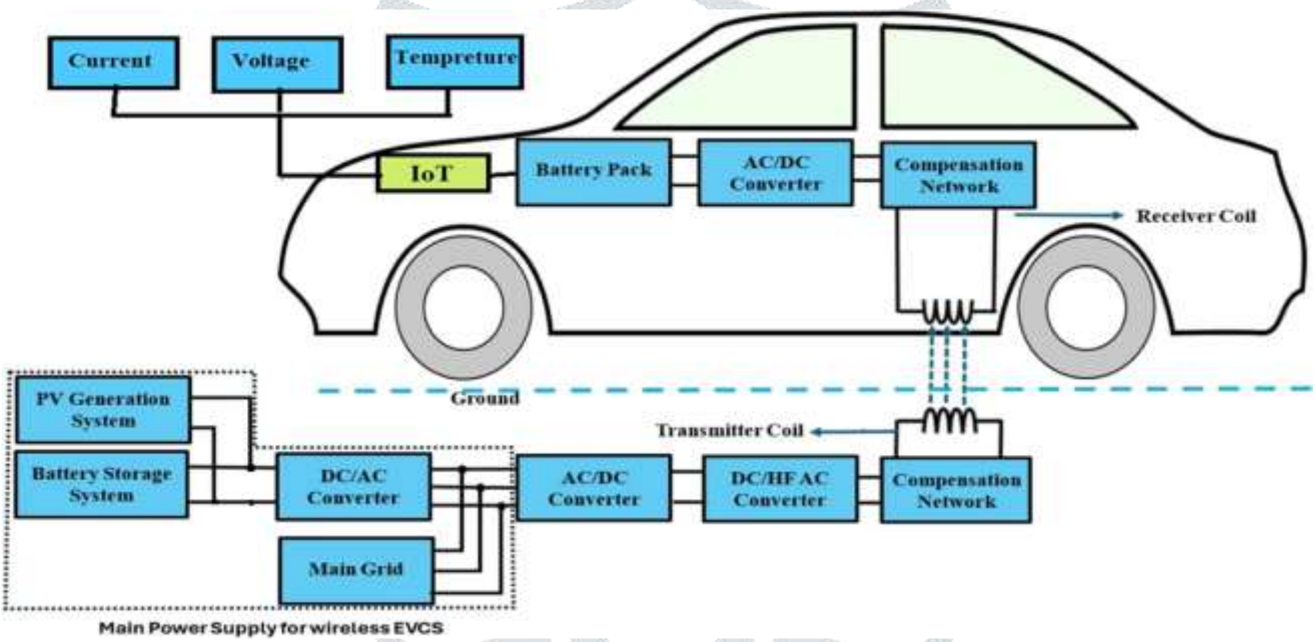


Fig1. Block Diagram for a possible real-life Charging system

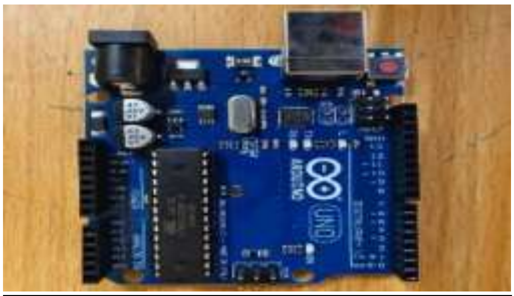
Above is the block diagram for a real-life wireless EV charging system. As shown above, the main power sources consist of Solar PV Module, a battery storage system and main grid. The power generated by these systems is different, therefore converters and transformers are used according to the requirement. After suitable conversion this power is transferred to the transmission coils for wireless power transfer.

As the receiver coil receives this power, it is transferred to the EV battery after suitable power level conversion for the battery charging. The IoT circuit, which consists of Arduino UNO, DHT-11 temperature sensor, ACS-712 current sensor and ESP8266 Wi-fi module work continuously to monitor the necessary battery parameters like Voltage, Current, Temperature & Humidity. Although the block diagram above shows a system working on AC power transfer, the prototype for this paper uses 5V DC For Wireless Power Transfer (WPT) system. The transmitter coils use an NPN Bipolar Junction Transistor which acts as a switching device to generate a changing magnetic field for flux linkage.

The Arduino UNO acts as a central microcontroller which houses all the required electronic components like the current sensor and temperature sensor along with ESP8266 Wi-fi module. First the data is recorded by the sensors and sent to the Arduino for processing according to the programming after which it is sent to the ESP8266 to transmit this data to the Internet. This data can be accessed by the user through an online website or a mobile application for remote monitoring. With proper training or by instruction manual, the user can take necessary precautions and actions in case the parameters go outside of the specified value which will increase the battery life and performance of the EV while also enhancing safety and preventing any sorts of accidents.

