Fraunhofer ISIT

Institute for Silicon Technology

Electronic Energy Systems research group

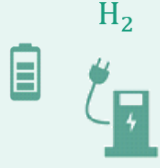**Bachelor's and Master's Thesis Catalogue**

Supervisor:
Prof. Dr.-Ing. Marco Liserre

Nov. 2023

In collaboration with the Chair of Power Electronics of Kiel University:

The main research topics addressed by the EES team are:

Technologies for hybrid grids

Medium Voltage DC distribution
Medium Voltage MMC
Power hardware in the loop (PHiL) testing
Grid forming strategies

Multi-energy power converters

Reliability-driven design
Application-tailored topologies
WBG-based power converters
Fault-tolerance with minimal hardware

Active reliability

Thermal modelling
Condition monitoring
Reliability-driven control

EES

From grid to device

H_2

For question relative to a specific thesis topic, please directly contact the listed supervisor.

For any general question about the thesis topics, please contact Dr. Yoann Pascal (yoann.pascal@isit.fraunhofer.de).

If you have interest in a topic marked as "already taken", feel free to contact the supervisor to discuss a possible replacement.

Topic

- Renewable Energy Integration
- E-Mobility
- External Cooperation

Renewable Energy Integration

B.Sc. Thesis:
Fault-Tolerant Control of Modular Multilevel Converter
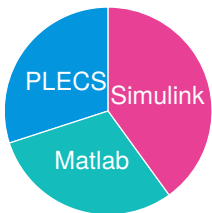### Future ac/dc Hybrid Grids

Requirements

Language
English

Theory
Multilevel converters ★★★★★
Grids ★★★★☆
Power Devices ★★★☆☆

Relevant Courses:
PPE
Bachelor Praktikum

IT-Skills

PLECS
Simulink
Matlab

Contact
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Supervisor:
Mahyar Hassanifar
Dr. Marius Langwasser
Prof. Marco Liserre

Project

SMARTGYsum
smartgysum.eu

October 2, 2023

Abstract

In recent years, modular multilevel converters (MMCs) have gained extensive adoption in high-voltage, high-power applications such as HVDC systems. The operational performance of MMCs is susceptible to a range of internal and external faults. To enhance the reliability of the MMC, additional reserved SMs can be integrated into the MMC. These reserved SMs can either operate continuously or be activated in response to faults, commonly referred to as "hot" and "cold" reserves, respectively. This thesis aims to explore the impacts of the reserve SMs on the performance of MMC.
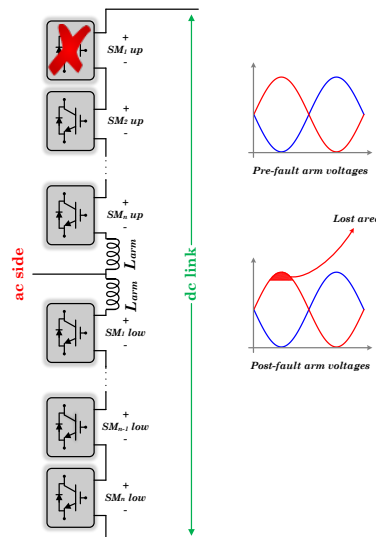
Figure 1: Arm voltages of MMC in pre and post fault conditions

Background

Reliability is crucial for power converters. MMC, which is made up of many semiconductors, is vulnerable to switch failures. Every component can be regarded as a potential failure point, which endangers the normal operation of the converter. To increase the reliability of MMC, it is crucial to quickly address and manage these faults. With the right approach to handling the faults, the MMC can continue working until the next regular maintenance.

Objectives

- Understanding the influences of submodule failure on the performance of MMC
- Development of fault tolerant method based on reserve submodules

M.Sc. Thesis:
A Thermal Balancing Control for Hybrid MMC
Offshore Windpark Integration
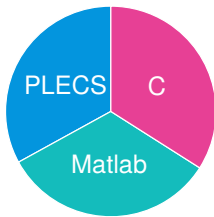
Requirements

Language
English/German

Theory
Multilevel Converters ★★★★☆
Active Thermal Control ★★★★☆
IGBT Power Modules ★★★☆☆

Related Courses
PoSSGRES ★★★★☆
Leistungselektronik
Grundlagen ★★★★☆

IT-Skills

PLECS   C   Matlab

Contact
Supervisor:
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Dr. Marius Langwasser
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Prof. Marco Liserre

Project

AC2DC: Increasing transmission capacity in the distribution grid with existing AC connections as DC links

ISIT@CAU

Fraunhofer ISIT

September 4, 2023

Abstract

The hybrid modular multilevel converter (HMMC) is employing the unipolar and bipolar submodule (SM) topologies, combining the advantages of both. However, due the different degree of freedom of each SM, different thermal stress can be experienced by the power semiconductors. Therefore, this thesis studies a thermal balancing control for the power semiconductors of the HMMC.
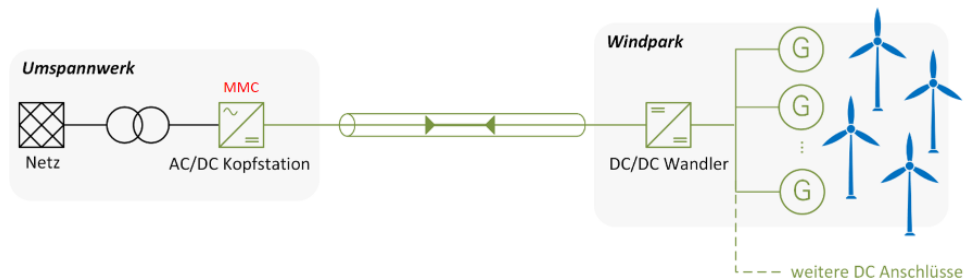
Figure 1: Three-phase topology of HMMC.

Background

The MMC-based on bipolar SM can ensure a dc fault blocking capability due the presence of SM capable of producing reverse biased voltage during the dc fault. Aiming to reduce the cost and to increase the converter efficiency, the converter can present both unipolar and bipolar SM topologies. However, the power devices in a unipolar topology could experience different thermal stress compared to a bipolar topology. Therefore, it is important to ensure a balancing thermal behavior between the power devices in both topologies, avoiding the device failures due to the thermal over-stress. This thesis study will be a great opportunity to improve your understanding of MMCs, which is a core technology in MV grids for offshore windpark integration.

Objectives

- Improvement of the student skills about active thermal control and offshore wind integration

- Impressive hands-on skills and experience with real laboratory measurement

- Analysis of hybrid MMC topologies;

- Proposal of a thermal balance control for hybrid MMC.

M.Sc. Thesis:
MMC submodule dc Capacitor Voltage Observation
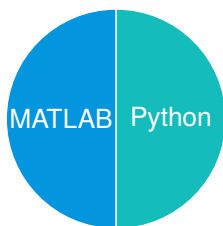### Artificial Intelligent for Power Electronics Converters

Requirements

Language
English

Theory
Power converter ★★★★☆
Programming ★★★☆☆

Related Course
Principles of Power
Electronics ★★★★☆

IT-Skills

MATLAB Python

Contact

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Prof. Marco Liserre

Project

AC2DC Increasing transmission capacity in the distribution grid with existing AC connection as DC links

September 4, 2023

Abstract

The main objective of this thesis work is to replace voltage sensors of submodules used in modular multilevel converters by using machine learning (ML). Reinforcement learning (RL), which is a subclass of ML, will be trained to predict and estimate dc capacitor voltage of SMs. After establishing Environment to train a RL agent, training will be carried out various conditions and performance of the trained result will be analyzed and evaluated.
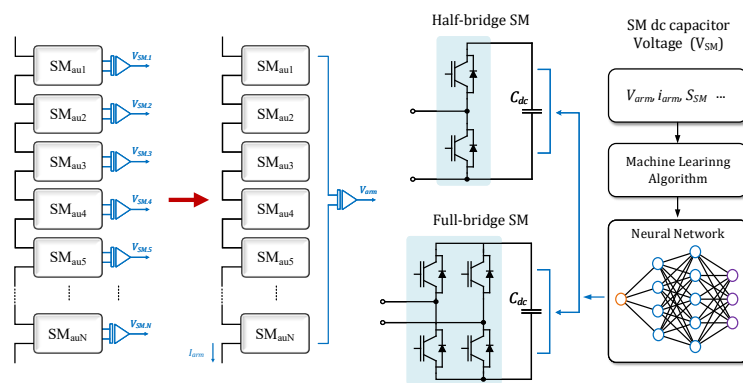
Figure 1: Training Machine learning for SM voltage observation

Background

MMC integrated in Offshore Windpark is a fairly complex system because it consists of many semiconductors and submodules (SMs). One of the important issues in this system is the guarantee of reliability. The factor that lowers the reliability of the system is the failure of the components in the SM, such as a voltage sensor. By replacing numerous voltage sensors with such an observer, it is possible to prevent deterioration of reliability due to failure and reduce manufacturing costs. Machine learning, which getting popular recently, shows strong performance in prediction and estimation. This thesis work will be helpful for understanding basic operating principles of machine learning and power converters.

Objectives

- Understanding converter behaviour and reinforcement learning
- Training the machine with the environment including MMCs.
- Verification of the trained agent for observing the SM voltage.

