Modularized, Reconfigurable and Bidirectional Charging Infrastructure for Electric Vehicles with Silicon Carbide Power Electronics (MoReSiC)

Deliverable D1.3 (Month 39)

Title: "Full control system with the digital control system and the PFLC along with supplementary modules for fast and reliable controller-to-converters communication adequate for every operation mode."

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Executive summary

The Deliverable contains the description of the full control system, including the digital control system and the constructed power flow controller hardware, along with supplementary modules for fast and reliable controller-to-converter communication that is adequate for every operation mode. The controller allows for the regulation of the whole advanced electric vehicle charging system, including the grid converter, battery energy storage converter, EV interfacing isolated dc-dc converters, and the later-included converter dedicated to photovoltaic integration. Details on the applied technologies in regard to the controller system, communication, measurements, and input/output signals are given. As show, the developed control system allows for full operational capability of the advanced charging station, including implementing the energy management algorithm, setting the modes parameters for each converter, as well as monitoring and data acquisition. Therefore, tasks T1.3 and T1.4 have been completed.

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1. Power flow controller for the advanced EV charging system

Given the substantial number of converters in the advanced EV charging station depicted in Fig. 1 and the requirement to implement the power flow algorithm provided in Deliverable D1.1, a robust and multifunctional control system ensuring fast and reliable communication was required.

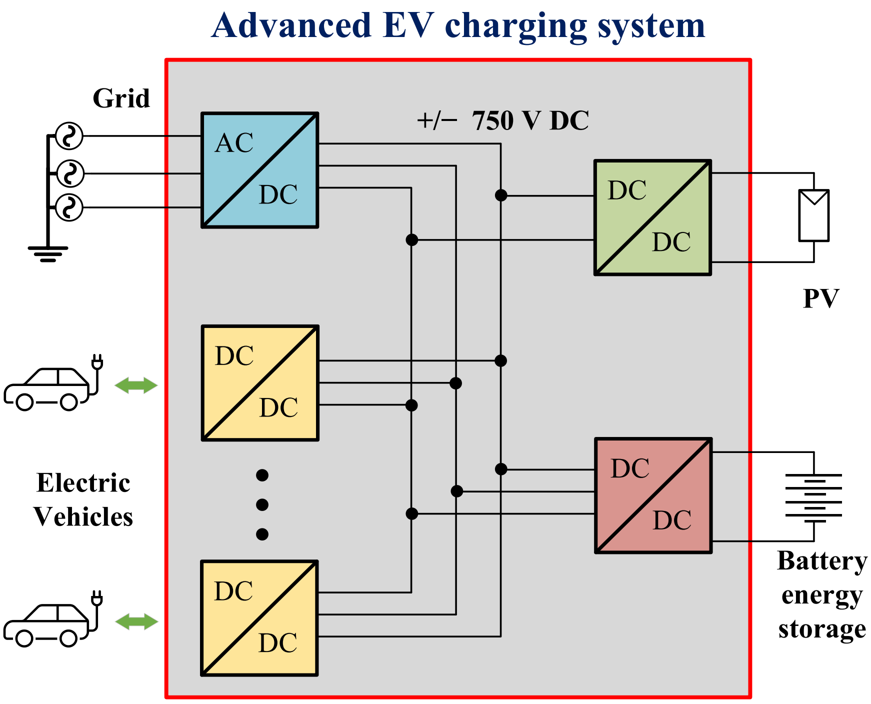

Fig. 1 Scheme of the advanced EV charging system enhanced with additional PV DC/DC converter.

At first, a number of options have been analyzed for an appropriate digital signal processor capable of all the requirements, including decent operational power, a series of modules for input/output communication, e.g., CAN for converter control, USB for user intractability, HDMI for display, etc. Considering characteristics such as cost, market availability, ease of use, a vast array of available modules, and a well-established user base that could be useful to speed up the coding process, a Raspberry Pi 4b development board has been chosen.

The main controller based on the Raspberry PI 4B evaluation board is depicted in Fig. 2. The internal connection and communication with the converters in the system is possible with the integration of the RS485 CAN HAT module for Raspberry Pi. For easier use for the operator, a graphical user interface has been developed to be displayed on a 15,6' touch monitor, later mounted in the front of the rack cabinet with the whole system. The monitor is connected to the Raspberry Pi via an HDMI cable and USB for touch operation. The Raspberry Pi's power supply comes from the monitor's USB port. Exemplary views of the graphical interface are shown in Fig. 3 and 4. The low-level control for each converter, including technical information as well as the possibility to alter the operating parameters, e.g., the controller parameters, used for the converter testing, is portrayed in Fig. 3. On the other hand, Fig. 4 exhibits the top-level control, focusing on the general operation of the station, the power flow between the converters, and the employed energy management algorithm.

