KEYSIGHT WORLD 2020

Enable Development of Fast Charging, Extended Range Batteries

Gary Hsiao

Project Manager / Keysight Technologies

Agenda

- Different Battery Requirements for Different Applications
- Measurement Toolbox for Finding the Right Battery for Your Application
- Case Studies
- Data Management
- Conclusion

Different Battery Requirements for Different Applications

Different Battery Requirements for Different Applications

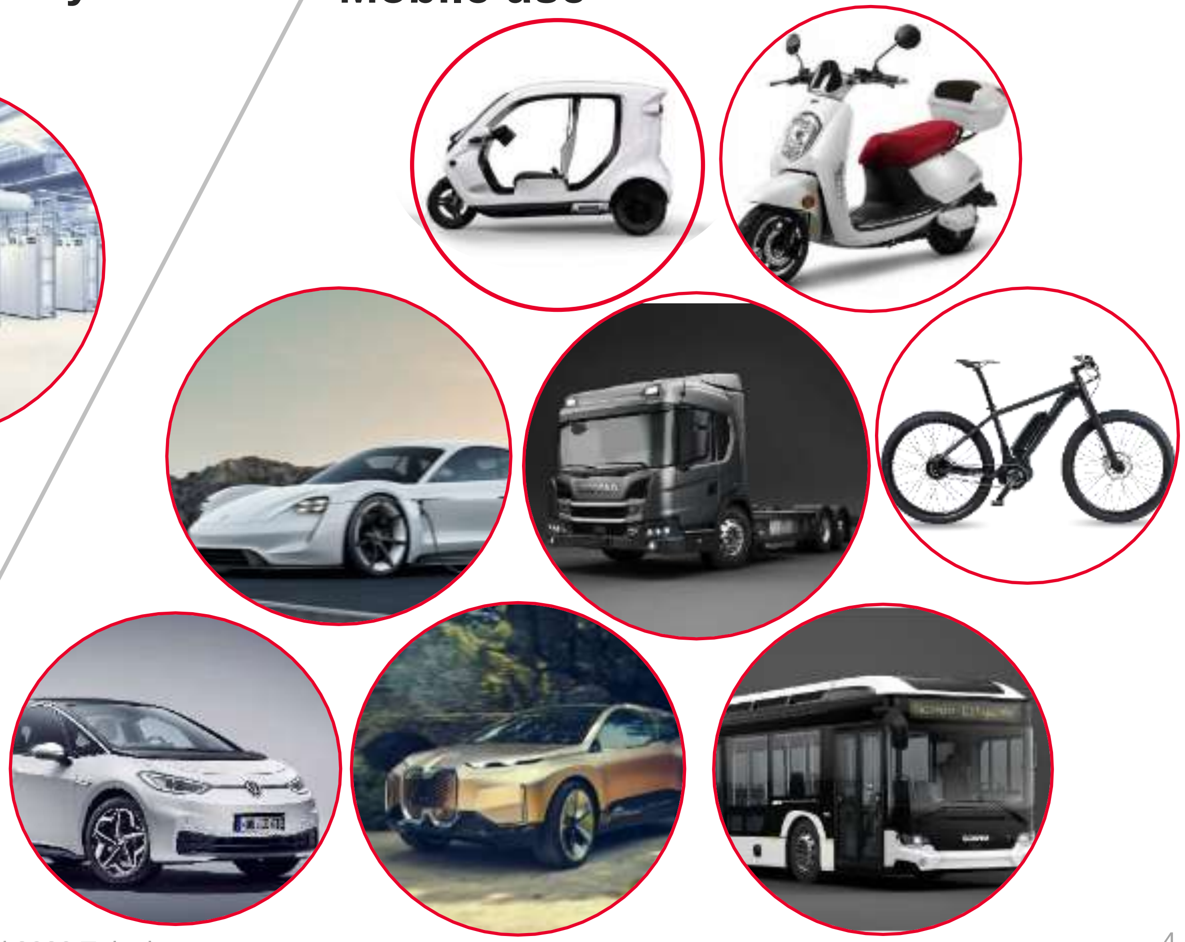
TARGET APPLICATIONS

Power Tools

Off-road use

Stationary use

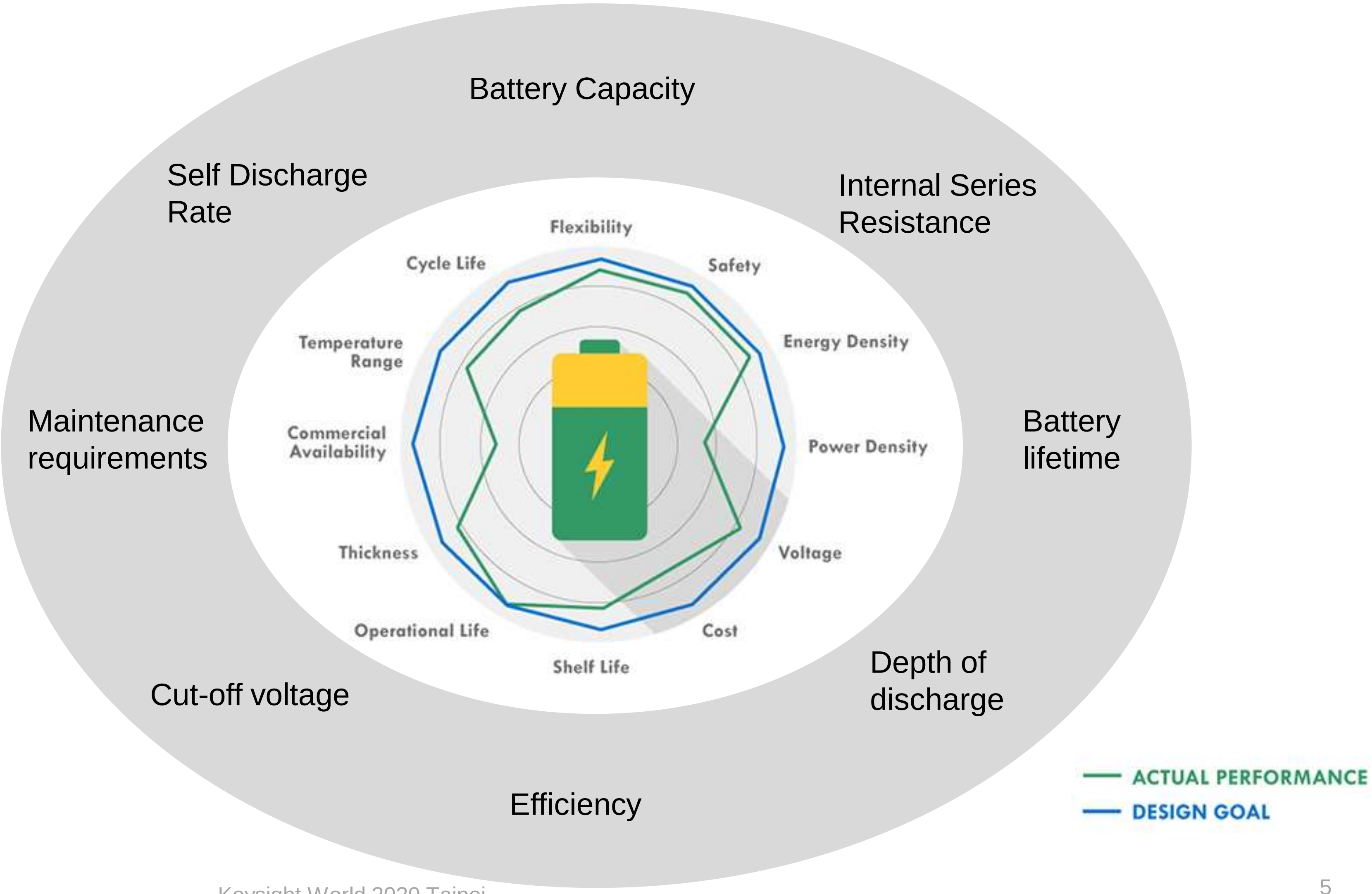
Mobile use



Different Battery Requirements for Different Applications

DEVELOPMENT GOALS FOR BATTERIES

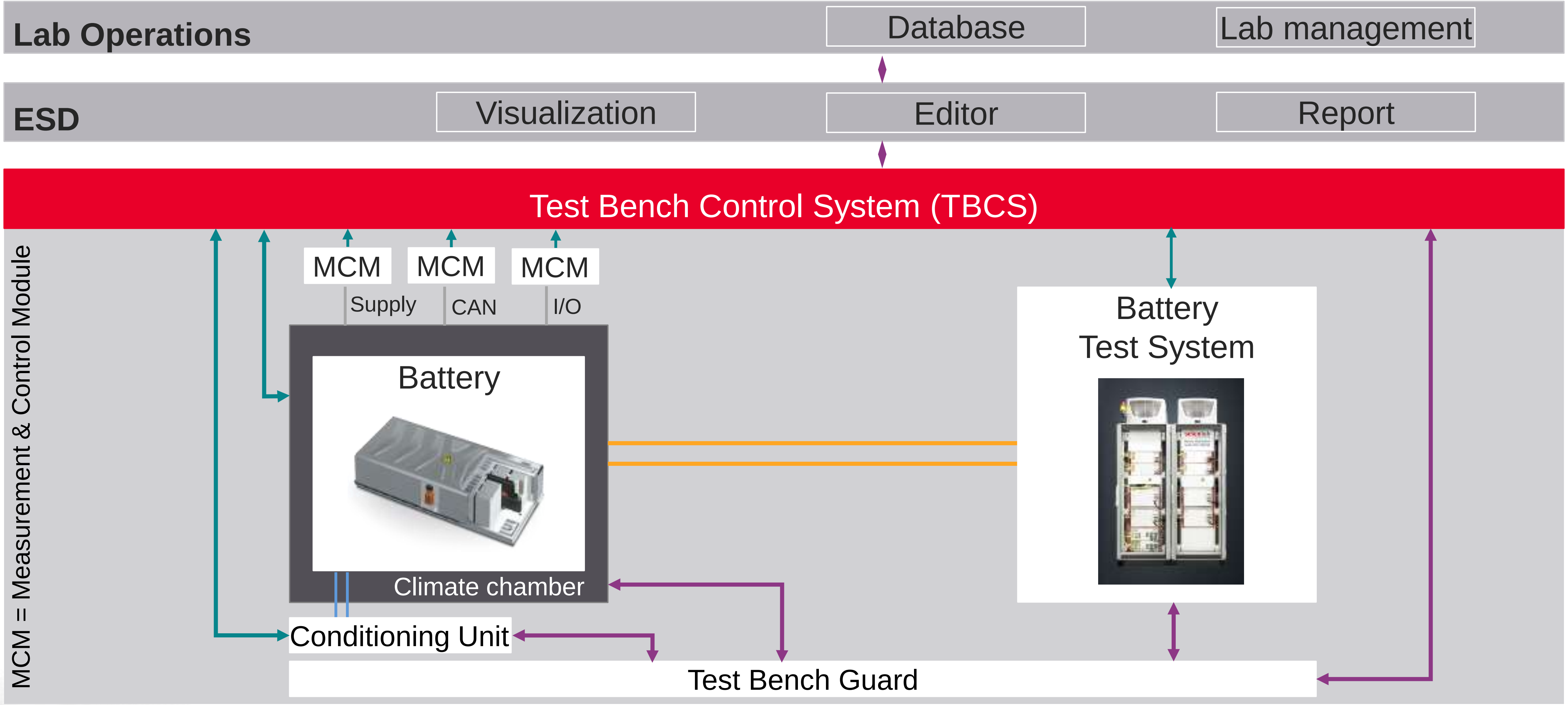
- The characteristics of each battery cell differ for each application
- Large number of battery parameters
- Some parameters are more important than others depending on the target application
- For EV/HEV fast charging and extended range is of high importance → improvement of battery capacitiy, efficiency, energy density etc.



Measurement Toolbox for Finding the Right Battery for Your Application

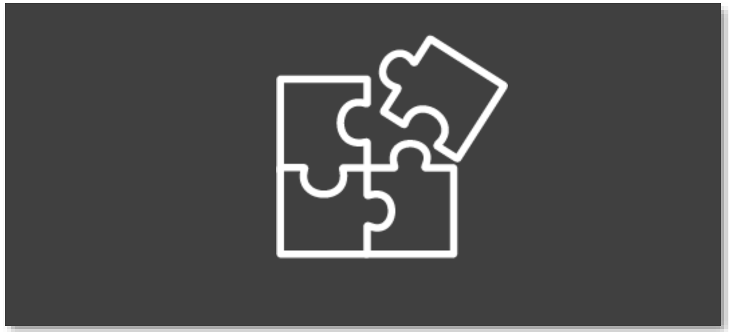
