p–ISSN: 2723 - 6609 e-ISSN: 2745-5254
Vol. 6, No. 2 February 2025 http://jist.publikasiindonesia.id/

Design and Interface Development in Electrical Vehicle Powerline Communication

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ABSTRACT

Keywords: EVPLC; Fusion360; HMI

The adoption of Electric Vehicles (EVs) is growing globally due to efficiency, technological advancements, and environmental benefits, though fossil-fueled vehicles still dominate Indonesia. Supported by government initiatives, Indonesia is transitioning to EVs, aiming for Net Zero Emissions by 2060. CAN-Bus technology is Critical to EV operation, enabling efficient communication between vehicle components. Integrating power line communication (PLC) with CAN-Bus, using existing electrical grids, enhances real-time monitoring and control, and companies like Continental Engineering Services are advancing gateway technologies for EV and charging station communication. This research proposes developing an Electrical Vehicle Power Line Communication (EVPLC) system to bridge this communication gap, supporting Indonesia's clean energy goals and EV adoption. Additionally, the project emphasizes the importance of effective design using Fusion 360 software and a user-friendly Human-Machine Interface (HMI) with Nextion. Combining these tools enhances the efficiency and accessibility of EV charging stations, contributing to a more robust and user-friendly EV ecosystem.

Introduction

Electric vehicles (EVs) have gained traction globally, particularly in advanced countries, due to their efficiency, technological advancements, and environmental benefits (Okoh & Onuoha, 2024; Sun, Li, Wang, & Li, 2019). However, fossil-fueled vehicles remain the dominant choice in Indonesia, mainly because of their affordability and the longstanding reliance on such vehicles (Komunikasi & Indonesia, 2022). Despite this, there is a growing shift towards EVs in Indonesia, supported by government incentives like lower taxes, exemptions from road regulations, and the rapid expansion of charging infrastructure. This transition is creating momentum for the broader adoption of EVs in the country. Central to EV functionality is the Controller Area Network (CAN)

Bus, a communication protocol developed by Bosch in 1989. CAN-Bus allows various vehicle components to communicate with each other, enabling real-time monitoring and control of systems such as energy storage, motor and power inverters, and vehicle support systems. This capability is essential for the efficient operation of electric vehicles (Astuti, Putra, & Ahya, 2024).

Integrating Power Line Communication (PLC) technology is proposed to enhance CAN-Bus's capabilities further. PLC uses existing electrical grids for data transmission, offering the advantage of utilizing already established infrastructure. However, even in advanced markets, EV-PLC technology is not widely adopted despite its potential

. The absence of EV-PLC means that users often need to visit workshops to analyze their EVs' conditions, especially for electric motorbikes that lack embedded diagnostic networks. By combining CAN-Bus with PLC, it is possible to create a system that can analyze vehicle components, allow for reprogramming, and enable self-diagnosis, improving maintenance and performance.

This project proposes developing an Electrical Vehicle Power Line Communication (EVPLC) system in Indonesia that communicates bidirectionally. The goal is to establish reliable communication between electric vehicle charging stations (EVCS) and the CAN-Bus system in EVs, simplify wiring, enhance safety, and enable real-time diagnostics. The research builds on previous work from Telkom University and aims to create a domestically manufactured EVPLC system that meets International Electrotechnical Commission (IEC) standards. This system will support Indonesia's growing interest in electric vehicles and contribute to global efforts to promote cleaner, more sustainable transportation options.

According to Carcangiu, Fanni, & Montisci, (2019) In this research, a procedure is proposed to design a power line communication (PLC) system to perform digital transmission in a distributed energy storage system consisting of fleets of electric cars. PLC uses existing power cables or wires as data communication multicarrier channels.

The novelty of this research lies in its focus on designing a domestically developed EVPLC system that adheres to International Electrotechnical Commission (IEC) standards. This system will enhance communication between EVs and charging infrastructure, reduce carbon emissions, and support the adoption of cleaner transportation technologies in Indonesia.

Indonesia's growing interest in transitioning to a sustainable energy future, particularly as part of the nation's commitment to achieving Net Zero Emissions by 2060, underscores the urgency of this study. Developing reliable and efficient EV technologies is crucial to accelerating the adoption of electric vehicles and reducing the nation's dependence on fossil fuels. This research seeks to address these challenges by focusing on developing an EVPLC system that can simplify communication, improve vehicle diagnostics, and support the smooth integration of EVs into the national energy grid.

