Keysight Technologies

Scienlab Charging Discovery System

SL1040A SL1093A

Testing charging function and interoperability

Both development and spread of electric and plug-in hybrid vehicles (EV, PHEV) depend on the expansion and interference-free utilization of the charging infrastructure (electric vehicle supply equipment, EVSE). Due to the relatively recent standards and the resulting lack of experience in the field, faults in the interaction of EV and EVSE can be observed frequently.

Key Benefits

- **Compliance with standards**
  Support of all available communication methods, in particular of basic communication (PWM) according to IEC 61851-1 and high-level communication according to DIN SPEC 70121, ISO 15118 (PLC), CHAdeMO and GB/T (CAN).
- **Real-time capable test procedure**
  Thanks to its powerful FPGAs and processors with real-time operating systems and its high-performance and synchronous interfaces, the CDS is consistently designed for real-time capability.
- **Open system**
  Emulation of any EV and EVSE by means of an openly accessible state machine (parameters and measured values).
- **Maximum measuring and control accuracy**
  High-resolution, differentially measuring AD converters, as well as an ideal grounding concept enable excellent measurement data acquisition.

KEYSIGHT TECHNOLOGIES

Modular Test Environment for Charging Technology

From mobile use to application in the laboratory

The Solution

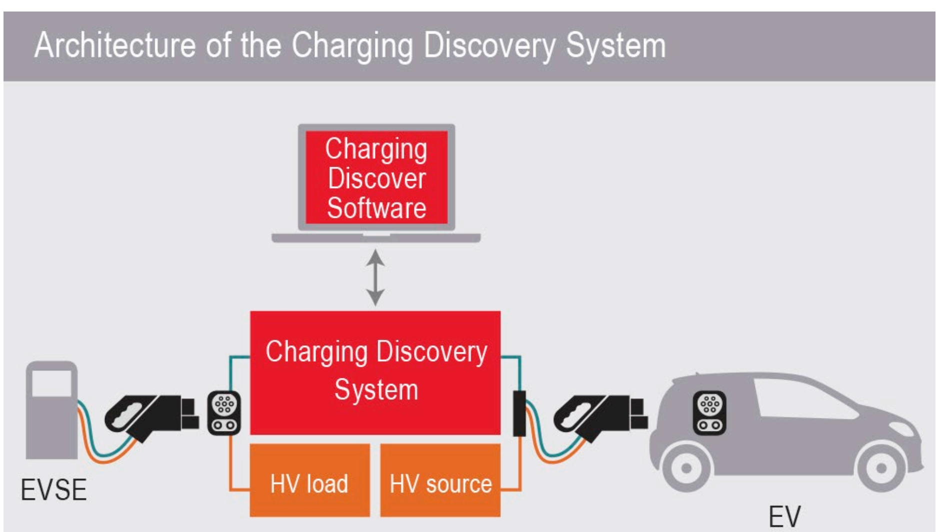
Keysight Technologies, Inc. offers a modular test environment for EV and EVSE charging systems from mobile use to comprehensive application in the laboratory. The CDS emulates as a central element the charging communication of EV or EVSE. At the same time, the electrical parameters are measured and checked for compliance with standards. The CDS also assumes synchronized triggering of additional power sources and sinks. All components are developed and manufactured by Keysight. Customer-specific requirements or modifications required by the standards can therefore be realized at short notice.

Possible areas of application are:

- Function tests of EV and EVSE charging interfaces with verification for compliance with the norm conformity
- Testing of interoperability
- Verification of charging components for international markets through emulation of international charging communication standards and low-voltage grids
- Targeted and reproducible testing of EV and EVSE fault response
- Automated endurance testing for quality assurance purposes, including multi-channel testing

