Electric Vehicle (EE60082)

Lecture 18: Charger part3

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Charging power requirements (recap)

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 (recap)

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

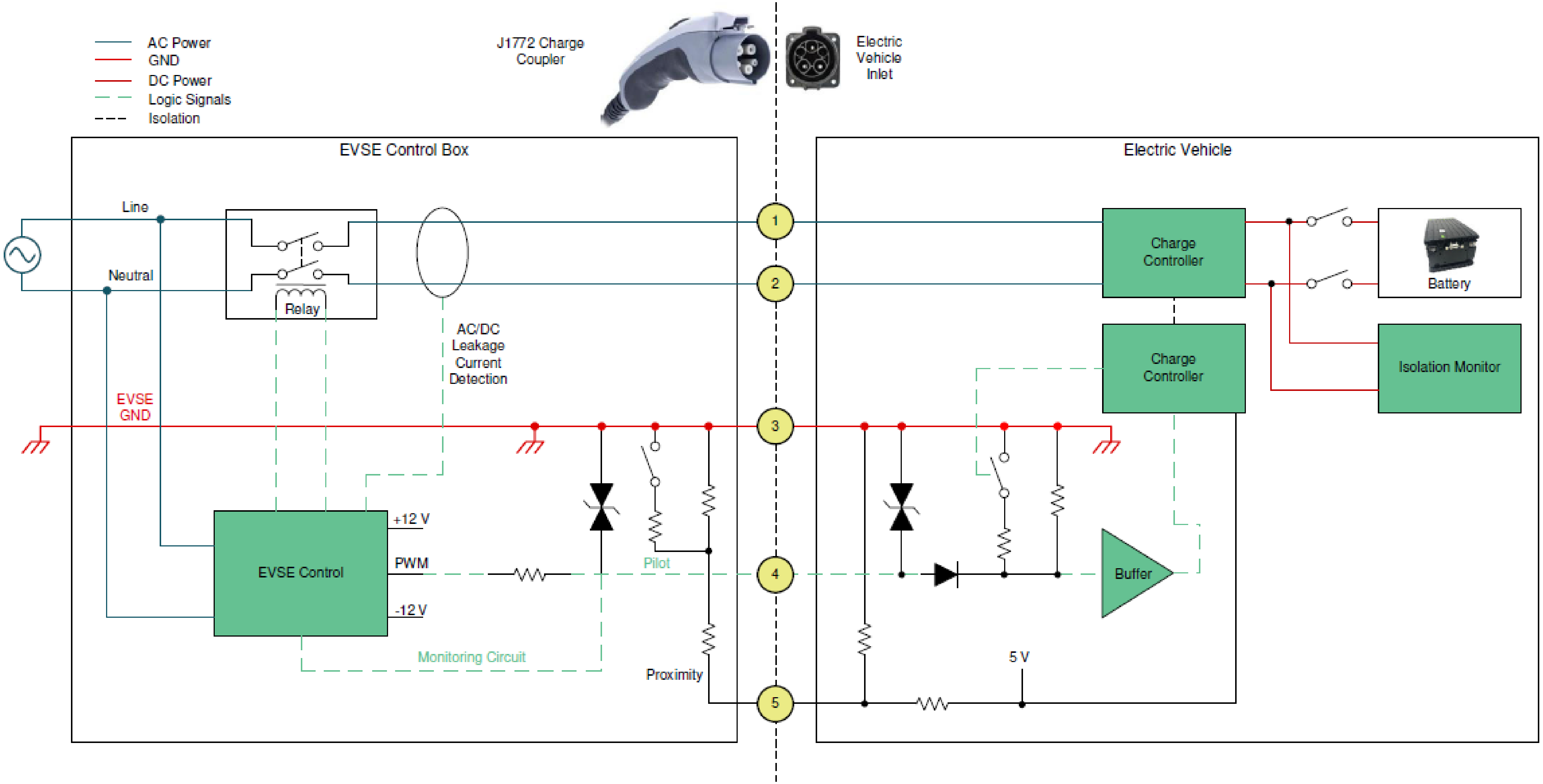
6. eBus Charging Station (Level-4: 250 to 500 kW)

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

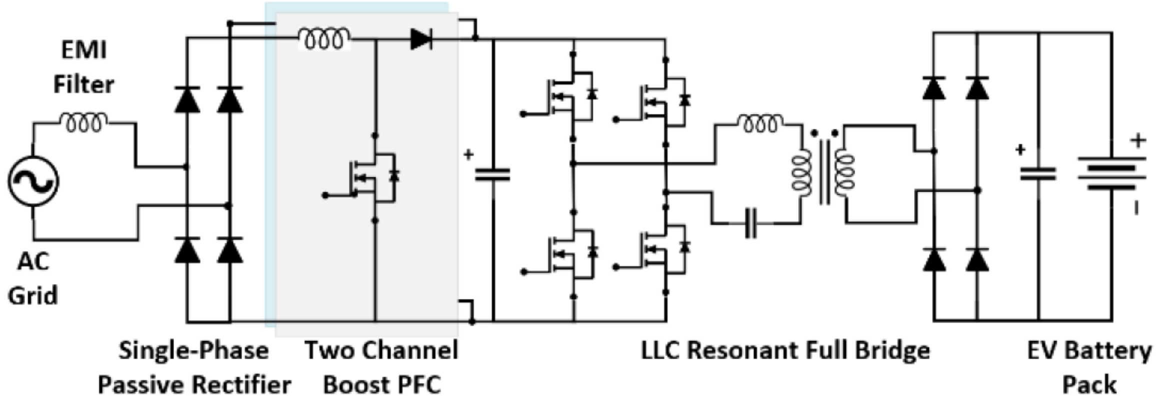
Electric Vehicle Supply Equipment (EVSE) (recap)

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

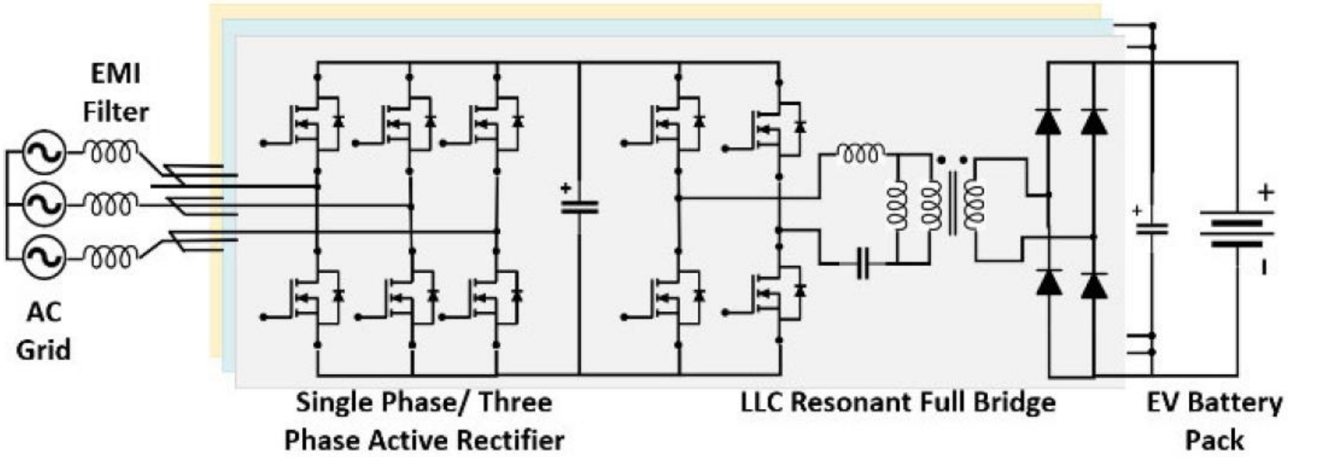
EVSE for level 1 and 2 (AC charging) (recap)



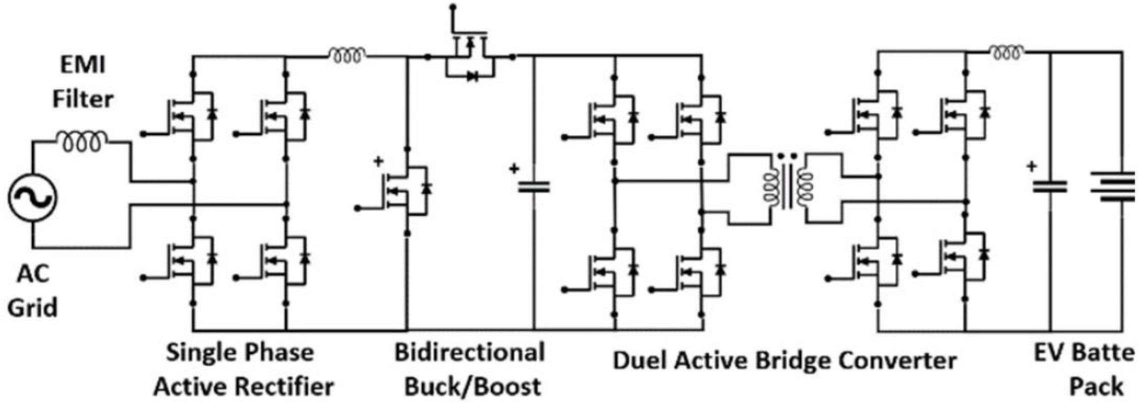
Some commercial on-board chargers (recap)



