Hybrid Charging Station for Multiple Devices with Theft Protection

Sumedh V Landage[1], Suhas L Galave[2], Ruturaj A Chorkar[3]
Swapnil S Sudake[4]
[1]*EE Students, SVERI'S College of Engineering, Pandharpur India*
[2]*Assistant Professor, SVERI'S College of Engineering, Pandharpur, India*

***Abstract*—With the rapid increase in the use of portable electronic devices, the demand for efficient, secure, and multi-functional charging solutions has significantly grown. This paper presents the design and development of a hybrid charging station for multiple devices with integrated theft protection. The proposed system combines renewable energy sources, such as solar power, with conventional electrical supply to ensure uninterrupted and energy-efficient operation. The hybrid architecture intelligently switches between power sources based on availability, thereby optimizing energy consumption and reducing dependency on non-renewable resources. The charging station is designed to support simultaneous charging of various devices, including smartphones, tablets, and laptops, through multiple output interfaces such as USB and wireless charging modules. To address security concerns in public and semi-public environments, an advanced theft protection mechanism is incorporated. This includes features such as RFID-based user authentication, smart locking compartments, and real-time alert systems that notify users in case of unauthorized access. Additionally, the system integrates IoT-based monitoring for tracking energy usage, device status, and security events, enhancing user convenience and system reliability. The proposed solution aims to provide a sustainable, user-friendly, and secure charging infrastructure suitable for locations such as universities, transportation hubs, and commercial spaces. Experimental results demonstrate improved energy efficiency, reliable performance, and enhanced security compared to conventional charging stations.**

***Index Terms*—Hybrid Charging Station, Solar Energy, Multi-Device Charging, Theft Protection, RFID Authentication, IoT Monitoring, Energy Efficiency, Smart Charging System**

I. INTRODUCTION

In today's digital era, the widespread use of portable electronic devices such as smartphones, tablets, and laptops has created an increasing demand for reliable and accessible charging infrastructure. Public places like educational institutions, transportation hubs, shopping canters, and workplaces often face challenges in providing sufficient and secure charging facilities. Conventional charging stations primarily depend on a single power source and lack advanced features such as energy optimization and user security, which limits their efficiency and usability.

To address these challenges, this project proposes a hybrid charging station for multiple devices with theft protection, which integrates both renewable and conventional energy sources. The hybrid approach utilizes solar energy as a primary power source while maintaining a backup connection to the electrical grid, ensuring uninterrupted charging even during low solar availability. This not only enhances energy efficiency but also promotes the use of sustainable and eco-friendly solutions.

Another critical concern in public charging systems is the safety of devices. Users are often hesitant to leave their devices unattended due to the risk of theft or unauthorized access. To overcome this issue, the proposed system incorporates an advanced theft protection mechanism, including secure compartments, authentication methods such as RFID or password-based access, and alert systems to ensure device safety.

Furthermore, the system is designed to support multiple devices simultaneously with various charging interfaces, improving convenience and accessibility. The integration of smart monitoring technologies, such as IoT-based tracking, allows users to monitor charging status and system performance in real time.

Overall, this project aims to develop a smart, energy-efficient, and secure charging solution that meets modern user demands while addressing environmental and security concerns. The proposed system has the potential to significantly improve the usability and reliability of public charging infrastructure.

II. PROBLEM STATEMENTS

The rapid growth in the use of portable electronic devices such as smartphones, tablets, and laptops has created a significant demand for accessible and efficient charging facilities, especially in public and semi-public environments. However, existing charging solutions face several limitations that reduce their effectiveness and user adoption.

Firstly, most conventional charging stations rely solely on grid electricity, leading to increased energy consumption and lack of sustainability. In situations of power outages or limited access to electricity, these systems fail to provide continuous service. There is a need for a hybrid solution that can integrate renewable energy sources, such as solar power, to ensure uninterrupted and eco-friendly operation.

Secondly, current charging stations often support a limited number of devices and lack compatibility with multiple charging standards, making them inconvenient for users with diverse devices. The absence of efficient power management systems further reduces their performance when multiple devices are connected simultaneously.

