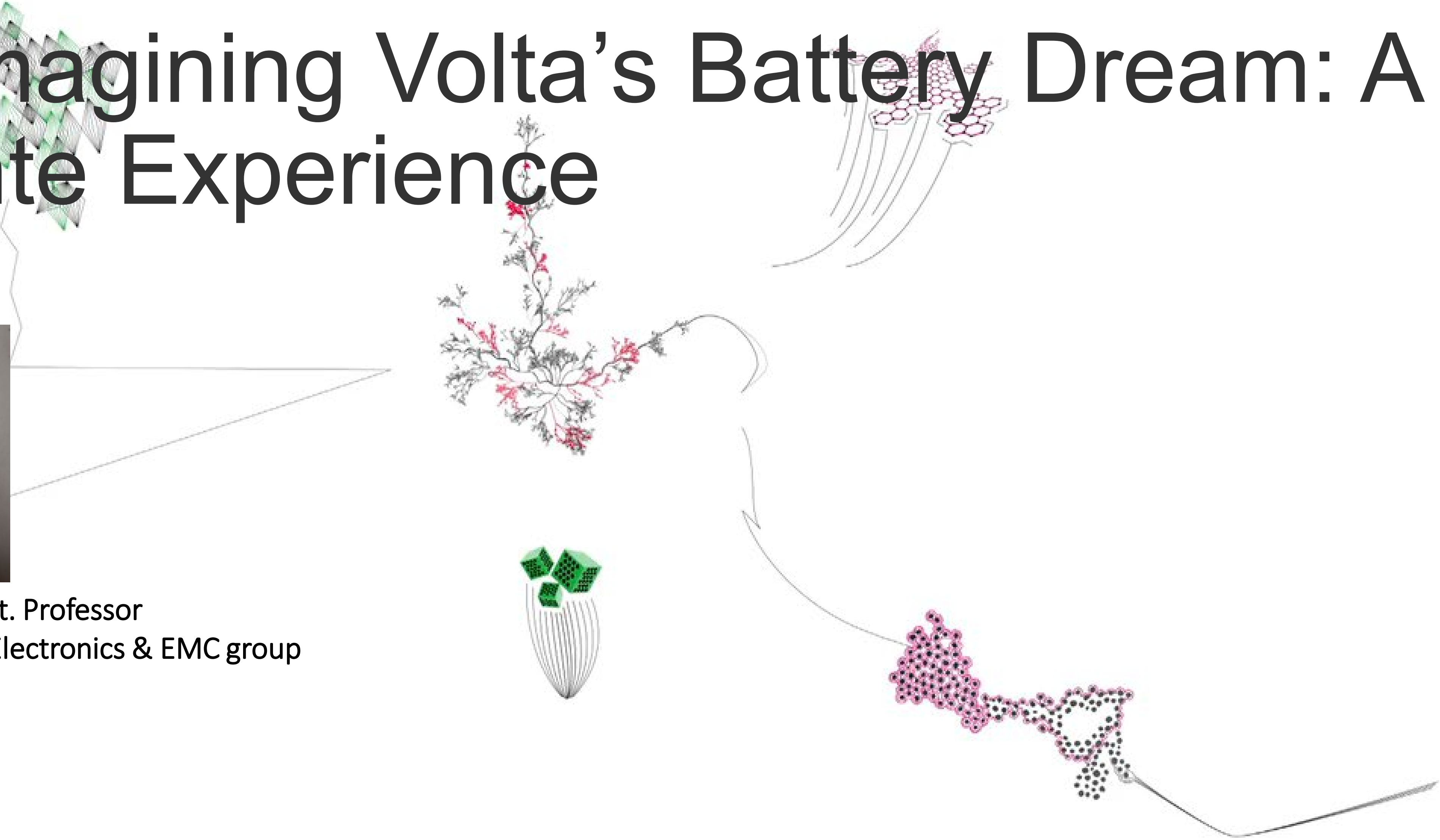
Power Electronics & EMC (PE) group

Re-imagining Volta's Battery Dream: A Twente Experience



Dr.ir. Prasanth Venugopal, Asst. Professor
University of Twente, Power Electronics & EMC group

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Outline

- Brief history PE group
- PE group
  - Staff members
  - Research themes
  - Battery Research
  - Battery Capabilities

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Brief History

- PE group set up by Prof. Ferreira and Prof. Leferink in 2019
  - Originally attracted by potential battery R&D site @ technology base Twente
  - PE + EMC is a very unique combination

PE Group, Research Themes

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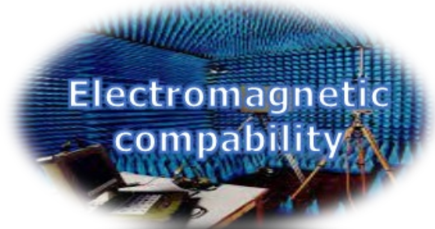

Modelling of conducted & radiated EMI and power quality. Development of test techniques to achieve immunity on PCB & system level.

