EMR-Based Simulation of EV Charging in Cold Conditions

Swapnil REVANKAR, Prof. Alain BOUSCAYROL[1], Dr. Ronan GERMAN[1]
Prof. Loïc BOULON [2], Prof. Audrey GROLEAU [2]

L2EP, University of Lille, France[1]
IRH, Université du Québec à Trois-Rivières, Canada[2]

« Context and Objective »

General Limitations of EV

Limited driving range

Long charging time

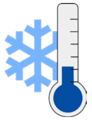
Battery ageing

Specific Limitations of EV

Low / high temperatures

Insufficient driving range

Longer charging time

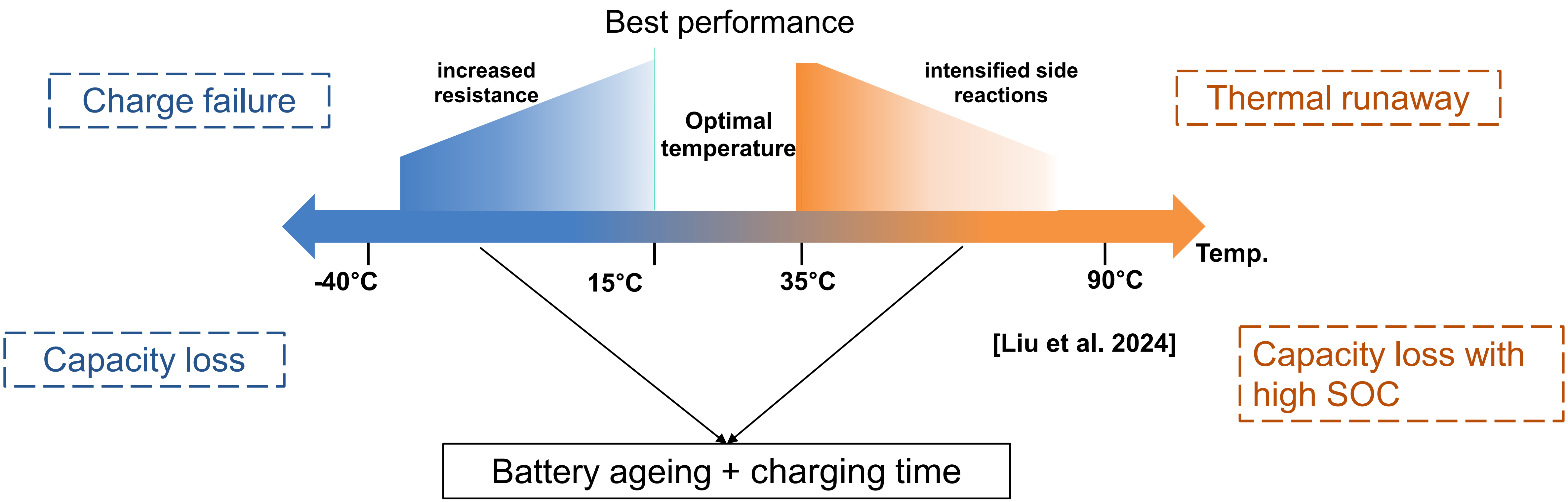


Faster battery ageing

Université de Lille

UQTR Université du Québec à Trois-Rivières

- Impact of Temperature on EV Battery Charging -

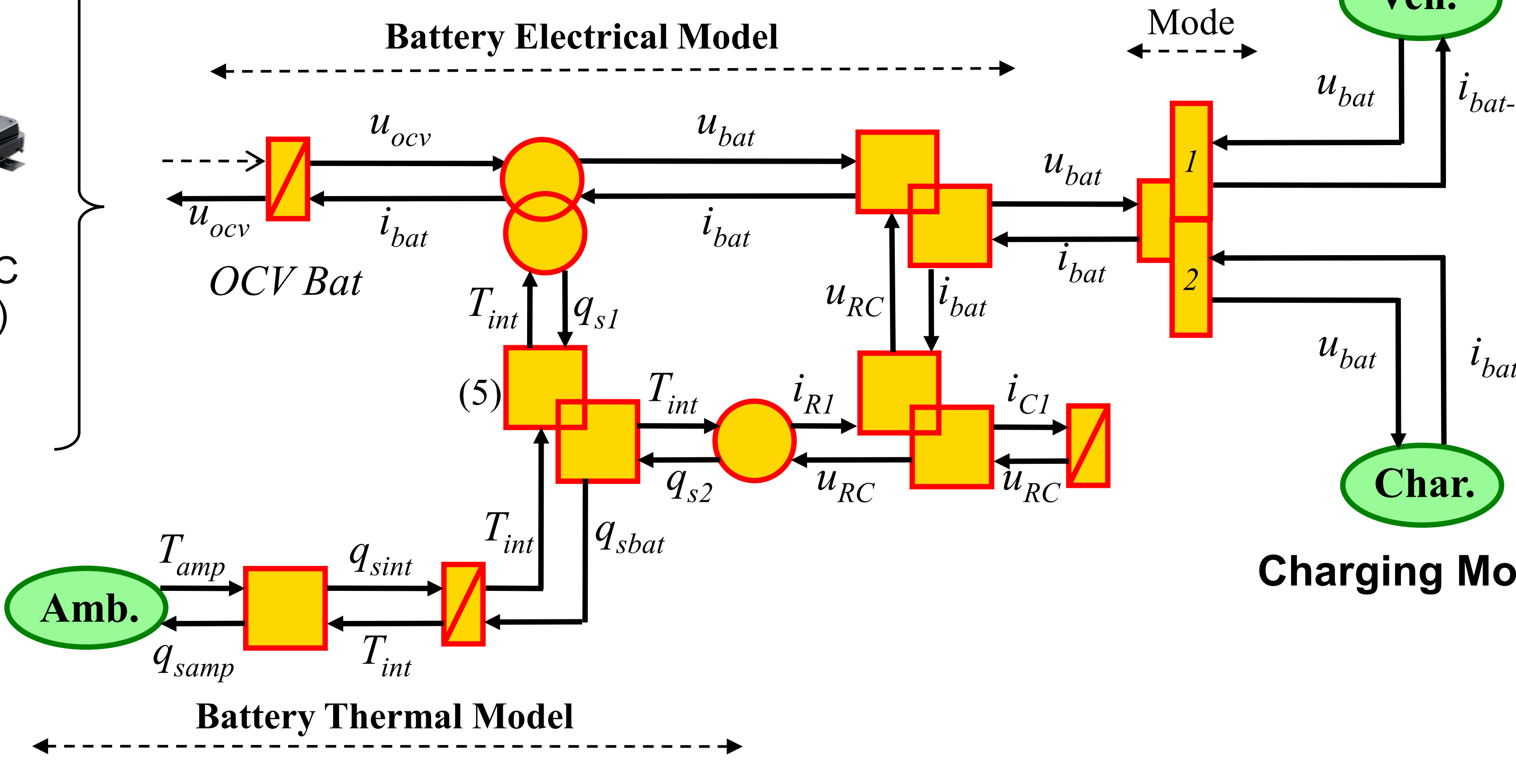


Objective: Studying EV battery charging in various temperatures using Energetic Macroscopic Representation

« EMR and System Modeling »

Modelling of 3 Sub-systems

Envison AESC (Nissan Leaf)



Vehicle Model

