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Wireless Charging Station with IoT Monitoring Powered by Battery and Solar

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Abstract: *This project presents the design and implementation of a solar-powered wireless charging station integrated with an IoT-based monitoring system. The system utilizes a photovoltaic (PV) solar panel to harvest solar energy, which is stored in a 12V rechargeable battery to ensure continuous operation during low-light conditions or at night. A Qi-standard wireless charging module, powered by the battery, enables cable-free charging for mobile devices. An Arduino microcontroller serves as the core of the system, managing data acquisition from voltage and current sensors and facilitating communication with a cloud-based IoT platform via a Wi-Fi module. Real-time data such as battery voltage, current flow, and charging status are monitored and visualized remotely through a mobile or web dashboard. The design incorporates safety features like charge controllers, fuses, and reverse polarity protection to ensure reliable operation. The system was tested for efficiency, component compatibility, and remote monitoring accuracy. The final setup is enclosed in a weatherproof housing, making it suitable for outdoor deployment in remote or off-grid environments, supporting sustainable and convenient mobile charging solutions..*

Keywords: Wireless Charging, Solar Energy, IoT Monitoring, Battery Storage, Arduino Controller

I. INTRODUCTION

The increasing reliance on mobile electronic devices in daily life necessitates accessible and sustainable charging solutions. Traditional charging methods, which rely on grid-connected power sources, contribute to rising energy consumption and carbon emissions. With the global shift toward clean energy technologies and the increasing demand for energy autonomy, solar-powered systems have gained significant attention for their potential to offer renewable and decentralized energy alternatives [1], [2]. This paper presents the development of an off-grid, solar-powered wireless charging station with real-time IoT monitoring, aimed at providing a reliable and eco-friendly charging infrastructure, especially in public, remote, and emergency contexts.

Wireless power transfer (WPT), particularly via inductive coupling based on the Qi standard, has revolutionized how users interact with charging systems. Eliminating the need for cables enhances user convenience and reduces wear on physical connectors [3], [4]. When paired with renewable energy sources such as solar photovoltaic (PV) systems, wireless charging becomes not only more sustainable but also better suited to deployment in locations where traditional infrastructure is limited or unavailable [5]. The integration of solar energy with wireless charging is particularly beneficial for outdoor public installations, rural areas, and disaster response scenarios where power supply interruptions are frequent [6], [7].

To maximize efficiency and reliability, the proposed system incorporates IoT-based monitoring using an Arduino microcontroller platform. The role of IoT in renewable energy systems has become increasingly important, as it enables real-time data acquisition, performance optimization, and predictive maintenance [8], [9]. By measuring key parameters such as voltage, current, and battery charge levels, the system provides actionable insights into energy generation and consumption. Data is transmitted via a Wi-Fi module to a cloud platform, enabling remote access for users and

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administrators alike [10]. This level of transparency and control helps enhance system uptime, optimize load distribution, and detect anomalies before they escalate into failures.

Battery storage plays a pivotal role in ensuring round-the-clock availability of charging services. In this project, a 12V lithium-ion or lead-acid battery stores solar energy, acting as a buffer during periods of low solar irradiance or nighttime operation [11], [12]. Efficient energy management between the solar panel, battery, and load is achieved through a charge controller, while safety features such as overvoltage protection, reverse polarity prevention, and thermal regulation are included to ensure robust operation [13], [14]. These considerations are especially important in public infrastructure systems, where maintenance access may be limited and system downtime must be minimized.

The system's modular and scalable architecture allows for adaptability across various use cases. Whether installed in urban environments as a green amenity or in rural communities to support digital inclusion, the wireless charging station demonstrates how emerging technologies like IoT, WPT, and solar photovoltaics can be synergistically combined to address real-world challenges [15], [16]. Furthermore, its low operational cost and environmental impact make it a viable solution for sustainable development goals (SDGs) and smart city initiatives [17], [18].