Cell-level power electronics in battery management system to extend battery lifetime. To improve reliability by new packaging technologies and EMC solutions.

New semiconductor devices, materials (*e.g.,* wide bandgap) and packaging technologies for high power density and better reliability.

Decentralized, bottom-up, off-grid solar systems for 3 billion people living in energy poverty. Sustainable, socio-technical solutions: socio-cultural context, business models, policies.

Accurate measurements of electrical power flow/energy efficiencies in electrical systems. New concepts to improve accuracy, explore fundamental limitations and devise calibration methods.

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Battery Research Projects at UT PE

- Interreg NW-Europe **STEPS** Project
    - Advising >200 e-storage local SMEs for new entrants
    - Market pull effects for new e-storage solutions
    - Implementing a 2 voucher based support program to transcend TRL 5/6→7

Interreg
EUROPEAN UNION
North-West Europe
STEPS
European Regional Development Fund

- OPoost EU **Accumulate** (Twinx, Van Raam, Brekr, DNV GL, Contour, Twente Safety)
    - Electrochemistry, Cell Quality (IMS)
    - Electronics, BMS and Safety (PE)

Europese Unie
OPoost operationeel programma oost
Europees Fonds voor Regionale Ontwikkeling

- 2 NWO Zero-emission and Circular Shipping Projects (TU Delft + Maritime Industry..)

STEPS Project & Experiences

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Battery cells

Exergy

Challenges:

- Improve interfacial transport at interface cell membrane
- Improve cell performance

Battery performance evaluation

Watt4Ever
Octave
Voltfang

Challenges:

- How to determine the SOH
- Quicker procedure for battery characterization
- What is the current state of health of a 2nd life battery as obtained from an electric vehicle
- Pros & cons of connecting multiple pack parallel after (AC) or before (DC) inverter

EMC

Power&Energy
OXTO
MC Energy
SolarTechno

Challenges:

- Will the system pass the EMC regulations
- EMC and thermal issues
- Do we meet the EMC standards
- Advice on EMC of BMS

Power electronics

OXTO
SolarTechno

Challenges:

- Are the power electronics within specs?
- Thermal issues with the power electronics
- Design of a micro inverter

Testing and certification

MC Energy
Voltfang
OXTO

Challenges:

- Will the product pass the standard
- Read-out problems with current sensor for testing of the (complete) system
- Are the standards met

Not listed:
OTG Energy, Zebra, Elestor

Note: a SME can have challenges in multiple technical topics.

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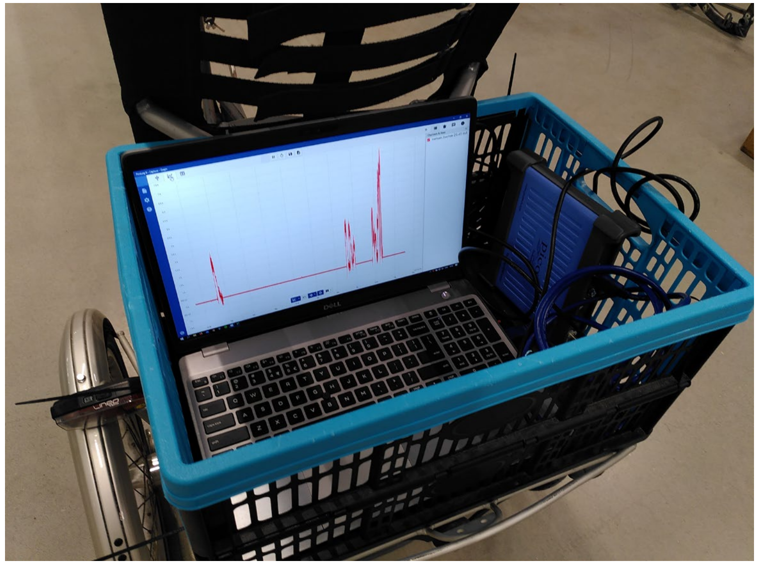
Accumulate In-Situ Measurements



Aim: To study the influence of driving cycles on degradation in light EVs using both in-situ and laboratory-based simulations