Emulated battery test environment

DIGITIZED, AUTOMATED AND NETWORKED LABORATORY



Finding the Right Battery for Your Application

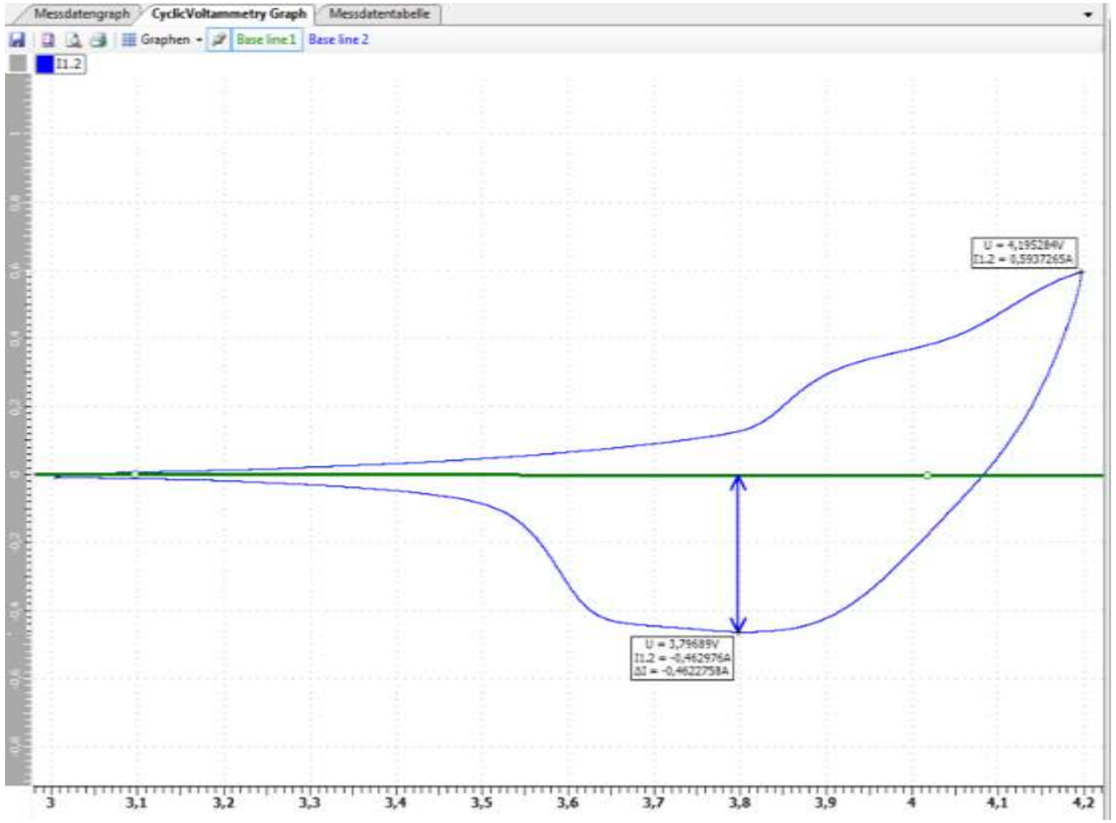
MEASUREMENT TOOLBOX

Which battery characteristic do you want to investigate?	Which measurement tool do you need?
	
Reduction and oxidation events	Cyclic voltammetry
Electrical battery parameter	Charge/Discharge measurement Direct self-discharge measurement Electrochemical Impedance Spectroscopy (EIS)
Thermal battery parameter	Direct temperature measurement Direct thermal impedance measurement

Investigating Reduction and Oxidation Events

CYCLIC VOLTAMMETRY

- Cyclic voltammetry is used to obtain electrochemical properties of an analyte that is adsorbed onto the electrode
- Voltage applied between the reference electrode and working electrode in-/decreases linear with time (cyclic sweep)
- The current is measured resulting in data that is plotted as current (I) vs. voltage (V)
- Obtaining information regarding:
  - Stability of transition metal oxidation state in the complexed form
  - Reversibility of electron transfer reactions
  - Information regarding reactivity