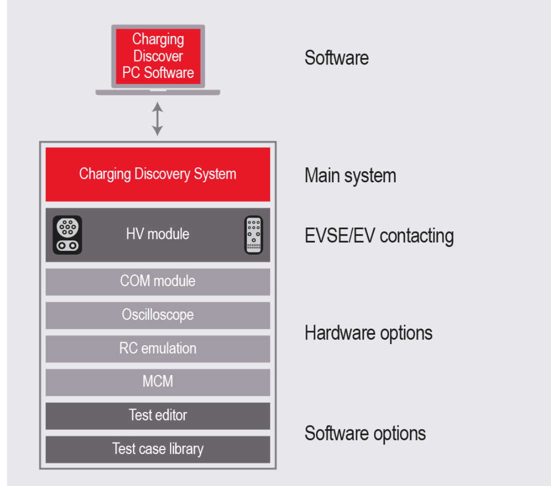
The following use cases are supported by the CDS:

- EVSE test: For the testing of charging stations, wall boxes and in-cable control box (ICCB) charging cables, the CDS is expanded with a high-voltage load and a grid emulation. This allows testing independently of an EV.
- EV test: The CDS can represent a freely-programmable AC or DC charging station by connecting it to a power source.
- Man-in-the-middle: Communication and power flow between EV and EVSE can be analyzed. Load and signal lines are connected by the CDS and recorded using measurement equipment.



The Charging Discovery System is designed to be configured in modular arrangements matching the respective application. Its main component is the real-time computer for autonomous execution of test sequences. The test sequence itself is defined and parameterized using the Charging Discover PC software or alternatively controlled directly from a Hardware-in-the-Loop (HiL) system. The CDS provides two manipulable PWM communication interfaces and records, stores, analyzes and evaluates the pilot signals (control pilot/CP, proximity pilot/PP). It also provides digital I/O signals for control and synchronization of external components.

Modular design of the Charging Discovery System



If necessary, this basic configuration can be expanded by additional communication modules for the use of DC charging standards. The following modules can be integrated:

- An HV module for safe contacting of EVSE DUTs
- An additional oscilloscope for the high-frequency analysis and optical evaluation of signals
- An RC emulation for the testing of safeguarding equipment
- Various passive and active sources and sinks for the flexible emulation of the respective high-voltage opposite side

OPTIONS AT A GLANCE	
Charging Discovery System	Basic product with PWM communication (IEC 61851-1)
HV module	EV charging inlet, connection for any kind of EV charging adapter, HV contactor, measuring technology and insulation monitor
COM module PLC	High-level communication support (DIN SPEC 70121, ISO 15118)
COM module GB/T	Digital communication support for control of DC charging processes (GB/T 20234)
COM module CHAdeMO	Digital communication support for control of DC charging processes (CHAdeMO)
Oscilloscope	Additional oscilloscope for the high-frequency analysis of the control pilot
RC emulation	Testing of residual current circuit breaker RCCB/insulation monitor by means of injecting a variable residual current
Measurement & Control Modules	Keysight’s Scienlab Measurement & Control Modules (MCM) can be integrated directly
Aluminum case	Sturdy aluminum case (IP65) for safe transportation
Charging Discover Software	Software for controlling the CDS and test evaluation (included in the basic product)
Test editor	Optional license for easy creation of individual test cases
Test case libraries	Ready-to-use test case collections available on request
Passive load	Passive loads are available for AC and DC in different voltage and performance classes between 3 and 50 kW
Active power source	Bi-directional AC and DC power source: U: 480...1,000 V, I: 16...1,200 A, P: 11 kW ...1 MW
Charging adapter EVSE	AC Type 1, AC Type 2 EU, AC Type 2 China and CCS Type 1 according to IEC 62196
Charging adapter EV	AC Type 1, AC Type 2 EU, AC Type 2 China and CCS Type 1 according to IEC 62196; GB/T AC, GB/T DC and CHAdeMO

Optimum Features for Every Test Requirement

All-in-one

The CDS provides all necessary functions required for the testing of charging infrastructure components. Additional analysis or measurement systems are not necessary. Predefined test sequences enable quick tests, also in the field. Digital inputs and outputs allow locking of charging inlets as well as triggering of LEDs and other freely-usable I/Os. The passive and active sources and sinks have been specially developed for this application and integrated in the test sequence.