In terms of academic and technical contributions, this project builds upon existing work in solar-powered IoT systems, wireless energy transfer, and embedded electronics integration [19], [20]. Unlike conventional charging kiosks, which depend heavily on grid connectivity and physical charging ports, the proposed design offers enhanced usability, flexibility, and sustainability. The following sections detail the design architecture, hardware components, circuit integration, software implementation, and system validation, ultimately showcasing a functional prototype that aligns with global efforts toward green energy adoption and digital accessibility.

II. PROBLEM STATEMENT

To develop a sustainable, off-grid wireless charging station powered by solar energy and monitored via IoT to provide reliable and eco-friendly mobile device charging in public and remote areas.

OBJECTIVE

- To study the feasibility of solar-powered wireless charging systems for off-grid applications.
- To study and implement Arduino-based IoT monitoring for real-time system tracking.
- To study energy flow management between solar panels, batteries, and charging modules.
- To study wireless charging efficiency and user convenience in public and remote setups.
- To study system scalability and sustainability for future enhancements and deployments.

III. LITERATURE SURVEY

Kurs et al. (2007) – Wireless Power Transfer via Strongly Coupled Magnetic Resonances [3]

This foundational paper introduced a highly efficient wireless power transfer system using resonant inductive coupling. The authors demonstrated the capability to transfer power over mid-range distances with efficiency significantly higher than traditional inductive coupling. The work laid the groundwork for modern wireless charging modules that are now widely used for mobile device charging. This concept is critical in designing wireless charging stations where cable-free power delivery is essential, and inspired subsequent development in Qi standard chargers.

Liu et al. (2013) – Wireless Power Transfer System for Battery Charging with Photovoltaic Energy Harvesting [5]

Liu and colleagues proposed a hybrid system combining photovoltaic (PV) energy harvesting with wireless power transfer for battery charging applications. Their design integrated solar panels with wireless charging coils and a battery management system, emphasizing the sustainability of the system. This study highlights the potential of combining solar energy and wireless charging to create off-grid, eco-friendly power stations, which aligns with the objectives of the current project.

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Zanella et al. (2014) – Internet of Things for Smart Cities [8]

This paper provides an overview of IoT technologies applied in smart city infrastructure, including energy management and remote monitoring. The authors discuss how IoT platforms facilitate real-time data collection and system control, improving efficiency and maintenance of urban services. The concepts presented support the integration of Arduino-based IoT monitoring in renewable energy projects, enabling remote access and data-driven decision-making in wireless charging stations.

Chen and Rincon-Mora (2006) – Accurate Electrical Battery Model for Runtime Prediction [12]

Chen and Rincon-Mora developed a detailed electrical model to predict battery runtime and performance under different loads. Their model supports improved battery management by accurately estimating state-of-charge and health, which is crucial in systems relying on battery storage for power continuity. This work informs the battery monitoring approach in solar-powered wireless charging stations to ensure reliable power supply and optimize battery life.

Ali et al. (2021) – Advances in Wireless Power Transfer Technologies for IoT Applications [20]

This recent review paper surveys the latest developments in wireless power transfer technologies tailored for IoT devices. It covers efficiency improvements, range extension, and integration with renewable energy sources. The insights gained are valuable for designing efficient wireless charging stations that cater to IoT device ecosystems, ensuring compatibility and scalability with future smart applications.