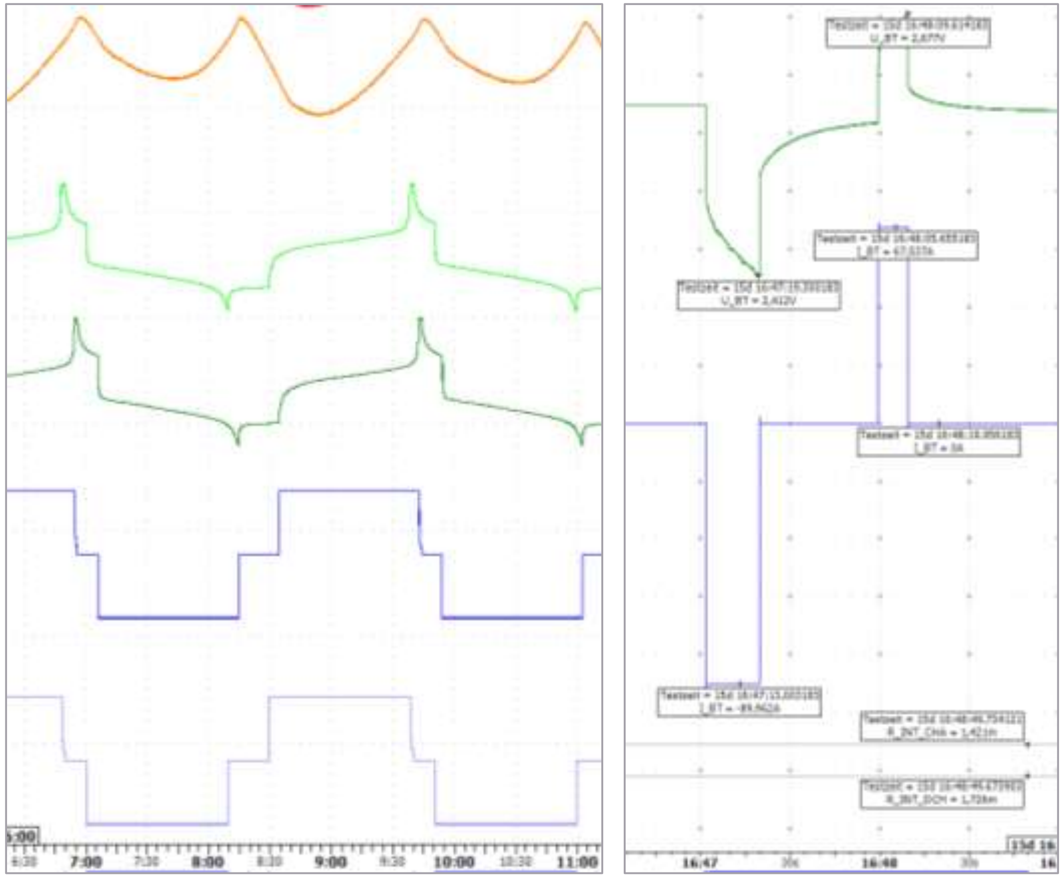


Immediate display of the cell current as a function of the voltage for direct analysis

Investigating Electrical Battery Parameter

CHARGE / DISCHARGE MEASUREMENT

- Charge and discharge cycling is used to obtain different characteristic values of batteries
- By applying (standardized) current, voltage or power curves under certain environmental conditions and based on measurement of the other respectively, various values can be calculated
- Obtaining information regarding:
  - Capacity, cut-off voltage, SOC, SOF, charge/discharge efficiency, energy efficiency, resistance, cyclic and calendric life time and many more
  - Application specific driving cycles provide information about the respective performance, e.g. mileage range
  - Equivalent circuit modeling (ECM) fitted by measured data using circuit elements

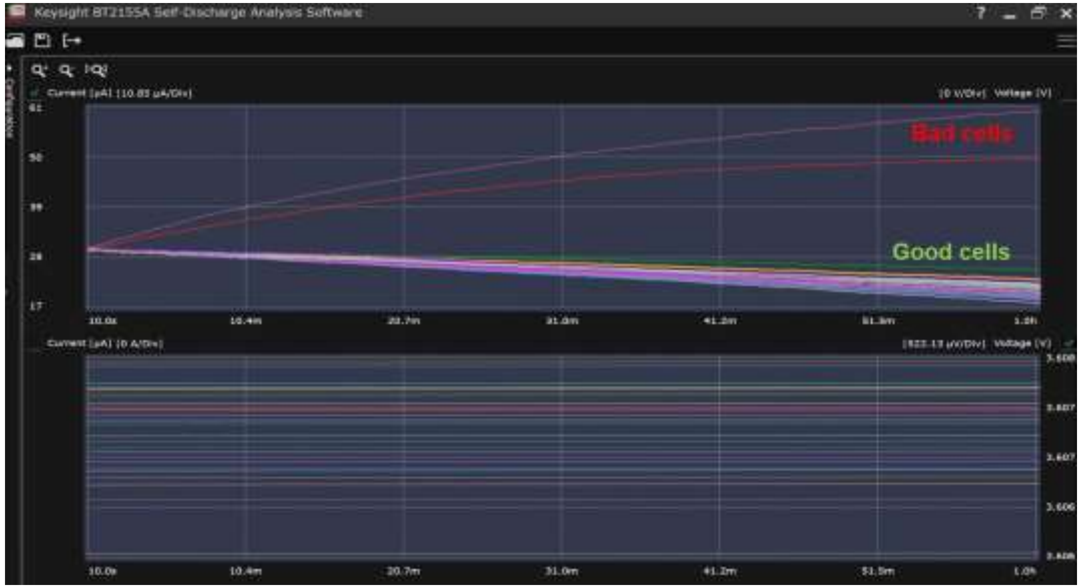


Display of the current and voltage over time and immediately calculated resistance

Investigating Electrical Battery Parameter

DIRECT SELF-DISCHARGE MEASUREMENT

- Direct self-discharge measurement is used to assess the quality of batteries
- Based on measurement of the current required to maintain a constant open cell voltage (OCV), the self-discharge is determined directly
- Obtaining information regarding:
  - Comparison of the leakage currents of several cells gives information about the quality of the battery type
  - Increased self-discharge imbalances otherwise matched cells in a battery assembly
  - High leakage current indicates internal damage like micro shorts which may lead to possible catastrophic failure

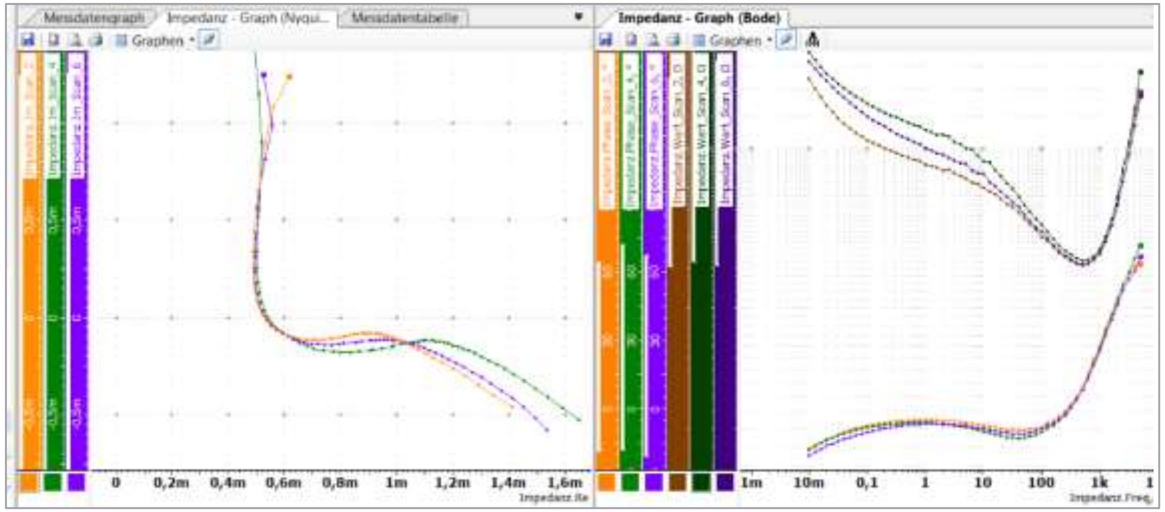


Direct measurement of the leakage current while keeping the OCV constant

Investigating Electrical Battery Parameter

ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

- Electrochemical Impedance Spectroscopy (EIS) is used to obtain impedance characteristics of batteries
- Based on voltage response impressed by a sinusoid current sweep, the complex impedance as a function of frequency can be determined
- Obtaining information regarding:
  - Equivalent circuit modeling (ECM) fitted by measured impedance data using circuit elements
  - Aging and state of health (SOH) research by analyzing the correlation between battery impedance and lifetime obtained under different life conditions through an high accelerated life test

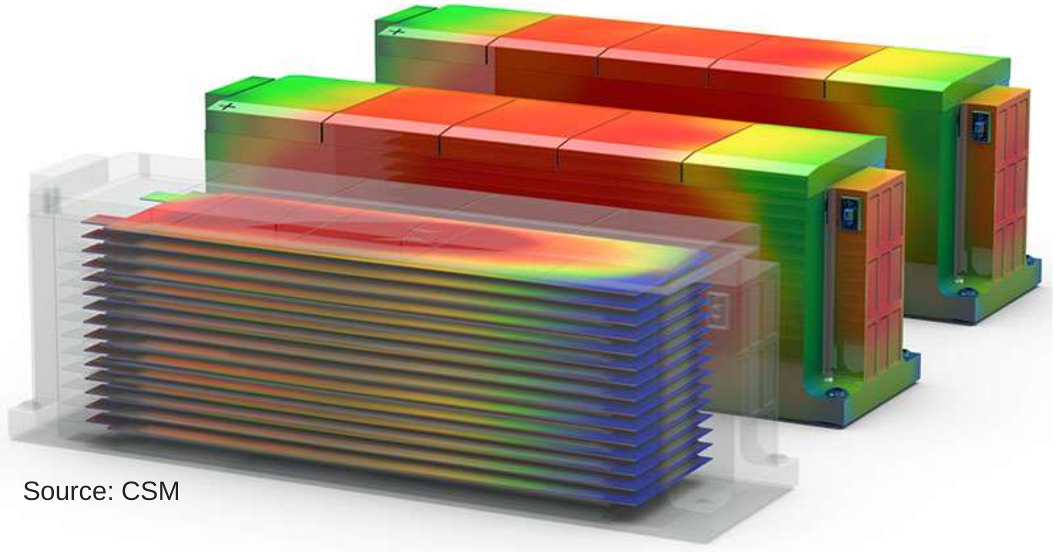


Immediate display of the impedance as a function of frequency as well as magnitude and phase for direct analysis