M.Sc. Thesis:
Effect of distributed inductances in MMC EMI
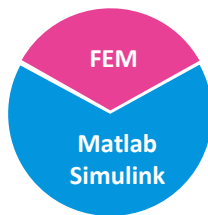### Interferences and noise in hybrid grids

## Requirements

Language
English

Theory
PE topologies ★ ★ ★ ★ ★
Analog filtering ★ ★ ★ ★ ★
EMI ★ ★ ★ ★ ★

Related Courses
DPEC ★ ★ ★ ★ ★

IT-Skills

FEM

Matlab Simulink

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Supervisor
Dr. Yoann Pascal
Prof. Marco Liserre

Project

ISIT@CAU
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Fraunhofer
ISIT

Aug. 25h, 2023

Abstract

MMC arms are typically composed of sub-modules and an inductor. This inductor filters the arm current and thereby limits the circulating current. This component is very bulky, since it must handle the fault current without going into saturation.
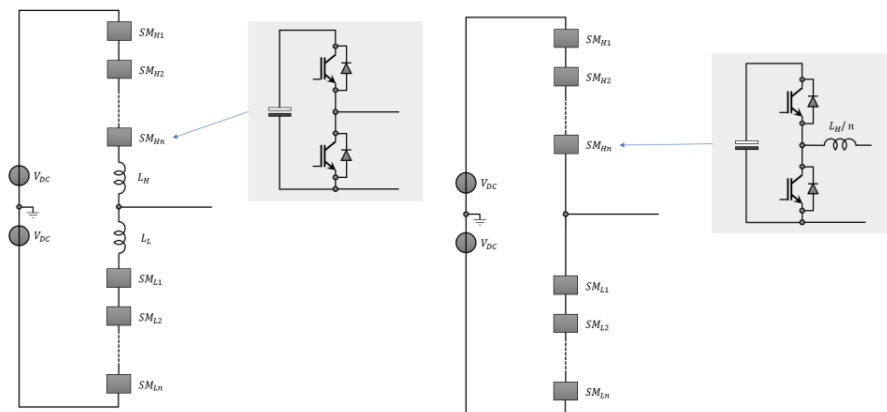
Conventionnal MMC (left) vs. MMC with distributed arm inductance (right)

Background

Preliminary work in the team has investigated the division of the arm inductor in smaller components integrated in each sub-module. In particular, this leads to gains in modularity and enhanced density – thanks to improved thermal management.
This thesis will investigate the gains in terms of conducted electromagnetic interferences (EMI), and more specifically of common mode current.

Objectives

- Developement of an EMI model of MMCs with lumped and distributed
- Analysis of the model, distributed inductor design recommandations
- Experiemental validation

CAU
Kiel University
Christian-Albrechts-Universität zu Kiel

Faculty of Engineering

PE
25th anniversary

BSc. Thesis:
Design of a Signal Conditioning Circuit for Switching Ripple Extraction
Innovative communication in power converters

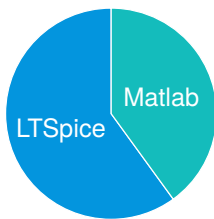## Requirements

Language
English

Theory
Analog Electronics ★★★★★
Power Converters ★★★☆☆

Related Bachelor Courses
Elektronik ★★★★★
Bachelorpraktikum ★★★★★
PPE ★★★☆☆

IT-Skills

LTSpice
Matlab

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Supervisor:
Prof. Marco Liserre

Project
SuperHEART

September 27, 2023

Abstract

Talkative power conversion (TPC) involves the simultaneous transfer of power and information, the latter usually embedded in the switching ripple. Owing to the small ripple amplitudes in power converters, TPC thus involves the challenge of conditioning the low-amplitude, noisy ripple signal to extract the embedded information. This thesis investigates the design of such an analog conditioning circuit to extract the switching ripple signal from a power converter.
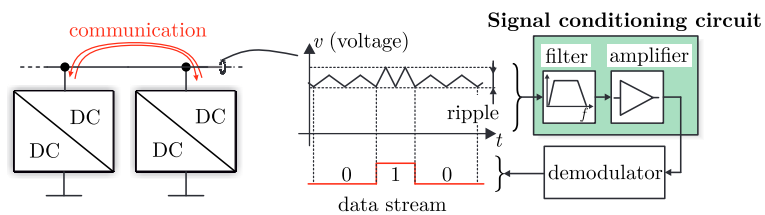

Figure 1: Schematic of TPC showing communication between two DC/DC converters through a shared power bus using the ripple frequency to convey information. The ripple signal is conditioned prior to demodulation to obtain the data stream.

Background

Talkative power converters transmit information by modifying only the switching ripple (current or voltage) in a power converter. This ripple is superposed on an average value and subject to electromagnetic interference, both of which are classified as noise in the context of communication. The removal of these unwanted signals necessitates the design of dedicated filtering and decoupling circuits. Further, the low-amplitude ripple is amplified for the subsequent demodulation stage that is typically implemented on a digital system.

Objectives

- Outlining circuit requirements in terms of the relative amplitude and frequency of power, ripple, and interference components in a power converter
- Design of passive and active filters to extract the ripple voltage
- Design of an amplifier stage for interfacing to a TTL-based digital platform
- Outlining general guidelines for the design of the signal conditioning circuit

M.Sc. Thesis:
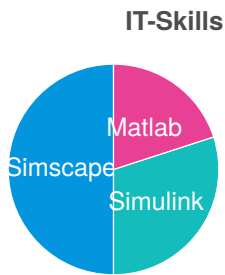## DC-DC Converter with Bidirectional Droop Control
Integrating Batteries into LVDC Microgrids

Requirements

Language
English/German

Mandatory Courses
Modelling and Control of Power
Electronic Converters (MoCoPEC)

Recommended Courses
Power System Elements for Smart
Grid and Renewable Energy
Integration (PoSSGREs)

IT-Skills

Matlab
Simscape
Simulink

Contact

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Prof. Marco Liserre

Project
Kopernikus-Project ENSURE
www.kopernikus-projekte.de

KOPERNIKUS
ENSURE ›› PROJEKTE
Die Zukunft unserer Energie

October 4, 2023

Abstract

Ensuring a stable operation of DC microgrids, the DC bus voltage must be maintained within specified boundaries. Its level results from the relation of generation and load: With increasing load the level falls towards the lower boundary, and vice versa. Thus, maintaining the voltage within a stable region means controlling the loads and sources accordingly. Droop control strategies have been identified as a suitable approach. The goal of this thesis is the implementation of a droop control strategy for a dual-active-bridge (DAB) converter. For this purpose, a DAB model including modulation and control shall be build up in Matlab/ Simulink. Then, a bidirectional droop control shall be added, which serves the integration of a battery with either feeding into the grid or storing energy depending on the voltage level. Finally, the control strategy is to be verified by simulating different load and source conditions.
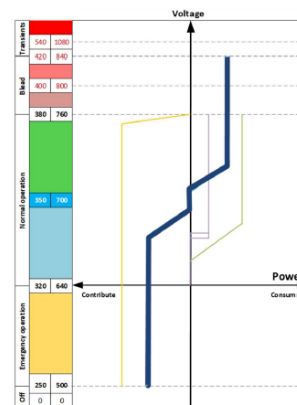
Figure 1: Qualitative bidirectional DC droop [Current OS, 2022]

Background

Considering renewable energy sources (RES), a great difference to conventional power plants is their weather-dependency that results in bad mid- and longterm predictability, and fluctuations, which have to be balanced. One possibility is the integration of batteries that can store energy or feed the grid in case of excessive load. Continuatively, even greater capacities could be accessed by implementing, e.g., Vehicle-to-Grid strategies. Since RES, such as battery systems and a lot of loads are DC-based, the research in DC grids is facing an increased interest as they offer reduced conversion stages, and thus losses. Therefore, the integration of batteries in DC grids represents a promising research area.

Objectives

- Modelling of a DAB converter including modulation, conventional voltage and current, and bidirectional droop control enabling the integration of batteries in Matlab/ Simulink-based LVDC microgrids

B.Sc. Thesis:

Design and Operation of a LVDC Microgrid in Matlab/ Simulink

DC Microgrid Topologies

Requirements

Language
English/German

Mandatory Courses
Power System Elements for Smart Grid and Renewable Energy Integration (PoSSGReS)
Principles of Power Electronics (PPE)

IT-Skills

Matlab Simulink Simscape

Contact

Supervisor:
Laura Bayerdörffer
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Prof. Marco Liserre

Project

Kopernikus-Project ENSURE
www.kopernikus-projekte.de

KOPERNIKUS
ENSURE PROJEKTE
Die Zukunft unserer Energie

September 8, 2023

Abstract

Although DC microgrids are a highly regarded area of research, their actual implementation and operation has so far mainly taken place within research projects. Consequently, there are a number of proposals for the design of DC microgrids, but no established topology yet. The preliminary development and testing of operational concepts is carried out by means of simulations. These simulations require realistic models of potential microgrids and, moreover, allow the investigation of the suitability of certain topologies. Therefore, the goal of this thesis is the implementation of a LVDC microgrid in Matlab/Simulink. For this purpose, previously proposed topologies will be researched and presented. Subsequently, a suitable topology shall be implemented in Matlab/Simulink with the final result of a statically stable operation of several DC microgrid components by means of a decentralized voltage regulation.
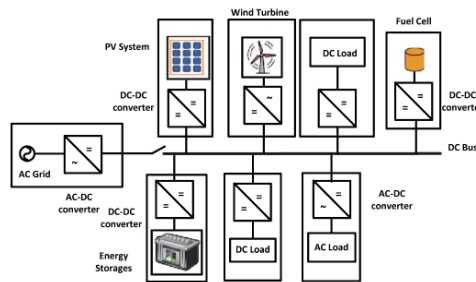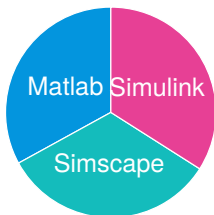
Figure 1: Examplary DC microgrid topology [Rangarajan, Shriram et al. 2023]

Background

RES have become indispensable for our power supply, but compared to conventional power plants their generation is weather-dependent, leading to strong fluctuations in the generation. Therefore, facing an increasing penetration of the energy grid with RES, new approaches are required to manage situations of under- and oversupply. However, not being AC-, but DC-based, they cannot directly be connected to the conventional grid, but local distribution via DC microgrids are gaining more interest, particularly with regard to the increasing amount of DC-based loads, e.g., electric vehicles (EV). One use case where new grid structures are being built is in the construction of new production facilities, which may include local RES, DC-based manufacturing equipment, or EV charging, making DC microgrids an attractive concept for industry. As a consequence, research is directed to operational concepts for DC microgrids, that altogether enable a reliable and stable DC-power supply.