V. COMPONENTS USED:

1) Arduino UNO:

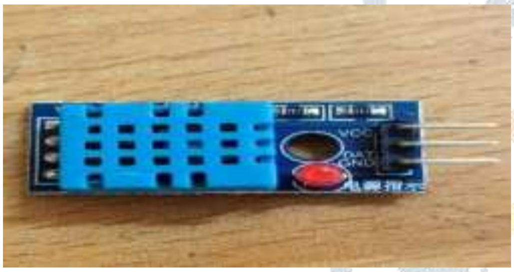


- Microcontroller – Atmega 328P
- Operating Voltage-5V
- Input Voltage (recommended)-7V to 12V
- Digital I/O Pins- 14 (of which 6 provide PWM output)
- PWM Digital I/O Pins- 6 (pins-3,5,6,9,10,11)
- Analog input pins-6 (pins- A0 to A5)

2) Electrobot ESP8266 ESP-01

- Flash memory-1Mb (1 Flash)
- Operating Voltage- 3V to 3.6V DC
- Digital I/O Pins- 2 (GPIO-0 and GPIO-2)
- Communication Interface- UART (Serial-TX/RX)
- Frequency Range- 2.4Ghz
- Power Consumption- 70mA

3) DHT11 Digital Temperature Sensor



- Sensor type- Digital Temperature & Humidity Sensor
- Temperature Range- 0°C to 50°C
- Humidity Range- 20% to 90% RH
- Humidity Accuracy - +- 5% RH
- Operating Voltage- 3.3V to 5V
- Calibration- Factory Calibrated

4)ACS712 5A Current Sensor Module

- Sensor IC- Allegro ACS712ELC-05B
- Current Measuring Range- +- 5A (AC or DC)
- Sensitivity- 185 m V/A
- Operating Voltage (VCC)- 5V DC
- Signal Pins- VCC, GND, OUT
- Output Voltage at 0A- 2.5V
- Response Time- <5 micro seconds

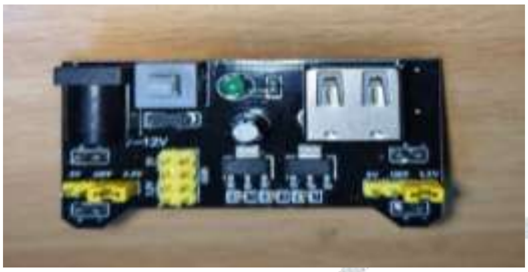
5)16x2 LCD Display with I2C Module

- I)16x2 LCD Module
  - Display Format- 16 Characters x 2 Lines
  - Driver IC- HD44780 or Compatible
  - Operating Voltage- 5V DC
- II) I2C Interface Adapter
  - Voltage Compatibility- 5V
  - Pins- VCC, GND, SDA, SCL

6)AC to DC Switch Mode Power Supply Module 230V/12V 2A

- Input Voltage: 100 V– 240 V AC, 50 Hz (mains)
- Supplied via two AC input wires. Internally rectified and filtered using diodes and capacitors
- Output Voltage: +5 V, +9 V, or +12 V DC (depends on design)
- Output wires: red (+ve) and black (–ve) on the left side
- Output Current:0.5 A – 2 A (small size, ~10–20 W power)
- Efficiency: 70–85% (better than linear supplies)

7) MB102Breadboard Power Supply Module (DC to DC Buck Converter)

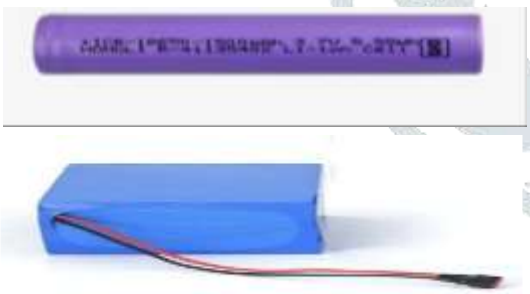


- Input Voltage: 6.5V – 12V (via DC jack) or 5V (via USB)
- Output Voltages: 3.3V and 5V regulated outputs
- Output Current (max): Typically up to 700 mA
- Output Interface: Male headers for +ve and –ve power rails
- Additional Ports: USB Type-A port for output or alternate input
- Onboard Switch: Power ON/OFF control

8)Solar Photovoltaic (PV) panel

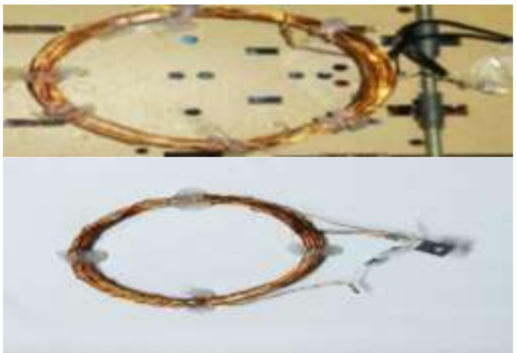
- Luminous LU 12 25*model
- Rated Power Output - 25 Watts (nominal)
- Nominal Voltage - 12V
- Open Circuit Voltage (Voc)- ~21V (typical for 12V, 25W panels)
- Short Circuit Current (Isc)- ~1.5 A (approx.)
- Max Power Voltage (Vmp)- ~17–18V
- Max Power Current (Imp) - ~1.4 A
- Cell Type - Polycrystalline silicon

