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The 27th INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION.

Barcelona, Spain
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Enhanced battery model including temperature effects

Bogdan Roşca, TNO, Steven Wilkins, TNO

Organized by Fira Barcelona avele

Hosted by AVERE mea Ajuntament de Barcelona

In collaboration with EVAAP EDTA

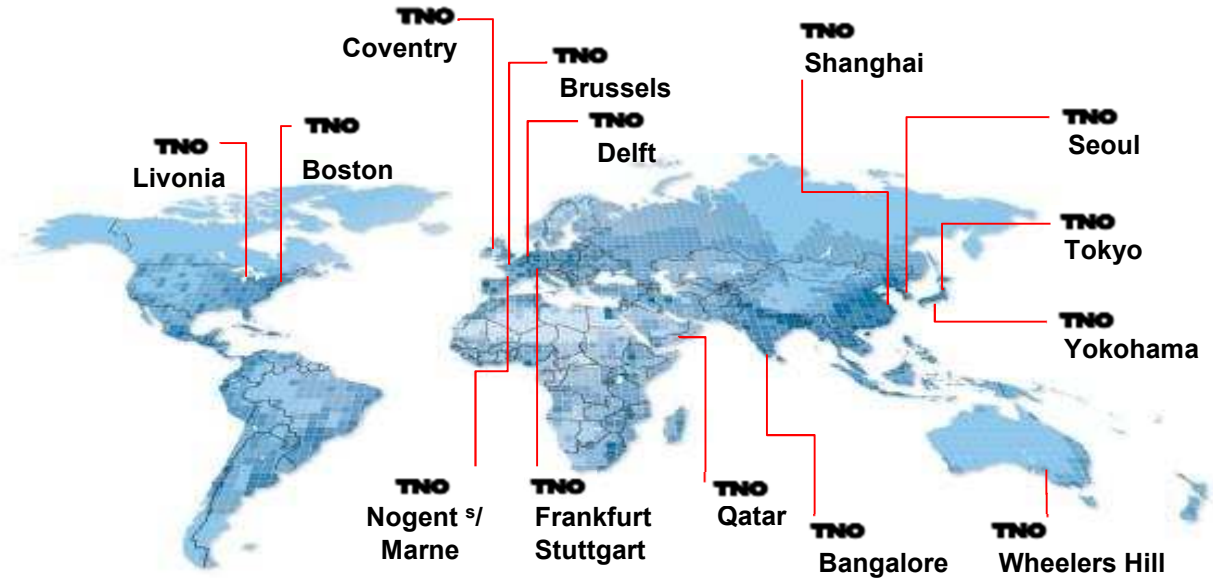
Supported by European Commission

Outline

1. Introduction TNO
2. Goal
3. Motivation of work
4. Battery modelling
5. Results
6. Applications
7. Conclusions

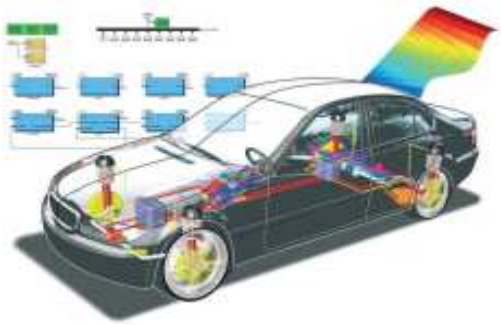
Introduction TNO

- TNO is the Netherlands' Organization for Applied Research
- Independent R&D organization
- Spin-off companies (e.g. tass international)
- Over 75 years of experience
- 4,000 employees world-wide
- HQ in Delft, the Netherlands
- Annual turnover approx. 550 M€



TNO Powertrains – R & D

- Detailed Powertrain Modelling and Control
- Energy and Emission Management
- Battery modelling and state estimation



Goal

Develop a battery model which captures temperature influences on the battery electrical behaviour

Motivation of work - performance

Battery performance strongly influenced by temperature

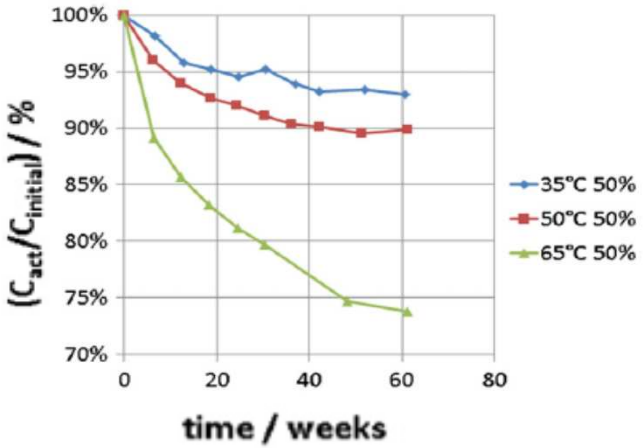
Accurate battery models needed for numerous automotive applications:

- Battery State-of-Charge (SoC) Estimation
- Battery Management Systems
- Range Prediction Algorithms
- Supervisory Control Algorithms

Higher accuracy over various operating temperatures → Temperature effects must be accounted for in battery modelling

Motivation of work - ageing

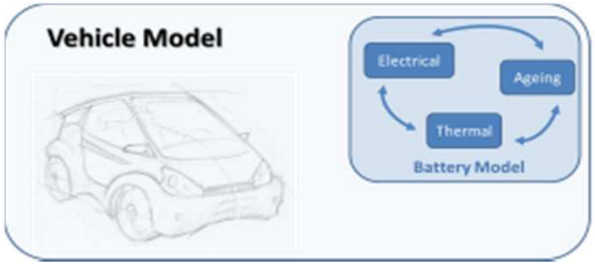
Battery ageing influenced by temperature.