The main objectives of this study are to design and develop a bidirectional EVPLC system for seamless communication between electric vehicles and charging stations in Indonesia. The research also aims to evaluate the performance and potential benefits of integrating PLC technology with the CAN-Bus system in real-world settings and assess its impact on the maintenance and operation of electric vehicles.

The findings of this research will provide valuable insights into the feasibility and effectiveness of using Power Line Communication in the electric vehicle sector. This technology offers a cost-effective and efficient solution to the communication challenges faced by the growing EV market. Moreover, it will contribute to developing an integrated, user-friendly ecosystem for EVs in Indonesia, with implications for enhancing the overall sustainability of the transportation sector.

Theoretical Study

3D Design

3D objects or three-dimensional objects refer to entities that have length, width, and height that form a space (Faiztyan, Isnanto, & Widianto, 2015; Sugiharto, 2019) 3D is used not only in mathematics and physics but also in graphics, animation, computers, tool design, and other fields.

Fusion360

Autodesk Fusion 360 is a computer-aided design (CAD) software with cloud capabilities for creating 2D and 3D design drawings. (Apriani, 2024; Kumari & Chaturvedi, 2023; Tigariev, Lopakov, Rybak, Kosmachevskiy, & Cioată, 2023). Fusion 360 uniquely combines parametric design, variable design, and feature modeling into a cohesive platform. This technology extends beyond traditional physical and surface modeling by integrating computer-aided manufacturing (CAM). This integration streamlines the design process, enhances computational accuracy, and enables automated control and optimization of CNC machining. (Barua, 2024; Senthilkumar, 2024). Additionally, Fusion 360 is a tool for users to conduct secondary development. (Afrah, Riady, Cundari, Rizan, & Aryansyah, 2020; Song, Qi, & Cai, 2018; Xie & Chang, 2021).

HMI (Human Machine Interface)

A human-machine interface (HMI) is a system that connects humans with machine technology. It is widely used in industries, typically as a computer with a CRT or LCD monitor display, allowing comprehensive system monitoring. Generally, HMI systems operate online and in real-time by reading data transmitted through I/O ports used by the control system. (López López et al., 2019).

Nextion Editor

The Nextion Editor is a software tool designed to create graphical user interfaces (GUIs) for Nextion Human Machine Interface (HMI) devices. It allows users to rapidly develop interfaces by utilizing a drag-and-drop system, significantly reducing the time required for GUI creation compared to traditional methods. The software supports various components such as buttons, sliders, and text boxes, enabling users to design interactive displays efficiently.

Research Methods

Design of Tool Concept

This design is carried out systematically to generate ideas and initial concepts that will be developed to ensure the tool created can be used to its fullest potential. In this case, building the EVPLC requires the design of PCB storage dimensions, communication modules, and power supply PCBs. Additionally, proper partition mapping is needed within the EVPLC and EVCS simulator, including components like MCB, power supply, EVCS PCB, circuit breaker, and terminal block, to optimize airflow and ensure components are placed securely and effectively. Several stages are required in the design of the product/tool. As follow:

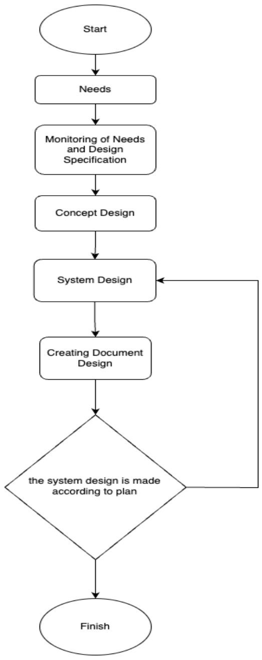

Figure 1. System Design Flowchart

Creating 3D Design EVPLC Sketches

Before constructing the design in 3D form, each design starts with creating a 2D sketch on the XZ plane. Afterward, the 2D sketch is transformed into a 3D shape using solid features. Next, the assembly process is carried out, where each component is placed according to its predetermined position and function in the previous 3D design. To achieve bidirectional functionality, this device is designed with two boxes of EVPLC dimensions of 18 cm in length, 10 cm in width, and 8 cm in height and additionally added a partition design for the power supply with a length of 13.5 cm width of 7 cm, height of 1.5 cm. With these EVPLC dimensions, Communication PCB and power supply can be accommodated within the EVPLC, as shown in Figure 2.

