Innovation in Low-carbon Vehicle Technologies-Vehicle to Grid (V2G) Systems and Integrated Power Train Solutions

EV R&D Center, Dynex Semiconductor Ltd
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Structure of the Presentation

Part 1	Introduction to Dynex and CRRC
Part 2	Vehicle to Grid (V2G) Charger for Electric Vehicles
Part 3	Integrated Power Train Solutions

Introduction to Dynex and CRRC

Structure Overview

CRRC (Chinese Railways Rolling Stock Corp）
- Employees: 187000
- Revenue: US$ 37.8 billion

CRRC Zhuzhou Institute Co,. Ltd.
- Employees: 20000
- Revenue: US$ 5.26 billion

Zhuzhou CRRC Times Electric Co., Ltd.
- Employees: 7960
- Revenue: US$ 2.38billion

Times Electric Innovation Centre (TEIC)
Opening Q3 2018,
Birmingham, UK

CRRC
Automobile Business Unit

CRRC
Semiconductor Business Unit

DYNEX
Dynex Semiconductor Ltd
Lincoln, UK

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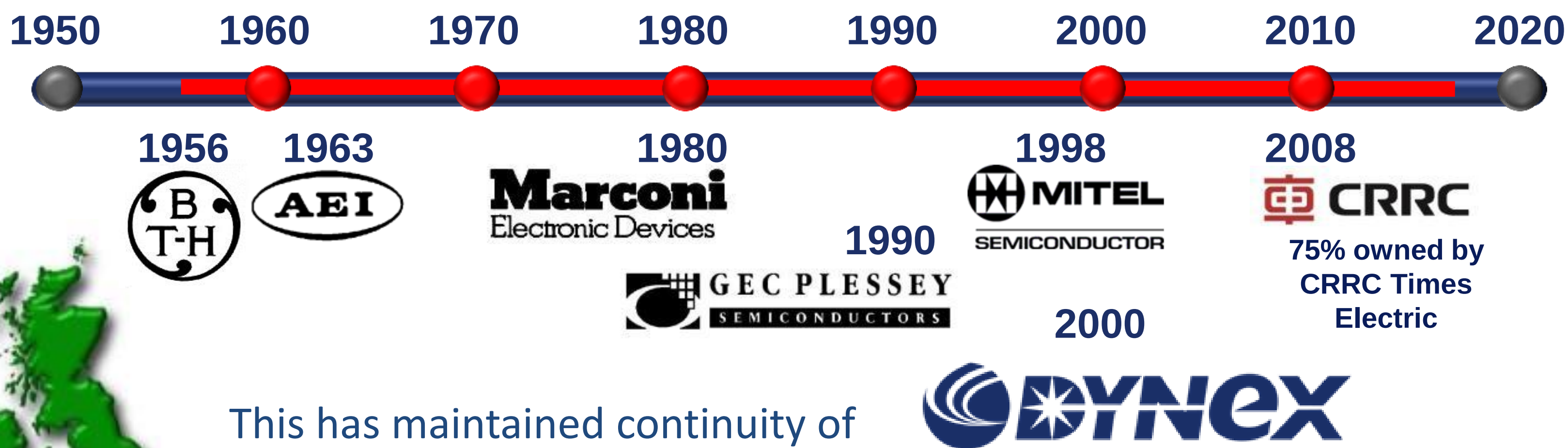
Introduction to Dynex and CRRC

Dynex Semiconductor Ltd

Dynex has more than 60 years experience in the design and production of high power semiconductors…

One constant throughout all this change is that the manufacturing and R&D has been based in Lincoln UK since 1956



This has maintained continuity of personnel which is important for:

- R&D
- Manufacturing expertise
- Our customers

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Introduction to Dynex and CRRC

Zhuzhou CRRC Times Electric Core Technology

The company focuses in independent innovation in ten major core technology fields and has a complete full life cycle research and development capability of software and hardware. It is committed to providing optimal solutions and products in rail transit equipment and extending technology towards correlated fields such as electric vehicle.