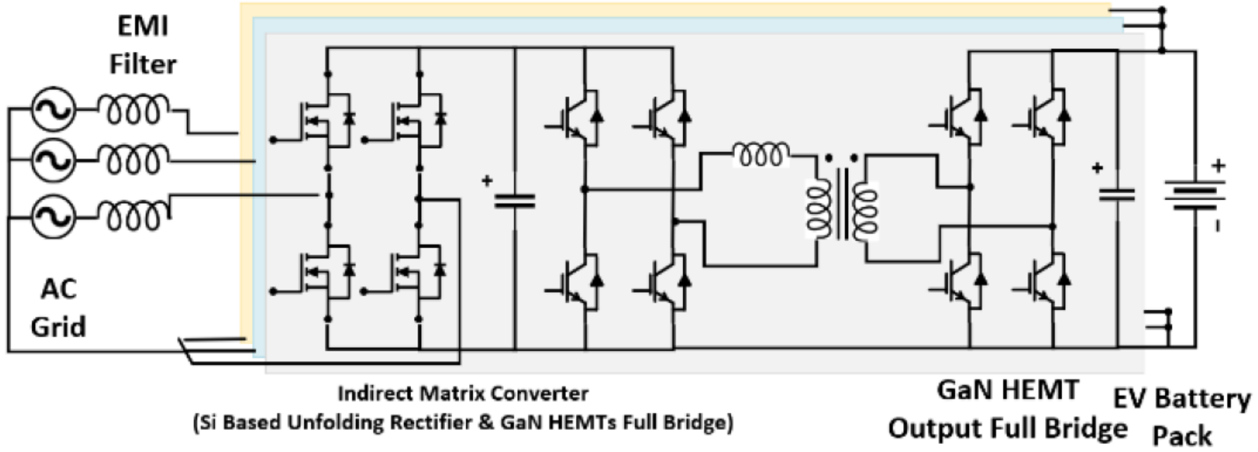
Volt



Tesla

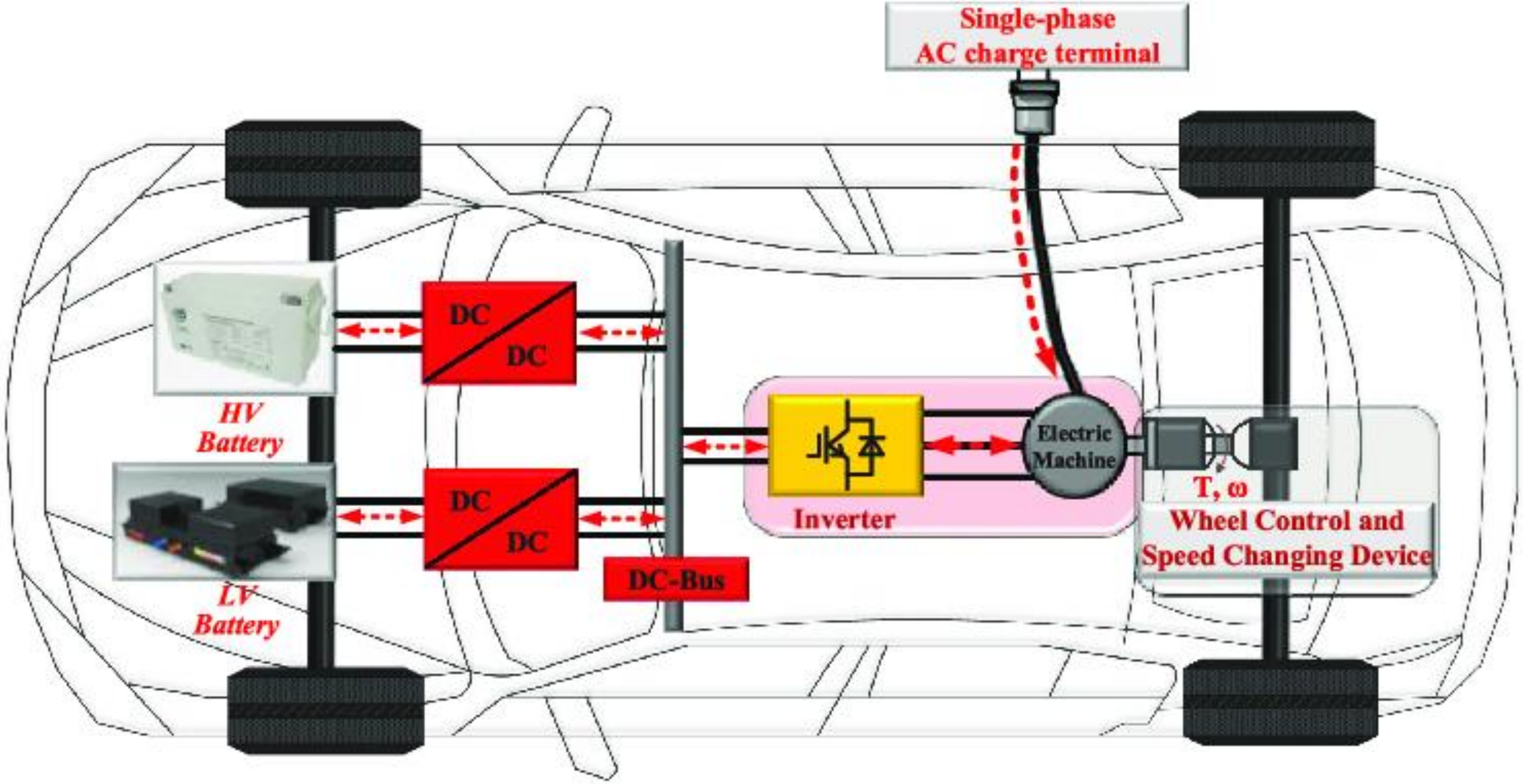


Hyundai



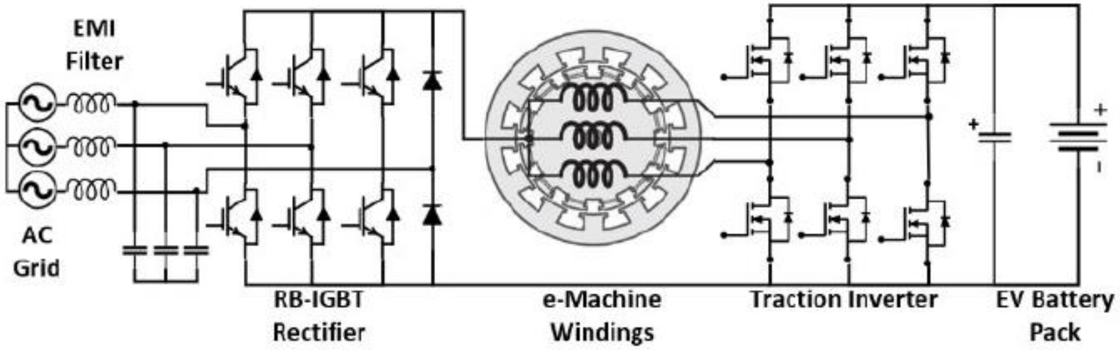
Hella electronics

Integrated Onboard Charger (recap)

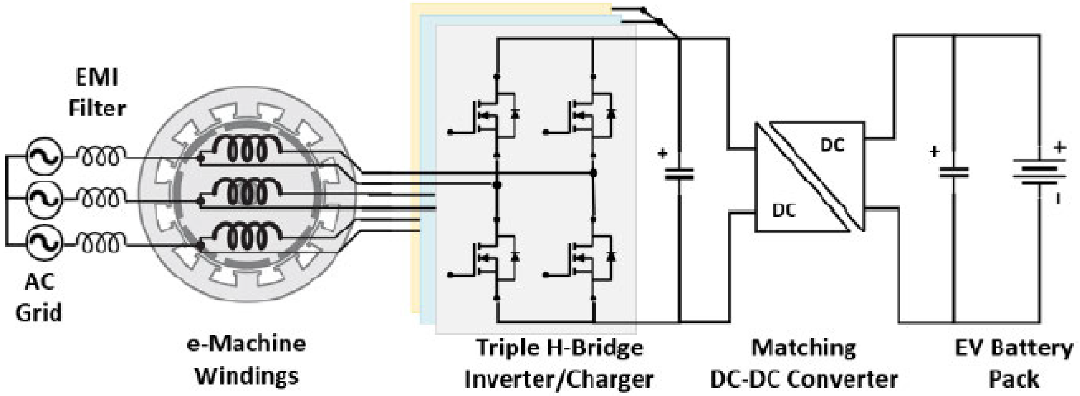


- Motor drive inverter and machine windings are multi-purposed as battery charger
- Reduced size, weight, and cost

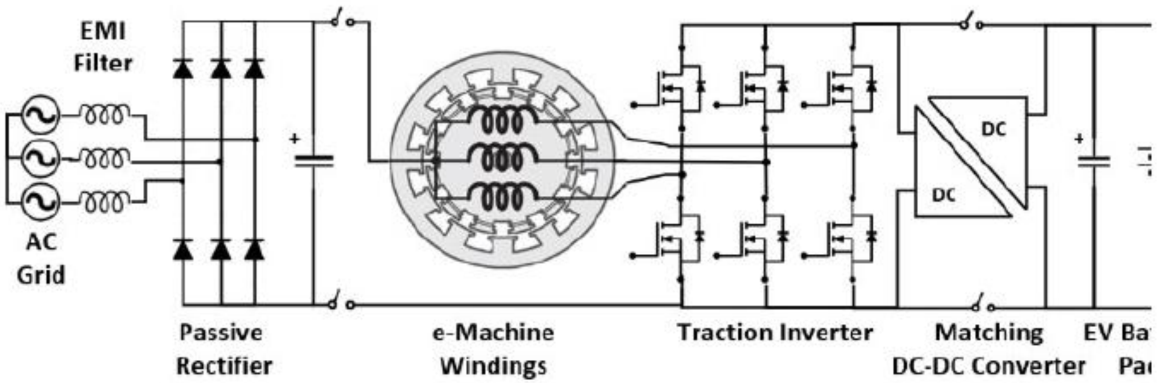
Some commercial integrated chargers (recap)