9)Lithium-ion rechargeable Batteries



- Model: ICR18650
- 18650 = 18 mm diameter and 65 mm length
- Capacity: 1500mAh, Nominal Voltage: 3.7V, Fully Charged: 4.2V, Discharged: 3.2V
- 12V lithium-ion rechargeable pack (wrapped in blue heat-shrink with a two-wire connector)
- Nominal Voltage: 12V (~11.1V depending on cell configuration)
- 3S (3 cells in series):11.1V nominal, 12.6V fully charged
- Capacity: ~2200mAh

10) Wireless Power Transmission Circuit (Copper Coils)



- WPT 5coils (4 transmitter ,1 receiver)
- Input Voltage: 5V DC (some can handle up to 12V)
- Output Voltage: 5V DC (regulated, on receiver side)
- Power Transfer: Typically, 1W to 5W
- Operating Frequency- 100 kHz to 200 kHz (depends on the module)
- Coil Diameter: ~50–75 mm
- Transistor Type: NPN Bipolar Junction Transistor (BJT)
- Resistance: 1k Ohm
- Power rating: 0.25W, Tolerance: +-5%

VI. ADVANTAGES OF THE SYSTEM

[1] Solar PV Modules generate clean, pollution free energy and also reduce carbon footprint leading to a cleaner environment.

[2] Use of multiple energy sources like Batteries and Main Grid Connection ensure power availability all the time for usage. More renewable energy sources like Wind Energy can also be implemented with further technological development.

[3] Wireless Charging system eliminates the tedious usage of Charging cable, while also preventing accidents which could occur due to cable damage.

[4] IoT monitoring system ensures continuous data collection, data processing and transmission of this data in the internet for user convenience.

[5] As remote monitoring becomes possible because of IoT integration, the safety of EV is ensured even when the user is not near the EV, leading to user comfort and assurance.

VII. RESULTS AND DISCUSSION

Fig 2: System Hardware during OFF State

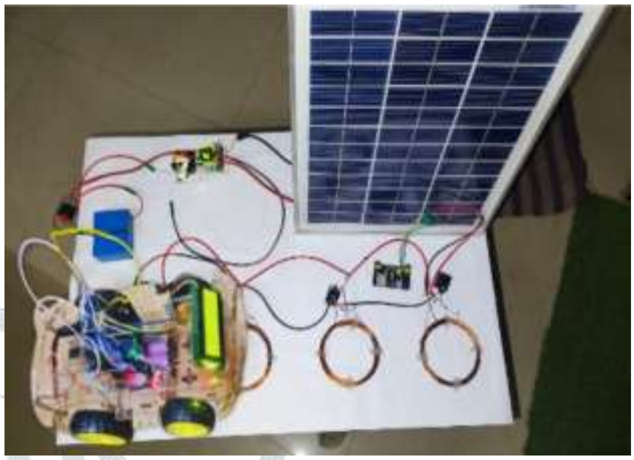


Fig 3: System Hardware during ON State

Fig 4: Display of Battery Parameters on an Online Website

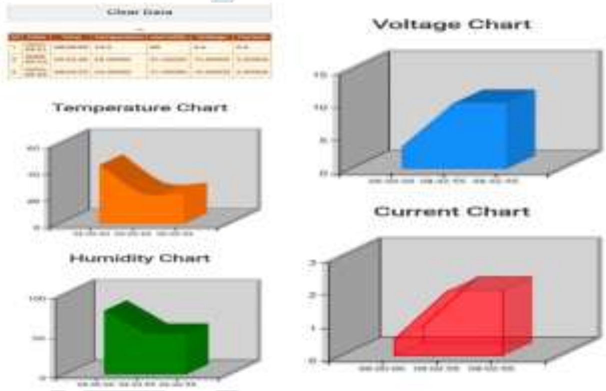


Fig 5: Display of Battery Parameters on a Mobile Application

In this way, the aforementioned prototype can help reduce the dependency of charging stations on centralized grid supply which depend on fossil fuel consumption and indirectly improve the condition of environment by reducing environmental pollution. It will spread awareness about the advantages of renewable energy sources and environmental awareness. As the system is wireless, Electrical hazards that could occur in a cabled EV charging system are eliminated entirely. Wireless system is also easier and less tedious to use for the user. This helps reduce accidents and other minor issues with EV charging experience for the user.

As the system also includes battery storage systems and main grid connection, power availability is always ensured in the charging station so that the user may recharge their vehicles without any power shortage or instability. In case of excess energy generation, the extra energy can be sent back to the grid for utilization aside from recharging the battery. With further development in technology more renewable energy sources like wind energy can also be integrated into this proposed system which will further increase the charging station's reliability and reduce dependency on the grid as it will be able to cover up the power generation shortage of solar panels, especially during rainy seasons and night time when solar energy generation is low. The IoT based real-time monitoring system ensures online data availability for the user to enable remote monitoring when the user is not near the EV to ensure battery health.

There is also room for further development for implementing remote controlling system, complete automation system for proper power source management, Hydraulic based Transmitter coil uplifting system for optimum power transfer and many other amazing development ideas with proper resources and time investment in the aforementioned system.

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