Another major concern is the lack of security in public charging infrastructures. Users are often reluctant to leave their devices unattended due to the risk of theft or unauthorized access. Existing systems generally do not provide adequate protection mechanisms such as authentication, secure storage, or real-time alerts

Additionally, there is limited integration of smart technologies in traditional charging systems. The absence of monitoring features prevents users from tracking charging status, energy usage, and system performance, resulting in poor user experience and inefficient resource utilization.

Therefore, there is a need to develop a hybrid charging station for multiple devices with integrated theft protection and smart monitoring, which ensures energy efficiency, device compatibility, security, and user convenience in modern environments.

III. LITERATURE SURVEY

Recent advancements in charging technologies and renewable energy systems have led to the development of smart and efficient charging infrastructures for portable electronic devices. Several researchers have focused on integrating renewable energy sources, particularly solar power, into charging stations to improve sustainability and reduce dependence on conventional electricity. Studies have demonstrated that solar-powered charging systems can significantly reduce operational costs and carbon emissions while maintaining reliable performance under varying environmental conditions. However, most of these systems are limited by their dependency on sunlight availability, which affects consistency in power generation.

To overcome this limitation, hybrid energy systems have been introduced, combining solar energy with traditional grid power. Research in this domain highlights the effectiveness of hybrid charging stations in ensuring uninterrupted power supply by automatically switching between energy sources based on availability. many hybrid models lack advanced energy management algorithms, which can lead to inefficient utilization of available resources when multiple devices are connected. In addition to energy efficiency, the increasing demand for charging multiple devices simultaneously has been addressed in various studies. Researchers have proposed multi-port charging stations equipped with USB interfaces, fast-charging capabilities, and wireless charging technologies. These systems are designed to accommodate different types of devices, improving user convenience in public spaces. However, challenges such as uneven power distribution, overheating, and limited scalability still exist, particularly when handling high loads or multiple users at the same time. Security remains a critical concern in public charging infrastructures. Several studies have explored the implementation of authentication mechanisms such as RFID, biometric systems, and password-based access to prevent unauthorized usage. Secure locker-based charging systems have also been proposed, where users can safely store their devices while charging. Some advanced models integrate alert systems and mobile notifications to enhance user confidence. Despite these developments, many existing solutions either increase system complexity or fail to provide real-time monitoring and efficient user management. The integration of Internet of Things technology has further improved the functionality of modern charging stations. IoT-based systems enable remote monitoring of charging status, energy consumption, and device connectivity. Researchers have demonstrated that such systems enhance operational efficiency and provide valuable data for optimizing performance. However, issues related to network reliability, data security, and implementation cost remain significant challenges in large-scale deployment.

Overall, the literature indicates that while significant progress has been made in developing solar-powered, hybrid, and multi-device charging systems, there is still a gap in creating a comprehensive solution that effectively combines energy efficiency, multi-device compatibility, robust theft protection, and smart monitoring features. The proposed project aims to address these limitations by integrating hybrid energy management, secure access control, and IoT-based monitoring into a unified and efficient charging system.

IV. PROJECT DESCRIPTION

The proposed system presents an advanced hybrid charging station for multiple devices with integrated theft protection, designed to meet the growing demand for efficient, secure, and sustainable charging solutions in public and semi-public environments. With the increasing dependency on portable electronic devices, there is a critical need for charging infrastructures that not only provide uninterrupted power but also ensure user safety and convenience.

The system adopts a hybrid energy model that combines solar power and conventional grid electricity. Solar energy is captured using photovoltaic panels and converted into electrical energy, which is then regulated through a charge controller and stored in a rechargeable battery system. This stored energy is used as the primary source for charging connected devices. When the solar energy or battery level falls below a certain threshold, the system automatically switches to grid power, ensuring continuous operation without any interruption. This intelligent energy management approach optimizes power usage, reduces energy wastage, and supports eco-friendly operation.

A key feature of the system is its capability to charge multiple devices simultaneously. The charging station is equipped with multiple output interfaces, including USB ports, Type-C connectors, and optional wireless charging modules. The system incorporates a smart power distribution unit that dynamically allocates power based on device requirements, preventing overloading and ensuring efficient charging performance. Protective mechanisms such as overvoltage protection, overcurrent protection, and thermal management are also implemented to enhance system reliability and safety.