Fig. 2 The Raspberry PI 4B evaluation board with the power flow controller used as the main control for the system.

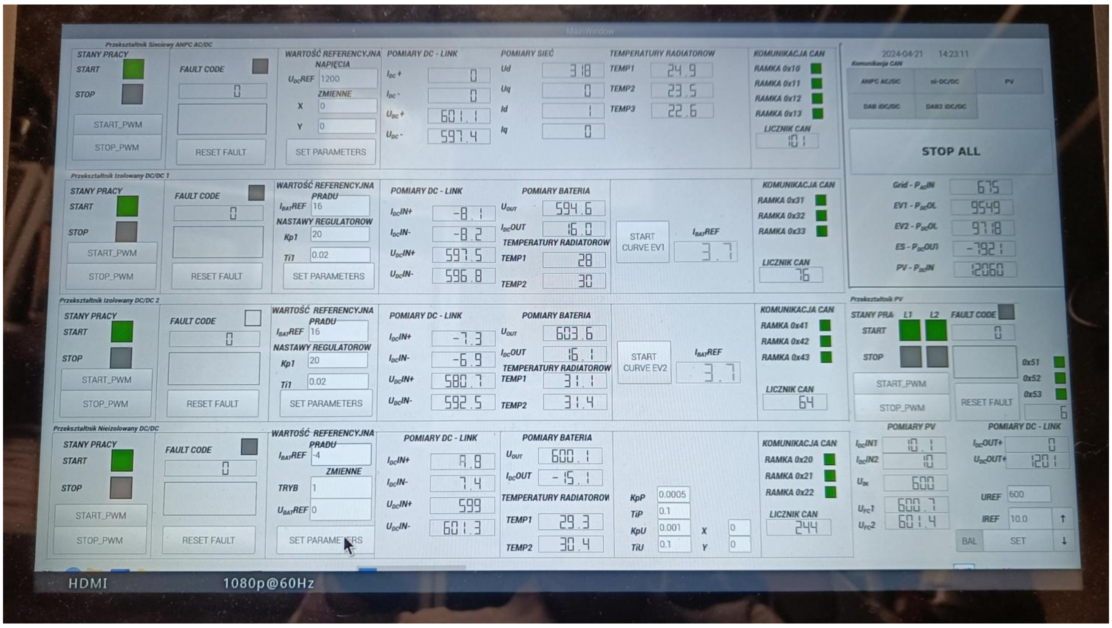

Fig. 4 The view of the dedicated control panel for the charging system containing details on low-level control for each converter.

