



Using Battery/Fuel Cell Emulation for Testing DC Fast Chargers & Powertrains

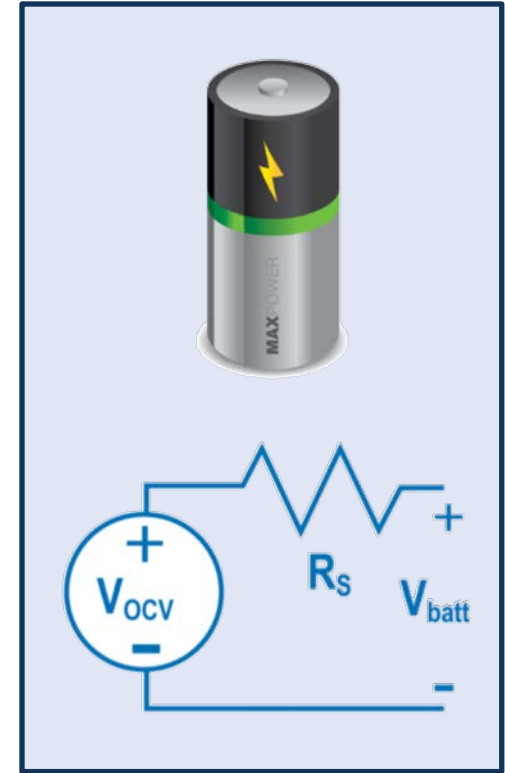
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Product Director

