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Electric Vehicle Charging Station with UPI Payment Service

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Abstract:- This research paper presents the electric vehicles (EVs) gain popularity, the need for user-friendly and efficient charging infrastructure has become critical. Integrating Unified Payments Interface (UPI) with EV charging stations offers a seamless and secure payment option, making the charging process more accessible to a wider audience. UPI, a real-time payment system developed in India, allows users to transfer funds instantly between bank accounts using mobile applications, eliminating the need for cards or cash.

This abstract explores the deployment of UPI-based payment systems in EV charging stations. The use of UPI provides several advantages, such as widespread adoption, ease of use, and the elimination of additional hardware like card readers. With UPI, users can scan QR codes at charging stations or initiate payments via their mobile banking apps, allowing for quick and contactless transactions**.**

Key Words: EV Charger / EVSE, Smart Charging, App Control / Mobile App, UPI Payment / Digital Payment, QR Code Payment, Real-time Monitoring.

1. INTRODUCTION

Introduction to EV Charging Stations with UPI Payment Options

Electric Vehicle (EV) charging stations, also known as charging points or Electric Vehicle Supply Equipment (EVSE), are vital infrastructures supporting the shift towards cleaner transportation by enabling EV owners to recharge their vehicle batteries. As the adoption of electric vehicles grows, providing seamless and user-friendly charging solutions becomes essential. One significant development in this ecosystem is the integration of UPI (Unified Payments Interface) payment options at EV charging stations, ensuring convenient and secure transactions for users across India.

Types of EV Charging Stations

EV charging stations can be categorized based on their charging speed, compatibility, and the types of charging connectors used. The main types are:

1. Level 1 Charging (Slow Charging):

Uses a standard 120V AC outlet. Provides 2-5 miles of range per hour of charging. Ideal for home or office setups where extended charging time is not a concern. UPI payment integration is not common in home setups but may be available for public slow-charging stations.

2. Level 2 Charging (Fast Charging):

Uses 240V AC and is more commonly found in public charging stations, businesses, and homes. Provides 10-20 miles of range per hour of charging. Suitable for long-term parking such as workplaces or shopping centers. These stations typically support UPI payment options through apps or on-site QR codes, allowing drivers to pay with ease.

3. DC Fast Charging (Rapid Charging):

Uses DC current and operates at higher voltages (400V–900V). Capable of delivering up to 80% of a vehicle's battery capacity in 30 minutes. Found at highways, public charging hubs, and high-traffic areas to support long-distance travel. UPI payment options are especially important for DC fast chargers to enable quick and frictionless payment for high-volume users.

4. Ultra-Fast Charging:

The latest advancement, offering charging speeds of 150 kW to 350 kW, reducing the charge time to minutes. Typically located along highways and major routes for inter-city travel. UPI payment integration ensures real-time, instant t

ransactions, avoiding delays for users in a hurry.

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UPI Payment Options in EV Charging Stations:

UPI (Unified Payments Interface) has become a ubiquitous and preferred method of payment in India due to its ease of use, secure framework, and support across a wide range of mobile apps (such as Google Pay, PhonePe, and Paytm). By integrating UPI payment systems into EV charging stations, operators provide an efficient and user-friendly experience for EV drivers. Users can pay instantly by scanning a QR code or entering the station's UPI ID, without needing a dedicated charging station membership or physical cards.

Key Benefits of UPI-Enabled EV Charging Stations:

1. Convenience: UPI is widely used and available on most smartphones, eliminating the need for special apps or cards.

2. Contactless Payment: With UPI, payments are completely digital, supporting a contactless experience that is fast and secure.

3. Low-Cost Transactions: UPI payments typically come with low or no transaction fees, benefiting both consumers and station operators.

4. Interoperability: UPI works across various banks and payment platforms, meaning users can access any EV charging station that supports UPI without worrying about compatibility issues.

5. Real-time Payments: UPI transactions occur in real time, ensuring quick charging session initiations and immediate confirmations of payment.

2. OBJECTIVES

- Installation of various types of charging stations (Level 1, Level 2, and DC fast chargers) in strategic locations such as urban areas, highways, malls, and residential complexes.
- Develop and implement UPI payment solutions that allow users to pay for charging sessions using QR codes or UPI-enabled apps, facilitating quick transactions.
- Create informational resources and customer support channels to educate users on how to use the charging stations and UPI payment systems effectively.
- Partner with local electricity providers to implement dynamic pricing strategies and ensure reliable energy supply for charging stations.
- Develop a user-friendly mobile app that allows users to locate charging stations, view real-time pricing, initiate charging sessions, and manage their payments.

