SNI IEC 61851-23:2014 Compliant Pre-Charge Insulation Test Setup Development in a DC EV Charger using Raspberry Pi and CAN Bus Communication Protocol

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Abstract. This thesis aims to develop the system setup for the Pre-Charging Insulation Test conducted in a DC EVCS utilizing Raspberry Pi 4, DPM750/20C, and SIM100MOD, with CAN Bus communication protocol as its communication means. The problems addressed in this thesis are the rarity of the implementation of standard SNI IEC 61851- 23:2014, the studies in Pre-Charging Insulation Monitoring using integrated modules because of the low number of electric vehicles and their infrastructure, especially for DC Chargers, and the incompatibility between devices when integrating the necessary components to perform the pre-charge insulation test according to the standards. The pre-charge insulation setup is developed by integrating the Raspberry Pi 4 with 2-CH CAN HAT Module as the charge controller, DPM750/20C as the EV power module, and SIM100MOD as the ground fault detector. The setup will then perform the pre-charge insulation test procedure according to the SNI IEC 61851-23:2014. The setup development for the pre-charge insulation test has succeeded. The data obtained from the performed pre-charge insulation tests shows that the components could communicate despite the differing baud rate requirements and that the pre-charge insulation test procedure can detect the insulation faults and act accordingly in the event of ground faults.

Keywords: Charging Station, Pre-Charge Insulation Test, SIM100MOD Ground Fault Detector, CAN Bus Communication, DPM750/20C Power Module, Raspberry Pi 4

1. INTRODUCTION

The beginning of the electric vehicle history comes from a barn owned by Thomas Edison in his home estate in Glenmont, West Orange, New Jersey, in 1904. The first residential electric vehicle charging station was shown to the public by Edison. Later, the charging station would be moved to his concrete garage, where he would continue to charge his electric vehicles. [1] Today, Electric Vehicles (EVs) are becoming more prevalent in everyday lives in multiple countries; therefore, the development of infrastructure to accommodate the operations of the EVs, such as Electric Vehicle Charging Stations (EVCSs), is needed. The EVCS has multiple essential components in its system. The controlling element that manages its operations and functions in charging EVs is the controller. The controller controls the power supply of the EVCS to charge the EVs and all its safety features, including Insulation management. Insulations in highpower electrical applications are needed to ensure the safety of parties involving all usage cases of the applied operations. Electric Vehicle Charging operations are one such. Thus, the implementations and development of EVCSs must have a standard in both safety and efficiency that has been curated extensively to fulfill the charger's role in the Electric Vehicle ecosystem. One such requirement is to enable the safety procedures and operations in the case of Insulation failures. A team does the project that this thesis is contained in with Ronanda Paramayuda [STUDENT: 11201802014] in different scopes. His scope analyzes communication between EV and EV Charger, system design, and data transfer.

2. LITERATURE REVIEW

Reviewed the literature regarding the topics involved in the precharge insulation test, from a general overview of the Electric Vehicle and its infrastructure, the types of charging processes, the charge controllers involved in the pre-charge insulation testing, the EV charger power module, the ground fault detector, standards that govern the DC EV chargers, and communication protocols, such as CAN Bus and MOD Bus.

3. METHODOLOGY

The methods done to reach the goal of the thesis. It includes surveying the requirements of the pre-charge insulation tests, designing the system architecture, configuring the hardware connection according to the requirements, testing the CAN Bus communication of the hardware, designing software scripts for the communication and pre-charge insulation test in compliance with the requirements, testing the insulation test script on the system setup.

Before designing the system architecture, the requirements are needed to determine the functions and features that the system needs to possess or limitations that affect the system development. These functions and features are configured, reconfigured, or utilized for the provided system elements to fulfill the goals of this thesis.

The EV charging system's general architecture shows the system's main components. The grid, which is the power source of the charging system, is consisted of the main power primary from the electrical energy provider and the infrastructure that contains the charging system charging unit and sub-units, public spaces, gas stations, homes, and other locations that can contain sufficient power outlet. The V2G unit is the component that connects and converts power from the power grid to charge electric vehicles' batteries, with different configurations depending on the standards and the type of electric vehicle it caters. The last component is the electric vehicle which has different power storage systems that need different types of charging units to charge. The scope of this thesis is in the V2G Station, a part of the encompassing architecture of a DC EV charging station. The general architecture of the DC EV charging station can be seen in Figure 1.

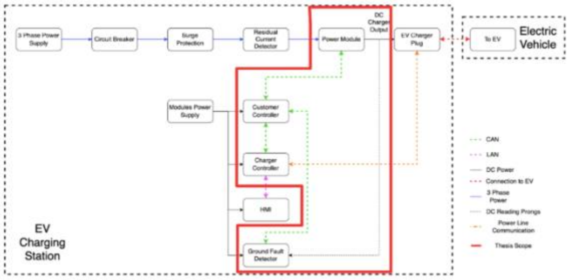

Figure 1. General DC Charging station architecture

The architecture in Figure 2 shows the General DC Charging Station system. The 3 Phase Power supply is the 3-phase power that comes from the power grid. The Circuit Breaker, Surge Protection, and the Residual Current Detector are the safety contactors that connect the power grid to the charging station, sudden power surge protection contactors, and residual current detection and contactors, respectively. The Power Module is the main power supply for the charging process. It converts 3-phase AC power to DC output power to the EV charger plug, which connects the EV power network to the EV charging output and communication. Another power supply powers the control system inside the charging station as it does not need considerable wattage. The control system includes the HMI, which enables customers to interact with the EV charger, the Ground fault Detector for insulation fault detection, and the Customer Controller and the Charge Controller.