Researcher:
Ir. Ing. Maarten Appelman

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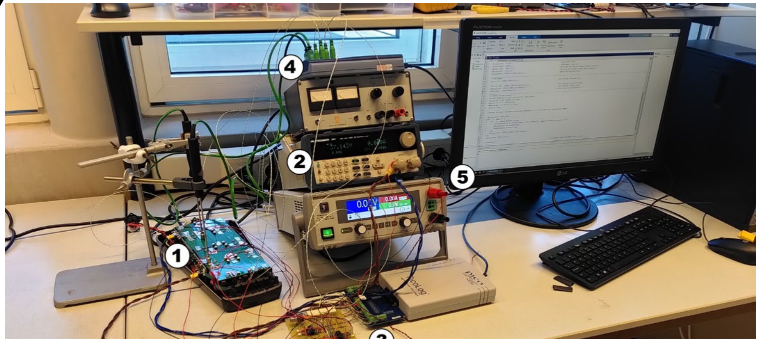
Accumulate Measurement Setup



- Battery pack
- Programmable DC-load
- Data logger + differential probes
- Thermocouple
- SCPI + PS API

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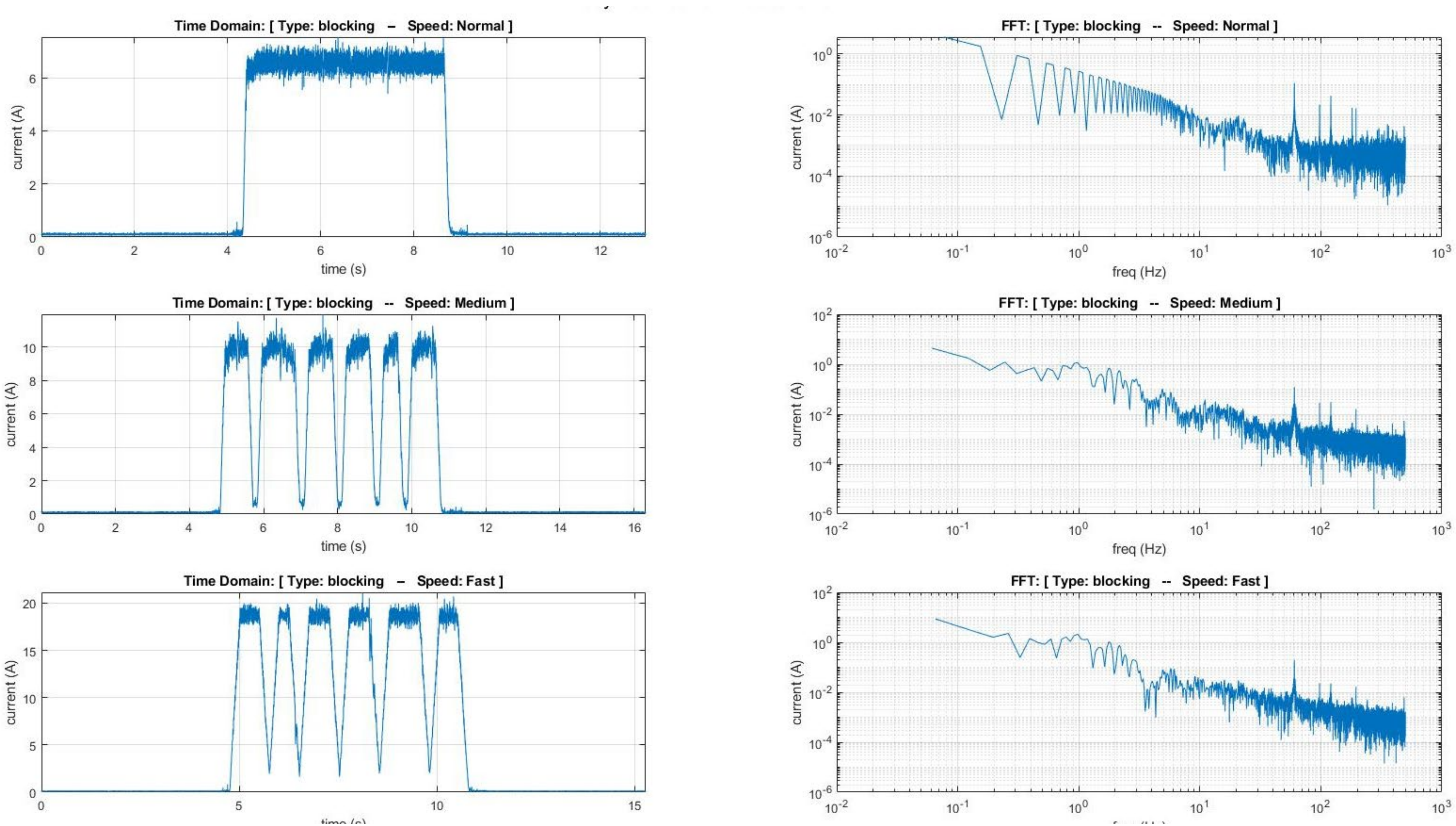
Accumulate – in situ measurements