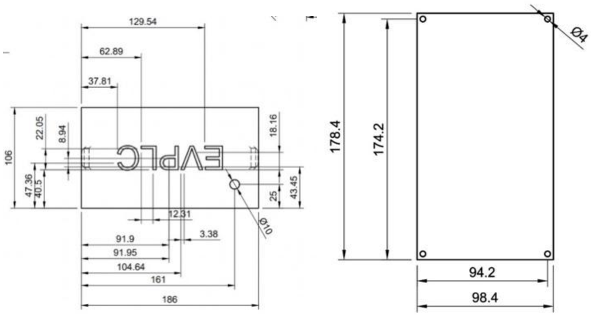

Figure 2. Front and Rear View Sketch of EVPLC

In Figures 3 and 4, in addition to considering the dimensions of the EVPLC box, important hole dimensions are required for communication pathways between the CAN and powerline communication located on the right and left sides of the box. The placement of key components for the communication system, along with the power supply and ventilation holes within the device, is crucial to prevent overheating during operation.

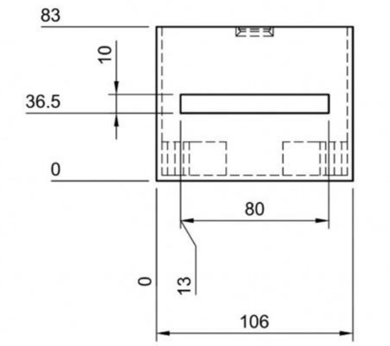

Figure 3. Side view sketch of EVPLC

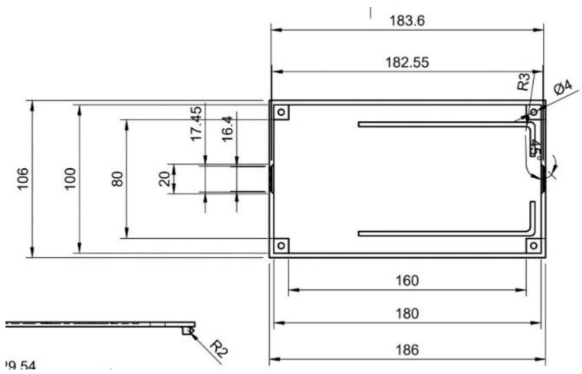

Figure 4. Top view sketch of EVPLC

Creating 3D Design EVCS Simulator Sketches

To visualize and optimize the layout of the Electrical Vehicle Charging Station (EVCS) simulator, we have developed 3D design sketches with precise dimensions: 49.6 cm in length, 34.6 cm in width, and 16.6 cm in height. This design accommodates essential components such as the Miniature Circuit Breaker (MCB), power supply, terminal block, voltage sensor, PCB, and circuit breaker. Each element is strategically positioned to ensure effective operation and safety while facilitating efficient airflow to prevent overheating. The 3D design is a comprehensive blueprint for assembling the EVCS simulator, ensuring all elements function harmoniously within the specified dimensions. Figure 5 shows the front and side views of the design.

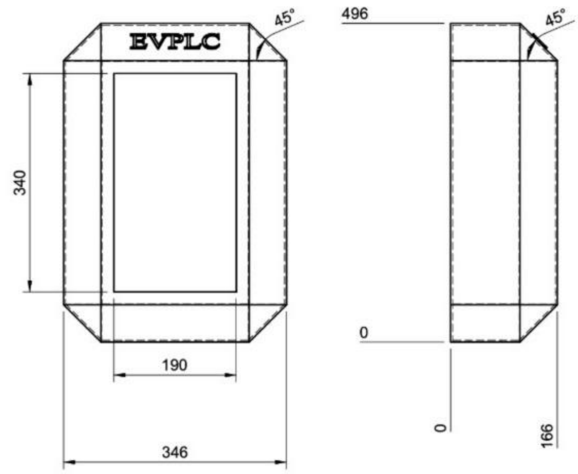

Figure 5. Front and side view sketch of EVCS

This figure illustrates the EVCS simulator's front and side perspectives, showcasing the layout and placement of all critical components. The detailed visualization serves as a guide for assembling and configuring the simulator, ensuring that all parts are properly integrated within the specified dimensions.

