Electric Vehicle (EE60082)

Lecture 17: Charger part2

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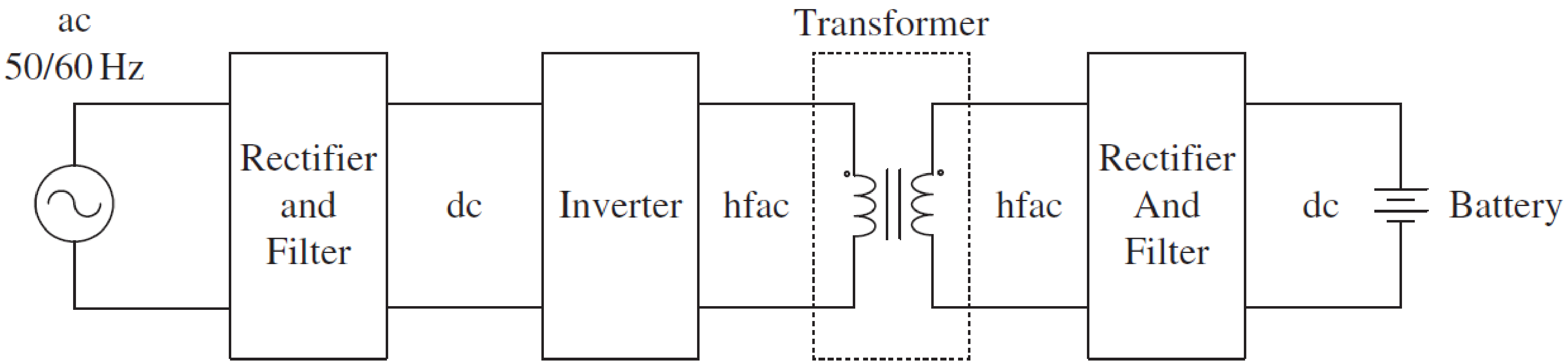
Basic requirements for a charger(recap)

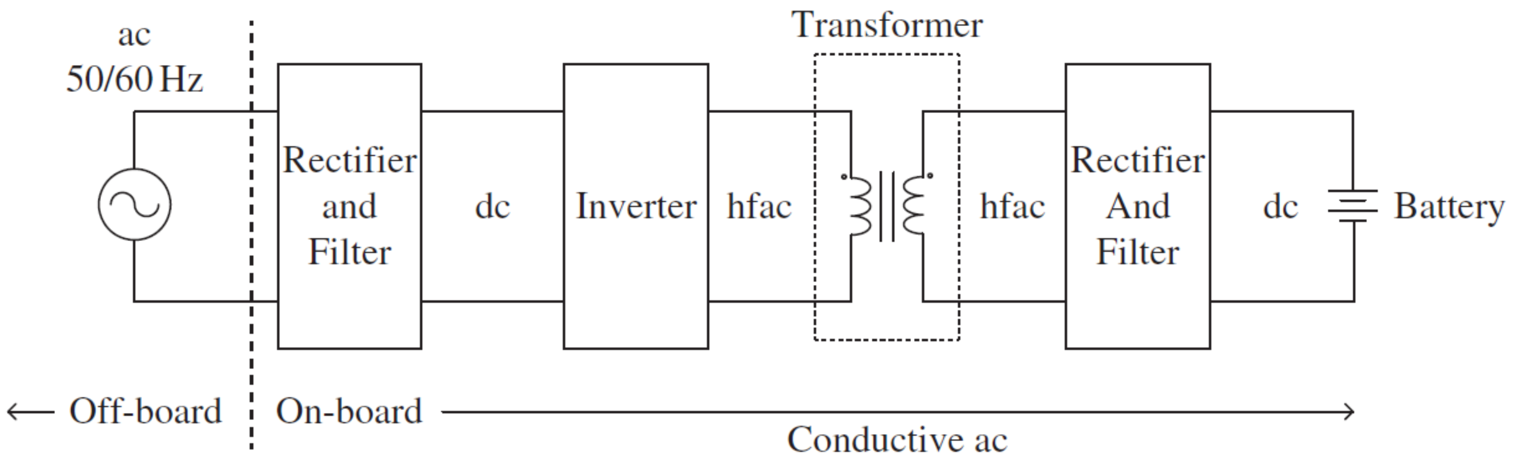
- Available power sources
  - 50/60 Hz single phase grid at home
  - 50/60 Hz three phase grid at charging stations

- Minimum requirements are
  - Controllable DC source
  - Isolation for safety

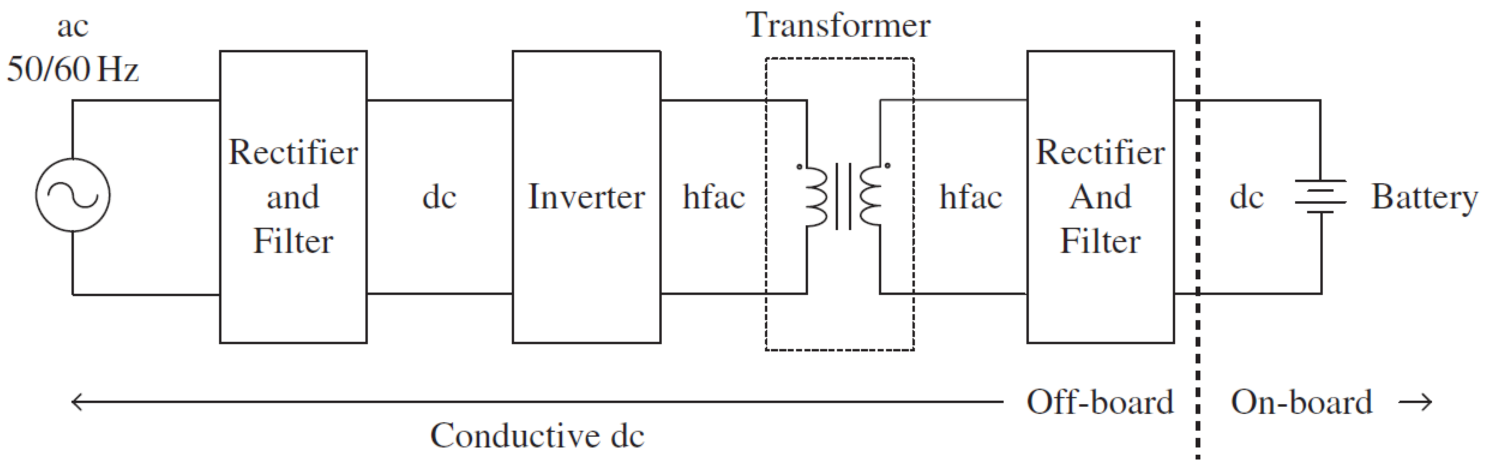


Charger architectures (recap)

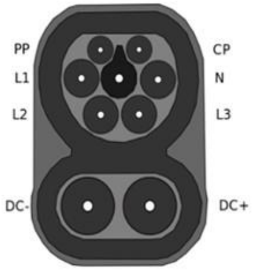
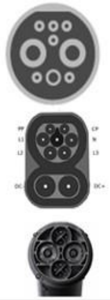
On-board charger
- Low power
- Slow charging
- Home charger
- Called AC charger



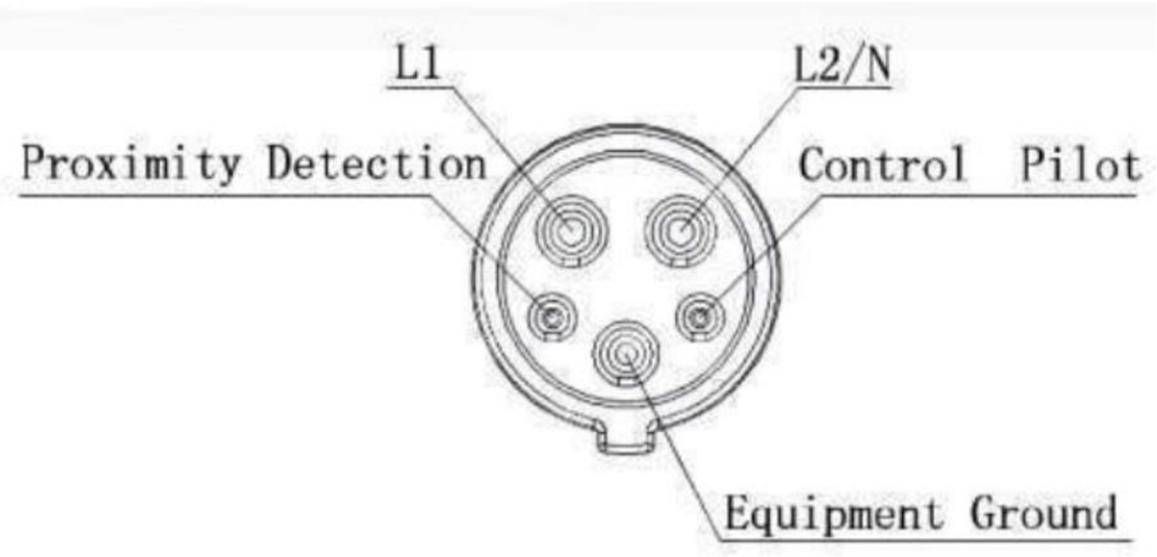
Off-board charger
- Medium to high power
- Fast charging
- Charging stations
- Called DC charger



Charger standards around the world (recap)

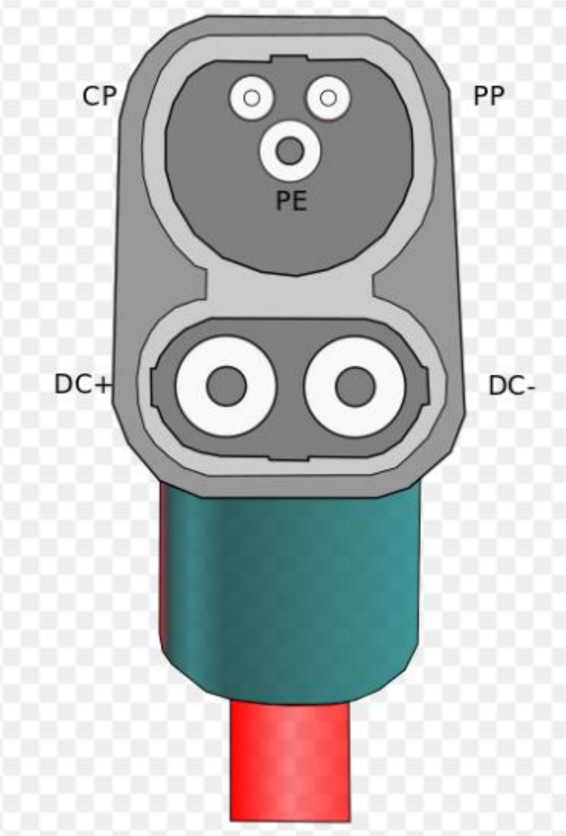
Type of Charging	North America	Japan	EU & rest of the market	China	All markets except EU	India
AC **Type1: 1-3kW** **Type2: 3-22kW**						
Plug Name	J1772 (Type 1)	J1772 (Type 1)	Mennekes (Type 2) IEC62196-2	GB/T		Commando (Type-1): IEC60309 Mennekes (Type-2): IEC62196-2
DC **10-400kW**						
Plug Name	CCS1	CHAdeMO	CCS2	GB/T	TESLA	GB/T, CCS2, CHAdeMO

SAE J1772 (AC) (recap)



Combined Charging Systems (CCS) (recap)

