Epic Power Converters, S.L.
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AN048
Bidirectional EVSE

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Application Note AN048

Bidirectional EVSE

Introduction

The increasing electrification of the automotive industry is leading to an extensive development of power electronics linked to electric vehicles. The similarity of features with a conventional combustion car is essential for end users; therefore, the autonomy and charging time of electric vehicles are a hot topic for stakeholders and many R+D efforts worldwide are undergoing.

Regarding charging station connection technologies, there are currently different types of connectors where CCS and CHAdeMO standards are the most prevalent for high power DC charging.

It is essential for EVSEs (Electric Vehicle Supply Equipment) not only to achieve high power delivering (that will reduce the EV charging time) but also to implement bidirectional capabilities in order to draw energy from the connected EV when the infrastructure needs to mitigate high power peak demands. This is commonly known as V2X (Vehicle-to-X), with particularizations such as V2G (Vehicle-to-Grid) or V2V (Vehicle-to-Vehicle) among others.

EVs are commonly parked outside a factory, company, commercial parking lots, homes, etc. for a relatively long period time (between 2 to 8 hours). Bidirectional EVSEs with a central neural machine-learning algorithm bring the possibility to smooth and undersize the overall demand from the utility power grid and therefore, the required infrastructure, among other benefits.

Epic Power has developed a Pilot Project, with support from the Ministry for the Ecological Transition and the Demographic Challenge under grant number PGE-MOVES-SING-2019-000070. This project demonstrates how to integrate our isolated DC/DC bidirectional converters (EPC) in a 20 kW EVSE that is capable of charging and/or discharging two vehicles at the same time (CCS and CHAdeMO one each). For this purpose, a small DC micro-grid has been created with a PV string supplying up to 4.6 kWp in a sunny day. PV panels are connected to the DC grid by means of another EPC converter with MPPT capability.

In this project, some machine-learning algorithms (in particular LSTM, Long Short-Term Memory Networks) have been implemented and take decisions based on the following predictions:

- Energy demand of the manufacturing facility
- PV solar energy generation
- EV plug-in time and duration

Infrastructure architecture

A DC micro-grid has been implemented in our facilities with the purpose of interconnecting EVSE, PV generation and the grid energy-sharing device.

The deployment of this small DC micro-grid gives us the advantage of adding more renewable energy sources (like hydrogen fuel cells, wind energy and other kind of harvesting technologies) or even battery packs by means of our Hybridation Cabinet in the near future.

In Fig. 1, an overview of the DC Micro-grid is presented.