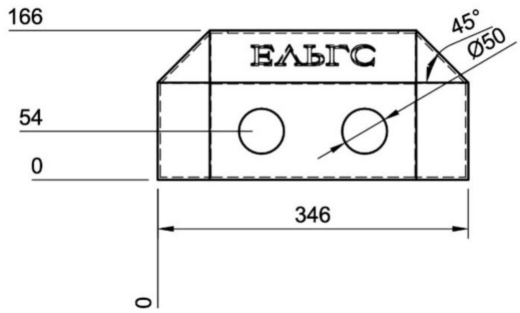

Figure 6. Rearview sketch of EVCS

The rear view looks at the back of the components, including the arrangement of power connections and ventilation slots. Additionally, the rear view of the EVCS simulator features two holes specifically designed as cable paths for charging connections to the powerline. These holes are strategically placed to facilitate secure and efficient cable management, ensuring the powerline communication module is effectively connected.

Human Machine Interface Design

The method used in the design of the Human Machine Interface (HMI) involves using a flowchart. Below is the flowchart of the basic system logic design for the EVCS HMI:

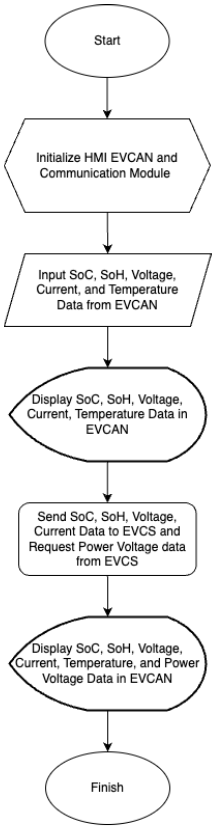

Figure 7. Flowchart system on HMI EVCAN

The flowchart in Figure 7 outlines the process for managing and displaying data on the Electric Vehicle Communication Area Network (EVCAN) HMI interface. The process begins with the initialization of the HMI and the communication module. This step ensures the system is ready to handle and accurately display data. Once initialized, the system inputs key parameters from EVCAN, including the State of Charge (SoC), State of Health (SoH), voltage, current, and temperature data. These parameters are crucial for monitoring the health and performance of the electric vehicle's battery system. After collecting this data, it is displayed on the HMI, allowing users to monitor the vehicle's current status. The next step involves sending the collected SoC, SoH, voltage, and current data to the Electric Vehicle Charging System (EVCS). In return, the system requests power voltage data from EVCS.

This bidirectional communication ensures that EVCAN and EVCS are synchronized and up-to-date with the latest data. Finally, the HMI EVCAN displays all the received data, including power voltage, providing a comprehensive overview of the vehicle’s and charging system’s status.

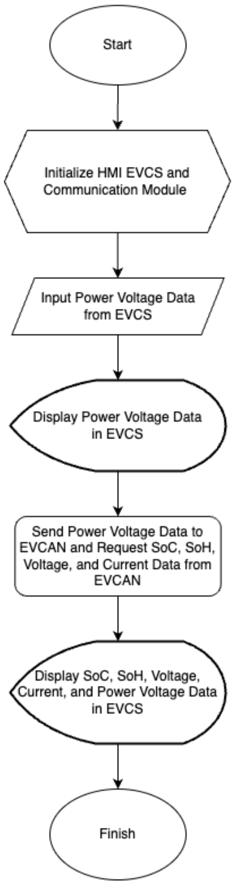

Figure 8. Flowchart system on HMI EVCS

Figure 8 presents the flowchart for the HMI interface of the Electric Vehicle Charging System (EVCS). The process starts similarly with the initialization of the HMI and communication module, preparing the system for data processing and display. The system then inputs power voltage data from EVCS, a critical parameter that reflects the charging system's current status. This data is immediately displayed on the HMI to give users real-time insights into the charging system's performance. Next, the power voltage data is sent to EVCAN, and in return, the system requests key parameters such as SoC, SoH, voltage, and current from EVCAN. This data exchange is essential for maintaining accurate and synchronized information between the vehicle and the charging system. Finally, the HMI EVCS displays all the relevant data, including the power voltage and the data from EVCAN, offering a complete view of the charging process and vehicle status.

These flowcharts illustrate the detailed steps involved in the communication and display processes between the electric vehicle and the charging system, emphasizing the importance of real-time data synchronization for efficient electric vehicle management.

