Design Integration, Development and Functional Verification of Communication System Between DC Charging Station Controller and Electric Vehicle Communication Controller by using Power Line Communication (PLC) Module

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Abstract. The purpose of this thesis is to design integration, development and functional verification of communication system between DC charging station controller and electric vehicle communication controller by using Power line Communication (PLC) module, Raspberry Pi 4, Pulse Width Modulation (PWM) converter circuit, and CAN Bus communication protocol. The problems that this thesis attempts to solve are transmitting High-Level Communication digital signal data passed through a Low-Level Communication conductor without interfering with one another. Low-Level Communication is in the form of an analog control pilot Pulse Width Modulation (PWM) signal, the signal with a frequency of 1 kHz is used in AC Charging Station. In certain cases, AC Fast Charging and DC Fast Charging require High-Level Communication in the form of digital signal data, this digital signal data is sent using the CAN Bus Protocol with a baud rate of 500 kbps. The communication system between the DC charging station and electric vehicle setup is developed by integrating Raspberry Pi 4 with 2-CH CAN HAT Module as the DC Charging Station Controller and Electric Vehicle Communication Controller, SICON EMI EVPLC Module as Power Line Communication (PLC) Module, and PWM converter circuit as PWM signal converter. According to IEC 61851-1:2017, this setup will carry out the communication system between a DC charging station and an electric vehicle. The setup of communication between the DC charging station and the electric vehicle has been successfully developed, and the Power Line Communication module used in this thesis is successful in transmitting High-Level Communication through a Low-Level communication conductor. The CAN data that has been sent and received by controllers shows the components used in this communication system are successful.

Keywords: Electric Vehicle, Charging Station, Power Line Communication, High-Level Communication, CAN Bus Protocol, Pulse Width Modulation, Raspberry Pi 4.

1. INTRODUCTION

Electric Vehicles are now an innovation developed in the world's transportation industry. Many well-known Electric Vehicle brands have started to launch several Electric Vehicles that have been developed. This innovation is developed because Electric Vehicles are more environmentally friendly than fossil fuel vehicles or conventional vehicles, the power resource is the difference between Electric Vehicles and conventional vehicles. Electric Vehicles use motors whereas gas-powered vehicles (fossil fuel) employ an internal combustion engine. Electric Vehicles provide low running costs such as fuel and taxes. In addition, they do not emit harmful gases such as CO2. Conventional Vehicles require a gas station to refill their fuel, while Electric Vehicles have 2 ways to charge the battery. The first way is to charge it with a factory default charger at home and the second way is to charge it through Charging Stations. There are some differences in the plug or connector for electric cars, such as Japanese cars use connector Type 1-J772 for AC Charging and CHAdeMO connectors for DC Charging, Chinese cars use GB/T connectors for AC Charging and GB/T connectors with the model specifically DC for DC charging, American cars use the same connector Type 1-J772 as Japan for AC charging and CCS-Type 1 connectors for DC charging, European cars use Type 2 Connectors for AC charging and CCS-Type 2 for DC Charging. In the Charging process, several states run between the Charging Station and the Electric Vehicle, one of them is the communication state. This thesis will discuss the design and analysis of the communication system between the Charging Station and the Electric Vehicle.

2. LITERATURE REVIEW

This chapter contains an overview of several key aspects of this study. Such as a brief explanation of the Electric Vehicle Charging Station or Electric Vehicle Supply Equipment (EVSE), Electric Vehicle (EV), Communication Protocol, and all the specifications of hardware and software used in this thesis.

3. METHODOLOGY

The general idea of this thesis is to use the PLC module to transmit CAN data between DC Charging Station Controller and Electric Vehicle Communication Controller. This chapter contains the general architecture of the DC Charging Station and electric vehicle, detailed design architecture of the DC Charging Station Controller and Electric Vehicle Communication Controller, research methods that explain methods to achieve the purpose of designing a communication system between DC Charging Station and Electric vehicle.

In order to contract the system architecture, it is necessary to define the functions and characteristics that the system must have as well as any constraints that will affect its development. To achieve the aims of the thesis, their features, and functionalities are set, changed, or used for the system components provided.

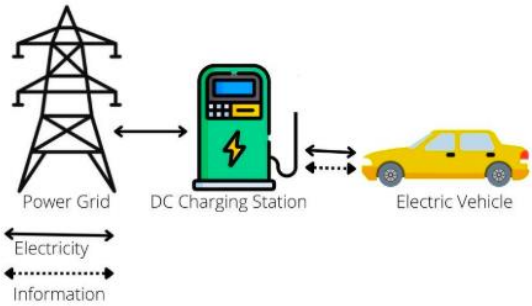

Figure 1. General Architecture of Charging System [24]

Figur 1 is the general architecture of the DC charging system, where the DC Charging Station gets its power supply from the power grid, this power grid is the main power supply to be able to power the DC Charging Station. The DC Charging Station, this DC Charging Station unit is available everywhere such as in public areas, offices, and at home. DC Charging Station supplies electric charge to the electric vehicle along with the exchange of information between DC charging station and electric vehicle. The information exchanged here is information on how much is the contents of the electric vehicle battery, battery health information, voltage, current, and battery ID. The scope that will be discussed in this thesis is the design and analysis of the communication system, doing information exchange that occurs between the DC Charging Station and the Electric Vehicle.

