XP4: ROMCon Reduced order models, control & degradation

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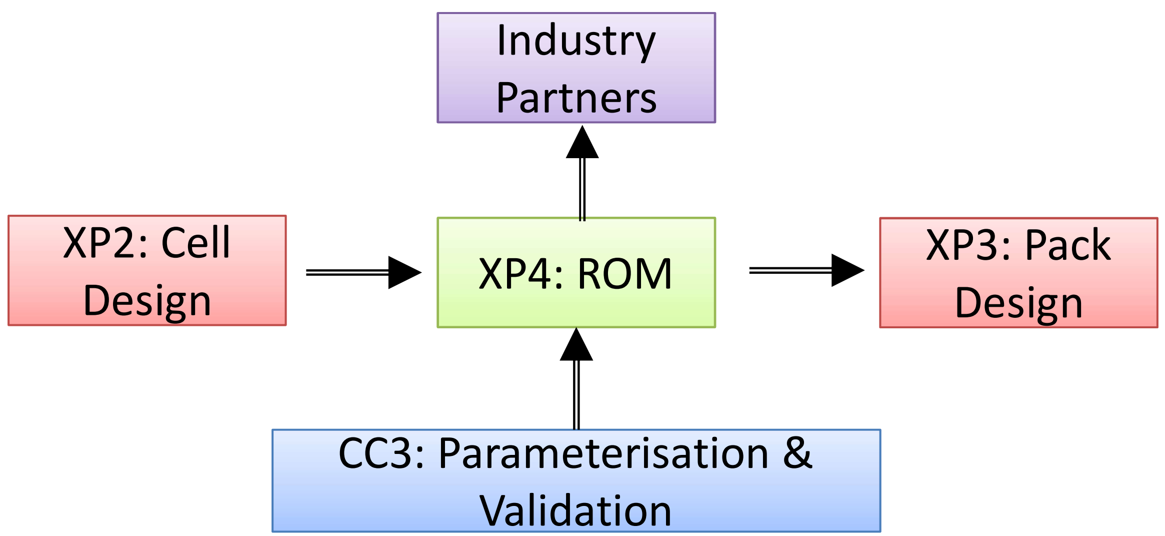
Contents

Aims and Objectives

- The Li-ion battery electrochemical model is subject to a complicated mathematical structure including partial-differential equations (PDE), ordinary differential equations (ODE) and algebraic equations.
- Control-oriented modelling is needed to enable real-time monitoring and control of the battery management system.
- The reduced order model (ROM) can be used for battery state estimation and control system optimisation.

Dependencies and Supports



Rely on:

- Parameterisation and validation project
- Cell design project

Benefit to:

- Pack design project
- Industry partners

Challenges and Obstacles

How can we simplify complex battery models but keep the physics we most care about?

↳ *Asymptotic analysis* (Moyles et at. 2018)

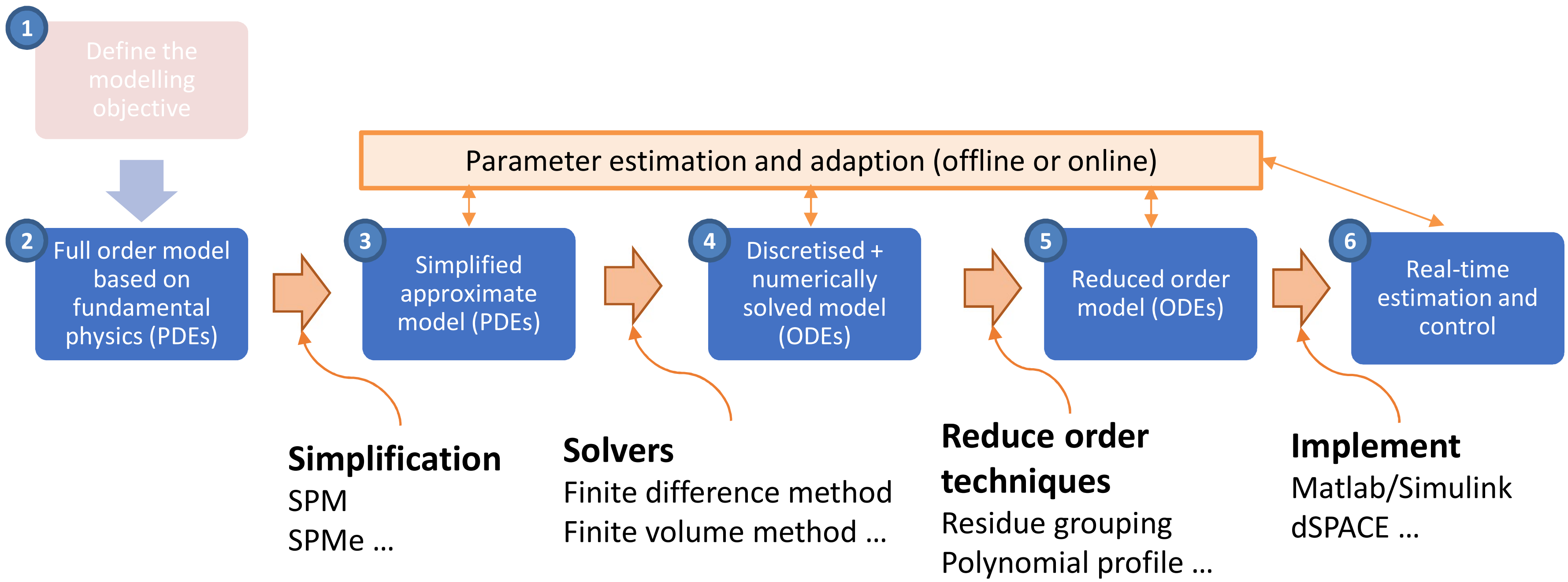
How can we make our models more computationally efficient?