Renault



Valeo

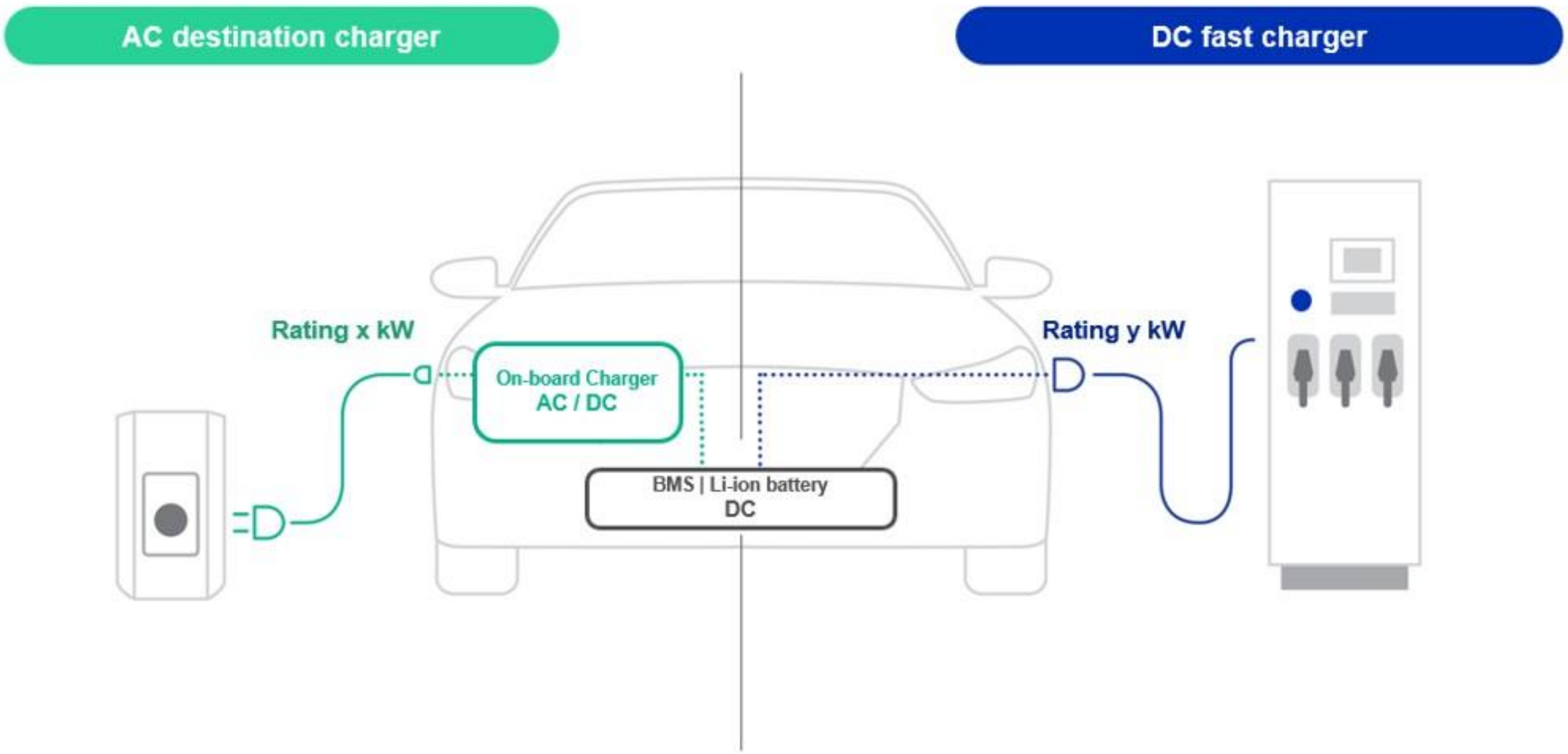


Continental

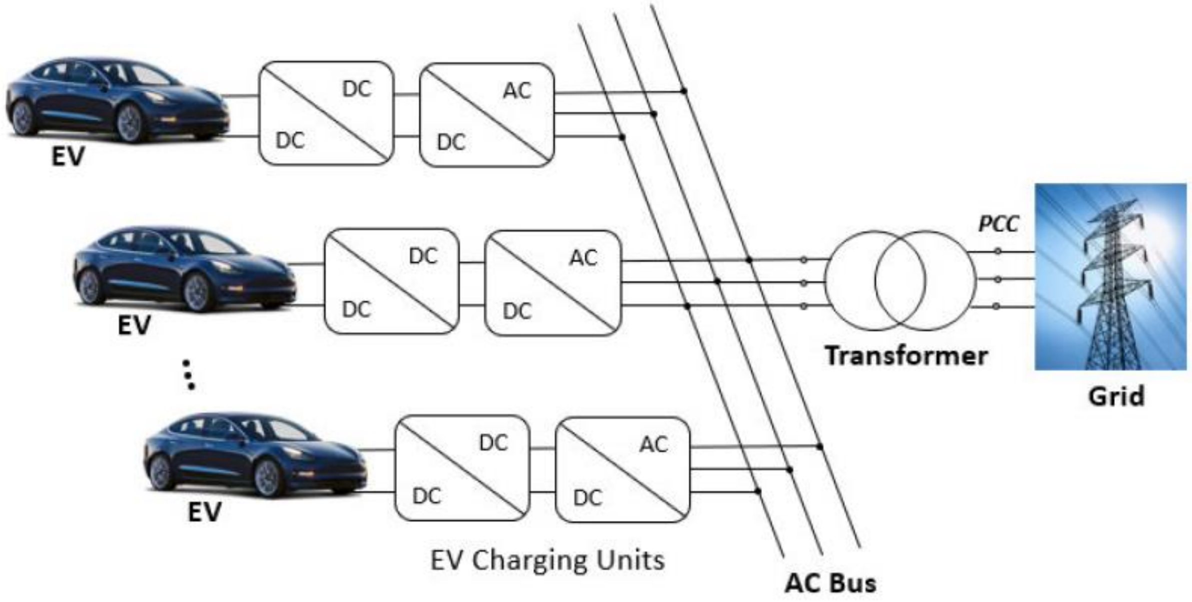
Level 3 and 4 (recap)

Level 1 and 2

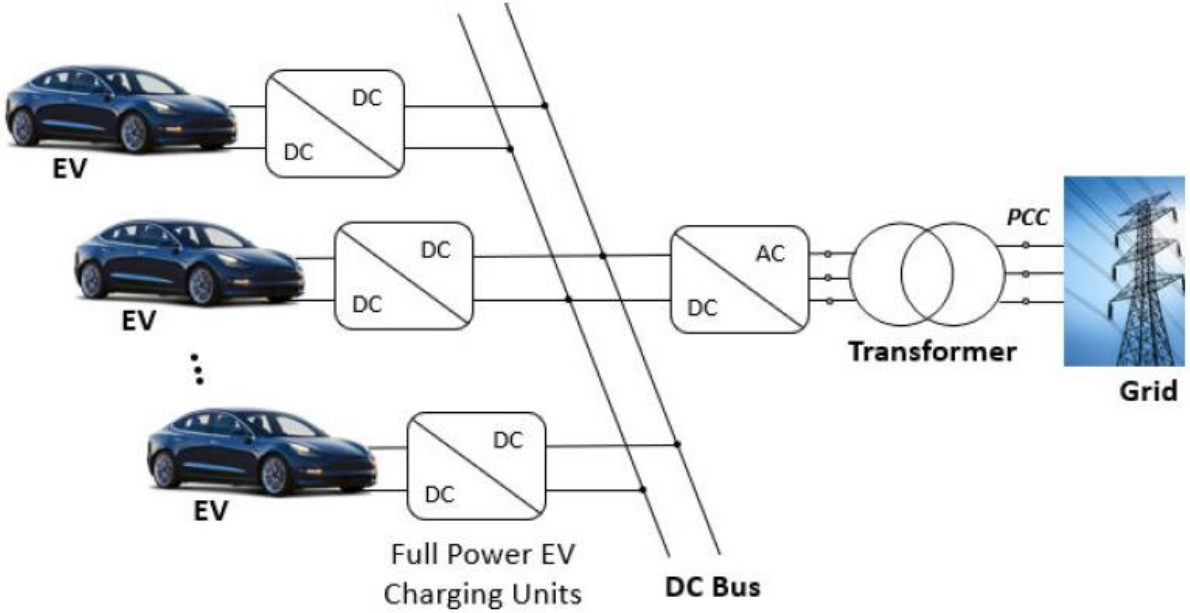
Level 3 and 4



Charging station structure (recap)



Common AC bus structure



Common DC bus structure

Converter topologies for Off-board chargers (recap)