Nissan Leaf MY2019

Charging Model

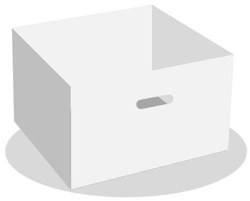
CHAdeMO 63 kW

1.5h to full charge

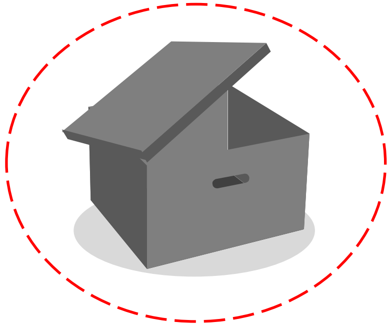
Battery Model

Classification

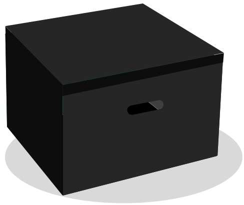
White box:
Detailed physical insight



Grey box:
Moderate physical insight

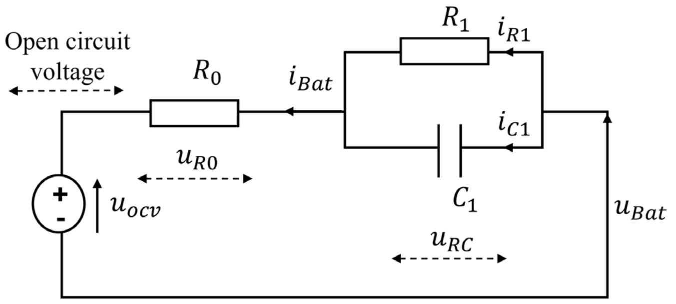


Black box:
Minimal/no physical insight



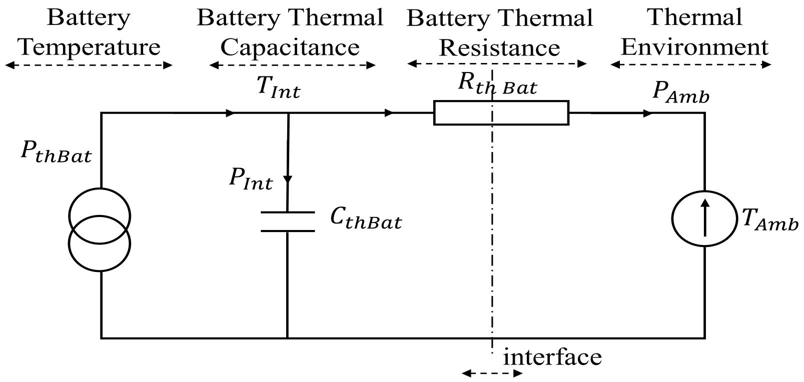
[Guo et al. 2022]

- Battery Electrical Model



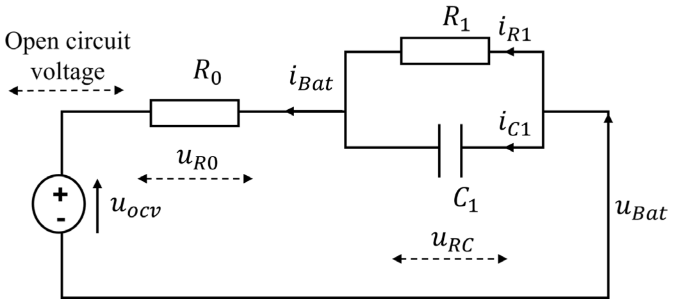
Lumped and simplified model

- Battery Thermal Model



EMR of Battery Electrical Model

1. Structural Representation



2. Equations

$$SoC\,(\%) = SoC_{Bat-Init} - \frac{100}{3600\ C_{Bat}} \int_0^t i_{Bat}\,dt \quad (1)$$
$$u_{R0} = u_{ocv} + i_{Bat} R_0 \quad (2)$$
$$u_{Bat} = u_{R0} + u_{RC} \quad (3)$$
$$i_{C1} = i_{Bat} + i_{R1} \quad (4)$$
$$u_{RC} = \frac{1}{C_1} \int_0^t i_{C1}\,dt \quad (5)$$
$$u_{RC} = i_{R1} R_0 \quad (6)$$