↳ *Model order reduction* (K. A. Smith et al., 2008)

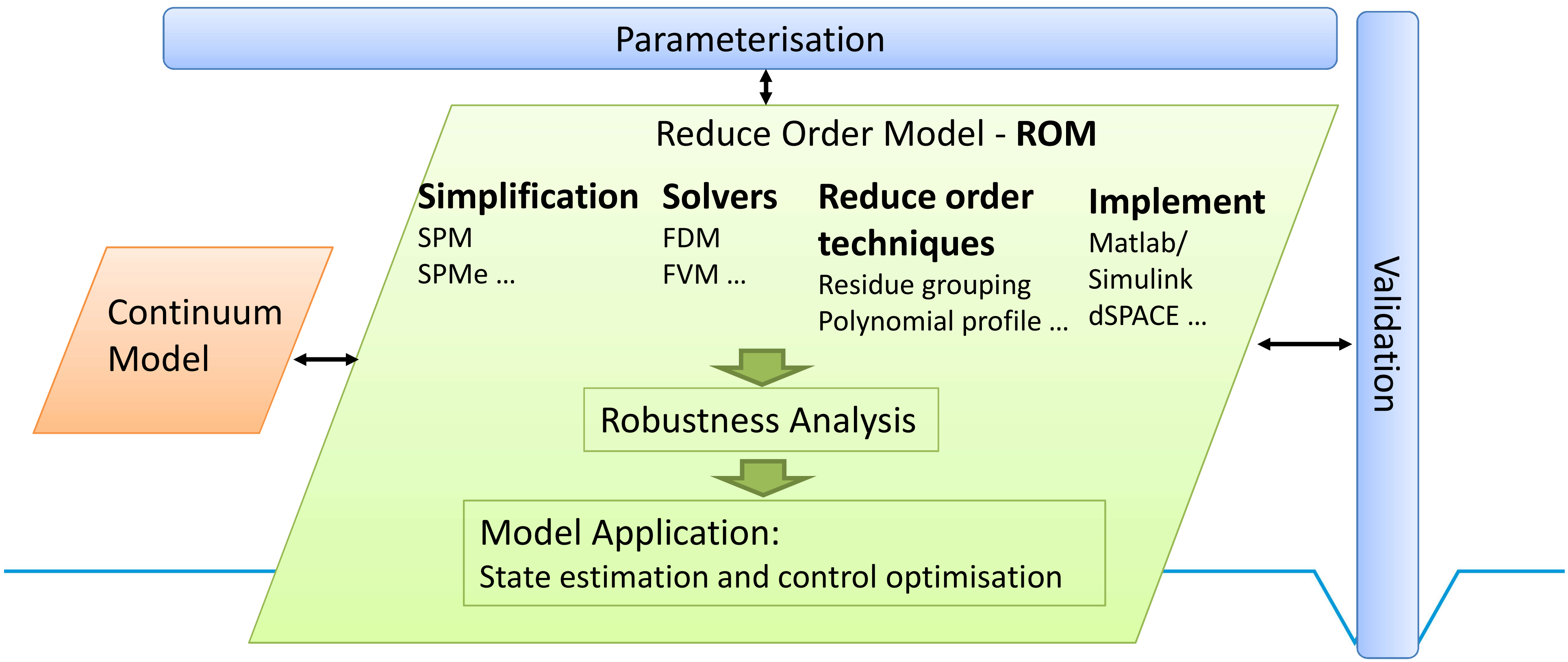
How do we fit model parameters from cell measurements, and check they are valid?