Results and Discussion

3D Design Result

Based on the sketches that have been created, the design in the form of 3D is as follows:

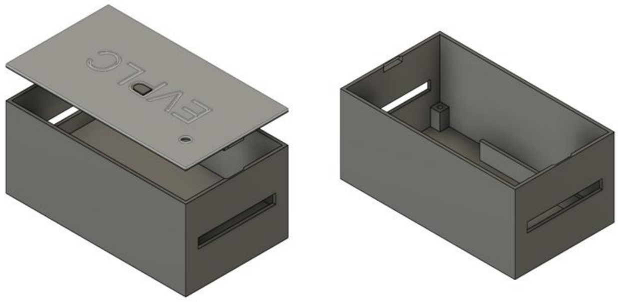

Figure 9. Front and Rear View of EVPLC

Figure 9 was designed based on the sketch that has been created. The front view of EVPLC has the label "EVPLC" and includes a switch button for any further development of interchangeability. The placement of the box and hole is intended to house the components used to operate the system on the EVPLC.

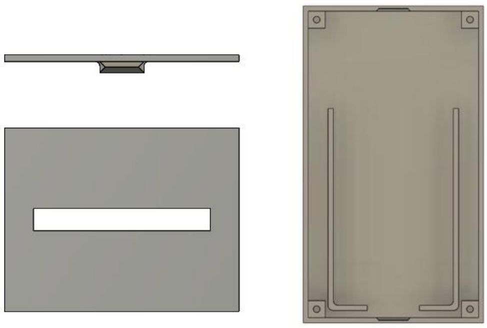

Figure 10. Upper and Side View of EVPLC

As seen in Figure 10 above, there are detailed locations for placing the components used in the EVPLC. At the top, a power supply is placed right between the partitions and the communication KQ330 PCB. Considering the dimensions of the EVPLC box, important hole dimensions are required for communication pathways between the CAN and powerline communication located on the right and left sides of the box. The placement of key components for the communication system, along with the power supply and ventilation holes within the device, is crucial to prevent overheating during operation.

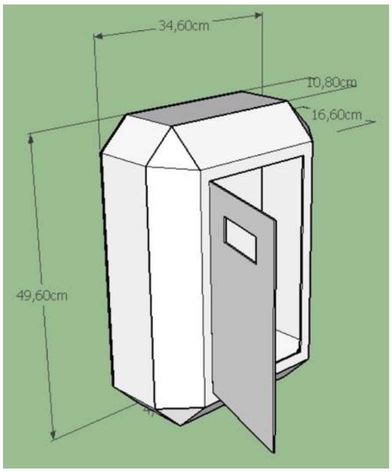

Figure 11. Design EVCS Simulation

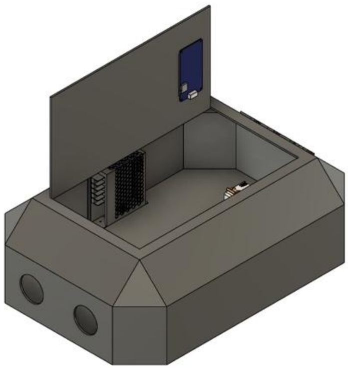

Figure 12. Side View Design EVCS Simulation

Figures 11 and 12 depict the front and side views of the EVCS simulator, highlighting the arrangement and positioning of all essential components. The detailed illustration guides assembling and configuring the simulator, ensuring that each part is correctly integrated within the specified dimensions. The rear view offers insight into the back of the components, showcasing the layout of power connections and ventilation slots. Additionally, the rearview features two specifically designed holes for cable pathways, enabling secure and efficient connections for charging to the powerline. These strategically placed holes ensure effective cable management, facilitating a reliable connection for the powerline communication module.

Human Machine Interface Design Result

The Nextion editor supports the HMI for this EVPLC, which displays several data points, including the State of Charge, State of Health, Voltage, Amperage, and Power Voltage.

1. First Condition

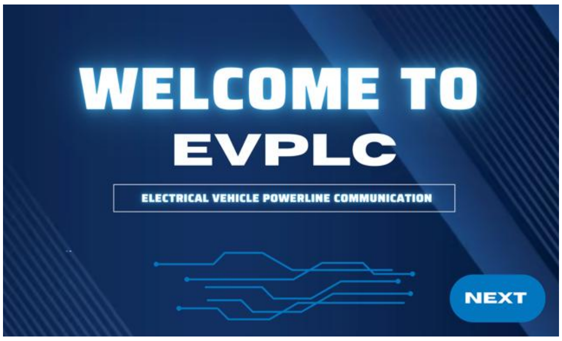

Figure 13. First Condition of HMI EVPLC

The statement refers to the initial screen or interface on the Human-Machine Interface (HMI) when the system is powered on or restarted. This initialization phase is crucial as it sets up the system, loads necessary data, and ensures all components function correctly before moving into operational mode.