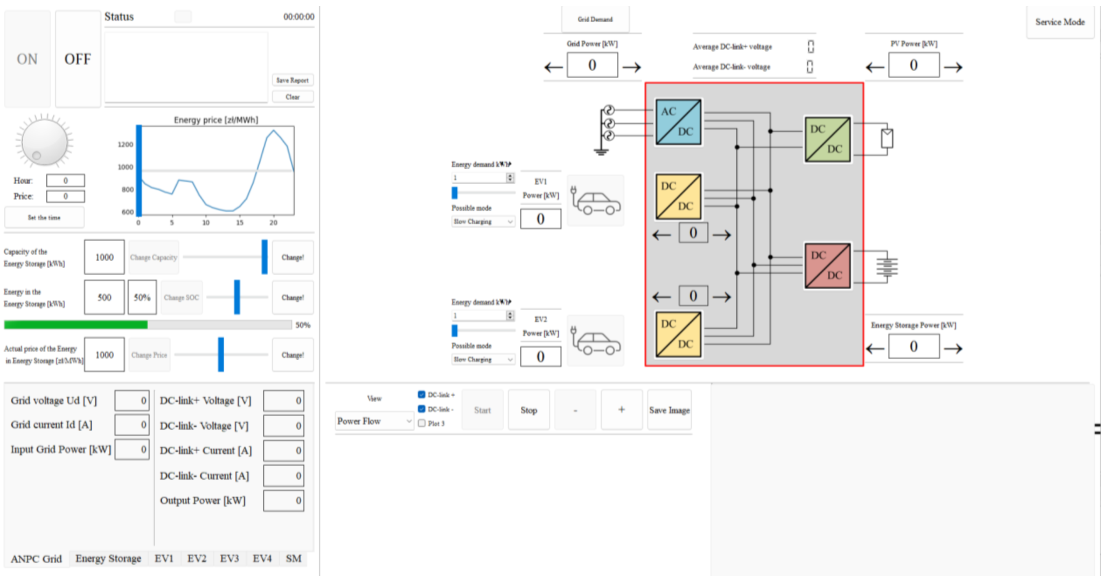

Fig. 5 The view of the dedicated control panel enabling observation of the status of the charging system from a top-level perspective, focusing on power flow and energy management.

In order to ensure high speed, low latency, and high reliability, a number of available communication protocols have been investigated. The considered solutions included CAN, RS485, and Ethernet-based EtherCat, Profinet, and Profibus standards. In the end, the CAN protocol was chosen, as it is characterized by good EMI immunity and full communication capability, and it is a conventional approach in the industry that is well-known by the project participants.

To be more precise, the power flow controller utilizes a dedicated communication protocol using the CAN standard to communicate with all converters in the system as well as with the control panel. Through the proper design of the communication network inside the rack cabinet with mounted converters, the communication system is practically immune to EMI emitted in the system and enables the safe operation of the entire system. The power flow controller allows for setting reference values in the test operating mode and also allows for the ability to control the system's operating status, ensuring monitoring capabilities. Through dedicated software created for the project, it is possible to read the parameters of the entire charging system, such as voltages, currents, and temperatures.

Obviously, CAN capability also had to be included in the low-level converter controllers based on DSP from Texas Instruments. The photograph of the control board with the appropriate communication module is shown in Fig. 5.

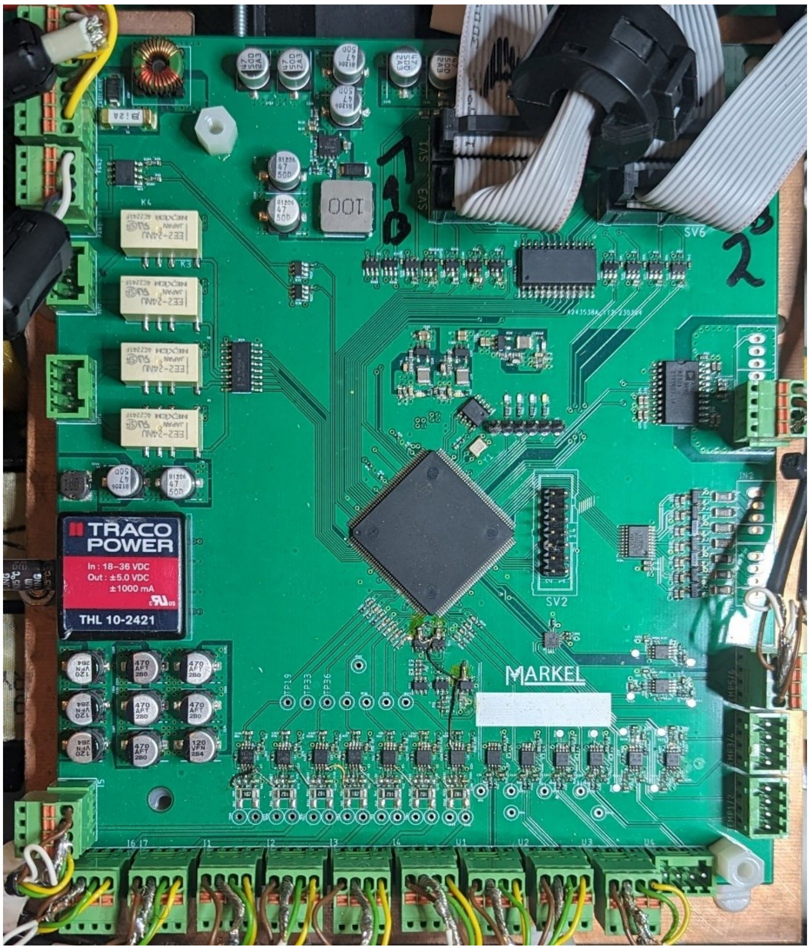

Fig. 5 Control board based on DSP applied in the converters, capable of CAN communication with the main power flow controller.