Investigating Thermal Battery Parameter

DIRECT TEMPERATURE MEASUREMENT

- Direct temperature measurement is used to obtain thermal dependency of batterie characteristic
- In addition to the ambient temperature, the battery temperature is measured at several points via sensors or IR camera
- Obtaining information regarding:
  - Battery behavior at different temperatures
  - Temperature dependency of specific characteristic values
  - Temperature distribution within a battery assembly



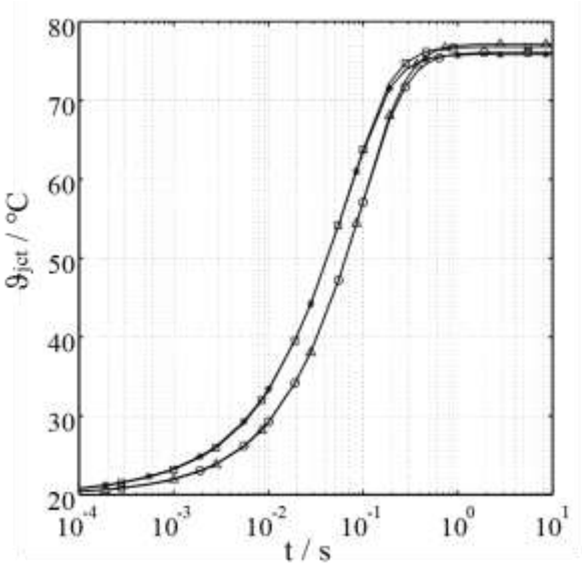
Source: CSM

Direct cell temperature measurement while cycling

Investigating Thermal Battery Parameter

DIRECT THERMAL IMPEDANCE MEASUREMENT

- Direct thermal impedance measurement is used to obtain thermal behavior of batteries and assemblies out of it
- Based on temperature curve over time due to an impressed defined constant active power, the thermal impedance Z_{th} can be measured directly for different measuring points
- Obtaining information regarding:
  - Equivalent circuit modeling (ECM) fitted by measured thermal impedance data using circuit elements
  - Local dynamic temperature rise due to locally high thermal resistance within a battery assemble can be identified and optimized



The complex thermal impedance can be read directly from the logarithmic representation of the temperature over time

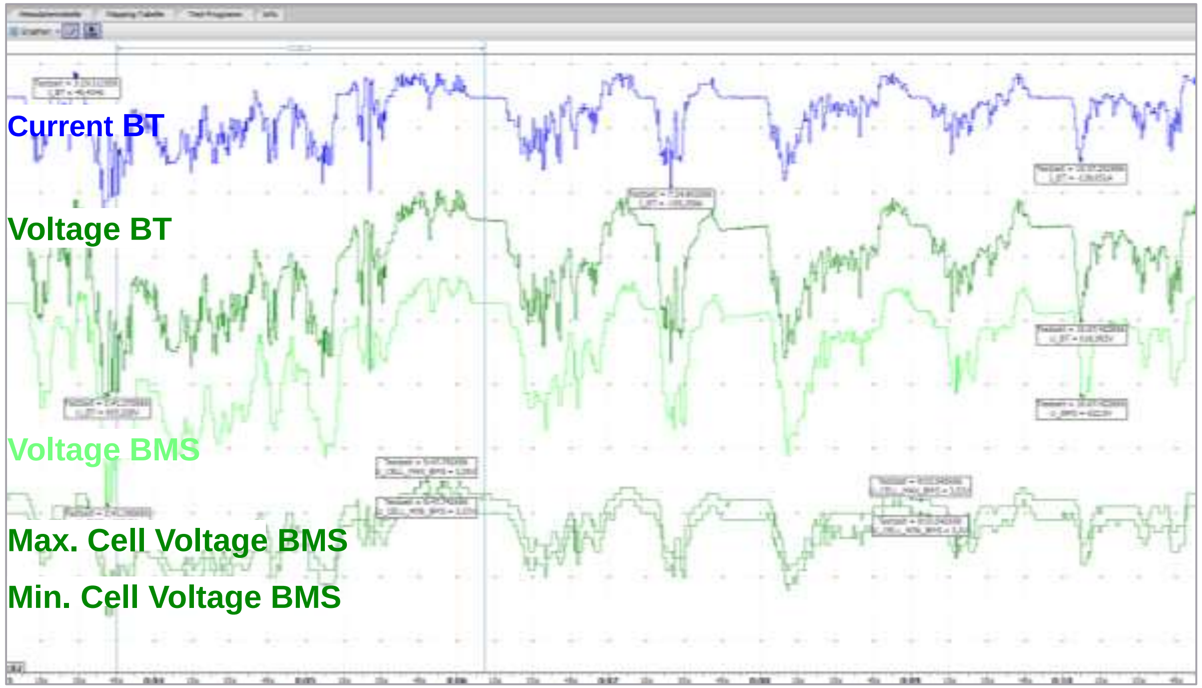
Case Studies

Case Studies

EXTENDED RANGE

- Challenge: Guaranteed mileage range
- Question: Mileage range over life time and applications
- Solution: Reproducible driving cycles under different boundary conditions


Source: www-pcwelt.de

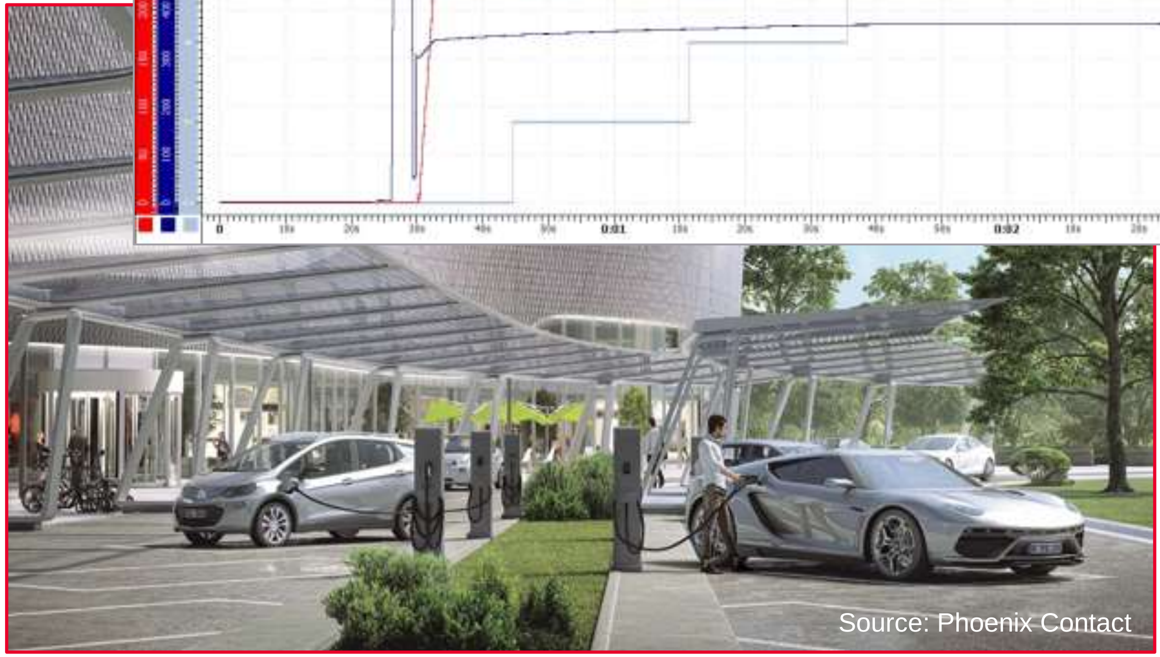


Driving profile: Import of profiles using .csv or .txt files or manual creation as preset of various parameters such as current, voltage or power; calculation of charge and energy throughput, state of charge, statistical means

Case Studies

FAST CHARGING

- Challenge:
  Battery overheating during fast charging
- Question:
  Maximum allowed current to shorten charging time
- Solution:
  Hotspots can be analyzed using the Z_{th} measurement method to optimize the assembly structure



Data Management

Data Management

PATHWAY LAB OPERATIONS FOR BATTERY TESTING

A large lab has many challenges. In general, it will require the management of **resources**, **hardware** and **information**.

