The DC energy meter: A key part of the DC fast charging infrastructure

Paul Pickering

Developing a charging infrastructure is a prerequisite for the widespread adoption of electric vehicles (EVs). Accurate measurement of power and secure billing of consumers are two key elements in any charging operation. This article will outline the EV charging infrastructure and its regulatory environment, review techniques for measuring EV power and highlight Isabellenhütte's DC energy meter that provides an accurate and secure means of meeting the various performance and regulatory requirements.

The EV charging ecosystem

At a high level, the EV charging ecosystem consists of an energy service provider (ESP) supplying power to an EV service provider (EVSP) who operates the charging station (electric vehicle supply equipment (EVSE)). A commercial transaction also takes place: the customer is billed based on either the units of electrical energy transferred in kWh or the connection time to the power source. Billing by transferred energy provides greater protection to the customer and is recommended by the NIST HB44 standard. With this method, the transaction requires precise measurement of the energy supplied and secure software for billing so the EVSP communicates with the ESP using a standard protocol such as OpenADR 2.0 or ESPI for load management and billing.

The EV charging system can be either AC or DC. Since the electrical grid is AC and the EV battery only accepts DC charging current, the difference between them lies in where the AC-to-DC conversion takes place. An AC charging system requires an AC-to-DC converter inside the vehicle whereas a DC charging system includes the converter inside the unit. The in-vehicle charger manages the energy transfer by communicating with the charging station via a standard network protocol such as CAN.

The Society of Automotive Engineers (SAE) classifies each type of system into three levels based on the maximum charging power in kilowatts; a higher charge rate reduces the time needed to replenish the battery. AC Level 1 and Level 2 charging was the first to be introduced since 120 V or 240 V single phase power is widely available in residential and work locations. Although AC systems currently dominate, Level 3 DC charging systems, also known as DC fast charging

(DCFC) can achieve much faster charging rates and are expected to become the primary charging topology.

There are currently three types of DC fast charging: combined charging system (CCS), CHAdeMO ("CHArge de MOve") and Tesla's Supercharger, each with a different charge port connector. CCS and CHAdeMO are both standard in a wide variety of automobile brands, but most public DC charging stations can accommodate both types. Tesla Superchargers only work with Tesla vehicles, but Teslas can also use CCS or CHAdeMO fast-chargers with an adaptor.

The regulatory environment around EV charging

The regulatory environment around EV charging is a complex one and includes both U.S. and international organizations. Three legislative bodies are currently involved in different aspects of EV charging infrastructure in the U.S.

- The SAE J1772 standard defines a common EV/PHEV and supply equipment vehicle conductive charging method including operational requirements and the functional and dimensional requirements for the vehicle inlet and mating connector.
- The National Institute of Standards (NIST) Handbook 44-3.40 (HB44) details requirements for equipment used to measure and sell electricity in commercial applications.
- The American National Standards Institute's (ANSI's) EVSP Roadmap aims to harmonize domestic and international standards in the whole EV environment.

EV power measurement methods

The DC energy meter is a key component in the EV ecosystem. It must precisely measure and record the power (voltage and current) delivered from the EVSE to the vehicle, compensating for cable losses, and then securely transmit the data upstream to ensure accurate billing.

Measuring the voltage is relatively standardized, but there are several approaches for measuring the charging current, each with a list of advantages and disadvantages. Isabellenhütte is a leading supplier of precisions current measurement systems that determine current flow based on the voltage drop across a precision shunt resistor made from a proprietary alloy such as Manganin, Isaohm and Zeranin. Shunt resistors made from these alloys combine low resistances with extremely low inductance, TCR and thermal EMF, and excellent long-term stability. Series shunt-based solutions are a superior choice where precise performance over a wide temperature range is a priority.

About the Isabellenhütte IEM-DCC

Isabellenhütte is actively developing DC energy meters designed for integration into the EV public DC charging infrastructure.

Figure 1: IEM-DCC-500 exterior view. Source: Isabellenhütte

The IEM-DCC-500 (Figure 1) is a high-precision meter for EVs with power classes of up to 500 kW. The unidirectional reference meter is designed to measure continuous electric currents up to 500 A and voltages of up to 1,000 V.

The compact tamper-proof design uses Isabellenhütte's proprietary shunt measurement technology that has been proven in millions of EV applications. Since lethal voltages and currents are present, the IEM-DCC-500 employs an isolated topology (Figure 2) that provides galvanic isolation between the high-voltage line and measurement connections and the low-voltage auxiliary voltage or communication connections. This insulation barrier is designed for use in EV charging stations with an operating voltage of 1,000 V and a maximum transient overvoltage of 4,000 V.

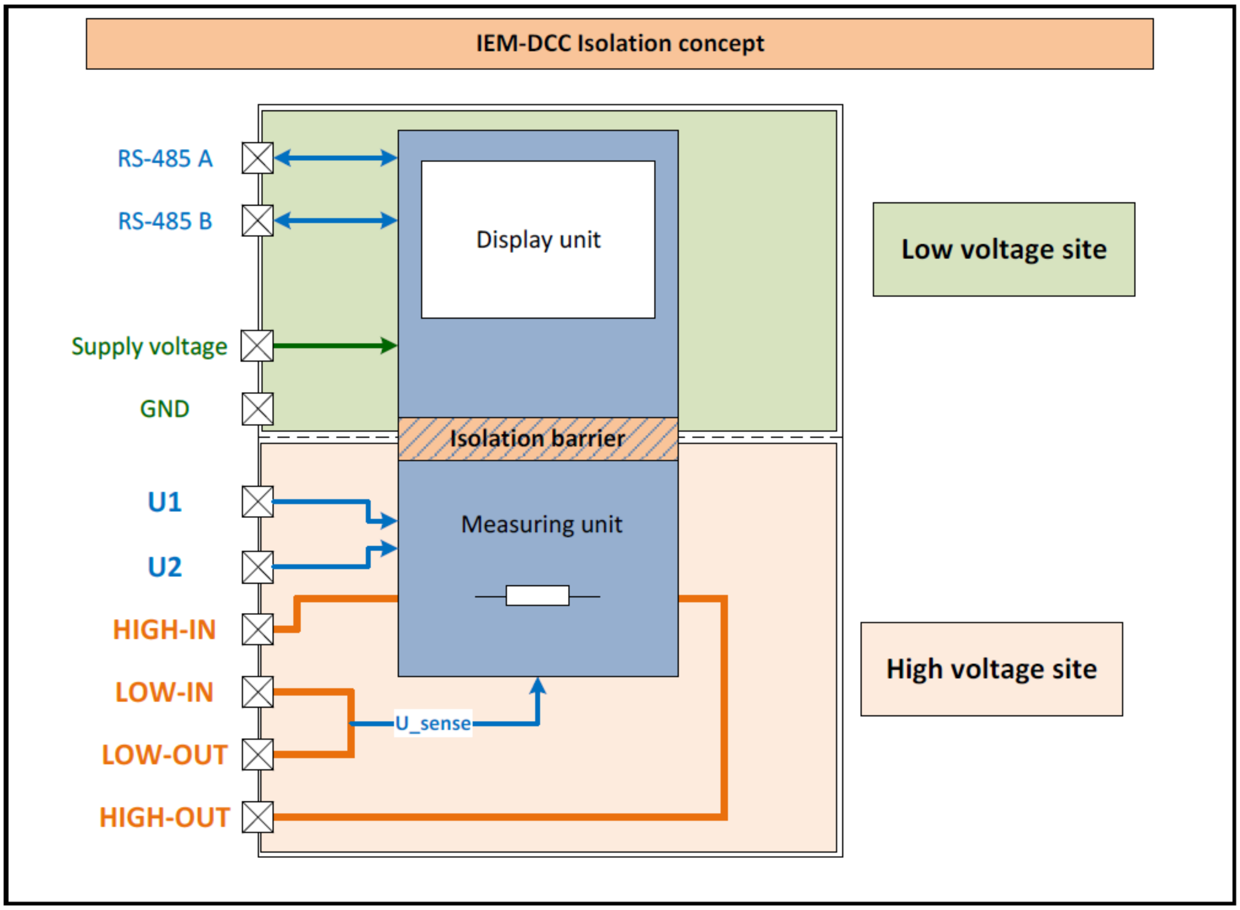

Figure 2: The IEM-DCC-500 features an isolated internal architecture. Source: Isabellenhütte

When the energy meter is integrated into an EVSE unit, the resistance of the DC charging cable results in a voltage drop proportional to both cable resistance and output current (I*R). This voltage drop is small compared to the charging voltage at the vehicle connector but can be as high as 1% of the EVSE output depending on charging current, cable resistance and charging voltage if the meter is not properly compensated or configured. The IEM-DCC-500 has integrated a four-wire measurement system, plus the option to store specific charging cable parameters. The measured value is corrected for charging cable losses in accordance with applicable calibration regulations. The charging device user is then billed only for energy actually consumed at the energy transfer point.

The IEM-DCC-500 complies with the German measurement and calibration law and fulfills the European EN50470-1/3 standard for smart energy meters where the measuring instrument directive (MID) requirements are implemented. The IEM-DCC-500 forms the basis of a billing system for a public charging station combined with a smart-meter SML-based communication protocol and associated standards such as EDL 40 and ISA EDL 40P for digital signing of information. In a charging station, the IEM-DCC-500 generates a data tuple consisting of the meter value, contract ID, legal time and meter status, digitally signs the tuple with its private key, and sends this billing-related data to a charge controller or other communication gateway. The digital signature allows to verify the origin of the billing-related data and ensure the detection of potential manipulation along the whole chain of communication. Figure 3 shows the IEM-DCC-500 integrated into a typical DC charging application.