3. WORKING PRINCIPLE

The working principle of a Bolt EV charging application and its associated hardware is a coordinated effort between software, communication protocols, and power electronics.

Application (Software) Working Principle:

The Bolt EV charging application (e.g., Bolt.Earth app) acts as the user's interface and control hub. Its core function is to facilitate a seamless charging experience from discovery to payment. Users start by using the app to locate available charging stations on a map, often filtering by charger type (AC/DC), power output (like 3.3 kW), and availability. Once a charger is selected, the app displays real-time status and pricing details (per kWh or per minute). To initiate charging, the user typically scans a QR code on the physical charger unit via the app, or uses RFID authentication. The app then sends a command to the hardware to begin the charging session. Throughout the session, the app provides real-time monitoring of charging progress, energy consumed (in kWh), and estimated cost. Payment is usually managed through a pre-linked wallet or directly linked payment method, with the app automatically deducting the charge value upon session completion. The app also serves for user authentication, booking, notifications, and provides a historical log of charging sessions. For public chargers, it often communicates with a Charger Management System (CMS) via protocols like OCPP (Open Charge Point Protocol) to manage transactions, monitor charger health, and push Over-The-Air (OTA) updates to the hardware.

Hardware (Charging Unit) Working Principle:

The 3.3 kW Bolt EV charging hardware (referred to as an EVSE or Electric Vehicle Supply Equipment) acts as a smart intermediary between the electricity grid and the electric vehicle's onboard charger. When the user plugs in the vehicle and initiates charging via the app, the hardware begins a "handshake" with the vehicle, using a pilot signal (control pilot wire in the cable) to confirm a safe connection and negotiate the maximum current the

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vehicle can draw. Safety checks are performed (e.g., ground fault detection, insulation monitoring). Once validated, the hardware switches on the AC power to the vehicle. Crucially, for 3.3 kW AC charging, the hardware *does not* convert AC to DC. Instead, it provides the regulated AC power to the vehicle's onboard charger (OBC). The OBC then converts this AC to DC for the battery while performing Power Factor Correction (PFC) for grid efficiency. The hardware continuously monitors power flow, voltage, and current, and communicates this data back to the central CMS (and thus the app) via wired (Ethernet) or wireless (4G, Wi-Fi, Bluetooth) connectivity. Integrated safety features like MCBs and RCCBs protect against electrical faults, and the hardware can autonomously cut power in case of a fault. Essentially, the hardware ensures safe power delivery and acts as the communication bridge between the vehicle and the backend cloud services managed by the application

4. PROPOSED METHODOLOGY

Payment Gateway: Partner with a payment service provider that supports UPI transactions. This could include banks or fintech companies that facilitate UPI. Develop a user-friendly interface for the charging station, displaying options for UPI payment (QR codes, payment links). Ensure compatibility with various mobile wallets that utilize UPI.

Develop software for monitoring, managing, and controlling the charging stations. Include features for user authentication, session management, and payment processing. Mobile Application: Optionally, create a mobile app for users to find charging stations, initiate charging, and make payments

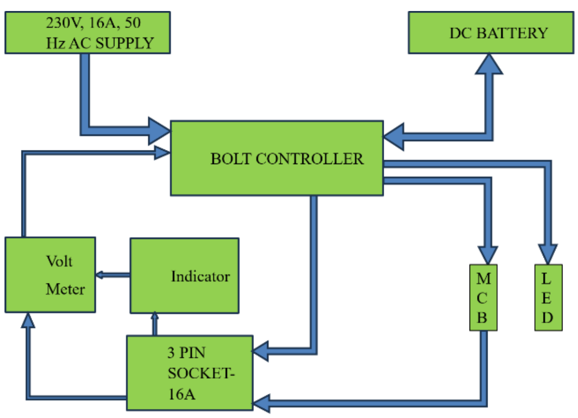

Fig 1. Block Diagram of the proposed model

The proposed model contains the following component as follows:

1. AD16-22FSV Square Frosted Surface LED Voltmeter Indicator Light: - The AD16-22FSV is a compact, square-faced LED voltmeter indicator light designed for panel mounting with a 22mm diameter hole. It features a bright, easy-to-read 7-segment digital display, commonly available in colors like green, yellow, red, blue, and white, and is capable of measuring AC voltages ranging from 60V to 500V (with some variations reporting 20V-500V or 50V-500V). This digital voltmeter is praised for its ease of installation, durable plastic construction, low power consumption, and good environmental protection, making it suitable for various applications in electrical systems, telecommunications, machine tools, and industrial equipment where clear and reliable voltage indication is required.