- Efficient planning and coordination of the entire battery test lab
- Integrated, web-based lab management platform for modernizing test workflows, eliminating legacy paper-based paper processes, and increasing data traceability
- Easily register and track test objects in your lab
- Quickly analyze your data and statistics
- Organize your documents, tasks, and lab orders

Conclusion

Conclusion

SOLUTIONS FOR TESTING BATTERIES DURING ENTIRE DEVELOPMENT CHAIN

- Different applications require different batteries
- For EV/HEV fast charging and extended range is of high importance → improvement of battery capacity, efficiency, energy density etc. is required
- Finding the right battery for your application requires a comprehensive measurement toolbox
- Keysight provides sophisticated Battery Test Solutions and Services for meeting all test requirements and finding the right battery for your application

Testing Conformance & Interoperability of EV and EVSE Charging Interfaces

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Agenda

Part I:
Why Do We Need More Testing and Why Hasn‘t it Been Done Yet?

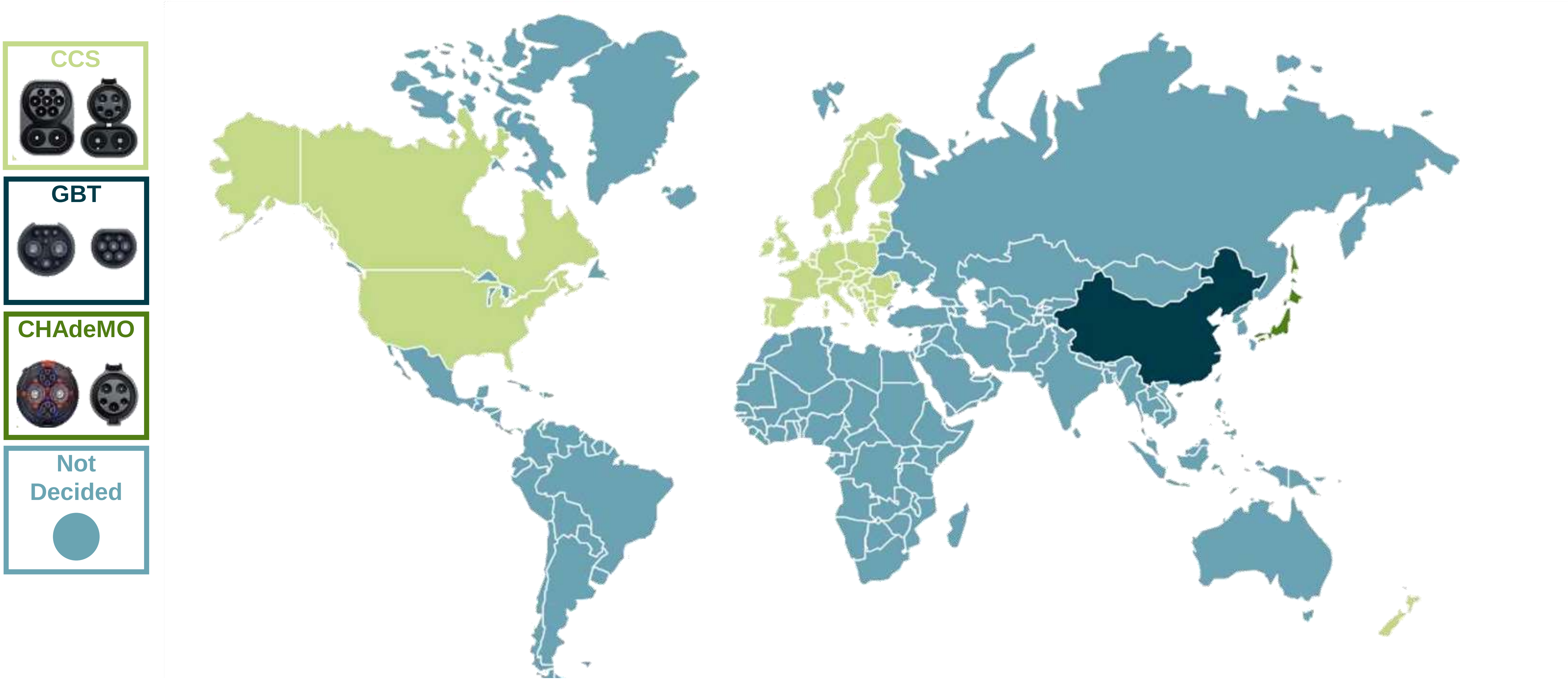
Part II:
How Does Keysight Help to Solve this Challenge?

Part III:
Example of an Automated EVSE DC Charging test

Wrap Up

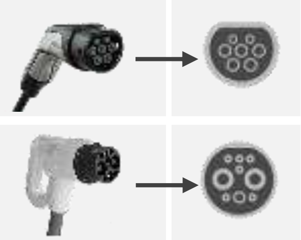
Part I:
Why Do We Need More Testing and Why Hasn‘t it Been Done Yet?

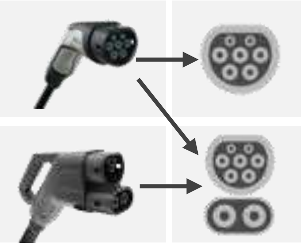
Multiple Charging Standards Co-Exist in the World

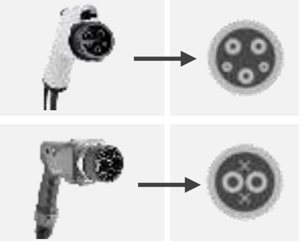


Multiple Charging Standards Co-Exist in the World

	Function	Connector	Inlet
CCS Type 1	1-phase AC charging		
	DC charging via extra DC-pins in Combo-1 connector		

	Function	Connector	Inlet
GB/T	1-phase AC charging		
	DC charging via separate connector and vehicle inlet		

	Function	Connector	Inlet
CCS Type 2	1-phase AC charging		
	3-phase AC charging		
	DC charging via extra DC-pins in Combo-2 connector		

	Function	Connector	Inlet
CHAdeMO	1-phase AC charging		
	DC charging via separate connector and vehicle inlet		

Each OEM of EVs or EVSEs must cover dozens or even hundreds of different product configurations.

But how to ensure interoperability for all of them?

Definition of Interoperability

International
Electrotechnical
Commission

INTEROPERABILITY

"property permitting diverse systems or components to work together for a specified purpose"

[Source: IEC 80001-1:2010, 2.11]

IDEAL WAY TO GET THERE

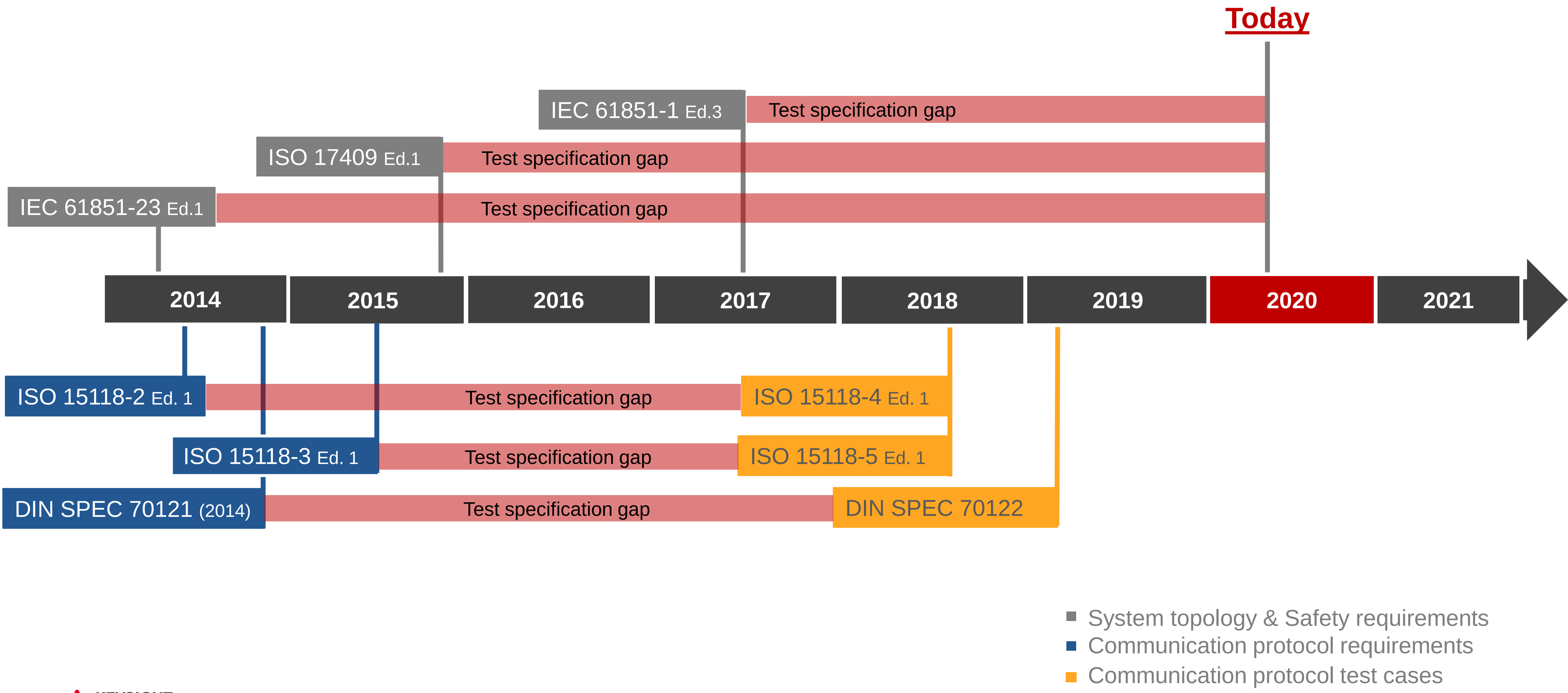
1. Design product respecting all relevant regulations and standards
2. Verify if product fulfills each given requirement