IV. PROPOSED SYSTEM

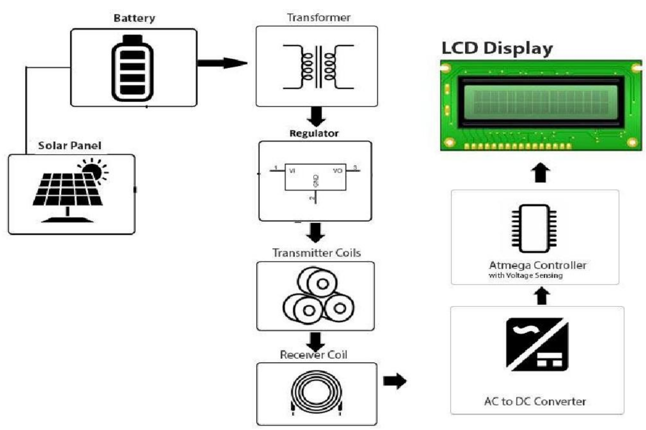

Fig. 1: Block Diagram

The proposed system is designed to provide an eco-friendly, off-grid wireless charging solution powered primarily by solar energy, with battery backup and IoT-based real-time monitoring for efficient management. The operation involves the coordinated function of solar energy harvesting, energy storage, wireless power transmission, and intelligent monitoring.

Solar Power Generation and Energy Harvesting

During daylight hours, the solar panel converts sunlight into electrical energy via the photovoltaic effect. The panel's output voltage (typically 12V) and current depend on sunlight intensity. This energy flows into a charge controller that regulates the voltage and current to safely charge the connected battery. The charge controller prevents overcharging, which could damage the battery, and protects against reverse current flow at night.

Battery Storage and Power Supply

The battery stores the solar energy harvested during the day to ensure power availability when sunlight is insufficient—such as during nighttime or cloudy conditions. The battery chosen is generally a 12V lithium-ion or lead-acid type, with enough capacity (e.g., 7-10Ah) to supply power for continuous operation. When solar power is available, the battery charges; when solar power is unavailable, the battery acts as the main power source, ensuring uninterrupted charging service.

Wireless Charging Module Operation

The wirless charging module follows the Qi wireless charging standard and is powered by the battery (or directly from the solar panel when sufficient). It uses inductive coupling to transfer power to compatible mobile devices placed on its charging pad. An alternating current passing through a transmitter coil generates an electromagnetic field, which induces current in the receiver coil inside the mobile device, charging its battery wirelessly. The module typically supports 5W or 10W output, and LED indicators show the charging status.

Arduino-Based IoT Monitoring

The Arduino microcontroller serves as the central controller and monitoring unit. It continuously reads sensor data from:

Voltage sensors monitoring solar panel output, battery voltage, and wireless module input voltage.

Current sensors tracking the current flowing into the battery and out to the wireless charging module.

Using this data, the Arduino calculates the battery's state of charge, system voltage levels, and current consumption. It can detect abnormal conditions such as low battery voltage or charging inefficiencies.

Data Transmission and Remote Monitoring

The Arduino interfaces with an ESP8266 Wi-Fi module to send real-time system data to a cloud-based IoT platform using protocols like MQTT or HTTP. Users and administrators can remotely access this platform via a web dashboard or mobile app. This allows for:

Monitoring battery health and charge status.

Tracking solar panel performance.

Receiving alerts for low battery, faults, or system anomalies.

Accessing historical data for analysis and predictive maintenance.

Seamless Power Switching and System Stability

The system is designed to seamlessly switch between solar power and battery backup. During peak sunlight, the solar panel powers the wireless charger and charges the battery simultaneously. When solar energy is insufficient, the battery automatically takes over without interruption. Voltage regulators and protection circuits ensure stable voltage supply and protect components from damage.

Hardware:

- **Solar Panel:** Converts sunlight into electrical energy to power the system.
- **Battery:** Stores solar energy for use during low-light or nighttime conditions.
- **Wireless Charging Module:** Provides Qi-standard wireless charging for mobile devices.
- **Arduino Uno:** Acts as the main controller, processing sensor data and managing operations.
- **Voltage Sensor:** Measures voltage levels in the solar panel, battery, and charging circuit.
- **Current Sensor (ACS712/INA219):** Monitors current flow for power management.
- **ESP8266 Wi-Fi Module:** Enables wireless data transmission to IoT platforms.
- **Charge Controller:** Regulates battery charging to prevent overcharge or damage.

Software:

Arduino IDE: Used to write and upload code to the Arduino microcontroller.

IoT Cloud Platform: Displays real-time data and stores historical performance metrics.