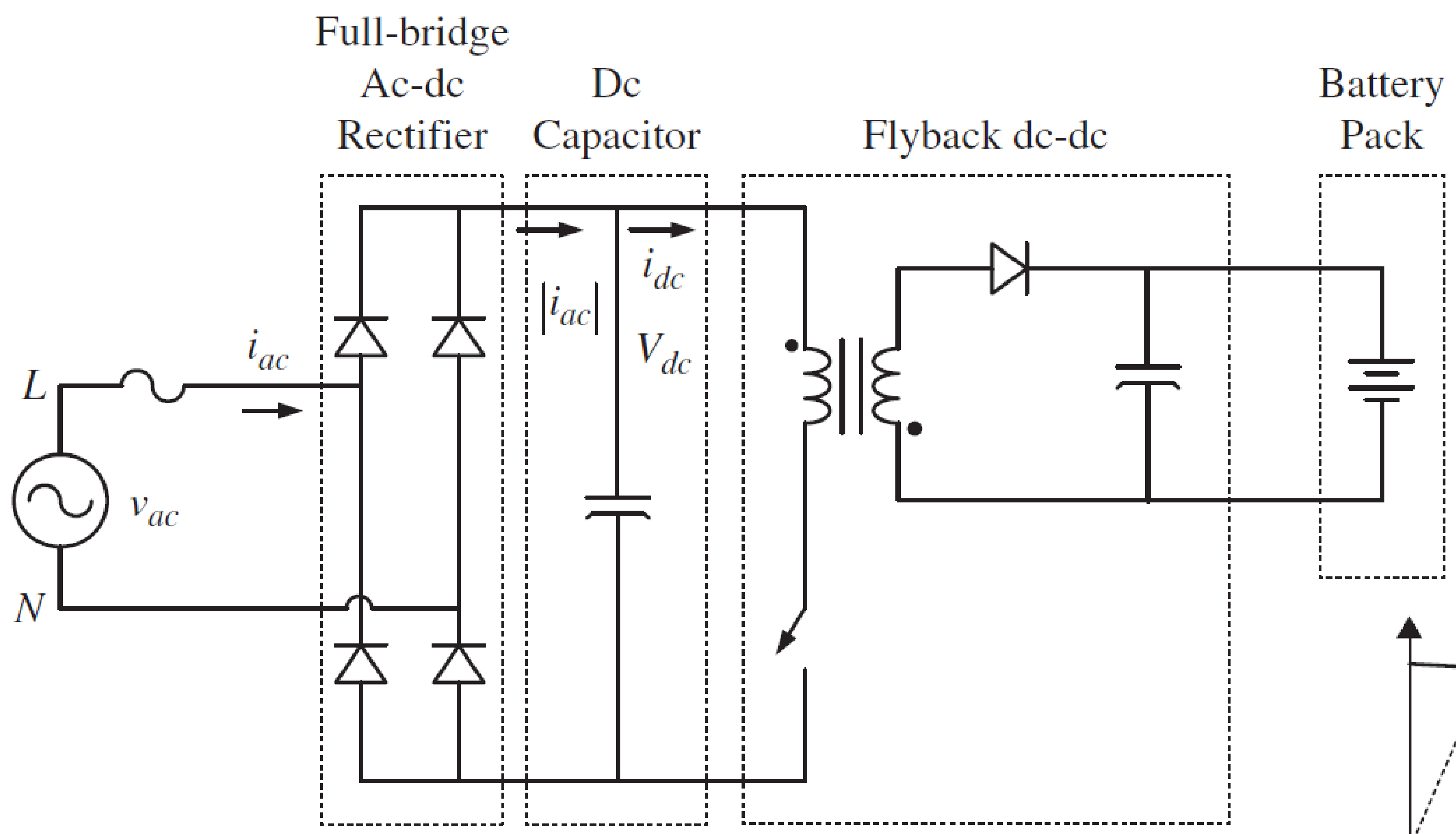
DC charger: Bypassing OBC, directly to battery

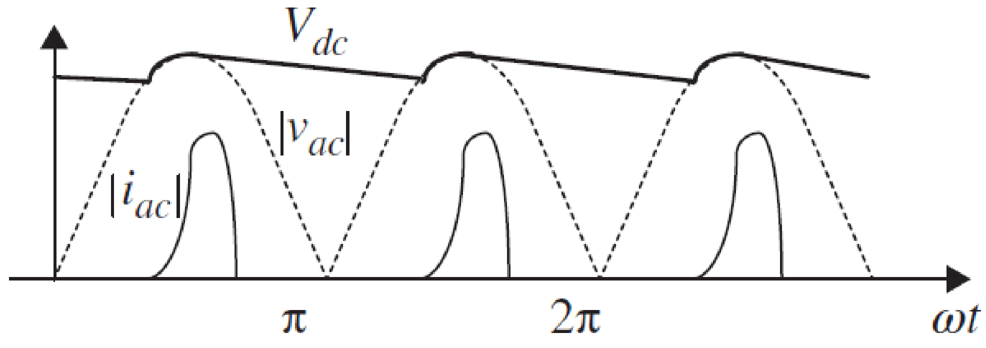


DC charger connector

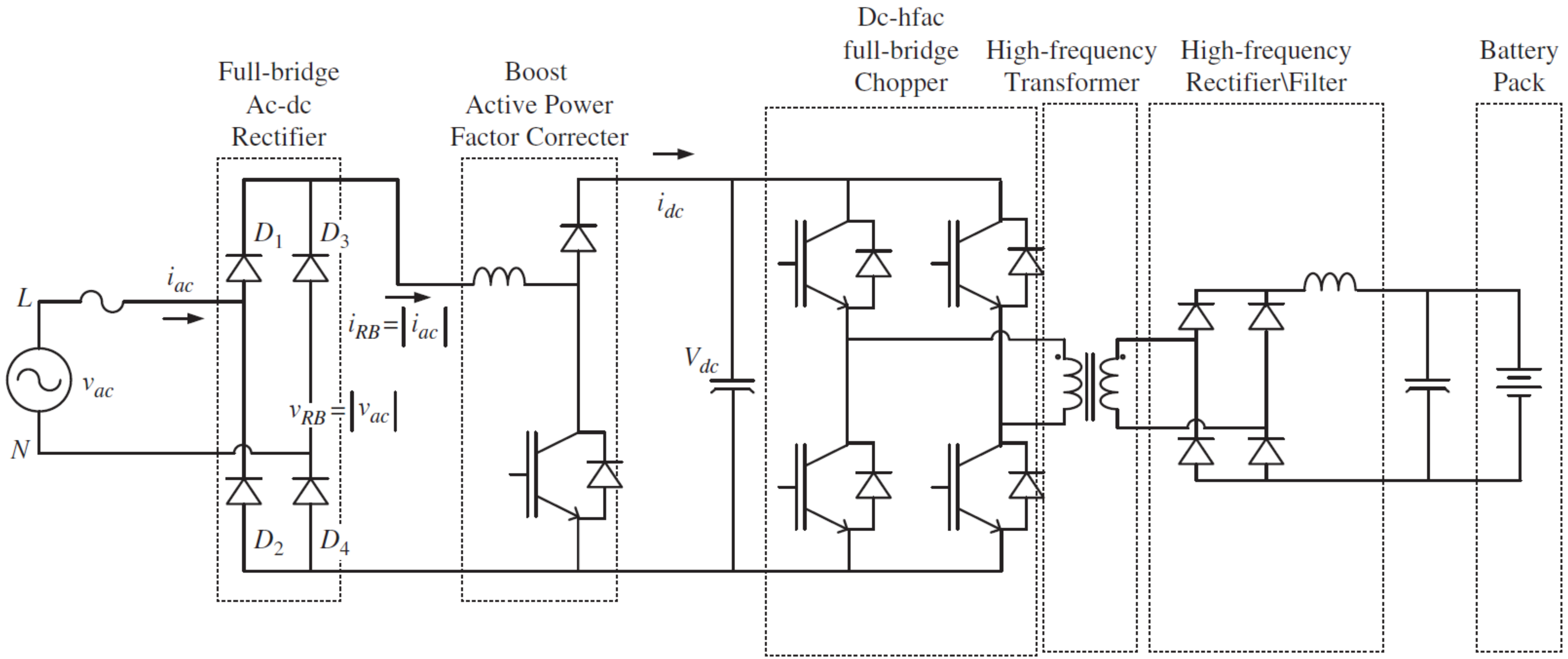
CCS

Charger with diode bridge rectifier (recap)

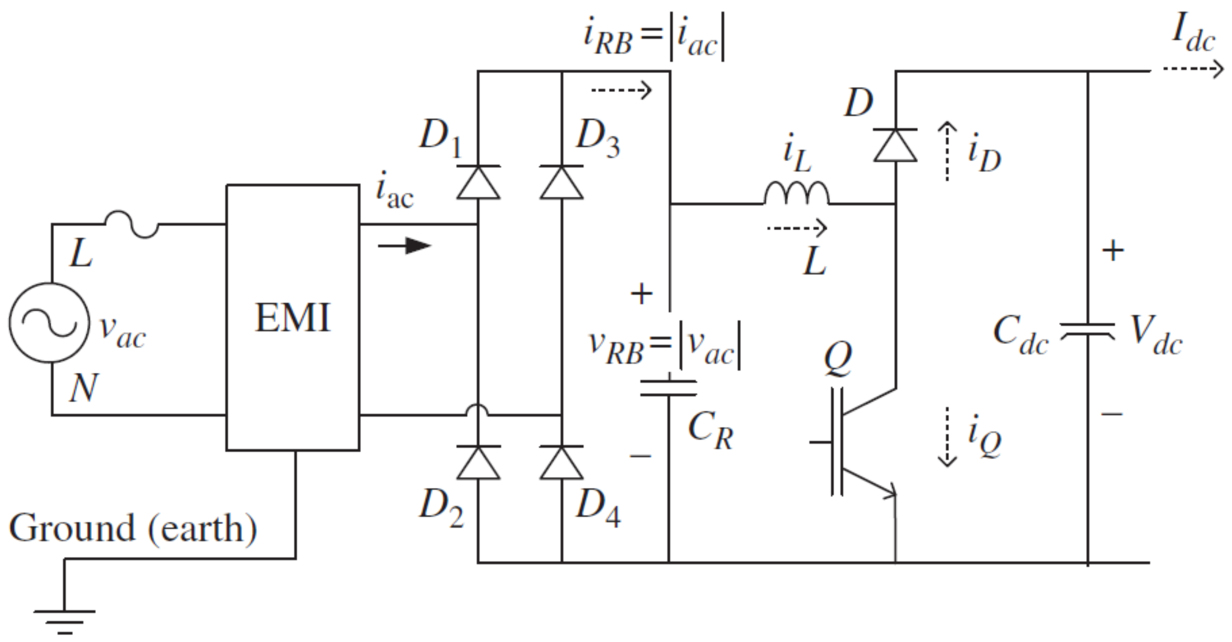


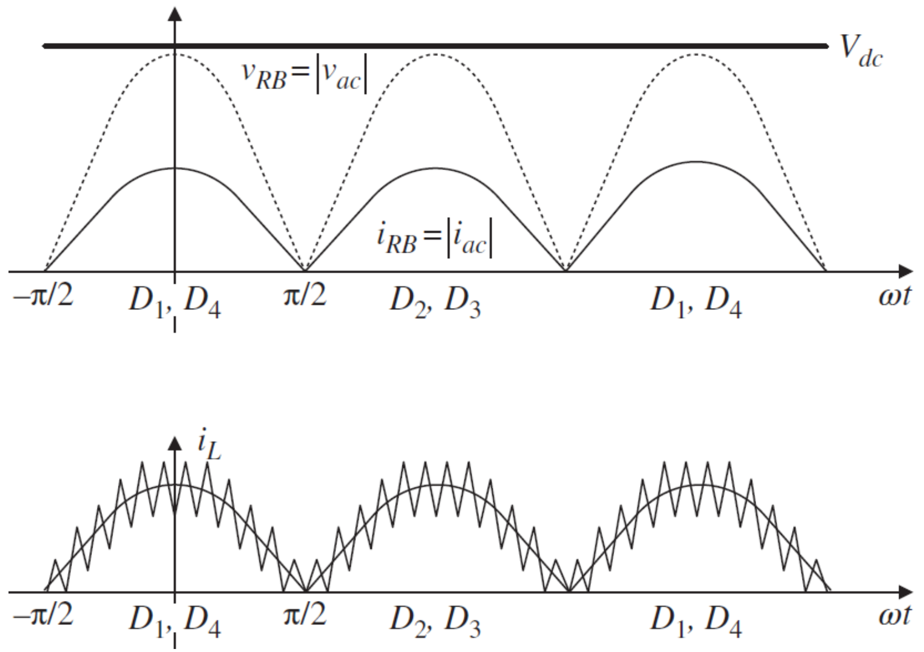


Charger with Power Factor Correction (PFC) (recap)