NH Research (NHR)
Enabling Electrification

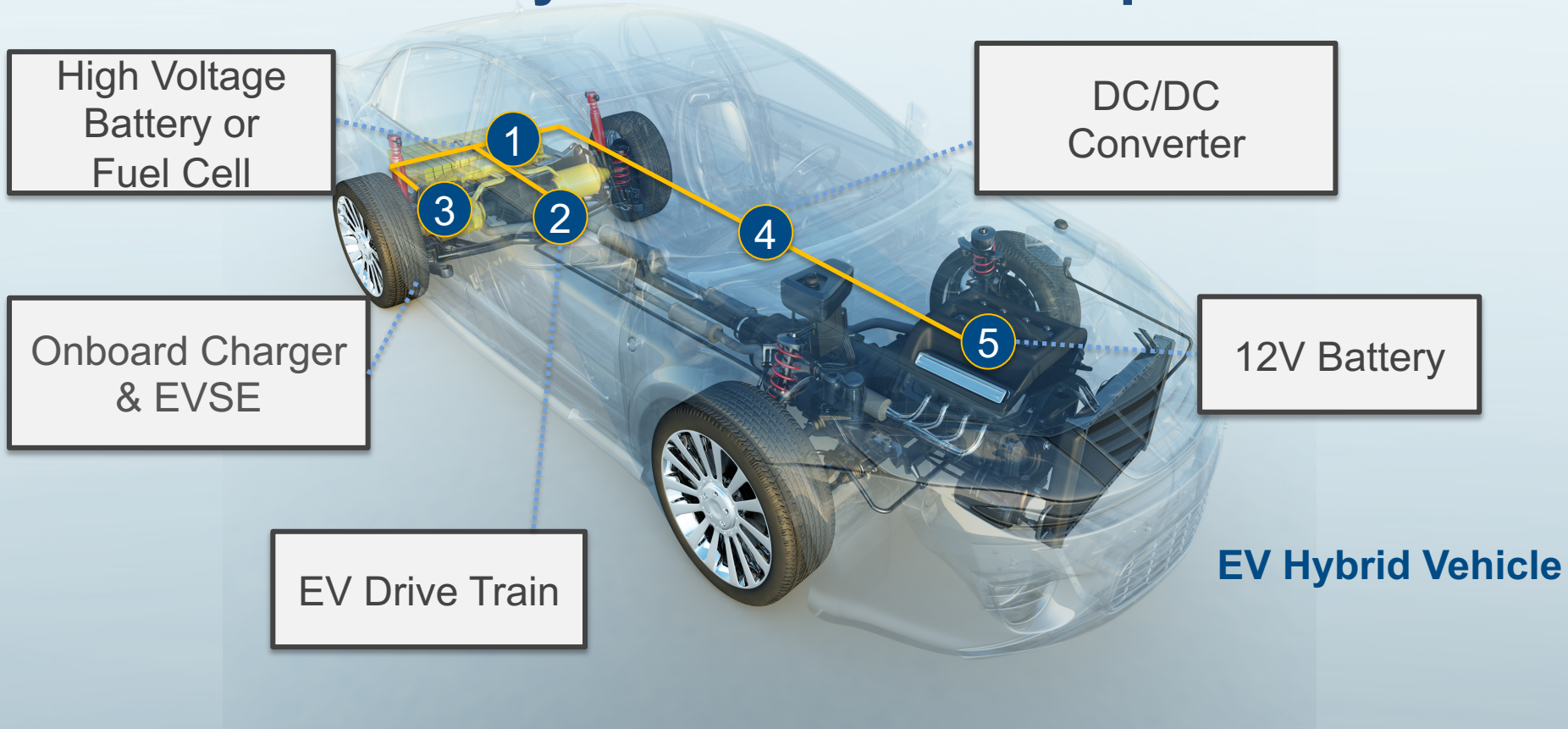


Agenda

- Industry Trends
- Test Approaches
- EV Industry Applications



EV Industry Trends & Test Requirements



Wide Operating Power Range



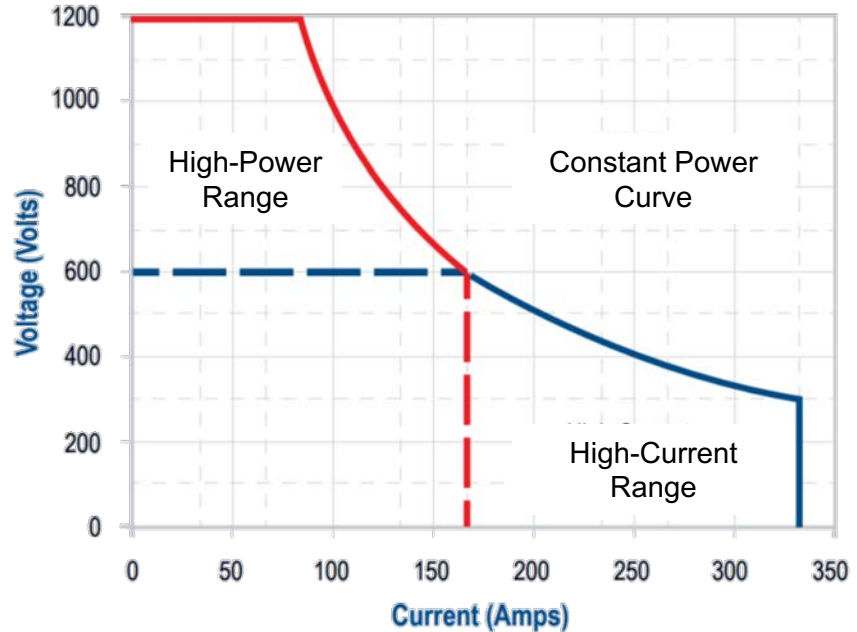
Image: Courtesy of Volkswagen Group (Porsche)