Objectives

- Overview on suggested LVDC microgrid topologies
- Matlab/ Simulink model of a promising LVDC topology integrating RES and EV charging and including a distributed voltage regulation

This topic has been already taken.
Please contact a supervisor to inquire more

M.Sc. Thesis:
Optimal Operation of Smart Transformer Based Dynamic Grids
Interdisciplinary Research with Mathematics

CAU
Kiel University
Christian-Albrechts-Universität zu Kiel
Faculty of Engineering

Requirements

Language
English

Theory
Load flow analysis ★★★★☆
Optimization techniques ★★★★☆

Related Courses
PoSSGRES ★★★★☆

IT-Skills

GAMS | PSCAD
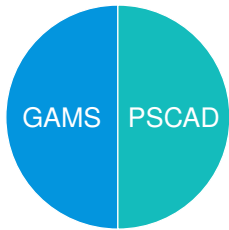
Contact

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Prof. Marco Liserre

Project
REFINE: Dynamically
REconFIgurable NEtwork based on
Smart Transformer

Note
This thesis is available from
1st February 2024

September 18, 2023

Abstract

The voltage variations in LVAC grids are very critical considering a grid with more EV charger installations. The smart transformer (ST) has the capability to dynamically control the voltage of the LV AC grid based on various objectives. Different parameter control capability exists for such a configuration, and the optimization problem needs to be solved in this thesis to minimize the voltage variations.
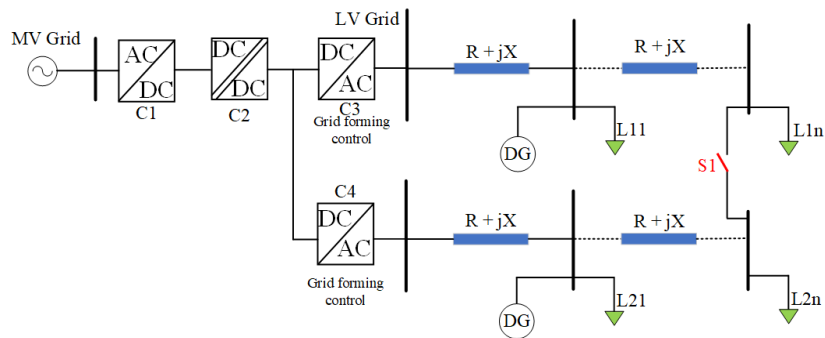
Figure 1: The smart transformer-based reconfigurable network.

Background

The voltage variations in the modern distribution grids are caused by the uncontrolled charging of electric vehicles (EVs). The ST-based LV AC grids can offer better voltage control solutions for minimizing these voltage variations. The ST can dynamically vary the set points of voltage, active, reactive powers for achieving the voltage control for the LV distribution system. This thesis aims to approach this problem in an optimization perspective. The setpoints for the active and reactive powers can be generated based on the optimization analysis. The network modeling and analysis will be carried out in an optimization tool, and the results will be validated in PSCAD simulation platform.

Objectives

- Learning the basics of optimization strategy and the realization tools
- Modelling of distribution system in the optimization platform and PSCAD
- Optimizing the operation of ST for minimizing the voltage variations

M.Sc. Thesis:
Condition monitoring of MMC using Radio-Frequency injection
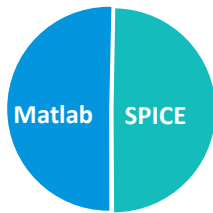## Diagnosis in hybrid grids

Requirements

Language
English

Theory
Reliability ★ ★ ★ ★ ★
General circuit theory ★ ★ ★ ★ ★
Electromag. Basics ★ ★ ★ ★ ★

Related Courses
DPEC ★ ★ ★ ★ ★

IT-Skills

Matlab | SPICE

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Supervisor
Dr. Yoann Pascal
Dr. Frank Daschner
Prof. Marco Liserre

Project

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Fraunhofer
ISIT

Aug. 25h, 2023

Abstract

As power electronics spreads to mission critical applications, reliability requirements increase. Condition monitoring, which consist in performing measurements to assess the state of the system (temperature, state of health, etc.) can help to ensure continuity of operation.

This thesis will investigate the use of online impedance measurement, using radio-frequency (lower micro-wave band) signal injection for in-situ condition monitoring. The analysis will be conducted with an half-bridge IGBT-based cell of MMC converter, and will aim at assessing simultaneously the state (considering temperature and health) of the transistors and the capacitor.
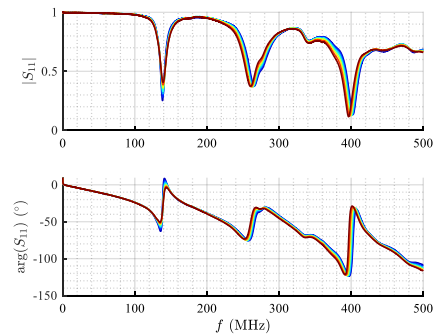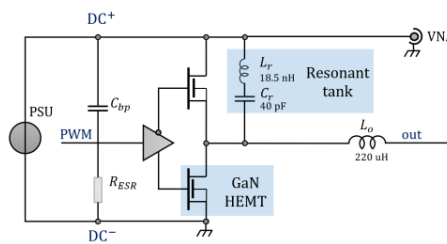
Measurement of the state of the low-side GaN transistor through a resonant circuit: shift in S11 parameter as a function of temperature at the resonant frequency.

Background

On-state voltage drop of IGBTs, as well as series-resistance (ESR) of electrolytic capacitors, have been demonstrated to exhibit clear variations with temperature and state of health. This has been exploited to assess the state of these devices in-situ using as many dedicated hardware and sensors.

Following promising preliminary work from the team (see above figure), a single measurement system is here intended to perform direct measurements in the frequency domain, and relying on a wider spectrum bandwidth to obtain more insights on the state of the system.

Objectives

• Analysis of the potential of RF-injection for condition monitoring, including temperature estimation, for the selected use case (MMC cell)
• Analysis and demonstration of the feasibility of the approach through circuit-level simulation
• Experimental validation on a functionnal IGBT-based MMC

MSc. Thesis:
Control Strategies for Increasing Lifetime of Modular Multicell Inverter
Lifetime Improvements in Power Converters

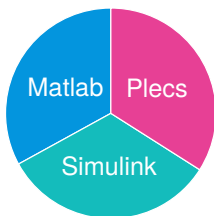## Requirements

Language
English

Theory
Power electronics ★★★★☆
Lifetime analysis ★★★☆☆
Optimization ★★☆☆☆

IT-Skills

Matlab · Plecs · Simulink

Related course
DPEC

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Supervisor:
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Project
ISIT@CAU

Fraunhofer
ISIT

October 4, 2023

Abstract

Modular multicell converter topologies have became wide spread in high-voltage, high-power applications. Indvidual converter cells are prone to degradation processes. Degradation is mostly dependent on power cycling. However, degradation speed of indvidual cells may also differ due to the random parameters given by ambient conditions and manufacturing process. The goal of the thesis is to propose a control strategy increasing converter lifetime by manipulating switching scheme based on state of health of individual cells.
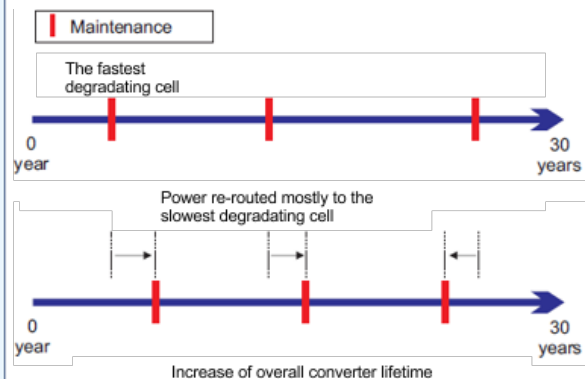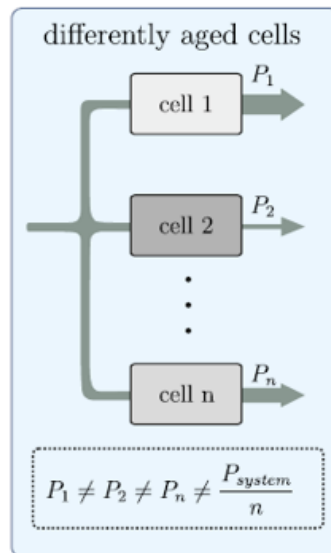
Figure 1: Maintenance delay given by power routing among cells of multicell converter.

Background

Degradation is mostly caused by junction temperature swings inside the power converter. Degradation speed is mostly dependent on swing magnitudes and junction temperature. To influence the lifetime of individual cells, a modulation scheme or a pulse pattern can be modified during operation. Control signals of individual transistors are modified so that both the junction temperature and temperature swings of less healthy cells are reduced.

Objectives

- Review of literature and previous work
- Propose and implement algorithm prolonging lifetime of multicell power converter.
- Analyse effects of the algorithm on lifetime prognosis.