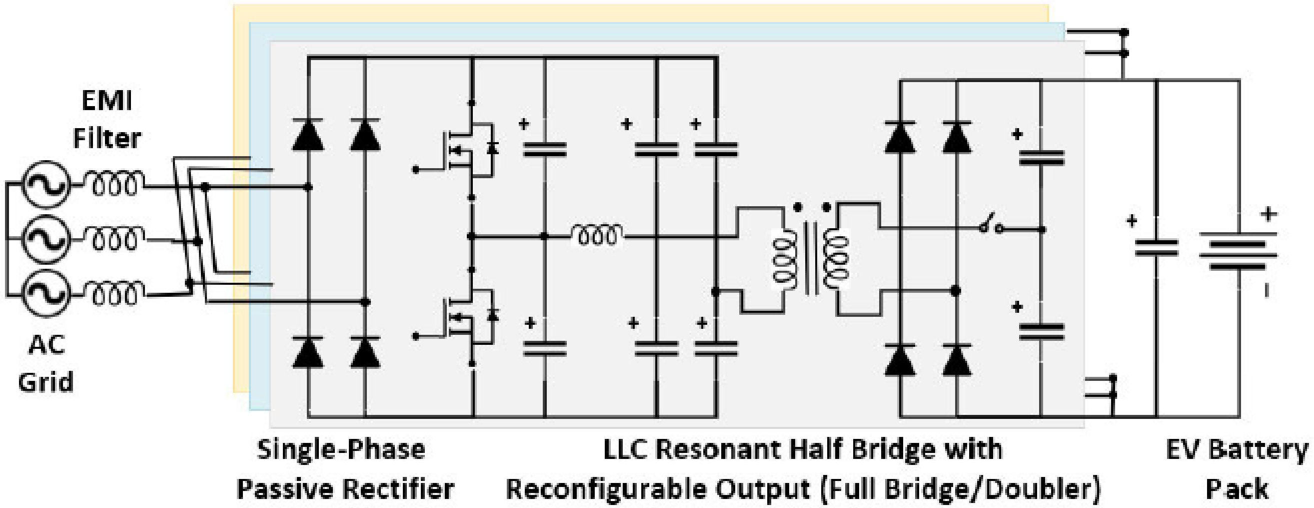


ABB Terra 53/54 50-kW fast charger

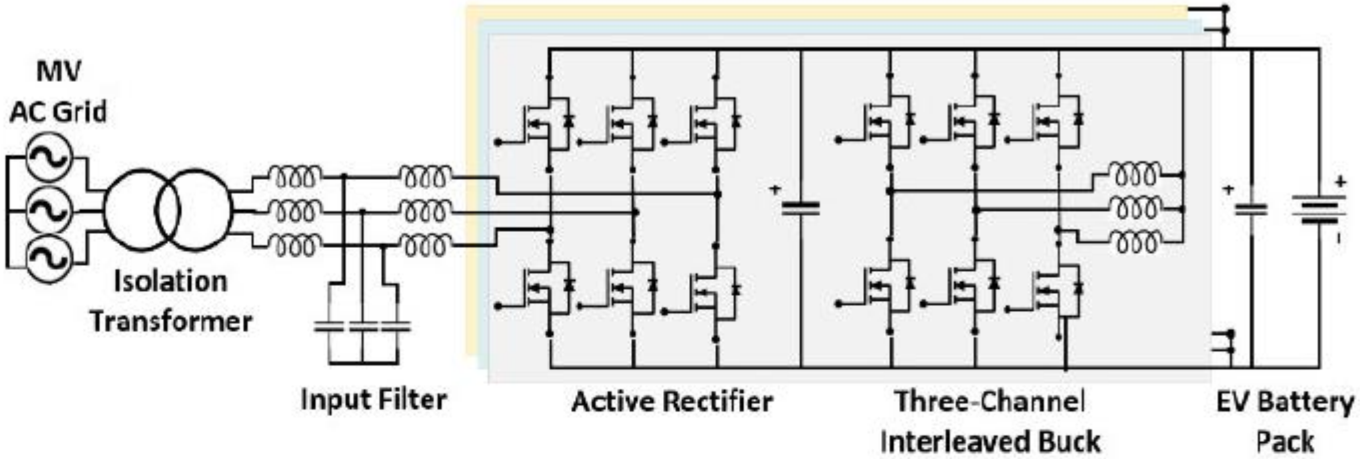
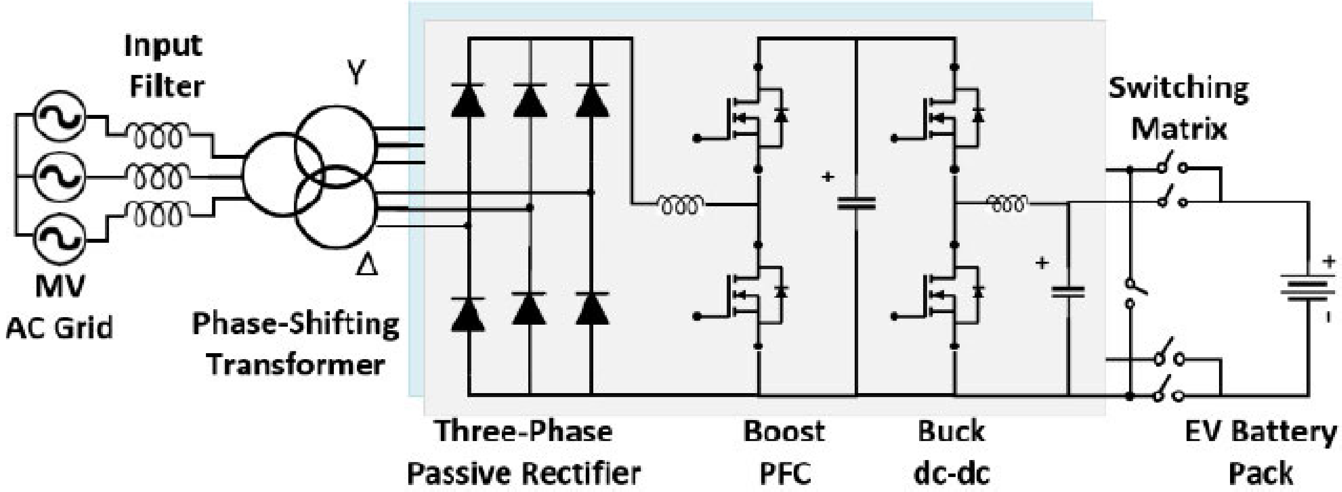
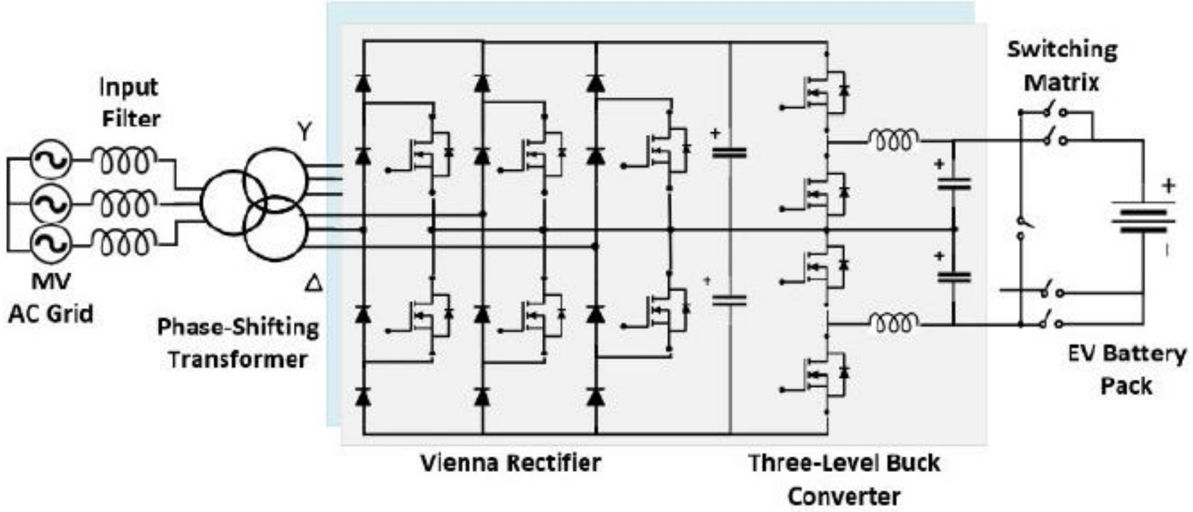


ABB Terra HP 150-kW high-power charger

Converter topologies for Off-board chargers (recap)

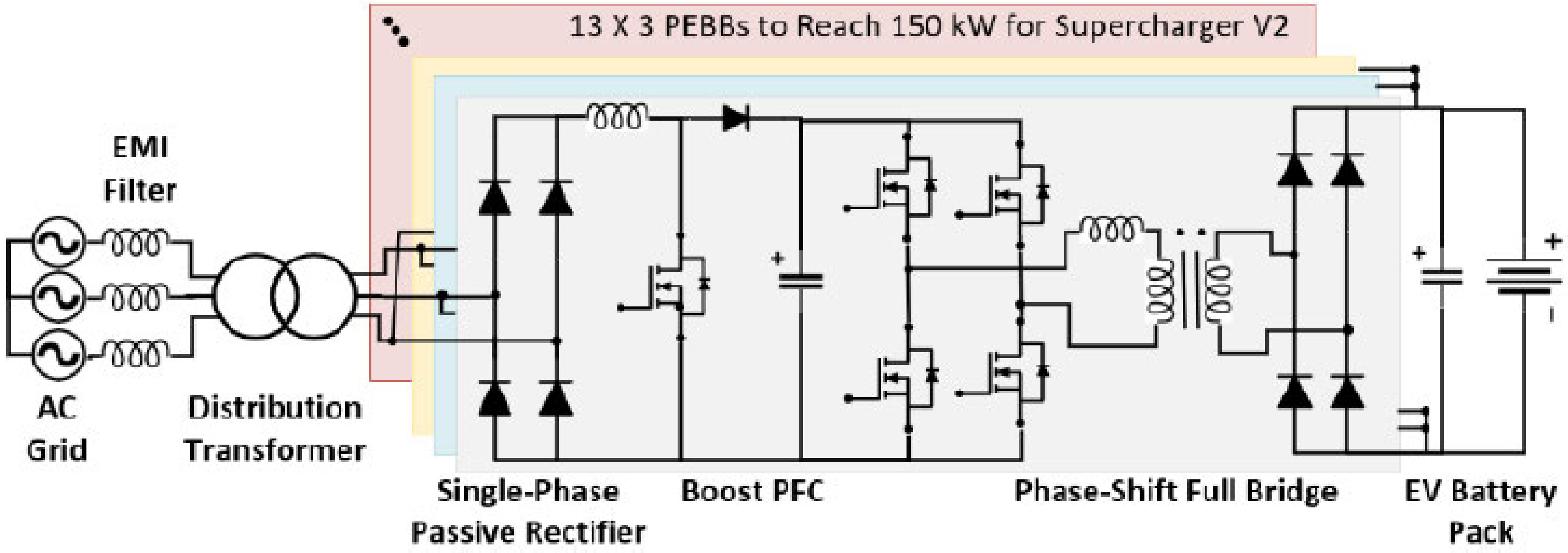


Porsche
modular fast charger Park A,
up to 400 kW



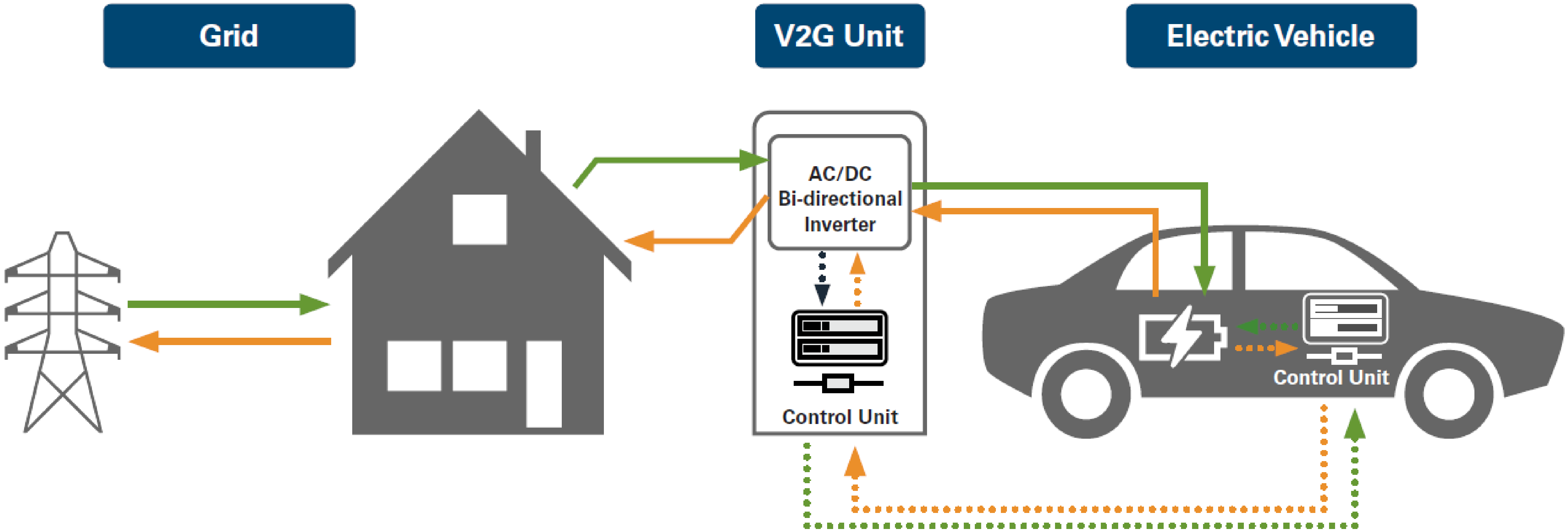
Porsche modular fast charging
Park B, up to 350 kW

Converter topologies for Off-board chargers (recap)



Tesla V2 Supercharger (150 kW)

Vehicle to grid (recap)