Open system architecture

Realistic emulation of EV and EVSE requires standard-compliant emulation of the behavior of each emulated side. The CDS offers a freely-parameterizable state machine that provides the required degree of freedom. Errors can thus be emulated in a controlled environment to examine the response of the DUT in all use cases and failures.

Real-time capable test system

The CDS is designed for real-time performance. This is ensured through the use of powerful FPGAs and microcontrollers on the electronic level, a scalable X86 multicore processor in the higher-level IPC and a real-time operating system. Time-sensitive tests can be handled on an event-controlled basis. Internal timer and synchronization mechanisms ensure runtime control, resulting in high system performance and low dead time.

International standards

Thanks to the IEC 61851 and ISO 15118 standards, the charging of electric vehicles has been standardized worldwide. The combined charging system (CCS) is used in Europe and the USA. It integrates AC and DC charging interfaces in a combined vehicle inlet specified in the standard IEC 62196-3. The data exchange between EV and EVSE takes place via a control and proximity signal (CP, PP) within the charging cable.

AC charging

The PWM-based basic communication is currently used worldwide for AC charging. The CDS therefore records all electrical parameters such as PWM amplitude, frequency, and duty cycle, as well as rise and fall times. The integrated PWM generator is programmable and can thus emulate the behavior of any charging infrastructure. Cable or plug defects can also be emulated.

DC charging

With the communication module for PLC, the CDS also supports the analysis and verification of charging interfaces according to DIN SPEC 70121 and ISO 15118. Here too, a parameterizable state machine is used. The CDS enables conformity testing of the vehicle and charging infrastructure by receiving and processing V2G messages and visualizing the content in clear text. Response times and timeout behavior of the emulated remote station can be parameterized in a targeted manner as well. Other communication modules for testing GB/T or CHAdeMO charging interfaces are also available.

Integrated HV measuring technology and sophisticated EMC design

For reproducible test results and proper interpretation of the control pilot, the measuring technology must clearly exceed the accuracy asked for in the standards. The CDS therefore measures all relevant control and proximity pilot parameters with maximum accuracy. The optionally-available oscilloscope can also be used to make high-frequency recordings of the time sequence and to perform a FFT frequency analysis. The measuring converters for current and voltage integrated in the HV module, as well as the highly-accurate 14 bit AD converters provide the synchronous recording of high-voltage parameters. During development of the CDS, great importance was attached to a holistic grounding concept and maximum immunity. Potential barriers with minimal coupling capacitance increase both signal quality and measuring accuracy.

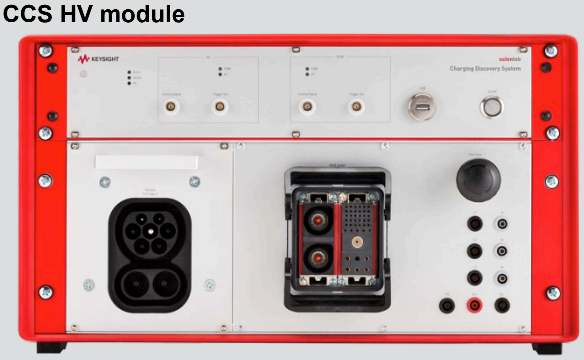
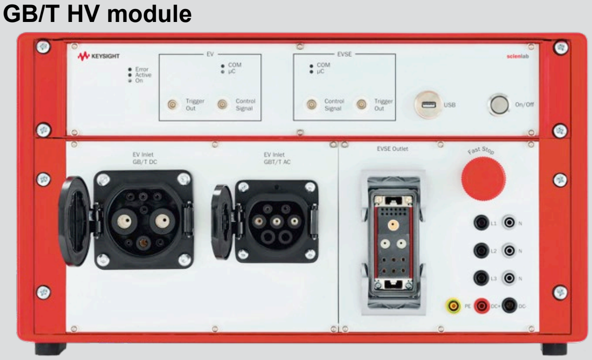
Flexible use

Whether for testing components in the laboratory during development or systems in the field, the CDS provides a solution for every application. For mobile use, the Charging Discovery System can be supplied in a portable version. Apart from the CP signal, all HV voltages are available for external measurement via break-out ports on the front panel of the CDS.