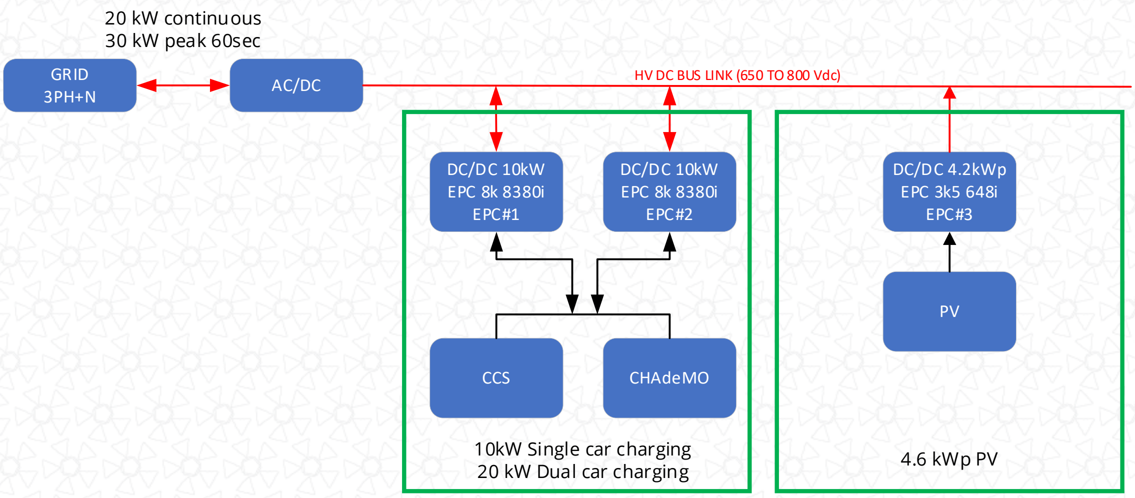


Fig. 1. DC Micro-grid overview

Power stage

This project gave us the opportunity to upgrade one of our EPC stock units: EPC 8k 8380i. Thanks to our R+D Engineering department efforts, we were able to deliver up to 10 kW (at nominal voltage) per unit where two units will be feeding the EVs, hence 20 kW.

Another EPC 3k5 648i (stock version) with an integrated MPPT Algorithm is used for PV solar generation, interfacing 48 V_{dc} to 700 V_{dc}. The conversion between PV panels and the DC micro-grid can be alternatively accomplished by other supplier's equipment.

Interconnection with the main grid is done by a 20 kW Yaskawa D1000 bidirectional frontend.

Thanks to the isolation incorporated between high and low sides in our DC/DC converters, the high side DC link can be shared among different EVs and feed them individually.

Furthermore, our DC/DC converters are easy to parallelize, just by wiring them in the right way. Looking into Fig. 2, K3 and K4 contactors enable to parallelize both converters to feed one car with up to 20 kW (CCS or CHAdeMO).

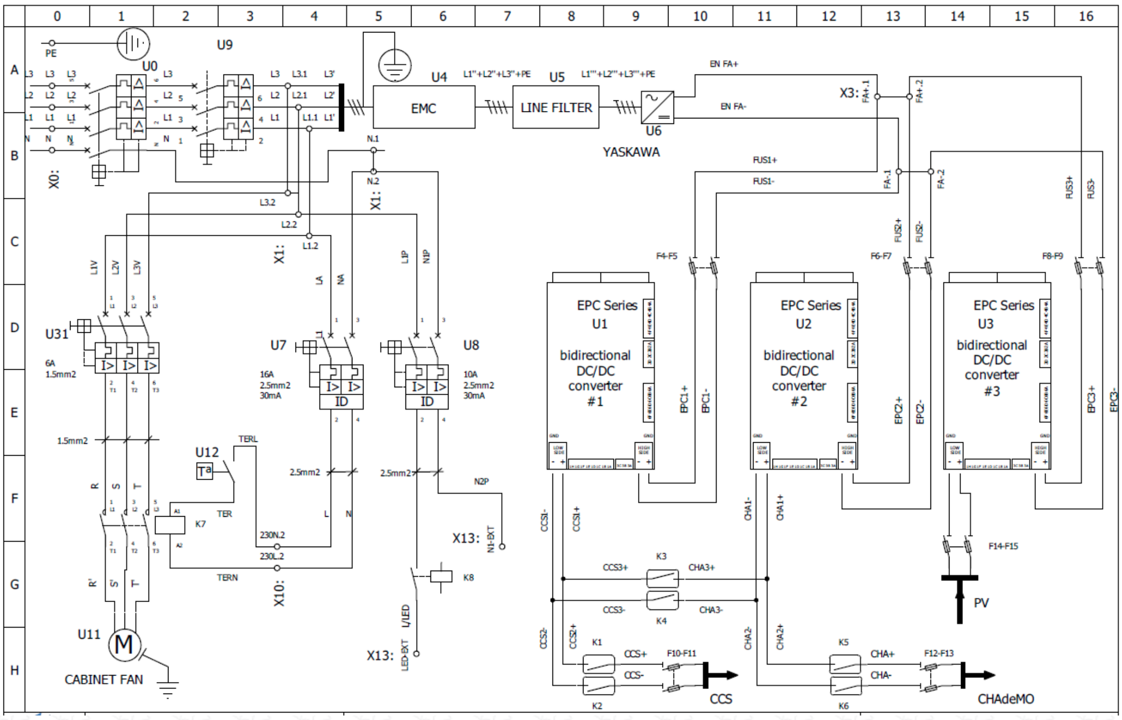


Fig. 2. Power Stage Schematic

Note that energy flow is bidirectional, thus bidirectional DC contactors must be used (i.e. C310 series from Schaltbau). For support in the design of electric cabinet and selection of components we must give credit to CuroCon GmbH.

