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Smart Charging System for Electric Vehicles

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ABSTRACT —

In this work is proposed the design of a system to create and handle Electric Vehicles (EV) charging procedures, based on intelligent processes. Due to the electrical power distribution network limitation and absence of smart meter devices, Electric Vehicles charging should be performed in a balanced way, taking into account past experience, weather information based on data mining, and simulation approaches. In order to allow information exchange and to help user mobility, it was also created a mobile application to assist the EV driver in these processes. This system also explores the new paradigm of Electrical Markets (EM), with deregulation of electricity production and use, in order to obtain the best conditions for commercializing electrical energy.Electric vehicle (EV) wireless charging using radio-frequency identification (RFID) is a novel technology that enables the charging of electric vehicles without the need for wires or cables. It offers numerous benefits, including increased convenience, efficiency, and safety, and has the potential to significantly reduce the environmental impact of transportation. The demand for electric vehicles (EVs) has been steadily increasing as society strives towards sustainable transportation solutions. To meet the charging needs of these vehicles, an efficient and reliable AC electric vehicle charger with a power rating of 3.3 kilowatts (kW) has been developed. This paper presents a comprehensive abstract outlining the key features, design principles, and advantages of the 3.3kW AC electric vehicle charger.

Keywords — Blynk Application, RFID Authentication, Status indication, Temperature Sensor, LCD display, Emergency switch.

I. INTRODUCTION

The rapid proliferation of electric vehicles (EVs) in recent years has necessitated the development of efficient and intelligent charging solutions. Our project, the "Smart Charging System for Electric Vehicles," addresses this demand by integrating advanced features to enhance user experience, safety, and overall charging efficiency. Our smart charging system is designed to cater to both three-wheeler and two-wheeler electric vehicles. In today's society the biggest concern raised is the exhaustion of fossil fuels, as fossil fuels constitute the backbone of the major day-to-day functions we carry in our everyday life, most importantly transport. In early days, transport did not hold the essential place in a man's life but now our life is completely dependent on it. As fossil fuels are depleting, it creates an urgency to find a suitable alternative for it, which is Electrical Vehicles (EV's). Electrical Vehicles can be defined as a vehicle that uses one or more electric motors for propulsion.

The evolution of Electric Vehicles (EVs) has led to a growing demand for efficient and smart Electric Vehicle Charging Stations. In this context, the integration of the ESP32 microcontroller opens up possibilities for creating a feature-rich and user-friendly EV charger. This EV charger incorporates Radio-Frequency Identification (RFID) technology for user authentication and control, as well as seamless interaction with a Blynk mobile application. The system operates with a 230V AC input, providing a versatile solution for both residential and commercial charging needs.

Electric vehicle wireless charging using RFID is an innovative technology that allows electric vehicles (EVs) to be charged wirelessly without the need for physical contact between the charging station and the vehicle. RFID stands for Radio Frequency Identification, which is a technology that uses radio waves to identify and track objects. In the context of electric vehicle charging, an RFID reader is used to identify the vehicle and initiate the charging process.

Smart electric vehicle (EV) charging uses intelligence and connectivity to manage when and how an EV plugged into a smart charger will receive power for charging based on the cost of electricity, its availability, and the driver's needs. EV Smart charging lets operators monitor, manage, and adjust energy consumption. It requires a data connection between the EV and the smart charger, and a data connection between the charger, the charge point operator's cloud-based EV charging management platform.

For home charging, WiFi connects the smart charger to a

mobile app and possibly to your energy provider. The smart charger connects to the EV, the home power supply, and possibly the grid. Drivers use the app to control the smart charger and determine when to charge the EV, avoiding peak usage times while ensuring the car is ready to drive at the right time.

II. PRIOR RESEARCH

[1] "Design and Implementation of an Online Location-Based Service Using Google Maps for Android Mobile" - Dr. Omar A. Ibrahim, Khalid J. Mohsen: This study may provide insights into the implementation of location-based services using Google Maps, which could be relevant for incorporating location features into an EV charger project. [2] "The Study and Implementation of Mobile GPS Navigation System Based On Google Maps" - H. Li, L. Zijian: This work may offer valuable information on the study and implementation of GPS navigation systems using Google Maps, potentially applicable to enhancing navigation features in an EV charger system.

[3] "GPS-Based Mobile Cross-Platform Cargo Tracking System with Web-Based Application" - A. M. Qadir, P. Cooper: This research could be useful for understanding GPS-based tracking systems, which might have applications in logistics and real-time tracking of charging station usage for EVs.