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$$u_{RC} = i_{R1} R_0 \quad (6)$$

(1)

(2)

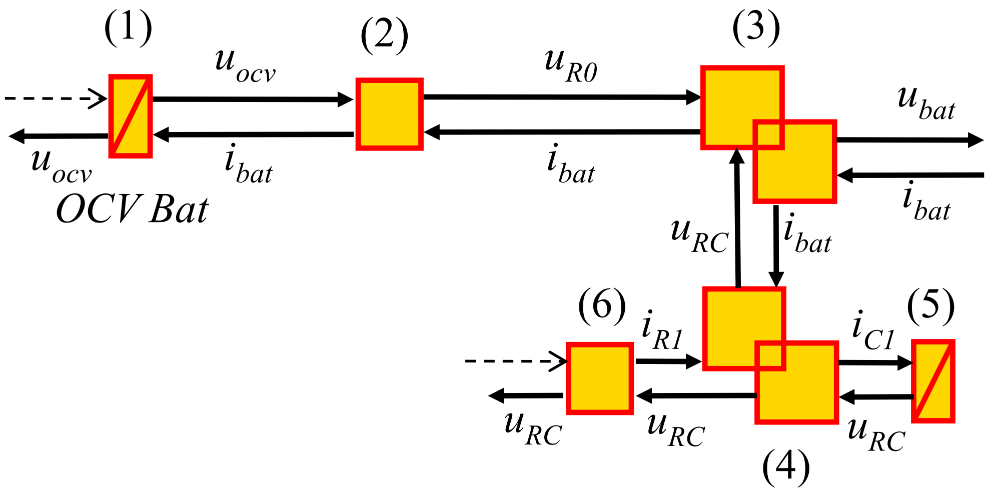
(3)

(4)

(5)

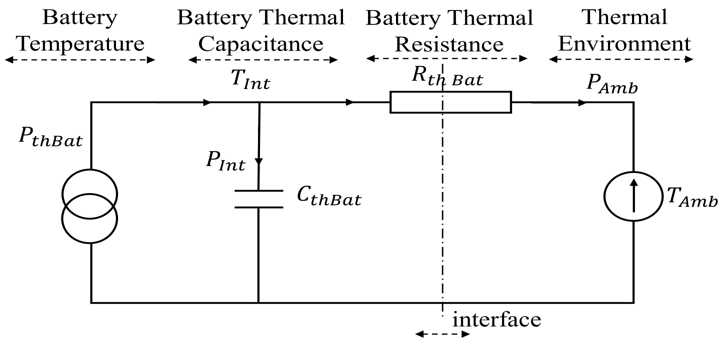
(6)

3. EMR



$SoC_{Bat-Init}$	= Initial SoC of the Battery
C_{Bat}	= Capacity Of Battery in Ah
i_{Bat}	= Battery Current (A)
u_{Bat}	= Equivalent Battery Voltage (V)
u_{ocv}	= Open Circuit Voltage (V)
R_0, R_1	= Series and Parallel Resistance
C_1	= Parallel Capacitance

1. Structural Representation



2. Equations

$$q_{s1} = \frac{R_0 i_{Bat}^2}{T_{Int}} \quad (7)$$

$$q_{s2} = \frac{R_1 i_{R1}^2}{T_{Int}} \quad (8)$$

$$q_{s1} + q_{s2} = q_{sbat} \quad (9)$$

$$T_{Int} = T_{int-Init}\ e^{\frac{1}{C_{thBat}} \int_0^t (q_{sBat} - q_{sInt})\, dt} \quad (10)$$

$$q_{sinr} = \frac{T_{Int} - T_{Amb}}{R_{ThBat}\ T_{Int}} \quad (11)$$

$$q_{sAmb} = \frac{T_{Int} - T_{Amb}}{R_{ThBat}\ T_{Amb}} \quad (12)$$

(7)

(8)