↳ *Identifiability analysis* (Bizeray. A. et al. 2018)

Workflow

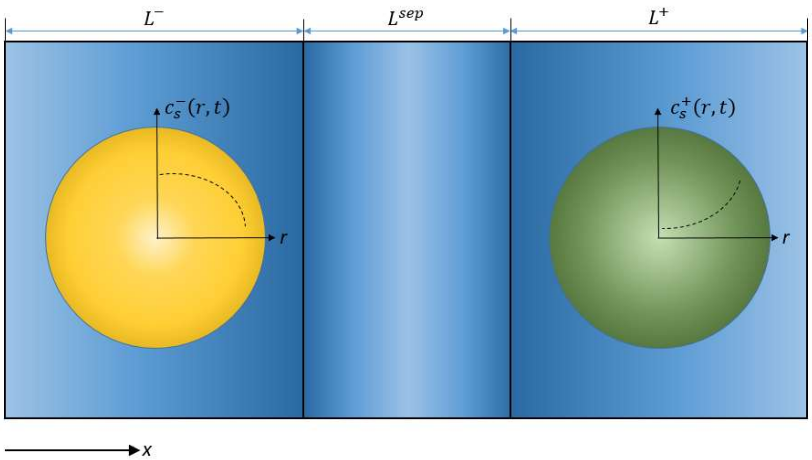

1
Define the modelling objective
Parameter estimation and adaption (offline or online)
2
Full order model based on fundamental physics (PDEs)
3
Simplified approximate model (PDEs)
4
Discretised + numerically solved model (ODEs)
5
Reduced order model (ODEs)
6
Real-time estimation and control
Simplification
SPM
SPMe …
Solvers
Finite difference method
Finite volume method …
Reduce order techniques
Residue grouping
Polynomial profile …
Implement
Matlab/Simulink
dSPACE …

Methodology



Case Study – Reduced order SPMe

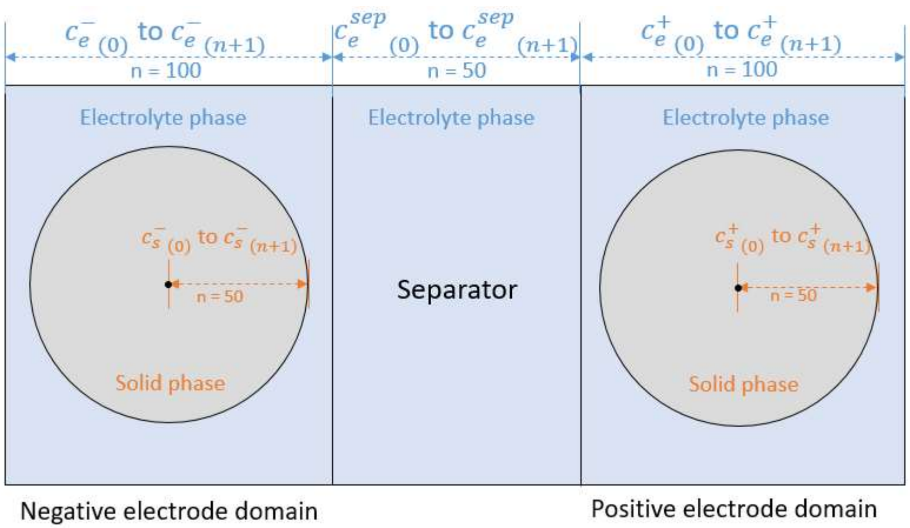
Single particle model with electrolyte (SPMe)

