Vehicle simulation platform for the development and evaluation of advanced energy management functions

Advanced energy management functions

- Or “features”:
  - Smart Fast Charging
  - Eco-Charging
  - Eco-driving
  - Thermal Management

- Work on **different aspects of energy consumption** (driving & charging, behavior & control)

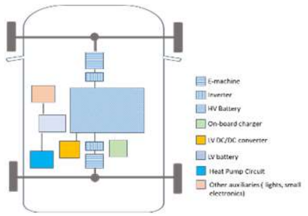
- Make features **co-operate** where possible.

- **Test** features **in simulation prior to demonstrator deployment**

⇒ Need for a simulation platform to develop, integrate and evaluate the CEVOLVER features

Development of the vehicle simulation platform

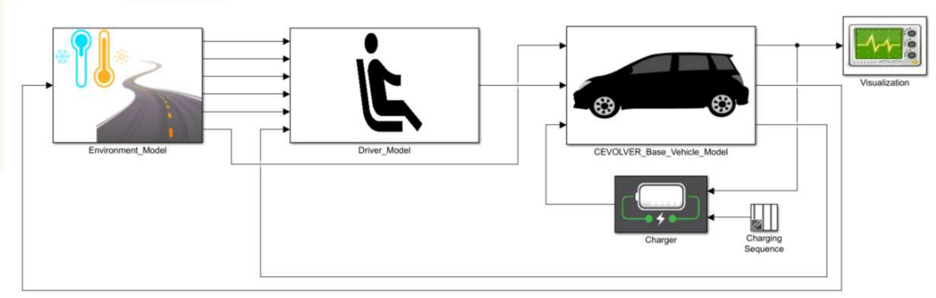
1. Definition of base vehicle model
   a. Definition of drivetrain topologies
   b. Definition of interfaces
   c. Definition of functional requirements

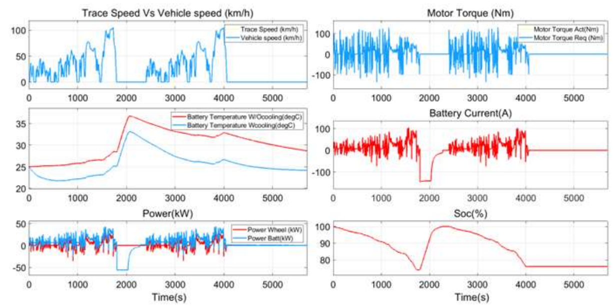


HIFI-ELEMENTS
High Fidelity Electric Modelling and Testing

Role I and Role II A. -Sizing & Features				Demonstrator during operation			
Subsystem	Functional requirement	Lo-Fi	Hi-FI	Demo Ford	Demo Bosch	Demo CRF 1 (Optimus 500e)	Demo CRF 2 (Future 500e)
Battery & BMS							
	Empirical model	X		X		X	X
	Model elektrothermal (semi-empirical)	X	X	X			
	Include thermal model=> thermal model with regards of fast charging required! If relevant, losses to ambient taken into account	X	X	X		X	X
	BMS and VCU in communication for safety	X	X	X		X	X
	losses should be considered (Losses depending on different input parameters)	X	X	X	X	X	X
	Includes ageing battery (Simplified e.g. increases internal resistance, SoH)	X		X		X	X
	Battery ageing (be able to represent the effect of fast charge)	X	X	X			
	Protection against short circuit, insulation fault, over						

2. Definition of simulation environment
   a) Matlab Simulink based
   b) Enabling use case simulations
      1. Driving & charging
      2. Environmental conditions