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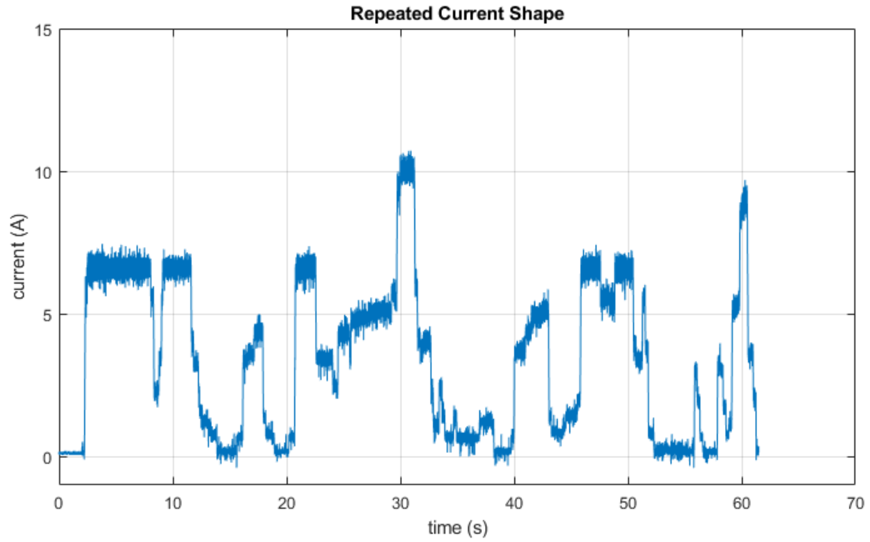
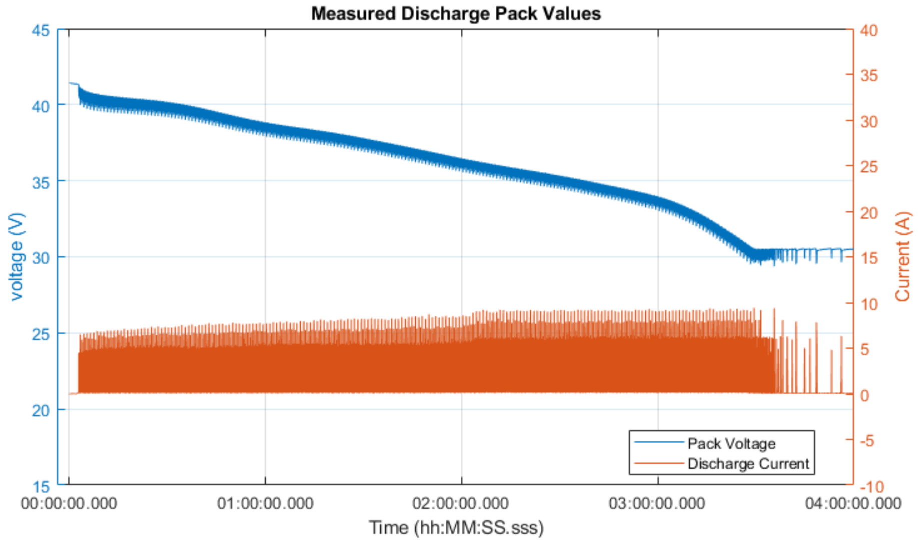
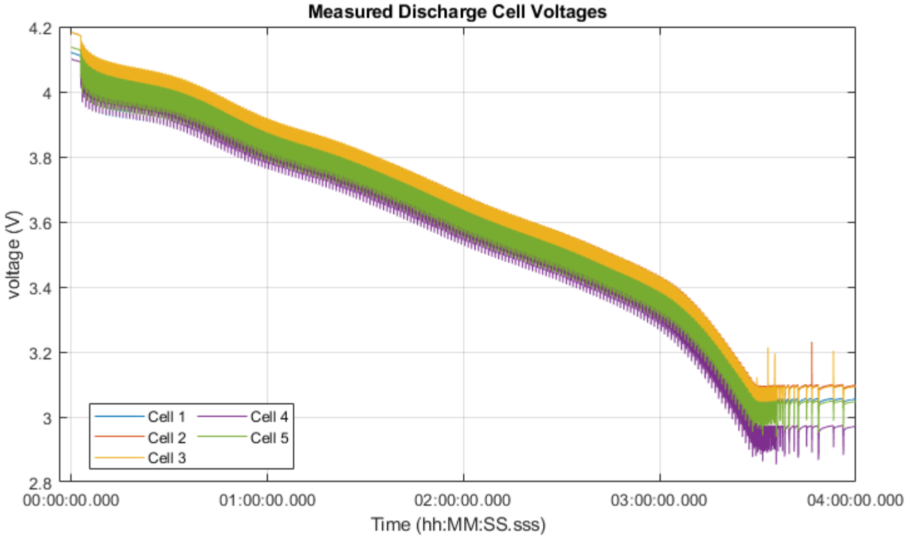
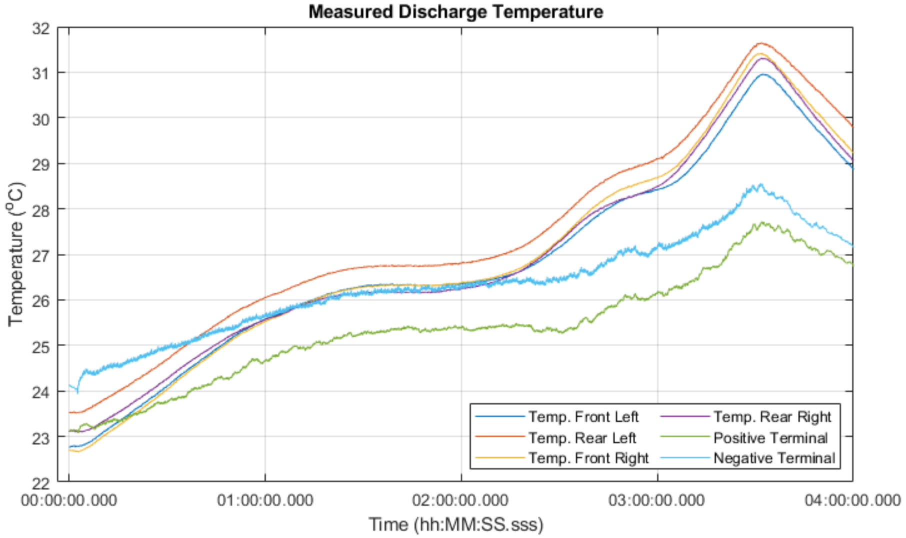
Accumulate – in situ measurements