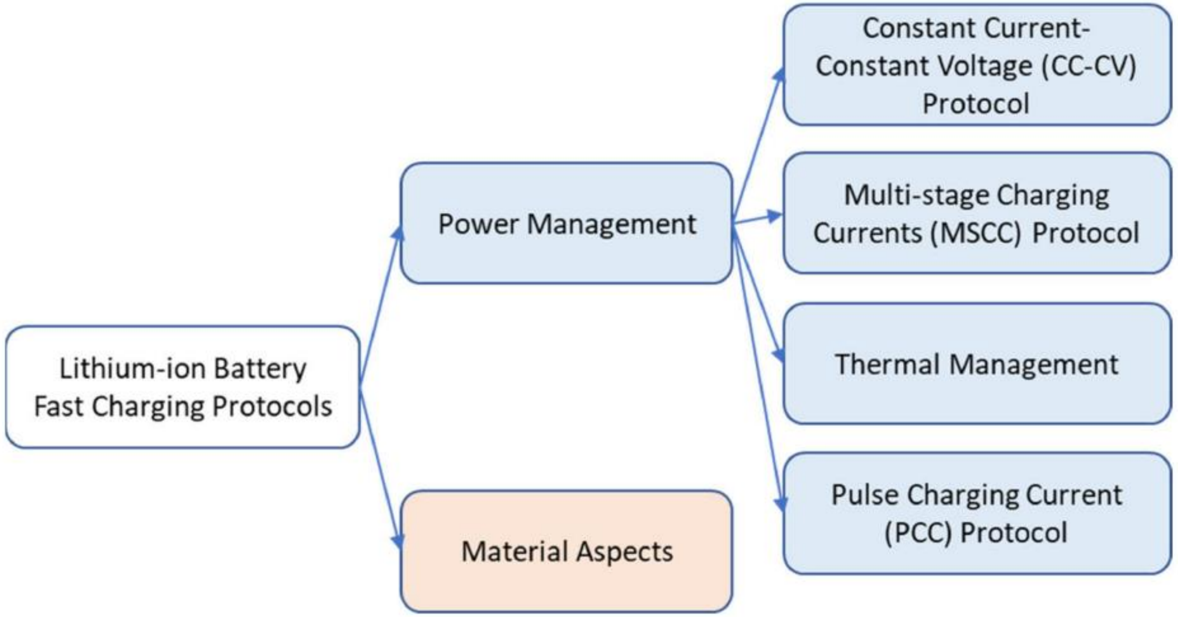
Advantages of V2G operation (recap)

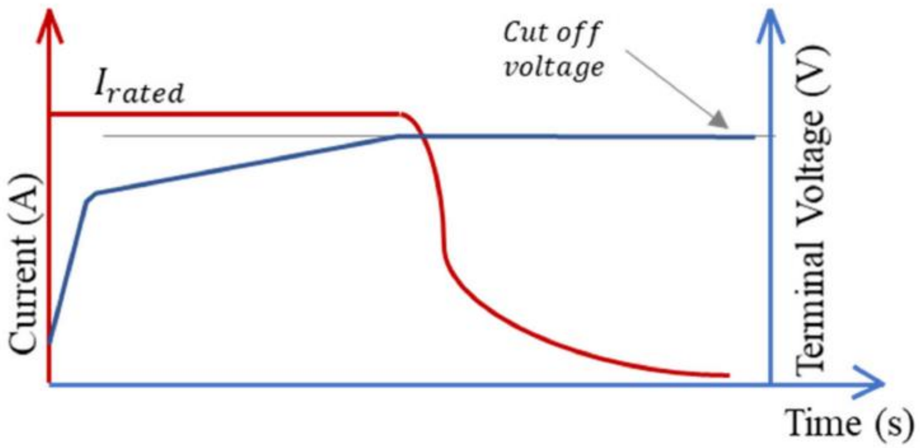
- Grid Stabilization & Support
  - Peak shaving
  - Frequency regulation
  - Emergency backup

- 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

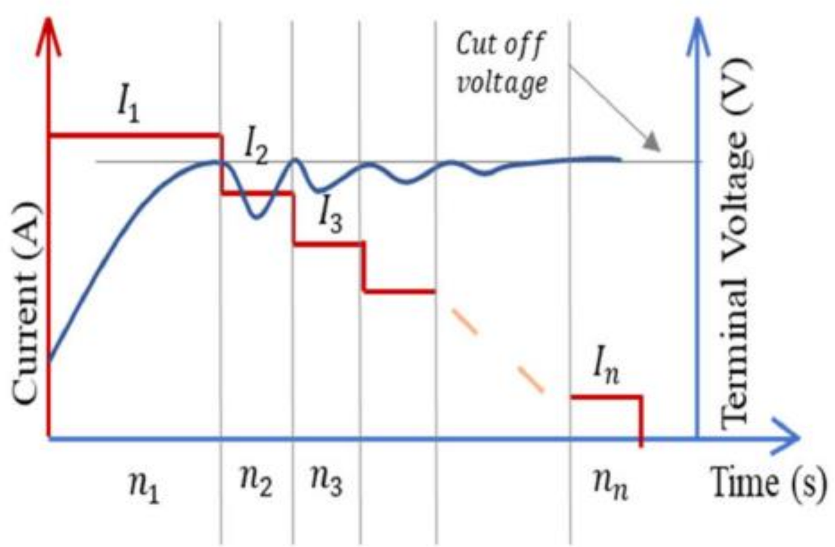
Charging protocols



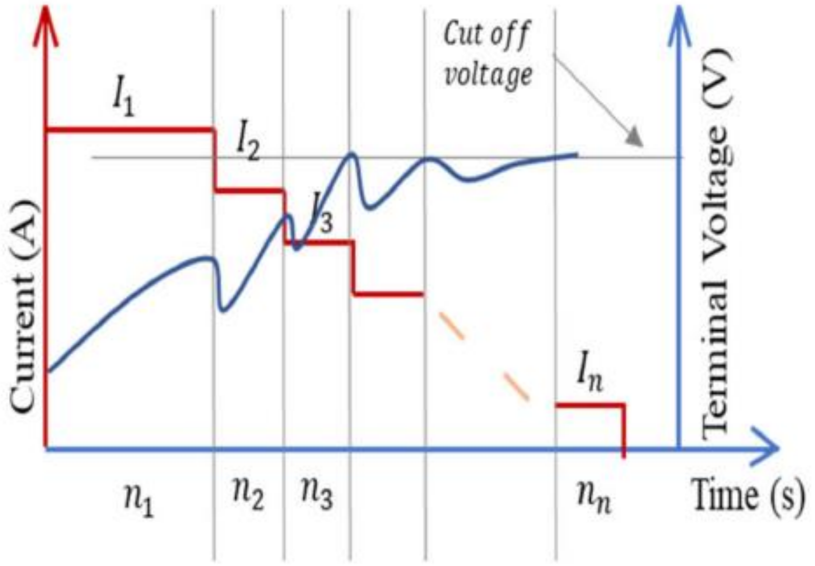


- CC-CV method:
  - Simple, effective, and popular
  - Long CV mode
  - Possibility of degradation from over-voltage

Multi-stage charging current protocol



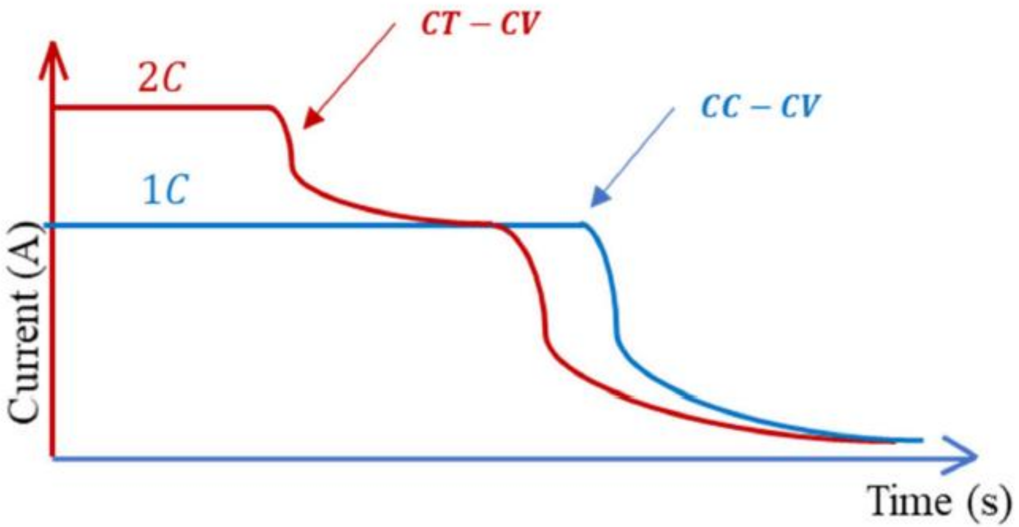
Fixed cut-off voltage technique



Hierarchical cut-off voltage technique

- MSCC method:
  - Many charging pattern possible
  - Optimization to be carried out for specific cell design and environmental conditions
  - Faster charging possible to reduce total charging time

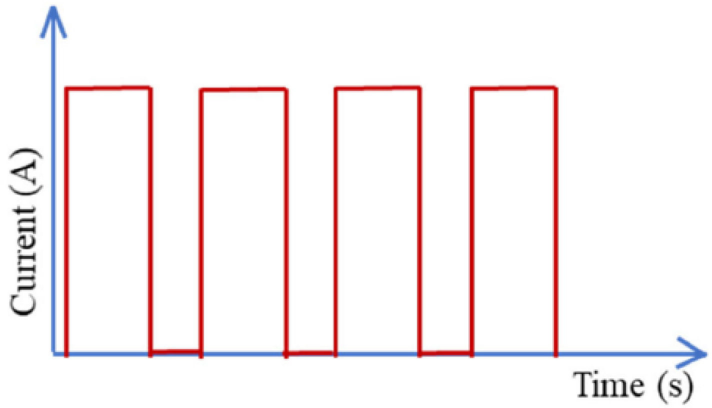
Thermal management protocol



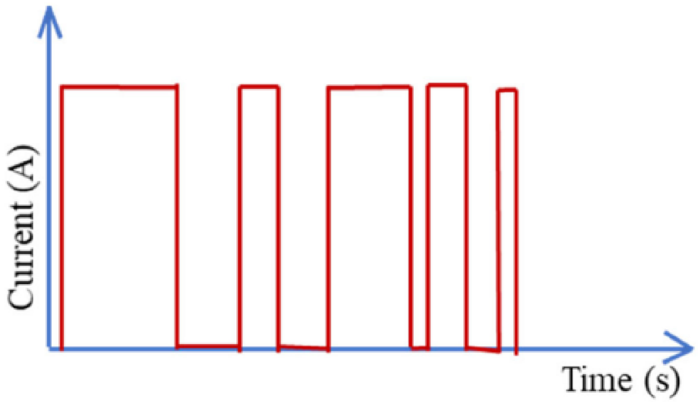
CT-CV protocol

- Constant temperature constant voltage (CT-CV) protocol:
  - Fast charging till temperature cut-off is reached
  - CV mode follows
  - Faster charging possible to reduce total charging time
  - Safer charging