Security is a major aspect of the proposed design. To address the risk of theft in public charging scenarios, the system includes individual secure compartments where users can safely place their devices while charging. Each compartment is integrated with an electronic locking mechanism controlled through authentication methods such as RFID cards, PIN-based access, or mobile application verification.
Only authorized users can access their respective compartments, ensuring protection against unauthorized removal. Additionally, the system can generate alerts through buzzers or mobile notifications if any suspicious activity or forced access is detected.

The integration of Internet of Things technology further enhances the functionality of the charging station. Sensors and communication modules enable real-time monitoring of parameters such as battery status, energy consumption, charging duration, and system health. This data can be accessed by users and administrators through a web or mobile interface, allowing better control and transparency. The IoT capability also facilitates predictive maintenance by identifying potential faults and improving overall system efficiency. From an implementation perspective, the system is built using embedded hardware components such as microcontrollers, voltage regulators, sensors, and communication modules like Wi-Fi or GSM. The software component includes control algorithms for energy management, authentication, and monitoring. The modular design of the system allows easy scalability, enabling additional charging ports or enhanced features to be integrated in the future. The proposed hybrid charging station is highly suitable for deployment in locations such as educational institutions, railway stations, bus terminals, airports, offices, and commercial complexes, where users frequently require secure and convenient charging facilities. By combining renewable energy utilization, multi-device compatibility, advanced security mechanisms, and smart monitoring, the system provides a comprehensive solution that overcomes the limitations of traditional charging stations.

Overall, this project contributes to the development of a modern charging infrastructure that is energy-efficient, reliable, secure, and adaptable to evolving technological needs, making it a valuable solution for smart cities and sustainable environments.

V. OBJECTIVE OF SYSTEM

The primary objective of the proposed system is to design and develop a hybrid charging station for multiple devices with integrated theft protection that provides an efficient, reliable, and secure charging solution in modern environments. The system aims to address the limitations of conventional charging infrastructure by incorporating advanced technologies and sustainable energy sources.

One of the key objectives is to utilize a hybrid energy approach by integrating solar power with conventional grid electricity. This ensures uninterrupted operation of the charging station even during power outages or low solar availability, while also promoting the use of renewable energy and reducing dependency on non-renewable resources. Another important objective is to enable simultaneous charging of multiple devices with different power requirements. The system is designed to support various charging interfaces such as USB, Type-C, and wireless charging, ensuring compatibility with a wide range of electronic devices. Efficient power distribution and load management are also targeted to maintain optimal performance and prevent overloading.

Enhancing user safety and device security is a major objective of the system. The project aims to implement a robust theft protection mechanism using secure compartments and authentication methods such as RFID, PIN-based access, or mobile verification. This ensures that only authorized users can access their devices, thereby minimizing the risk of theft in public spaces. The system also aims to incorporate smart monitoring and control features using Internet of Things technology. This enables real-time tracking of charging status, energy consumption, and system performance, providing improved user experience and operational efficiency. Remote monitoring capabilities for administrators are also considered to facilitate maintenance and fault detection. Another objective is to design the system with high energy efficiency and reliability by integrating protective mechanisms such as overvoltage, overcurrent, and temperature control. This helps in ensuring safe operation and extending the lifespan of both the charging station and connected devices.

The project further aims to develop a cost-effective and scalable solution that can be easily deployed in various environments such as colleges, offices, transportation hubs, and commercial areas. The modular design allows future enhancements and integration of additional features without significant redesign. Finally, the system is intended to contribute to the development of smart and sustainable infrastructure by combining renewable energy utilization, advanced security features, and intelligent monitoring into a single unified platform.

VI. ADVANTAGES AND APPLICATIONS

A. Advantages:

1. The proposed hybrid charging station offers improved energy efficiency by utilizing solar power along with conventional electricity, reducing dependency on non-renewable energy sources and lowering operational costs. The hybrid system ensures uninterrupted power supply by automatically switching between energy sources, making it reliable even during power outages or low sunlight conditions.