[4] "API Recommendation System for Software Development" - F. Thung: Insights from this study may be relevant for developing API systems within the context of software development, potentially applicable to the implementation of APIs in an EV charger project.

[5] "Smart Electric Vehicle Charging System" - JoaoC. Ferreira, Victor Monteiro, Joao L. Afonso, Alberto Silva (IEEE): This IEEE publication likely provides information on a smart EV charging system. Reviewing this work may offer valuable insights into the design, implementation, and smart features of EV charging systems.

[6] "Location Tracking Using Google Geolocation API" - Monika Sharma, Sudha Morwal: This study may provide insights into location tracking using Google's Geolocation API, potentially useful for incorporating advanced location-based features into an EV charger project.

[7] "Traffic and Mobility Data Collection for Real-Time Application" - J. Lopse, E. Huang, C. Antoniou, M. Ben-Akiva: This research may be beneficial for understanding methods of collecting traffic and mobility data in real-time, which could be relevant for optimizing the location and accessibility of EV charging stations.

[8] "Trip Planning Route Optimization with Operation Hour and Duration of Stay Constraints" - Wai Chong Chia, Lee Seng Yeong, Fennie Jia Xian Lee, Sue Inn Ch'ng: Insights from this study may be applicable for optimizing routes and scheduling in an EV charging system, considering constraints such as operation hours and duration of stay.

[9] "Coordinated Charging of Multiple Plug-in Hybrid Electric Vehicles in Residential Distribution Grids" - K. Clement, E. Haesen, J. Drisen: This paper might provide insights into coordinated charging strategies for multiple electric vehicles, which could be relevant for optimizing charging station usage. [10] "An Efficient Scheduling Scheme on Charging Station for Smart Transportation" - H-J Kim, J. Lee, G-L. Park, M-J Kang, M. Kang: This study may offer information on efficient scheduling schemes for charging stations in the context of smart transportation, potentially relevant for optimizing EV charging infrastructure.

III. PROBLEM STATEMENT

The widespread adoption of Electric Vehicles (EVs) has led to an increasing demand for efficient and accessible charging infrastructure. However, several challenges hinder the seamless integration of EV chargers into our transportation system. Many regions lack an adequate number of EV charging stations, resulting in inconvenience for EV owners and limiting the potential for widespread EV adoption. The absence of standardized charging protocols across different manufacturers and models complicates the user experience and poses interoperability issues, discouraging EV adoption.

There are several compelling reasons to use electric vehicles (EVs), and these reasons contribute to the growing popularity and adoption of electric mobility. One of the primary benefits of electric vehicles is their lower environmental impact compared to traditional internal combustion engine vehicles. EVs produce zero tailpipe emissions, contributing to improved air quality and a reduction in greenhouse gas emissions. EVs often have lower operating costs per mile compared to traditional vehicles. Electricity is generally cheaper than gasoline, and electric vehicles have fewer moving parts, resulting in reduced maintenance expenses.

IV. SYSTEM ARCHITECTURE

A. Switched Mode Power Supply (SMPS)

An SMPS is a type of power supply that uses switching devices (such as transistors) to control the power flow, converting electrical power more efficiently than traditional linear power supplies. Input Stage: The input stage rectifies the incoming AC power into DC. This DC voltage is then passed through a filter to smooth out any remaining ripples. Switching Stage: The heart of an SMPS is the switching stage, where transistors rapidly switch on and off to control the flow of electrical energy. This high-frequency switching allows for smaller and lighter transformers. Output Stage: The switched signal is then passed through an output transformer, rectified again, and filtered to obtain a stable DC output. This output voltage is regulated to ensure a constant voltage level.

B. 20x4 LCD Display

A 20x4 LCD display is a type of liquid crystal display (LCD) that has 20 characters in each of its 4 rows, resulting in a total of 80 characters that can be displayed simultaneously. These displays are commonly used in various electronic devices, microcontroller projects, and embedded systems where a simple and compact text-based interface is needed. Here are some key features and considerations related to a 20x4 LCD display:

1. **Characteristics:** 20x4 Format: Indicates the number of characters in each row (20) and the number of rows (4). Can display up to 80 characters at once. Each character position is a dot matrix, allowing the display of alphanumeric characters and symbols.
2. **Communication Interface:** Many 20x4 LCD displays use a parallel interface, requiring several data lines for communication. Common configurations include 4-bit or 8-bit parallel communication. Some 20x4 LCD displays come with an I2C (Inter-Integrated Circuit) interface, simplifying the connection and reducing the number of required pins on a microcontroller.
3. **Backlighting:** Some 20x4 LCD displays come with an integrated backlight for better visibility in low-light conditions. Backlighting can be controlled separately, allowing users to adjust brightness or turn it on/off as needed.
4. **Power Supply:** Typically operate at 5V for logic power and may require a separate voltage source for the backlight, if applicable.
5. **Application:** Used for displaying text messages, sensor readings, or status information in various electronic projects. Commonly interfaced with microcontrollers like Arduino, Raspberry Pi, or other embedded systems.
6. **Programming:**There are libraries available for popular microcontroller platforms that simplify the programming of 20x4 LCD displays.