Worldwide plug types can be used

The CDS can be configured with all common charging inlets and types of charging plugs for AC and DC, analogous to the communication modules. The charging adapters to the vehicle are connected via a specific HV socket.

Comparison of Europe/USA and China

Europe and USA **Combined Charging System (CCS)**	**China** **GB/T**
Background The CCS is the global charging standard of the future, since it covers all important requirements with just one standard. It is also the only standard to permit AC and DC charging within one vehicle inlet.	**Background** The CCS standard does not yet exist in China because China has developed its own national standard. The charging interface therefore has to be implemented in accordance with the standards GB/T 18487 (general requirements), 20234.1-3 (connection set) and 27930 (communication protocols).
Challenge The standard ISO 15118 is still largely unproven. Prepared use cases such as public charging with automatic payment by the vehicle need to be validated with respect to security, interoperability and reliability. The first generation of CCS charging stations offers maximum charging power of 50 kW at a maximum battery voltage of 500 V. In order to meet future requirements and keep charging times to a minimum even with much bigger HV batteries, charging power of up to 350 kW at a maximum battery voltage of 1,000 V will be required.	**Challenge** The specific Chinese standard is very different to the international CCS or the Japanese CHAdeMO. Hardware and software need to be validated with respect to interoperability. In particular, high immunity on the CAN bus must be ensured at the hardware level. From the software perspective, the wide variety of solutions available on the market must be taken into consideration, for example in terms of timing, data conformance or the permissible tolerance ranges. The standard GB/T 27930 is currently being revised and is at a draft stage.
Solution The modular CDS is available as a CCS variant. The system is compatible with 1,000 V and can be operated with charging power of up to 360 kW in combination with a Scienlab Dynamic DC Emulator from Keysight. The DIN SPEC 70121 and ISO 15118 protocols are constantly being updated and current changes to standards taken into consideration.	**Solution** The CDS is also available as a GB/T variant. This is accomplished by equipping the HV module with the necessary GB/T AC and DC EV inlets and adding the appropriate GB/T communication module to the control unit. The GB/T communication module also has a special CAN interface that is voltage-proof up to 1,000 V. Changes to GB/T standards can be taken into consideration at a later date through software updates.
CCS HV module 	**GB/T HV module** 

Convenient Test Procedure

The CDS is designed for use as a stand-alone test system or as a component in a HiL test bench. In both cases, communication with the CDS takes place via a gigabit Ethernet interface. In the first case, the Charging Discover PC software supports the user in test definition and control. In the second case, the HiL system can directly access the appropriate parameters and functions via the open interface.

The Charging Discover software

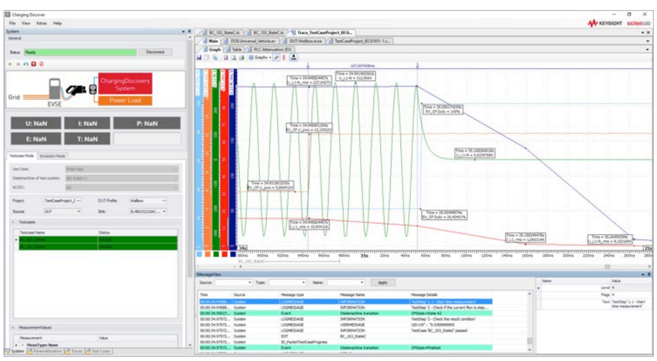
The Windows-based Charging Discover PC software not only enables fast selection and execution of predefined test cases but also provides an editor for the creation of customer-specific tests. The entire test project is then transferred to the CDS and is executed there autonomously. The software includes all necessary functions for the visualization and evaluation of individual messages and measured values.