PFC stage design (recap)





$$v_{ac}(\theta) = \sqrt{2}V_{ph}\cos\theta$$

$$v_{RB}(\theta) = \sqrt{2}V_{ph}|\cos\theta|$$

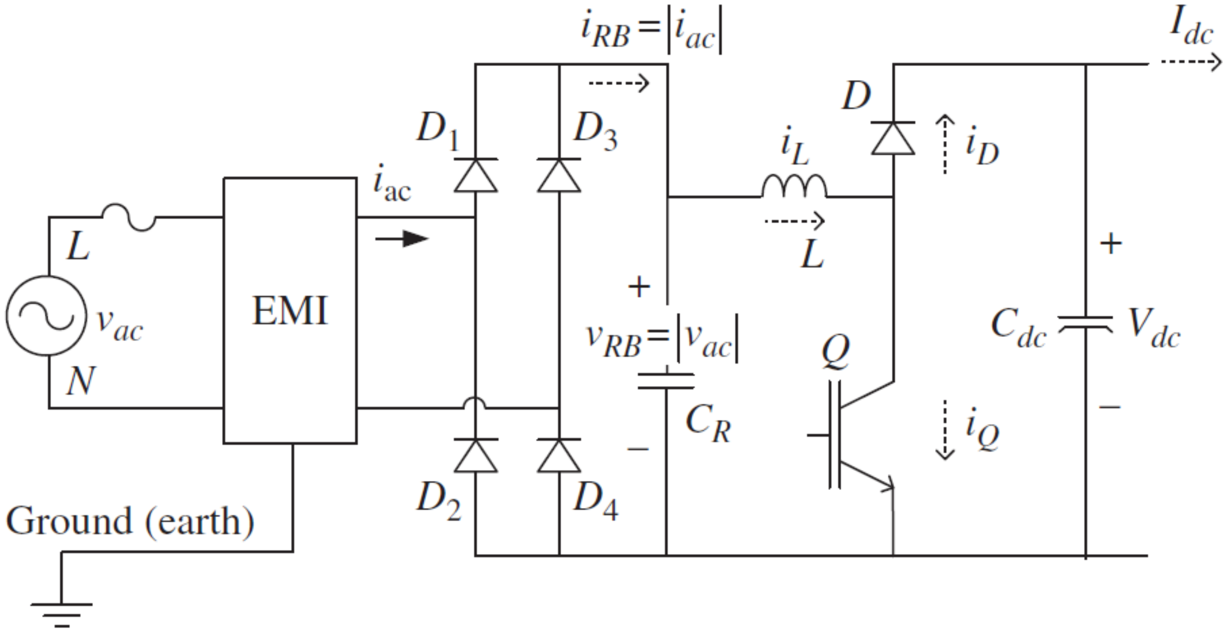
$$i_{ac}(\theta) = \sqrt{2}I_{ph}\cos\theta$$

$$i_{RB}(\theta) = \sqrt{2}I_{ph}|\cos\theta|$$

PFC boost inductor design (recap)

- Duty cycle for the switch

$$d(\theta) = 1 - \frac{v_{RB}(\theta)}{V_{dc}} = 1 - \frac{\sqrt{2}V_{ph}|\cos\theta|}{V_{dc}}$$



- Peak-peak current ripple

$$\Delta I_{L(p-p)}(\theta) = \frac{\sqrt{2}V_{ph}|\cos\theta|}{f_s L} d(\theta) = \frac{\sqrt{2}V_{ph}}{f_s L}\left(|\cos\theta| - \frac{\sqrt{2}V_{ph}\cos^2\theta}{V_{dc}}\right)$$

DC capacitor design (recap)

- Challenges: presence of second harmonic current
- Option 1: allow this current into battery
- Option 2: Filter out this current with the DC capacitor
- Option 3: active dc bus

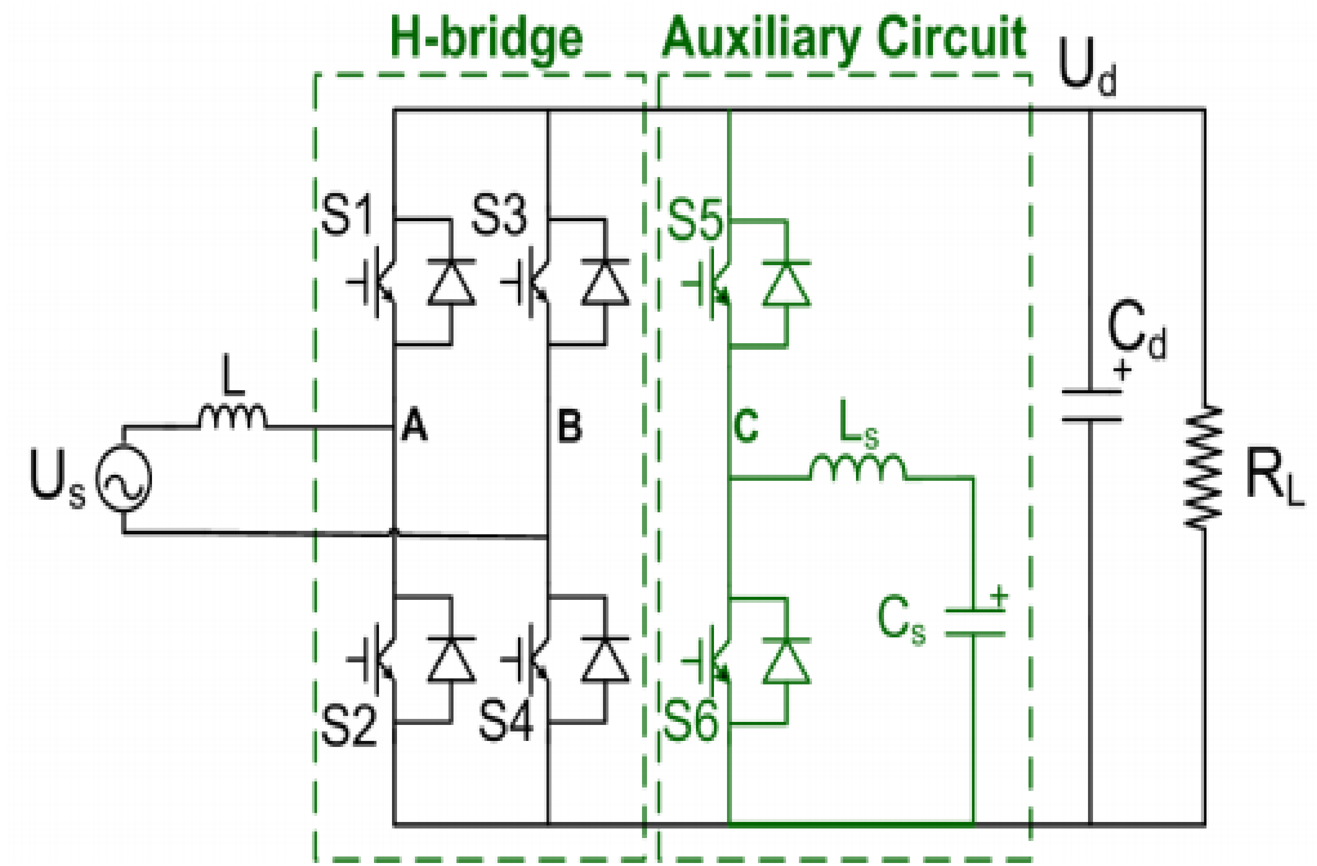
Active filtering (recap)

Drawbacks of passive filtering:

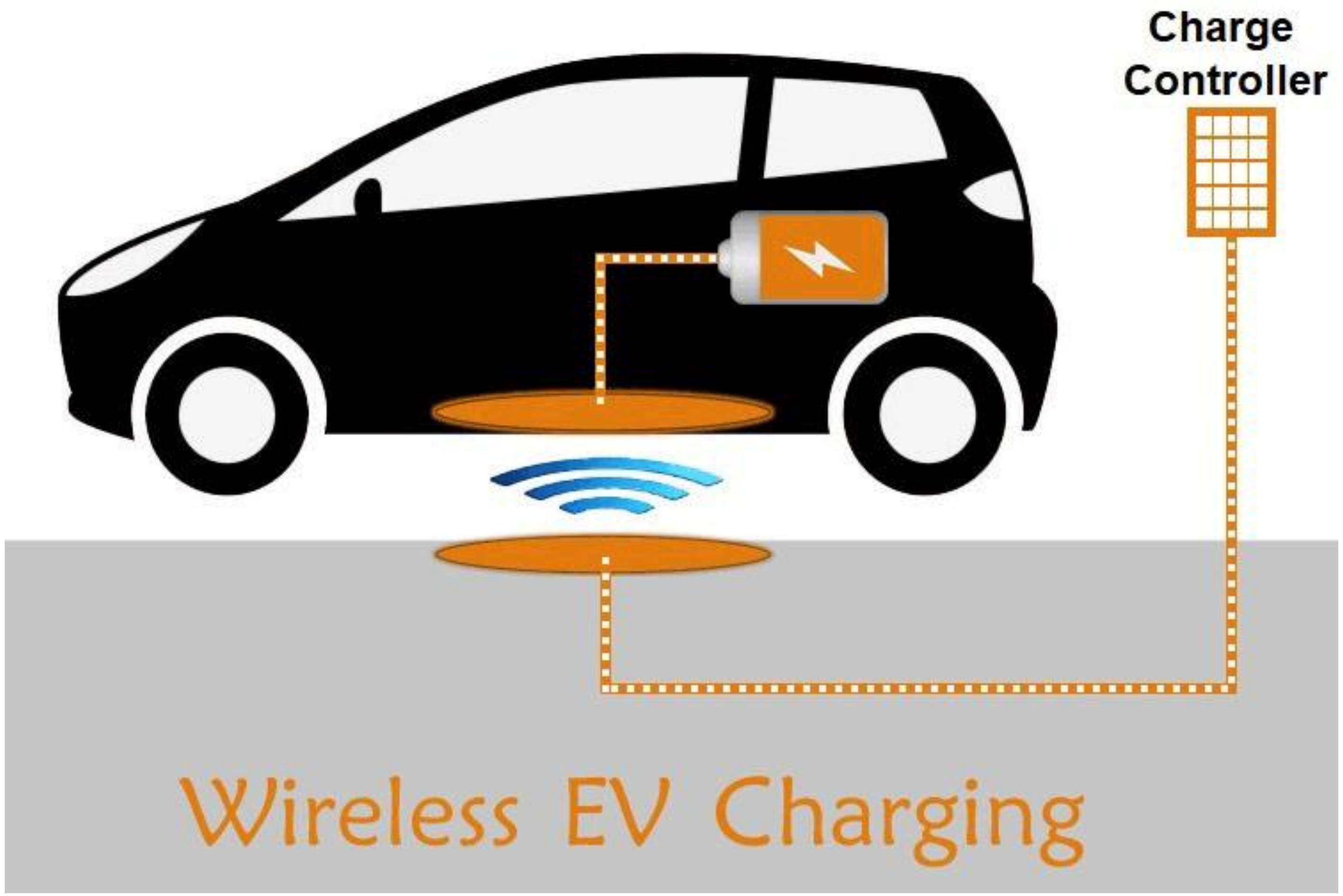
- Very costly (especially if High-Voltage / High-Power)
- Large weight

Active filtering:

- Use additional circuitry to source/sink current into a "energy reservoir"
- Capacitor Cs can be small as it does not have any ripple specification

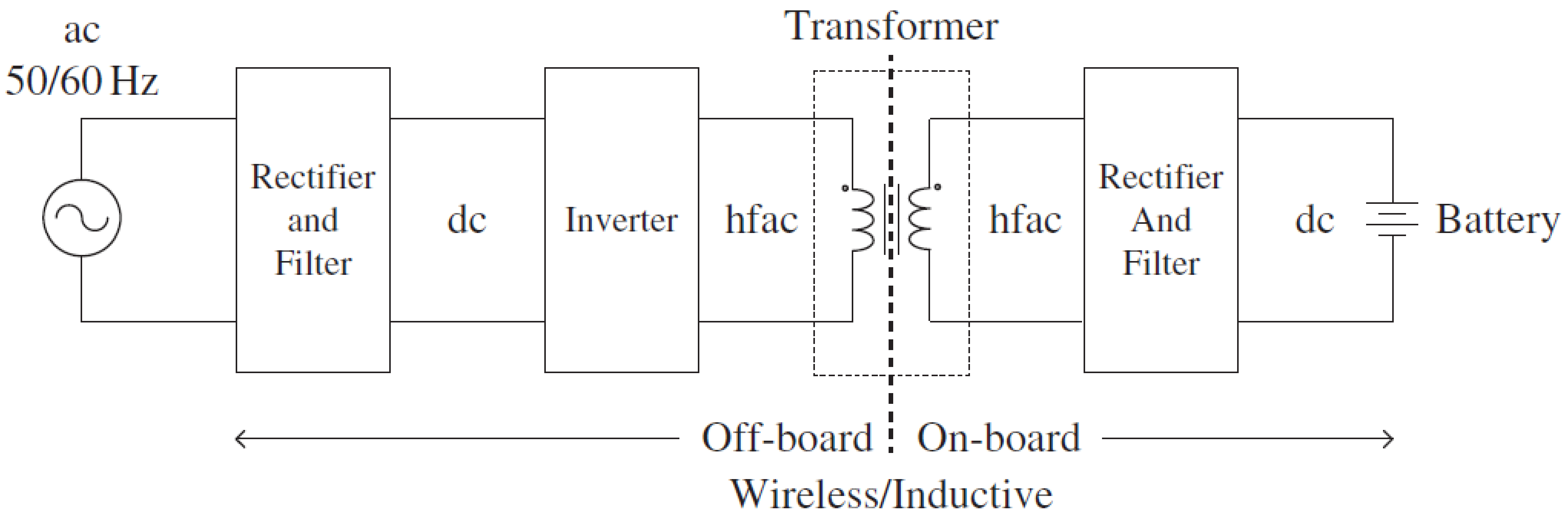


Wireless charging (recap)