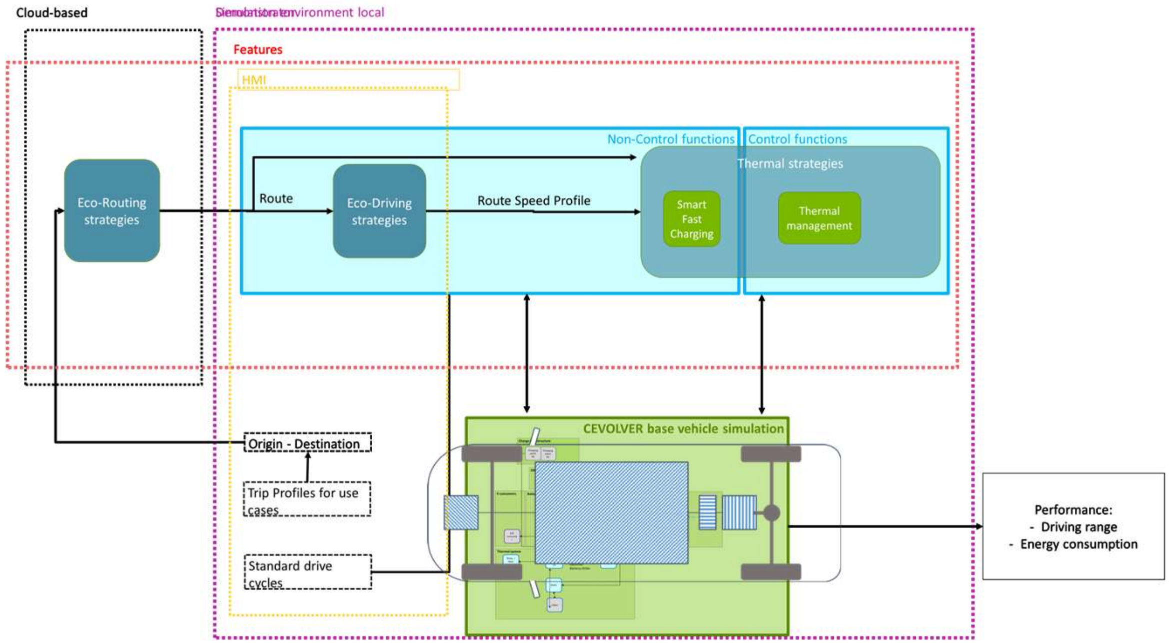
Development of the vehicle simulation platform

3. Understanding the features and their interactions
    - Definition of a functional architecture
    - Definition of control & non-control (advice) features
    - Partitioning features between vehicle (i.e. VCU) and cloud-based

4. Extend platform with connectivity

5. Develop, integrate and test features

6. Implement feature with demonstrator



Smart Fast Charging: the concept

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Define the **cooling** or **heating** strategy such that:

- Given the expected driving profile
- Given the planned charging power
- Given the planned arrival time at charging station
- Given the predicted environmental conditions during driving and at the charging location

- The battery operating boundaries are respected
- The time loss due to charging is minimum (maximum charging power)
- The energy consumption of the of the system is minimal.