Electrical system technology

Electric-drive &Converter technology

Train control and diagnosis technology

Rail Construction machinery technology

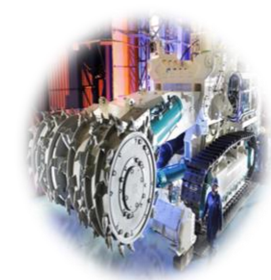
Power semiconductor technology

Railway Signal system technology

Information technology

Traction power supply system

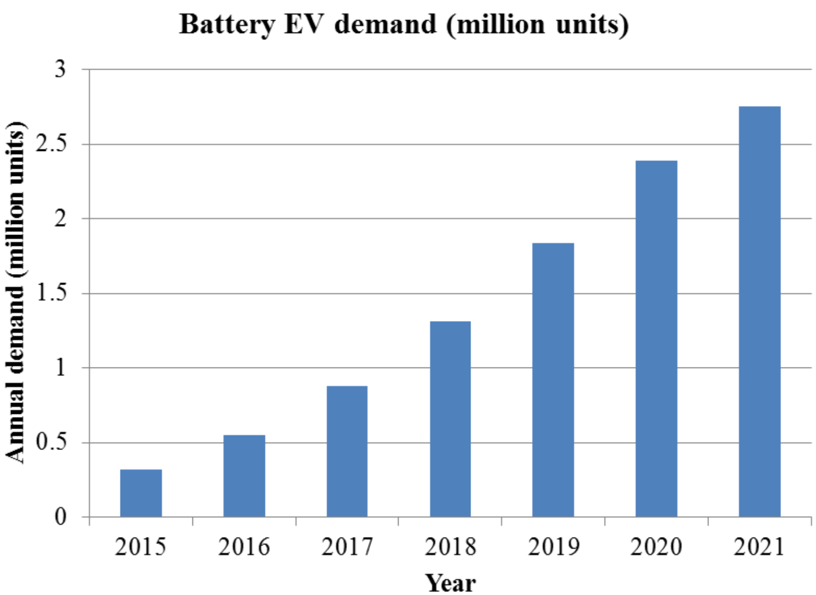
Detection and test technology

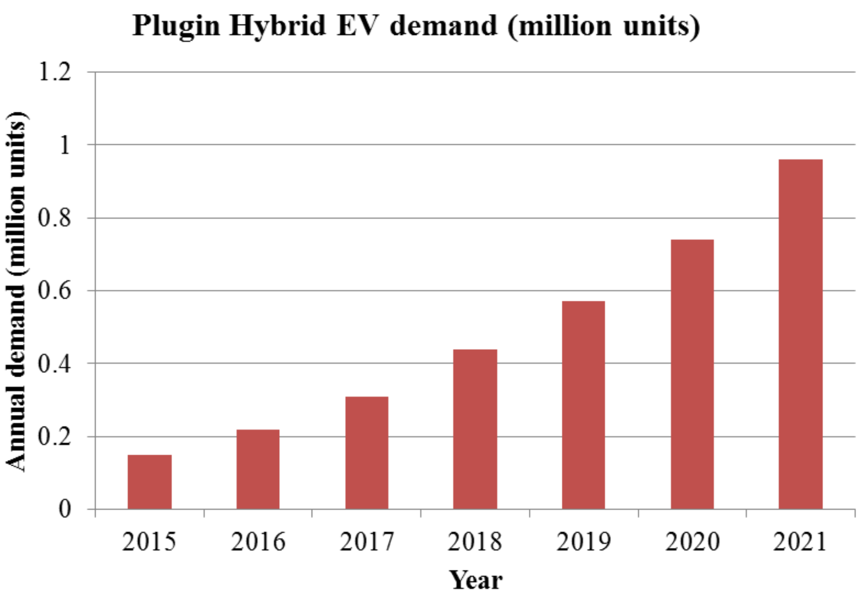


Deep-sea robot technology

Introduction to Vehicle to Grid (V2G) Charger

- High voltage battery charger is an essential element for Battery EV and Plugin Hybrid EV
- Demand for both is rapidly growing in recent years driven by the environmental regulations of OECD countries