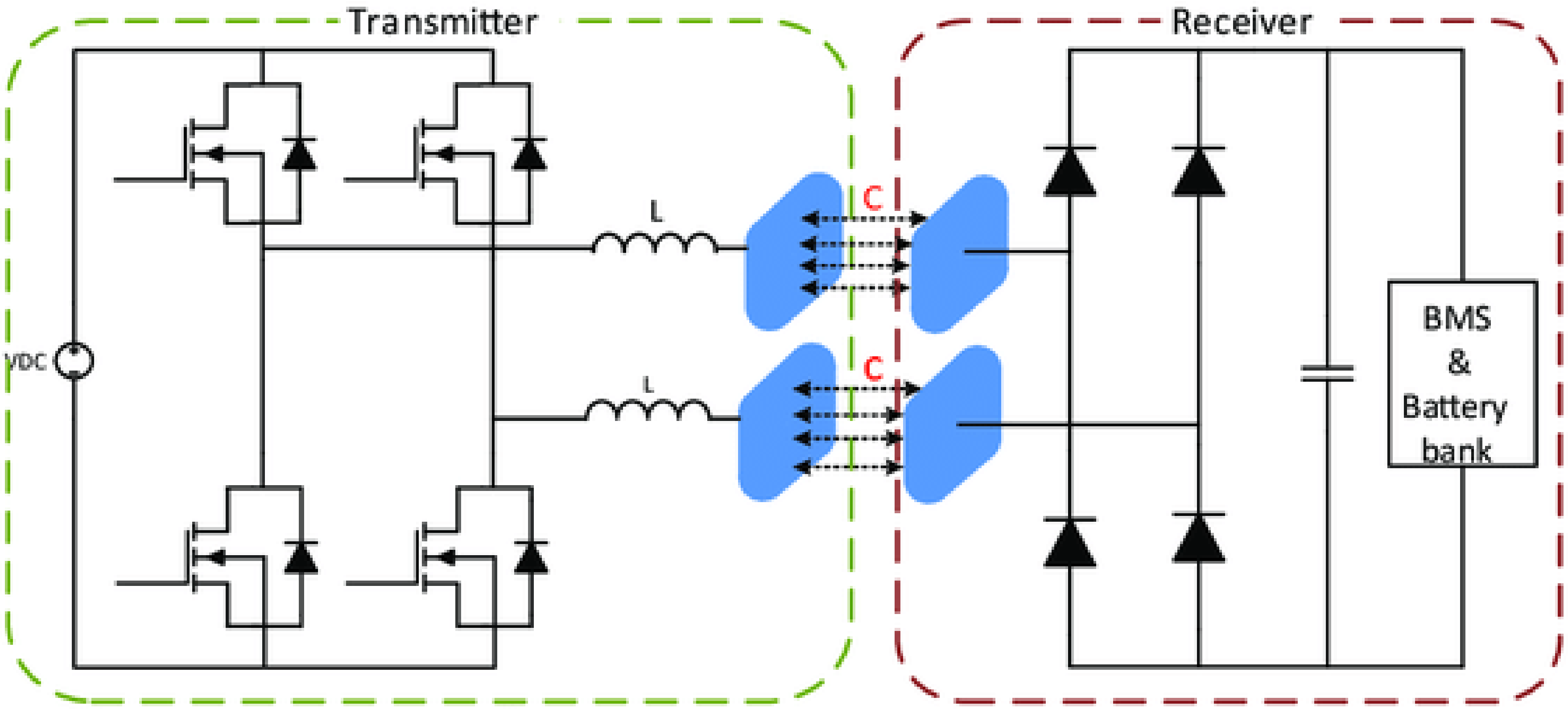


- enhanced safety
- More user friendly
- Higher technical challenges and cost

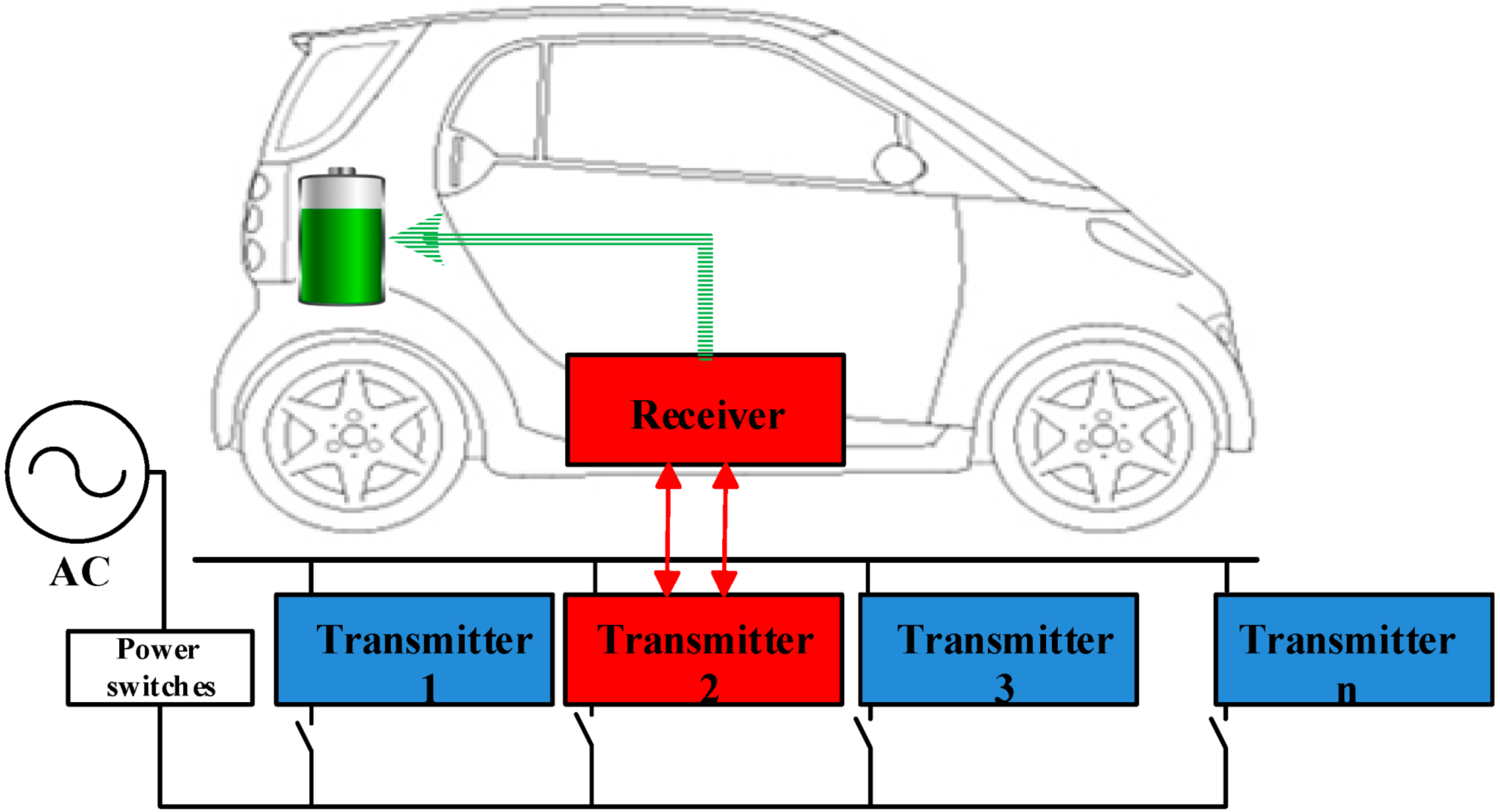
Wireless charger (inductive) (recap)



Wireless charger (capacitive) (recap)



Dynamic wireless charger (recap)



Charging infrastructure

Charging power requirements

Top 15 PHEVs and EVs

(in terms of year to date unit sales) in 2020 in Europe

Legend: PHEV BEV

Brand	Model	Battery Capacity kWh	AC Charging Capacity kW	DC Charging Capacity kW
Renault	Zoe	44.1	22	50
Tesla	Model 3	75	11	145
VW	ID.3	48	7.2	50
Hyundai	Kona EV	67.1	7.2	77
Audi	e-Tron	95	22	150
VW	e-Golf	35.8	7.2	44
Nissan	LEAF	40	3.6	46
Peugeot	208 EV	46	11	100
KIA	Niro EV	67.1	7.2	77

Legend: PHEV BEV

Brand	Model	Battery Capacity kWh	AC Charging Capacity kW	DC Charging Capacity kW
Mercedes	A250e	15.6	3.7	NA
Volvo	XC40 PHEV	10.7	3.7	NA
Mitsubishi	Outlander PHEV	13.8	3.7	22
VW	Passat GTE	13	3.7	NA
BMW	330e	7.6	3.6	NA
Volvo	XC60 PHEV	10	3.7	NA

Source: CleanTechnica.com

Charging infrastructure levels

Indian Standards EV Charging notified by BIS of 01.11.2021

1. ***Light EV AC Charge Point***

Power Level 1	Charging Device	EV-EVSE Communication	Charge Point Plug/ Socket	Vehicle Inlet/ Connector
Up to 7 kW	IS-17017-22-1	Bluetooth Low Energy	IS-60309	As per EV manufacturer

2. ***Light EV DC Charge Point***

Power Level 1	Charging Device	EV-EVSE Communication	Charge Point Plug/ Socket	Vehicle Inlet/ Connector
Up to 7 kW	IS-17017-25 [CAN]		Combined Socket under development	IS-17017-2-6

3. ***Parkbay AC Charge Point***

Power Level-2	Device/ Protocol	EV-EVSE Communications	Infrastructure Socket	Vehicle Connector
Normal Power ~11kW/ 22 kW	IS-17017-1	IS-15118 [PLC] for Smart Charging	IS-17017-2-2	IS-17017-2-2

4. ***Parkbay DC Charge Point***

Power Level-2	Device/ Protocol	EV-EVSE Communications	Infrastructure Socket	Vehicle Connector
Normal Power ~11kW/ 22 kW	IS-17017-23	IS-17017-24 [CAN] IS-15118 [PLC]	IS-17017-22-2	IS-17017-2-3

5. ***DC Charging Protocol***

Power Level 3	Charging Device	EV-EVSE Communication	Connector
DC 50 kW to 250 kW	IS-17017-23	IS-17017-24 [CAN] IS-15118 [PLC]	IS-17017-2-3

6. ***eBus Charging Station (Level-4: 250 to 500 kW)***

Power Level 4 DC High Power (250 kW --> 500 kW)	Charging Device	EV-EVSE Communication	Connector
Dual Gun Charging Station	IS-17017-23-2	IS-15118 [PLC]	IS-17017-2-3
Automated Pantograph Charging Station	IS-17017-3-1		IS-17017-3-2