Longrun









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Accumulate Results

- Heating of cells is not just related to average temperature
- First hypothesis that SOC can influence rate of temperature rise
- The discharge profiles with relatively long cool-down periods, show significantly lower maximum temperatures.

Second Life Batteries

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- Battery Echelon Utilization.
- Different screening and cell selection methods for second life batteries.
- Battery SOH measurement (Fast and accurate methods for testing the state of health of used battery).
- Laboratory study to find a new definition on battery SOH.
- Remaining Useful Life Prediction (RUL) methods for SLBs based on different application.

Ph.D. Researcher: Reza Azizighalehsari

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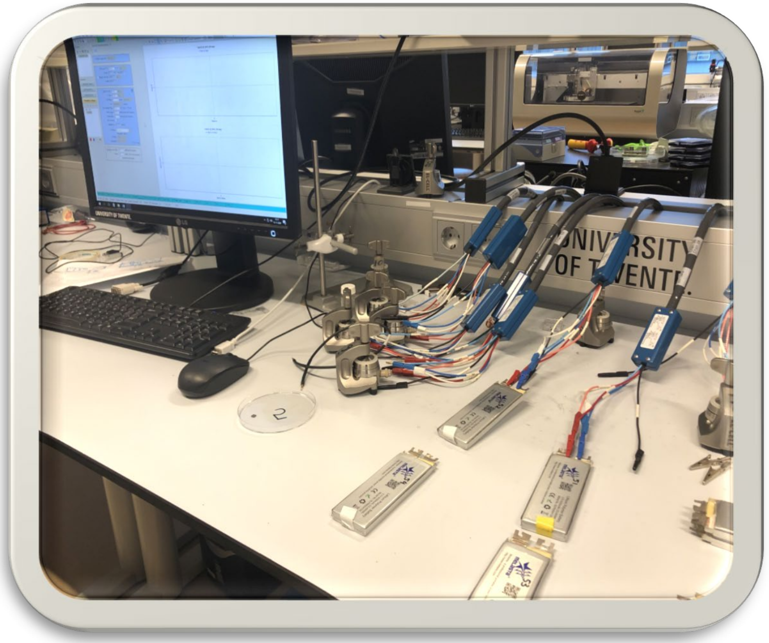
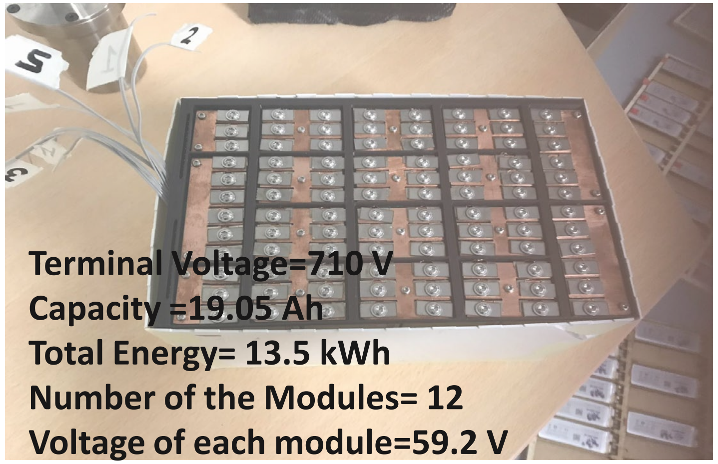
Cell Selection Criteria for Superbike