M.Sc. Thesis:

Robust stability analysis of grid forming converter-dominated grids

How to assess stability when a controller is protected by Intellectual Property

Contact
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Supervisor:
Prof. Marco Liserre

Abstract
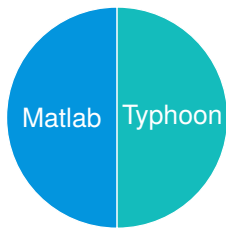
Power converters are becoming the main actors in modern power grids. The converters' control system has a relevant impact on the grid, nevertheless, converter industries do not usually provide many details on the converter control structure, representing a source a model uncertainty. Robust stability analysis allow to represent and quantify the model uncertainty and investigate the robust stability margins. The results obtained by the analyses will be validated in real-time simulation in Typhoon Hardware-In-the-Loop platform.
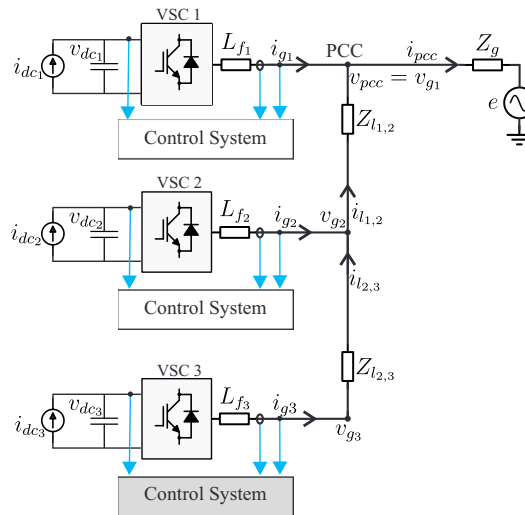
Figure 1: Example of power grid with unknown control system in some converters.

Background

A state-space model of a power grid, including uncertainty in the control system, has been already done considering grid following converters. The model will be provided together with useful literature. The target is to extend the proposed methodology to power grids with the presence of grid forming converters. In the Typhoon Hardware-In-the-Loop (HIL) platform, a model of a power grid with grid following converters has been already built. Also in this case, the duty is to model grid forming converters and successfully simulate the considered grid.

Objectives

- Modeling of grid forming converter with uncertain control system
- Robust stability analysis of a grid with both grid forming and grid following converters
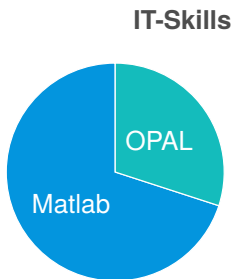- Model and test the power grid in Typhoon Hardware-In-the-Loop platform.

Kiel University
Christian-Albrechts-Universität zu Kiel

Faculty of Engineering

M.Sc. Thesis:
Modeling and control of standardized DC grids
Understanging Direct Current (DC) distribution grids with Current/OS standard

Requirements

Language
English/Deutsch

Theory
Grid-connected
converters ★★★★★
State-space modeling ★★★★★
Simulink Modeling ★★★★☆

IT-Skills

OPAL

Matlab

Contact
Dr.-Ing. Federico Cecati
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Dr.-Ing. Muhammad Umair Mutarraf
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Supervisor:
Prof. Marco Liserre

Project
ISIT@CAU

October 6, 2023

Abstract

DC grids are a recent trend and a promising technology for future power systems. With respect to the well-consolidated AC power distribution, DC distribution is still an emerging technology, for which control and protection strategies must be investigated and tested to ensure resilience, sustainability, and safety. The Current/OS foundation is working toward standardization to promote the adoption of DC grids, exploiting the experience and collaboration with a large number of industries. This thesis investigates modeling and control in DC grids, in collaboration with Maschinenfabrik Reinhausen GmbH.
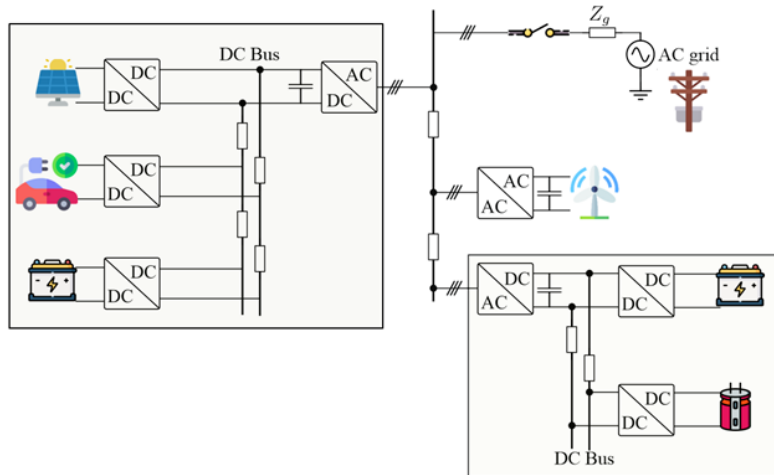
Figure 1: Example DC grids connected to the main AC grid.

Background

The first step of the thesis is the investigation of the control and protection problems in DC grids, and the understanding of the Current/OS standard. A real-world example of DC grid interlinked to the main AC utility grid will be given. A nonlinear state-space modeling tool for converter dominated grids will be provided, and target of the thesis is to start from the existing framework and use it to model the considered DC grid and the interconnection to the main AC grid. Opal-RT model for the DC grid will be an additional target; existing converters models will be provided.

Objectives

- Deep understanding of the Current/OS standard.

- Power grid modeling by means of nonlinear state-space equations.

- Learning and implementation in Opal-RT for DC distribution grids.

E-Mobility

M.Sc. Thesis:
Design of Medium-Voltage Medium-Frequency Transformer
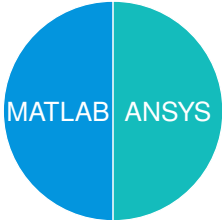### Fast Charging Station for E-Mobility

Requirements

Language
English

Theory
Magnetic ★★★★★
Transformers ★★★★☆
Thermal Design ★★★★☆
DC-DC converters ★★★☆☆

Laboratory
Transformers ★★★★★

Relevant Courses:
DPEC
MOCOPEC

IT-Skills

MATLAB | ANSYS

Contact

Supervisors:
Dr.-Ing. Hamzeh Beiranvand
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Prof. Marco Liserre

Project

DFG: MVDC Fast Charging Station

Internship

Yes

November 24, 2022

Abstract

E-mobility industry is ramping up in development where fast charging stations are playing a central role. Galvanic isolation between electric vehicles (EVs) and the upstream grid is mandatory for safety purposes which is realized by medium frequency transformers (MFTs). This thesis targets the design optimization of medium voltage (MV) multiwinding MFTs to achieve high efficiency and power density. In the other word, energy losses and volume are minimized which are critical for e-mobility industry.
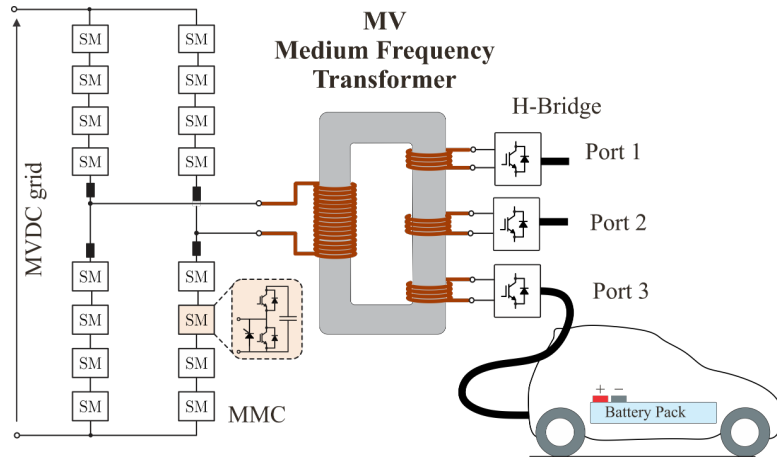
Figure 1: Medium-voltage medium-frequency transformer as the isolation stage of the fast charging stations.

Background

To achieve extremely fast charging speeds, integration to MV grid is a necessity. Therefore, in this thesis MVDC based fast charging stations are exploited where MFT is the key component. The project includes optimization of the MFT core shape and the windings configuration. If you are interested to join E-Mobility industry, this thesis is a perfect starting point where you will learn industrial software beside research and develop your competences.

Objectives

After you successfully completed this thesis, you will be able to:

- 3D CAD design of transformers using ANSYS
- Static and transient analysis of the fast charging station
- Power losses and thermal analysis
- Building experimental prototypes

MSc. Thesis:

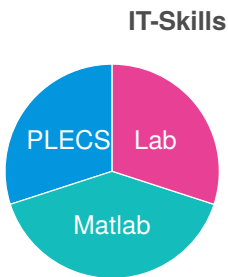## Comparative Analysis of DC-DC Converters for Supercapacitor Interfacing
Energy Buffering for Data Centers

Requirements

Language
English

Theory
Power Converters ★★★★★
Magnetics ★★★★☆
Control Design ★★★☆☆

Related Master's Course
DPEC ★★★★★
MoCoPEC ★★★☆☆

IT-Skills

PLECS | Lab
Matlab

Contact
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Supervisor:
Prof. Marco Liserre

Project
SuperHEART

August 24, 2023

Abstract

High availability applications such as data centers require energy storage for short-term backup. Supercapacitors possess a higher energy density than conventional electrolytic capacitors, motivating their use as both power and energy buffers in these applications. However, owing to limitations on the rated voltage of commercial supercapacitors, they are interfaced to a practical system using power converters. The aim of this thesis is to compare the steady-state and transient performance of existing high gain DC-DC converter topologies for interfacing supercapacitors to a DC bus.
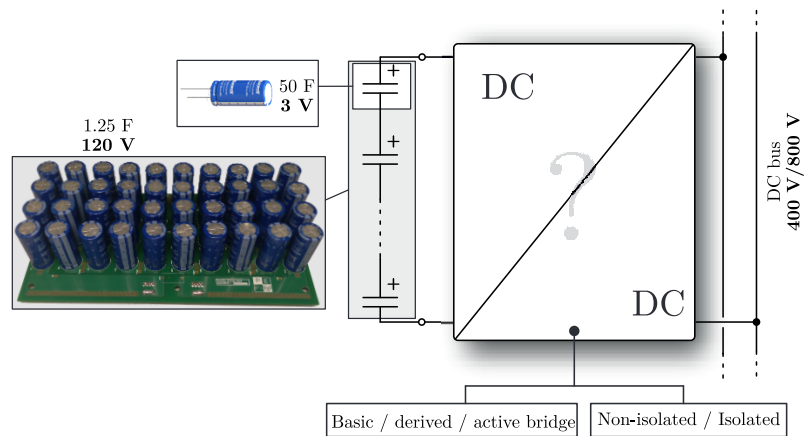
Figure 1: Schematic of system interfacing supercapacitor stack to DC bus.