2. The system supports simultaneous charging of multiple devices with different charging interfaces, providing high convenience and flexibility to users. Its intelligent power management ensures balanced energy distribution, preventing overloading and enhancing overall performance.

3. A major advantage of the system is its integrated theft protection mechanism. The use of secure compartments and authentication methods such as RFID or PIN-based access significantly reduces the risk of device theft, making it suitable for public environments. The addition of alert systems further enhances security by notifying users of unauthorized access attempts.

4. The integration of IoT technology enables real-time monitoring of charging status, energy consumption, and system health. This improves user experience and allows efficient system management and maintenance. The system is also designed with safety features such as overvoltage, overcurrent, and thermal protection, ensuring safe operation and durability.

5. Furthermore, the modular and scalable design of the system allows easy expansion and future upgrades, making it adaptable to evolving technological requirements. The use of renewable energy also contributes to environmental sustainability by reducing carbon emissions.

B. Applications:

1.The proposed system can be widely used in educational institutions such as colleges and universities, where students frequently require charging facilities for their devices in a secure environment. It is also highly suitable for transportation hubs such as railway stations, bus stands, and airports, where travellers need reliable and safe charging options.

2. In commercial spaces such as shopping malls, offices, and co-working spaces, the system provides a convenient charging solution while ensuring device security. It can also be deployed in public places like parks, smart city infrastructures, and tourist locations to enhance user accessibility to charging facilities.

3. The system is beneficial in workplaces and corporate offices where employees need secure charging stations during working hours. Additionally, it can be used in events, exhibitions, and conferences where temporary but efficient charging solutions are required for many users.

4. The hybrid charging station can also be implemented in rural or remote areas with limited access to electricity, utilizing solar energy to provide essential charging services. This makes it a versatile solution for both urban and semi-urban environments.

VII. RESULTS AND DISCUSSION

A. Results:

1. The prototype demonstrated effective multi-device charging capability using hybrid power sources such as solar energy and conventional electrical supply. The solar panel contributed significantly during daylight hours, reducing dependency on grid power and improving energy efficiency. The battery storage system ensured uninterrupted charging even during low sunlight or power outages.

2. The charging station supported simultaneous charging of multiple devices, including smartphones, tablets, and small electronic gadgets, without significant voltage drops. The implemented power distribution system maintained stable output, ensuring safe and efficient charging performance.

3. The theft protection mechanism, which includes authentication (such as password, RFID, or OTP-based access) and physical locking, performed reliably. Unauthorized access attempts were successfully prevented, and alerts were generated when suspicious activity was detected. The locking system ensured that devices remained secure during the charging process.

4. Additionally, the system showed good performance in terms of energy utilization, with optimized charging cycles and minimal energy wastage. The integration of smart control features helped in monitoring power usage and system status.

B. Discussion:

1. The results indicate that the hybrid charging station is a practical and efficient solution for public and semi-public environments such as colleges, railway stations, airports, and cafes. The use of solar energy enhances sustainability and reduces operational costs over time, making the system environmentally friendly.

2. Multi-device support addresses the increasing demand for charging infrastructure due to the widespread use of portable electronics. Compared to traditional charging stations, this system offers improved flexibility and user convenience.

3. The inclusion of theft protection significantly increases user trust and system reliability. In many public charging setups, security is a major concern; therefore, the implemented protection mechanisms provide a competitive advantage and make the system more user-centric.

4. However, certain limitations were observed during testing. The efficiency of the solar panel depends on weather conditions, which may affect overall performance. Additionally, the cost of implementing advanced security features and hybrid components may be higher compared to basic charging stations.

5. Future improvements can include the integration of IoT-based monitoring systems, mobile app connectivity for user authentication, real-time tracking, and AI-based energy optimization. Enhancing battery capacity and using higher efficiency solar panels can further improve system performance.

6. Overall, the project successfully meets its objectives by providing a reliable, energy-efficient, and secure charging solution for multiple devices, demonstrating its potential for real-world applications.