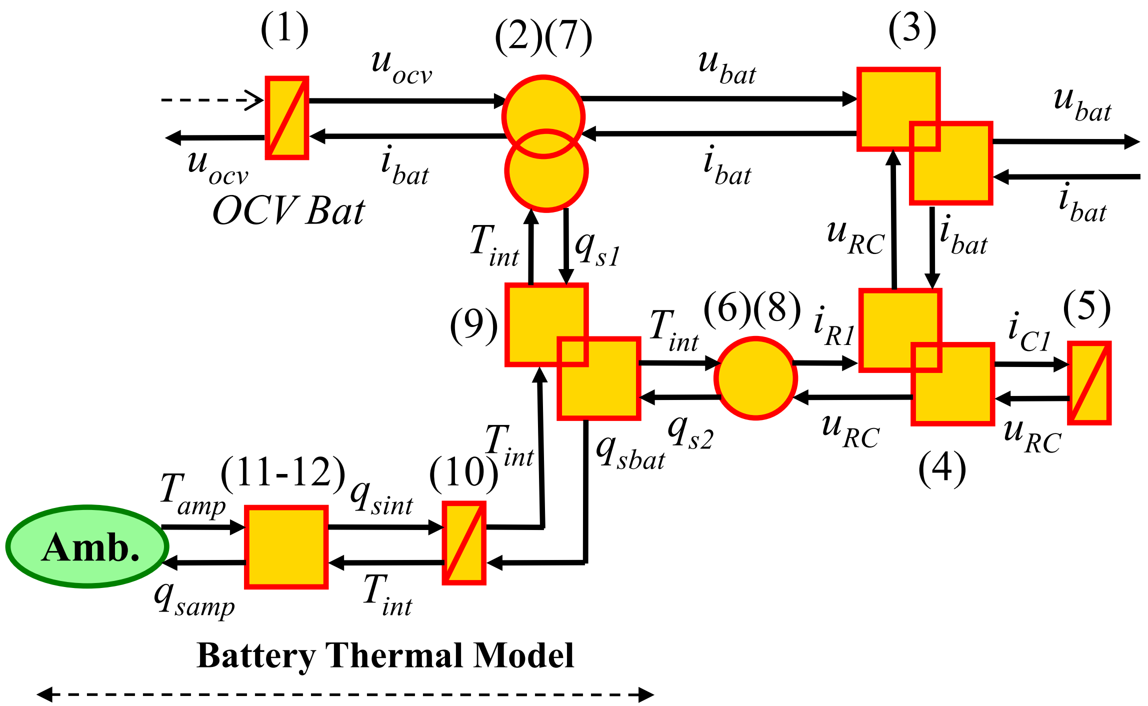
(9)

(10)

(11)

(12)

3. EMR



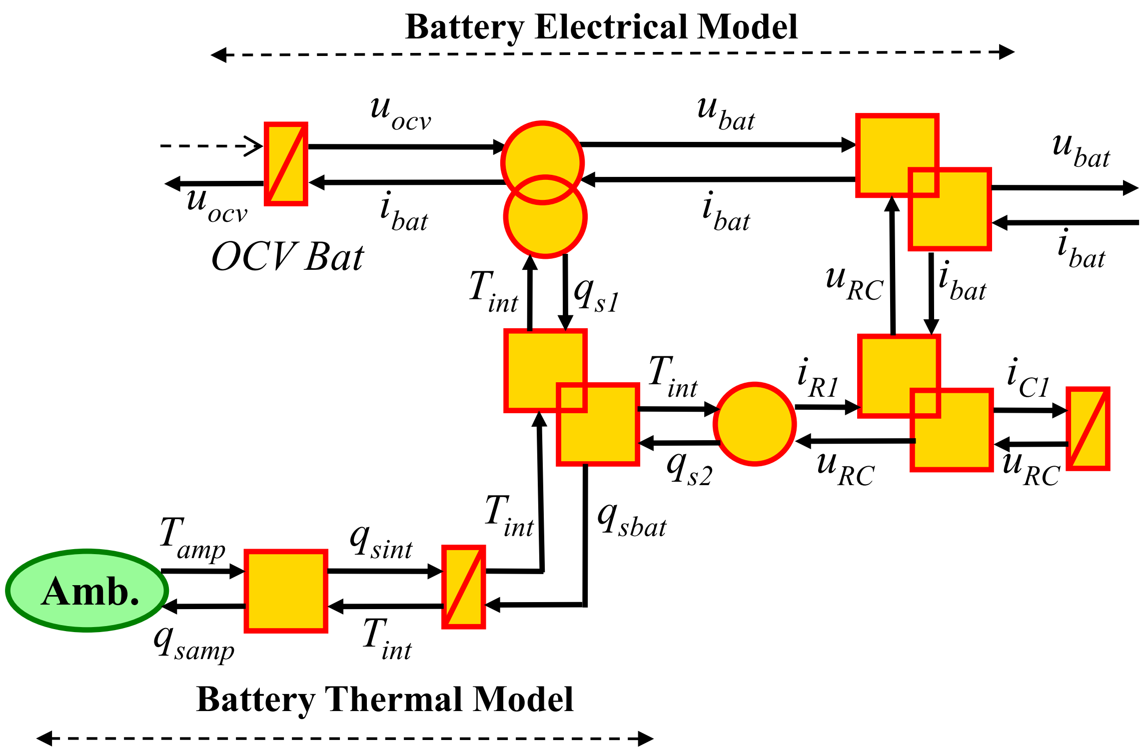
P_{thBat} = $q_s\ T_{Int}$, thermal power in battery

q_s = entropy flow (W/K)