Display of measurements

The recorded measured values of the CDS are visualized as a live data stream. For high-level communication, V2G or CAN messages are recorded synchronously and shown in plain text. Test and intermediate results are evaluated at runtime and can be displayed at a glance using appropriate visual cues. Up to six CAN buses can be synchronously recorded when using a Scienlab Measurement & Control Module (MCM) from Keysight. This way, the user is able to read and record vehicle data directly from ECUs. This data can be interpreted by importing a dbc database file and visualized together with other measured data in a graph with a timestamp.

Reporting

Once the test has been executed, the log data can be stored and loaded offline at any time. The test results can also be saved as a short PDF report.



Main operating screen after an AC test is conducted

Measurement graph after a DC test is conducted

This includes information on all test cases conducted and the results. The user decides which measurement results will be output in detail and how the individual test will be evaluated during the definition of the test case.

Test editor

In addition to the basic configuration, customer-specific test cases can be created, stored and maintained with the aid of the test editor. Each individual test sequence can be defined in terms of content and time using an application-friendly language. The intuitive graphical user interface suggests suitable language elements and commands to the user while typing. Freely configurable I/Os, for example, can be actively included in a routine in order to inject errors at a specified time or to activate external measuring equipment.

Key Benefits of the Charging Discover Software

- Extensive options for creation, display and evaluation of test sequences
- Fast results due to use of predefined test cases
- Creation of individual test cases using the optional test editor
- High usability thanks to an intuitive user interface
- Synchronous data recording
- Reports provide a quick and clear way of documenting the results without the need for post-processing
- Efficient representation and labeling of measurement data using clear graphs and tables, as well as export function
- Freely positionable and resizable program windows, especially helpful when using multiple screens

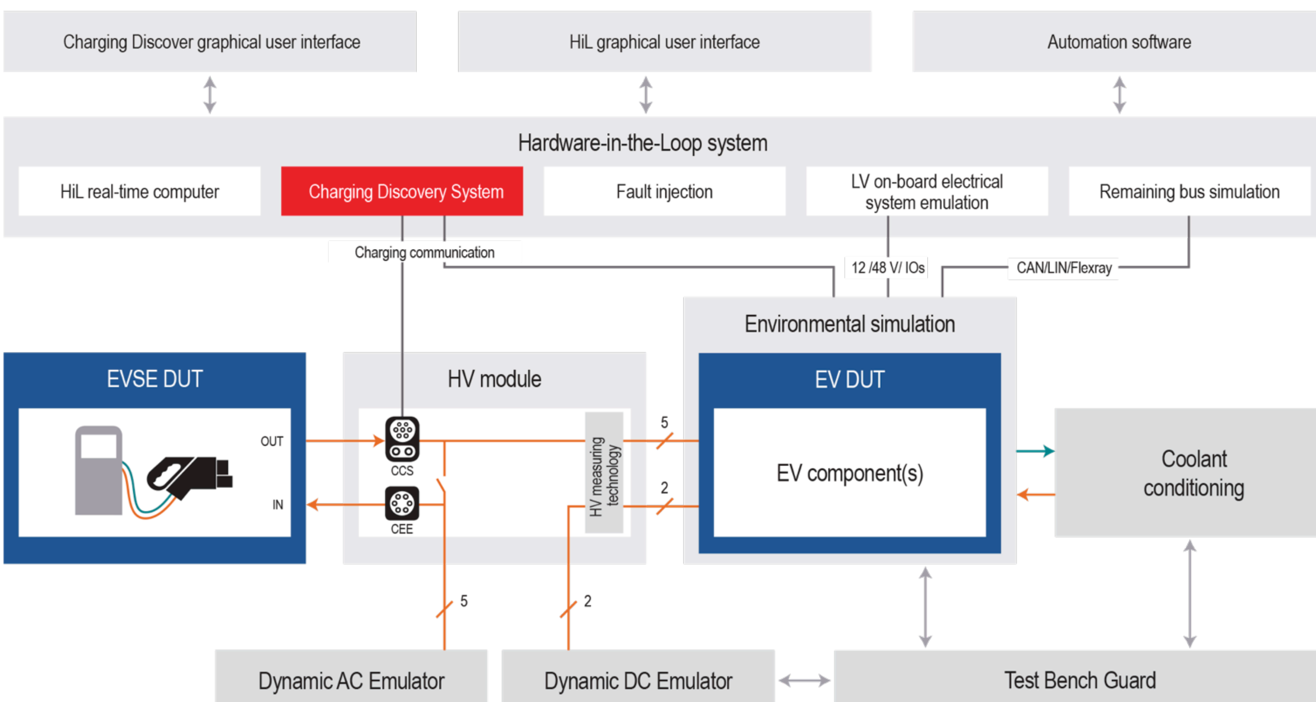
The Charging Discovery System used in the field as a man-in-the-middle system