CCS Standards | Requirements vs Test Specification

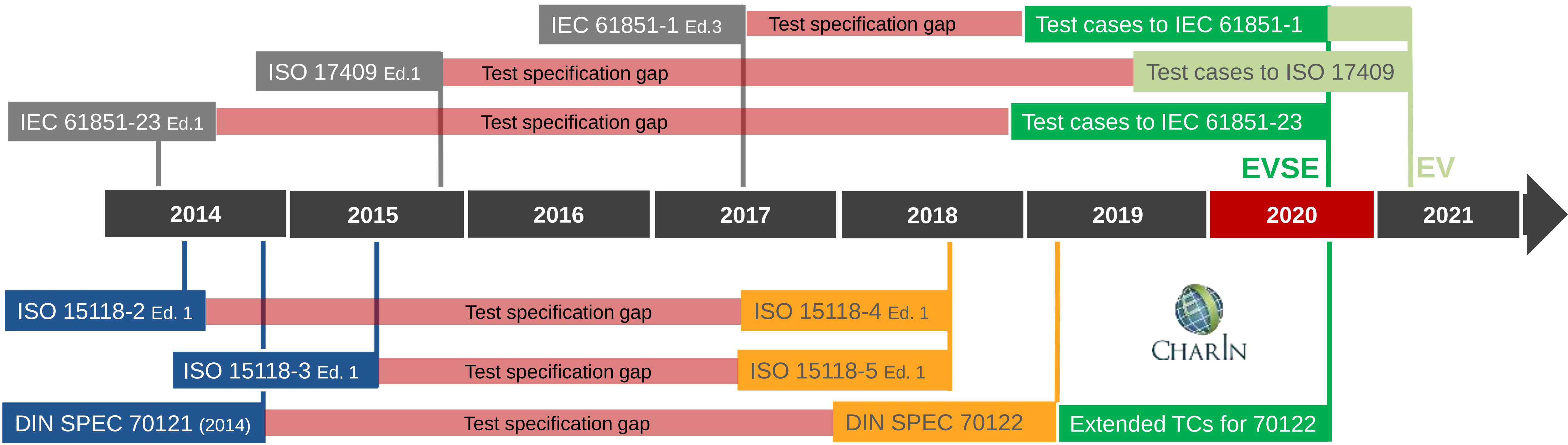
CATEGORY	DOCUMENT	CURRENT VERSION	TEST SPEC.	EXTERNAL TEST SPEC.
System topology & Safety	IEC 61851-1 IEC 61851-23 ISO 17409	Ed.3 | 2017-02 Ed.1 | 2014-03 Ed.2 | 2020-02	Not included Not included Not included	missing missing missing
Communication protocols	DIN SPEC 70121 ISO 15118-2 ISO 15118-3	Ed.1 | 2014-12 Ed.1 | 2014-04 Ed.1 | 2015-05	Not included Not included Not included	DIN SPEC 70122 ISO 15118-4 ISO 15118-5
EMC	ECE R10 Directive 2014/30/EU IEC 61851-21-1 IEC 61851-21-2	Rev6 | 2019-11 2014-02 Ed.1 | 2017-06 Ed.1 | 2018-04	Included Not included Included Included	IEC 61000-3/4, etc.

Note: Scope limited to EU/IEC standards & conductive charging only, for better overview

Timeline of CCS Interop Related Documents



When Will the Test Specification Become Available?



- System topology & Safety requirements
- Communication protocol requirements
- Communication protocol test cases
- Specification of CharIN e.V.

Key Technology Trends in E-Mobility Charging

TREND 1

Bigger EV Batteries resolve range anxiety, but also require **Higher DC Charging Power** for long distance travel

Photos: Volkswagen

20 kWh ➡ 60..100 kWh

Photos: ABB

50 kW / 125 A ➡ 350+ kW / 500 A

HPC

CHAdeMO Version 3.0

超级 ChaoJi

TREND 2

With **Plug & Charge** charging electric vehicles becomes more convenient than filling up gasoline at a gas station

Home and opportunity charging (e.g. at work, super market, restaurant) will eliminate the need to visit gas stations for most EV drivers

Photo: Hubject

Plug & Charge technology and ACD (automated connecting devices) will simplify charging process. No need for authorization/payment or even plugging the charging connector

ISO 15118-2

PnC

TREND 3

Intelligent load management and bidirectional charging enables true **Smart Charging**

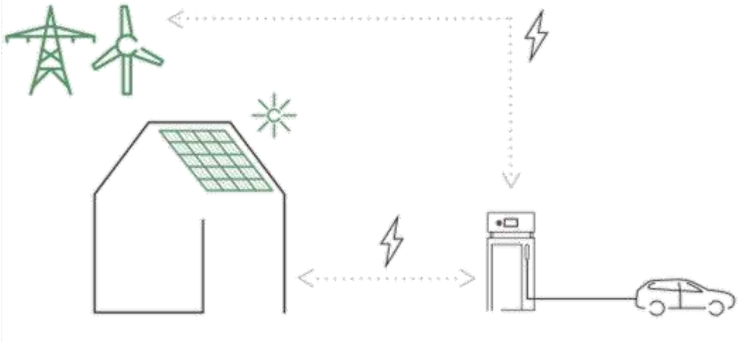


Photo: CHAdeMO

Advanced charging protocols and HEMS (Home Energy Management Systems) allow intelligent timing of taking or providing energy to the grid. In combination with smart meters and renewable energy sources, the grid can be balanced.

ISO 15118-20

CHAdeMO V2H/V2L

Summary Part I

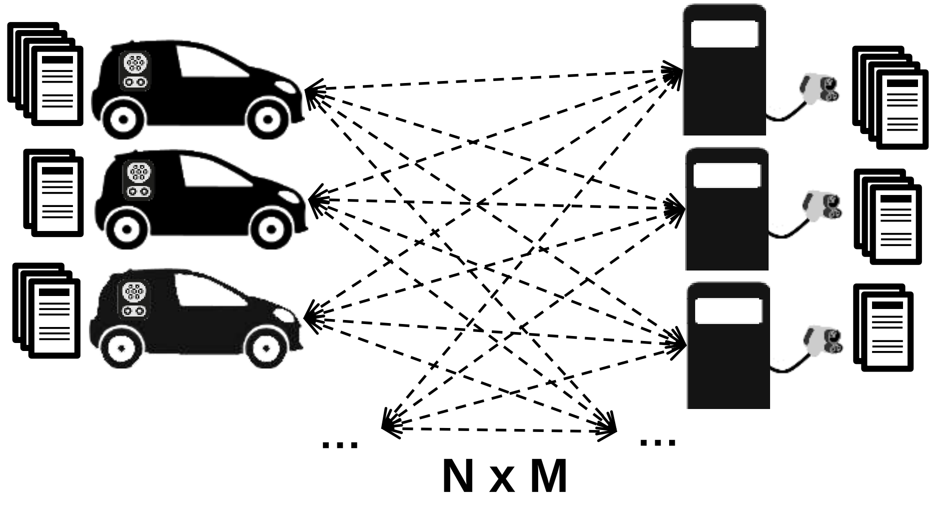
- Worldwide we do have a highly **heterogenic charging protocol and connector landscape**
- As bigger batteries become state of the art also for middle class vehicles, the **demand for high power charging increases**
- The E-mobility market drives technology rapidly. **Standard, regulation and certification bodies can hardly catch up**.
- In 2020, harmonized test specification finally become available and are **substantial for overcoming interoperability issues**.

Part II
How Does Keysight Help to Solve this Challenge?