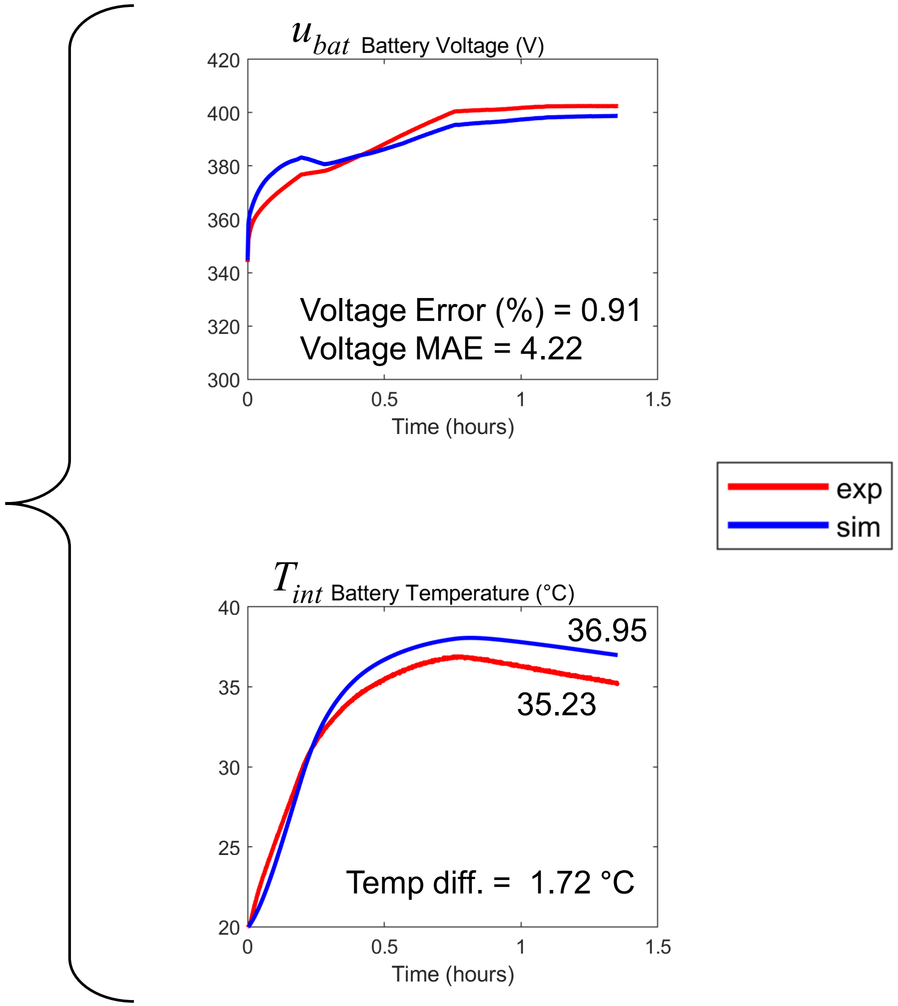
T_{Int} = inner of battery temperature (K)

$T_{int-Init}$ = initial temperature of battery (K)