https://electricsuperbiketwente.nl/

- Qualification testing to design a battery pack for a fully electric racing motorcycle.
- Obtain the best performance from the cells.
- To avoid impedance mismatching between the cells inside the battery pack.
- Finding optimal configuration and cells sequence.

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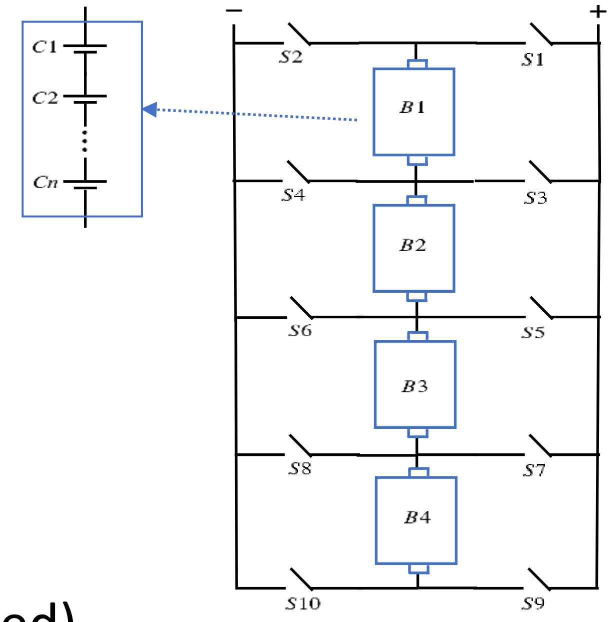
Highly Integrated Battery Electronics

- Multi-level AC output can be achieved by taking advantage of power switches of reconfigurable batteries and their customized output voltage
- The charger on the grid or inverter can be eliminated
- Extra battery cell balancing circuitry can be eliminated
- The output voltage THD can be reduced
- Smaller filter is required
- Low voltage MOSFETs are used



Challenges:

- High number of switches (Application dependent trade-offs)
- Complex control (multi-layer decentralized controller can be employed)

A Marie-Skłodowska-Curie Action (MSCA) Innovative Training Network (ITN) European Joint Doctorates (EJD) within the Horizon 2020 Programme of the European Commission.