M. Ecker et al - *Development of a lifetime prediction model for lithium-ion batteries based on extended accelerated aging test data*

ABattReLife European project: battery ageing during vehicle usage and second life applications.

Vehicle simulator including coupled electro-thermal-ageing battery model used for sensitivity analysis of battery degradation phenomena in vehicular applications.



Battery modelling

TNO use cases

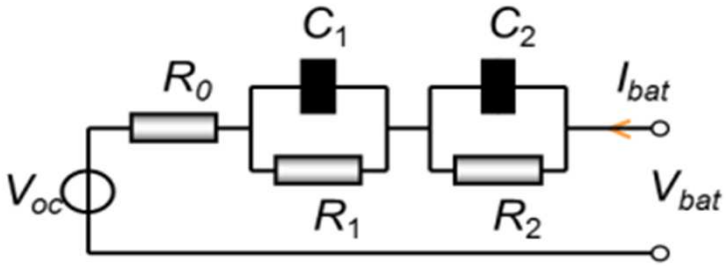
- SoC estimation, BMS, System level simulation, Total Cost of Ownership (TCO) tools

Approach

- Electric circuit equivalent, phenomenological dynamic battery model
- On-line implementable
- Temperature dependent components
- Automatic model identification procedure starting from measurements

$$\begin{pmatrix} SoC_k \\ V_{1,k} \\ V_{2,k} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1-\frac{\Delta t}{R_1 C_1} & 0 \\ 0 & 0 & 1-\frac{\Delta t}{R_2 C_2} \end{pmatrix} \begin{pmatrix} SoC_{k-1} \\ V_{1,k-1} \\ V_{2,k-1} \end{pmatrix} + \begin{pmatrix} \frac{\Delta t}{C_n} \\ \frac{\Delta t}{C_1} \\ \frac{\Delta t}{C_2} \end{pmatrix} I_{bat,k-1}$$

$$V_{bat,k} = V_{oc}(SoC_k, T_k) + V_{1,k} + V_{2,k} + R_0(SoC_k, T_k) I_{bat,k}$$



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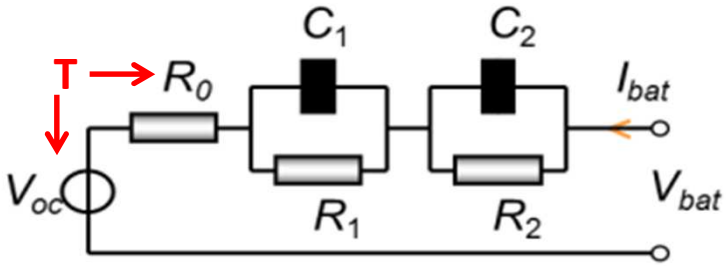

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Battery modelling

Experimental validation

- Battery cycling within a climatic chamber

Test number	1	2	3	4	5	6
Ambient temperature [°C]	-18	-10	0	10	25	40

- Validation approach: tests 1, 2, 4, 5 and 6 used for model identification and test 3 for model validation

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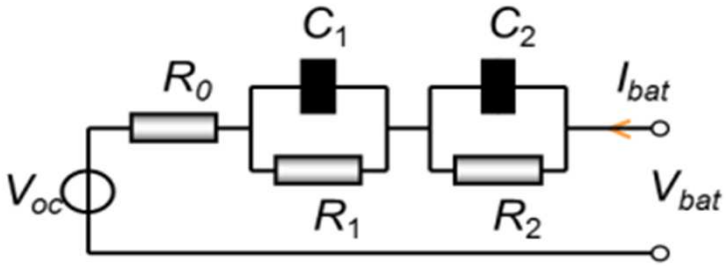