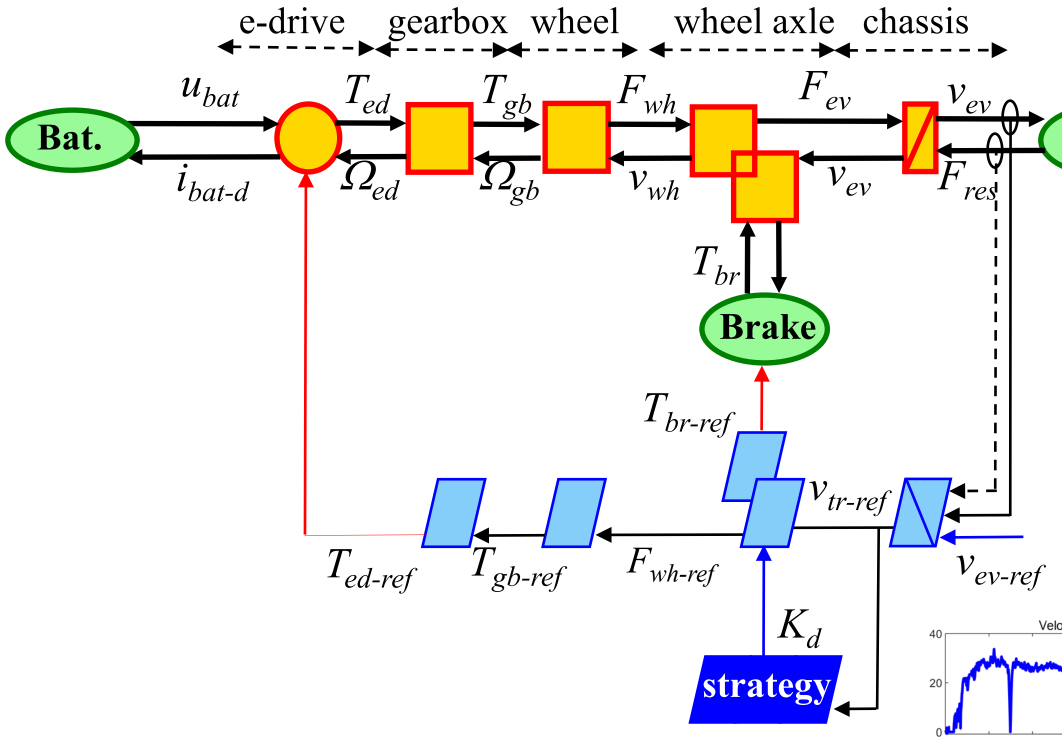
Battery Model Validation

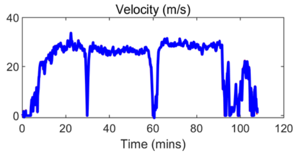


Input Vectors: Battery Current, Ambient Temp



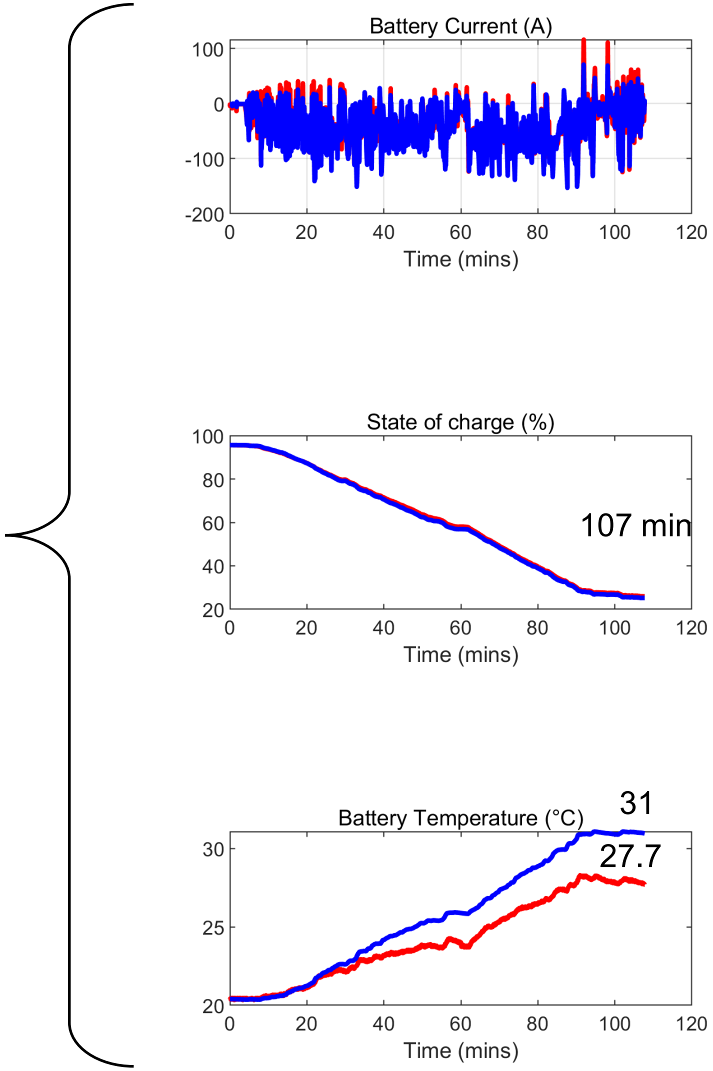
Vehicle Model Validation



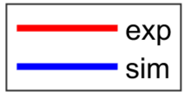


Input Vectors: Driving Profile, Environment Conditions

Highway trip
driving profile



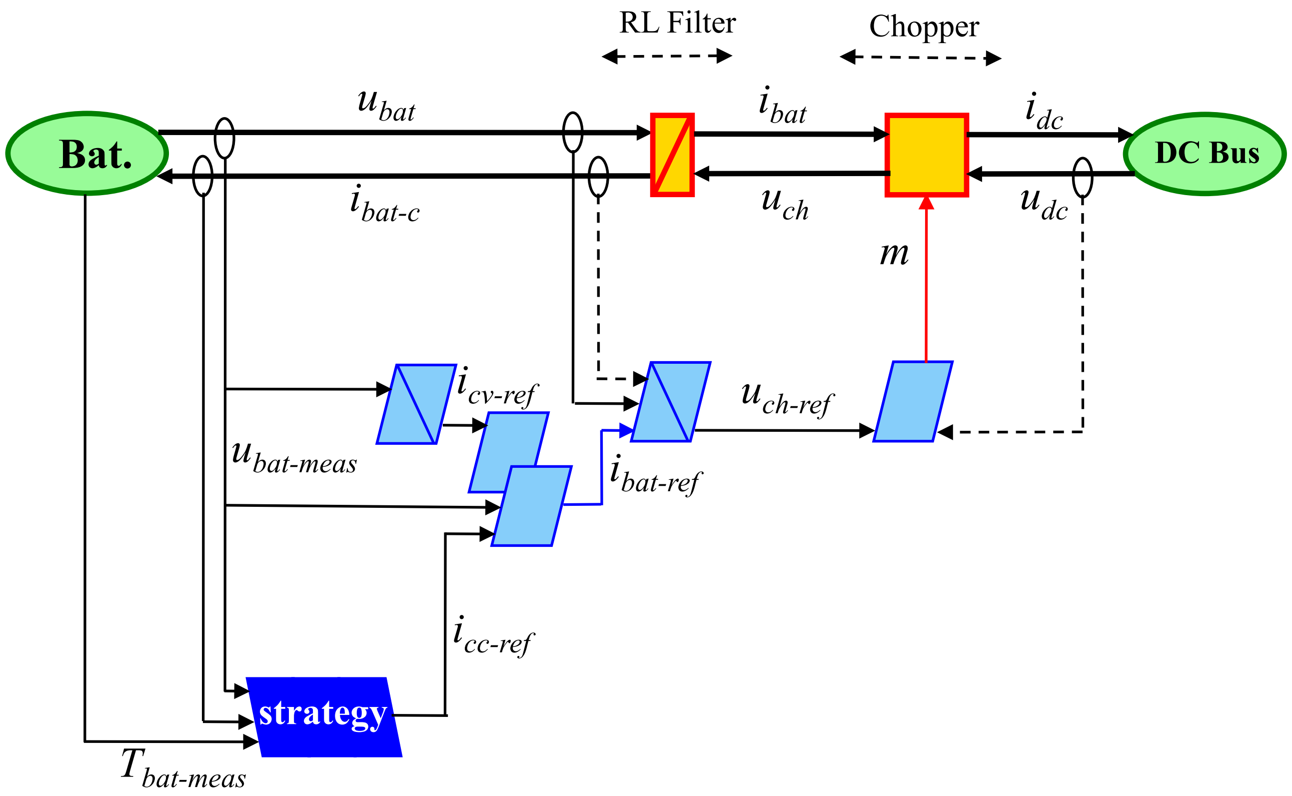