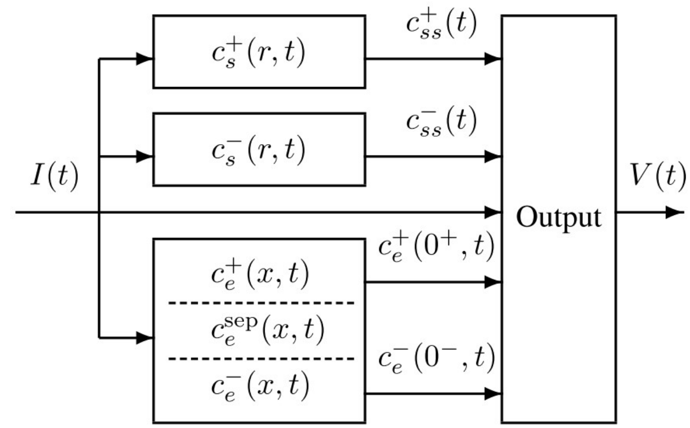


Eq. no.	Governing equations
(1)	$\frac{\partial c_s^\pm}{\partial t}(r,t) = \frac{1}{r^2}\frac{\partial}{\partial r}\left[D_s^\pm r^2 \frac{\partial c_s^\pm}{\partial r}(r,t)\right]$
(2)	$\frac{\partial c_e^j}{\partial t}(x,t) = \frac{\partial}{\partial x}\left[\frac{D_e^{eff}}{\varepsilon_e^j}\frac{\partial c_e^j}{\partial x}(x,t)\right] \mp \frac{(1-t_c^0)}{\varepsilon_e^j F L^j} I(t) \qquad j\epsilon\{-, sep, +\}$
(3)	$\sigma^{eff,\pm}\frac{\partial \phi_s^\pm}{\partial x}(x,t) = i_e^\pm(x,t) - I(t)$
(4)	$\kappa^{eff}\frac{\partial \phi_e^{\pm,s}}{\partial x}(x,t) = -i_e^\pm(x,t) + \kappa^{eff}(c_e)\cdot\frac{2RT}{F}(1-t_c^0)\times\left(1+\frac{d\ln f_{c/a}}{d\ln c_e}(x,t)\right)\frac{\partial \ln c_e}{\partial x}(x,t)$
(5)	$\frac{\partial i_e^\pm}{\partial x}(x,t) = a^\pm F j_n^\pm(x,t)$
(6)	$j_n^\pm(t) = \mp\frac{I(t)}{Fa^\pm L^\pm}$
(7)	$i_0^\pm(x,t) = k^\pm\left[c_{s,sur}^\pm(x,t)\right]^{\alpha_c}\times\left[c_e(x,t)\left(c_{s,max}^\pm - c_{s,sur}^\pm(x,t)\right)\right]^{\alpha_a}$
(8)	$\eta^\pm = \phi_s^\pm(x,t) - \phi_e(x,t) - U^\pm\left(c_{s,sur}^\pm(x,t)\right) - FR_f^\pm j_n^\pm(t)$

Case Study – Reduced order SPMe

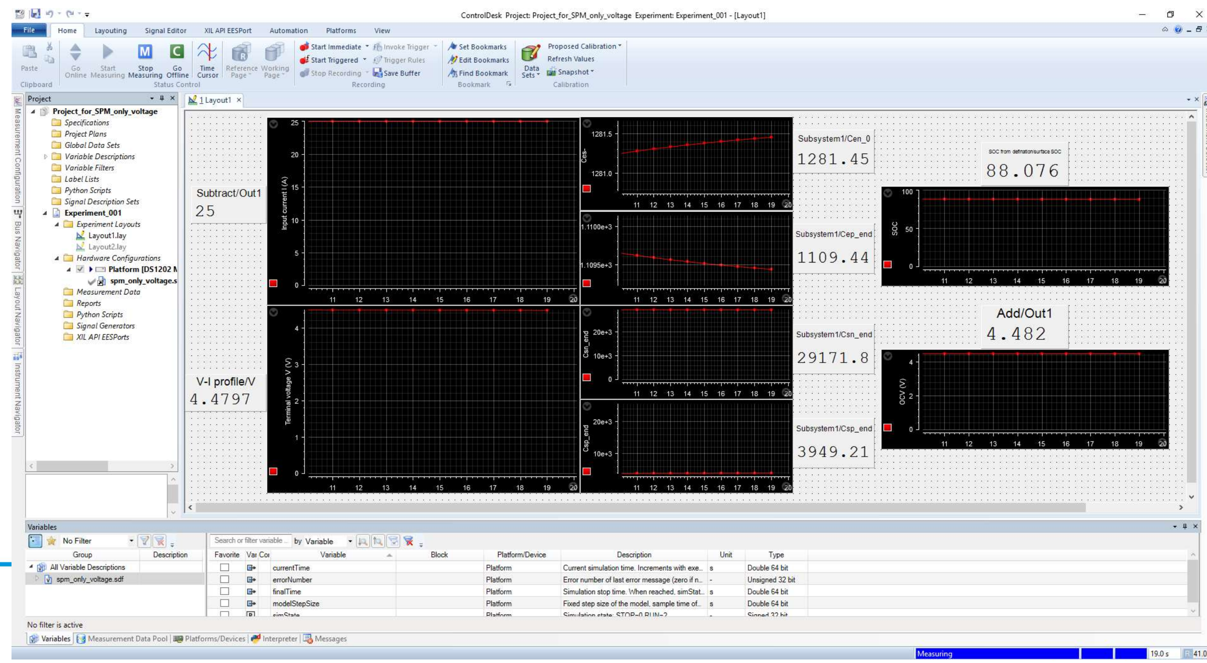
SPMe model solved by finite difference method (FDM)