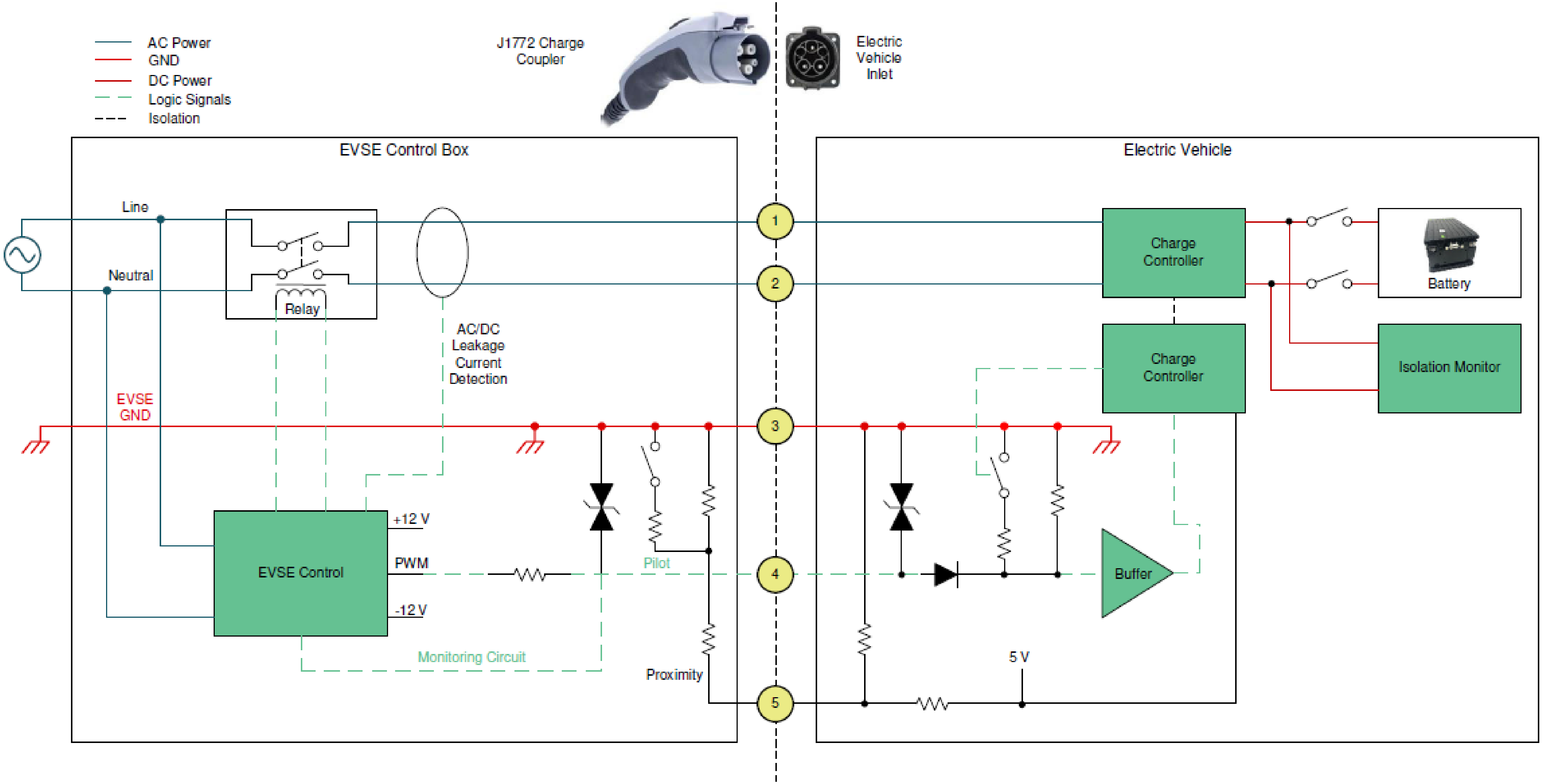
Electric Vehicle Supply Equipment (EVSE)

- Required hardware between charging plug and AC grid
- Can be simple or sophisticated based on the power level

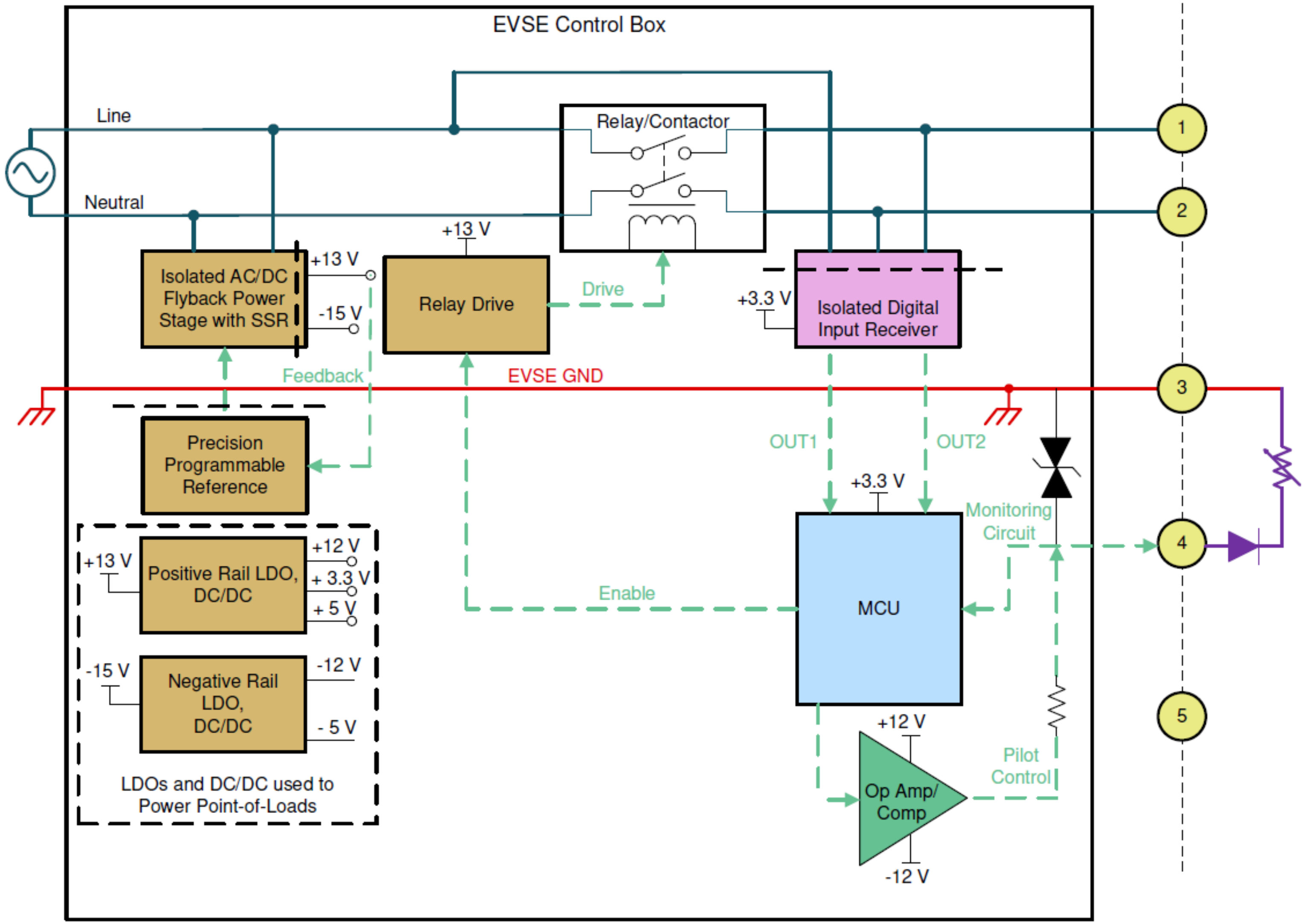
Functions of EVSE

- Power delivery to the EV
  - Simple for Level 1 and 2
  - Complicated for level 3 and 4
- User interface (screen, buttons, indicators)
- Safety mechanisms (earth fault, overcurrent, etc.)
- Communication with the EV (to negotiate charging speed)
- Authentication & billing (in public chargers)

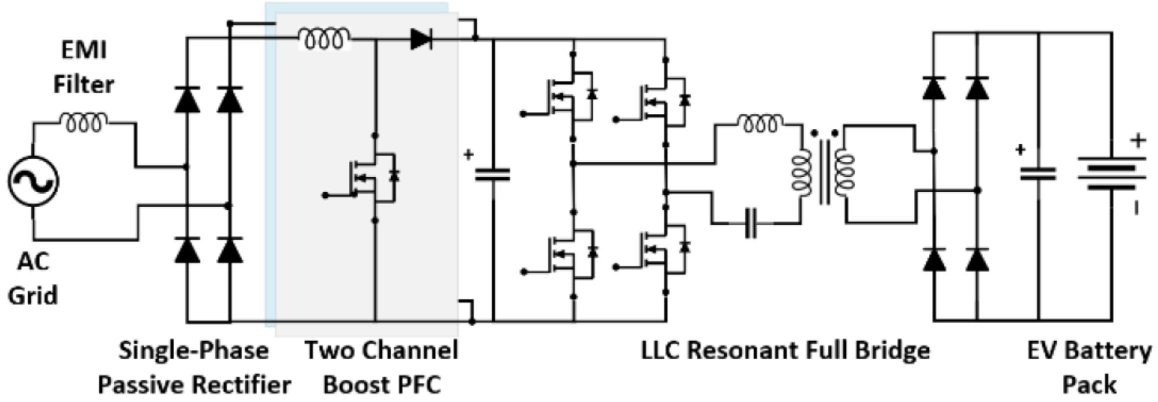
EVSE for level 1 and 2 (AC charging)



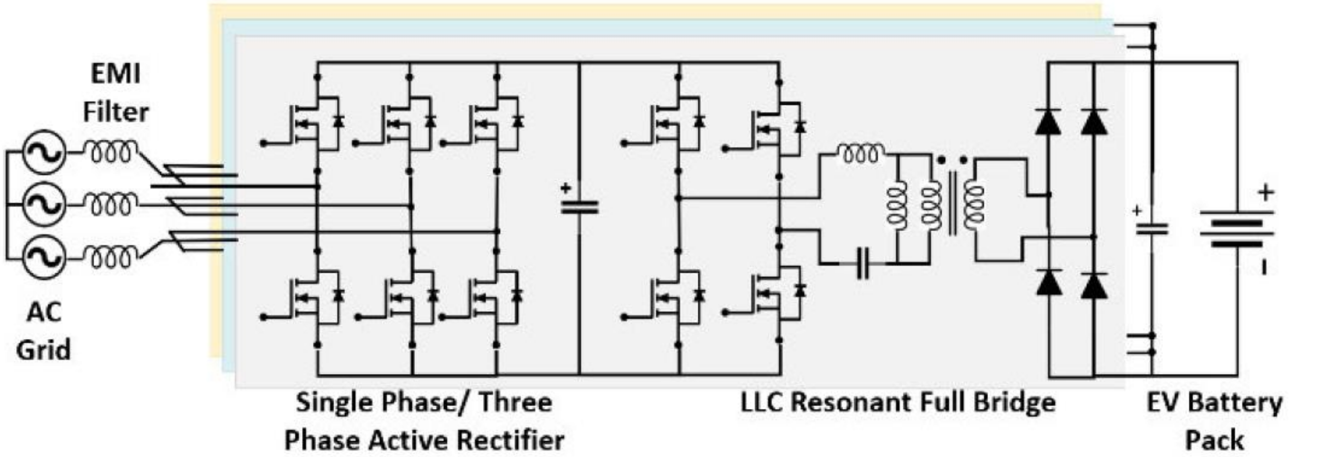
EVSE for level 1 and 2 (AC charging)