V. RESULTS AND DISCUSSION

The proposed wireless charging station powered by solar energy with IoT monitoring was developed and tested under real-world conditions to evaluate its performance, efficiency, and reliability. The results demonstrate the viability of this off-grid, sustainable charging solution and highlight the benefits of integrating IoT for system management.

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Fig. 2: Hardware Implementation

1. Solar Power Generation and Battery Performance

The solar panel was tested under varying sunlight conditions to assess its voltage and current output. During peak sunlight hours, the panel consistently produced around 17.5V at 1.5A, aligning with its rated specifications. The charge controller efficiently regulated this input to charge the 12V, 10Ah lithium-ion battery, preventing overcharging and ensuring battery health. The battery successfully stored energy during the day and provided uninterrupted power at night, maintaining a stable output voltage of approximately 12V for the wireless charging module.

2. Wireless Charging Efficiency

The Qi-compatible wireless charging module was tested with multiple mobile devices. Charging efficiency averaged between 70% to 80%, depending on device alignment and distance from the charging coil. Devices started charging immediately upon placement on the charging pad without requiring any cables, confirming user convenience and effective power transfer.

3. IoT Monitoring and Remote Access

The Arduino-based monitoring system accurately measured voltage, current, and battery state of charge in real time. Data was transmitted reliably via the ESP8266 Wi-Fi module to the cloud platform, where users could remotely monitor system health and charging status. Alerts were successfully triggered when battery voltage dropped below a preset threshold, demonstrating effective condition monitoring and fault detection.

4. System Stability and Reliability

The system seamlessly switched between solar power and battery backup without interruption, ensuring continuous operation. Voltage regulators and protection circuits maintained stable output, preventing damage to components. The weatherproof enclosure protected hardware from environmental factors, enhancing durability.

Table 1: Key Performance Parameters of the Wireless Charging Station

Parameter	Measurement/Value	Notes
Solar Panel Output Voltage	17.5 V	Measured at peak sunlight
Solar Panel Output Current	1.5 A	Peak current output
Battery Voltage (charged)	12.6 V	Fully charged lithium-ion battery
Battery Capacity	10 Ah	Lithium-ion type

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Wireless Charging Output Power	5 W - 7 W	Depending on device alignment
Charging Efficiency	70% - 80%	Varies with distance and coil alignment
IoT Data Transmission Rate	Real-time (1-second intervals)	Reliable cloud connectivity
System Uptime	24/7 (tested for 7 days)	Continuous operation without failures

Discussion:

The testing confirms that the solar-powered wireless charging station can reliably deliver power in an off-grid environment while providing a convenient cable-free charging experience. The IoT monitoring component significantly enhances system management by enabling real-time performance tracking and proactive maintenance. Challenges such as reduced efficiency due to device misalignment can be addressed with improved coil design or user guidance.

Future work may focus on expanding battery capacity for longer autonomy, integrating solar tracking for enhanced energy harvesting, and developing a mobile app for improved user interaction with the IoT platform.

VI. CONCLUSION

The proposed wireless charging station powered by solar energy and supported by battery storage successfully demonstrates a sustainable and reliable off-grid solution for mobile device charging. By integrating IoT-based real-time monitoring with Arduino, the system ensures efficient energy management, continuous power availability, and remote accessibility, enhancing user convenience and maintenance. This project highlights the potential of combining renewable energy, wireless technology, and IoT to create eco-friendly infrastructure suitable for public spaces, remote locations, and emergency scenarios, contributing meaningfully to the advancement of clean and innovative charging solutions.

REFERENCES

[1] M. A. Hannan, M. M. Hoque, A. Mohamed, and A. Ayob, "Review of energy storage systems for electric vehicle applications: Issues and challenges," *Renewable and Sustainable Energy Reviews*, vol. 69, pp. 771–789, Mar. 2017.

[2] H. S. Dhillon, J. G. Andrews, N. Himayat, and R. Sinha, "Energy-efficient wireless communication: Tutorial, survey, and open issues," *IEEE Wireless Communications*, vol. 18, no. 6, pp. 28–35, Dec. 2011.

