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Off-vehicle energy store selection for high rate EV charging station

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ELEVATE – ELEctrochemical Vehicle Advanced Technology (EP/M009394/1)

EPSRC CDT in Energy Storage and its Applications (EP/L016818/1)

EPSRC Centre for Doctoral Training esa in Energy Storage and its Applications

Background to Project

- ELEVATE (ELEctrochemical Vehicle Advanced TEchnology)
  - Technology innovation chain that adopts a material-to-system approach
    - 5 Universities
    - 7 Project partners
- University of Southampton: Optimised Design of High-Rate Grid Interface

Current Fast Charging

- DC fast chargers

	CHAdeMo	GB/T	Combined Charging System	Tesla Supercharger
Chargers currently installed in UK?	✓	×	✓	✓
Defined in IEC 61851-23:2014?	✓	✓	✓	×
Current maximum power	50 kW	50 kW	60 kW	120 kW
Current theoretical power capability	62.5 kW	180 kW	100 kW	145 kW
Vehicle Inlet			 Europe  USA	 Europe  US

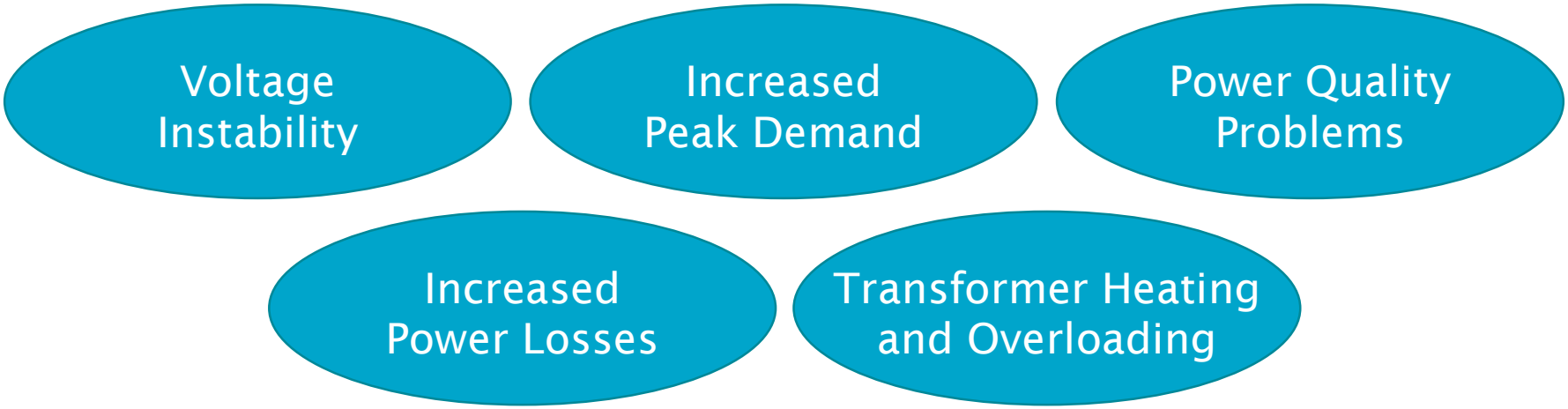
Source: https://www.asa.org.uk/Rulings/Adjudications/2016/7/Tesla-Motors-Ltd/SHP_ADJ_316424.aspx#.WBZODi2LTIU

- 2014 fast chargers installed worldwide:
  - 65% CHAdeMO, 7% CCS, 28% Other

Source: http://press.ihs.com/press-release/automotive/global-ev-charging-stations-skyrocket-2020-ihs-report-says