The designed electrical and communication connection between the Modules and the Controller with CAN Bus communication monitoring is shown in Figure 2.

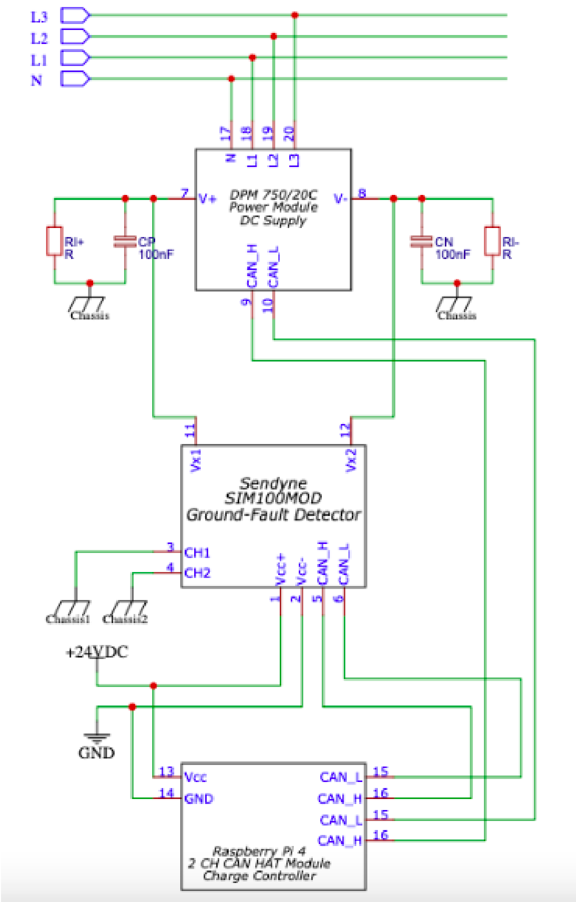

Figure 2. Hardware Connection Diagram

The Raspberry Pi 4 with the 2-CH CAN HAT Expansion Module is to control and govern the CAN communication from and to the DPM750/20C and the SIM100MOD. The chassis connected to the SIM100MOD are the DIN railing mounts that are connected to the ground. It would work as a regular ground, replacing the chassis. The DPM750/20C DC power output would not be attached to a DC EV charger plug, as the scope of this thesis do not include processes that involves an EV or a plug. HMI and other user interaction devices are also excluded as the thesis scope do not include user verification and authentication process. The thesis only covers the pre-charge insulation test setup with no additional processes before or after the test.

The goal to develop the pre-charge insulation testing software is to incorporate the SNI IEC 61851-23:2014 Annex AA.4.2.3, pre-charge insulation testing procedures, and Section 6.4.3.106, pre-charge insulation resistance minimum value, into the python script that will run the pre-charge insulation test, as the pre-charge insulation test procedure executed by the charge controller Raspberry Pi 4 must comply to the SNI IEC 61851-23:2014 standards.

The CAN Bus Communication Testing for the SIM100MOD is done to ensure that the components can receive and respond to CAN messages sent into their CAN interfaces.

4. RESULT

The Chassis 1 Grounded and Chassis 2 floating test shows the same insulation errors as the Chassis 1 and Chassis 2 floating test. The read insulation data from the SIM100MOD in Table 1 and also from the initial calculations, and the ground fault detector cannot create new estimates.

Table 1. Leakage Resistor 20kW Insulation Test Data

Insulation Resistance + (kΩ)	Insulation Resistance - (kΩ)	Insulation (Ω/V)	DPM Voltage (V)	Test Voltage (V)	Time	Insulation Error Binary (*status_bits*)
18	2726	36	0.00	500	2022-06-16 12:56:16	00100111
18	2726	36	5.05	0	2022-06-16 12:56:16	initial
18	240	36	5.05	500	2022-06-16 12:56:16	00100111

The 20kW leakage resistor insulation test results are the same as the 30kW leakage resistor insulation test. Table 1 shows the insulation resistance and insulation are below the minimum threshold, 50kW and 100 W/V respectively, and the status_bits reflect the results. The pre-charge insulation test performance test concludes that the pre-charge insulation testing system setup can initiate and complete the insulation test using the integrated Raspberry Pi 4 with 2-CH CAN HAT as the central controller, DPM750/20C power converter, and the SIM100MOD ground fault detector and in compliance with the SNI IEC-61851-23:2014 section 6.4.3.106, AA.4.2.3, and section 101.2.1.2.2. Data transaction between the Raspberry Pi 4 with the DPM750/20C and the SIM100MOD is done without complications, as the data has been parsed correctly from the voltage values, insulation values, and insulation resistance values, and hardware errors. The data obtained can be processed in the insulation fault checking, and the Raspberry Pi 4 managed to stop the insulation testing process when an insulation fault is detected.

5. CONCLUSION

The Pre-Charging Insulation Testing system setup using Raspberry Pi 4 with 2- CH CAN HAT, DPM750/20C, and SIM100MOD is successfully developed. The setup is proven capable of performing the pre-charge insulation test without complications while complying with the SNI IEC 61851-23:2014 regarding the insulation test before charging. The python script follows the SNI IEC 61851-23:2014 Annex AA.4.2.3 and is functional in detecting insulation faults and hardware errors, as shown in 4.2 Pre-Charge Insulation Testing Hardware Setup Results. It can also execute tasks and give responses when the insulation fault is detected in the pre-charge insulation testing with multiple insulation faults scenarios such as faulty hardware connections and the presence of a leakage resistor.

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