Control stage

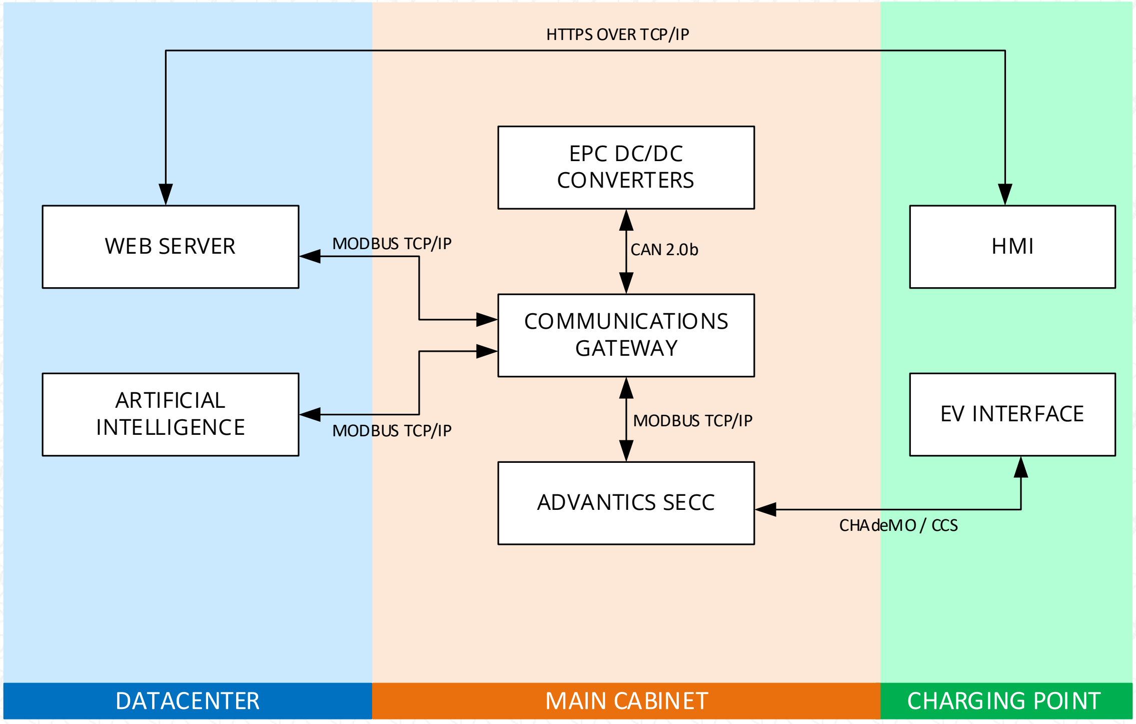


Fig. 3. Control Stage Diagram

The integration of several and different components increases the communication layer complexity. We have had to deal with five different communication protocols:

- ModBus TCP/IP
- HTTP/HTTPS
- CAN 2.0b
- CHAdeMO
- CCS

A communication gateway has been developed by epic power that not only translates between protocols but also implements some advance control techniques to command the EPC DC/DC converters in parallel mode.