Background

Data centers include energy storage to buffer short-term disturbances. Supercapacitor energy storage is suitable in such cases due to its long life and high power density. However, the low voltage ratings (~ 3 V) of available supercapacitors as well as their inherent voltage variation, make their integration into practical DC systems (~ 50 - 1000 V) possible only through an interfacing DC-DC converter. Available high gain converter topologies require a comparison in terms of size, complexity, cost, and efficiency, to select the most suitable topolog(y/ies) for the application.

Objectives

- Review and analysis of steady-state and transient requirements for a supercapacitor interface DC-DC converter,

- Establishing metrics of comparison for various converter topologies based on these requirements,

- Analysis and simulation of selected DC-DC converter topologies with respect to the metrics identified.

Kiel University
Christian-Albrechts-Universität zu Kiel

Faculty of Engineering

B.Sc. Thesis:

Extreme Fast Charging of Lithium Ion Batteries

A Thermal Digital twin application

Requirements

Language
English

Theory
Li-ion Batteries ★★★☆☆
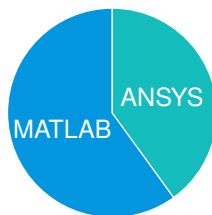Thermal Measurement ★★★★☆
Thermal Modeling ★★★★☆

Lab Work
Battery Tests ★★★★☆
Thermal Camera ★★★★☆

Relevant Courses:
Battery Technologies

IT-Skills

ANSYS
MATLAB

Contact

Supervisors:
Msc. Riccardo Sancio
Dr.-Ing. Hamzeh Beiranvand
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Prof. Marco Liserre

Project

September 11, 2023

Abstract

Fully electric vehicle (EV), which are powered by lithium Ion (Li-ion) batteries, are substituting the fossil-based vehicles, gradually. Extreme fast charging (XFC) will lead to a further spreading of EVs in the next years. However, the high required current rates and their related thermal stress still represent the main limitations for XFC application. Charging protocols with thermal digital twin application may represent a way to monitor and control the battery thermal transient in order to comply with the standards requirements during XFC.
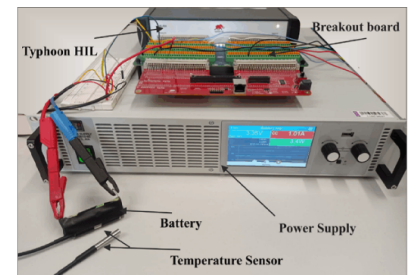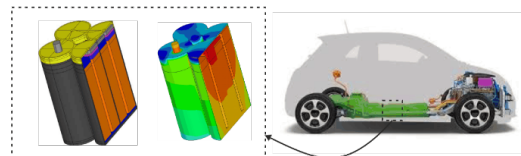
Figure 1: Battery Temperature Characterization for EVs (Source: National laboratory of the U.S. Department of Energy).

Background

Thermal stresses put firm limitation and constraints on the Li-ion battery pack performance. Moreover, their normal operation is impacted greatly by the surrounding temperature. **The thesis is recommended for those students who want to join the e-mobility industry and follow their interest on batteries there.**

Objectives

After you successfully completed this thesis, you will be able to:

- Understanding the charging strategies for li-ion batteries
- High power testing of Li-ion batteries to reach thermal limits
- Thermal characterization of Li-ion batteries using thermal camera
- Thermal simulation in CAD software
- Designing extreme fast charging techniques for EVs

MSc. Thesis:
State of Health Estimation for Increasing the Power Electronics
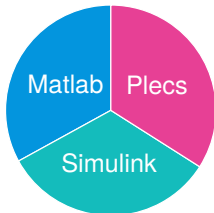## Reliability in Electromobility and Renewable Energy Sources

Requirements

Language
English

Theory
Power electronics ★★★★☆
State estimation ★★☆☆☆
Lifetime analysis ★★☆☆☆

IT-Skills

Matlab · Plecs · Simulink

Related course
DPEC

Contact
Martin Votava, Ph.D.
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Supervisor:
Prof. Marco Liserre

Project
ISIT@CAU

Fraunhofer
ISIT

September 27, 2023

Abstract

Assessment of state of IGBT health is essential for estimating the remaining useful lifetime of converter. Conventional methods rely on indirect estimation of state of health by monitoring collector emitter voltage or thermal resistance. As the sensitivity of these two observation toward the degradation is low, the estimation is prone to errors caused by noise and sensor offset. The goal of the thesis is to improve the accuracy of state of health estimation utilizing multiple observations and a lifetime model.
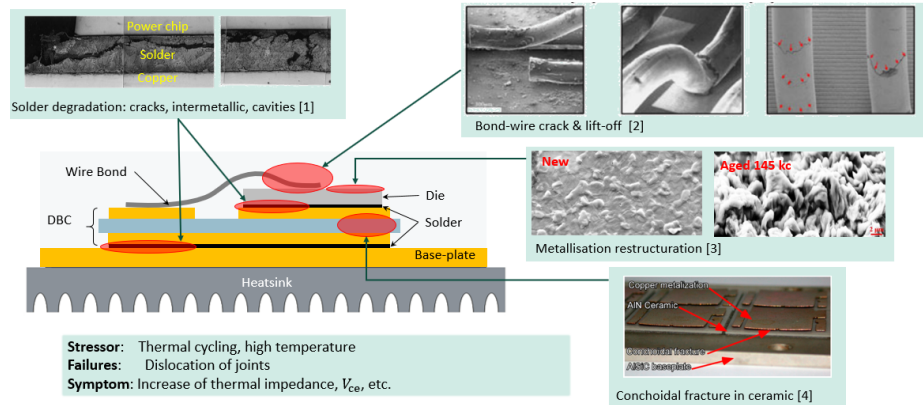
Figure 1: Overview of degradation mechanisms in power module.

Background

Power modules are exposed to varying humidity levels and thermal cycling. The two most common degradation mechanisms are bond wire lift-off and solder fatigue. Direct observation of degradation requires an invasive examination which is either too expensive or not available on site. Therefore, the power module state of health is commonly monitored indirectly through collector- emitter voltage. The challenge is that such monitoring has low sensitivity to degradation but is highly influenced by operating conditions and other variables. In several fields other than power electronics, this problem has been overcome by observing multiple features together. The results showed less susceptibility to noise and spuriousness in the degradation parameters.

Objectives

- Review of the state of the art in state of health estimation from multiple observations.

- Propose an algorithm that fuses multiple indirect observations into a single state of health.

- Investigate the algorithm estimation accuracy and compare the algorithm performance with the algorithms using single indirect observation.

M.Sc. Thesis:
Medium-Voltage Medium-Frequency Transformer Design
Transformer Design for Fast Charging Station

Requirements

Language
English

Theory
Transformers ★★★★★
Multilevel converters ★★★★☆
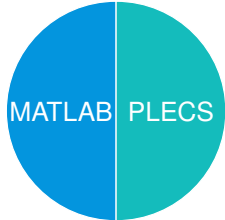DC-DC converters ★★★☆☆

Laboratory
Transformers ★★★★★
Medium voltage ★★★★★

Relevant Courses:
DPEC
MOCOPEC

IT-Skills

MATLAB | PLECS

Abstract

The industrial development of EVs has required the necessity to increase the power of the fast charging station (FCS) to reduce the charging duration. Connecting FCS to the medium-voltage (MV) grid can provide the opportunity to transfer high power with low losses. In the structure of this FCS, a medium-frequency transformer (MFT) is required to change the voltage level and provide isolation between input and output ports. In this thesis, optimization design of a MFT used in the MV FCS will be investigated. This FCS is based on modular multilevel converter (MMC) and MFT. This MFT is a multiwinding transformer that can provide output ports to charge several electrical vehicles. This project is very important for EV industry.
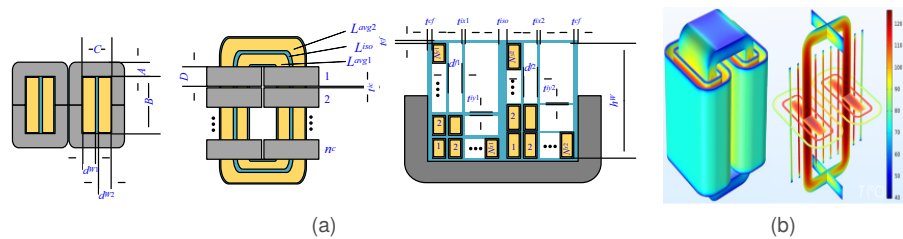
Figure 1: (a) Structure of a MFT, (b) Distribution of electrical field in a MFT (source: Super grid)

Background

The most common configurations of fast charging station (FCS) have been connected to a low voltage grid and use low-frequency transformer, which causes limitations in space, flexibility, and charging duration. Using the medium-voltage (MV) FCS can be a significant development to charge the electrical vehicles in a short time. In addition, the possibility of using a medium-frequency transformer (MFT) instead of low-frequency transformer can reduce the volume, weight, and loss of the FCS. In this project, the design of the MV MFT will be studied in different aspects.