Automated Interoperability Testing

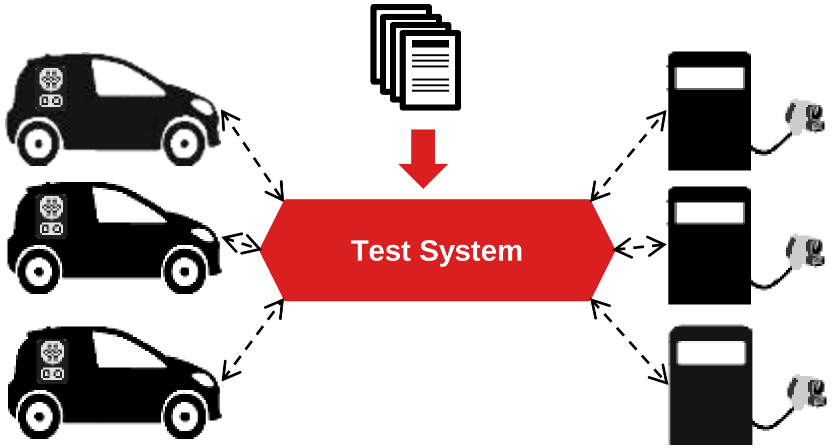
MANUAL TESTING

- Implementation vs. Implementation (good case only)
- Not feasible for growing market



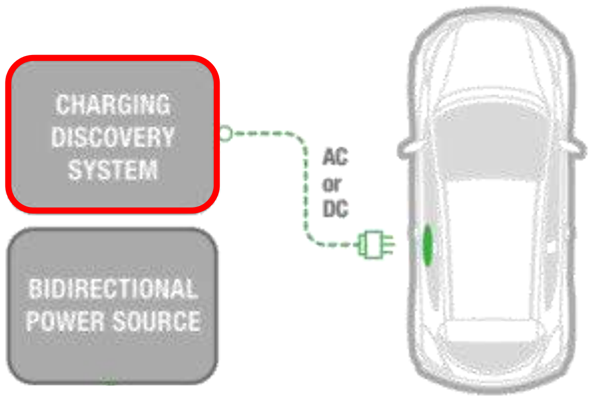
AUTOMATED TESTING

- Test cases vs. Implementation (good AND error cases)
- Scalable for growing market

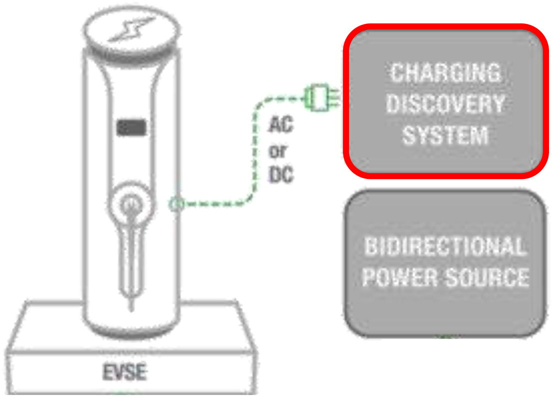


CDS Covers Three Use Cases And Full Automated Testing

EV TEST

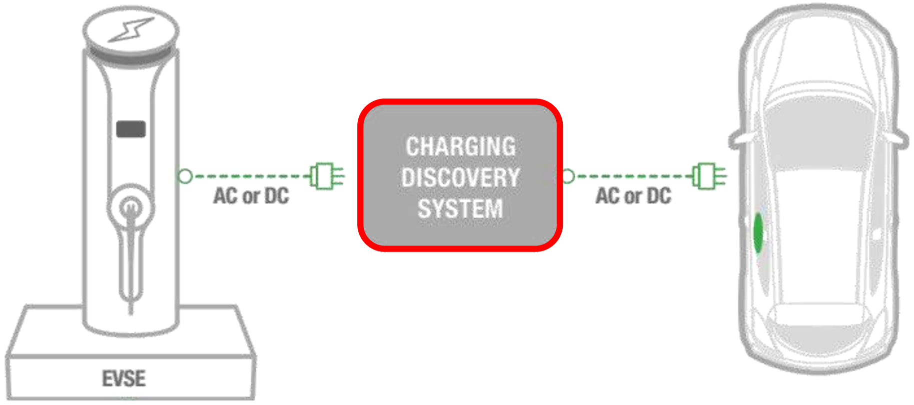


EVSE TEST

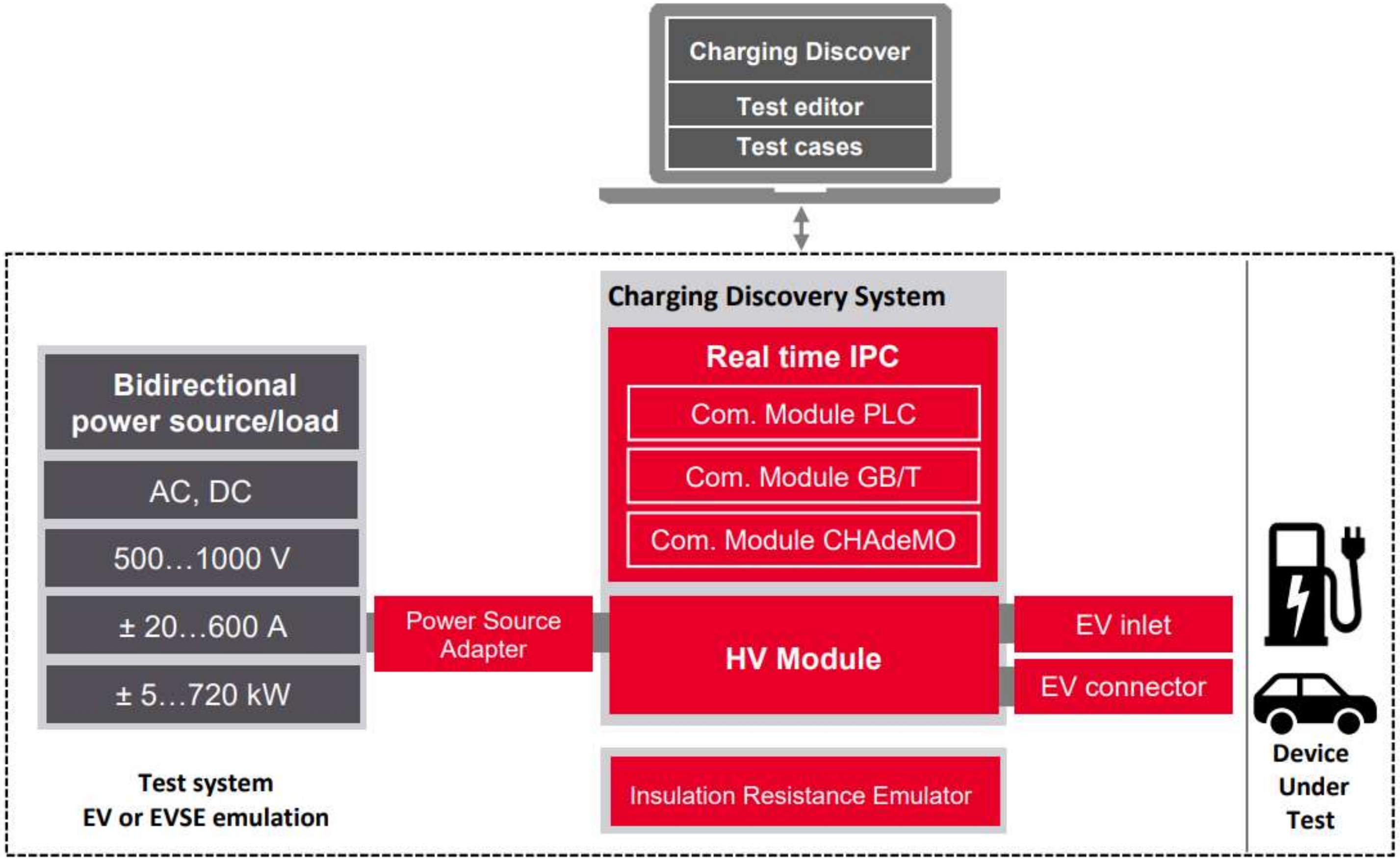


→ Example follows in part III

MAN-IN-THE-MIDDLE TEST



Modular All-In-One Solution: Charging Discovery System



Charging Discovery System – Portable Series

HARDWARE SET-UP

Scienlab Charging Discovery System
Portable Series
EV and EVSE Emulation
Up to 1000 V, 400 A DC
440 V AC, 32 A rms

Scienlab Dynamic DC Emulator
Mid Power Series
Regenerative DC Power Source
Up to 950 V, ± 100 A, 50 kW

Charging Discovery System – High Power Series

HARDWARE SET-UP

Scienlab Charging Discovery System
High Power Charging Series
EV and EVSE Emulation
Up to 1500 V DC, 600 A DC, 900 kW
500 V AC, 100 A AC

Scienlab Dynamic DC Emulator
High Power Series
Regenerative DC Power Source
Up to 1000 V, 600 A DC, 360 kW