800 VDC



Image: Courtesy of Tesla Motors

<500 VDC

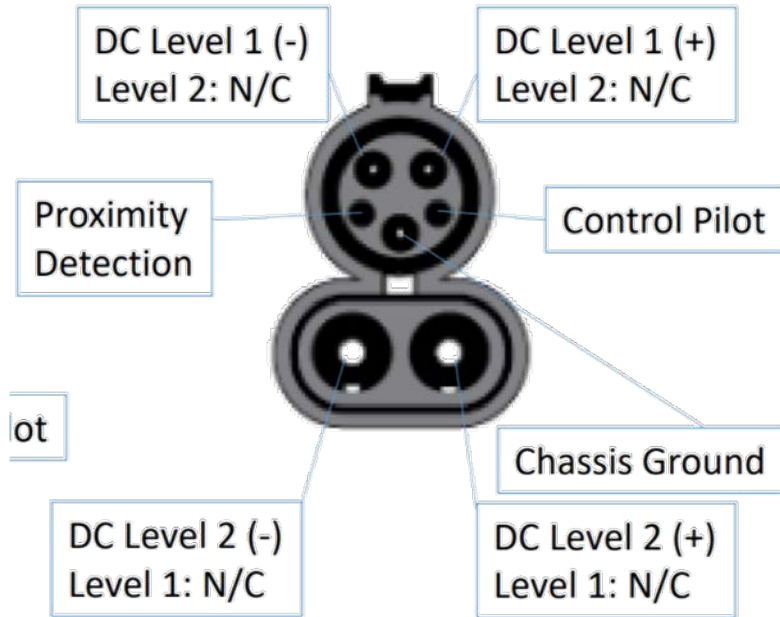


NHR 9300 Series

DC Fast Charging



DC Levels 1 & 2

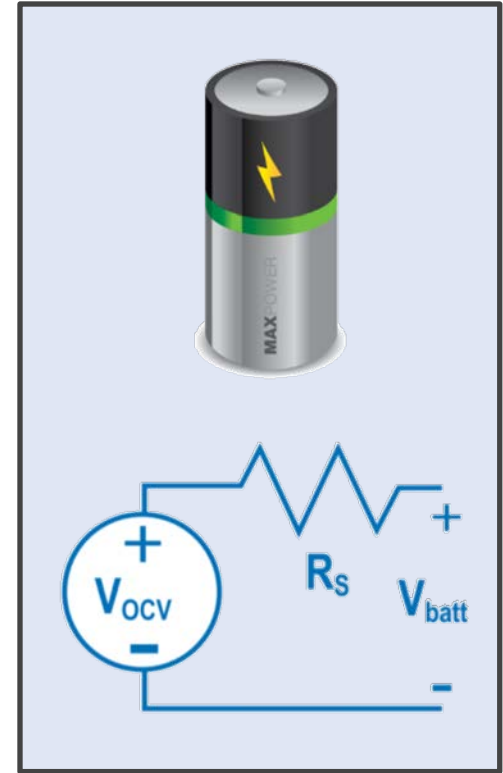


Battery Emulation

- **Acts as the DC Battery**
i.e. Connects to DC +/-
- **Bi-Directional**
V2L, V2H, V2V, V2G
- **Scalable 100kW modules**
- **Wide Operating Range**
500V – 600 V, 1000V +
Tesla Supercharge, CCS1 & CCS2,
GB/T 20234, CHAdeMO

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Testing with Batteries *is Costly*

- **Preparing the Battery for Test → Time**
- **Battery Availability → Project Time**
- **Battery Effects → Test Repeatability**
- **Battery Safety Risks → Lab Safety**
- **No Corner Cases → Limits Test Coverage**

The Benefits of Testing Without Batteries

NHR
NH Research

Introduction

There are many benefits to testing batteries by emulating, or simulating, battery characteristics rather than using a real battery. The emulated battery dramatically reduces testing time, provides highly repeatable test results, and creates a safer test environment. Also, preparation time, operator errors, and result variations due to battery temperature or aging, are eliminated.

Test Time (in Days)

Week							Week (partial)			
M	T	W	T	F	S	S	M	T	W	
1	2	3	4	5	6	7	8	9	10	

■ REST BEFORE DISCHARGE ■ REST BEFORE CHARGE
■ DISCHARGE ■ ACTUAL TEST

Using Emulation

Week (partial)		
M	T	W
1	2	3

■ REST BEFORE CHARGE ■ ACTUAL TEST

Figure 1 - Testing with Real Battery Versus Using Emulation

Battery Emulation Reduces Testing Time

Testing a real battery often requires operator preparation for each step. Batteries must first be charged, or discharged, then allowed to rest, and finally tested. The significant battery preparation time can be avoided by using an emulated battery.

Figure 1 above shows actual customer data from nine (9) tests conducted with both a real battery and then an emulated battery. Upon comparison between the tests, in these cases, emulation reduces the total test time by more than 70%.

Battery Emulation Provides Repeatable Test Results

Over time, batteries provide inconsistent test results, wear out, and need to be replaced. Battery age, internal temperature, and cycling are all contributing factors to the limited battery life-span. Manual battery operation, including real time facilitation, can also cause inaccurate test results. Battery emulation provides consistent and repeatable test results, unlike those from real battery testing, during which battery changes and operator errors cause variations in test results.

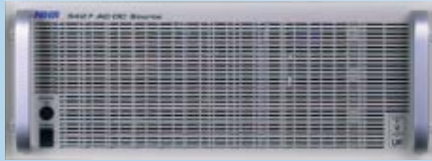
Battery Emulation Improves Safety

Although batteries are generally safe when operated within normal operating ranges, they are high energy devices that may pose serious risks upon battery or unit under test (UUT) failure. Such risks include exposure to dangerous gases, fires, explosions, or corrosive chemicals. These concerns have led to safety policies stating that tests must be conducted and monitored during working hours. Furthermore, testing extreme cases of over-discharged or over-charged batteries can pose unpredictable risks and safety hazards.

Battery emulation creates a safe testing environment without any of the concerns that arise when real batteries are used. Also, emulation safely verifies UUT behavior when a battery is outside a normal operating condition.

Battery Characteristics are Unique

Power Supplies



maintains voltage &
“supply” current



Loads



Draw or “Sink” current

Power Supplies often have very high capacitance to stiffly regulate output voltage
Loads often have very low capacitance to quickly regulate to changes on the input

Batteries are Bi-Directional

They are simultaneously (and neither) a source or load.

Uni-directional vs. Bi-directional Power

Traditional power supplies and loads were designed for *uni-directional power*.