2. Main controller capabilities

The main advanced charging station power flow controller is founded on one main window on the 15" touchscreen. It enables complete control of the whole charging infrastructure from the top-level perspective. It is separated into five different sections, which are dedicated to either controlling or monitoring the system. It is shown in Fig. 6, whereas the operative description of each section of the user interface is explained below.

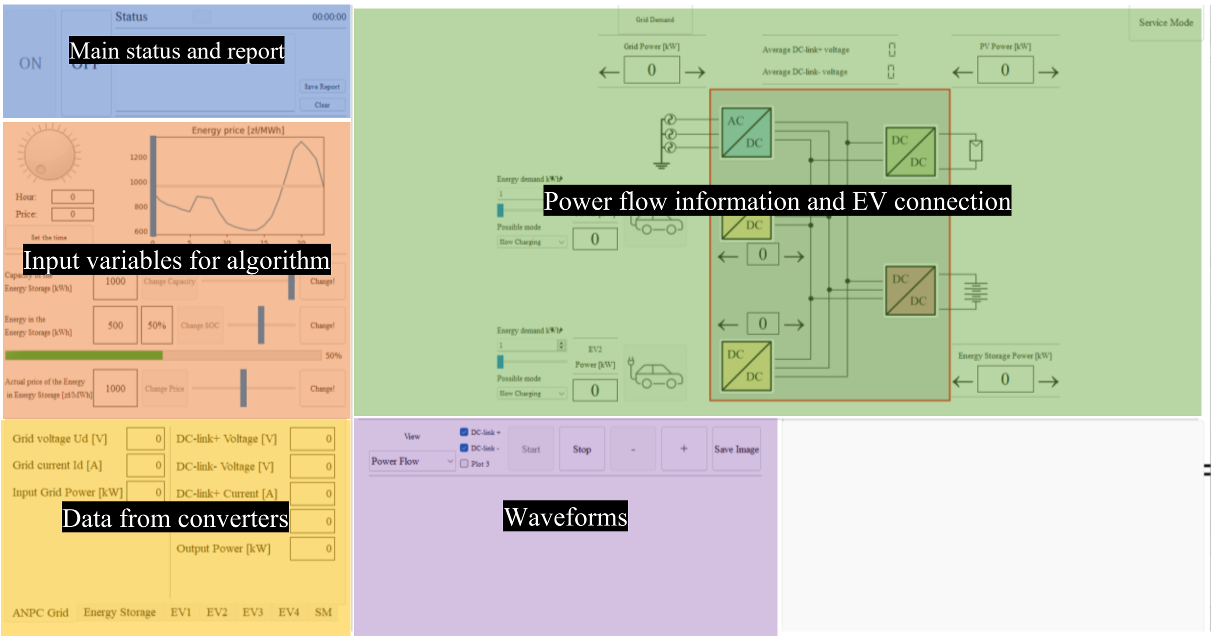

Fig. 6 Main controller of the advanced charging station - user interface.

2.1 Main status and report

This section aims to allow simple turn-on/off of the charging infrastructure, including all the converters. It also has a status indicator that informs about the operation of the converters or possible errors. The blank window is for report generation. Every significant change in inputs and outputs is listed together with the specific time of its operation there. This report can be saved into a text file format to examine the process afterward, e.g., for further data curation, failure analysis, and so on.

2.2 Input variables for the algorithm

This particular section is essential from the point of view of the power flow and energy management algorithm. Information about the state of charge and the energy storage capacity is crucial to demonstrate and verify the algorithm's performance. In this section, the user can define the actual market price of the grid energy, the capacity of the additional energy storage, its actual state of charge, the estimated price of that stored energy, and also the information on the PV plant state so that several scenarios can be analyzed an emulated.

2.3 Data from the converters

The CAN network established in the whole infrastructure allows for the sending and receiving of various data. This section represents the received data from each of the particular converters. In detail, the current and voltage from both the input and output side of the converter, and the calculated power. To view the parameters of a specific converter, e.g., for low-level control, the user may touch the label with the name of the converter lister at the bottom of the section or the converter on the visualization in the section "Power flow information and EV connection."

2.4 Waveforms

In this section, there is a possibility of exploring the collected data through time, similar to an oscilloscope. The information about the power flow from the various sources, as well as the averaged voltages in the DC-link circuit, are collected and presented in the window. It is also possible to zoom in and out, start/stop the trace, and save the current view into the image and the data into the CSV file. This feature is very useful for general monitoring of the station.

2.5 Power flow information and EV connection

This section represents a schematic connection of the built EV charging infrastructure. Each of the presented converters on the screen acts as a button and can be "touched," which directly changes the displayed information in the "*Data from the converters"* section to the corresponding converter. The buttons below the charging infrastructure correspond to the EV, which can arrive at the charging station. This was made to test the algorithm and the built infrastructure. It emulates the connection plug to the EVs. Below the EV buttons, there are parameters that define the EV battery's status, which corresponds to the energy demand. There is also a box that can be specified for the operation, e.g., fast charging, slow charging, or V2G. Furthermore, this window shows the status of charging and the required energy to charge the EV fully. Near each converter, there is a box showing the power with which the converter operates. The arrows and the color helps to identify the direction of the power flow. At the top, there is also information about the averaged DC-link voltage values, which are crucial from the point of view of the whole station operation.

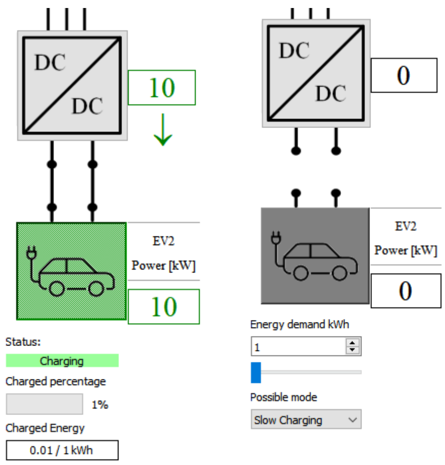

Fig. 7 User interface example – basic EV parameters and connection information.

If the user chooses to charge fast (if that option is available), there is information on the screen that the outputs of all converters connectors are connected in parallel to combine the power of several converters to deliver fast charging capability. If another user wants to connect to the charger at that time, it will be queued and served when the fast charging ends.

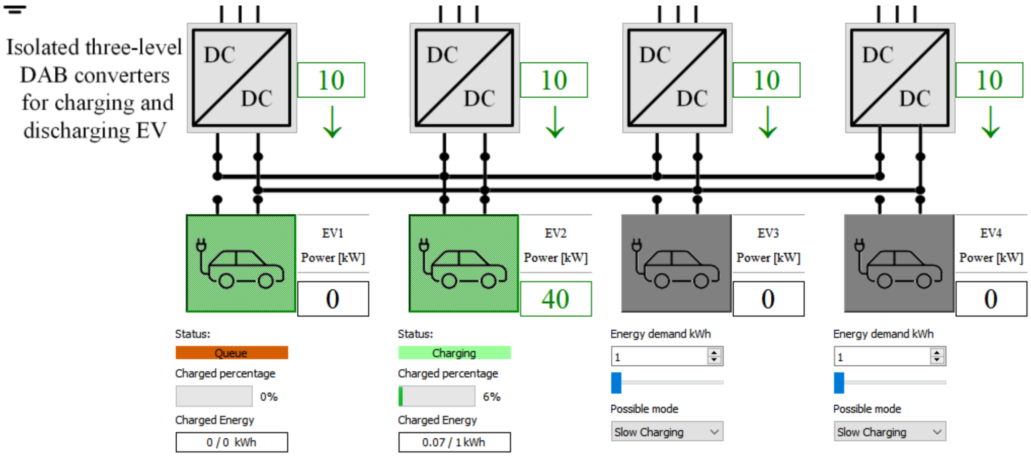

Fig. 8 User interface example – EVs reconfigured in fast charging operation.

3. Conclusion

In Deliverable D1.3, the full power flow control system with its hardware realization was presented. The controller based on Raspberry PI 4B evaluation board with the communication with the system components via CAN, has been constructed and validated. The control system is further expanded with a dedicated graphical user interface, including touchscreen operation for ease of use. The developed control program allows for full operational capability of the advanced charging station, including the implementation of the energy management algorithm, setting the modes, and parameters for each converters, as well as monitoring and data acquisition. Therefore, Task T1.3 Design of the digital control system, as well as Task T1.4 Internal and External Communication, have been finished in this Deliverable, and with all the other Deliverables in WP1 completed, the work package has been fully done as well.