Ph.D. Researcher: Reyhaneh Eskandari

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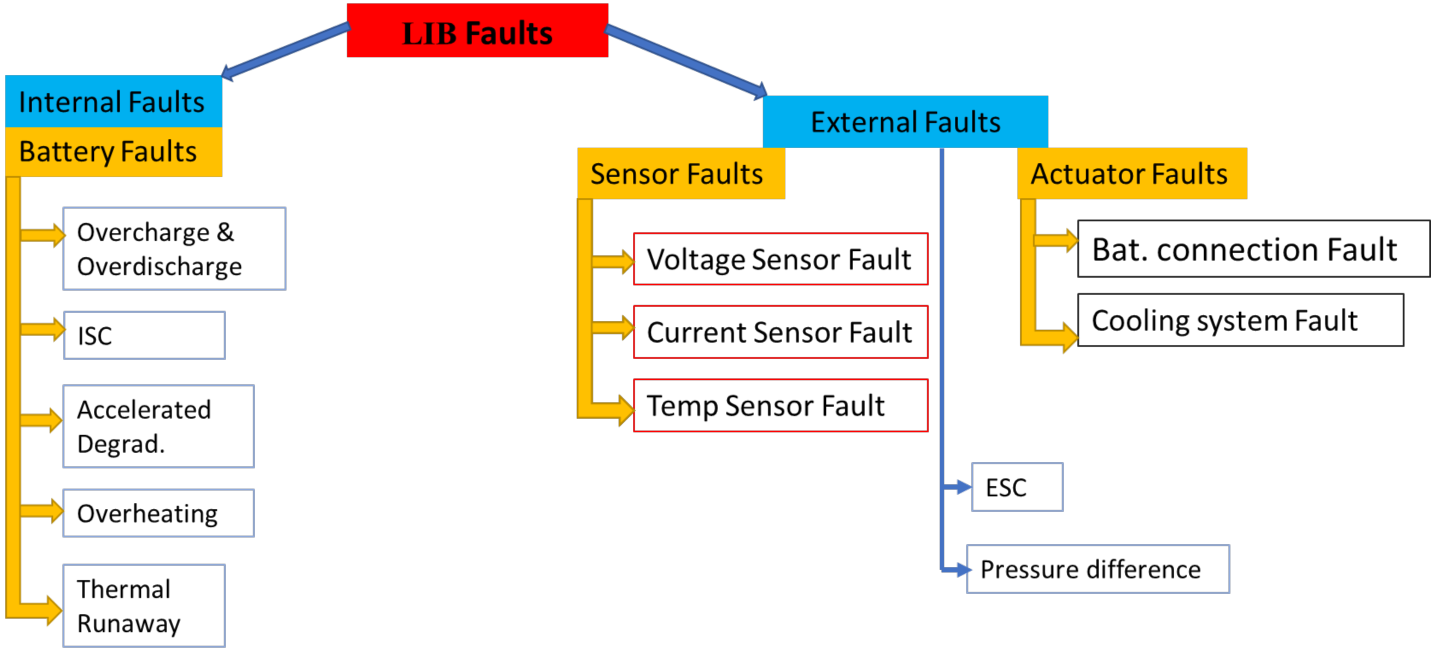
Battery Safety:
Fault Diagnostics and Mitigation

- Understanding of Faults mechanism serves as a foundation for developing faults diagnostic methods
- Li-ion battery faults are usually categorized into internal and external faults:



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Ph.D. Researcher: Regis Nibaruta

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Top Sector Infrastructure: Battery Lab

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- Battery Laboratory Equipment
    1. Keysight Impedance Analyzer (E4990A)
    2. Solartron EIS for Battery Measurements (Potentiostat)
    3. Battery Cell Cycler: Arbin Instruments LBT 5V-30A-8CH
    4. Chroma DC Electronic Loads
    5. Battery Climate Chambers (Hielkema)
    6. Battery Module Cycler (Almost finalized)
    7. BMS, battery emulators etc…….

Battery Testing Capabilities

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C/M/P Performance Testing	
	Module/pack cycler: up to 60V, 50A, 4 channels
	BMS evaluation (Cell simulator: 5V, 12 channel)
	Cyclic ageing, for varying load cycles (Max 1500V, 600A, 6kW)
	Charge and discharge (Max 1500V, 600A, 6kW)
	Performance testing incl. SOC, SOH, roundtrip efficiency etc.
	Climate chamber: (-20 to +80 degC)
C/M/P EIS - Electrochemical Impedance Spectroscopy	
	Range: 0.01 mHz - 1MHz, 100V, 3A
	Impedance testing and analysis (detailed behavior, ageing effects, etc.)

Battery Diagnostics and Prognostics

WORKSHOP

IN-PERSON || ONLINE

University of Twente
Power Electronics and EMC
Drienerlolaan 5, 7522 NB, Enschede

28 October 2022

Motivation:

- Create awareness about R&D within the field of power electronics, measurements, and the battery ecosystem.
- Bridge the gap between knowledge institutions and the battery industry in the Netherlands.
- Train industry partners from the Netherlands and north-west Europe on battery performance and testing within the ambit of the STEPS project.
- Future collaboration between various stakeholders and the University of Twente.