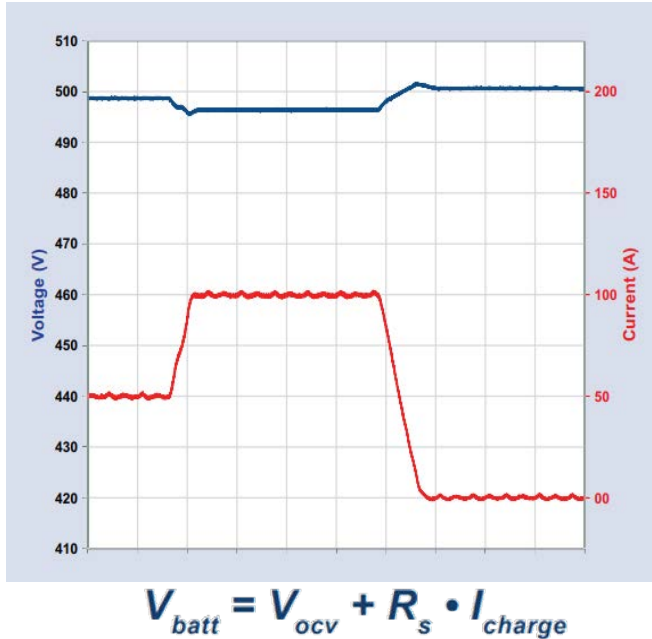
Making into *bi-directional power* is difficult.

- Extensive programming
- Quadrant change issues & limited/no resistance
- Lots of integration time instead of actual testing
- Supply capacitance limits response capability



Image: Automated Test System using source & load circa 2006

Batteries have Series Resistance



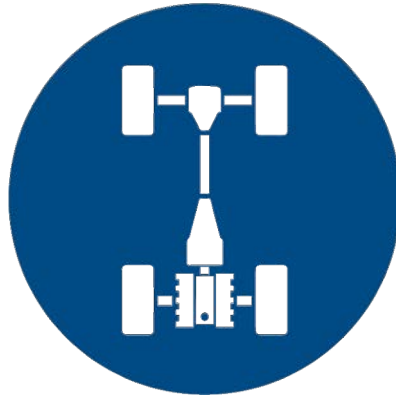
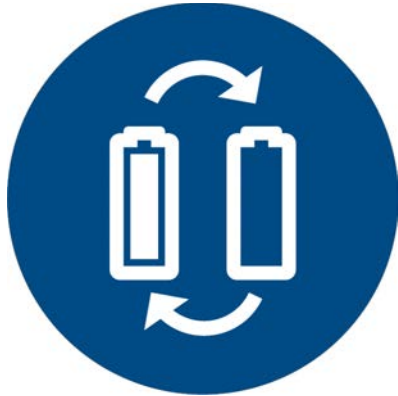
A Built-in Series Resistance is Critical to Emulate Batteries

Battery Emulation Technical Considerations

- **Bi-Directional → Modern Power Flows**
Batteries are bidirectional, traditional power supplies are not
- **Low vs. High Output Capacitance → Accurate Simulation**
dynamic simulation of output voltage changes
- **Programmable Series Resistance → Real World Test Conditions**
Built into the hardware vs. software only
- **Battery Emulation Mode → Test Efficiently & Safely**
Removing the risks associated with using batteries in test
- **Wide Operating Envelope → Future-proof Testing Capability**
Modular expansion with dual range for current & future EV systems

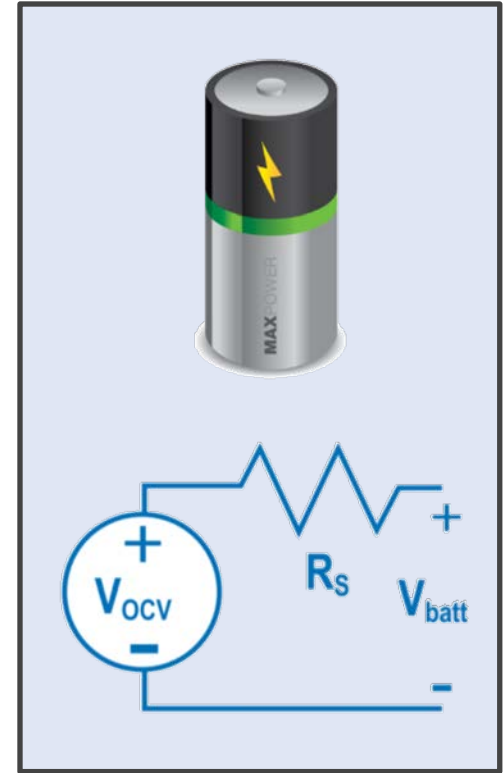
Battery Emulation *Advantages*

Faster, scalable & more repeatable testing of EV power electronic components & systems.