Integration into a HiL Test Environment

The CDS can be expanded into a comprehensive charging technology test laboratory by adding high-voltage power sources and a Hardware-in-the-Loop system (HiL). On the infrastructure side, the high-voltage emulators allow emulation of international low-voltage grids or any AC and DC charging stations. On the vehicle side, all internal components involved in the charging system such as charger, charging controller, battery management system and battery, including the related peripheral devices, can be emulated in all configurations or integrated as real parts. This provides extensive testing capabilities from analysis of individual components and subsystems in the vehicle, to automated release tests of the entire charging function of EV and EVSE.

The application of HiL solutions for the verification of electrical and electronic (E/E) components is very common in the automotive sector. While a classic HiL system is typically limited to the low-voltage (LV) interfaces for the emulation and simulation of E/E components, a power-HiL system includes all DUT interfaces thanks to the integration of HV emulators. This is the only way to test the DUT as a closed system. For example, if the charging function of control units and power electronics in the vehicle is to be examined, the CDS in combination with a HV source can be configured as freely programmable charging station emulation. In this context, the CDS also handles control of the AC and/or DC emulators.

The components of the HiL test environment



Scienlab Power HiL System

A Scienlab Power-HiL system is configured and accordingly matched to the respective customer requirements in terms of performance, I/O and measurement channels, as well as software interfaces. Customer specifications such as preferred operating or automation tools can thus be considered, even by means of subsequent extensions and upgrades of existing test laboratories.

At the core of each HiL test environment is a real-time computer that calculates at runtime all signals required by the DUT in the vehicle (in particular, sensors and residual bus simulation) and emulates them via corresponding I/O hardware. All relevant cases of failure can be injected selectively, e.g. as short circuits to ground or 12 V battery. The HiL system also controls the Scienlab HV emulators and other LV sources/sinks. Since charging standards and the state machines contained are implemented directly in the CDS, charging attempts can be defined and executed from the HiL system with little effort. Even easier is the execution of test cases stored in the CDS, as they can be selected and started via the HiL interface.

The HV module ensures safe contact with EVSE DUTs. The highly accurate measuring technology in the CDS and the HV emulator is recorded time-synchronously by the HiL system. Moreover, all LV and HV signals are equipped scoop-proof so that external measuring equipment for high-frequency signal testing can be utilized without any detours.

The HIL test bench is operated via a PC using the manufacturer-specific test software. For open experimental software environments such as ControlDesk (manufacturer dSPACE GmbH), a customized project is supplied. This also includes the vehicle, battery and interface models for environmental simulation, cooling conditioning and measuring instruments. This allows direct setup of an automation software to be able to implement reproducible endurance tests and overnight tests very quickly.

The test bench guard maximizes safety in the laboratory by coordinating power switches required by the use case and by forcing a fast and safe shutdown of all systems in the event of faults or emergencies. The Test Bench Guard is usually implemented as a SIL3-enabled soft PLC and runs entirely independent of the remaining test environment.