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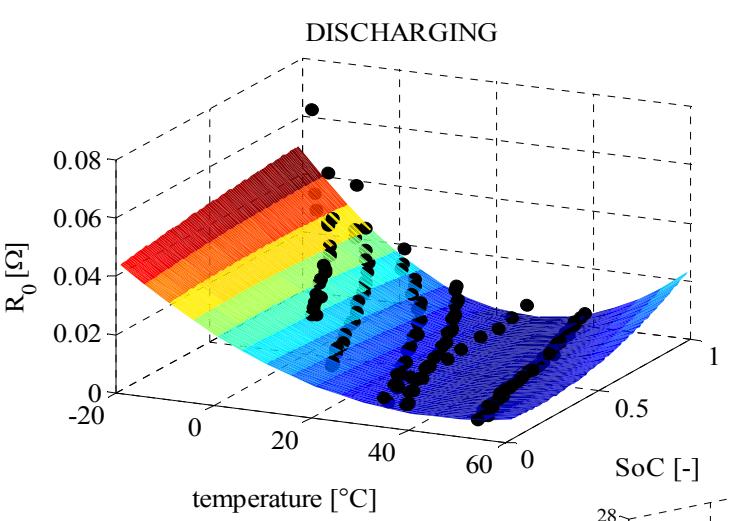
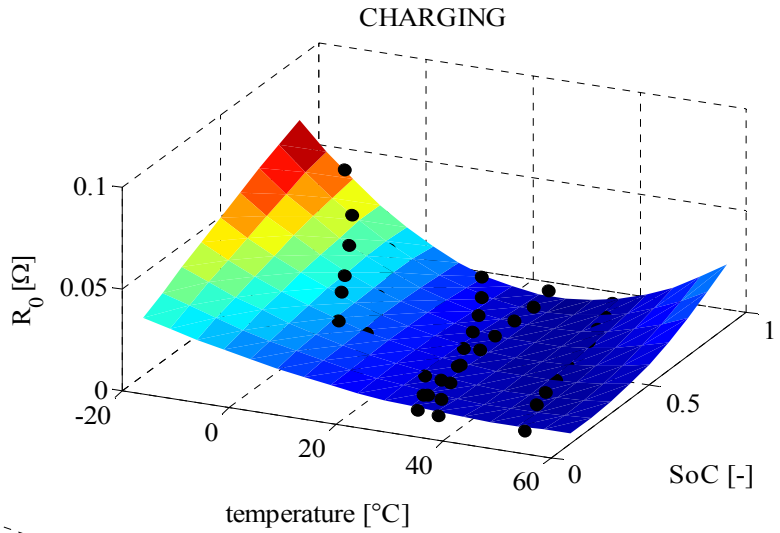
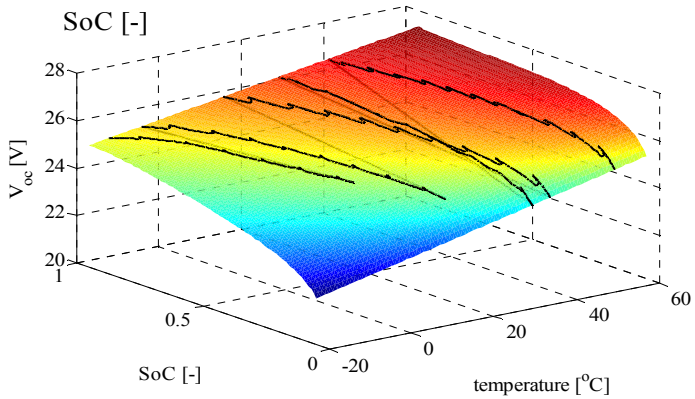
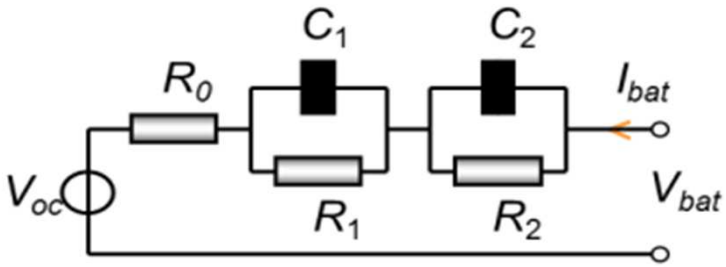
Battery modelling