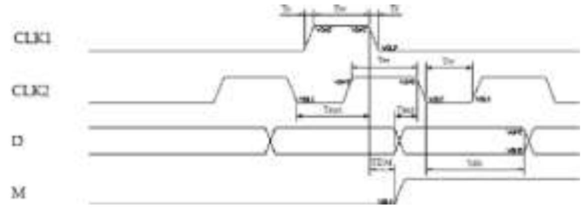


fig. Interface mode withextension driver timing diagram

C. LED Indicator

An LED is a light-emitting diode that can produce a wide range of colors by combining different intensities of three primary colors: Red (R), Green (G), and Blue (B). RGB LEDs are widely used in various applications, including lighting, displays, and decorative elements. An RGB LED contains three separate LED chips within a single package—one for red, one for green, and one for blue. By adjusting the intensity of each of these colors, the LED can produce a broad spectrum of colors. For each color (R, G, B), PWM is used to vary the intensity. A higher duty cycle results in a higher intensity, producing a brighter color. By adjusting the PWM values for each color, you can achieve the desired overall color. RGB LEDs are often controlled by microcontrollers or dedicated RGB LED controllers. Microcontrollers, like Arduino or Raspberry Pi, can generate PWM signals to control the color of RGB LEDs.

D. 12V RELAY

A 12V relay is an electromechanical switch that uses an electromagnetic coil to control the opening and closing of one or more sets of contacts. When a specific voltage, in this case, 12 volts, is applied to the relay coil, it energizes, causing the contacts to move and complete or interrupt an electrical circuit. Here are some key features and considerations related to 12V relays:

Voltage Rating: A 12V relay is designed to operate with a nominal coil voltage of 12 volts. It is important to use the correct voltage to ensure reliable and proper functioning.

Current Rating: The relay's contacts are rated for a specific current. It's crucial to choose a relay with contacts that can handle the current of the load you intend to switch.

Switching Capacity: The switching capacity of a relay indicates the maximum power (voltage and current) it can handle. This is important for ensuring that the relay can safely switch the intended load.

E. ESP32 Module

ESP32 is capable of functioning reliably in industrial environments, with an operating temperature ranging from –40°C to +125°C. Powered by advanced calibration circuitries, ESP32 can dynamically remove external circuit imperfections and adapt to changes in external conditions.ESP32 is highly-integrated with in-built antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power management modules. ESP32 adds priceless functionality and versatility to your applications with minimal Printed Circuit Board (PCB) requirements. Engineered for mobile devices, wearable electronics and IoT applications, ESP32 achieves ultra-low power consumption with a combination of several types of proprietary software. ESP32 also includes state-of-the-art features, such as fine-grained clock gating, various power modes and dynamic power scaling. ESP32 can perform as a complete standalone system or as a slave device to a host MCU, reducing communication stack overhead on the main application processor. ESP32 can interface with other systems to provide Wi-Fi and Bluetooth functionality through its SPI / SDIO or I2C / UART interfaces.

F. Energy Meter Module (HLW8032)

This module is basically a breakout board for HLW8032 IC which is a high precision Energy Metering IC. The HLW8032 IC uses a CMOS manufacturing process and is primarily intended for single phase applications. It can measure line voltage and current, and can calculate active power, apparent power and power factor. The device integrates two ∑-Δ ADCs and a high-precision energy metering core. The HLW8032 can communicate

data through the UART port.

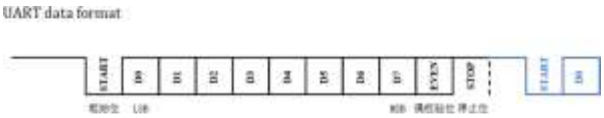


Fig. UART frame data

Every complete transmission of data by HLW8032 is 24 bytes. The transmission of a group of data starts from register 1 (State REG) and ends at register 11 (CheckSum REG), involving altogether 11 registers and data of 24 bytes. HLW8032 Energy Metering IC adopts 5 Volts power supply, built-in 3.579M crystal oscillator and 8 PIN SOP package. HLW8032 IC has the advantages of high precision, low power consumption, high reliability, strong applicable environment, etc. It is suitable for electric energy measurement of single phase two-wire power users.

