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

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

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Outline

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

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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
  - …May 2021…

PE Group, Research Themes

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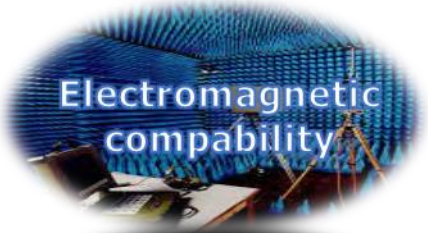

Modelling of conducted & radiated EMI and power quality. Development of test techniques to achieve immunity on PCB & system level.

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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Twente Centre for Advanced Battery Technology

Strategic Focus Points	**Next gen. materials & cells**	**Energy-efficient packs & systems**	**Advanced manufacturing**	**Smart applications**
Organisation	PI: Mark Huijben *(Fac. TNW)*	PI: Prasanth Venugopal *(Fac. EEMCS)*	PI: Sebastian Thiede *(Fac. ET)*	PI: Maarten Bonnema *(Fac. ET)*
	business development: Dirk van Asseldonk			
	>100 multidisciplinary researchers from 4 different UT faculties in project driven activities			
	Hosted by: Centre for Energy Innovation (SBD) & MESA+			
Infrastructure	**Equipment for material processing and characterization**	**Pilot lines for cell and pack manufacturing**	**Test facilities for lab/industrial cells and packs**	

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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 in NEW for new e-storage solutions
  - Implementing a 2 voucher based support program to transcend TRL 5/6→7

Interreg North-West Europe STEPS
EUROPEAN UNION
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

STEPS Project & Experiences

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Battery cells	Battery performance evaluation	EMC	Power electronics	Testing and certification
Exergy	**Watt4Ever** **Octave** **Voltfang**	**Power&Energy** **OXTO** **MC Energy** **SolarTechno**	**OXTO** **SolarTechno**	**MC Energy** **Voltfang** **OXTO**

Challenges:

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

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

Challenges:

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

Challenges:

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

Challenges:

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

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

Not listed:

OTG Energy, Zebra, Elestor

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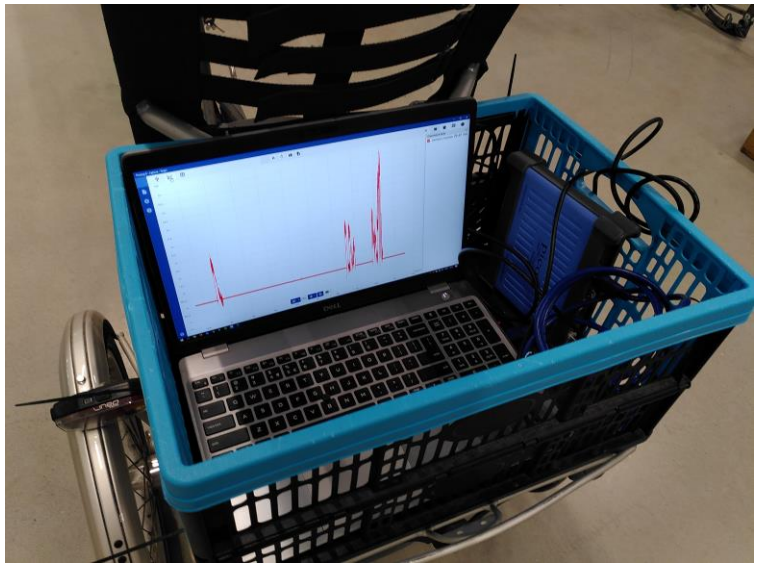
Accumulate In-Situ Measurements



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

Researcher: Ir. Ing. Maarten Appelman

Power Electronics & Energy Storage event
POWER ELECTRONICS 2022
ENERGY STORAGE EVENT 2022
14 juni 2022 | 1931 Congrescentrum 's-Hertogenbosch

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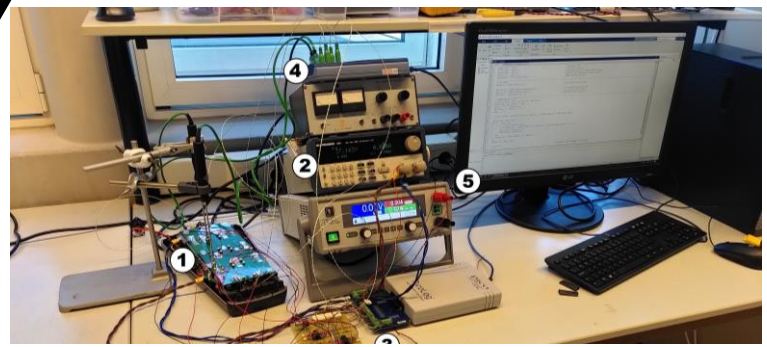
Accumulate Measurement Setup



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

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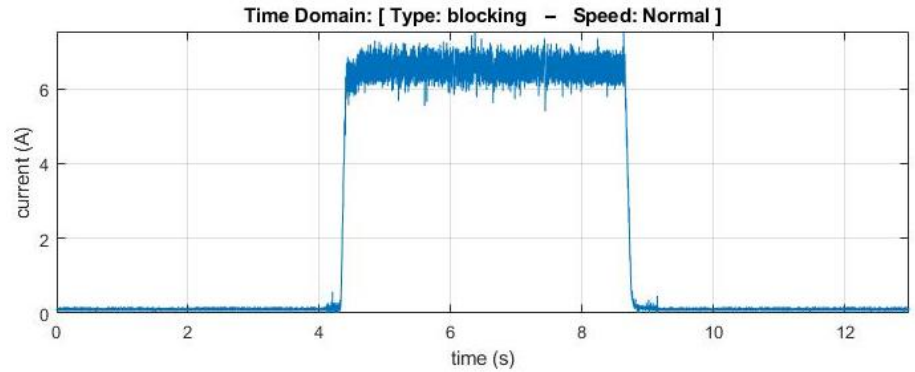
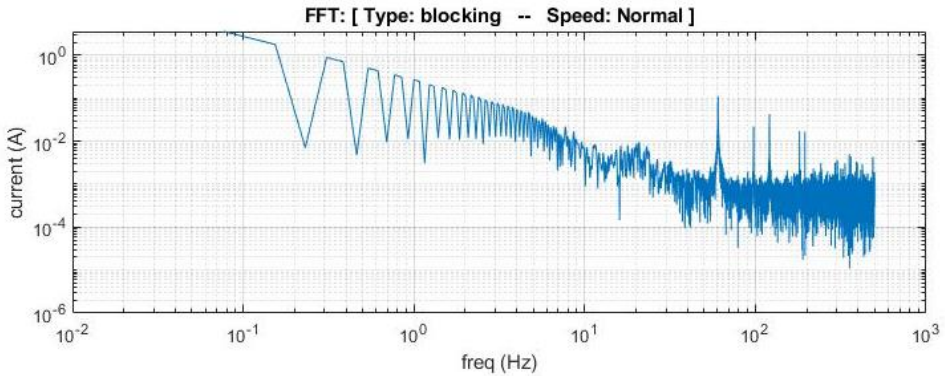
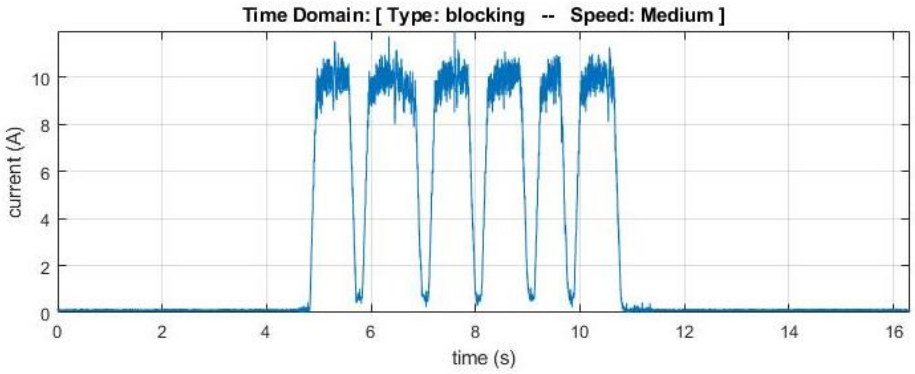
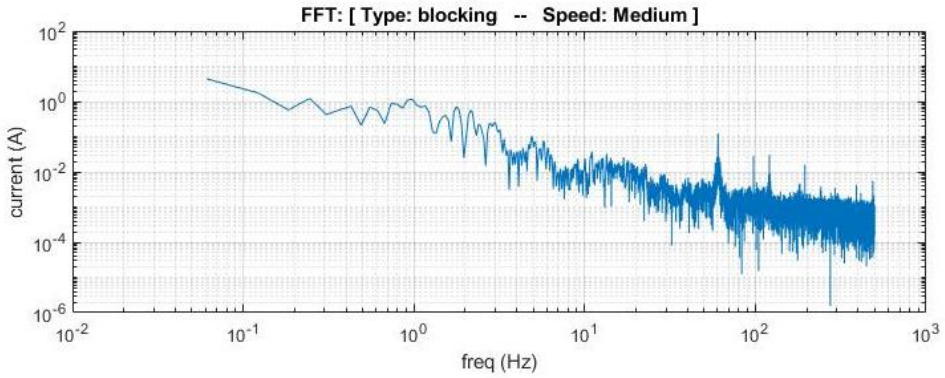
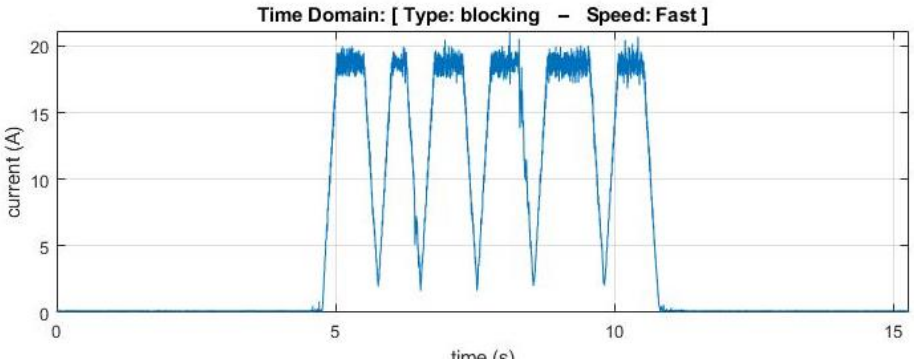
Accumulate – in situ measurements

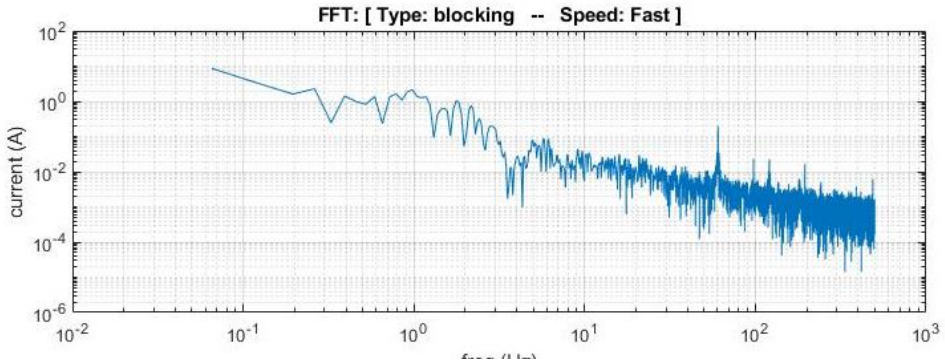












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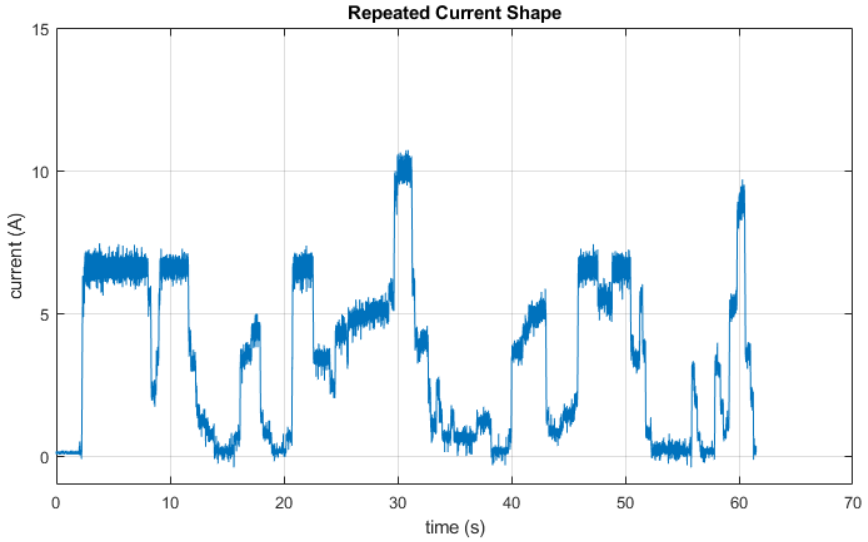
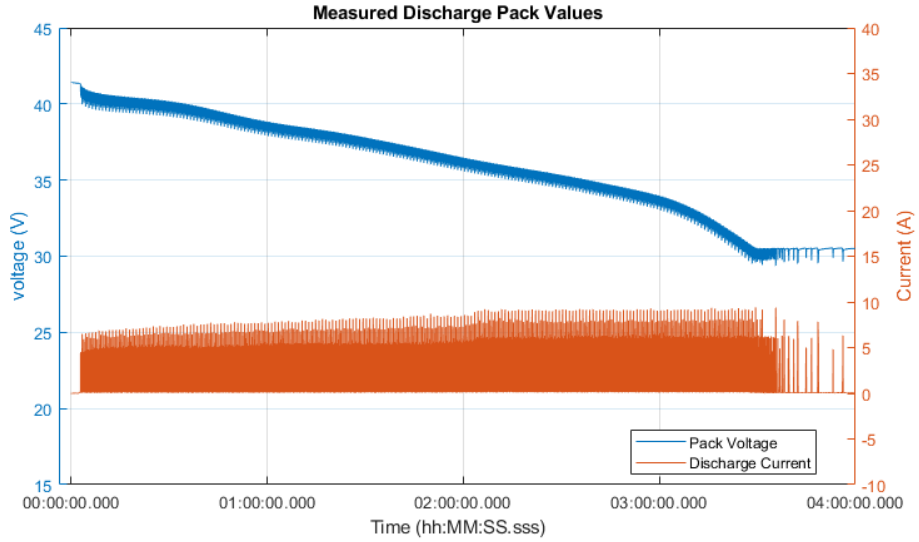
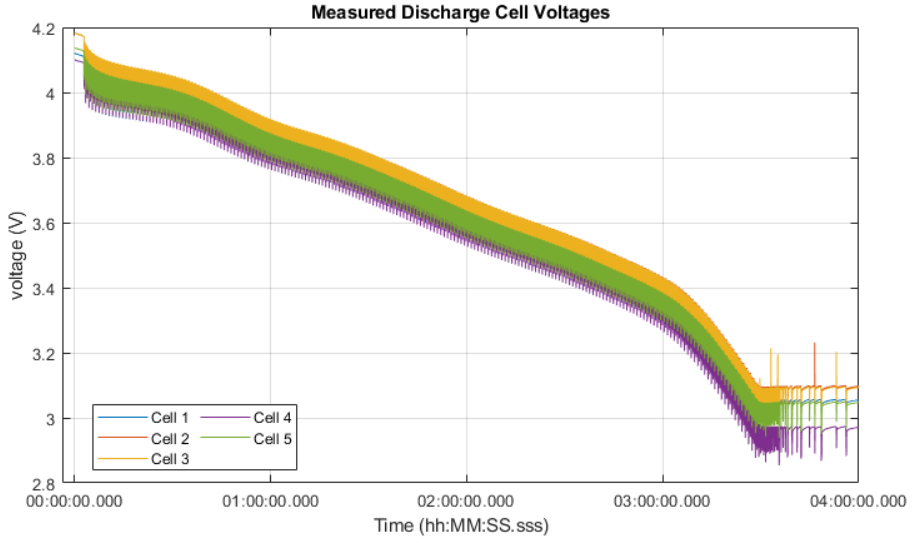
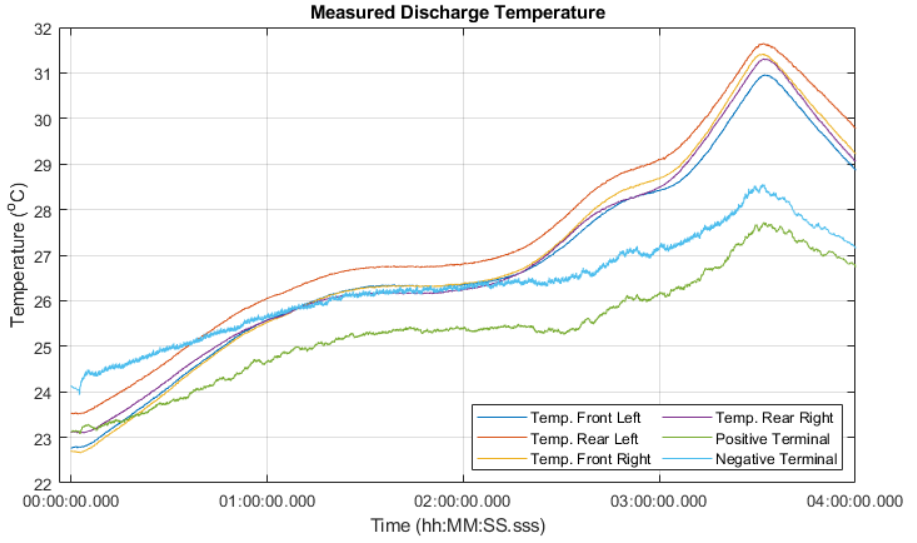
Accumulate – in situ measurements

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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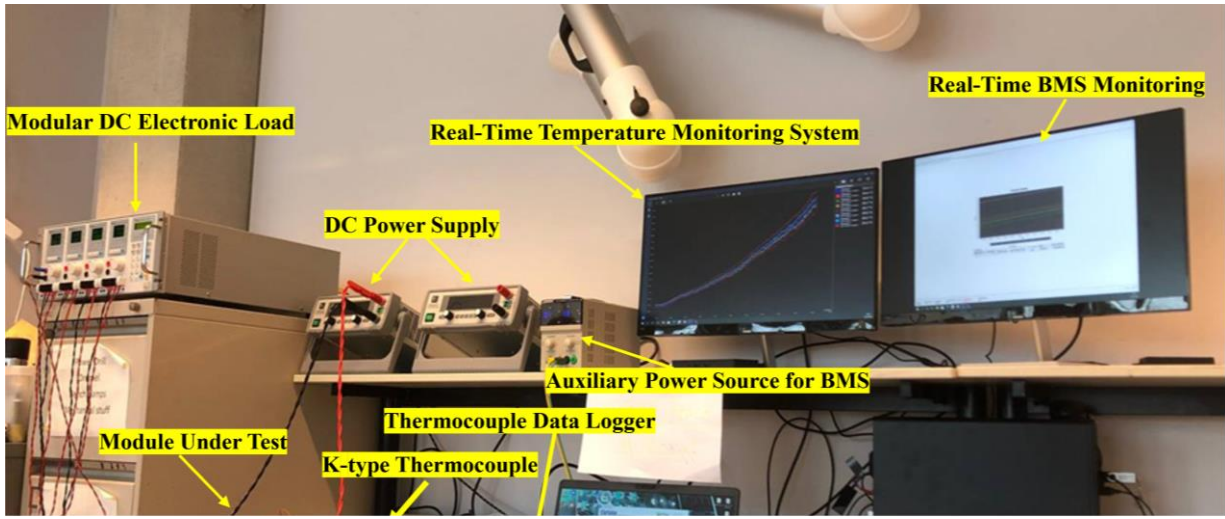

- Battery Echelon Utilization.
- Different screening and cell selection methods for second life batteries.
- Battery SOH measurement (Fast and accurate methods for testing the state of health of used battery).
- Laboratory study to find a new definition on battery SOH.
- Remaining Useful Life Prediction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

Ph.D. Researcher: Reza Azizighalehsari

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utwente.nl/en/eemcs/pe/people/phd/Azizighalehsari/

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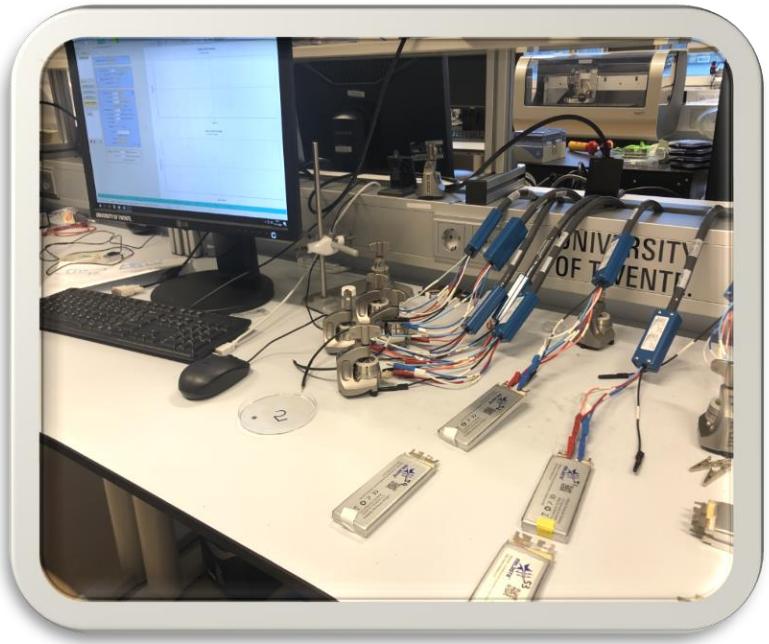
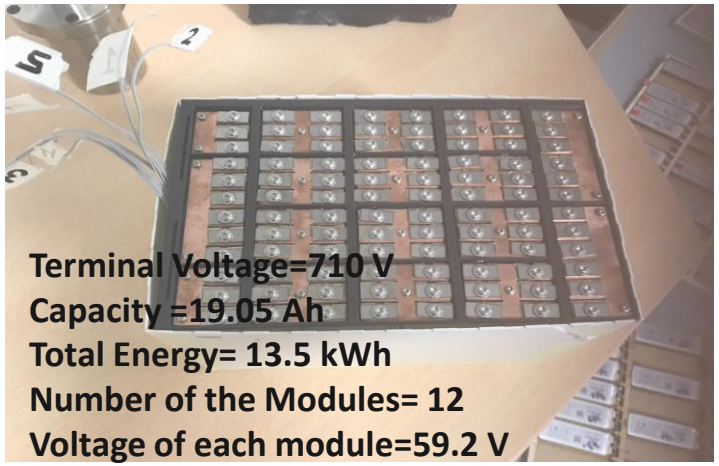
Cell Selection Criteria for Superbike





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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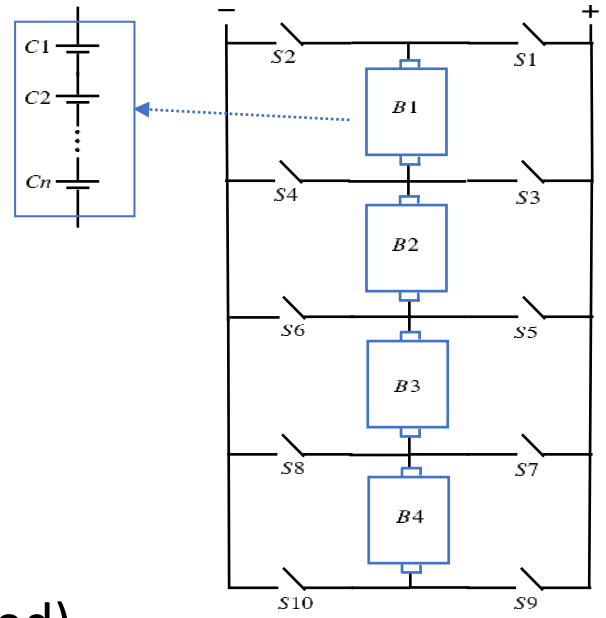
Highly Integrated Battery Electronics

- 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)

Ph.D. Researcher: Reyhaneh Eskandari

Contact information:

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Reyhaneh Eskandari

https://people.utwente.nl/r.eskandari

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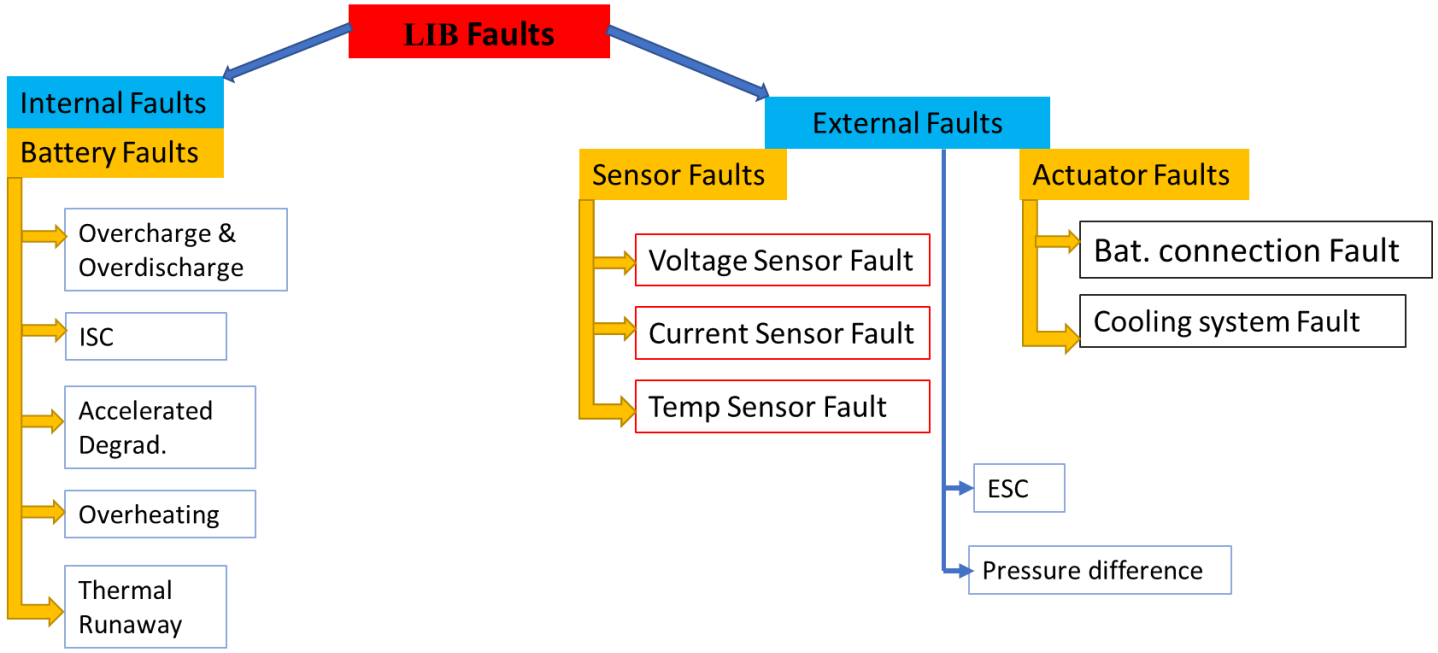
Battery Safety:
Fault Diagnostics and Mitigation

- 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:



Ph.D. Researcher: Regis Nibaruta

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Regis Nibaruta

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Top Sector Infrastructure: Battery Lab

- 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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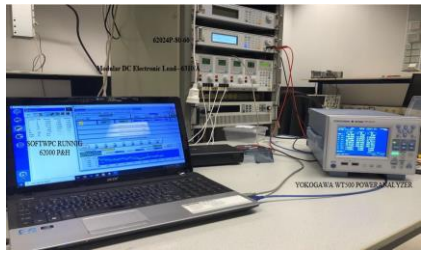
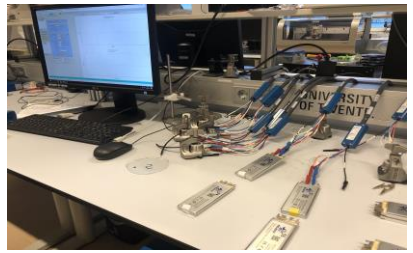
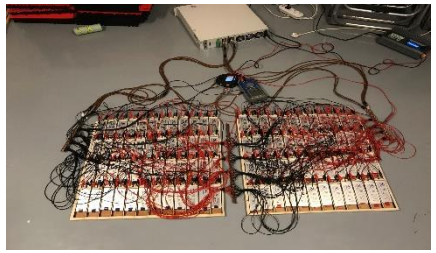
Advanced Battery Charging/ Power Electronics

- 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
- Ph.D. 3: Regis Nebaruta (Ukraine) – Battery Safety and SOH
- 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

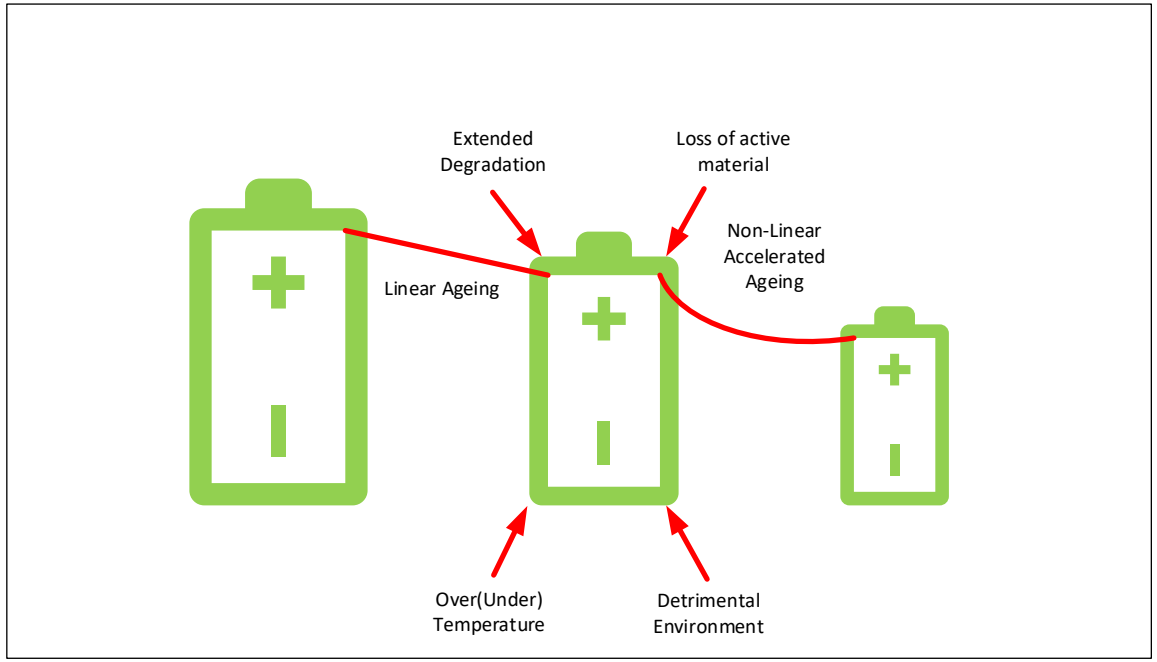
Key R&D N/W

THE FARADAY INSTITUTION

PTB

VSL

NPL National Physical Laboratory



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/

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