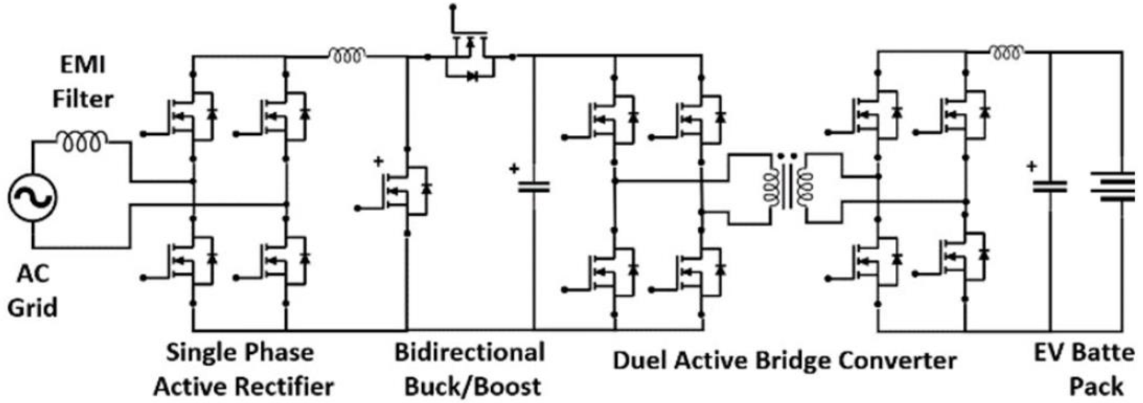
Some commercial on-board chargers



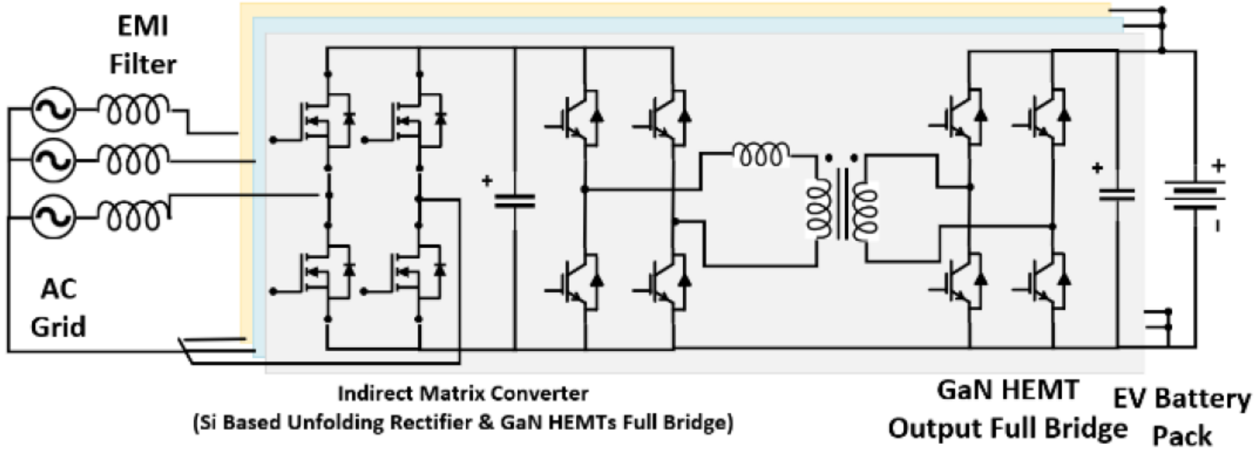
Volt



Tesla

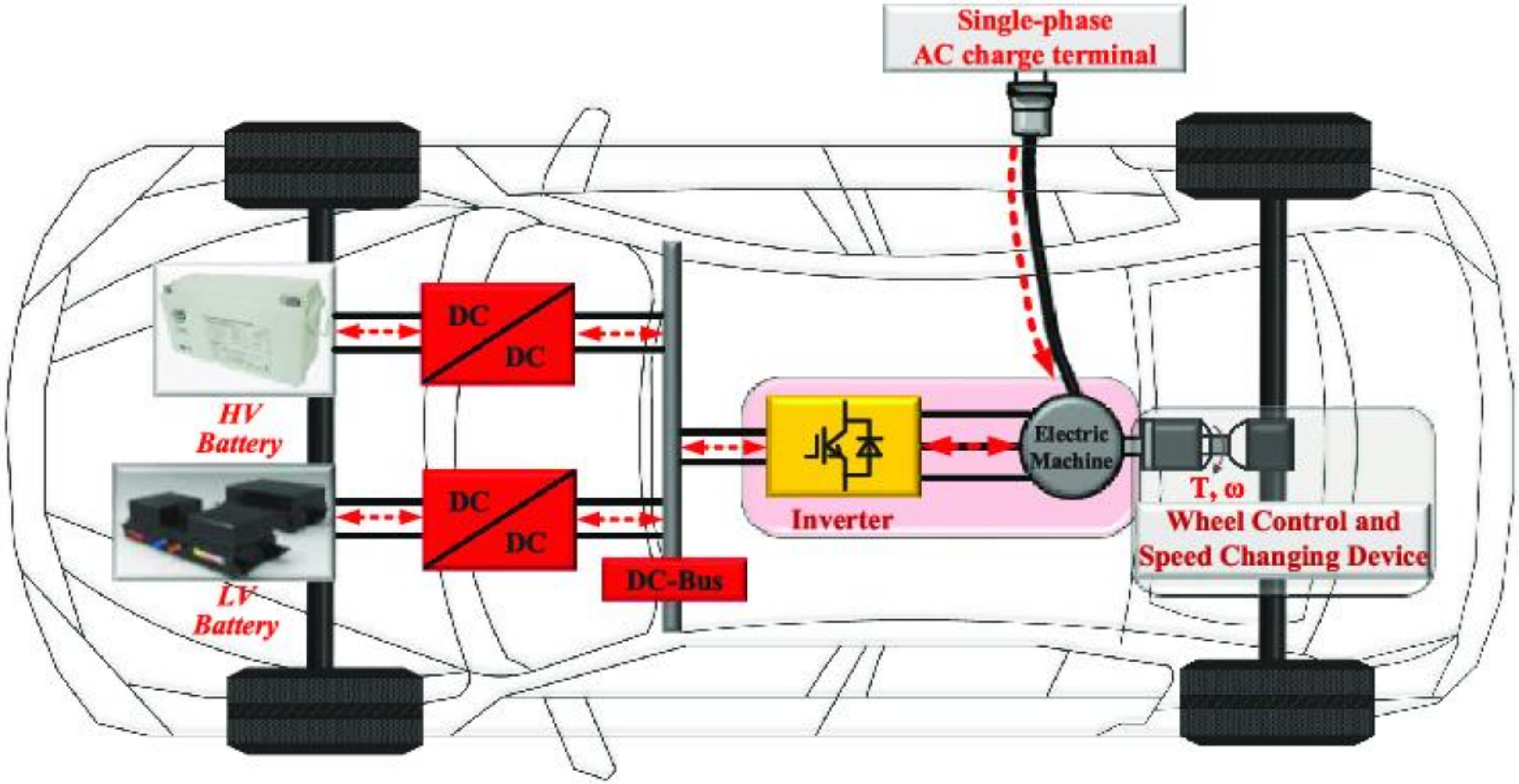


Hyundai



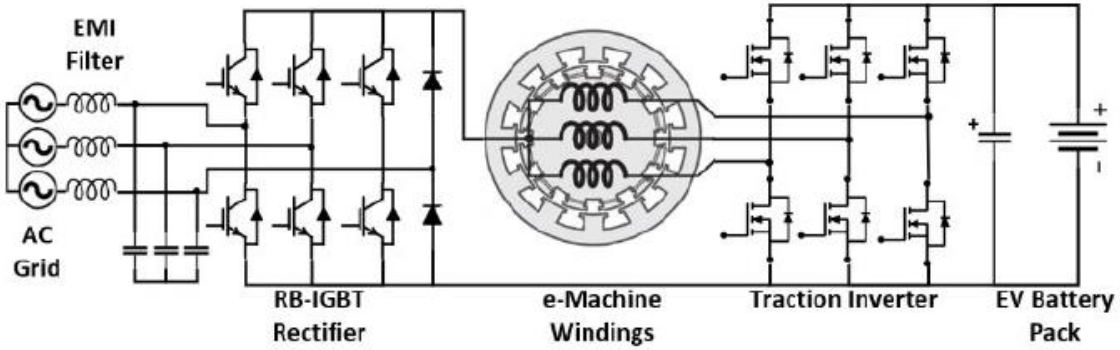
Hella electronics

Integrated Onboard Charger

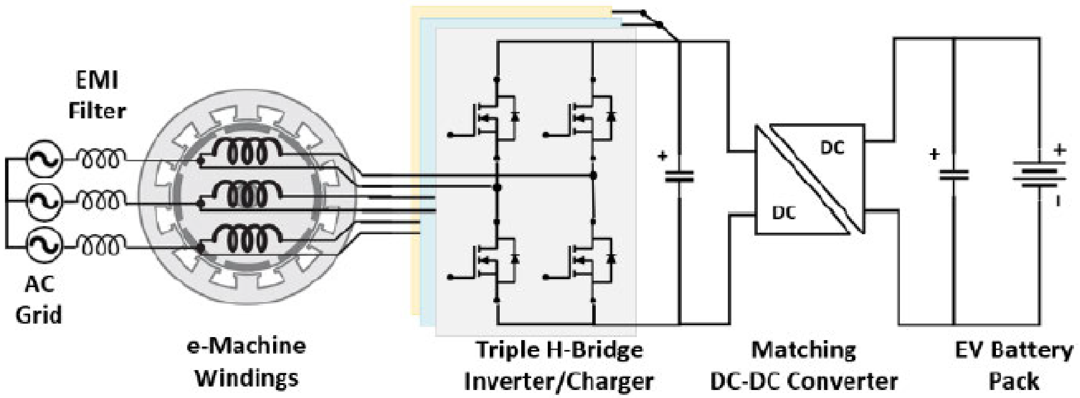


- Motor drive inverter and machine windings are multi-purposed as battery charger
- Reduced size, weight, and cost

