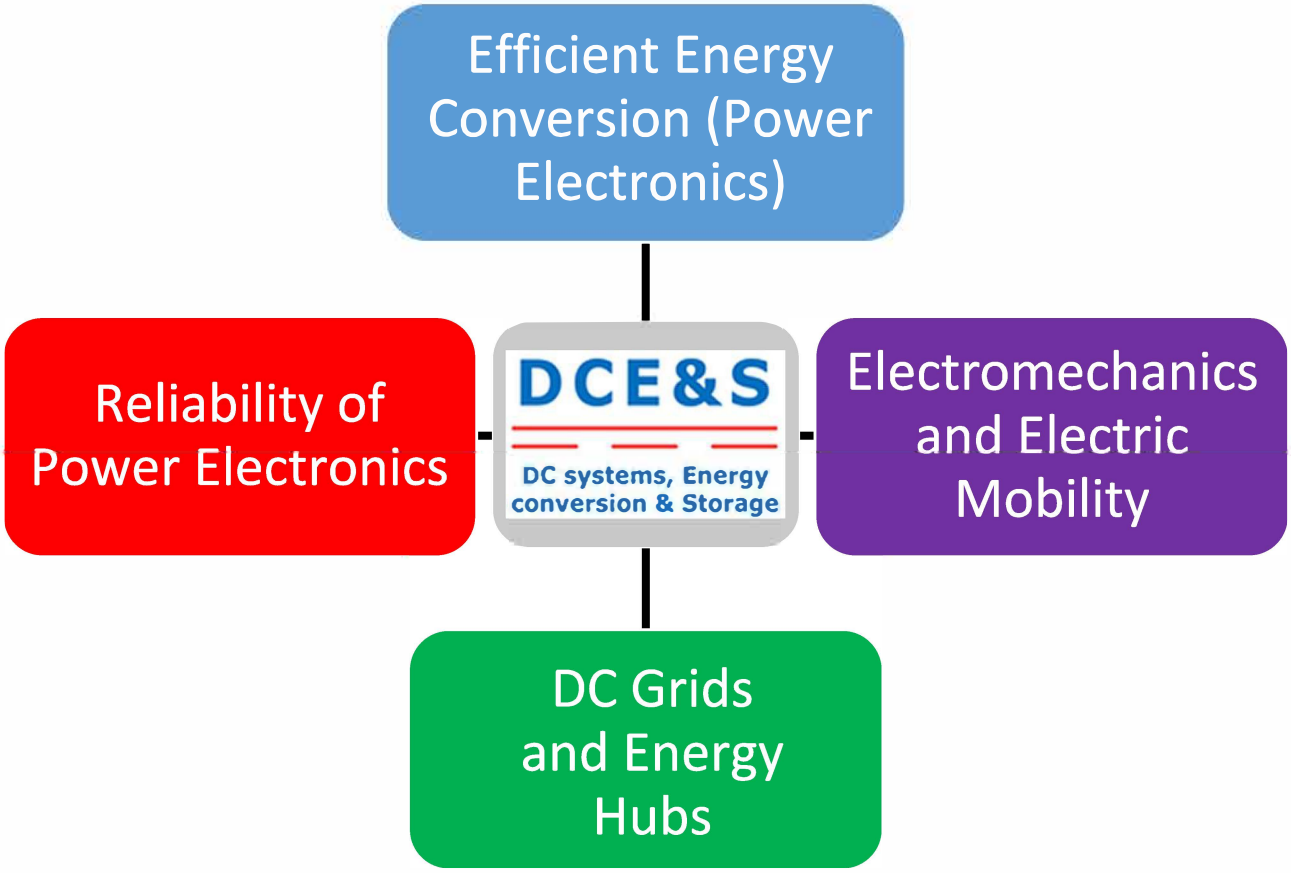
DC Systems, Energy conversion & Storage
Matchmaking Event

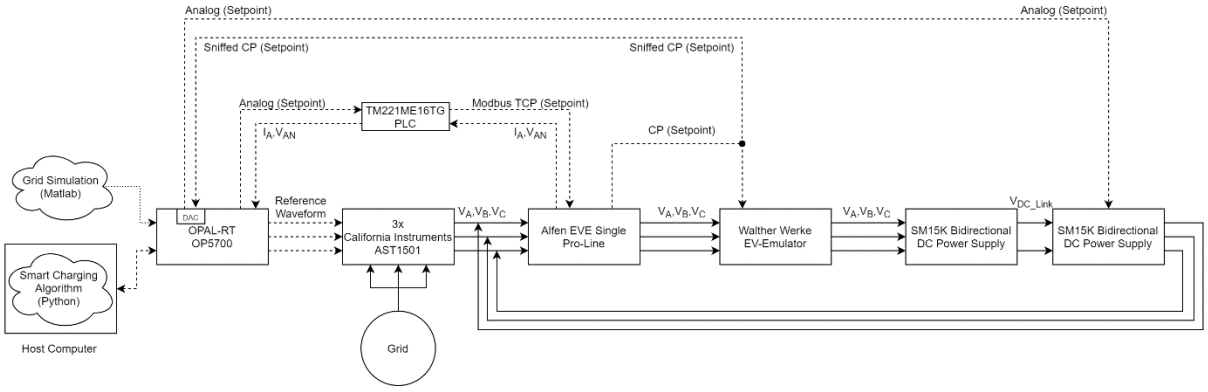
13th November 2024

12.30 - 14.00



BUILDING A HIL SETUP WITH V2G CAPABILITY

Type of project: MSc thesis



Scope:

The goal of this project is to build a Hardware In the Loop (HIL) setup in the laboratory, which is capable of emulating bidirectional charging of Electric Vehicles (EVs), and develop the necessary control algorithms.

Problem definition:

The increasing number of EVs will significantly impact the power grid because of the substantially increased electricity demand for charging the vehicles. On the other hand, with proper charging strategies and using vehicle-to-grid (V2G) technology, EVs can also offer services to the grid. The charging algorithms in the literature are usually only verified using simulations. A HIL setup can offer more insights and give a more accurate picture during testing.

Research Objectives:

- Build the V2G-capable HIL setup using the already available parts and integrating the new components (V2G charger, EV emulator)
- Modify or extend the control algorithms and communication between the components.
- Test the V2G charger alone and together with the EV emulator (the whole setup).

Methodology:

This project includes both hardware and software work. A base setup with only unidirectional charging (shown in the picture) is already available, but some components must be replaced. The bidirectional charger will soon be available, and a new EV emulator was developed in a separate project. The integration of these components and the testing of the new setup will be the primary goal of this project. Optionally, the California Instruments grid emulator could also be replaced by a Cinergia grid emulator, as the latter offers higher power limits. Apart from the hardware changes, the control algorithm for the charger (running on the OPAL-RT unit), the grid simulation and communication between the components also need to be revised. If time allows, different bidirectional optimisation and charging algorithms could be tested.

Contact details:

- PhD student: István Bara, I.Bara@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

TU Delft

MULTI-OBJECTIVE OPTIMISATION FOR EV CHARGING STATIONS

Type of project: MSc thesis

Scope:

The first goal of this project is to develop a Multi-Criteria Decision Making (MCDM) algorithm suitable for an Electric Vehicle Charging Station (EVCS). The second objective is to compare unidirectional (V1G) and bidirectional (V2G) charging in different scenarios using the developed algorithm.

Problem definition:

The increasing number of EVs will significantly impact the power grid because of the substantially increased electricity demand for charging the vehicles. On the other hand, with proper charging strategies and using vehicle-to-grid (V2G) technology, EVs can also offer services to the grid. The different objectives often conflict, which makes multi-objective optimisation approaches (specifically a posteriori methods) have significant advantages compared to single-objective methods.

Research Objectives:

- Develop decision-making algorithm(s) based on 1 or 2 chosen method(s) from the literature.
- Test the algorithm together with the multi-objective optimisation and energy management system.
- Compare V1G and V2G charging in different scenarios using the whole EVCS model and control algorithms.

Methodology:

A multi-objective optimisation framework and Energy Management System (EMS) have been already developed (although they could be modified or extended). However, they require a separate decision-making algorithm to choose the most appropriate solution. After the selection, the Energy Management System (EMS) can execute the chosen schedule. Thus, the EVCS can operate independently (without a human decision-maker). The focus is on selecting the most suitable solution from the Pareto front using different external inputs (e.g. local grid conditions, renewable energy source forecasts) and operator preferences. The whole model will then be used to compare V1G and V2G charging in different scenarios.
The already existing parts of the algorithm are written in Julia. Other languages could also be used for the MCDM module, but compatibility must first be checked. Computer simulations will be used for the comparison.

Contact details:

- PhD student: István Bara, I.Bara@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

TU Delft

DC Systems, Energy Conversion & Storage

CONTROL WITH MODE TRANSITIONS OF THREE-PHASE EV AC & DC CHARGING

Type of project: MSc thesis

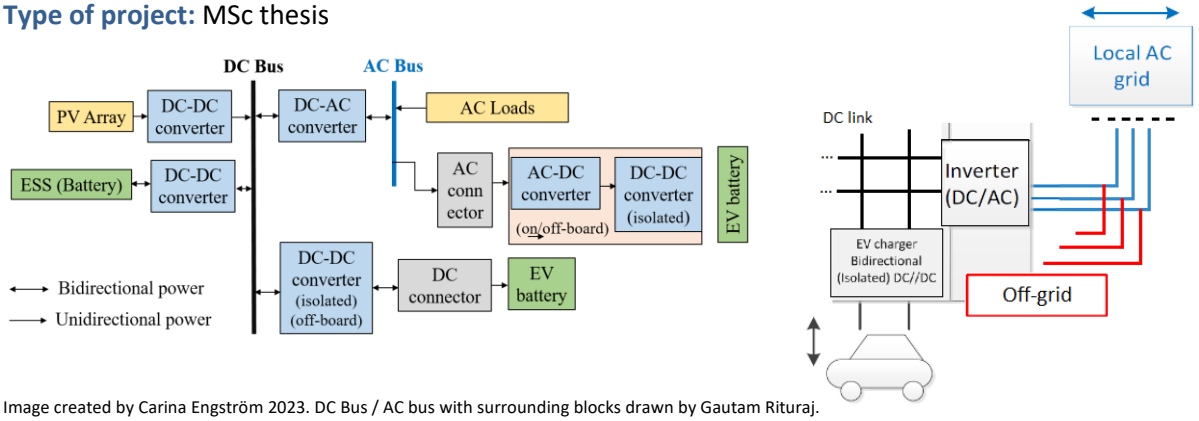


Image created by Carina Engström 2023. DC Bus / AC bus with surrounding blocks drawn by Gautam Rituraj.

Scope:

In this project, the investigation is focused on combining off-grid operation with regular grid operation of a DC EV charger. Standalone EV charging can provide a seamless charging infrastructure in urban and rural areas where the electrical grid is unreliable or unavailable, so EV adoption can realistically be implemented worldwide. If not, the EV might remain a luxury item. When the grid is connected, the charger could also assist the grid with V2G services to alleviate grid congestion problems. What is expected from you is interest in and good understanding of EV charging on low voltage networks, and that questions and ideas are communicated openly with the PhD student and supervisor. It is preferred, but not required, that the student has followed or will follow the courses: ET4116, ET4119, EE4515 and EE4755. 60 ECTS from the Master's program must have been completed before signing an official thesis agreement.

Problem definition:

A voltage source inverter (VSI) must be able to track its reference voltage or form the reference for the off-grid mode, compensate for unbalanced voltage and reject load disturbances. Unbalanced loading is inevitable in this charging system due to various AC loads. The transition from and to off-grid mode are essential for this system's full functionality.

Methodology:

You will start with reviewing existing control methods for unbalanced load, islanding detection, and mode transition. Then, the same is implemented on the digital controller. Hardware for testing is available. The stand-alone control has been partially developed, and the full two-mode control can be based on this, but we are open to hear your own ideas.

Proposed Research Objectives:

- Develop the control for the unbalanced load (to maintain the output voltage and frequency), islanding detection scheme and smooth mode transition and its controller implementation.
- Validation of developed controls in the lab's available EV charging system hardware.

Contact details:

- PhD student: Carina Engström, c.b.m.engstrom@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

TU Delft DRIVE2X

DCE&S
DC Systems, Energy Conversion & Storage

EV CHARGER PARTIAL LOAD EFFICIENCY CHARACTERISATION AND IMPROVEMENT

Type of project: MSc thesis

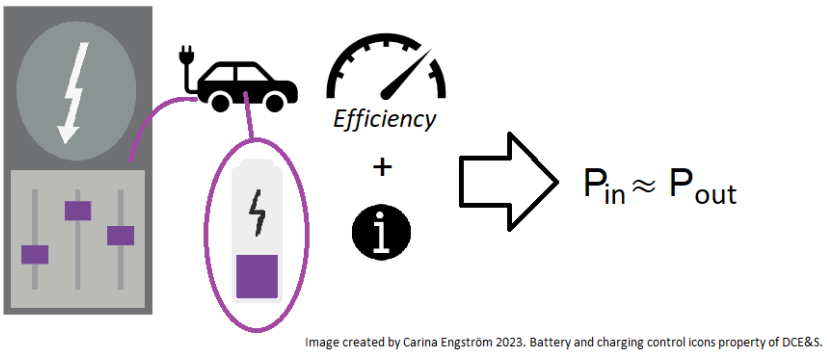


Image created by Carina Engström 2023. Battery and charging control icons property of DCE&S.

Scope:

In this project, the all-range efficient operation of a DC EV charger is investigated. It is desirable that the EV charging is efficient across the entire load range, which varies depending on, for example, the battery's State of Charge (SoC) to minimise losses and realise EV adoption based on renewable energy only. Today, even though many chargers appear smart from a first glance, there is still work to be done under the hood regarding the power electronics and their energy management. What is expected from you is interest in and good understanding of EV charging on low voltage networks, and that questions and ideas are communicated openly with the PhD student and supervisor. It is preferred, but not required, that the student has followed or will follow the courses: ET4116, ET4119, EE4515 and EE4755. 60 ECTS from the Master's program must have been completed before signing an official thesis agreement.

Problem definition:

Many converters optimise their efficiency to a nominal operating range. However, care has to be taken for battery recharging so as not to overcharge the cells, especially those close to their full SoC. To achieve this, the output power from the converter is lowered at the end of the charging cycle. This is at the converter's partial load and thus below the nominal operating range.

Methodology:

You will start with reviewing the literature on partial load decreased efficiency. As the reasons for the drop in efficiency vary across converter topologies and applications, it is good to understand why and when it occurs. Example tasks: Measuring on hardware which is available for testing. Simulation of components to detail the causes of loss at partial load. Switching pattern redesign to optimize for partial loading.

Proposed Research Objectives:

- Characterization of the partial load efficiency.
- Accurate modelling of losses during partial load for the converter setup used.
- Suggest improvements to increase the efficiency during partial load conditions.

Contact details:

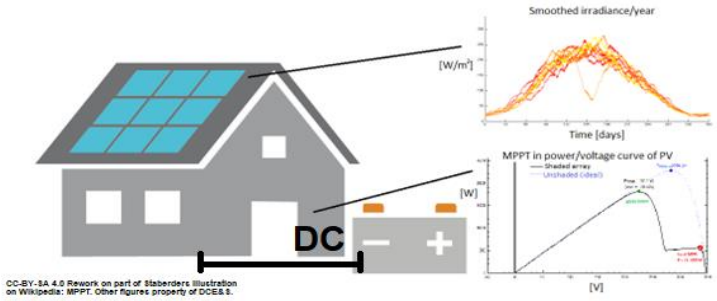
- PhD student: Carina Engström, c.b.m.engstrom@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

TU Delft DRIVE2X

DC Systems, Energy Conversion & Storage

IMPLEMENTATION OF DC BUS CONTROL AND PV MPPT FOR OFF-GRID APPLICATIONS

Type of project: Extra Project



Scope:

Off-grid energy systems can provide renewable electricity where the electrical grid is unreliable or unavailable, ensuring renewable energy access for all. This project aims to implement a DC bus control loop for a Hybrid Energy Storage System (HESS) power module operating in off-grid mode. It will ensure that the system's photovoltaic (PV) panels and the connected battery storage can maintain the electric supply during an outage. What is expected from you is interest in and good understanding of PV energy systems on small scale, and that questions and ideas are communicated openly with the PhD student and supervisor. It is preferred, but not required, that the student has followed or will follow the courses: ET4116, ET4119, EE4515 and EE4755.

Problem definition:

When there is no grid power, the DC bus stabilises voltage and ensures the off-grid power balance. The self-generated power is thus sufficient for cooking, lightning etc. during power outages. While the concept exists for microgrids, it is novel for EV charging systems (this project). MPPT for PV operating under partial shading is interesting, as the PV characteristics include multiple peaks with only one representing the true maximum, and conventional MPPT techniques need to be adapted.

Methodology:

You will review the literature on DC bus control loops and MPPT algorithms and suggest a few implementation approaches. Then, the method will be implemented in Simulink (optional: in C) to test the available models of the HESS system. Furthermore, there is opportunity to also consider curtailed PV mode*, and to expand this extra project to a Thesis project.

Proposed Research Objectives:

- Identify the mismatching operating conditions arising from the power modules connected on the DC bus and for PV and adapt the MPPT algorithm
- Maintain a robust system reliant on a stable DC bus
- Maximize energy yield in relation to the energy storage

Contact details:

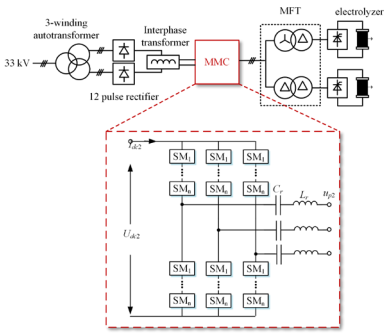
- PhD student: Carina Engström, c.b.m.engstrom@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

TU Delft

* In Conference Proceedings of 2024 International EPE-PEMC Conference

MIGRATION OF SOLID STATE TRANSFORMER MODELING TO PSCAD

Type of project: Extra Project



Scope:

This project focuses on modeling a Solid State Transformer (SST) in PSCAD. We will migrate an existing closed-loop control SST model from Simulink to PSCAD to leverage PSCAD's electromagnetic transient (EMT) simulation capabilities, which allow for detailed analysis of fast-changing electrical behaviors in power electronics.

Problem definition:

Solid State Transformers (SSTs) are advanced transformers that are smaller and lighter than traditional ones. While Simulink is useful for control design, PSCAD offers a distinct advantage in EMT simulation, which can more accurately capture SSTs' high-speed switching and dynamic responses. By transitioning the SST model to PSCAD, we aim to better analyze these transient behaviors critical for SST applications.

Methodology:

We will start by comparing Simulink and PSCAD modeling methods, focusing on how EMT simulation affects accuracy. Next, we will rebuild the SST model in PSCAD and test it under different operating conditions to validate its performance.

Research Objectives:

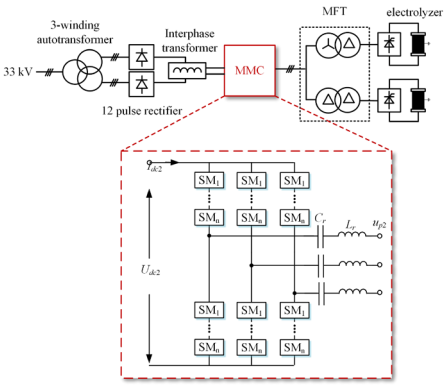
- To understand PSCAD's EMT simulation for modeling SSTs.
- To adapt and enhance the SST control model from Simulink to PSCAD.
- To validate and analyze the PSCAD SST model under dynamic conditions, ensuring accuracy in transient behavior.

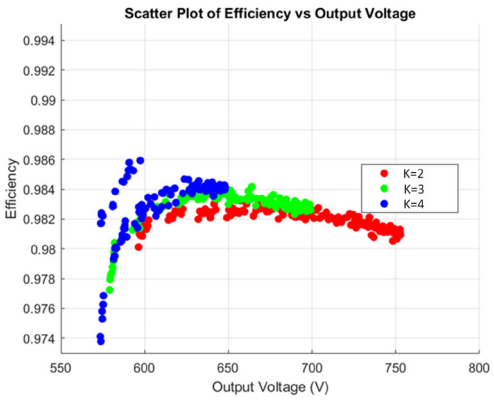
Contact details:

- PhD student: Zhengzhao Li, z.li-20@tudelft.nl
- Supervisor: Zian Qin, z.qin-2@tudelft.nl

OPTIMAL CONTROL OF MODULAR MULTILEVEL RESONANT CONVERTER BASED SOLID STATE TRANSFORMER

Type of project: MSc thesis





Scope:

The objective of this project is to identify the optimal control strategy for the modular multilevel resonant converter. The control variables include frequency and phase shift angle, with the ultimate goal of minimizing power loss.

Problem definition:

Solid State Transformers (SSTs) use medium-frequency transformers to reduce size and weight compared to traditional line frequency transformers. For this project, the modular multilevel resonant converter, similar in working principle to the LLC resonant converter, is selected to decrease switching loss. Control parameters such as phase delay and frequency are adjustable to meet desired voltage and power targets, with an optimal combination of these parameters yielding the lowest system power loss. **A closed-loop control SST model has already been established in Simulink. The project aims to identify this optimal control strategy using advanced methods. If artificial intelligence is foreseen as needed, we have ready-to-use FNN models in python**. The optimal control strategy will be developed and tested using Simulink/PSCAD or the real-time simulator OPAL-RT.

Methodology:

First, conduct a literature review on the optimal control method for power converters. Then adapt existing optimal control method to the solid state transformer in Simulink or other software. Finally, it is expected to build the model in real time simulator.

Research Objectives:

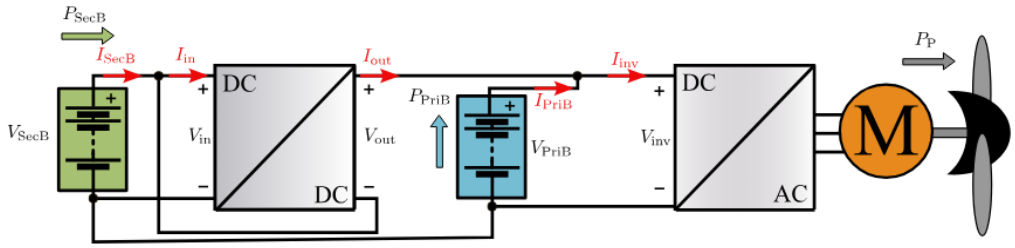
- Gain a deep understanding of the fundamental operating principles of MMR.
- Understand how to design the optimal control strategies with multiple control parameters
- Validate the effectiveness of the developed control algorithms through Simulink or OPAL-RT.

Contact details:

- PhD student: Zhengzhao Li, z.li-20@tudelft.nl
- Supervisor: Zian Qin, z.qin-2@tudelft.nl

PARTIAL POWER PROCESSING CONVERTER FOR ALL-ELECTRIC AIRCRAFT

Type of project: MSc thesis



Scope:

The aim of this thesis is to design a partial power processing converter for electric vertical takeoff and landing (eVTOL) aircraft with a hybrid battery pack

Problem definition:

Since 2007, the aviation industry's CO2 emissions from jet fuel combustion has become an increasing concern. Electrification of aircraft presents a promising solution to reduce fuel consumption and emissions. However, designing an all-electric powertrain for eVTOL aircraft poses a significant challenge, particularly in meeting the unique requirements of achieving both high power density and high energy density simultaneously.

Methodology:

First, a comprehensive literature review of the partial power processing (PPP) concept will be conducted. Next, the sizing methodology for an eVTOL with a hybrid battery pack—comprising a secondary pack using high-power density cells and a primary pack using high-energy density cells—will be thoroughly studied and understood. Following this, the partial power converter for the battery pack will be designed to optimize gravimetric energy density and maintain high efficiency throughout the entire flight mission.

Research Objectives:

- Understand of the PPP converter concept and the eVTOL power profile throughout the flight mission.
- Optimize the voltage for the two battery packs while minimizing the processed power ratio of the PPP, and maintain the voltage conversion ratio of the DC/DC converter at its highest efficiency operating point throughout the entire flight mission.
- Conduct a multi-objective optimization of the PPP converter to maximize efficiency and gravimetric power density.
- Build a prototype of the PPP converter using a dual active bridge topology and evaluate its performance by assessing gravimetric energy density and efficiency.

Contact details:

- PhD student: Yawen Liang, Y.Liang-3@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, G.R.ChandraMouli@tudelft.nl

OPTIMISATION OF IMC CHARGING CORRIDOR

Type of project: Msc thesis

Scope:

Traditional trolleybus operates on a fixed route determined by trolleybus overhead line catenary (OHL), but modern trolleybuses with autonomous battery supply are closer to battery electric buses: they are equipped with a battery that allows them to work without supply from overhead wires. The trolleybus catenary can therefore be considered as a linear charging corridor that allows the battery to be charged on the motion. This solution is often so called In Motion Charging (IMC). Due to the very high costs of building the traction network, the key issue is the optimization of the parameters of the charging corridor in the IMC system.

Problem definition:

Optimization of the charging corridor localisation in the IMC, including battery costs and degradation

Methodology:

- Energy consumption calculations for the selected bus line (e.g. Matlab)
- Determining variants of the location of the charging corridor
- Calculation of battery load profile and comparison of degradation rate (e.g. Open Sesame)
- Calculation of the current load of the charging corridor

Research Objectives:

- On the basis of several case studies to show how placement of IMC charging corridor along the route influences the battery capacitance, degradation process and charging process

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Contact details:

- Visiting Professor: Mikołaj Bartłomiejczyk, m.b.bartlomiejczyk@tudelft.nl
- Supervisor: Ibrahim Diab, I.Diab@tudelft.nl

TU Delft

APPLICATION OF IMC CHARGING SYSTEM IN AMSTERDAM PUBLIC TRANSPORT STSTEM

Type of project: Msc thesis

Scope:

Modern solutions provide new possibilities and greatly increase the attractiveness of trolleybus transport, in particular when trolleybuses are equipped with traction batteries enabling fee cathenary driving. This solution is called as IMC (In Motion Charging) – trolleybus equipment with traction batteries, which use overhead cathenary as linear charger and runs mainly in the battery mode as standard electric bus. IMC allows also to use of existing energy infrastructure of trams or metro, e.g. to supply the traction network or fast charging stations for trolleybuses, the so-called IMC Plus.

Problem definition:

Electrification of public transport in Amsterdam based on IMC technologies

Methodology:

- Power and energy consumption simulation in Matlab or similar software
- Analysis of battery degradation, eg. in Open Sesame
- Spatial analysis of bus routes

Research Objectives:

- Choosing routes predestined for IMC electrification and for OPP electrification
- Choosing placement of trolleybus overhead cathenary and charging stations
- Analysis of the use of existing infrastructure

Contact details:

- Visiting Professor: Mikołaj Bartłomiejczyk, m.b.bartlomiejczyk@tudelft.nl
- Supervisor: Ibrahim Diab, I.Diab@tudelft.nl

FAST CHARGING SATION FOR IMC ELECTRIC BUS

Type of project: Msc thesis

Scope:

There are two basic means of trackless electrified urban public transport: trolleybus and battery electric bus. The combination of both solutions – trolleybus traction network and stationary charging - is called IMC technology (In Motion Charging) which allows charging battery vehicle in motion from the trolleybus traction network and go outside traction network with battery mode. In addition, stationary battery charging is also possible, as in battery buses. An important element of this system may be a charging station acting as a range extender (basing charging: trolleybus OHL, supplementary charging: stationary charging).

Problem definition:

Analysis of IMC stationary charging station power profiles for selected implementation. Proposing of Storage Energy System usage for peak shaving (Grid Booster).

Methodology:

- Analysis of a selected bus line: presentation of timetables and their daily variability
- Energy consumption calculations of bus line (e.g. Matlab)
- Proposing of algorithm for stationary charging
- Analysis of battery discharge profiles in IMC electric buses - trolleybus
- Determination of charging station load profiles for different operational conditions
- Analysis of Storage Energy System installation in charging station for peak shaving

Research Objectives:

- Determining the optimal stationary charging algorithm
- Setting of optimal system parameters for charging station peak power demand optimisation

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Contact details:

- Visiting Professor: Mikołaj Bartłomiejczyk, m.b.bartlomiejczyk@tudelft.nl
- Supervisor: Ibrahim Diab, I.Diab@tudelft.nl

TU Delft

EHIGWAY AND ITS IMPACT ON THE LOAD ON THE POWER GRID

Type of project: Msc thesis

Scope:

The electrification of heavy goods transport is an integral part of reducing the consumption of fossil fuels. However, in the case of heavy goods vehicles, their electric power supply is associated with the need to use large batteries and build a dense network of high-power charging stations. This brings problems, among others, with a high load on the power grid.

An alternative solution is to power and charge trucks in motion using a pantograph current collector from the catenary placed on motorways. This allows for a significant reduction in battery capacity, as well as an even distribution of charging power. Thanks to this, the negative impact of vehicle charging on the congestion of the electrical power grid is reduced.

Problem definition:

Analysis of the possibilities of using the eHigway system for truck transport in the Netherlands, with particular emphasis on limiting the impact of the charging system on the power grid.

Methodology:

Power and energy consumption simulation in Matlab/Python or similar software

Research Objectives:

- Defining technical requirements for eHighway, eg. energy consumption demand
- Comparison of the impact of stationary vs. highway charging systems on the load on the power grid
- Analysis of the use of existing infrastructure for supply of eHigway

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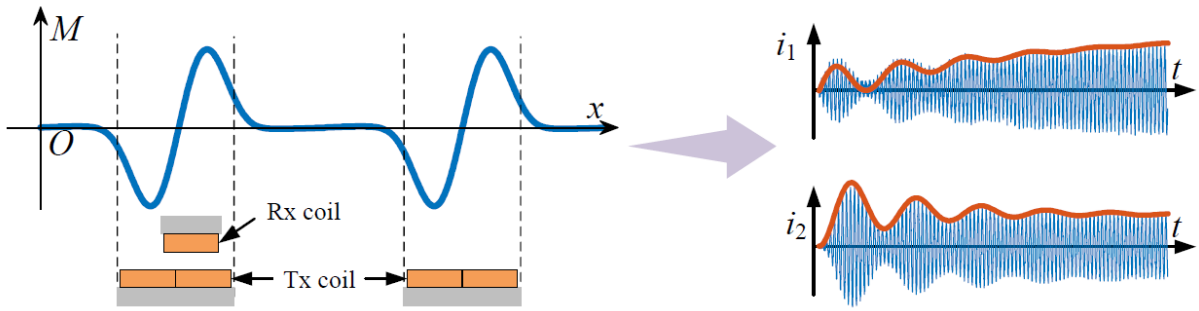
Contact details:

- Visiting Professor: Mikołaj Bartłomiejczyk, m.b.bartlomiejczyk@tudelft.nl
- Supervisor: Ibrahim Diab, I.Diab@tudelft.nl

TU Delft

PARAMETER IDENTIFICATION AND MODEL PREDICTIVE CONTROL FOR POWER REGULATION OF WIRELESS CHARGING SYSTEMS

Type of project: MSc thesis



Scope: Wireless charging technology tends to replace the conductive alternative as the power transfer capacity and efficiency are demonstrated to be high enough to achieve fast charging above 50 kW. A great attention has been paid to dynamic wireless charging where EVs can pick up power in motion.

Problem definition: As EV moves, the magnetic coupling changes between transmitter and receiver sides, and the power transfer fluctuates under open loop conditions. To effectively protect the electric components from overcurrent/-voltage and minimize electric power fluctuation, the controller should be able to rapidly regulate the charging behaviour under varying magnetic coupling conditions. It has been found that model predictive control can be a promising candidate in terms of transient response. However, parameter identification becomes prominent before model predictive controller can be built.

Methodology:

- Study of the basic principles of inductive power transfer technology
- Identify suitable a primary side control method and a parameter identification method
- Build simulation model of a dynamic wireless charging system with feedback control
- Design and build a primary-side controlled dynamic wireless charging system
- Verify the effectiveness of the designed controller

Research Objectives:

- Simulation model using model predictive control
- Hardware demonstration of the designed controller and power electronic converters

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Contact details:

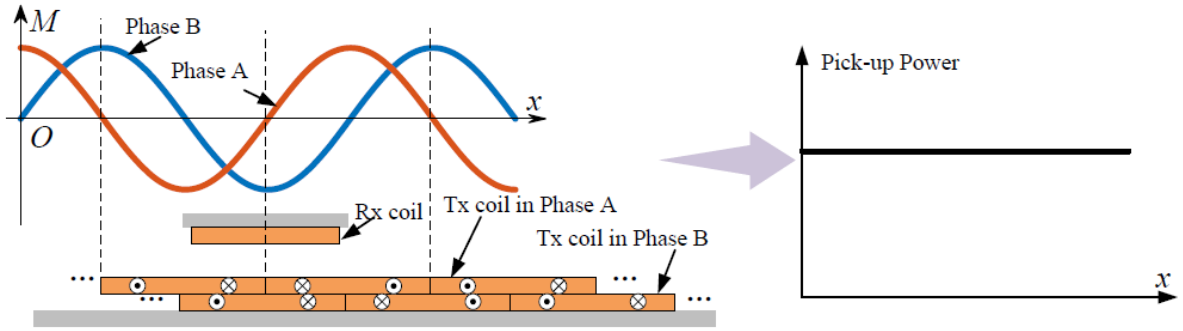
- Supervisor: Dr. Wenli Shi, W.Shi-3@tudelft.nl, LB 02.860
  Prof. Pavol Bauer p.bauer@tudelft.nl, LB 03.600

TU Delft

DCE&S
DC Systems, Energy Conversion & Storage

POWER STABILIZER FOR DYNAMIC WIRELESS CHARGING APPLICATIONS

Type of project: MSc thesis



Scope: In the TU Delft ESP lab, a wireless charger with 97.7% efficiency at 50 kW has been achieved at stationary condition. This results are strong support to advance this technology to dynamic applications where electric vehicles can get charged in motion. Theoretically, dynamic wireless charging technology makes it possible to have indefinite driving range.

Problem definition: In dynamic wireless charging systems, the transmitter coils are buried on the road in a discrete manner. It is inevitable that the magnetic coupling between the transmitter and receiver sides fluctuates as the relative position changes. As a consequence, it becomes a challenge to stabilize the pick-up power. The solution lies in innovative design of magnetic coupling mechanism and control of a back-end dc-dc converter.

Methodology:

- Study of the basic principles of inductive power transfer technology
- Study the operating principle of muti-phase dynamic wireless charging system
- Simulation models including a back-end dc-dc converter
- Design and control of a back-end dc-dc converter
- Build a dc-dc converter and its controller
- Test the power fluctuation on a dynamic wireless power transfer system

Research Objectives:

- Simulation model of a dynamic wireless charging system
- Control algorithm for power stabilization
- Stabilize the output power of a dynamic wireless charging system

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Contact details:

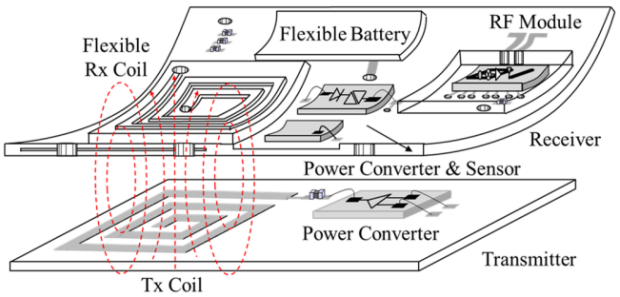
- Supervisor: Dr. Wenli Shi, W.Shi-3@tudelft.nl, LB 02.860
  Prof. Pavol Bauer p.bauer@tudelft.nl, LB 03.600

TU Delft

DC Systems, Energy Conversion & Storage

WIRELESS CHARGING SYSTEMS BASED ON BENDABLE PCB ORIENTED FOR WEARABLE ELECTRONICS

Type of project: MSc thesis



Scope: Due to the flexibility of wireless charging technology, research interests arises in applying this technology in wearable consumer electronics like health monitoring devices, smartwatches, electronics textile, etc. Wireless charging technology makes it possible to empower wearable devices with wear-free, waterproof and easy integration features.

Problem definition: Wireless charging technology uses high frequent magnetic field achieve energy interaction between a transmitter coil to a receiver coil. Conventionally, coils and PCBs on the transmitter and receiver sides are rigid, which has to be made bendable/foldable for wearable applications. Meanwhile, magnetic field exposure to human body should be limited to sure safety. Systematic analysis and design methodology should be carried out for this new application scenario.

Methodology:

- Study of the basic principles of inductive power transfer technology
- Review of compensation and coil topology for low powre applications
- Finite element modelling of coils with/without ferrite cores
- Analysis of magnetic field exposure, power transfer capability under bended conditions
- Design and implementation of a wireless charging system using flexible PCB.

Research Objectives:

- Circuit and coil topology suitable for low power applications
- Design methodology of wireless charging system using flexible PCB
- Design and build a wireless charging system

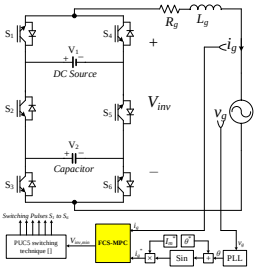
Contact details:

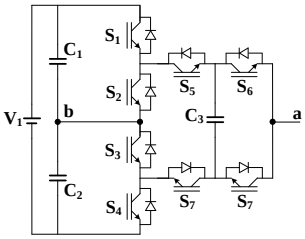
- Supervisor: Dr. Wenli Shi, W.Shi-3@tudelft.nl, LB 03.680
  Prof. Pavol Bauer p.bauer@tudelft.nl, LB 03.600

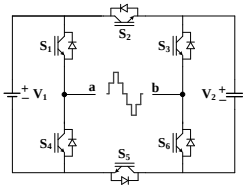
TU Delft

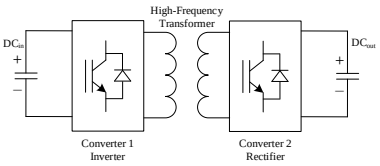
FINAL THESIS OR EXTRA PROJECT TOPICS IN MY GROUP (DR. HANI VAHEDI)

Type of project: Master Thesis or Extra Project









Scope:

My group has various project topics focusing on designing and controlling power electronics converters for different applications. Students interested in **hardware** design can work on power converter topologies to improve existing technologies or propose new ones. Students interested in designing **controllers** and switching algorithms for power converters should have a strong background in mathematics and **Artificial Intelligence** techniques to dive into the modeling and control of power converters.

Another topic is the Green Village 24/7 Energy hub project, which aims to investigate the green hydrogen production from solar energy and store it for future use. Students interested in **data analysis**, **condition monitoring**, **fault detection**, and modeling **energy hubs** can work on it.

Methodology:

Each project can be done through theoretical studies and simulations with the opportunity to extend the work through real-time simulations, Hardware-In-the-Loop, or experimental tests with hardware design. You have the opportunity to learn how to work with **Opal-RT** or **Plecs RT-Box** real-time simulators, OP8666/TI/STM **microcontrollers**, **LTspice**, and **Altium** Designer.

The Extra Project will be a literature review, initial simulation, or PCB design of the above topics.

Research Objectives:

- Designing enhanced topologies, controller algorithms, and switching techniques of power converters for different applications such as green hydrogen production, fuel cells, bidirectional EV chargers, renewable energy, electrification of industrial processes
- Implementing the ideas on real-time simulators, Hardware-in-the-loop, experimental setups
- Working on cutting-edge technologies in the field of power electronics, such as multilevel converters, AI-based controllers, Data-Driven modeling, etc.

* Interested students can send me an email to get more details.

Contact details:

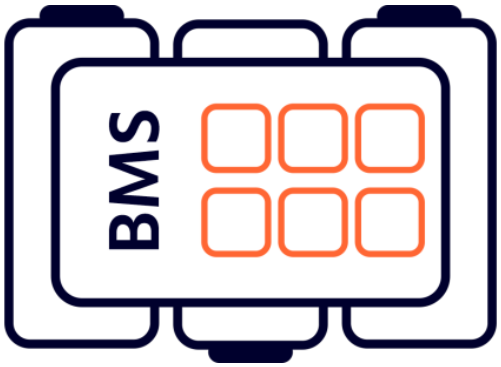
- Supervisor: Dr. Hani Vahedi, H.Vahedi@tudelft.nl (with my PhD students)

TU Delft

DCE&S
DC Systems, Energy Conversion & Storage

BATTERY MANAGEMENT SYSTEM (BMS) DESIGN FOR HEAVY-DUTY VEHICLES

Type of project: Thesis at Company



Scope:

Electrification is not limited to passenger cars but extends to heavy-duty vehicles and industrial machinery, which can benefit from reduced operational costs and lower environmental impact. The scope of **Maxwell & Spark** is industrial mobility systems electrification by using Li-ion technology. In this regard, Maxwell & Spark has a plan to develop a new BMS. A Battery Management System (BMS) is crucial for the electrification of vehicles, ensuring the safe and efficient operation of electric vehicle (EV) batteries. For electrifying vehicles, especially heavy-duty applications, a robust BMS is essential to manage large-scale battery packs, ensure energy efficiency, and maintain the overall safety and reliability of the electric powertrain, contributing to the broader adoption of electric mobility. This project aims to implement a universal BMS for different heavy-duty industrial vehicles. After that, a smart energy management system will be designed based on this BMS.

Methodology:

A detailed study of conventional BMS features and specifications will be done. The new feature will be added to the BMS based on company needs. Simulations will be done in MATLAB/Simulink. Model-based design and Digital Twin are preferred methods, in which different sections of the system will be modeled and simulated as follows:

1. System Design and Architecture
2. Battery Monitoring and Control
3. Thermal Management
4. Power Electronics and Energy Management
5. Safety and Fault Diagnosis
7. Vehicle Integration and Real-world Application

Research Objectives:

- Contribute to the system architecture design, focusing on BMS integration into industrial and electrified vehicle platforms.
- Explore and refine the use of model-based design using tools like MATLAB/Simulink to design BMS.
- Delivering the software and hardware of the battery management system

Contact details:

Supervisor: Dr. Hani Vahedi: H.Vahedi@tudelft.nl

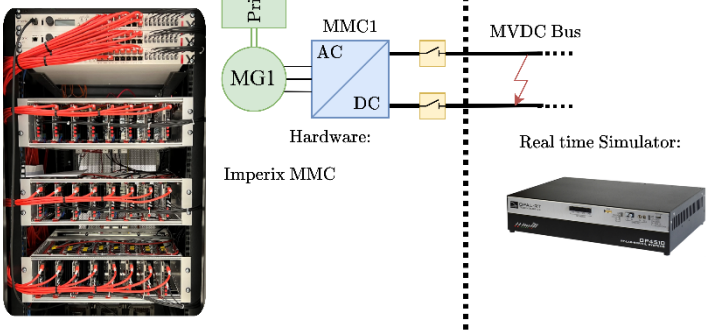
Company supervisor: Dr. Rasoul Faraji

TU Delft

DCE&S
DC Systems, Energy Conversion & Storage

PHIL SIMULATION OF MODULAR MULTILEVEL CONVERTER FOR DC BUS FAULTS

Type of project: <MSc thesis>



Scope:

Design a power hardware in the loop (PHIL) simulation for a modular multilevel converter (MMC) implementing a shipboard MVDC bus. Using this setup, test and reduce the impact of a bus fault on the Naval shipboard power system operation.

Problem definition:

For the electrification of the maritime sector, future vessels are expected to have an MVDC shipboard power system (SPS). Although the DC-SPS has shown significant advantages over AC, it does come with a compromise on protection. State-of-the-art DC circuit breakers (CB) are lossy, expensive, and unable to reach the large current breaking requirements of the SPS. The MMC is an innovative technology that has become one of the favorable converters that act as the interface between AC and DC networks. A significant advantage of MMC is its ability to mitigate and control fault currents, reducing the CB requirements [1]. This property can improve the overall ship survivability, which is crucial for future naval vessels. In this project, you will develop a PHIL setup for the MMC emulating a shipboard DC bus to test and improve the fault mitigation properties of the converter.

Methodology:

The student shall start with a literature study on MMC dynamics, controller design, and DC-SPS architectures. After that, the student is expected to use this knowledge to develop a real-time digital twin (RTDT) model for the MMC in a shipboard DC bus. Then, the student shall develop the interface between RTDT and the lab-scale MMC. Finally, the impact of the bus fault on the SPS operation shall be tested, and improvements will be proposed.

Research Objectives:

- Literature review on DC-SPS architectures, MMC dynamics, and control.
- Design a RTDT model of the MMC in a shipboard bus.
- Develop the interface between the OPAL-RT and Imperix MMC.
- Test the impact of a bus fault on the shipboard bus.

Contact details:

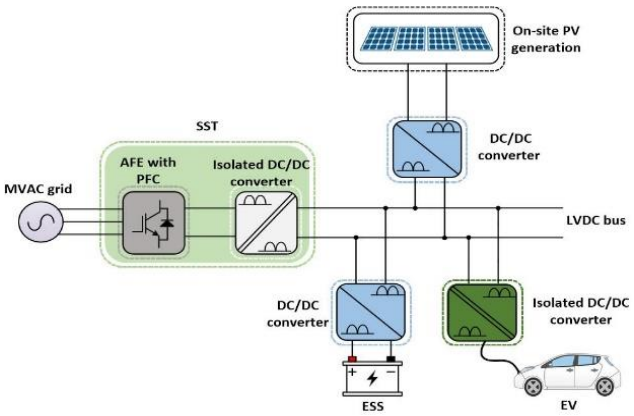
- PhD student: Robin van der Sande, R.P.J.vanderSande@tudelft.nl
- Supervisor: Dr.ir. Aditya Shekhar, A.Shekhar@tudelft.nl
  Prof. Dr. Ir. Pavol Bauer, P.bauer@tudelft.nl

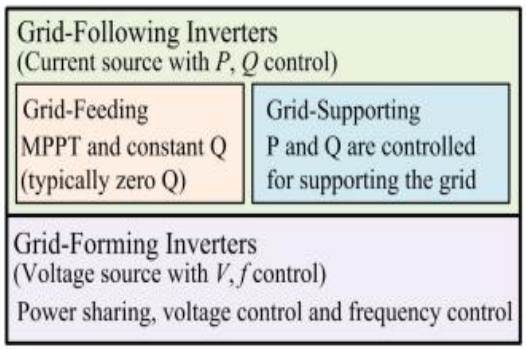
[1] V. Staudt et al., 'Short-circuit protection in DC ship grids based on MMC with full-bridge modules', in ESARS, Mar. 2015, pp. 1–5.

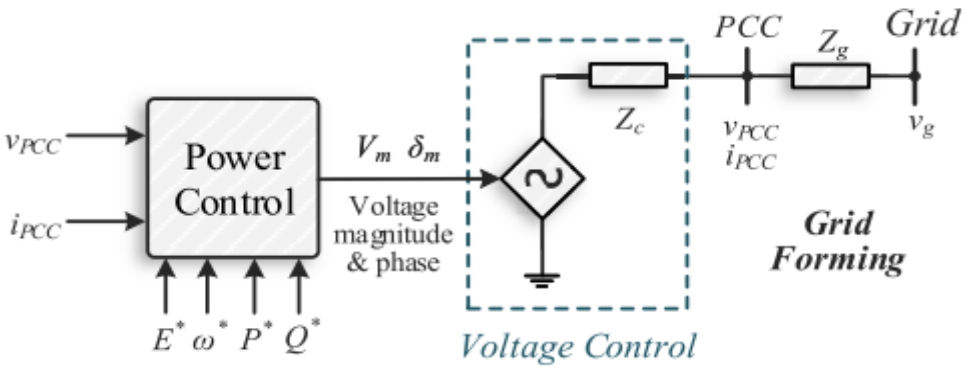
TU Delft

GRID FORMING CONTROLS OF ULTRA-FAST CHARGING STATIONS WITH INTEGRATED ENERGY STORAGE SYSTEM

Type of project: <MSc thesis>







Scope:

To study and implement grid-forming control for voltage and frequency regulation at the point of common coupling between grid and Solid-State Transformer (SST) based Ultra-fast charging station (UFCS).

Problem definition:

Electric power systems are increasingly being augmented with inverter-based resources (IBRs). And IBRs are experiencing an increasing demand for mimicking the behaviour of synchronous generators, which is not possible with conventional grid-following inverters (GFLIs). As a solution, the concept of Grid-forming inverters (GFMIs) is emerging, drawing increased attention from academia and the industry. The challenges in adding GFMIs into existing power systems include a seamless transition from grid-connected mode to the standalone mode and vice versa. In this study, We will use SST-based UFCS with integrated energy storage systems (ESS) to implement and examine the Grid-forming control architecture.

Research Methodology & Objectives:

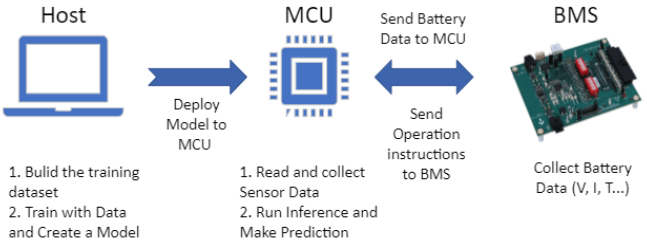
- Literature review of GFMIs Control Methods
- Mathematical modelling and simulation of the GMFI Methods
- Implementation and comparison of the developed control techniques

Contact details:

- PhD student: Adnan Ahmad, A.ahmad-2@tudelft.nl
- Supervisor: Dr. Zian Qin, Z.qin-2@tudelftl.nl
  Prof. Dr. Ir. Pavol Bauer, P.bauer@tudelft.nl

EMPOWERING EDGE AI FOR REAL-TIME BATTERY HEALTH MANAGEMENT

Type of project: MSc thesis



Scope:

Develop a robust edge AI platform that enables real-time battery health management through an advanced integration of host systems and lithium batteries.

Problem definition:

As machine learning continues to reshape industries, deploying trained models into high-performance edge AI systems has become vital for real-world impact. Battery health management is particularly crucial, as it underpins the reliability and safety of electric vehicles, consumer electronics, and industrial systems. While extensive research has been conducted on machine learning applications within Battery Management Systems (BMS), the challenge remains in creating powerful, real-time edge platforms that can effectively monitor and manage battery health on the device level. This project aims to bridge the gap by establishing an advanced edge AI-based hardware platform that continuously assesses battery health in real time, setting a benchmark for efficient and intelligent energy management.

Methodology:

The student will start by conducting a comprehensive review of machine learning techniques for battery health assessment, with a focus on their applications in BMS. Following this, an optimal Microcontroller Unit (MCU) will be selected to deploy the AI model, facilitating real-time data acquisition from the BMS and enabling on-device battery health monitoring. The project will culminate in the development of an intelligent, integrated hardware platform that seamlessly connects the host system to lithium battery modules for autonomous health management.

Research Objectives:

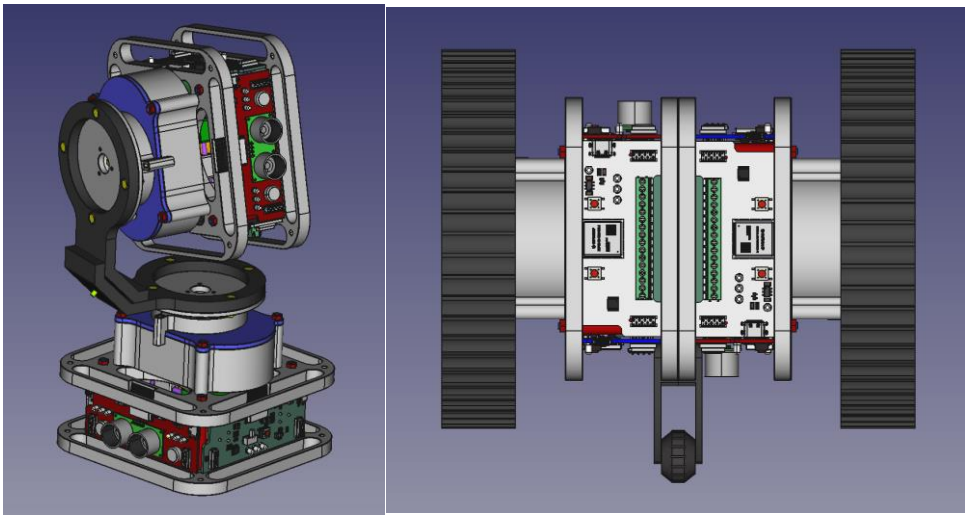
- Conduct a comprehensive review on the current applications of edge AI in BMS.
- Utilize BMS evaluation board to measure battery cells.
- Identify and select an MCU optimized for embedding AI models and BMS applications.
- Implement functions for real-time data acquisition and battery health monitoring on the MCU.
- Build the hardware platform from host to MCU to BMS.

Contact details:

- PhD student: Ruijun Liu, Ruijun.Liu@tudelft.nl
- Supervisors: Dr. Zian Qin, Z.Qin-2@tudelft.nl

IMPLEMENTATION AND CONTROL OF 3D PRINTED ROBOTS

Type of project: MSc thesis project



Scope:

This project aims at building up and optimising two robotic systems based on given 3D printed components and modular electronic hardware. Control and communcation of the robots to realize the required dynamic performance will also be implemented

Problem definition:

In the project you are expected to work on: 1) modelling the dynamics of the robotic systems, 2) implementing and testing the robotic systems, 3) implementing the control algorithms and communication protocols to realize the dynamic functionalities of the robots.

Methodology:

- Electromechanics modelling
- Digital modelling and contrl of dynamic systems
- Prototype building and testing

Research Objectives:

- Apply the theory on electromechanics, system and control
- Control of an electromechanical energy conversion device

Contact details:

- Supervisor: Jianning Dong (J.dong-4@tudelft.nl)

DC Systems, Energy Conversion & Storage

PCB COIL BASED CONTACTLESS POWER TRANSFER

Type of project: MSc thesis project

Scope:

Current inductive power transfer based e-bike charging system often uses Litz wire to implement the high frequency AC link, which leads to big physical footprint and high manufacturing cost. The PCB coils, although having least copper area, can potentially have a high quality factor at higher operation frequencies and may lead to a cost-effective solution.

Problem definition:

In the project you are expected to study the feasibility to transfer about 150 W to 200 W of power for e-bike charging using a pair of PCB coils separated by several centimeters. Numerical models for magnetic field and circuit analysis will be built for design and optimisation. A lab prototype is expected to be implemented by the end of the project.

Methodology:

- Analytical or numerical magnetic field analysis
- Circuit modelling and simulation
- Prototyping and validation

Research Objectives:

- Apply the theory on electromagnetics, circuit and power electronics
- Design and optimisation of an electromechanical energy conversion device

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Contact details:

- Supervisor: Jianning Dong (J.dong-4@tudelft.nl)

TU Delft

WIND GENERATOR WITH EXTREME MODULARITY

Type of project: MSc thesis project

Scope:

This project aims at designing and optimizing a novel wind turbine generator with extreme modularity. The concept of the generator has been studied by TU Delft and the industrial partner MegaWindForce. A prototype has been implemented for model validation.

Problem definition:

In the project you are expected to work on: 1) modelling of the novel wind generator, 2) Testing the prototype for validation and improvements of the model, 3) make an analytical or finite-element-method based multi-objective optimisation framework for the investigated wind turbine generator.

Methodology:

- Analytical magnetic circuit analysis
- Finite element method (FEM) based electromagnetic modelling
- Thermal modelling (circuit based or FEM)
- Multi-objective optimisation

Research Objectives:

- Apply the theory on electrical machines and electromagnetics
- Design and optimisation of an electromechanical energy conversion device

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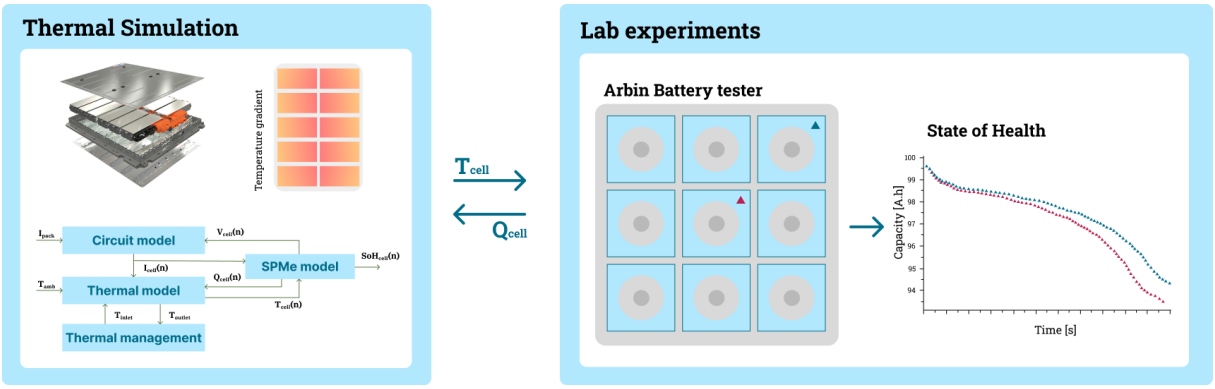
Contact details:

- Supervisor: Jianning Dong (J.dong-4@tudelft.nl)

DCE&S
DC Systems, Energy Conversion & Storage

HYBRID BATTERY PACK DEGRADATION TESTER

Type of project: MSc Thesis



Scope:

Degradation of an EV battery pack is hard to examine because battery packs are expensive and big. When degradation from an EV is measured directly during operation, the ageing depends on many factors, making structured and repeatable tests difficult. For this reason, many researchers choose to measure the degradation of a cell and extrapolate this to a full battery pack, completely overlooking cell-to-pack degradation differences that occur from cell heating, voltage and current deviations, and capacity mismatch. In this thesis, a new hybrid degradation test will be developed that combines simulation of an EV battery pack together with cell degradation measurements.

Problem definition:

Battery pack degradation is hard to measure an extrapolated cell degradation measurements overlook important cell-to-pack influences

Methodology:

During this thesis you will develop a battery pack simulator that models all thermal and electrical influences between cells and the environment (outside air, charging plug, etc.). This simulation will run in real time to calculate the temperatures and currents of all the cells in the battery pack. The output of the simulation will serve as a setpoint for the Arbin multi-chamber battery tester. This battery tester has multiple chambers that can be controlled individually to mimic the battery pack.

Research Objectives:

- Develop a thermal and electrical model for the battery pack
- Setup a degradation measurement setup in the lab
- Integrate the simulation output with the real degradation setup

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Contact details:

- PhD student: Koen Linders, k.s.j.linders@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

TU Delft

DESIGN OF LARGE-SCALE BATTERY PACK FOR REGIONAL ELECTRIC AIRCRAFT

Type of project: MSc thesis

source: Electroflight

Scope:

The aim of this thesis is to design an optimal large-scale battery pack for future regional all-electric aircraft, utilizing an electrical, thermal, and aging battery pack model.

Problem definition:

Since 2007, aviation's impact on climate change has been an increasing concern, principally focused on noise and CO_2 emissions from the combustion of jet fuel. Aircraft electrification is very promising for reducing fuel consumption and emissions. However, the design of a battery pack that can meet the unique demands of electric aircraft remains a significant challenge, especially the gravimetric energy density.

Methodology:

First, a comprehensive literature review will be conducted, focusing on battery chemistries suitable for electric aircraft and battery pack design methodologies. Next, the electrical-thermal-aging model, which accounts for the interactions between electrical, thermal, and aging behaviours, will be thoroughly studied and understood. Following this, the thermal management system for the battery pack will be designed with the aim of optimizing gravimetric energy density at the pack level, extending battery life, and ensuring safe and efficient operation.

Research Objectives:

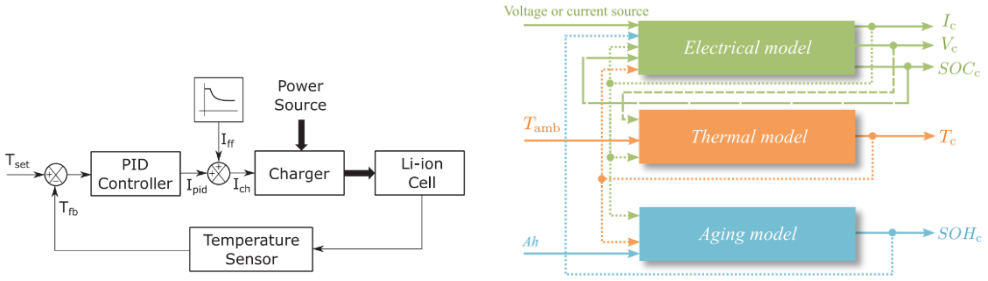
- Understand the thermal management system design and the electrical-thermal-aging battery pack model.
- Perform multi-objective optimization of the thermal management system to maximize energy density, enhance battery efficiency, and extend battery lifetime.
- Evaluate the performance of the designed battery pack by assessing its gravimetric energy density, efficiency, and aging characteristics through COMSOL/Ansys simulation.

Contact details:

- PhD student: Yawen Liang, Y.Liang-3@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, G.R.ChandraMouli@tudelft.nl

OPTIMIZATION OF CLOSED-LOOP CHARGING STRATEGY FOR LITHIUM-ION BATTERY

Type of project: MSc thesis



source: [A Closed-Loop Constant-Temperature Constant-Voltage Charging Technique to Reduce Charge Time of Lithium-Ion Batteries]

Scope:

This thesis aims to develop a closed-loop multi-objective optimal charging strategy that considers factors such as charging time, battery aging, and energy loss for lithium-ion battery (LIB) cell based on a complete electro-thermal-aging cell model.

Problem definition:

Since 2007, the aviation industry's environmental impact has become an increasing concern, primarily centered on noise and CO_2 emission. To address this, there's been growing interest in electrifying aviation. LIBs are the attractive candidate for near-term small all-electric aircraft. Therefore, it is thus crucial to study the tradeoff between charging time, battery degradation, and charging efficiency and then develop a optimally health-efficiency conscious closed-loop fast charging protocols.

Methodology:

First, a literature review regarding optimal charging strategy is needed. Next, the electrical, thermal, and ageing behaviour of the battery cell, etc., needs to be understood. After that, how to shorten the charging time, extend the battery lifetime, and improve the charging efficiency need to be figured out. Then, develop a closed-loop optimal charging strategy using a proportional-integral-derivative (PID) controller that adjust the magnitude of charging current in response to the instantaneous battery condition, e.g. cell temperature, voltage.

Research Objectives:

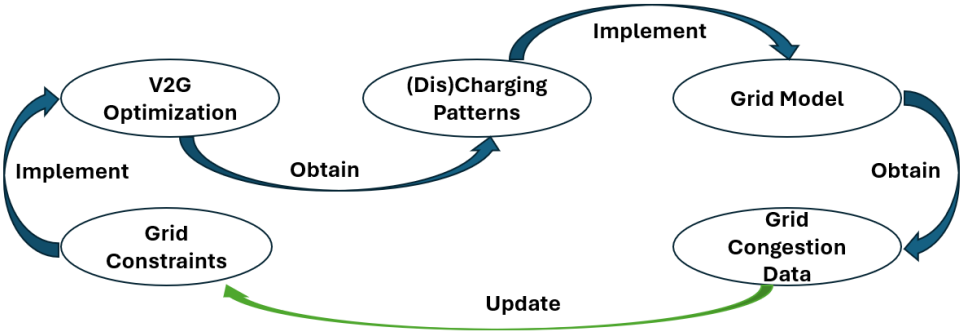
- Develop an optimal charging profile based on a priori knowledge of electro-thermal-aging model via multi-objective optimization that reduces the charging duration, extend the battery lifetime, and improve charging efficiency.
- Propose a closed-loop charging technique using PID controller that adjust the charging current in response to the battery conditions.
- Evaluate the optimal charging strategy performance via experiment validation in the lab.

Contact details:

- PhD student: Yawen Liang, Y.Liang-3@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, G.R.ChandraMouli@tudelft.nl

AN ITERATIVE VEHICLE-TO-GRID OPTIMIZATION APPROACH TO REDUCE GRID CONGESTION ON A LOW-VOLTAGE DUTCH GRID

Type of project: MSc Thesis



Scope:

The goal of this project is to develop an iterative process between the optimization V2G algorithm and the Low Voltage grid model to reduce grid congestion.

Problem definition:

Vehicle-to-grid optimization algorithms often focus on price signals to know the optimal moment to (dis)charge overlooking what is actually happening on the grid. Although electricity cost is a direct result of the demand-offer balance, the most profitable (dis)charging pattern is not always the most beneficial for reducing grid congestion. An iterative approach that considers how the change in charging patterns affects line loading is needed to reduce grid congestion. This iterative approach will use the grid line loading data to update the optimization constraints and create new charging patterns that will reduce the line loading.

Methodology:

The V2G optimization algorithm and the low voltage grid model have already been developed. The master student will need to add an iterative approach between the two with the use of Python and PowerFactory. The iterative algorithms will automatically run the optimization algorithm, implement the charging patterns in the grid, run the powerflow with PowerFactory, extract the line loading, adapt the optimization constraints accordingly and iterate again until it converges.

Research Objectives:

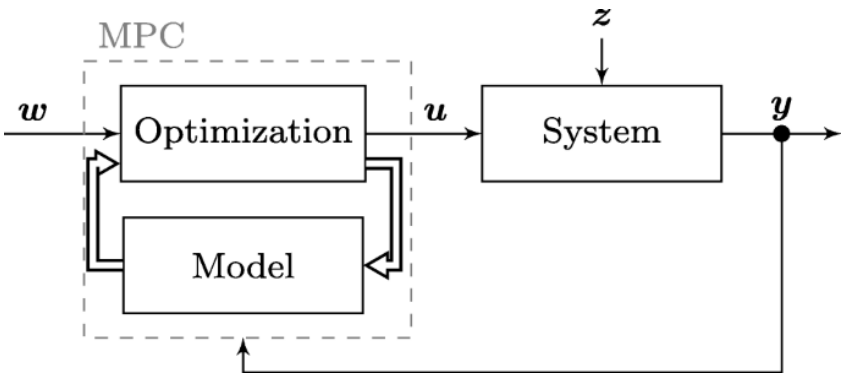
- Adapt the V2G algorithms so they can be implemented in the grid model.
- Develop an algorithm to use PowerFactory from Python directly.
- Develop the automated iterative process to reduce grid congestion.

Contact details:

- PhD student: Alvaro Menendez Agudin, a.m.a.menendezagudin@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

DEALING WITH UNCERTAINTIES IN A VEHICLE-TO-GRID OPTIMIZATION ALGORITHM FOR FLEXIBLE ENERGY COMMUNITIES

Type of project: MSc Thesis



Source: Review on model predictive control: an engineering perspective

Scope:

This project aims to develop a Model Predictive Control strategy to deal with uncertainties in a Flexible Energy Community V2G optimization algorithm.

Problem definition:

In Flexible Energy Communities, Electric Vehicles (EVs) equipped with Vehicle-to-Grid (V2G) capabilities offer the potential to optimize energy use by storing and supplying energy when and where it is needed. However, uncertainties in energy demand, generation from renewable sources, and EV availability make it challenging to fully realize these benefits. This project seeks to develop a Model Predictive Control (MPC) strategy to dynamically adjust V2G operations within the Flexible Energy Community, continuously adapting to real-time changes and uncertainties.

Methodology:

This project will implement a Model Predictive Control (MPC) strategy into an existing V2G optimization model to adaptively manage uncertainties in EV availability and if possible energy demand and generation. The MPC approach will adjust in real time to optimize V2G operations based on forecast data.

Research Objectives:

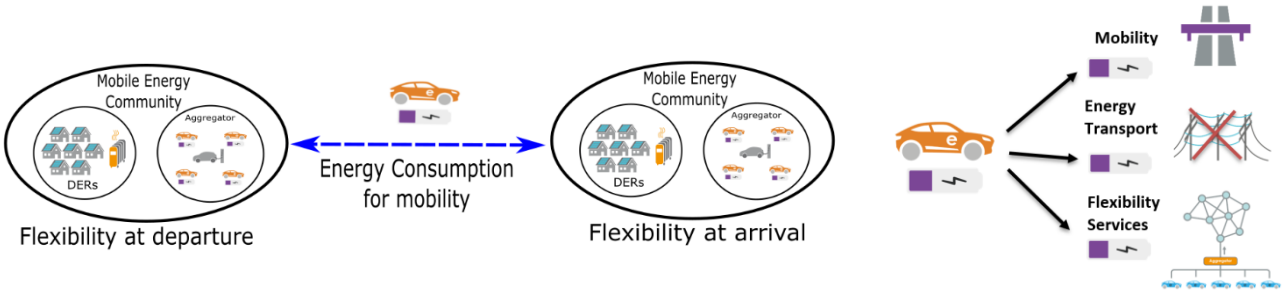
- Identify key uncertainties and design scenarios to evaluate their impacts on the V2G model.
- Design and integrate an MPC module to dynamically adjust for uncertainties in energy demand and EV availability.
- Analyse the MPC-enhanced model's ability to maintain optimal charging patterns compared to the original model.

Contact details:

- PhD student: Alvaro Menendez Agudin, a.m.a.menendezagudin@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

QUANTIFYING THE EV BATTERY CAPACITY LOSS WHEN IT IS USED AS AN ENERGY TRANSPORTER AND FLEXIBILITY PROVIDER

Type of project: MSc Thesis



Scope:

The goal is to study the impact on the battery of using EVs as an energy transporter between Energy Communities with a spatio-temporal EV model.

Problem definition:

Current EV models usually do not include energy transport as one of the uses of the EV. With bidirectional charging and V2G capability, the EV can be considered as a Battery on Wheels. Transporting energy with the EV will increase the number of cycles and thus the ageing of the battery. Different energy transport strategies can transport the same amount of energy but have different impacts on battery ageing. An optimal strategy that transports enough energy while considering battery ageing needs to be developed.

Methodology:

The student will start with a literature review to understand the concept of bidirectional charging and empirical battery ageing models. Once the student is familiar with the processes that impact battery ageing several strategies will be developed. The strategies will be tested on different empirical models with different chemistries with the use of the already developed battery toolbox. A V2G optimization algorithm with an empirical linear model will be used to study the optimal charging patterns to minimise battery ageing.

Research Objectives:

- Evaluate the loss in the EV battery capacity if it is used for transporting energy and providing flexibility services.
- Analyse how different uses of the EV and different chemistries affect battery capacity loss.
- Evaluate the consequences of the capacity loss on the flexibility and energy transport capabilities of EVs.

Contact details:

- PhD student: Alvaro Menendez Agudin, a.m.a.menendezagudin@tudelft.nl
- Supervisor: Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl

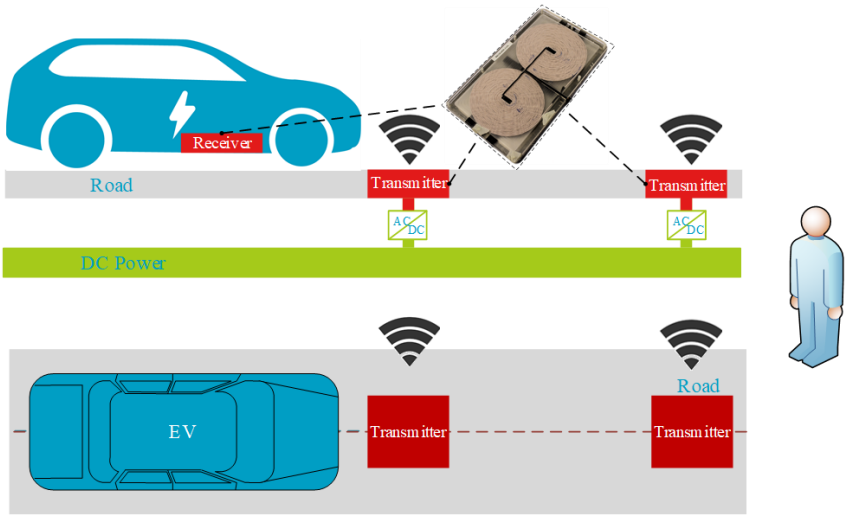
Master's Thesis Proposal

DCE&S

DC Systems, Energy Conversion & Storage

ANALYSIS OF THE ELECTROMAGNETIC FIELD RADIATION OF WIRELESS CHARGING SYSTEMS

Type of project: MSc thesis/Extra project



Scope: As an approach to mitigate the range anxiety and bulky battery packages of EVs, dynamic inductive power transfer (DIPT) for EVs charging attracts lots of attention. As a loosely-coupled power transfer system, leakage field cannot be avoided. For the safety of users, the magnetic radiation has to be considered.

Problem definition: When the DIPT system is energized, a certain amount of magnetic field may be exposed to pedestrians and pose a threat to their health. On one hand, the radiation of a DIPT system should be identified according to the international standards. On the other hand, proper measures should be taken to decrease the radiation, including shielding and coupler design.

Methodology:

- Study of the basic principles of inductive power transfer technology
- Review of relevent EMC international standards
- Finite element modelling of a DIPT charger and human body
- Analysis of EMF radiation exposure at different scenarios
- Shielding method to reduce EMF radiation

Research Objectives:

- Finite element model of IPT charger and human body
- Possible solutions to reduce the radiation of DIPT systems

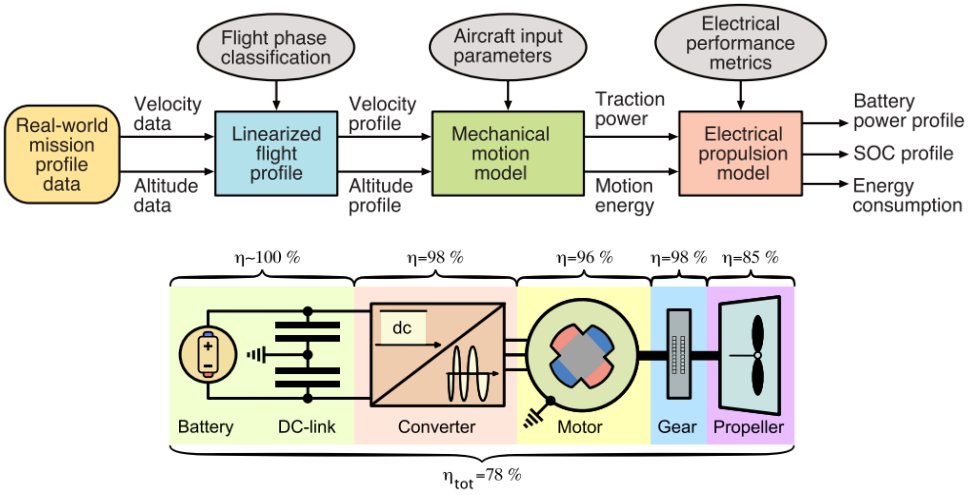
Contact details:

- Supervisor: Dr. Wenli Shi, W.Shi-3@tudelft.nl, LB 02.860
  Prof. Pavol Bauer p.bauer@tudelft.nl, LB 03.600

TU Delft

ELECTRIC AIRCRAFT SYSTEM MODELLING BASED ON REAL-WORLD FLIGHT DATA

Type of project: MSc thesis



T. Bærheim, J. J. Lamb, J. K. Nøland, and O. S. Burheim, 'Potential and Limitations of Battery-Powered All-Electric Regional Flights—A Norwegian Case Study', IEEE Transactions on Transportation Electrification, vol. 9, no. 1, pp. 1809–1825, Mar. 2023,

Scope: Due to increasing carbon emission from air transport, a great attention has been paid to electrification of aircraft. With the support of emerging advanced power electronics and battery technologies, all electric aircraft using battery as the sole energy source becomes feasible.

Problem definition: There are several hurdles in designing all electric aircraft, including battery, electric motor and electric power conversions. An electric aircraft model should be built to evaluate the performance of all electric aircraft by using real-world flight data. The electric aircraft model should be able to describe the simplified aerodynamics and on-board electric power system. By taking as input the state-of-the-art of battery, motor and power electronics technologies, the model is able to drive the optimal power system structure and give guidance on future research of all electric aircraft.

Methodology:

- Review of all electric aircraft technologies
- Survey the state-of-the-art performances of batteries, motors, and converters
- Build simplified mechanical motion model and electrical propulsion model
- Process real-world flight data and select studied cases
- Analyse all electric aircraft performances in different cases
- Summarize findings based on the developed model

Research Objectives:

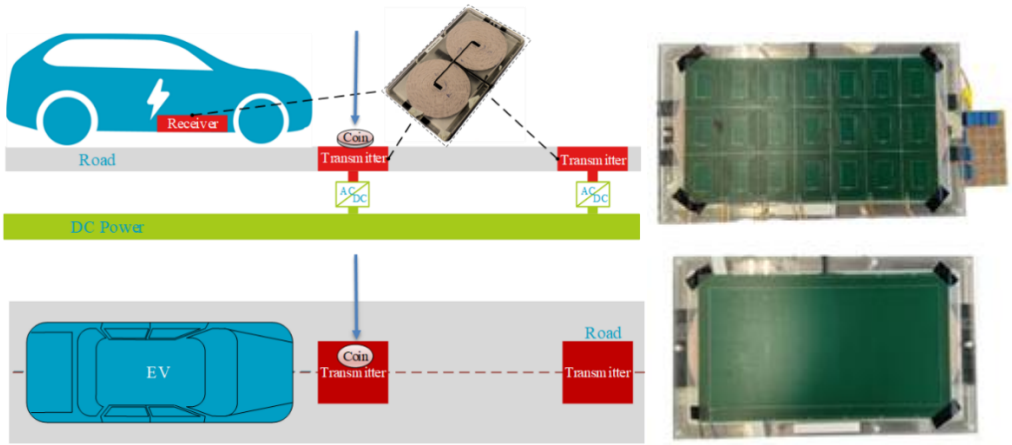
- An electric aircraft model that can evaluate aircraft performances
- Limitation and future trend of all electric aircraft

Contact details:

- Supervisor: Dr. Wenli Shi, W.Shi-3@tudelft.nl, LB 03.680
  Prof. Pavol Bauer p.bauer@tudelft.nl, LB 03.600

ELECTRIC VEHICLES AND FOREIGN OBJECTS DETECTION FOR DYNAMIC WIRELESS CHARGING SYSTEMS

Type of project: MSc thesis



Scope: As an approach to mitigate the range anxiety and bulky battery packages of EVs, dynamic inductive power transfer (DIPT) for EVs charging attracts lots of attention. Foreign objects like coins and cans may exist on the road, and performances of dynamic IPT system can be affected if these objects are placed on top of transmitters under roads. Besides, detection of EVs is needed to switch on the transmitter only when it is coupled with a receiver.

Problem definition: The detection of EVs and foreign objects can be realized by using auxiliary coil. These auxiliary coils can sense the magnetic field variation by measuring their induced voltage and input impedance. Different architectures of the detection system will be explored. Besides, the digital controller should be built to process the detection signal and determine the operation of transmitters.

Methodology:

- Study of the basic principles of inductive power transfer technology
- Understand how to detect EVs using coil sensors
- Understand how to detect metal and living foreign objects
- Build sensor coils and digital controller to identify EVs and foreign objects

Research Objectives:

- Detection principles for different detection tasks
- Design of coil sensors that is suitable for DIPT applications

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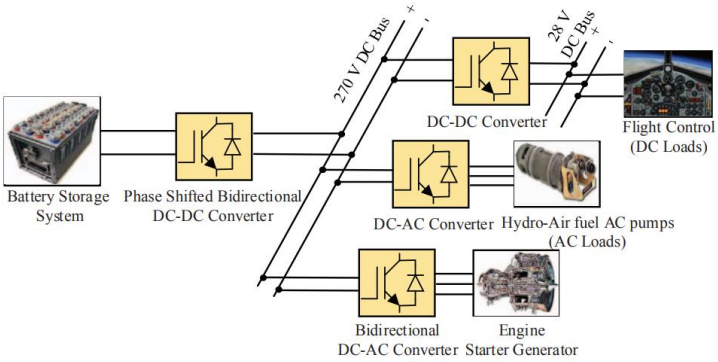
Contact details:

- Supervisor: Dr. Wenli Shi, W.Shi-3@tudelft.nl, LB 02.860
  Prof. Pavol Bauer p.bauer@tudelft.nl, LB 03.600

REAL TIME DIGITAL SIMULATION OF AN ELECTRIC AIRCRAFT ON-BOARD DC POWER DISTRIBUTION SYSTEM

Type of project: MSc thesis



M. Tariq *et al.*, 'Battery integration with more electric aircraft DC distribution network using phase shifted high power bidirectional DC-DC converter', in *2015 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC)*, Nov. 2015, pp. 1–5.

Scope: Due to increasing carbon emission from air transport, a great attention has been paid to electrification of aircraft. With the support of emerging advanced power electronics and battery technologies, all electric aircraft using battery as the sole energy source becomes feasible.

Problem definition: To improve the power capacity and efficiency, the on-board power distribution systems is changing from AC to DC. As there are more power electronic converters connected to the DC bus, power flow control under varying load conditions and protection scheme under fault conditions become prominent. As the number of load connection increases, the transient behaviours of the on-board system becomes more complex. A digital simulation model should be built to predict the transients and facilitate power flow control and protection.

Methodology:

- Review of all electric aircraft technologies
- Survey the state-of-the-art on-board power system architecture
- Develop simulation model of the on-board power system
- Identify load characteristics through the whole flight cycle
- Propose power flow control and protection schemes based on simulated results

Research Objectives:

- Digital simulation model of the on-board DC power distribution system
- Power flow control and protection schemes

Contact details:

- Supervisor: Dr. Wenli Shi, W.Shi-3@tudelft.nl, LB 03.680
  Prof. Pavol Bauer p.bauer@tudelft.nl, LB 03.600

Master's Thesis Proposal

DC Systems, Energy Conversion & Storage

DEVELOPMENT OF A CHARGING SCHEME FOR AMSTERDAM'S ELECTRIC BUSES

Type of project: MSc Thesis

Scope:

The feasibility and success of bus electrification projects are heavily dependent on the proper charging scheme. This is especially true in congested electricity grid areas like The Netherlands. These charging schemes could be, for example, Overnight Charging where relatively large batteries are charging overnight to last a full day, Terminus Charging where the buses are charged at the start and end terminals, Opportunity charging where the buses are charged, when possible, at certain locations in the city, or a combination of these schemes or others.

Each one of these schemes would dictate a different battery size, battery technology, charger power, energy efficiency, battery lifetime, bus fleet size, and overall system costs. There is no one fit-all solution for this problem, which makes its answer to every city and concession period unique and challenging.

Problem definition:

Design and compare different charging schemes for the buses of the GVB, the transport operator of Amsterdam. When possible, these chargers should be connected to a nearby tram or metro network, making the best use of the existing infrastructure and spare grid power and energy capacity.

Methodology:

The work will be done in direct contact with the GVB. The thesis will be carried out using MATLAB and/or Python simulations that the student (co-)develops as well as existing power flow simulation models.

Research Objectives:

- Perform a literature review of existing charging schemes and ebus battery technologies.
- Develop a bus vehicle and fleet model and a modest battery degradation model.
- Compare the different charging scheme possibilities using the above-mentioned parameters.

Contact details:

- Supervisors: Dr. Ibrahim Diab <i.diab@tudelft.nl, ibrahim.diab@gvb.nl>
  Prof. Pavol Bauer <P.bauer@tudelf.nl>

TU Delft

Master's Thesis Proposal

DCE&S

DC Systems, Energy Conversion & Storage

DEVELOPMENT OF A CHARGING SCHEME FOR AMSTERDAM'S ELECTRIC FERRIES

Type of project: MSc Thesis

Scope:

GVB has multiple ferry lines that serve as an indispensable link between Amsterdam Noord and the rest of the city. Currently, these ferries run on diesel, while some have been piloted as hybrid.

The goal of the city is to have all ferries electric, but this is a major challenge. This is because the congested electricity grid has strict limits on the power of the chargers and the vessel design has strict limitations on the battery pack capacity. Additionally, the operational constraints regarding schedules and delays are very demanding since the ferries serve effectively as the only biking and pedestrian bridge across Het IJ.

Multiple charging schemes can therefore be developed. Each one of these schemes would dictate a different battery size, battery technology, charger power, energy efficiency, battery lifetime, ferry fleet size and route, and overall system costs.

Problem definition:

Design and compare different charging schemes for the ferries of the GVB, the transport operator of Amsterdam. The schemes have multiple degrees of freedom in terms of charger location, charging power, charging time, battery pack size, and ferry route, among others.

Methodology:

The work will be done in direct contact with the GVB. The thesis will be carried out using MATLAB and/or Python simulations that the student (co-)develops. Ideally, the final results would be reduced into an accessible python or excel tool for management-level decision making.

Research Objectives:

- Perform a literature review of existing ferry charging projects and their applicability to GVB.
- Develop a ferry route and fleet model and a modest battery degradation model.
- Compare the different charging scheme possibilities using the above-mentioned parameters.

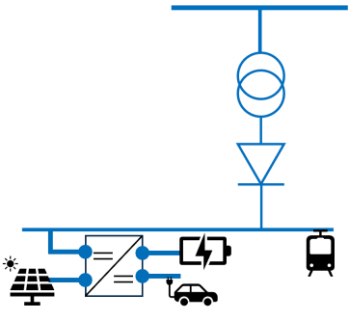
Contact details:

- Supervisors: Dr. Ibrahim Diab <i.diab@tudelft.nl, ibrahim.diab@gvb.nl>
  Prof. Pavol Bauer <P.bauer@tudelf.nl>

TU Delft

ASSESSMENT OF PV SYSTEMS PERFORMANCE ON THE DC SIDE OF TRACTION GRIDS

Type of project: MSc Thesis



Scope:

Traction grids such as metro, tram, trolleybus, and trains are interesting systems. Their loads are constantly moving, and can even become power generating nodes when the vehicles are braking. However, the power generated on the DC side cannot be sent back to the main AC grid as the traction grids are typically built using rectifiers, meaning the energy can only flow in one direction.

For this reason, PV systems on the DC side of traction grids have been typically overlooked. The power mismatch is poor as the traction loads are constantly appearing and disappearing, and there is no return path for the excess generated power which would then need to be curtailed. Still, a placement on the DC side means the possibility for distributed generation and a more efficient DC/DC conversion.

PV systems on the AC side of traction grids have not been too promising either, with only about 30% direct utilization. With the increasingly attractive possibility of connecting third-party loads to the DC side of traction grids, the DC-side PV system is again worth investigating as the presence of a base load on the DC side might finally allow it to become techno-economically feasible.

Problem definition:

Investigate the generation and the direct utilization of a PV system connected on the DC side of a traction grid, with and without third party users and energy storage, using Python/MATLAB simulations and both new or existing models. The case study could be the Amsterdam metro or tram grids of the GVB and/or the Arnhem trolleybus grid.

Methodology:

The work will be done in direct contact with the GVB and/or the municipality of Arnhem. The thesis will be carried out using MATLAB and/or Python simulations that the student (co-)develops.

Research Objectives:

- Update and co-build PV power generation models for the city of choice.
- Develop and update the vehicle and fleet models and a modest battery degradation model.
- Compare the different placement and sizing schemes using the above-mentioned models.

Contact details:

- Supervisors: Dr. Ibrahim Diab <i.diab@tudelft.nl, ibrahim.diab@gvb.nl>
  Prof. Pavol Bauer <P.bauer@tudelf.nl>

TU Delft

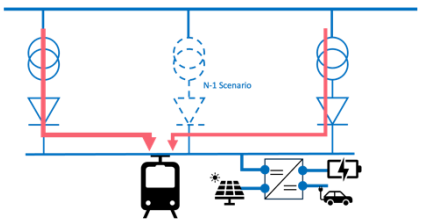
Master's Thesis Proposal

DCE&S

DC Systems, Energy Conversion & Storage

TO INFINITY AND BEYOND: ASSESSMENT OF THE POWER SUPPLY LIMITS OF TRACTION GRID SUBSTATIONS AND EFFECTIVE EXTENSION MEASURES

Type of project: MSc Thesis



Scope:

Traction grids such as metro, tram, trolleybus, and trains are rely on substations that bring the medium voltage AC input to a low voltage DC using a transformer and an uncontrolled rectifier.

These substations are typically rated for the highest, yet very infrequent, power demand peaks. That the power electronics need to tolerate. On the other hand, the grid connection is contracted in 15-minute averages. Still, this contract is typically overestimated. For example, a connection rated at 1MVA could be contracted for 0.5MVA and sees on a 15-min average only 0.1MVA. There would be some instants in the day or the week though, for a few seconds, when the power demand reaches up to 2MA or close to it. In times of grid congestion, it is imperative to free up the excessive spare capacity of traction grids for other urban loads, or to integrate these third-party loads into the traction grid itself to relieve the urban electricity grid from additional grid connections.

To understand how much can be done with traction grids under existing and future infrastructures and contracts, it is important to quantify the present and flexible limits of the power supply substations. Examples of the methods of extension can be the installation of onboard and/or stationary storage, bidirectional converters, active rectifier substations, PV systems, EV chargers with V2G, etc.

Problem definition:

Investigate, by means of power flow models, the present and the achievable limits of the infrastructure and grid contracts of traction substations in terms of traffic frequency, vehicle size, and third-party users that can be connected to a traction grid. The metro/tram grid of Amsterdam (and possibly the trolleygrid of Arnhem) would be used as a case study.

Methodology:

The work will be done in direct contact with the GVB (and maybe the municipality of Arnhem). The thesis will be carried out using MATLAB and/or Python simulations that the student (co-)develops.

Research Objectives:

- Develop and update the vehicle and fleet models and the grid power flow models.
- Quantify the theoretical limits of a traction grids in terms of the above-mentioned parameters.
- Quantify and compare the limits of a substation with capacity-increasing measures using a case study of a Dutch traction grid.

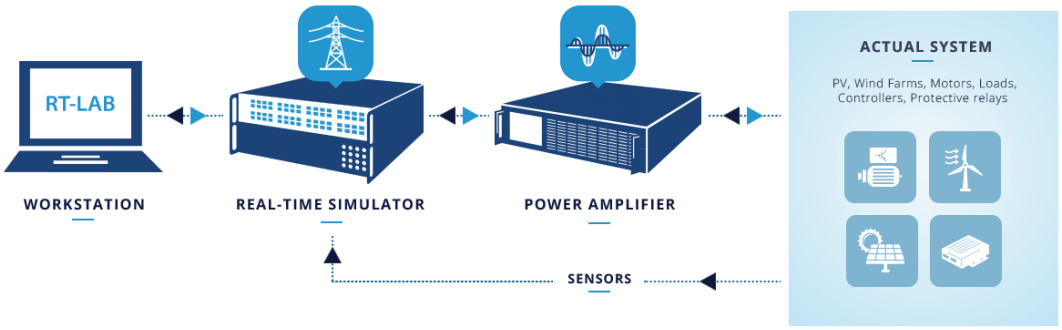
Contact details:

- Supervisors: Dr. Ibrahim Diab <i.diab@tudelft.nl, ibrahim.diab@gvb.nl>
  Prof. Pavol Bauer <P.bauer@tudelf.nl>

TU Delft

COORDINATED CONTROL OF PV GENERATION, ELECTRIC VEHICLES, HEAT PUMPS AND ENERGY STORAGE WITH HARDWARE-IN-THE-LOOP (HIL) SIMULATION

Type of project: MSc Thesis



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Scope:

The goal of this thesis is the experimental testing of power control of PV generation, flexible loads and energy storage with hardware-in-the-loop (HIL) simulation setup.

Problem definition:

Power control of PV generation, flexible loads such as electric vehicles (EVs) and heat pumps (HPs), and energy storage will play an important role in the future distribution grids. However, most grid-level power control studies remain only on simulations level because of the difficulty of testing in real physical systems. Hardware-in-the-loop (HIL) simulation is a control validation technique, which creates a virtual real-time environment that represents the physical system and realizes behaviour testing without physical prototypes.

Methodology:

In this thesis, the student shall firstly study and understand the power control framework of PV generation, flexible loads, and energy storage. Consequently, the student shall study and understand the experimental setup of the HIL simulation with the use of the OPAL-RT simulator. Finally, the integration of the power control model into the HIL simulation and its testing under various case studies and scenarios are needed. A basic level of knowledge on Python and Matlab environments is highly expected. Previous knowledge on HIL and Opal-RT, while highly recommended, is not a prerequisite.

Research Objectives:

- Study of coordinated power control of flexible loads and energy storage
- Study of the HIL simulation concept, and the experimental HIL setup with use of the Opal-RT simulator
- Experimental lab integration and testing of coordinated power control with HIL simulation

1 https://www.opal-rt.com/

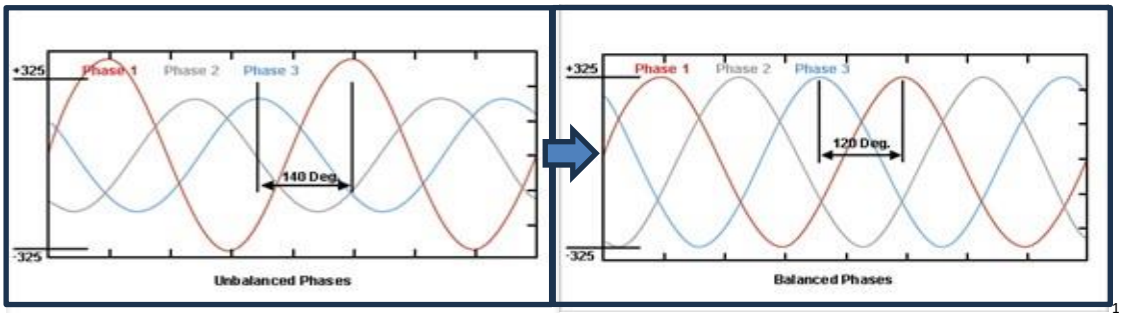
Contact details:

- PhD student: Nikolaos Damianakis, N.Damianakis@tudelft.nl, LB.03.690
- Supervisors: Dr. Gautham Ram Chandra Mouli; Prof. P Bauer

1

DEVELOPMENT AND EXPERIMENTAL TESTING OF COORDINATED POWER & PHASE CONTROL OF PV GENERATION, ELECTRIC VEHICLES AND HEAT PUMPS

Type of project: MSc thesis



1

Scope:

The scope of this thesis is the development of a power & phase control model of PV generation, electric vehicles (EVs) and heat pumps (HPs) and its experimental testing with the use of the Zaptec phase-changing charger and hardware-in-the-loop (HIL) simulation.

Problem definition:

Phase imbalance is a well-known undesired grid state which can be caused by random single-phase connections of loads in different phases and can result in negative grid impacts such as thermal losses, decreased efficiency & power quality issues. Residential heat pumps (HPs) and a vast number of low rated-power PVs and electric vehicles (EVs) are single-phase connected and can provoke a high impact on grid unbalance which has already been quantified in 6 Dutch LV distribution grids. A development of a phase control model of PVs, EVs, and HPs and its experimental testing are needed.

Methodology:

The student is expected to perform a literature study concerning grid phase imbalance by connections of PVs, EVs, and HPs and its already identified impact on the acquired LV distribution grids. Then, the student will be provided with a power control model of PV, EVs and HPs and is expected to enhance it integrating phase control features. Finally, with the use of the newly installed Zaptec phase-changing charger, the model is expected to be tested in practise with lab experiments, using e.g. hardware-in-the-loop (HIL) simulation. Prior basic knowledge on Python is expected while knowledge on PowerFactory grid simulation tool and/or Opal-RT simulator is also highly recommended.

Research Objectives:

- Study of phase imbalance and its identified impact on the acquired LV distribution grids.
- Study of the experimental use of the Zaptec phase-changing charger.
- Enhancement of power control model of PVs, EVs, and HPs with phase control features.
- Experimental testing of the phase control model with the use of the Zaptec charger.

1 https://cauk.tv/articles/power-quality-issues-voltage-and-phase-balancing/

Contact details:

- PhD student: Nikolaos Damianakis, N.Damianakis@tudelft.nl, LB.03.690
- Supervisors: Dr. Gautham Ram Chandra Mouli; Prof. P Bauer

BATTERY MODELING FOR ENERGY MANAGEMENT IN HEAVY-DUTY ELECTRIC VEHICLE CHARGING STATIONS: A COMPARATIVE ANALYSIS OF NEW AND SECOND-HAND BATTERY SYSTEMS

Type of project: MSc thesis

Photo from Tesla website. Megapack, Massive Energy Storage: https://www.tesla.com/megapack/

Scope:

Designing and comparing energy management systems (EMS) for heavy-duty electric vehicle (HDEV) charging stations using either new or second-hand battery systems.

Problem definition:

As the demand for HDEV charging infrastructure grows, energy storage plays a key role in ensuring efficient operation and minimizing grid stress. While new batteries provide high performance and reliability, second-hand batteries offer a cost-effective, sustainable alternative. However, second-hand batteries come with varying levels of degradation, potentially affecting system efficiency and longevity. This project aims to develop an EMS that optimizes charging station operations with either new or second-hand batteries and compares their performance based on metrics such as battery aging, energy efficiency, and overall system effectiveness. The results will help identify the most suitable battery model for HDEV charging stations.

Methodology:

The project will begin with a comprehensive study on battery modeling for EV charging stations, focusing on the characteristics of new and second-hand batteries. Next, An EMS model will be developed and applied to both battery types, considering critical factors like charge-discharge cycles, degradation rates, and storage capacity. The performance will be evaluated based on key metrics like battery aging, system efficiency, operational costs, and grid impact, allowing for a detailed comparison between new and second-hand battery models.

Research Objectives:

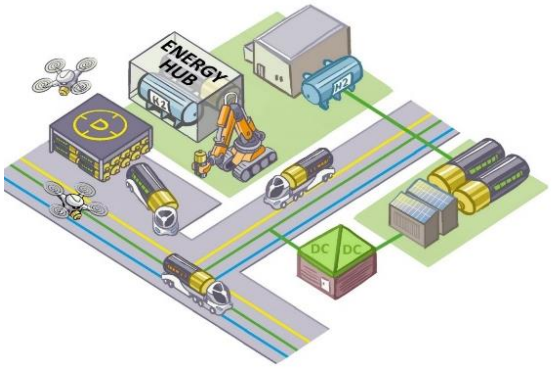
- Conduct a study on battery modeling for charging stations, focusing on the characteristics of new and second-hand batteries.
- Develop and model both new and second-hand battery systems based on their characteristics.
- Implement and test a single EMS model using both battery types to evaluate system performance.
- Compare the results to assess the impact of new versus second-hand batteries on battery aging, efficiency, and overall system effectiveness in HDEV charging stations.

Contact details:

- PhD student: Leila Shams Ashkezari, l.shamsashkezari@tudelft.nl
- Supervisor: Dr. Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl
  Dr. Neil Yorke-Smith, N.Yorke-Smith@tudelft.nl
  Prof. Dr. Pavol Bauer, P.bauer@tudelft.nl

BUILDING THE CHARGING DEMAND CURVE AT A HEAVY DUTY ELECTRIC VEHICLE CHARGING STATION

Type of project: MSc thesis



Scope:

Building the charging demand curve at a heavy-duty electric vehicle (HDEV) charging station and assessing the environmental and grid Impact of electrifying HDEVs.

Problem definition:

The European Commission has set forth a plan to align the European Union with the goal of achieving climate neutrality by 2050, aiming for a substantial 90% reduction in emissions associated with transportation. Within this sector, freight transportation emerges as a substantial contributor to emissions, and its role is anticipated to grow in the coming years. Therefore, the electrification of heavy-duty vehicles stands as a critical measure. Given that HDEVs are currently not in widespread use, this study is designed to predict the charging demand at charging stations for these vehicles and devise strategies to meet this growing energy demand effectively.

Methodology:

The proposed study will begin with an in-depth examination of recent trends in HDEVs electrification, considering the energy demand and charging requirements that have emerged in recent years. Then an algorithm need to be developed to allocate charging stations to HDEVs ,taking into account their battery state of charge and the distance they intend to travel after stopping at the charging station. Additionally, the approximate waiting time for each truck at the charging station needs to be identified as well considering their trip length and EU regulations. Finally, the data will be expanded to cover a one-year period, taking into account seasonal variations, workdays, holidays, and other relevant factors.

Research Objectives:

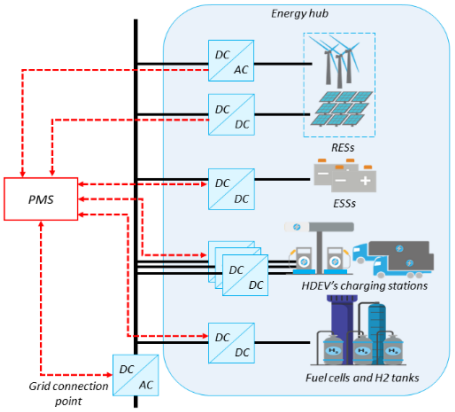
- Conduct a comprehensive literature review on the charging demands of heavy-duty electric vehicles and the chargers available for these vehicles.
- Develop an algorithms to allocate charging stations to trucks based on their battery state of charge, trip length, and EU goals.
- Determine approximate waiting time for each truck at the charging station ensuring compliance with EU regulations.

Contact details:

- PhD student: Leila Shams Ashkezari, l.shamsashkezari@tudelft.nl
- Supervisor: Dr. Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl
  Dr. Neil Yorke-Smith, N.Yorke-Smith@tudelft.nl
  Prof. Dr. Pavol Bauer, P.bauer@tudelft.nl

ENERGY MANAGEMENT SYSTEM FOR AN ENERGY HUB WITH HYDROGEN-TO-POWER OPERATION AS AN ENERGY RESERVE

Type of project: MSc thesis



Scope:

Defining an energy management system (EMS) for a multi-carrier heavy-duty electric vehicle (HDEV) charging station considering hydrogen as a complementary reserve system.

Problem definition:

Meeting the demand of a charging station for HDEVs can require charging rates of several MWs when multiple vehicles are charging concurrently. Uncontrolled charging of HDEVs can strain the power grid, especially in areas with limited grid capacity. To address this challenge, the development of an EMS is crucial to optimize on-site energy sources and energy storage systems. In this multi-carrier charging station hydrogen generation and storage is also considered, leveraging hydrogen as a flexible energy reserve in Hydrogen-to-Power (H2P) mode.

Methodology:

This study will start with a literature review of recent trends in multicarrier electrical systems and HDEV electrification and charging. Then, each element within the EH need to be mathematically modeled, capturing their operational characteristics, constraints, and interactions. Subsequently, a linear optimization model for the EMS will be developed to regulate power and energy flow within the charging station. Finally, a sensitivity analysis will be conducted to evaluate the impact of hydrogen utilization in H2P mode on key performance metrics such as energy efficiency, cost-effectiveness, and system resilience.

Research Objectives:

- Conduct a comprehensive literature review on multi-carrier charging station and HDEV electrification and charging stations.
- Development and implementation of an EMS using MILP techniques for optimal energy management within the EH.
- Insights from the sensitivity analysis regarding the role of hydrogen in H2P mode and its impact on EH performance.

Contact details:

- PhD student: Leila Shams Ashkezari, l.shamsashkezari@tudelft.nl
- Supervisor: Dr. Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl
  Dr. Neil Yorke-Smith, N.Yorke-Smith@tudelft.nl
  Prof. Dr. Pavol Bauer, P.bauer@tudelft.nl

REINFORCEMENT LEARNING-BASED ENERGY MANAGEMENT SYSTEM FOR HEAVY-DUTY ELECTRIC VEHICLE CHARGING STATION

Type of project: MSc thesis

Photo from Milence website. The Milence Charging Hubs: A Place to Rest & Recharge. Retrieved from https://milence.com/insight/the-milence-charging-hubs-a-place-to-rest-recharge/

Scope:

Reinforcement Learning (RL)-Based Energy Management System (EMS) for Heavy-Duty Electric Vehicle (HDEV) Charging Stations: A Comparative Study of Different RL Learning Algorithms and Hyperparameter Tuning.

Problem definition:

As the electrification of HDEVs accelerates, the demand for efficient and intelligent EMSs in charging stations becomes increasingly critical. Traditional EMS methods struggle with the complexity of variable energy demand, grid constraints, and renewable integration. RL offers a more adaptive solution by enabling real-time optimization. This thesis explores using various RL algorithms to develop an EMS for HDEV charging stations. The study will compare the performance of these algorithms and involve hyperparameter tuning to maximize the efficiency of the RL-based EMS.

Methodology:

The methodology involves implementing RL-based EMSs utilizing various RL algorithms, such as Actor-Critic methods, PPO, and DQN. An HDEV charging station simulation model is already available for these algorithms' training and testing environments, incorporating energy resources like grid power, energy storage systems, and renewable sources. The student will modify the existing environment to achieve the desired behavior and evaluate each algorithm's performance using the same setup. A backup policy will also be integrated into the model to ensure compliance with hard constraints and prevent violations. After comparative analysis, hyperparameter tuning will be conducted for the RL algorithm that demonstrates the best performance to optimize its effectiveness further.

Research Objectives:

- Design and Implement RL-based EMSs that utilize various learning algorithms, including Actor-Critic methods, PPO, and DQN, within an HDEV charging station simulation model.
- Integrate a Backup Policy into the EMS model to ensure compliance with hard constraints, preventing violations and enhancing the reliability of the system's operation.
- Compare the performance of different RL algorithms in optimizing charging station operations.
- Tune hyperparameters for the chosen RL algorithm to enhance the learning process and improve system performance.

Contact details:

- PhD student: Leila Shams Ashkezari, l.shamsashkezari@tudelft.nl
- Supervisor: Dr. Gautham Ram Chandra Mouli, g.r.chandramouli@tudelft.nl
  Dr. Neil Yorke-Smith, N.Yorke-Smith@tudelft.nl
  Prof. Dr. Pavol Bauer, P.bauer@tudelft.nl

AVTIVE THERMAL CONTROL OF BATTERY AGEING

Type of project: MSc thesis

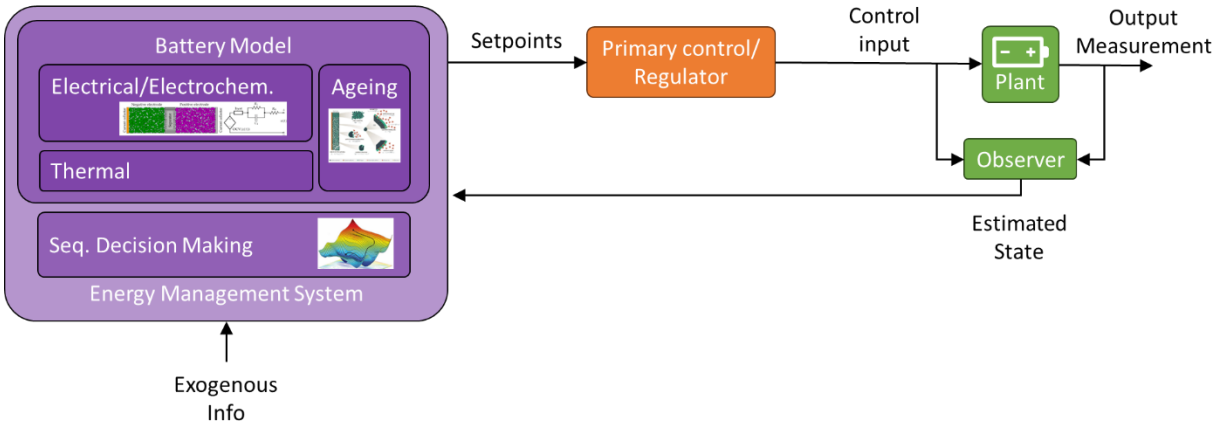


Fig 1: Project workflow

Scope:

Develop control algorithms to actively control battery ageing through temperature and current.

Problem definition:

In the future energy storage devices are expected to play a large role in stationary applications, such as building energy storage or grid support applications. These devices might come from different applications (stationary, mobility, etc.) and manufacturers. Unfortunately, battery degradation is an important question. Several advanced controls are proposed in the literature which propose controlling the battery and its degradation by using its current/power. A dimension often disregarded is the temperature effect of the operation and its dynamics.

The goal of this Thesis is too integrate the temperature dynamics into the current aging aware controls.

The models and algorithms are encouraged to be developed in Julia/Python and (optionally) to be experimentally validated in our lab.

Methodology:

- Perform a literature study on battery modeling and degradation and adaptive control techniques.
- Integrate temperature models in the EMS.
- Validate control approach experimentally (Optional)

Research Objectives:

- Literature review.
- Novel multi-physics control algorithm integrating temperature control and degradation.

Contact details:

- PhD student: Dario Slaifstein, D.A.Slaifstein@tudelft.nl , LB.03.820
- Supervisors: Dr. Gautham Ram Chandra Mouli; Prof. P Bauer

TU Delft

MULTIPHYSICS BATTERY DIGITAL TWIN FOR CONTROL

Type of project: MSc thesis

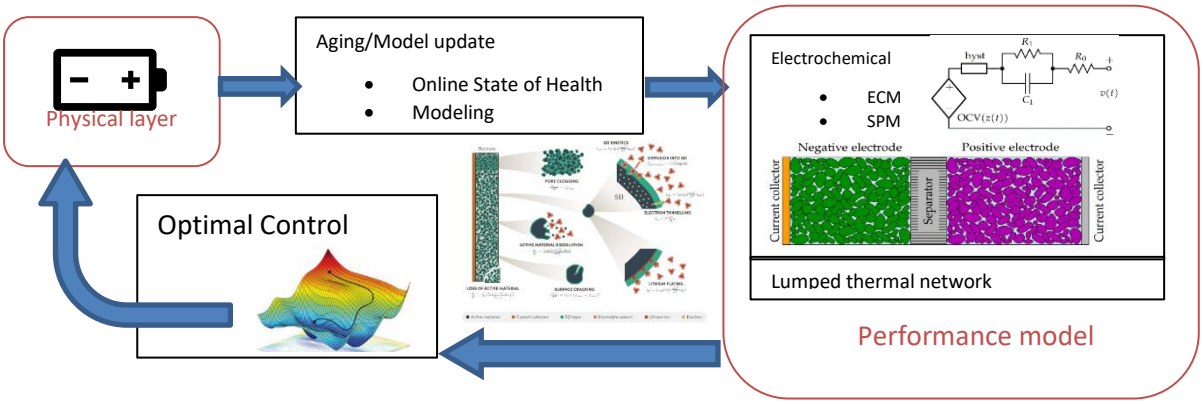


Fig 1: Project workflow

Scope:

Develop algorithms for online state of health estimation

Problem definition:

In the future energy storage devices are expected to play a large role in stationary applications, such as building energy storage or grid support applications. These devices might come from different applications (stationary, mobility, etc.) and manufacturers. Hence, we face the issue of encountering ourselves with many different batteries connecting to the grid, even to the same node. To optimally operate them advanced battery models are used. Once batteries are connected we need to first fit a model to it, but also update that model online to maintain a digital twin which is running in real-time in parallel to the physical battery.

The models and algorithms are encouraged to be developed in Julia/Python/Matlab-Simulink and tested in our lab.

Methodology:

- Perform a literature study on battery modeling and degradation and adaptive control techniques.
- Develop real-time online algorithms that update the models.

Research Objectives:

- Literature review.
- Multiphysics control oriented digital twin of a battery pack.
- Develop online parameter estimation algorithms.

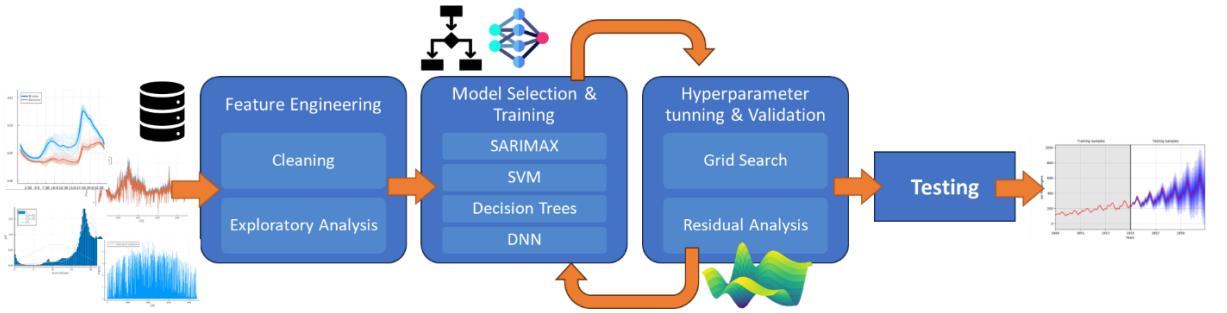
Contact details:

- PhD student: Dario Slaifstein, D.A.Slaifstein@tudelft.nl , LB.03.820
- Supervisors: Dr. Gautham Ram Chandra Mouli; Prof. P Bauer

DCE&S
DC Systems, Energy Conversion & Storage

FORECASTING MODULE DEVELOPMENT

Type of project: MSc Thesis / Extra Project/ SIP 2



Scope:

Develop a Forecasting module for internal use of the DCE&S section. The module will include different forecasting methods based on state-space models, filtering and machine learning.

Problem definition:

The integration of renewable energy sources possess a significant challenges for current markets and analytical tools. One the biggest challenge is the integration of uncertainty into decision-making at every time scale (long-term planning, day-ahead and real-time operation). Thus the quantification and modelling of such uncertainties is a key step to develop and deploy future energy systems. This extra project aims to develop a basic open-software module that can be used, in principle, inside the DCE&S section. The models to be implemented will vary from classical methods (autoregressive state-space like SARIMA) to machine learning methods (decision trees or deep learning).

The models and algorithms are encouraged to be developed in Julia/Python and tested in current projects. Strong control, optimization and/or mathematical background are encouraged.

Methodology:

Initially the toolbox has to setup a pipeline for:

1. Data acquisition/Database management.
2. Feature/Data engineering
3. Model tunning/training, testing and validation.
4. Forecast utilization.

Research Objectives:

- Setup a basic and expandable forecasting pipeline.
- Develop module documentation.

Contact details:

- PhD student: Dario Slaifstein, D.A.Slaifstein@tudelft.nl , LB.03.820
- Supervisor:
  Dr. Gautham Ram Chandra Mouli G.R.Chandramouli@tudelft.nl
  Dr. Laura Ramirez Elizondo l.m.ramirezelizondo@tudelft.nl
  Prof. Dr. Ir.Pavol Bauer, P.Bauer@tudelft.nl

TU Delft

OPTIMAL SIZING OF MULTICARRIER URBAN ENERGY SYSTEMS

Type of project: MSc thesis

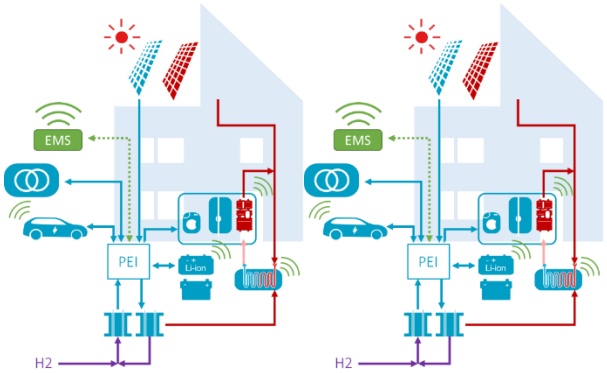


Fig 1: Preliminary FLEXINet households.

Scope:

Develop sizing strategies for multicarrier urban energy systems.

Problem definition:

In the future, urban energy systems will be decarbonize combining different carriers. In this context, the question of how big each device is and how the size depends on the supplied demand is vital. The goal of this project is to propose different sizing strategies for electrified buildings.

The households will follow the FLEXINet and 24/7 projects design. Sizing of the devices will have to consider several aspects: relationship between sizing and optimal operation of the system, size/efficiency trade-off of pseudo-thermal (heat and H2) carriers, battery aging, cooperation between individual systems.

The models and algorithms are encouraged to be developed in Python/Julia/Matlab-Simulink and tested in our lab.

Methodology:

- Perform a literature study.
- Model multicarrier households, blocks and neighbourhoods.
- Propose sizing strategies for the different systems.

Research Objectives:

- Literature review.
- Sizing strategies for multicarrier urban energy systems.

Contact details:

- PhD student: Dario Slaifstein, D.A.Slaifstein@tudelft.nl , LB.03.820
- Supervisors:
  Dr. Gautham Ram Chandra Mouli G.R.Chandramouli@tudelft.nl
  Dr. Laura Ramirez Elizondo l.m.ramirezelizondo@tudelft.nl
  Prof. Dr. Ir.Pavol Bauer, P.Bauer@tudelft.nl

REINFORCEMENT LEARNING FOR MULTICARRIER URBAN SYSTEMS

Type of project: MSc thesis

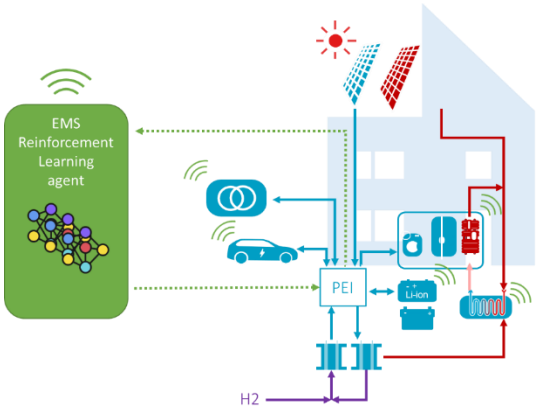


Fig 1: Project overview.

Scope:

Develop energy management system based on continuous time reinforcement learning (RL) algorithms.

Problem definition:

In the future, urban energy systems will be decarbonized. How this will happen is still an open question. It is possible that multiple energy carriers will coexist in the urban environment to fulfil such demand. In this context, the problem of scheduling and controlling the different devices during the day, month and year is non-trivial. Recently, machine learning techniques have acquired a lot of attention due to their speed and performance. The goal of this project is to propose control algorithms based on continuous-time reinforcement learning agents. Special focus should be made on the utilization of different energy storage devices for the different timescales.

The models and algorithms are encouraged to be developed in Julia/Python and tested in our lab. Strong control, optimization and/or mathematical background are encouraged.

Methodology:

- Perform a literature study on reinforcement learning and its application in control setups.
- Build and simulate energy management algorithms based on RL.
- Test the robustness of the algorithms in relevant operation scenarios.

Research Objectives:

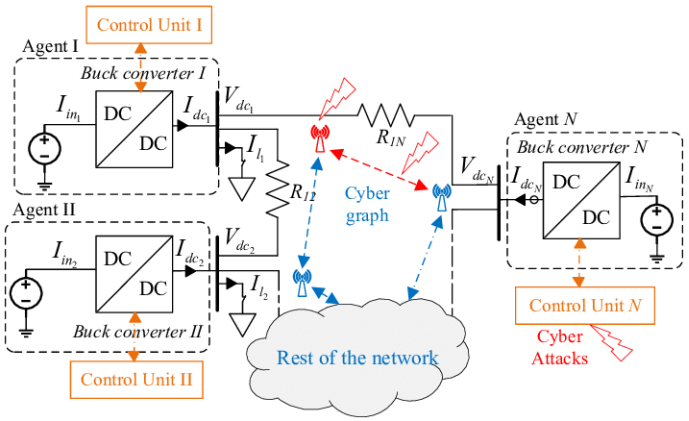
- Literature review.
- Performance of RL algorithms for energy management systems.
- Investigate the impact of incorporating models into the RL framework.

Contact details:

- PhD student: Dario Slaifstein, D.A.Slaifstein@tudelft.nl , LB.03.820
- Supervisors: Dr. Gautham Ram Chandra Mouli; Prof. P Bauer

CYBERSECURITY AND RESILIENCY IN POWER ELECTRONICS FOR DC MICROGRIDS

Type of project: Master Thesis



Scope:

This research addresses cybersecurity challenges in DC microgrids—localized energy systems utilizing direct current for power generation, distribution, and consumption. As DC microgrids integrate distributed energy resources (DERs) and communication technologies, they become vulnerable to cyber threats. The study aims to identify these vulnerabilities, assess potential threats, and develop strategies to enhance cybersecurity.

Problem definition:

As the adoption of DC microgrids grows, they face cyber threats that can compromise their functionality and security. Vulnerabilities may lead to service disruptions, unauthorized access, and manipulation of critical system components, compromising the reliability and safety of power delivery. The absence of standardized cybersecurity frameworks specifically designed for DC microgrids further complicates efforts to secure these systems.

Methodology:

The research will involve a literature review to identify existing cybersecurity frameworks, simulations to analyze different cyber-attacks and their impacts, and case studies of current DC microgrid systems to assess vulnerabilities and existing security measures.

Research Objectives:

- Analyze the vulnerabilities of DC microgrids related to their architecture and operational characteristics.
- Develop a systematic framework for assessing potential cyber threats specific to DC microgrid systems.
- Propose robust cybersecurity strategies and protocols to enhance the resilience of DC microgrids against identified threats.
- Provide practical guidelines for the integration of cybersecurity measures into the design and operation of DC microgrids.

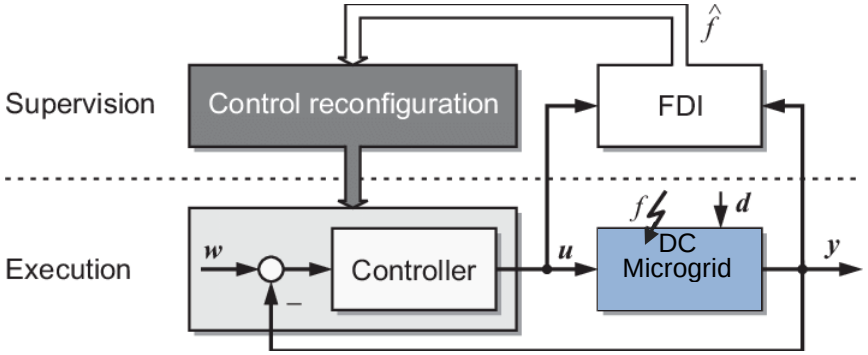
Contact details:

- Supervisor(s): Dr. Qobad Shafiee, Q.Shafiee@tudelft.nl
  Dr. Alex Stefanov, a.i.stefanov@tudelft.nl
  Prof. Pavol Bauer, P.Bauer@tudelft.nl

TU Delft

FAULT-TOLERANT CONTROL FOR ENHANCED RESILIENCE IN DC MICROGRIDS

Type of project: Master Thesis



Scope:

DC microgrids are increasingly deployed in applications requiring high reliability, including critical infrastructure, and remote communities. Their vulnerability to faults—such as line faults, converter failures, or component degradation—presents challenges for maintaining stable operation. This research focuses on designing fault-tolerant control strategies to ensure resilient and reliable operation of DC microgrids, even under fault conditions.

Problem definition:

DC microgrids lack inherent fault isolation due to their low system inertia, making them sensitive to disturbances. Traditional control strategies may not effectively detect, isolate, and mitigate faults, leading to potential system instability. There is a critical need for fault-tolerant control methods that can autonomously manage faults, and ensure smooth operation during and after faults.

Methodology:

- Conduct a comprehensive review of existing fault-tolerant control strategies, fault types, and their impacts on DC microgrid stability.
- Develop a detailed model of the DC microgrid, incorporating common fault scenarios such as short circuits, open circuits, and converter failures.
- Develop control strategies, such as adaptive and predictive control, to respond dynamically to faults and adjust system parameters to maintain stability.
- Test the developed control strategy through simulations and, if possible, on a laboratory-scale DC microgrid setup to verify its practical feasibility and effectiveness.

Research Objective(s):

Develop and implement fault-tolerant control strategies that enable DC microgrids to autonomously detect, isolate, and mitigate faults, ensuring continuous operation and stability under various disturbance scenarios.

Contact details:

Supervisor(s): Dr. Qobad Shafiee, Q.Shafiee@tudelft.nl

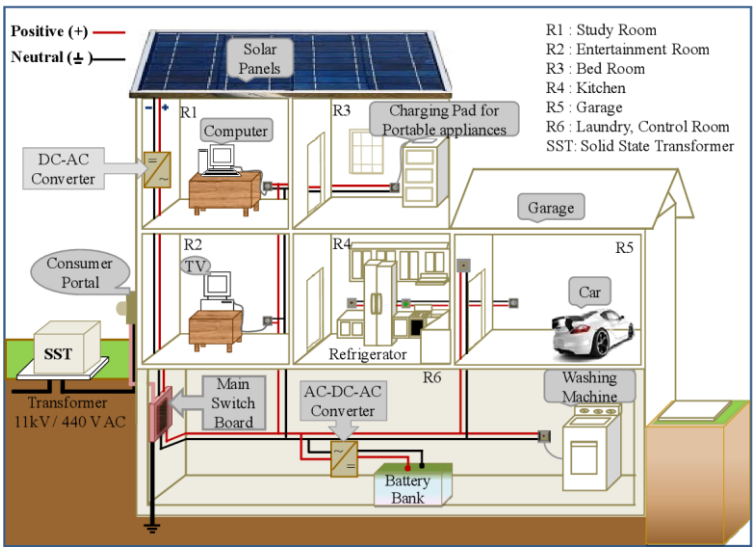
Prof. Pavol Bauer, P.Bauer@tudelft.nl

OPTIMAL DESIGN OF DC MICROGRIDS FOR RESIDENTIAL APPLICATIONS

Type of project: Master Thesis

Scope:

This research focuses on the optimal design of DC microgrids specifically tailored for residential applications. DC microgrids are localized energy systems that utilize direct current to integrate renewable energy sources, energy storage systems, and load management effectively. This research aims to enhance energy efficiency, reliability, and integration of distributed energy resources in residential applications under the concept of DC microgrids.



Problem definition:

With the increasing demand for sustainable energy solutions, conventional AC systems may not efficiently support the integration of renewable energy technologies in residential areas. Existing residential energy systems often face challenges such as high energy losses during conversion, increased complexity in management, and limited reliability. This research addresses the need for an optimal design framework that uses DC microgrid technology to overcome these limitations and enhance energy delivery in residential environments.

Methodology:

- Conduct a literature review of existing research on DC microgrids for residential applications.
- Develop a simulation model of a DC microgrid, integrating components such as photovoltaic systems, battery storage, and load profiles typical of residential users.
- Utilize optimization algorithms or a software to identify optimal sizing and configuration of microgrid components.
- Perform simulations under varying load conditions and renewable generation scenarios to evaluate performance metrics such as energy efficiency, reliability, and cost-effectiveness.
- Analyze real-world case studies to validate simulation results and refine design parameters.

Research Objectives:

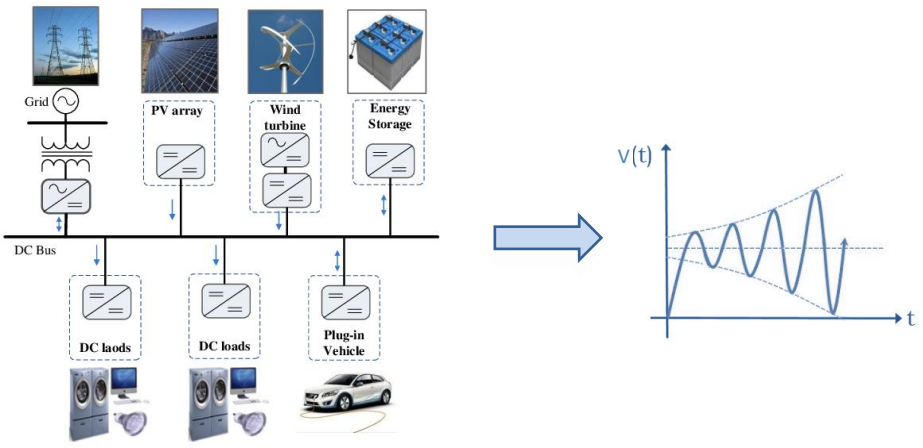
- Establish a design framework for optimizing the configuration and sizing of DC microgrid components for residential applications.
- Evaluate the performance of the proposed DC microgrid designs through simulations and real-world case studies, focusing on efficiency, reliability, and economic feasibility.
- Provide practical recommendations for implementation of DC microgrids in residential areas.

Contact details:

- Supervisor(s): Dr. Qobad Shafiee, Q.Shafiee@tudelft.nl
  Dr. Laura Ramirez, l.m.ramirezelizondo@tudelft.nl

STABILITY OF DC MICROGRIDS UNDER DIFFERENT OPERATIONAL SCENARIOS

Type of project: Master Thesis



Scope:

DC microgrids are increasingly adopted in various applications due to their high efficiency, simplicity, and compatibility with modern DC loads. However, ensuring stability across varying operational scenarios, such as load changes and fluctuating energy sources, remains a critical challenge for these systems. This research focuses on understanding the stability of DC microgrids across varying scenarios and identifying factors that influence system stability.

Problem definition:

DC microgrids lack inherent rotational inertia, making them more sensitive to disturbances and stability issues, especially as DERs and loads vary. Small-signal stability concerns arise with minor disturbances that can lead to oscillatory modes, while large-signal stability is crucial for handling significant changes or faults. Analyzing both types of stability across different scenarios is essential for understanding and improving microgrid resilience.

Methodology:

- Investigate existing models and stability criteria for DC microgrids, identifying common small-signal and large-signal stability challenges.
- Develop a comprehensive model of a DC microgrid, incorporating the essential dynamics.
- Simulate the microgrid under various scenarios, including grid-connected vs. islanded modes, variable DER output, and load fluctuations.
- Apply eigenvalue analysis to evaluate system response to minor perturbations. Use time-domain and Lyapunov-based methods to assess system resilience to larger disturbances, such as load switching and DER faults.

Research Objectives:

1. Identify key factors influencing small-signal and large-signal stability in DC microgrids under various scenarios.
2. Evaluate both small-signal and large-signal stability to determine the impacts of different load, source, and fault conditions.

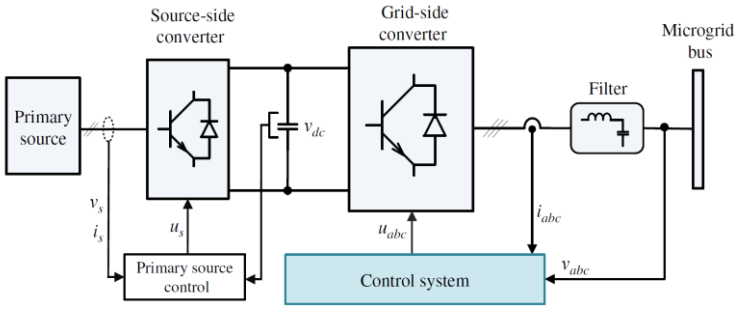
Contact details:

Supervisor(s): Dr. Qobad Shafiee, Q.Shafiee@tudelft.nl
Dr. Laura Ramirez, l.m.ramirezelizondo@tudelft.nl

TU Delft

UNIFIED GRID-FORMING AND GRID-FOLLOWING CONTROL STRATEGY FOR POWER CONVERTERS

Type of project: Master Thesis



Scope:

The growing integration of renewable energy resources within power grids has led to the adoption of power converters in grid-forming (GFM) and grid-following (GFL) configurations. GFM converters maintain grid stability by regulating voltage and frequency, effectively acting as virtual synchronous generators. GFL converters, in contrast, rely on an established grid to synchronize current injections, making them suitable for renewable integration. This research explores a unified control approach, enabling a single converter to switch between GFM and GFL modes dynamically, improving resilience and adaptability.

Problem definition:

Current GFM and GFL functionalities require separate physical converters, increasing complexity, and cost. As renewable penetration increases, the system needs both grid-forming stability and grid-following adaptability to handle varying grid conditions. However, coordinating separate GFM and GFL converters can lead to synchronization challenges, and inefficiencies. This research addresses the need for a hybrid control mechanism that utilizes a single converter for both GFM and GFL tasks, thus providing resilience in both islanded and grid-connected modes.

Methodology:

- Conduct a detailed review of existing GFM and GFL control techniques, identifying strengths, limitations, and challenges.
- Develop a unified control solution that dynamically switches between GFL and GFM modes based on real-time grid conditions, and load demands.
- Validate the proposed control strategy through detailed simulations and laboratory experiments, comparing its performance with conventional GFL and GFM control approaches.

Research Objectives:

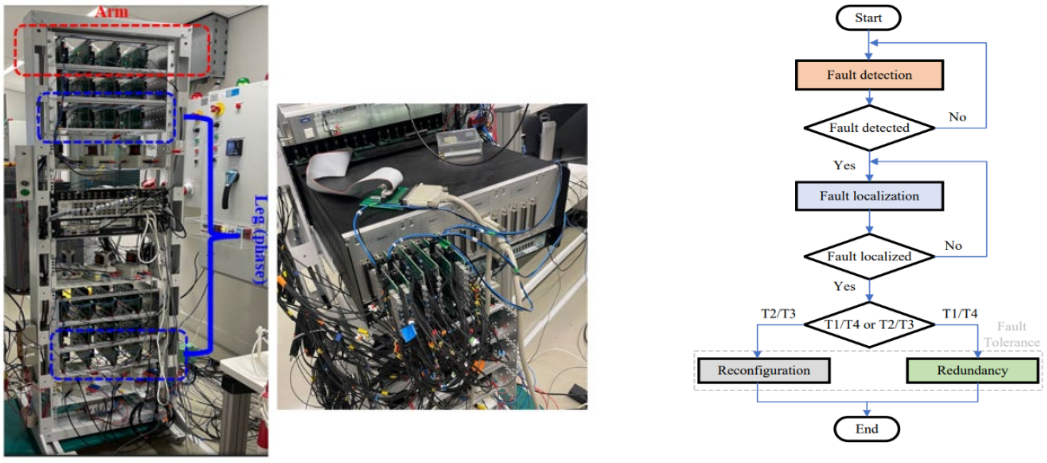
1. Design a unified control solution for flexible GFM-GFL operation in a single converter,
2. Reduce complexity and cost by consolidating GFM and GFL functions into one unit,
3. Validate the control strategy performance under different scenarios, and demonstrate improvements in stability, and adaptability in converter-dominated girds.

Contact details:

- Supervisor(s): Dr. Qobad Shafiee, Q.Shafiee@tudelft.nl
  Dr. Zian Qin, z.qin-2@tudelft.nl
  Prof. Pavol Bauer, P.Bauer@tudelft.nl

ADAPTIVE RECONFIGURABILITY IN MMC FOR SMART FAULT MANAGEMENT

Type of project: MSc thesis



(a) (b) (c)

(a) front-end, and (b) back-end(a) of assembled lab scale MMC tower, (c) Adaptive fault-tolerance algorithm

Scope:

This project explores an adaptive reconfiguration strategy for Modular Multilevel Converters (MMC) that adjusts to different fault types and system loads in real-time. The aim is to develop a more intelligent reconfiguration approach to selectively activate or bypass sub-modules based on fault location, load requirements, and system stress levels.

Problem definition:

Standard reconfiguration approaches for MMCs mainly address fixed scenarios and predictable faults, like single open-circuit or short-circuit events. However, in practice, faults can vary in severity, location, and impact, and MMCs may face dynamic loads that influence how faults affect performance. An adaptive reconfiguration approach would improve MMC resilience by tailoring reconfiguration methods to current operating conditions, helping maintain efficiency and reduce wear on unaffected components.

Methodology:

The project will start with a review of existing fault tolerance and reconfiguration strategies for MMCs. The student will then develop a MATLAB model of an MMC capable of handling adaptive reconfiguration with control algorithms that adjust the system response based on real-time fault detection and load analysis. This includes developing a decision-making algorithm that determines the best reconfiguration strategy based on the detected fault type and system load. Experimental validation is optional but encouraged.

Research Objectives:

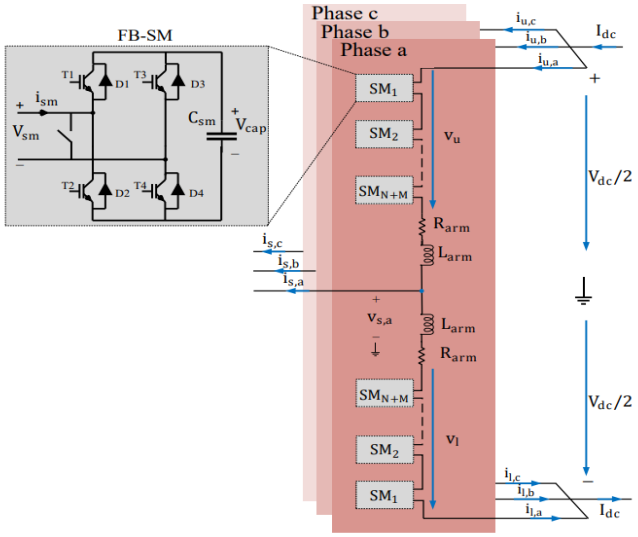
- Design a control algorithm that adjusts reconfiguration based on fault type and load conditions.
- Simulate adaptive reconfiguration scenarios to analyze improvements in reliability and efficiency.
- (Optional) experimental validation of the adaptive system response to fault and load conditions.

Contact details:

- PhD student: Miad Ahmadi (M.ahmadi-3@tudelft.nl)
- Supervisor: Dr. Aditya Shekhar (A.Shekhar@tudelft.nl)
- Promoter: Prof. Dr. Pavol Bauer (P.bauer@tudelft.nl)

RELIABILITY-AWARE ENERGY MANAGEMENT FOR MMC

Type of project: MSc thesis



MMC configuration with full bridge submodule

Scope:

This project investigates the integration of reliability assessments into real-time energy management strategies for MMCs, leveraging redundancy schemes to optimize reliability without sacrificing efficiency. The goal is to design an energy management system that uses reliable data to balance energy consumption and minimize stress on sub-modules in real time.

Problem definition:

Traditional MMCs operate based on fixed or load-driven control schemes without accounting for real-time reliability data. By embedding reliability metrics into energy management strategies, we can reduce the stress on specific sub-modules and prioritize their usage based on condition and predicted failure rates. This novel approach seeks to use redundancy to respond to faults and proactively manage sub-module usage, extending the lifespan of critical components.

Methodology:

The student will begin with a literature review on reliability assessments and energy management in MMCs. Then, they will develop a MATLAB model for an MMC that incorporates a redundancy configuration, with a reliability-aware control algorithm that shifts energy flow based on real-time reliability data. The project will include simulations to test how different configurations impact both energy efficiency and system reliability.

Research Objectives:

- Develop an energy management strategy that considers reliability metrics in real-time to extend component lifespan.
- Analyze energy and reliability trade-offs using simulated load conditions and fault scenarios.
- Provide recommendations for implementation of reliability-aware control in MMC applications.

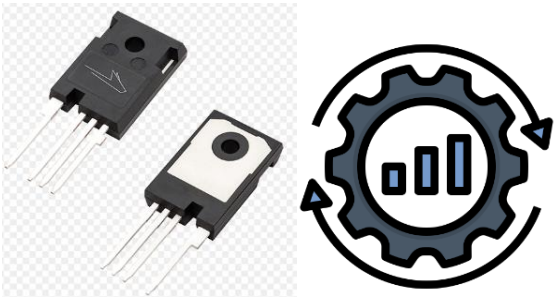
Contact details:

- PhD student: Miad Ahmadi (M.ahmadi-3@tudelft.nl)
- Supervisor: Dr. Aditya Shekhar (A.Shekhar@tudelft.nl)
- Promoter: Prof. Dr. Pavol Bauer (P.bauer@tudelft.nl)

TU Delft

MULTI-OBJECTIVE OPTIMIZATION-BASED DESIGN FOR RELIABILITY FRAMEWORK FOR SIC BASED DC-DC CONVERTERS IN EV FAST CHARGERS

Type of project: <MSc thesis>



Scope:

The goal of this thesis is to develop a Design for Reliability (DfR) for Silicon Carbide-based DC-DC converters in electric vehicle fast chargers. The framework uses multi-objective optimization to balance reliability, efficiency, and cost, supporting the design of reliable and cost-effective charging systems.

Problem definition:

SiC technology in EV fast chargers offers efficiency and thermal benefits like higher switching frequency, higher operating temperature, and larger thermal conductivity. However, reliability under harsh conditions is not well understood. A systematic approach is needed to optimize design for reliable, efficient, and cost-effective solutions.

Methodology:

The research will analyse SiC-based DC-DC converters in EV fast chargers, focusing on thermo-mechanical stresses. A DfR framework will be established using simulation and literature data to identify failure mechanisms. Multi-objective optimization will balance reliability, efficiency, cost, thermal management, and robustness, targeting reduced component stress and thermal hotspots.

Research Objectives:

- Identify major reliability challenges, including repeated thermal changes, and high humidity.
- Apply multi-objective optimization techniques to enhance reliability, maximize efficiency, and minimize costs.

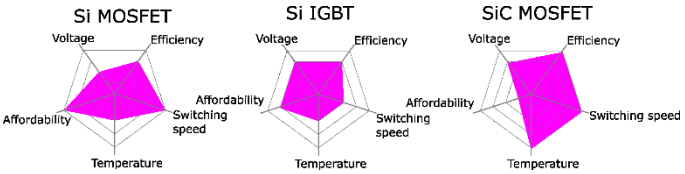
Contact details:

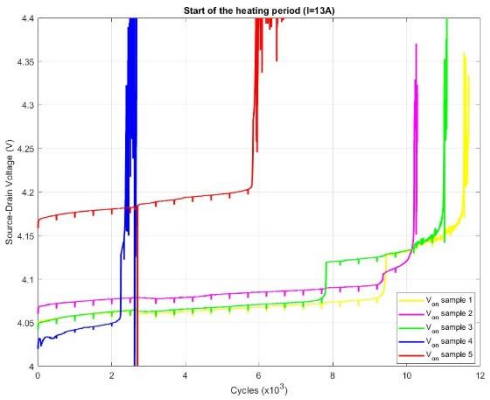
- PhD student: Faezeh Kardan, F.kardanhalvaei@tudelft.nl
- Supervisor: Dr. Ir. Aditya Shekhar, A.Shekhar@tudelft.nl
  Prof. Dr. Ir. Pavol Bauer, P.bauer@tudelft.nl

DC Systems, Energy Conversion & Storage

PREDICT THE REMAINING USEFUL LIFETIME OF SEMICONDUCTOR DEVICES BY USING MACHINE LEARNING METHODS.

Type of project: <MSc thesis>





Scope:

Predict the remaining useful lifetime of SiC MOSFETs and Si IGBTs and Si MOSFETs by using machine learning methods.

Problem definition:

Semiconductor devices, i.e. MOSFETs and IGBTs, are a major cause of failure in high power converters. The lifetime of converters can be increased by placing a redundant MOSFET in parallel. However, the redundant MOSFET can only work when the first MOSFET has not yet failed, i.e. creating a short. Therefore, it is important to predict the lifetime of the MOSFET. Many electrical and thermal parameters are measured throughout the degradation of the MOSFET, but not all will be relevant for predicting the remaining useful lifetime. Data collection, feature engineering and model selection are essential for obtaining an accurate prediction of the remaining useful lifetime of the semiconductor devices.

Methodology:

- Collecting data
- Feature engineering: Decide which data has physical correlations with lifetime
- Compare different machine learning models: Regression, SVM, Trees or KNN
- Optimize model parameters and performance metrics

Research Objectives:

- Literature review on thermos-mechanical fatigue mechanisms and machine learning models.
- Build a model to predict the remaining useful lifetime of the MOSFET.

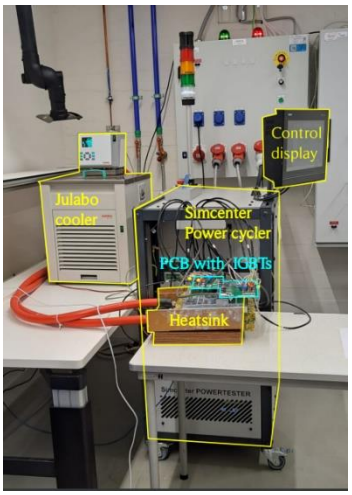
Contact details:

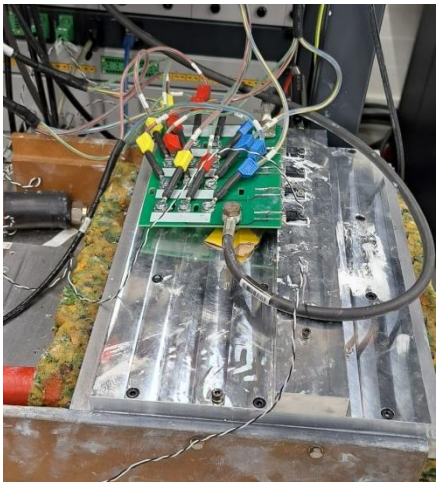
- PhD student: Margo Molenaar, m.molenaar-1@tudelft.nl, LB.02.860
- Supervisor: Dr.ir. Aditya Shekhar and Prof. Dr. Ir. Pavol Bauer

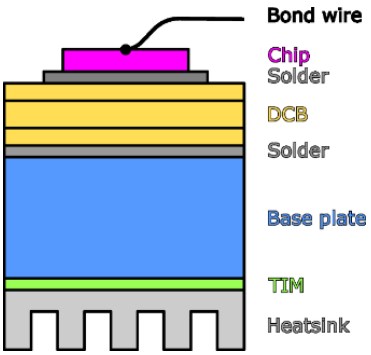
TU Delft

FEM ANALYSIS OF HEAT FLOW AND THERMAL RESISTANCE/CAPACITANCE OF THE MOSFET PACKAGE AND HEATSINK

Type of project: < Extra Project / MSc thesis>







Scope:

Make a finite element model of the MOSFET, thermal pad and heatsink. Analyse the temperature flow and calculate the thermal resistances and thermal capacitance of each layer.

Problem definition:

In order to study the degradation of the MOSFET, we have a power cycling test in the ESP lab. To verify the result and understand the setup, we need more details about our setup. This includes the temperature flow within the setup when the MOSFET is heated internally with its losses as well as the thermal resistances and thermal capacitances of the setup.

Methodology:

Firstly learning the basic things about FEM and our experimental setup. You can measure the dimensions as well as the temperature at different locations and calculate expected thermal resistance and thermal capacitance. The next step is making the FEM and simulate the heat flow. Verify the model with the measured temperatures of the experimental setup.

Research Objectives:

- Calculate expected thermal resistances and thermal capacitances
- Develop finite element model of the MOSFET package, thermal pad and heatsink
- Simulate the heat flow within the setup
- Verify the model with temperatures measured on the experimental setup
- Thesis: Improve the heat flow and thermal resistance/capacitance
- Thesis: Literature review

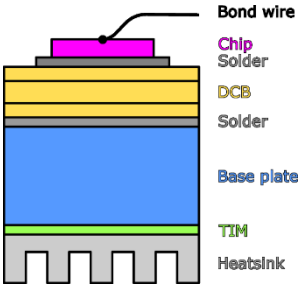
Contact details:

- PhD student: Margo Molenaar, m.molenaar-1@tudelft.nl, LB.02.860
- Supervisor: Dr.ir. Aditya Shekhar and Prof. Dr. Ir. Pavol Bauer

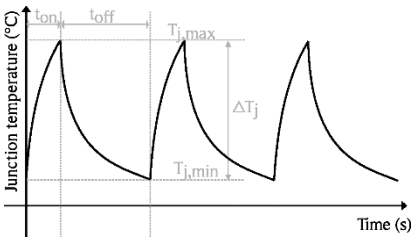
DC Systems, Energy Conversion & Storage

SIMULATION-BASED ESTIMATION OF THE THERMOMECHANICAL FAILURES IN HIGH POWER AC/DC CONVERTER

Type of project: <MSc thesis>



Layer	CTE (10^{-6} K^{-1})
Bond wire	23 for Al
Chip	3.5 for Si and 4.0 for SiC
Solder	19 for PbSN and 23.5 for SAC305 (SnAgCu)
DCB	8.2 for AlN and 10.7 for Al2O3
Base plate	7 for AlSiC and 17 for Cu



Scope:

Simulate the temperature fluctuation within AC/DC converters and estimate their lifetime and fault tolerance.

Problem definition:

Losses in the MOSFETs create temperature fluctuations and thermomechanical stresses, which are a major cause of failure in high-power applications. Knowing the lifetime of the AC/DC converters will benefit designers of high-power applications and planners of preventive maintenance. Moreover, the lifetime of converters can be increased by placing a redundant MOSFET in parallel. However, the redundant MOSFET can only work when the first MOSFET has not yet failed, i.e. creating a short. Therefore, it is important to predict the lifetime of the MOSFET.

Methodology:

The student will start by doing a literature study to understand the failure mechanisms and electrical behaviour of different AC/DC converters. With Matlab/Simulink/PLECS the losses and temperature fluctuations of high-power AC/DC converters can be simulated. Next their fault tolerances and lifetimes must be investigated by using available tools like the Weibull distribution and LESIT study. The simulation results can be verified with practical experiments, like the accelerated degradation test with the power cycling machine.

Research Objectives:

- Literature study on failure mechanisms and electrical behaviour of AC/DC converters
- Simulate losses and temperature fluctuations in AC/DC converters in Simulink or LTSpice
- Investigate fault tolerance of AC/DC converters
- Estimate the lifetime with LESIT study and Weibull distribution
- Verify simulation results with practical experiments

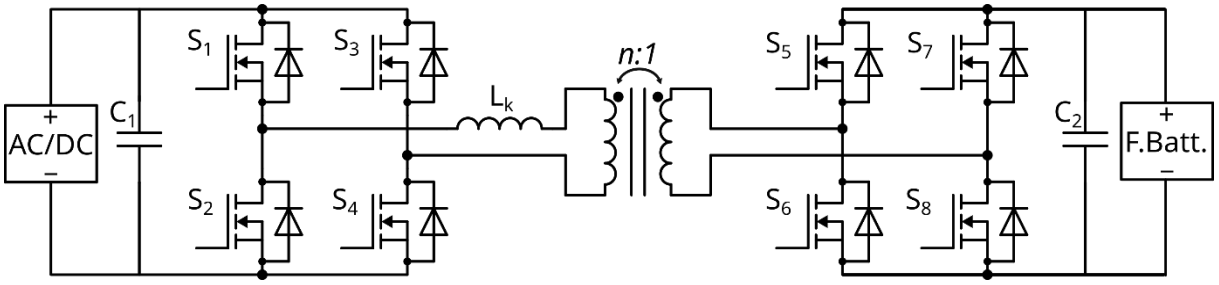
Contact details:

- PhD student: Margo Molenaar, m.molenaar-1@tudelft.nl, LB.02.860
- Supervisor: Dr.ir. Aditya Shekhar and Prof. Dr. Ir. Pavol Bauer

TU Delft

DESIGN OPTIMISATION FOR A ROBUST DUAL ACTIVE BRIDGE CONVERTER FOR FLOW BATTERY APPLICATION

Type of project: MSc thesis



Scope:

To optimise the design parameters of a DAB converter for CC, CV and CP operating modes of Flow Battery.

Problem definition:

The Flow Battery charge or discharge operation observes a significant voltage variation. The Dual Active Bridge (DAB) converter connected to the Flow Battery to facilitate power transfer has to operate in Constant Current – Constant Voltage (CC-CV) during charging and Constant Power during discharge. The design parameters for the DAB need to be optimised for all three modes to find a balance between reduced losses and enhanced reliability.

Methodology:

The student will start with a literature review to build their foundational knowledge on the Dual Active Bridge and the electrical characteristics of the flow battery. Then, an analytical model of the DAB will be created to evaluate the power losses of the converter at different operating points, followed by implementing an optimisation strategy to find a balance between efficiency and reliability. All of the various operating conditions need to be analysed for optimisation.

Research Objectives:

- Literature review of the DAB and the electrical characteristics of the Flow battery.
- Investigation of power losses as a function of varying voltage of the Flow battery.
- Optimisation of DAB design parameters for better efficiency and reliability.

Contact details:

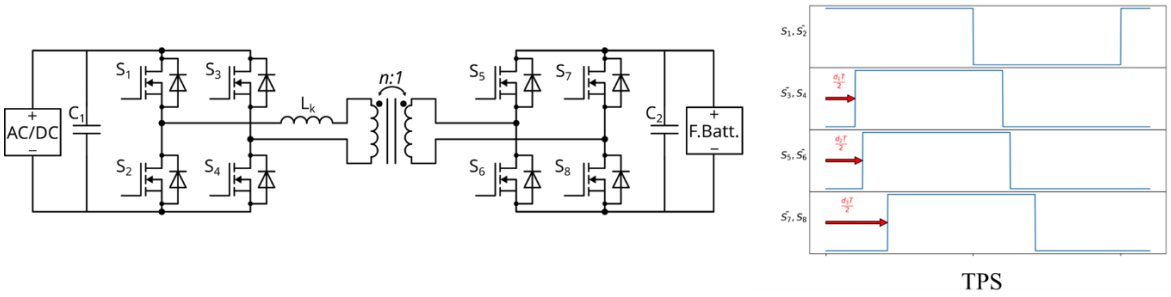
- PhD student: Sourabh Singh, s.singh-9@tudelft.nl
- Supervisor: Aditya Shekhar, A.Shekhar@tudelft.nl

Prof. Dr. Ir. Pavol Bauer, P.Bauer@tudelft.nl

DC Systems, Energy Conversion & Storage

RELIABILITY ANALYSIS OF DUAL ACTIVE BRIDGE CONVERTER FOR FLOW BATTERY APPLICATION

Type of project: MSc thesis



TPS

Scope:

To analyse and compare the reliability of Dual Active Bridge converter for different modulation schemes for Flow battery application.

Problem definition:

The Flow Battery operation observes a significant voltage variation as the battery cycles. The Dual Active Bridge (DAB) converter connected to the Flow Battery, to facilitate power transfer, can be controlled with various modulation schemes such as Single, Double, Triple and Extended phase shift. With wide voltage variations, the thermal stresses subjected to the devices increase, leading to reliability issues.

Methodology:

The student will start with a literature review to build their foundational knowledge on the Dual Active Bridge and the electrical characteristics of the flow battery. Then, a PLECS of the DAB will be created to evaluate the power losses of the converter for different control schemes, followed by implementing reliability models of the switches in MATLAB or Python. Finally, the reliability and lifetimes of various components will be compared.

Research Objectives:

- Literature review of the DAB and the electrical characteristics of the Flow battery.
- Investigation of power losses as a function of varying voltage of the Flow battery.
- Comparison of reliability of the DAB for different control schemes.

Contact details:

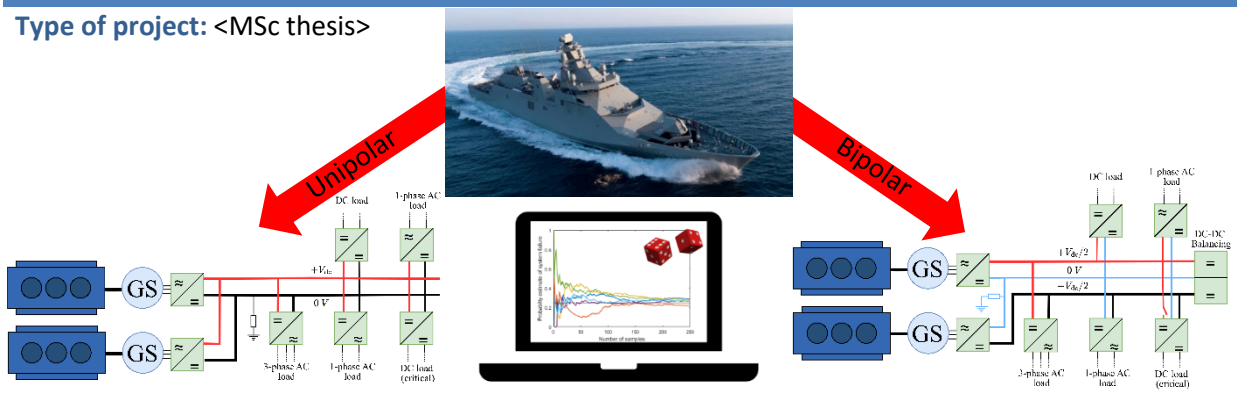
- PhD student: Sourabh Singh, s.singh-9@tudelft.nl
- Supervisor: Aditya Shekhar, A.Shekhar@tudelft.nl

Prof. Dr. Ir. Pavol Bauer, P.Bauer@tudelft.nl

TU Delft

RELIABILITY COMPARISON OF UNIPOLAR AND BIPOLAR DC SHIPBOARD POWER SYSTEMS

Type of project: <MSc thesis>



Scope:

Develop a hierarchical reliability model for a unipolar and bipolar DC shipboard power system to compare their adequacy/availability performance. By combining the two, define the optimal bus design strategy for high reliability.

Problem definition:

The energy transition in the maritime sector necessitates the electrification of the ship's propulsion system. Therefore, future all-electric ships (AES) will be equipped with a shipboard power system (SPS) that connects all electrical loads (including propulsion) to the power generation modules. However, as the propulsion system is vital to the ship's mission and crew safety, ensuring supply adequacy is critical for the adoption of the AES. DC grids have shown significant advantages over AC for shipboard applications, including improved efficiency, power density, source synchronization, and energy storage system integration. However, the high penetration of power electronic devices in DC grids, along with enhanced network interconnectivity, can significantly compromise the system's reliability. A solution to improve the SPS reliability is to use a bipolar DC bus. This three-conductor system provides a redundant power path for critical loads, benefiting the adequacy. On the other hand, the added system complexity can also negatively impact the system's reliability.

Methodology:

The student shall start with a literature study on shipboard DC bus design and reliability modelling. Thereafter, the student is expected to design and validate a hierarchical reliability model which is then used to compare the reliability of the two bus configurations. Finally, the student shall propose a dc-bus design strategy to maximise the system's availability while accounting for other parameters like efficiently, cost, space.

Research Objectives:

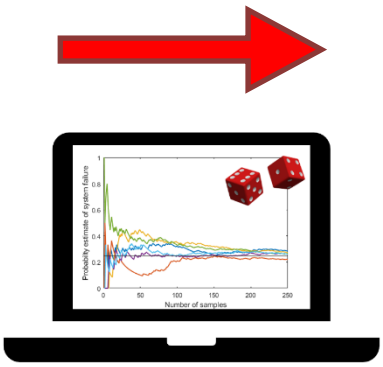
- Literature review on shipboard DC bus design and reliability modelling.
- Develop and validate a hierarchical reliability model for DC SPSs.
- Compare the reliability/availability performance of the two DC bus configurations.
- Define an optimized dc bus design strategy for high reliability.

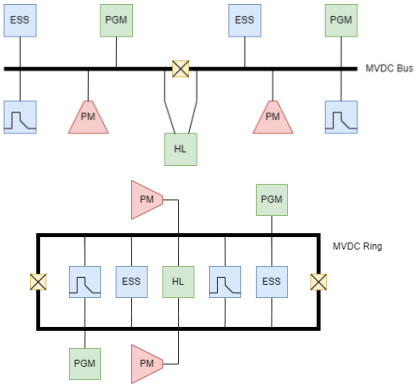
Contact details:

- PhD student: Robin van der Sande, R.P.J.vanderSande@tudelft.nl
- Supervisor: Dr.ir. Aditya Shekhar, A.Shekhar@tudelft.nl
  Prof. dr. Ir. Pavol Bauer, P.bauer@tudelft.nl

RELIABILTY COMPARISON OF NAVAL DC SHIPBOARD POWER SYSTEMS

Type of project: <MSc thesis>





Scope:

Evaluate the reliability of different DC shipboard integrated power systems using stochastic simulation in order to maximize the availability of a naval ship.

Problem definition:

The energy transition of the maritime sector imposes the electrification of the ship's power system. Future all-electric ships (AES) need an intelligent shipboard power system (SPS) architecture which connects loads, like the propulsion system, to the power generation modules (PGM). For ship applications, DC SPS has shown significant advantages over AC, like increased efficiency, improved power flow control, reduced SPS weight and size, no synchronization problems, and more.

Though to be used in industry, a DC-AES requires a minimal level of reliability and availability. This requirement is getting even more severe for Navy SPS applications. Following [1], it can be observed that the power system structure significantly affects the ship's reliability. In this project, you will compare different DC-SPS structures in order to maximize the reliability of the naval ship.

Methodology:

The student shall start with a literature study on the DC SPS topologies and reliability evaluation methods. Thereafter, the student is expected to design and validate a stochastic simulation model framework which is then used to compare the reliability of different SPSs. Finally, the student shall improve the SPS to maximise the system's availability while maintaining parameters like cost, space.

Research Objectives:

- Literature review on the different DC SPS topologies and reliability evaluation methods.
- Develop and validate a stochastic simulation model framework for the DC SPSs.
- Determine the optimal power system architecture considering reliability.
- Evaluate the weak spots of the architecture and propose improvements.

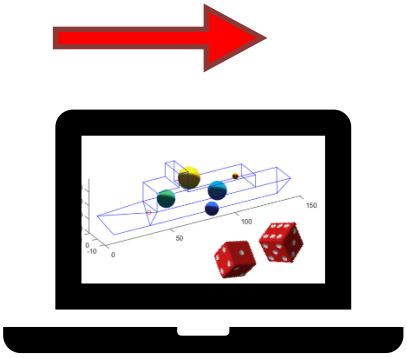
Contact details:

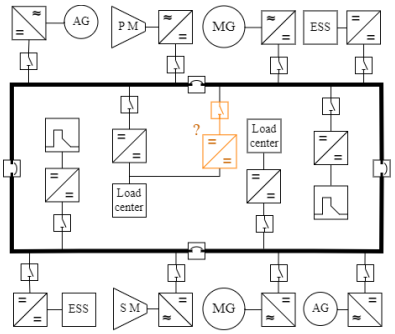
- PhD student: Robin van der Sande, R.P.J.vanderSande@tudelft.nl
- Supervisor: Dr.ir. Aditya Shekhar, A.Shekhar@tudelft.nl
  Prof. Dr. Ir. Pavol Bauer, P.bauer@tudelft.nl

[1] B. Stevens and S. Santoso, "Reliability analysis of a shipboard electrical power distribution system based on breaker-and-a-half topology," 2013 IEEE Electric Ship Technologies Symposium (ESTS), Arlington, VA, USA, 2013, pp. 387-393

SURVIVABILITY ASSESMENT OF DC SHIPBOARD POWER SYSTEMS

Type of project: <MSc thesis>





Scope:

Evaluate the survivability of a DC shipboard power system using stochastic simulation and analyse how methods like redundancy, modularity, and reconfiguration impact the resilience of a vessel.

Problem definition:

The energy transition of the maritime sector imposes the electrification of ship power and propulsion systems. Future all-electric ships (AES) need an intelligent shipboard power system (SPS) which connects loads, like the propulsion system, to the power generation modules (PGM). For ship applications, a DC-SPS has shown significant advantages over AC, like increased efficiency and improved power flow control. However, protecting these DC systems against faults is one of the biggest challenges currently faced in the industry.

To be applied in naval vessels a DC-SPS must secure the supply of power to the critical shipboard loads even under hostile environments. In this project, you will consider the spatial stochastic character of an unanticipated event (flood, fire, or missile impact) and analyse the impact on the performance of the DC-SPS[1]. The probability for availability will then highlight vulnerabilities in the design which can be improved using redundancy, modularity, or reconfiguration.

Methodology:

The student shall start with a literature study on the DC SPS topologies and vulnerability assessment methods. Thereafter, the student is expected to design and implement a stochastic vulnerability assessment model which is used to analyse the survivability of different SPSs. Finally, the student shall improve the DC-SPS using redundancy, modularity, or reconfiguration to improve the system's resilience while maintaining parameters like cost and space.

Research Objectives:

- Literature review on the different DC-SPS topologies and vulnerability assessment methods.
- Develop a stochastic vulnerability assessment model for the DC-SPSs.
- Determine the vulnerabilities of common power system architectures.
- Using redundancy, modularity, or reconfiguration improve the survivability of the DC-SPS.

Contact details:

- PhD student: Robin van der Sande, R.P.J.vanderSande@tudelft.nl
- Supervisor: Dr. Ir. Aditya Shekhar, A.Shekhar@tudelft.nl
  Prof. Dr. Ir. Pavol Bauer, P.bauer@tudelft.nl

[1] Jansen, AC Habben. "A Markov-based vulnerability assessment of distributed ship systems in the early design stage." Delft University of Technology (2020).

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