Model identification









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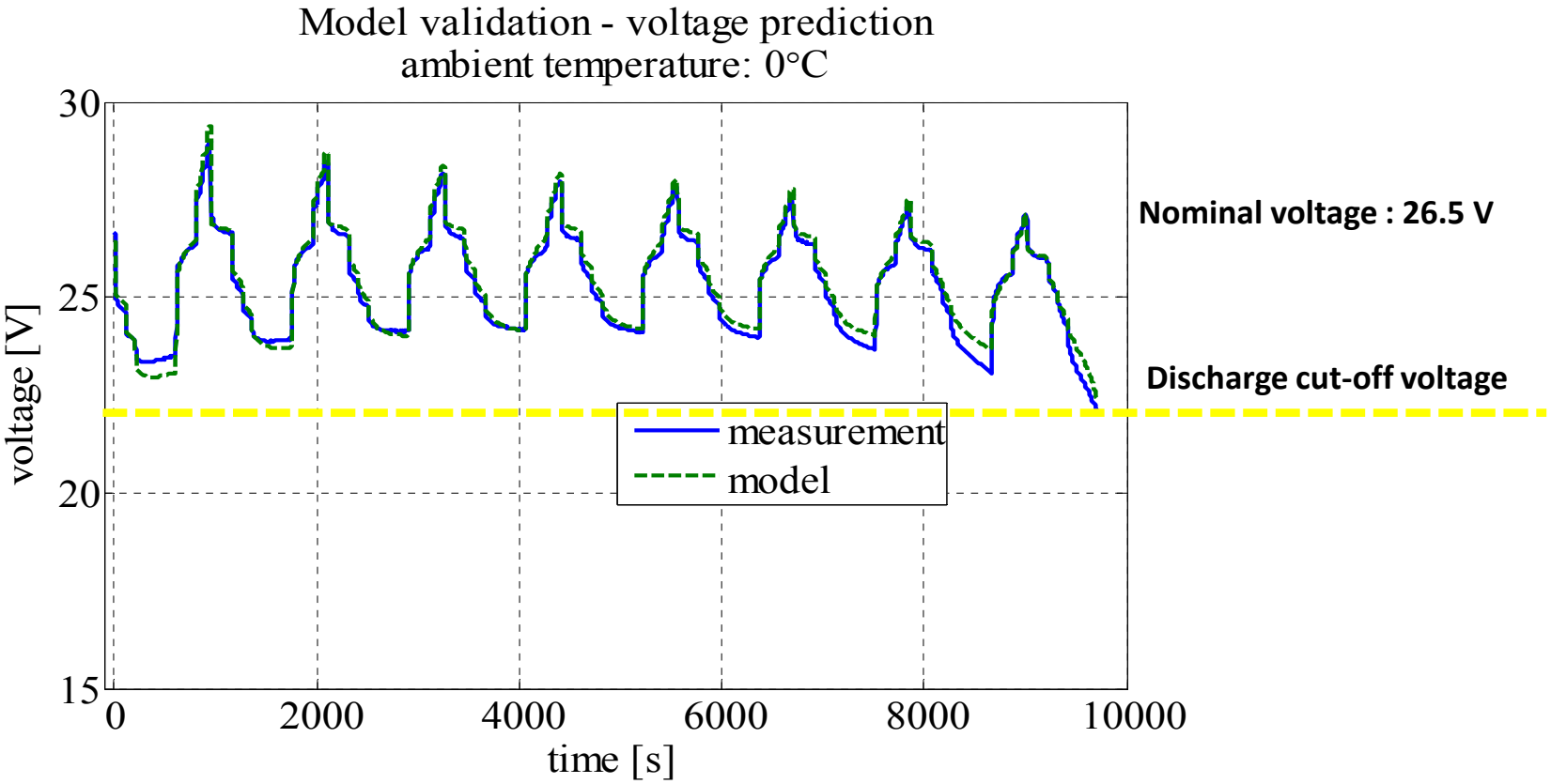
Battery modelling

Experimental validation



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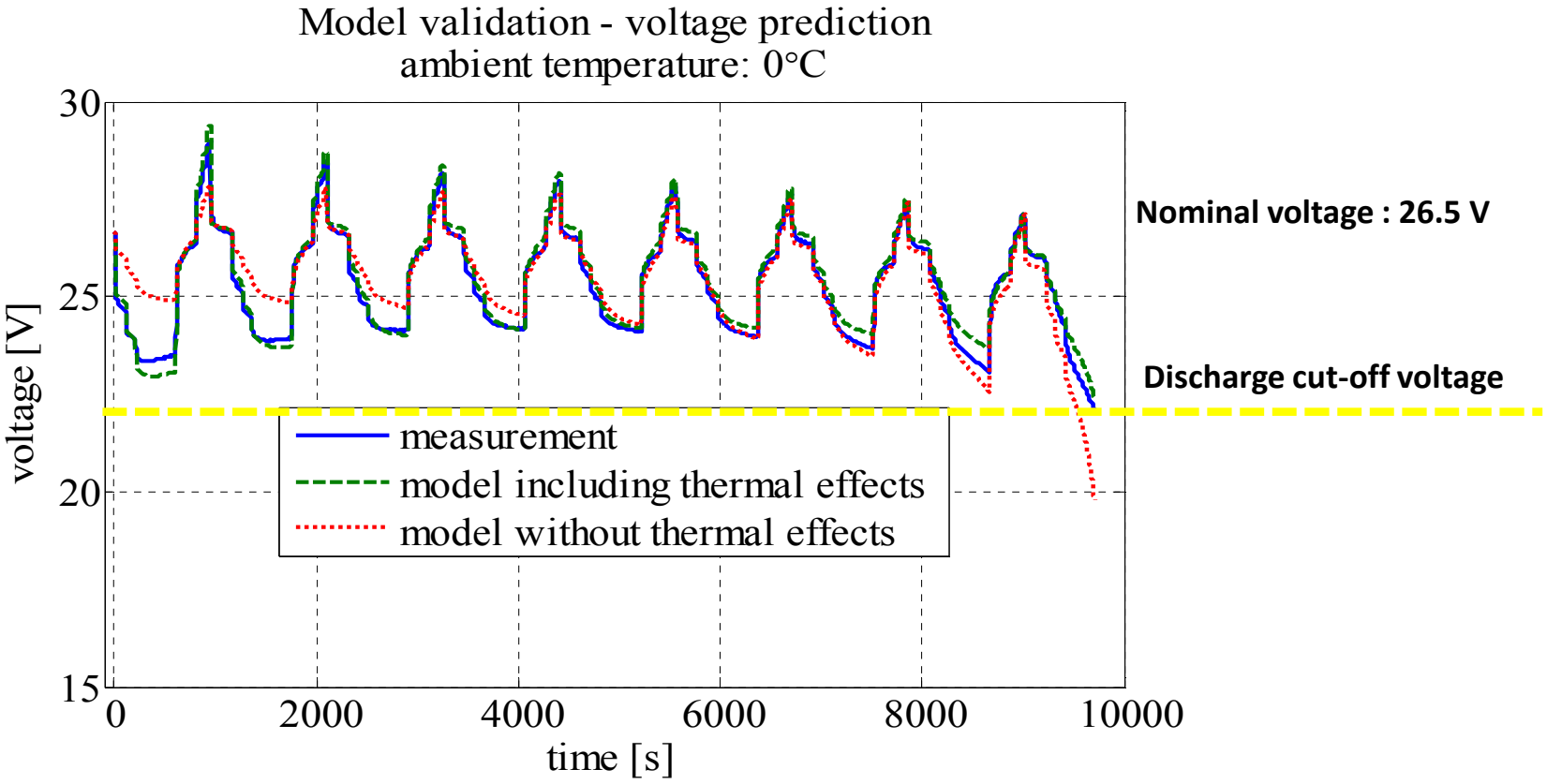