Objectives

After you successfully completed this thesis, you will be able to:

- Design of medium-frequency transformer (MFT)
- Power losses analysis

Contact

Supervisors:
M.Sc. Sattar Bazyar
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Dr.-Ing. Hamzeh Beiranvand
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Prof. Marco Liserre

Project

DFG: MVDC Fast Charging Station

September 16, 2023

B.Sc. Thesis:
Medium-Voltage Medium-Frequency Transformer Design
Fast Charging Station for E-Mobility

Requirements

Language
English

Theory
Transformers ★★★★★
Insulation Design ★★★★☆
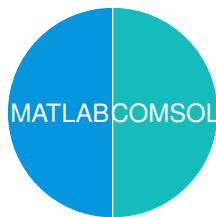DC-DC converters ★★★☆☆

Laboratory
Transformers ★★★★★
Medium voltage ★★★★★

Relevant Courses:
DPEC
MOCOPEC

IT-Skills

MATLAB COMSOL

Contact

Supervisors:
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Dr.-Ing. Hamzeh Beiranvand
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Prof. Marco Liserre

Project

DFG: MVDC Fast Charging Station

September 16, 2023

Abstract

In response to the substantial production of electrical vehicles (EVs), many studies have been carried out on high-power fast charging stations (FCSs). In high power FCSs, medium voltage (MV) is preferred to transfer high power with low losses, and a transformer is used to step down the voltage and provide galvanic isolation between input and output ports. Within this context, the adoption of a medium-frequency transformer (MFT) proves advantageous in terms of downsizing and cost reduction for FCSs. In this thesis, the insulation design of a MFT in MV rated will be investigated. The main challenges of industry dealing with MFT are the proper design and manufacturing.
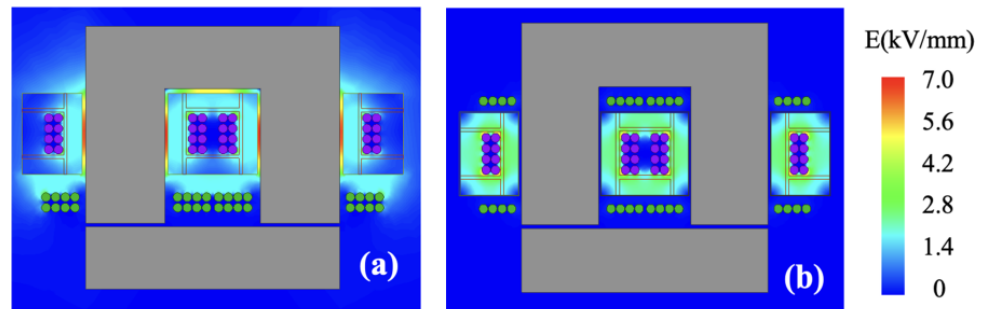
Figure 1: Effect of shielding layer on electrical-field distribution. (a) Without conductive shielding, (b) With conductive shielding ((Source: Zheqing Li et al 2023, TPEL)

Background

Experience in selection of insulation material in low-frequency transformer (LFT) can be used in medium-frequency transformer to choose the appropriate insulation and design the transformer. In LFT, air, oil, and epoxy are the typical insulator utilized in MV applicaion. However, in MFT, other issues such as the eddy-current loss and surface partial discharge (PD) should be considered in the insulation design. Addressing these issues are the main challenges of this topic. This thesis is a part of a DFG project which is very helpful for your carrier development in industry and academia.

Objectives

After you successfully completed this thesis, you will be able to:

- Design of medium-voltage medium-frequency transformer (MFT)
- Power losses analysis
- Ansys 2D simulation (Industrial software)
- Measurement techniques for medium voltage

M.Sc. Thesis:
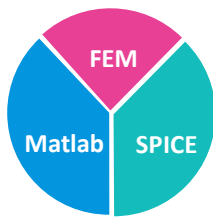## Application of tuneable magnetics to active filtering
### New class of components, new degree of freedom

Requirements

Language
English

Theory
Filtering ★ ★ ★ ★ ☆
Magnetics ★ ★ ★ ★ ☆
EMC ★ ☆ ☆ ☆ ☆

Related Courses
DPEC ★ ★ ★ ★ ☆

IT-Skills
FEM
Matlab
SPICE

Contact
Dr.-Ing. Yoann Pascal
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Supervisor
Dr. Yoann Pascal
Prof. Marco Liserre

Project
ISIT@CAU
www.isit.fraunhofer.de/ees

Fraunhofer
ISIT

Aug. 25h, 2023

Abstract

Passives, and more generally filters, consume a significant share of the volume of power converters. The trend towards higher switching frequencies, enabled by SiC and GaN transistors, results in a reduction of the size of passives, but on the other hand yield to stronger and higher frequency switching noise that needs to be filtered out to ensure proper operation and meet standards (EMC).
Active filtering constitutes a relevant approach to reduce the size of passives.
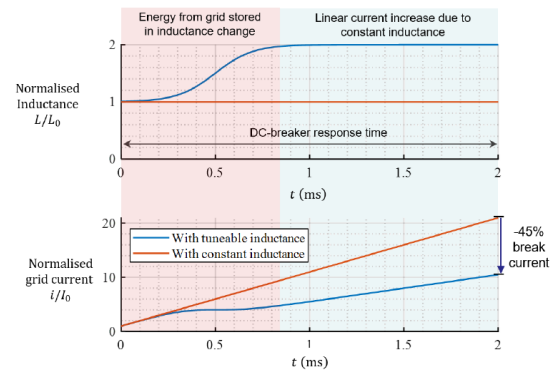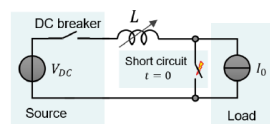
Use of variable inductance to filter the transient due to a short-circuit in a HVDC transmission line, by storing energy in the change of inductance itself.

Simulation performed with $V_{DC} = 400 \text{ kV}$, $I_0 = 2 \text{ kA}$, $L_0 = 20 \text{ mH}$

Background

Dynamically tuneable inductors are magnetics components which inductance can be adjusted online, using an external control signal. Following cooperative work between material science and power electronics, they receive growing interest. In such device, the relation between current i, inductance L, and voltage u_L reads:

$$u_L = L \cdot \frac{di}{dt} + i \cdot \frac{dL}{dt}$$

This thesis will aim at exploiting the 2nd term of this equation, which constitutes an additional degree of freedom to further attenuate unwanted spectral components.

Objectives

• Investigation of the potential of tuneable inductances for active filtering, assessment of the devices' requirements
• Experimental validation

B.Sc. or M.Sc. Thesis:
Modelling of a tuneable inductor
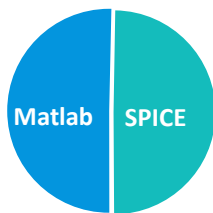### A dive in magnetics… ill-understood components

Abstract

Inductance design are governed by many trade-offs, such as filtering performance vs. response time, size vs. overload capability, etc. Dynamically tuneable inductors, which are coils the inductance of which can be tuned online using an external signal, constitute a family of semi-active components with great potential to better optimise these trade-offs. Such components have so far mostly been used in a quasi-static way, i.e. assuming that the inductance value varies slowly compared to the other time-constants of the system.
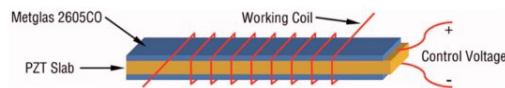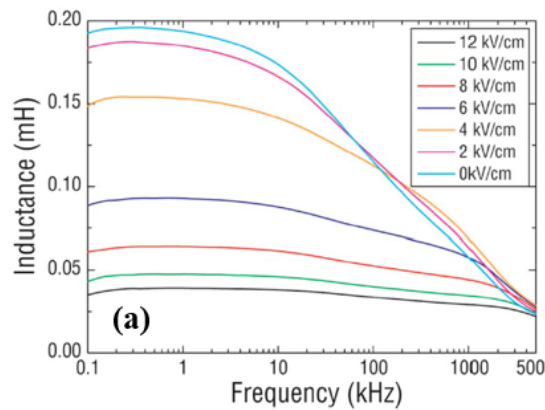
Measured inductance of an integrated tunable inductor vs frequency, as a function of the applied control electric field.
Schematic of the magnetoelectric inductor with a multiferroic composite core.

from J. Cui, L. Qu and W. Qiao, "A Three-Phase Adjustable-Voltage-Ratio Transformer Based on Magnetic Flux Valves„ ECCE'18

Background

This thesis aims at developing a simulation model of such tuneable inductor, without formulating the "quasi-static" hypothesis.

Objectives

- Development of a simulation model (Matlab/simulink or LTSpice) of a specific structure of device
- Experimental validation
- Depending on progress: exploitation of the model: evaluation of the potential of the technology in sample applications.