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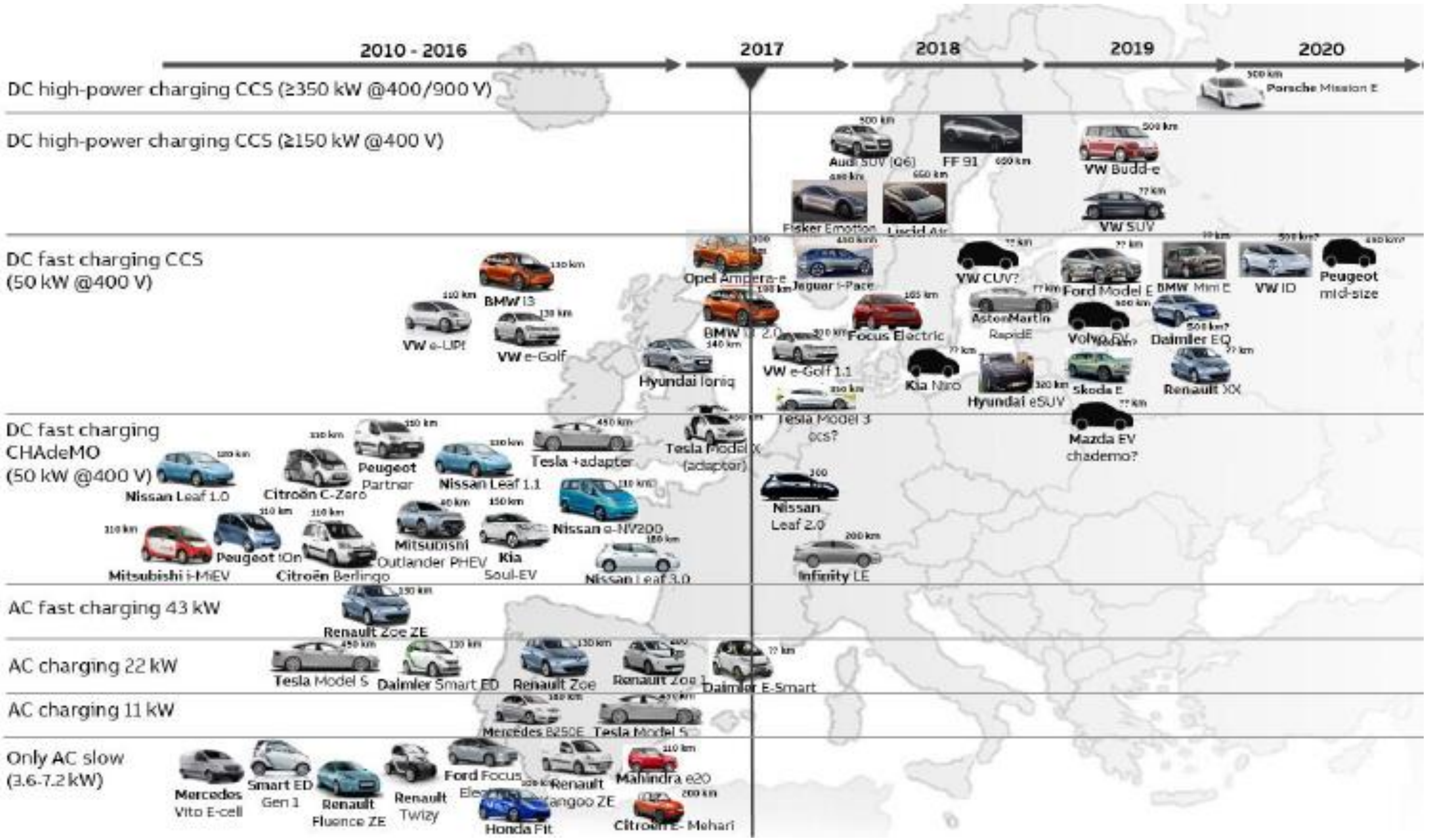
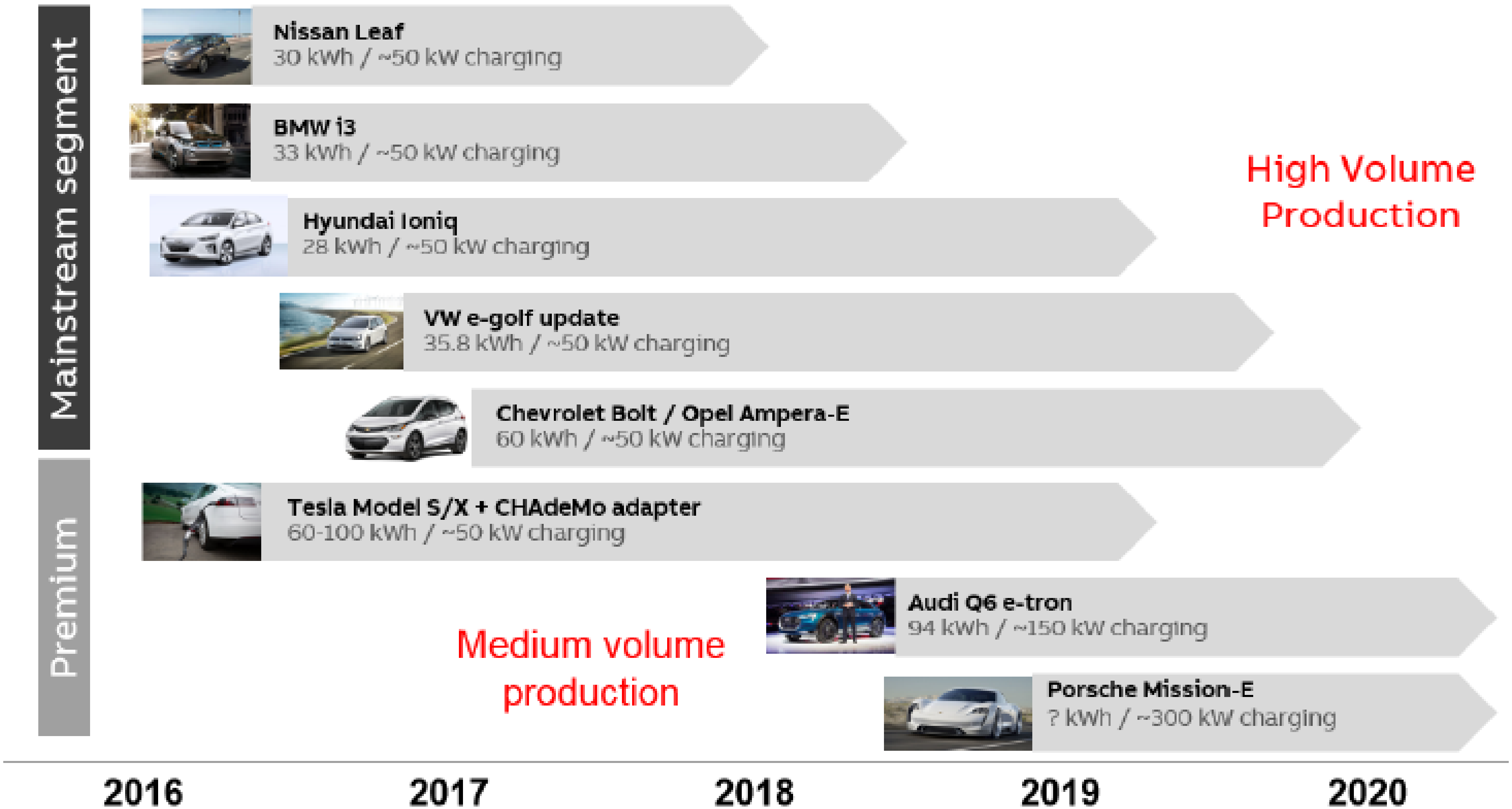
Introduction to Vehicle to Grid (V2G) Charger