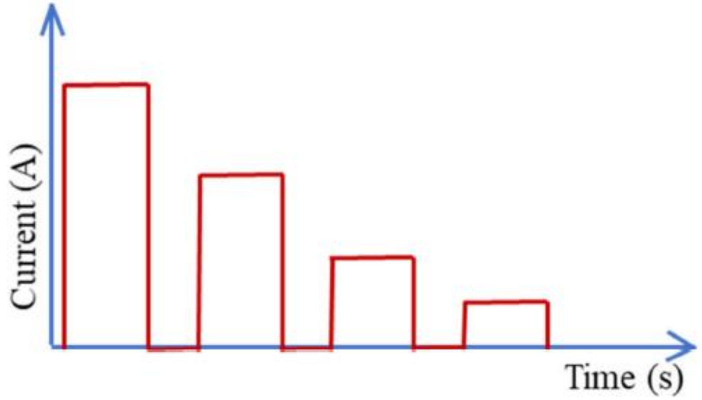
Pulse charging current (PCC) protocol



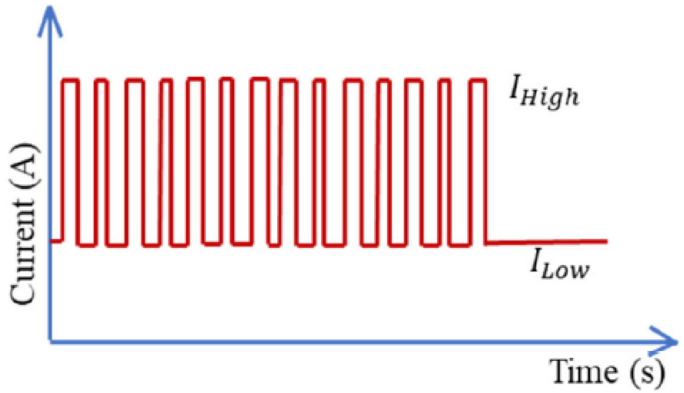
Equal duty protocol



Variable duty protocol



Decaying current protocol



Upper and lower current limit protocol

- PCC protocol:

Pros:

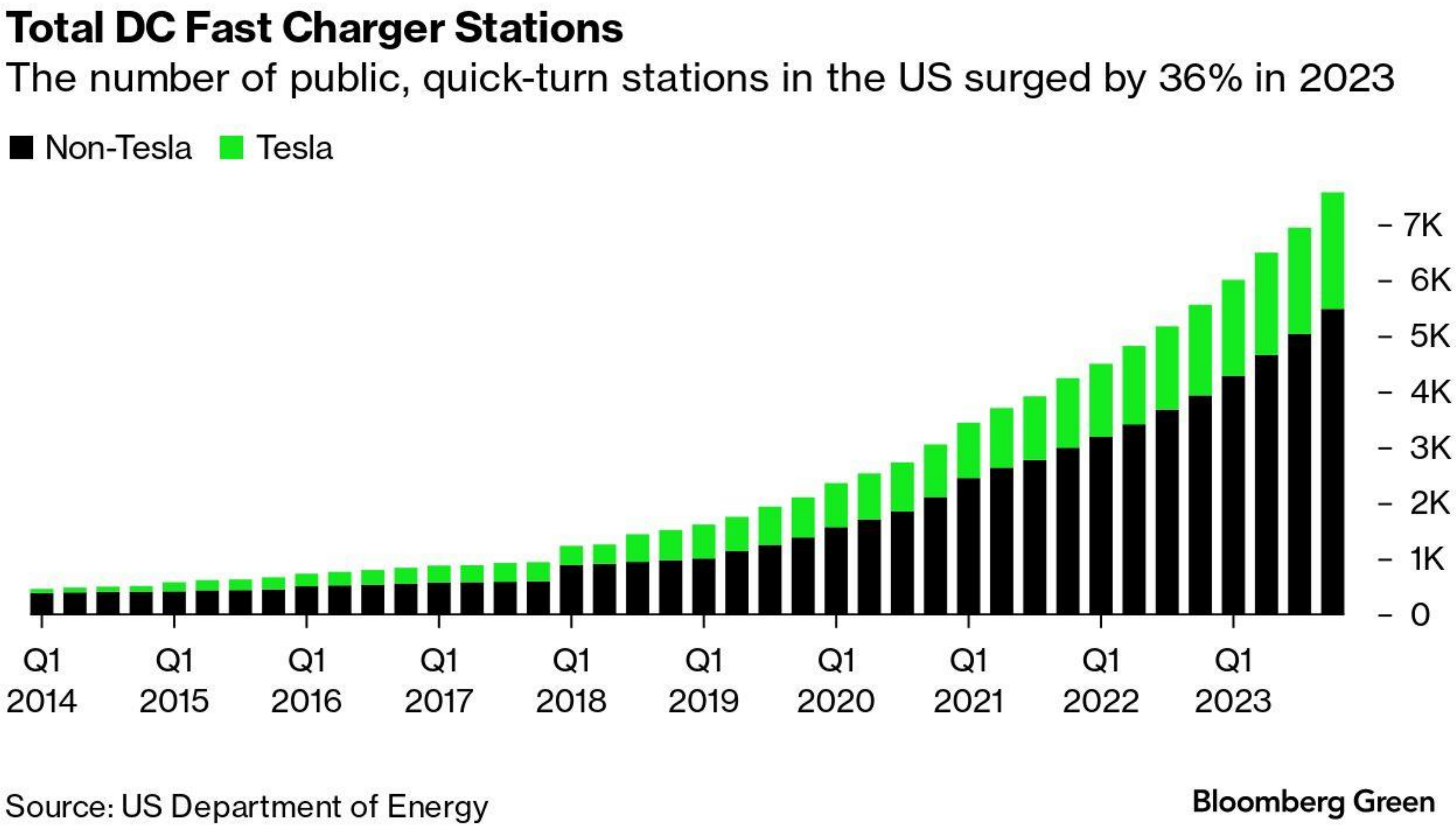
- Rest between current pulses
- Helps in diffusion of ions
- Reduction in diffusion resistance

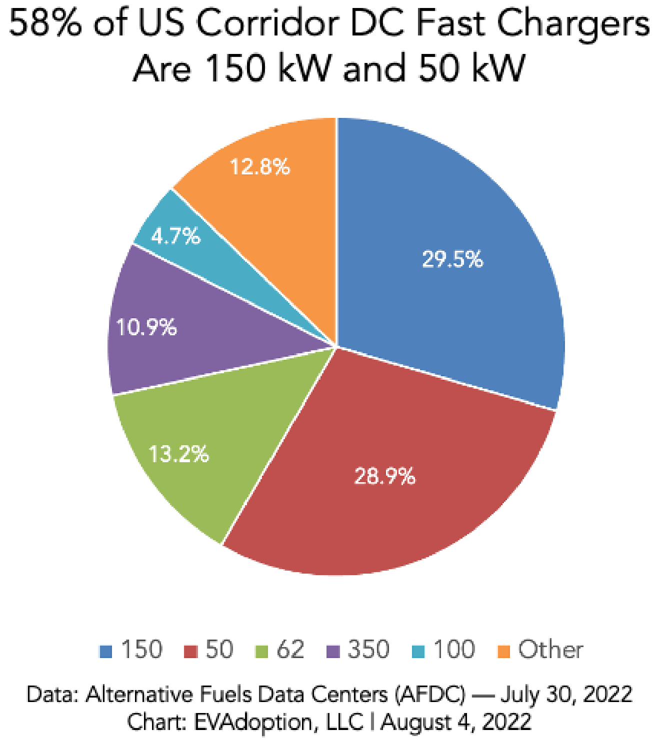
Cons:

- Cost and complexity of charger increases
- Marginal benefits for a large battery pack
- Stress on power grid
- May have adverse impact on battery life

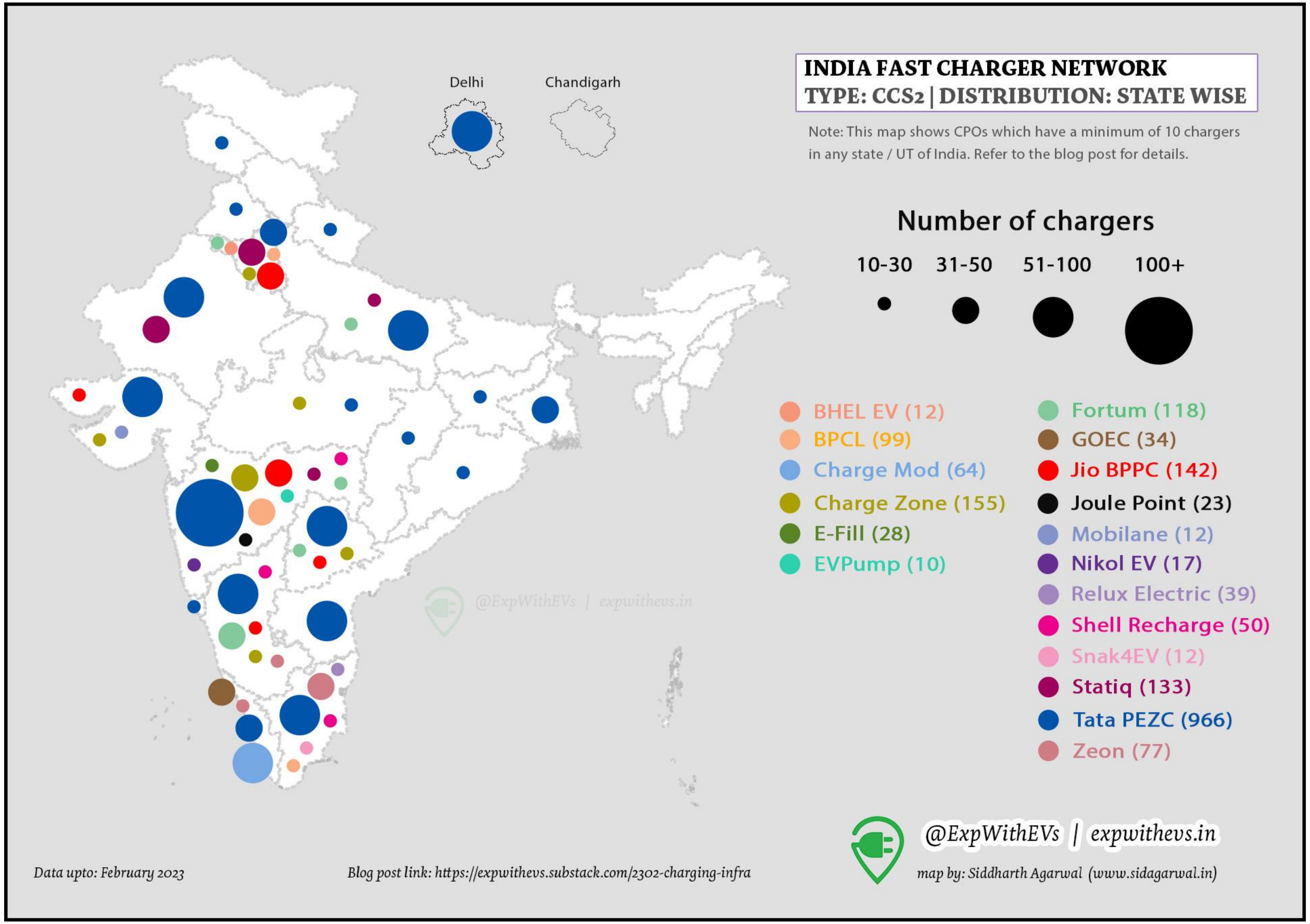
DC fast chargers

DC fast charging in USA

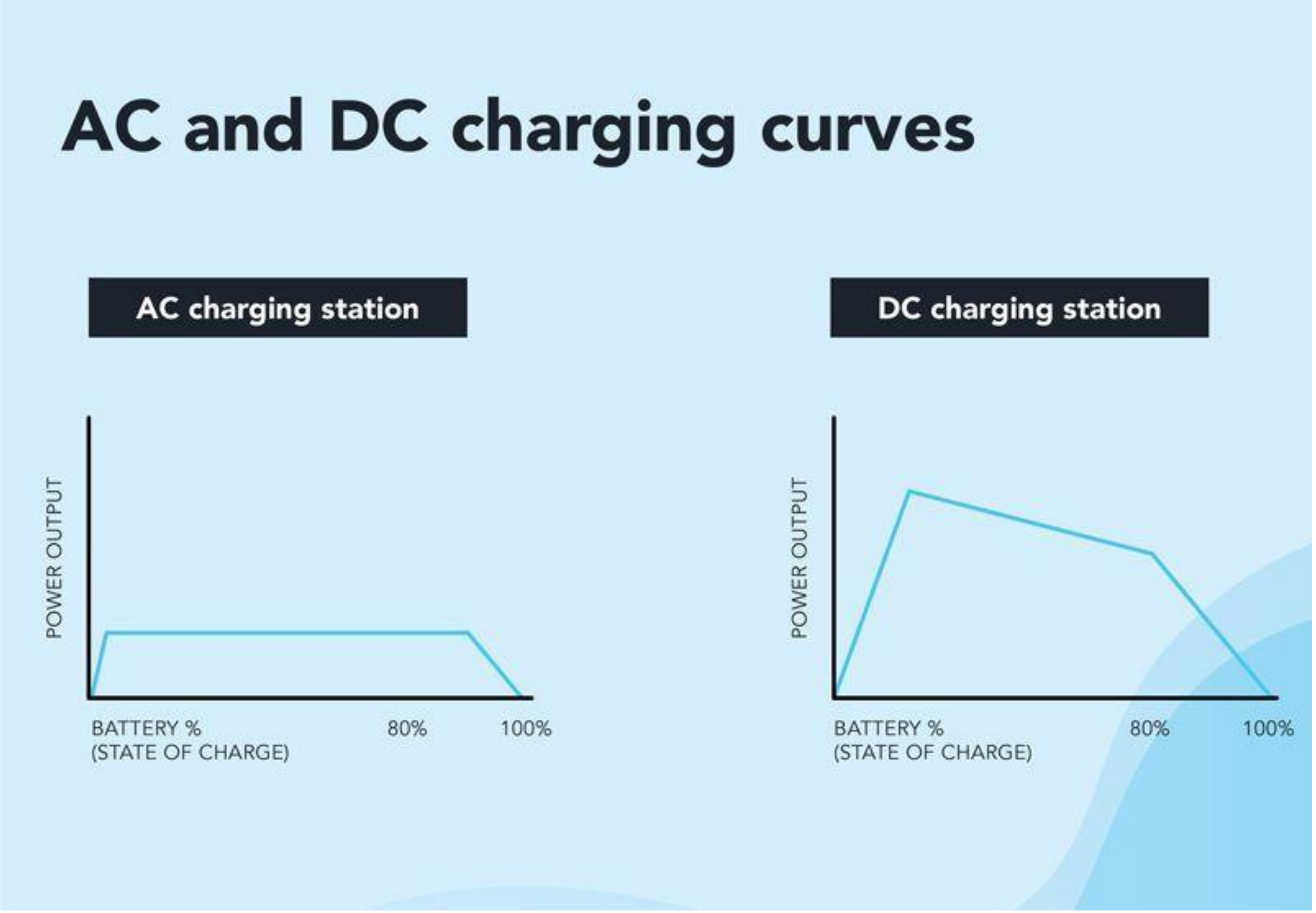




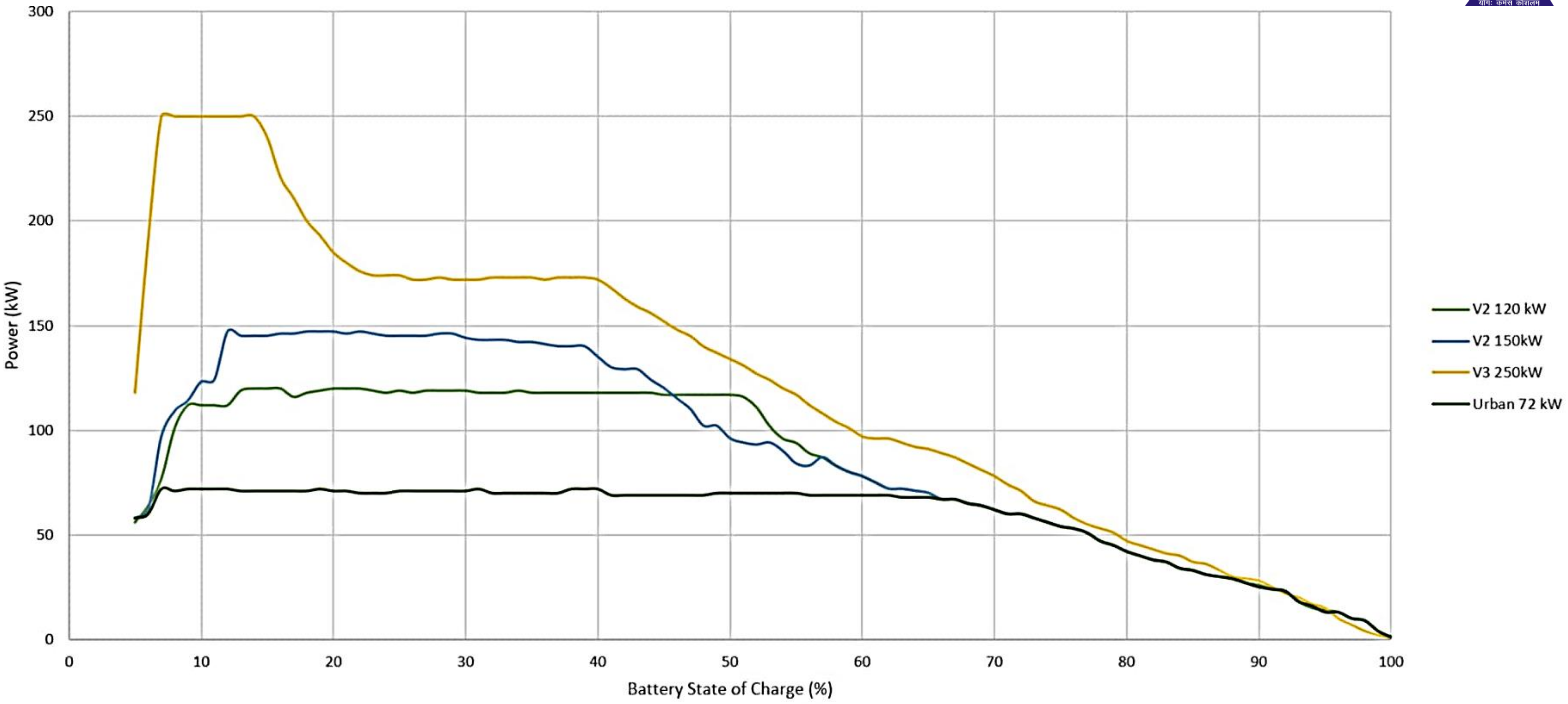
DC fast charging in India



DC fast charging – charging profiles



Performances of Tesla superchargers



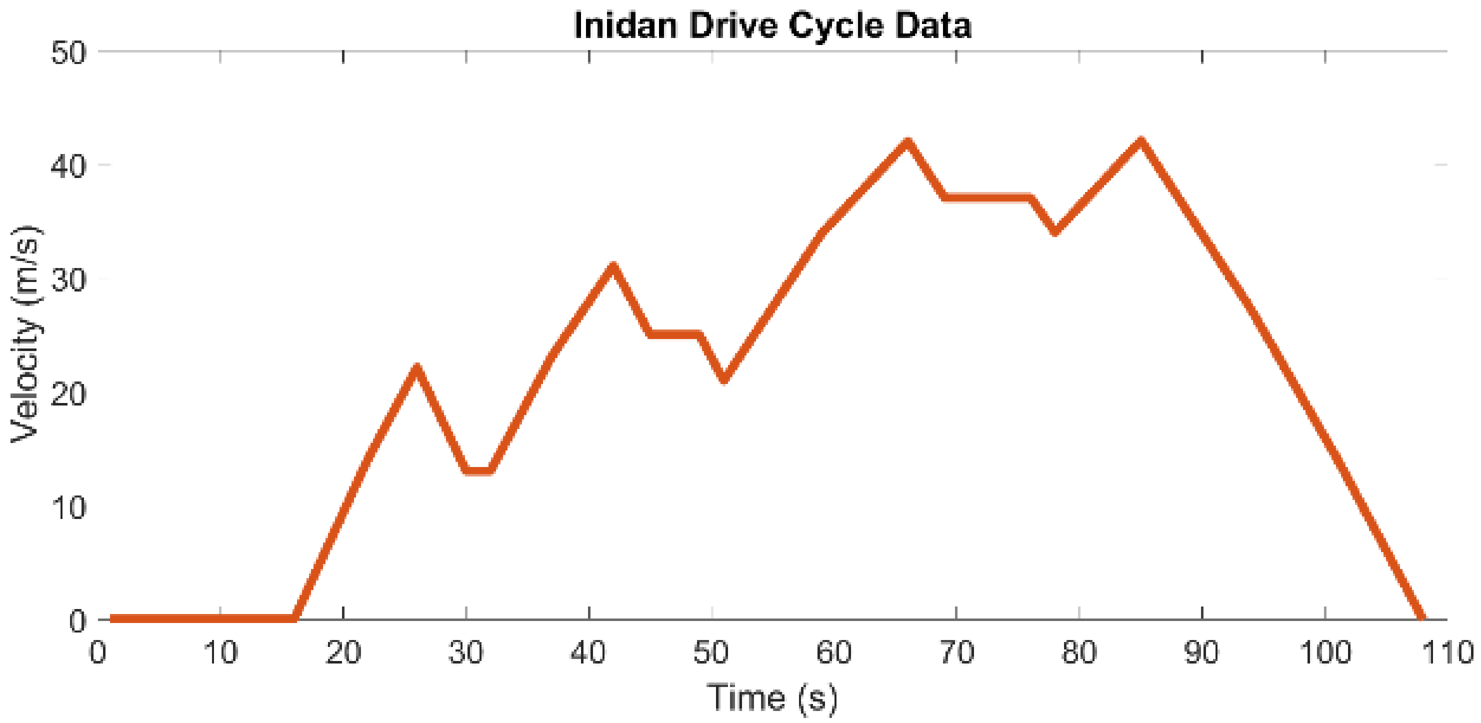
Practice

For Tesla model 3 extended range vehicle, energy stored in battery pack is 82 kWh. Ignoring current and temperature dependance of SOC, find out the followings from the charging current profiles,

- average charging power for each stage
- charging time of each stage
- compare total charging times of different chargers
- plot the charger power rating utilization with time
- calculate and compare average power rating utilizations

Drive cycle to test and certify EV

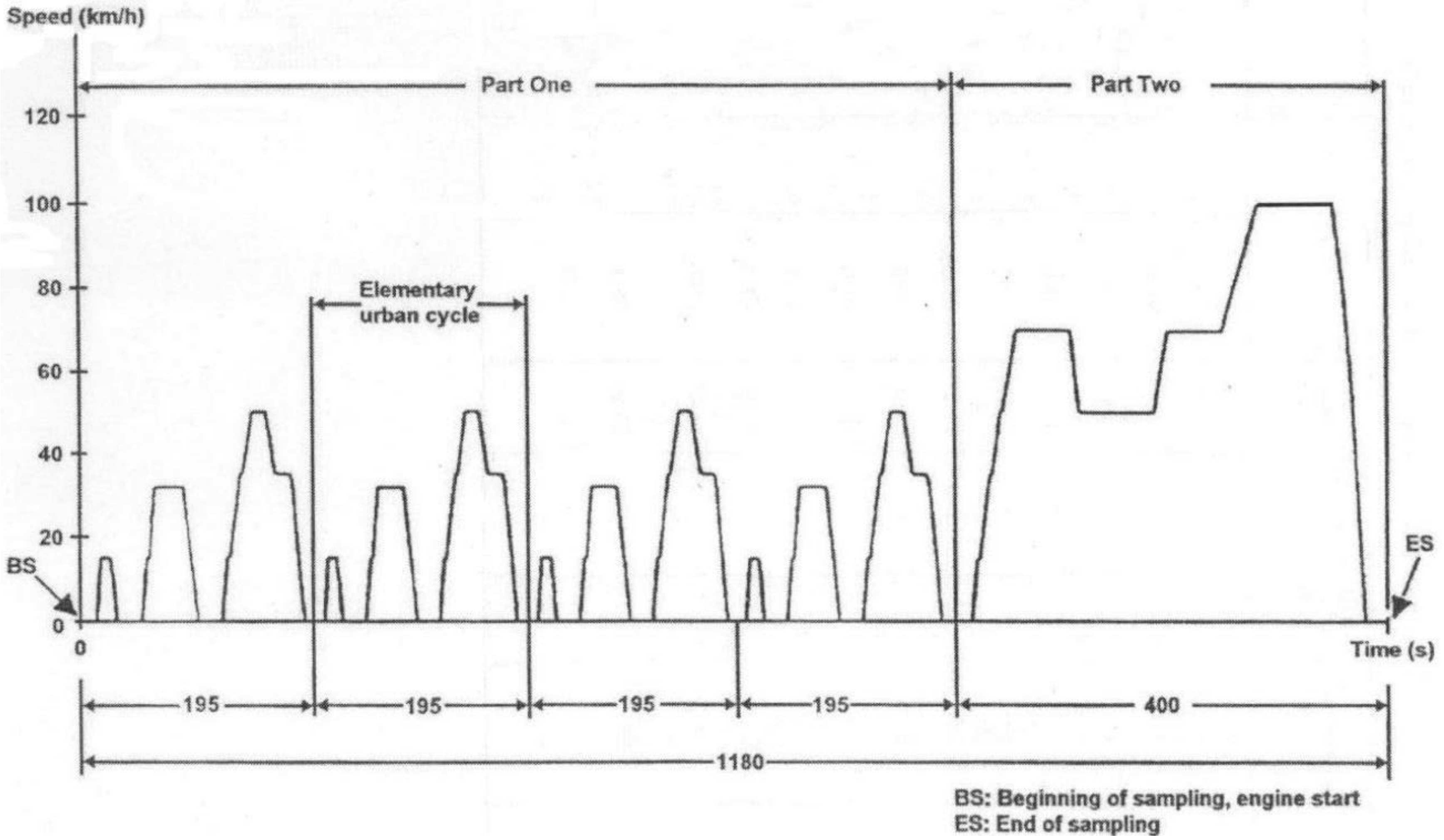
- A standard drive cycle is required to certify the range of vehicle under realistic driving scenario



Indian Driving cycle (IDC)

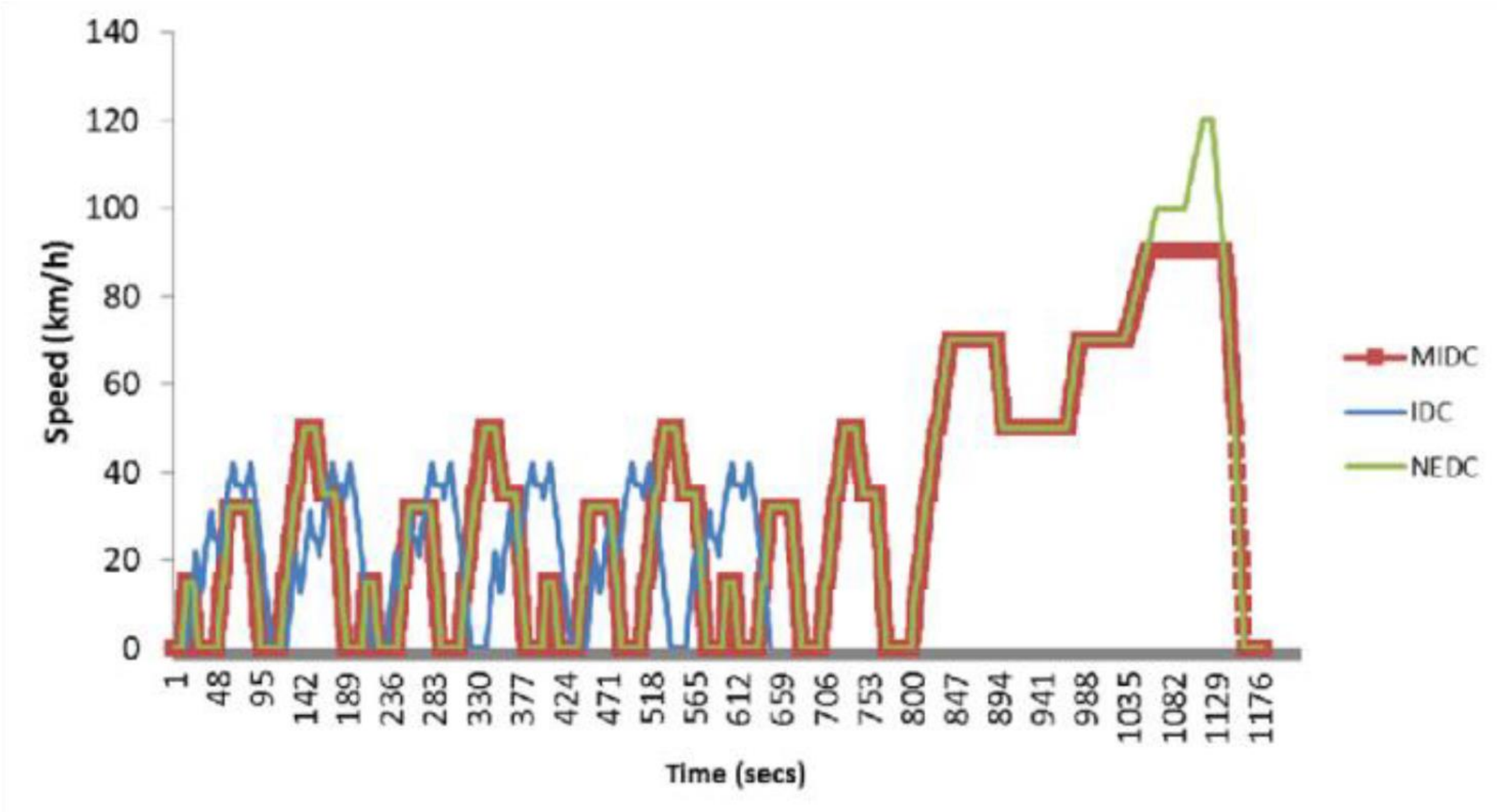
- Indian Driving Cycle (IDC) is developed for Indian city road condition
- Not very realistic
- Average velocity is too high

Modified IDC



- Developed by ARAI to capture more realistic driving pattern
- Two parts
- **Part one:** Urban Driving Cycle (UDC): is for slow city driving
- **Part two:** Extra-Urban Driving Cycle (EUDC): is highway and suburban driving

IDC vs. MIDC



- Modified IDC (MIDC) is almost same as New European Driving Cycle (NEDC)

Practice

A vehicle has following parameter values:

m=692kg, C_D = 0.2, A_F = 2m^2, f_0 = 0.009,

f_s = 1.75*10^{-6} s^2/m^2, ρ = 1.18 kg/m^3, g = 9.81 m/s^2

- Find the required battery capacity (in kWh) to get a range of 100 km under IDC.
- What is the time needed to travel this distance

- Vehicle dynamic equations
  - $m\frac{dV}{dt} = F_{TR} - F_r - F_g - F_w$
  - Required tractive power:

$$F_{TR} = m\frac{dV}{dt} + F_r + F_g + F_w$$

$$F_r = mg\cos\alpha\,(f_0 + f_s V^2)$$

$$F_g = mg\sin\alpha$$

$$F_W = \frac{1}{2}\rho A_f C_D (V - V_w)^2$$

  - Power delivered by vehicle engine = $F_{TR}V$

Thank you!