HLW8032 has a simple UART interface, using asynchronous serial communication, allowing two unidirectional pins for data communication. The UART interface only needs a low-cost photoelectric opto-coupler to realize isolated communication. The UART interface is 4800 bps, this is a fixed baud rate.The interval time of sending data is 50mS, suitable for low-speed design.

Corresponding pulse count of 2 and 1 kwh

Pulse count of 1kwh

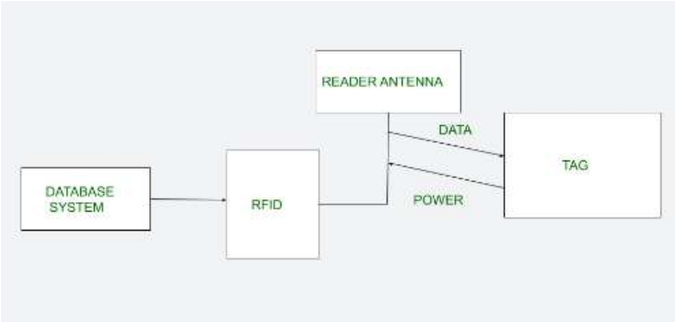
$$= \frac{1}{\text{Power parameter REG}} \times \frac{1}{\text{Voltage coefficient} \times \text{Current coefficient}} \times 10^{9} \times 3600$$

When the count of PF_{cnt} is equal to the pulse count of 1kwh, this means 1 kwh has been tallied accumulatively;

$$\text{Current electrical quantity (KW.h)} = \frac{PF_{cnt}}{\text{pulse}} \text{count for 1kwh}$$

G. Radio Frequency Identification (RFID)

RFID is an acronym for “radio-frequency identification” and refers to a technology whereby digital data encoded in RFID tags or smart labels (defined below) are captured by a reader via radio waves. RFID is similar to barcoding in that data from a tag or label are captured by a device that stores the data in a database. RFID, however, has several advantages over systems that use barcode asset tracking software. The most notable is that RFID tag data can be read outside the line-of-sight, whereas barcodes must be aligned with an optical scanner. RFID belongs to a group of technologies referred to as Automatic Identification and Data Capture (AIDC). AIDC methods automatically identify objects, collect data about them, and enter those data directly into computer systems with little or no human intervention. RFID methods utilize radio waves to accomplish this. At a simple level, RFID systems consist of three components: an RFID tag or smart label, an RFID reader, and an antenna. RFID tags contain an integrated circuit and an antenna, which are used to transmit data to the RFID reader (also called an interrogator). The reader then converts the radio waves to a more usable form of data. Information collected from the tags is then transferred through a communications interface to a host computer system, where the data can be stored in a database and analyzed at a later time. As stated above, an RFID tag consists of an integrated circuit and an antenna. The tag is also composed of a protective material that holds the pieces together and shields them from various environmental conditions. The protective material depends on the application. For example, employee ID badges containing RFID tags are typically made from durable plastic, and the tag is embedded between the layers of plastic. RFID tags come in a variety of shapes and sizes and are either passive or active. Passive tags are the most widely used, as they are smaller and less expensive to implement. Passive tags must be “powered up” by the RFID reader before they can transmit data. Unlike passive tags, active RFID tags have an onboard power supply (e.g., a battery), thereby enabling them to transmit data at all times.



V. WORKING

The described electric vehicle (EV) charging system presents a sophisticated and user-centric solution, prioritizing both efficiency and safety. Powering up the charger will initially indicate a rainbow color and establish a connection to Wi-Fi. Once successfully connected to Wi-Fi, it transitions into an idle state. Initiate the electric vehicle (EV) charging process remotely through the Blynk app. The Blynk application enables users to remotely initiate or terminate charging sessions at their convenience. The intuitive interface displays real-time information, including voltage, current, power, and energy consumption, providing users with a comprehensive view of their charging sessions. During the charging process, the Blynk application displays dynamic information, allowing users to track the charging progress. Voltage, current, power, and energy consumption are presented in real-time, offering transparency and control to the EV owners.