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Battery modelling

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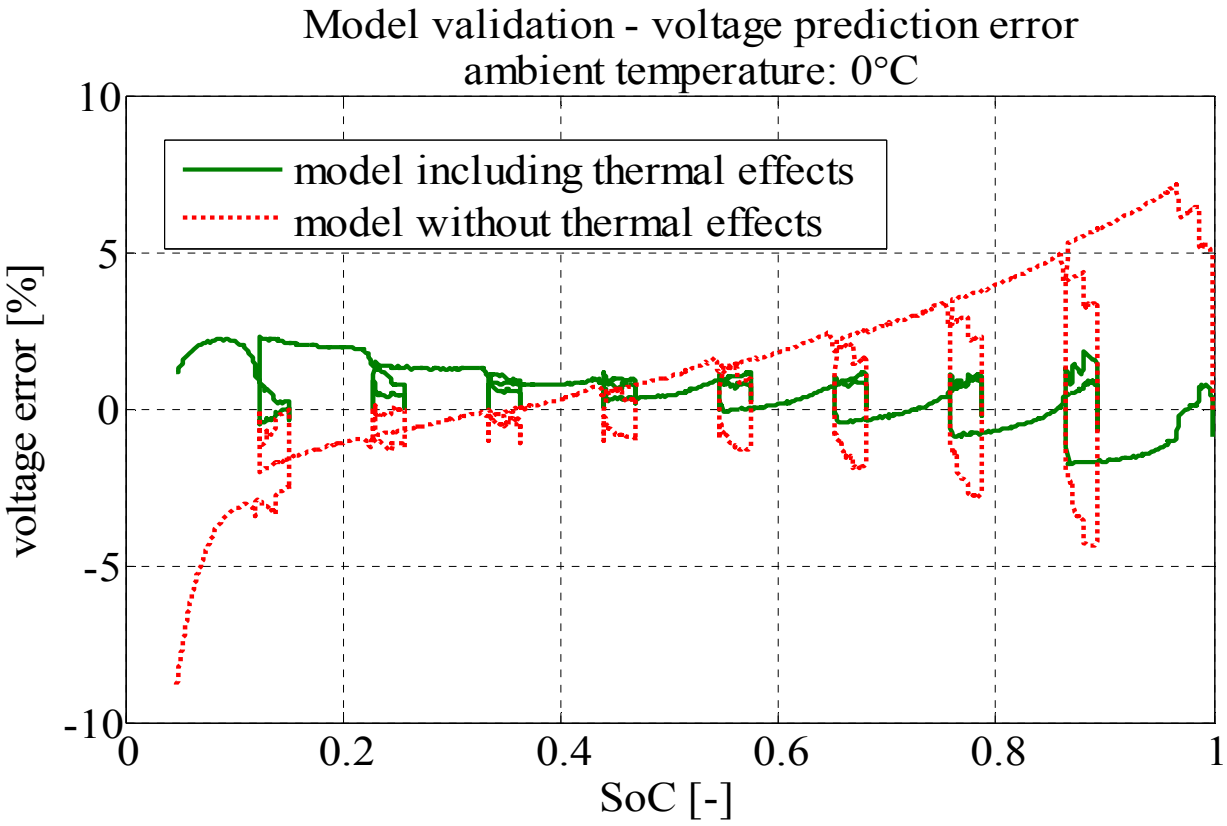