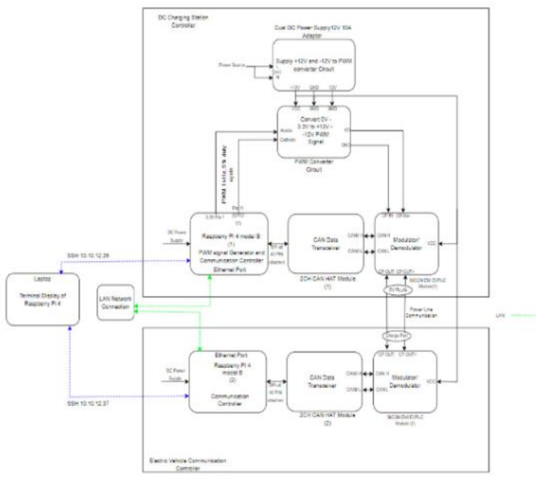

Figure 2. Design Architecture of DC Charging Station Controller and Electric Vehicle Communication Controller Experiment

Figure 2 shows the detailed design architecture the of DC Charging Station Controller and Electric Vehicle Communication Controller and describes all the functions of the components in the purple line which is the scope of this thesis. This design is a connection between components that will carry out the communication process between the Raspberry Pi 4 model B (1) and Raspberry Pi 4 model B (2) using the CAN Bus module through the SICON EMI EVPLC (power line communication) module.

Raspberry Pi 4 model B is a controller that will control all communication processes that occur and generate a PWM signal on the DC Charging Station Controller side. Raspberry Pi 4 model B is a single-board computer and dual-display, it is highly economical and has a leg over previous modules in terms of speed and performance. Raspberry Pi 4 model B has many features such as gigabit ethernet, coupled with onboard wireless networking, Bluetooth, 1.5GHz quad-core processor that is powerful and efficient, 2 USB 3.0 ports, 2 USB 2.0 ports, 2 micro-HDMI ports, and Micro-SD slot.

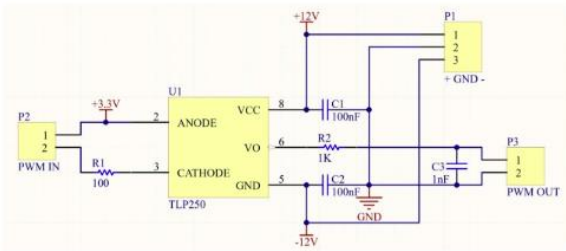

Figure 3. PWM converter circuit which refers to IEC 61851-1 standard

The purpose of designing the prototype of the PWM converter circuit is to convert DC PWM signal 0V – 3V to AC PWM signal +12V - -12V in accordance with IEC 61851-1 standard.

4. RESULT

The standards that have been identified to be followed are concerning the Communication system between DC Charging Station and Electric Vehicle by using Power Line Communication Module, which are : 1. IEC 61851:2017 Annex A about the Control pilot function through a control pilot circuit using a PWM signal and a control pilot wire 2. IEC 61851:2017 Annex A about digital communication at 5% duty Cycle

The data sent and received by the two raspberries are summarized in table 4.1 and table 4.2, where on the sending side the data type is decimal, and on the receiving side it will convert decimal data into hexadecimal then decoded by 2CH CAN HAT module and read on the Raspberry Pi 4 model B. Python-can library does not recognize CAN hexadecimal data, in sending CAN data with python scripts and python-can library can only send CAN data in decimal form but the frame ID of CAN data can be in hexadecimal form. If the CAN data is in decimal form, the receiving side will convert to hexadecimal and read in hexadecimal form. This is where the role of the MCP2515 chip that can convert decimal to hexadecimal.

5. CONCLUSION

The design of the communication system between the DC Charging Station Controller and the Electric Vehicle Communication Controller is carried out using a Raspberry Pi 4 model B as a controller from both sides, 2CH CAN HAT module as a CAN transceiver module, and SICON EMI EVPLC module as a PLC Module in charge of modulating and demodulating data. The setup of the communication system is capable of performing the communication system in accordance with IEC 61851-1:2017 Annex A regarding Control Pilot PWM signal with 1 kHz frequency and 5% duty cycle digital communication. CAN data generated from the Raspberry Pi 4 model B success received by other Raspberry Pi 4 model B to communicate with each other, this thesis is successful because the Raspberry Pi 4 model B successfully communicates through the SICON EMI EVPLC module and carries the same data and corresponds to what is sent by each Raspberry Pi 4 model B. PWM signal generation, sending, and receiving data is done in the CMD terminal of the laptop that accesses the Raspberry Pi 4 model B via SSH, using a python script to run all communication processes. SICON EMI EVPLC module is successful in transmitting High-Level Communication through Low-Level communication conductor.

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