The use of RFID technology simplifies the vehicle charging process with a straightforward operation. Simply tap the card or key on the RFID section to initiate charging, and a subsequent tap with the same card or key will halt the charging. This user-friendly and efficient approach represents a straightforward and excellent method for electric vehicle charging. This charger comes equipped with numerous safety features, encompassing protection against over-temperature, over-current, under-current, over-voltage, and under-voltage. Under all circumstances, these features ensure the safety of both the charger and the electric vehicle (EV). The primary focus of these chargers is not only to efficiently charge the EV but also to safeguard both the EV and the charger from potentially harmful conditions.

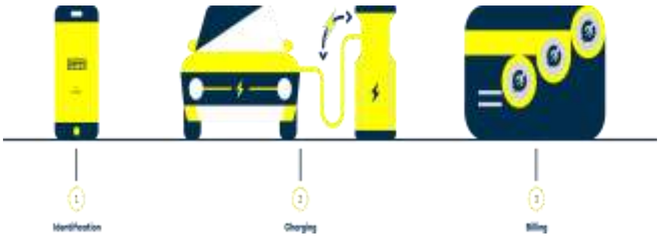


fig. Charging process

The charging system is equipped with robust error handling mechanisms. In the event of anomalies such as overvoltage, undervoltage, over-temperature, or undercurrent, the system promptly halts the charging process, ensuring user safety and preventing potential damage to the EV or the charging infrastructure. Neopixel LEDs provide clear visual indications of the system's status, making it easy for users to understand the charging state at a glance. Different colors and patterns are used to signify various conditions, enhancing the user interface and experience.

fig. Connectivity process

VI. EXPERIMENTAL RESULTS

The result of this innovative EV charging system project is a sophisticated and user-centric solution that seamlessly integrates advanced technologies for efficient and secure electric vehicle charging. The 3.3 kW (kilowatt) rating of an electric vehicle (EV) charger denotes the charging power it can supply to an electric vehicle. In the context of EV charging, the power rating is commonly expressed in kilowatts, indicating the speed at which the EV charger can deliver energy to the vehicle's battery.

During the charging process, pressing the emergency switch initiates the buzzer sound, and the LED indication begins blinking in Magenta color. Simultaneously, the display shows "E. switch pressed." Releasing the emergency switch silences the buzzer, and the charger smoothly transitions to idle mode within 10 seconds.

Charging can also be activated using a TAG or KEY. To do so, tap the TAG or KEY on the RFID icon. Initially, the NeoPixel will display a steady yellow light, indicating readiness, and will then shift to a gradually increasing green light as the charger enters the charging mode. The charger will shift into the charging mode within a timeframe of 05 seconds.

While in the charging phase, not connecting the gun to the charger will transition the charger into the no-load state. During this period, the first 5 LEDs blinks in red, and the display indicates "no load." Should the charger voltage drop below 195V, the NeoPixel indicator exhibits a blinking pattern with the first three LEDs in red. In such a scenario, once the voltage stabilizes, the charger seamlessly switches to the charging mode. Conversely, if the charger voltage exceeds 265V, the NeoPixel indicator showcases a blinking pattern with the first two LEDs in red. Again, after the voltage stabilizes, the charger transitions to the charging mode.

fig. Hardware

Likewise, if the temperature climbs to 80°C, the charger enters the "over temperature" state, and the NeoPixel indicator displays a red blinking pattern with the first seven LEDs. In the event of a current surge to 18.4A, the charger shifts to the "over current" state. Simultaneously, on the charger, the NeoPixel indicator exhibits a blinking pattern with the first four LEDs in red.

VII. CONCLUSION

In conclusion, the innovative EV charging system project stands as a pinnacle of technological sophistication and user-centric design, delivering an unparalleled charging experience for electric vehicle owners. Successful design and development have been achieved for a 3.3 kW AC Electric Vehicle (EV) charger. This accomplishment involves a comprehensive understanding and integration of power electronics, control systems, and safety features. The power electronics design is efficient, converting input power to the required charging voltage and current. A reliable power supply system has been implemented to ensure consistent charging performance.

The creation of a robust control system is a key success, effectively managing the charging process. Intelligent battery monitoring and adaptive charging profiles have been integrated for optimal functionality. Essential safety features, such as overcurrent protection, overvoltage protection, and temperature monitoring, are seamlessly incorporated.

Furthermore, the implementation of safety protocols ensures user and vehicle protection. Rigorous testing procedures have been employed for both functional and performance validation. The safety features have been successfully validated, and the design is in compliance with relevant standards, reflecting the commitment to achieving a high-quality and secure electric vehicle charging solution.

VIII. REFERENCES

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