The initial display might show basic information such as system status, loading progress, or a welcome message. It may also serve as a checkpoint to confirm that the HMI and connected devices are ready for use, ensuring that the system is fully prepared to handle subsequent tasks like monitoring and controlling the Electric Vehicle Power Line Communication (EVPLC) system. This phase is important for the overall reliability and user experience, as it provides feedback that the system is functioning correctly and is ready to process and display data related to the electric vehicle's state of charge, state of health, voltage, current (ampere), and power voltage.

2. Second Condition

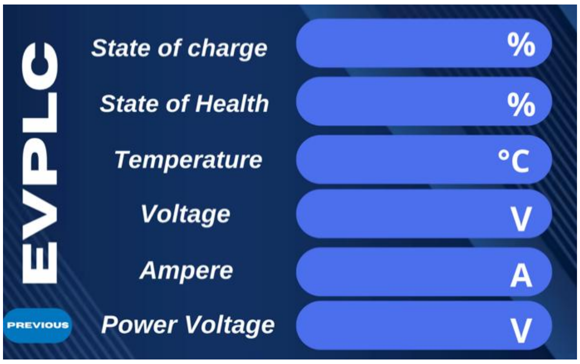

Figure 14. Second Condition of HMI EVPLC

In this state, the Human-Machine Interface (HMI) screen is designed to display key metrics such as the State of Charge (SoC), State of Health (SoH), Voltage, Ampere, and Power Voltage. These values are crucial for monitoring the performance and condition of the electric vehicle's battery and overall system. The data is dynamically updated on the HMI based on real-time information transmitted from the microcontroller via the powerline communication (PLC) system. The seamless integration of this data allows users to continuously monitor and assess the vehicle's electrical parameters, ensuring efficient operation and early detection of potential issues. This setup is essential for maintaining optimal performance and extending the lifespan of the vehicle's battery and other electrical components.

3. HMI Design on EVCAN Simulator

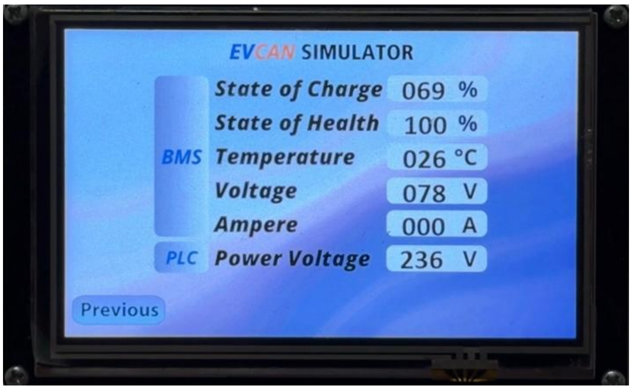

Figure 15. HMI Design on EVCAN Simulator

In this condition, the Human-Machine Interface (HMI) on the EVCAN is set to display crucial data received from both the powerline and the EVCAN Simulator. Specifically, the HMI shows the Power Voltage data transmitted through the powerline communication system. Alongside this, it also presents key metrics such as the State of Charge (SoC), State of Health (SoH), Voltage, and current (measured in Amperes) coming from the EVCAN Simulator. This setup ensures the user has a comprehensive view of the vehicle's electrical parameters in real-time, allowing for effective monitoring and management of the vehicle's battery and overall electrical system.

Testing

This test was conducted to verify the consistency of the data from the EVCAN, which is collected via the CAN bus and transmitted through the powerline, and ensure that it matches the data displayed on the HMI of the EVCS Simulator.

1. Testing Step

EVCS Simulator Setup:

a. Turn on the EVCS using the MCB switch.
b. Connect the male to female EVCS port.
c. Connect the output from the female port to the outlet.
d. Connect EVPLC port 1 to EVCS, ensuring correct high and low connections.
e. Upload the source code to the EVPLC microcontroller.
f. Open the Arduino IDE connected to the microcontroller.
g. Check the HMI EVPLC to ensure that the displayed data matches what is shown on the Arduino.