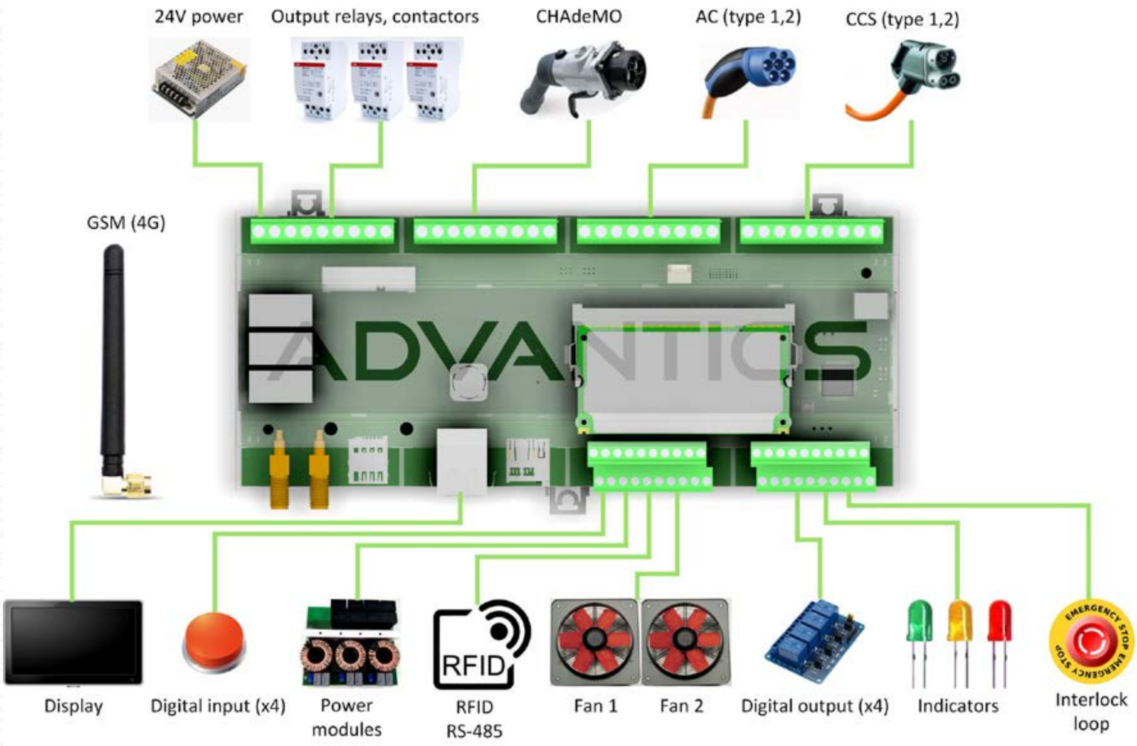


Fig. 4. Advantics SECC connection diagram

Advantics has developed an easy to use state machine controlled through the CAN 2.0b bus where all the car information is filtered and shown; that gives the ability to be controlled not only through scripts inside its device but also from external ones (as we have made in this project).

CCS and CHAdeMO protocols are very strict regarding timings and sequences that are being treated by Advantics SECC in a transparent way to the external controller.

Protocol updates are also available through their support team and can be carried out in a simple way.

Precharge

CHAdeMO protocol does not have any precharge stage before connecting the car directly to the power modules; instead, you must have a precharge resistor with a bypass contactor to limit inrush current flowing from the car’s battery.