Fig 2. Voltage indicator

2. Li-Ion Rechargeable Battery:-

Original Rechargeable Lithium Ion 18650 Cell 3.7V 1800mAh 3C DIY Charging for Laptop battery, Power Bank and Camera, Neck fan, F95 Fan, Mic etc (not AAA or AA) Power Supply. Capacity: 2000 mAh Capacity Cell with Voltage: 3.7 Volts Cell, Size: Diameter- 18mm x Length- 65mm. (Standard- 18650) Application: Small DRONES, GPS, Mp4 player, Power bank, This li-ion Cell is very convenient to install in your project where 3.7 Volt with high capacity is needed. The standard 18650 2000 mAh 3.7V rechargeable li-ion Cell is a source of power for various portable devices including flashlights. Suitable for DIY combination of import batteries -With professional battery holder to the traditional general glue, which would brings convenient combination and more firm connection, as well as brings convenient battery maintenance. are the best choice of battery combination -Type 18650 belong to necessary support of high-end battery combination, can withstand high drop, high strength support, easy to heat dissipation, convenient combination, fixed specifications, and free combination -With card slot on edge, any size can merge, match up firmly, with strong, and no need for other device connected by vibration test.

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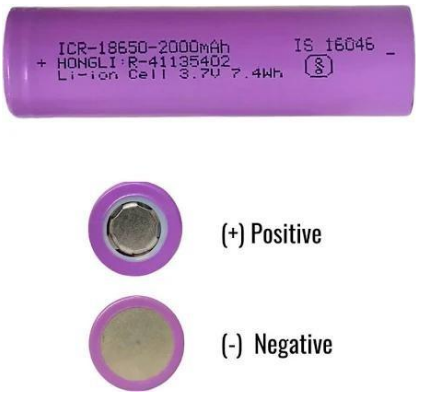

Fig 2. Li-Ion Rechargeable Battery

3. ESP32 WROOM 32D:

At the core of this module is the ESP32-D0WDQ6 chip*. The chip embedded is designed to be scalable and adaptive. There are two CPU cores that can be individually controlled, and the clock frequency is adjustable from 80 MHz to 240 MHz The user may also power off the CPU and make use of the low-power co-processor to constantly monitor the peripherals for changes or crossing of thresholds. ESP32 integrates a rich set of peripherals, ranging from capacitive touch sensors, Hall sensors, SD card interface, Ethernet, high-speed SPI, UART, I2S and I2C. If you compare the ESP32-WROOM-32D with the ESP32-WROOM-32U you will find that the ESP32 WROOM 32D module has the onboard Antenna while the ESP32 WROOM 32U has the U.FL connector which needs to be connected to an external IPEX antenna.

Fig.3 ESP32 WROOM 32D

4. Electromagnetic Relay:

The HFD27/005-S is a subminiature electromagnetic relay manufactured by Hongfa, designed for PCB mounting with an 8-pin DIP (Dual In-line Package) configuration. This sensitive type relay operates with a 5V DC coil and features a DPDT (Double Pole Double Throw), also known as 2 Form C, contact arrangement, providing versatile switching capabilities. It can handle a maximum contact current of 2A, with specific ratings of 1A at 125V AC and 2A at 30V DC (resistive load), and a maximum switching power of 125VA/60W. Key features include bifurcated contacts for enhanced reliability and reduced contact bounce, epoxy sealing for automatic wave soldering and cleaning processes, and a compact body measuring 20.2x10x11.5mm. With a low coil power consumption of 200mW, an operating temperature range of -40 to 85°C, and an operate time of 7ms (release time of 4ms), it is a reliable choice for applications requiring low-power signal switching in telecommunications, industrial equipment, and various electronic circuits.