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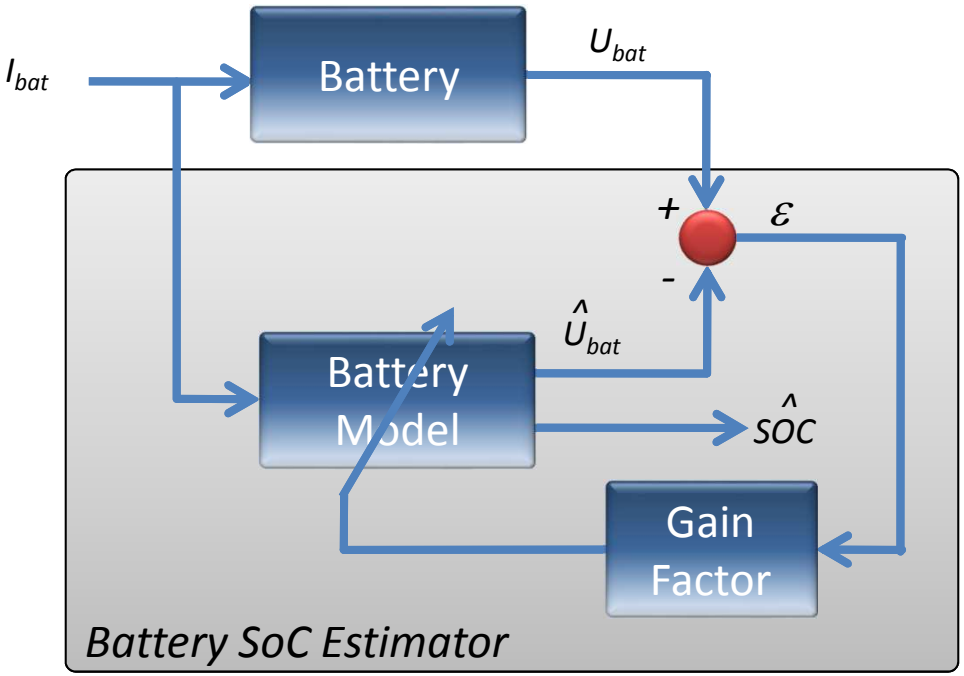
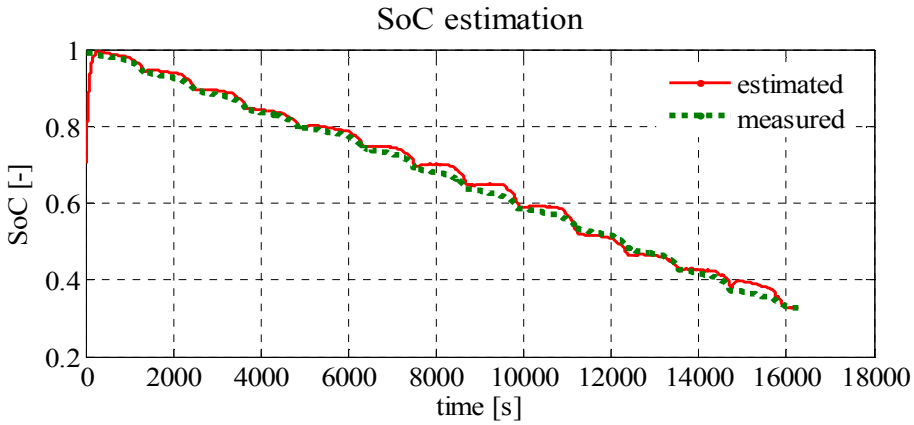
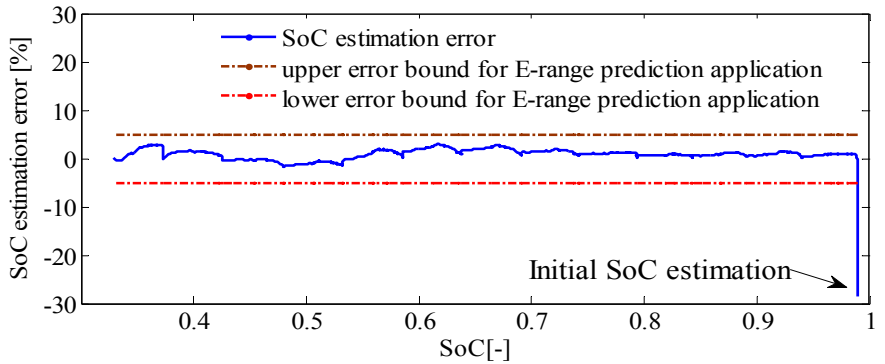
Applications