*EV charging infrastructure, Daniel Lautensack, ABB

Introduction to Vehicle to Grid (V2G) Charger

- Increased battery capacity for improving range



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*EV charging infrastructure, Daniel Lautensack, ABB

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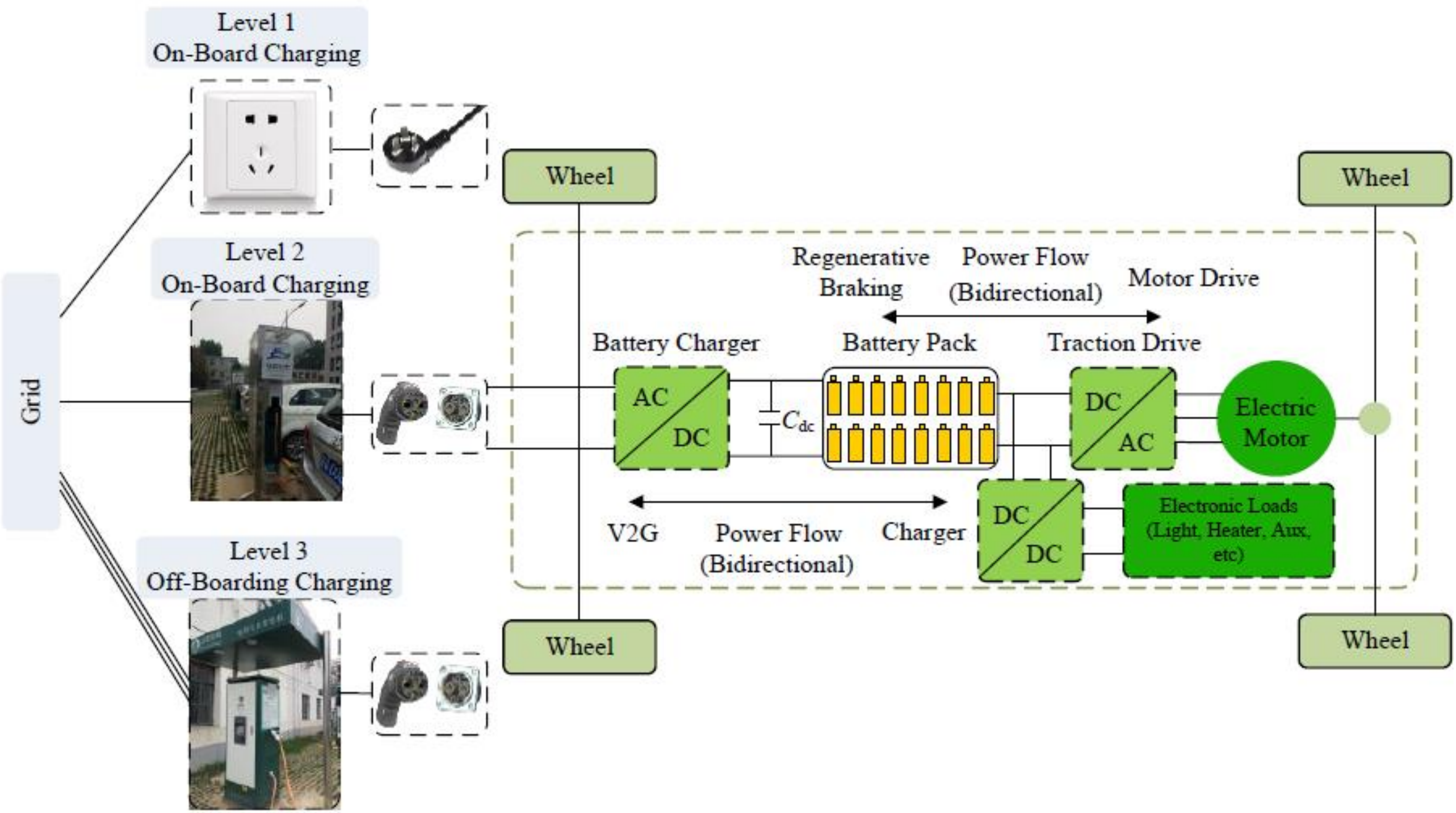
Classification of AC Chargers by SAE



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*Yilmaz, Murat, and Philip T. Krein. "Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles." *IEEE Transactions on Power Electronics* 28, no. 5 (2013): 2151-2169.

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V2G Charging R&D

- If millions of EV batteries act as random loads on the grid without any control, the grid will be in chaos
- Real demand to integrate the millions of batteries in the grid in a very intelligent and sophisticated way
- NREL energy systems integration (ESIF) project with BMW, Uni of Delaware and AC Propulsion - 600 MINI Es with bidirectional charger tested in V2G systems
- NREL Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) project
- Interconnection tests with the bi-directional charging station purpose-built for use with the five medium-duty EVs

V2G Charging R&D (NREL-ESIF)

Research on the basic electrical characteristics of the V2G vehicles, such as the:

- Round-trip efficiency after providing grid services
- Robustness during voltage transients and electrical faults
- Latency between sending a control signal to the vehicles and seeing a response in power output
- Any impacts on power quality as the battery discharges.
- Quantifying the vehicles’ response to simulated utility control signals