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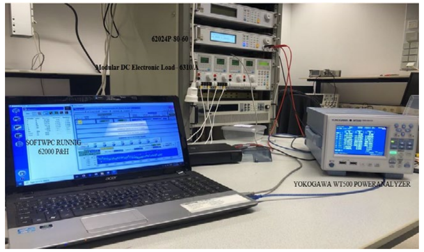
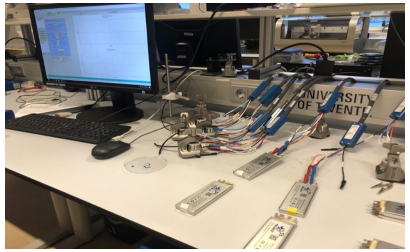
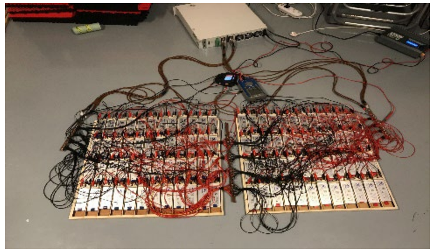
Advanced Battery Charging/ Power Electronics

- Research Topics:
- Cell → Module → Pack based Power Electronics
- Battery Second Life Sorting and Utilization
- Battery Performance Measurements: SOC, SOH, SOP → Accurate and Fast
- Advanced BMS and Reconfigurable Batteries
- Modelling and Impact of Ageing/ Degradation → Module-to-Pack
- Extension to Chemistry-Agnostic Impact Assessment

- Ph.D. 1: Reza Azizighalehsari – Echelon Utilisation of Automotive LiB Packs for a Second Life in Grid
- Ph.D. 2: Reyhaneh Eskandari – Advanced BMS Systems in Transportation (MSC ETUT)
- Ph.D. 3: Regis Nebaruta (Ukraine) – Battery Safety and SOH (MSC ETUT)
- Ph.D. 4: Ning Zhansheng* – Modelling & Impact of Ageing in LiB (*Sept 2022)
- Several MSc. + BSc. Researchers







Key Academic N/W: TU Delft; The University of Nottingham (United Kingdom · China · Malaysia); Universiteit Gent; Technische Universität Darmstadt

Key R&D N/W: The Faraday Institution; PTB; VSL; NPL National Physical Laboratory

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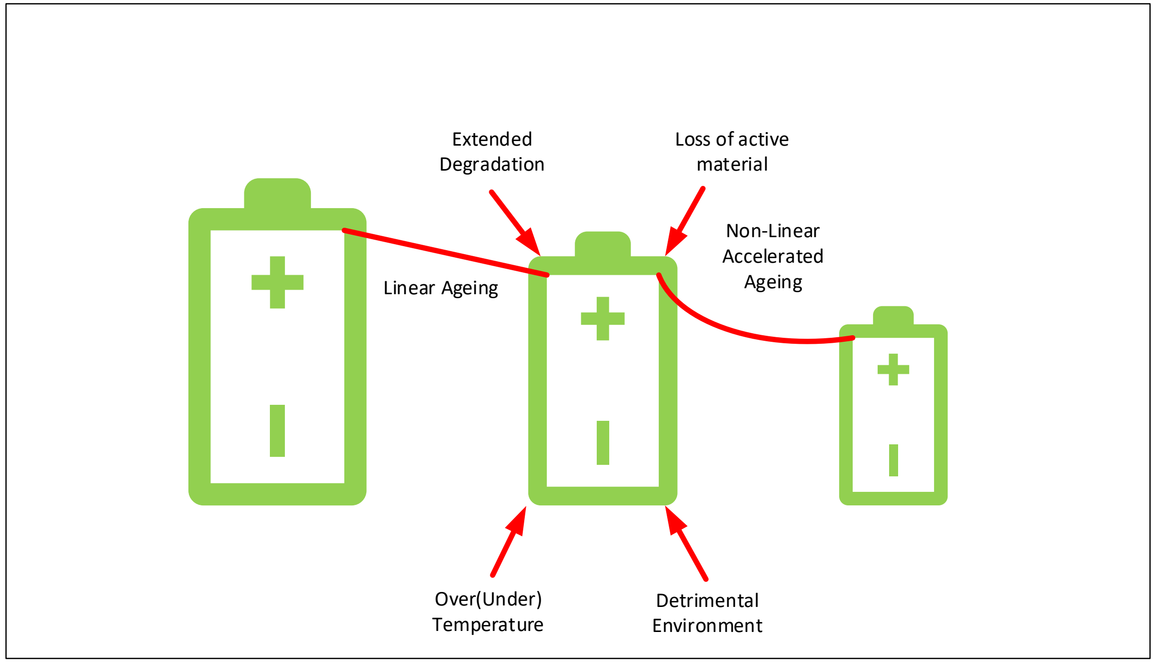

Battery Charge For Thought Quotes:

1. Battery is a Deterministic system and must be "measurable accurately"
2. Non-linear ageing is not comparable to a bucket with holes; but a Deflatable Balloon with holes

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https://www.utwente.nl/en/eemcs/pe/4.people-new/scientificstaff/venugopal_p/