Battery state estimator - SoC







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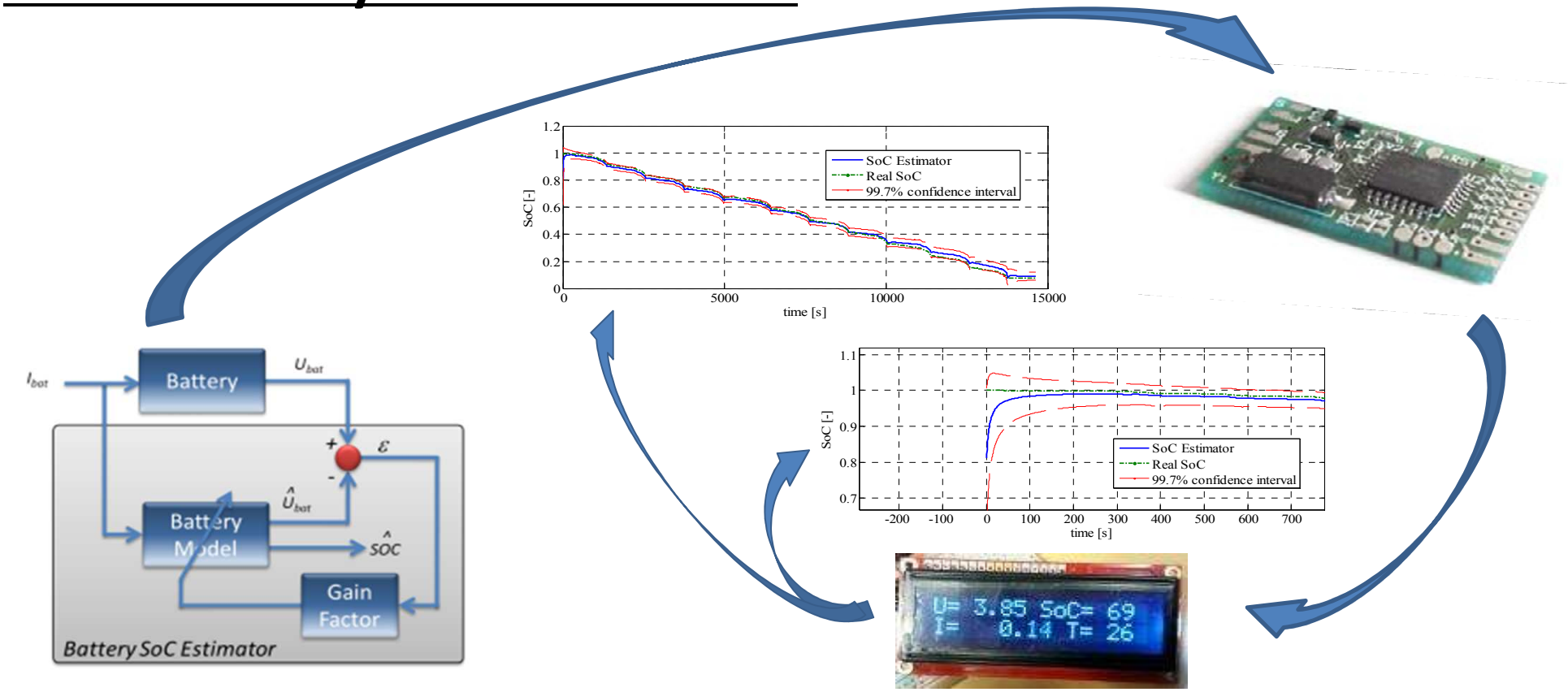
Applications

Robust battery state estimation



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Applications

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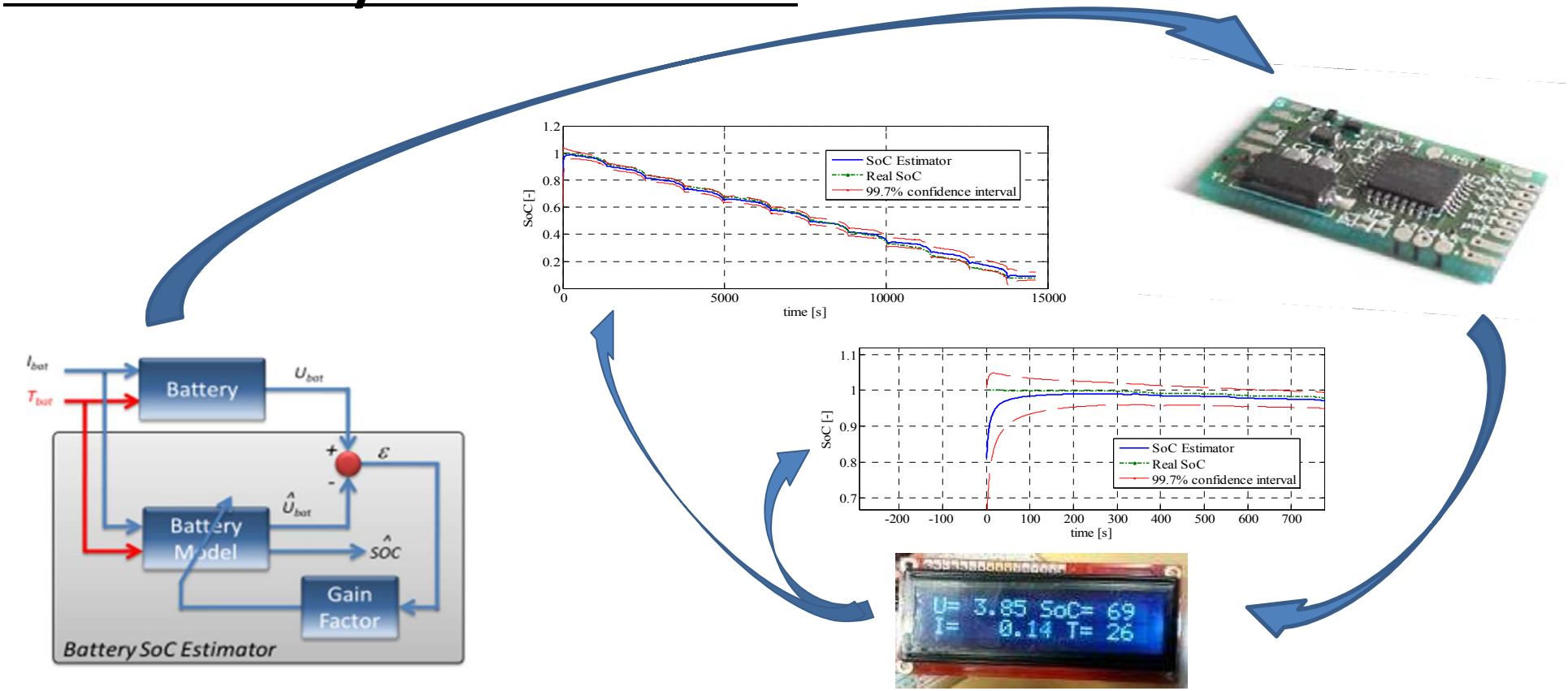