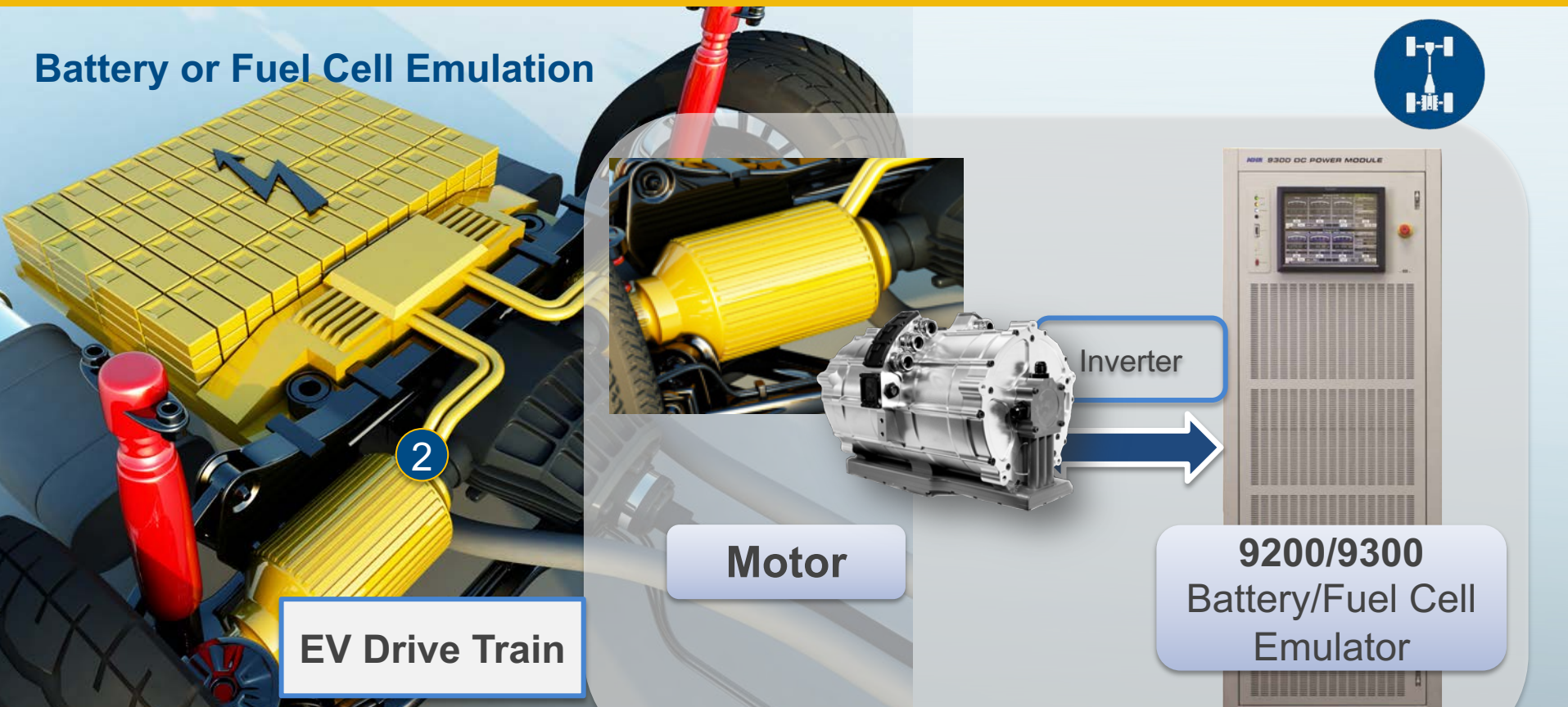


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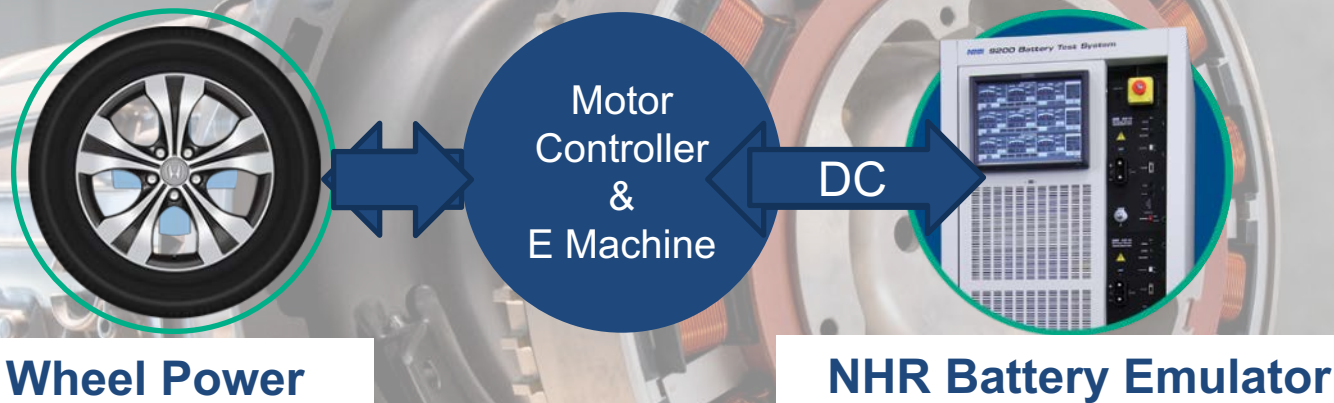
- Industry Trends
- Test Approaches
- **EV Industry Applications**



Battery or Fuel Cell Emulation

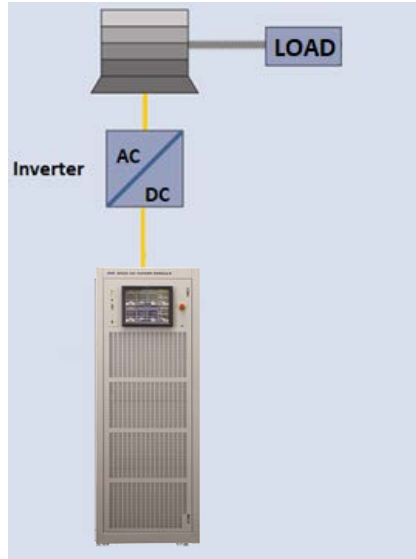


Powertrain Test Solutions

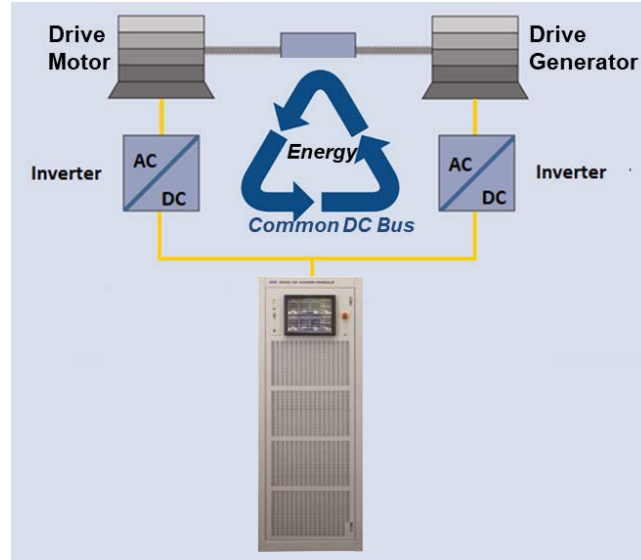