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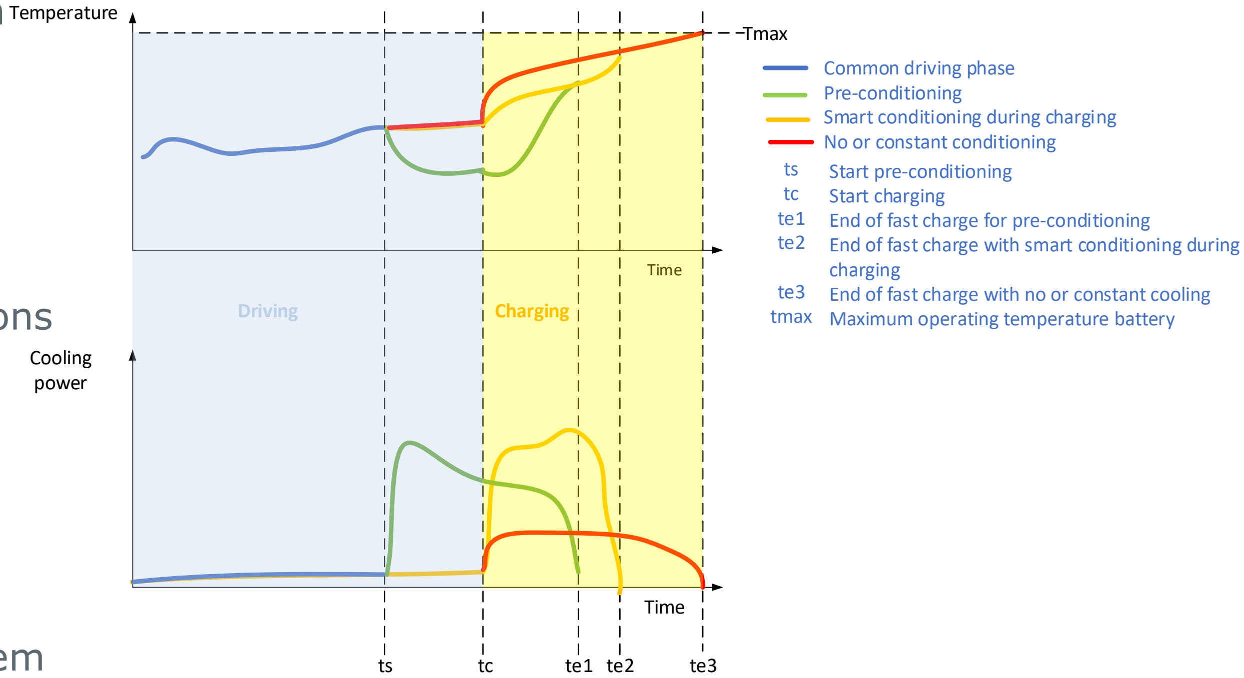
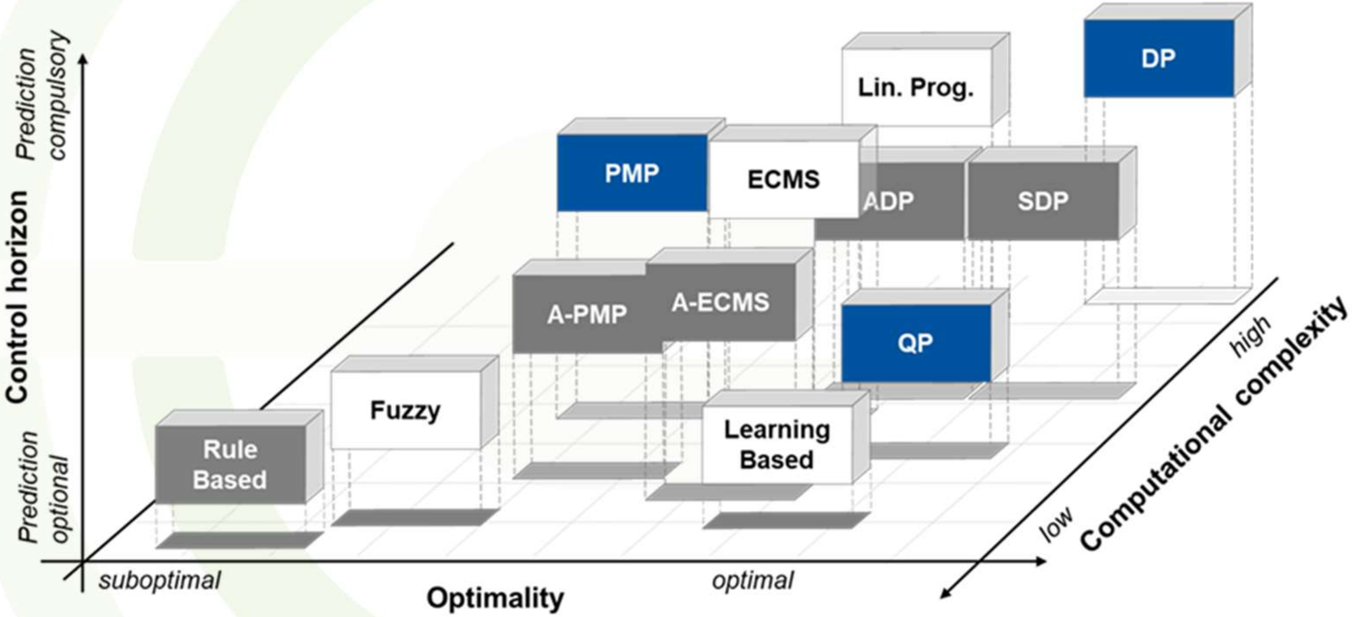


Smart Fast Charging: Methodology

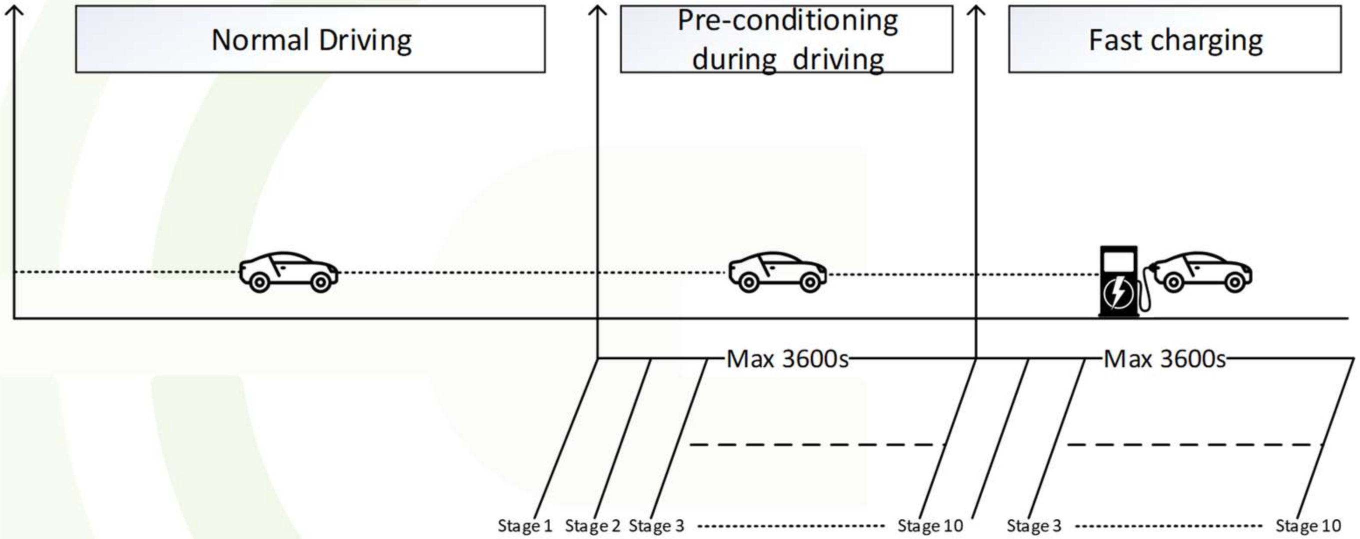


- No availability of (big) testing data =>model based
- Have real-time capable calculation in the VCU
- Use current available model =high fidelity semi-empirical electrothermal battery model

=> Generate solution off-line

=> Use dynamic programming

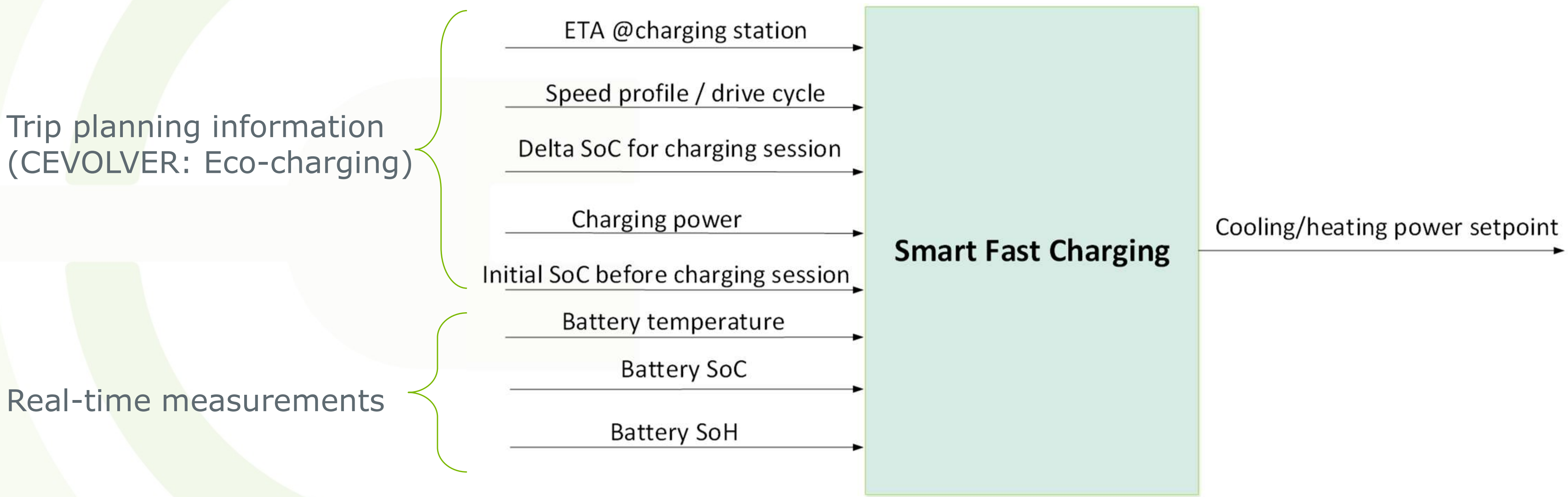
Smart Fast Charging: Methodology



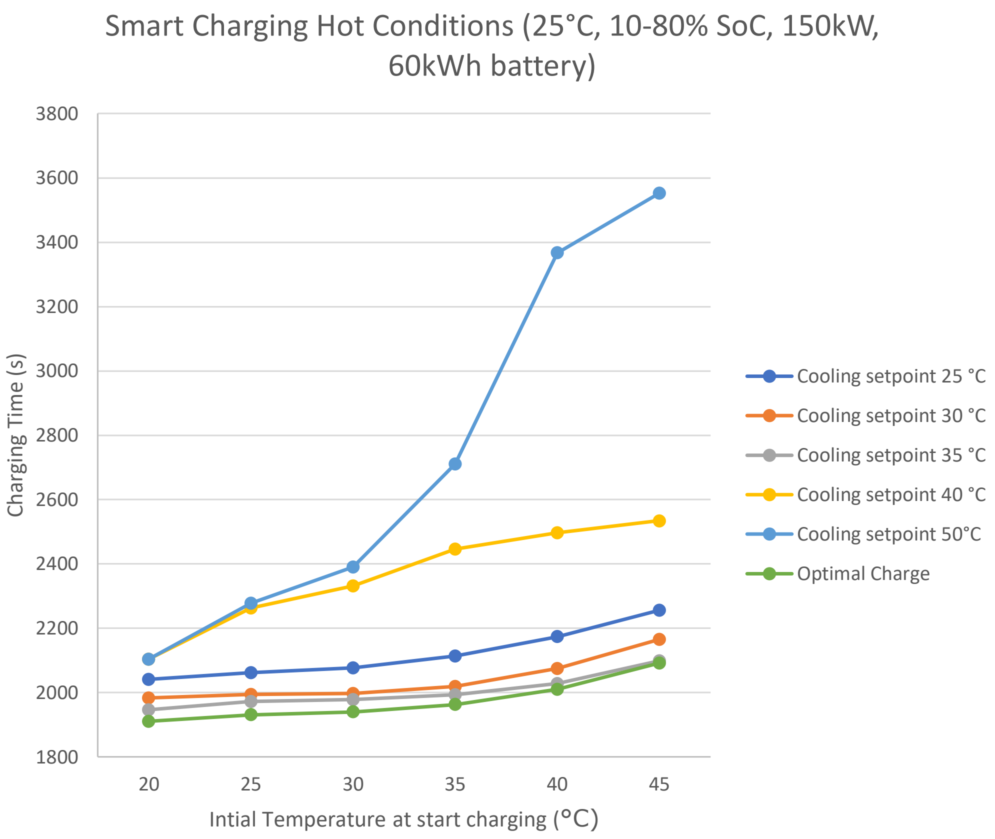
- Each phase split into stages with fixed states
- Offline optimization using Dynamic Programming (DP)

- DP runs simulations through stages with different control settings to find optimal control for states
- Results stored results in multi-dimensional maps

Smart Fast Charging: the function



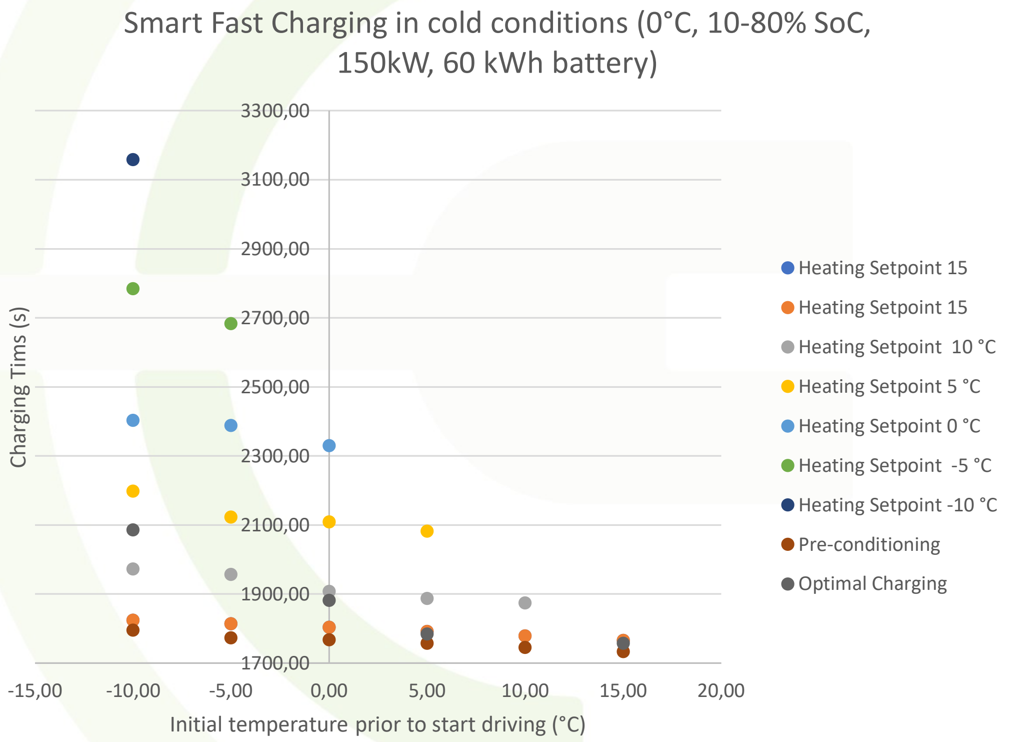
Smart Fast Charging – Simulation results hot conditions



Simulation example for 60kWh battery, 150kW charging, WLTC driving 25 degrees ambient:

- Advantage of Smart Fast Charging dependent on competing control strategy and characteristics of power de-rating during charging
- Optimal charging is very competitive strategy compared to pre-conditioning.
- Pre-conditioning only relevant at higher C-rate or extreme conditions

Smart Fast Charging – Simulation results cold conditions



- Pre-conditioning has significant advantage to only optimal charging unless battery is actively heated during driving to moderate temperatures already

Conclusions

- Knowledge transfer from other European H2020 project (HIFI-ELEMENTS) valuable
- Simulation platform powerful tool for feature development and evaluation
  - To define and finetune functional architectures (with interfaces)
  - To test and calibrate features prior to vehicle deployment
- Smart Fast Charging provides significant time gains in cold conditions and potential for significant time gains in severe hot conditions
- Smart Fast Charging was deployed and tested in demonstrator vehicle and results in line with simulations