V2G Charging R&D (NREL-ESIF)

- Demonstrated autonomous operation for grid support based on local frequency and voltage measurements
- In two additional cases, the vehicles were paired with home-sized photovoltaic systems
- The solar-EV test was used firstly to minimize power injected into the grid— minimizing customer bill impact
- Secondly to store peak solar generation and discharge at a time of minimum solar generation—helping to better match the solar generation to the load

V2G Charging R&D (NREL DC Charging)

Coritech EV supply equipment (EVSE) for grid interconnection

Table 1: Coritech EVSE Specifications

Electrical Specifications	
Continuous AC power	100 kW
AC connection to grid	3-phase (no neutral)
Nominal AC voltage	480 Vac
Maximum fault current contribution (to grid)	1700 A for 3 ms
Maximum continuous AC current	133 A
AC voltage operating range	480 Vac ± 10%
Frequency range	57.0 – 60.5 Hz
Maximum DC fault current	600 Adc
Maximum operating DC current	285 Adc
Physical Specifications	
Weight	2,450 lbs
Dimensions	48” W x 36” D x 100” H
Environmental/Cooling Specification	
Cooling type	Closed loop air conditioning

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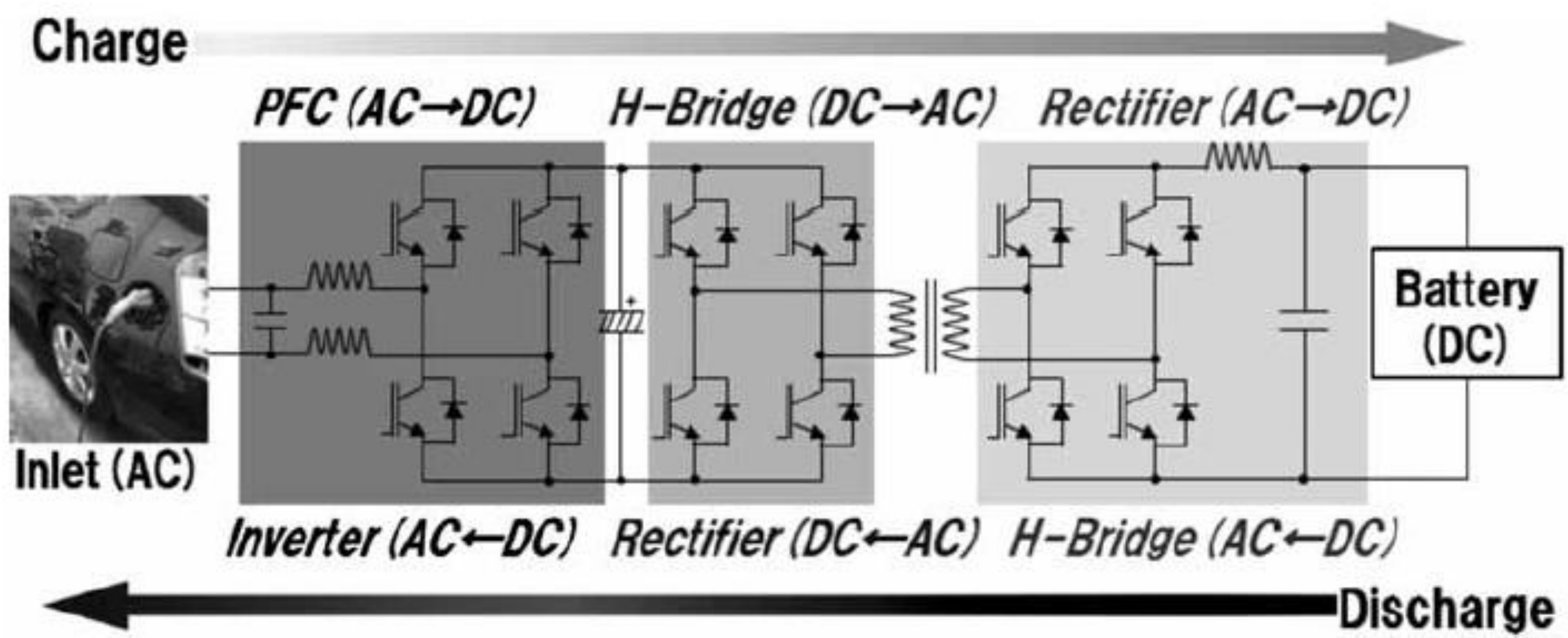
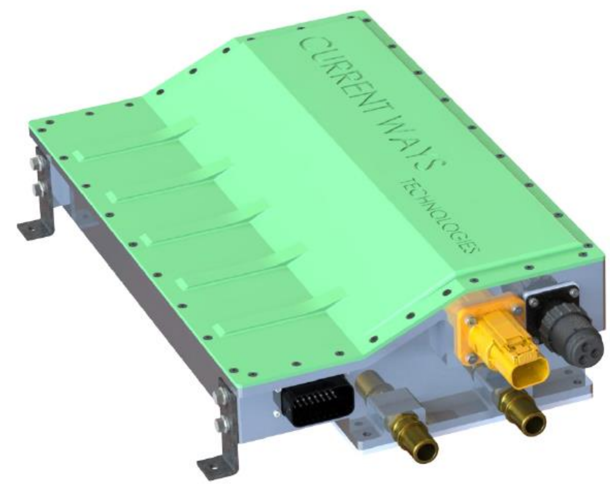
V2G Charging R&D