- Historically round-trip efficiency $< 50\%$
- Improve motor / controller & new batteries → efficiency gains

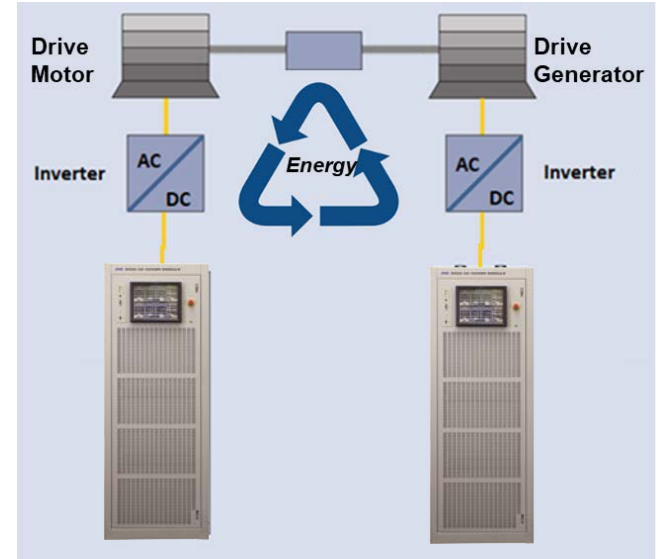
Powertrain Test Approaches



Single-ended DC Bus



Common DC Bus



Isolated DC Bus

The **NHR Approach** accepts back EMF and prevents safety hazards. Isolated input and output paths eliminates single points of failure.