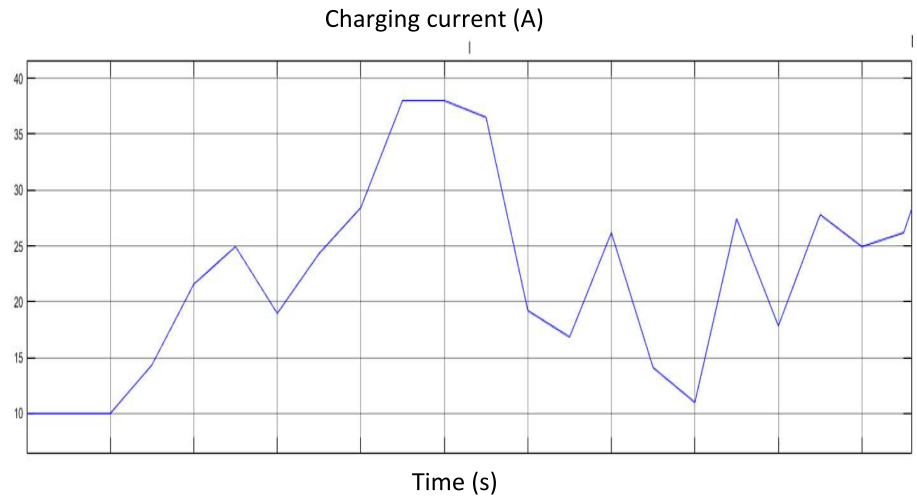
Case Study – Reduced order SPMe

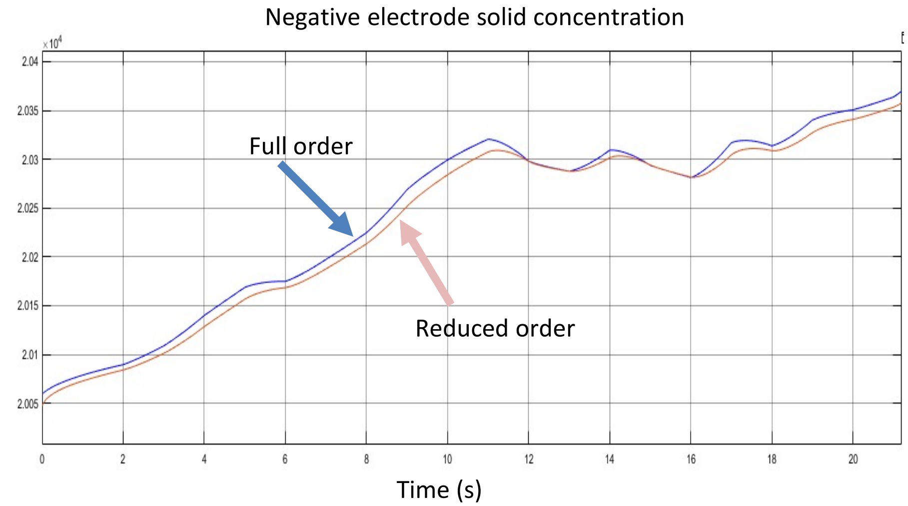
SPMe full order model real time simulation with dSPACE



Case Study – Reduced order SPMe

Reduce order - Residue grouping method





Example of simulation of ROM vs. full order

Conclusions and Future Work

- Research on solvers and reduce order techniques.
- Apply the reduced order electrochemical model in state estimation and control optimisation.
- Getting a good starting point to analyse coupled thermal-electrochemical models.
- We have a framework to study parameter validity for the coupled models that we will develop.

Thank you ! ☺

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