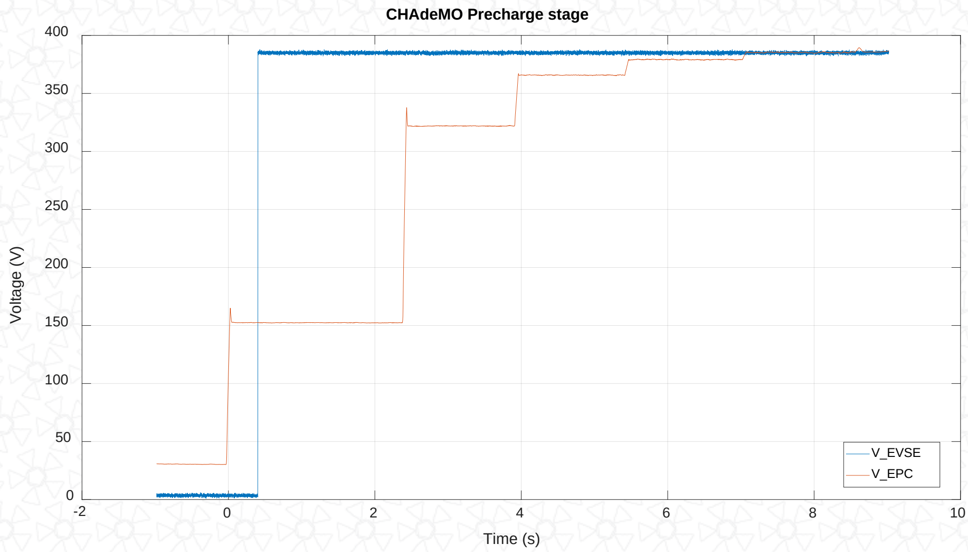


Fig. 5. CHAdeMO Precharge Stage

We have designed a precharge method to avoid the use of this precharge resistor that consists of reading the battery voltage before closing our own contactor, then command our EPC converters to precharge the bus from 0V to the battery level (with no more than a ±5% of deviation) and finally close the contactor. This stage is made between the ready to charge and charging stages of the car.

A precharge stage of a CHAdeMO connection can be seen on Fig. 5

Charging point

On the charging point side, an IP65 anti-vandal Android touch screen has been used as a HMI and an Android APP has been developed to show the webpage hosted in our Webserver.

Fig. 6. CCS (left) and CHAdeMO (right) charging cables

The EV Interface is a charging post with two charging cables. The CCS one is a Phoenix Contact CHARX T2G4CC and the CHAdeMO one is a Sumitomo Electric SEVD-02E (Fig. 4).

The CCS charging cable is able to deliver up to 200A @ 1000 V_{dc} meanwhile the CHAdeMO delivers up to 125A @500 V_{dc}.

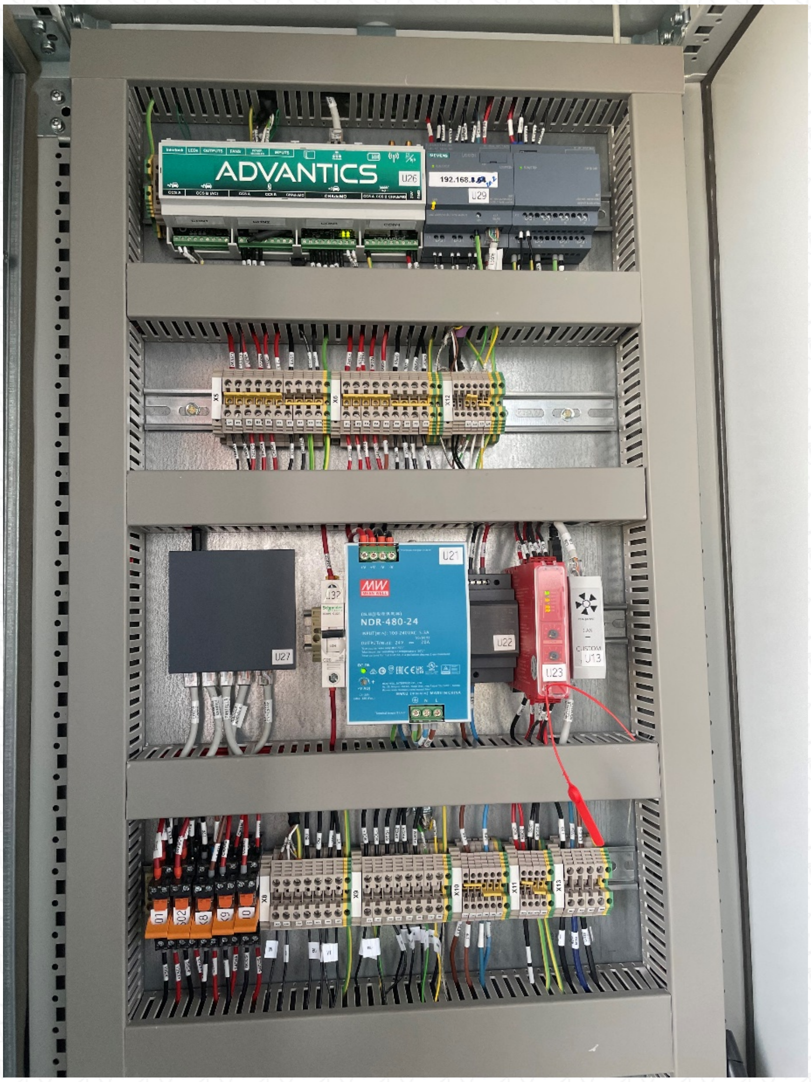
Figure 5 shows the status of the charging post that can be customized to meet the client needs.