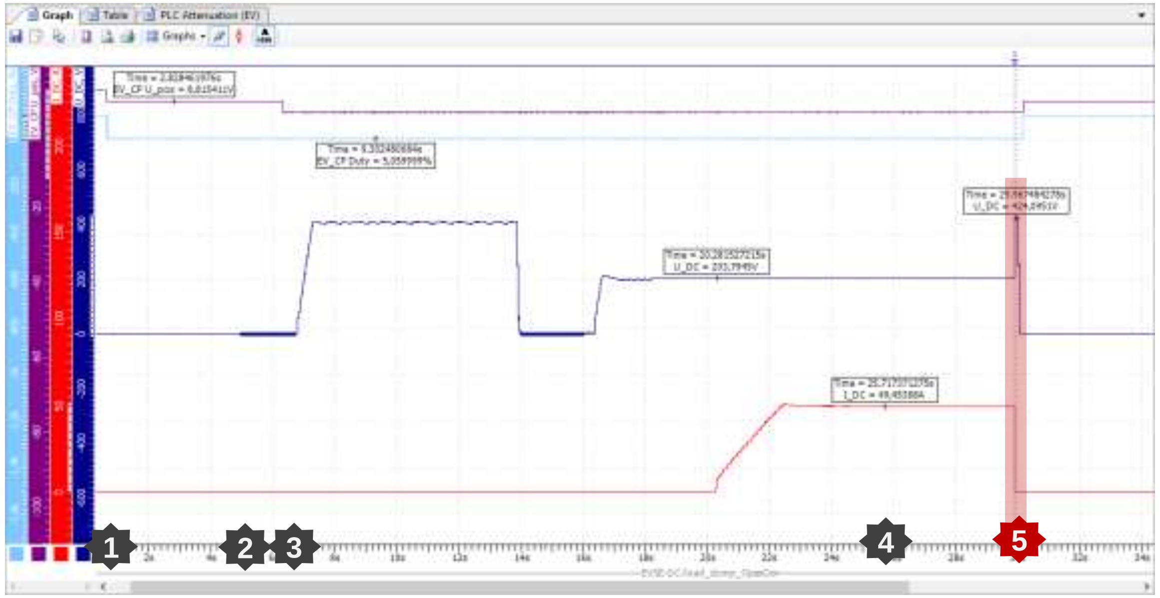
Part III
Example of an Automated EVSE DC Charging Test

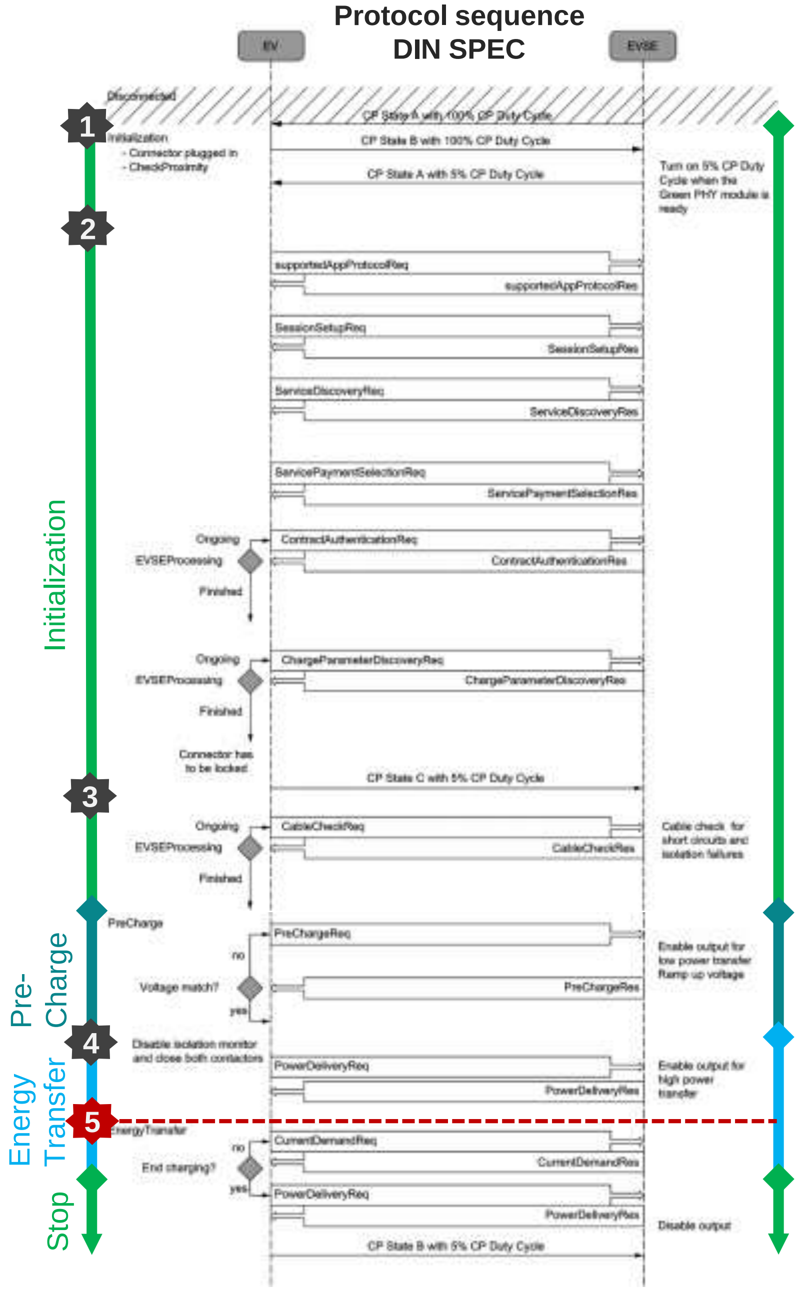
Example: Load Dump Test

EVSE TEST

Test sequence

1. Connect SUT connector to EV emulation
2. Establish digital communication between EVSE and EV emulation (SLAC, IP assignment and TCP connection)
3. Exchange all mandatory charge parameters (incl. authentification and payment)
4. Start charging and reach desired operating point
5. Interrupt DC circuit, compare voltage output to expected behavior

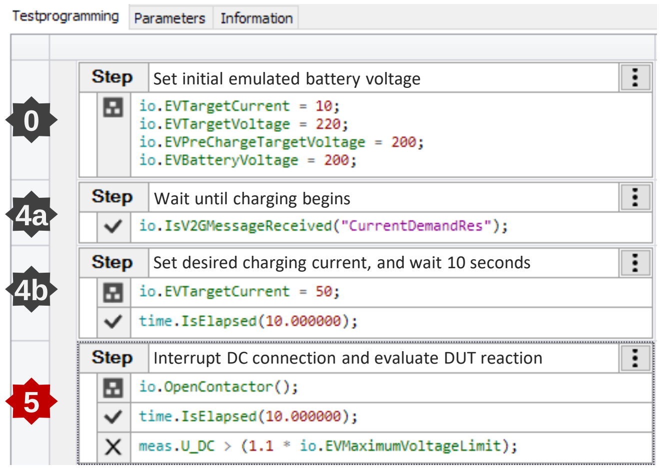


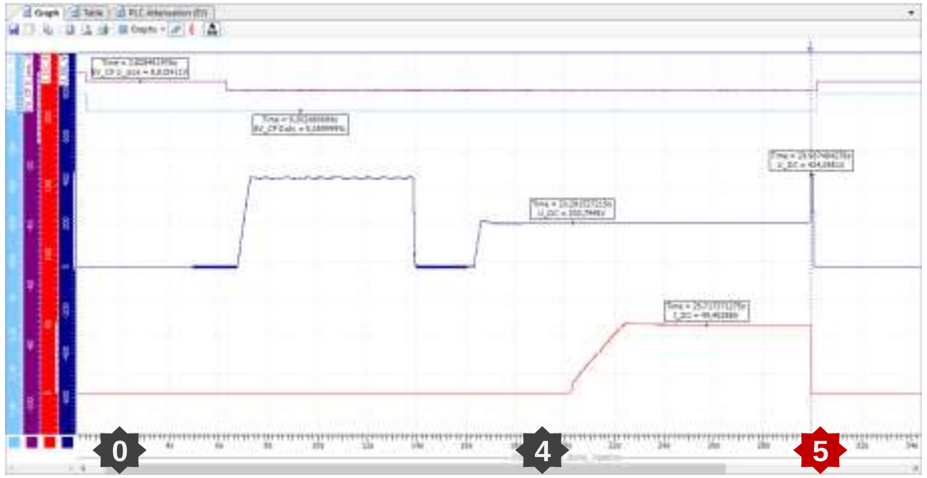


Source: DIN SPEC 70121, Figure 78, 79 and 80

Example: Load Dump Test

IMPLEMENTATION EFFORT?





Implementation in Charging Discovery System

- <u>Only four steps required</u>, because CDS handles all regular charging sequence automatically. User only needs to inject test case specific events and define fail/pass criteria.

Wrap Up

- Portable and High Power Charging Discovery System from Keysight:
  - offers a **holistic and future proof solution** designed according to most recent international standards
  - is the **only fully modular solution** which allows testing of **EV and EVSE during high power charging**
  - offers **certified and automated test cases** for all existing and future worldwide standards
  - delivers **significant advantages** for the customer by **reducing time to market** and **enhancing product quality**

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