Fig 2. hfd27/005-s Electromagnetic Relay

5. Miniature High Power Relay

The O/E/N 26-12-1CKE-S is a miniature high-power electromagnetic relay manufactured by O/E/N India Ltd., a well-known Indian electronics component company. This through-hole PCB mountable relay features a 12V DC coil and a SPDT (Single Pole Double Throw) contact arrangement, also known as 1 Form C. It is characterized by its high switching capacity, rated for a maximum continuous current of 16A at 250V AC or 28V DC (resistive load), with a maximum switching voltage of 400V AC. The "K" in the model number signifies a special contact type (K-type), and the "S" indicates it's a sensitive version, likely requiring less coil power for operation. Key attributes include a low height, a sealed construction for dust protection and suitability for automated soldering/cleaning, high dielectric strength of 5000V RMS between coil and contacts, and 1000V RMS between open contacts. It has an operate time of typically 10ms and a release time of 6ms, operating across a wide temperature range of -40°C to +85°C. This robust relay is commonly used in industrial electronics, PLCs, timers,

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UPS systems, office automation, home appliances, and even EV chargers, where its compact size and high power switching capabilities are beneficial

Fig 2. Miniature High Power Relay

6. 16A single pole MCB

A 16A Single Pole Miniature Circuit Breaker (MCB) is an essential electrical safety device designed to protect a single phase of an electrical circuit from damage caused by overcurrent, specifically from overloads and short circuits. It has a rated current of 16 Amperes and typically operates at a voltage of 230V AC for single-phase applications. When the current exceeds 16A due to an overload or a sudden surge from a short circuit, the MCB automatically "trips" or breaks the circuit, preventing potential hazards like wiring damage, equipment failure, or even fire. These MCBs are commonly used in residential, commercial, and light industrial settings, often featuring a C-curve tripping characteristic, meaning they trip instantaneously for short-circuit currents between 5 to 10 times their rated current, making them suitable for general-purpose circuits with inductive loads

5. WORKING MODEL

A 3.3 kW EV charger functions as an onboard charger (OBC) within the electric vehicle, converting incoming AC electricity from the grid into DC power that the vehicle's high-voltage battery can store. The process begins when an external AC charging station (EVSE) safely connects and signals the vehicle's OBC with available power. Inside the OBC, the AC power undergoes a two-stage conversion: first, a Power Factor Correction (PFC) stage rectifies the AC to DC and actively shapes the input current to draw power efficiently from the grid, often boosting the voltage to an internal DC bus. Second, an isolated DC-DC converter stage then takes this DC and precisely transforms it into the specific DC voltage and current required by the battery, providing crucial galvanic isolation for safety via a high-frequency transformer. Throughout this, a sophisticated microcontroller manages the entire process, communicating with the vehicle's Battery Management System (BMS) to ensure optimal charging voltage and current, prevent overcharging, and implement multiple safety protections, following a Constant Current/Constant Voltage (CC/CV) charging profile.

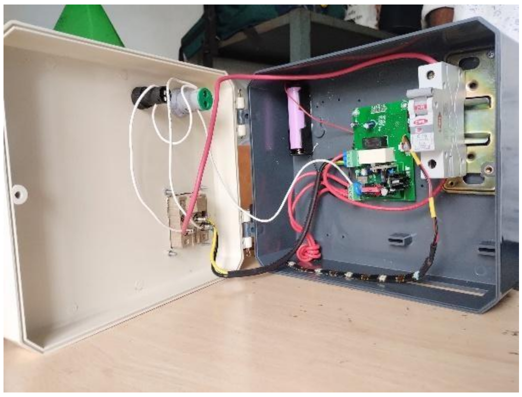

Fig.7 Internal connection of circuit

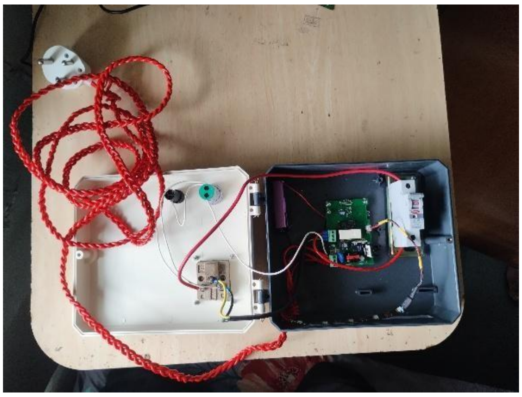

Fig.7 Internal connection of circuit

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Testing: - The Working Model was developed and tested under varied lawn conditions:

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For a Bolt EV charger app (like Bolt.Earth, which is prevalent in India) during charging, payment typically works as follows:

Before charging, the user opens the app, locates a compatible charger on the map, and can view its real-time status and pricing details (e.g., per kWh or per minute). Once at the charger, they initiate the session, often by scanning a QR code on the unit via the app. The app then usually requires confirmation of the charge session, and the user selects their preferred payment method, which is typically linked to an integrated wallet within the app (pre-loaded with funds) or a directly linked credit/debit card. As the charging progresses, the app monitors the energy consumed (kWh) or the duration. Upon completion, the app automatically calculates the total cost based on the pre-defined pricing and deducts the payment value from the user's selected payment source, providing a detailed transaction history for transparency.

Table 1 Experimental Results

Operation	Units (kWh)	Per Unit Charges	Time required (in min)
EV Charging	1	10	20

6. MERITS OF THE SYSTEM.

- **Convenience and Speed:**

UPI allows for instant transactions without the need for cash, cards, or any physical contact. Users simply scan a QR code and complete the payment in seconds, making the charging experience faster and more efficient.

- **Wider Accessibility:**

UPI is widely adopted and accessible through many banking apps and digital wallets, so users can use it without needing specific cards or accounts. This makes EV charging stations accessible to a broader range of users, especially in areas where UPI is popular.

- **Lower Transaction Costs:**

UPI generally has lower transaction fees than credit and debit card payments, which can reduce costs for charging station operators and may even translate to lower prices for users.

- **Enhanced Security:**

UPI payments are encrypted and verified, offering a high level of security for users. This minimizes risks compared to using physical cards or cash, as users don't have to share sensitive financial information.

- **Seamless User Experience:**

UPI provides a seamless, hassle-free experience. Users don't need to fill in details repeatedly or go through complex steps. This smooth process can enhance customer satisfaction and encourage repeat usage.

- **Real-Time Digital Records:**

With UPI, users have an instant digital record of every transaction, which helps them keep track of their charging expenses. This is especially helpful for regular EV users who need to monitor their charging costs.

- **Encourages EV Adoption:**

By simplifying payments, UPI integration can make charging more convenient, supporting the growth of EV infrastructure and encouraging more people to consider EVs as a viable option.

- **Environmental Impact Assessment:**

The Environmental Impact Assessment (EIA) of EV chargers considers their entire lifecycle, from manufacturing to operation and end-of-life.

- **Manufacturing:**

The production of EV chargers involves extracting and processing raw materials like metals (aluminum, copper) and plastics, which are energy-intensive processes with associated emissions and potential habitat disruption. However, manufacturers are increasingly adopting recycled materials and more sustainable production methods to mitigate these impacts.

- **Operation:**

The primary environmental impact during operation stems from the source of electricity used for charging. If

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the electricity comes from fossil fuels (coal, natural gas), then the charging process indirectly contributes to greenhouse gas emissions and air pollution. Conversely, if the electricity is sourced from renewables (solar, wind, hydro), the operational carbon footprint is significantly reduced, aligning with the core environmental benefit of EVs. Efficiency of the charger also plays a role, as energy losses during conversion contribute to the overall impact.

- **End-of-Life:**

Proper disposal and recycling of EV chargers are crucial to prevent electronic waste and recover valuable materials. Designs that prioritize durability, repairability, upgradability, and recyclability are essential to minimize environmental burdens at this stage.

7. RISK ASSESSMENT AND SAFETY GUIDELINES

Risk Assessment for EV chargers involve systematically identifying potential hazards like electrical shock, fire (especially from battery thermal runaway), and physical damage, then evaluating their likelihood and severity. Safety guidelines mandate proper installation by qualified electricians, adherence to relevant electrical codes (like India's BIS standards for EVSEs), regular maintenance checks for wear, damage, and functionality, and ensuring adequate protective devices like RCDs and MCBs. Crucially, charging areas should be well-ventilated, kept clear of combustible materials, and emergency shut-off mechanisms must be readily accessible. User safety practices, like inspecting cables and not using damaged equipment, are also paramount.

8. CONCLUSION

The objectives and scope of electric vehicle charging stations with UPI payment options focus on enhancing the user experience, promoting the adoption of electric vehicles, and ensuring efficient operation. By integrating advanced payment solutions and creating a robust infrastructure, these charging stations can play a significant role in the transition to sustainable transportation while addressing the needs of modern consumers.

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