Fig. 7. Charging post

Main cabinet

The following pictures display the actual implementation of this pilot project inside an ample electric cabinet. The overall size can be optimized and reduced which was not the objective for this pilot project.

(a)



(b)

Fig. 8. Main cabinet. (a) Power stage and (b) control stage

The developed communications gateway is running in an embedded Linux RTOS with Python Scripts capabilities where:

- A MODBUS TCP/IP Server has been implemented as the main intercommunication point between devices and datacentre computers where all relevant data is gathered and served.
- A CAN communication script layer for commanding EPC DC/DC Bidirectional converters (one, two or in parallel mode).
- A MODBUS TCP Client script layer for interoperability with ADVANTICS SECC.

Datacenter

Web Server

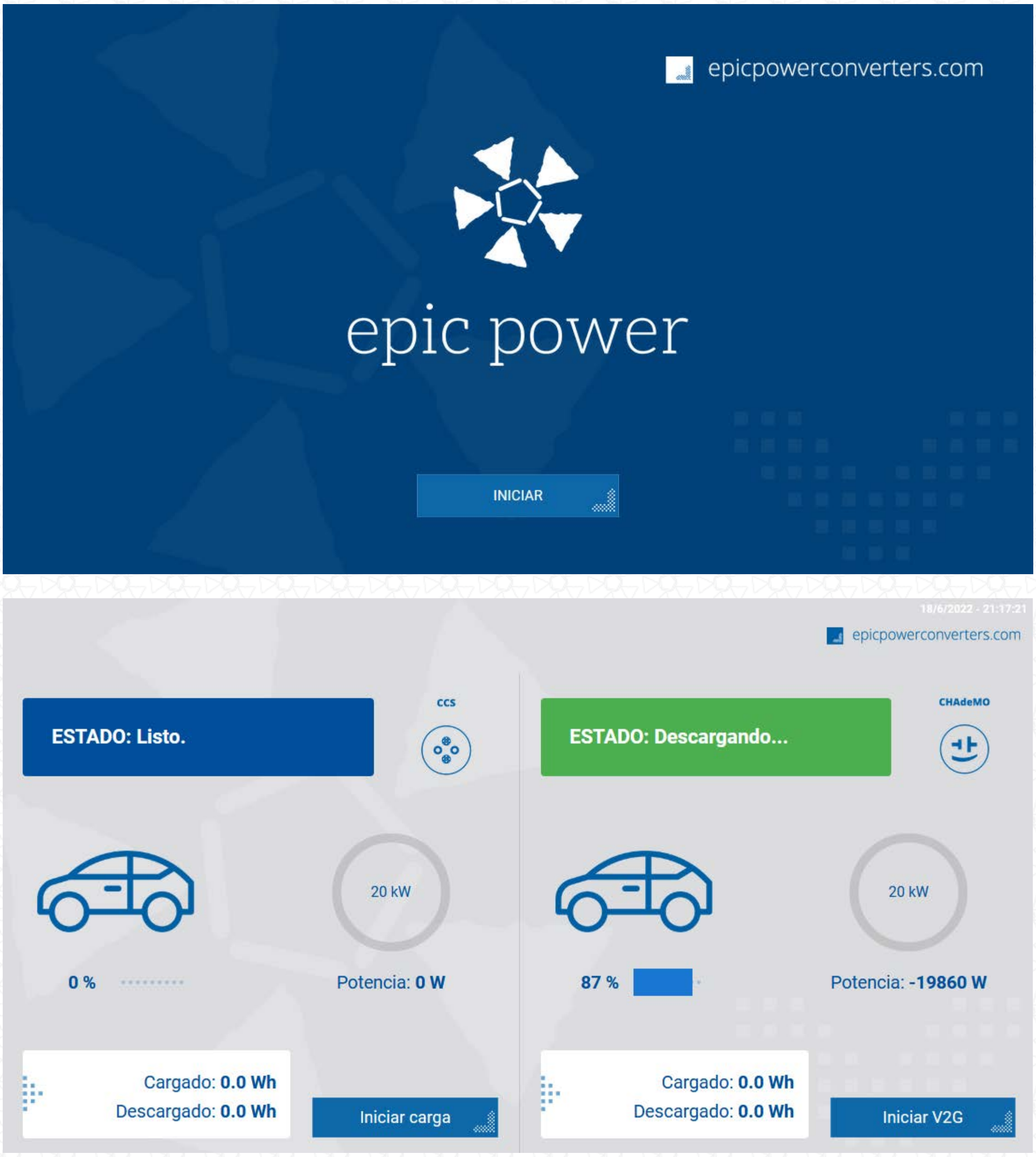


Fig. 9. Customer charging point frontend

The customer charging point frontend has been developed with the Flutter Framework, and shows the following modes of operation:

- CCS Charging:
  For charging/discharging one CCS enabled car up to 20 kW
- CHAdeMO Charging:

For charging/discharging one CHAdeMO enabled car up to 20 kW

- CCS+CHAdeMO Charging:

  For charging/discharging one CCS enabled car up to 10 kW and

  For charging/discharging one CHAdeMO enabled car up to 10 kW.

A backend has been developed with Django that is in charge of translate JSON posts from the Frontend to MODBUS TCP registers, from the Communications Gateway (both input/output) and registering Charging/Discharging sessions into a MySQL database.

This frontend (along with the HMI device) has not been secured at first, but it is prepared to implement NFC / QR / Bluetooth or any other kind of technology to validate the user/car if required.

Artificial Intelligence

Among other challenges, the main goal was to predict the power demand of our facilities in order to mitigate the higher peaks that most companies suffer mainly due to air conditioning compressors, production line processes, etc.

A LSTM (Long-Short-Term Memory) algorithm has been implemented and trained with more than one year of historical data gathered by a wattmeter connected directly in the mains input of the AC Grid. As a result, in Fig. 7 the accuracy to predict future consumptions can be seen.

Once a week, this algorithm again is retrained with new real logged data. This further improves its future accuracy.

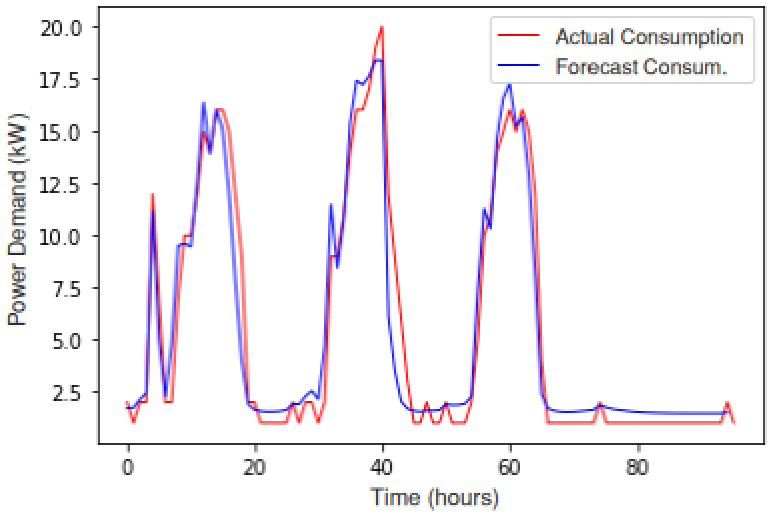


Fig. 10. Facilities power consumption prediction vs real

Moreover, another LSTM algorithm is being implemented to predict EV cars plug-in/plug-off schemes. A PV energy production predictive algorithm developed by the University of Zaragoza is also being used to predict generation.

By using these predictions, decisions regarding when to charge or discharge the EV are taken.

Main premise for these decisions is that an EV car must leave with at least the same SOC (Status of Charge) as it arrived, always above a 50% and always try to use the renewable energy for charging. These parameters may evolve with time.

Results

As this is an ongoing project, preliminary results show how our implemented control logic and AI algorithms are working so far but more tests shall be done.

Initial tests are made through a CHAdeMO V2G enabled car (Nissan Leaf) as we have not been able to locate a CCS V2G one as of the date of this AN. However, we estimate doing tests with a CCS V2G car by end of 2022 (Volkswagen Group announced to have V2G enabled CCS cars by mid-2022).

In Fig. 9, a 6 kW Discharge from a Nissan Leaf EV and injected to the main DC Grid is shown.

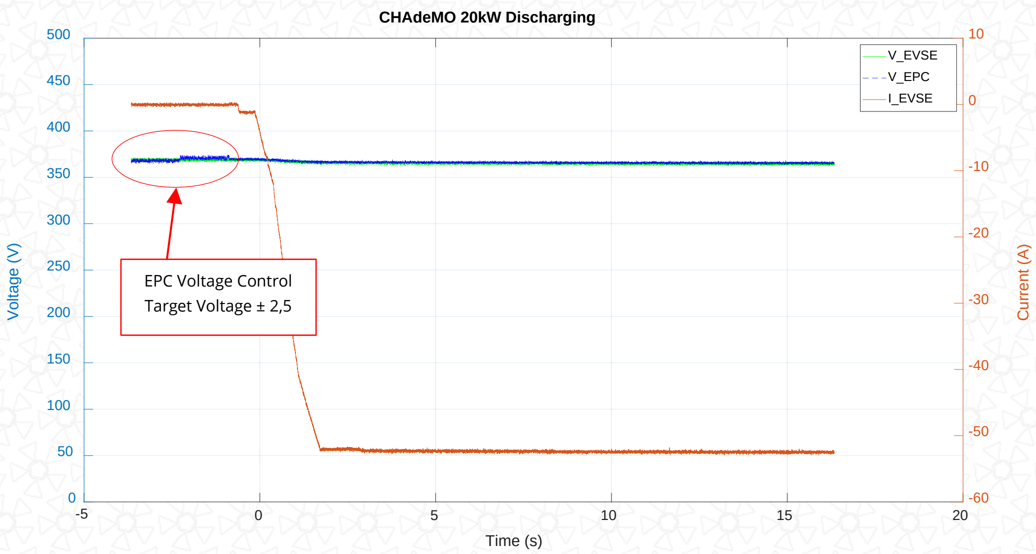


Fig. 11. 20 kW Discharge from Nissan Leaf (V2G)

For the shake of briefness, No more charging graphs have been included in this AN but they are available on request (support@epicpower.es).

Conclusions

A Pilot Project for demonstrating the use of our DC/DC Bidirectional Converters (EPC series) has been developed and implemented in our facilities.

A gateway interface was developed as a result of interconnecting all devices involved in the project expanding the communication possibilities of our converters and giving our customers an approach on how to do it, available under request.

Initial tests have been carried out with CHAdeMO V2G protocol. Experiments and verification with CCS V2G, expected to be draft published by mid 2022, should be underway by the end of 2022.

We are in conversations with other SECC manufacturers for integrating our converters with their devices by installing their units in our cabinet increasing the EV capacity in our facilities.

This project has received funding from the IDAE Instituto para la Diversificación y el Ahorro de la Energía (Institute for the Diversification and Saving of Energy) under grant number PGE -MOVES – SING - 2019 – 000070

Ministerio para la Transición Ecológica (Ministry for the Ecological Transition and the Demographic Challenge)

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