M.Sc. Thesis:
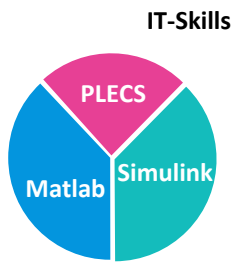## Lifetime extension of power electronic inverter
How to extend lifetime of power converters for electric autos

Requirements

Language
English

Theory
Filtering ★ ★ ★ ★ ☆
Magnetics ★ ★ ★ ☆ ☆
EMC ★ ☆ ☆ ☆ ☆

Related Courses
DPEC ★ ★ ★ ★ ☆

IT-Skills

PLECS
Simulink
Matlab

Contact
Karthik Debbadi
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Supervisor
Karthik Debbadi
Prof. Marco Liserre

Project

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Fraunhofer
ISIT

Sep. 26th, 2023

Abstract

In emobility, power electronics plays the crucial role for several parts of the drive train, battery charging and electric machine driving. During the lifetime operation of the power electronic converter, the capacitors and power semiconductor devices degrade and could be a cause for failure of the system. In this thesis, the proposal is to understand the state-of-health of capacitor and power semiconductor. With this information of state-of-health, take the required action at control/modulation/switching level to improve the overall lifetime of the converter in operation.
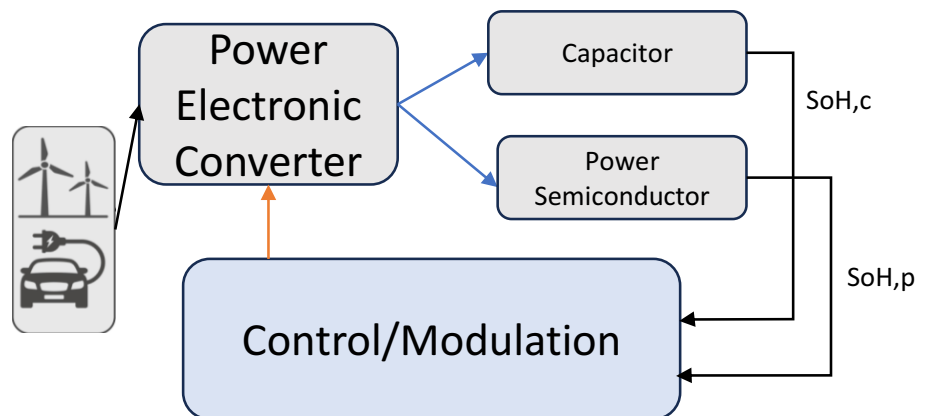
Power electronic converter State-of-Health Monitoring and active control strategy

Background

The power electronic converter is composed of power processing components such as passive elements (capacitors, inductors) and active components (IGBTs, MOSFETs) for power conversion. Due to repeatitive heating and cooling of these components, there is degradation which leads to failure of one of these components or reduction of operation lifetime of the application. Monitoring of these degradation of these components can help predictive maintenance of the application, increase the lifetime of the application. For example, the junction temperature is a vital parameter to predict the lifetime of power semiconductor device (Si IGBT, SiC MOSFET). Measuring and utilization of this parameter can help provide vital information of the health of this component.

Objectives

- Identify the parameters for monitoring the degradation of the power semiconductor, capacitor
- Estimate the state-of-healt of these components
- Actively control the degradation either by manipulation of the switching of power semiconductor, switching frequency, modulation and control

B.Sc. Thesis:
Pulse placement for high reliability GaN-based power module
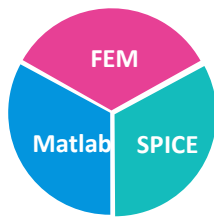## Next generation of power converters for long-range autos

Abstract

GaN devices holds strong promises for high density and high efficiency power electronics conversion. However, fundamental as well as practical restrictions limit the maximum current that can be delivered by each transistor (in the order of 100 A). Reaching higher current, required for instance by e-Mobility and renewable energy production applications, require the paralleling of transistors. Due to their high switching speed, these devices are very sensitive to unbalanced parasitic elements, which can result in inhomogeneous heating and reliability issues. This thesis aims at investigating active methods to control the temperatures of an high-current GaN power module by controlling the placement of the PWM pulses.
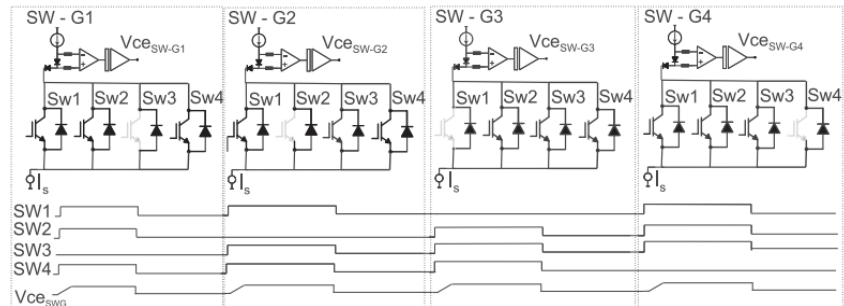
Pulse shadowing in an IGBT power module

V. Ferreira, … M. Liserre, "Pulse-Shadowing-Based Thermal Balancing in Multichip Modules," in IEEE Trans Ind App, 2020, doi: 10.1109/TIA.2020.2993526.

Background

GaN promises to be the next frontier in development of high efficiency and medium to high power applications, such as grid-connected converters and automotive. However, due to their high density and limited manufacturing yield, reaching high current requires paralleling of multiple devices. However, owing to their high switching speed, GaN devices are very sensitive to parasitic elements and paralleling them remains very challenging. Unbalanced electrical and thermal parasitic elements can lead to inhomogeneous device temperatures, leading to early ageing and failures.

Following previous work developed in the team using IGBTs, this thesis will investigate the potential of die-level pulse placement for active thermal control of high-current GaN-based power modules. Several manipulation strategies (pulse shadowing, soft-turn-on, etc.) will be investigated in terms of thermal balancing capabilities, overall efficiency, electrical stress, etc.

Objectives

- Update of a design of high current power module with distributed drivers
- Simulation-based investigation of the potential of pulse-level control for active thermal control
- Experimental validation

Requirements

Language
English

Theory
Thermal modelling ★ ★ ★ ★ ★
Controle ★ ★ ★ ★ ★

Related Courses
DPEC ★ ★ ★ ★ ★

IT-Skills

FEM
Matlab SPICE

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Supervisor
Dr. Yoann Pascal
Prof. Marco Liserre

Project

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www.isit.fraunhofer.de/ees

Fraunhofer
ISIT

Aug. 25h, 2023

External Cooperation

M.Sc. Thesis:
Condition monitoring using high frequency injection
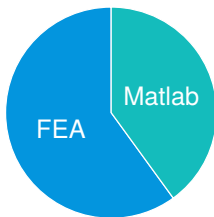### Interdisciplinary research with the Chair of Microwave Engineering

Requirements

Language
English/German

Theory
Component reliability: ★ ★ ★ ★ ★
Wave theory: ★ ★ ★ ★ ★
Packaging technology: ★ ★ ★ ★ ★

Related courses
Design of Power Elec.: ★ ★ ★ ★ ★

IT-Skills

Matlab
FEA

Contact

Supervisor:
Yoann Pascal, PhD
yoann.pascal@isit.fraunhofer.de
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November 11, 2022

Abstract

Thermal cycling has been identified as the main cause for ageing in power electronics. Monitoring the state of health (SoH) of the system enables failure prediction and active maintenance strategies to increase lifetime and reduce repair- and downtime- costs.

The response under micro-wave excitation has been little investigated, although it showed great promises for SoH estimation.

This thesis will therefore investigate how measuring the impedance and S parameters of a power module online can help estimate its state of health.
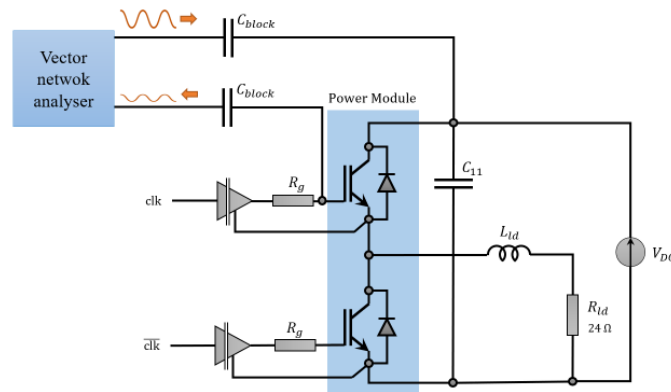
Figure 1: System overview: vector network analyser connected to a power module for online measurements

Background

Power electronics components and systems have limited lifetime and are prone to failure. In the meantime, power electronics is investing fields with increasing availability requirements, and where failures can induce very high costs (exploitation loss, repair costs, induced degradation or destruction of other sub-systems, etc.), and even be life critical.

As a matter of facts, fields such as renewables, heavy duty e-mobility, aerospace, industry, etc. require high availability power systems.

Objectives

- Modelling (CST-Microwave Studio) of a power module
- Simulation of the effect of ageing on the S-parameters of a power module
- Experimental validation: power converter testing and S-parameter measurements
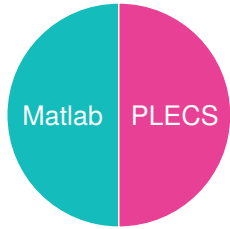
MSc. Thesis:

Design and Control of Multi-MW Power Electronic Converter
System Analysis for High Power Applications

Requirements

Language
English

Theory
Power Converters ★★★★☆
Control ★★★★☆

IT-Skills

Matlab | PLECS

Contact

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Fraunhofer ISIT

Prof. Dr. Marco Liserre
CAU

Mohamad El-Ghouti
Infineon Bipolar

Project

Cooperation with Infineon Bipolar

Infineon

Infineon Technologies Bipolar

October 5, 2023

Abstract

This thesis will target on the exploitation of state-of-the-art electric systems for the production of greener hydrogen through renewable energy sources using an electrolysis process. In this regard, the P2X converter (AC-DC) as shown in Figure. 1 plays a key role to fulfill the requirements from the perspective of low voltage and high currents (thousands of Amps). The right topology selection is critical as it will not only impact the power quality but also the lifetime of electrolyzer. To address these challenges, the best suitable topologies of the P2X converter will first be identified and the performance of selected topologies will be evaluated based on different perspectives. The selected topology will then be designed, controlled, and implemented in a simulation platform.
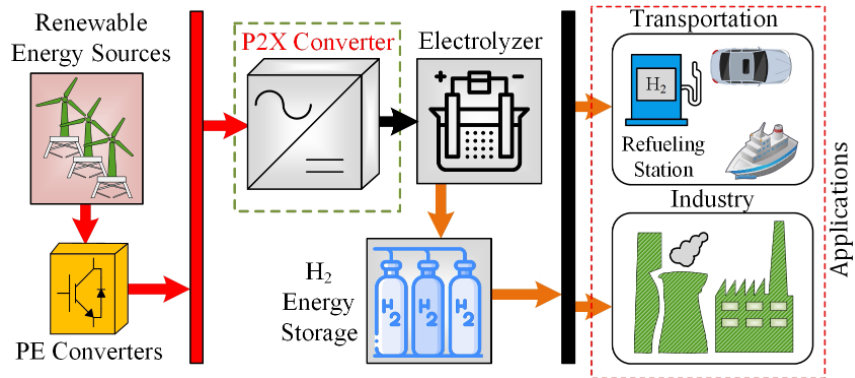
Figure 1: Overview of hydrogen production through renewables and its applications

Background

The biggest difficulties of our day are revolutionizing the energy industry and accomplishing sustainability objectives! And the key to achieving this transformation is to compare several systems and identify the one best suited for a given application. The only way to speed up the energy transition and build a sustainable future is to comprehend complicated systems and translate consumer needs into technical solutions.