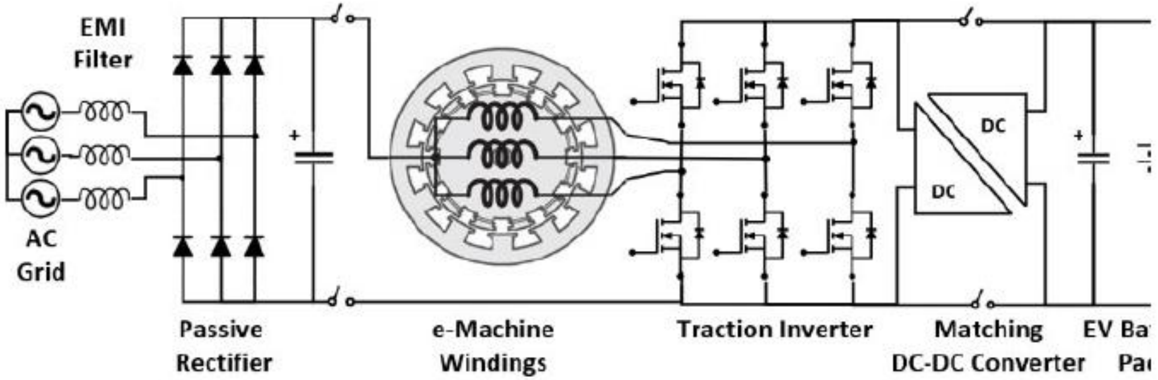
Some commercial integrated chargers



Renault

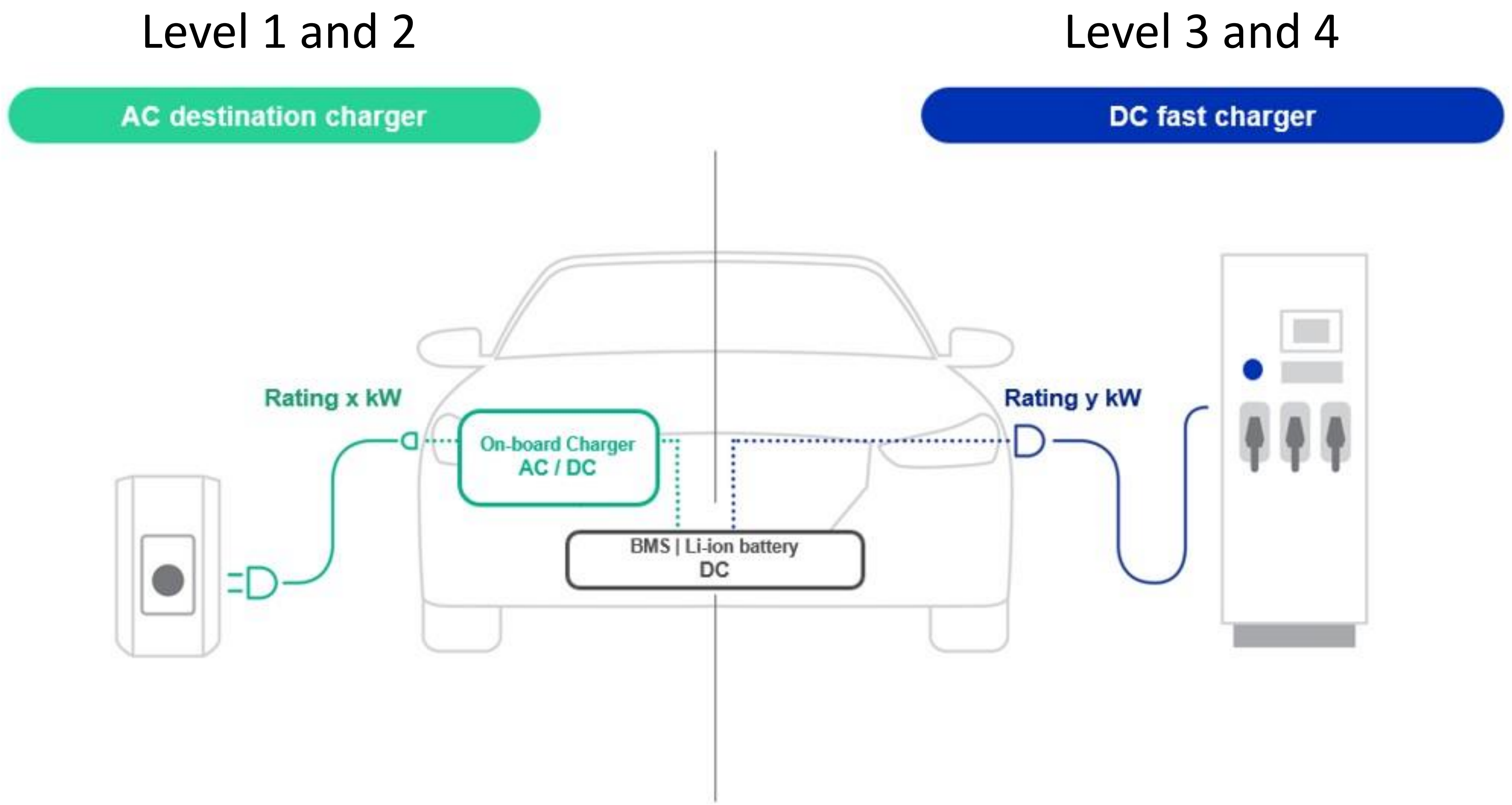


Valeo

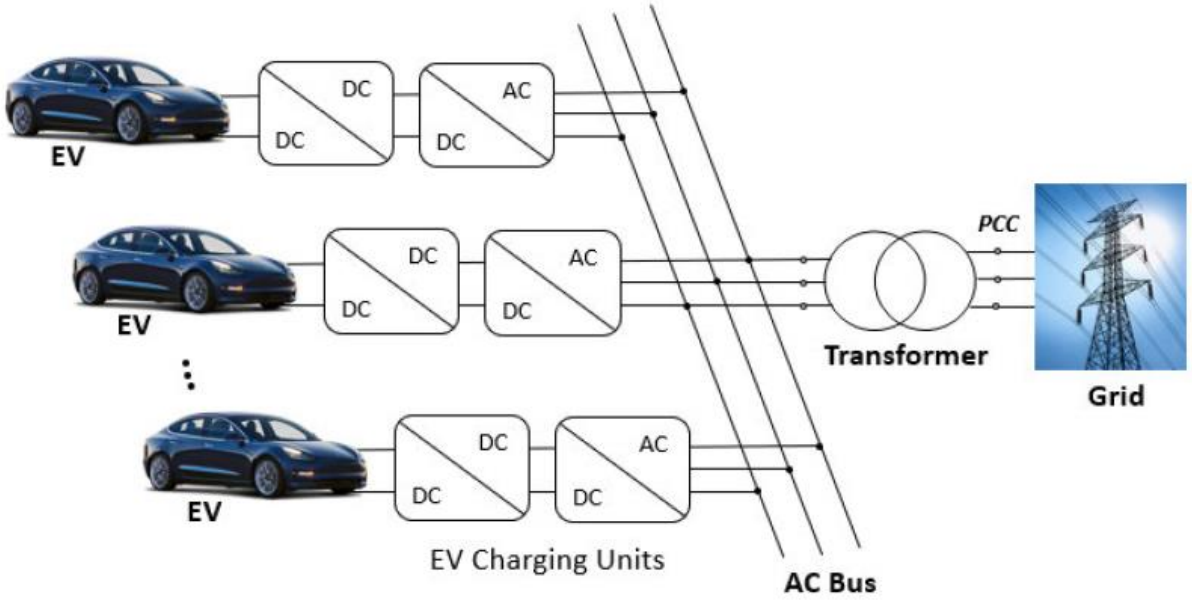


Continental

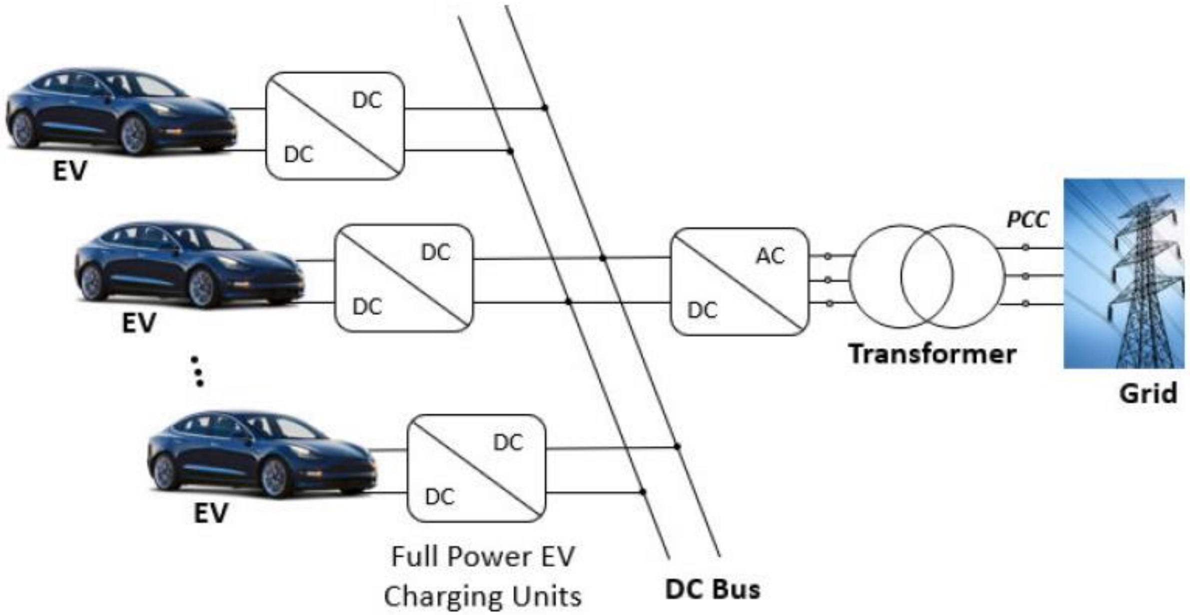
Level 3 and 4


Level 1 and 2
Level 3 and 4
AC destination charger
DC fast charger
Rating x kW
On-board Charger
AC / DC
BMS | Li-ion battery
DC
Rating y kW