Bi-directional Power



The Grid



Charger



Battery



E-Mobility



Key Benefits

- ✓ Real-world conditions
- ✓ Fast transient speeds
- ✓ Accepts back EMF
- ✓ Improves safety
- ✓ Validate system



Propulsion

Battery emulation provides speed & accuracy
to emulate real world conditions

Electrified Planes, Trains & Automobiles



Photo Credit: Tesla



Photo Credit: Embraer



Photo Credit: Daimler



Photo Credit: Collins Aerospace

Test individual components & systems



High Voltage Batteries/ Fuel Cells

- Performance
- Cycling, etc.



Drivetrain/Propulsion

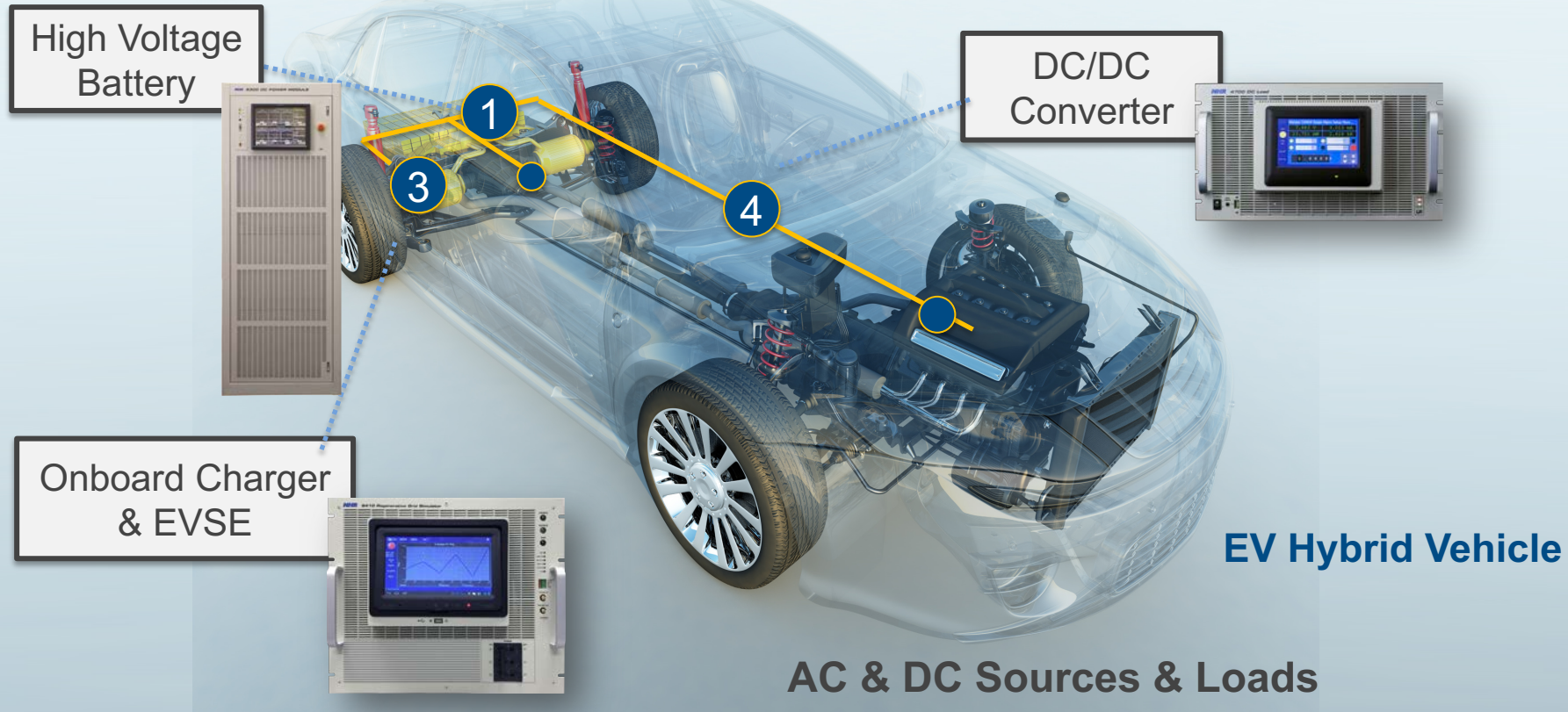
- Motor, Inverter
- Battery or Fuel Emulation