Objectives

- Sorting state-of-the-art high current and low voltage AC-DC converter topologies.
- Comparative analysis on the selected topologies best fit for this application.
- Implementation of power sources and electrolyzer in a simulation environment.
- Design and control of P2X converter for selected topology.

M.Sc. Thesis:
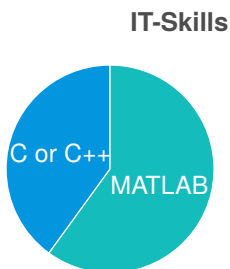## Parallel-Connected Converter for High Power Variable Frequency Drives
Cooperation with Danfoss Drives

CAU
Kiel University
Christian-Albrechts-Universität zu Kiel
Faculty of Engineering

PE
25th
anniversary

Abstract

The main scope of this thesis is to design, develop, and implement three-phase parallel-connected inverters for high power drives. The main focus will be the minimization of losses in the overall inverter system by suppressing the circulating current with a special modulation scheme, control algorithm and coupled inductor design.
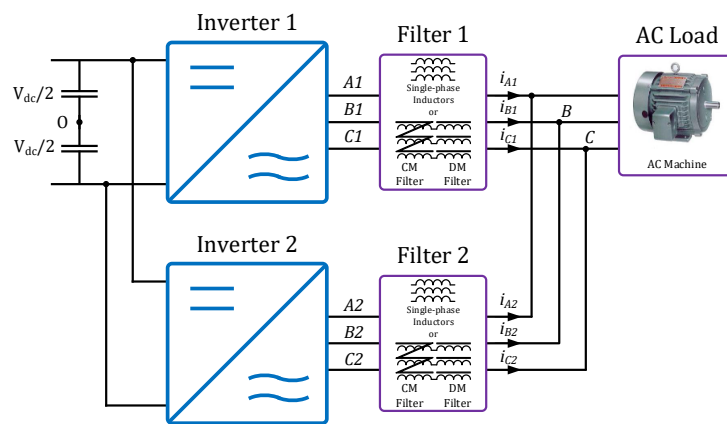
Figure 1: Parallel Connected Inverter for high-power ac machine

Background

Parallel-connected VFDs modules for realizing high power drive have several advantages, such as low current ripple, modularity, improved thermal management, increased power capability, redundancy, easy maintenance etc. The parallel connected voltage source inverters (VSIs) have common dc-link, ac sides are connected through inductors, and the common-point is connected to load. The parallel connected VSIs should be operated ideally using the modulating reference signals having same frequency, phase, amplitude, and uniform modulation. However, the parallel connected VSIs are conventionally modulated using interleaved carrier signals to reduce the ac side harmonic distortion and line current ripple. This interleaving of carrier signals introduces an instantaneous common-mode (CM) voltage difference between the VSIs. Due to this CM voltage difference, a circulating current flows between the VSIs. This circulating current flow is restricted using common-mode inductors, coupled inductors, or integrated inductors.

Objectives

- Design the inductor effective in reducing the circulating current.
- Implement suitable modulation strategy and control systems, which minimizes the overall losses in the drive system.

CAU
Kiel University
Christian-Albrechts-Universität zu Kiel
Faculty of Engineering

PE
25th anniversary

MSc. Thesis:
Evaluation of Ultra-Compact/Efficient DC/DC Converters
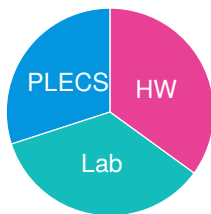### Ultra-Demanding Power Supply Modules

Requirements

LANGUAGE
English

THEORY
Power Converters ★★★★★
Control Theory ★★★★☆
Magnetics ★★★☆☆
A/D Electronics ★★★☆☆

RELATED MASTER'S COURSE
DPEC ★★★☆☆

SKILLS

PLECS / HW / Lab

Contact

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Project
Cooperation with ISIT@CAU and Thyssenkrupp Marine Systems
www.isit.fraunhofer.de/ees

Fraunhofer
ISIT

August 25, 2023

Abstract

This work aims to conceptualize, design, model, and fabricate a cost-effective power supply module that meets the demanding specifications of high-reliability industrial applications while maximizing efficiency and power density. More specifically, a DC/DC converter with a low-voltage output and a wide-range input has to be developed. The converter must be integrated into a PCB and regulated by a straightforward control system, which has not been effectively achieved previously in the literature.

Background

Power electronics plays a key role in designing supply systems to cope with the ultra-demanding specifications required by several areas of electrification. These supplies may, for example, drive servo systems, charge EV batteries or energize IT systems, and the low-voltage output must deliver hundreds of amperes of current while the system still excels in performance, achieving high efficiency, high power density, and low-cost. Besides the ultra-demanding performance, such power supplies must also be reliable and fulfil hold-up time criteria
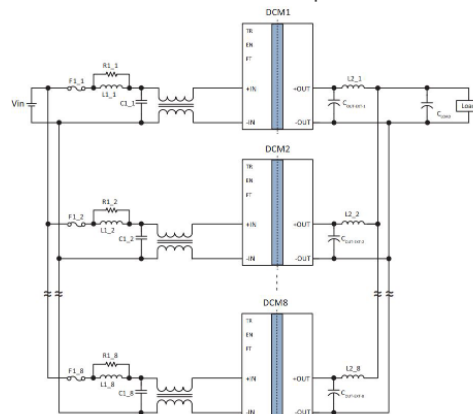
(a) General Diagram

(b) Hardware Demonstrator

Figure 1: Paralleling multiple converters for ultra-demanding power supply modules.

Objectives

The student will have to perform a experimental analysis of DC/DC converter demonstrator considering the following objectives:

- Heat dissipation considering a cooling system reach the full power
- PCB design for parallel operation of 8 converters
- Paralleling 8 converters (load sharing by playing with TR functionality)
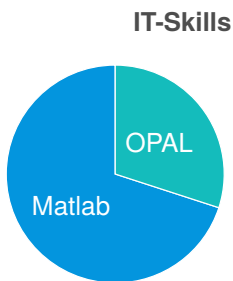- Dynamic behavior of single and multiple systems

M.Sc. Thesis:
Modeling and control of standardized DC grids
Understanging Direct Current (DC) distribution grids with Current/OS standard

Requirements

Language
English/Deutsch

Theory
Grid-connected
converters ★★★★★
State-space modeling ★★★★★
Simulink Modeling ★★★★☆

IT-Skills

OPAL
Matlab

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Supervisor:
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Project
ISIT@CAU

October 2, 2023

Abstract

DC grids are a recent trend and a promising technology for future power systems. With respect to the well-consolidated AC power distribution, DC distribution is still an emerging technology, for which control and protection strategies must be investigated and tested to ensure resilience, sustainability, and safety. The Current/OS foundation is working toward standardization to promote the adoption of DC grids, exploiting the experience and collaboration with a large number of industries. This thesis investigates modeling and control in DC grids, in collaboration with Maschinenfabrik Reinhausen GmbH.
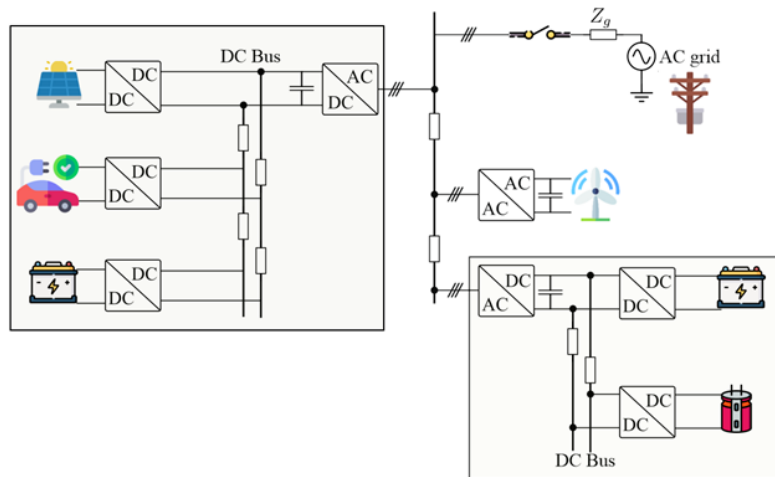
Figure 1: Example DC grids connected to the main AC grid.

Background

The first step of the thesis is the investigation of the control and protection problems in DC grids, and the understanding of the Current/OS standard. A real-world example of DC grid interlinked to the main AC utility grid will be given. A nonlinear state-space modeling tool for converter dominated grids will be provided, and target of the thesis is to start from the existing framework and use it to model the considered DC grid and the interconnection to the main AC grid. Opal-RT model for the DC grid will be an additional target; existing converters models will be provided.

Objectives

- Deep understanding of the Current/OS standard.

- Power grid modeling by means of nonlinear state-space equations.

- Learning and implementation in Opal-RT for DC distribution grids.