EVCAN Simulator Setup:

h. Turn on the EVCAN Simulator using the available switch.

i. Connect the Agile charge port to the Agile battery.
j. Connect the CAN main from the EVCAN Simulator to the EVPLC, ensuring correct high and low connections.
k. Check the HMI installed on the EVCAN Simulator for the results.

2. Testing Result

Figure 16. HMI of EVCAN Simulator

From the picture above, we can see the results shown on the EVCAN Simulator HMI. BMS stands for Battery Management System, which shows the data from the plugged battery in the EVCAN Simulator. Under that part, there is PLC, which stands for Power Line Communication. The power voltage value on that part is shown, which is 245 V. The value is gained from the sensor embedded in the EVCS Simulator, which represents the voltage used to power the whole system of the EVCS Simulator. The presence of the value from the EVCS Simulator's sensor shows that the communication sent through the power line is successful. (Ariviadi, Turnip, & Antonius, 2021).

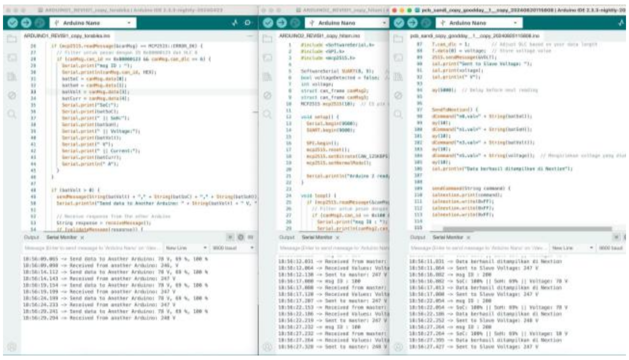

Figure 17. Serial Monitor Result of Bidirectional Communication

From the screen capture above, we can see that the left serial monitor represents the serial monitor of the Arduino that is embedded in the EVPLC module and plugged into the EVCAN Simulator. We can see that the EVCAN Simulator is trying to communicate three types of data, which are the voltage of the battery, which is 78 V, the SoC (State of Charge) of the battery, which is 69%, and the SoH (State of Health) of the battery which is 100%. Under those data, we can see that the EVPLC connected to the EVCAN Simulator successfully received the sensor reading value from the EVCS Simulator, which is 246 V and fluctuates in time according to the sensor reading.

Figure 18. HMI of EVCS Demo Module

The picture above is the documentation of the HMI plugged into the EVCS Simulator. From the picture above, we can see six lines of data: state of charge, state of health, temperature, voltage, ampere, and power voltage. Between those six lines, the researchers only used 4 of them since the Temperature and Ampere data are not used in this testing application. The power voltage represents the value from the sensor reading in the EVCS Simulator, while the voltage represents the voltage state of the battery in the EVCAN Simulator. We can see that all of those results align with the previous results on the serial monitor. By the presence and accuracy of data that are shown on the HMI from the EVCS Simulator, the bidirectional communication process is successful.

3. Testing Analysis

The communication system demonstrated good performance, with clear and accurate results on the EVCAN Simulator HMI and no interference affecting the data transmission. However, some areas need improvement. The robustness of the wiring needs enhancement to prevent interruptions from physical disturbances, as minor nudges can cause data interruptions or blanks. Additionally, the initial startup time requires optimization, as there is a noticeable delay in data stabilization, which might be addressed with better hardware and communication modules.

For Specification 2, the system met the requirements and effectively showcased bidirectional communication. The testing confirmed that the EVCAN Simulator displayed accurate data and demonstrated that the EVCS Simulator could charge the battery in the EVCAN Simulator. Although minor issues related to robustness and startup time were observed, they were consistent with those found in Specification 1. Overall, the testing proceeded as planned and yielded promising results, with areas identified for future development.

Conclusion

This journal focuses on the design of three-dimensional modeling and the design and testing of the HMI integrated with data from Nextion to support the use of EVPLC. The 3D design can be realized as a finished tool ready to be integrated with the components used to operate the EVPLC system.

The results of the HMI testing show that the interface successfully achieves its goals, with consistent data that matches what is recorded on the Arduino IDE. Instructions based on data from the HMI allow users to quickly understand the battery percentage level, voltage, and current. This represents a step towards the effectiveness and reliability of EVPLC.

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