Current MAE = 10.741



SoC Error (%) = 2.7958

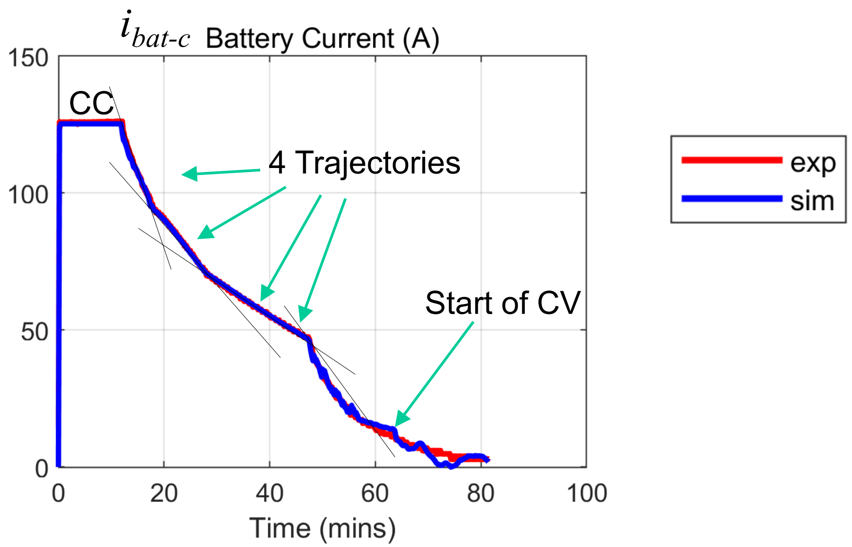
Temp diff. = 3.27 °C

Charging Model Validation



Input Vectors: Battery Voltage, Battery temperature

charging strategy

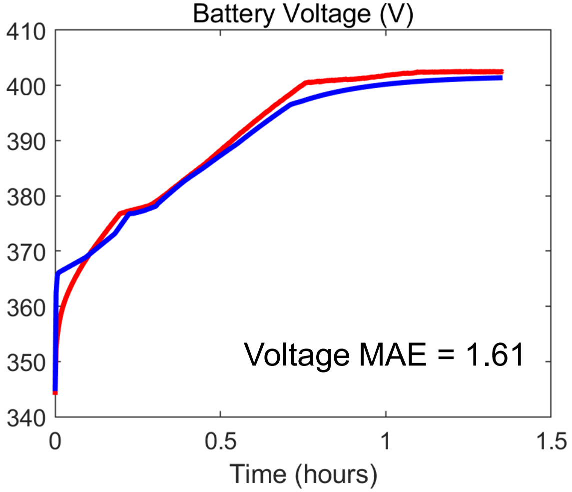


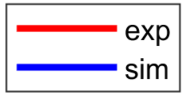
Initial battery temperature = 20°C

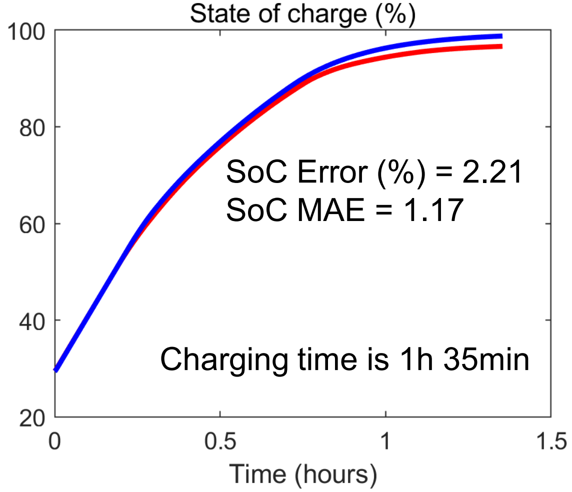
« First Results »