CDS integration into an existing HiL system

The Charging Discovery System can be added to an existing HiL solution easily. We provide exactly the test systems needed. The CDS is always supplied with an open and well-documented Ethernet interface, allowing integration into any external HiL or automation environment. The Charging Discover operating software can be used in parallel so that the main configuration tasks (which usually take place before the test procedure) can still be easily performed via the user interface provided. The advantage of this is that the implementation of the CDS interface on the customer side is greatly simplified, as only the setpoint and actual parameters required at runtime must be sent or received. The customer decides which CDS parameters should be varied and which measured variables are evaluated, depending on the application and the test.

High-Voltage Emulation

Power sources for emulation of AC and DC interfaces

Highly dynamic power sources are available especially for the requirements in the area of charging technology. The systems are characterized by maximum measuring and control accuracy and a high level of efficiency. Thanks to the modular design, subsequent power enhancements by parallel connection of several emulators are also possible. All Scienlab Emulators from Keysight use an active front end and are energy-regenerative by default, bi-directional and highly efficient. Cooling is provided depending on the performance class and customer requirements.

Scienlab Dynamic AC Emulator

The Scienlab Dynamic AC Emulator can be used as a programmable AC power source to emulate global low-voltage grids. Due to their inherent bi-directional regenerative power stage, testing of vehicle-to-grid scenarios for EV and EVSE is possible. Important EMC tests for compliance of grid compatibility required by DIN EN 50160 can also be conducted. The system emissions (IEC 61000-3) and immunity (IEC 61000-4) of the DUT can be tested in this way. The Dynamic AC Emulator also provides a DC option with which all charging modes can be mapped in a single device. The following operating modes can therefore be configured:

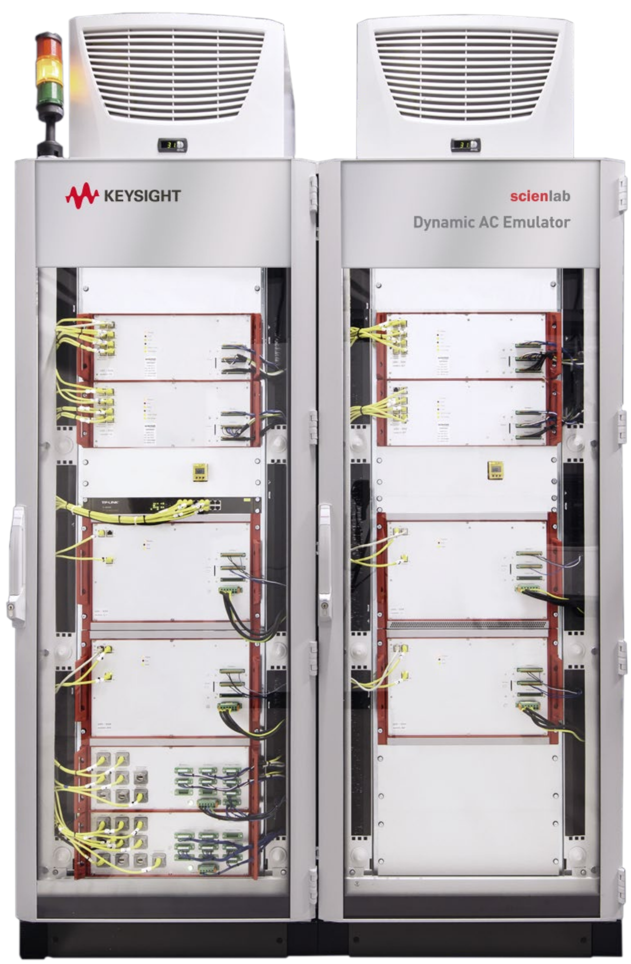
- Emulation of global LV grids such as EU, US, and Japan
- Regulated harmonics
- Emulation of active bi-directional loads (e.g. charger)
- Emulation of high-voltage sources (e.g. DC charging station) and sinks (e.g. lithium-ion battery pack) with dynamic voltage and current limit