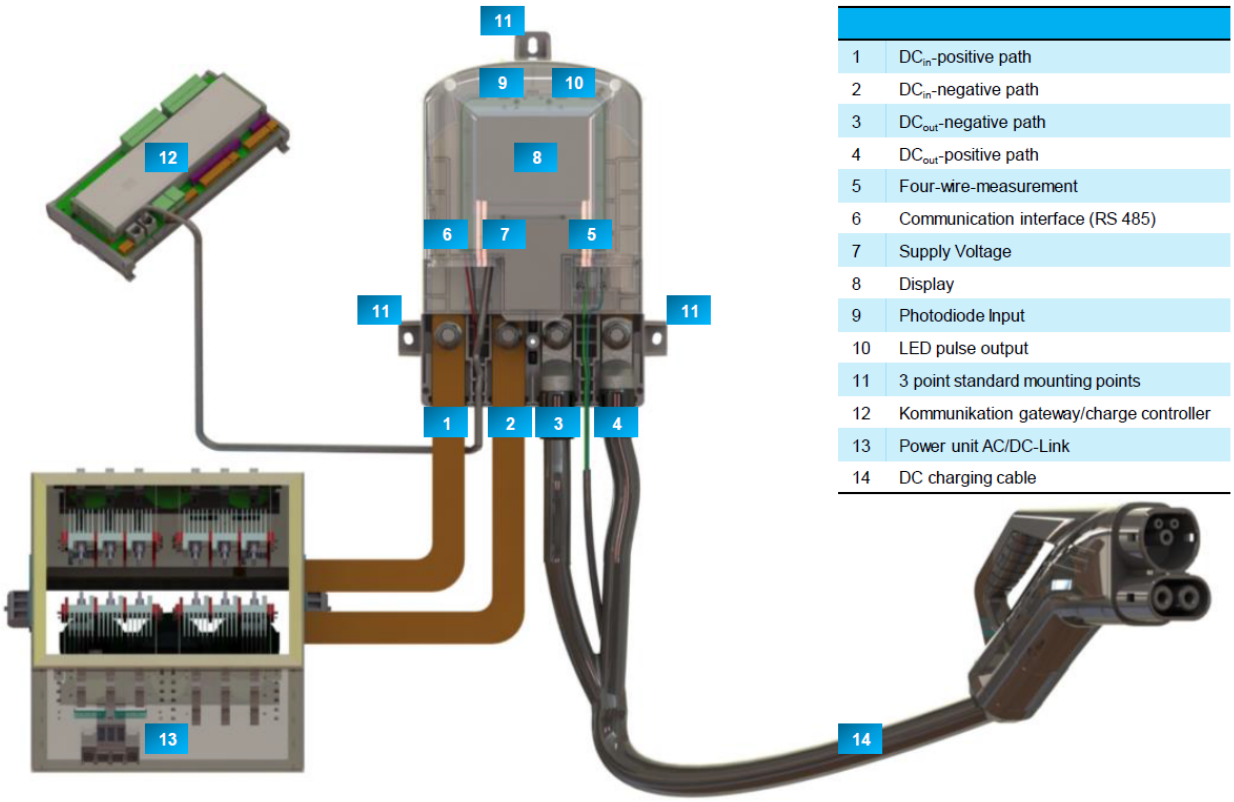

Figure 3: The DCC-500 energy meter provides a simple interface to the EVSE. Source: Isabellenhütte

Independent test results

In Europe, the IEM-DCC-500 has earned an examination certificate from the Physikalisch-Technische Bundesanstalt, the German national metrology institute. This certificate confirms an EN50470-1/3 class B accuracy rating for the IEM-DCC-500, and Isabellenhütte can issue a declaration of conformity to this standard.

In the U.S., the Argonne National Laboratory has tested the IEM-DCC-500 to the HB44 requirements as part of a comprehensive evaluation of DC energy meters. The Argonne report verified that the IEM-DCC-500 satisfied the SAE J1772-CCS/Tesla SuperCharger/CharIN MCS power delivery capability up to 1,000 V DC, 350 A to 500 A, as well as nameplate accuracy within the HB44 range (+/-1% error tolerance).

Conclusion

The energy meter is a key part of a DC fast-charging system for EVs, but the design must satisfy a long list of regulatory requirements covering both performance and data security. Isabellenhütte's IEM-DCC-500 meter meets the applicable standards in both the U.S. and Europe and combines a compact tamper-proof solution with easy integration into both new and existing installations.

More information on the IEM-DCC-500 can be obtained here.