Conclusions

- **Temperature** has **a strong influence** on battery performance and ageing behavior
- To correctly capture that influence, temperature effects have been included in the existing battery model, leading to **increased model accuracy** under different operating temperatures
- Enhanced battery model supports the development of embedded **SoC estimation** algorithms
- Enhanced battery model supports the development of battery lifetime assessment tools, essential for **Total Cost of Ownership** analysis for hybrid and electric vehicles

Thank you for your attention!

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Research Engineer Powertrains

TNO innovation for life

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You are welcome at the tass international booth G710

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Extra slide

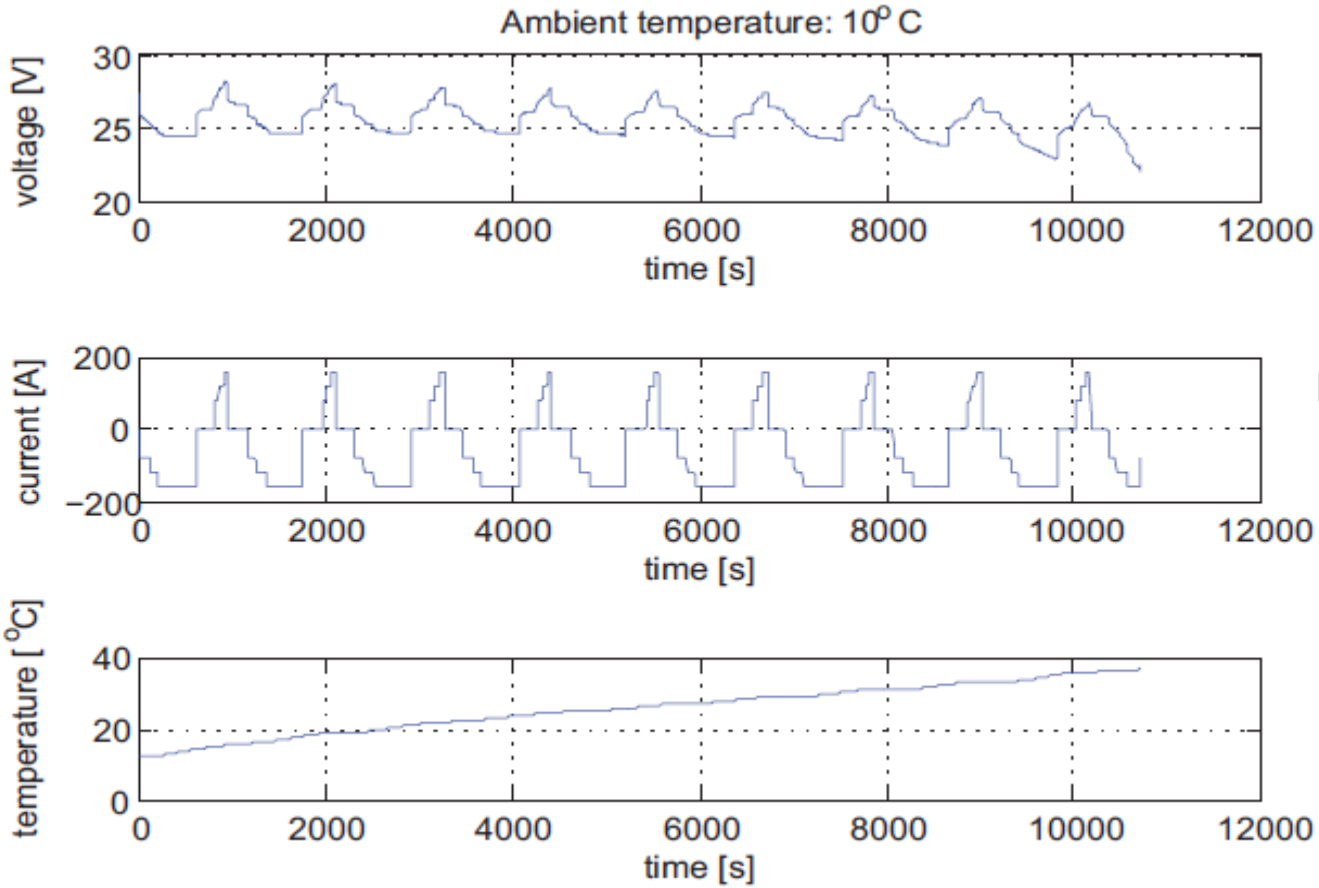
Top down vs. bottom up modelling

Top down – simple, fast, many simplifying assumptions

Bottom up – more complex, more effort needed, different layers of validation, can capture subsystem interactions

Choice: application dependent

Extra slide



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Maximum current: 160A

Extra slide