VIII. WORKING OVERVIEW

Block diagram:

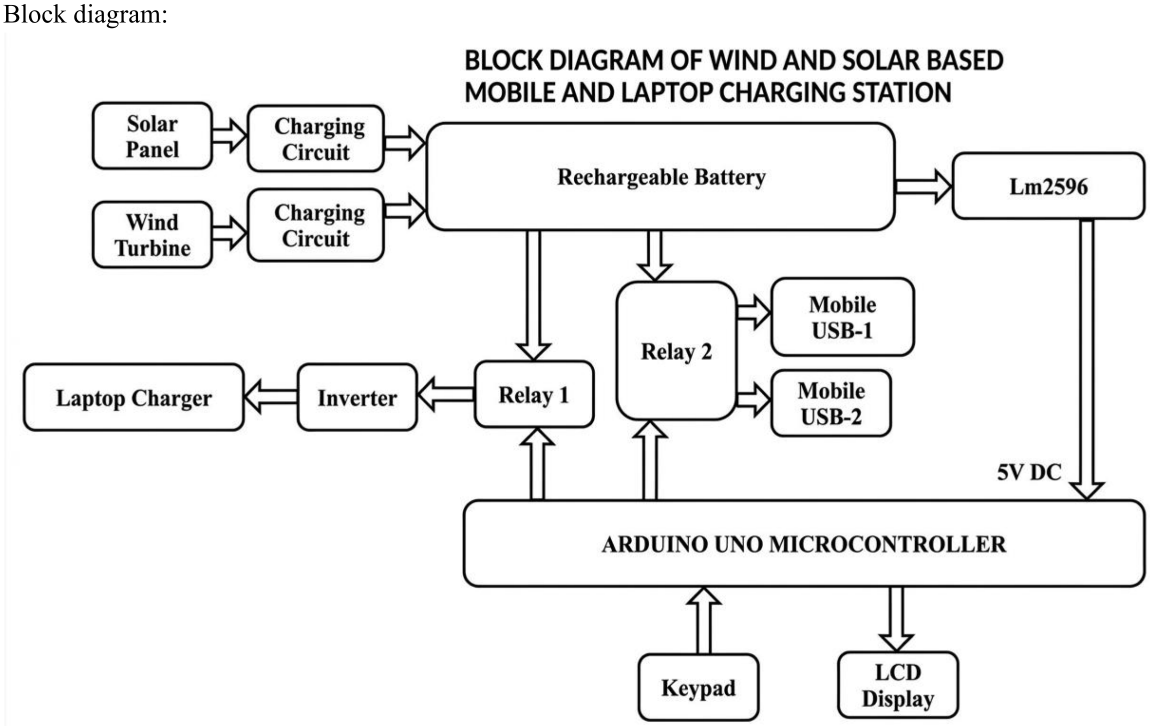

Fig1.: Block diagram of wind and solar based mobile and laptop charging stationEnergy Generation Section

1. Solar Panel:
- Converts sunlight into electrical energy (DC power).
- Acts as the primary renewable energy source during daytime.

2. Wind Turbine
- Generates electricity from wind energy.
- Useful when sunlight is not available (night/cloudy weather).

A. Energy Conditioning Section

3. Charging Circuits (2 blocks)
- Separate circuits for solar and wind inputs.
- Regulate and stabilize the voltage before sending it to the battery.
- Prevent overcharging and ensure safe energy transfer.

B. Energy Storage:

4. Rechargeable Battery
- Stores energy generated from both solar and wind sources.
- Supplies power to devices when generation is low or unavailable.
- Acts as a backup and ensures continuous operation.

C. Power Conversion & Distribution

5. LM2596 (DC-DC Buck Converter)
- Steps down battery voltage to a stable 5V DC.
- Used mainly for USB charging ports.

6. Relay 1
- Controls power flow to the inverter (for laptop charging).
- Acts as a switch controlled by the microcontroller.

7. Relay 2
- Controls power to USB outputs (mobile charging).
- Allows selective switching of charging ports.

8. Inverter
- Converts DC power from battery into AC power.
- Required for laptop charger, which typically uses AC input.