Charging station structure

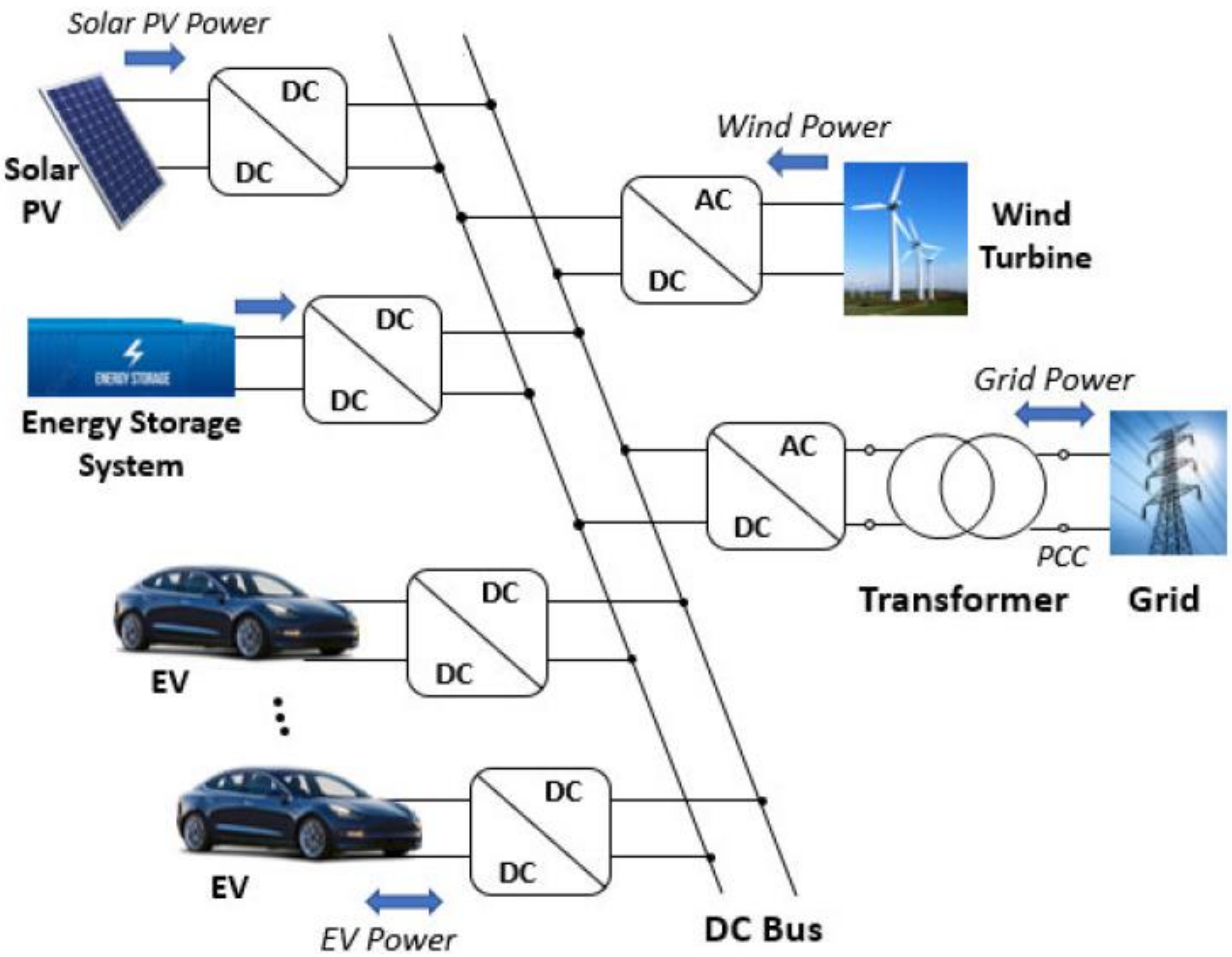


Common AC bus structure



Common DC bus structure

Charging station with renewable sources



Converter topologies for Off-board chargers

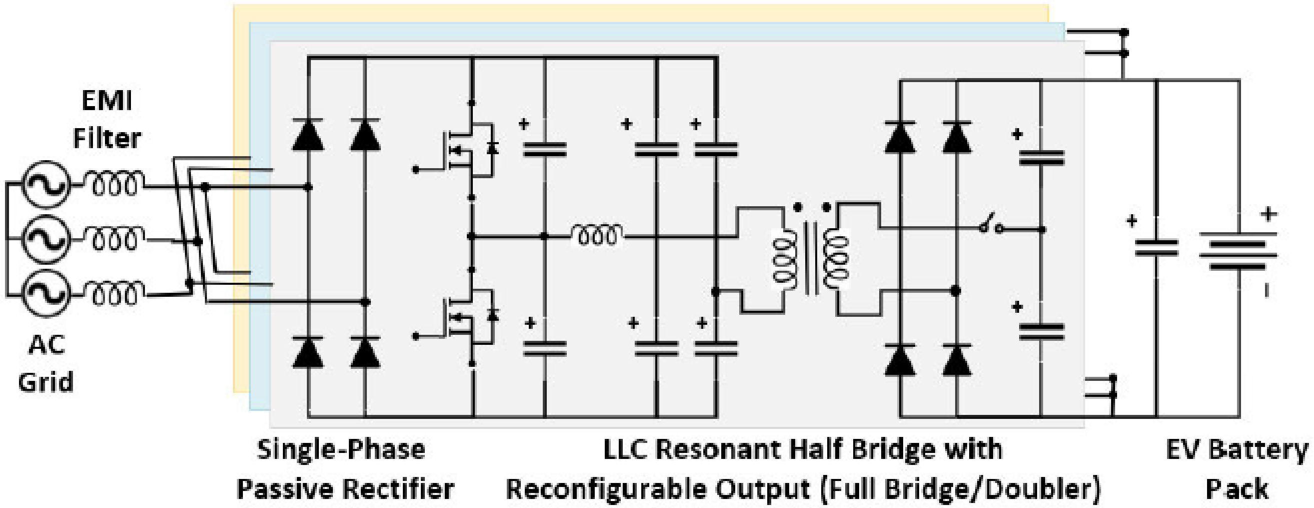


ABB Terra 53/54 50-kW fast charger

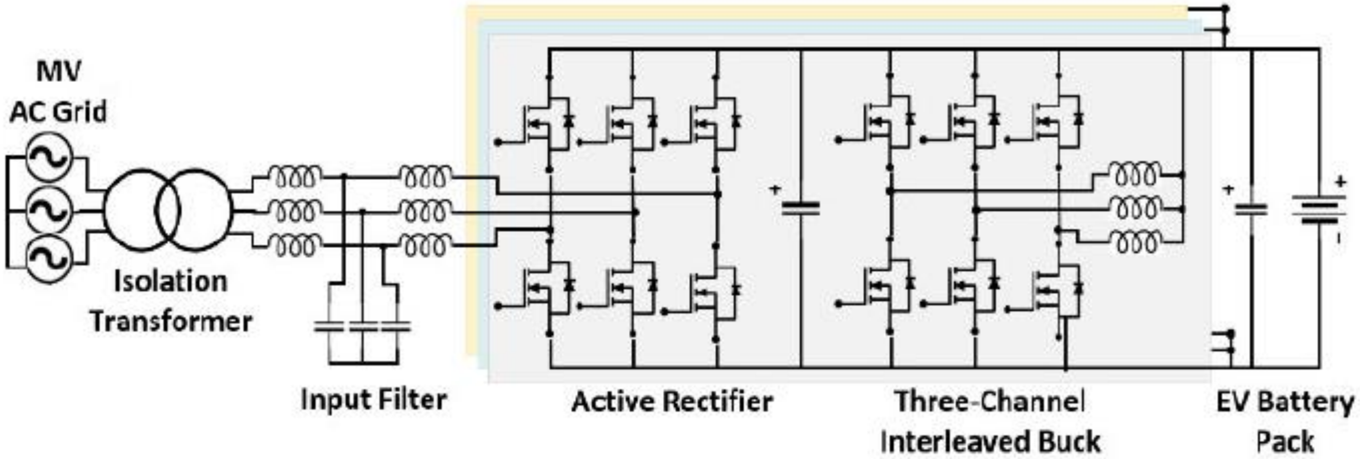
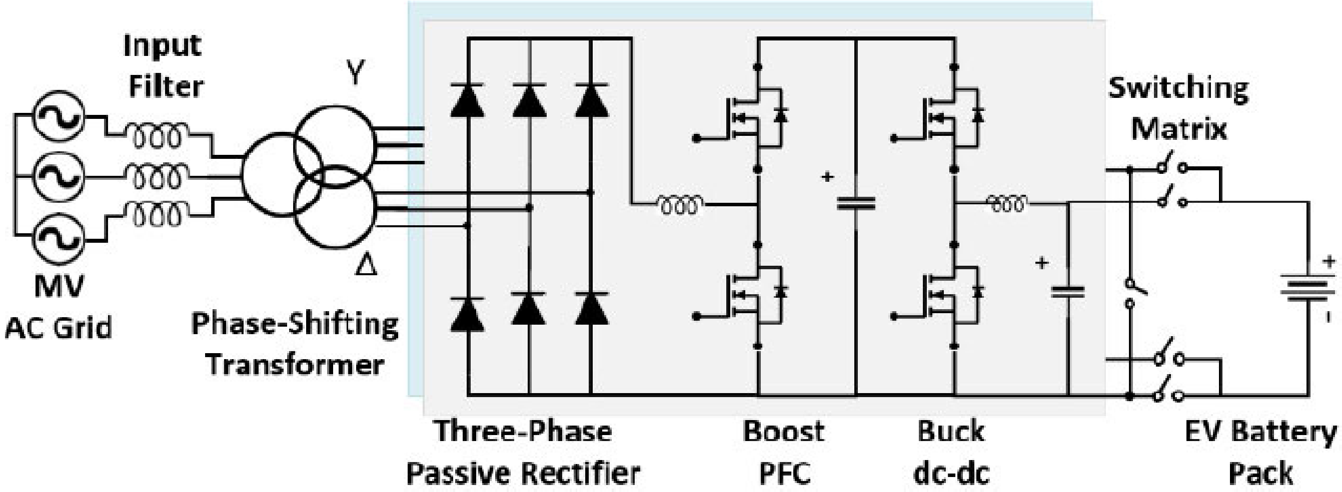
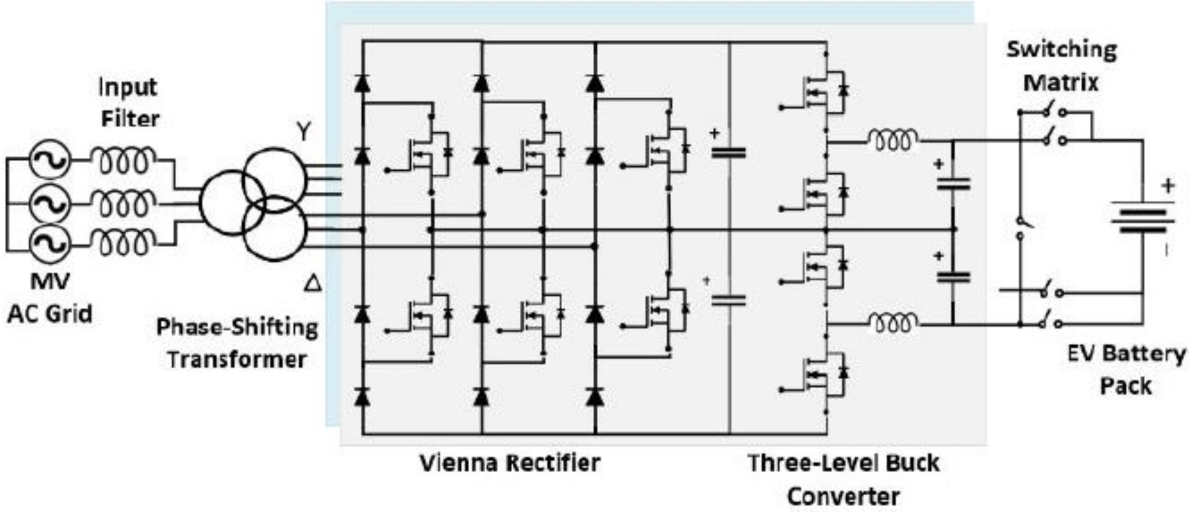


ABB Terra HP 150-kW high-power charger

Converter topologies for Off-board chargers

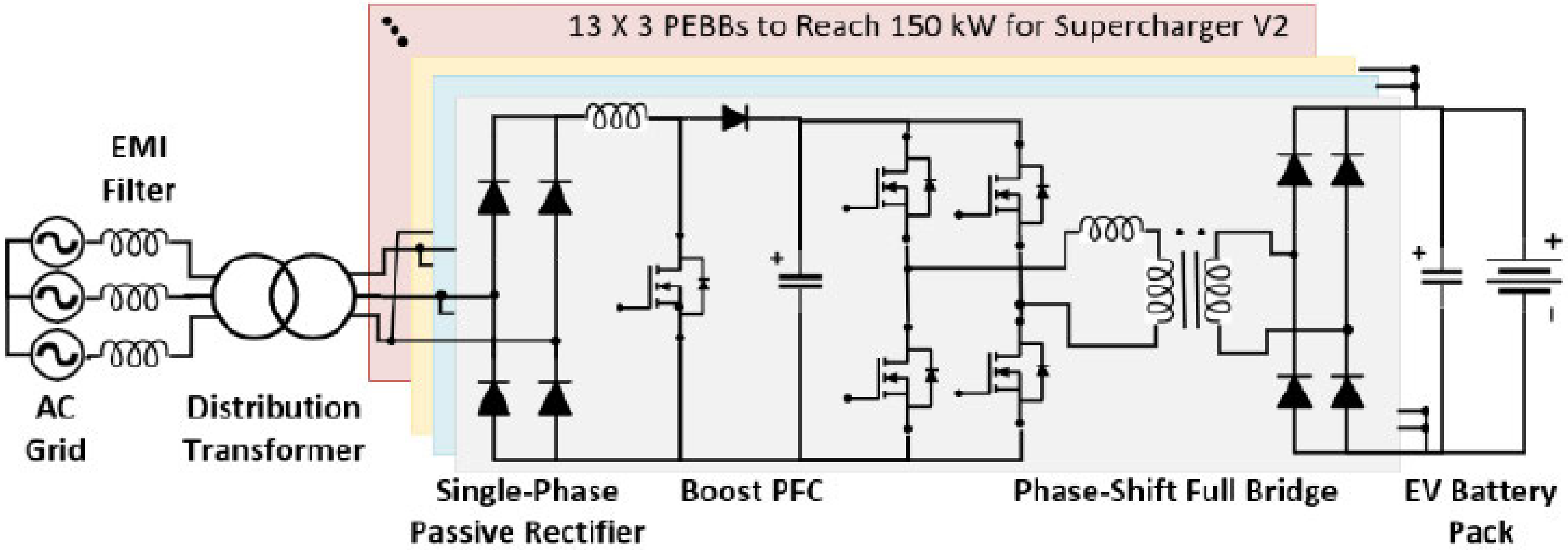


Porsche modular fast charger Park A, up to 400 kW



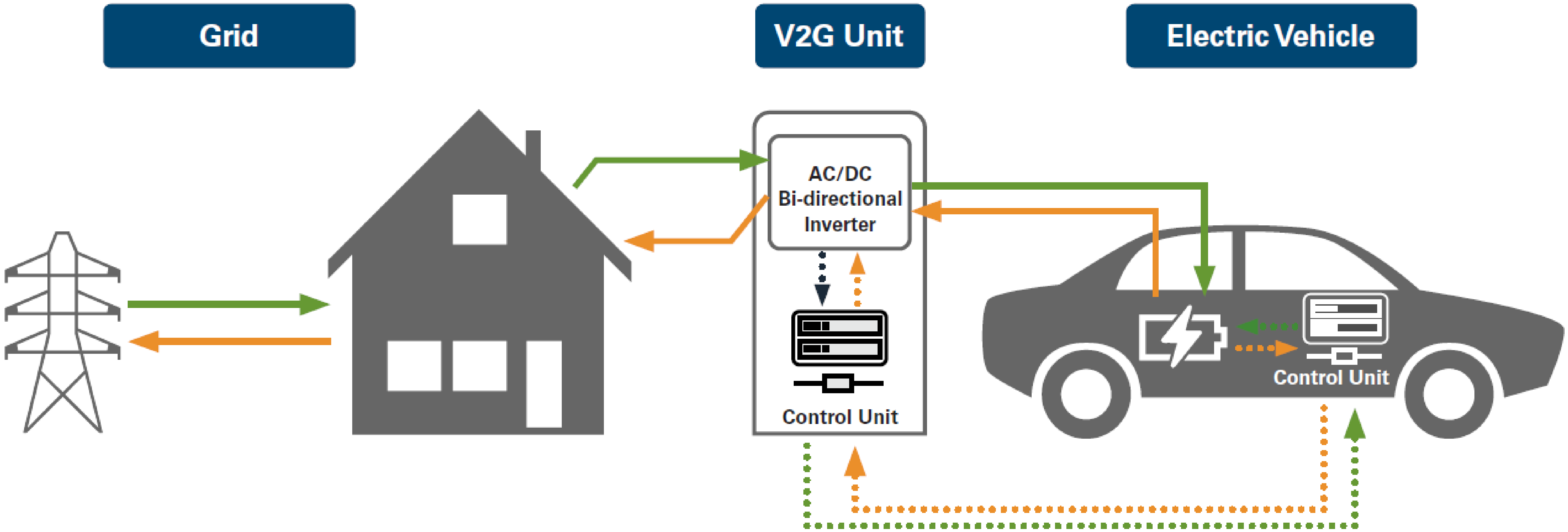
Porsche modular fast charging Park B, up to 350 kW

Converter topologies for Off-board chargers



Tesla V2 Supercharger (150 kW)

Vehicle to grid



Advantages of V2G operation

- Grid Stabilization & Support
  - Peak shaving
  - Frequency regulation
  - Emergency backup

- Financial benefits to EV owners
  - Reduced energy bills
  - Utility may pay back to EV owner

- Environmental Impact
  - Better renewable integration
  - Better utilization of battery assets

Thank you!