2 kW on board prototype built by Advanced Automotive Systems R&D Centre (Japan)



EV bidirectional On Board Charger (BD-OBC)

- Hyundai Mobis, Current Ways, PRE and Convertronix developed current state-of-the-art BD-OBC systems
- Pre-production or low volume
- Low power density (~ 1kW/L)



Currentways 6.6 kW BD-OBC (5.3 litres)

Convertronix 6.6 kW BD-OBC (6 litres)

Dynex Modular On Board V2G Charger R&D

Robust grid integration and control (In development)

- Enhanced phase-locked loop (PLL) for 1 phase AC synchronisation, more challenging than 3 phase due to the lack of orthogonal reference
- Dynamic DC link voltage control to increase reactive power capability
- Active current clamping circuit for riding through short circuit faults
- Low voltage ride-though, peak-shaving, valley-filling, anti-islanding, unbalanced operation and standalone operation will be experimentally validated

Integrated Power Train Solutions

Double-sided cooling IGBT and Si-SiC hybrid modules

Integrated inverter-machine for the EV power train

Integrated inverter-converter system for the EV traction drive

Challenges and Targets for EV Power Trains

Challenges of Vehicle Electronics Package	
Electrical	High power density, high switching frequency, low loss, low parasitic, and high SOA
Thermal	High operation temperature, low thermal resistance, matched CTE
Mechanical	Anti vibration and shock capabilities, small volume, light weight
Reliability	Thermal cycling and power cycling capabilities, mechanical and EMC reliability

APC Development Target of Vehicle Electronics Assembly			
Year	Cost($/kW)	Power Ratio (kW/kg)	Power Density (kW/l)
2020	3.3	14.1	13.4
2025	2.1	15.8	17.6

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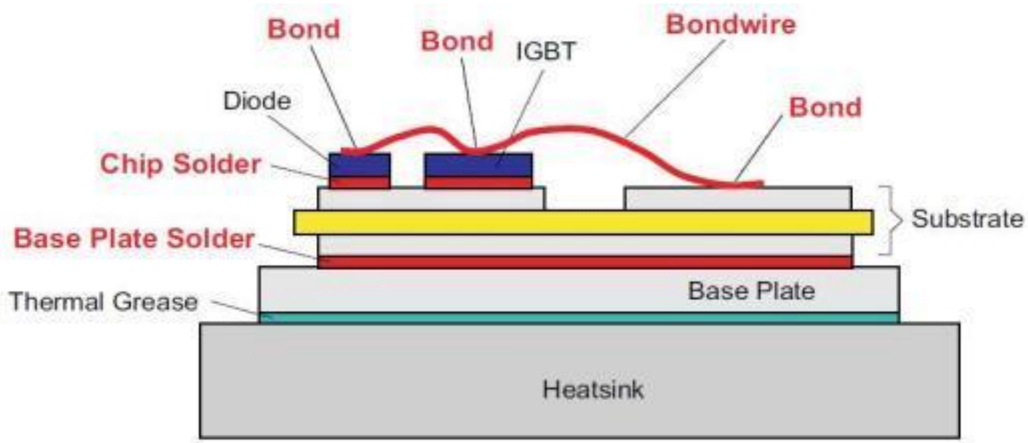
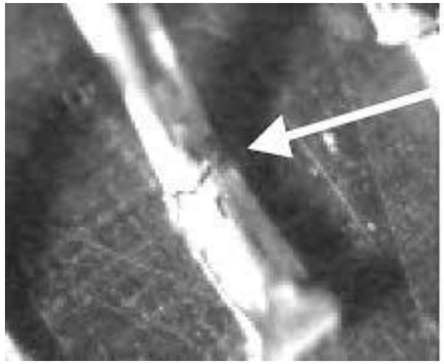
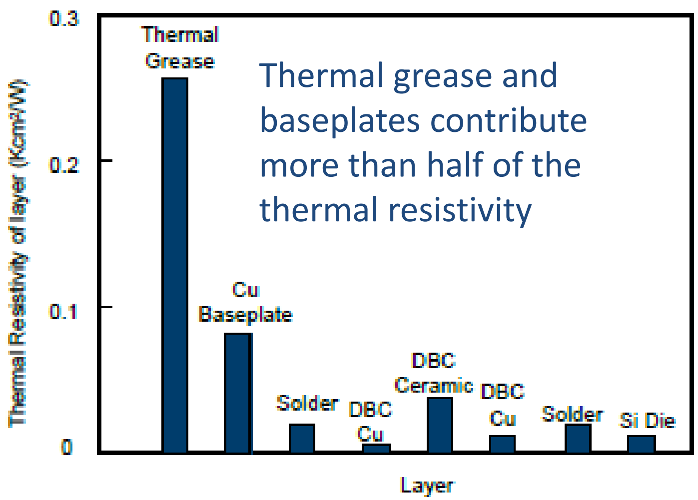
State of the Art Power Modules for EVs

Issues in Conventional IGBT Module Packaging





Heel crack

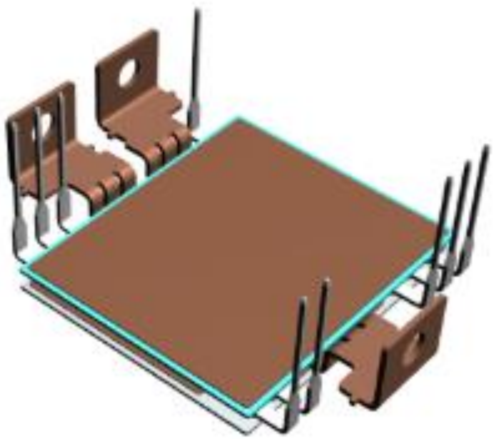


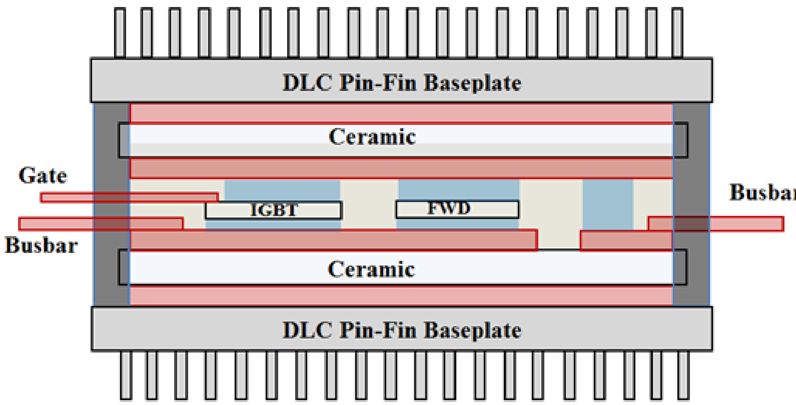
The broken aluminum wire bond, high parasitic inductance and unevenly distributed temperature of dies lead to performance and reliability issues

*Semikron, Reliability Engineering in Power Electronics

Double-sided cooling of IGBT

- Double-sided planar bonding, double-sided cooling and double-sided integrated heatsink





- Double-sided cooling delivers the following advantages:
  - Reduced thermal resistance (23%) – more power for a given die area
  - Reduced inductance for higher speed switching
  - Enhanced reliability and lifetime from wirebond removal

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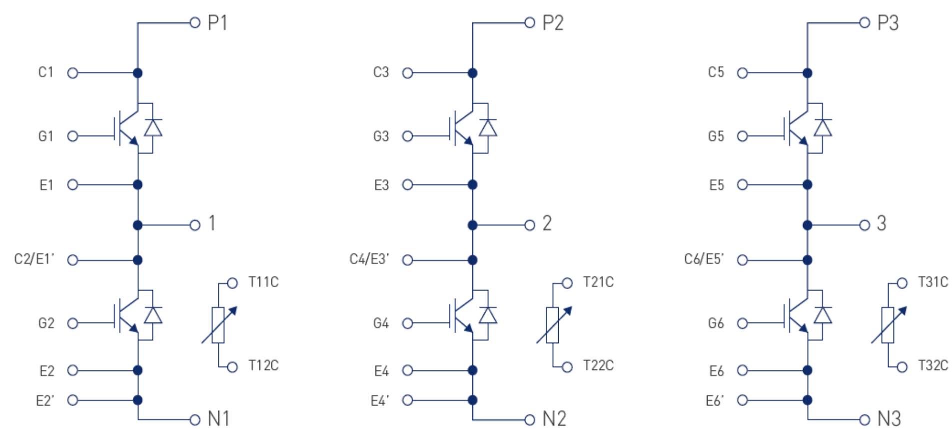
HIPA IGBT Power Modules

Features

- 6 IGBTs with integrated NTC temperature sensor
- Double-sided cooling
- Baseplate-less packaging with direct bonded cold plate
- Wireless planar bonding
- High thermal cycling capability
- Trench gate Technology
- High power density

Circuit diagram



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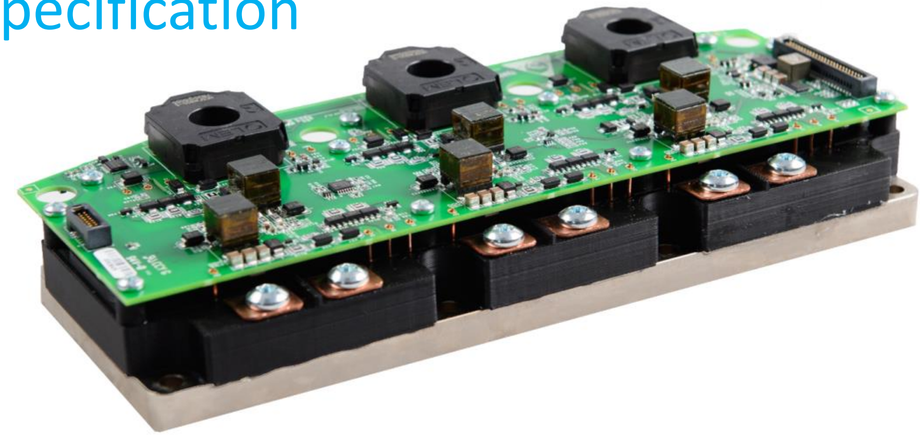
HIPA2 IGBT Power Modules