Future Challenges

- Grid infrastructure challenges

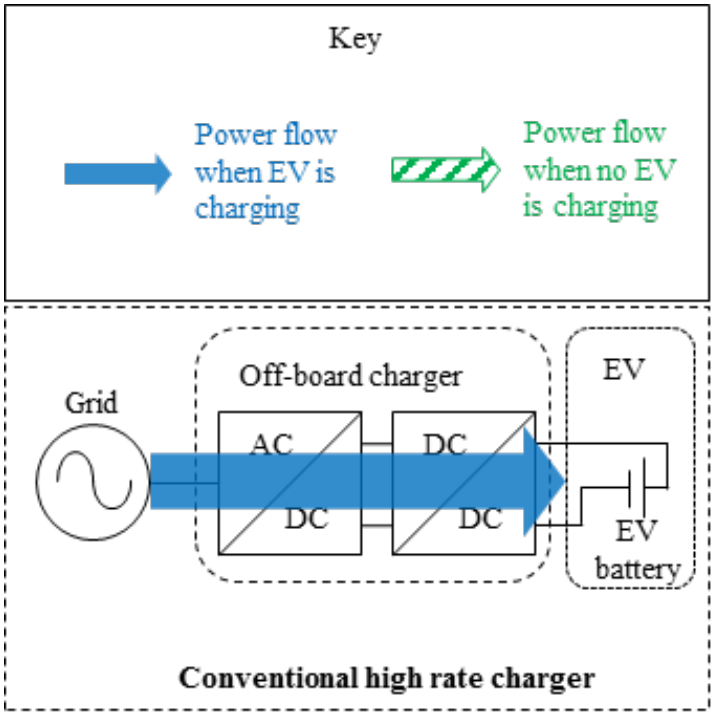


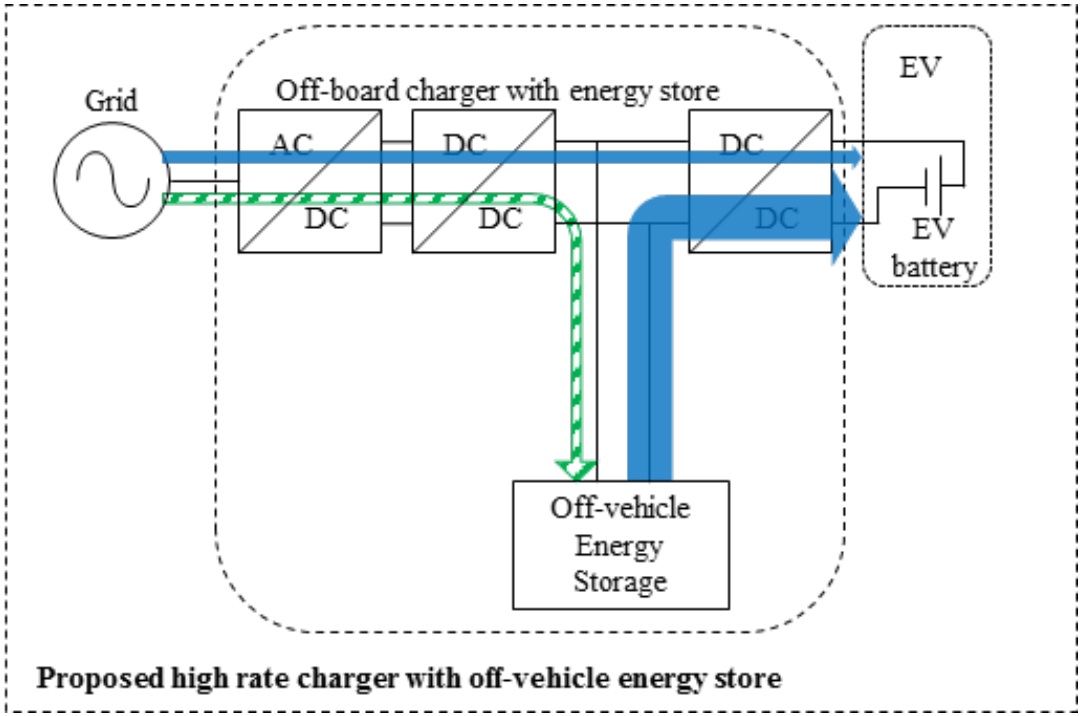
Source: H. Shareef, M. M. Islam, A. Mohamed. "A review of the stage-of-the-art charging technologies, placement methodologies, and impacts of electric vehicles", Renewable and Sustainable Energy Reviews, 64, pp. 403-420, (2016)

- Specific costs:
  - Grid infrastructure upgrade costs
  - Connection charges (p/kVA/day)

Off-Vehicle Energy Store

- Aim to reduce maximum power demand from grid to minimise connection cost





Project Structure

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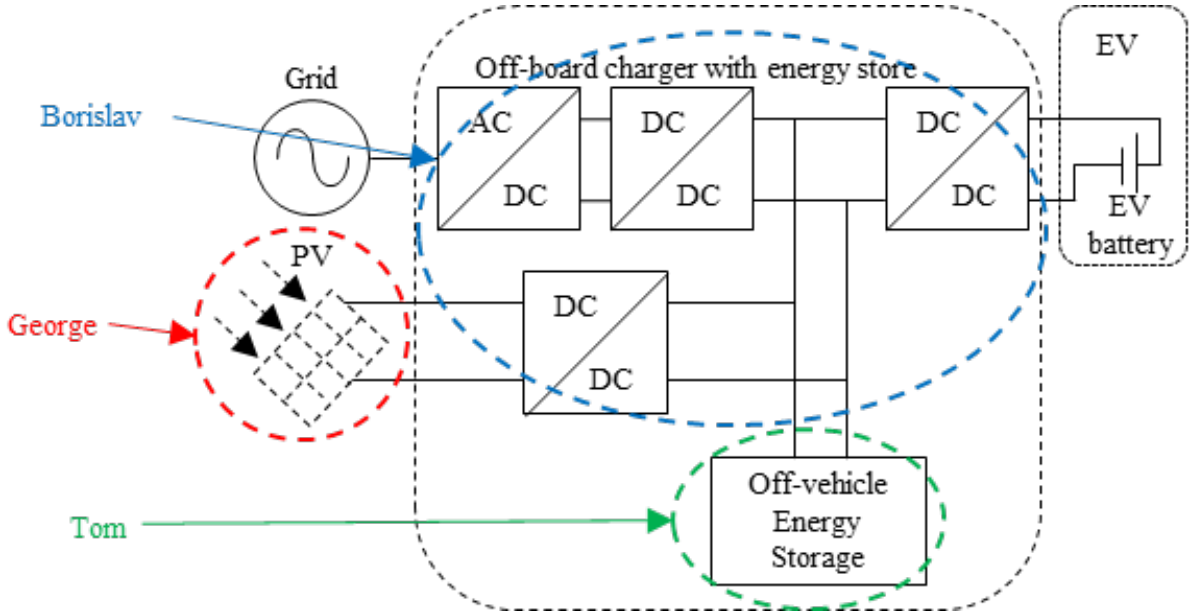
- University of Southampton
  - Research team:



Project Structure

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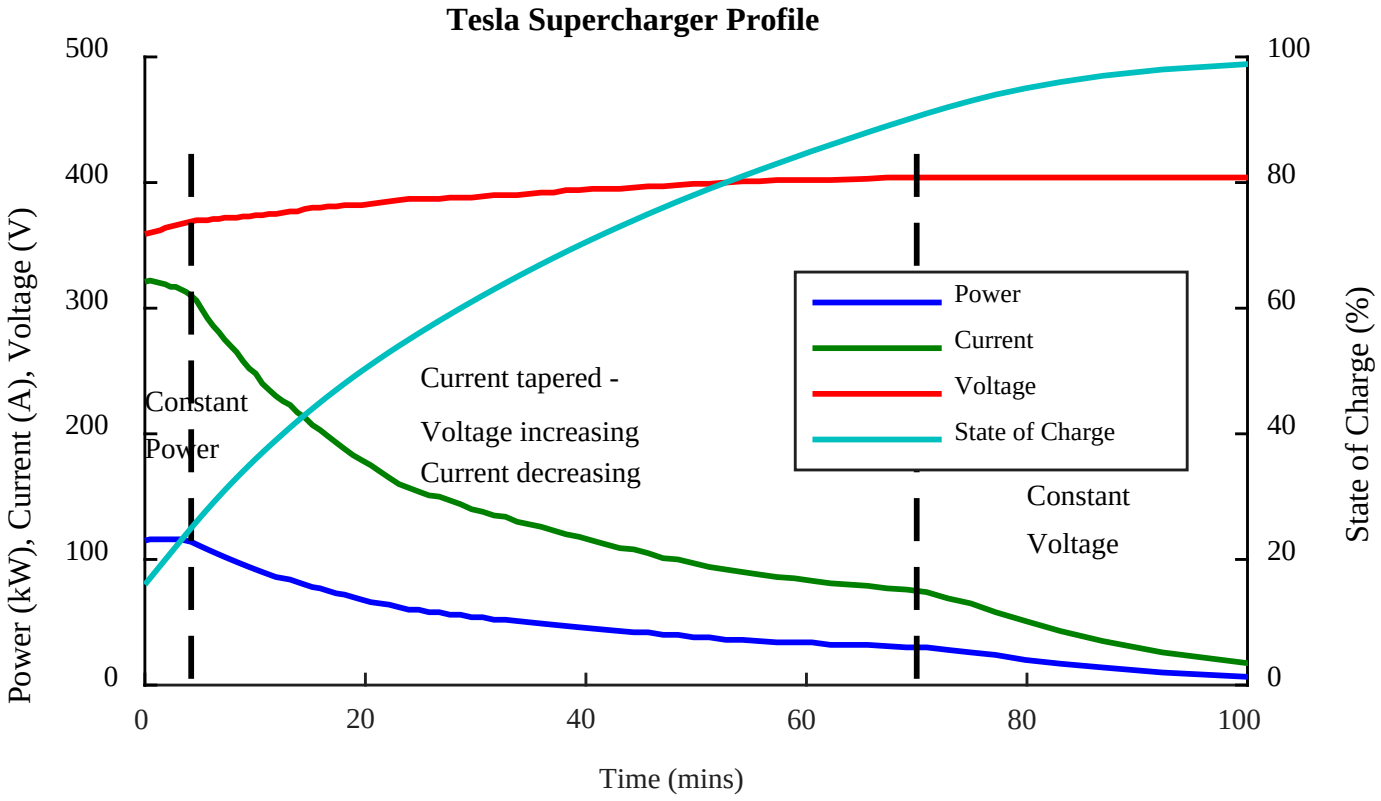
- Future EV fast charging power profile from the grid
- Future usage of fast charging stations
- Grid connection costs
- Capabilities and costs of potential off-vehicle energy stores

Project Structure

- **Future EV fast charging power profile from the grid**
- Future usage of fast charging stations
- Grid connection costs
- **Capabilities and costs of potential off-vehicle energy stores**

Future fast charging power profile

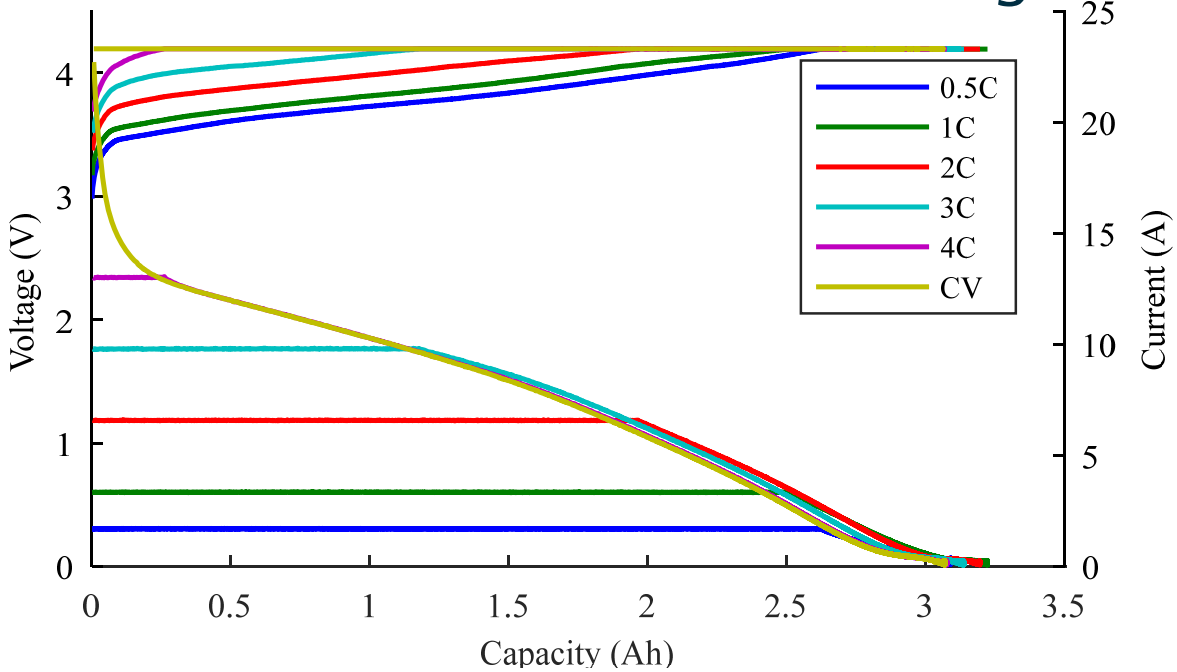
- Current fast charging power profile

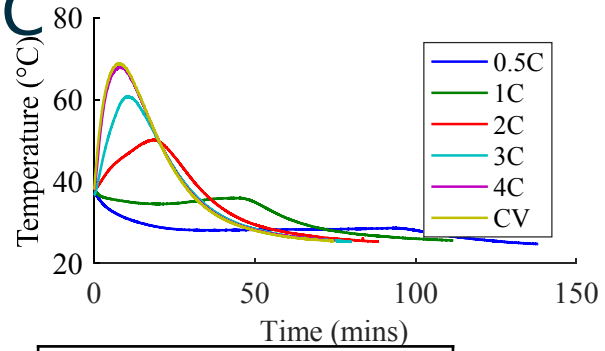


Source: https://teslamotorsclub.com/tmc/

Future fast charging power profile

- Future fast charging power profile
  - Taking a Lithium ion (3.35Ah, Nickel Cobalt Aluminium) battery to its limits
    - Manufacturer max charge: 0.5C

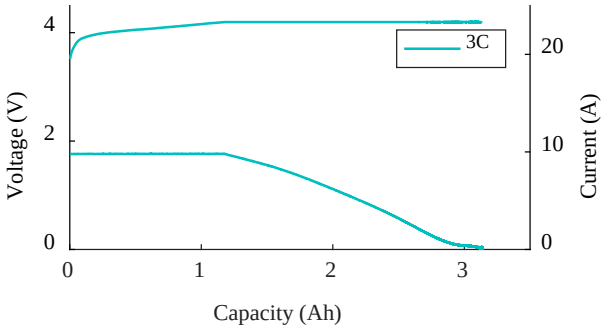




Time to 80% State of Charge	
0.5C	92 mins
1C	47 mins
2C	26 mins
3C	22 mins
4C	22 mins
CV	22 mins

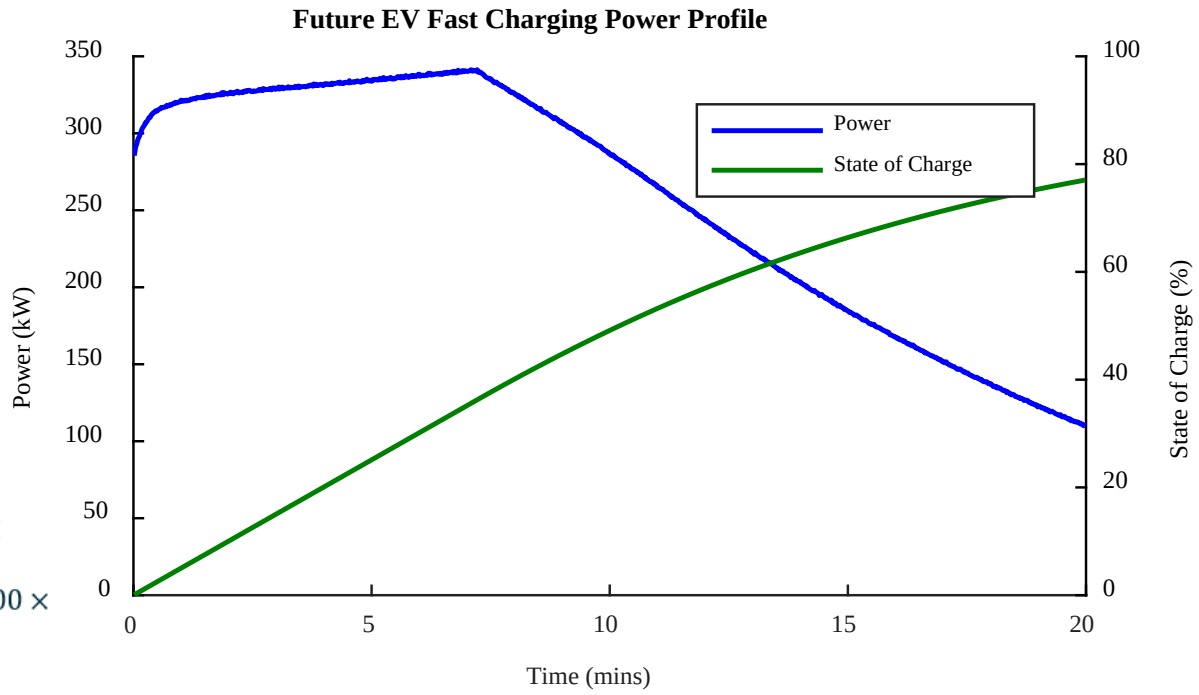
Future fast charging power profile

- Future predicted fast charging power profile
  - Scale fast charging test results
  - Not simply constant power



Scale power from experiments by:

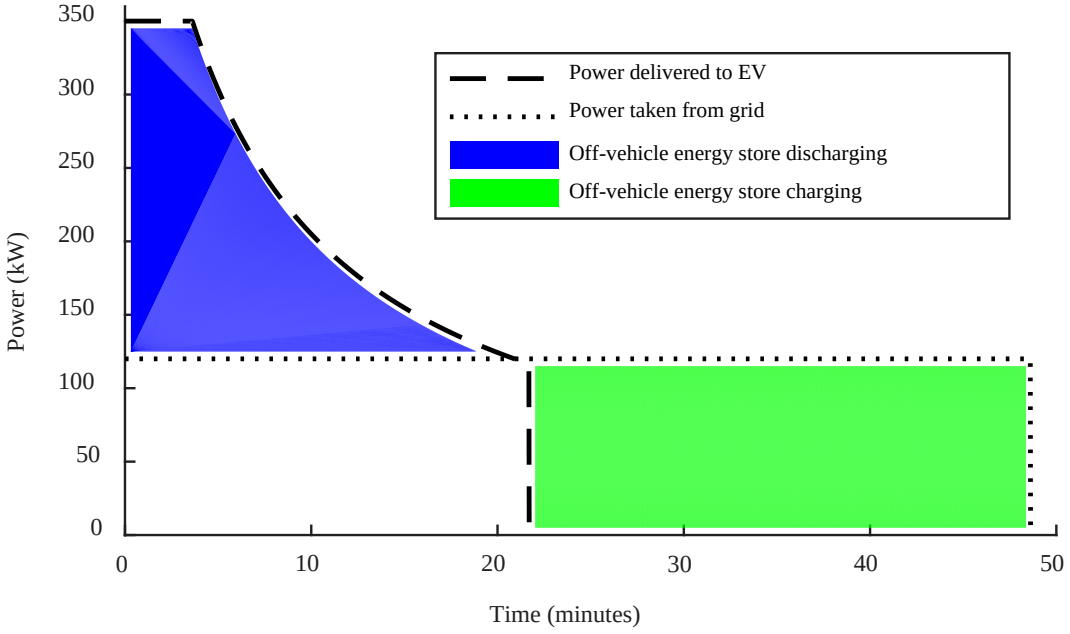
$$\frac{100kWh\ (Assumed\ EV\ battery\ capacity)}{12Wh\ (Tested\ cell\ capacity)} = 8000\times$$