EMR-based simulation of EV charging in cold conditions

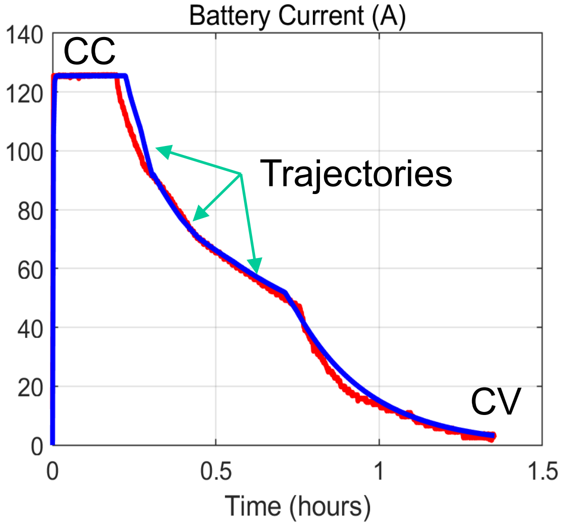
- Simulation vs Experiment -



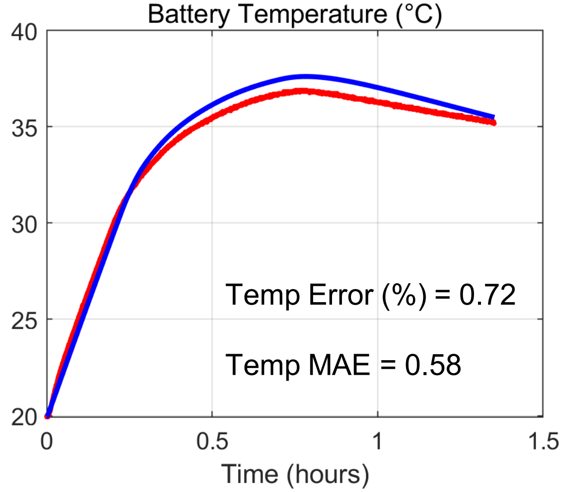


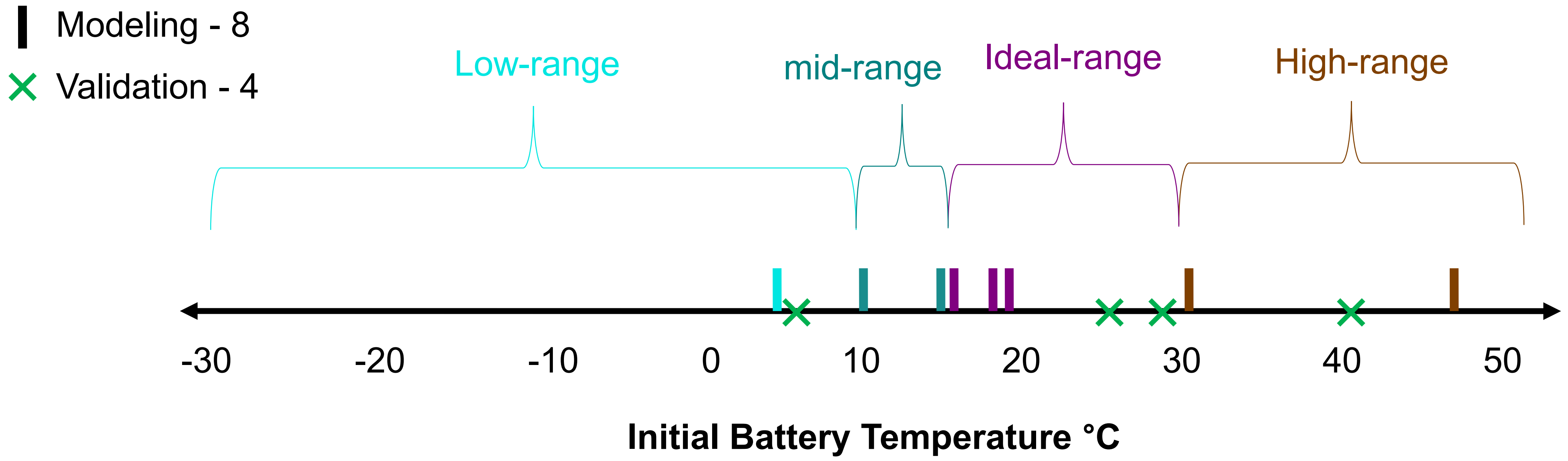


Initial battery temperature = 20°C



CC and CV implemented using switches





Ambient temperature **affects** initial battery temperature but its impact on the charging beyond that is **unknown**.

« CONCLUSION »

Modeling:

1. EMR enabled seamless organisation and interconnection of all subsystems.

1. Multi-physical modelling across electrical, thermal, and mechanical domains.

1. Experimental results confirm the efficiency and relevance of the EMR-based approach.

Perspective

- EMR utilization for modelling and organizing Battery Aging Model
- Validation under extreme temperatures

« Biographies and references »

Mr. Swapnil REVANKAR,
PhD student at University of Lille (France) and Université du Québec à Trois-Rivières (Canada)
Masters in Electrical Engineering at RIT, India
Research topics: EV, EV Charging Infrastructure

swapnil.revankar@univ-lille.fr

Prof. Alain BOUSCAYROL, University of Lille, L2EP,
Head of the Master "Automatic control & Electrical Systems"
Coordinator of the CUMIN interdisciplinary programme
Chair of the steering committee of IEEE-VPP Conference
PhD in Electrical Engineering at University of Toulouse (1995)
Research topics: EMR formalism, HIL testing, control & EV-HEVs

alain.bouscayrol@univ-lille.fr

- Authors -

Prof. Loïc Boulon, Université du Québec à Trois-Rivières, IRH, Canada
Senior Research Chair of Energy Sources for Vehicles of the Future
PhD in Electrical Engineering at University of Franche-Comté, France.
Research topics: EV-HEVs, Fuel Cell Systems, Multiphysics Systems

loic.boulon@uqtr.ca

Prof. Audrey GROLEAU, Université du Québec à Trois-Rivières, Canada
Professor of Science and Technology
Ph.D. in Science Education from Laval University
Research topics: Science and Technology Education, Science Studies

audrey.groleau@uqtr.ca

Dr. Ronan German, University of Lille, L2EP
Associate Professor L2EP Laboratory
Coordinator of the CUMIN interdisciplinary programme
Chair of IEEE-VPP Conference
PhD in Electrical Engineering at University Lyon 1, France
Research topics: Batteries, energy storage systems, HIL testing

ronan.german@univ-lille.fr

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Thanks for your attention !