D. Output Section

9. Mobile USB 1 & Mobile USB 2
- Provide 5V DC output for charging mobile phones.
- Powered through LM2596 and controlled by Relay 2.

10. Laptop Charger
- Receives AC power from the inverter.
- Used to charge laptops.

E. Control Unit

11. Arduino UNO Microcontroller
- The brain of the system.
- Controls relays, monitors inputs/outputs, and manages power distribution.
- Ensures efficient switching between devices.

F. User Interface

12. Keypad
- Allows user input (e.g., selecting which device to charge).
- Can be used for system control and settings.

13. LCD Display

Displays system status:
- Battery level
- Charging status
- Device selection

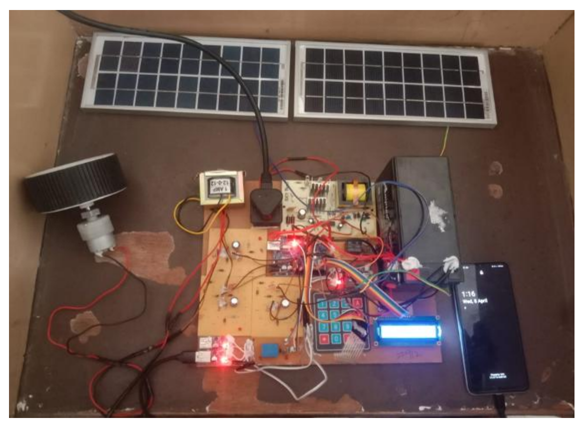

Fig.2: Working of project

IX. CONCLUSION

The proposed hybrid wind and solar based mobile and laptop charging station with theft protection successfully demonstrates an efficient, reliable, and eco-friendly solution for portable power generation. By integrating both solar and wind energy sources, the system ensures continuous energy availability under varying environmental conditions, overcoming the limitations of single-source renewable systems.

The incorporation of a rechargeable battery enables effective energy storage, allowing uninterrupted charging even during low generation periods. The use of power conditioning components such as charging circuits, DC-DC converters, relays, and an inverter ensures safe and stable power delivery to multiple devices, including mobile phones and laptops.

Furthermore, the implementation of a microcontroller-based control system enhances automation, improves energy management, and provides user-friendly operation through the keypad and LCD interface. The addition of theft protection increases the practicality and security of the system in public or shared environments.

Overall, this project highlights the potential of hybrid renewable energy systems in addressing modern energy demands sustainably. It is particularly suitable for applications in public places, rural areas, and emergency situations where conventional power sources are limited or unavailable. Future improvements can focus on increasing system efficiency, integrating IoT-based monitoring, and enhancing security features for real-world deployment.

X. FUTURE SCOPE

The hybrid wind and solar based mobile and laptop charging station presents significant potential for further development and real-world implementation. In the future, the system can be enhanced by integrating high-efficiency solar panels and advanced wind turbines, which will improve energy generation even under low sunlight and low wind conditions.

The incorporation of IoT (Internet of Things) technology can enable remote monitoring and control of the system. Users and administrators can track parameters such as battery status, energy generation, and usage through a mobile application or web interface, making the system smarter and more user-friendly. Additionally, the system can be upgraded with smart energy management algorithms using artificial intelligence to optimize power distribution based on demand and availability. This will increase overall efficiency and reduce energy wastage. For better storage performance, advanced battery technologies such as lithium-ion or solid-state batteries can be used to provide longer life, faster charging, and higher energy density. Integration of fast-charging USB ports (like USB-C PD) can further enhance usability for modern devices. The project can also be scaled for larger applications, such as charging stations for electric vehicles, smart city infrastructure, or rural electrification. Adding GPS and GSM-based theft tracking systems can further strengthen the security aspect.

Moreover, incorporating modular and portable design improvements will make the system easy to install in public places such as bus stops, railway stations, parks, and campuses. The use of weatherproof and durable materials will improve reliability in outdoor environments. In conclusion, with advancements in renewable energy, smart technologies, and storage systems, this project can evolve into a highly efficient, scalable, and intelligent charging solution contributing to sustainable energy development.

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