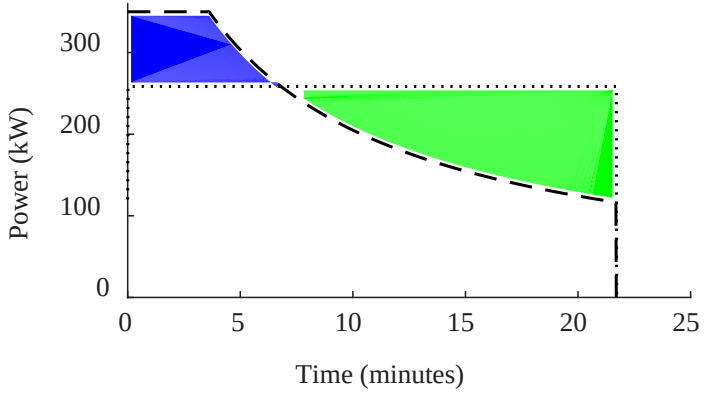
Uses for an off-vehicle energy store

- Recharging the off-vehicle energy store

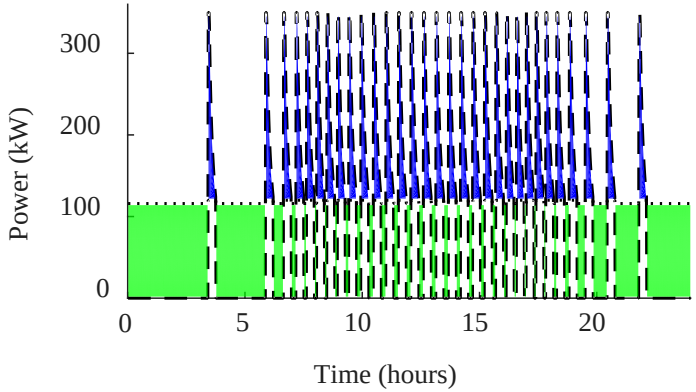
Recharge once the EV has finished charging



Recharge while the EV is charging

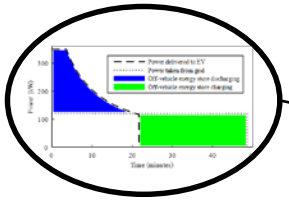


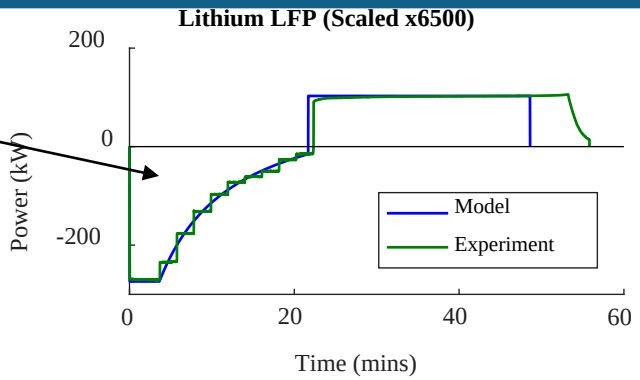
Recharge at night

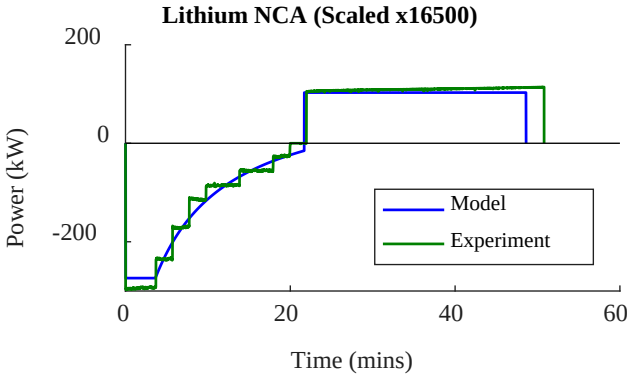


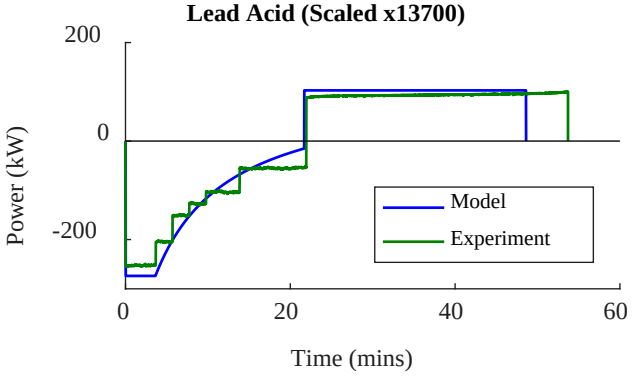
Off-vehicle energy store selection

- Lithium ion
  - Iron Phosphate
    - Design for energy (50kWh)
    - 85% efficient
  - Nickel Cobalt Aluminium
    - Design for power (180kWh)
    - 87% efficient
- Lead Acid
    - Design for power (450kWh)
    - 93% efficient









Conclusions and Further Work

- Conclusions
  - The use of off-vehicle energy stores at fast charging stations will depend on location
  - Future fast charging power profiles will not simply be constant power
  - Lithium-ion iron phosphate batteries
    - Good rate capability, high cycle life
- Further Work
  - Take potential energy stores to their charge and discharge limits