Power Electronics

- OBC, APM, EVSE
- PDU, generator
- Electric actuators

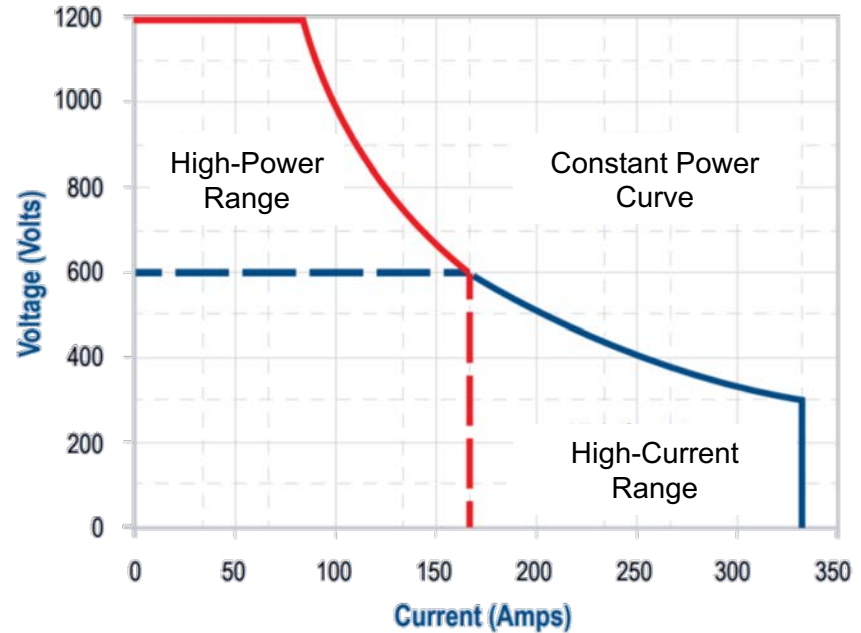
Additional EV Testing Solutions



Wide Operating Power Range



NHR 9300 Series



Modularity for Today & the Future



**Covers All Power Levels
from 100kW to 2.4MW**



You Control Size

You Control How to Use System

Write your own software - Enerchron Test Executive - Work with your favorite Integrator

Flexible Data Control Options



Touch I/F



Remote



<Main>		<Abort>		Check Test Information		DMHT Profile		<Log End of>	
		Delete	Insert	Label	Action	Action Data			
7				Procedure 1.2.7	4Box Operation	DC PM 2 Discharge @ A=48			
8				Procedure 1.2.8	Set Variables	US0 = (DC PM 2/Voltage V)			
9				Procedure 1.2.9	4Box Operation	DC PM 2 Discharge @ A=300			
10				Procedure 1.2.10	Set Variables	US1 = (DC PM 2/Voltage V)			
11				Procedure 1.2.11	Set Variables	US = int((Cycle_Count)*1.1) US = int((Cycle_Count)*1.1)			
12				Procedure 1.2.12	4Box Operation	DC PM 2 Stand By			
13				Procedure 1.2.13	Set Variables	US1 = int((Cycle_Count)*1.1) US1 = int((Cycle_Count)*1.1)			

Enerchron

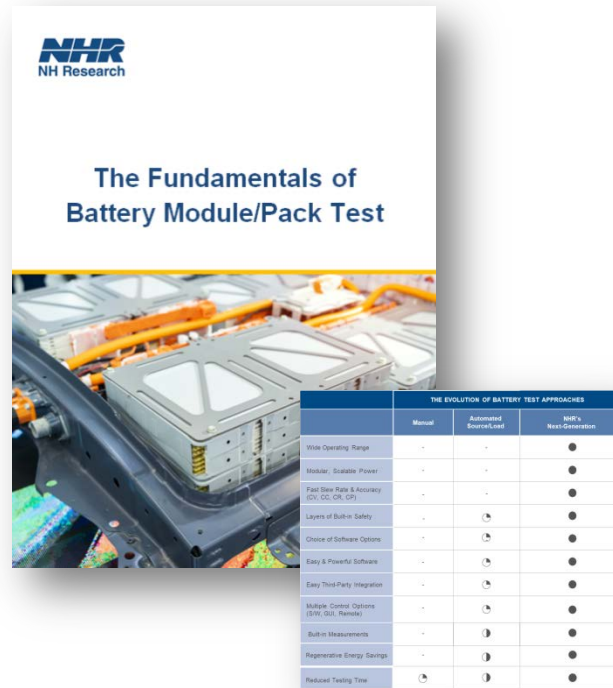


LabVIEW

Access Battery Test Resources

Visit us at <http://nhresearch.com>

- NHR's 9200/9300 Battery Test Solutions
- The Benefits of Battery Emulation
- On-Demand Webinars
- Schedule a consultation





Thank you for attending

For more resources

Visit: <http://nhresearch.com>

Call: **949-474-3900**

Email: **sales@nhresearch.com**



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