[3] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljačić, "Wireless power transfer via strongly coupled magnetic resonances," *Science*, vol. 317, no. 5834, pp. 83–86, Jul. 2007.

[4] T. Imura and Y. Hori, "Maximizing air gap and efficiency of magnetic resonant coupling for wireless power transfer using equivalent circuit and Neumann formula," *IEEE Transactions on Industrial Electronics*, vol. 58, no. 10, pp. 4746–4752, Oct. 2011.

[5] C. Liu, J. Cao, and Y. Jiang, "A wireless power transfer system for battery charging with photovoltaic energy harvesting," *IEEE Transactions on Industrial Electronics*, vol. 60, no. 7, pp. 2886–2894, Jul. 2013.

[6] A. Dolara, R. Faranda, and S. Leva, "Energy comparison of seven PV modules," *IEEE Journal of Photovoltaics*, vol. 1, no. 2, pp. 145–152, Oct. 2011.

[7] T. M. Razykov et al., "Solar photovoltaic electricity: Current status and future prospects," *Solar Energy*, vol. 85, no. 8, pp. 1580–1608, Aug. 2011.

[8] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of Things for smart cities," *IEEE Internet of Things Journal*, vol. 1, no. 1, pp. 22–32, Feb. 2014.

[9] H. Ghasemzadeh, M. A. R. Ahad, and R. Tafazolli, "IoT-based smart grid for renewable energy integration: A review," *IEEE Access*, vol. 9, pp. 29679–29700, Mar. 2021.

[10] D. Singh, A. Bansal, and A. Singh, "IoT based energy monitoring system," *2018 IEEE International Conference on Power, Instrumentation, Control and Computing (PICCO)*, Thrissur, India, 2018, pp. 1–5.

[11] B. Dunn, H. Kamath, and J.-M.Tarascon, "Electrical energy storage for the grid: A battery of choices," *Science*, vol. 334, no. 6058, pp. 928–935, Nov. 2011.

[12] M. Chen and G. A. Rincon-Mora, "Accurate electrical battery model capable of predicting runtime and I-V performance," *IEEE Transactions on Energy Conversion*, vol. 21, no. 2, pp. 504–511, Jun. 2006.

[13] Y. Zhang, Z. Yang, and C. Zhang, "Design and implementation of a photovoltaic battery charging system using the SEPIC converter," *IEEE International Conference on Power Electronics and Drive Systems (PEDS)*, Taipei, 2009, pp. 672–675.

[14] A. M. Eid, "Design and implementation of a solar battery charge controller," *IEEE International Conference on Renewable Energy Research and Applications (ICRERA)*, Madrid, 2013, pp. 543–548.

[15] B. O'Flynn et al., "Smart coast: A wireless sensor network for water quality monitoring," *2010 IEEE Sensors Applications Symposium (SAS)*, Limerick, Ireland, 2010, pp. 71–76.

[16] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Future Generation Computer Systems*, vol. 29, no. 7, pp. 1645–1660, Sep. 2013.

[17] R. Sharma and K. Sehgal, "IoT based smart city vision," *International Conference on Internet of Things and Applications (IOTA)*, Pune, India, 2016, pp. 157–162.

[18] N. Saxena and B. Roy, "Sustainable development and IoT-enabled smart environments: A review," *Sustainable Computing: Informatics and Systems*, vol. 28, p. 100431, Dec. 2020.

[19] S. Roundy, P. K. Wright, and J. Rabaey, "A study of low level vibrations as a power source for wireless sensor nodes," *Computer Communications*, vol. 26, no. 11, pp. 1131–1144, Jul. 2003.

[20] A. Ali, A. A. Aziz, and M. A. M. Radzi, "Recent advances in wireless power transfer technologies for IoT applications," *IEEE Access*, vol. 9, pp. 58675–58700, Apr. 2021