HIPA2-07A090 Specification



Rated Voltage and Current	**650V/900A**
Peak collector current (1ms)	**1200A**
Maximum Temperature under Switching Conditions	**150℃**
Per IGBT Thermal Resistance,(Junction to cooling fluid, 50% water/50% ethylene glycol, 8L/min)	**0.09K/W**
Per Diode Thermal Resistance,(Junction to cooling fluid, 50% water/50% ethylene glycol, 8L/min)	**0.15K/W**
Module inductance	**12.5nH**

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Integrated Inverter-Machine

Current Market Practice of EV e-Machine and Inverters

- Electrical machine separated from the power electronic drive system
- Larger production time and cost
- Lower system reliability
- Lower power density
- Some integration such as power electronics placed on the outer surface of the machine housing- surface mount integration
- Siemens Sivetec MSA 3300 (60kW)

Integrated Inverter-Machine (IIM)

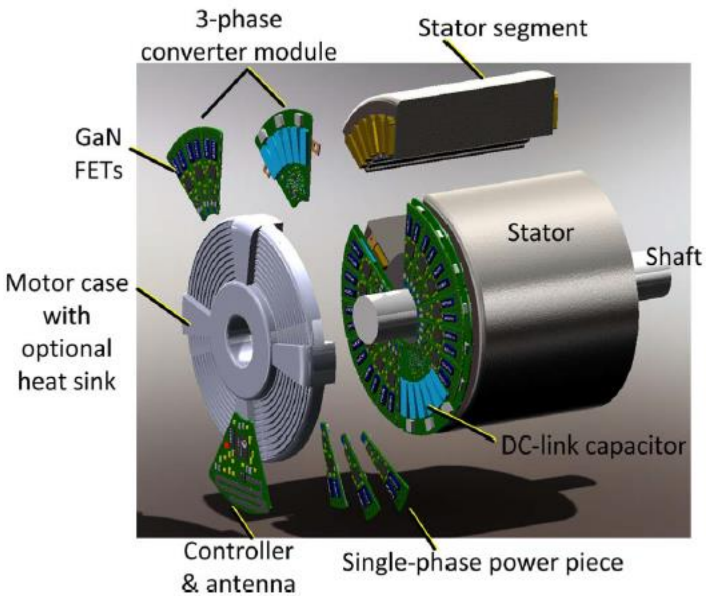
Topologies (R&D Phase)

End plate mount integration

- Available space in the axial direction being used to place power electronics either inside or outside the end-plate

Stator iron mount integration

- Power electronics with heat sink attached to the stator back iron directly

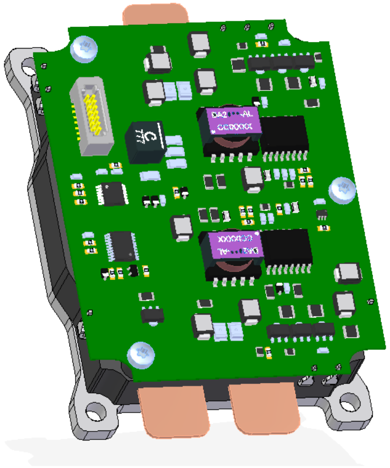


IGBT Module for Inverter integrated machine

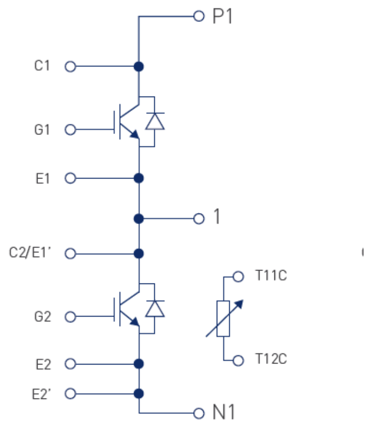
IIM IGBT Module Specification (In development)

CONFIGURATION	HALF BRIDGE WITH NTC
Rated Voltage and Current	650V/1200A
Maximum Temperature (Under Switching Conditions)	150℃
Cooling Method	Double -sided liquid cooling
*Module inductance	10nH
Dimension	90×65×25
*Per Diode Thermal Resistance,(Junction to cooling fluid, 50% water/50% ethylene glycol, 12L/min)	0.08K/W

*Parameters are calculated by simulation



Circuit diagram



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Integrated Inverter-Converter System (ICS)

Challenges

- Minimum functional integration between the components of inverter and the HV-LV DC-DC converter in the state-of-the-art, low power density
- Non-integrated system create EMC issues for high speed wide band-gap devices
- Thermal, mechanical and reliability issues arising from the compact installation of devices and components

Key targets-

- 20% reduction of specific cost for the inverter
- 30% reduction of specific cost for the HV-LV DC-DC converter
- Achieve at least 20 kW/litre power density for the ICS
- Achieve 98% peak efficiency for the ICS

Conclusion

- V2G on board chargers could reduce the peak power demand, reinforce the reliability and capability of the grid
- Double-sided cooling of power module is becoming the leading technology for EV power trains
- Dynex has developed the know-how and expertise in double-sided cooled IGBT and EV power train solutions based on this technology
- Several challenging projects tackling the limitations of power electronics of EV/HEV
- Developing cost effective and power dense technology targeting the future EV/HEV models
- The group has the technical expertise, industrial capability and a clear R&D strategy