Scienlab Dynamic DC Emulator

The Scienlab Dynamic DC Emulator includes a freely-parameterizable battery model and can therefore be ideally employed for battery emulation. In interaction with the CDS, dynamic controllers with seamless alternation between current and voltage control also facilitate operation as an universal DC charging station. Configurations of 600 V to 1,000 V and 100 A to 1,200 A are available. The DCE offers the following operating modes:

- Emulation of a DC charging station
- Emulation of a high-voltage battery
- Emulation of any high-voltage sources and sinks

	DYNAMIC AC EMULATOR	DYNAMIC DC EMULATOR
Output power	±11/22/44/66/88 kW	11 kW...1 MW
AC operation		
Voltage (single-phase)	5...270 V_{eff}	
Voltage (three-phase)	5…480 V_{eff}	
Fundamental frequency	40…75 Hz	
Max. current (single-phase)	±48 A, ±96 A, ±192 A, ±288 A, ±384 A	
Max. current (three-phase)	16 A, 32 A, 63 A	
DC operation		
Output voltage	0...600 V	80 V, 600 V, 850 V, 1,000 V
Output current	±33 A, ±66 A, ±132 A, ±198 A, ±264 A	100…1,000 A
Measuring accuracy		
Voltage	±0.25% of measured value; ±0.05% of measured value	±0.05% of measured value; ±0.01% of measured value
Current	±0.25% of measured value; ±0.05% of measured value	±0.05% of measured value; ±0.01% of measured value
Energy conversion efficiency	>85%	>90%



TECHNICAL DATA FOR THE CHARGING DISCOVERY SYSTEM

Power supply	DC, 24 V, external 230 VAC desktop power supply unit included
Interface to workstation	1,000 Mbps Ethernet, RJ45
Potential separation	Consistently between power supply, electronics, measuring technology and DUT PE
Max. power consumption	300 W
Permissible operating temperature	6 °C...35 °C (extended temperature range on request)
Dimensions H x W x D	Min. 90 x 490 x 400 mm (19“ plug-in unit), max. 290 x 520 x 500 mm (in the housing)
Weight	20...30 kg, depending on configuration

Electrical specifications PWM	**Range**	**Tolerance**
Frequency (specification or measurement)	900…1100 Hz	±0.1 Hz
Voltage (specification, idle)	±0…14 V	±0.02 V
Voltage measurement	Measuring range: –15 V ... +15 V	±10 mV
Pulse width (specification or measurement)	0%…100%	±0.05%
Fall/rise time (idle)	2 µs	±1 µs
Input resistance R1	970 / 1,000 / 1,030 Ω	±0.1%
Capacitance Cc	CP | PE 300 / 1,600 / 1,800 / 3,100 pF (switchable)	±5%
PWM EV emulation (via R cascade)	0.0…11.0 V	0.05%
PP resistance measurement	50…4,500 Ω	±0.3%
PP emulation (via R cascade)	220 / 680 / 1,500 / 4,500 / 9,000 Ω + 0…1,000 Ω	±0.5%

HV measuring technology	**Range**	**Tolerance**
Voltage DC	–1,000…1,000 V	±0.5%
Voltage AC	–500…500 V	±0.5%
AC current (L1, L2, L3)	–50…50 A	±0.5%
DC current	–500…500 A	±0.5%
Residual current PE	–50…50 mA	±1 mA

Interface charging inlet (2x)	
Control locking actor	±24 V DC; max. 1.8 A
Control ext. LEDs	12 V DC, RGB LED
Measurement temperature sensor	PT1000 sensors for AC and DC contacting

Passive load for EVSE test	
External load AC and DC	Max: 500 V DC, 440 V AC (three-phase); P_{max}: 15 kW (continuous), short-term up to tripled overload; Weight: 20 kg
Other passive and active loads on request	

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus